Appendix E Avoidance and Minimization Measures

Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

E.1 General Avoidance and Minimization Measures

The general avoidance and minimization measures (AMMs) described here have been developed to avoid and minimize effects that could result from the proposed action on listed species covered by the Biological Assessment (BA). These AMMs will be implemented as part of the proposed action[1]. General AMMs are implemented primarily during siting through design and construction, but may also be implemented during operations and maintenance. Table E-1 briefly summarizes the general AMMs.

Table E-1. Summary of the General Avoidance and Minimization Measures

Number	Title	Summary
AMM1	Worker Awareness Training	Includes procedures and training requirements to educate construction personnel on the applicable environmental rules and regulations, the types of sensitive resources in the project area, and the measures required to avoid and minimize effects on these resources.
AMM2	Construction Best Management Practices and Monitoring	Standard practices and measures that will be implemented prior to, during, and after construction to avoid or minimize effects of construction activities on sensitive resources (e.g., species, habitat), and monitoring protocols for verifying the protection provided by the implemented measures.
AMM3	Stormwater Pollution Prevention Plan	Includes measures that will be implemented to minimize pollutants in stormwater discharges during and after construction, and that will be incorporated into a stormwater pollution prevention plan to prevent water quality degradation related to project area runoff to receiving waters.
AMM4	Erosion and Sediment Control Plan	Includes measures that will be implemented for ground-disturbing activities to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities, and that will be incorporated into plans developed and implemented as part of the National Pollutant Discharge Elimination System permitting process for covered activities.

[1] Consistent with the environmental review process under various regulatory requirements, the proposed action including these AMMs might require revision as consultation progresses.

Number	Title	Summary
AMM5	Spill Prevention, Containment, and Countermeasure Plan	Includes measures to prevent and respond to spills of hazardous material that could affect navigable waters, as well as emergency notification procedures.
AMM6	Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material	Includes measures for handling, storage, and disposal of excavation or dredge spoils, including procedures for the chemical characterization of this material or the decant water to comply with permit requirements, and reducing potential effects on aquatic habitat, as well as specific measures to avoid and minimize effects on species in the areas where materials would be used or disposed.
AMM7	Barge Operations Plan	Includes measures to avoid or minimize effects on aquatic species and habitat related to any necessary barge operations by establishing specific protocols for the operation of all project-related vessels at construction and/or barge landing sites, if the latter are required. Also includes monitoring protocols to verify compliance with the plan and procedures for contingency plans.
AMM8	Fish Rescue and Salvage Plan	Includes measures that detail procedures for fish rescue and salvage to avoid and minimize the number of Chinook salmon, steelhead, green sturgeon, and other listed species of fish stranded during construction activities, especially during the placement and removal of enclosures (e.g., cofferdams or exclusion netting) at construction sites.
AMM9	Underwater Sound Control and Abatement Plan	Includes measures to minimize the effects of underwater construction noise on fish, particularly from any required impact pile driving activities. Potential effects of pile driving will be minimized by restricting work to the least sensitive period of the year and by controlling or abating underwater noise generated during pile driving.
AMM10	Methylmercury Management	Design and construction of tidal wetland restoration and mitigation sites to minimize ecological risks of methylmercury production.
AMM11	Design Standards and Building Codes	Ensure that the standards, guidelines, and codes, which establish minimum design criteria and construction requirements for project facilities, will be followed. Follow any other standards, guidelines, and code requirements that are promulgated during the detailed design and construction phases and during operation of facilities.
AMM12	Transmission Line Design and Alignment Guidelines	Design the alignment of proposed transmission lines to minimize impacts on sensitive terrestrial and aquatic habitats when siting poles and towers. Restore disturbed areas to preconstruction conditions. In agricultural areas, implement additional best management practices (BMPs). Site transmission lines to avoid greater sandhill crane roost sites or, for temporary roost sites, relocate roost sites prior to construction if needed. Site transmission lines to minimize bird strike risk.
AMM13	Noise Abatement	Develop and implement a plan to avoid or reduce the potential in-air noise impacts related to construction, maintenance, and operations.
AMM14	Hazardous Material Management	Develop and implement site-specific plans that will provide detailed information on the types of hazardous materials used or stored at all sites associated with facilities and required emergency-response procedures in case of a spill. Before construction activities begin, establish a specific protocol for the proper handling and disposal of hazardous materials.
AMM15	Construction Site Security	Provide all security personnel with environmental training similar to that of onsite construction workers, so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.

Number	Title	Summary
AMM16	Fugitive Dust Control	Implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust and ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedures are followed.
AMM17	Notification of Activities in Waterways	Before in-water construction or maintenance activities begin, notify appropriate agency representatives when these activities could affect water quality or aquatic species.

The proposed action has been designed to avoid and minimize effects on listed species. Reclamation will ensure that activities under the proposed action are sited and designed to minimize take of listed species, by means of the applicable AMMs. During the project design phase, measures set forth in AMMs to avoid and minimize effects on listed species will be included in the following plans developed as needed to comply with state and federal regulations.

- Stormwater pollution prevention plan (SWPPP) as required by the Central Valley Regional Water Quality Control Board (AMM3).
- Erosion and sediment control plan (AMM4).
- Spill prevention, containment, and countermeasure (SPCC) plan (AMM5).
- Disposal and reuse of spoils and dredged material (AMM6).
- Barge operations plan (AMM7).
- Fish rescue and salvage plan (AMM8).
- Underwater sound control and abatement plan (AMM9).

E.1.1 AMM1 Worker Awareness Training

Reclamation or its designees will provide training to field management and construction personnel on the importance of protecting sensitive natural resources (i.e., listed species and designated critical and/or suitable habitat for listed species). Training will be conducted during preconstruction meetings so that construction personnel are aware of their responsibilities and the importance of compliance. All trainees will be required to sign a sheet indicating their attendance and completion of environmental training. The training sheets will be provided to the fish and wildlife agencies if requested. These requirements also pertain to operations and maintenance personnel working in and adjacent to suitable habitat for listed species.

Construction personnel will be educated on the types of sensitive resources located in the project area and the measures required to avoid and minimize effects on these resources. Materials covered in the training program will include environmental rules and regulations for the specific project, requirements for limiting activities to approved work areas, timing restrictions, and avoidance of sensitive resource areas. In general, trainings will include the following components.

- Important timing windows for listed species (i.e., timing of fish migration, spawning, and rearing; and wildlife mating, nesting, and fledging).
- Specific training related to the relevant AMMs that will be implemented during construction for the protection of listed species and their habitat.
- The legal requirements for resource avoidance and protection.

- Identification of listed species potentially affected at the worksite, which will depend upon the work to be performed and the location of the work.
- Protocol for identifying the proper AMMs to implement for the protection of listed species based upon the nature, timing, and location of construction activities to be performed.
- Brief discussions of listed species of concern.
- Boundaries of the work area.
- Avoidance and minimization commitments.
- Exclusion and construction fencing methods.
- Roles and responsibilities.
- What to do when listed species are encountered (dead, injured, stressed, or entrapped) in work areas.
- Penalties for noncompliance.

A fact sheet or other supporting materials containing this information will be prepared and will be distributed along with a list of contacts (names, numbers, and affiliations) prior to initiating construction activities. A representative will be appointed by the project proponent to be the primary point of contact for any employee or contractor who might inadvertently take a listed species, or a representative will be identified during the employee education program and the representative's name and telephone number provided to the fish and wildlife agencies.

If new construction personnel are added to the project, the contractor will ensure that the personnel receive the mandatory training and sign a sheet indicating their attendance and completion of the environmental training before starting work. The training sheets for new construction personnel will be provided to the fish and wildlife agencies, if requested.

E.1.2 AMM2 Construction Best Management Practices and Monitoring

All construction and operation and maintenance activities in and adjacent to suitable habitat for listed species will implement BMPs and have construction monitored by a qualified technical specialist(s). Depending on the resource of concern and construction timing, construction activities and areas will be monitored for compliance with water quality regulations (SWPPP monitoring) and with AMMs developed for sensitive biological resources (biological monitoring).

Before initiating construction, Reclamation or its designee will prepare a construction monitoring plan for the protection of listed species. The plan will include, but not be limited to, the following elements.

- Reference to or inclusion of the SWPPP prepared under the Construction General Permit (CGP), where one is needed (AMM3).
- Summaries or copies of planning and preconstruction surveys (if applicable) for listed species.
- Description of AMMs to be implemented.
- Descriptions of monitoring parameters (e.g., turbidity), including the specific activities to be monitored (e.g., dredging, grading activities) and monitoring frequency and duration (e.g., once per hour during all in-water construction activities), as well as parameters and reporting criteria.
- Description of the onsite authority of the monitors to modify construction activity and protocols for notifying CDFW, NMFS, and USFWS, if needed.

- A daily monitoring log prepared by the construction monitor, which documents the day's construction activities, notes any problems identified and solutions implemented to rectify those problems, and notifies the construction superintendent and/or the fish and wildlife agencies of any exceedances of specific parameters (e.g., turbidity) or observations of listed species. The monitoring log will also document construction start/end times, weather and general site conditions, and any other relevant information.

The following measures will be implemented prior to and during performance of the proposed action, for the protection of listed species and their habitat.

- All in-water construction activities within jurisdictional waters will be conducted during the following in-water work windows:
  - Within the legal Delta and Suisun Bay/Suisun Marsh: August 1 to October 31;
  - Sacramento River upstream of the Delta:
    - Keswick Dam (RM 302) to approximately 1.5 miles downstream (Zone 1): year-round (any time flows are less than 15,000 cfs);
    - Approximately 1.5 miles downstream of Keswick Dam (RM 300.5) to Cow Creek (RM 280) (Zone 2): October 1 to May 15 (any time flows are less than 10,000 cfs; pre-construction salmonid redd surveys conducted);
    - Cow Creek (RM 280) to Red Bluff Diversion Dam (RM 243): October 1 to March 1 (any time flows are less than 10,000 cfs; pre-construction salmonid redd surveys conducted);
    - Downstream of Red Bluff Diversion Dam (RM 243) to the boundary with the legal Delta: June 1 to October 1.
  - American River:
    - July 1 to September 30.
  - Feather River:
    - August 1 to October 31.
  - Stanislaus River:
    - July 15 to October 15.
  - Other locations proposed through programmatic actions (e.g., San Joaquin River, Battle Creek):
    - To be developed through coordination with NMFS, USFWS, and DFW.
  - Note: Work windows will be refined as necessary through coordination with NMFS, USFWS, and DFW. Work windows for some activities such as pile driving may be lengthened subject to agency approval based on demonstrated success of mitigation (e.g., bubble curtains) and real-time monitoring for fish presence. In-water activities associated with mobilization and demobilization are not subject to the work windows. Apart from impact pile driving, any other work may occur within a dewatered cofferdam regardless of the timing of in-water work windows. In-water impact pile installation may occur outside of the work windows if performed within a dewatered cofferdam and with in-channel acoustic monitoring to verify that generated sound thresholds do not exceed the 150-dB behavioral criterion. Any extension/reduction of work windows would focus on half-month increments.

- To the extent possible, in-water work will only occur for up to 12 hours per day, or from at least one hour after sunrise to at least one before sunset, in order to provide a crepuscular/nocturnal time window for fish migration without disturbance. Timing of this daily in-water work window will be refined as necessary through coordination with NMFS, USFWS, and DFW.
- Qualified biologists will monitor construction activities in areas identified as having listed species or their designated critical habitat. The intent of the biological monitoring is to ensure that specific AMMs that have been integrated into the project design and permit requirements are being implemented correctly during construction and are working appropriately and as intended for the protection of listed species.
- Biological monitors will be professional biologists selected for their knowledge of the listed species that may be affected by construction activities. The qualifications of the biologist(s) will be presented to the fish and wildlife agencies for review and written approval prior to initiating construction. The biological monitors will have the authority to temporarily stop work in any area where a listed species has been observed until that individual has passively or physically been moved outside of the work area, or when any AMMs or BMPs are not functioning appropriately for the protection of listed species.
- Exclusionary fencing may be placed at the edge of active construction activities and staging areas (after having been cleared by biological surveys) to restrict wildlife access from the adjacent habitats. The need for exclusionary fencing will be determined during the preconstruction surveys and the construction planning phase and may vary depending on the species and habitats present. Exclusionary fencing will consist of taut silt fabric (non-monofilament), 24 inches high (36 inches high for California red-legged frog and giant garter snake), staked at 10-foot intervals, with the bottom buried 6 inches below grade. Fence stakes will face toward the work area (on the opposite side of adjacent habitat) to prevent wildlife from using stakes to climb over the exclusionary fencing. Exclusionary fencing will be maintained such that it is intact during rain events. Fencing will be checked by the biological monitor or construction foreman periodically throughout each work day. If fencing becomes damaged, it will be immediately repaired upon detection and the monitoring biologist will stop work in the vicinity of the fencing as needed to ensure that no sensitive wildlife species have entered. Active construction and staging areas will be delineated with high-visibility temporary fencing at least 4 feet in height, flagging, or other barrier to prevent encroachment of construction personnel and equipment outside the defined project footprint. Such fencing will be inspected and maintained daily by the construction foreman until completion of the project. Fencing will be removed from work areas only after all construction activities are completed and equipment is removed. No project-related construction activities will occur outside the delineated project construction areas.
- Project-related vehicles will observe a speed limit of 20 miles per hour in construction areas where it is safe and feasible to do so, except on county roads and state and federal highways. A vehicle speed limit of 20 miles per hour will be posted and enforced on all nonpublic access roads, particularly on rainy nights when California tiger salamanders and California red-legged frogs are most likely to be moving between breeding and upland habitats. Extra caution will be used on cool days when giant garter snakes may be basking on roads.
- All ingress/egress at the project site will be restricted to those routes identified in the project plans and description.
- All vehicle parking will be restricted to established areas, existing roads, or other suitable areas.
- To avoid attracting predators, all food-related trash items such as wrappers, cans, bottles, and food scraps will be disposed of in enclosed containers and trash will be removed and disposed of at an appropriate facility at least once a week from the construction or project site.

- To avoid injury or death to wildlife, no firearms will be allowed on the project site except for those carried by authorized security personnel or local, state, or federal law enforcement officials.
- To prevent harassment, injury, or mortality of sensitive wildlife by dogs or cats, no canine or feline pets will be permitted in the construction area.
- To prevent inadvertent entrapment of wildlife during construction, all excavated, steep-walled holes or trenches more than 1 foot deep will be covered at the close of each working day with plywood or similar material, and/or provided with one or more escape ramps constructed of earth fill or wooden planks. Before such holes or trenches are filled, they will be thoroughly inspected for trapped animals. If a listed species is encountered during construction work, to the extent feasible, construction activities should be diverted away from the animal until it can be moved by a USFWS- or CDFW-approved biologist.
- Capture and relocation of trapped or injured wildlife will only be performed by personnel with appropriate USFWS and CDFW handling permits. Any sightings and any incidental take will be reported to CDFW and USFWS via email within 1 working day of the discovery. A follow-up report will be sent to these agencies, including dates, locations, habitat description, and any corrective measures taken to protect listed species encountered. For each listed species encountered, the biologist will submit a completed CNDDB field survey form (or equivalent) to CDFW no more than 90 days after completing the last field visit to the project site.
- Plastic monofilament netting or similar material will not be used for erosion control, because smaller wildlife may become entangled or trapped in it. This includes products that use photodegradable or biodegradable synthetic netting, which can take several months to decompose. Acceptable materials include natural fibers such as jute, coconut, twine, or other similar fibers or tackified hydroseeding compounds. This limitation will be communicated to the contractor through specifications or special provisions included in the construction bid solicitation package.
- Listed species of wildlife can be attracted to den-like structures such as pipes and may enter stored pipes and become trapped or injured. All construction pipes, culverts, or similar structures, construction equipment, or construction debris left overnight in areas that may be occupied by wildlife will be inspected by the biological monitor or the contractor prior to being used for construction. Such inspections will occur at the beginning of each day’s activities, for those materials to be used or moved that day. If necessary, and under the direct supervision of the biologist, the structure may be moved up to one time to isolate it from construction activities, until the listed species has moved from the structure of their own volition, been captured and relocated, or otherwise been removed from the structure.
- Rodenticides and herbicides will be used in accordance with the manufacturer-recommended uses and applications and in such a manner as to prevent primary or secondary poisoning of listed species and depletion of prey populations upon which they depend. All uses of such compounds will observe label and other restrictions mandated by the U.S. Environmental Protection Agency (EPA), the California Department of Pesticide Regulation, and other appropriate state and federal regulations, as well as additional project-related restrictions imposed by USFWS, NMFS and/or CDFW. If rodent control must be conducted in San Joaquin kit fox habitat, zinc phosphide should be used because of its proven lower risk to kit fox. In addition, the method of rodent control will comply with provisions of the 4(d) rule published in the final listing rule for California tiger salamander (69 *Federal Register* [FR] 47211–47248).
- Nets or bare hands may be used to capture and handle individuals of listed species. A professional biologist will be responsible for and direct any efforts to capture and handle listed species. Any person who captures and handles listed species will not use soaps, oils, creams, lotions, insect

repellents, solvents, or other potentially harmful chemicals of any sort on their hands within 2 hours before handling listed species. Latex gloves will not be used either. To avoid transferring diseases or pathogens between aquatic habitats during the course of surveys or the capture and handling of listed species, all species captured and handled will be released in a safe, aquatic environment as close to the point of capture as possible, and not transported and released to a different water body. When capturing and handling listed species of amphibians, the biologists will follow the Declining Amphibian Task Force's *Code of Practice* (U.S. Fish and Wildlife Service no date). While in captivity, individual amphibians will be kept in a cool, moist, aerated environment such as a dark (i.e., green or brown) bucket containing a damp sponge. Containers used for holding or transporting these species will be sanitized and will not contain any standing water.

- CDFW, NMFS and/or USFWS will be notified within 1 working day of the discovery of, injury to, or mortality of a listed species that results from project-related construction activities or is observed at the project site. Notification will include the date, time, and location of the incident or of the discovery of an individual listed species that is dead or injured. For a listed species that is injured, general information on the type or extent of injury will be included. The location of the incident will be clearly indicated on a U.S. Geological Survey 7.5-minute quadrangle and/or similar map at a scale that will allow others to find the location in the field, or as requested by CDFW, NMFS and/or USFWS. The biologist is encouraged to include any other pertinent information in the notification.
- Permanent and temporary construction disturbances and other types of ongoing project-related disturbance activities in suitable habitat for listed species will be minimized by adhering to the following activities.
    - Project designs will limit or cluster permanent project features to the smallest area possible while still permitting achievement of project goals.
    - To minimize temporary disturbances, all project-related vehicle traffic and material storage will be restricted to established and/or designated ingress/egress points, construction areas, and other designated staging/storage areas. These areas will be included in preconstruction surveys and, to the extent possible, will be established in locations disturbed by previous activities to prevent further effects.
    - To the extent possible, minimize effects to sensitive habitats outside of construction footprints. For example, in upstream areas, conduct aerial or boat pre-construction redd surveys downstream of construction areas and implement avoidance and minimization measures to limit potential effects, e.g., modification of work area, turbidity management (such as a sediment curtain), or placement of a gravel berm to redirect flow away from sensitive areas.
    - Upon completion of the project, all areas subject to temporary ground disturbance will be recontoured to preproject elevations, as appropriate and necessary, and revegetated with native vegetation to promote restoration of the area to preproject conditions. An area subject to "temporary" disturbance is any area that is disturbed to allow for construction of the project, but is not required for operation or maintenance of any project-related infrastructure, will not be subject to further disturbance after project completion, and has the potential to be revegetated. Appropriate methods and native plant species used to revegetate such areas will be determined on a site-specific basis in consultation with USFWS, NMFS, and/or CDFW, and biologists.
- Equipment will be inspected prior to arrival at the construction area, including the physical removal of plant seed and parts from equipment, and freezing equipment and saturation of

equipment in chemical solution(s) to avoid the spread of invasive species such as zebra and quagga mussels, New Zealand mudsnails and Chytrid Fungus.

E.1.3 AMM3 Stormwater Pollution Prevention Plan

Reclamation commits to implementing measures, as described below, as part of the construction activities and in advance of any necessary permit(s). In accordance with these environmental commitments, Reclamation will ensure the preparation and implementation of SWPPPs to control short-term and long-term effects associated with construction-generated stormwater runoff. It is anticipated that multiple SWPPPs may be prepared for different aspects of the PA, each taking into account site-specific conditions (e.g., proximity to surface water, drainage). The SWPPPs will include all the necessary state requirements regarding construction-generated stormwater collection, detention, treatment, and discharge that will be in place throughout the construction period.

Reclamation is required to obtain coverage under the General Permit for Construction and Land Disturbance Activities (CGP) (currently, Order No. 2010-0014-DWQ) issued from the State Water Resources Control Board (SWRCB), for projects that will disturb 1 or more acres of land. The intent of the CGP is to protect receiving waters from pollutants potentially occurring in construction stormwater discharges. The CGP requires the development and implementation of a SWPPP for National Pollutant Discharge Elimination System (NPDES) permit coverage for stormwater discharges. Projects that disturb 1 or more acres of land have the potential to alter stormwater runoff. This includes projects that require excavation, grading, or stockpiling material at project sites, which could result in temporary and/or permanent changes to drainage patterns, paths, and facilities that would, in turn, cause changes in drainage flow rates, directions, and velocities of runoff, or constituents of runoff. For the PA, a series of separate but related SWPPPs will be prepared by a Qualified SWPPP Developer (QSD) and will be implemented under the supervision of a Qualified SWPPP Practitioner (QSP).

As part of the procedure to gain coverage under the CGP, the risk level of the site will be determined. This determination will be based on the probability of a significant risk of causing or contributing to an exceedance of a water quality standard, based on the construction activities to be performed, the existing water quality, soil and sediment conditions, without the implementation of additional requirements (per Order No. 2009-0009-DWQ as amended by Order Nos. 2010-0014-DWQ and 2012-2006-DWQ). The risk is calculated separately for sediment and receiving water, with two risk categories for receiving water (low and high) and three risk categories for sediment risk (low, medium, and high). The overall project risk levels (1, 2, or 3) are then determined through a matrix, where Risk Level 1 applies to projects with low receiving water and sediment risks, Risk Level 3 applies to projects with high receiving water and sediment risks, and Risk Level 2 applies to all other combinations of sediment and receiving water risks. These project risk levels determine the level of protection (i.e., BMPs) and monitoring that is required for the project. If the site is Risk Level 2 or 3, water sampling for pH and turbidity will be required and the SWPPP will specify sampling locations and schedule, sample collection and analysis procedures, and recordkeeping and reporting protocols. Other typical requirements for such situations are provided below under Risk Levels 2 and 3.

Changes in runoff characteristics associated with construction activities have the potential to be detrimental to listed species, as well as aquatic habitat associated with receiving waters, through changes in ambient water temperature, sediment, and pollutants resulting from stormwater runoff. The objectives of the SWPPP are to identify pollutant sources associated with construction activities and operations that may affect the quality of stormwater and to identify, construct, and implement stormwater pollution prevention measures to reduce pollutants in stormwater discharges during and after construction. The SWPPP will be kept onsite during construction activity and operations and will be made available upon request to representatives of the San Francisco Bay and Central Valley Regional Water Quality Control Boards.

In accordance with the CGP, the SWPPP will describe site topographic, soil, and hydrologic characteristics; construction activities and schedule; construction materials, including sources of imported fill material to be used and other potential sources of pollutants at the construction site; potential nonstormwater discharges (e.g., trench dewatering); erosion and sediment control measures; "housekeeping" BMPs to be implemented; a BMP implementation schedule; a site and BMP inspection schedule; and ongoing personnel training requirements. The SWPPP will also include a hazardous materials management plan, described in AMM14.

These SWPPP provisions are intended to prevent water quality degradation related to pollutant discharge to receiving waters, and to prevent or constrain changes to the pH of receiving waters. Performance standards will be met by implementing standard stormwater pollution prevention BMPs, as well as those tailored to site-specific conditions, including determining the risk level of individual construction sites. These environmental commitments mirror the requirements to gain and maintain coverage under the CGP. Reclamation will coordinate with the appropriate regional water quality control board to determine the appropriate aggregation of specific construction activities, or groups of activities, to be authorized under the CGP.

It is anticipated that multiple SWPPPs will be prepared for different construction sites, with a given SWPPP prepared to cover a specific project component (e.g., Delta Smelt Conservation Hatchery or tidal habitat restoration site) or groups of components (e.g., several water diversions to be screened within a certain area). The risk level will be identified for each action covered by a specific SWPPP. These SWPPPs will generally follow the EPA (2007) guidelines for such plans and will typically identify the following list of BMPs, which are requirements common to all risk-level sites; however, some detail is provided under the "Inspection and monitoring" bullet, below, on various risk-level requirements.

- Erosion control measures
    - Implement effective wind erosion BMPs, such as watering, application of soil binders/tackifiers, and covering inactive stockpiles.
    - Provide effective soil cover for inactive areas and all finished slopes and utility backfill areas, such as seeding with a native seed mix, application of hydraulic mulch and bonded fiber matrices, and installation of erosion control blankets and rock slope protection.
- Sediment control measures
    - Prevent transport of sediment at the construction site perimeter, toe of erodible slopes, soil stockpiles, and into storm drains.
    - Capture sediment via sedimentation and stormwater detention facilities.
    - Reduce runoff velocity on exposed slopes.
    - Reduce offsite sediment tracking.
- Management measures for construction materials
    - Cover and berm loose inactive stockpiled construction materials.
    - Store chemicals in watertight containers.
    - Minimize exposure of construction materials to stormwater.
    - Designate refueling and equipment inspection/maintenance locations.

   - Control drift and runoff from areas treated with herbicides, pesticides, and other chemicals that may be harmful to aquatic habitats.
- Waste management measures
   - Prevent offsite disposal or runoff of any rinse or wash waters.
   - Implement concrete and truck washout facilities and appropriately sized storage, treatment, and disposal practices.
   - Ensure the containment of sanitation facilities (e.g., portable toilets).
   - Clean or replace sanitation facilities (as necessary) and inspect regularly for leaks/spills.
   - Cover waste disposal containers during rain events and at end of any day when rain is forecast.
   - Protect stockpiled waste material from wind and rain.
- Construction site dewatering and pipeline testing measures
   - Reclaim site dewatering discharges to the extent practicable, or use for other construction purposes (e.g., dust control).
   - Implement appropriate treatment and disposal of construction site dewatering from excavations to prevent discharges to surface waters, unless discharge is permitted by authorities having jurisdiction.
   - Dechlorinate pipeline testing discharges to surface waters.
- Accidental spill prevention and response measures
   - Maintain equipment and materials necessary for cleanup of accidental spills onsite.
   - Clean up accidental spills and leaks immediately and dispose of properly.
   - Ensure that trained spill response personnel are available.
- Nonstormwater management measures
   - Control all nonstormwater discharges during construction.
   - Wash vehicles in such a manner as to prevent nonstormwater discharges to surface waters.
   - Clean streets in such a manner as to prevent nonstormwater discharges from reaching surface water.
   - Discontinue the application of any erodible landscape material during rain, or within 2 days before a forecasted rain event.
- Inspection and monitoring common to all risk-level sites
   - Ensure that all inspection, maintenance repair, and sampling activities at the construction site are performed or supervised by a QSP representing the discharger.
   - Develop and implement a written site-specific construction site monitoring program.
   - Inspection, monitoring, and maintenance activities based on the risk level of the construction site (as defined in the SWRCB General Permit)
- Risk Level 1 sites
   - Perform weekly inspections of BMPs, and at least once each 24-hour period during extended storm events.

  - At least 2 business days (48 hours) prior to each qualifying rain event (a rain event producing 0.5 inch or more of precipitation), visually inspect: stormwater drainage areas to identify any spills, leaks, or uncontrolled pollutant sources; all BMPs to identify whether they have been properly implemented in accordance with the SWPPP; and stormwater storage and containment areas to detect leaks and ensure maintenance of adequate freeboard.
  - Visually observe stormwater discharges at all discharge locations within 2 business days (48 hours) after each qualifying rain event, identify additional BMPs as necessary, and revise the SWPPP accordingly.
  - Conduct minimum quarterly visual inspections of each drainage area for the presence of (or indications of prior) unauthorized and authorized nonstormwater discharges and their sources.
  - Collect one or more samples of construction site effluent during any breach, malfunction, leakage, or spill observed within the construction site during a visual inspection that could result in the discharge of pollutants to surface waters whether visually detectable or not.
- Risk Level 2 sites
  - Perform all of the same visual inspection, monitoring, and maintenance measures specified for Risk Level 1 sites.
  - Perform sampling and analysis of stormwater discharges to characterize discharges associated with construction activity from the entire disturbed area at all points where stormwater is discharged offsite.
  - At a minimum, collect three samples per day of a qualifying rain event and analyze for pH and turbidity. The CGP also requires the discharger to revise the SWPPP and immediately modify existing BMPs and/or implement new BMPs such that subsequent discharges are below the relevant numeric action levels (NALs). It may be a violation of the CGP if the discharger fails to take corrective action to reduce the discharge below the NALs specified by the CGP.
  - When an active treatment system is deployed on the site or a portion of the site, collect active treatment system effluent samples and measurements from the discharge pipe or another location representative of the nature of the discharge.
- Risk Level 3 sites
  - Perform all of the same visual inspection, monitoring, and maintenance measures specified for Risk Level 1 and 2 sites.
  - In the event that a numerical effluent limit (NEL) of the CGP (i.e., pH and turbidity) is violated and has a direct discharge into receiving waters, the discharger will subsequently sample receiving waters for all parameter(s) monitored in the discharge. An exceedance of the NEL is considered a violation of the CGP, and the discharger must electronically submit all storm-event sampling results to the state and regional water boards via Stormwater Multiple Application and Report Tracking System (SMARTS) no later than 5 days after the conclusion of the storm event.
  - If disturbing 30 acres or more of the landscape and discharging directly into receiving waters, conduct a benthic macroinvertebrate bioassessment of receiving waters prior to and after commencement of construction activities to determine if significant degradation to the receiving water’s biota has occurred. However, if commencement of construction is outside of an index period (i.e., the period of time during which bioassessment samples must be collected to produce results suitable for assessing the biological integrity of streams and

rivers) for the site location, the discharger will participate in the State of California's Surface Water Ambient Monitoring Program (SWAMP).

The SWPPP will also specify the forms and records that must be uploaded to SWRCB online SMARTS, such as quarterly nonstormwater inspection and annual compliance reports.

If the QSP determines the site is Risk Level 2 or 3, water sampling for pH and turbidity will be required, and the SWPPP will specify sampling locations and schedule, sample collection and analysis procedures, and recordkeeping and reporting protocols. In accordance with the CGP NAL requirements, Reclamation's contractor's QSD will revise the SWPPP and modify existing BMPs or implement new BMPs when effluent monitoring indicates that daily average runoff pH is outside the range of 6.5 to 8.5 and that the daily average turbidity is greater than 250 nephelometric turbidity units (NTUs). Such BMPs may include those that are more costly to construct and maintain, such as construction of sediment traps and sediment basins, use of Baker tanks, installation of rock slope protection, covering of stockpiles with water-repellant geotextiles, dewatering basins, and use of Active Treatment Systems. The ability of other areas to withstand excessive erosion and sedimentation may be increased by applying additional mulching, bonded fiber matrices, and erosion control blankets; reseeding with a native seed mix; and installing additional fiber rolls, silt fences, and gravel bag berms. The QSD may also specify changes in the manner and frequency of BMP inspection and maintenance activities. The determination of which BMP should be applied in a given situation is very site-specific. QSDs typically refer to the California Stormwater Quality Association's *Stormwater Best Management Practice Handbook Portal: Construction* or the similar Caltrans manual for selecting BMPs for particular site conditions.

Additionally, if a given construction component is Risk Level 3, Reclamation will report to the SWRCB when effluent monitoring for that component indicates that daily average runoff pH is outside the range of 6.0 to 9.0 or the daily average turbidity is greater than 500 NTUs. In the event that the turbidity NEL is exceeded, Reclamation may also be required to sample and report pH, turbidity, and suspended sediment concentration of receiving waters to the SWRCB for the duration of construction.

The contractor will also conduct sampling of runoff effluent when a leak, spill, or other discharge of pollutants is detected.

The CGP has specific monitoring and action level requirements for the risk levels, which are summarized in Table E-2.

Table E-2. Stormwater Pollution Prevention Plan Monitoring and Action Requirements

Stormwater Pollution Prevention Plan Requirements	Risk Level/Type		
	1	2	3
Minimum stormwater and nonstormwater BMPs	✓	✓	✓
Numeric action levels (NAL) NAL for pH: 6.5–8.5 pH units NAL for turbidity: 250 NTU		✓	✓
Numeric effluent limitations (NEL) NEL for pH: 6–9 pH units NEL for turbidity: 500 NTU			✓
Visual monitoring (weekly; before, during, after rain events; non-stormwater)	✓	✓	✓
Runoff monitoring		✓	✓
Receiving water monitoring			✓

Note: The SWRCB has suspended the applicability of NELs for pH and turbidity at Risk Level 3/LUP Type 3 construction sites. In addition, because receiving-water monitoring is required only if the NELs are triggered, all receiving-water monitoring requirements are also suspended. The Level 3/Type 3 NEL are presented here assuming that such NELs will be reinstated when project construction commences.

BMP = best management practice; pH = potential hydrogen; NTU = nephelometric turbidity unit.

The QSD preparing a SWPPP may include in the SWPPP BMPs such as preservation of existing vegetation, perimeter control, seeding, mulching, fiber roll and silt fence barriers, erosion control blankets, protection of stockpiles, watering to control dust entrainment, rock slope protection, tracking control, equipment refueling and maintenance, concrete and solid waste management, and other measures to ensure compliance with the pH and turbidity level requirements defined by the CGP. Partly because the potential adverse effect on receiving waters depends on location of a work area relative to a waterway, the BMPs will be site-specific. For example, BMPs applied to level island-interior sites will be different than BMPs applied to water-side levee conditions. The QSP will be responsible for day-to-day implementation of the SWPPP, including BMP inspections, maintenance, water quality sampling, and reporting to SWRCB. If the water quality sampling results indicate an exceedance of NALs and NELs for pH and turbidity, as described above, the QSD will modify the type and/or location of the BMPs by amending the SWPPP to reduce pH, turbidity, and other contaminants to acceptable levels, consistent with NALs and NELs and with the water quality objectives and beneficial uses set forth in the Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region (Central Valley Regional Water Quality Control Board 2011).

E.1.4 AMM4 Erosion and Sediment Control Plan

An erosion and sediment control plan is typically required for ground-disturbing projects as part of the NPDES permitting process (U.S. Environmental Protection Agency 2007), depending on the size of the disturbed area. The proposed Phase II EPA rules would cover projects with greater than 1 acre of ground disturbance. Reclamation commits to implementing measures as described below as part of the construction activities and in advance of any necessary permit. In accordance with these environmental commitments, Reclamation will ensure the preparation and implementation of erosion and sediment control plans to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities. It is anticipated that multiple erosion and sediment control plans will be prepared for the construction activities included in the proposed action, each taking into account site-specific conditions such as proximity to surface water, erosion potential, drainage, etc. The plans will include all the necessary state requirements regarding erosion control and will implement BMPs for erosion and sediment control that will be in place for the duration of construction activities. These BMPs will be incorporated into the SWPPP (Section 3.F.1.1.1, *Conduct Planning-Level Surveys*).

The following erosion control measures will be included in the SWPPP.

- Install physical erosion control stabilization BMPs (hydroseeding with native seed mix, mulch, silt fencing, fiber rolls, sand bags, and erosion control blankets) to capture sediment and control both wind and water erosion. Erosion control may not utilize plastic monofilament netting or similar materials.
- Maintain emergency erosion control supplies onsite at all times during construction and direct contractor(s) to use these emergency stockpiles as needed. Ensure that supplies used from the emergency stockpiles are replaced within 48 hours. Remove materials used in construction of erosion control measures from the work site when no longer needed (property of the contractor).
- Design grading to be compatible with adjacent areas and result in minimal disturbance of the terrain and natural land features and minimize erosion in disturbed areas to the extent practicable.
- Divert runoff away from steep, denuded slopes, or other critical areas with barriers, berms, ditches, or other facilities.
- Retain native trees and vegetation to the extent feasible to stabilize hillsides, retain moisture, and reduce erosion.
- Limit construction, clearing of native vegetation, and disturbance of soils to areas of proven stability.
- Implement construction management and scheduling measures to avoid exposure to rainfall events, runoff, or flooding at construction sites to the extent feasible.
- Conduct frequent site inspections (before and after significant storm events) to ensure that control measures are intact and working properly and to correct problems as needed.
- Install drainage control features (e.g., berms and swales, slope drains) as necessary to avoid and minimize erosion.
- Install wind erosion control features (e.g., application of hydraulic mulch or bonded fiber matrix).

The following sediment control measures will be included in the SWPPP.

- Use sediment ponds, silt traps, wattles, straw bale barriers, or similar measures to retain sediment transported by onsite runoff.
- Collect and direct surface runoff at non-erosive velocities to the common drainage courses.
- When ground-disturbing activities are required adjacent to surface water, wetlands, or aquatic habitat, use of sediment and turbidity barriers, and implement measures for soil stabilization and revegetation of disturbed surfaces.
- Prevent mud from being tracked onto public roadways by installing gravel on primary construction ingress/egress points, and/or truck tire washing.
- Deposit or store excavated materials away from drainage courses and cover if left in place for more than 5 days or if storm events are forecast within 48 hours.

After construction is complete, site-specific restoration efforts will include grading, erosion control, and revegetation. Self-sustaining, local native plants that require little or no maintenance and do not create an extreme fire hazard will be used. All disturbed areas will be recontoured to preproject contours as feasible, and seeded with a native seed mix. Consideration will also be given to additional replacement of or upgrades to drainage facilities to avoid and minimize erosion. Paved areas damaged from use over and above ordinary wear-and-tear from lawful use by construction activities will be repaved to avoid erosion due to pavement damage.

E.1.5 AMM5 Spill Prevention, Containment, and Countermeasure Plan

As required by local, state, or federal regulations, Reclamation will require that construction contractors develop an SPCC plan for implementation at each site where ground-disturbing activities occur. Each SPCC plan will comply with the regulatory requirements of the Spill Prevention, Control, and Countermeasure Rule (40 Code of Federal Regulations [CFR] 112) under the Oil Pollution Act of 1990. This rule regulates non-transportation-related onshore and offshore facilities that could reasonably be expected to discharge oil into navigable waters of the United States or adjoining shorelines. The rule requires the preparation and implementation of site-specific SPCC plans to prevent and respond to oil discharges that could affect navigable waters. Each SPCC plan will address actions used to prevent spills in addition to specifying actions that will be taken should any spills occur, including emergency notification procedures. The SPCC plans will include the following measures and practices.

- Discharge prevention measures will include procedures for routine handling of products (e.g., loading, unloading, and facility transfers) (*40 CFR 112.7(a)(3)(i)*).
- Discharge or drainage controls will be implemented such as secondary containment around containers and other structures and equipment, and procedures for the control of a discharge (*40 CFR 112.7(a)(3)(ii)*).
- Countermeasures will be implemented for discharge discovery, response, and cleanup (both the facility's capability and those that might be required of a contractor) (*40 CFR 112.7(a)(3)(iii)*).
- Methods of disposal of recovered materials will comply with applicable legal requirements (*40 CFR 112.7(a)(3)(iv)*).
- Personnel will be trained in emergency response and spill containment techniques, and will also be made aware of the pollution control laws, rules, and regulations applicable to their work.
- Petroleum products will be stored in nonleaking containers at impervious storage sites from which an accidental spill cannot escape.
- Absorbent pads, pillows, socks, booms, and other spill containment materials will be stored and maintained at the hazardous materials storage sites for use in the event of an accidental spill.
- Watertight forms and other containment structures will be used to prevent spills or discharge of raw concrete, wash water, and other contaminants from entering surface waters and other sensitive habitats during overwater activities (e.g., casting of barge decks).
- Contaminated absorbent pads, pillows, socks, booms, and other spill containment materials will be placed in nonleaking sealed containers until transported to an appropriate disposal facility.
- When transferring oil or other hazardous materials from trucks to storage containers, absorbent pads, pillows, socks, booms, or other spill containment material will be placed under the transfer area.
- Refueling of construction equipment will occur only in designated areas that will be a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands.

- Equipment used in direct contact with water will be inspected daily for oil, grease, and other petroleum products. All equipment will be cleaned of external petroleum products prior to beginning work where contact with water may occur in order to prevent the release of such products to surface waters.
- Oil-absorbent booms will be used when equipment is used in or immediately adjacent to waters.
- All reserve fuel supplies will be stored only within the confines of a designated staging area, to be located a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands.
- Fuel transfers will take place a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands, and absorbent pads will be placed under the fuel transfer operation.
- Staging areas will be designed to contain contaminants such as oil, grease, fuel, and other petroleum products so that should an accidental spill occur they do not drain toward receiving waters or storm drain inlets.
- All stationary equipment will be staged in appropriate staging areas and positioned over drip pans.
- In the event of an accidental spill, personnel will identify and secure the source of the discharge and contain the discharge with sorbents, sandbags, or other material from spill kits and will contact appropriate regulatory authorities (e.g., National Response Center will be contacted if the spill threatens navigable waters of the United States or adjoining shorelines, as well as other appropriate response personnel).

Methods of cleanup may include the following.

- Physical methods for the cleanup of dry chemicals include the use of brooms, shovels, sweepers, or plows.
- Mechanical methods could include the use of vacuum cleaning systems and pumps.
- Chemical methods include the use of appropriate chemical agents such as sorbents, gels, and foams.

E.1.6 AMM6 Disposal of Spoils and Dredged Material

In the course of constructing or operating project facilities, substantial quantities of material are likely to be removed from their existing locations based upon their properties or the need for excavation of particular features. Spoils refer to excavated native soils and are associated with construction of proposed new facilities. Dredged material refers to sediment removed from the bottom of a body of water for the purposes of in-water construction. The quantities of these materials generated by construction or operation of proposed facilities will vary based on various factors, such as location, topography, and structure being constructed. These materials will require handling, storage, and disposal, as well as chemical characterization. Storage areas are designated for these materials. Many of these materials will be suitable for reuse (e.g., as engineered fill or for purposes of habitat restoration), but such use is not part of the PA and projects using this material have not been identified.

E.1.6.1 *Storage Area Determination*

Spoils and dredged material will be stored in designated storage areas, with these locations to be provided by Reclamation during consultation with NMFS and USFWS.

The designated storage areas are sized to accommodate all material expected to be generated by the proposed action, i.e., it is assumed that none of that material will be reused, sold, or otherwise relocated under the proposed action. In practice, the area that will be needed for material storage will depend on several factors.

- The speed with which material is brought to the surface, stored, dried, tested, and moved to storage locations will be important in determining the final size of storage areas. If alternative end uses for the material can be identified and if those uses can be permitted within the timeframe of the proposed action (such permitting is not included in the proposed action, so separate authorizations would have to be obtained), then a smaller area may be needed for material storage.
- The depth to which the material is stacked. Material that is stored in deeper piles will require less area but may dry more slowly. Calculation of needed materials storage areas has assumed that materials would be placed in piles with a depth of six feet.

E.1.6.2 *Storage Site Preparation*

A portion of the storage sites selected for storage of spoils and dredged material will be set aside for topsoil storage. The topsoil will be saved for reapplication to disturbed areas postconstruction. Vegetative material from work site clearing will be chipped, stockpiled, and spread over the topsoil after earthwork is completed, when practicable and appropriate to do so and where such material does not contain seeds of undesirable nonnative species (i.e., nonnative species that are highly invasive and threaten the ecological function of the vegetation community to be restored in that location). Cleared areas will be grubbed as necessary to prepare them for grading or other construction activities. Rocks and other inorganic grubbed materials will be used to backfill borrow areas. The contractor will remove from the work site all debris, rubbish, and other materials not directed to be salvaged, and will dispose of them in an approved disposal site after obtaining all permits required.

E.1.6.3 *Draining, Chemical Characterization, and Treatment*

In instances of spoils and dredged material being deemed unsuitable for reuse, the material will be disposed of at a site for which disposal of such material is approved.

Hazardous materials excavated during construction will be segregated from other construction spoils and properly handled in accordance with applicable federal, state, and local regulations. Riverine or in-Delta sediment dredging and dredged material disposal activities may involve potential contaminant discharges not addressed through typical NPDES or SWRCB CGP processes. Construction of dredge material disposal sites will likely be subject to the SWRCB General Permit (Order No. 2009-0009-DWQ).

To better define potential effects to listed species or aquatic habitat, and to streamline the collection and incorporation of newer information (i.e., monitoring data or site-specific baseline information), the following protocol will be followed. Reclamation will work with State and Federal resource agencies with authorization and jurisdiction to identify the timeline for information gathering in relation to initiation of the specific action, but it is anticipated to be at least several months prior to the initiation of the action. At that time, Reclamation will follow the protocol below.

- Reclamation will ensure the preparation and implementation of a pre-dredge sampling and analysis plan (SAP). The SAP will be developed and submitted by the contractor(s) as part of the water plan required per standard DWR contract specifications (Section 01570). Prior to initiating any dredging activity, the SAP will evaluate the presence of contaminants that may affect water quality from the following discharge routes.

  - Instream discharges during dredging.
  - Direct exposure to contaminants in the material through ingestion, inhalation, or dermal exposure.
  - Effluent (return flow) discharge from an upland disposal site.
  - Leachate from upland dredge material disposal that may affect groundwater or surface water.
- Concentrations of the identified chemical constituents in the core samples will be screened through appropriate contaminant screening tables to ensure compliance with applicable agency guidelines.
- Results of the sediment analyses and the quality guidelines screening will determine the risk associated with the disturbance of the sediment horizons by identifying specific pathways of exposure to adverse effects.
- Results of the testing will be provided to all relevant State and Federal agencies for their use in monitoring or regulating the activities under consideration.
- If the results of the chemical analyses of the sediment samples indicate that one or more chemical constituents are present at concentrations exceeding screening criteria, then additional alternative protocols to further minimize or eliminate the release of sediments into the surrounding water column must be implemented.
- The applicant must provide to CDFW, NMFS and USFWS a plan to reduce or eliminate the release of contaminated sediment prior to the start of any actions that will disturb the sediments in the proposed construction area. Plans using a shrouded hydraulic cutterhead, or an environmentally sealed clamshell bucket may be acceptable provided that adequate supporting information is provided with the proposed plan. Plans should also include descriptions of the methods employed to treat, transport, and dispose of the contaminated sediment, as well as any resulting decant waters.

The following list of BMPs will be implemented during handling and disposal of any potentially hazardous dredged material.

- Conduct dredging within the allowable in-water work windows specified in AMM2 *Construction Best Management Practices*.
- Conduct dredging activities in a manner that will not cause turbidity in the receiving water, as measured in surface waters 300 feet down-current from the construction site, to exceed the Basin Plan objectives beyond an approved averaging period by the Central Valley Regional Water Quality Control Board and CDFW. Existing threshold limits in the Basin Plan for turbidity generation are as follows.
  - Where natural turbidity is between 0 and 5 NTUs, increases will not exceed 1 NTU.
  - Where natural turbidity is between 5 and 50 NTUs, increases will not exceed 20%.
  - Where natural turbidity is between 50 and 100 NTUs, increases will not exceed 10 NTUs.
  - Where natural turbidity is greater than 100 NTUs, increases will not exceed 10%.
- If turbidity generated during dredging exceeds implementation requirements for compliance with the Basin Plan objectives, silt curtains will be used to control turbidity. Exceptions to turbidity limits set forth in the Basin Plan may be allowed for dredging operations; in this case, an allowable zone of dilution within which turbidity exceeds the limits will be defined and prescribed in a discharge permit.

- The dredged material disposal sites will be designed to contain all of the dredged material. All systems and equipment associated with necessary return flows from the dredged material disposal site to the receiving water will be operated to maximize treatment of return water and optimize the quality of the discharge.
- The dredged material disposal sites will be designed by a registered professional engineer.
- The dredged material disposal sites will be designed, constructed, operated, and maintained to prevent inundation or washout due to floods with a 100-year return frequency.
- Two feet of freeboard above the 100-year flood event elevation will be maintained in all dredged material disposal site settling ponds at all times when they may be subject to washout from a 100-year flood event.
- Dredging equipment will be kept out of riparian areas and dredged material will be disposed of outside of riparian corridors.

Temporary storage sites will be constructed using appropriate BMPs such as erosion and sediment control measures (*AMM4 Erosion and Sediment Control Plan* and *AMM3 Stormwater Pollution Prevention Plan*) to prevent discharges of contaminated stormwater to surface waters or groundwater.

Once the excavated spoils or dredged material have been suitably dewatered, and as the constituents of the material will allow, it will be placed in either a lined or unlined storage area suitable for long-term storage. These long-term storage areas may be the same areas in which the material was previously dewatered or it may be a new area adjacent to the dewatering site. The storage areas will be created by excavating and stockpiling the native topsoil for future reuse. Once the area has been suitably excavated, and if a lined storage area is required, an impervious liner will be placed on the invert of the material storage area and along the interior slopes of the berms surrounding the pond. Due to the expected high groundwater tables at some storage areas, it is anticipated that there will be minimal excavation for construction of the long-term material storage areas. Additional features of the long-term material storage areas will include berms and erosion protection measures to contain storm runoff as necessary and provisions to allow for truck traffic during construction.

E.1.7 AMM7 Barge Operations Plan

Reclamation will require that any construction contractor proposing to use barges (to perform construction or to transport materials or equipment) develop a barge operations plan as required by local, state, or federal regulation. Each plan will be developed and submitted by the construction contractors per standard DWR contract specifications as part of the traffic plans required by those specifications (Section 01570 of standard DWR construction contracts). Each barge operations plan will be part of a comprehensive traffic control plan coordinated with the U.S. Coast Guard for large channels. The comprehensive traffic control plan will address traffic routes and machines used to deliver materials to and from the barges. The barge operations plan will address the following.

- Bottom scour from propeller wash.
- Bank erosion or loss of submerged or emergent vegetation from propeller wash and/or excessive wake.
- Accidental material spillage.
- Sediment and benthic community disturbance from accidental or intentional barge grounding or deployment of barge spuds (extendable shafts for temporarily maintaining barge position) or anchors.

- Hazardous materials spills (e.g., fuel, oil, hydraulic fluids).

The barge operations plan will serve as a guide to barge operations and to a biological monitor who will evaluate barge operations on a daily basis during construction with respect to stated performance measures. This plan, when approved by the Reclamation and other resource agencies, will be read and followed by barge operators and kept aboard all vessels operating at the construction sites and barge landings.

E.1.7.1 *Sensitive Resources*

The barge operations plan is intended to protect listed species of fish in the vicinity of barge operations. The plan will be developed to avoid barge-related effects on listed species of fish; if and when avoidance is not possible, the plan will include provisions to minimize effects on listed species of fish as described in Section 3.F.2.7.3, *Avoidance Measures*, Section 3.F.2.7.4, *Environmental Training*, and Section 3.F.2.7.5, *Dock Approach and Departure Protocol*. The sensitive resources potentially affected by barge maneuvering and anchoring in affected areas are listed below.

- Sediments that could cause turbidity or changes in bathymetry if disturbed.
- Bottom-dwelling (benthic) invertebrates that provide a prey base for listed species of fish.
- Riparian vegetation that provides shade, cover, habitat structure, and organic nutrients to the aquatic environment.
- Submerged aquatic vegetation that provides habitat structure and primary (plant) production.

E.1.7.2 *Responsibilities*

Construction contractors operating barges in the process of constructing the water conveyance facilities will be responsible for the following.

- Operate vessels safely and following the barge operations plan and other reasonable measures to prevent adverse effects on aquatic resources of the Delta and other waterways.
- Read, understand, and follow the barge operations plan.
- Report to the project biological monitor any vessel grounding or other deviations from the barge operations plan that could have resulted in the disturbance of bottom sediments, damage to river banks, or loss of submerged, emergent, or riparian vegetation.
- Immediately report material fuel or oil spills to the CDFW Office of Spill Prevention and Response, the project biological monitor, and Reclamation.
- Follow all other relevant plans, including the hazardous materials management plan, SWPPP, and SPCC plan.

The biological monitor will be responsible for the following.

- Observe a sample of barge operation activities including loading and unloading at least one barge at each of the barge loading and unloading facilities.
- Provide same-day reports to Reclamation on any observed problems with barge operations.
- Provide annual reports to Reclamation, summarizing monitoring observations over the course of each construction year, including an evaluation of the plan performance measures. The annual

report will also include a description of and representative photographs and/or videos of conditions of river banks and vegetation.

- Visit each intake and barge landing site to determine the extent of emergent and riparian vegetation, bank conditions, and general site conditions during the growing season prior to initiation of construction and then annually during and after construction. Monitor construction including observation of barge landing, loading, or unloading; departure of one or more barges at each active barge landing site and the condition of both river banks at each landing site; pile-driving; and other in-water construction activity as directed by Reclamation. The condition of river banks and vegetation will be photographed and verbally described in an annual monitoring report.

E.1.7.3 *Avoidance Measures*

The following avoidance measures will be implemented to ensure that the goal of avoiding impacts on aquatic resources from tugboat and barge operations will be achieved: training of tug boat operators; limiting vessel speed to minimize the effects of wake impinging on unarmored or vegetated banks and the potential for vessel wake to strand small fish; limiting the direction and/or velocity of propeller wash to prevent bottom scour and loss of aquatic vegetation; and prevention of spillage of materials and fluids from vessels.

If deviations from these procedures are required to maintain the safety of vessels and crew, the biological monitor will be informed of the circumstances and any apparent impacts on water quality, habitats, fish, or wildlife. Any such impacts will be brought to the attention of the applicable fish and wildlife agency to ascertain and implement appropriate remedial measures.

E.1.7.4 *Environmental Training*

All pilots operating at the barge landings and intake construction sites will be required to read and follow the barge operations plan and to keep a copy aboard and accessible. All pilots responsible for operating a vessel at either the intake or barge landing sites will read the barge operations plan and sign an affidavit as provided in the plan.

E.1.7.5 *Dock Approach and Departure Protocol*

Reclamation will require that construction contractors develop and implement a protocol for dock approach and departure to ensure the following.

- Vessel operators will obey all federal and state navigation regulations that apply to the Delta and other waterways.
- All vessels will approach and depart from the intake and barge landing sites at dead slow in order to reduce vessel wake and propeller wash at the sites frequented by tug and barge traffic.
- To minimize bottom disturbance, anchors and barge spuds will be used to secure vessels only when it is not possible to tie up.
- Barge anchoring will be preplanned. Anchors will be lowered into place and not be allowed to drag across the channel bed.
- Vessel operators will limit vessel speed as necessary to maintain wake heights of less than 2 feet at shore.

- Vessel operators will avoid pushing stationary vessels up against the cofferdam, dock, or other structures for extended periods, because this could result in excessive directed propeller wash impinging on a single location. Barges will be tied up whenever possible to avoid the necessity of maintaining stationary position by tugboat or by the use of barge spuds.
- Barges will not be anchored where they will ground during low tides.
- All vessels will obey U.S. Coast Guard regulations related to the prevention, notification, and cleanup of hazardous materials spills.
- All vessels will keep an oil spill containment kit and spill prevention and response plan onboard.
- In the event of a fuel spill, CDFW Office of Spills Prevention and Response will be contacted immediately at 800-852-7550 or 800-OILS-911 (800-645-7911) to report the spill.
- When transporting loose materials (e.g., sand, aggregate), barges will use deck walls or other features to prevent loose materials from blowing or washing off of the deck.

E.1.7.6 *Performance Measures*

Performance will be assessed based on the results of the biological monitoring reports. The assessment will evaluate observations for the following indicators of impacts.

- **Emergent vegetation loss.** The extent and dominant species of emergent vegetation will be determined and mapped by a global positioning system (GPS) unit at and cross-channel from each of the intake and barge landing sites during the growing seasons prior to, during, and after construction. Extent will be mapped as linear coverage along the landing and opposite banks. In the event that the linear extent of emergent vegetation is found to have decreased by 20% or more following construction (or as otherwise conditioned by applicable CDFW streambed alteration agreements), the position and nature of the change will be evaluated for the probability that the loss was due to barge grounding, propeller wash, or other effects related to barge operations. Adequate performance will be achieved if the linear extent of riparian and emergent vegetation following construction is at least 80% of the preconstruction extent (or as otherwise conditioned by applicable CDFW streambed alteration agreements).
- **Bank erosion and riparian vegetation loss.** The linear extent of bank erosion will be mapped by GPS at each of the intake and barge landing sites prior to, during, and after construction. Photos and written descriptions will be recorded for each area of eroded bank to describe the extent of the erosion. In the event that the linear extent of eroded bank is found to have increased by 20% or more following construction, the position and nature of the change will be evaluated for the probability (low, moderate, or high) that the erosion was due to barge grounding, propeller wash, or other effects related to barge operations, and preconstruction and postconstruction photographs will be compared to determine if riparian vegetation was also lost as a result of the erosion.
- **Cargo containment.** The biological monitor will note the use of deck walls or other appropriate containment during loading and unloading of sand, aggregate, or other materials from a barge at each landing site. Adequate performance will be achieved if appropriate measures are in use during each observed loading and unloading. In the unlikely event that an accidental spill occurs in spite of appropriate containment, the barge crew will describe the type, amount, and location of the spill to the biological monitor. The biological monitor will make observations at the site of the material spill and evaluate the potential impacts of the spill on biological resources. This will help the biological monitor evaluate whether mitigation is required and will be included in the annual monitoring report. Any such impacts will be brought to the attention of the applicable fish and wildlife agency to ascertain and implement appropriate remedial measures.

- **Fuels spill prevention.** Vessels operating in accordance with the SPCC plan and all applicable federal, state, and local safety and environmental laws and policies governing commercial vessel and barge operations will be considered to be performing adequately with regard to fuel spill prevention.
- **Barge grounding.** Barges are not to be grounded or anchored where falling tides are reasonably expected to cause grounding during a low tide. Barge grounding has the potential to disturb bottom sediments and benthic organisms, as well as creating a temporary obstacle to fish passage. Performance will be considered adequate if no cases of vessel grounding occur.

E.1.7.7 *Contingency Measures*

In the event that the performance measures are not met, Reclamation will coordinate with NMFS, USFWS, CDFW, and Central Valley Regional Water Quality Control Board to determine appropriate rectification or compensation for impacts on aquatic resources.

E.1.8 AMM8 Fish Rescue and Salvage Plan

Fish rescue operations will occur at any in-water construction site where dewatering and resulting isolation of fish may occur, or where fish exclusion netting is placed to exclude fish. Fish rescue and salvage plans will be developed by Reclamation or its contractors and will include detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to stranding during placement and removal of cofferdams or enclosure by exclusion netting. The plans will identify the appropriate procedures for removing fish from construction zones and preventing fish from reentering construction zones prior to dewatering and other construction activities. A draft plan will be submitted to the fish and wildlife agencies for review and approval. An authorization letter from NMFS, USFWS, and CDFW will be required before in-water construction activities with the potential for stranding fish can proceed.

Some construction activities may involve placement of cofferdams to isolate construction areas and minimize adverse effects to aquatic species and habitat during construction activities. However, these species can become trapped within the cofferdam and will need to be rescued or salvaged prior to dewatering. Although the following discussion focuses primarily on the application of this plan to cofferdam construction, the plan will also need to describe potential fish protection methods that may be implemented during other in-water activities with the potential to trap fish. For example, potential measures to exclude fish from active dredging areas may include deployment of silt curtains in a manner that directs fish away from the silt curtains and prevents fish from re-entering these areas during dredging operations. To the extent possible, fish will be gently encouraged (e.g., swept with seine nets; see below) to leave any areas that are scheduled to be dewatered or otherwise disturbed.

All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist and in accordance with required permits. Each fish rescue plan will identify the appropriate procedures for excluding fish from the construction zones, and procedures for removing fish, should they become trapped. The primary procedure will be to block off the construction area and use seines (nets) and/or dip nets to collect and remove fish, although electrofishing techniques may also be authorized under certain conditions. It is critical that fish rescue and salvage operations begin as soon as possible and be completed within 48 hours after isolation of a construction area to minimize potential predation and adverse water quality impacts (high water temperature, low dissolved oxygen) associated with confinement. In the case of cofferdam construction, the cofferdam will be installed to block off the construction area before fish removal activities occur. For other in-water construction activities, block nets or other temporary exclusion methods (e.g., silt curtains) could be used to exclude fish or isolate the construction area prior to the fish removal process. The appropriate fish exclusion or collection method will be determined by a qualified fish biologist, in consultation with a designated fish and wildlife agency biologist, based on site-specific conditions and construction methods. Capture, release, and relocation measures will be consistent with the general guidelines and procedures set forth in Part IX of the most recent edition of the *California Salmonid Stream Habitat Restoration Manual* (currently, California Department of Fish and Game 2010) to minimize impacts on listed species of fish and their habitat.

All fish rescue and salvage operations will be conducted under the guidance of a fish biologist meeting the qualification requirements of Section 3.F.2.8.1 *Qualifications of Fish Rescue Personnel*. The following description includes detailed fish collection, holding, handling, and release procedures of the plan. Unless otherwise required by project permits, the construction contractor will provide the following:

- A minimum 7-day notice to the appropriate fish and wildlife agencies, prior to an anticipated activity that could result in isolating fish, such as installation of a cofferdam.
- A minimum 48-hour notice to the appropriate fish and wildlife agencies of dewatering activities that are expected to require fish rescue.
- Unrestricted access for the appropriate fish and wildlife agency personnel to the construction site for the duration of implementation of the fish rescue plan.
- Temporary cessation of dewatering if fish rescue workers determine that water levels may drop too quickly to allow successful rescue of fish.
- A work site that is accessible and safe for fish rescue workers.

E.1.8.1 *Qualifications of Fish Rescue Personnel*

Personnel active in fish rescue efforts will include at least one person with a 4-year college degree in fisheries or biology, or a related degree. This person also must have at least 2 years of professional experience in fisheries field surveys and fish capture and handling procedures. The person will have completed an electrofishing training course such as Principles and Techniques of Electrofishing (USFWS, National Conservation Training Center), or similar course, if electrofishing is used. In order to avoid and minimize the risk of injury to fish, attempts to seine and/or net fish will always precede the use of electrofishing equipment.

E.1.8.2 *Seining and Dipnetting*

Fish rescue and salvage operations will begin prior to or immediately after completing the cofferdam. For example, it may be necessary to herd fish from the construction area before installing the last sections of the cofferdam. Where larger areas are being enclosed by cofferdams, fish exclusion and/or rescue activities may need to be conducted incrementally in coordination with cofferdam placement to minimize the number of fish subjected to prolonged confinement and stressful conditions associated with crowding, capture, and handling. If the enclosed area is wadable (less than 3 feet deep), fish can be herded out of the cofferdam enclosure by dragging a seine (net) through the enclosure, starting from the enclosed end and continuing to the cofferdam opening. Depending on conditions, this process may need to be conducted several times. After completing this fish herding process, the net or an exclusion screen will be positioned at the cofferdam opening to prevent fish from reentering the enclosure while the final section of the cofferdam is installed. The net or screen mesh will be no greater than 0.125 inch, with the bottom edge of the net (lead line) securely weighted down to prevent fish from entering the area by moving under the net. Screens will be checked periodically and cleaned of debris to permit free flow of water.

After installing the last sections of the cofferdam, remaining fish in the enclosed area will be removed using seines, dip nets, electrofishing techniques, or a combination of these depending on site conditions. If the water depth within the cofferdam is too deep to effectively remove fish using these methods, dewatering activities may be used to reduce the water level to an appropriate and safe depth (Section 3.F.2.8.5, *Contingency Plans*). Dewatering activities will also conform to the guidelines specified below (Section 3.F.2.8.4, *Dewatering*).

Following each sweep of a seine through the enclosure, the fish rescue team will do the following.

- Carefully bring the ends of the net together and pull in the wings, ensuring the lead line is kept as close to the substrate as possible.
- Slowly turn the seine bag inside out to reveal captured fish, ensuring fish remain in the water as long as possible before transfer to an aerated container.
- Follow the procedures outlined in Section 3.F.2.8.3, *Electrofishing*, and relocate fish to a predetermined release site.

Dipnetting is best suited for very small, shallow pools in which fish are concentrated and easily collected. Dip nets will be made of soft (nonabrasive) nylon material and small mesh size (0.125 inch) to collect small fish.

E.1.8.3 *Electrofishing*

After conducting the herding and netting operations described above, electrofishing may be necessary to remove as many fish as possible from the enclosure. Electrofishing will be conducted in accordance with NMFS electrofishing guidelines (National Marine Fisheries Service 2000) and other appropriate fish and wildlife agency guidelines. Electrofishing will be conducted by one or two 3- to 4-person teams, with each team having an electrofishing unit operator and two or three netters. At least three passes will be made through the enclosed cofferdam areas to remove as many fish as possible. Fish initially will be placed in 5-gallon buckets filled with river water. Following completion of each pass, the electrofishing team will do the following.

- Transfer fish into 5-gallon buckets filled with clean river water at ambient temperature.
- Hold fish in 5-gallon buckets equipped with a lid and an aerator, and add fresh river water or small amounts of ice to the fish buckets if the water temperature in the buckets becomes more than 2°F warmer than ambient river waters.
- Maintain a healthy environment for captured fish, including low densities in holding containers to avoid effects of overcrowding.
- Use water-to-water transfers whenever possible.
- Release fish at predetermined locations.
- Segregate larger fish from smaller fish to minimize the risk of predation and physical damage to smaller fish from larger fish.
- Limit holding time to about 10 minutes, if possible.
- Avoid handling fish during processing unless absolutely necessary. Use wet hands or dip nets if handling is needed.
- Handle fish with hands that are free of potentially harmful products, including but not limited to sunscreen, lotion, and insect repellent.

- Avoid anesthetizing or measuring fish.
- Note the date, time, and location of collection; species; number of fish; approximate age (e.g., young-of-the-year, yearling, adult); fish condition (dead, visibly injured, healthy); and water temperature.
- If positive identification of fish cannot be made without handling the fish, note this and release fish without handling.
- In notes, indicate the level of accuracy of visual estimates to allow appropriate reporting to the appropriate fish and wildlife agencies (e.g., "Approx. 10–20 young-of-the-year steelhead").
- Release fish in appropriate habitat either upstream or downstream of the enclosure, noting release date, time, and location.
- Stop efforts and immediately contact the appropriate fish and wildlife agencies if mortality during relocation or the limits on take (harm or harassment) of federally listed species exceeds 5%.
- Place dead fish of listed species in sealed plastic bags with labels indicating species, location, date, and time of collection, and store them on ice.
- Freeze collected dead fish of listed species as soon as possible and provide the frozen specimens to the appropriate fish and wildlife agencies, as specified in the permits.
- Sites selected for release of rescued fish either upstream or downstream of the construction area will be similar in temperature to the area from which fish were rescued, contain ample habitat, and have a low likelihood of fish reentering the construction area or being impinged on exclusion nets/screens.

E.1.8.4 *Dewatering*

Dewatering will be performed in coordination with fish rescue operations as described above. A dewatering plan will be submitted as part of the SWPPP/Water Pollution Control Program detailing the location of dewatering activities, equipment, and discharge point. Dewatering pump intakes will be screened to prevent entrainment of fish in accordance with NMFS screening criteria for salmonid fry (National Marine Fisheries Service 1997), including the following.

- Perforated plate: screen openings shall not exceed 3/32 inch (2.38 mm), measured in diameter.
- Profile bar: screen openings shall not exceed 0.0689 inch (1.75 mm) in width.
- Woven wire: screen openings shall not exceed 3/32 inch (2.38 mm), measured diagonally (e.g., 6–14 mesh).
- Screen material shall provide a minimum of 27% open area.

During the dewatering process, a qualified biologist or fish rescue team will remain onsite to observe the process and remove additional fish using the rescue procedures described above.

E.1.8.5 *Contingency Plans*

Where fish rescue and salvage operations cannot be conducted effectively or safely by fish rescue workers, it may be necessary to begin the dewatering process prior to fish rescue. During the dewatering process, a qualified biologist or fish rescue team will be onsite with the aim of minimizing the number of fish that become trapped in isolated areas or impinged on pump screen(s) or isolation nets, based on the professional judgment of the onsite fish biologist and the terms and conditions of the incidental take permit. In the event that the proposed methods are found to be insufficient to avoid undue losses of fish, the qualified biologist will modify these methods or implement alternative methods to minimize subsequent losses.

E.1.8.6 *Final Inspections and Reporting*

Upon dewatering to water depths at which neither electrofishing nor seining can effectively occur (e.g., less than 3 inches [0.1 meter]), the fish rescue team will inspect the dewatered areas to locate any remaining fish. Collection by dip net, data recording, and relocation will be performed as necessary according to the procedures outlined in Section 3.F.2.8.3, *Electrofishing*. The fish rescue team will notify the contractor when the fish rescue has been completed and construction can recommence. The results of the fish rescue and salvage operations (including date, time, location, comments, method of capture, fish species, number of fish, approximate age, condition, release location, and release time) will be reported to the appropriate fish and wildlife agencies, as specified in the pertinent permits**.**

E.1.9 AMM9 Underwater Sound Control and Abatement Plan

Reclamation will develop and implement an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed species of fish, particularly the underwater noise effects associated with impact pile driving activities. Potential underwater noise effects on listed species from impact pile driving will be avoided and minimized by regulating the period during which impact pile driving is permitted and by controlling and/or abating underwater noise generated during impact pile driving.

The underwater sound control and abatement plan will be provided to the appropriate fish and wildlife agencies for their review and approval prior to implementation of any in-water impact pile driving activities. The plan will evaluate the potential effects of underwater noise on listed species of fish in the context of applicable and interim underwater noise thresholds established for disturbance and injury of fish (California Department of Transportation 2009). The thresholds include the following.

- Injury threshold for fish of all sizes includes a peak sound pressure level of 206 decibels (dB) relative to 1 micropascal.
- Injury threshold for fish less than 2 grams is 183 dB relative to 1 micropascal cumulative sound exposure level, and 187 dB relative to 1 micropascal cumulative sound exposure level for fish greater than or equal to 2 grams.
- Disturbance threshold for fish of all sizes is 150 dB root mean square relative to 1 micropascal.

The specific number of pilings that will be driven per day with an impact pile driver, and thus the number of pile strikes per day, will be defined as part of the design of project elements that require pilings.

The sound control and abatement plan will restrict in-water work to the in-water work windows specified in specified in AMM2 *Construction Best Management Practices*.

The underwater noise generated by impact pile driving will be abated using the best available and practicable technologies. Examples of such technologies include, but are not limited to, the use of cast-in-drilled-hole rather than driven piles; use of vibratory rather than impact pile driving equipment; using an impact pile driver to proof piles initially placed with a vibratory pile driver; noise attenuation using pile caps (e.g., wood or micarta), bubble curtains, air-filled fabric barriers, or isolation piles; or installation of piling-specific cofferdams. Specific techniques to be used will be selected based on site-specific conditions.

In addition to primarily using vibratory pile driving methods and establishing protocols for attenuating underwater noise levels produced during in-water construction activities, Reclamation will develop and implement operational protocols for when impact pile driving is necessary. These operational protocols will be used to minimize the effects of impact pile driving on listed species of fish. These protocols may include, but not be limited to, the following: monitoring the in-water work area for fish that may be showing signs of distress or injury as a result of pile driving activities and stopping work when distressed or injured fish are observed; initiating impact pile driving with a “soft-start,” such that pile strikes are initiated at reduced impact and increase to full impact over several strikes to provide fish an opportunity to move out of the area; restricting impact pile driving activities to specific times of the day and for a specific duration to be determined through coordination with the fish and wildlife agencies; and, when more than one pile driving rig is employed, ensure pile driving activities are initiated in a way that provides an escape route and avoids “trapping” fish between pile drivers in waters exposed to underwater noise levels that could potentially cause injury. These protocols are expected to avoid and minimize the overall extent, intensity, and duration of potential underwater noise effects associated with impact pile driving activities.

E.1.10 AMM10 Methylmercury Management

Tidal and other habitat restoration under the proposed action has the potential to result in increased availability of mercury, and specifically the bioavailable form methylmercury, to the foodweb in the Delta and river systems where restoration would occur. Due to the complex and very site-specific factors that will determine if mercury becomes mobilized into the foodweb, AMM10 *Methylmercury Management* is included to provide for site-specific evaluation for each restoration project. AMM10 will be implemented in coordination with other similar efforts to address mercury in the Delta and other waterways, and specifically with the DWR Mercury Monitoring and Analysis Section, as further described below.

This AMM will promote the following actions.

- Assessment of pre-restoration conditions to determine the risk that the project could result in increased mercury methylation and bioavailability
- Definition of design elements that minimize conditions conducive to generation of methylmercury in restored areas
- Definition of strategies that can be implemented to monitor and minimize actual postrestoration creation and mobilization of methylmercury into environmental media and biota

The restoration design will always focus on the ecosystem restoration objectives and design elements to mitigate mercury methylation that will not interfere with restoration objectives. Design elements that help to mitigate mercury methylation will be integrated into site-specific restoration designs based on site conditions, community type (tidal marsh, nontidal marsh, floodplain, riverine habitats), and potential concentrations of mercury in pre-restoration sediments. Strategies to minimize postrestoration creation and mobilization of methylmercury can be applied where site conditions indicate a high probability of methylmercury generation and effects on listed species.

E.1.10.1 *Implementation*

AMM10 will be developed and implemented in coordination with the Sacramento-San Joaquin Delta Methylmercury Total Maximum Daily Load (Methylmercury TMDL) (Central Valley Regional Water Quality Control Board 2011a) and Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary (Mercury Basin Plan Amendments)(Central Valley Regional

Water Quality Control Board 2010 and 2011). AMM10 will also be implemented to meet requirements of the U.S. Environmental Protection Agency (EPA) or the California Department of Toxic Substances Control actions.

The DWR Mercury Monitoring and Evaluation Section is currently working on DWR's compliance with the Methylmercury TMDL and Mercury Basin Plan Amendments. The Methylmercury TMDL programs are responsible for developing measures to control methylmercury generation and loading into the Delta in accordance with Methylmercury TMDL goals. Phase I emphasizes studies and pilot projects to develop and evaluate management practices to control methylmercury. Phase I (effective October 2011) will be underway for the next 7 years, with an additional 2 years to evaluate Phase I results and plan for Phase II. Phase II involves implementation of mercury control measures.

The DWR Mercury Monitoring and Evaluation Section is required as part of Phase I to submit final reports that present the results and descriptions of methylmercury control options, their preferred methylmercury controls, and proposed methylmercury management plan(s) (including implementation schedules) for achieving methylmercury allocations. Results will be integrated into Project-Specific Mercury Management Plans, which will be developed for each tidal wetland restoration project. The Plans will include the components listed below.

- A brief review of available information on levels of mercury expected in site sediments/soils based on proximity to sources and existing analytical data.
- A determination if sampling for characterization of mercury concentrations
- A plan for conducting the sampling, if characterization sampling is recommended.
- A determination of the potential for the restoration action to result in increased mercury methylation
- If a potential for increased mercury methylation under the restoration action is identified, the following will also be included:
    - Identification of any restoration design elements, mitigation measures, adaptive management measures that could be used to mitigate mercury methylation, and the probability of success of those measures, including uncertainties
    - Conclusion on the resultant risk of increased mercury methylation, and if appropriate, consideration of alternative restoration areas

Because methylmercury is an area of active research in the Delta and elsewhere in the Central Valley, each new project-specific methylmercury management plan will be updated based on the latest information about the role of mercury in Delta and other ecosystems or methods for its characterization or management. Results from monitoring of methylmercury in previous restoration projects will also be incorporated into subsequent project-specific methylmercury management plans.

In each of the project-specific methylmercury management plans developed under AMM10, relevant findings and mercury control measures identified as part of TMDL Phase I control studies will be considered and integrated into restoration design and management plans.

E.1.11 AMM11 Design Standards and Building Codes

Reclamation will ensure that the standards, guidelines, and codes listed below (or the most current applicable version at the time of implementation), which establish minimum design criteria and construction requirements for project facilities, will be followed by the design engineers. The design engineers will also follow any other standards, guidelines, and code requirements not listed below that are promulgated during the detailed design and construction and can feasibly be incorporated into the work. Reclamation will also ensure that the design specifications are properly executed during construction. The minimum design and construction requirements act as performance standards for engineers and construction contractors. Because the design and construction parameters of these codes and standards are intended to reduce the potential for structural damage or risks to human health due to the geologic and seismic conditions that exist at construction sites, project area and in the surrounding region, as well as climate change, an uncontrolled release of water, a flood event, and accidents during construction, their use is considered an environmental commitment of Reclamation. These standards, guidelines, and codes include the following.

- California Code of Regulations, Title 8.
- DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- State of California Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team, Sea-Level Rise Interim Guidance Document, 2010.
- U.S. Army Corps of Engineers (Corps, CESPK-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- USACE Engineering and Design—Structural Design and Evaluation of Outlet Works, EM 1110-2-2400, 2003.
- USACE Slope Stability, EM 1110-2-1902, 2003.
- USACE Engineering and Design—Settlement Analysis, EM 1110-1-1904, 1990.
- USACE Engineering and Design—Design of Pile Foundations, EM 1110-2-2906, 1991.
- U.S. Department of the Interior and U.S. Geological Survey Climate Change and Water Resources Management: A Federal Perspective, Circular 1331.

E.1.12 AMM12 Transmission Line Design and Alignment

The location and design of the proposed any new transmission lines will be in accordance with electric and magnetic field guidance adopted by the California Public Utility Commission (2006) *EMF Design Guidelines for Electrical Facilities*. The guidelines describe the routine magnetic field reduction measures that all regulated California electric utilities will consider for new and upgraded transmission line and transmission substation construction.

The alignment of proposed transmission lines will be designed to avoid sensitive terrestrial and aquatic habitats when siting poles and towers, to the maximum extent feasible. Lines will be co-located where feasible, when such co-location would minimize effects on sensitive resources. In cases where this is not feasible, Reclamation will ensure that impacts are minimized to the greatest degree feasible, and disturbed areas will be returned as near as reasonably and practically feasible to preconstruction conditions by reestablishing surface conditions through careful grading, reconstructing features such as irrigation and drainage facilities, and replanting vegetation and crops and/or compensating farmers for crops losses. Temporary transmission lines will be designed to avoid removal of wetted acres of vernal pools and alkali seasonal wetlands.

Further, tower and pole placement will avoid existing structures to the extent feasible. Where poles or towers are to be constructed in agricultural areas, the following BMPs will be implemented as applicable and feasible.

- Use single-pole structures instead of H-frame or other multiple-pole structures to reduce the potential for land impacts and minimize weed-encroachment issues.
- Locate new transmission lines along existing transmission line corridors to the extent feasible.
- Use special transmission designs to span existing irrigation systems or, if necessary, reconfigure the irrigation system at the utilities' expense, if feasible.

For stringing transmission lines between 230 kV towers, cranes and helicopters will be used. Helicopters may fly as low as the top of the transmission towers, which may be as low as 60 feet. They will take-off and land in the right of ways obtained for transmission line construction, within the corridor identified on the construction footprint, or on other property obtained for the project, and identified on the project construction footprint, or designated existing helicopter pads (airstrips). They will not be allowed to land in sensitive habitat.

E.1.13 AMM13 Noise Abatement

In addition to the underwater sound control and abatement plan (AMM9), Reclamation and contractors hired to construct any components of proposed facilities will implement a noise abatement plan to avoid or reduce potential in-air noise impacts related to construction, maintenance, and operations. As applicable, the following components will be included in the plan.

E.1.13.1 *Construction and Maintenance Noise*

- To the extent feasible, the contractor will employ best practices to reduce construction noise during daytime and evening hours (7:00 a.m. to 10:00 p.m.) such that construction noise levels do not exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour) at the nearest residential land uses.
- Limit construction during nighttime hours (10:00 p.m. to 7:00 a.m.) such that construction noise levels do not exceed 50 dBA L_{max}[2] at the nearest residential land uses. Limit pile driving to daytime hours (7 a.m. to 7 p.m.).
- In the event of complaints by nearby residents due to construction noise generated during nighttime hours, the contractor will monitor noise levels intermittently between 10:00 p.m. to 7:00 a.m. at the property line of the nearest residential use. In the event that construction noise during nighttime hours exceeds 50 dBA L_{max}, the construction contractor will cease nighttime construction activity in the area until sound-attenuating mitigation measures, such as temporary sound walls, are implemented, and nighttime construction noise at the nearest residential use is reduced to a level of 50 dBA L_{max}or lower.
- Locate, store, and maintain portable and stationary equipment as far as possible from nearby residents.
- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
- Route truck traffic in order to reduce construction noise impacts and traffic noise levels at noise-sensitive land uses (i.e., places where people reside, schools, libraries, and places of worship).

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[2] L_{max} is the maximum sound level measured for a given interval of time.

- To the extent feasible, schedule construction activities so that the loudest noise events, such as blasting, occur during peak traffic commute hours.
- Limit offsite trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m. to minimize impacts on nearby residences.

E.1.13.2 *Operation Noise*

Facilities will be designed and constructed such that facility operation noise levels at nearby residential land uses do not exceed 50 dBA L_{eq} during daytime hours (7:00 a.m. to 10:00 p.m.) and 45 dBA L_{eq} during nighttime hours (10 p.m. to 7 a.m.). Acoustical measures such as terrain shielding, enclosures, and acoustical building treatments will be incorporated into the facility design to meet this performance standard.

E.1.14 AMM14 Hazardous Materials Management

Reclamation will ensure that each contractor responsible for site work under the proposed action will develop and implement a hazardous materials management plan (HMMP) before beginning construction. It is anticipated that multiple HMMPs will be prepared for the various construction sites, each taking into account site-specific conditions such as hazardous materials present onsite and known historical site contamination. A database on historical instances of contamination and results of any field inspections regarding the presence of hazardous chemicals will be maintained. The HMMPs will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities (e.g., intake pumping plants, maintenance facilities); phone numbers of applicable city, county, state, and federal emergency response agencies; primary, secondary, and final cleanup procedures; emergency-response procedures in case of a spill; and other applicable information. The HMMPs will include appropriate practices to reduce the likelihood of a spill of toxic chemicals and other hazardous materials during construction and facilities operation and maintenance. A specific protocol for the proper handling and disposal of hazardous materials will be established before construction activities begin and will be enforced by Reclamation.

The HMMPs will include, but not be limited to, the following measures or practices.

- Fuel, oil, and other petroleum products will be stored only at designated sites.
- Hazardous materials containment containers will be clearly labeled with the identity of the hazardous materials contained therein, handling and safety instructions, and emergency contact.
- Storage, use, or transfer of hazardous materials in or near wet or dry streams will be consistent with California Fish and Game Code (Section 5650) and/or with the permission of CDFW.
- Material Safety Data Sheets will be made readily available to the contractor’s employees and other personnel at the work site.
- The accumulation and temporary storage of hazardous wastes will not exceed 90 days.
- Soils contaminated by spills or cleaning wastes will be contained and removed to an approved disposal site.
- Hazardous waste generated at work sites, such as contaminated soil, will be segregated from other construction spoils and properly handled, hauled, and disposed of at an approved disposal facility by a licensed hazardous waste hauler in accordance with state and local regulations. The contractor will obtain permits required for such disposal.

- Emergency spill containment and cleanup kits will be located at the facility site. The contents of the kits will be appropriate to the type and quantities of chemical or goods stored at the facility.

E.1.15 AMM15 Construction Site Security

To ensure adequate construction site security, Reclamation or their contractors will arrange to provide for 24-hour onsite security personnel. Security personnel will monitor and patrol construction sites, including staging and equipment storage areas. Security personnel will serve as the first line of defense against criminal activities and nuisances at construction sites. Private patrol security operators hired to provide site security will have the appropriate licenses from the California Bureau of Security and Investigative Services. Individual security personnel will have a minimum security guard registration license that meets the California Bureau of Security and Investigative Services requirements for training and continuation training as required for that license. All security personnel will also receive environmental training similar to that of onsite construction workers so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.

Security operations and field personnel will be given the emergency contact phone numbers of environmental response personnel for rapid response to environmental issues resulting from vandalism or incidents that occur when construction personnel are not onsite. Security operations will also maintain a contact list of backup support from city police, county sheriffs, California Highway Patrol, water patrols (such as the Contra Costa County Marine Patrol), helicopter response, and emergency response (including fire departments, ambulances/emergency medical technicians). The appropriate local and regional contact list will be made available to security personnel by Reclamation or their contractors, as will the means to make that contact via landline phones, mobile phones, or radios. When on patrol, security personnel will always have the ability to contact backup using mobile phones or two way radios. Security personnel who are on patrol will have the appropriate geographic contact list for their location and the ability to summon appropriate backup or response via the security patrol local dispatch site or outside authorities.

E.1.16 AMM16 Fugitive Dust Control

Reclamation or their contractors will implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust. Although the following measures are outlined in the Sacramento Metropolitan Air Quality Management District's (SMAQMD) CEQA guidelines, they are required for the entirety of the construction area, including areas within the Bay Area Air Quality Management District (BAAQMD), San Joaquin Valley Air Pollution Control District (SJVAPCD), and Yolo-Solano Air Quality Management District (YSAQMD), and are sufficient to address BAAQMD, SJVAPCD, and YSAQMD fugitive dust control requirements. Reclamation or their contractors will ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedure is followed.

E.1.16.1 *Basic Fugitive Dust Control Measures*

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during general construction activities.

- Water will be applied to all exposed surfaces as reasonably necessary to prevent visible dust from leaving work areas. Frequency will be increased during especially dry or windy periods or in areas with a lot of construction activity. Exposed surfaces include (but are not limited to) soil piles, graded areas, unpaved parking areas, staging areas, and access roads.

- Cover or maintain at least 2 feet of freeboard space on haul trucks transporting soil, sand, or other loose material on the site. Any haul trucks that will be traveling along freeways or major roadways should be covered.
- Use wet power vacuum street sweepers to remove any visible trackout mud or dirt onto adjacent public roads at least once a day. Use of dry power sweeping is prohibited.
- Limit vehicle speeds on unpaved roads to 15 miles per hour.
- All roadway, driveway, sidewalk, and parking lot paving should be completed as soon as possible. In addition, building pads should be laid as soon as possible after grading unless seeding or soil binders, or other reasonable mitigation measures are used.

E.1.16.2 *Enhanced Fugitive Dust Control Measures for Land Disturbance*

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during soil disturbance activities.

- Water exposed soil with adequate frequency for continued moist soil. However, do not overwater to the extent that sediment flows off the site.
- Suspend excavation, grading, and/or demolition activity when wind speeds exceed 20 miles per hour.
- Install wind breaks (e.g., plant trees, solid fencing) on windward side(s) of construction areas.
- Plant vegetative ground cover (fast-germinating native grass seed) in disturbed areas as soon as possible after construction is completed. Water appropriately until vegetation is established.

E.1.16.3 *Measures for Entrained Road Dust*

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control entrained road dust from unpaved roads.

- Install wheel washers for all exiting trucks, or wash off all trucks and equipment leaving the site.
- Treat site accesses to a distance of 100 feet from the paved road with a 6- to 12-inch layer of wood chips, mulch, or gravel to reduce generation of road dust and road dust carryout onto public roads.
- Post a publicly visible sign with the telephone number and person to contact at the lead agency regarding dust complaints. This person will respond and take corrective action within 48 hours. The phone number of the air quality management district will also be visible to ensure compliance.

E.1.16.4 *Measures for Concrete Batching*

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during concrete batching activities.

- Implementation of fugitive dust control measures to achieve a 70% reduction in dust from concrete batching.
- Implementation of fugitive dust control measures to achieve an 80% reduction in dust from aggregate and sand pile erosion at the concrete batch plants.

- Use of a hood system vented to a fabric filter/baghouse during cement delivery and hopper and central mix loading.

E.1.17 AMM17 Notification of Activities in Waterways

Similar to the requirements specified in the barge operations plan (AMM7), fish rescue and salvage plan (AMM8), and underwater sound control and abatement plan (AMM9), before in-water construction or maintenance activities begin, Reclamation will ensure notification of appropriate fish and wildlife agency representatives when these activities could affect water quality or aquatic species. The notification procedures will follow stipulations included in applicable permit documents for the construction operations. However, in general, the notification information will include site location(s), schedules, and work activities. Information on detours will include site-specific details regarding any temporary partial channel closures, including contacting the U.S. Coast Guard, boating organizations, marina operators, city or county parks departments, and the California Department of Pesticide Regulation, where applicable.

E.2 Terrestrial Species Avoidance and Minimization Measures

The species-specific avoidance and minimization measures (AMMs) described here have been developed to avoid and minimize effects that could result from the proposed action on listed species covered by the Biological Assessment (BA) and describe offsetting measures intended to compensate for adverse effects on listed species of wildlife. These AMMs will be implemented as part of the proposed action[3]. Table E-3 below briefly summarizes the species-specific AMMs.

Table E-3. Summary of the Species-Specific Avoidance and Minimization Measures

Number	Title	Summary
AMM18	Riparian Woodrat and Brush Rabbit	
AMM19	Riparian Brush Rabbit	
AMM20	Salt Marsh Harvest Mouse	
AMM21	Giant Garter Snake	
AMM22	California Ridgway’s Rail	
AMM23	Least Bell’s Vireo	
AMM24	Western Yellow-Billed Cuckoo	
AMM25	Valley Elderberry Longhorn Beetle	
AMM26	Suisun Thistle and Soft Bird’s-Beak	
AMM27	Vernal Pool Fairy Shrimp and Vernal Pool Tadpole Shrimp	
AMM28	California Tiger Salamander	
AMM29	California Least Tern	

[3] Consistent with the environmental review process under various regulatory requirements, the proposed action including these AMMs might require revision as consultation progresses.

E.2.1 AMM18 Riparian Woodrat and Riparian Brush Rabbit

AMMs for riparian woodrat and riparian brush rabbit will be implemented for projects occurring within suitable habitat. Within the action area, based on the known distribution of the species, suitable habitat is defined to include the areas within the legal Delta along San Joaquin and Stanislaus Rivers south of SR 4 and Old River Pipeline. Within this area, suitable riparian habitat includes the vegetation types that comprise a dense, brushy understory shrub layer with a minimum patch size of 0.05 acres. Riparian brush rabbit grassland habitat includes grasslands with a minimum patch size of 0.05 acres that are adjacent to riparian brush rabbit riparian habitat.

A qualified biologist will conduct a field evaluation of suitable habitat for both species for all covered activities that occur within the defined area for these species' habitat as described above. If the project cannot fully avoid effects on suitable habitat, the following measures will be required.

- A qualified biologist will assess habitat suitability for both species. If the qualified biologist determines the habitat to be suitable for the species, then Reclamation will avoid disturbing suitable habitat while accessing restoration sites (i.e., access to enhancement sites for in-stream activities such as gravel placement).
- If a habitat or floodplain restoration component would disturb suitable habitat, Reclamation will assume presence or conduct protocol-level surveys according to the USFWS *Draft Habitat Assessment Guidelines and Survey Protocol for the Riparian Brush Rabbit and the Riparian Woodrat* (Appendix K).
- If occupied riparian woodrat or riparian brush rabbit habitat is present, or the habitat is assumed to be occupied, Reclamation will redesign the project to avoid occupied habitat. Avoidance requires the following buffers and avoidance measures:
    - Establish minimum 250-foot nondisturbance buffers between project activities and suitable riparian habitat that is occupied or assumed to be occupied. The nondisturbance buffer is not necessary for access to restoration sites provided existing access roads are used.
    - Establish a 1,400-foot buffer between any lighting and suitable riparian habitat that is occupied or assumed to be occupied.
    - Screen all lights and direct them down toward work activities away from riparian habitat that is occupied or assumed to be occupied. A biological construction monitor will ensure that lights are properly directed at all times.
    - Operate portable lights at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's *Report 498: Illumination Guidelines for Nighttime Highway Work*.
- If the suitable habitat is determined through surveys to be unoccupied, Reclamation will implement the following measures to minimize long-term effects on the habitat so that it may provide for the recovery of the species. No more than 45 acres of suitable, unoccupied riparian habitat and 30 acres of adjacent grasslands may be permanently removed by levee construction in the San Joaquin River watershed. No more than 35 acres of suitable riparian habitat and 20 acres of adjacent grassland habitat may be temporarily removed for levee construction in the San Joaquin watershed. No more than ten acres of suitable, unoccupied riparian habitat may be affected in the Stanislaus River watershed.
    - Floodplain restoration projects will be designed to minimize the removal of mature oaks in areas providing suitable habitat for the riparian woodrat.

- o Include refugia within the restored floodplains to provide refugia from flood events for any individuals of these species that may come to occupy the area.
- o Offset any unavoidable loss of suitable riparian habitat through restoration at a 3:1 ratio, using the following restoration design measures:
  - Meets specific ecological requirements for the species as described in Appendix J, *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat*)
  - Is adjacent to, or facilitates connectivity with, existing occupied or potentially occupied habitat.
- o Reclamation may substitute all or a portion of the riparian restoration requirement with preservation of existing occupied riparian brush rabbit riparian habitat.
- o Reclamation will offset loss of grasslands adjacent to suitable habitat resulting from floodplain restoration by protecting grasslands adjacent to suitable riparian habitat, on the landward side of the levee to provide refugia from flood events.

E.2.2 AMM19 Riparian Brush Rabbit

E.2.2.1 *Habitat Description*

Avoidance and minimization measures Riparian brush rabbit suitable habitat is defined as large patches (at least 0.05 acre) of brushy understory shrub layer of valley riparian forests. Most occupied sites are in riparian settings with an open overstory canopy or savannah-like settings that support patches of low-growing wild rose, wild grape, blackberry, and coyote bush, where the brush rabbits move through the dense brush and thickets by creating tunnels through the vegetation. Riparian forests that support a closed overstory canopy generally lack sufficient understory shrubs to support riparian brush rabbits (Williams 1988; U.S. Fish and Wildlife Service 1998). SuiTable Erassland habitat consists of grassy patches very near to dense brush, which provide foraging opportunities near cover (Kelly et al. 2011). Riparian brush rabbit suitable habitat is geographically constrained to the mainstem of the San Joaquin Old River from Highway 4 south to the southern edge of the action area (legal Delta), on the intersection of Old River and Highway 4 south to the confluence with the mainstem of the San Joaquin River, Thomas Paine Slough, and Paradise CutWithin the action area, based on the known distribution of the species, suitable habitat is defined to include the area south of SR 4 and Old River Pipeline.

E.2.2.2 *Avoidance and Minimization Measures*

E.2.2.2.1 <u>Spawning Habitat Enhancement</u>

Reclamation will implement the following measures to avoid and minimize noise and lighting related effects on riparian brush rabbit:

- Establish a 1,200-foot nondisturbance buffer between any project activities and suitable riparian habitat.

E.2.3 AMM20 Salt Marsh Harvest Mouse

Where suitable salt marsh harvest mouse habitat has been identified within a tidal restoration work area or within 100 feet of a tidal restoration work area where ground-disturbing activities will occur (e.g., at a levee breach or grading location) a CDFW- and USFWS-approved biologist will conduct pre-construction surveys for the mouse prior to ground disturbance. If a mouse is discovered, tidal restoration activities near the mouse will cease until wildlife staff can be contacted and a relocation plan can be developed). Prior to tidal restoration ground-disturbing activities, vegetation will first be removed with nonmechanized hand tools (e.g., goat or sheep grazing, or in limited cases where the biological monitor can confirm that there is no risk of harming salt marsh harvest mouse, hoes, rakes, and shovels may be used) to allow salt marsh harvest mouse to passively move out of the location. Vegetation must be cleared to bare ground and removed from the work area including roads, work area, etc. The upper six inches of soil excavated within salt marsh harvest mouse habitat will be stockpiled and replaced on top of backfilled material. Vegetation will be removed under supervision of a CDFW- and USFWS-approved biological monitor familiar with salt marsh harvest mouse. Vegetation removal will start at the edge farthest from the salt marsh and work its way towards the salt marsh. This method of removal provides cover for salt marsh harvest mouse and allows them to move towards the salt marsh as vegetation is being removed.

Temporary exclusion fencing will be placed around a defined tidal restoration work area before construction activities start and immediately after vegetation removal. The fence should be made of material that does allow a salt marsh harvest mouse to pass through and should be buried to a depth of 2 inches so that mice cannot crawl under the fence. Supports for the fence must be placed on the inside of the exclusion area. Prior to the start of daily activities during initial ground disturbance, the CDFW- and USFWS-approved biologist will inspect the salt marsh harvest mouse-proof boundary for holes or rips. The work area will also be inspected to ensure no mice are trapped inside. Any mice found along or outside the fence will be closely monitored until they move away from the construction site. Tidal restoration work will be scheduled to avoid extreme high tides (6.5 feet or above, as measured at the Golden Gate Bridge) to allow for salt marsh harvest mouse to more easily move to higher grounds.

The CDFW- and USFWS-approved biologist with previous salt marsh harvest mouse experience will be on site during construction activities related to tidal restoration in suitable mouse habitat. The biologist will document compliance with the project permit conditions and avoidance and conservation measures. The approved biologist has the authority to stop tidal restoration activities if any of the requirements associated with these measures is not being fulfilled. If the CDFW- and USFWS-approved biologist requests work stoppage because of take of any listed species, CDFW and USFWS staff will be notified within one day by e-mail or telephone.

E.2.4 AMM21 Giant Garter Snake

E.2.4.1 *Habitat Definition*

Giant garter snake suitable habitat is defined as [*to be developed*].

E.2.4.2 *Avoidance and Minimization Measures*

During project implementation and prior to project construction, Reclamation, in agreement with CDFW and USFWS, will:

- When each site is available for surveys, a giant garter snake biologist, approved by USFWS and CDFW, will then delineate giant garter snake habitat at each project site, based on the definition of suitable habitat, including both aquatic and upland habitat.
- To the greatest extent possible, identified and delineated habitat will be completely avoided.

When avoidance is not possible, the following measures are required:

- Initiate construction between May 1 and October 1 within suiTable EGS upland habitat, which corresponds with the snake's active period. Work in GGS upland habitat may also occur between October 2 and November 1 or between April 1 and May 1 if ambient temperatures exceed 75°F during construction activities and maximum daily maximum daily temperatures have exceeded 75°F for a least 3 consecutive days immediately preceding work. During these periods GGS are more likely to be active in aquatic habitats and less likely to be found in upland habitats.To the extent practicable, conduct all activities within paved roads, farm roads, road shoulders, and similarly disturbed and compacted areas; confine ground disturbance and habitat removal to the minimal area necessary to facilitate construction activities. For construction activities and any conveyance facility maintenance involving heavy equipment, giant garter snake aquatic and upland habitat that can be avoided will be clearly delineated on the work site, with high-visibility fencing and signage identifying these areas as sensitive. The fencing will be installed before equipment is moved on site and before any ground-disturbing activities begin. The purpose of the fencing is to prevent construction activities from encroaching into sensitive habitat areas and not intended to exclude animals. To minimize the potential for snakes and other ground-dwelling animals from being caught in the construction fencing, the fencing will be placed with at least a 6-inch gap between the ground and the bottom of the fencing to allow animals to pass under. .
- All construction personnel, and personnel involved in operations and maintenance in or near giant garter snake habitat, will attend worker environmental awareness training as described in *AMM1 Worker Awareness Training*. This training will include instructions to workers on how to recognize giant garter snakes, their habitat(s), and the nature and purpose of protection measures.
- Within 24 hours prior to construction activities or maintenance activities requiring heavy equipment within giant garter snake habitat, a USFWS-approved biologist will survey all areas planned for disturbance and at least 50 feet outside the disturbance area where giant garter snake could be present. The surveyor will inspect all burrows, soil cracks, and crevices that could be used by giant garter snake. To the extent that these habitat features can be avoided within the work area, they will be flagged and the locations will be provided to the biological monitor. This survey of the work area will be repeated if a lapse in construction activity of two weeks or greater occurs during the giant garter snake inactive period (October 1 - May 1) or if the lapse in construction activity is more than 12 hours during the active period (May 1–October 1). If a giant garter snake is encountered during surveys or construction, cease activities until appropriate corrective measures have been completed, it has been determined that the giant garter snake will not be harmed, or the giant garter snake has left the work area.
- For all construction activities that occur in giant garter snake habitat that could result in injury or mortality of snakes (e.g., movement of heavy equipment, excavation of soil, rock, or existing structures, grading, vegetation removal), a USFWS-approved biologist will be present to monitor these activities. As work is performed, the biologist will visually scan work areas, under equipment, and excavated materials for giant garter snakes. The biologists will also help guide access and construction work around wetlands, active rice fields, and other sensitive habitats capable of supporting giant garter snake, to minimize habitat disturbance and risk of injuring or killing giant garter snakes.
- Report all observations of giant garter snakes to the USFWS-approved biological monitor. If a giant garter snake is observed in the work area, the monitor will have the authority to stop work in the immediate vicinity of the snake. If possible, the snake will be allowed to leave the work area on its own volition and the monitor will remain in the area until the snake is safely out of harm's way. A giant garter snake may be captured and relocated out of the work area with prior authorization from USFWS and by an individual with the appropriate handling permit. The snake will be relocated to suitable habitat at least 200 feet from the work area.

- Maintain all construction and operations and maintenance equipment to prevent leaks of fuel, lubricants, and other fluids and use extreme caution when handling and or storing chemicals (such as fuel and hydraulic fluid) near waterways, and abide by all applicable laws and regulations. Follow all applicable hazardous waste best management practices (BMPs) and keep appropriate materials on site to contain, manage, and clean up any spills as described in *AMM5 Spill Prevention, Containment, and Countermeasure Plan.*
- Conduct service and refueling procedures in uplands in staging areas and at least 200 feet away from waterways when practicable. See also *AMM5, Spill Prevention, Containment, and Countermeasure Plan*.
- During construction and operation and maintenance activities in and near giant garter snake habitat, employ erosion (non-monofilament silt fence), sediment, material stockpile, and dust control (BMPs on site). Avoid fill or runoff into wetland areas or waterways to the extent practicable.
- Return temporary work areas to pre-existing contours and conditions upon completion of work. Where re-vegetation and soil stabilization are necessary in non-agricultural habitats, revegetate with appropriate non-invasive native plants at a density and structure similar to that of pre-construction conditions. Restoration of aquatic vegetation in GGS aquatic habitat and annual grassland within GGS upland habitat will be detailed in a mitigation and monitoring plan that will be reviewed and approved by USFWS prior to the start of construction. Habitat will be restored within one season (defined as May 1–October 1).
- Properly contain and remove from the worksite all trash and waste items generated by construction and crew activities to prevent the encouragement of predators such as raccoons and coyotes from occupying the site.
- Permit no pets, campfires, or firearms at the worksite.
- Store equipment in designated staging area areas at least 200 feet away from giant garter snake aquatic habitat to the extent practicable.
- Confine any vegetation clearing to the minimum area necessary to facilitate construction activities.
- Limit vehicle speed to 10 miles per hour (mph) on access routes (except for public roads and highways) and within work areas that are within 200 feet of giant garter snake aquatic habitat but not protected by exclusion fencing to avoid running over giant garter snakes.
- Visually check for giant garter snake under vehicles and equipment prior to moving them. Cap all materials onsite (conduits, pipe, etc.), precluding wildlife from becoming entrapped. Check any crevices or cavities in the work area where individuals may be present including stockpiles that have been left for more than 24 hours where cracks/crevices may have formed.

For activities that will occur within the giant garter snake inactive season (October 2 through April 30) where there has not been at least 3 consecutive days when ambient air temperatures exceeded 75°F, and activities will last more than two weeks, Reclamation will implement the following additional avoidance and minimization measures.

- For proposed activities that will occur within suitable aquatic giant garter snake habitat, during the active giant garter snake season (May 1 through October 1) prior to proposed construction activities that will commence during the inactive period, and when unavoidable, all aquatic giant garter snake habitat will be dewatered for at least 14 days prior to excavating or filling the dewatered habitat. De-watering is necessary because aquatic habitat provides prey and cover for giant garter snake; de-watering serves to remove the attractant, and increase the likelihood that giant garter snake will move to other available habitat. Any deviation from this measure will be done in coordination with, and with approval of, the U.S. Fish and Wildlife Service.

- Following de-watering of aquatic habitat, all potential impact areas that provide suitable aquatic or upland giant garter snake habitat will be surveyed for giant garter snake by the USFWS-approved biologist. If giant garter snakes are observed, they will be passively allowed to leave the potential impact area, or the USFWS will be consulted to determine the appropriate course of action for removing giant garter snake from the potential impact area.

Maintenance activities such as vegetation and rodent control, embankment repair, and channel maintenance will occur at conveyance facilities with permanent structures (e.g., NDD, pumping plant, etc.). The following avoidance and minimization measures will be applied to maintenance activities in suitable aquatic habitat and uplands within 200 feet of suitable aquatic habitat, to minimize effects on the giant garter snake.

- Vegetation control will take place during the active period (May 1 through October 1) when snakes are able to move out of areas of activity.
- Trapping or hunting methods will be used for rodent control, rather than poison bait. All rodent control methods will be approved by USFWS. If trapping or other non-poison methods are ineffective, the USFWS will be consulted to determine the best course of action.
- Movement of heavy equipment will be confined to outside 200 feet of the banks of giant garter snake aquatic habitat to minimize habitat disturbance.
- All construction personnel, and personnel involved in operations and maintenance in or near giant garter snake habitat, will attend worker environmental awareness training as described in Appendix 3.F *General Avoidance and Minimization Measures*, *AMM1 Worker Awareness Training*. This training will include instructions to workers on how to recognize giant garter snakes, their habitat(s), and the nature and purpose of protection measures.

Maintenance activities such as vegetation and rodent control, embankment repair, and channel maintenance will occur at conveyance facility and restoration sites with flexible locations (e.g., transmission line right of ways, restoration locations, etc.). The following avoidance and minimization measures will be applied to maintenance activities in suitable aquatic habitat, as delineated by an USFWS approved biologist, and uplands within 200 feet of suitable aquatic habitat, to minimize effects on the giant garter snake.

- Vegetation control will take place during the active period (May 1 through October 1) when snakes are able to move out of areas of activity.
- Trapping or hunting methods will be used for rodent control, rather than poison bait. All rodent control methods will be approved by USFWS. If trapping or other non-poison methods are ineffective, the USFWS will be consulted to determine the best course of action.
- Movement of heavy equipment will be confined to outside 200 feet of the banks of potential giant garter snake habitat to minimize habitat disturbance.
- Construction personnel will receive USFWS-approved worker environmental awareness training instructing workers to recognize giant garter snakes and their habitat.

Maintenance activities that cannot avoid giant garter snake habitat will implement the avoidance and minimization measures described in Section 3.4.5.5.2.1, *Activities with Fixed Locations*.

E.2.4.3 *Compensation for Unavoidable Effects*

Where identified and delineated giant garter snake habitat cannot be avoided, compensation for the permanent loss of the habitat will occur at a rate of 3:1 for each, aquatic and upland habitat. An estimated [*to be determined*] acres of giant garter snake habitat will be permanently affected.

E.2.5 AMM22 California Ridgway's Rail

If construction or restoration activities are necessary during the breeding season, preconstruction surveys for California Ridgway's rail will be conducted where suitable habitat for these species occurs within or adjacent to work areas. Surveys will be initiated sometime between January 15 and February 1. A minimum of four surveys will be conducted. The survey dates will be spaced at least 2 to 3 weeks apart and will cover the time period from the date of the first survey through the end of March and mid-April. This will allow the surveys to encompass the time period when the highest frequency of calls is likely to occur. These surveys will involve the following protocols (based on U.S. Fish and Wildlife Service 2005 and Evens et al. 1991), or other USFWS- and CDFW-approved survey methodologies that may be developed based on new information and evolving science, and will be conducted by biologists with the qualifications stipulated in the USFWS- or CDFW-approved methodologies.

- Listening stations will be established at 200-meter intervals along roads, trails, and levees that will be affected by covered activities.
- California Ridgway's rail vocalization recordings will be played at each station, and playing will cease immediately once a response is detected.
- For California Ridgway's rail, each listening station will be occupied for a period of 10 minutes, followed by 1 minute of playing California Ridgway's rail vocalization recordings, then followed by an additional minute of listening.
- Sunrise surveys will begin 60 minutes before sunrise and conclude 75 minutes after sunrise (or until presence is detected).
- Sunset surveys will begin 75 minutes before sunset and conclude 60 minutes after sunset (or until presence is detected).
- Surveys will not be conducted when tides are greater than 4.5 National Geodetic Vertical Datum or when sloughs and marshes are more than bankfull.
- California Ridgway's rail vocalizations will be recorded on a data sheet. A GPS receiver and compass will be used to identify surveys stations, angles to call locations, and call locations and distances. The call type, location, distance, and time will be recorded on a data sheet.

If California Ridgway's rail is present in the immediate construction area, the following measures will apply during construction activities.

- To avoid the loss of individual California Ridgway's rails, activities within or adjacent to the species' habitat will not occur within 2 hours before or after extreme high tides (6.5 feet or above, as measured at the Golden Gate Bridge), when the marsh plain is inundated. During high tide, protective cover for California Ridgway's rail is sometimes limited, and activities could prevent them from reaching available cover.
- To avoid the loss of individual California Ridgway's rails, activities within or adjacent to tidal marsh areas will be avoided during the rail breeding season (February 1 through August 31), unless surveys are conducted to determine rail locations and territories can be avoided.

- If breeding California Ridgway's rail are determined to be present, activities will not occur within 500 feet of an identified calling center (or a smaller distance if approved by USFWS and CDFW). If the intervening distance is across a major slough channel or across a substantial barrier between the rail calling center and any activity area is greater than 200 feet, it may proceed at that location within the breeding season.
- **Exception:** Inspection, maintenance, research, or nonconstruction monitoring activities may be performed during the California Ridgway's breeding season in areas within or adjacent to breeding habitat (within 500 or 200 feet, as specified above) with USFWS and CDFW approval and under the supervision of a qualified, permitted biologist.

E.2.6 AMM23 Least Bell's Vireo

E.2.6.1 *Habitat Definition*

AMMs for least Bell's vireo will be required for activities occurring within suitable habitat within the species' range. Prior to disturbing an area potentially supporting habitat for the species, a USFWS approved biologist will evaluate the area to identify suitable habitat. Suitable least Bell's vireo habitat is defined as [*to be developed*].

The following avoidance and minimization measures will be applied within suitable habitat for least Bell's vireo, within the species' range.

E.2.6.2 *Avoidance and Minimization Measures*

Activities with flexible locations will be located to avoid or minimize disturbance of least Bell's vireo suitable habitat within the species' range. The following measures will be required for project components unable to avoid least Bell's vireo habitat.

- Prior to construction, all suitable least Bell's vireo habitat within the species' range ([*Figure of species range overlaid on action area*) in the construction area will be surveyed.
- At least five surveys will be conducted in suitable habitats within 30 days of the onset of construction, with the last within 3 days of the onset of construction, by a qualified biologist with experience surveying and observing these species and familiar with their vocalizations.
- If an active nest site is present, a 500-foot no-disturbance buffer will be established around nest sites during the breeding season (generally, late February through late August).
- Disturbance to previous least Bell's vireo nesting sites (for up to 3 years since known nest activity) will also be avoided during the breeding season unless the disturbance is to maintain public safety. Least Bell's vireo uses previous nesting sites, and disturbance during the breeding season may preclude birds from using existing unoccupied nest sites.
- The required buffer may be reduced in areas where barriers or topographic relief are sufficient protect the nest from excessive noise or other disturbance. Implementation Office technical staff will coordinate with the fish and wildlife agencies and evaluate exceptions to the minimum no-disturbance buffer distance on a case-by-case basis.
- If occupied nests are identified, a qualified biologist will monitor construction activities in the vicinity of all active least Bell's vireo nests to ensure that covered activities do not affect nest success.

- If surveys find least Bell's vireos in the area where vegetation will be removed, vegetation removal will be done when the birds are not present.
- If an activity is to occur within 1,200 feet of least Bell's vireo habitat (or within 2,000 feet if pile driving will occur) during the breeding period for least Bell's vireos, the following measures will be implemented to avoid noise effects on least Bell's vireo.
    - Prior to the construction, a noise expert will create a noise contour map showing the 60 dBA noise contour specific to the type and location of construction to occur in the area.
    - During the breeding period for least Bell's vireo, a USFWS-approved biologist will survey any suitable habitat for least Bell's vireo within the 60 dBA noise contour on a daily basis during a two-week period prior to construction. While construction is occurring within this work window, the USFWS-approved biologist will conduct daily surveys in any suitable habitat where construction related noise levels could exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour). If a least Bell's vireo is found, sound will be limited to 60dBA in the habitat being used until the USFWS-approved biologist has confirmed that the bird has left the area.
- Limit pile driving to daytime hours (7:00 a.m. to 7:00 p.m.).
- Locate, store, and maintain portable and stationary equipment as far as possible from suitable least Bell's vireo habitat.
- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
- Route truck traffic in order to reduce construction noise impacts and traffic noise levels within 1,200 feet of suitable least Bell's vireo habitat during migration periods.
- Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m.
- Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.
- Operate portable lights at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's *Report 498: Illumination Guidelines for Nighttime Highway Work*.

E.2.6.3 *Compensation to Offset Impacts*

Reclamation will offset the loss of 32 acres of least Bell's vireo habitat through habitat creation or restoration at a 2:1 ratio, for a total of 64 acres of riparian habitat creation or restoration in the action area. Reclamation will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to USFWS approval.

E.2.7 AMM24 Western Yellow-Billed Cuckoo

E.2.7.1 *Habitat Definition*

AMMs for western yellow-billed cuckoo will be required for activities occurring within suitable habitat, or in the vicinity of suitable habitat. Suitable habitat for western yellow-billed cuckoo is defined as [*to be developed*]. Prior to disturbing an area potentially supporting habitat for the species, a USFWS approved biologist will evaluate the area to identify suitable habitat. The following avoidance and minimization measures will be applied within suitable habitat for western yellow-billed cuckoo.

E.2.7.2 *Avoidance and Minimization Measures*

Activities with flexible locations will be located to avoid or minimize disturbance of western yellow-billed cuckoo suitable habitat within the species' range. The following measures will be required for project components unable to avoid western yellow-billed cuckoo habitat.

Permanent or temporary loss of all suitable migratory habitat will be minimized by all activities associated with the proposed action through project design and no more than [TBD] acres habitat will be removed by activities associated with the proposed action.

- Prior to construction, all suitable western yellow-billed cuckoo habitat in the construction area will be surveyed.
- At least five surveys will be conducted in suitable habitats within 30 days of the onset of construction, with the last within 3 days of the onset of construction, by a qualified biologist with experience surveying and observing these species and familiar with their vocalizations.
- If an active nest site is present, a 500-foot no-disturbance buffer will be established around nest sites during the breeding season (generally, late February through late August).
- The required buffer may be reduced in areas where barriers or topographic relief are sufficient protect the nest from excessive noise or other disturbance. Implementation Office technical staff will coordinate with the fish and wildlife agencies and evaluate exceptions to the minimum no-disturbance buffer distance on a case-by-case basis.
- If occupied nests are identified, a qualified biologist will monitor construction activities in the vicinity of all active western yellow-billed cuckoo nests to ensure that covered activities do not affect nest success.
- If surveys find cuckoos in the area where vegetation will be removed, vegetation removal will be done when cuckoos are not present.
- If an activity is to occur within 1,200 feet of western yellow-billed cuckoo habitat (or within 2,000 feet if pile driving will occur) during the period of from June 15 through September 1[4], the following measures will be implemented to avoid noise effects on migrating western yellow-billed cuckoos.
    - Prior to the construction, a noise expert will create a noise contour map showing the 60 dBA noise contour specific to the type and location of construction to occur in the area.
    - During the period between June 15 and September 1, a USFWS-approved biologist will survey any suitable migratory habitat for yellow-billed cuckoos within the 60 dBA noise contour on a daily basis during a two-week period prior to construction. While construction is occurring within this work window, the USFWS-approved biologist will conduct daily surveys in any suitable habitat where construction related noise levels could exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour). If a yellow-billed cuckoo is found, sound will be limited to 60dBA in the habitat being used until the USFWS-approved biologist has confirmed that the bird has left the area.
- Locate, store, and maintain portable and stationary equipment as far as possible from suitable western yellow-billed cuckoo habitat.

[4] Based on occurrence data, this is the period within which yellow-billed cuckoos have been observed in the legal Delta.

- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
- Route truck traffic in order to reduce construction noise impacts and traffic noise levels within 1,200 feet of suitable western yellow-billed cuckoo migratory habitat during migration periods.
- Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m.
- Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.
- Operate portable lights at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's *Report 498: Illumination Guidelines for Nighttime Highway Work*.

E.2.7.3 *Compensation to Offset Impacts*

Reclamation will offset the loss of [*to be determined*] acres of western yellow-billed cuckoo migratory habitat through the creation or restoration at a 3:1 ratio, for a total of [*to be determined*] acres of migratory riparian habitat creation or restoration in USFWS-approved location. For restoration, Reclamation will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to USFWS approval.

E.2.8 AMM25 Valley Elderberry Longhorn Beetle

E.2.8.1 *Suitable Habitat*

Valley elderberry longhorn beetle (VELB) habitat is defined as elderberry shrubs within the action area. Elderberry shrubs in the action area could be found in riparian areas, along levee banks, grasslands, and in agricultural settings where vegetation is not being maintained (e.g., fence rows, fallow fields).

E.2.8.2 *Avoidance and Minimization Measures*

Activities with flexible locations will be located to avoid or minimize disturbance of western yellow-billed cuckoo suitable habitat within the species' range. The following measures will be required for project components unable to avoid valley elderberry longhorn beetle habitat.

Reclamation will avoid valley elderberry longhorn beetle critical habitat during implementation of the project components.

Preconstruction surveys for elderberry shrubs will be conducted within all facility footprints and areas within 165 feet by a biologist familiar with the appearance of valley elderberry longhorn beetle exit holes in elderberry shrubs. When possible, preconstruction surveys will be conducted in the calendar year prior to disturbance and will follow the guidance of USFWS's *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017), herein referred to as the 2017 VELB Framework. Elderberry shrubs will be avoided to the greatest extent practicable. Complete avoidance (i.e., no adverse effects) may be assumed when activities occur in non-riparian habitat and elderberry shrubs are not present or within a 165-foot buffer of the activity. USFWS will be consulted before any disturbances, including construction, within the 165-foot buffer area if it contains elderberry shrubs and/or riparian habitat.

- For elderberry shrubs not directly affected by construction but that occur between 20 feet and 165 feet from ground-disturbing activities, the following measures will be implemented.
- Fencing. All areas to be avoided during construction activities will be fenced and/or flagged as close to construction limits as feasible.
- Avoidance area. Activities that may damage or kill an elderberry shrub (e.g., trenching, paving, etc.) may need an avoidance area of at least 6 meters (20 feet) from the drip-line, depending on the type of activity.
- Worker education. A qualified biologist will provide training for all contractors, work crews, and any onsite personnel on the status of the VELB, its host plant and habitat, the need to avoid damaging the elderberry shrubs, and the possible penalties for non- compliance.
- Construction monitoring. A qualified biologist will monitor the work area at project- appropriate intervals to assure that all avoidance and minimization measures are implemented. The amount and duration of monitoring will depend on the project specifics and should be discussed with the Service biologist.
- Timing. As much as feasible, all activities that could occur within 50 meters (165 feet) of an elderberry shrub, will be conducted outside of the flight season of the VELB (March - July).
- Trimming. Trimming may remove or destroy VELB eggs and/or larvae and may reduce the health and vigor of the elderberry shrub. In order to avoid and minimize adverse effects to VELB when trimming, trimming will occur between November and February and will avoid the removal of any branches or stems that are ≥ 1 inch in diameter. Measures to address regular and/or large-scale maintenance (trimming) should be established in consultation with the Service.
- Chemical Usage. Herbicides will not be used within the drip-line of the shrub. Insecticides will not be used within 30 meters (98 feet) of an elderberry shrub. All chemicals will be applied using a backpack sprayer or similar direct application method.
- Mowing. Mechanical weed removal within the drip-line of the shrub will be limited to the season when adults are not active (August - February) and will avoid damaging the elderberry.
- Erosion Control and Revegetation. Erosion control will be implemented and the affected area will be revegetated with appropriate native plants.
- Dust Control. The potential effects of dust on valley elderberry longhorn beetle will be minimized by applying water during construction activities or by presoaking work areas that will occur within 100 feet of any potential elderberry shrub habitat.
    - Elderberry shrubs with stems greater than 1 inch that are directly affected by construction should be transplanted under the following conditions:
        - If the elderberry shrub cannot be avoided.
        - If indirect effects will result in the death of stems or the entire shrub.

The removal may either include the roots or just the removal of the aboveground portion of the plant. When possible, the entire root ball will be retained and the elderberry shrub will be transplanted as close as possible to their original location. Elderberry shrubs will be relocated adjacent to the project footprint if: 1) the planting location is suitable for elderberry growth and reproduction; and 2) the project proponent is able to protect the shrub and ensure that the shrub becomes reestablished. If these criteria cannot be met, the shrub may be transplanted to an appropriate Service-approved mitigation site. Any elderberry shrub that is unlikely to survive transplanting because of poor condition or location, or a shrub that would be extremely difficult to move because of access problems, may not be appropriate for transplanting. The following transplanting guidelines may be used by agencies/applicants in developing their VELB conservation measures:

- Monitor. A qualified biologist will be on-site for the duration of transplanting activities to assure compliance with avoidance and minimization measures and other conservation measures.
- Exit Holes. Exit-hole surveys will be completed immediately before transplanting. The number of exit holes found, GPS location of the plant to be relocated, and the GPS location of where the plant is transplanted will be reported to the Service and to the California Natural Diversity Database (CNDDB).
- Timing. Elderberry shrubs will be transplanted when the shrubs are dormant (November through the first two weeks in February) and after they have lost their leaves. Transplanting during the non-growing season will reduce shock to the shrub and increase transplantation success.
- Transplanting Procedure. Transplanting will follow the most current version of the ANSI A300 (Part 6) guidelines for transplanting (http://www.tcia.org/).
- Trimming Procedure. Trimming will occur between November and February and should minimize the removal of branches or stems that exceed 1 inch in diameter.

E.2.8.3 *Compensation to Offset Unavoidable Impacts*

Reclamation will coordinate with the USFWS to offset impacts on elderberry shrubs by either creating valley elderberry longhorn beetle habitat or by purchasing the equivalent credits at a USFWS approved conservation bank with a service area that overlaps with the action area. Compensatory mitigation will be coordinated with the USFWS to determine the appropriate type and amount of compensatory mitigation and follow criteria in the 2017 VELB Framework. These guidelines recommend that the permanent loss of VELB habitat be replaced with habitat that is commensurate with the type (riparian or non-riparian) and amount of habitat lost. For plants in riparian areas, compensation may be appropriate for any impacts to VELB habitat. In non-riparian areas, compensation may be appropriate for occupied shrubs Suitable riparian habitat may be replaced, at a minimum of 3:1 for all acres that will be permanently impacted by the project. Suitable non-riparian habitat may be replaced, at a minimum of 1:1 for all acres that will be permanently impacted by the project. Impacts to individual shrubs in riparian areas may be replaced by the purchase of 2 credits (one credit = 1,800 sq. ft.) at a Service-approved bank for each shrub that will be trimmed regardless of the presence of exit holes. If the shrub will be completely removed by the activity, the entire shrub may be transplanted to a Service-approved location in addition to the credit purchase. Impacts to individual shrubs in non- riparian areas be replaced through a purchase of 1 credit at a Service-approved bank for each shrub that will be trimmed if exit holes have been found in any shrub on or within 165 feet of the project area. If the shrub will be completely removed by the activity, the entire shrub be transplanted to a Service-approved location in addition to a credit purchase. These ratios may apply if compensation occurs prior to or concurrent with the impacts. If compensation occurs after the impacts, a higher ratio may be required by USFWS. Appropriate compensatory mitigation may include purchasing credits at a Service- approved conservation bank, providing on-site mitigation, or establishing and/or protecting habitat for VELB.

E.2.9 AMM26 Suisun Thistle and Soft Bird's-Beak

A complete botanical survey of project sites will be completed using Guidelines for Conducting and Reporting Botanical Inventories for Federally Listed, Proposed and Candidate Plants (U.S. Fish and Wildlife Service 1996) and Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities (California Department of Fish and Game 2009). The surveys will be floristic in nature and conducted in a manner that maximizes the likelihood of locating Suisun thistle and soft bird's-beak (i.e., during the appropriate season and at an appropriate level of ground coverage).

Plant surveys required for project-specific permit compliance will be conducted early in the planning process to allow design of the individual restoration projects to avoid adverse modification of habitat for specified covered plants. The purpose of these surveys will be to verify that the locations of Suisun thistle and soft bird's-beak identified in previous record searches or surveys are extant, identify any new occurrences, and cover any portions of the project area not previously identified. The extent of compensation for direct loss of or indirect effects on Suisun thistle and soft bird's-beak will be based on these survey results. Locations of the plants in proposed construction areas will be recorded using a GPS unit and flagged.

The following measures will be implemented.

- Design restoration projects to avoid the direct, temporary loss of occupied habitat from construction activities for Suisun thistle. In tidal restoration areas, Suisun thistle occurrences may experience the indirect effect of tidal damping. This effect will be monitored and adaptively managed to ensure the occurrence is protected from loss.
- If a soft bird's-beak occurrence has more than 10 individuals, no more than 5% of the total number of individuals in the occurrence will be removed. If an occurrence has 10 or fewer individuals, all individuals may be removed. Loss of individuals for all occurrences will be offset through replacement of occupied habitat at a ratio of at least 1:1, to achieve no net loss of occupied habitat.
- To minimize the spread of nonnative, invasive plant species from restoration sites, the Reclamation will retain a qualified botanist or weed scientist prior to clearing operations to determine if affected areas contain invasive plants. If areas to be cleared contain invasive plants, then chipped vegetation material from those areas will not be used for erosion control; in these cases the material will be disposed of to minimize the spread of invasive plant propagules (e.g., burning, composting).
- To minimize the introduction of invasive plant species, construction vehicles and construction machinery will be cleaned prior to entering construction sites that are in or adjacent to natural communities other than cultivated lands, and prior to entering any restoration sites or conservation lands other than cultivated lands. Vehicles working in or travelling off paved roads through areas with infestations of invasive plant species will be cleaned before travelling to other parts of the Plan Area. Cleaning stations will be established at the perimeter of covered activities along construction routes as well as at the entrance to reserve system lands. Biological monitoring will include locating and mapping locations of invasive plant species within the construction areas during the construction phase and the restoration phase. Infestations of invasive plant species will be targeted for control or eradication as part of the restoration and revegetation of temporarily disturbed construction areas.
- Reclamation will ensure that covered activities in designated critical habitat areas for Suisun thistle or soft bird's-beak (Figure 3.C-6 and Figure 3.C-7), if any, will not result in the adverse modification of any of the primary constituent elements for Suisun thistle or soft bird's-beak critical habitat. The CDFW Suisun Marsh Unit tracks both of these species (GIS-mapped) in Suisun. No covered activities will take place within designated Suisun thistle or soft bird's-beak critical habitat areas without prior written concurrence from USFWS that such activities will not adversely modify any primary constituent elements of Suisun thistle or soft bird's-beak critical habitat. Primary constituent elements for Suisun thistle are defined as follows.

- Persistent emergent, intertidal, estuarine wetland at or above the mean high water mark as extended directly across any intersecting channels).
- Open channels that periodically contain moving water with ocean-derived salts in excess of 0.5%.
- Gaps in surrounding vegetation to allow for seed germination and growth.
- Primary constituent elements for soft bird's-beak are defined as follows.
- Persistent emergent, intertidal, estuarine wetland at or above the mean high water mark (as extended directly across any intersecting channels).
- Rarity or absence of plants that naturally die in late spring (winter annuals).
- Partially open spring canopy cover (i.e., photosynthetic photo flux density of approximately 790 nMol/m2/s) at ground level, with many small openings to facilitate seedling germination.

E.2.10 AMM27 Vernal Pool Fairy Shrimp and Vernal Pool Tadpole Shrimp

For restoration projects, Reclamation will avoid occupied vernal pool fairy shrimp and vernal pool tadpole shrimp habitat with a minimum 250-foot non-disturbance buffer. Reclamation will either conduct protocol-level surveys to assess whether habitat is occupied, or will assume presence of the species. Reclamation will avoid affecting any of the primary constituent elements of critical habitat for vernal pool fairy shrimp or vernal pool tadpole shrimp within designated critical habitat units.

E.2.11 AMM28 California Tiger Salamander

For restoration projects, Reclamation will avoid California tiger salamander upland and aquatic habitat. Reclamation will avoid affecting any of the primary constituent elements of critical habitat for California tiger salamander within designated critical habitat units.

E.2.12 AMM29 California Least Tern

For restoration projects, Reclamation will avoid California least tern nesting colony sites.

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Appendix F Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS

Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

F.1 Introduction

This appendix contains graphical summaries of juvenile salmonid monitoring, sampling, and salvage timing in the Central Valley, as produced by the Central Valley Prediction and Assessment of Salmon database (SacPAS; http://www.cbr.washington.edu/sacramento/). The appendix is organized by species, monitoring location, and hatchery origin (clipped or unclipped). The maximum number of years (25) was selected in each case, giving summaries from 1993 onwards where available. Trawl and beach seine data are presented as catch indices (trawls = 10 tows/day; each seines = 8 hauls/day). Beach seine data represent stations in the vicinity of Sacramento (Verona, Elkhorn, Sand Cove, Miller Park, Sherwood Harbor, Discovery Park, American River, and Garcia Bend).

F.2 Winter-Run Chinook Salmon

F.2.1 Winter-Run Chinook Salmon: Red Bluff Diversion Dam

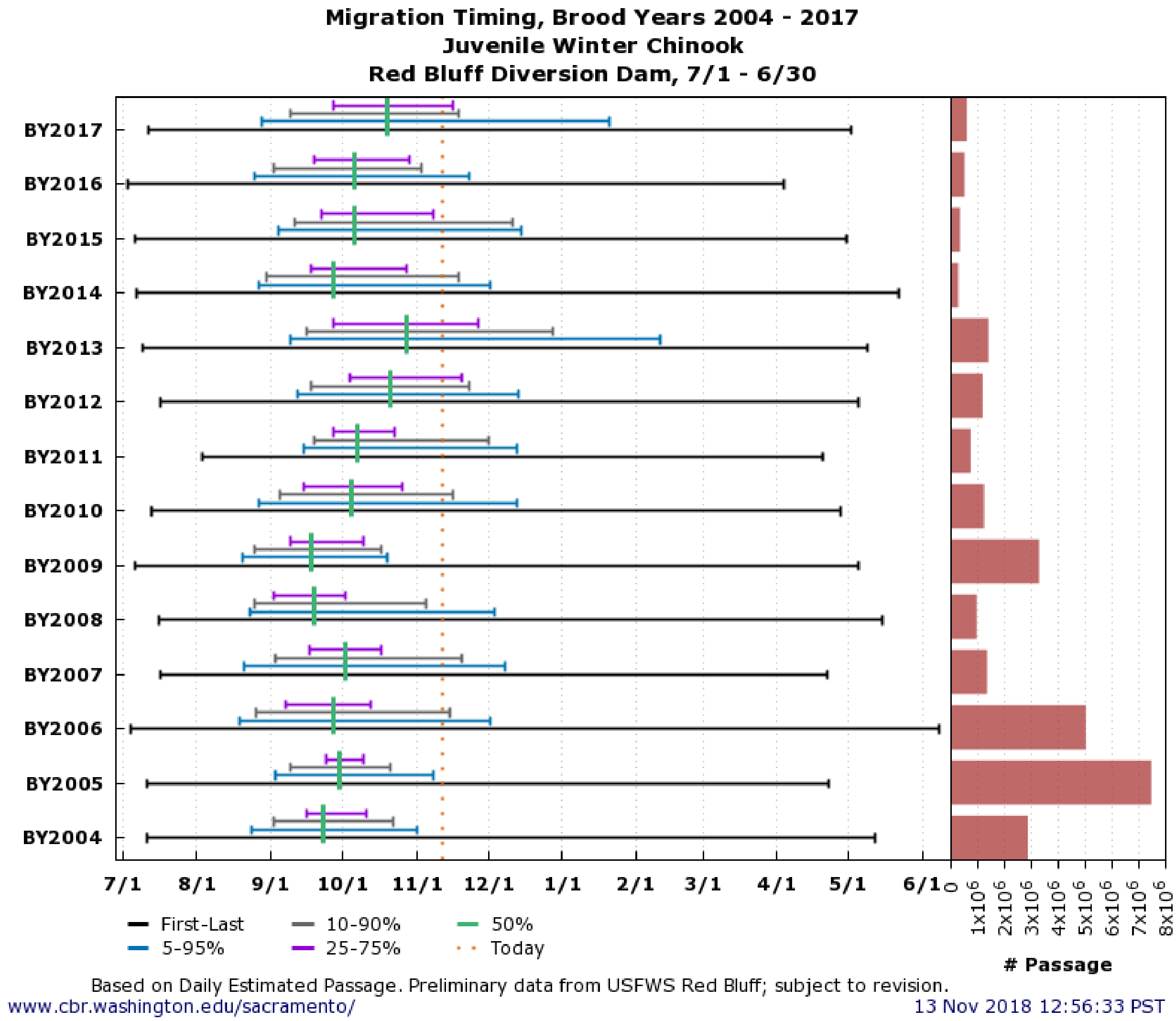


Figure WR_RBRST. Timing and Number of Juvenile Winter-Run Chinook Salmon in Red Bluff Diversion Dam Rotary Screw Traps.

F.2.2 Winter-Run Chinook Salmon: Tisdale Weir Rotary Screw Traps

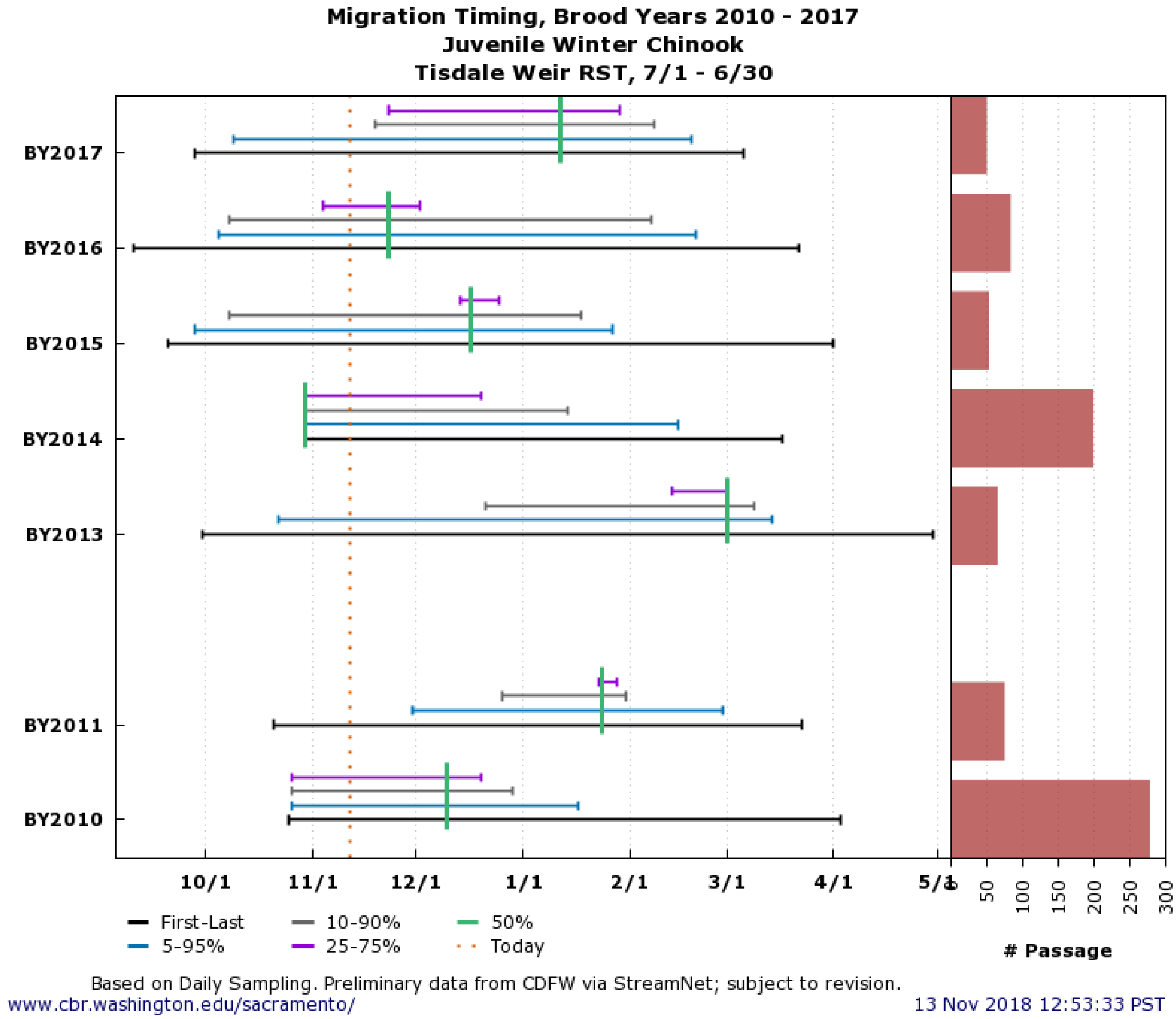


Figure WR_TWRST. Timing and Number of Juvenile Winter-Run Chinook Salmon in Tisdale Weir Rotary Screw Traps.

F.2.3 Winter-Run Chinook Salmon: Knights Landing Rotary Screw Traps

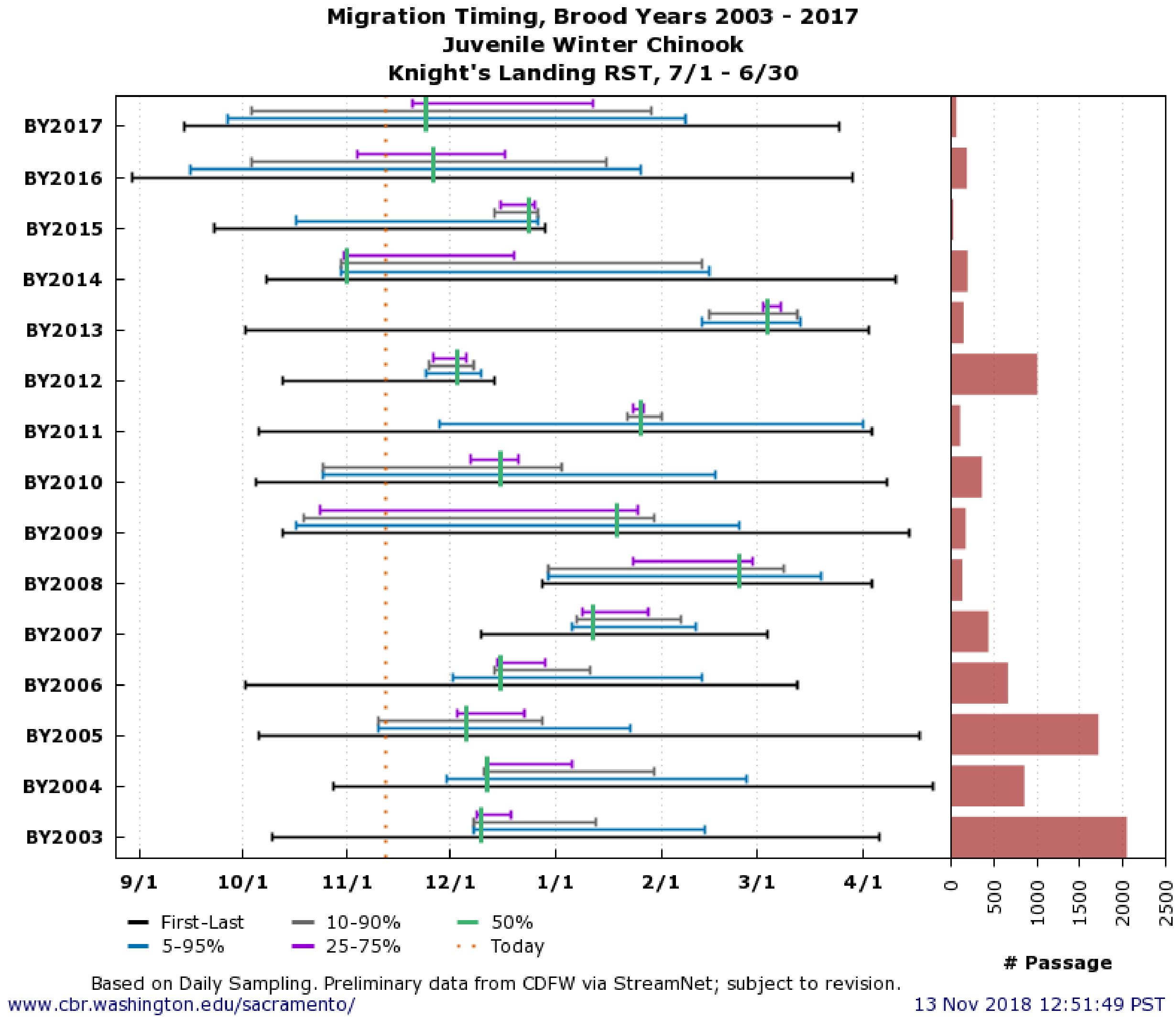


Figure WR_KLRST. Timing and Number of Juvenile Winter-Run Chinook Salmon in Knights Landing Rotary Screw Traps.

F.2.4 Winter-Run Chinook Salmon: Sacramento Beach Seines Combined

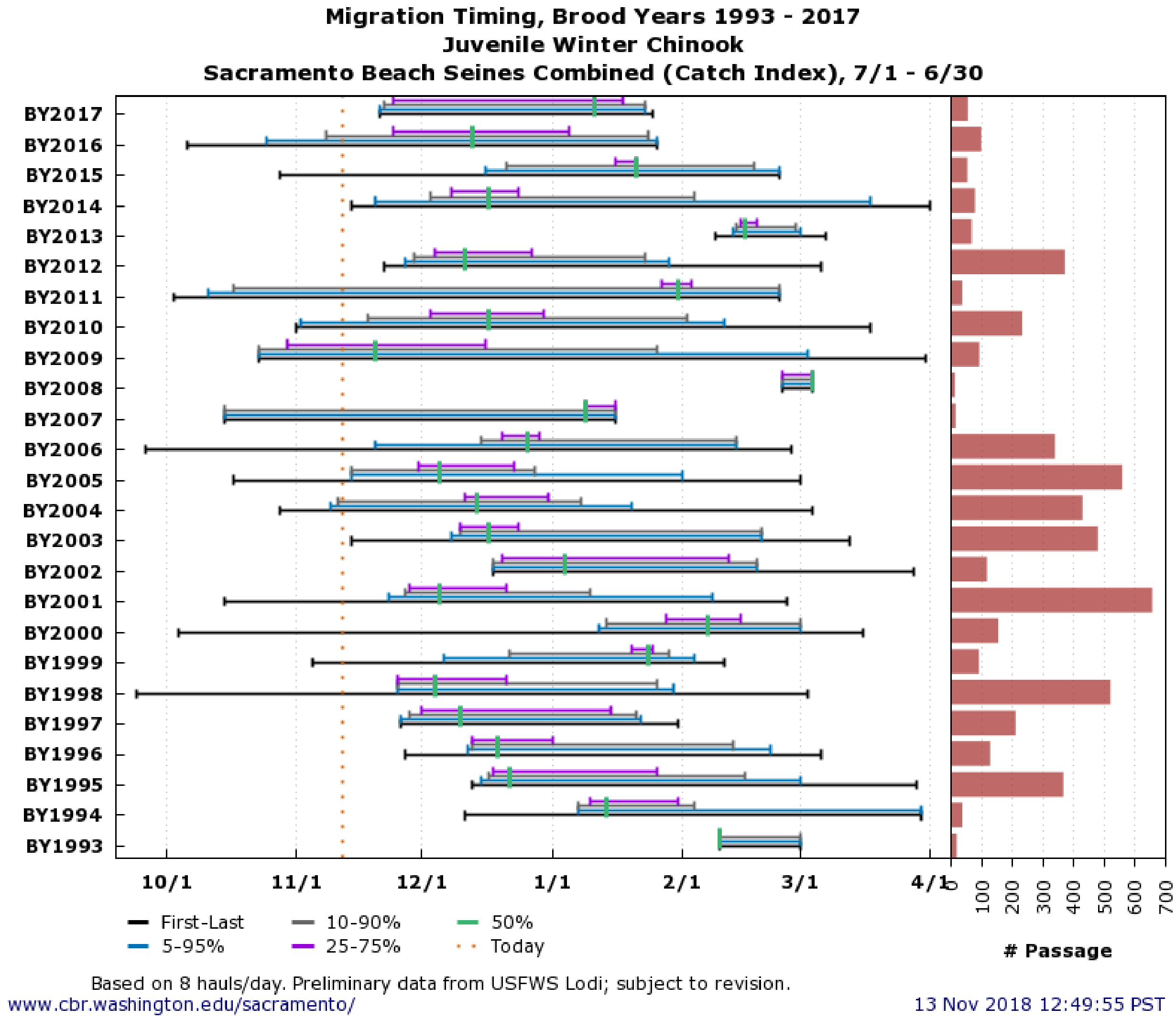


Figure WR_Seines. Catch Index Timing and Number of Juvenile Winter-Run Chinook Salmon in Sacramento Beach Seines.

F.2.5 Winter-Run Chinook Salmon: Sacramento Trawls (Sherwood Harbor)

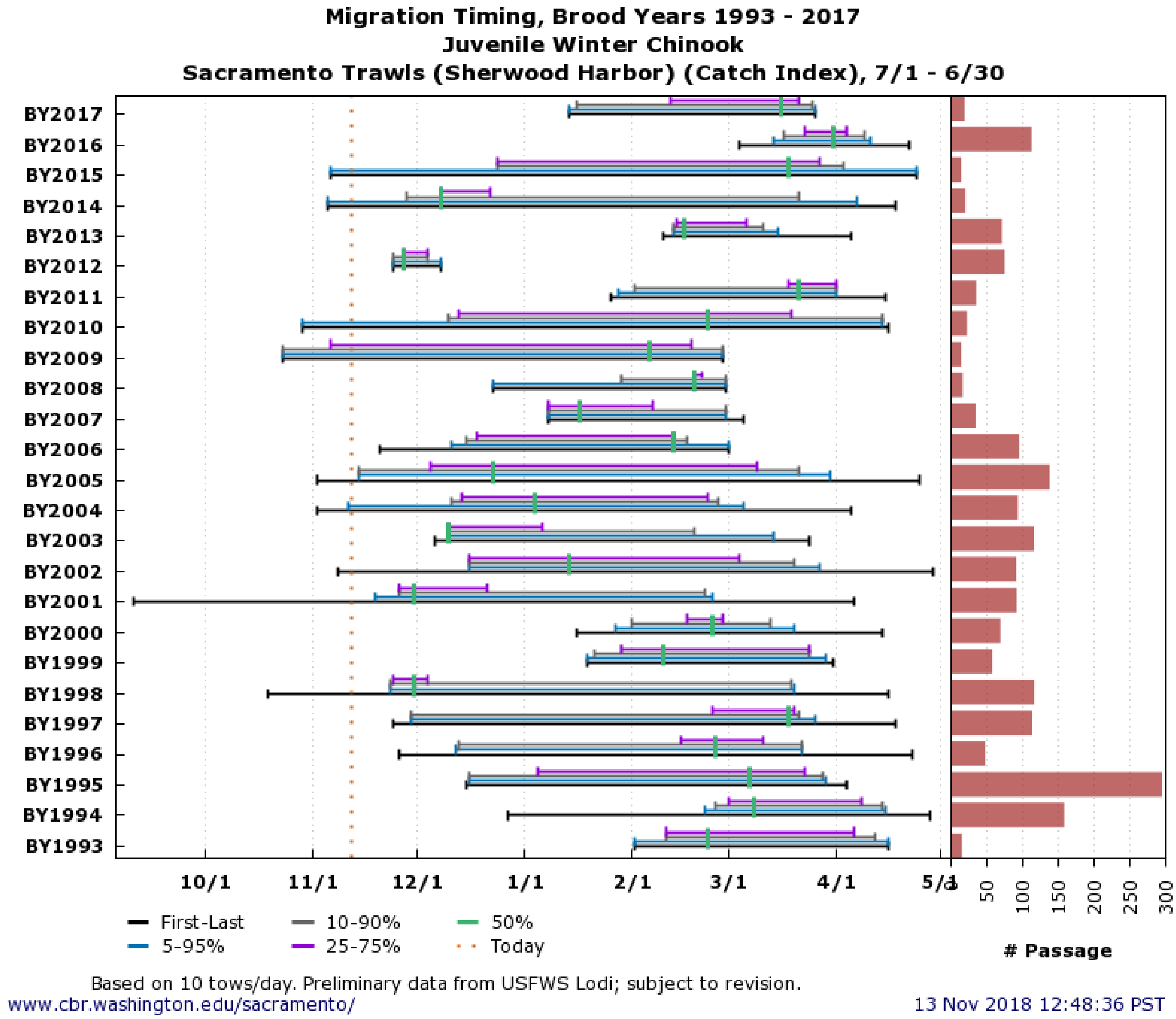


Figure WR_Sherwood. Catch Index Timing and Number of Juvenile Winter-Run Chinook Salmon in Sacramento Trawls at Sherwood Harbor.

F.2.6 Winter-Run Chinook Salmon: Chipps Island Trawls

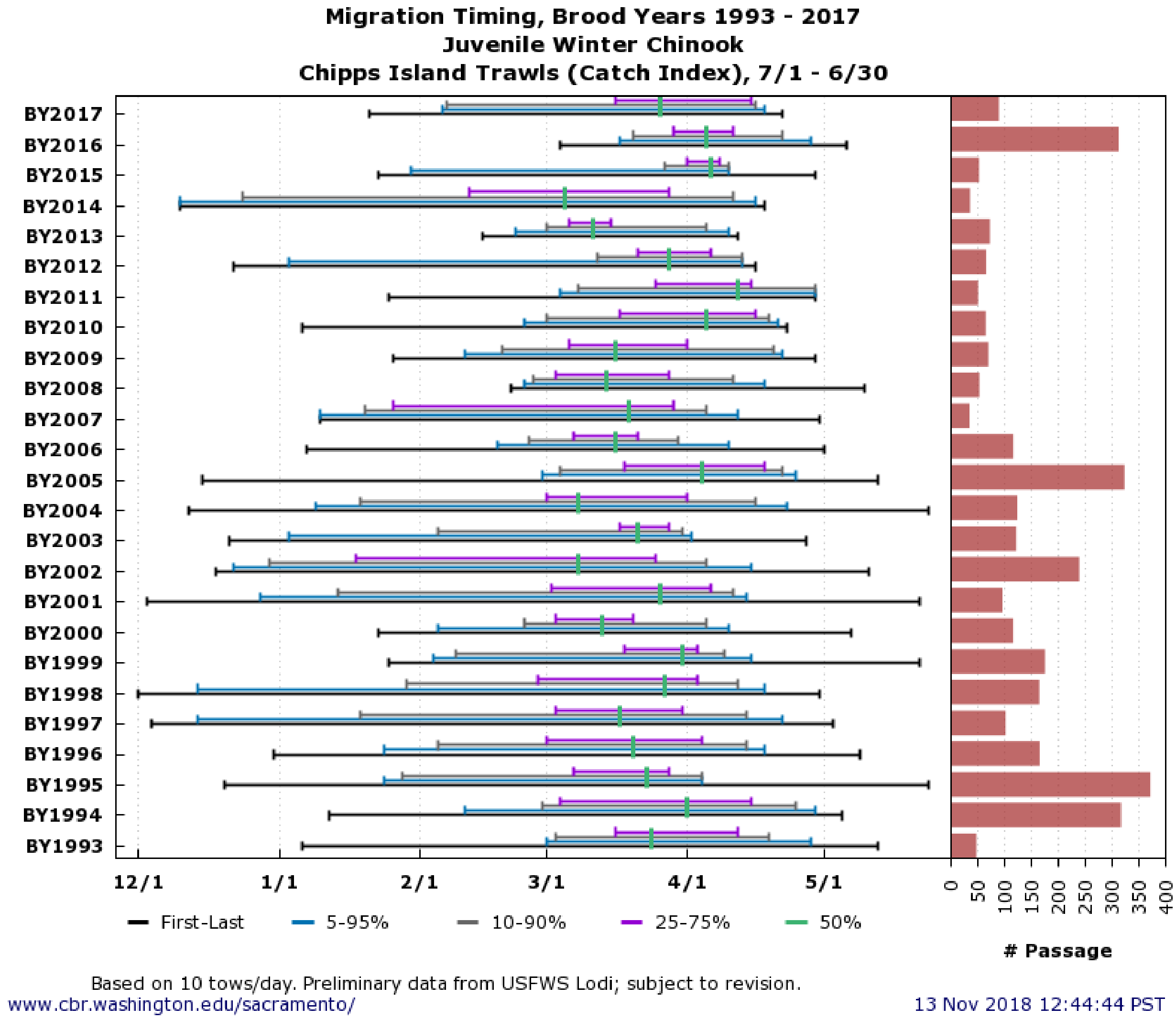


Figure WR_Chipps. Catch Index Timing and Number of Juvenile Winter-Run Chinook Salmon in Chipps Island Trawls.

F.2.7 Winter-Run Chinook Salmon Salvage: Unclipped (Length-at-Date)

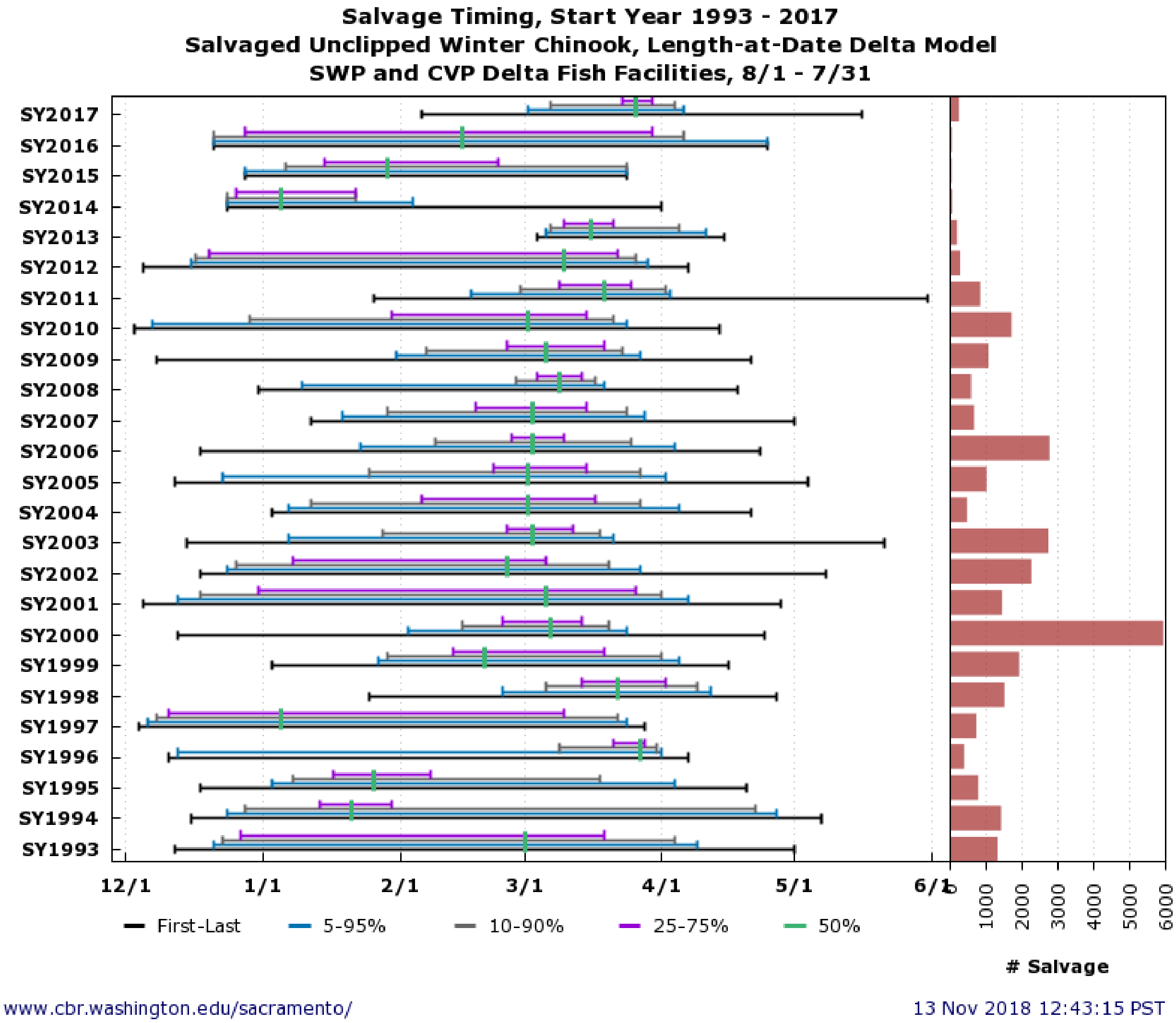


Figure WR_salvage_unclipped_date. Timing and Number of Unclipped Juvenile Winter-Run Chinook Salmon (Race Determined from Length at Date) at the State Water Project and Central Valley Project South Delta Fish Salvage Facilities.

F.2.8 Winter-Run Chinook Salmon Salvage: Clipped (Length-at-Date)

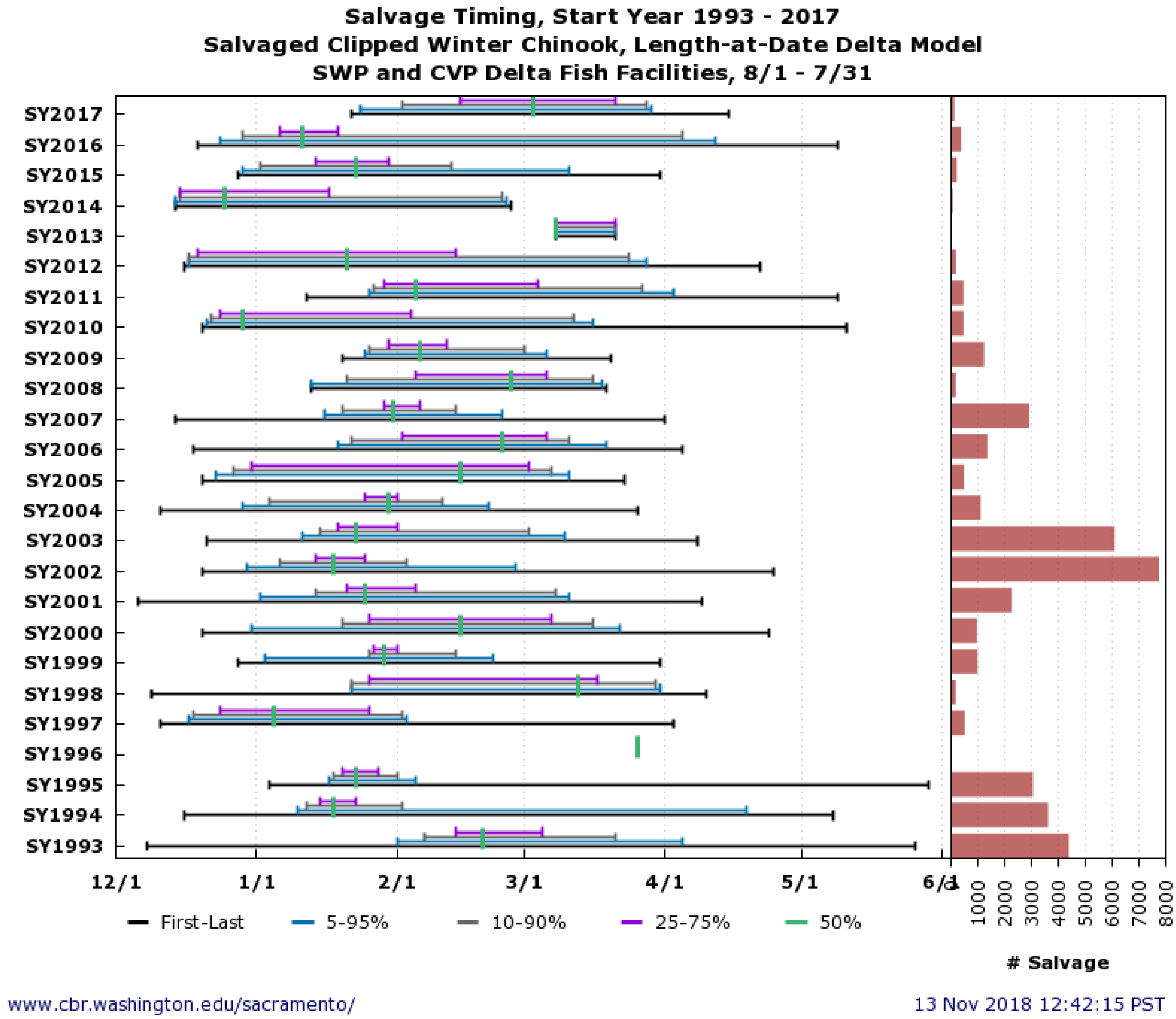


Figure WR_salvage_clipped_date. Timing and Number of Clipped Juvenile Winter-Run Chinook Salmon (Race Determined from Length at Date) at the State Water Project and Central Valley Project South Delta Fish Salvage Facilities.

F.2.9 Winter-Run Chinook Salmon Salvage: Clipped (CWT-Race)

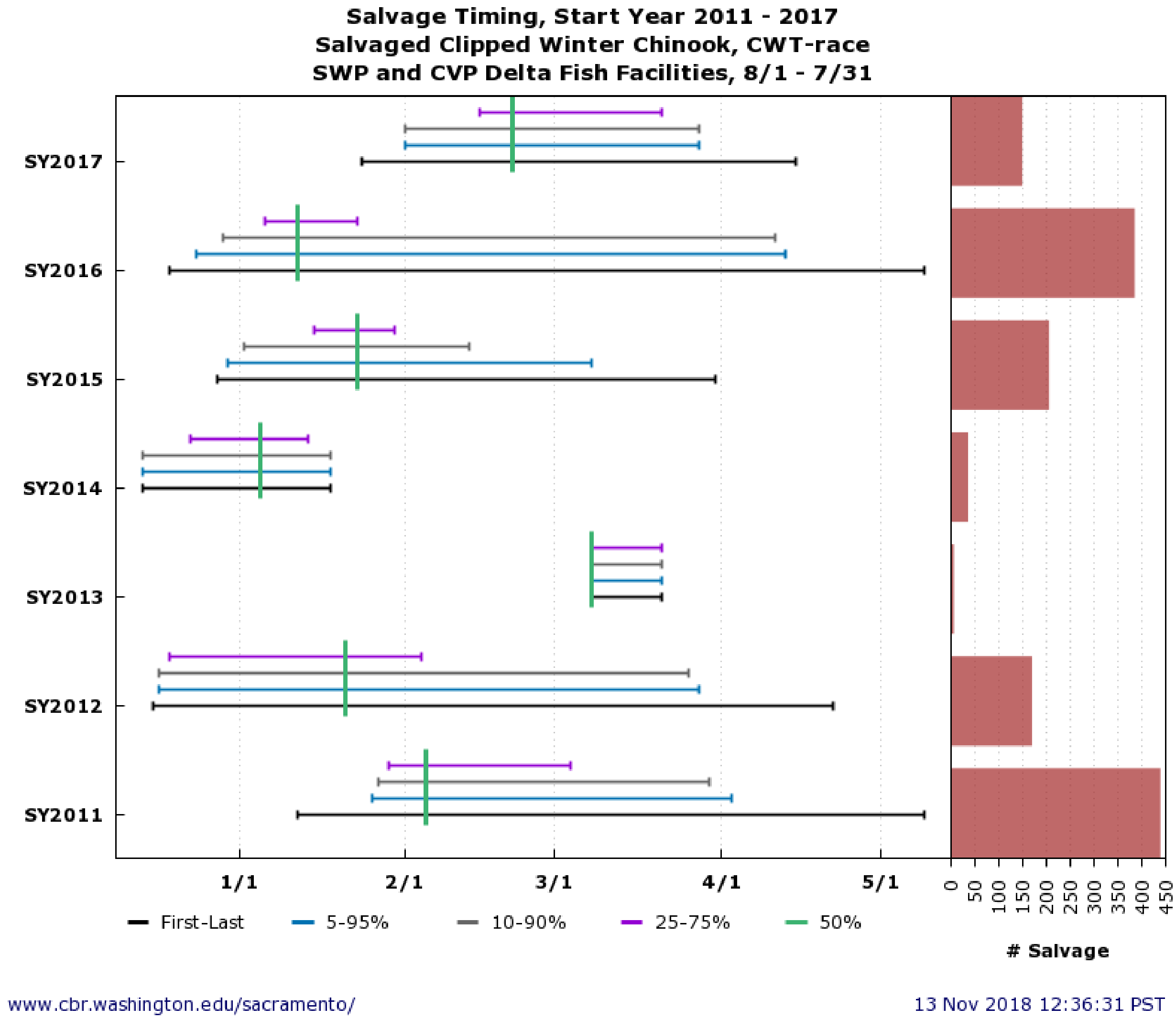
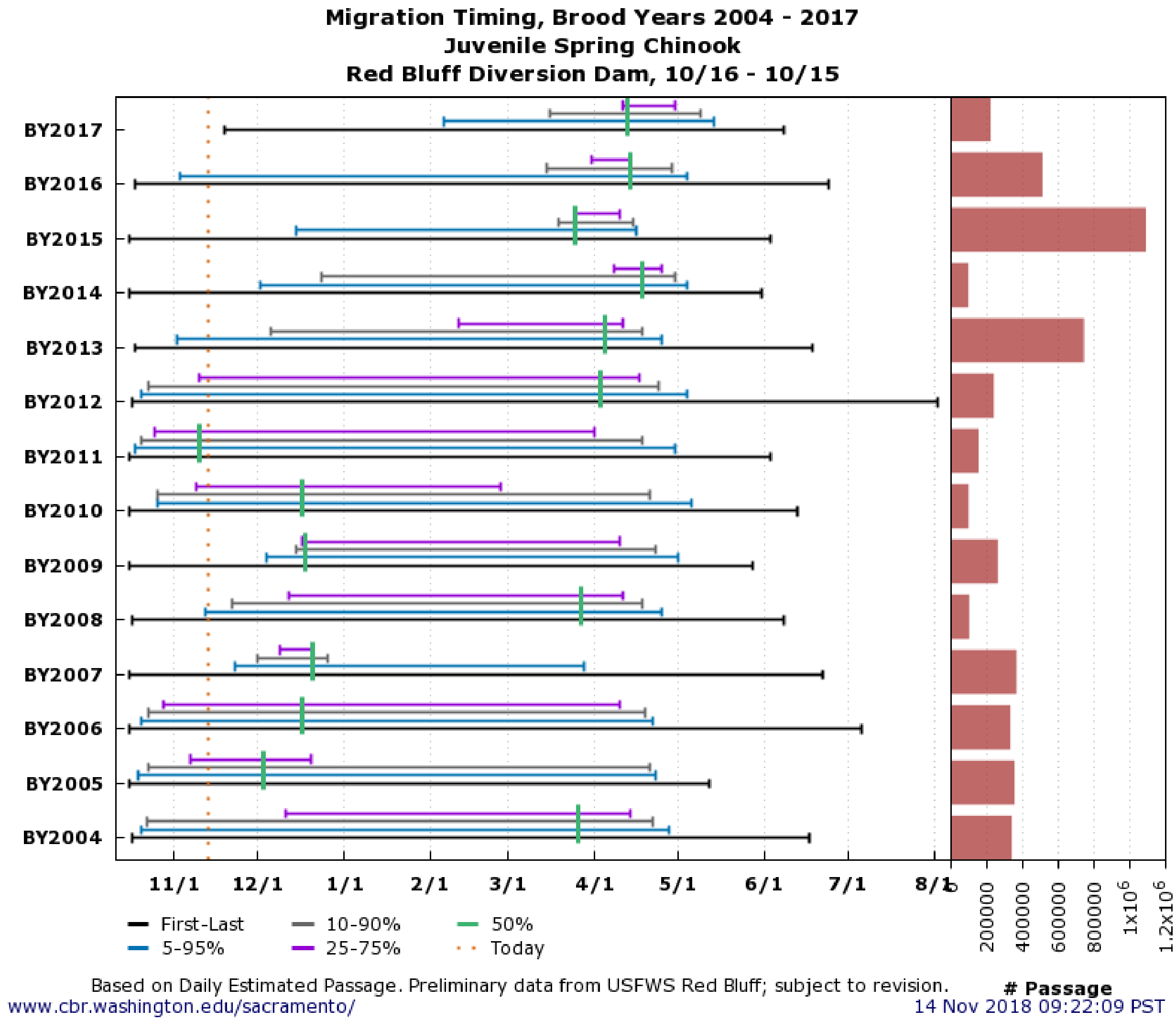


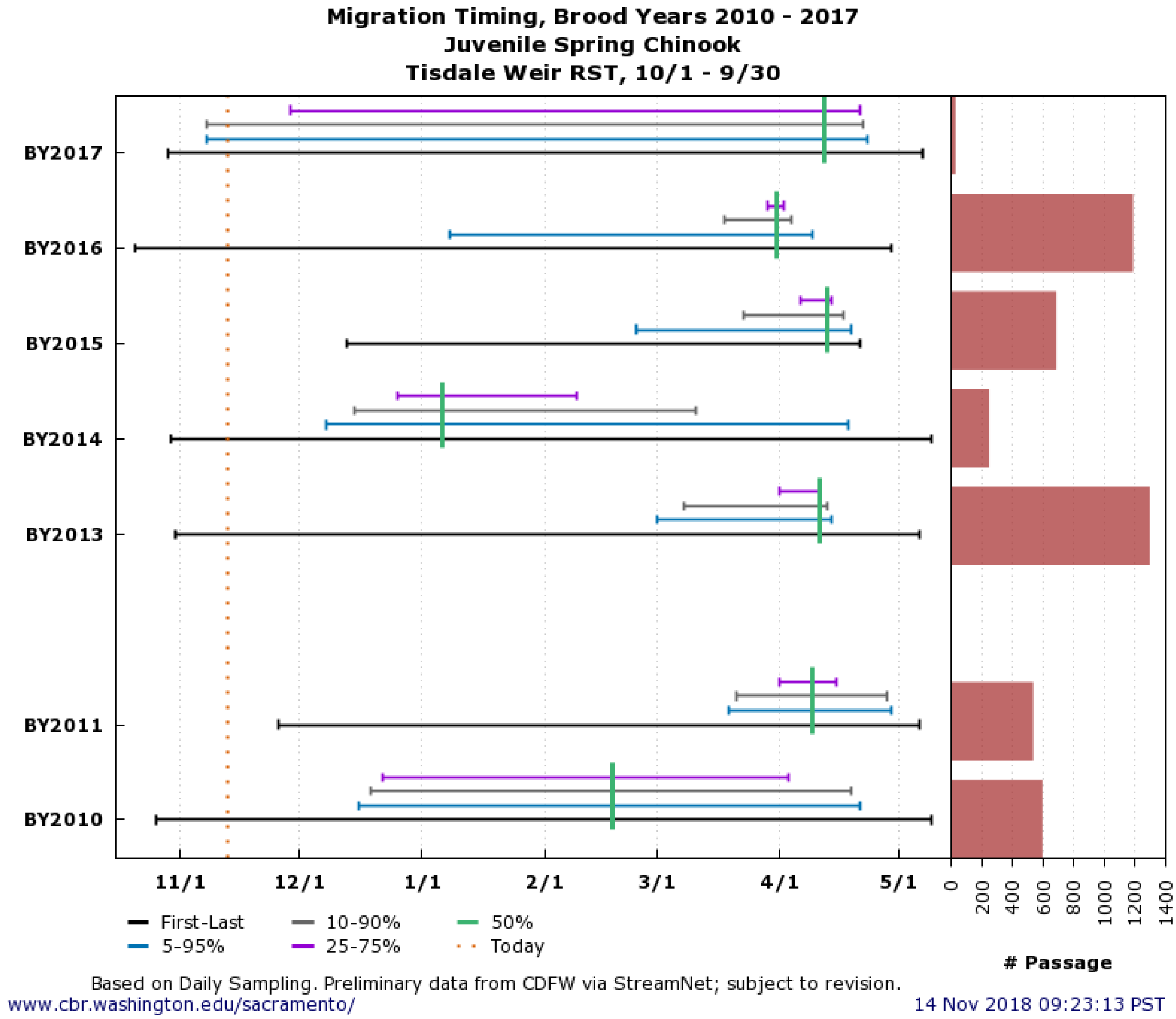
Figure WR_salvage_clipped_CWT_race. Timing and Number of Clipped Winter-Run Juvenile Chinook Salmon (Race Determined from Coded Wire Tag) at the State Water Project and Central Valley Project South Delta Fish Salvage Facilities.

F.3 Spring-Run Chinook Salmon

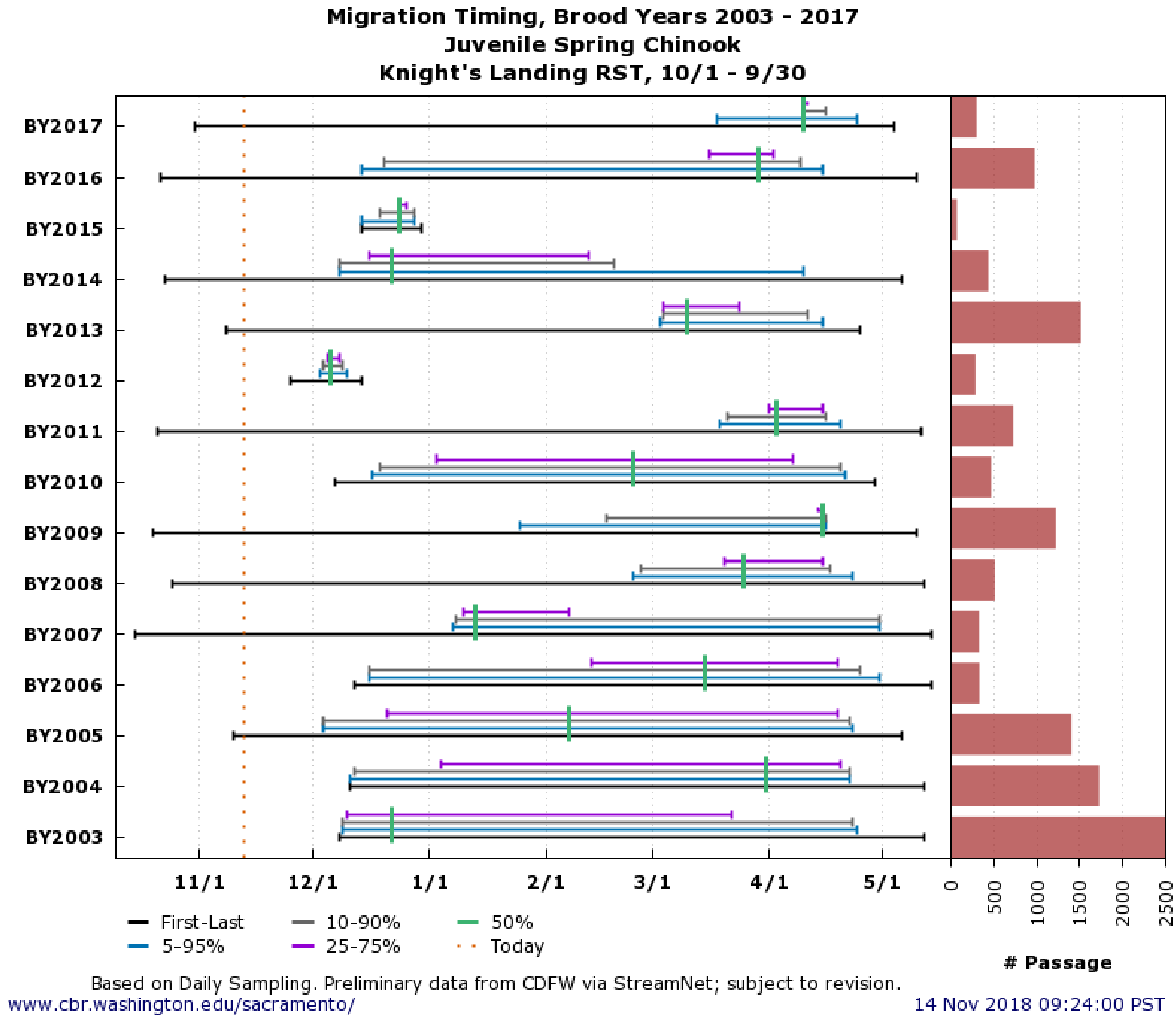
F.3.1 Spring-Run Chinook Salmon: Red Bluff Diversion Dam



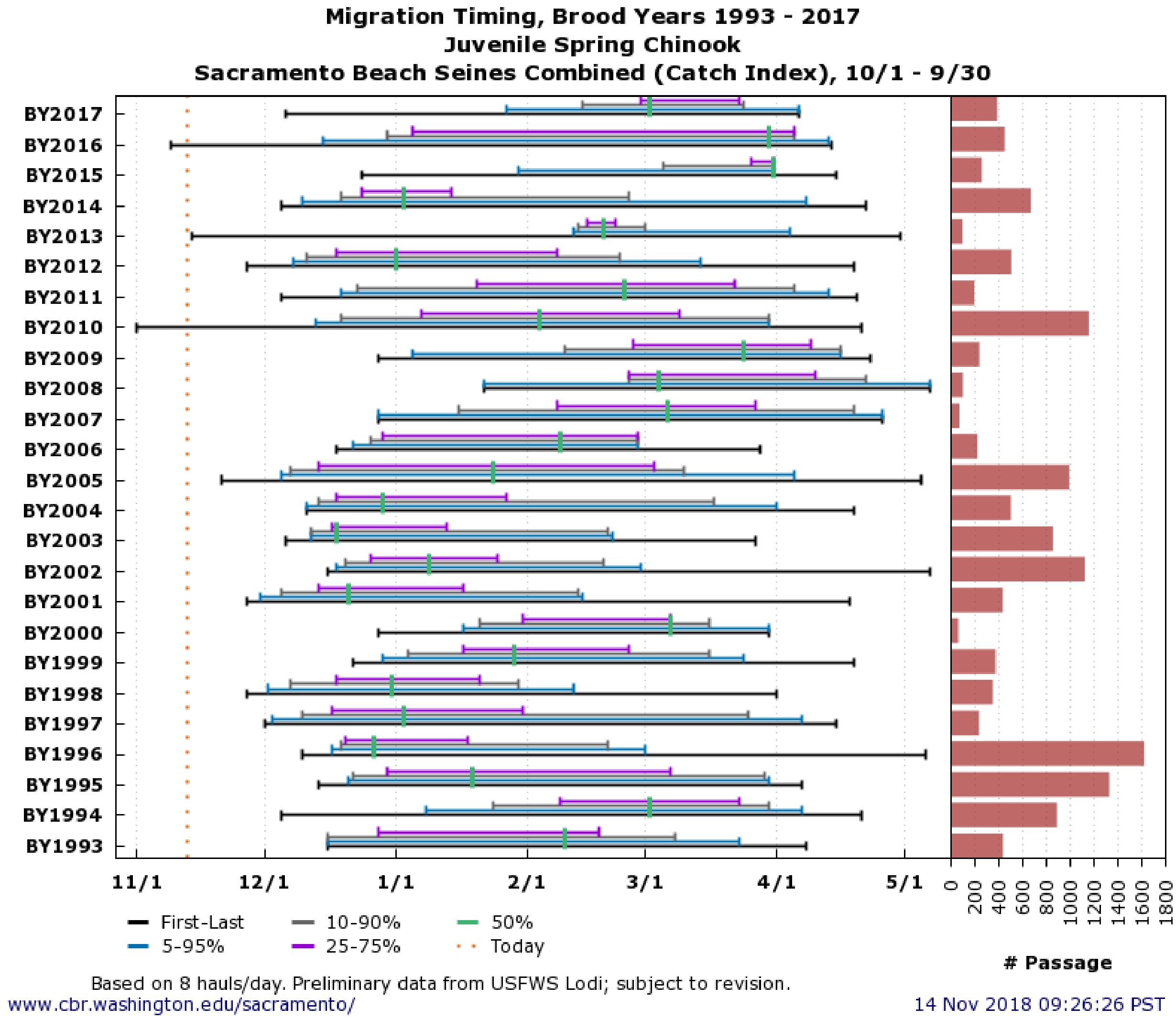
F.3.2 Spring-Run Chinook Salmon: Tisdale Weir Rotary Screw Traps



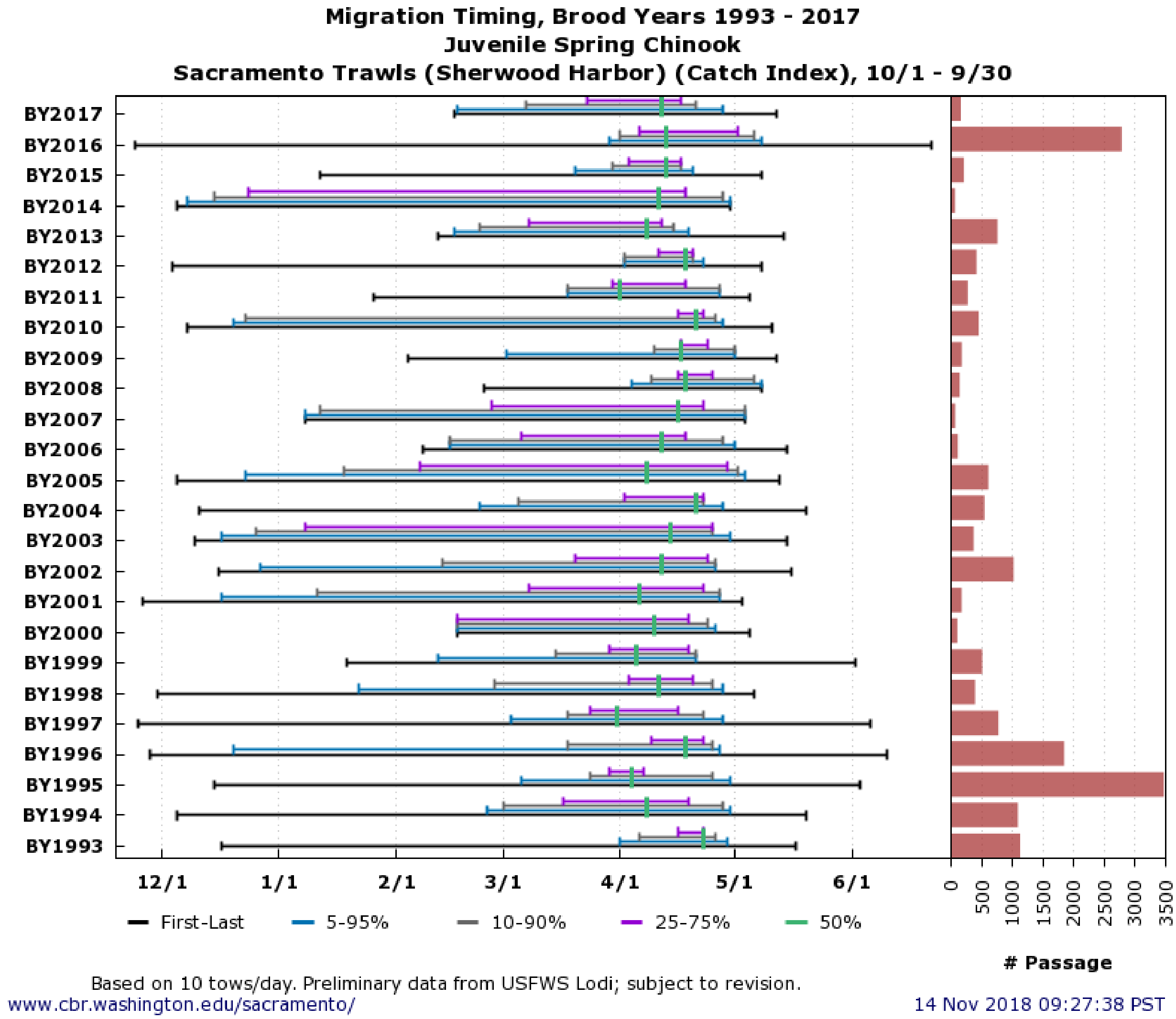
F.3.3 Spring-Run Chinook Salmon: Knights Landing Rotary Screw Traps



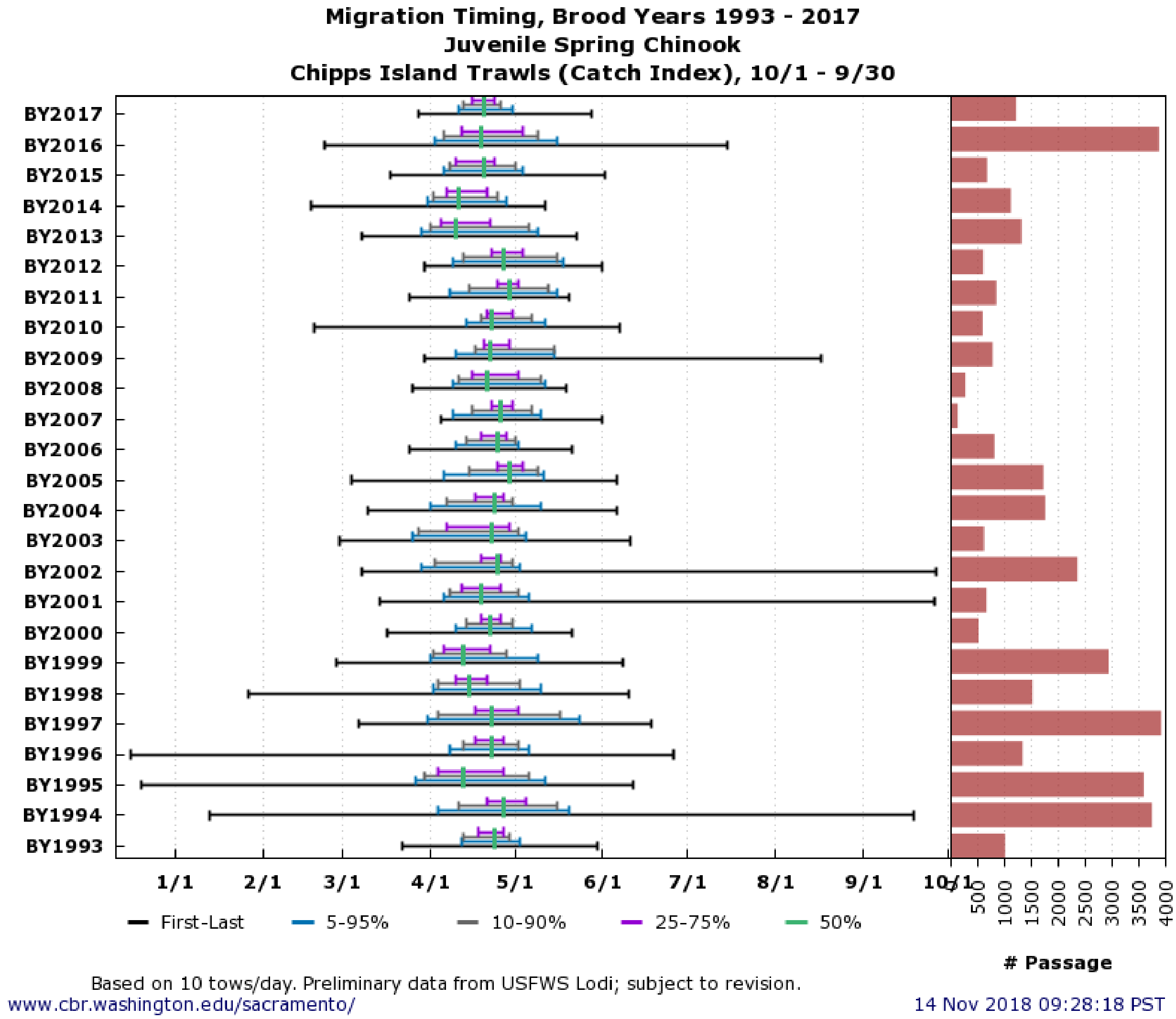
F.3.4 Spring-Run Chinook Salmon: Sacramento Beach Seines Combined



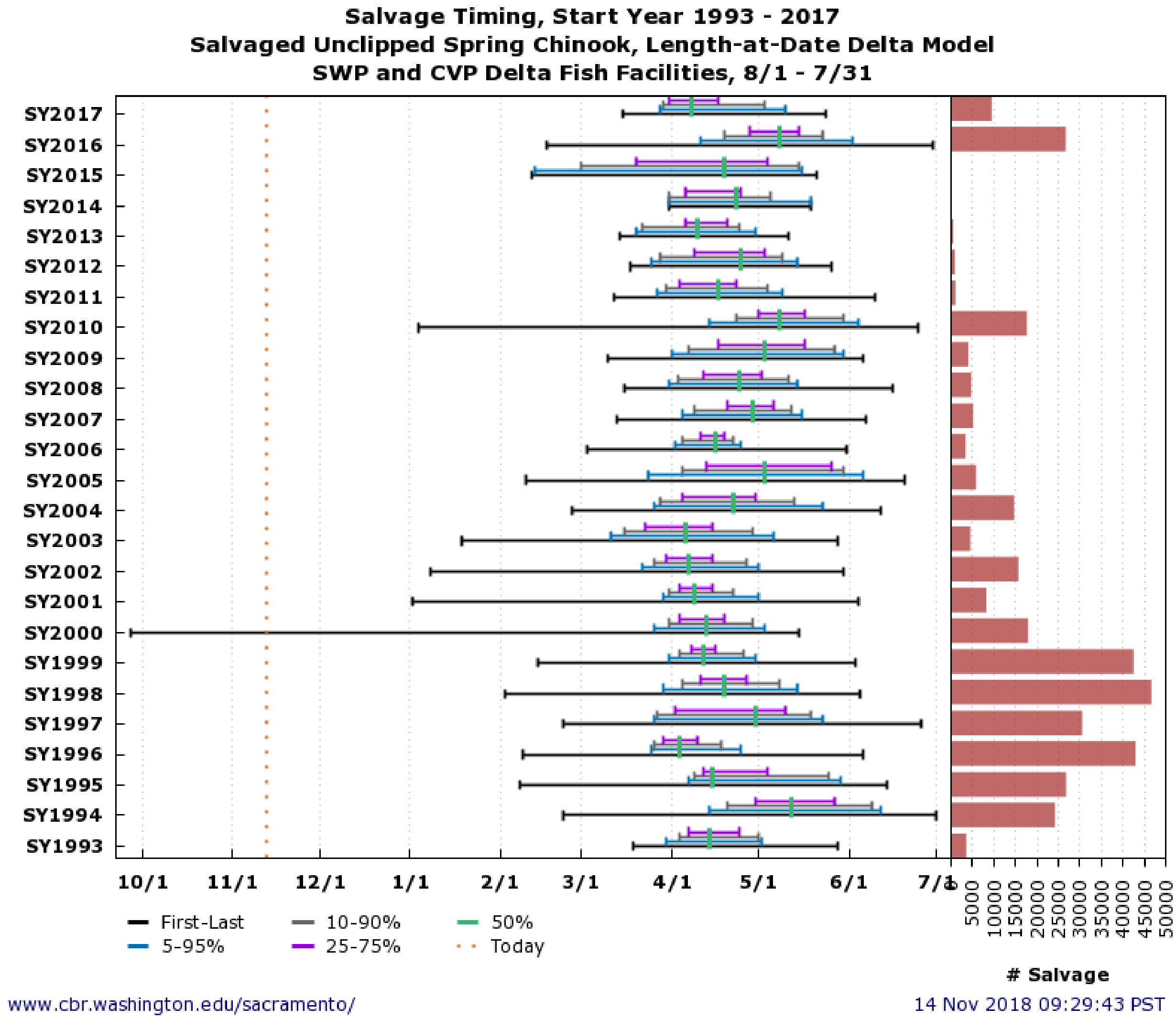
F.3.5 Spring-Run Chinook Salmon: Sacramento Trawls (Sherwood Harbor)



F.3.6 Spring-Run Chinook Salmon: Chipps Island Trawls



F.3.7 Spring-Run Chinook Salmon Salvage: Unclipped (Length-at-Date)



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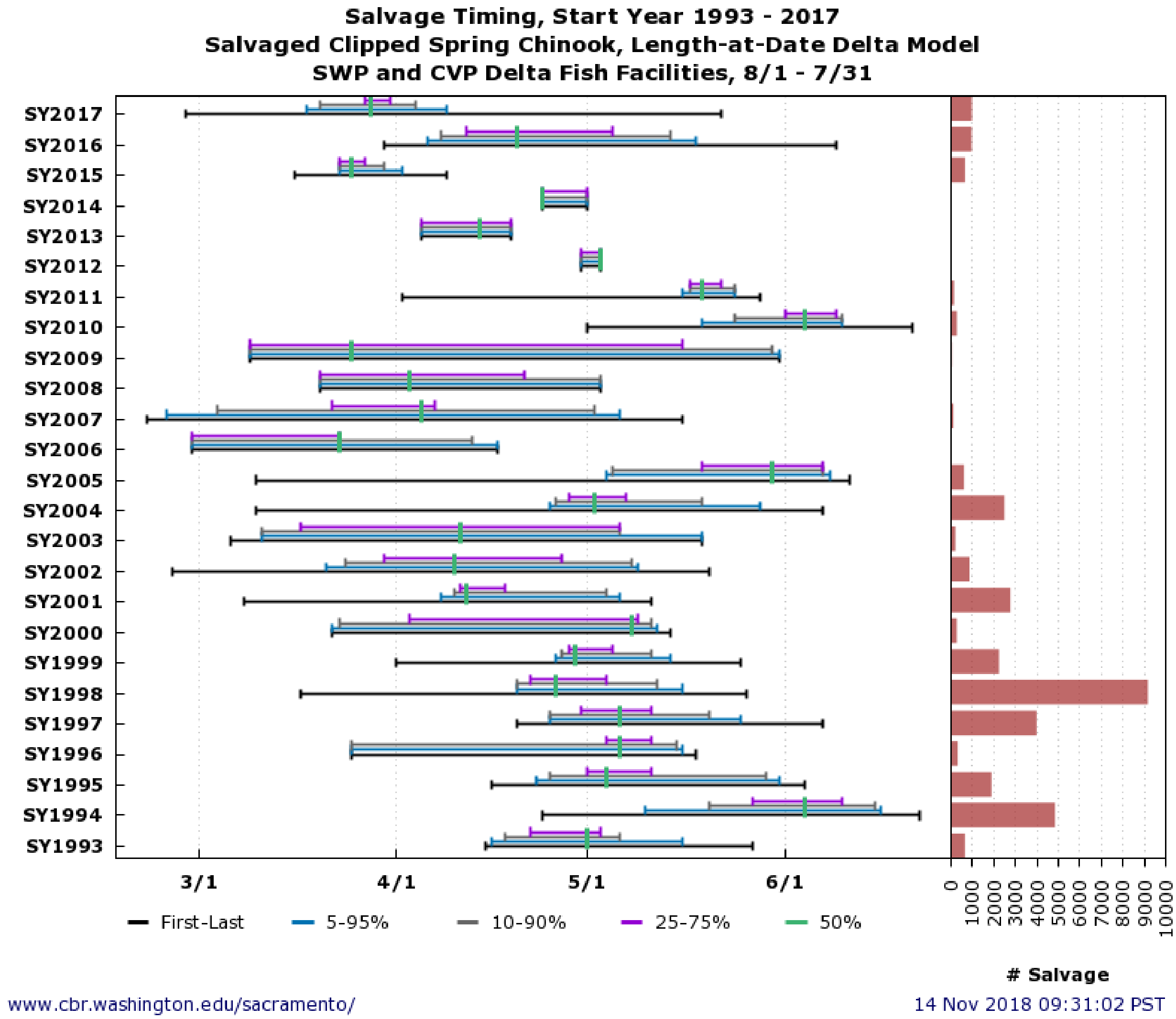
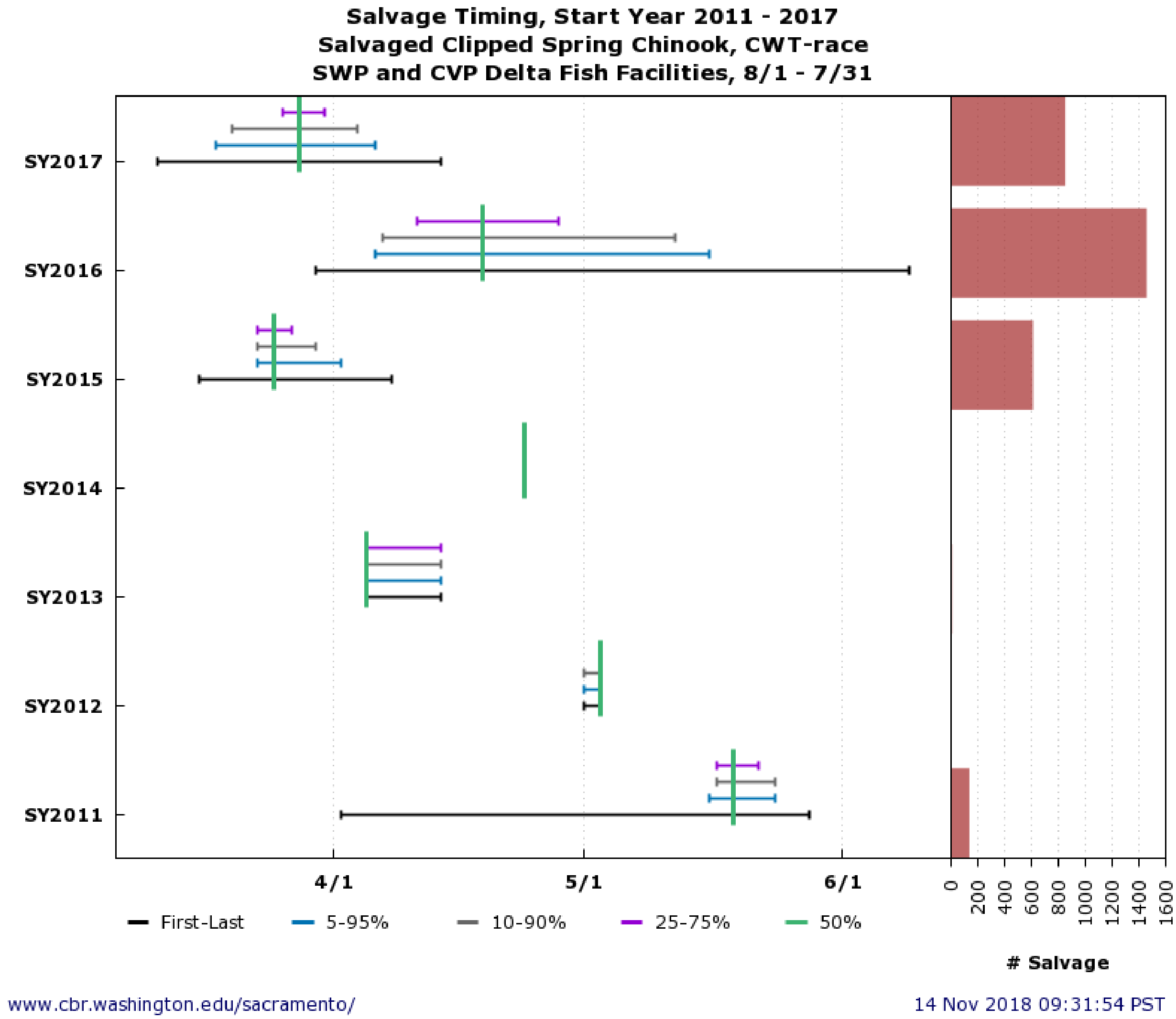
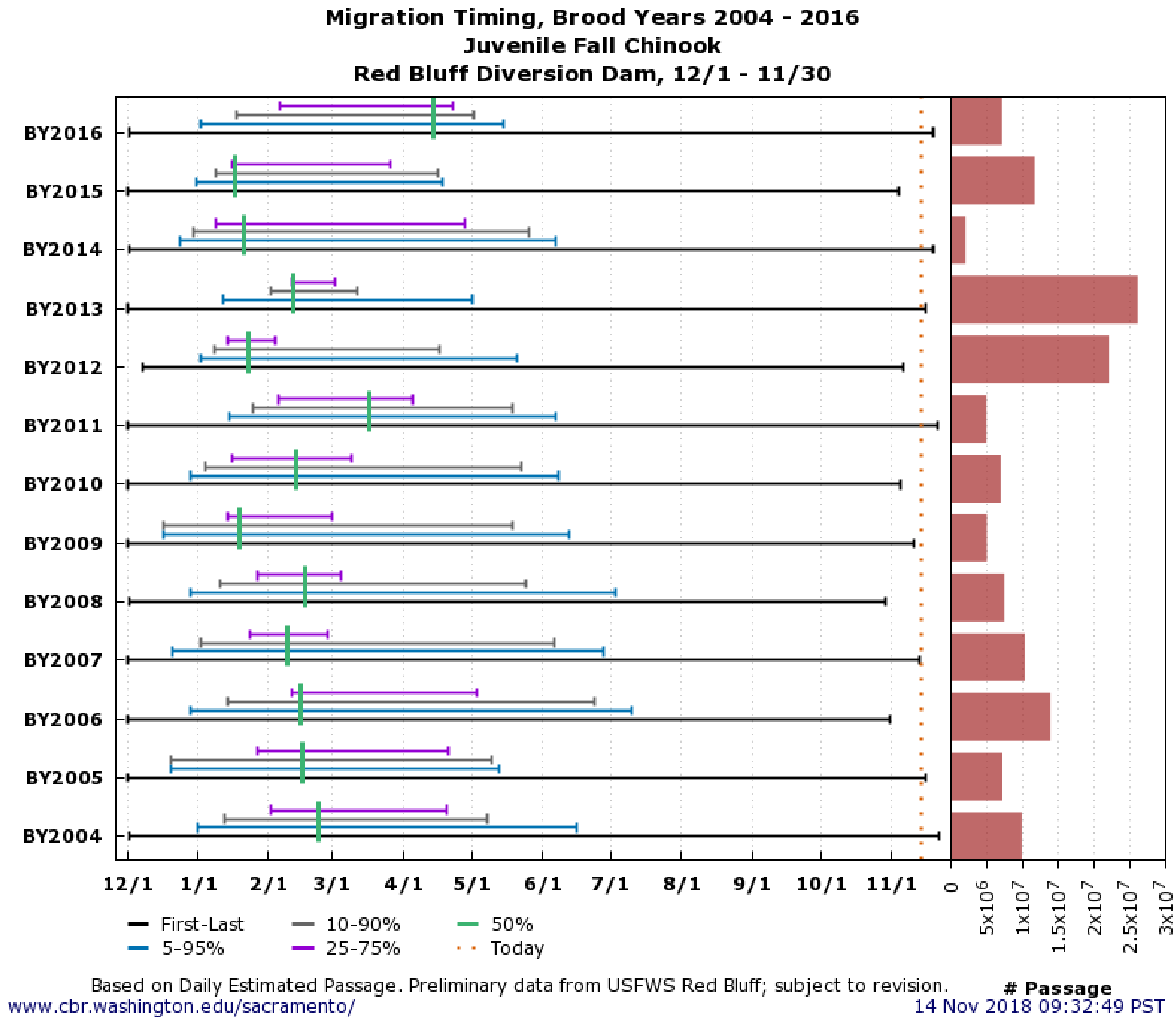


F.3.9 Spring-Run Chinook Salmon Salvage: Clipped (CWT-Race)

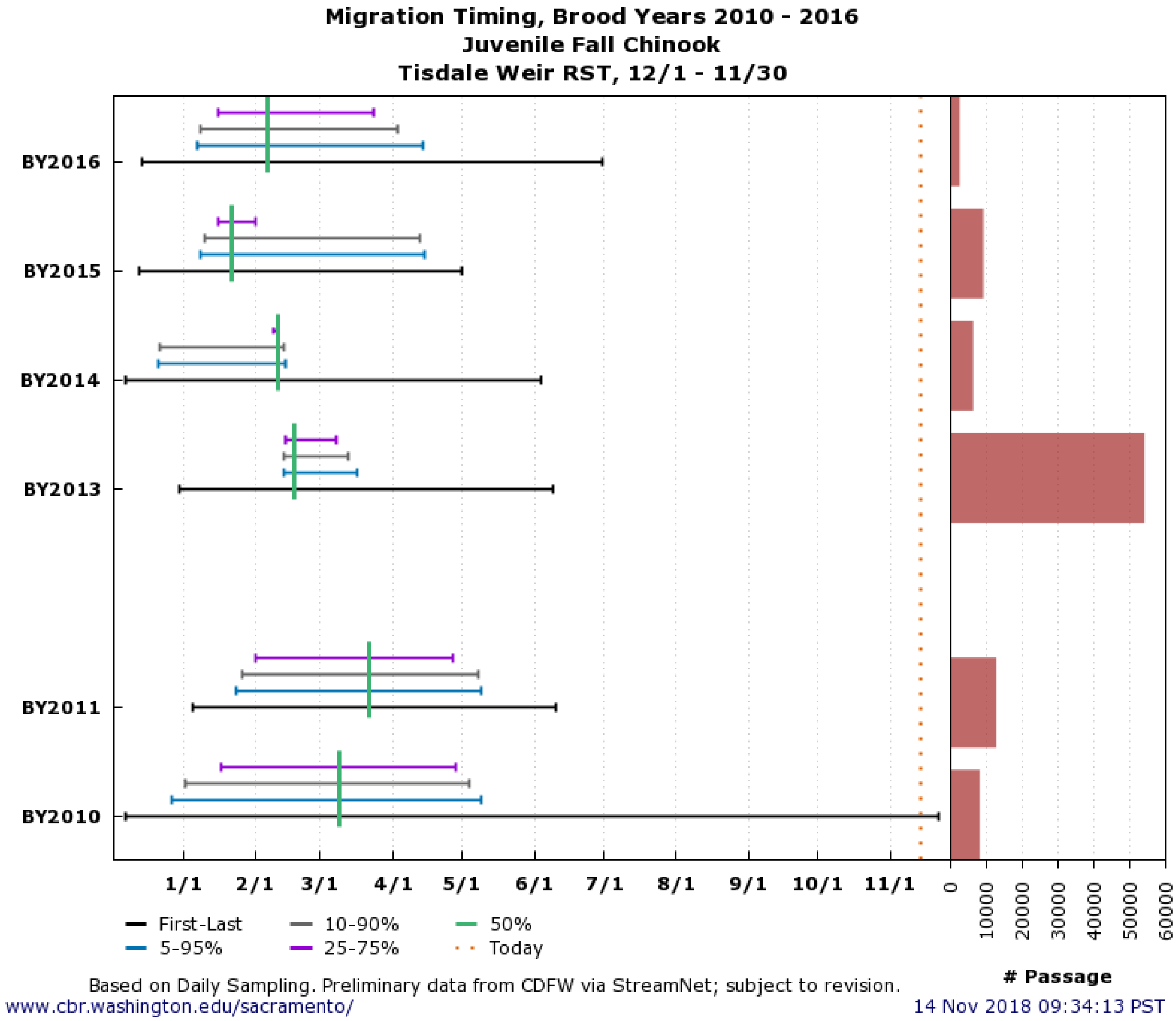


F.4 Fall-Run Chinook Salmon

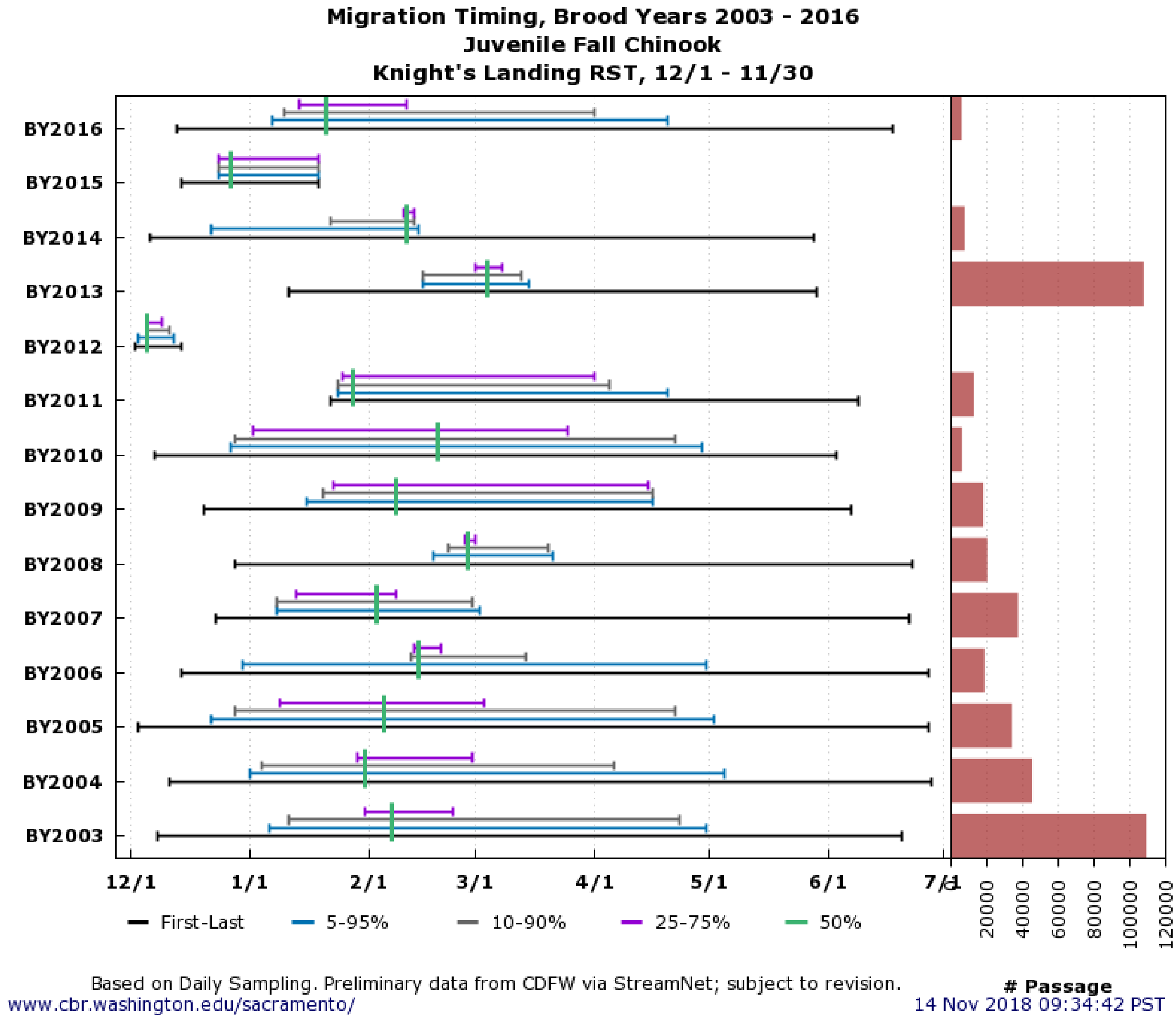
F.4.1 Fall-Run Chinook Salmon: Red Bluff Diversion Dam



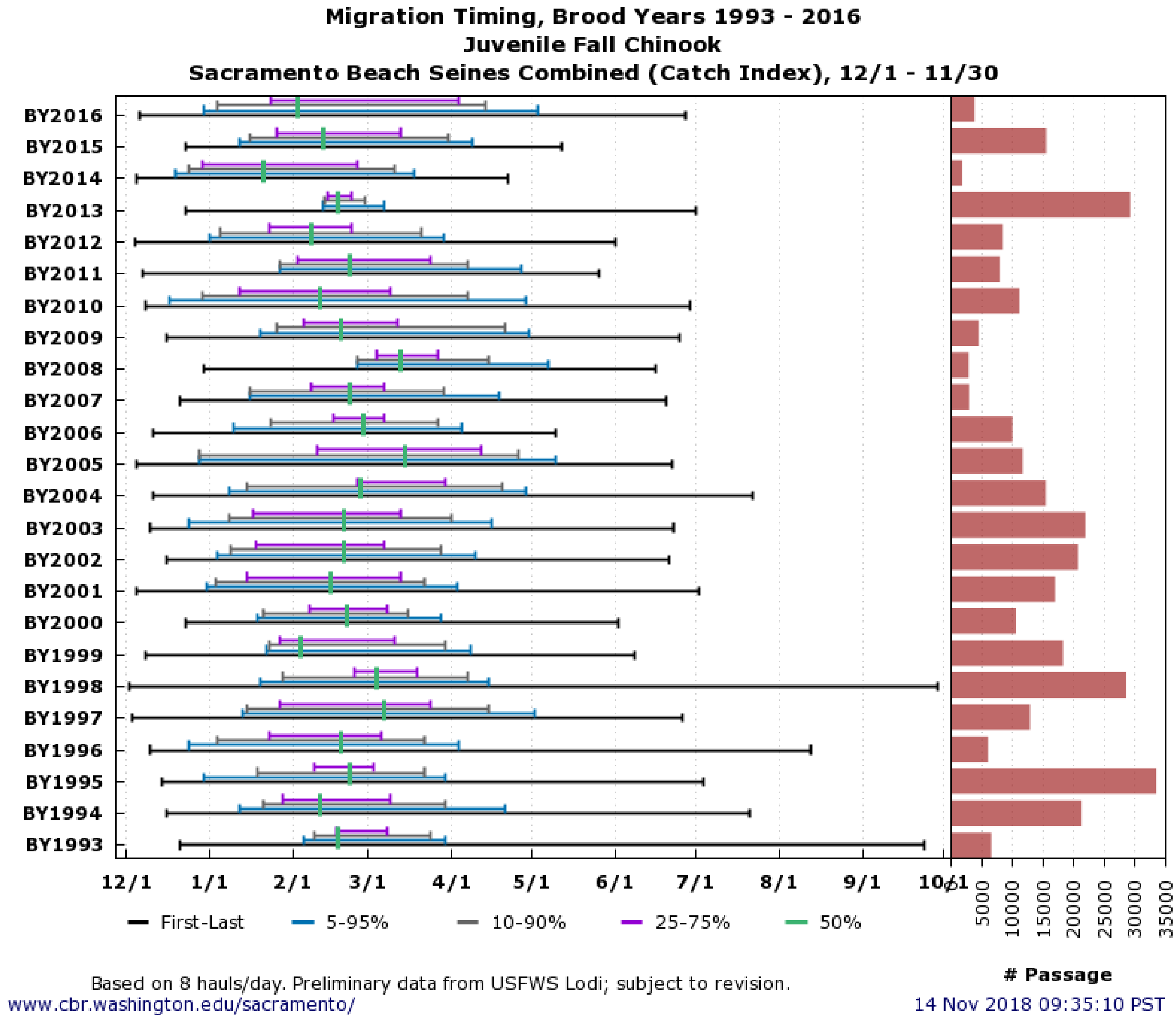
F.4.2 Fall-Run Chinook Salmon: Tisdale Weir Rotary Screw Traps



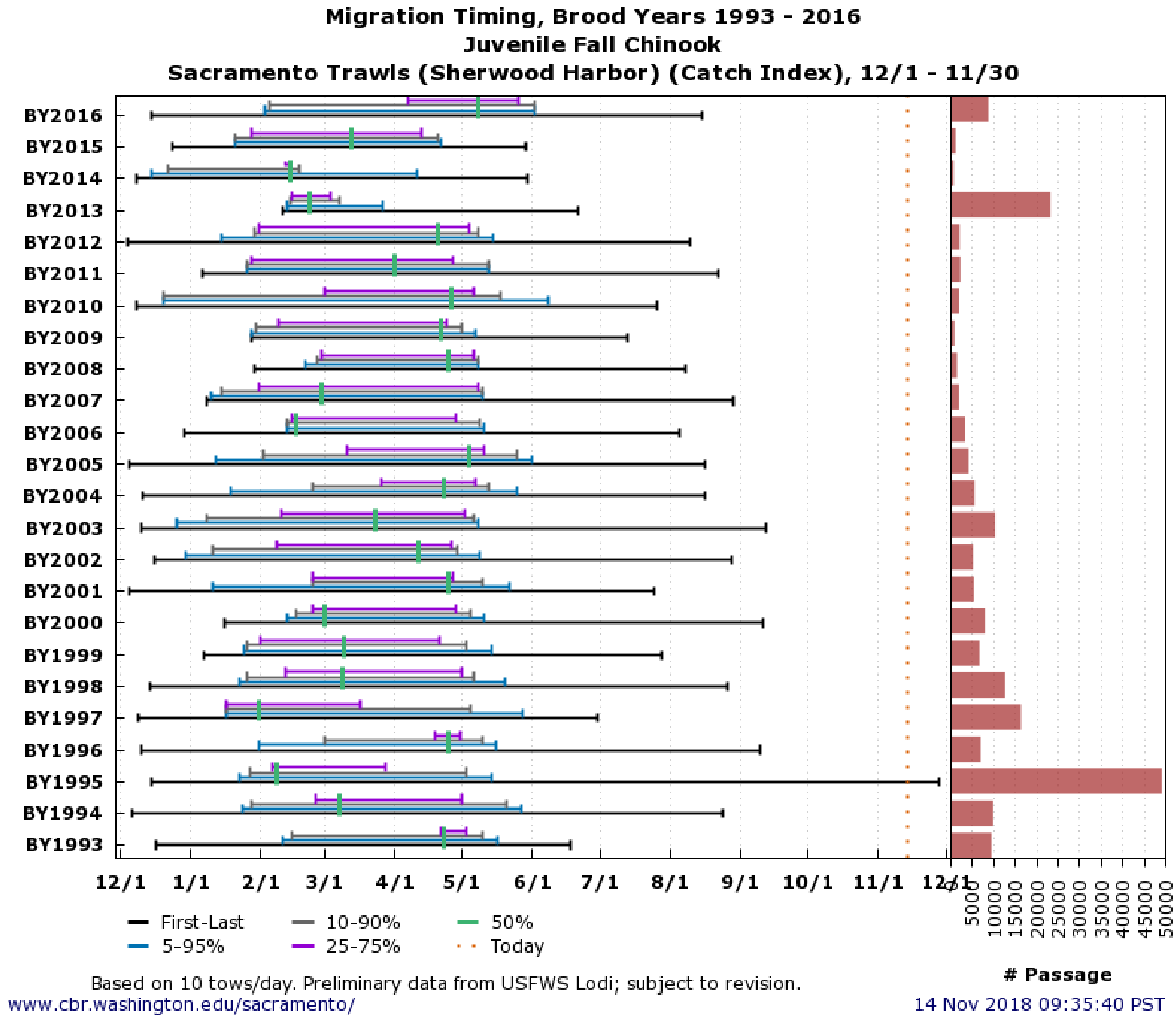
F.4.3 Fall-Run Chinook Salmon: Knights Landing Rotary Screw Traps



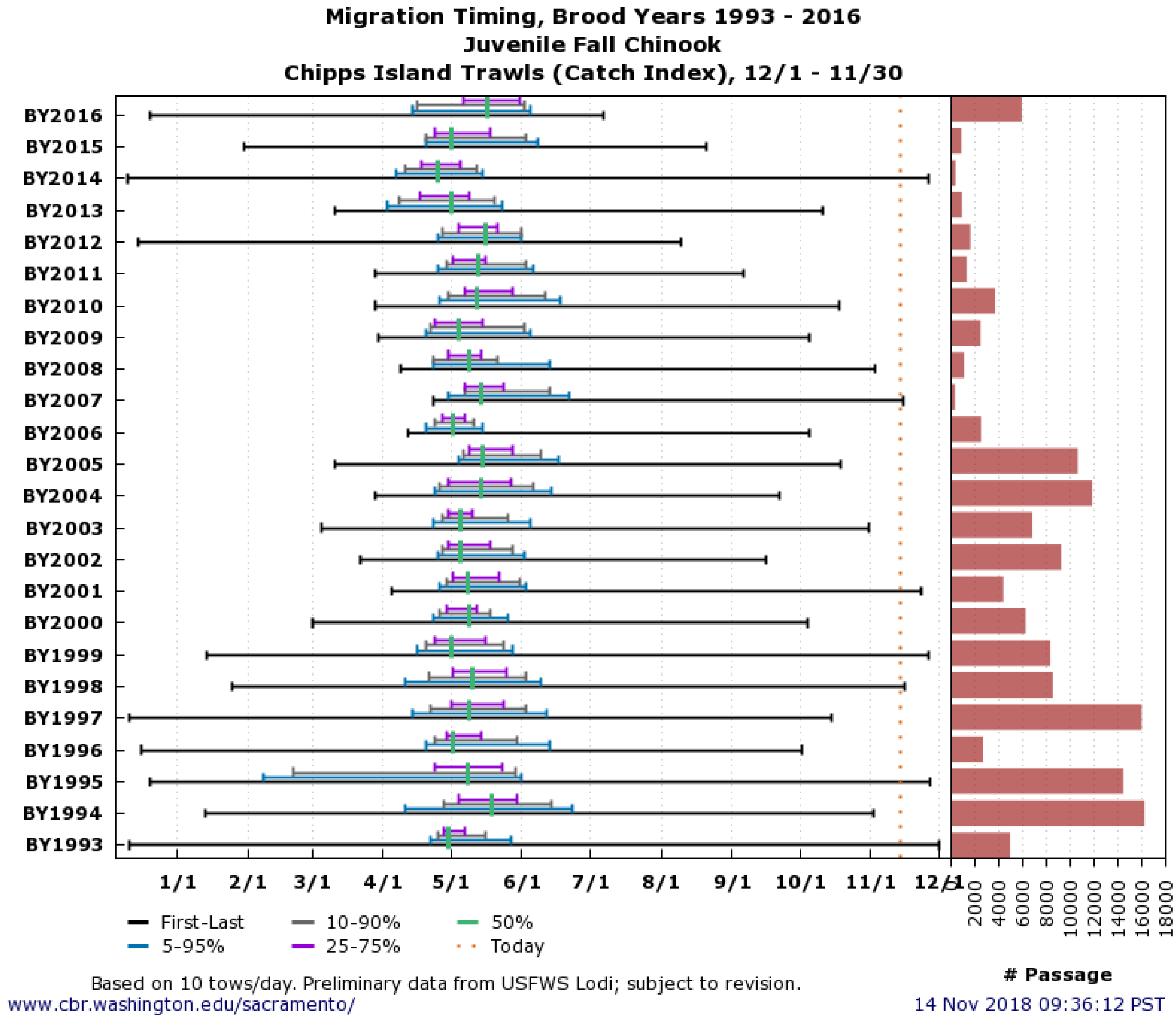
F.4.4 Fall-Run Chinook Salmon: Sacramento Beach Seines Combined



F.4.5 Fall-Run Chinook Salmon: Sacramento Trawls (Sherwood Harbor)



F.4.6 Fall-Run Chinook Salmon: Chipps Island Trawls



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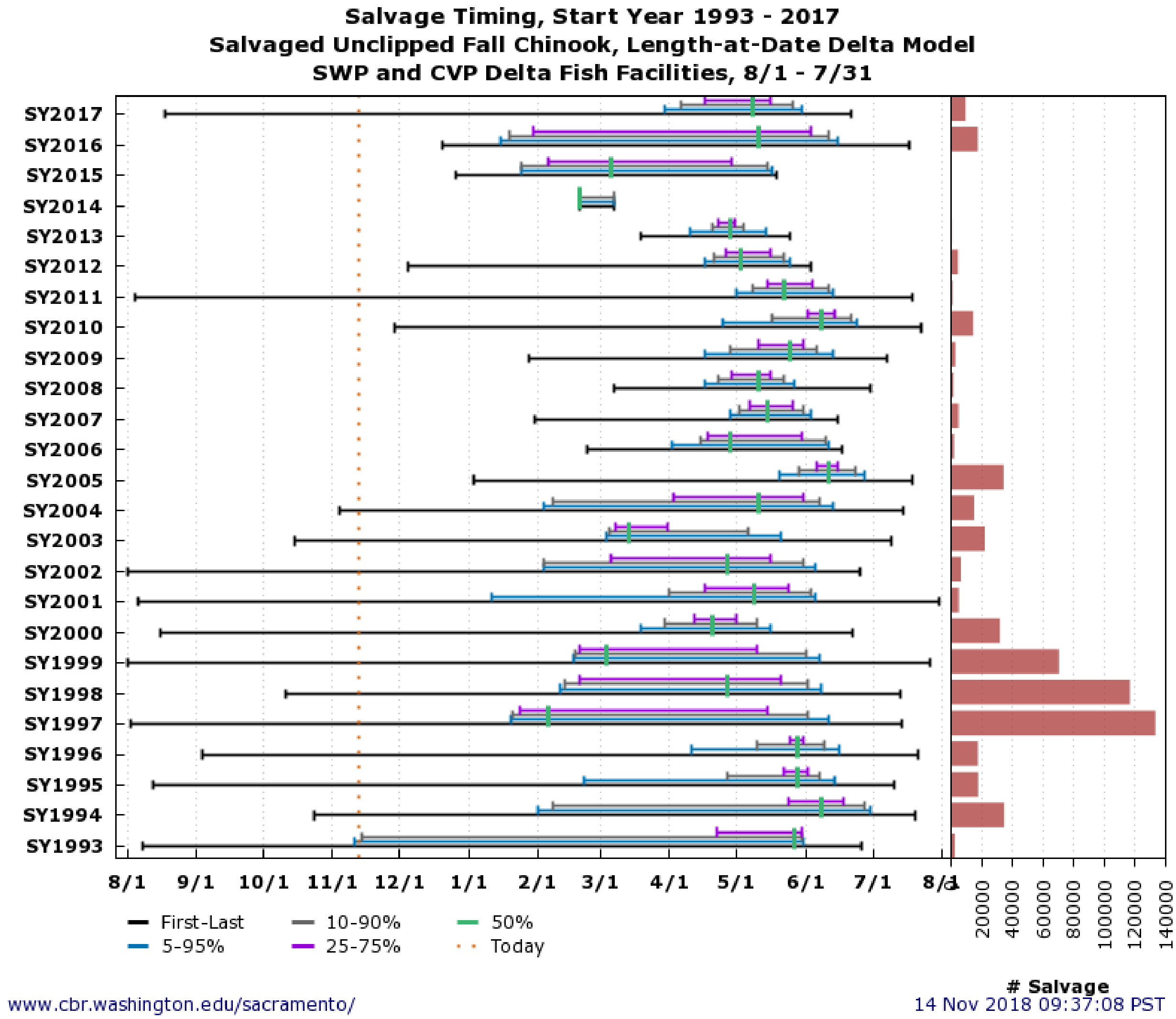

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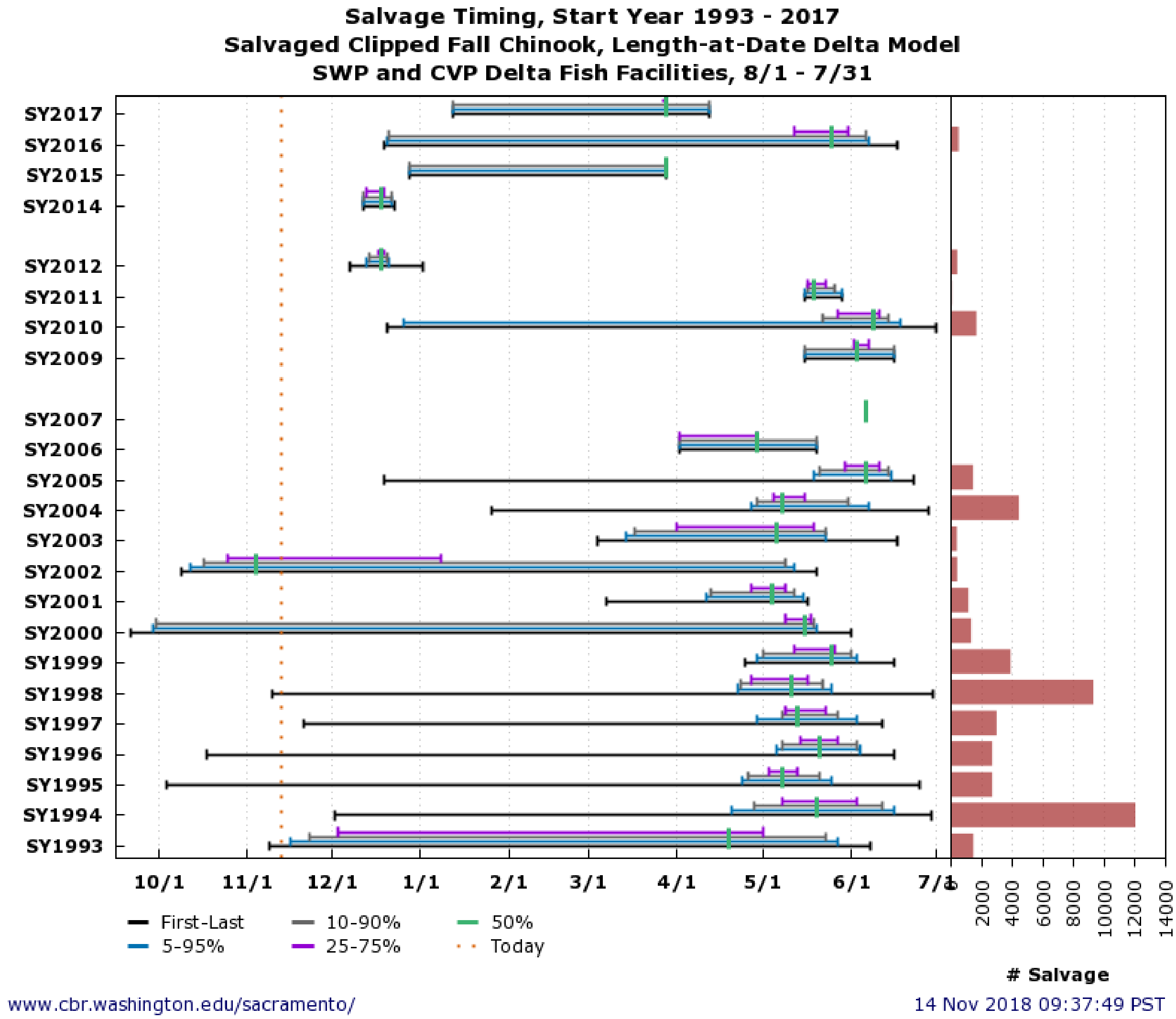
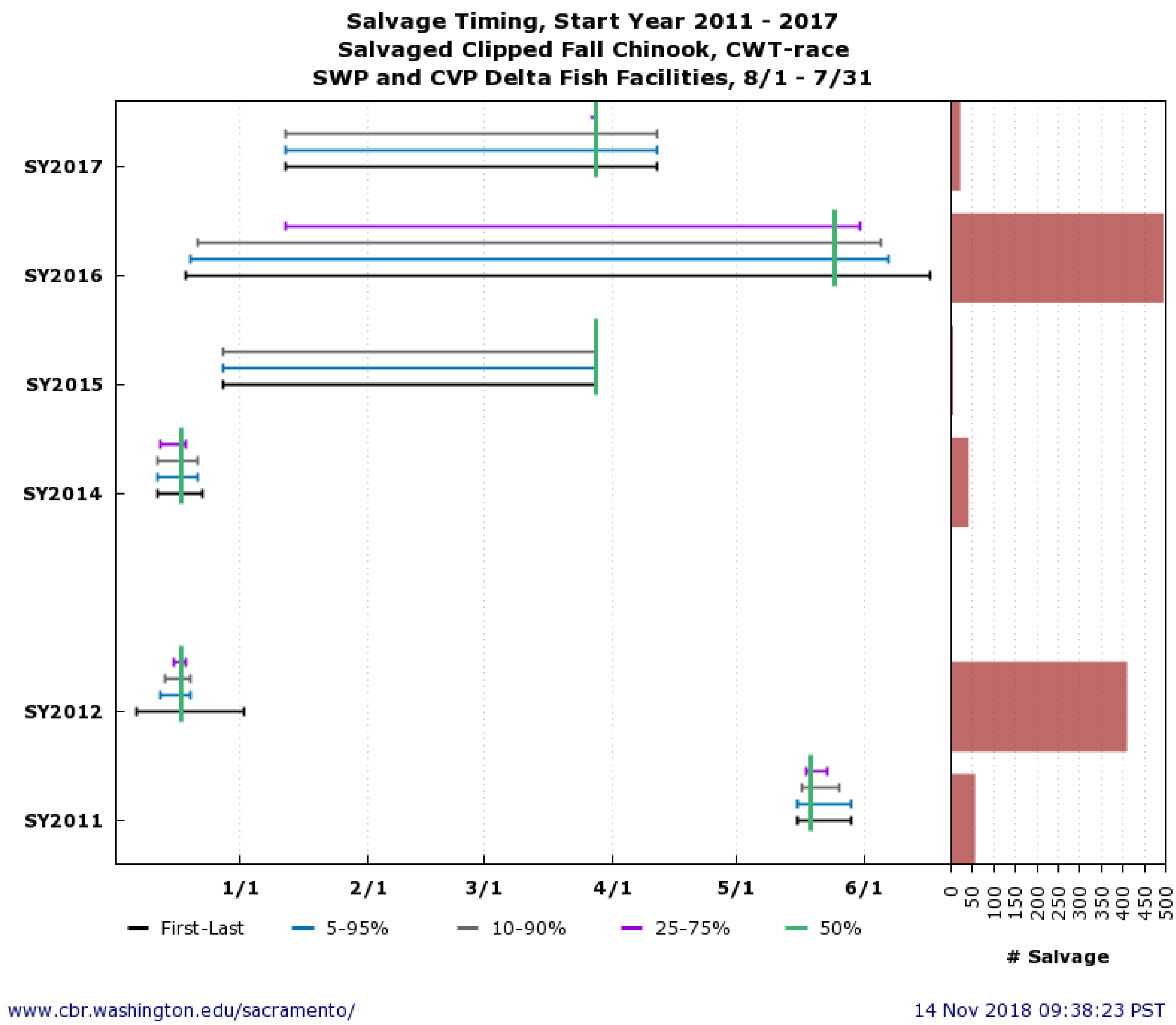
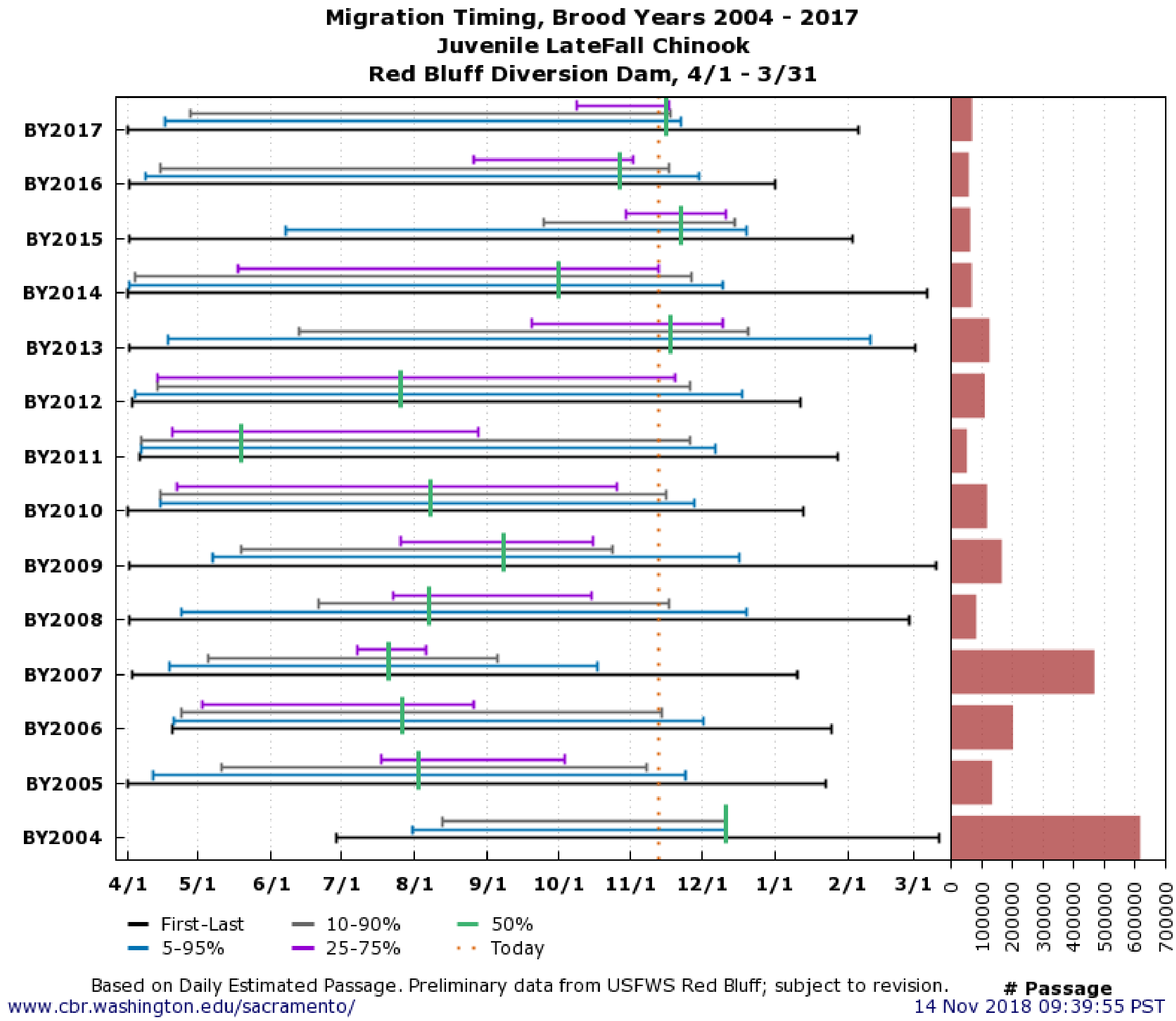


F.4.9 Fall-Run Chinook Salmon Salvage: Clipped (CWT-Race)

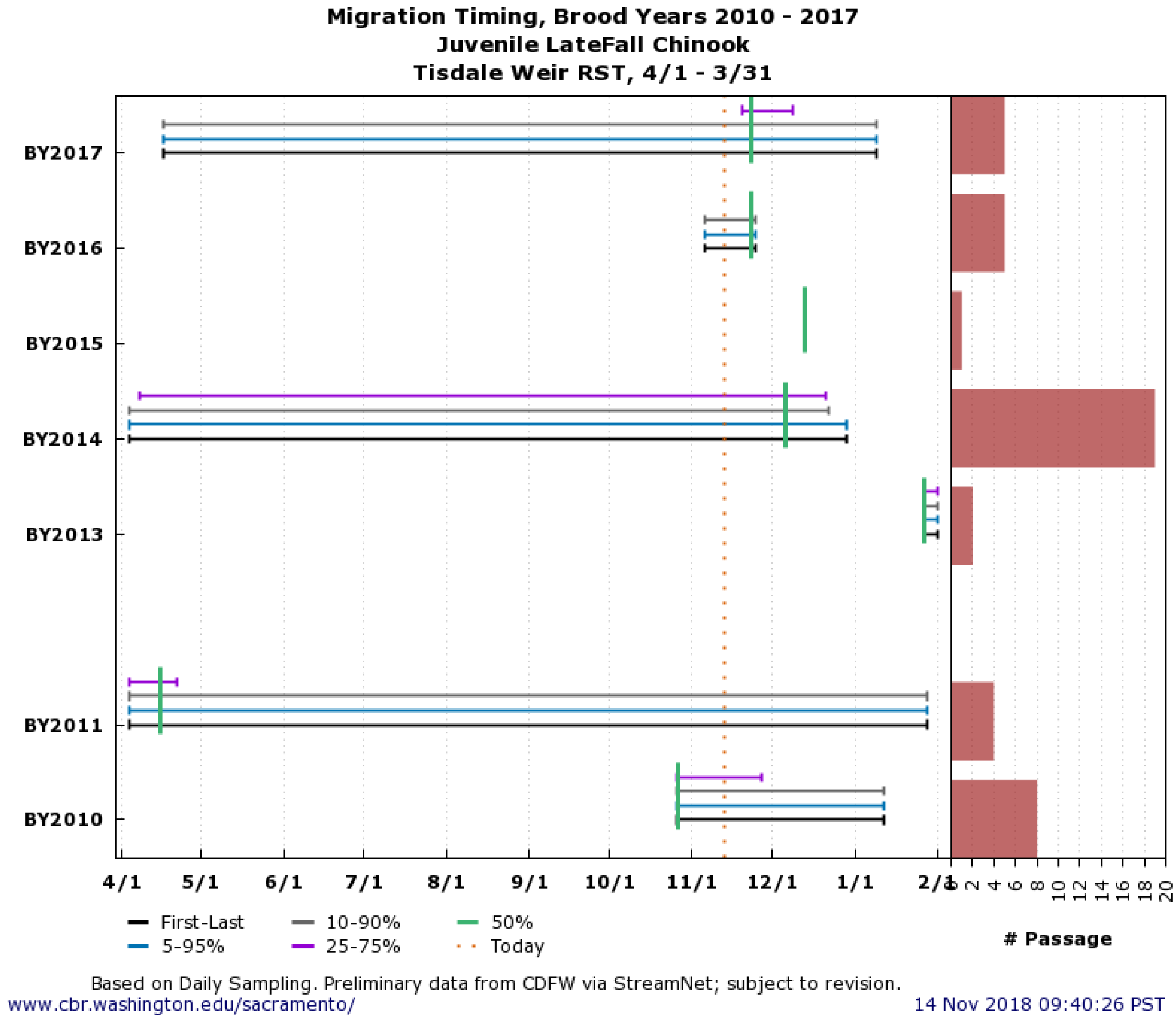


F.5 Late Fall-Run Chinook Salmon

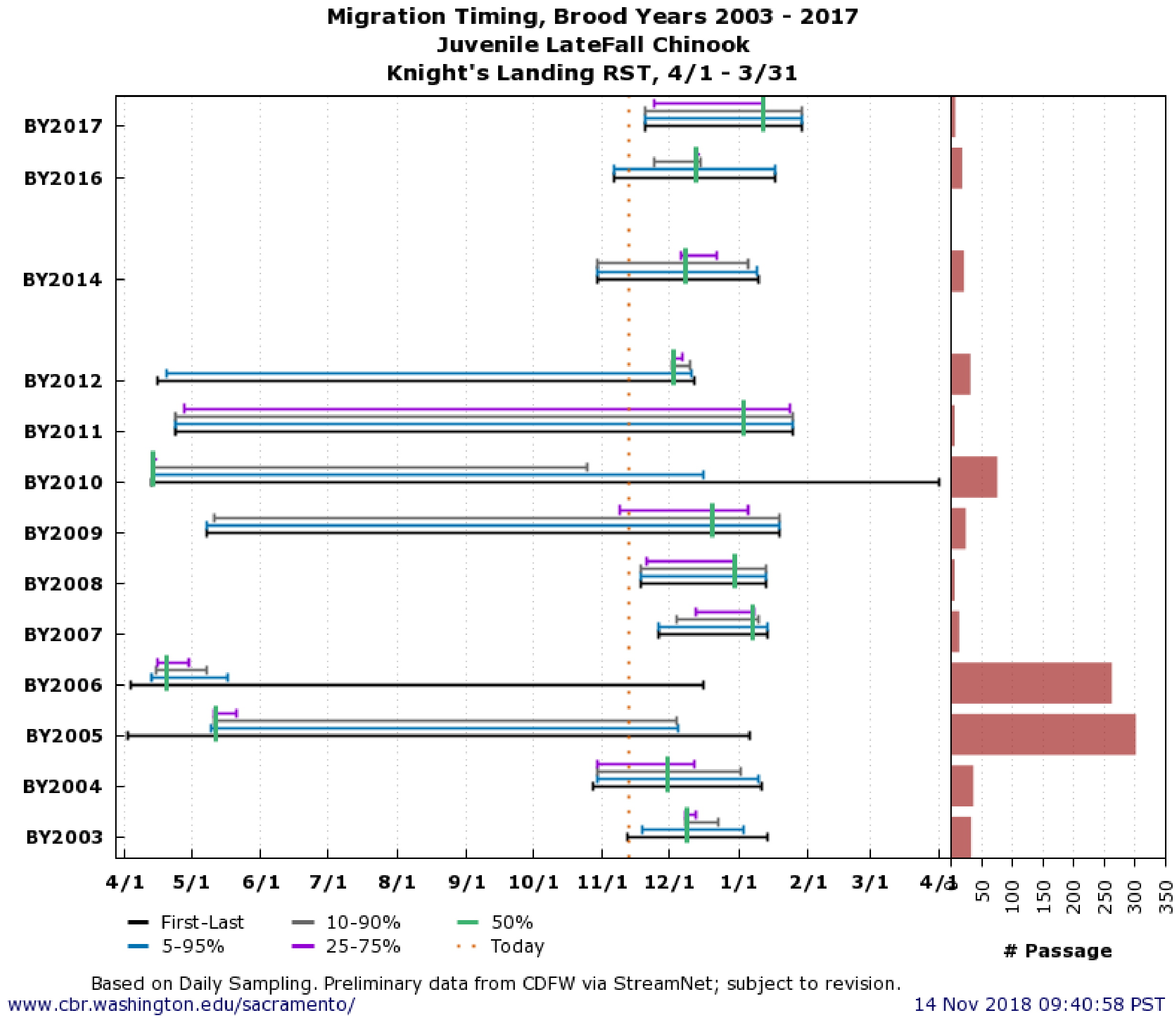
F.5.1 Late Fall-Run Chinook Salmon: Red Bluff Diversion Dam



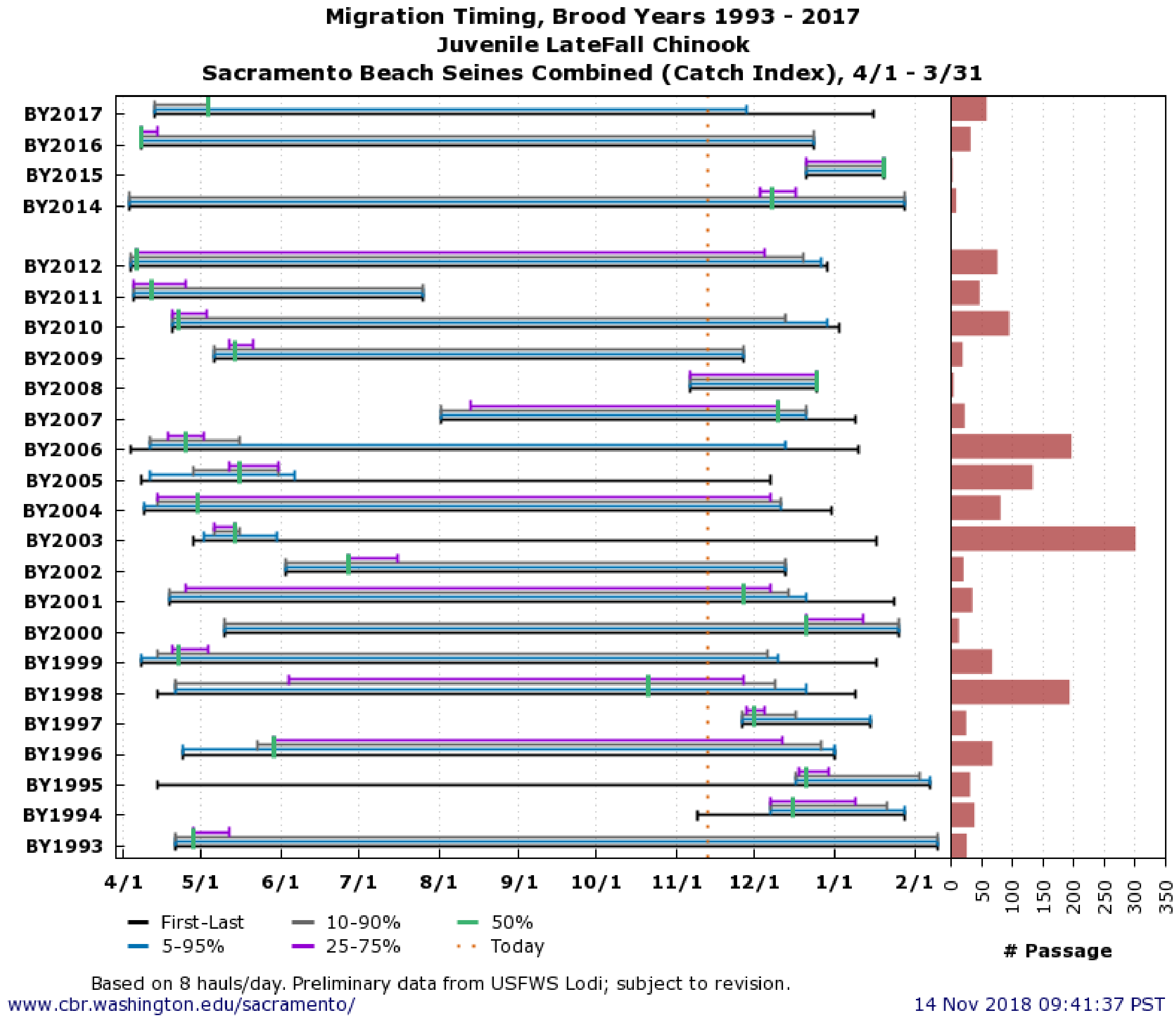
F.5.2 Late Fall-Run Chinook Salmon: Tisdale Weir Rotary Screw Traps



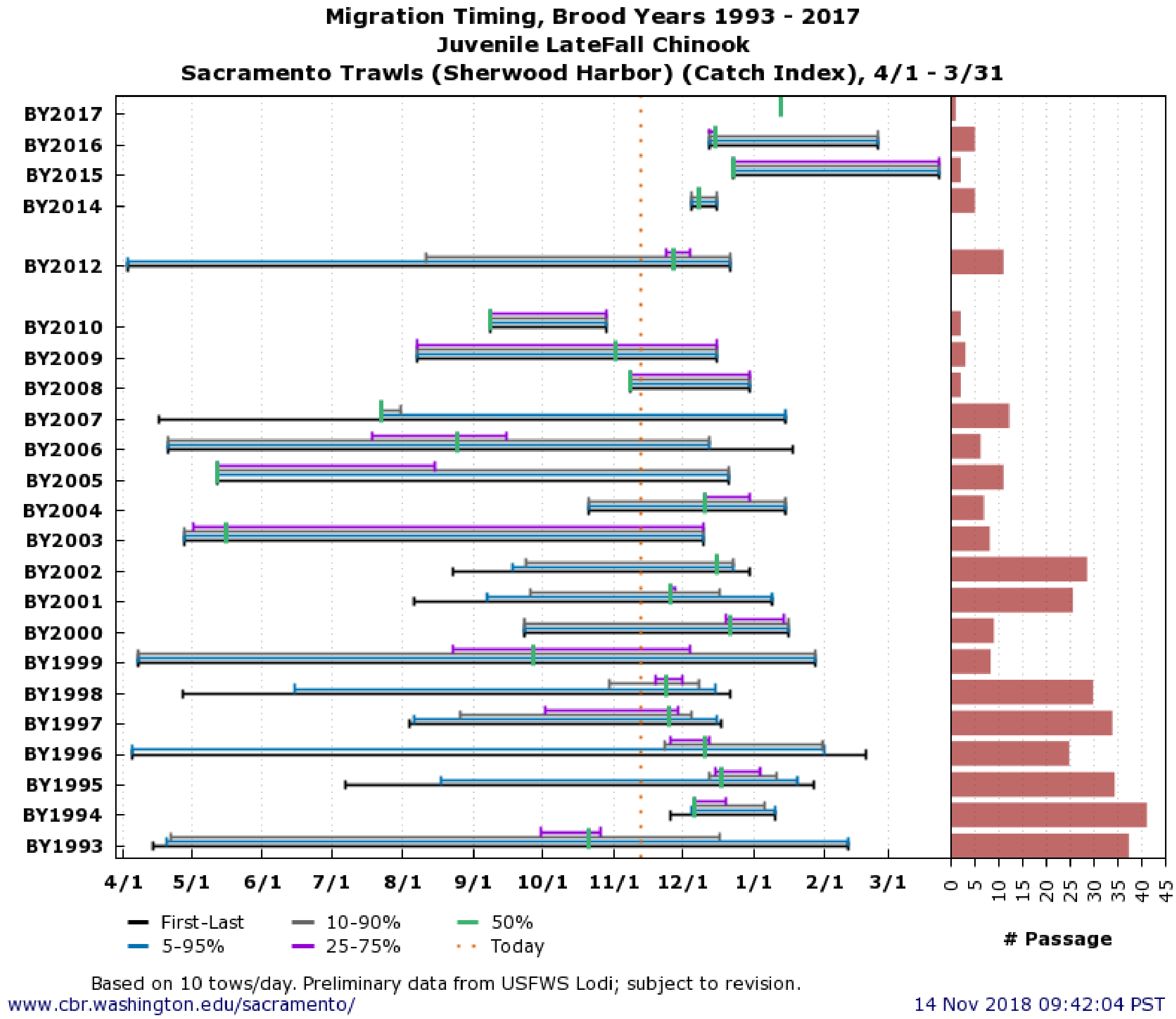
F.5.3 Late Fall-Run Chinook Salmon: Knights Landing Rotary Screw Traps



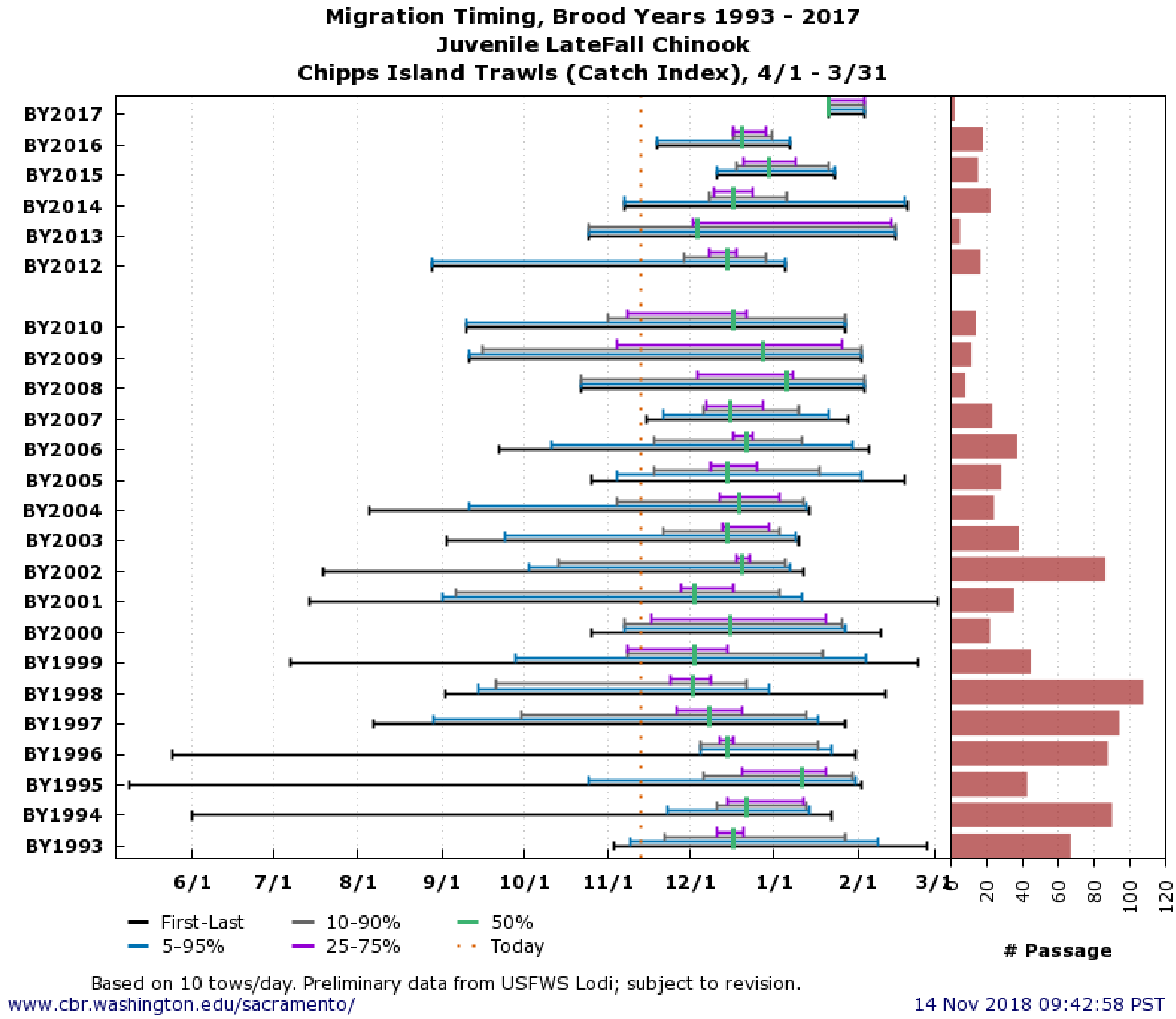
F.5.4 Late Fall-Run Chinook Salmon: Sacramento Beach Seines Combined



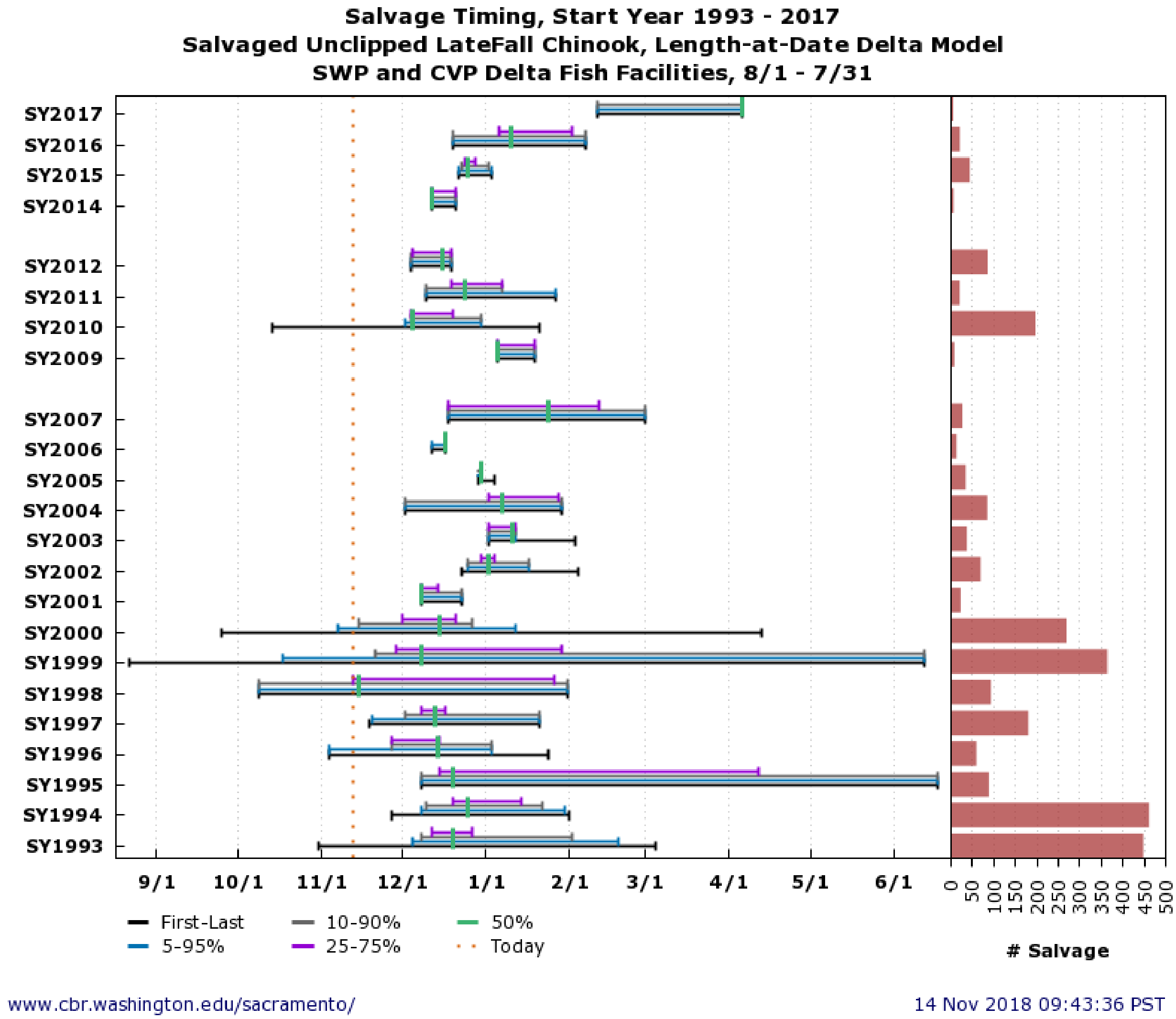
F.5.5 Late Fall-Run Chinook Salmon: Sacramento Trawls (Sherwood Harbor)



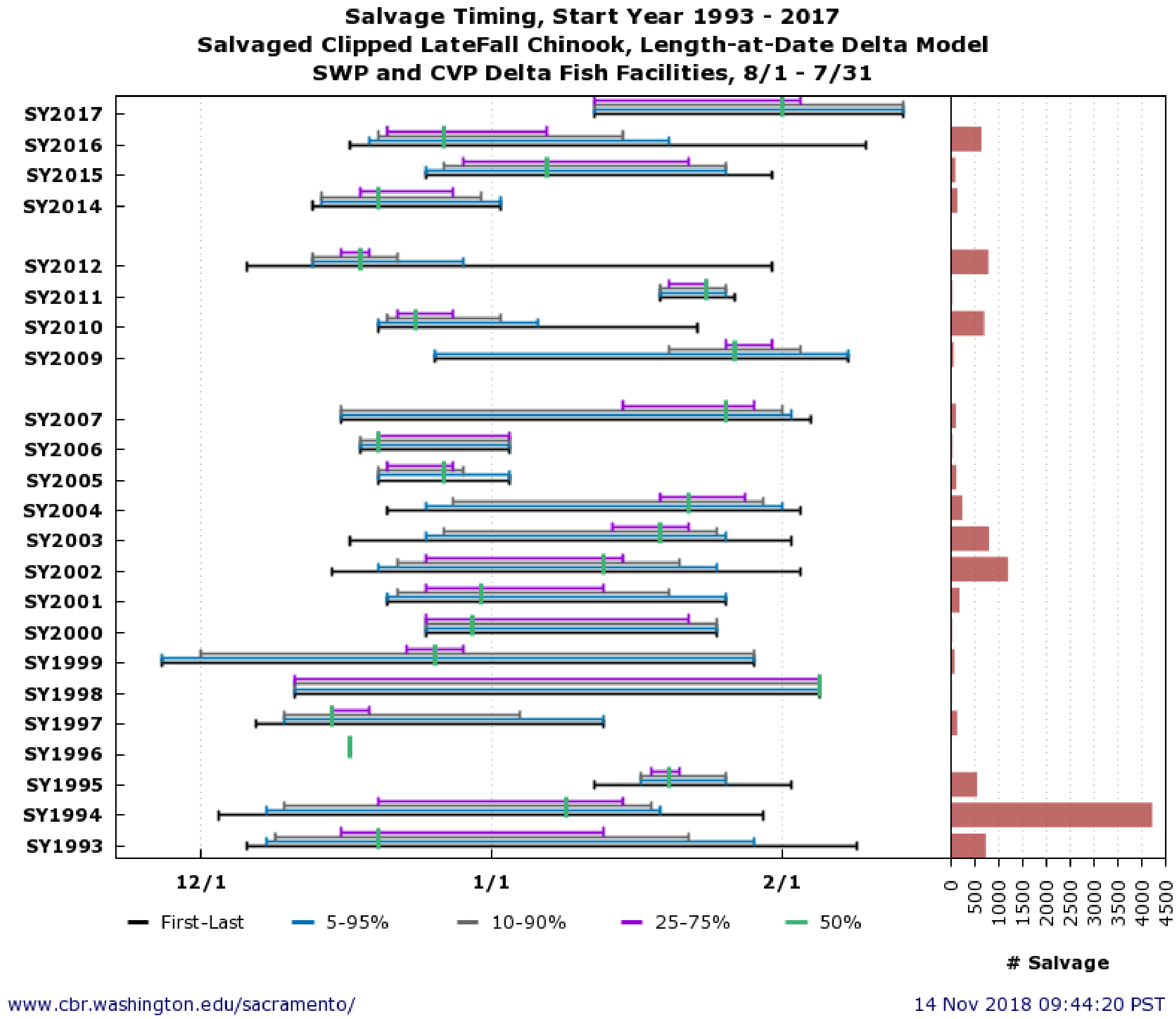
F.5.6 Late Fall-Run Chinook Salmon: Chipps Island Trawls



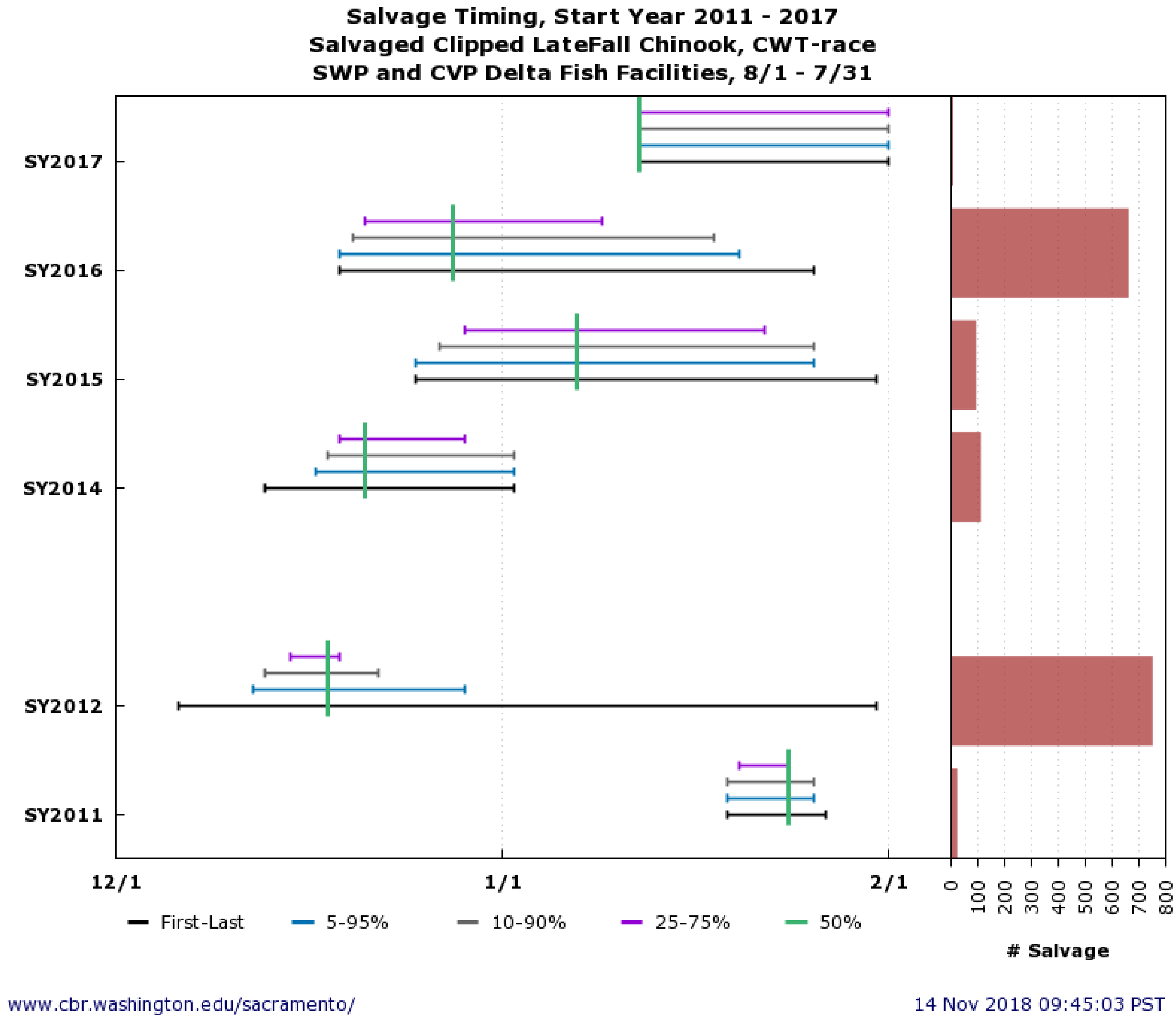
F.5.7 Late Fall-Run Chinook Salmon Salvage: Unclipped (Length-at-Date)



F.5.8 Late Fall-Run Chinook Salmon Salvage: Clipped (Length-at-Date)

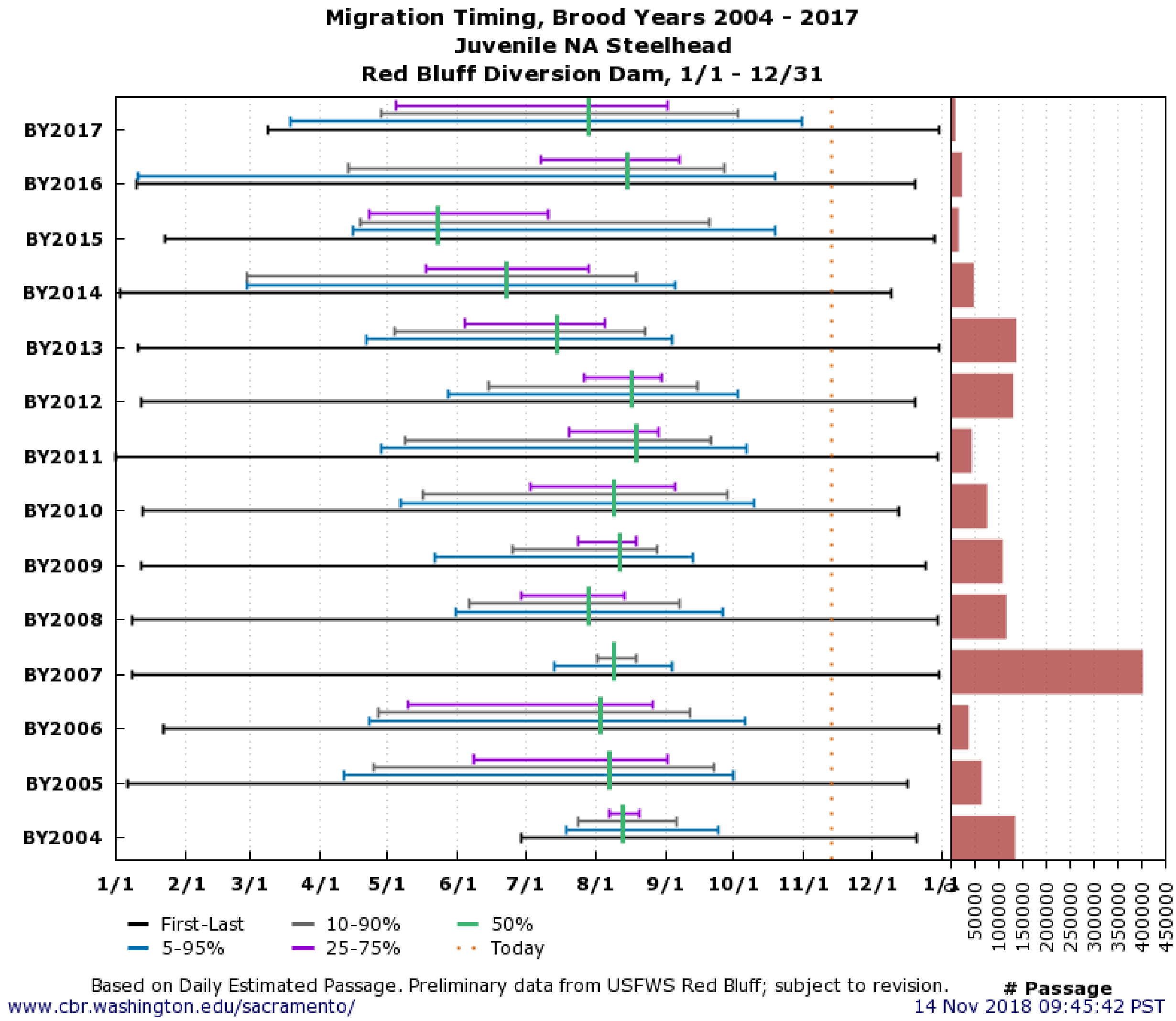


F.5.9 Late Fall-Run Chinook Salmon Salvage: Clipped (CWT-Race)

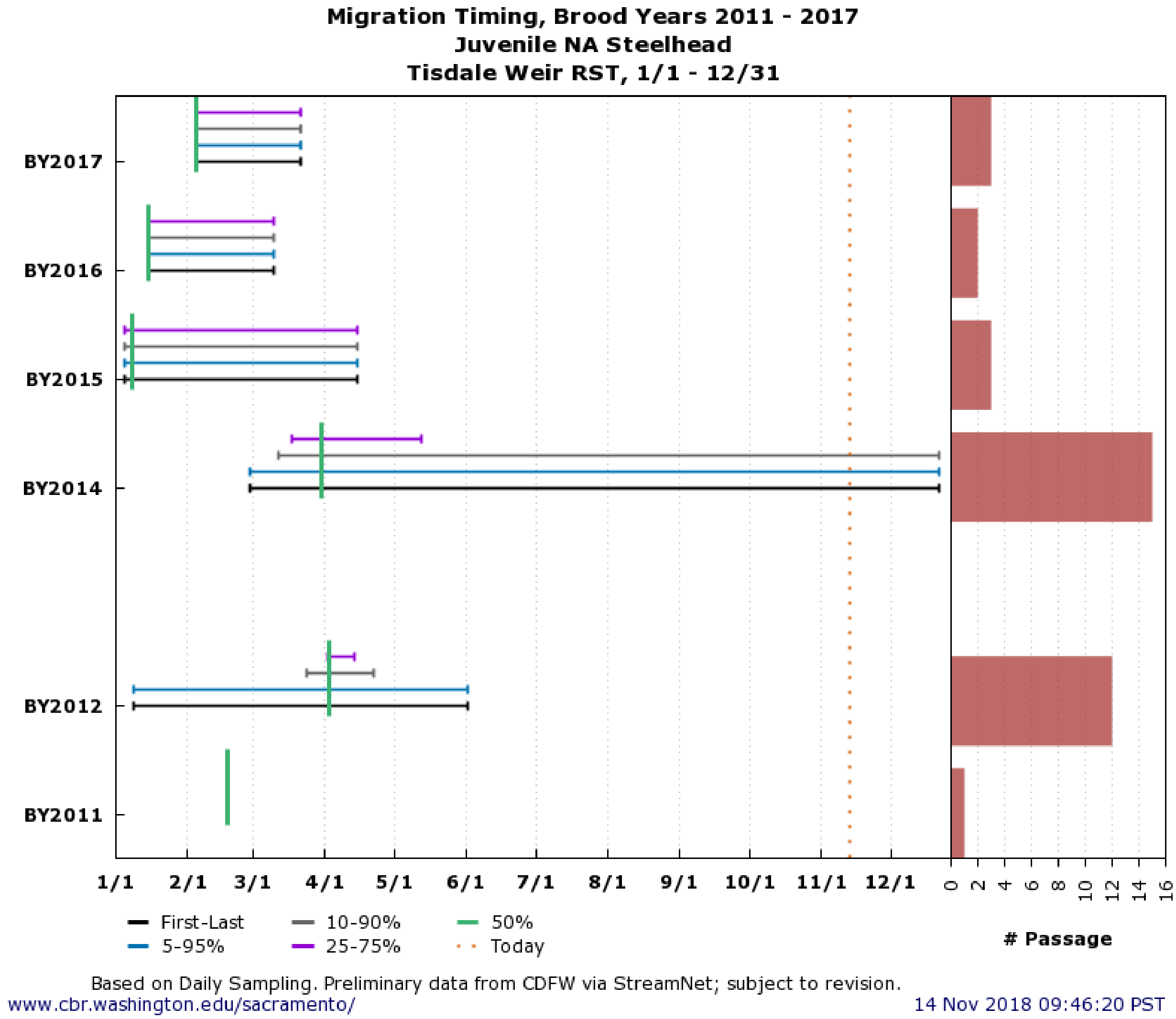


F.6 Steelhead

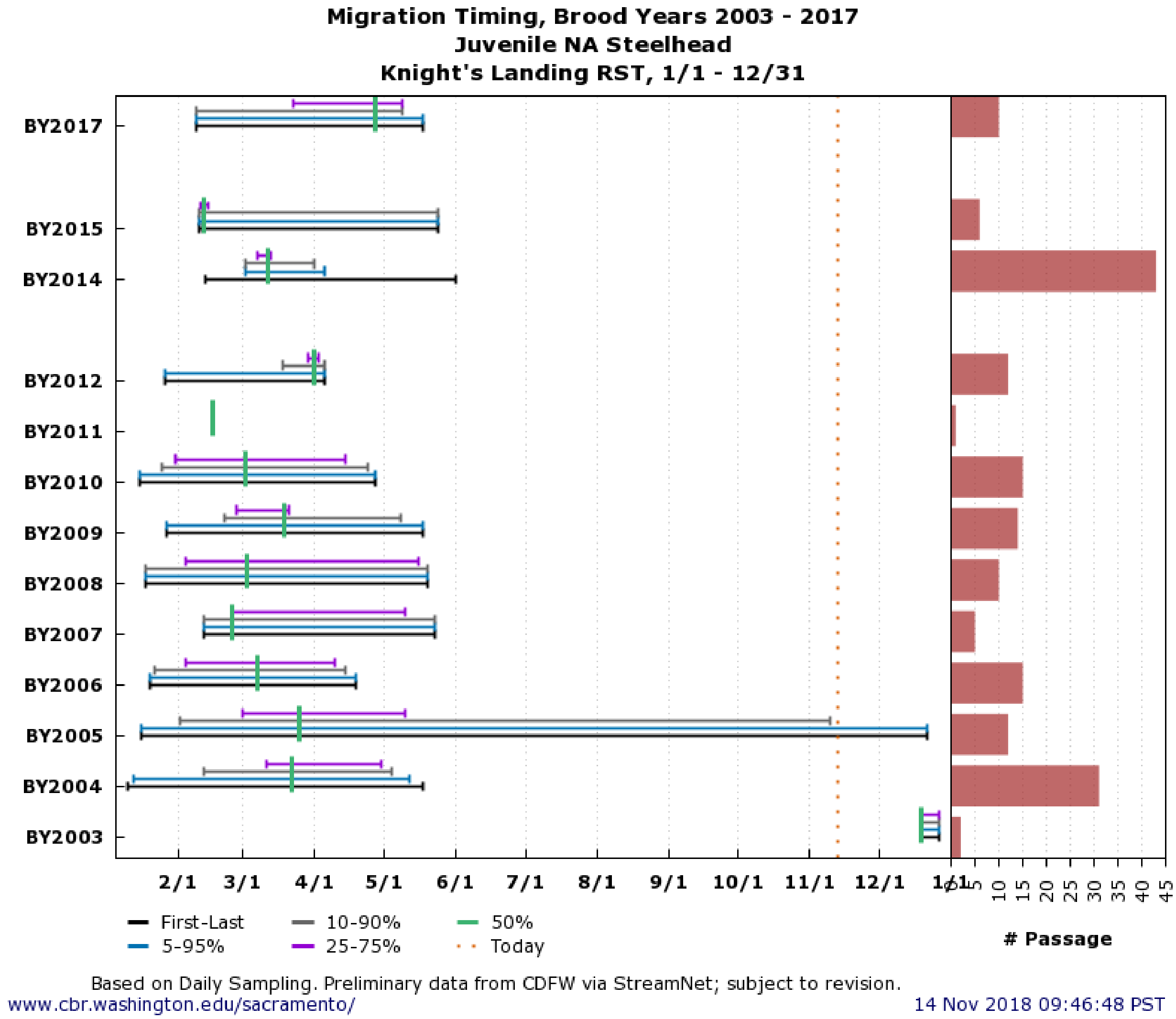
F.6.1 Steelhead: Red Bluff Diversion Dam



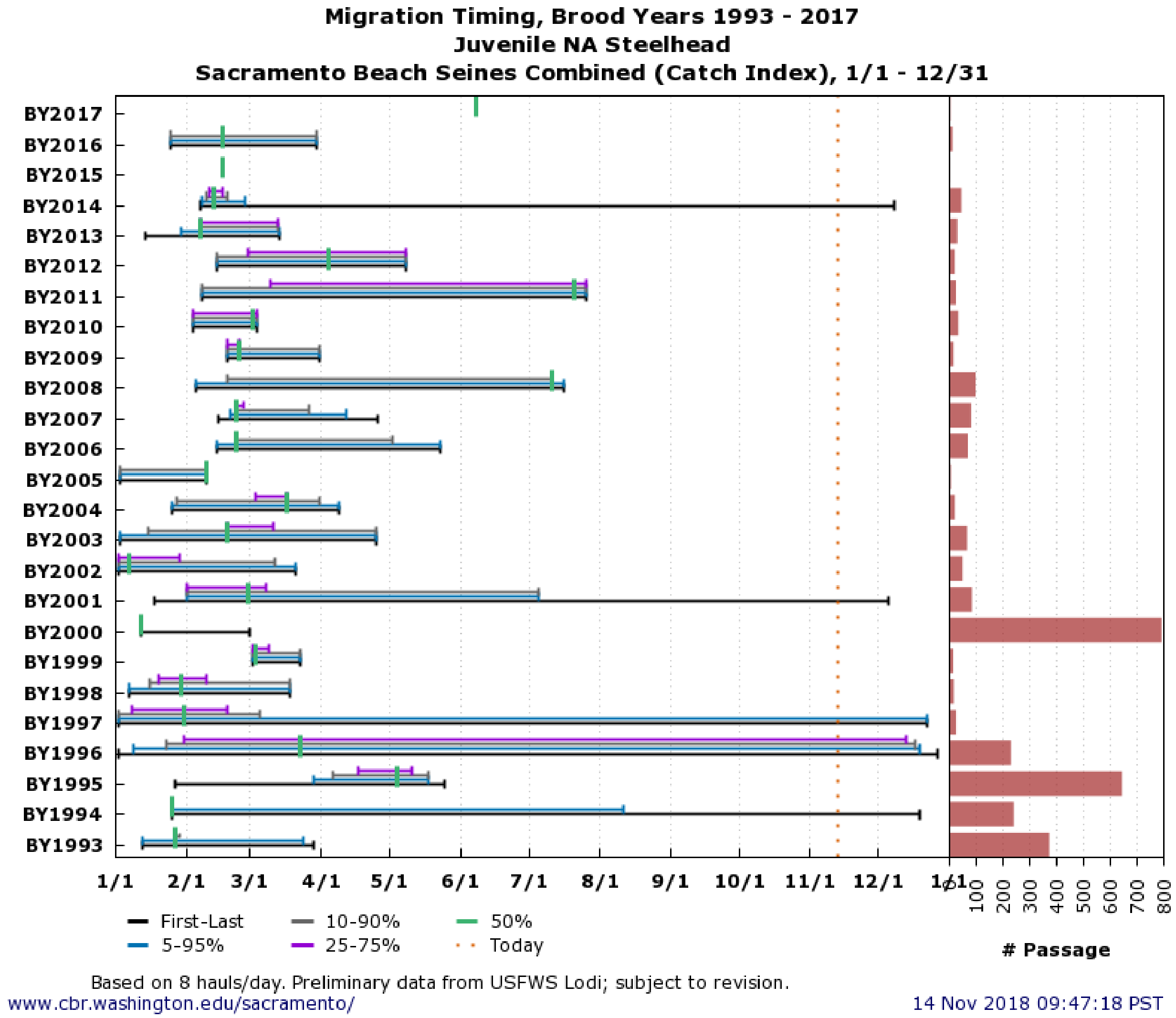
F.6.2 Steelhead: Tisdale Weir Rotary Screw Traps



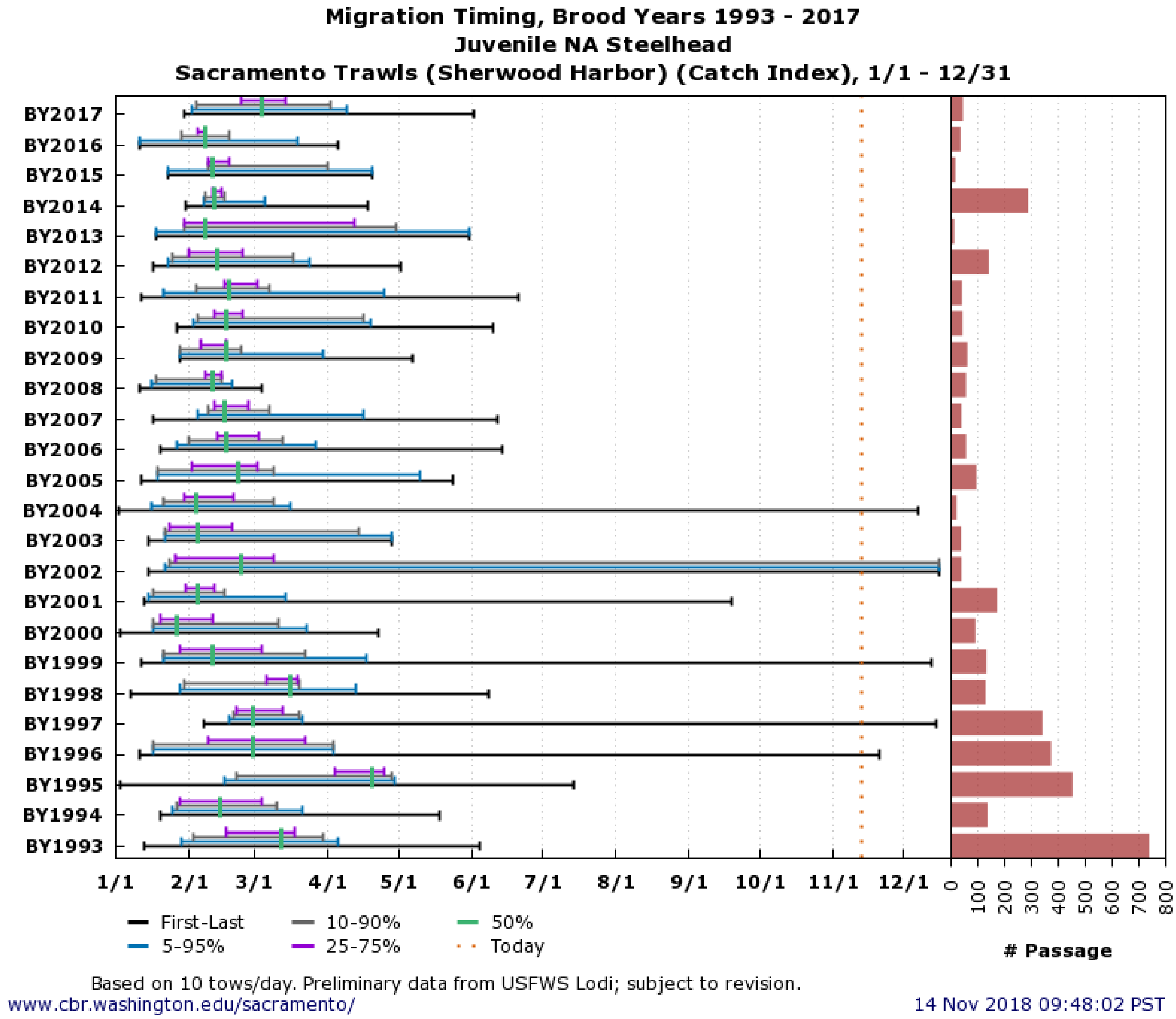
F.6.3 Steelhead: Knights Landing Rotary Screw Traps



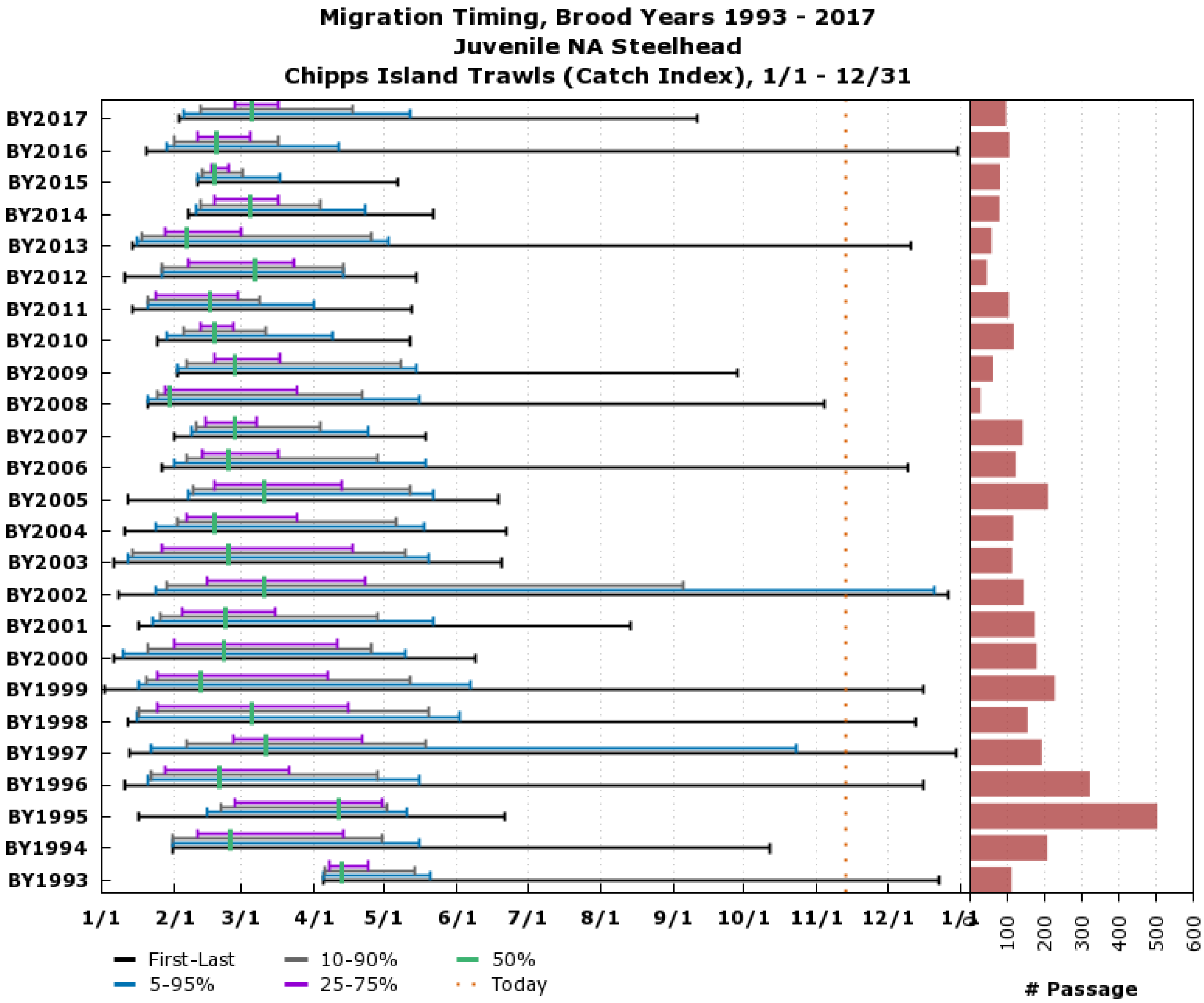
F.6.4 Steelhead: Sacramento Beach Seines Combined



F.6.5 Steelhead: Sacramento Trawls (Sherwood Harbor)

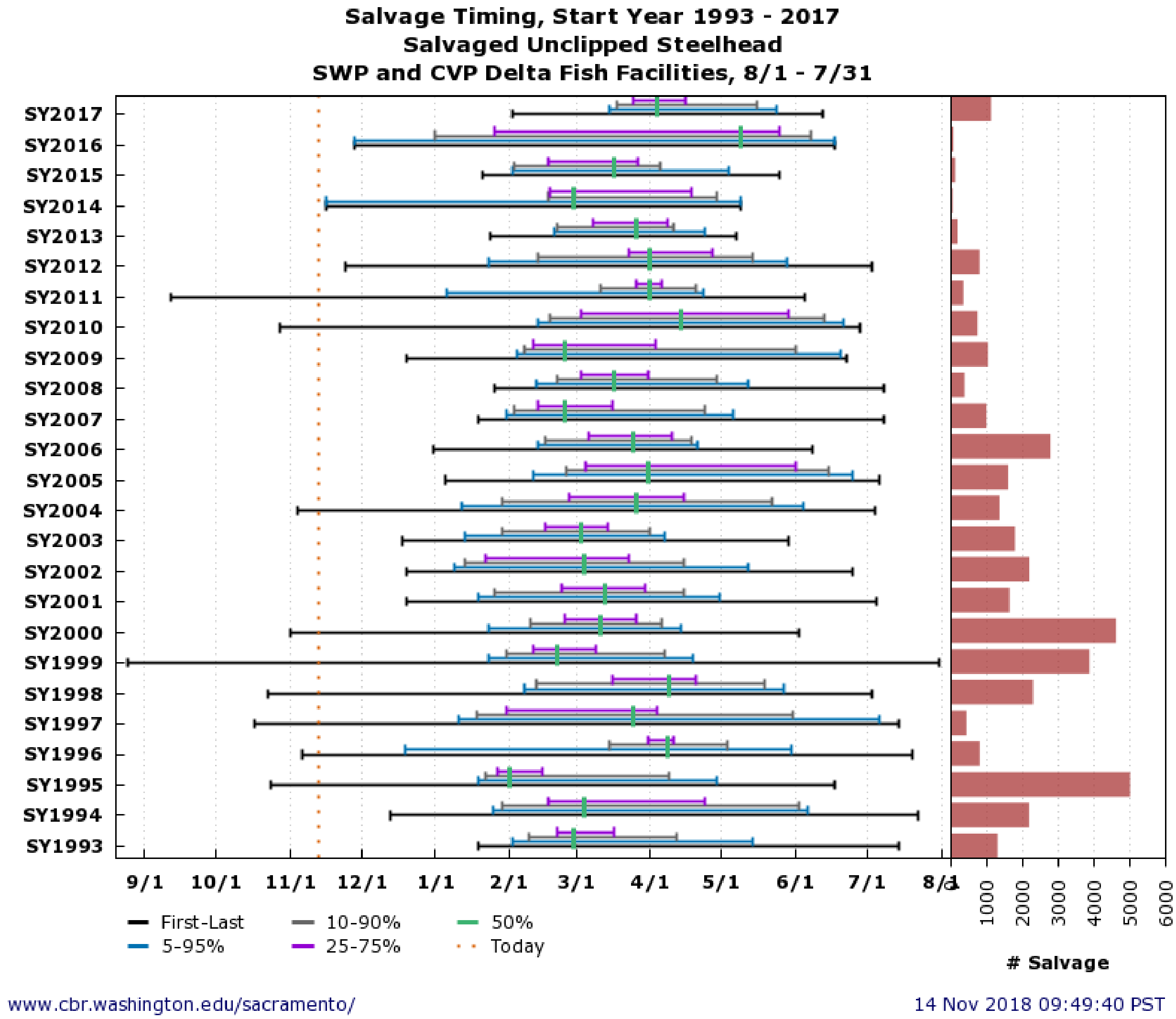


F.6.6 Steelhead: Chipps Island Trawls

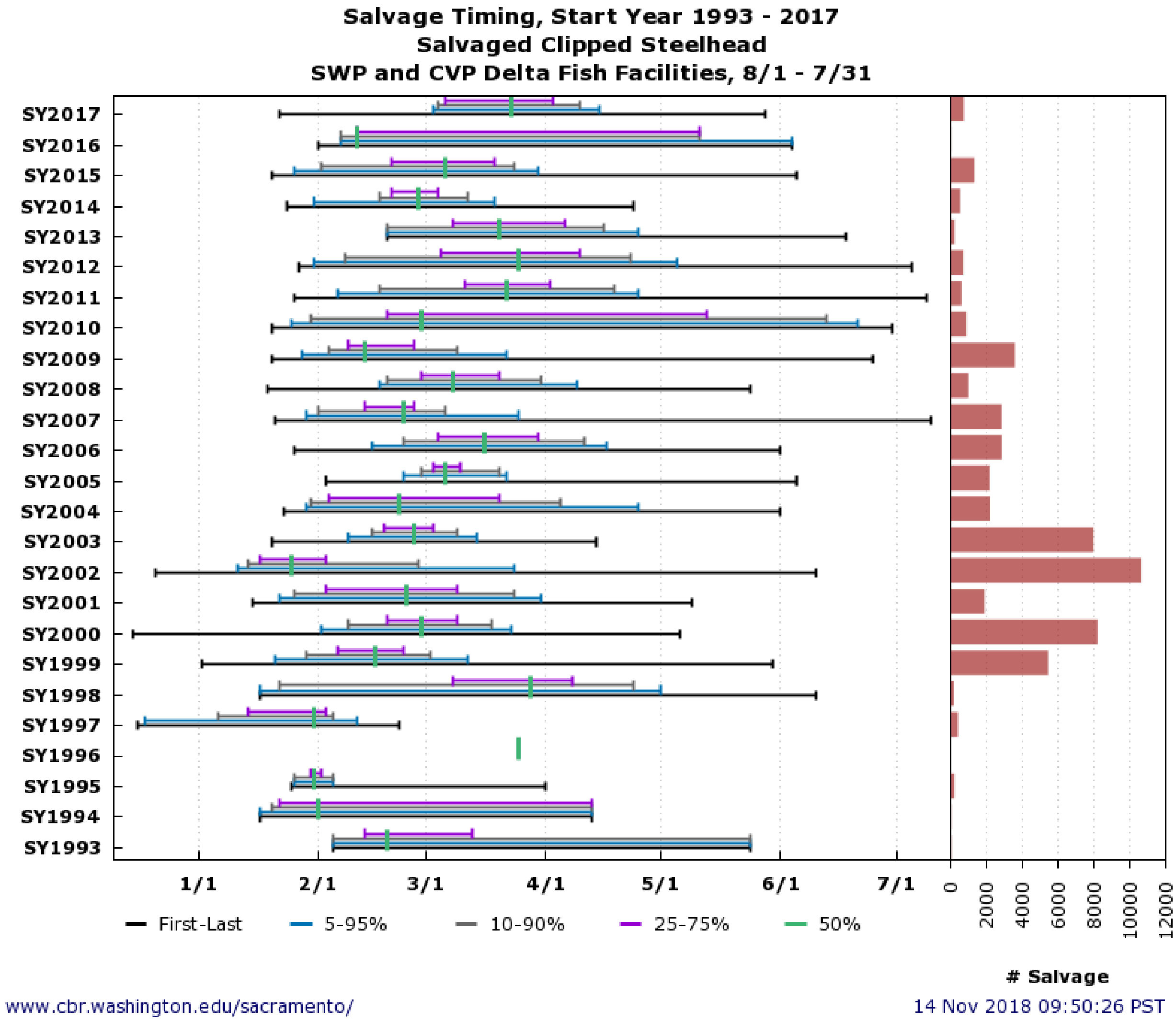


Based on 10 tows/day. Preliminary data from USFWS Lodi; subject to revision.
www.cbr.washington.edu/sacramento/ 14 Nov 2018 09:48:33 PST

F.6.7 Steelhead Salvage: Unclipped



F.6.8 Steelhead Salvage: Clipped



Appendix G Clifton Court Forebay Predation Studies

State of California
The California Natural Resources Agency
Department of Water Resources

Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay

March 2009

Arnold Schwarzenegger
Governor
State of California

Mike Chrisman
Secretary
California Natural Resources Agency

Lester Snow
Director
Department of Water Resources

State of California
The California Natural Resources Agency
Department of Water Resources

Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay

Prepared by:

Kevin W. Clark[1], Mark D. Bowen[2], Ryan B. Mayfield[3], Katherine P. Zehfuss[4], Justin D. Taplin[5], and Charles H. Hanson[6]

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In collaboration with:
National Marine Fisheries Service
Central Valley Fish Facilities Review Team
Interagency Ecological Program Management Team

Prepared under the supervision of

Zaffar Eusuff
Chief, Fishery Improvements Section

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List of Abbreviations

ANOVA	Analysis of Variance
CHTR	Collection, Handling, Transport, Release
CIMIS	California Irrigation Management Information System
CPUE	Catch Per Unit Effort
CVFFRT	Central Valley Fish Facility Review Team
Delta	Sacramento-San Joaquin Delta
DFG	(California) Department of Fish and Game
DMR	Daily Movement Rate
DO	Dissolved Oxygen
DWR	(California) Department of Water Resources
EC	Electrical Conductivity
ESA	Endangered Species Act
FCCL	(UC Davis) Fish Conservation and Culture Laboratory
GPS	Global Positioning System
ID	Identification
MAP	Management Action Plan
MD	Maximum Hourly Sum of Detections
MR	Movement Rate
NMFS	National Marine Fisheries Service
No.	Number
OCAP	Operations Criteria and Plan
PAR	Photosynthetically Available Radiation
PIT	Passive Integrated Transponder
PST	Pacific Standard Time
SAIC	Science Application International Corporation
SFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project
TD	Total Number of Detections
TFCF	Tracy Fish Collection Facility
USFWS	United States Fish and Wildlife Service
UV	Ultraviolet
VAMP	Vernalis Adaptive Management Plan

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Executive Summary

In response to the 2004 National Marine Fisheries Service (NMFS) biological opinion, the California Department of Water Resources (DWR) conducted a study in 2005, 2006, and 2007 to assess and quantify steelhead pre-screen losses within Clifton Court Forebay. Steelhead entrained in the Forebay are subject to predation, synonymous with pre-screen loss, as they traverse the Forebay toward the John E. Skinner Delta Fish Protective Facility (SFPF). The investigation was developed to provide useful information that could serve to reduce the potential vulnerability of steelhead to predation mortality in Clifton Court Forebay. Results from this study may be used in the calculation of Central Valley steelhead incidental take as a result of State Water Project (SWP) operations.

A pilot-scale telemetry experiment utilizing hatchery reared steelhead was conducted in April – June, 2005 to develop an understanding of the movement of juvenile steelhead through the Forebay and identify potential areas of increased vulnerability to predation mortality. The 2005 pilot study utilized thirty hatchery reared juvenile steelhead which were surgically implanted with acoustic tags prior to release into the Forebay. Three groups of ten tagged steelhead were released immediately upstream of the radial gates to expose them to the high water velocities and turbulence experienced by wild fish entrained into the Forebay.

Additionally, the 2005 pilot study was conducted to identify movement patterns of predator-size striped bass and evaluate fundamental assumptions used in developing the experimental design for a full-scale mark-recapture survival study. Sixteen adult striped bass, the primary predator species thought to be responsible for the pre-screen loss of steelhead, were collected in the Forebay, externally tagged using acoustic tags, and subsequently released back into the Forebay. Movement of the juvenile steelhead and adult striped bass was monitored continuously using fixed-position acoustic receivers deployed adjacent to the radial gates, in the Forebay, in the SFPF salvage holding tanks, and in Old River. Mobile monitoring was also conducted to track the movements of these fish throughout the Forebay.

Telemetry results showed that of the thirty steelhead released upstream of the radial gates, twenty were last detected in the Forebay at the end of the tag's battery life (approximately 60 days), four were detected in the SFPF salvage holding tanks, four were detected emigrating through the radial gates into Old River, one was not entrained into the Forebay, and one tagged steelhead failed to be detected. Seventeen of the twenty-eight steelhead entrained into the Forebay were detected entering the intake canal leading to the SFPF. Thirteen of those seventeen were detected in the general vicinity of the trashboom, while only four of the tagged steelhead were detected in the SFPF salvage holding tanks.

Striped bass telemetry results revealed that adult striped bass moved throughout the Forebay. However, they were concentrated in the area immediately adjacent to the radial gates and within the intake canal leading to the SFPF. Adult striped bass were also observed to emigrate from the Forebay into Old River during periods when the radial gates were open. Recreational anglers within the Forebay harvested at least two of the acoustic tagged striped bass in 2005 illustrating that adult striped bass tagged for this study were actively seeking prey for consumption.

The 2005 pilot study provided useful information on movement patterns and residence time of juvenile steelhead and adult striped bass within the Forebay. Findings of the 2005 pilot study also documented emigration of both steelhead and striped bass from the Forebay during periods when the radial gates were open and identified areas within the Forebay where juvenile steelhead may have an increased vulnerability to predation. The 2005 pilot study indicated that the methods and technologies tested were appropriate and could be utilized in the full-scale study to evaluate the pre-screen loss rate of juvenile steelhead. The 2005 pilot study also indicated that a high percentage of steelhead remain in the Forebay longer than the battery life of the acoustic tagging technology utilized. To ascertain the fate of these fish, an additional tagging technology would need to be utilized in the full-scale study.

Another pilot-scale telemetry study was conducted in March – July, 2006 to further investigate the movements of juvenile steelhead through the Forebay and to refine the placement of acoustic tag receivers for optimal fish tag detections for the full-scale study. In 2006, changes were made to the fixed position acoustic receiver grid to address issues with signal overlap between the receivers as experienced in the 2005 pilot study. The new receiver grid covered the majority of Clifton Court Forebay rather than a center transect, as was covered in 2005. Similar to the 2005 pilot study, the 2006 pilot study utilized thirty hatchery reared juvenile steelhead. These steelhead were surgically implanted with acoustic tags and twenty-nine were released into the Forebay in three groups.

Results of the 2006 pilot study were similar to those in 2005. Juvenile steelhead monitoring revealed that of the twenty-nine steelhead released, twenty-two were last detected in the Forebay at the end of the tag's battery life (approximately 60 days), two were detected in the SFPF salvage holding tanks, and five were detected emigrating through the radial gates into Old River. The new acoustic receiver grid revealed that steelhead moved throughout the Forebay, including the most northern and southern areas not covered by the acoustic grid in 2005. The majority of the tagged steelhead released in the 2006 study were last detected in the Forebay, conceivably lost to predation.

A full-scale mark-recapture study was conducted between December, 2006 and June, 2007, and was designed to quantify steelhead pre-screen loss. Additionally, the 2007 full-scale study was designed to evaluate the behavior and movement patterns of steelhead and striped bass within the Forebay and identify environmental or operational factors that may contribute to steelhead pre-screen loss. In 2007, two tagging technologies, acoustic and Passive Integrated Transponders (PIT) tags, were utilized. Similarly to the 2005 and 2006 pilot studies, acoustic tags were used to gain information about the movement patterns of steelhead and striped bass within Clifton Court Forebay. In response to the 2005 pilot study recommendations, PIT tags were used to quantify the pre-screen loss rate and the SFPF loss rate. In contrast to acoustic tags, PIT tags do not have a battery and could be detected for the entire duration of the full-scale study. In addition, PIT tags are inexpensive when compared to acoustic tags and allowed for a larger sample size.

The movement patterns of steelhead and striped bass were examined using acoustic telemetry. Sixty-four steelhead were surgically implanted with acoustic tags and released immediately upstream of the radial gates between February – April, 2007. Fifteen acoustic tagged steelhead were also released directly into the SFPF primary louver bays. Twenty-nine striped bass collected in the Forebay were externally tagged and subsequently released back into the Forebay. Movements of the acoustic tagged juvenile steelhead and adult striped bass were monitored continuously using fixed-position acoustic receivers deployed in a similar grid to that of the 2006 pilot study.

Acoustic tagged steelhead entrained into Clifton Court Forebay through the radial gates showed varied movement patterns. Many steelhead remained near the radial gates for the duration of the study period and yet other steelhead moved into the northern and central portions of the Forebay. Of the 64 steelhead entrained into the Forebay, 12 (19%) steelhead were detected in the intake canal. Ten of the 12 steelhead detected in the intake canal were also detected at the trashboom. However, only two acoustic tagged steelhead were detected as having been successfully salvaged. No steelhead released directly upstream of the radial gates were lost through the primary louvers. Twenty of the acoustic tagged steelhead entrained were detected emigrating to Old River through the radial gates. However, it cannot be confirmed conclusively that the steelhead observed emigrating had not been preyed upon within the Forebay and their predators moved from the Forebay through the radial gates into Old River. Of the sixty-four juvenile steelhead entrained into the Forebay, 44 (69%) remained in the Forebay at the end of the study period. Twenty-nine of those 44 were last detected at the radial gates. Several of the steelhead last detected at the radial gates were stationary for a long period of time with no subsequent movements. These stationary tags may be attributed to steelhead that were consumed by striped bass with subsequent tag deposition.

Steelhead movement rates were calculated hourly and tested for correlation with environmental and operational conditions. Data analysis revealed that there was no correlation between steelhead movement rates and water temperature, export rate, turbidity, radial gate water velocities, or light intensity. However, steelhead movement rates were correlated to the length of time spent within Clifton Court Forebay. The longer steelhead remained within the Forebay the less they moved.

Similar to the steelhead telemetry results, striped bass telemetry results showed varied movement patterns. Striped bass were observed to move throughout the Forebay with a few striped bass spending considerable time in the northern portion of the Forebay. However, many of the tagged striped bass also spent long periods of time either near the radial gates or in the intake canal upstream of the SFPF. A few striped bass were observed to make many trips between the radial gates and the intake canal. However, neither radial gate operations nor Harvey Banks Pumping Plant operations had an effect on the proportion of time tagged striped bass spent near the radial gates or in the intake canal.

Striped bass were commonly observed emigrating from the Forebay. Eighteen of the 29 tagged striped bass were detected emigrating from Clifton Court Forebay into Old River. Three of these striped bass returned to the Forebay through the radial gates. Previous studies have documented striped bass emigration through the radial gates (Kano, 1990; Gingras and McGee, 1997). Thus, striped bass located within the Forebay are not isolated from the rest of the Delta population. The striped bass emigrating from the Forebay in the 2007 study were detected as far away as the Golden Gate Bridge and above Colusa on the Sacramento River.

Striped bass movement rates were calculated hourly and tested for correlation with environmental conditions. Data analysis indicated that there was no correlation between striped bass movement rates and water temperature, turbidity, or light intensity.

The 2007 full-scale study used nearly 1,200 juvenile steelhead obtained from the Mokelumne River Fish Hatchery for the PIT tag mark-recapture survival experiment. Pre-screen loss rate was quantified using 922 PIT tagged steelhead released immediately upstream of the radial gates. PIT tagged steelhead releases began in January and continued through April. SFPF loss rate, loss of fish within the SFPF due to predation or losses of fish through the primary louvers, was quantified using PIT tagged steelhead released directly into the SFPF primary louver bays. PIT tagged steelhead were detected post salvage by antennae installed at the SFPF salvage release sites.

Pre-screen loss rate was calculated from recoveries of the PIT tagged steelhead released immediately upstream of the radial gates and was 82 ±3% (mean ± 95% confidence interval). However, this estimate may have underestimated the number of steelhead emigrating from Clifton Court Forebay and into Old River leading to an overestimate of pre-screen loss rate. A second estimate of pre-screen loss rate, calculated from recoveries of the PIT tagged steelhead, included information gained about emigration based on acoustic tagged steelhead movements. This estimate of pre-screen loss rate was 78 ±4% (mean ± 95% confidence interval). However, this estimate may underestimate pre-screen loss rate given the uncertainty in the acoustic telemetry results for the steelhead emigrating from the Forebay to Old River. Statistical analysis showed that pre-screen loss rate did not differ by month of release. However, the time to salvage was greater for PIT tagged steelhead released at the radial gates in February than those released in January or April. In contrast to the high pre-screen loss rate, the SFPF loss rate was 26 ±7% (mean ± 95% confidence interval).

In 2007 an avian point count survey was conducted to determine the prevalence of avian predation occurring in the Forebay. This survey focused on the abundance, distribution, and behavior of birds in the Forebay that were capable of preying on juvenile steelhead. The frequency of survey observation periods ranged from two to three times per week. A total of 87 observation periods were completed during the study. Observational data indicated that Double Crested Cormorants, gulls, and Great Blue Herons, were present within Clifton Court Forebay for the entire duration of the 2007 study period. Double Crested Cormorant numbers declined through time. Other avian predators, including Western Grebes, Clarke's Grebes, Great Egrets, and White Pelicans were also present within the Forebay, but not in high enough numbers to conduct any statistical analyses.

Avian predation on fishes was observed in the Forebay and was linked to radial gate operations for certain bird species. Data analysis showed that the percentage of Double Crested Cormorants foraging near the radial gates increased when the radial gates were open. The presence of stationary debris (i.e. tree branches) in the Forebay near the radial gates provides roosting habitat for Double Crested Cormorants and may be a contributing factor to the predation occurring near the radial gates.

Results of the steelhead pre-screen loss studies indicated that the pre-screen loss of steelhead is between 78 ±4% and 82 ±3% within Clifton Court Forebay. This result is similar to previous pre-screen loss studies of other fish species including Chinook salmon and juvenile striped bass (Schaffter, 1978; Hall, 1980; and Kano, 1985). Radial gate operations may contribute to these losses as avian predators and striped bass are foraging near the radial gates. Additionally, striped bass are spending long periods of time in the intake canal leading to the SFPF potentially foraging on fish as they approach the SFPF.

A population risk analysis should be completed for the Central Valley Steelhead that takes into account this pre-screen loss rate. In addition, a management action plan (MAP) should be created that includes steps to reduce the pre-screen loss rate of Central Valley steelhead within Clifton Court Forebay. At this point no recommendations have been made for changes to radial gate or Harvey Banks Pumping Plant operations. However, if entrained fish could be moved to the SFPF sooner by altering the hydrodynamics within the Forebay or SFPF intake canal, then exposure time to predators could decrease and this may result in the reduction of pre-screen losses. Many steelhead were detected within the intake canal leading to the SFPF, but were never salvaged. Steelhead may perceive the trash rack as a barrier or there may be an attraction problem at the SFPF. Future studies should focus on the area directly in front of the trash rack to determine if modifications can be made to attract more steelhead from the intake canal into the SFPF louver bays and fish salvage holding tanks. Future studies should also focus on measuring the hydrodynamics within the Forebay and how it impacts fish movements. As striped bass continue to be linked to pre-screen loss, the predator removal investigations conducted in the 1990's should be revisited. Moderate reductions in predator numbers could yield an increase in steelhead survival. Facilitating greater public fishing pressure may assist in this regard. Additionally, as avian predation was shown to occur, further avian predation investigations should be conducted with an emphasis on diet composition and consumption-rate. Avian diet composition and consumption rate studies would provide information on prey selectivity of the avian predators near the radial gates and the magnitude of pre-screen loss rate due to avian predation.

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1.0 Introduction

Clifton Court Forebay (Figure 1) is operated as a regulating reservoir within the tidally influenced region of the Sacramento-San Joaquin Delta (Delta) to improve operations of the State Water Project (SWP) Harvey Banks Pumping Plant and water diversions to the California Aqueduct. The Forebay was created in 1969 by inundating a 8.9 km^2 (2,200 acre) tract of land approximately 4.2 km (2.6 miles) long and 3.4 km (2.1 miles) across (Kano, 1990).

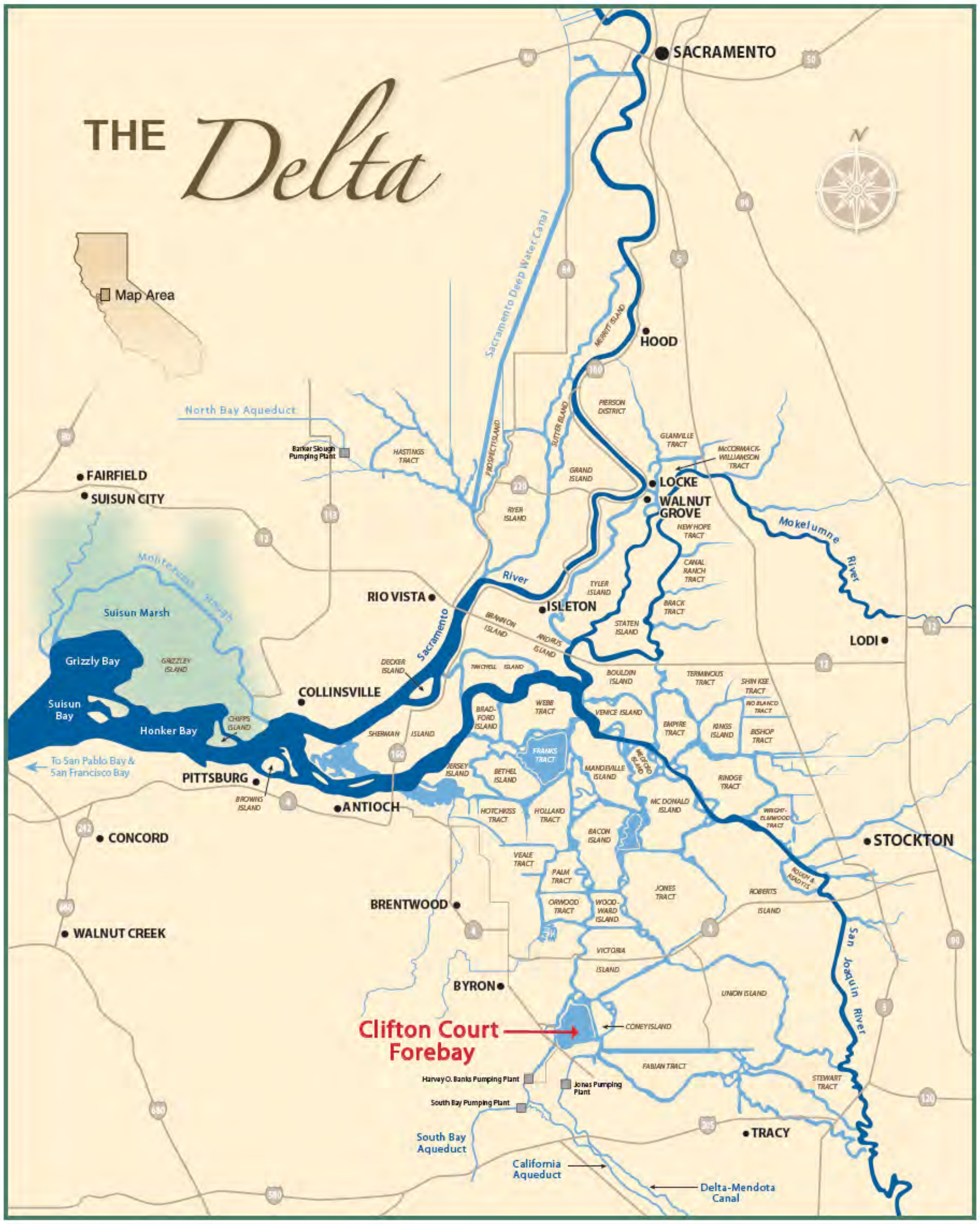

Figure 1. Location of Clifton Court Forebay in the Sacramento-San Joaquin Delta. (Source: DWR Graphic Services)

During high tide cycles when water elevation in Old River is greater than the water elevation in Clifton Court Forebay, water is diverted from the Delta into the Forebay via five radial gates (each 6.1m (20 ft) by 6.1 m (20 ft)) located in the southeast corner of the Forebay (Figure 2). Daily operation of the gates depends on scheduled water exports, tides, and storage availability within the Forebay (Le, 2004). Typically, diversions into the Forebay occur during the ebb stage of a tidal cycle (Kano, 1990) and only when a stage differential occurs between Old River and the Forebay. Water velocities passing through the gate openings typically approach 4.3 m/s (14 ft/s) at maximum stage differential. These high velocities have resulted in an approximately 18.3 m (60 ft) deep scour hole located immediately downstream of the radial gates, surrounded by a shallow shoal, revealed in recent bathymetry mapping (Figure 3).

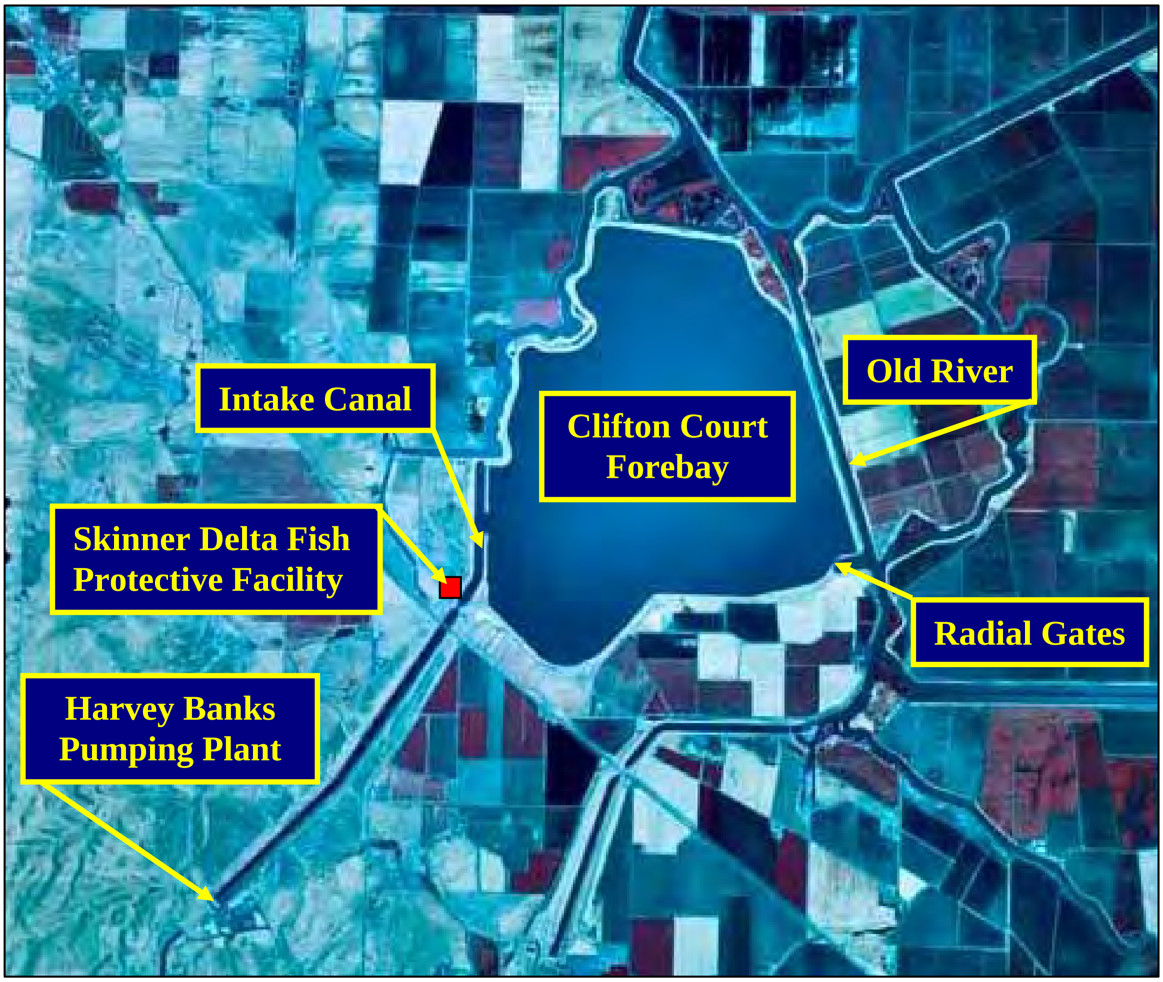

Figure 2. Aerial photograph of Clifton Court Forebay showing the locations of Old River, radial gates, intake canal, Harvey Banks Pumping Plant, and the John E. Skinner Delta Fish Protective Facility. (National High Altitude Photography courtesy of the United States Geological Survey)

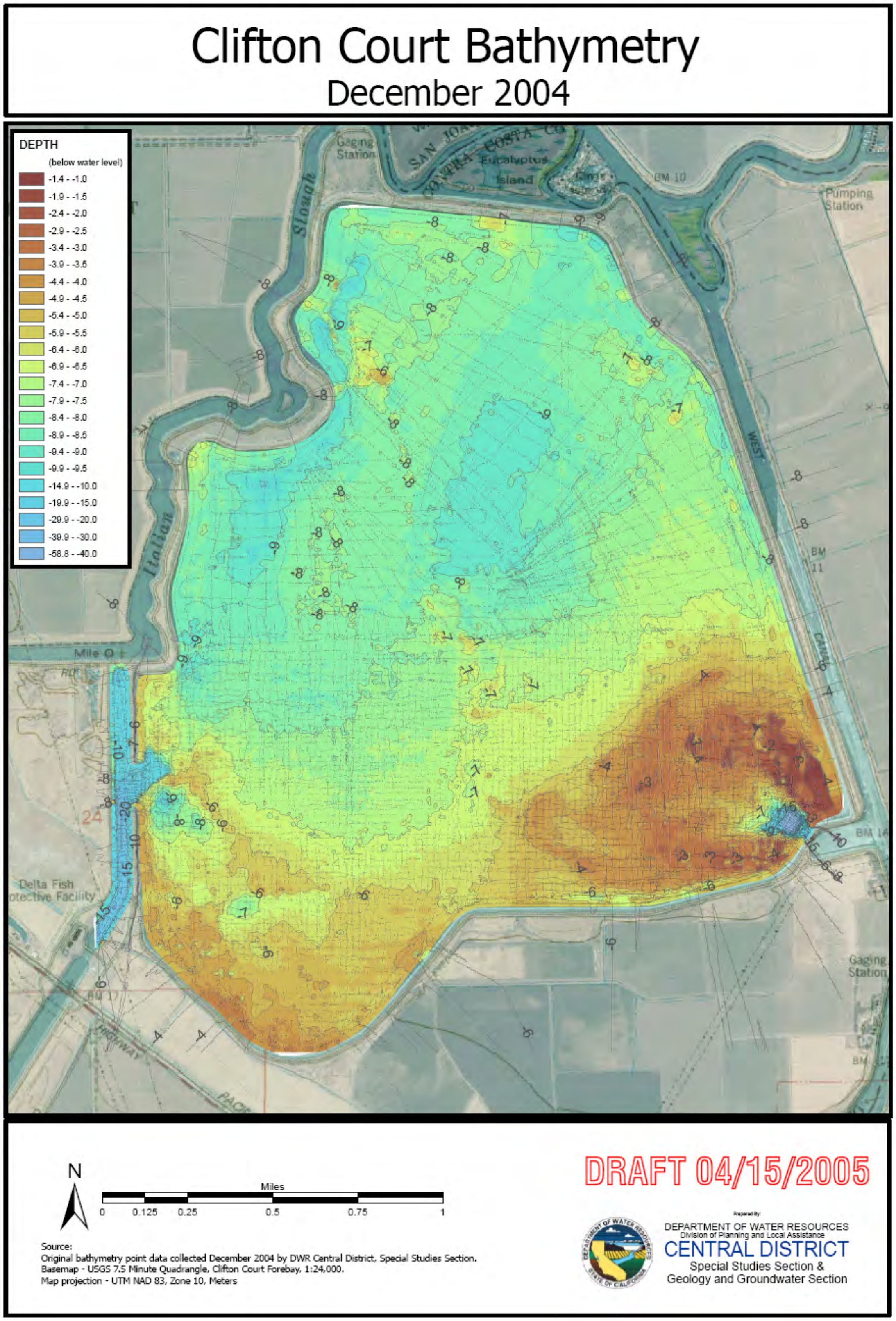

Figure 3. Clifton Court Forebay bathymetry map. (Source: DWR Central District)

Numerous fish, including Central Valley steelhead (*Oncorhynchus mykiss*), delta smelt (*Hypomesus transpacificus*), and Chinook salmon (*O. tshawytscha*), all of which have been listed under the California and/or Federal Endangered Species Acts (ESA), are entrained into the Forebay as water is diverted from Old River through the radial gates. Operation of the SWP, therefore, is necessarily performed in compliance with the terms and conditions of the National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS) biological opinions and incidental take permits.

Fish entrained in the Forebay must make a minimum 3.4 km (2.1 mile) crossing of the Forebay before reaching the John E. Skinner Delta Fish Protective Facility (SFPF). The SFPF was designed to protect fish from entrainment into the California Aqueduct, and to safely return salvaged fish to the Delta. Water is drawn to the SFPF from Clifton Court Forebay through the intake canal (Figure 2) to a floating trashboom. The trashboom is designed to intercept floating debris and guide it to a trash conveyor on shore. Water and fish then flow through a trash rack, equipped with a trash rake, to a series of louvers arranged in a Vee pattern. Fish are “screened” via the louvers, kept in salvage holding tanks, and ultimately transported and released into the Delta.

Losses of fish during movement from the radial gates to the SFPF, termed pre-screen loss, include predation by fish and birds. A series of mark/recapture experiments (Table 1; cf. Gingras, 1997) were conducted by the California Department of Fish and Game (DFG) within Clifton Court Forebay between 1976 and 1993 to determine pre-screen loss of juvenile Chinook salmon and juvenile striped bass (*Morone saxatilis*). Of the 10 studies conducted, eight evaluated losses to hatchery reared juvenile Chinook salmon, and two evaluated losses to hatchery reared juvenile striped bass. Pre-screen loss was calculated as a function of the proportion of marked fish released at the radial gates and at the trashboom that were recaptured during salvage operations at the SFPF (Gingras, 1997). Proportions of recovered fish were adjusted for handling mortality, louver efficiency, and any sub-sampling at the facility. These studies showed the range of pre-screen juvenile Chinook salmon losses to be 63-99%. Striped bass pre-screen loss ranged from 70-94%. The high mortality rates have been largely attributed to predation by fish, particularly by adult and sub-adult striped bass (Gingras, 1997; Gingras and McGee, 1997), and birds. Kano (1990) and Brown and others (1995) have described pre-screen loss as synonymous with predation by striped bass.

Although predation of juvenile salmon and juvenile striped bass by predatory fish in the Forebay has been well documented (Kano, 1990; Brown and others, 1995), current literature lacks information on avian predation on fishes in the Forebay. Avian predation can be a source of significant mortality for juvenile salmonids. Birds have high metabolic rates and require large quantities of food relative to their body size (Ruggerone, 1986). Ruggerone estimated that 2% of the outmigrating salmonids on the lower Columbia River were lost to gulls. Various avian species are present within and around Clifton Court Forebay that could potentially prey on juvenile steelhead including: Great Blue Heron (*Ardea herodias*), Western Grebe (*Aechmophorus occidentalis*), Clark’s Grebe (*Aechmophorus clarkia*), White Pelican (*Pelecanus erythrorhynchos*), Great Egret (*Ardea albus*), Double-crested Cormorant (*Phalacrocorax auritus*), and several species of gulls.

Table 1. Summary of pre-screen loss estimates within Clifton Court Forebay based upon mark-recapture experiments using juvenile Chinook salmon and striped bass.

Year-Month	Species	Pre-Screen Loss (%)	Mean Fork Length (mm)
1976-Oct	Salmon	97	114
1978-Oct	Salmon	88	87
1984-Apr	Salmon	63	79
1984-Jul	Striped bass	94	52
1985-Apr	Salmon	75	44
1986-Aug	Striped bass	70	55
1992-May	Salmon	99	77
1992-Dec	Salmon	78	121
1993-Apr	Salmon	95	66
1993-Nov	Salmon	99	117

Source: Gingras, M. 1997. Mark/recapture experiments at Clifton Court Forebay to estimate prescreening loss to juvenile fishes: 1976-1993.

Investigations have not been conducted to assess the potential predation mortality by fish and birds on juvenile steelhead within the Forebay. Since pre-screen loss within Clifton Court Forebay is included in the incidental take calculations for salvage losses of salmonids, the NMFS Operations Criteria and Plan (OCAP) biological opinion (2004) required investigations to (1) quantify predation losses (pre-screen loss) on juvenile steelhead within Clifton Court Forebay, and (2) identify potential management actions to reduce predation mortality of juvenile steelhead. The steelhead predation investigation is a pre-condition to the construction of the South Delta Improvements Program's permanent operable gates.

In response to the biological opinion requirements, the California Department of Water Resources (DWR) conducted a study over several years to evaluate steelhead predation mortality within the Forebay. A pilot-scale telemetry experiment using hatchery steelhead was conducted in April and May, 2005 to develop an understanding of the movement of juvenile steelhead through the Forebay and identify potential areas of increased vulnerability to predation mortality. Additionally, the 2005 pilot study was developed to identify movement patterns of predator-size striped bass and evaluate fundamental assumptions used in developing the experimental design for a full-scale mark-recapture steelhead survival study. Another pilot-scale telemetry study was conducted in March and April, 2006 to further investigate the movements of juvenile steelhead through the Forebay and to refine the placement of acoustic tag receivers for optimal fish tag detections. The full-scale mark-recapture and telemetry experiments were conducted December, 2006 – June, 2007 and were designed to meet the study objectives.

2.0 Objectives

In compliance with the requirements of the 2004 NMFS OCAP Biological Opinion, DWR designed and initiated an experimental field investigation to:

1. Evaluate predation losses (pre-screen loss) and the behavior/movement patterns of juvenile steelhead during passage through Clifton Court Forebay;

2. Evaluate behavior and movement patterns of adult striped bass which were identified as the primary predatory fish species that could potentially prey on juvenile steelhead within Clifton Court Forebay;

3. Identify physical locations and environmental and operational factors that contribute to increased vulnerability of juvenile steelhead to predation within the Forebay;

4. Determine the prevalence of avian predation within the Forebay; and

5. Develop quantitative estimates of pre-screen loss of juvenile steelhead within the Forebay.

3.0 Previous Studies

Gingras (1997) summarized the results of mark/recapture experiments conducted by DFG as part of the Interagency Ecological Program (IEP). These studies, conducted between 1976 and 1993, were designed to estimate pre-screen loss of juvenile Chinook salmon and juvenile striped bass entrained into Clifton Court Forebay. The average pre-screen loss of the three earliest studies was integrated into the Four-Pumps Agreement as mitigation for direct fish losses due to operation of the State Water Project. The following describes the previous pre-screen loss research conducted within Clifton Court Forebay.

Kano (1990) published data on the abundance of predatory fish inhabiting Clifton Court Forebay. This study, conducted between March 1983 and February 1984, provided important information on the composition and abundance of predatory fish within the Forebay that could contribute to pre-screen loss of juvenile fish entrained in the Forebay. White catfish and striped bass were found to be the two most abundant predators. The possibility of predation accounting for the loss of fish crossing the Forebay was strong due to the numbers of predatory fish observed inhabiting the Forebay.

Kano (1990) hypothesized that striped bass may impact losses of fish within the Forebay in two ways. First, striped bass schooling behavior may increase predation effects on fish. Schooled predators could increase the number of encounters between striped bass and fish entering the Forebay. The confusion resulting from schooled predators might also enhance predation success. Second, striped bass are highly mobile. Striped bass may track the sources of prey throughout the Delta, moving to the locations of highest prey availability.

Population abundance of striped bass fluctuated throughout the year with the lowest abundance occurring in early summer and highest abundance occurring in late fall (Kano, 1990). Levels of angler harvest and salvage of large fish by the SFPF were not high enough during the study to account for removal of significant numbers of striped bass. Emigration through the radial gates was hypothesized as a likely explanation for seasonal decreases in striped bass abundance. Before this study, fish emigrating from the Forebay were assumed to be prevented by the high water velocities passing through the radial gates. Velocities of less then 0.6 m/s (2.0 ft/s) were observed for short periods when the radial gates were open and suggested that flow through the gates may not act as a barrier to movement by larger fish during such times. Although fish emigrating through the radial gates was not monitored, anglers reported catching tagged striped bass from the study outside the Forebay. Recent studies utilizing radio and/or acoustic tagged adult striped bass have confirmed these earlier speculations. Gingras and McGee (1997) conducted telemetry studies using striped bass and documented emigration from Clifton Court Forebay through the radial gates. The implication that striped bass are not isolated from the rest of the Delta population complicates the task of regulating the population size of this species in the Forebay through traditional fisheries management techniques.

A number of studies were conducted between 1976 and 1993 to estimate predation losses of fish moving through Clifton Court Forebay. Studies evaluating predation losses of juvenile Chinook salmon within Clifton Court Forebay revealed pre-screen loss rates of 97% and 88% (Schaffter, 1978; Hall, 1980; cited in Kano, 1985). Kano (1985) conducted further studies to estimate pre-screen loss rates of juvenile Chinook salmon and juvenile striped bass within the Forebay. Survival of salmon from the radial gates to the trashboom was estimated at 37%. This evaluation was consistent with results of previous experiments conducted to determine pre-screen losses within Clifton Court Forebay. Pre-screen loss rate for juvenile Chinook salmon was estimated to be 63% between the radial gates and the SFPF trashboom. This pre-screen loss rate was lower than in previous studies (Schaffter, 1978; Hall, 1980). Kano (1985) conducted the study in the spring and used salmon that were smaller than the fish used in the earlier studies. The earlier studies were conducted in the fall. This seasonal difference was suggested as a major contributor to the difference in pre-screen loss rates.

In summarizing results of the mark/recapture studies conducted in Clifton Court Forebay, Gingras (1997) suggests there may be common biases throughout the studies due to the experimental methods used. Despite the biases, the results still identify predation as a major underlying mechanism that influences pre-screen loss rate. Tillman (1993a; cited in Gingras, 1997) suggests evaluating the relationship between pre-screen loss and factors such as experimental fish size, water export rate, water temperature, and predator-sized striped bass abundance in Clifton Court Forebay to better understand the mechanisms contributing to pre-screen loss in Clifton Court Forebay.

4.0 Regulatory Compliance

The experimental design was developed to avoid the potential take of listed species which resulted in minimal take of ESA-listed species. Hatchery steelhead were used as surrogates for wild steelhead and neither PIT tag nor acoustic telemetry monitoring required recapture sampling or modifications to the SFPF's normal fish salvage operations. However, the study intended to use a small number of wild juvenile steelhead (less than 20 individuals) to validate the telemetry results seen with hatchery steelhead. To properly address this issue, NMFS extended the ESA 4(d) research limit take exemption to include 20 wild steelhead potentially to be given to the pre-screen loss principle investigators. To facilitate the collection of these fish, DFG issued a Scientific Collecting Permit, which allowed for the collection of wild steelhead as bycatch through predator removal procedures of the secondary louvers at the Tracy Fish Collection Facility (TFCF). One wild steelhead was collected during a predator removal and was turned over to the DFG lead biologist. The take of this one wild steelhead was reported to DFG in an annual report and subsequently reported to NMFS. The wild steelhead had sustained a physical injury prior to collection and was held for treatment until succumbing to its injuries.

Another potential take issue of ESA-listed species was the use of gill nets and angling to acquire striped bass to be used for predator behavior studies. Incidental take for gill netting was covered through coordination and collaboration between the DFG lead biologist and NMFS. No ESA-listed species were taken during angling and/or gill net sampling.

Installation of the PIT tag detection systems at the SFPF salvage release sites required that the two sites be temporarily taken offline. Regulatory agencies require that the SFPF alternate fish releases between the two sites. Therefore, NMFS and DFG were contacted and the SFPF operators were given permission to release fish solely at one release site during the time the PIT tag detection system was installed at the second release site. Each site was taken offline for less than one work week. Releases resumed per normal operating procedures, once installation of the PIT tag detection system antennae was completed at both sites.

To conduct tagged steelhead releases immediately upstream of the radial gates, safety improvements to the site needed to be made. Uneven walkways, due to large rocks, and a slippery levee slope posed safety hazards for those conducting steelhead releases. DWR conducted a site survey and found no species of concern. DWR submitted a 1600 Notification of Streambed Alteration to DFG as gravel was proposed to fill in the uneven walkway and a concrete interlocking mat was proposed to alleviate the slipperiness of the levee. DFG reviewed the notification, conducted a site survey, and found it was not necessary to issue an agreement, therefore, DWR filed a Notification of Exemption with the State Clearinghouse. Safety improvements to the site were subsequently completed.

5.0 SWP Pumping and Radial Gate Operations

Clifton Court Forebay hydrodynamics can vary substantially within and among days depending on factors such as water export rates, radial gate operations, tidal conditions, weather conditions, and water storage within the Forebay. These variables, along with other physical factors such as debris, could affect salvage rates of fish at the SFPF. Harvey Banks Pumping Plant mean daily pumping (export) rates were variable in 2005, 2006, and 2007, ranging from approximately 0 to 226 m^3/s (0 to 8,000 cfs) (Figure 4). In all three study years, there was a marked decline in mean daily export rates beginning in mid to late-April with initiation of the Vernalis Adaptive Management Plan (VAMP). During May 2007, pumping was stopped for several days to protect delta smelt.

Flow rates and velocities of water entering the Forebay are regulated by operation of the five radial gates and export pumping rates. Gate operations are constrained by a scouring limit at the gates and south Delta water level concerns (Le, 2004). The radial gates are tidally operated with water flowing into the Forebay during high tide cycles when the water elevation in Old River is greater than the Forebay surface elevation. Flows were calculated using gate opening height and stage differential between Old River and the Forebay (Le, 2004). The water velocities for the intake channel leading to the radial gates, radial gate intake channel velocities, were calculated according to the equation $V_{ic}= Q/A$ where Q equals the calculated flow and A equals the area of the channel. The area of the channel was estimated from V and Q values published in the DWR Bulletin 200 (1974) where V_{ic} equals 0.9 m/s (3 ft/s) and Q equals 453 m^3/s (16,000 cfs). Therefore, the area of the channel was estimated at 495.5 m^2 (5,333 ft^2). The water velocities at the radial gate openings, radial gate water velocities, were calculated according to the equation $V_{rg}= Q/A$ where Q equals the calculated flow and A equals the sum of the areas of the radial gate openings. Because the radial gate water velocities are calculated from computed flows rather than measured flows, they should be treated as estimates.

Maximum hourly water flow, maximum hourly radial gate intake channel water velocities, and maximum hourly radial gate water velocities during the three study periods do not show much variation (Figure 5, 6, and 7). When the radial gates were open, the water flow into the Forebay typically averaged approximately 283 m^3/s (10,000 cfs) with typical maximum flows of approximately 425 m^3/s (15,000 cfs) (Figure 5). The fluctuation in flow and water velocity can be attributed to either changes in gate height operations or the change in differential head as the water surface elevations equalize between the Forebay and Old River. Historical data records show that there are times when the water surface elevations are almost equal and the gates are partially open, resulting in either very low flow into the Forebay or, at times, negative flow out of the Forebay and into Old River. As the radial gates are opened, water flow and water velocity rapidly increase and is dependent on the stage difference between the Forebay and Old River. As the water surface elevations begin to equalize, flow and water velocity decrease (Figure 8). However, the radial gates can be lowered or raised to change the amount of water flow and/or water velocity entering the Forebay. One extreme flow event occurred on April 16, 2007 with calculated flows approaching 600 m^3/s (21,200 cfs) (Figure 9). However, the spreadsheet developed to calculate water flow was not calibrated at high flows and thus may overestimate the true flow. Nonetheless, water flow through the gates was observed to be higher on April 16, 2007 than all other days during the study period.

Extremely high flow events, such as the one occurring on April 16, 2007, are rare and do not persist for long durations. After the first hour, the calculated flow during this event was greatly reduced as the radial gates were lowered from approximately 4 m (13 ft) to approximately 3 m (10 ft). Additionally, high water velocities through the radial gates did not always correspond with high flows. There were times during low flows when the radial gate water velocities were elevated due to relatively small gate openings (Figure 10).

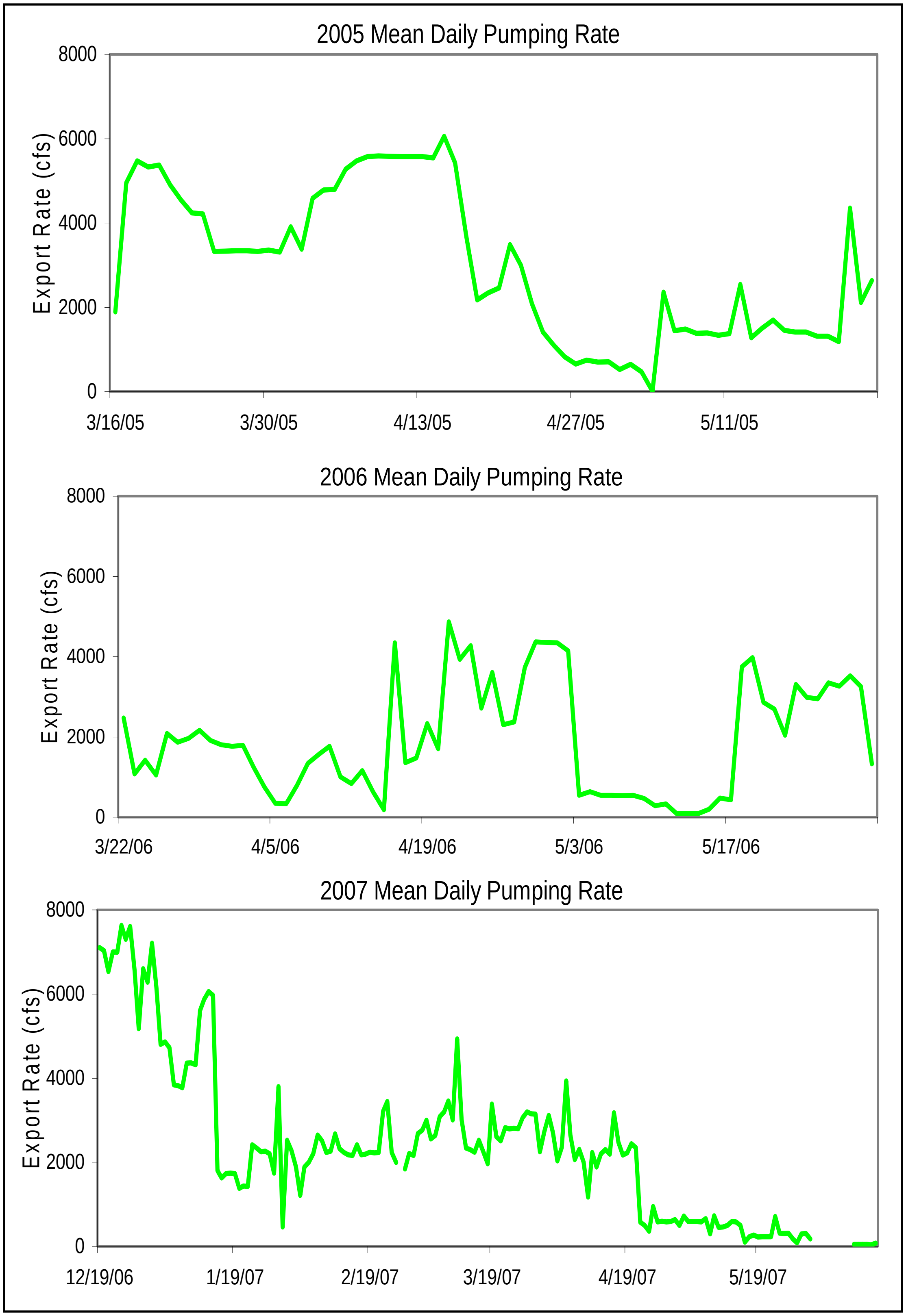

Figure 4. SWP mean daily export rates (cfs) during the 2005 and 2006 pilot studies and the 2007 full-scale study.

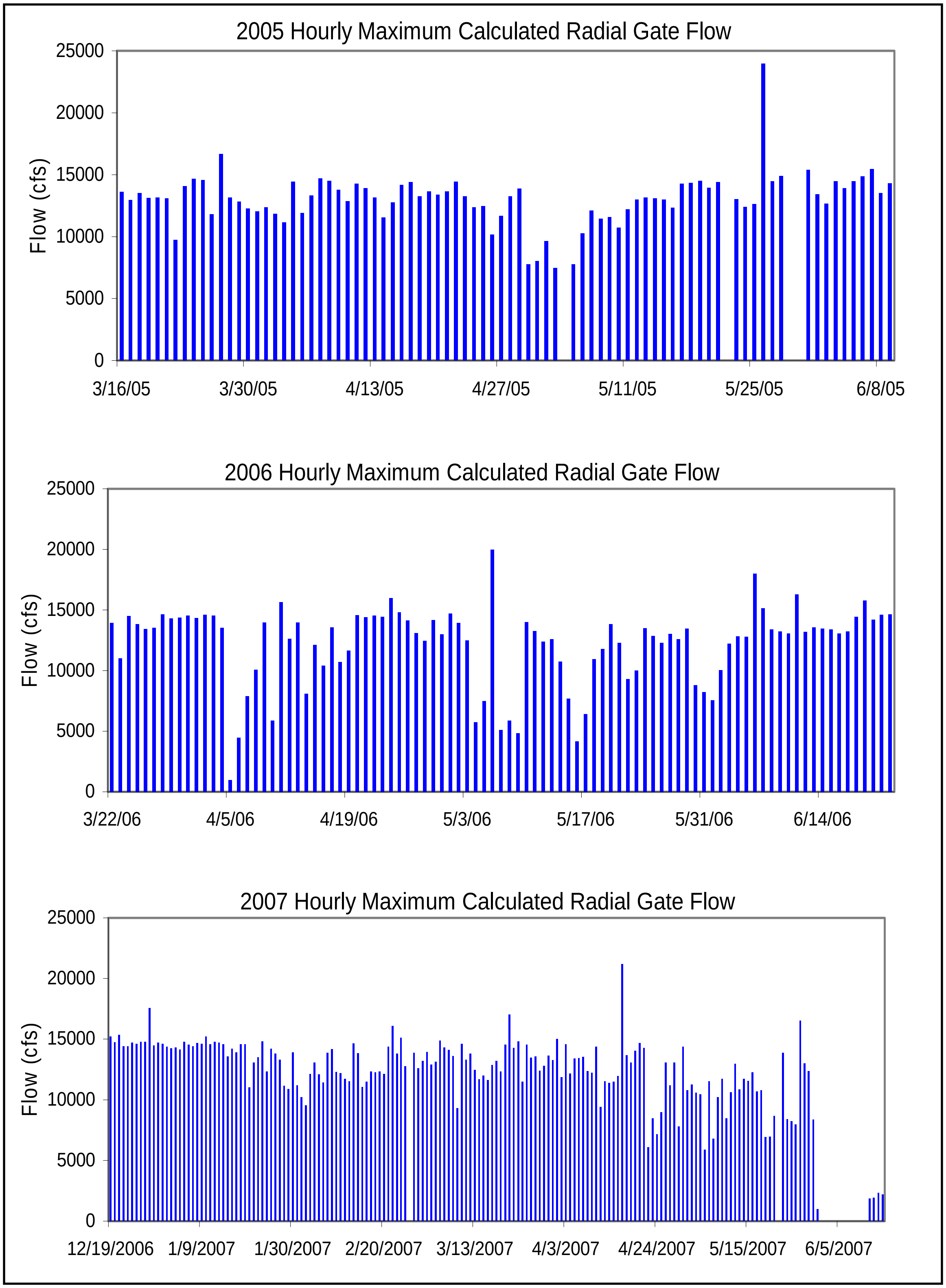

Figure 5. Estimated hourly maximum flow (cfs) at the radial gates during the 2005 and 2006 pilot studies and the 2007 full-scale study.

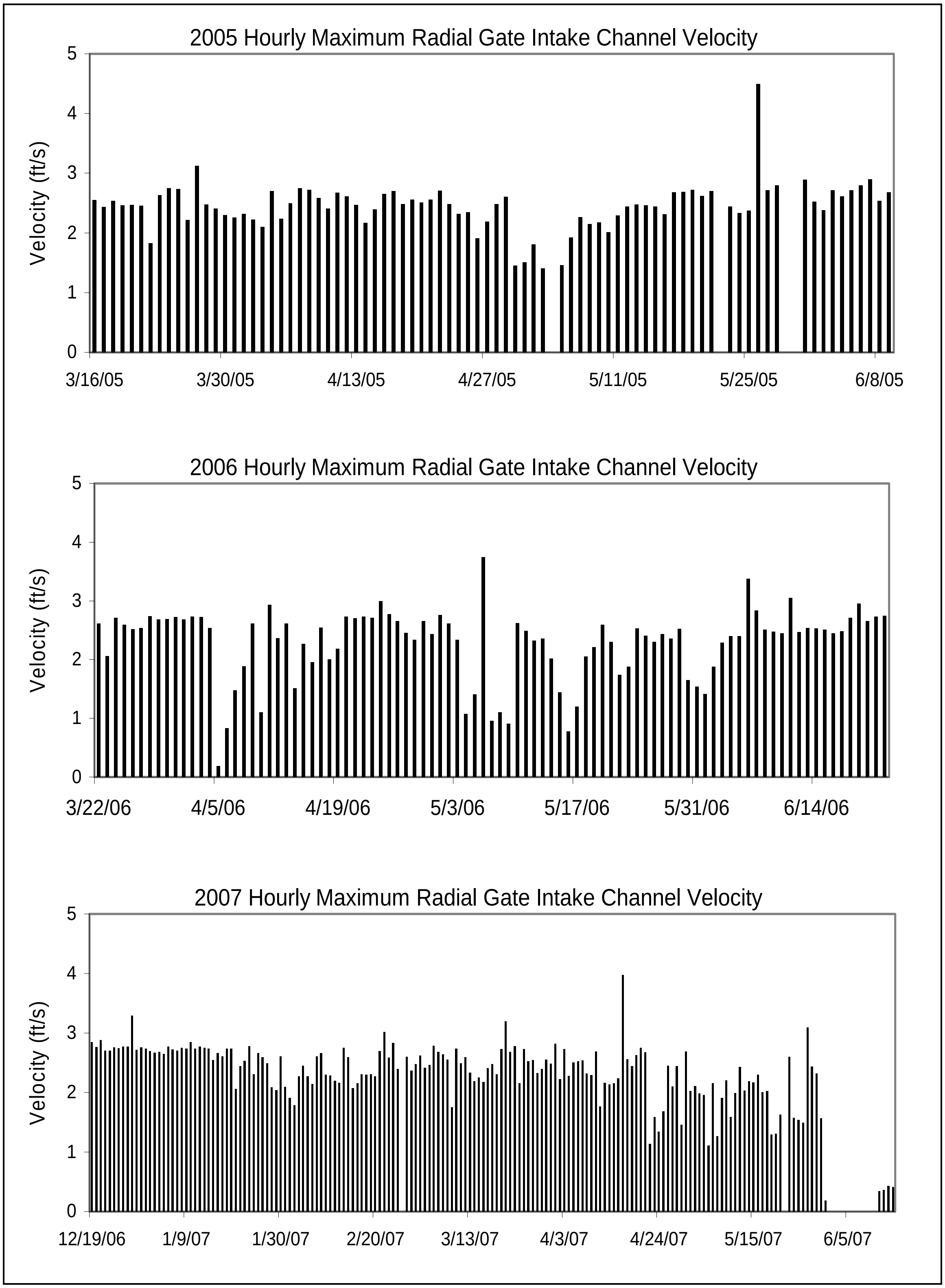

Figure 6. Estimated hourly maximum intake channel velocities (ft/s) directly upstream of the radial gates during the 2005 and 2006 pilot studies and the 2007 full-scale study.

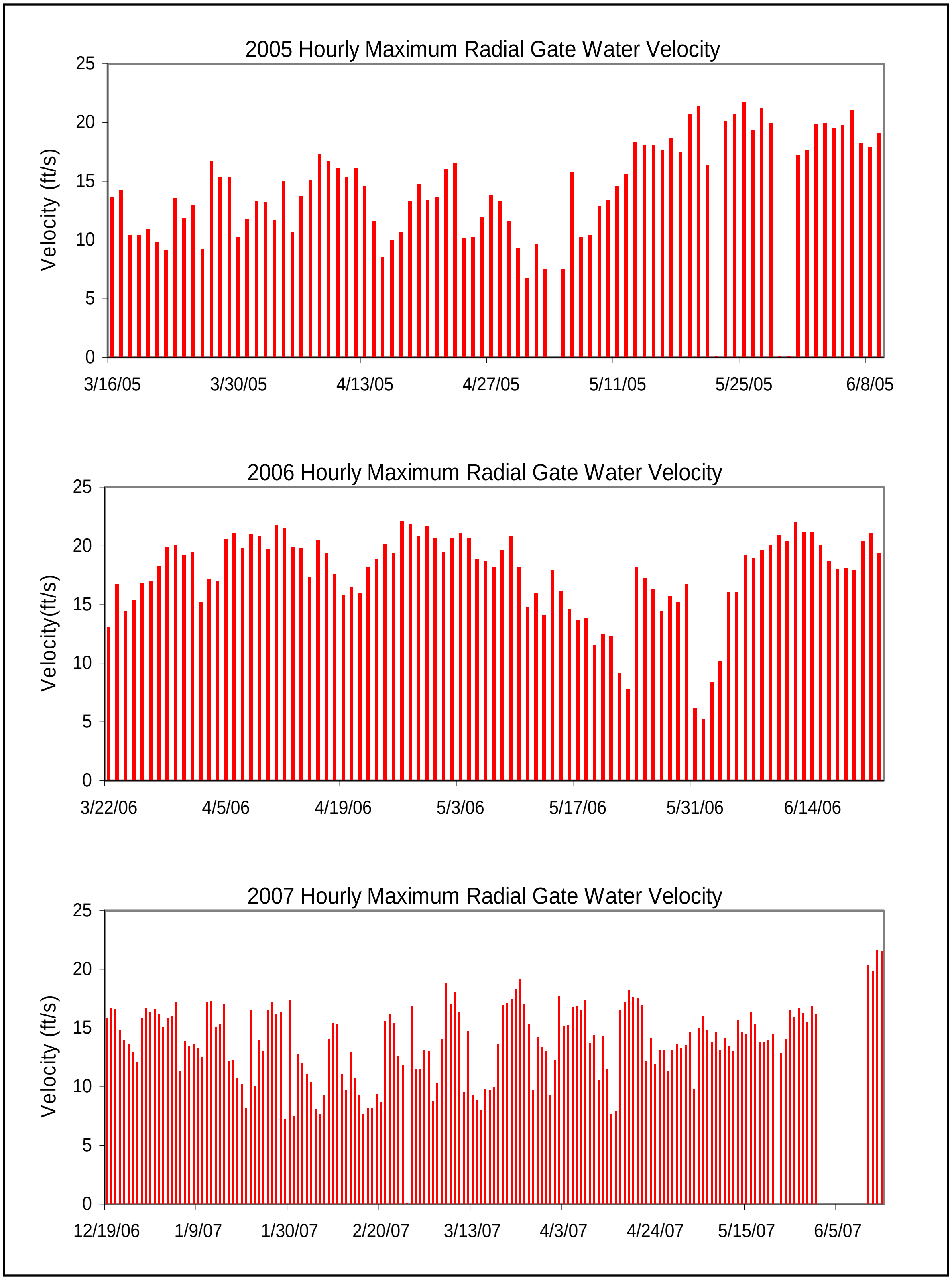

Figure 7. Estimated hourly maximum water velocity (ft/s) at the radial gates during 2005 and 2006 pilot studies and the 2007 full-scale study.

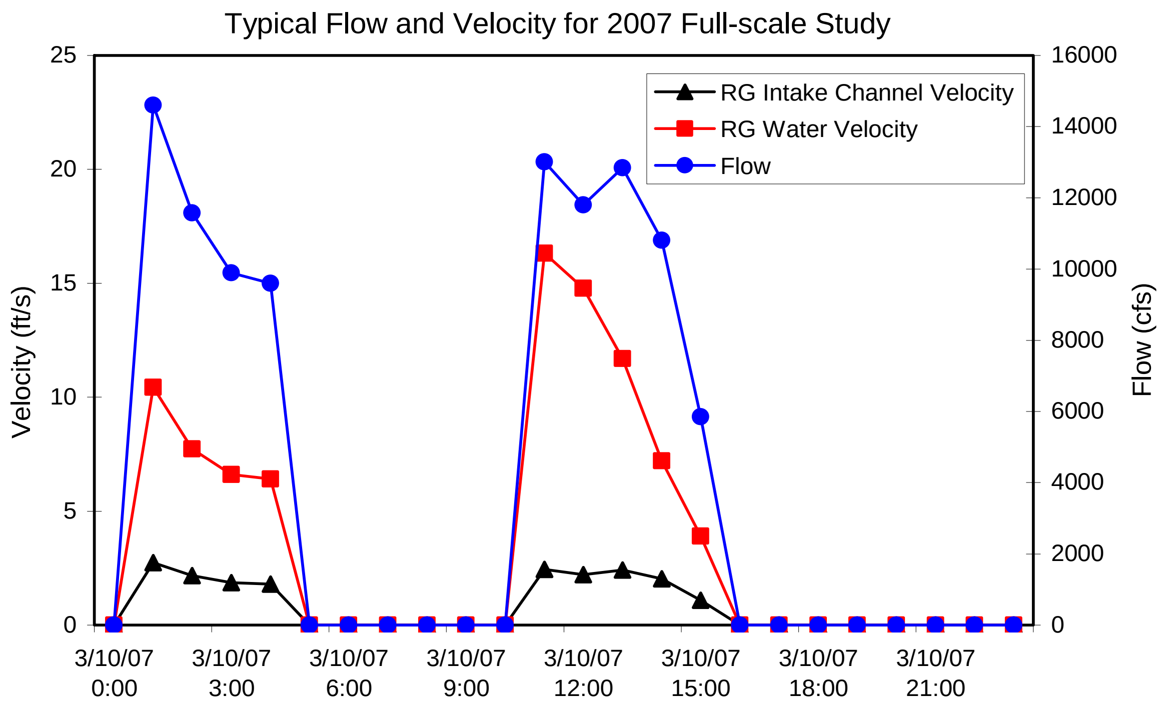

Figure 8. Flow (cfs) and velocity (ft/s) through the radial gates for a 24 hour period in 2007. The radial gates were open from 01:00 to 04:00 and from 11:00 to 15:00.

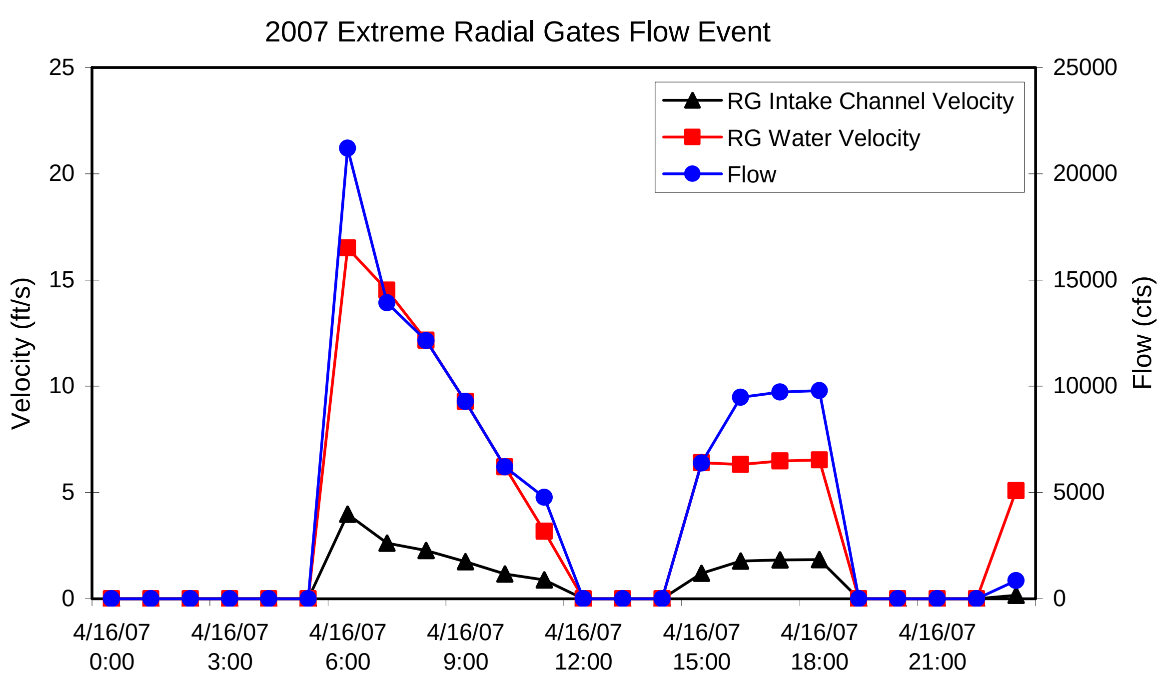

Figure 9. Radial gates extreme flow event April 16, 2007.

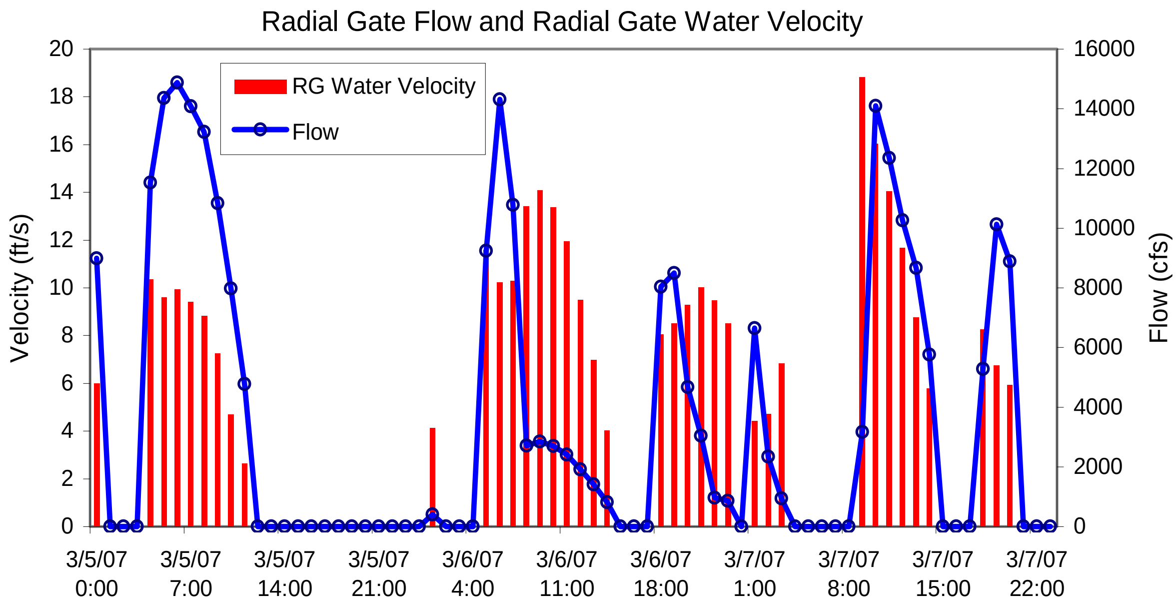

Figure 10. Radial gate flow (cfs) and radial gate water velocity (ft/s) for a 36 hour period during 2007.

6.0 2005 Pilot Study

6.1 Methods

A pilot-scale telemetry study was conducted April – May, 2005 to develop an understanding of the movement of juvenile steelhead through the Forebay and identify potential areas of increased vulnerability of steelhead to predation mortality. Additionally, the study was designed to identify movement patterns of predator-size striped bass and evaluate fundamental assumptions used in developing the experimental design for a full-scale, mark-recapture, steelhead survival study. To meet these objectives acoustic tags were utilized as steelhead and striped bass were tagged, released, and tracked within the Forebay.

6.1.1 Physical Parameters

Temperature was monitored at mid-depth using temperature recorders (Onset, model HOBO Water Temp Pro) from March to June, as water temperature may play an important role in the pre-screen loss of steelhead. Temperature recorders were deployed south-west of the radial gates approximately 61 m (200 ft) south of the southern wing wall within the Forebay and approximately 61 m (200 ft) upstream of the trash rack near the trashboom in the intake canal. Water temperatures at the radial gates and the intake canal increased from approximately 15 °C (59 °F) in March, 2005 to approximately 20 °C (68 °F) at the beginning of June, 2005 (Figure 11). Water temperatures monitored at the radial gates location increased to approximately 25 °C (77 °F) by the end of June (Figure 11). However, there was more variability in water temperature in the intake canal than at the radial gates. This difference in variability may be attributed to the surface area to volume relationship in the Forebay, bathymetry differences of the Forebay and intake canal, and/or variable pumping rates over time. Lethal water temperatures for steelhead have been reported to range between 21 to 24 °C (70 to 75 °F) (Nielsen and others, 1994; Coutant, 1970; cited in Richter and Kolmes, 2005). Therefore, lethal water temperatures for steelhead could have occurred in early June 2005.

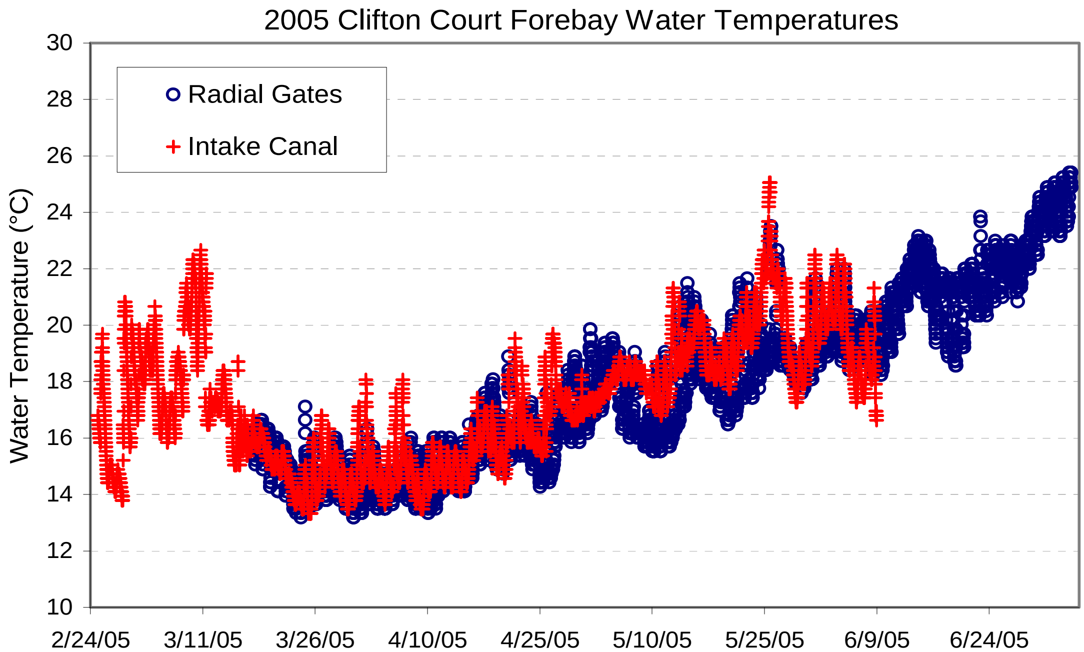

Figure 11. Water temperature (°C) at the radial gates and intake canal for the duration of the 2005 pilot study.

6.1.2 Acoustic Tagging of Striped Bass

Although a variety of predatory fish inhabit the Forebay, striped bass were thought to be the primary predatory fish species that could prey on juvenile steelhead because of their large size. The striped bass targeted for collection in 2005 were greater than 650 mm (26 in) in length. According to the literature (Walter and Austin, 2003; Manooch, 1973; Overton, 2002), this was near the lower size limit of striped bass capable of preying on juvenile steelhead 200 to 275 mm (7.8 to 10.8 in) in length. Walter and Austin (2003) reported that large striped bass consumed prey approaching 40% of their body length. This equaled the mean maximum forage length to striped bass length found by Manooch (1973). Overton (2002) predicted the optimal prey size to be 21% of the striped bass length. Manooch (1973) found that the mean forage length to striped bass length was 21%, but that striped bass are capable of eating fish approximately 60% of their total length. For purposes of the 2005 investigation we assumed a predator to prey length ratio of 30%.

In 2005, striped bass were captured by hook and line sampling in close proximity to the radial gates, trash rack, intake canal, and at various other locations throughout the Forebay. However, sampling effort at all locations was not equal, as the majority of the sampling effort was concentrated near the radial gates and within the intake canal. Water depth immediately adjacent to the radial gates ranged from approximately 18 m (60 ft) within the scour hole, with depth declining to approximately 1.5 m (5 ft) on the shoal surrounding the scour hole (Figure 3). There was a visually, well-defined velocity and turbulent zone around the gates and scour hole when the radial gates were open. The highest success for striped bass collection occurred around the perimeter of the scour hole and turbulent mixing zone either when the radial gates were open with water flowing into the Forebay, or within one hour of the gates closing. Only the striped bass captured near the radial gates met the 30% predator to prey length ratio and were of a sufficient size for inclusion in the 2005 pilot study.

Each striped bass captured that met the minimum size criterion was tagged with a coded acoustic transmitter (VEMCO, model V16) and released back into the Forebay. Each striped bass that was captured was transferred to an aerated holding tank onboard the sampling boat using a soft mesh dip net. Each fish was observed for signs of stress (loss of equilibrium). When the fish was no longer showing signs of stress from capture and handling, the fish was then transferred to a canvas cradle where the fish could be measured for length and tagged. External tagging of striped bass was similar to the method described by Chadwick (1963), Gray and Haynes (1979), and Gingras and McGee (1997). For respiration, a soft tube attached to a pump was used to irrigate the gills and was held in the mouth of the fish for the duration of the tag operation. No anesthesia was used. The acoustic tag, mounted on a soft rubber plate with thin stainless steel wire attachments, was externally attached by passing the wires through the body of the fish under the dorsal fin using hypodermic syringe needles. Another soft rubber plate was attached to the tag wires protruding through the fish to minimize tissue damage and irritation. The wires and tag were then secured in place by twisting the wires and trimming any excess (Figure 12). The tagged striped bass was placed back into the aerated tank and observed for signs of stress, then released into the Forebay at approximately the same location as capture. The external tagging operation lasted approximately four minutes per fish. The time, date, fish length, and Global Positioning System (GPS) coordinates were recorded for each striped bass captured, tagged, and released.

The size distribution for the 16 striped bass tagged as part of the 2005 pilot study ranged in total length from 625 to 940 mm (24.5 to 37 in) with a mean of 726 ±40 mm (28.6 ±1.6 in), Figure 13). Herein, all means are reported as mean ±95% Confidence Interval. One striped bass was tagged that was smaller than the minimum size requirement of 650 mm (26 in). Based on the length-weight relationship (Clark, 1938) for striped bass, the predators tagged and monitored during the 2005 pilot study ranged in size from 2,722 to 5,216 g (6.0 to 11.5 lb) with a mean of 3,799 g (8.4 lb) and ranged in age from 6 to 10 years old. Ideally, tag to body weight ratio should be approximately 2% or less to avoid impairing the swimming ability and behavior of the fish (Winter, 1983; 1996; Nielson, 1992; and Brown and others, 1999). The tag to body weight ratio was below 0.40% for all tagged striped bass during the 2005 pilot study.

Figure 12. Striped bass captured, externally tagged, and released in 2005.

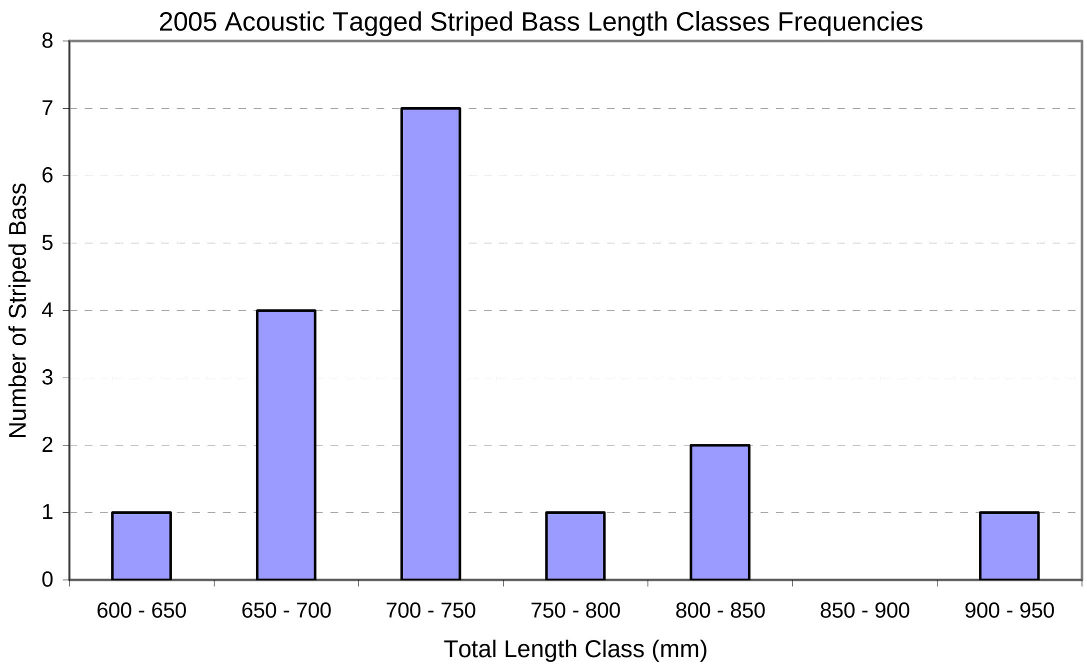

Figure 13. Externally tagged striped bass size class frequencies, for fish captured and tagged March 16 through March 18, 2005.

6.1.3 Acoustic Tagging of Steelhead

To determine the timing and size of steelhead entrained in the Forebay SFPF salvage data (DFG, 2008) was examined. SFPF salvage data shows that juvenile steelhead are present in the fish salvage from January to June, with peak abundance observed during February (Figures 14 and 15). Juvenile steelhead observed in the SFPF salvage typically range in length from approximately 200 to 300 mm (7.9 to 11.8 in) (Figure 16). The steelhead used in this study were representative of the general size distribution of juvenile steelhead entrained into the Forebay and recorded in the salvage data. The 30 juvenile steelhead selected for surgical implantation of acoustic tags ranged in total length from 221 to 275 mm (8.7 to 10.8 in) with a mean of 245 ±5 mm (9.6 ±0.2 in).

Juvenile steelhead used in the 2005 pilot study were obtained from the Mokelumne River Fish Hatchery and used as surrogates for wild fish. These juvenile steelhead were transported from the hatchery and held at the UC Davis Fish Conservation Culture Lab (FCCL) and the Collection, Handling, Transport and Release (CHTR) Study Facility (adjacent to the Forebay) for a one-week period to recover from transportation and handling stress and to acclimate to water quality conditions at the site. Thirty juvenile steelhead were tagged with acoustic coded transmitters (VEMCO, model V8SC) and released into the Forebay during April to coincide with the seasonal period that steelhead have been observed in the SFPF salvage.

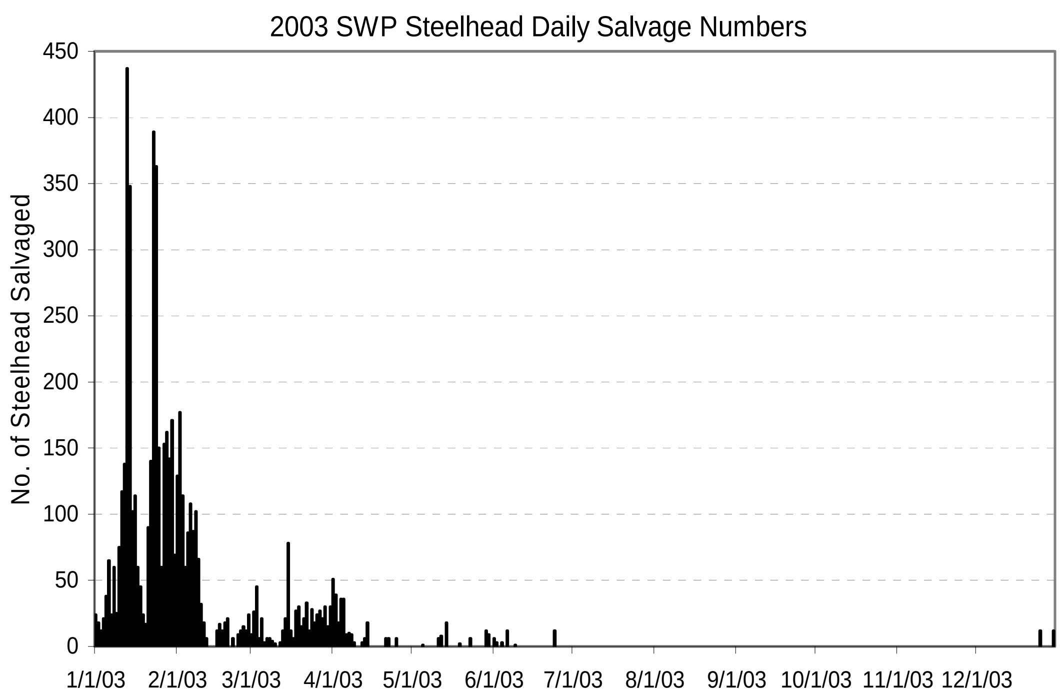

Figure 14. Steelhead salvaged at the SFPF, 2003.

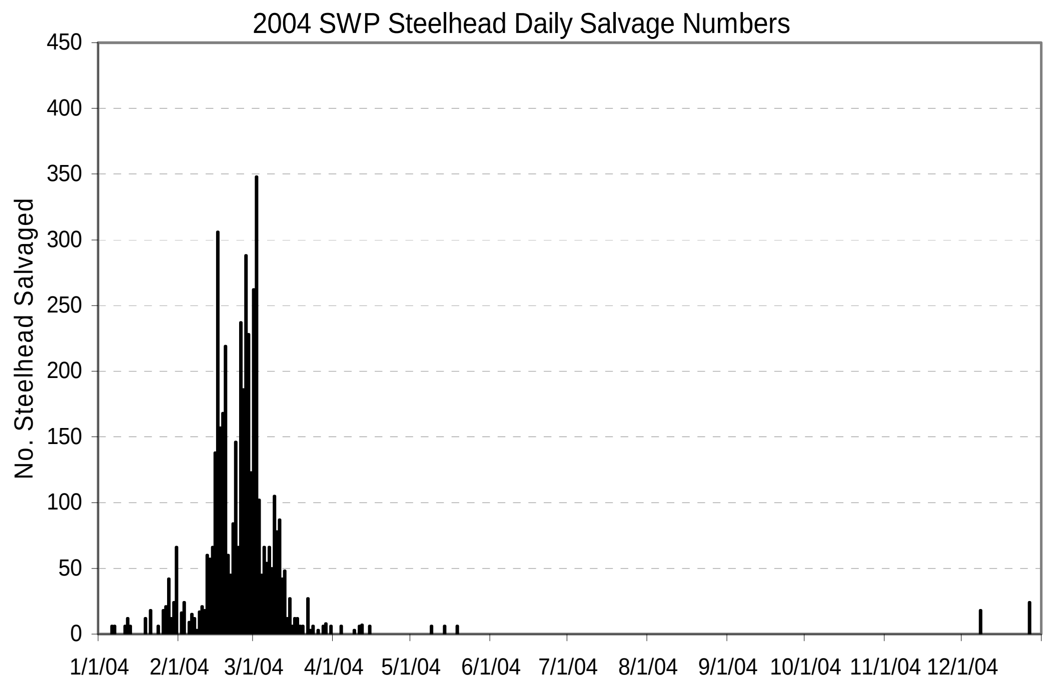

Figure 15. Steelhead salvaged at the SFPF, 2004.

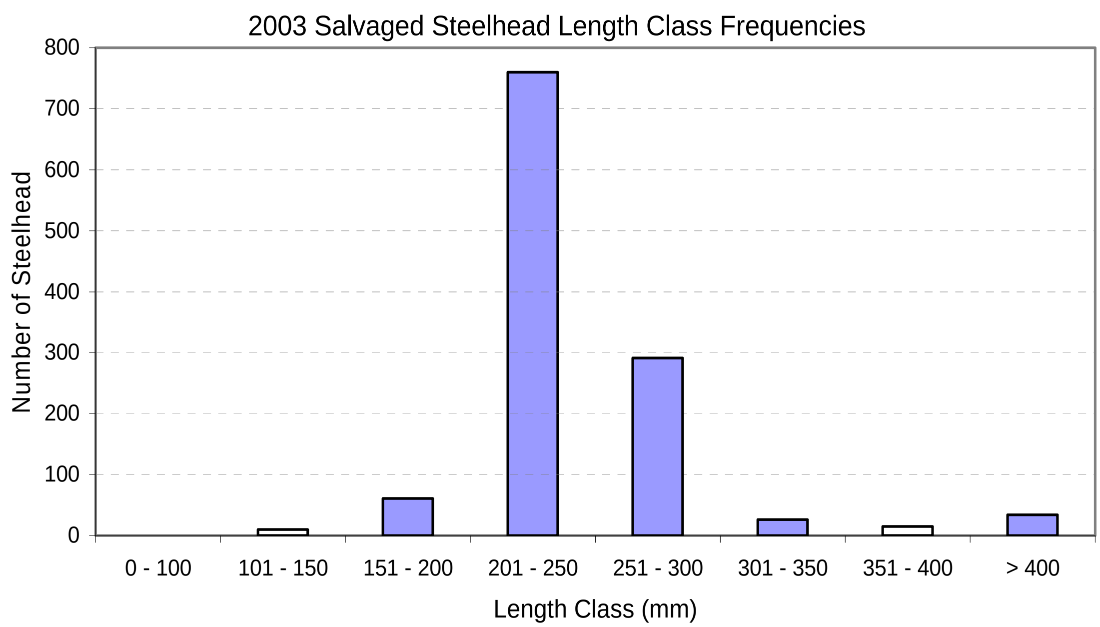

Figure 16. Length class frequencies for steelhead salvaged at the SFPF, 2003.

Surgical implantation of the acoustic tags took place between March 22 and April 5 according to the following procedure. Each juvenile steelhead was netted from the holding tank and measured for length and a sub-sample of steelhead was weighed. After measurement each steelhead was placed in a 18.9 L (5 gal) bucket that contained 106 mg/L (0.014 oz/gal) of MS-222. The juvenile steelhead was left in the bucket for approximately one minute until anesthetized. At this point the juvenile steelhead was placed into a holding cradle treated with Stress Coat®. Handling of the fish causes damage to the slime coat of the fish and Stress Coat® replaces the fish's natural slime coat with a synthetic one, thereby reducing stress. The gills were irrigated with water containing 53 mg/L (0.007 oz/gal) of MS-222 through a soft rubber tube to maintain anesthesia during surgery. The incision area near the posterior end of the abdominal cavity was swabbed with a Betadine Solution containing 10% povidone-iodine and a 25 mm incision was made along the linea alba immediately posterior to the pelvic fins. Antibiotic solution, containing oxytetracycline, was injected into the incision to avoid infection and the acoustic tag, coated in beeswax to slow rates of foreign body rejection, was inserted into the abdominal cavity. The incision was then closed with three to five synthetic absorbable sutures and the suture area was treated with a povidone-iodine ointment. During insertion of the last suture the gill irrigation water supply was switched from the MS-222 maintenance solution to fresh water to begin the recovery process. Once the surgical procedure was completed the juvenile steelhead was moved to a recovery bucket and then transferred to the holding tank for observation and recovery. The total surgical procedure took approximately four minutes in duration from initial measurement through recovery. A new pair of sterile surgical gloves and a new, sterile scalpel blade were used during each surgery to minimize infection and cross contamination. All instruments were kept in cold sterile solution. After surgery the tagged juvenile steelhead were observed in the holding tank for a minimum of two days to ensure recovery and suture stability prior to experimental release.

Just prior to tagging, a sub-sample of steelhead (7 of the 30 tagged fish) was weighed using a digital scale to estimate the tag percentage of body weight. The tag percentage of body weight for the sub-sample ranged from 1.94% to 2.73% with a mean of 2.18% ± 0.24%. It has been suggested in the literature that fish should not be tagged with transmitters that weigh more than 2% of the fish's body weight (Winter, 1983; 1996; Nielson 1992; Brown, and others 1999). The tag percentage of body weight was slightly higher than the suggested 2%. However, Brown and others (1999) found that swimming performance in juvenile rainbow trout was not affected by transmitters weighing up to 12% of the body weight. Also, Anglea and others (2004) found that juvenile Chinook salmon tagged with transmitters weighing up to 6.7% of the fish's body weight were not affected in terms of swimming performance or predation susceptibility.

6.1.4 Steelhead Surgical Procedure Control Group

To monitor the long-term effects of surgical implantation of acoustic tags on fish mortality, a group of 10 steelhead was surgically implanted with dummy acoustic tags and observed over a 30 day period. These steelhead were tagged following the same procedures as the steelhead tagged for release into the Forebay, described above. Also, a group of 10 steelhead randomly selected from the holding tank were kept as a control group for observation of long-term mortality. The 10 juvenile steelhead implanted with dummy tags and the 10 juvenile steelhead selected as a control group were kept in two separate aerated holding tanks and fed twice daily. Both groups were observed to have no mortality after a 30 day observation period. The control group experienced no mortality after a 46 day observation period at which point observations were ceased.

6.1.5 Acoustic Tagged Steelhead Releases

The live-car, shown in Figure 17, was constructed of aluminum perforated plate and steel tubing with a volume of 0.25 m^3 (9 ft^3) and was specially designed to release steelhead upstream of the radial gates. Prior to acoustic tagged juvenile steelhead release, the live-car was tested for potentially adverse effects. These adverse effects could include degradation of water quality associated with low flow through the live-car and/or overcrowding. During the tests, the live-car was placed in the radial gate intake canal and anchored to the shore allowing it to float naturally in the water via two boat bumpers. Ten juvenile steelhead with surgically implanted dummy tags were placed in the live-car and two water quality parameters were monitored over a 3 hr period. Dissolved oxygen and temperature were measured inside and outside the live-car to test for a significant reduction of water quality that would potentially stress steelhead during a pre-release acclimation period. No significant reduction in water quality within the live-car was detected for a 3 hr period with 10 tagged steelhead housed within the live-car (Table 2). Thus, the live-car was used to conduct all steelhead releases in 2005.

Figure 17. Release of tagged steelhead immediately upstream of the radial gates using the live-car. Two blue floats were attached to the live-car and used to float the live-car into position directly upstream of the radial gates.

Table 2. Live-car water quality conditions compared to ambient radial gate intake water quality conditions over time.

Live-car Water Quality			Radial Gate Intake Water Quality			
			Surface		Bottom	
Time	DO (mg/l)	Temp (°C)	DO (mg/l)	Temp (°C)	DO (mg/l)	Temp (°C)
1230	8.47	14.93	8.25	14.92	8.45	14.81
1330	8.24	15.03	8.42	15.07	8.37	14.88
1530	8.74	15.73	9.09	15.72	9.26	15.67

The 30 acoustic tagged juvenile steelhead were released immediately upstream of the radial gates over three days in groups of 10 fish each. Each group of 10 tagged steelhead was transported in an aerated tank to the release site. The acoustic tags were monitored to ensure correct operation using a mobile monitoring unit (VEMCO, model VR60) and the tag ID numbers for each release group were recorded. The group of 10 tagged steelhead was loaded into the live-car while the live-car was floating in Old River outside the Forebay. The live-car was positioned against the wing wall leading to radial gate number one and gate one was closed during the steelhead acclimation period. Prior to release, the tagged steelhead were acclimated in the live-car for a minimum of 2 hr to recover from transportation and handling stress. Once the acclimation period was complete, radial gate number one was opened. Once open, the downstream door of the live-car was released via remote cable. This allowed the tagged steelhead to exit the live-car into the flow passing through the radial gates from the velocity refuge of the live-car. After 10 minutes, the upstream door of the live-car was triggered to open and flush any remaining steelhead into the flow for entrainment into the Forebay. Releases of acoustic tagged steelhead via the live-car were conducted between April 5 and 7 with acclimation occurring from 06:30 to 08:15.

6.1.6 Fixed Station Receiver Grid

A network of fixed-station receivers (Vemco, model VR2) was placed throughout the Forebay to track the movement of tagged predator (striped bass) and prey (juvenile steelhead) within the Forebay, SFPF, Old River, and the intake canal leading to Harvey Banks Pumping Plant (Figure 18). The receiver array was installed in early March 2005 before either tagged striped bass or juvenile steelhead were released into the Forebay.

The VR2 is a submersible, multi-channel acoustic receiver capable of identifying VEMCO coded transmitters. The VR2 records the code number and date/time of each valid acoustic tag detection. This information is stored in memory until downloaded from the receiver using a VR PC interface and a computer running VR2PC software. The fixed station receivers were attached to a mooring line with the use of cable ties and kept in an upright position submerged completely in the water column between a mooring anchor and a float.

The fixed station receiver array was designed to achieve the following objectives:

1. Track steelhead movement patterns and transit times across the Forebay after entrainment through the radial gates;

2. Track steelhead movement through the intake canal to the trashboom and from the trashboom to the SFPF salvage holding tanks;
3. Track striped bass movement patterns and transit times in the Forebay;
4. Track striped bass accumulations within the Forebay;
5. Track potential emigration of steelhead and striped bass from Clifton Court Forebay into either Old River, through the radial gates, or into the Harvey Banks Pumping Plant intake canal through the primary louvers.

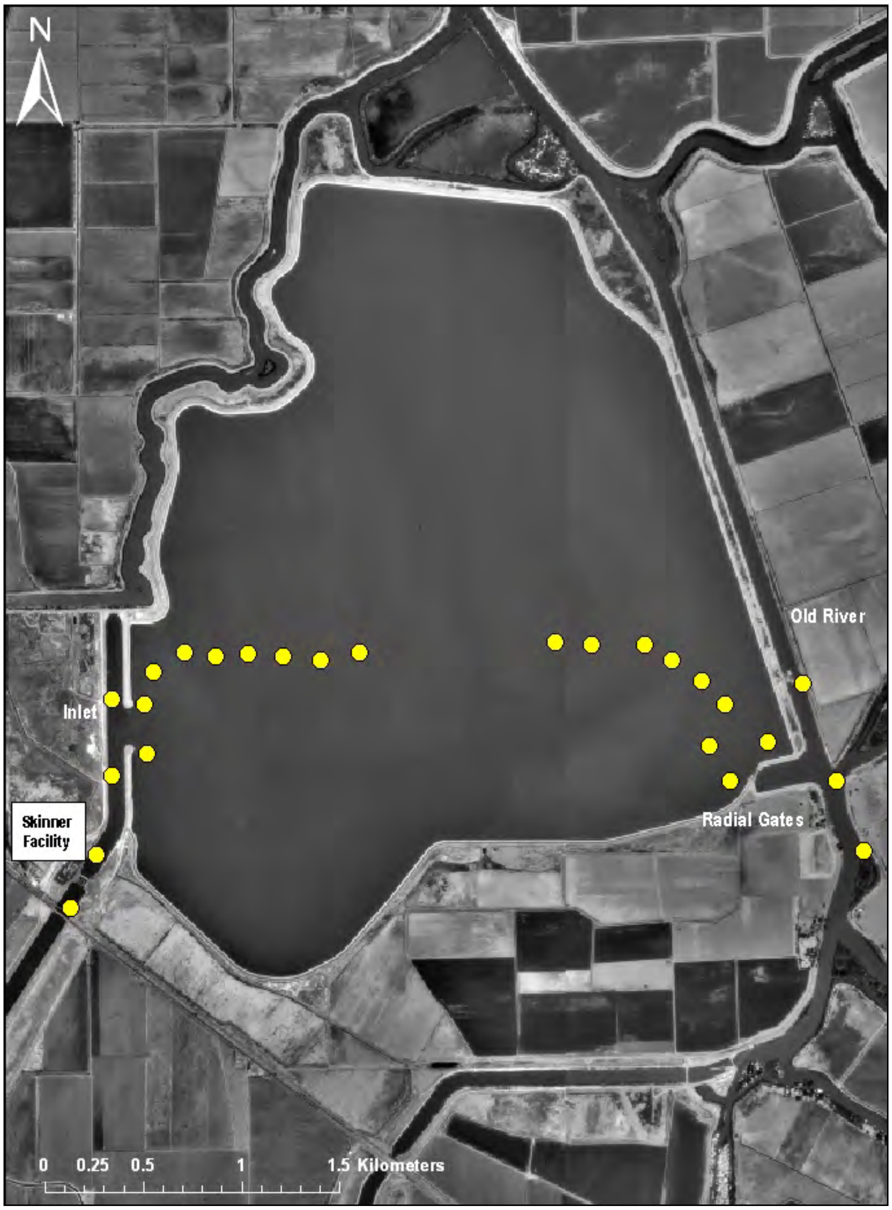

Figure 18. Fixed station receiver (29 total) locations within Clifton Court Forebay and Old River during the 2005 pilot study. The four receivers located within the SFPF are not shown. Locations of the receivers are indicated by yellow circles.

6.1.7 Mobile Monitoring

Mobile monitoring of acoustic tagged striped bass and juvenile steelhead was conducted within the Forebay to track fish movement patterns. The mobile monitoring transect patterns covered the areas of the Forebay outside the detection range of the fixed station receiver array (Figure 19). Mobile monitoring was also conducted along an additional transect between the trashboom and the radial gates (Figure 19). The data collected from the radial gates transect was used to validate the monitoring process by ensuring that both systems of data collection, fixed and mobile, recorded similar telemetry data when occurring simultaneously.

Mobile monitoring was conducted during the daylight hours on an almost daily basis from March 15 through April 30. Mobile monitoring was conducted from a boat within the Forebay using a handheld GPS unit (Garmin, model GPS 12) and a mobile monitoring unit (VEMCO, model VR60) equipped with an omni-directional hydrophone. The mobile monitoring was conducted following the transect patterns outlined in Figure 19 on a rotational daily basis (i.e. one portion of the Forebay was covered each day). Using GPS reference points and land based reference points, the transect pattern was traveled using the research boat. Approximately every 61 m (200 ft), the boat was fully stopped and the engines switched off to avoid signal contamination from noise and cavitation. The omni-directional hydrophone was submerged to a depth of approximately 0.9 m (3 ft) and left for tag detection for three to four minutes. Any coded tag detections received on the mobile monitoring unit were recorded onto data sheets identifying time, date, tag ID number, fish species, and GPS coordinates, with the approximate position within the Forebay marked on a field guide map. Also noted on the data sheets were the positions of the radial gates (open or closed) when possible.

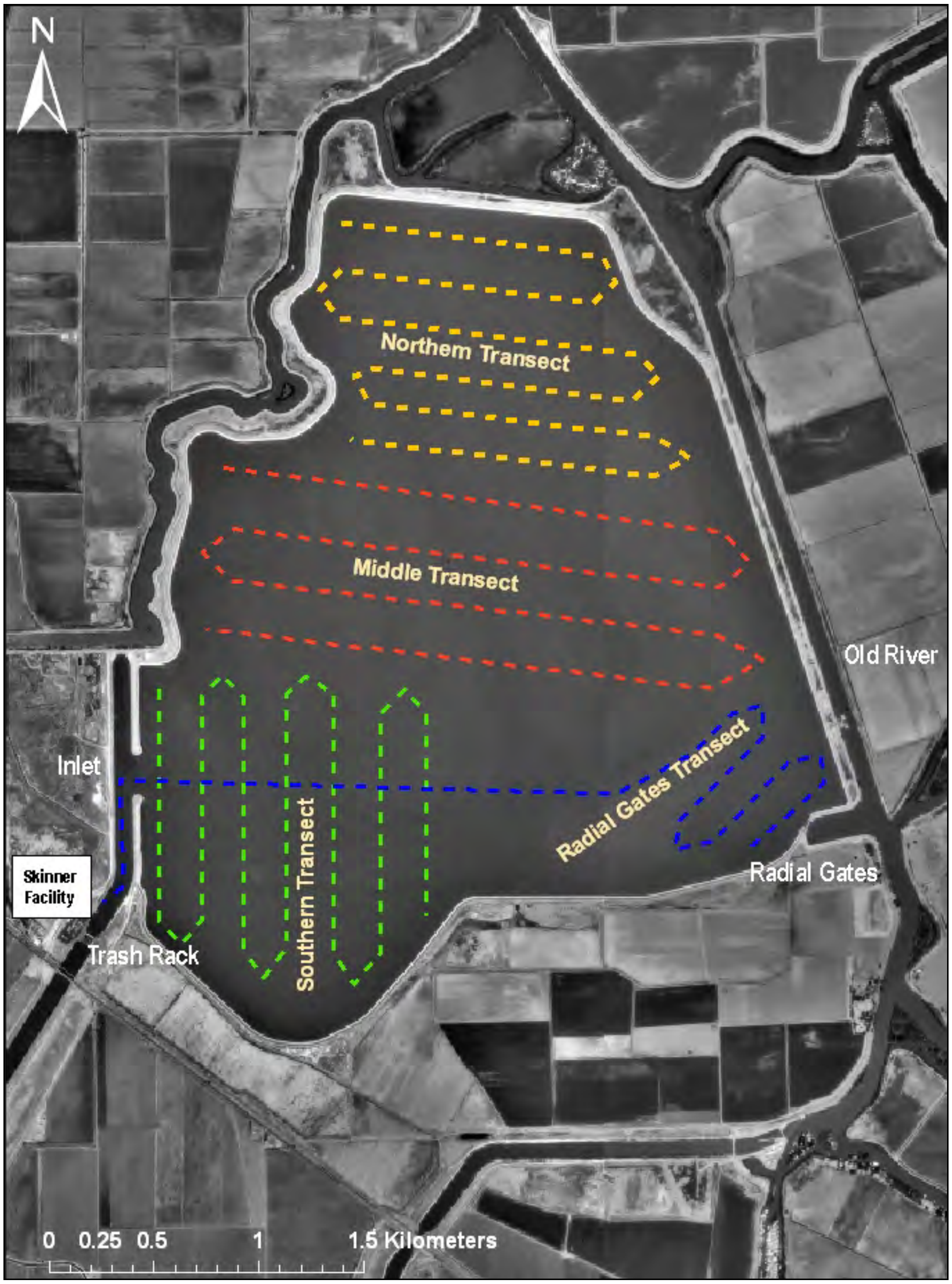

Figure 19. Mobile monitoring transect patterns for monitoring fish movement within the southern (green), northern (yellow), and middle (red) portion of the Forebay in 2005. An additional transect pattern (blue) was located near the radial gates.

6.1.8 Tag Signal Interference Testing

Testing was conducted to determine if the louvers of the SFPF interfere with the detection of a juvenile steelhead acoustic tag by a fixed station receiver. Tests were performed in July 2005 over two days. Weather conditions were similar for both days: sunny, air temperature above 38 °C (100°F), and winds out of the West at approximately

16 km (10 mph). The pumping rate for both tag signal interference testing days was identical at 234.6 m^3/s (8,285 cfs).

A fixed station receiver (VEMCO, model VR2) was placed downstream from the SFPF louvers, fastened to the railroad bridge, and submerged in approximately 6 m (20 ft) of water. The receiver was fastened at a location approximately 1 m (3 ft) from the bottom of the channel. An acoustic tag (VEMCO, model V8SC) was prepared for use as a mobile control tag. It was wrapped in netting with a 907 g (2 lb) weight with rope secured to the netting and a float placed on the rope approximately 1.5 m (5 ft) from the tag.

On day one of the tag signal interference testing, an acoustic tag was lowered into the water for approximately 10 minutes, followed by five minute intervals before the next reading. Within a 2 hr period, data from the following seven locations were collected: upstream of the trashboom, upstream of the trash rack, inside louver bay 1, inside louver bay 2, inside louver bay 3, inside louver bay 4, and the foot bridge immediately downstream from the louvers (Figure 20).

On day two of the tag signal interference testing, an acoustic tag was lowered into the water at the same starting location. The tag was lowered into the water for approximately 10 minutes, followed by five minute intervals before the next reading. Within a 2 hr period, data from the following seven locations were also collected: inside louver bay 1, outside louver bay 1, inside louver bay 2, outside louver bay 2, inside louver bay 3, outside louver bay 3, and the foot bridge immediately down stream from the louvers (Figure 20).

Figure 20. Acoustic tag signal interference testing positions within the SFPF louvers. The acoustic tag (VEMCO, model V8SC) was lowered into the water at the trashboom, at the trash rack, inside the louver bays (L1, L2, L3, L4), outside the louver bays (OL1, OL2, OL3), and at the foot bridge.

6.2 2005 Results and Discussions

6.2.1 Tag Signal Interference Testing Within the SFPF

Results from the tag signal interference testing demonstrated that the fixed station receiver, located at the railroad bridge downstream of the louvers, could not detect the acoustic tag within the SFPF. When the acoustic tag was lowered outside the louvers or off of the footbridge, the fixed station receiver detected a signal. At no other locations did the receiver detect the acoustic tag. When the acoustic tag was lowered into the water upstream of the trash rack or at the trashboom, no detection was recorded by the fixed station receiver downstream of the SFPF. Thus, fish moving within the SFPF primary louver bays and/or upstream of the SFPF would not be detected by the fixed station receiver deployed at the railroad bridge downstream of the SFPF.

6.2.2 Acoustic Tagged Striped Bass

Mobile monitoring data were analyzed separately from fixed station receiver data. Mobile monitoring detections were examined to determine the locations striped bass were located within the study area. For each day of mobile monitoring the monitoring time was recorded and the number of acoustic tagged striped bass detected was totaled and converted to a percentage of the total tagged striped bass assumed to be in the Forebay at the time (Table 3). As shown in Table 3, the number of tagged striped bass within the Forebay was reduced after a recreational angler harvested a tagged striped bass. The number of striped bass assumed to be in the Forebay was not adjusted for striped bass that possibly emigrated from Clifton Court Forebay and into Old River. All mobile monitoring events detected at least 1 striped bass within the Forebay. The percentage of tagged striped bass detected daily fluctuated throughout the monitoring period. However, the mobile monitoring daily coverage range typically was only approximately a quarter of the Forebay so movement out of the monitoring area could not be detected. The area of most frequent striped bass detection was directly between the radial gates and the intake canal, in line with the fixed station receivers. Striped bass were found to disperse into the extreme north and south of the Forebay, but generally only a low percentage of the tagged striped bass was observed in these areas. The majority of the tagged striped bass were detected either at the radial gates, within the intake canal near the trashboom, or in a direct line between these two areas within the Forebay. Figures 21 and 22 demonstrate detected striped bass from the mobile monitoring data.

Table 3. Daily mobile monitoring results for striped bass tracking.

Date	Start Time	End Time	No. Tagged Striped Bass Potentially in Forebay	No. Tagged Striped Bass Detected	% Tagged Striped Bass Detected
3/16	1430	1630	16	2	12%
3/17	1300	1500	16	4	24%
3/18	1130	1330	16	7	41%
3/22	0930	1330	16	10	59%
3/23	0930	1330	16	10	59%
3/25	0930	1330	16	1	6%
3/28	1300	1700	16	5	29%
4/1	1400	1600	16	4	24%
4/4	1230	1530	16	5	29%
4/5	0900	1500	16	6	38%
4/6	0900	1500	16	11	69%
4/7	0900	1500	16	6	38%
4/8	0800	1500	16	8	50%
4/12	1300	1800	16	2	13%
4/13	0730	1730	16	10	63%
4/18	0730	1530	15	5	31%
4/19	0900	1600	15	3	19%
4/20	0830	1730	15	4	25%
4/21	0830	1730	15	1	6%
4/22	0830	1730	15	5	31%
4/25	0830	1730	15	1	6%

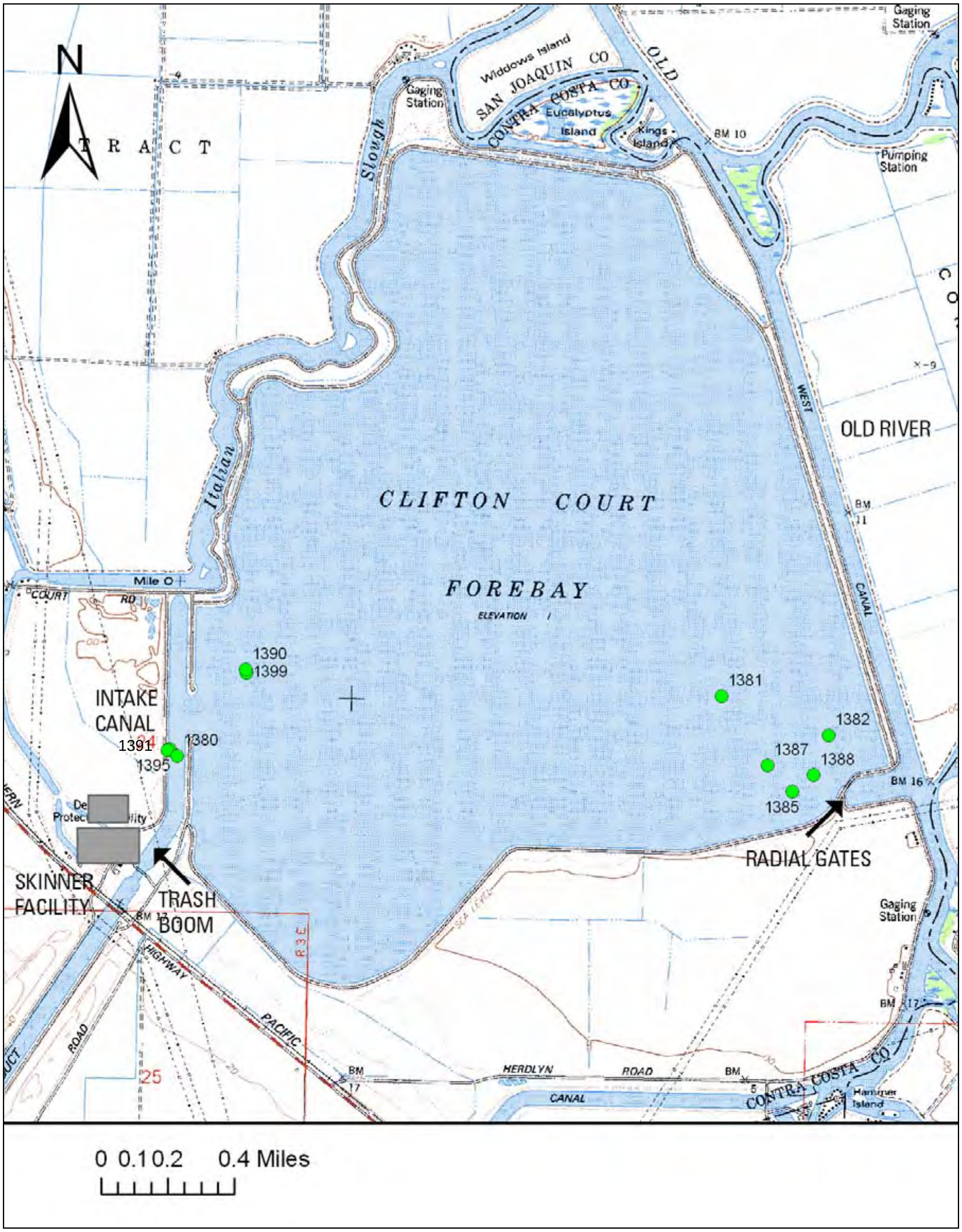

Figure 21. Striped bass locations on March 22, 2005, detected by mobile monitoring. The four digit codes next to the green location points indicate the tag identification number for each striped bass detected.

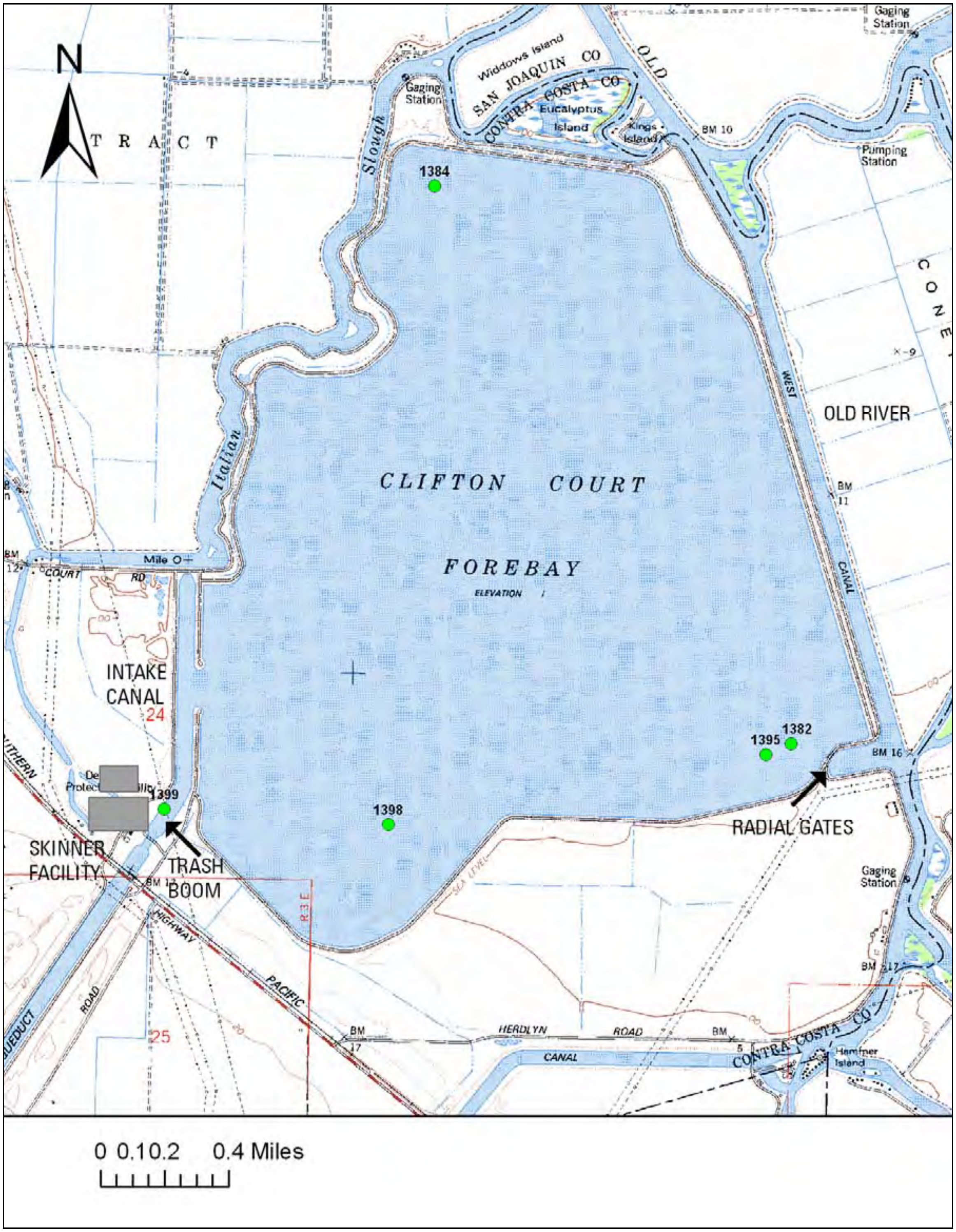

Figure 22. Striped bass locations on April 18, 2005 detected by mobile monitoring. The four digit codes next to the green location points indicate the tag identification number for each striped bass detected.

Fixed station receiver detections were summarized for the 16 acoustic tagged striped bass at selected locations within the Forebay and Old River. Fixed station receiver data showed that 11 (69%) of the tagged striped bass moved, at some time, from the release location at the radial gates to the intake canal entrance (Table 4). Furthermore, 10 (63%) moved from the release location at the radial gates to the trashboom immediately upstream of the SFPF (Table 4). Emigration from the Forebay was observed with 7 (44%) of the striped bass being detected in Old River after passing through the radial gates (Table 4).

Table 4. Fixed station receiver data summary for 12 of 16 acoustic tagged striped bass that were detected at either the intake canal, trashboom, and/or in Old River. Striped bass not detected at any of these locations were not included in the table. The total number of striped bass tagged and released was used to calculate the percentage of fish detected at the four locations.

Tag ID	Release Date	Intake Canal	Trash-boom	Old River
1380	3/16	X	X	-----
1381	3/18	X	X	-----
1382	3/18	X	-----	X
1383	3/18	X	X	-----
1389	3/17	X	X	-----
1390	3/18	X	X	X
1391	3/18	X	X	X
1394	3/17	X	X	-----
1395	3/18	X	X	X
1396	3/18	-----	-----	X
1398	3/17	X	X	X
1399	3/17	X	X	X
Fish Detected (% of total released)		11 (69%)	10 (63%)	7 (44%)

Analysis of all telemetry data for striped bass shows that striped bass moved throughout the Forebay and in some cases, moved multiple times between the radial gates and the trashboom. For example, striped bass tag ID 1398 was released at the radial gates on March 17 and was monitored moving from the radial gates to the intake canal and trashboom eleven times during the course of the monitoring period. Striped bass were also detected emigrating out of the Forebay, then re-entering the Forebay through the radial gates. Striped bass tag ID 1398 was detected moving out of the Forebay into Old River, returned to the Forebay and was monitored at the radial gates area, and then emigrated out of the Forebay to Old River in early June.

As part of the striped bass movement pattern analysis summarized in Table 4, transit times were calculated for striped bass movements. The transit times were calculated from the release date and time for each fish at the radial gate area to the first date time record of each striped bass at the intake canal entrance, the trashboom, and Old River using the fixed station receiver data. Of the eleven striped bass that moved from the radial gates to the intake canal, the mean transit time was 4 days, with a range in transit times from 7 hours to almost 17 days. Of the ten striped bass that moved from the radial gates to the trashboom, the mean transit time was 10 days with a range in transit times from approximately 1 to 45 days. Of the seven striped bass that were detected emigrating out of the Forebay into Old River, the mean transit time was 31 days with a range in transit times from 3 to 49 days.

Striped bass final detection locations were determined from a combination of mobile and fixed-position receiver monitoring data. Final destinations were determined as the last recorded detection location for each striped bass (Table 5). In the case of striped bass emigrating into Old River, these fish continued to disperse beyond the range of the study area. For the striped bass remaining in the Forebay in early June, the final detection locations were determined at the time the receivers were removed from the Forebay.

Table 5. Striped bass final detection summary for the 2005 pilot study.

Tag ID	Location Description	Date of Last Detection
1380	Trashboom	3/27
1381	Clifton Court Forebay	4/6
1382	Old River	4/21
1383	Clifton Court Forebay	4/20
1384	Clifton Court Forebay	4/20
1385	Clifton Court Forebay	5/4
1387	Clifton Court Forebay	6/9
1388	Clifton Court Forebay	4/29
1389	Trashboom	3/20
1390	Old River	4/15
1391	Old River	4/16
1394	Clifton Court Forebay	6/1
1395	Old River	4/21
1396	Old River	3/21
1398	Old River	6/6
1399	Old River	5/1

6.2.3 Acoustic Tagged Steelhead

Mobile monitoring of the steelhead produced varied results. Of the thirty steelhead released into the Forebay, one juvenile steelhead remained in Old River near the release site. Another juvenile steelhead was not detected after release either within the Forebay or in Old River and may have experienced a tag malfunction (tag 1987). Alternatively, this steelhead may have been consumed by an avian predator that left the study area. For the other 28 acoustic tagged steelhead mobile monitoring was able to capture the dispersion of tagged steelhead as they were entrained. Once entrained into the Forebay, steelhead displayed varied movement patterns (Figures 23, 24, and 25). Several moved to the intake canal within hours of entrainment (Figure 24). Others remained near the radial gates. While some steelhead dispersed to the extreme northern and southern areas of the Forebay (Figure 25).

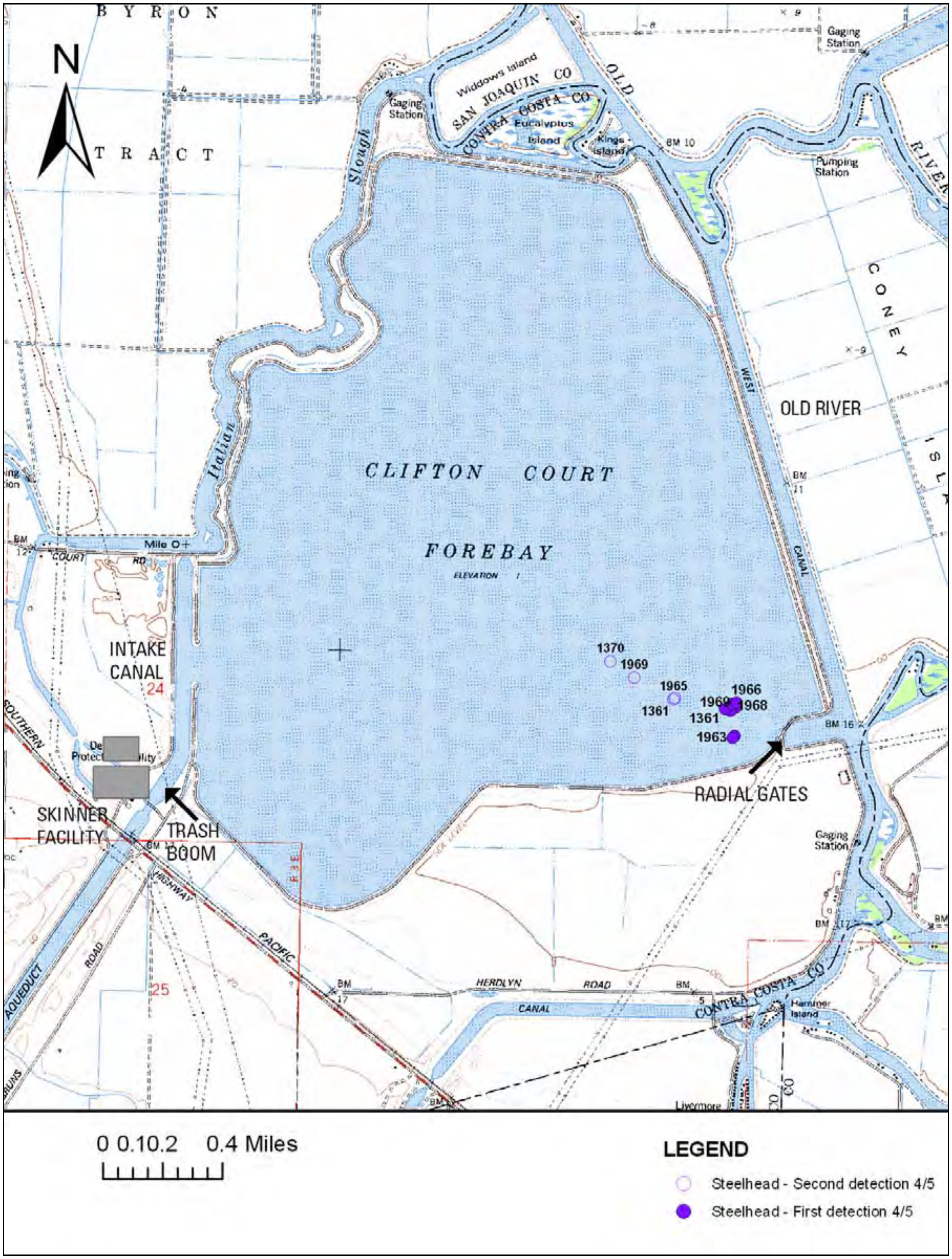

Figure 23. Steelhead locations on April 5, 2005 detected by mobile monitoring. The four digit codes next to the location points indicate the tag identification number for each steelhead detected.

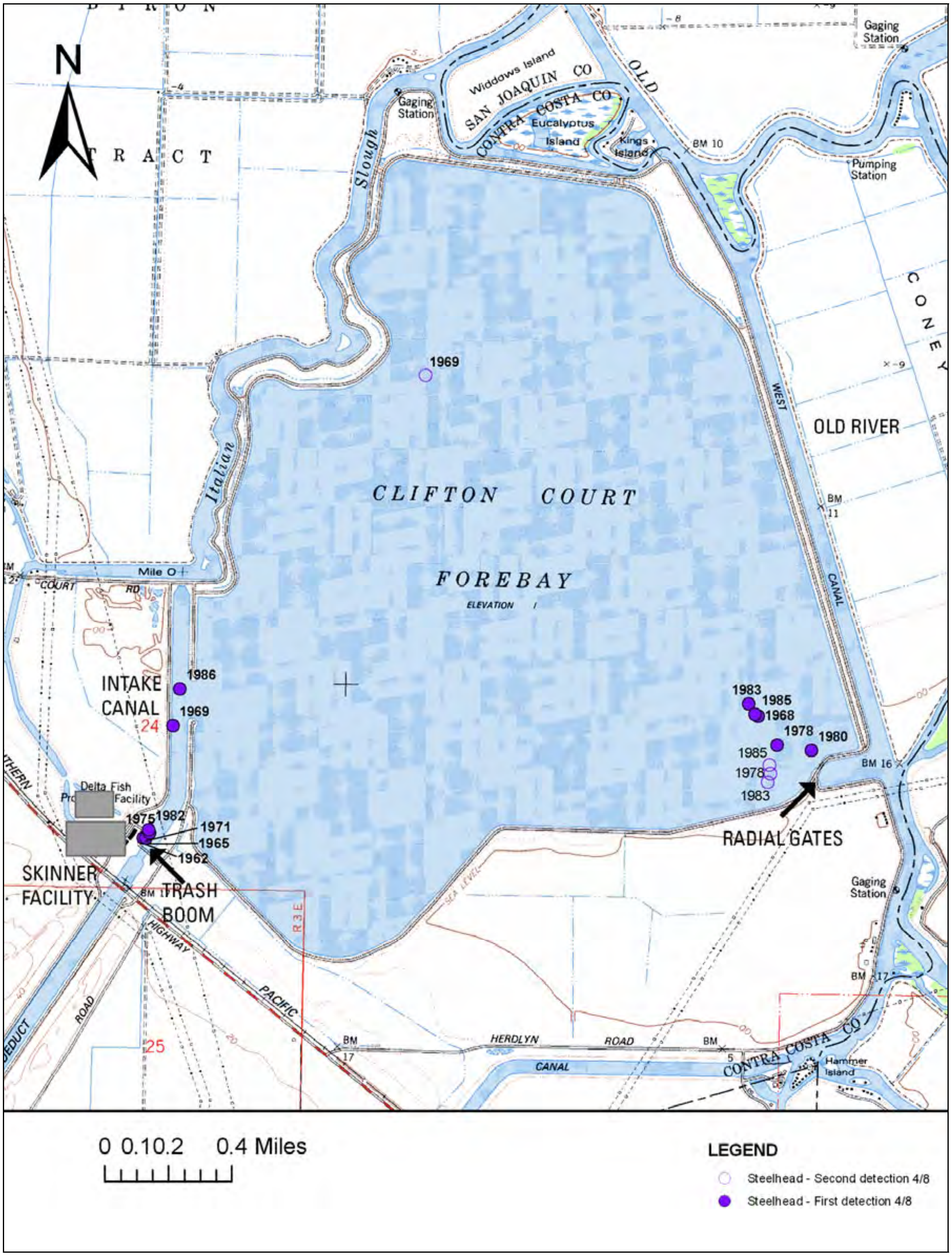

Figure 24. Steelhead locations on April 8, 2005, detected by mobile monitoring. The four digit codes next to the location points indicate the tag identification number for each steelhead detected.

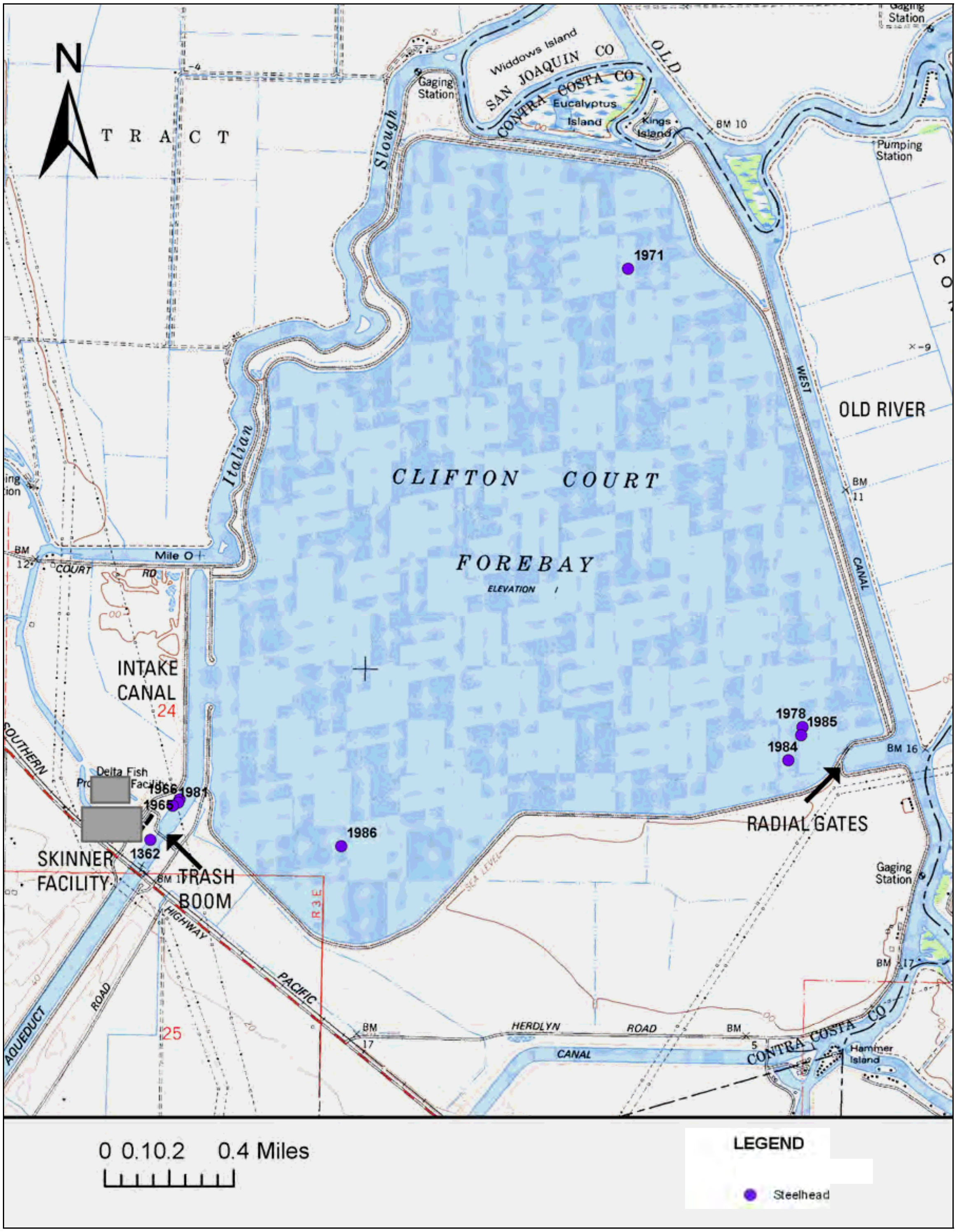

Figure 25. Steelhead locations on April 18, 2005, detected by mobile monitoring. The four digit codes next to the location points indicate the tag identification number for each steelhead detected.

Juvenile steelhead were also tracked by the fixed station receiver array deployed within the Forebay. Tracking by the array continued until June 1, after which the tag signals were unreliable due to battery extinction. Of the 30 acoustic tagged steelhead released, 17 (57%) were detected in the intake canal (Table 6). Twelve (71%) of the steelhead detected in the intake canal were also detected at the trashboom. Four (13%) of the tagged steelhead were detected as having emigrated from the Forebay into Old River (Table 6). Of the steelhead released, four (13%) were detected as having been successfully salvaged (Table 6). Even though only four steelhead were detected within the SFPF holding tanks, 17 steelhead reached the trashboom at least once. This may indicate that there is a delay problem and/or an attraction problem at the SFPF.

Table 6. Fixed station receiver data summary for 19 of 30 steelhead that were detected at either the intake canal, trashboom, salvage holding tank, and/or in Old River. Steelhead not detected at any of these locations were not included in the table. The total number of steelhead released was used to calculate the percentage of fish detected at the four locations.

Tag ID	Release Date	Intake Canal	Trash-boom	Salvage Holding Tank	Old River
1961	4/5	-----	-----	-----	X
1962	4/5	X	X	X	-----
1963	4/5	X	X	-----	-----
1965	4/5	X	X	-----	-----
1966	4/5	X	X	-----	-----
1968	4/5	X	X	-----	X
1969	4/5	X	X	-----	-----
1970	4/5	X	X	-----	-----
1971	4/7	X	X	-----	-----
1974	4/5	X	X	-----	-----
1975	4/6	X	X	X	-----
1976	4/6	X	X	X	-----
1980	4/6	X	-----	-----	-----
1981	4/6	X	X	-----	X
1982	4/6	X	-----	X	-----
1986	4/6	X	-----	-----	-----
1988	4/7	-----	-----	-----	X
1989	4/7	X	-----	-----	-----
1990	4/7	X	-----	-----	-----
Fish Detected (% of total released)		17 (57%)	12 (40%)	4 (13%)	4 (13%)

One steelhead was detected moving through the SFPF primary louvers into the aqueduct leading to Harvey Banks Pumping Plant, and was later detected moving back through the trash rack indicating that this fish was able to move both upstream and downstream through the SFPF louvers. This steelhead moved upstream through the primary louvers during the periods of time when Harvey Banks Pumping Plant export flows were reduced or during periods of time when there was a stoppage in pumping. This steelhead was last detected at the trashboom on April 19, 2005.

Transit times for steelhead were calculated from the release point at the radial gates to the intake canal, trashboom, SFPF salvage holding tanks, and Old River. From point of release to the intake canal, the mean transit time was 5 days. However, this mean time is skewed somewhat by two steelhead with transit times of 11 and 32 days. Nine of the seventeen steelhead detected at the intake canal had transit times of less than 1 day. The mean transit time from the release point to the trashboom was 9 days, however five of the thirteen steelhead detected at the trashboom had transit times less than 1 day. Mean transit time to the SFPF salvage holding tank from point of release was 14 days. However, only four of the twenty-nine active steelhead tags were detected as being salvaged with transit times ranging from 2 days to 31 days. Mean transit time for steelhead emigrating out to Old River was 9 days, but similar to the transit data for steelhead being salvaged, ranging from 1 days to 23 days. It is not possible to say with certainty whether these transit times were affected by striped bass predation.

Of the four steelhead salvaged, transit times from release to the trashboom varied widely. The progression from release to trashboom to salvage ranged from approximately 2 days up to 30 days from time of release. One steelhead moved from the trashboom to the salvage holding tank in a matter of hours, while two steelhead remained at the trashboom for over a week before being salvaged. The fourth steelhead was not detected at the trashboom before being detected in the salvage holding tank. Figure 26 illustrates the transit pattern for one of the salvaged steelhead. After release, the steelhead (tag 1962) moved from the radial gates at approximately 08:30 on April 5 to the trashboom at 02:22 on April 6, a transit time of approximately 18 hours. Between April 6 and April 18, the steelhead remained at the trashboom, a period of 12 days, before being salvaged on April 19. Of the four steelhead successfully salvaged, three were lost from the SFPF holding tank receivers in under eight hours from first contact, presumably as they were collected and released.

Figure 26. Steelhead tag ID 1962 path to the SFPF salvage holding tank.

Steelhead final detection locations were determined from fixed station receiver grid data and/or mobile monitoring data. At the end of the pilot study (June 1, 2005), four (13%) of the steelhead had been salvaged and 20 (68%) steelhead remained in the Forebay (Figure 27). Of the steelhead tags remaining within the Forebay, seven tags were detected near the radial gates, five remained in the wider Forebay, five were located within the intake canal, and three were located at the trashboom (Table 7). One (3%) steelhead was never detected after release and one (3%) steelhead may not have been entrained and was last detected in the live-car (Figure 27). Four (13%) of the steelhead had emigrated to Old River (Figure 27).

Time periods exist when water surface elevations within the Forebay and Old River are similar and water velocities passing through the radial gates are reduced, or under extreme circumstances, water is actually flowing from the Forebay through the radial gates to Old River. Juvenile steelhead have been shown to have a critical swimming velocity of 7.90 bl/s (Hawkins and Quinn, 1996). Thus, juvenile steelhead that have been entrained into the Forebay would have the swimming performance capability to effectively swim out of the Forebay when either of these conditions occur or when water velocities at the radial gates are approximately below 1.2 m/s (4 ft/s). Acoustic tagged steelhead were detected as moving from the Forebay through the radial gates to Old River at periods of low velocity. However, it cannot be confirmed conclusively that these acoustic tagged steelhead had not been preyed upon within the Forebay and their predators moved from the Forebay through the radial gates into Old River.

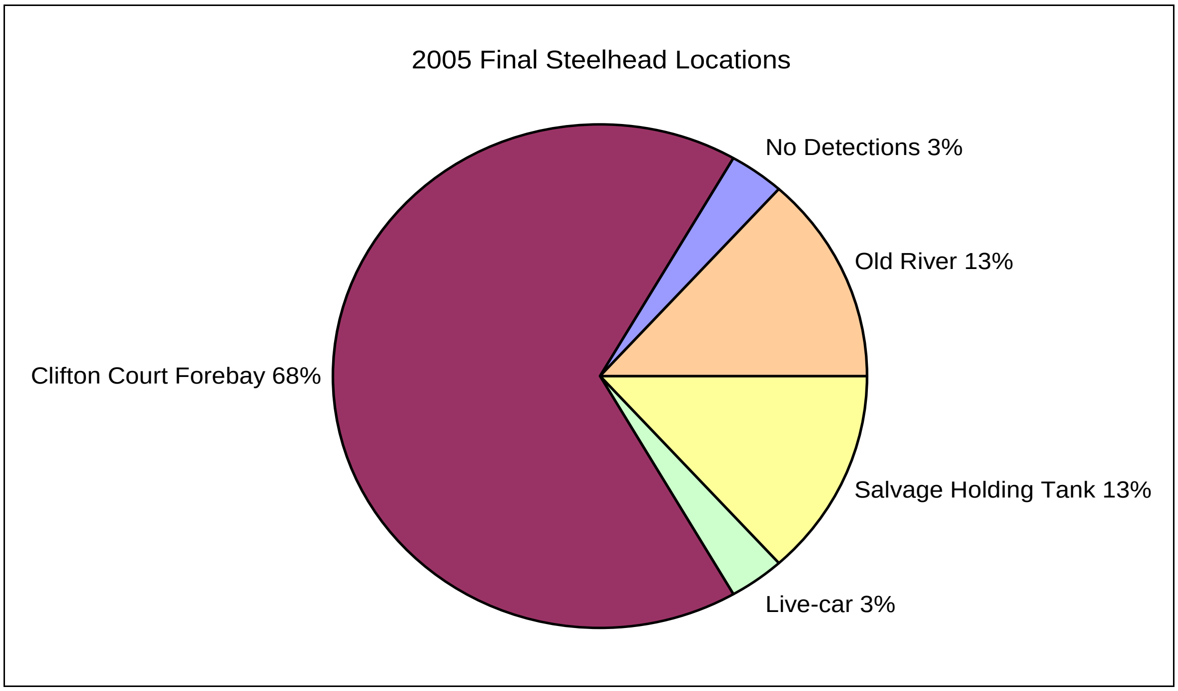

Figure 27. Percentages and locations for final detections of acoustic tagged steelhead released during the 2005 pilot study.

Table 7. Final detection locations for acoustic tagged steelhead in 2005.

Tag ID	Location Description	Date of Last Detection	Days After Release
1961	Old River	6-Apr	1
1962	**Salvage Holding Tank**	**20-Apr**	**15**
1963	Intake Canal	16-Apr	11
1964	East Side of Forebay	5-Apr	0
1965	Trashboom	1-Jun	57
1966	Trashboom	19-Apr	14
1967	East side of Forebay	7-Apr	0
1968	Old River	14-Apr	9
1969	Intake Canal Opening	26-May	21
1970	Intake Canal Opening	5-Apr	0
1971	Radial Gates	29-May	52
1972	Radial Gates	31-May	54
1973	West Side of Forebay	12-Apr	5
1974	Trashboom	7-May	32
1975	**Salvage Holding Tank**	**17-Apr**	**11**
1976	**Salvage Holding Tank**	**7-May**	**31**
1977	Radial Gates	1-Jun	56
1978	Radial Gates	1-Jun	55
1979	Live-car	7-Apr	0
1980	Middle of Forebay	16-Apr	10
1981	Old River	29-Apr	23
1982	**Salvage Holding Tank**	**8-Apr**	**2**
1983	East Side of Forebay	26-May	50
1984	Radial Gates	1-Jun	56
1985	Radial Gates	1-Jun	56
1986	Intake Canal	26-Apr	20
1987	No detections		
1988	Old River	9-Apr	2
1989	Radial Gates	1-Jun	55
1990	Intake Canal	27-May	50

Note: Bold lines are for steelhead recovered at the SFPF

6.3 Recommendations for the Full-scale Investigation

Based upon results of the 2005 pilot study, recommendations for the full-scale investigation included the following:

- The experimental investigation should occur coincident with the period of juvenile steelhead salvage extending from January through April.

- Seasonal variation in water temperatures and potential abundance and behavior of predatory striped bass during the winter and early spring should be taken into account in the experimental design by stratifying experimental design and recapture releases on a monthly basis, as well as evaluating the potential relationship between juvenile steelhead predation mortality and water temperatures within the Forebay. The experimental design should allow for calculating independent estimates of juvenile steelhead survival monthly over the January – April period.

- Juvenile steelhead ranging in length from approximately 200-300 mm were used successfully in the 2005 pilot study and represent the size distribution of juvenile steelhead actually observed in SFPF salvage. Juvenile steelhead used in the full-scale investigation should range in length from 200-300 mm.

- Juvenile steelhead that were used in the 2005 pilot study were obtained from the Mokelumne River Fish Hatchery. The 2005 pilot study was not designed to determine whether or not there was a difference in predation mortality between hatchery produced fish and wild fish. Given the difficulty of obtaining an adequate sample size of wild steelhead, as well as impacts to ESA listed species that may occur as a result of extensive in-river sampling, it is recommended that juvenile steelhead from the Mokelumne River Fish Hatchery, or other hatchery, be used as surrogates for determining pre-screen loss during the full-scale investigation.

- The live-car method of releasing juvenile steelhead directly into the flow passing through the radial gates proved to be an effective release technique in the 2005 pilot study. Releasing fish immediately upstream of the radial gates provides for a representative introduction of the juvenile fish into the Forebay and is thought to more accurately represent the vulnerability of juvenile steelhead entrained through the radial gates. The live-car release techniques developed during the 2005 pilot study should be employed as part of the full-scale investigation.

- Juvenile steelhead were effectively tagged using surgical implantation of individually coded acoustic transmitters during the 2005 pilot study. After developing these surgical techniques, there was no mortality among tagged fish prior to release or for a sub-sample of tagged fish held for a 30 day observation period. The VEMCO V8SC acoustic tag was within the 2% body weight guideline for most of the juvenile steelhead used in the pilot study. In addition, the acoustic tag does not require an external antenna that may affect the behavior or ability of a juvenile steelhead to avoid predation. The use of acoustic tags as part of the full-scale investigation offers the opportunity to quantify emigration of juvenile steelhead from Clifton Court Forebay through the radial gates, passage of juvenile steelhead through the louvers into the canal leading to the Harvey Banks Pumping Plant, and provides valuable information on behavior patterns of juvenile steelhead within the Forebay. The full-scale investigation should include proportional marking of juvenile steelhead using acoustic tags.

- Modifications to the fixed position receiver array should include locating additional receivers in the canal leading to the Harvey Banks Pumping Plant to document potential steelhead movement through the primary louvers, within Old River, and within the Forebay. Analysis of the 2005 fixed position receiver data was difficult due to simultaneous detections on multiple receivers. Methods for optimizing the acoustic tag detection array as suggested by Clements and others (2005) should be used in establishing the full-scale receiver array. Also, the sensitivity of the system for tag detection should be verified.

- Based on the residence time of juvenile steelhead within Clifton Court Forebay observed during the pilot study, PIT tags should be used to mark juvenile steelhead releases as part of the full-scale investigation, with subsequent monitoring using PIT tag detectors positioned on the release pipes at the SFPF salvage release sites. The use of PIT tags will substantially reduce manpower required for sampling, as well as avoid disruption to routine salvage operations and eliminate additional stress and impacts to salvaged fish. PIT tags are also cheaper than acoustic tags and will allow for larger sample sizes.

- Acoustic tagging of striped bass and the use of both fixed position and mobile acoustic monitoring provided valuable insight into the behavior and geographic distribution of adult striped bass within the Forebay. Additional acoustic tagging of adult striped bass should be included as part of the full-scale experimental design to provide further insight into the dynamics of predation in the Forebay and help identify specific locations, operations, or other factors influencing either the concentration of predatory fish or vulnerability of juvenile steelhead to predation.

- Avian predation has been noted as a significant source of mortality for juvenile downstream migrating Chinook salmon in other river systems (Ryan and others, 2001a; 2001b; 2003; Collis and others, 2001) and, therefore, as part of a rigorous experimental design systematic observations and documentation of potential avian predation should be included as part of the full-scale study design.

7.0 2006 Pilot Study

7.1 Methods

Another pilot-scale telemetry study was conducted March – June, 2006. This pilot study was conducted to further investigate the movements of juvenile steelhead through the Forebay, to refine the placement of telemetry receivers for optimal fish tag detections, and to facilitate the training of new project staff. To meet these objectives, steelhead were acoustic tagged, released, and tracked throughout the Forebay. However, the 2006 pilot study data were not completely analyzed until after completion of data collection for the 2007 full-scale study.

7.1.1 Acoustic Tagging of Steelhead

Juvenile steelhead used in the 2006 pilot study were obtained from the Mokelumne River Fish Hatchery and used as surrogates for wild fish. These juvenile steelhead were transported from the hatchery and held at the CHTR Study Facility for 10 days to recover from transportation and handling stress and to acclimate to water quality conditions at the site. The steelhead were selected to be representative of the general size distribution of juvenile steelhead entrained into the Forebay. The 30 juvenile steelhead selected for surgical implantation of acoustic tags ranged in total length from 235 to 280 mm (9.25 to 11.00 in) with a mean of 254 ±0.4 mm (10 ±0.016 in). These steelhead were tagged with acoustic coded transmitters (VEMCO, model V8SC) on March 17 following the same surgical procedure used in the 2005 pilot study. Unlike in 2005, all tagged juvenile steelhead were weighed in 2006 to determine the tag percentage body weight. Tag percentage of body weight ranged from 1.57 to 2.94% with a mean of 2.21 ±0.13%. Similar to the 2005 pilot study, the tag percentage of body weight in 2006 was slightly higher than the accepted 2% tag to body weight rule established by Winter (1983 and 1986). The tagged juvenile steelhead were kept for observation in a holding tank for a minimum of three days to ensure recovery and suture stability prior to experimental release. One acoustic tagged steelhead died and the remaining twenty-nine were released into the Forebay during March to coincide with the seasonal period that steelhead have been observed in the SFPF salvage.

7.1.2 Tagged Steelhead Releases

Similarly to the 2005 pilot study, a special designed live-car was used to release the acoustic tagged steelhead (Figure 17). Three releases of 10 acoustic tagged steelhead each were scheduled for March 2006. However, one acoustic tagged steelhead died prior to release. Therefore, twenty-nine acoustic tagged juvenile steelhead were released immediately upstream of the radial gates over three days in 2 groups of 10 fish and one group of 9 fish. Each group of acoustic tagged steelhead was transported in aerated 18.9 L (5 gal) buckets to the release site adjacent to the radial gates. The acoustic tags were monitored to ensure correct operation using a mobile monitoring unit (VEMCO model VR100) and the tag ID numbers for each release group were recorded. Each release group of acoustic tagged steelhead was loaded into the live-car while the live-car was floating in Old River immediately outside of the Forebay. The live-car was positioned against the wing wall leading to radial gate number one. The tagged steelhead were acclimated in the live-car for 2 hr to recover from transportation and handling stress prior to release. All radial gates were closed during the 2 hr acclimation period. Once the acclimation period was complete and after the radial gates were opened, the live-car was moved into position immediately upstream of the radial gates by pulling the floating live-car along the wing wall. Once in position, the front door of the live-car was released via remote cable. This allowed steelhead to exit the live-car into the flow passing through the radial gates from the velocity refuge of the live-car and become entrained into the Forebay. After a few minutes, the back door of the live-car was triggered to open and flush any remaining steelhead into the flow passing through the radial gates.

Releases of acoustic tagged steelhead via the live-car were conducted during the night on March 22 and March 23 and at dawn on March 28 with acclimation occurring from 00:00 to 02:00, 00:05 to 02:05, and 04:45 to 06:45 respectively. During the March 22 release, one acoustic tagged steelhead jumped out of the aerated bucket into the radial gate intake channel as the fish were loaded into the live-car. All acoustic tagged steelhead appeared to be in good health at the time of release with the exception of one fish showing signs of stress, tag ID 1694, released on March 28.

7.1.3 Fixed Station Receiver Grid

In 2006 a new network of fixed station receivers was designed to cover the entire Forebay and to track the movement of acoustic tagged juvenile steelhead near key locations within the Forebay, the SFPF, Old River, and the intake canal leading to the Harvey Banks Pumping Plant (Figure 28). The new network was designed to reduce the number of simultaneous detections on multiple receivers and to cover the entire Forebay.

The fixed station receiver array was installed in January 2006 before acoustic tagged steelhead were released and remained in the Forebay through the entire 2006 pilot study period. Fixed station receivers (VEMCO, model VR2) were attached to a mooring line with the use of cable ties and kept in an upright position submerged completely in the water column between a mooring anchor and a float. The fixed station receivers were removed from the study area in August 2006 and all data was uploaded for future analysis.

Two Vemco, model VR3-UWM units were utilized in addition to the VR2 receivers for the 2006 field season. One VR3-UWM was deployed from the trashboom upstream of the SFPF and the second VR3-UWM was deployed from the boat dock immediately upstream of the radial gates in Old River. The VR3-UWM is a submersible, multi-channel acoustic receiver capable of identifying VEMCO coded transmitters. The VR3-UWM records the code number and date/time of each valid acoustic tag detection. This information is stored in the VR3-UWM memory until the data is downloaded to a computer at the surface using an underwater modem. Thus, data can be retrieved without retrieving the VR3-UWM.

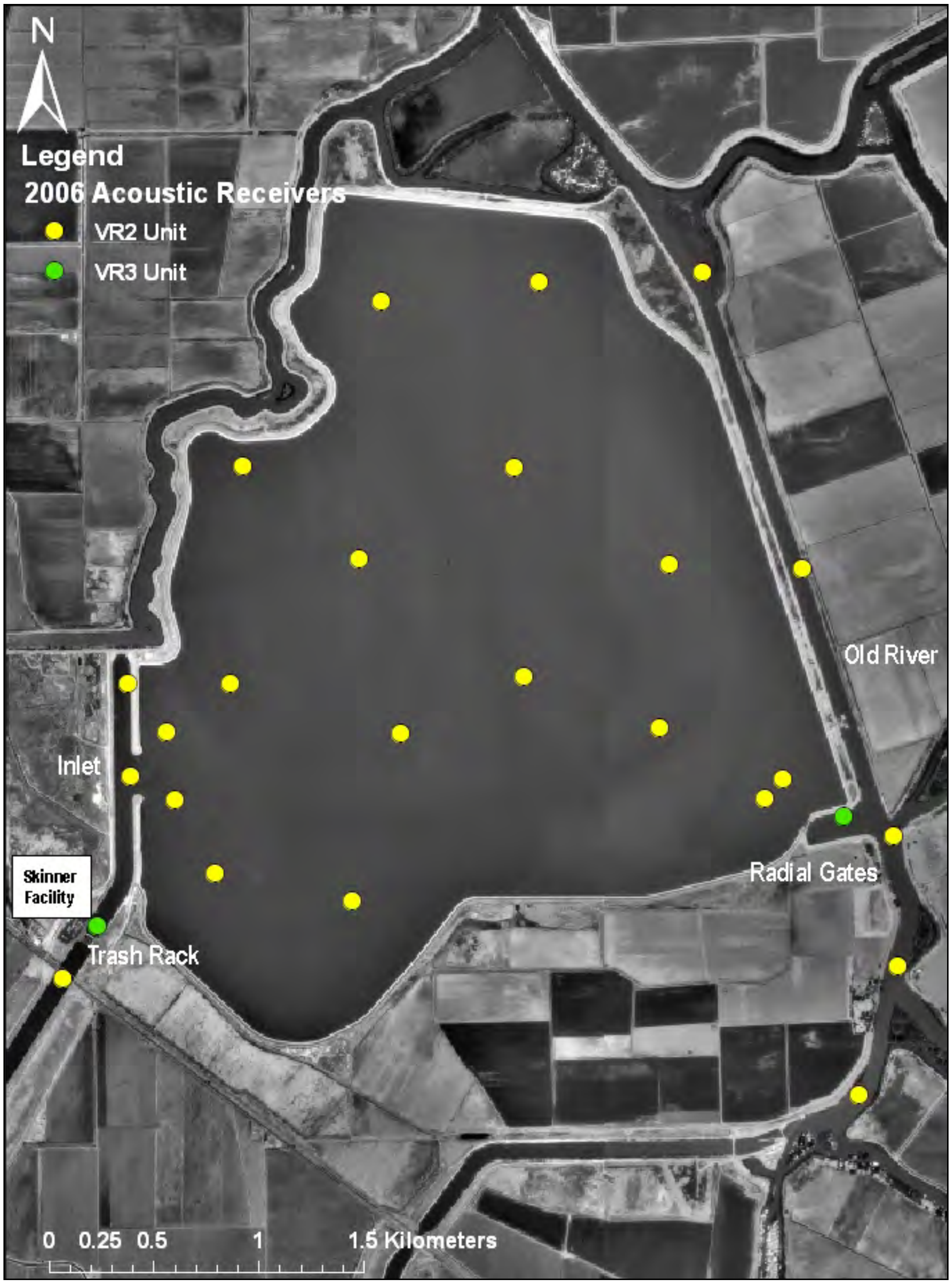

Figure 28. 2006 VR2 and VR3-UM acoustic fixed receiver locations within Clifton Court Forebay, Old River, and the John E. Skinner Delta Fish Protective Facility.

7.2 2006 Results and Discussions

7.2.1 Acoustic Tagged Steelhead

Similarly to the 2005 pilot study, acoustic tagged steelhead detection data was examined using VEMCO VR2 pc software. However, unlike the 2005 pilot study, the 2006 pilot study data was not analyzed using GIS techniques and no GIS graphics were produced. The following is a description of the raw detection data as examined.

All released steelhead were not initially detected as having been entrained. One steelhead, tag ID 1679, jumped out of the live-car prior to acclimation and was detected in Old River for six days with initial movements toward the TFCF. After initially moving towards the TFCF, this steelhead was later detected north of the radial gate intake channel. Ultimately, this steelhead was entrained through the radial gates six days after jumping out of the live-car. Thus, all 29 juvenile steelhead intended for release were entrained.

Entrained steelhead displayed varied movement patterns. Some steelhead were observed to move to the intake canal within hours of entrainment. Other steelhead were observed to remain near the radial gates. Yet, other steelhead dispersed to the extreme northern and southern areas of the Forebay. Of the 29 steelhead entrained into the Forebay, 17 (59%) steelhead were detected in the intake canal (Table 8). Thirteen (76%) of the 17 steelhead detected within the intake canal were also detected at the trashboom. Two (7%) acoustic tagged steelhead were detected as having been successfully salvaged and no steelhead were detected moving through the primary louvers towards Harvey Banks Pumping Plant (Table 9). Six (21%) steelhead tags were detected as having emigrated from the Forebay into Old River (Table 8).

Transit times for steelhead were calculated from the release point at the radial gates to the intake canal, trashboom, SFPF salvage holding tanks, and Old River. For those steelhead detected in the intake canal, the mean transit time was 5 days. However, this mean time is skewed somewhat by three steelhead with transit times of 27, 16, and 12 days. Eleven of the seventeen steelhead detected at the intake canal had transit times of fewer then 3 days. The mean transit time from the release point to the trashboom was 9.5 days. However, six of the thirteen steelhead detected at the trashboom had transit times less than 3 days. Mean transit time to the SFPF salvage holding tank from point of release was 12 days, however, only two of the twenty-nine steelhead tags were detected as having been salvaged with transit times of 4 days and 20 days. Mean transit time for steelhead emigrating out to Old River was 25 days with a wide range from less than 1 day to 57 days. However, the single steelhead detected in Old River immediately after the release time (less than 1 day) was attributed to the steelhead observed jumping out of the live-car prior to release. It is not possible to say with certainty whether any of the calculated transit times were affected by striped bass predation and subsequent striped bass movements.

Steelhead final detection locations were determined using the fixed station receiver data. The fixed station receivers were removed well after the expiration of the battery life of the steelhead tags. Thus, a tagged steelhead's final location was assigned at the location of last tag detection. Of the 29 juvenile steelhead entrained into the Forebay, 22 (76%) remained in the Forebay at the end of the study period (Figure 29). Of the steelhead tags remaining within the Forebay, 13 tags were detected near the radial gates, seven remained in the wider Forebay, and two were located within the intake canal (Table 9).

Several of the steelhead last detected within the Forebay were stationary for a long period of time at a single location. One steelhead was detected at the radial gates for 12 weeks continuously. Similar to the 2005 pilot study, these data demonstrate that either juvenile steelhead may remain resident within the Forebay for extended periods of time before salvage or that the steelhead tags lay on the bottom as a result of predation. A total of two (7%) juvenile steelhead were detected in SFPF salvage holding tanks, and five (17%) were detected in emigrating through the radial gates into Old River (Figure 29). However, these acoustic tagged steelhead seen emigrating from the Forebay may have been preyed upon within the Forebay and their predators moved from the Forebay through the radial gates into Old River. Striped bass were able to emigrate from the Forebay through the radial gates during the 2005 pilot study. However, no striped bass were acoustically tagged in 2006. There was some evidence of possible avian predation, as two steelhead were only detected for a single day with no subsequent detections. It could be possible for an avian predator to consume a steelhead and fly away with the tag in the bird's stomach, thus, accounting for never detecting the tag again. However, the possibility remains that the two tags simply malfunctioned.

Table 8. Fixed station receiver data summary for 19 of 29 steelhead that were detected at either the intake canal, trashboom, salvage holding tank, and/or in Old River. Steelhead not detected at any of these locations were not included in the table. The total number of steelhead released was used to calculate the percentage of fish detected at the four locations.

Tag ID	Release Date	Intake Canal	Trash-boom	Salvage Holding Tank	Old River
1672	3/28	X	-----	-----	X
1673	3/28	X	X	-----	-----
1674	3/22	X	X	-----	X
1675	3/28	X	X	-----	-----
1678	3/22	X	X	-----	-----
1679	3/22	X	X	-----	-----
1680	3/22	X	X	-----	-----
1683	3/28	X	-----	-----	-----
1684	3/22	X	-----	-----	-----
1686	3/22	X	-----	-----	-----
1687	3/22	X	-----	-----	X
1688	3/23	X	X	X	-----
1689	3/23	X	X	-----	-----
1690	3/23	X	X	X	-----
1693	3/23	-----	-----	-----	X
1694	3/28	X	X	-----	-----
1695	3/23	-----	X	-----	-----
1699	3/23	X	X	-----	X
1700	3/28	X	X	-----	X
Fish Detected (% of total released)		17 (59%)	13 (45%)	2 (7%)	6 (21%)

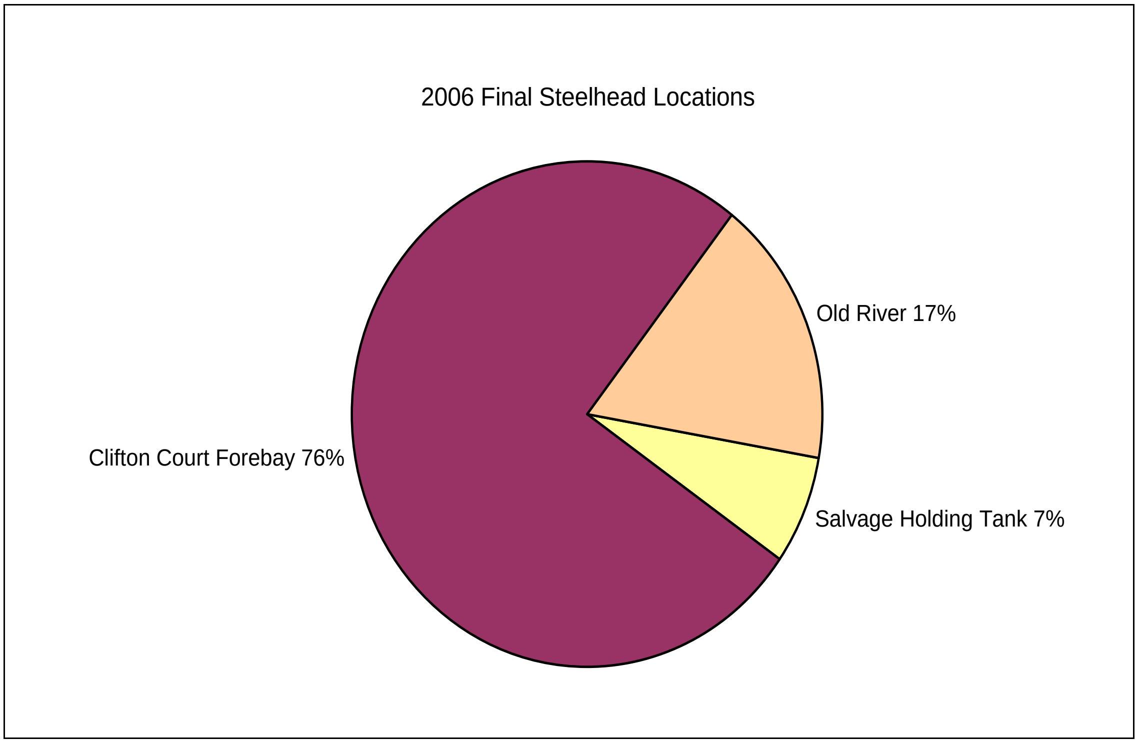

Figure 29. Percentages and locations for final detections of acoustic tagged steelhead released during the 2006 pilot study.

Table 9. Final detection locations for acoustic tagged steelhead in 2006.

Tag ID	Location Description	Date of Last Detection	Days After Release
1671	Radial Gates	6/3	74
1672	Old River	5/23	56
1673	Intake Canal Opening	5/21	54
1674	Old River	5/18	57
1675	Intake Canal Opening	4/3	7
1676	Radial Gates	6/22	86
1677	South Side of Forebay	3/23	1
1678	South Side of Forebay	4/30	39
1679	Radial Gates	5/18	57
1680	East Side of Forebay	4/18	28
1681	Radial Gates	6/3	73
1683	South Side of Forebay	5/5	38
1684	Radial Gates	5/23	63
1685	South Side of Forebay	3/23	1
1686	Radial Gates	6/3	74
1687	Radial Gates	5/3	42
1688	**Salvage Holding Tank**	**3/27**	**4**
1689	Radial Gates	5/30	68
1690	**Salvage Holding Tank**	**4/12**	**20**
1691	Radial Gates	5/24	63
1692	South Side of Forebay	4/12	22
1693	Old River	3/27	4
1694	Radial Gates	6/6	70
1695	South Side of Forebay	4/28	36
1696	Radial Gates	6/7	76
1697	Radial Gates	7/11	105
1698	Radial Gates	4/28	31
1699	Old River	3/27	4
1700	Old River	5/18	51

Note: Bold lines are for steelhead recovered at the SFPF

8.0 2007 Full-scale Study

8.1 Methods

Unlike the 2005 and 2006 pilot studies, the 2007 full-scale study was designed to quantify steelhead pre-screen loss within Clifton Court Forebay. Additionally, the full-scale effort was designed to evaluate the behavior and movement patterns of steelhead and striped bass within the Forebay and identify environmental or operational factors that may contribute to steelhead pre-screen loss. A mark-recapture and telemetry study was conducted December, 2006 – June, 2007 and utilized two tagging technologies, acoustic and Passive Integrated Transponders (PIT) tags. Similarly to the 2005 and 2006 pilot studies, acoustic tags were used to gain information about the movement patterns of steelhead and striped bass within Clifton Court Forebay. In response to the 2005 pilot study recommendations, PIT tags were used to quantify the pre-screen loss rate and the SFPF loss rate. In contrast to acoustic tags, PIT tags do not have a battery and could be detected for the entire duration of the full-scale study. PIT tags are also inexpensive when compared to acoustic tags and allowed for a larger sample size. In addition to the mark-recapture and telemetry study, an avian predation study was conducted to determine the prevalence of avian predation occurring in the Forebay. This study focused on the abundance, distribution, and behavior of birds in the Forebay that were capable of preying on juvenile steelhead.

8.1.1 Water Quality

As changes in water quality conditions may contribute to steelhead pre-screen loss, water quality measurements were recorded hourly for the duration of the 2007 study. Water temperature was monitored using temperature recorders (Onset, model HOBO Water Temp Pro V2) from January to June and by a mulitprobe water quality meter (HACH, model Hydrolab®). The water quality meter was deployed from the SFPF trashboom at mid-depth and the temperature recorders were attached to VR2 units located in the Forebay, Old River, and intake canal. Water temperatures at the trashboom increased from approximately 9 °C (48 °F) in January to approximately 25 °C (77 °F) at the beginning of June (Figure 30). However, in 2007 there was a cold weather event in January with a low water temperature of 5 °C (41 °F). Additionally there was a warm weather event in April with a high water temperature of approximately 20 °C (68 °F).

Additional water quality variables were also measured via the trashboom-installed, multiprobe water quality meter (HACH, model Hydrolab®). These were: electrical conductivity (EC), salinity, turbidity, and dissolved oxygen (DO) concentration. EC decreased from 0.64 mS/cm in December 2006 to 0.27 mS/cm in April 2007 and increased to 0.42 by June 2007. Likewise salinity decreased from 0.33 ppt in December 2006 to 0.13 ppt in April 2007 and increased to 0.22 ppt by June 2007. Turbidity fluctuated greatly, especially in April, May, and June 2007, and was probably dependent on wind patterns (Figure 31). The wind can cause surface currents and waves within the Forebay which can cause the deposited sediment to become suspended. Turbidity values were typically measured between 1 NTU and 200 NTU. DO slowly decreased from 14 mg/L in December 2006 to 5 mg/L in June 2007. This decrease in dissolved oxygen concentration corresponds with the increase in water temperature for the same time period.

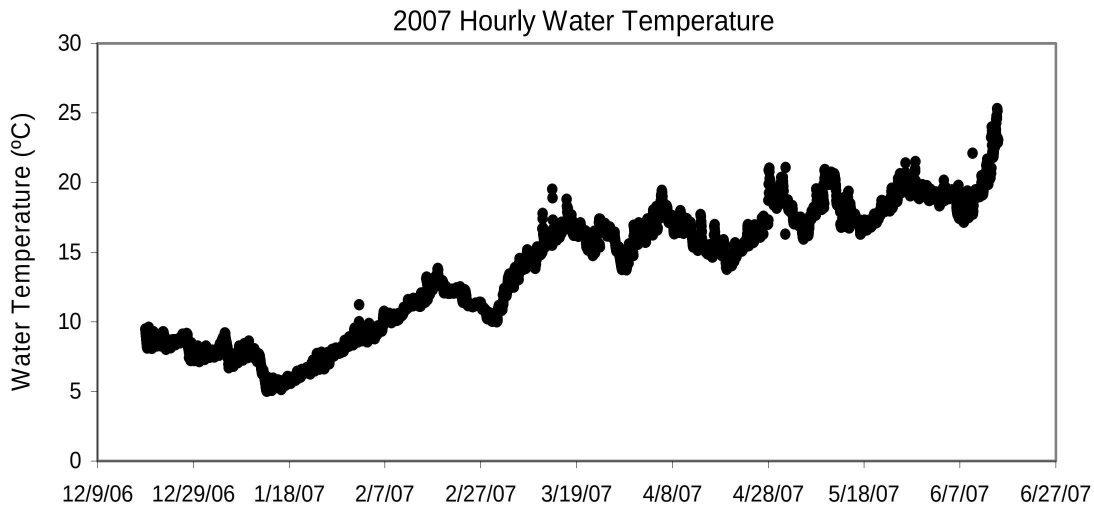

Figure 30. 2007 water temperatures measured hourly via a HACH Hydrolab at the SFPF trashboom and a HOBO temperature logger in the intake canal.

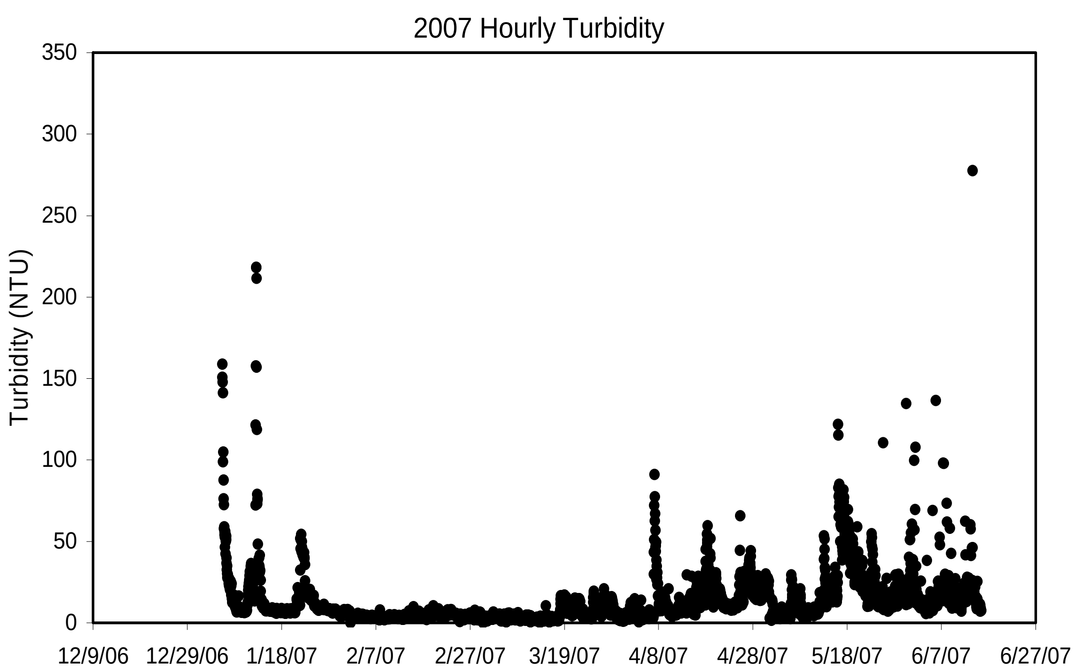

Figure 31. 2007 turbidity measured hourly via a HACH Hydrolab deployed at the SFPF trashboom.

8.1.2 Light Intensity and Day, Night, Crepuscular Classification

Light intensity may also contribute to the pre-screen loss of steelhead within Clifton Court Forebay and was recorded during the study. Light sensors measuring Photosynthetically Available Radiation (PAR) were chosen because striped bass have a peak spectral sensitivity in the 400 to 650 nm range (Horodysky, 2007). Light intensity in the 400 to 700 nm was measured by a light sensor (Onset, model S-LIA-M003) and data logger (HOBO®, model Micro Station) every five minutes starting January 11, 2007 at 11:00. The remote light sensing unit was setup near the CHTR Study Facility building which is adjacent to Clifton Court Forebay. The light sensor was pointed to the sky. Leading averages were calculated for each hour from the five minute light intensity measurements.

Light measurement data prior to January 11, 2007 was taken from the Brentwood #47 weather station (see appendices) in the California Irrigation Management Information System (CIMIS) database (CIMIS, 2007). This data was appended to the hourly light dataset recorded at the CHTR Study Facility. During the study, light intensity ranged from approximately 0 to 2,000 μmol/m^2/s (Figure 32), increasing from February 2007 through June 2007. Daily variation in the remote light sensor readings may be attributed to changes in weather, primarily by cloud cover or changes in density of fog. Weather observations were recorded daily by an observer starting January 10, 2007 and ending June 14, 2007. These observations included estimated percent cloud cover, presence or absence of fog, and light observations. Light intensity was also measured using a handheld light meter (LI-COR, model LI 250 Light Meter) with a PAR light sensor (LI-COR, model LI-190 Quantum Sensor). These additional light intensity measurements were used to verify the light intensity measurements taken by the fixed light station.

Light intensity measurements were used to classify night, crepuscular, and day. On January 5, 2008 an observer using the handheld light meter, measured light intensity every five minutes starting at sunrise and continuing until the observer determined that there was sufficient light to have the classification of day (Figure 33). The observer determined that crepuscular changed to day at 30 minutes post sunrise. Light was measured to be approximately 50 μmol/m^2/s at sunrise + 30 minutes, the observer's designation of day. These measurements were similar to measurements recorded by observers at the CHTR Study Facility while recording weather observations. Thus, categories for night, crepuscular, and day were established at 0-10 μmol/m^2/s, >10-50 μmol/m^2/s, and >50 μmol/m^2/s respectively.

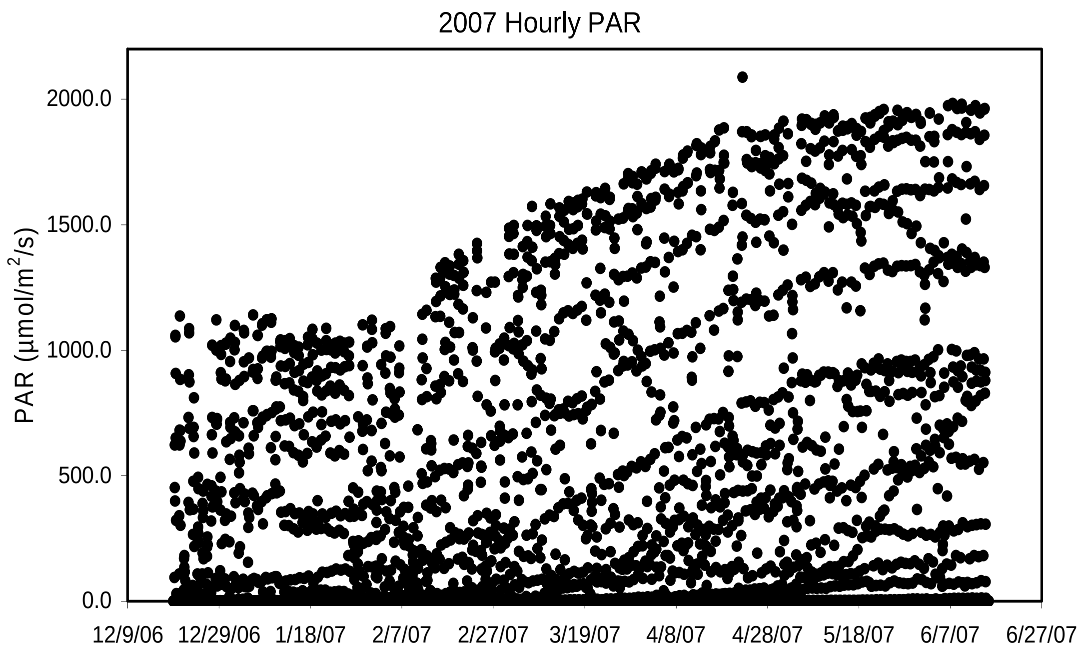

Figure 32. Hourly photosynthetically available radiation (PAR) measured via a remote station near the CHTR Study Facility including estimates from the CIMIS database in December.

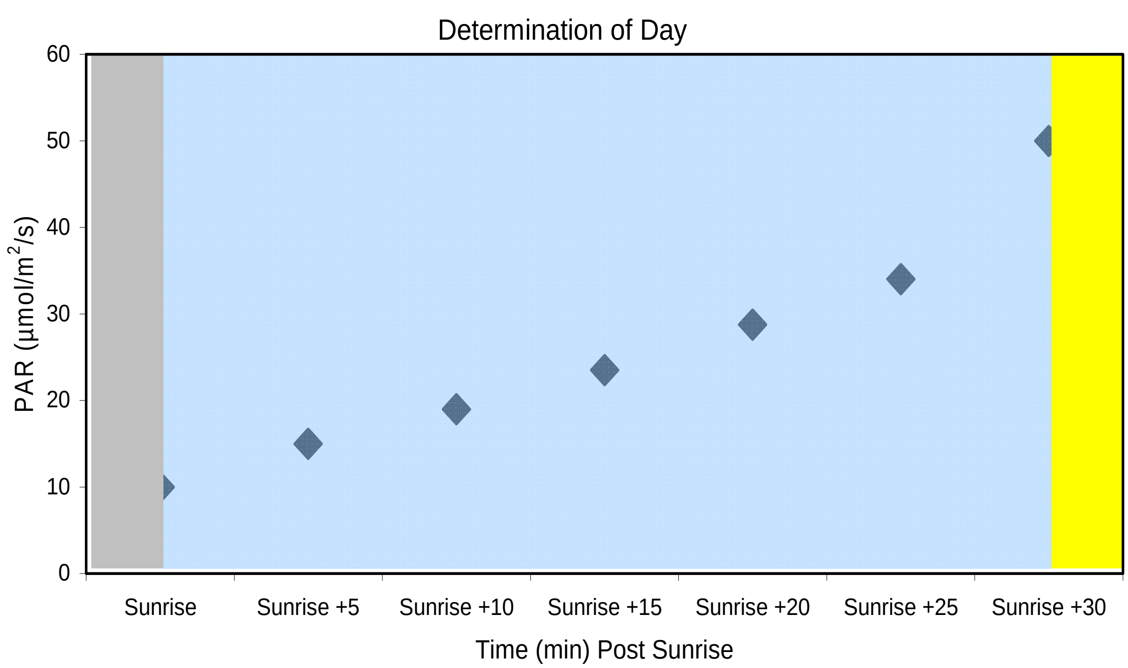

Figure 33. Day determination by an observer on January 5, 2008 during a 30 minute observation period using a handheld light meter. Grey, blue, and yellow represent night, crepuscular, and day, respectively.

8.1.3 Acoustic Tagging of Striped Bass

To gain telemetry information on striped bass, the predatory fish species of particular interest in this study, 29 striped bass were captured, acoustic tagged and released. Striped bass were captured by hook and line sampling and gill netting in close proximity to the radial gates and within the intake canal. Sampling effort at all locations was not equal. The minimum size requirement for tagging was reduced from 650 mm (26 in) (2005 pilot study criteria) to 550 mm (22 in) in order to maximize the number of striped bass tagged. Manooch (1973) and Walter and Austin (2003) found that striped bass commonly consumed prey up to 40% of the striped bass length. Thus, a 550 mm (22 in) striped bass could consume a 220 mm (8.5 in) steelhead. Manooch (1973) also found that some striped bass are capable of consuming fish that are up to 60% of the striped bass length.

Acoustic tagging of striped bass followed a similar procedure to that used in the 2005 pilot study. Each striped bass collected that was greater than 550 mm (22 in) was transferred to an aerated holding tank located onboard the sampling boat using a large rubber dip net. Each striped bass was observed for signs of stress (loss of equilibrium). When the fish was no longer showing signs of stress from capture and handling, the fish was weighed using a Boga-Grip (spring loaded suspension scale with fish lip grip) and transferred to a canvas cradle. The fish was then measured for length and was externally tagged with an acoustic transmitter (VEMCO, model V13) following the same procedure used in 2005 with minor modifications to the way in which the stainless steel wires were attached to the acoustic tag. Prior to tagging, stainless steel wires were attached to each acoustic tag by surrounding the wire and tag with heat shrink rubber tubing. The heat shrink tubing was used to replace the soft rubber backing plate used in the 2005 pilot study. The tagged striped bass was released into the Forebay at approximately the same location as capture. The external tagging operation lasted approximately four minutes per fish. The date, total length, weight, and collection location were recorded for most striped bass captured, tagged, and released. The tagged striped bass ranged in length from 550 mm (22 in) to 810 mm (32 in) with a mean of 653 ±32 mm (26 ±1.26 in) and ranged in weight from 1,360 to 6,349 g (3 to 14 lb) with a mean of 3,038 ±546 g (6.7 ±1.2 lb). The tag to body weight ratio was below 0.8% for all tagged striped bass.

8.1.4 Steelhead Fish Husbandry

Juvenile steelhead used in the 2007 full-scale study were obtained from the DFG Mokelumne River Fish Hatchery. The steelhead provided by the hatchery were selected to be representative of the general size distribution of juvenile steelhead entrained into the Forebay. These juvenile steelhead were transported in three separate events using a 1,700 L (449 gal) hauling tank and held at the CHTR Study Facility to recover from transportation and handling stress and to acclimate to water quality conditions at the site. Upon arrival at the CHTR Study Facility, fish were transferred to a 4,500 L (1189 gal) D-shaped, indoor tank with a center wall. The D-shaped tank with center wall simulated water flow in a hatchery raceway. This tank was part of a flow through system with water supplied from the intake canal. Water supplied from the intake canal was mechanically filtered via a sand filtration system and sterilized via ultraviolet (uv) sterilizers. The steelhead were held in this tank until they were tagged and moved to one of three tanks. The tagged steelhead were held in the CHTR Study Facility in two 1,500 L (396 gal) white fiberglass tanks and one 1,500 L (396 gal) black fiberglass tank. These three tanks were also part of the flow through system with water supplied from the intake canal. Air pumps delivered air to the fish tanks. The steelhead were fed a floating pellet via belt feeders daily, except when fasted for 24 hr before and after tagging. The fish tanks were cleaned and checked for mortalities daily. Water temperature was generally kept at ambient, however, a chiller was used to buffer water temperatures and keep tagged fish from experiencing stress due to elevated water temperatures. The chiller was used when water temperatures were approaching 18ºC (64.4 ºF). Even with a chiller buffering the water system, the water temperatures within the fish tanks reached 18.5 ºC (65.3 ºF) for a duration of 2 days in April.

Midway through the 2007 study (March 14th), a low DO event in the D-shaped tank was observed and a large die-off of untagged steelhead occurred over several weeks. During this die-off, several internal parasites were observed floating in the water column of the D-shaped tank. The internal parasites appeared to be an intestinal tapeworm (*Eubothrium salvelini*), but a positive identification was not obtained. Generally, tapeworms do not cause mortalities in their host, but can reduce growth and reduce condition factor. All mortalities observed were dissected and approximately 20% were infested with the internal parasites. Internal parasites were not limited to untagged steelhead. A small number of PIT tagged steelhead were found dead in the CHTR Study Facility fish tanks and upon dissection only a small percentage of those contained internal parasites.

Due to the high number of mortalities of untagged steelhead in the D-shaped tank, a new group of steelhead was procured from the Mokelumne River Hatchery. The replacement fish were held at the UC Davis Fish Conservation and Culture Laboratory (FCCL) in an outdoor rectangular tank. The tank was part of a flow through system with water supplied from the intake canal. The water was mechanically filtered via a sand filtration system and sterilized via ozonation. A chiller was used to keep water temperatures below ambient and was successful at preventing stress and mortalities due to increasing water temperatures in April 2007.

8.1.5 Acoustic Tagging of Steelhead

As part of the telemetry component of the full-scale study, juvenile steelhead were tagged with acoustic coded transmitters (VEMCO, modelV9). These transmitters were identical to the VEMCO, model V8SC used in 2005 and 2006 pilot studies, but renamed by the manufacturer. The juvenile steelhead selected for surgical implantation of acoustic tags ranged in fork length from 195 to 363 mm (7.6 to 14.3 in) with a mean of 237 ±4.81 mm (9.3 ±0.19 in). These juvenile steelhead were tagged following a similar surgical procedure to that used in the 2005 and 2006 pilot studies. Three to five surgical skin staples (3M Precise™, model Vista 35W) were used to close the incision rather than the sutures used in the 2005 and 2006 pilot studies. This change in the surgical procedure was made to reduce the time the steelhead were kept in anesthesia. The surgical procedure typically took less than two minutes from initial incision through recovery.

The use of skin staples to close the incision effectively reduced the surgical procedure by two to three minutes per fish. The acoustic tagged steelhead ranged in weight from 75.3 to 310.8 g (0.17 to 0.68 lb) with a mean of 146.0 ±8.1 g (0.32 ±0.02 lb). Tag percentage of body weight ranged from 0.93% to 3.85% with a mean of 2.16 ± 0.10%. The acoustic tagged steelhead were kept for observation in a holding tank for a minimum of 25 days to ensure recovery prior to experimental release. A few mortalities occurred and the tags were taken from those mortalities and reused. Including those reused tags, a total of 130 juvenile steelhead were acoustically tagged.

8.1.6 PIT Tagging of Steelhead

In response to the recommendations developed in the 2005 pilot study, PIT tags (Destron, model TX1411ST) were utilized as the major marking method in 2007. The juvenile steelhead selected for PIT tag implantation ranged in fork length from 111 to 310 mm (4.4 to 12.2 in) with a mean of 216.9 ±1.4 mm (8.5 ±0.05 in). These juvenile steelhead were tagged following a PIT tagging procedure manual prepared by the Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee (1999). Each juvenile steelhead was netted from the holding tank and placed into a 18.9 L (5 gal), rectangular tub that contained 106 mg/L (0.014 oz/gal) of MS-222. The juvenile steelhead was left in the tub for approximately one minute until anesthetized. The juvenile steelhead was measured for length and weight. A PIT tag implanter (Biomark, model MK7) was used to inject the PIT tag into the abdominal cavity and New-Skin liquid bandage was applied to the puncture wound to aid the healing process (Figure 34). The time to PIT tag each steelhead was less than one minute. To ensure proper disinfection the implanters were held in a 91% isopropyl alcohol for a minimum of 10 minutes before use. The PIT tagged juvenile steelhead were kept for observation in a holding tank to ensure recovery prior to release.

Figure 34. A MK7 implanter was used to insert PIT tags into steelhead in 2007.

8.1.7 Tagged Steelhead Releases

8.1.7.1 Radial Gate Releases

To simulate the exposure to the high water velocity and turbulence experienced by wild fish entrained into the Forebay, small groups of tagged steelhead were released immediately upstream of the radial gates using a specially constructed live-car. Prior to transportation of the tagged steelhead to the radial gates release site, all PIT and acoustic tags were checked for proper operation and the tag identification recorded. Each group of tagged steelhead was transported in aerated 18.9 L (5 gal) buckets to the release site. Releases were scheduled to target the time when the radial gates were initially opened. The timing of the releases varied with the daily changes in routine radial gate operations. Each release group of tagged steelhead was loaded into the live-car in Old River immediately outside of the Forebay. The live-car was positioned against the wing wall leading to radial gate number one. The tagged steelhead were acclimated for 2 hours to recover from transportation and handling stress prior to release. The radial gates were closed during the acclimation period. Once the acclimation period was complete and after the radial gates were opened, the live-car was moved into position immediately upstream of the radial gates by manually pulling the floating live-car along the wing wall. Once in position, the front door of the live-car was released via remote ropes (Figure 17). This allowed the tagged steelhead to exit the velocity refuge of the live-car, into the flow passing through the radial gates, and become entrained into the Forebay. After a few minutes, the back door of the live-car was triggered to open and flush any remaining steelhead from the live-car. Figure 8 shows an example of the typical calculated flow rates passing through the radial gates at the time of steelhead release. However, there was one extremely high flow event on April 16, 2007 (Figure 9).

PIT tagged steelhead were released using the live-car as part of the mark-recapture experiment. PIT tagged steelhead releases began on January 8, 2007 and were generally conducted 5 days or nights per week through April 16, 2007 with alternating release group sizes of 10 or 20 fish. However, there were two weeks in which releases were not conducted due to equipment failure and safety concerns. In total, 922 PIT tagged steelhead were released upstream of the radial gates, with 220, 260, 260, 182 PIT tagged steelhead released in January, February, March, and April, respectively.

Acoustic tagged steelhead were released as part of the telemetry component of the experiment. The acoustic tagged steelhead were released into the Forebay during February – April, 2007 to coincide with the seasonal period that steelhead have been observed in SFPF salvage data. January releases were precluded by the steelhead received from the hatchery not yet being of taggable size. Releases of acoustic tagged steelhead began on February 7, 2007 using the live-car method described above. However, the last radial gate release of acoustic tagged steelhead was conducted using 18.9 L (5 gal) buckets rather than the live-car due to safety concerns with the high flow event observed on April 16, 2007 (Figure 9). During the last radial gate release the acoustic tagged steelhead were lowered to the water surface utilizing a bucket with a rope attached to the handle. A second rope was attached to the bottom of the bucket and was used to subsequently tip the bucket into the flow and release the fish. Therefore, there was no acclimation period. Acoustic tagged steelhead were generally released in groups of 10 or 20 fish. Not all acoustic tagged steelhead were released. In comparison to the 2005 and 2006 pilot studies, the standard for the quality of acoustic tagged steelhead was raised in 2007. Those acoustic tagged steelhead showing abnormal swimming behavior or appearing stressed were not released. In total, 64 acoustic tagged steelhead were released upstream of the radial gates, with releases of 30, 30, and 4 acoustic tagged steelhead in February, March, and April, respectively.

8.1.7.2 Tagged Steelhead Releases Within the SFPF

To estimate the salvage efficiency of the SFPF tagged steelhead were released within the SFPF immediately downstream of the trash rack which is immediately upstream of the primary louvers in the primary louver bays. Beginning January and February 2007, PIT and acoustic tagged fish, respectively, were released using a bucket release technique. These releases were generally conducted 5 days or nights per week and were scheduled to coincide with the releases conducted at the radial gates. Generally, 25 PIT tagged steelhead per week or 10 acoustic tagged steelhead per week were released within the SFPF coinciding with the type of tagged steelhead being released upstream of the radial gates. Tagged steelhead were released at the SFPF in smaller groups than at the radial gates, but consisted of a daily ratio consistent with the daily ratio at the radial gates. For example, if on Monday 20 PIT Tagged fish were released upstream of the radial gates (25% of the week's scheduled radial gate released fish) then 6 PIT tagged fish were released inside the SFPF (~25% of the week's scheduled fish releases within the SFPF). Similarly, acoustic tagged steelhead were released according to a daily ratio. Tagged steelhead were lowered to the water surface utilizing a bucket with a rope attached to the handle. A second rope was attached to the bottom of the bucket and was used to tip the bucket into the water and release the fish. Again, not all tagged steelhead were released. Those showing abnormal swimming behavior or appearing stressed were not released. During the 2007 study, 239 PIT tagged steelhead were released within the primary louver bays, with releases of 12, 86, 81, 60 PIT tagged steelhead in January, February, March, and April, respectively. During the 2007 study, 15 acoustic tagged steelhead were released within the primary louver bays, with releases of 9 and 6 acoustic tagged steelhead in February and March, respectively.

8.1.8 Acoustic Fixed Station Receiver Grid

To track acoustic tagged striped bass and steelhead throughout the Forebay, a similar receiver network to that used in the 2006 pilot study was employed in 2007. The network of fixed station receivers (VEMCO, VR2) was designed to cover the entire Forebay, SFPF, Old River, and the intake canal leading to the Harvey Banks Pumping Plant (Figure 35). The receiver array was installed November - December 2006 before acoustic tagged steelhead were released and remained in the Forebay through the entire 2007 study period. The VR3-UM receivers used in the 2006 pilot study were not used in the 2007 full-scale study. The fixed station receivers were attached to a mooring line with the use of cable ties and kept in an upright position while submerged completely underwater between a mooring anchor and a float. Downloads of the receivers' internal memory were conducted monthly to ensure that the units were working properly. The monthly receiver interrogation also prevented the receiver's internal memory from becoming full and thus prevented the loss of tag detection data. During the study, two fixed station receivers were found to be malfunctioning and were replaced. All receivers were removed from the study area June 15, 2007.

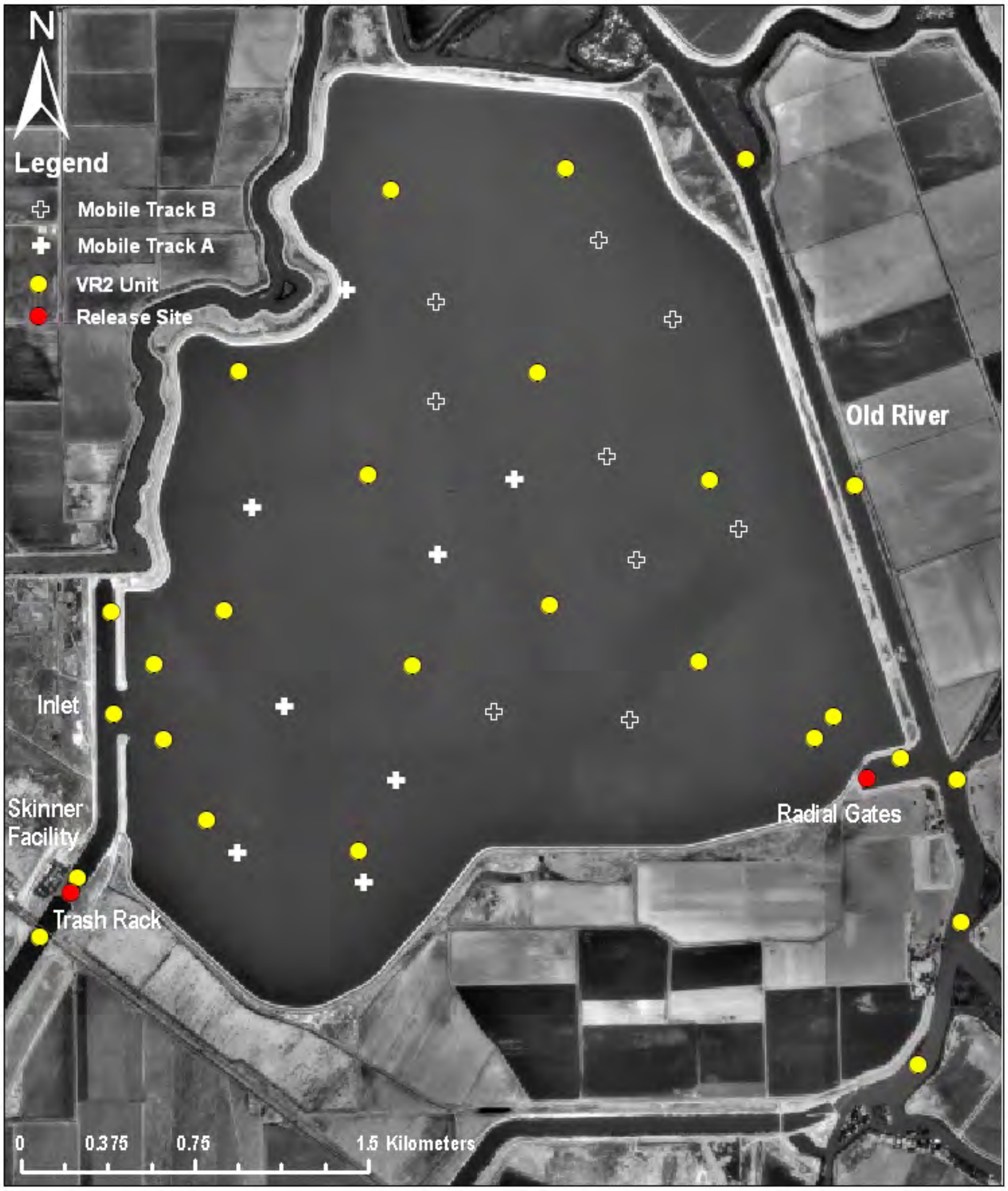

Figure 35. 2007 fixed station receiver array and mobile monitoring locations. Yellow circles indicate the VR2 locations. The plus symbols indicate the mobile monitor locations. The red circles indicate the steelhead release locations.

8.1.9 Mobile Monitoring

Mobile monitoring of acoustic tagged steelhead and acoustic tagged striped bass was conducted within the Forebay to track fish movement patterns throughout the Forebay and to validate the fixed receiver data. Mobile monitoring began in February and continued through early June 2007. Mobile monitoring was conducted from two boats using handheld GPS units and two mobile monitoring units (VEMCO, model VR100) equipped with omni-directional and/or directional hydrophones. In 2007, mobile monitoring stations were established creating two mobile monitoring transects, transects A and B. The mobile monitoring stations were setup to fill in the areas between fixed station receivers and were no closer than 530 m (0.33 mile) to the closest VR2 unit (Figure 35). Numbered buoys were deployed at each mobile monitoring station and GPS positions for these stations were recorded for easy identification by mobile monitoring crews. Using GPS reference points and the numbered buoys, a transect pattern was traveled using the research boats covering the entire Forebay in a single day. When using a mobile monitoring unit, the boat was fully stopped and the engine was switched off to avoid signal contamination from noise and cavitations. The omni-directional hydrophone was submerged to a depth of approximately ½ the distance to bottom or a maximum of 1.5 m (5 ft). Any coded tag detections received on the mobile monitoring unit were recorded onto data sheets identifying time, date, tag ID number, GPS coordinates and the approximate position within the Forebay was marked on a field map. Also noted were the positions of the radial gates (open or closed) and weather conditions when possible.

8.1.10 Central Valley Fish Tacking Consortium Database

The Central Valley Fish Tracking Consortium (CVFTC) database was used to track acoustic tagged juvenile steelhead and adult striped bass that emigrated from Clifton Court Forebay either via the radial gates or through the salvage process in 2007. The CVFTC is a collaboration between several academic, government, and private organizations working together to answer questions regarding anadromous fish life histories. The CVFTC fixed station receivers (VEMCO, VR2) cover the Sacramento River directly below Lake Shasta to the Golden Gate Bridge. VR2 receivers are also located within the Sacramento-San Joaquin Delta and Carquinez Straits. The CVFTC receiver grid is primarily used to track the movement of acoustic tagged anadromous fish and to estimate mortality of those fish in the Sacramento River watershed. UC Davis and NMFS researchers maintain the database of acoustic tag detections and receiver deployment locations for those receivers that are maintained by CVFTC scientists. The database is available to all members of the CVFTC.

8.1.11 Acoustic Tag Detection Analysis

VEMCO VR2pc software and Microsoft Excel were used to analyze the downloaded fixed station receiver detections. Using the VEMCO VR2pc software, all receiver detections were “searched” for each steelhead’s and striped bass’ tag ID and a “search” file was created containing the receiver serial IDs and the dates and times of detection for each acoustic tagged fish. Once "searched", the detection locations and times were examined to determine the movement of each acoustic tagged steelhead and striped bass.

8.1.12 Steelhead Acoustic Data Consolidation

To further analyze the steelhead acoustic data, Microsoft Excel was used to consolidate and summarize the telemetry data. The fixed station receivers were capable of detecting a fish approximately every 10 to 20 seconds, therefore there could be as many as 180 detections per hour per fish at each location. Within a one minute period, several juxtapositioned receivers could simultaneously detect an individual fish, resulting in significant tag signal overlap and hence difficulty in determining fish position among receivers. In addition, because the environmental, physical, and operational conditions were sampled or recorded hourly, a consolidated hourly fish position for each fish was needed for comparison to those recorded conditions.

To determine a consolidated hourly position for each fish, each acoustic tagged steelhead's detection history was first tabulated, with the number of detections at each receiver for each one hour study period summed. Next, these hourly sums for each receiver were totaled across the hour period to yield the Total Number of Detections across receivers per hour (TD). Then a maximum hourly sum of detections (MD) was determined across the receivers for each hour, yielding the receiver location with the most detections for that hour. Finally, a ratio was calculated between the MD and the TD for each hour. If the MD/TD ratio was greater than 50%, and the TD was greater than 2 detections, then the MD receiver location was selected as the fish position for that hour. Hence the spatial location of that fish for that hour was assigned to the location of the MD receiver. If the MD receiver consisted of less than 50% of the total number of detections (MD/TD<0.50), then no fish position was recorded for that hour. It was assumed that the fish stayed at the previous hour's location for that hour. False detections were low and were usually indicated by a receiver with less than two detections per hour, thus the need for the requirement of more than two detections for positive location identification. For an example of the consolidation process, if one steelhead was detected twice in hour number one at VR2 #11 and was not detected at any other receiver within that hour, then no location was assigned for that hour. However, if that same steelhead was detected ten times at VR2 #6, and five times at VR2 #2 in hour number two, then that steelhead was assigned a position at VR2 #6. If that same steelhead was detected five times at VR2 #6, seven times at VR2 #2, and three times at VR2 #11 in hour number three, then the steelhead was not assigned a location for hour number three, because less than 50% of the total detections were at VR2 #2, the receiver with the maximum summed detections (MD).

A limitation of the employed telemetry equipment included tag signal collisions between acoustic tags (Pincock, 2008). As more and more steelhead tags were located for long durations of time at the radial gates (VR2 #27 and VR2 #28), tag signal collisions and tag detections became an issue. Signals being detected from one tag could prevent the detection of signals from other tags in the same location. VEMCO has a tag collision calculator for their tags located at http://www.vemco.com/education/collision.php. Using this calculator one could see that if ten tags were in close proximity to each other, then it could take 60 minutes for all of the tags to be detected. Thus, in our data consolidation process, when summing detections over an hourly period and comparing those sums across receivers, VR2 #27 and VR2 #28 could have been underrepresented as those receivers were the two closest receivers to the radial gates within the Forebay. To address this issue, VR2 #27 and VR2 #28 detection files were merged into one file and treated as having been recorded on a single fixed station receiver. By merging these two files, the radial gate location was weighted to alleviate the tag signal collision limitation. At no other location was signal collision deemed an issue.

8.1.13 Steelhead Acoustic Trimming

Another limitation of telemetry equipment is that the behavior of a predator cannot be distinguished from that of the prey, if a tagged prey fish is consumed (Beland and others, 2001). In other words, if an acoustic tagged steelhead was consumed by a striped bass the steelhead's tag would still be received by the fixed station receivers. Thus, there was the potential to have "steelhead" detections that really belonged to a striped bass. To account for these possible striped bass movements as a result of predation on the acoustic tagged steelhead, the steelhead acoustic tag detection data were "trimmed". Evacuation rates for predated steelhead tags in striped bass were considered a function of water temperature (Johnson and others, 1992). The temperature at the last received detection was therefore inputted to an evacuation rate regression equation derived from estimated striped bass stomach evacuation rates (Johnson and others, 1992) (Figure 36). The result of which predicted time between predation and evacuation. For the purpose of this analysis, it was assumed that unless the tag was stationary for a long period of time (several days), the last received detection of each steelhead was that of an evacuated tag. In the case where a steelhead tag was stationary for several days, the date and time of the first stationary detection was recorded as the last received detection. Therefore, the outputted number of hours after predation until evacuation for each steelhead was used as the number of records (hours) to trim off the end of each acoustic tagged steelhead's detection data. For purposes of this analysis, the remaining data (unpredated steelhead records) were called "Remain", and the records that were trimmed off (predated steelhead records) were called "Trim". Thus, "trim" records correspond to the records when the steelhead acoustic tags could have been in a striped bass intestinal tract.

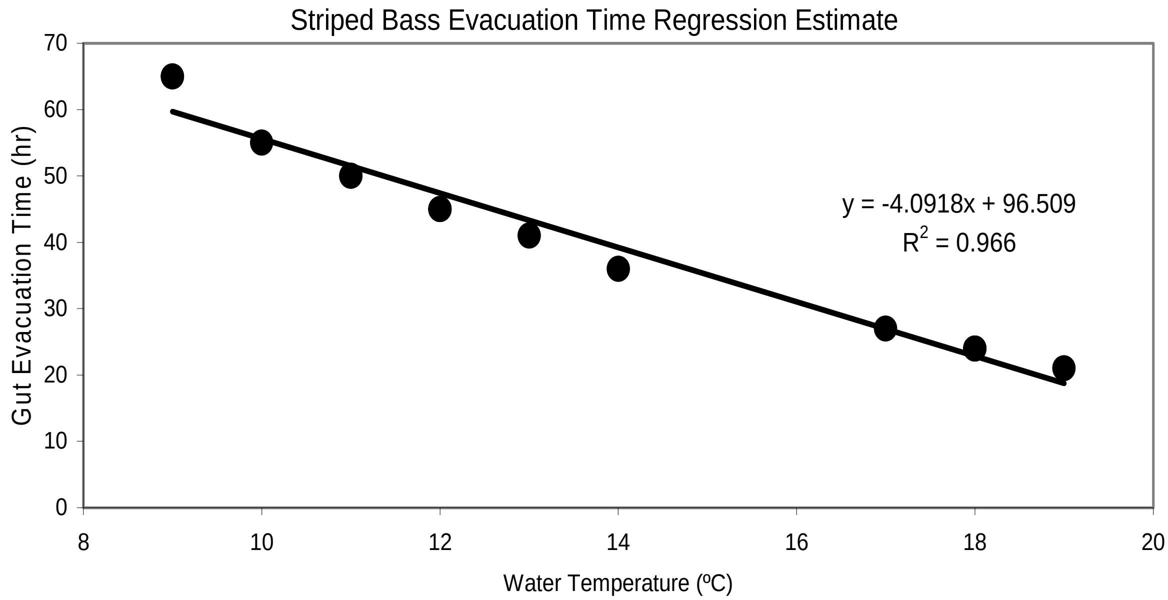

Figure 36. Linear regression of striped bass gut evacuation rates from data derived from Johnson and others 1992.

8.1.14 Striped Bass Acoustic Data Consolidation

The hourly position for each striped bass was determined in the same manner as was used for the acoustic tagged steelhead. Striped bass acoustic tag detections were recorded via the fixed station receiver network deployed in Clifton Court Forebay, Old River, SFPF salvage holding tanks, and the intake canal. Several juxtapositioned receivers could simultaneously detect an individual fish, resulting in significant tag signal overlap that made it difficult to determine fish position among receivers. In addition, because the environmental, physical, and operational conditions were sampled or recorded hourly, a consolidated hourly fish position was needed for comparison to those recorded conditions.

8.1.15 PIT Tag Detection System

To detect salvaged, PIT tagged steelhead released as part of the mark-recapture experiment, a PIT tag detection system was installed at the two SFPF salvage release sites. The detection system consisted of three custom made, circular antennae at the Horseshoe Bend release site (Figure 37) and two custom made, circular antennae at the Curtis Landing release site. Fish salvaged were trucked to the release sites and released through these pipes outfitted with PIT antennae according to the SFPF standard operating procedures. Thus, all detections of PIT tagged steelhead were made post salvage. All PIT tagged steelhead detected during the salvage release process were considered successfully salvaged and alive. Striped bass of the size required to consume the PIT tagged steelhead are rarely seen within the SFPF fish hauling truck. Attached to each antenna was a tuning box and a reader (Destron, model FS2001F-ISO), capable of storing 4400 tag detections each with a time and date stamp. Once the equipment was installed, the antennae were tuned according to manufacturer specifications. Multiple antennae and readers were used at a single site to create redundancy lest one antenna reader combination missed a tagged steelhead moving through the pipe. As a precautionary measure, the PIT tag detection system data was uploaded frequently to prevent loss of data due to possible equipment failure.

Eight tag detection efficiency tests were conducted throughout the 2007 study with four at each of the two SFPF salvage release sites. The efficiency tests utilized groups of 10 PIT tagged steelhead which were placed directly into the SWP fish hauling truck tank or the SFPF salvage holding tank. These fish were subsequently taken to the release site during a routine fish haul and were released through the release pipe outfitted with the PIT tag detection system antennae. Results of the tag detection efficiency test indicated that the efficiency of the two systems was a combined 98.75%.

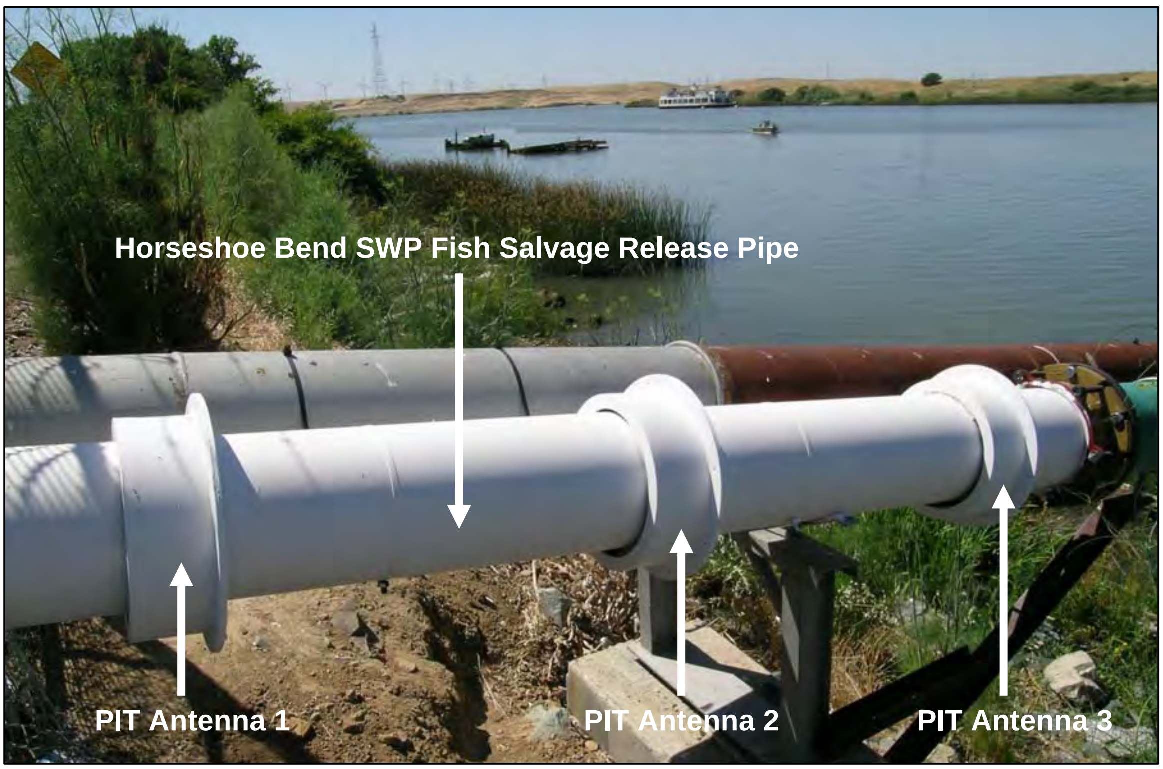

Figure 37. PIT antennae installed around the release pipe at the Horseshoe Bend, SFPF salvage release site.

8.1.16 Avian Predation Monitoring

A predatory bird point-count survey was completed to discover if avian predation on juvenile steelhead in Clifton Court Forebay was occurring. This survey focused on the abundance, distribution, and behavior of birds in the Forebay. Specific focus was given to birds that were capable of preying on juvenile steelhead 200 to 300 mm FL (7.9 to 11.8

in) during the period when steelhead emigrate through the Delta. The Forebay was divided into 3 zones (Figure 38), each with a corresponding vantage point. Vantage points were located on a road that surrounds the Forebay and collectively provided visual coverage of the entire reservoir surface area. A survey consisted of one observation at each of the vantage points. Bird observations were aided with a 20 X 60-power spotting scope and 8 X 42-power binoculars. Birds were identified to species with the aid of a field guide (Peterson, 1998). Each observation was 5 to 15 minutes per zone depending on bird densities present. Surveys were completed 2 to 3 times per week with a total of 87 surveys for the entire sampling season. Typically, one survey was performed per sampling day, although two surveys were conducted on a small number of sampling days. Timing of these surveys was fairly random and predominantly during daylight hours, with occasional attempts to target crepuscular periods.

During each observation the following data were recorded: zone number, bird location within a particular zone, time of observation, abundance/species or taxa, and general behavior. Behavior fell into 4 categories: roosting, flying, floating, and foraging. Foraging strategies varied among species and ranged from diving below the water’s surface (Double Crested Cormorant and grebe) to slowly walking along the shoreline (Great Blue Heron). Foraging data were expressed as the percentage of a species foraging in a particular zone during a single observation.

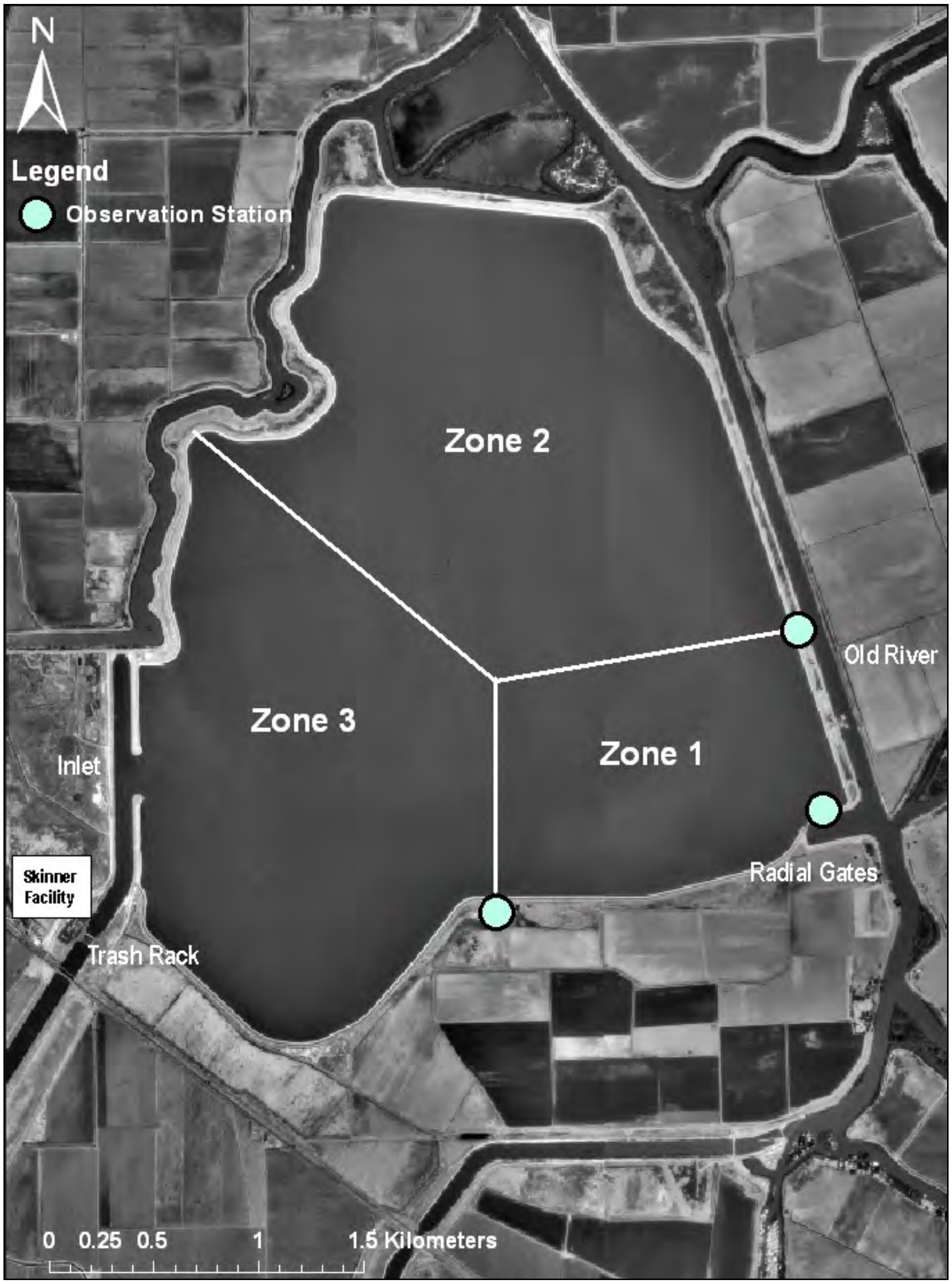

Figure 38. Avian point count zones within Clifton Court Forebay. The circles denote the three observation stations.

8.1.17 Statistical Methods

Microsoft Excel®, SigmaStat® 3.5, SigmaPlot® 10.0.1, and Systat® 11 software were used to perform statistical analyses. Descriptive statistics were used to characterize samples. For all hypothesis tests, the following procedure was followed: determine if the data met the assumptions of parametric statistical testing procedures (independence of observations, normality, and homogeneity of variance). If the data met these assumptions a parametric hypothesis test was used. If the data did not meet these assumptions the appropriate non-parametric equivalent was used.

8.2 Results

8.2.1 Acoustic Tagged Steelhead Movements

Once entrained into the Forebay, the 64 acoustic tagged steelhead displayed varied movement patterns. A few steelhead were observed to move to the intake canal within hours of entrainment (Figure 39). Many steelhead were observed to remain near the radial gates for the duration of the tags' battery life (Figure 40). Yet, other steelhead dispersed to the extreme northern and southern areas of the Forebay (Figures 41 and 42). Of the 64 steelhead entrained into the Forebay, 12 (19%) steelhead were detected in the intake canal (Table 10). Ten of the 12 steelhead detected in the intake canal were also detected at the trashboom (Table 10). However, six of the steelhead detected at the trashboom were subsequently detected in Old River indicating that they had emigrated through the radial gates (e.g. Figure 42) (Table 10). Only two (3%) acoustic tagged steelhead were detected as having been successfully salvaged (Figures 39 and 41) (Table 10). Of the 64 entrained steelhead, none were detected moving through the primary louvers towards Harvey Banks Pumping Plant. Twenty (31%) of the acoustic tagged steelhead entrained were detected in Old River with two of those steelhead being entrained a second time.

Salvage of the 15 acoustic tagged steelhead released directly into the primary louver bay was high. Twelve (80%) of the steelhead released directly into the SFPF primary louver bays were detected within the SFPF holding tanks. However, one (7%) steelhead released within the primary louver bays was detected moving through the louvers and downstream of the SFPF. Two (13%) of the steelhead released within the primary louver bays were detected moving upstream through the trash rack and past the trashboom. Neither of these two steelhead was subsequently salvaged and one (tag ID # 1351) of the two was detected directly under the trashboom without movement for nearly two months.

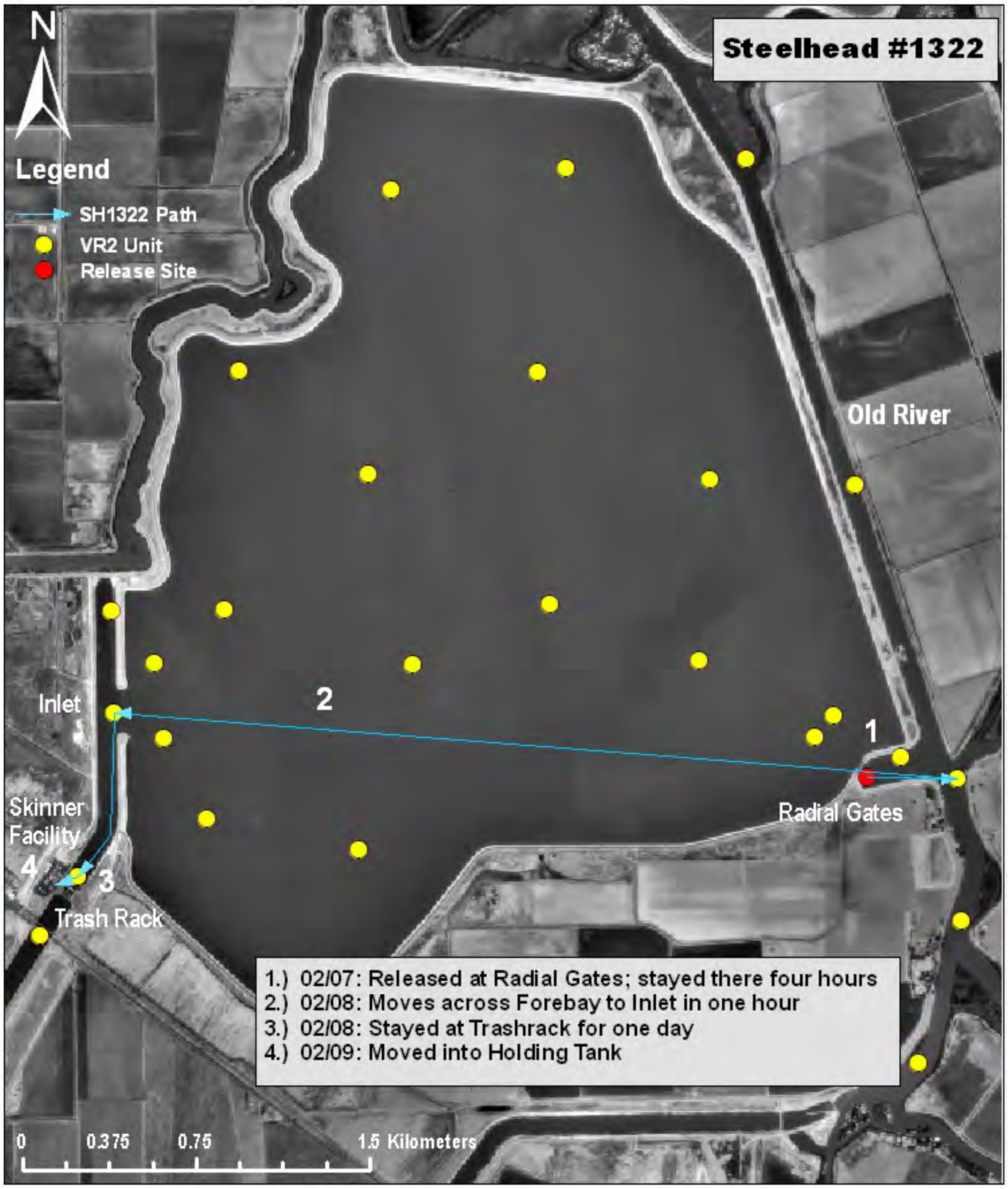

Figure 39. Steelhead tag ID 1322 path to the SFPF holding tank.

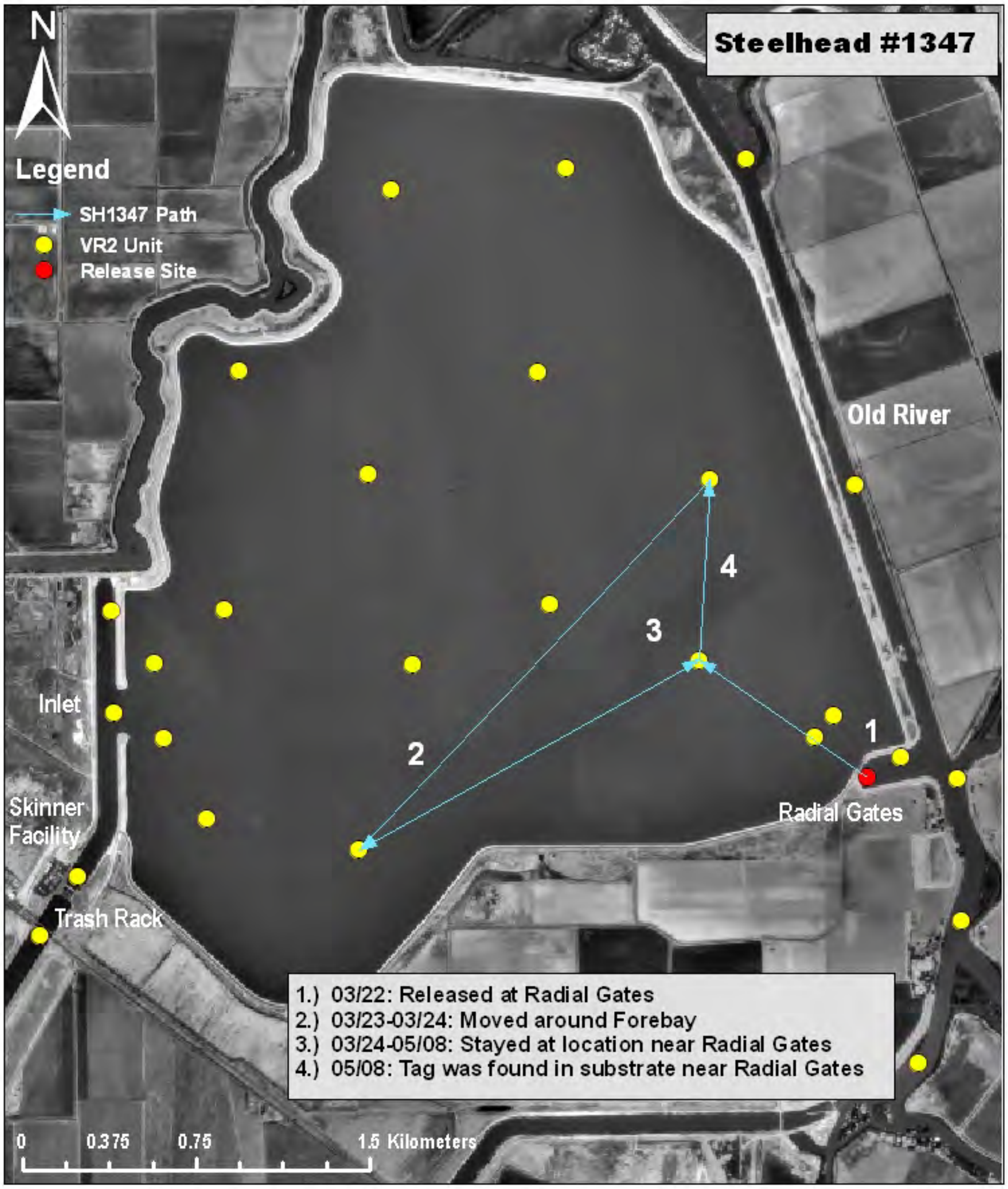

Figure 40. Steelhead tag ID 1347 was detected near the radial gates for 45 days. The acoustic tag was recovered from the bottom of the Forebay while conducting mobile monitoring.

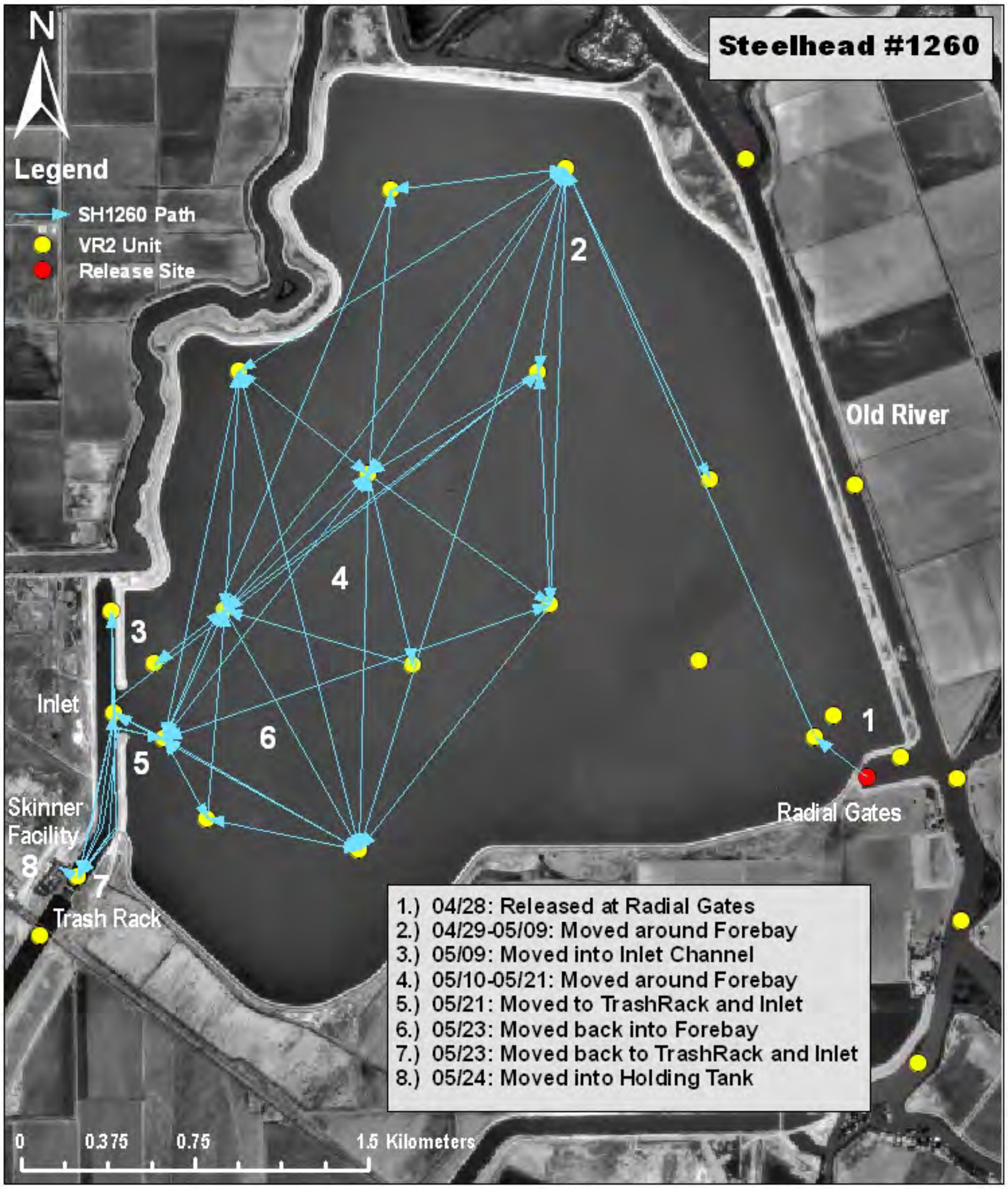

Figure 41. Steelhead tag ID 1260 path to the SFPF salvage holding tank.

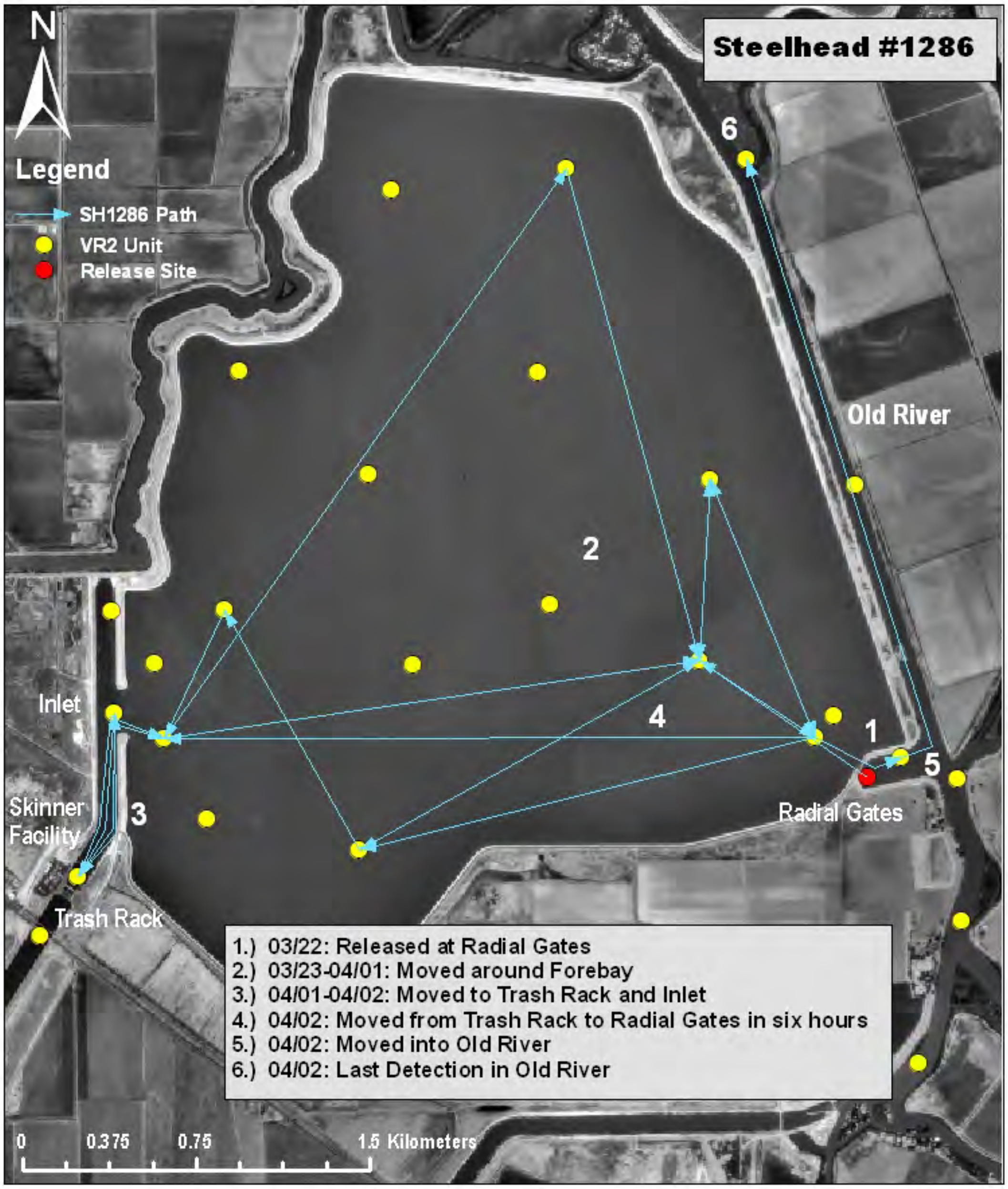

Figure 42. Steelhead tag ID 1286 was detected moving into the intake canal leading to the SFPF and then moved across the Forebay and emigrated into Old River.

Table 10. Fixed station receiver data summary for 25 of 64 steelhead entrained that were detected at either the intake canal, trashboom, SFPF, and/or Old River. Steelhead not detected at any of these locations were not included in the table. The total number of acoustic tagged steelhead released was used to calculate the percentage of fish detected at the four locations.

Tag ID	Release Date	Intake Canal	Trash-boom	Salvage Holding Tank	Old River
1236	3/22	-----	-----	-----	X
1260	4/28	X	X	X	-----
1285	3/23	-----	-----	-----	X
1286	3/22	X	X	-----	X
1288	4/28	X	X	-----	-----
1294	3/23	-----	-----	-----	X
1296	3/23	-----	-----	-----	X
1297	2/8	X	X	-----	X
1299	2/7	X	-----	-----	-----
1300	2/7	X	X	-----	X
1301	2/8	X	X	-----	-----
1304	2/8	-----	-----	-----	X
1322	2/8	X	X	X	-----
1332	2/7	-----	-----	-----	X
1336	2/8	-----	-----	-----	X
1339	3/23	-----	-----	-----	X
1346	3/23	X	X	-----	X
1349	3/23	-----	-----	-----	X
1353	3/22	-----	-----	-----	X
1360	3/23	-----	-----	-----	X
1368	3/23	-----	-----	-----	X
1369	3/22	-----	-----	-----	X
1371	3/22	X	-----	-----	X
1372	3/23	X	X	-----	X
1373	3/23	X	X	-----	X
Fish Detected (% of total released)		12 (19%)	10 (16%)	2 (3%)	20 (31%)

Transit times for steelhead were calculated from the release point at the radial gates to the first detection at the intake canal, trashboom, SFPF salvage holding tanks, and Old River. For those steelhead detected in the intake canal, the mean transit time was 7.2 days. Three of the 12 steelhead detected at the intake canal had transit times of fewer then 1 day. The mean transit time from the release point to the trashboom was 12.4 days, however 3 of the 9 steelhead detected at the trashboom had transit times greater than 20 days. Mean transit time to the SFPF salvage holding tank from point of release was 13.5 days, however, only 2 of the 64 steelhead tags were detected as having been salvaged with transit times of 1 day and 26 days. Mean transit time for the steelhead released at the radial gates observed emigrating out of the Forebay and into Old River was 10.4 days with a wide range of transit times from less than 1 to 46 days. Thirty percent of the steelhead emigrating from Clifton Court Forebay through the radial gates were earlier detected at the SFPF trashboom.

Fixed receiver tracking within Clifton Court Forebay ended at the time the receivers were removed from the water, June 25, 2007. Steelhead final detections were based on those receivers' data. Of the 64 juvenile steelhead entrained into the Forebay, 44 (69%) remained in the Forebay at the end of the study period (Figure 43). Of the 44 steelhead tags remaining within the Forebay, 29 tags were last detected at the radial gates and one was located at the trashboom. Several of the steelhead last detected within the Forebay were stationary for a long period of time with no subsequent movements. For example, one steelhead was detected at the radial gates for 17 weeks continuously. Similar to the 2005 and 2006 pilot studies, these data demonstrate that either juvenile steelhead may remain resident within the Forebay for extended periods of time before salvage or that the steelhead tags lay on the bottom of the Forebay as a result of tag shedding or predation. A total of two (3%) of the juvenile steelhead were detected in SFPF salvage holding tanks and 18 (28%) were last detected in Old River (Figure 43). One of the steelhead last detected in Old River was detected at a single fixed receiver location within Old River for five weeks.

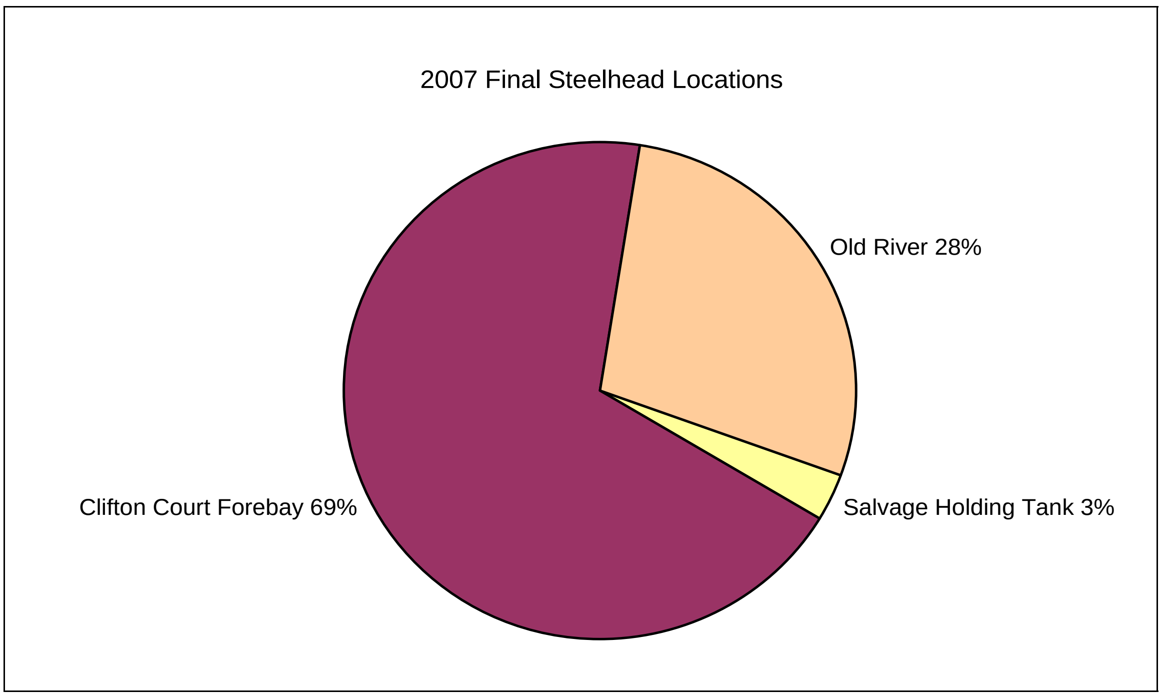

Figure 43. Percentages and locations for final detections of acoustic tagged steelhead released during the 2007 full-scale study.

The Central Valley Fish Tracking Consortium (CVFTC) database was also searched for records of the steelhead that were last detected in Old River or were salvaged at the SFPF. Of the two steelhead released at the radial gates and salvaged, one was not detected on the CVFTC network of receivers. The other salvaged steelhead was detected moving downstream from the SWP fish release site past Chipps Island, the Benicia Bridge, Carquinez Bridge, Richmond Bridge, Bay Bridge and last detected in the Port of Oakland. Of the eighteen last detected in Old River, several were observed near Decker Island and Horseshoe Bend. Two steelhead last detected in Old River were detected on the CVFTC network of receivers moving rapidly upstream on the Sacramento River as far as the confluence of the Feather and Sacramento Rivers. These rapid, lengthy movements are indicative of possible predation of the tagged steelhead while in the Forebay. However, it cannot be confirmed that any of the acoustic tagged steelhead emigrating from the Forebay had been preyed upon, and that their predators moved from the Forebay through the radial gates and into Old River.

Steelhead released within the SFPF primary louver bays and salvaged displayed similar movement patterns. Of the 12 steelhead released within the SFPF primary louver bays and salvaged one was detected moving rapidly upstream from the SWP fish release site and eventually passed the confluence of the Feather and Sacramento Rivers. Another steelhead released within the SFPF and salvaged was detected moving downstream from the SWP fish release site and eventually passed the Golden Gate Bridge.

8.2.2 Acoustic Tagged Steelhead Movement Rates

Remain and Trim steelhead movement rates (MR) were estimated hourly by calculating the distance moved between two receivers in one hour for the duration of the study period. To compare the MR between the Remain and Trim datasets for all steelhead, a Mann-Whitney Rank Sum test was used as data were not normally distributed. Remain MR was significantly different ($U = 15950645.0$; $T = 19594216.0$; $p < 0.001$) from the Trim MR, with the mean Trim MR being greater than the mean Remain MR (Table 11). This suggests the Trim MR contains many movements by striped bass and that striped bass move considerably more than steelhead. Both Remain MR and Trim MR contained many movement rate records of 0 m/hr (fish remained at same location) as indicated by the median MR of both datasets.

Table 11. Summary statistics for steelhead hourly Remain movement rate (m/hr) (steelhead alive) and hourly Trim movement rate (m/hr) (steelhead presumed eaten by predator).

	Remain Movement Rate	Trim Movement Rate
N	17830	1893
Minimum	0.0	0.0
Mean	86.5	145.9
Median	0.0	0.0
Standard Deviation	302.8	421.1
Maximum	3745.2	3651.1

Because of the high variance inherent to hourly movement rates, steelhead acoustic data were analyzed as “pooled”. To pool the data, for each study day, all steelhead received at VR2s on that day had their Remain movement rate data for that day pooled together and averaged to obtain a mean daily movement rate (DMR). For example, if twelve fish were received in hours 0:00 through 23:00 then there was a total of 288 movement rates, one per hour per steelhead. The 288 movement rates were summed and divided by 288 to calculate mean DMR. If no steelhead were received during a study day, DMR was recorded as missing. Pooled mean daily movement rate was variable and ranged from 0 m/hr to 282 m/hr. Variation in mean DMR increased after acoustic tagged steelhead were released in March.

Mean DMR could be influenced by a number of factors including but not limited to water temperature, turbidity, light intensity, radial gate water velocity, and Harvey Banks Pumping Plant export rate. To statistically test the relationship between each of these factors and DMR, Spearman Rank Order Correlation was used as the data were not normally distributed. Neither water temperature ($R_S = 0.0872$; $n = 121$; $p = 0.341$), turbidity ($R_S = 0.0841$; $n = 121$; $p = 0.358$), light intensity ($R_S = 0.131$; $n = 121$; $p = 0.152$), radial gate water velocity ($R_S = -0.0872$; $n = 120$; $p = 0.343$), nor Harvey Banks Pumping Plant export rate ($R_S = -0.117$; $n = 120$; $p = 0.203$) had a significant relationship with DMR.

The time between when a steelhead was released and when it was detected, or "Days Out", may have an effect on Mean DMR. Days Out were rounded to the nearest day (ex. 1.23 days = 1 day) and for each Day Out, all steelhead received at VR2s during that period of time had their movement rate data pooled together and averaged to obtain a mean Days Out movement rate. A maximum Days Out movement rate was calculated as well. As the Days Out data were normally distributed, a Pearson Product Moment Correlation was used to test the relationship between mean Days Out movement rate and Days Out. Mean Days Out movement rate was significantly ($R = -0.889$; $n = 59$; $p < 0.001$) related to Days Out. An R value close to -1 indicates a negative relationship between the two variables with Days Out movement rate decreasing with increasing Days Out (Figure 44). Also, a Pearson Product Moment Correlation was used to test the relationship between mean maximum Days Out movement rate and Days Out. Maximum Days Out movement rate was significantly ($R = -0.880$; $n = 59$; $p < 0.001$) related to Days Out. Again, an R value close to -1 indicates a negative relationship between the two variables with maximum Days Out movement rate decreasing with increasing Days Out (Figure 45).

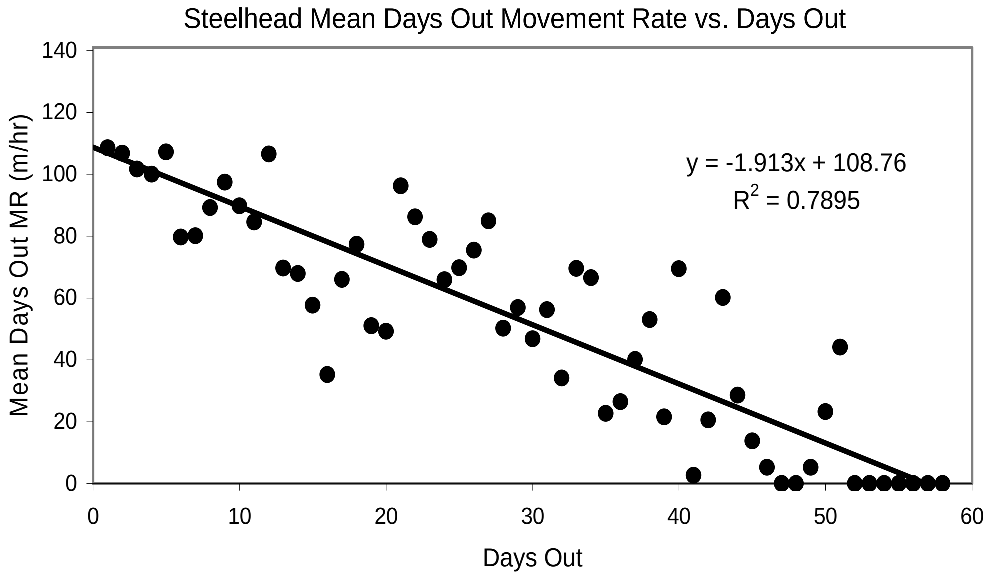

Figure 44. Plot of linear relationship between steelhead mean Days Out movement rate (MR) and time in days since release (Days Out).

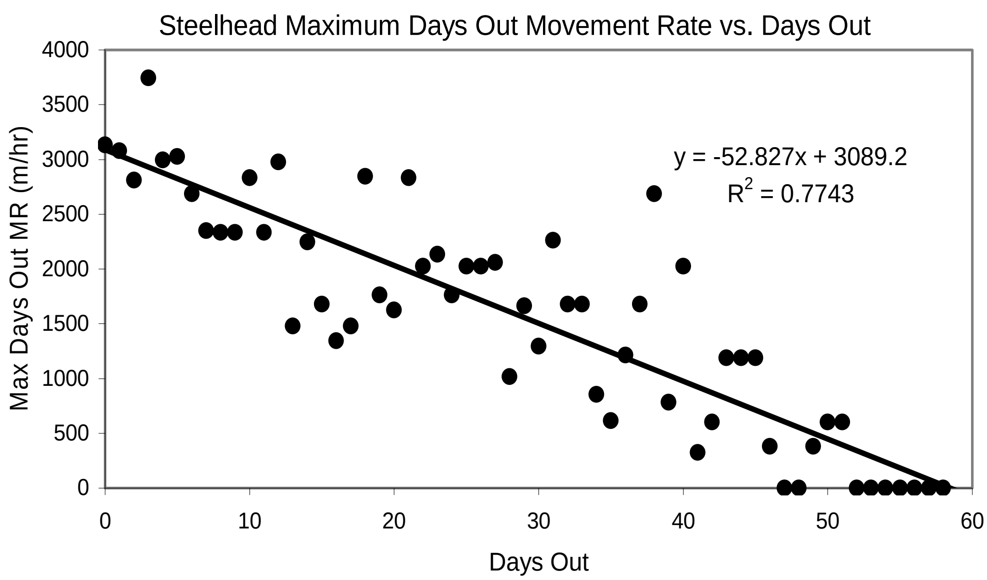

Figure 45. Plot of linear relationship between steelhead maximum Days Out movement rate (MR) and time in days since release (Days Out).

8.2.3 Acoustic Tagged Striped Bass Movements

Striped bass utilized the entire Forebay, but many of the striped bass spent long periods of time near either the radial gates or the trashboom or both. A few striped bass were observed to make trips between the radial gates and the trashboom with one striped bass (tag 1375) making 23 such trips. Striped bass were also observed to move from the radial gates to other areas within the Forebay only to return to the radial gates several times (Figure 46). One striped bass was never detected and another striped bass was found dead and impinged on the SFPF trash rack. Eighteen of the 29 tagged striped bass were detected emigrating from Clifton Court Forebay into Old River (e.g. Figure 46). Three striped bass, observed emigrating into Old River, returned to the Forebay through the radial gates. Surprisingly, one striped bass (tag 1420) was detected in a SFPF salvage holding tank. The striped bass detected in the holding tank was 686 mm (25.9 in) in total length and weighed 2267 g (5 lb). In order to be detected in the SFPF holding tank, this striped bass had to move through the SFPF trash rack with a bar spacing of approximately 50.8 mm (2 in).

The Central Valley Fish Tracking Consortium (CVFTC) database was also searched for records of the striped bass that were last detected in Old River. The striped bass emigrating from the Forebay were detected on the CVFTC receiver grid as far away as the Golden Gate Bridge and above Colusa on the Sacramento River. One striped bass (tag 1413) was observed to emigrate through the radial gates into Old River and was subsequently detected near Decker Island and Rio Vista. Eight days later this striped bass was detected moving through Threemile Slough to Franks Tract and subsequently Old River near the radial gates. The striped bass emigrating through the radial gates were detected in Old River in the same time span as the steelhead emigrating through the radial gates. However, those striped bass and steelhead moving through the Delta were not detected simultaneously at the same locations, so it is unlikely that any of the tagged striped bass were transporting any of the tagged steelhead in their stomachs.

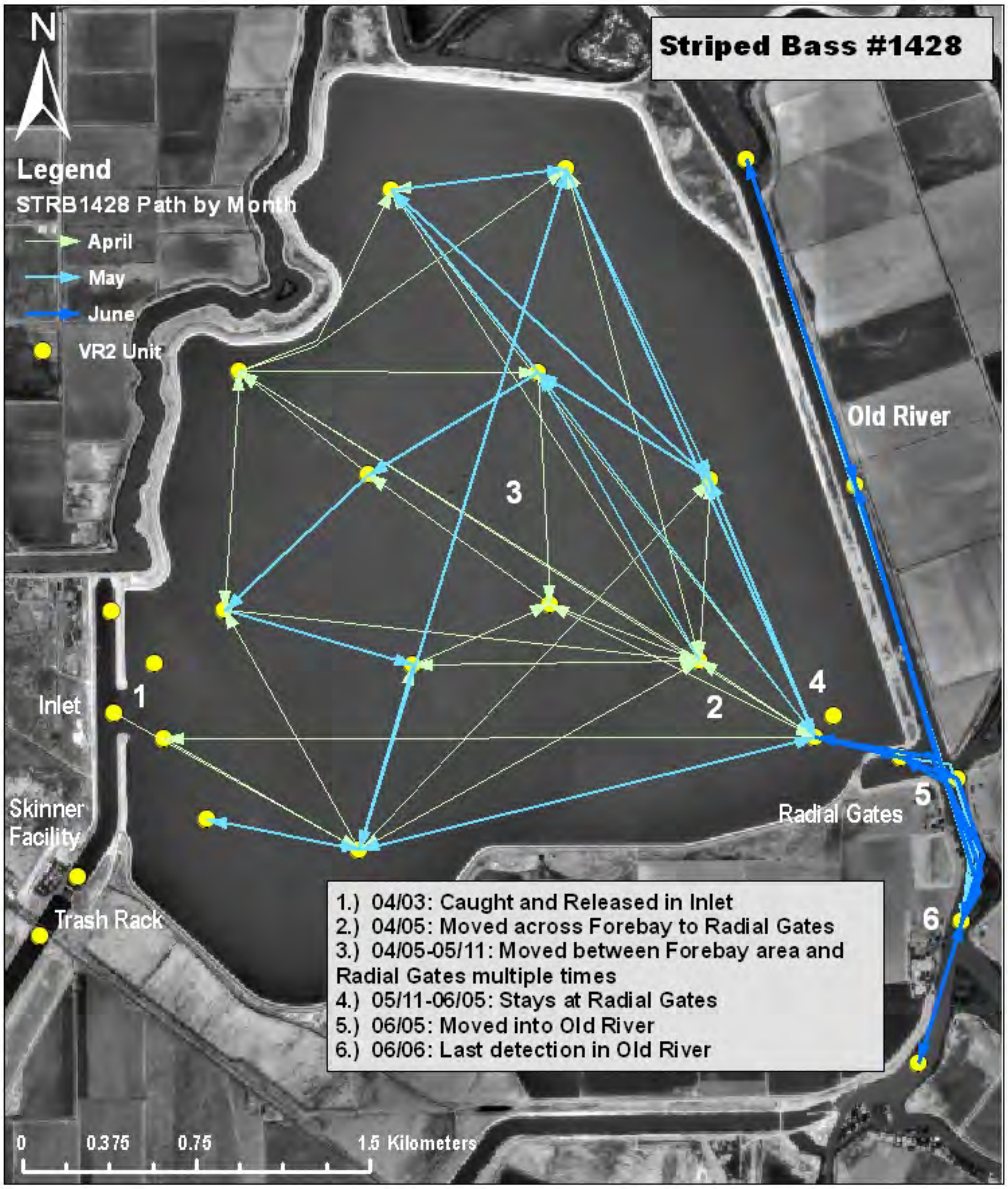

Figure 46. Striped bass #1428 moved throughout the Forebay and emigrated into Old River in June, 2007.

8.2.4 SWP Operation Effects on Striped Bass Time Spent at the Radial Gates and the Intake Canal

SWP operations could have an effect on striped bass behavior and movement patterns, as striped bass spent a majority of time at the radial gates and in the intake canal, which are two areas affected by operations. To determine if SWP operations affect the proportion of time striped bass spent at the radial gates, the hourly detection data was separated into two categories: “gates open” and “gates closed”. Once separated, the proportion of hours spent at the two VR2 receivers located at the radial gates was calculated for gates open and gates closed time periods. Also, the proportion of hours spent at all other VR2 receivers was calculated for gates open and gates closed time periods. To test the null hypothesis that gate operations (gates open and gates closed) had no effect on the proportion of time striped bass spent at the radial gates, a Chi-square test was used. The Chi-square test ($\chi^2 = 1.481$; n = 33581; df = 1; p = 0.224) suggested that radial gate operations had no effect on the amount of time striped bass spent near the radial gates (Figure 47).

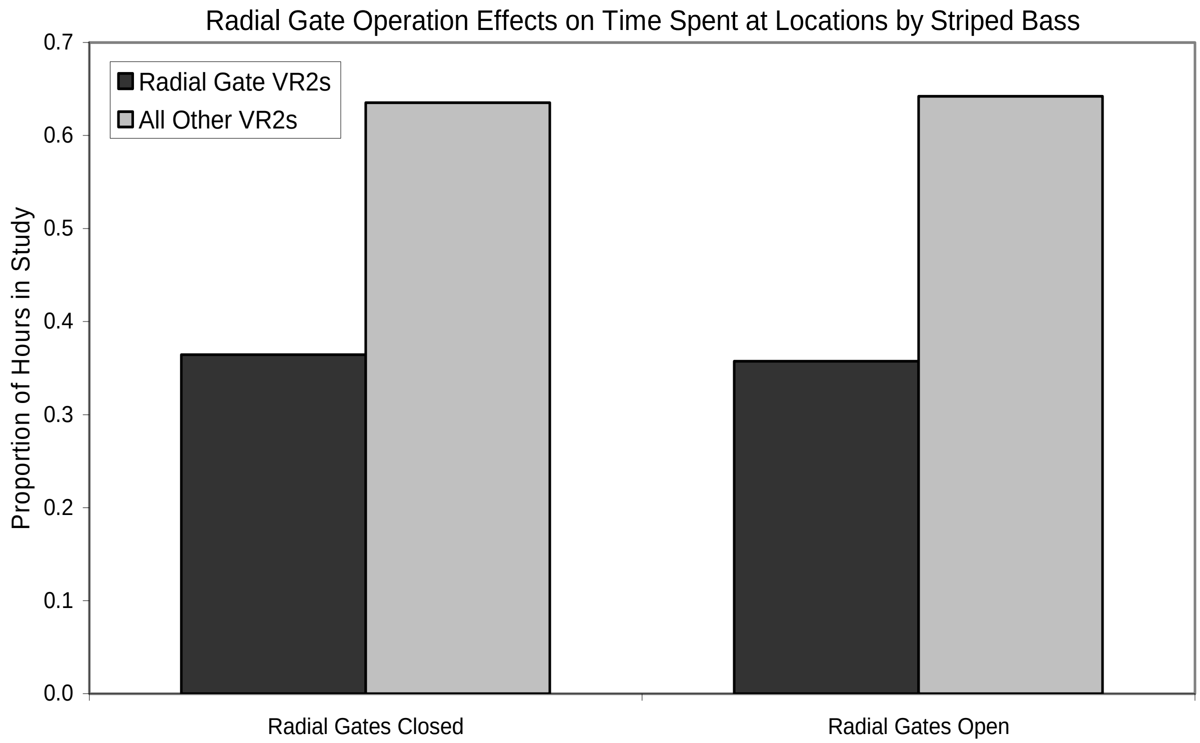

Figure 47. Proportion of study hours striped bass spent near the radial gates when the radial gates were closed or open.

To determine if SWP operations affect the proportion of time striped bass spent in the intake canal, the hourly detection data was separated into two categories: “pumping” and “not pumping”. Once separated, the proportion of hours spent at the three VR2 receivers located in the intake canal and at the trashboom was calculated for pumping and not pumping time periods. Also, the proportion of hours spent at all other VR2 receivers was calculated for pumping and not pumping time periods. To test the null hypothesis that pumping operations had no effect on the proportion of time striped bass spent in the intake canal to the SFPF, a Chi-square test was used. The Chi-square test ($\chi^2 = 0.004$; n = 33581; df = 1; p = 0.949) suggested that pumping operations had no effect on the proportion of time striped bass spent in the intake canal (Figure 48).

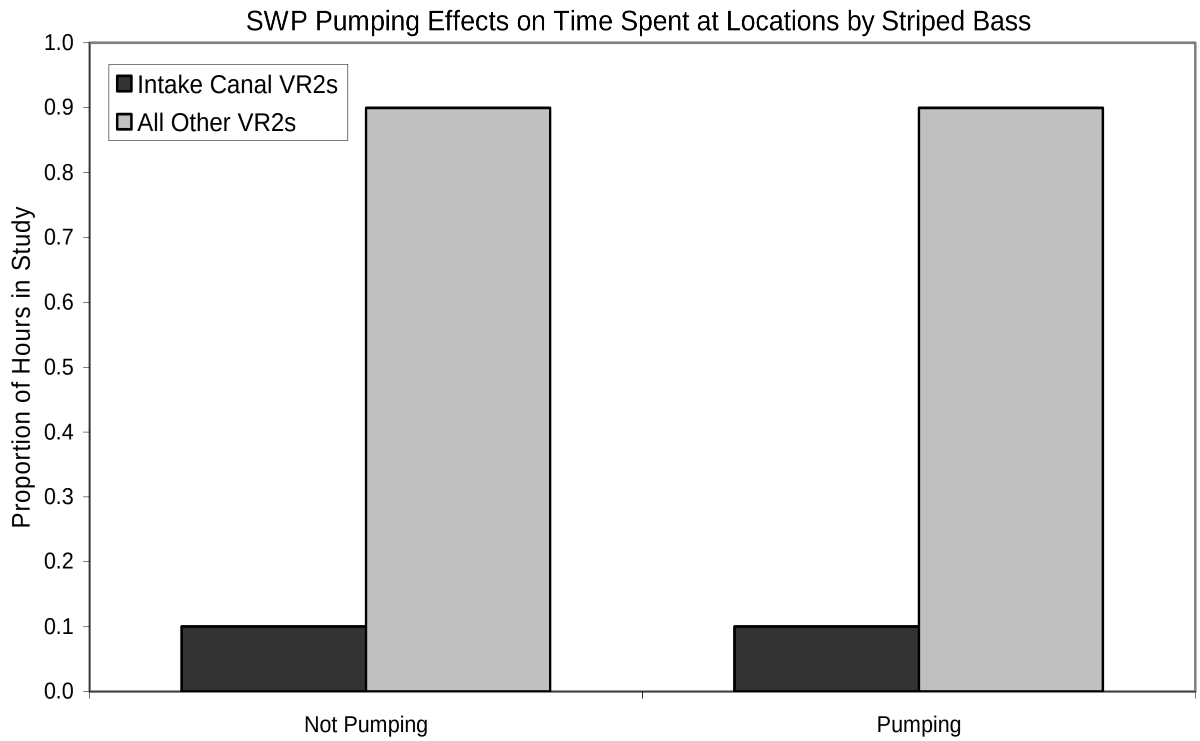

Figure 48. Proportion of study hours striped bass spent in the intake canal when Harvey Banks Pumping Plant was not pumping or pumping.

8.2.5 Acoustic Tagged Striped Bass Movement Rates

Similarly to steelhead, striped bass acoustic data were "pooled" to reduce the high variance in the hourly MR. For each study day, all striped bass received at VR2s on that day had their movement rate data for that day pooled together and averaged to obtain a mean daily movement rate (DMR). Pooled mean daily movement rate was variable and ranged from 21 m/hr to 365 m/hr.

Variables such as water temperature, turbidity, and light intensity could have an effect on Mean DMR. To statistically test the relationship between each of these variables and DMR, Spearman Rank Order Correlation was used as the data were not normally distributed. Neither water temperature (R_S = -0.106; n = 177; p = 0.162), turbidity (R_S = -0.0794; n = 162; p = 0.315), nor light intensity (R_S = -0.113; n = 177; p = 0.134) had a significant effect on DMR.

8.2.6 PIT Tagged Steelhead Total Loss, SFPF Efficiency, and Pre-screen Loss

Pre-screen loss rate for this study was defined as the proportion of steelhead released at the radial gates that are lost within Clifton Court Forebay as they travel to the SFPF. Pre-screen loss rate could not be directly determined, but was calculated by finding the Total

Loss (TL_P) from radial gate to SFPF fish release pipe and the SFPF loss. Total Loss estimates for juvenile steelhead were based upon detections (recoveries) of PIT tagged steelhead at the SFPF salvage release sites. Total Loss was calculated for each of the 58 radial gate release groups as:

$$TL_P = \left(1 - \left(\frac{Rec_{rg}}{Rel_{rg} \text{ x } A}\right)\right) \text{ x } 100$$

Rec_{rg} = # PIT tagged steelhead recovered from radial gate releases
Rel_{rg} = # PIT tagged steelhead released at the radial gates
A = PIT antennae detection efficiency (98.75%)

Based on PIT tagged steelhead detections, TL_P was estimated to be 87 ±2.5% (mean ±95% Confidence Interval). TL_P estimates ranged from 59 to 100% for the 58 release groups. Summary statistics for TL_P are summarized in Table 12. Only one PIT tagged steelhead was directly measured as having emigrated from Clifton Court Forebay into Old River. This single PIT tagged steelhead was detected in a TFCF 10 minute count and this steelhead was subtracted from its release group. TL_P is a conservative estimate because emigration may be grossly underestimated given the acoustic telemetry results.

A second estimate of Total Loss (TL_{PA}) was calculated using an estimate of emigration. Emigration was estimated from the results of the 64 acoustic tagged steelhead released directly upstream of the radial gates. TL_{PA} was calculated for each of the 58 radial gate release groups as:

$$TL_{PA} = \left(1 - \left(\frac{Rec_{rg}}{(Rel_{rg} - (Rel_{rg} \text{ x } E_{rg})) \text{ x } A}\right)\right) \text{ x } 100$$

Rec_{rg} = # PIT tagged steelhead recovered from radial gate releases
Rel_{rg} = # PIT tagged steelhead released at the radial gates
A = PIT antennae detection efficiency (98.75%)
E_{rg} = Emigration rate through the radial gates assumed constant at (28%)

Based on PIT and acoustic tagged steelhead detections, TL_{PA} was estimated to be 82 ±3% (mean ±95% Confidence Interval). TL_{PA} estimates ranged from 44 to 100% for the 58 release groups. Summary statistics for TL_{PA} are summarized in Table 12. TL_{PA} is a liberal estimate because emigration may be overestimated given the uncertainty of the acoustic telemetry results. Many of the acoustic tagged steelhead seen emigrating from the Forebay may have been in the stomach of a striped bass. Thus, the error in the emigration constant may be large.

SFPF salvage efficiency (F_P) was defined as the proportion of PIT tagged steelhead released within the SFPF primary louver bays that were successfully salvaged. F_P was calculated for each of the 47 trash rack release groups as:

$$F_P = \left(\frac{Rec_{tr}}{Rel_{tr} \times A} \right) \times 100$$

Rec_{tr} = # PIT tagged steelhead recovered from trash rack releases
Rel_{tr} = # PIT tagged steelhead released at the trash rack
A = PIT antennae detection efficiency (98.75%)

Based on PIT tagged steelhead detections, SFPF efficiency (F_P) was estimated to be 74 ±7% (mean ±95% Confidence Interval) for the 2007 study period. F_P ranged from 17 to 100% for the 47 release groups. Summary statistics for SFPF efficiency can be found in Table 12. F_P is a conservative estimate because emigration out of the primary louver bay and into the Forebay may have occurred.

PIT tagged steelhead emigrating through the trash rack and into the Forebay were not included in the SFPF efficiency test. Direct measurements of emigration through the trash rack by PIT tagged steelhead was not possible. However, acoustic tagged steelhead released within the SFPF primary louver bays were observed to emigrate through the trash rack and into the Forebay. Thus, a second estimate of SFPF efficiency (F_{PA}) was calculated using an estimate of emigration. Emigration was estimated from the results of the 15 acoustic tagged steelhead released within the primary louver bays. F_{PA} was calculated for each of the 47 trash rack release groups as:

$$F_{PA} = \left(\frac{Rec_{tr}}{(Rel_{tr} - (Rel_{tr} \times E_{tr})) \times A} \right) \times 100$$

Rec_{tr} = # PIT tagged steelhead recovered from trash rack releases
Rel_{tr} = # PIT tagged steelhead released at the trash rack
A = PIT antennae detection efficiency (98.75%)
E_{tr} = Emigration rate through trash rack assumed constant (13.33%)

Based on PIT and acoustic tagged steelhead detections, SFPF efficiency (F_{PA}) was estimated to be 82 ±7% (mean ±95% Confidence Interval) for the 2007 study period. F_{PA} ranged from 19 to 100% for the 47 release groups. Summary statistics for SFPF efficiency can be found in Table 12. F_{PA} is a liberal estimate because emigration out of the primary louver bay and into the Forebay was based on two acoustic steelhead releases. Therefore, the error associated with the emigration constant may be large.

Table 12. Summary statistics for total loss (%) and SFPF efficiency (%) estimates.

	Total Loss (TL_P)	**Total Loss (TL_{PA})**	**SFPF Efficiency (F_P)**	**SFPF Efficiency (F_{PA})**
No. of Release Groups	58	58	47	47
Minimum	59	44	17	19
Mean	87	82	74	82
Median	90	86	76	88
Standard Deviation	10	13	24	24
Maximum	100	100	100	100

Pre-screen loss rate (PSL_P) estimates were calculated based upon recoveries of PIT tagged steelhead. PSL_P was calculated for each of the 58 radial gate release groups as:

$$PSL_P = \left(1 - \left(\frac{Rec_{rg}}{Rel_{rg} \text{ x } A \text{ x } F_P}\right)\right) \text{ x } 100$$

Rec_{rg} = # PIT tagged steelhead recovered from radial gate releases
Rel_{rg} = # PIT tagged steelhead released at the radial gates
A = PIT antennae detection efficiency (98.75%)
F_P = Facility efficiency estimated by trash rack releases (74%)

Based on PIT tagged steelhead detections, PSL_P was estimated to be 82 ±3% (mean ±95% Confidence Interval). PSL_P release group estimates ranged from 45 to 100% for the 58 release groups. Summary statistics for PSL_P are summarized in Table 13.

Because PSL_P may not accurately account for emigration into Old River, PSL_P may overestimate loss. In addition, the SFPF efficiency (F_P) used to calculate PSL_P does not account for steelhead that emigrated from the SFPF into the Forebay through the trash rack. Thus, a second estimate of pre-screen loss rate (PSL_{PA}) was calculated using an estimate of emigration and F_{PA}. Emigration was estimated from the results of the 64 acoustic tagged steelhead released directly upstream of the radial gates. PSL_{PA} was calculated for each of the 58 radial gate release groups as:

$$PSL_{PA} = \left(1 - \left(\frac{Rec_{rg}}{(Rel_{rg} - (Rel_{rg} \text{ x } E_{rg})) \text{ x } A \text{ x } F_{PA}}\right)\right) \text{ x } 100$$

Rec_{rg} = # PIT tagged steelhead recovered from radial gate releases
Rel_{rg} = # PIT tagged steelhead released at the radial gates
A = PIT Antennae detection efficiency (98.75%)
F_{PA} = Facility efficiency estimated by trash rack releases including emigration (82%)
E_{rg} = Emigration rate through the radial gates assumed constant at (28%)

Based on PIT and acoustic tagged steelhead detections, PSL_{PA} was estimated to be 78 ±4% (mean ±95% Confidence Interval). PSL_{PA} release group estimates ranged from 31 to 100% for the 58 release groups. Summary statistics for PSL_{PA} are summarized in Table 13. PSL_{PA} may underestimate pre-screen loss given the uncertainty in the acoustic tagged steelhead results. As a result, NMFS recommended the use of pre-screen loss (PSL_P), the most conservative estimate, for all subsequent data analysis of PIT tagged steelhead losses within Clifton Court Forebay.

Table 13. Summary statistics for pre-screen loss rate (%).

	Pre-screen Loss (PSL_P)	**Pre-screen Loss (PSL_{PA})**
No. of Release Groups	58	58
Minimum	45	31
Mean	82	78
Median	86	83
Standard Deviation	13	16
Maximum	100	100

8.2.7 Comparing Pre-screen Loss Rate to SFPF Loss Rate

SFPF loss rate for this study was defined as the loss of PIT tagged steelhead within the SFPF. SFPF efficiency (F_P) was converted to a loss rate by 1-F_P. SFPF loss rate ranged from 0 to 83% with a mean of 26 ±7% (Table 14).

Table 14. Summary statistics for the SFPF loss rate (%) and pre-screen loss rate (%).

	SFPF Loss Rate	Pre-screen Loss (PSL_P)
No. of Release Groups	47	58
Minimum	0	45
Mean	26	82
Median	24	86
Standard Deviation	24	13
Maximum	83	100

The SFPF loss rate observed for the groups of PIT tagged steelhead released into the primary louver bays was dissimilar to that observed for the acoustic tagged steelhead released at the same location. Of the 15 acoustic tagged steelhead released into the primary louver bays, 12 were recovered in a SFPF salvage holding tank. Of the three acoustic tagged steelhead not salvaged, one was detected downstream of the SFPF having been lost through the louvers and two were detected moving upstream through the trash rack. A SFPF loss rate of 8% was calculated for the acoustic tagged steelhead released in the primary louver bays. However, this SFPF loss rate was based on only two acoustic tagged steelhead release groups.

To determine if there was a statistically significant difference between the SFPF loss rate and the pre-screen loss rate (PSL_P) for PIT tagged steelhead, the non-parametric Mann-Whitney Rank Sum test was used as data were not normally distributed. There was a significant difference ($U = 2623.0$; $T = 1231.0$; $p < 0.001$) found between the two medians. Median pre-screen loss rate (PSL_P) was greater than the median SFPF loss rate (Table 14). Although, SFPF loss rate was on occasion as high as the pre-screen loss rate.

8.2.8 Monthly Pre-screen Loss Rate Estimates and Time to Salvage for PIT Tagged Steelhead

Monthly adjusted pre-screen loss rate estimates were determined by taking the calculated pre-screen loss rate (PSL_P) for each radial gate release group and pooling them by release month. Summary statistics for the monthly pre-screen loss estimates are summarized in Table 15. ANOVA was used to determine if there was a statistically significant difference in monthly pre-screen loss estimates. There was no significant difference ($F = 1.382$; $df = 3$; $p = 0.258$) between monthly pre-screen loss estimates. Therefore, pre-screen loss rate estimates did not differ between months during the 2007 full-scale study and can be pooled for a single pre-screen loss rate (PSL_P) estimate.

Table 15. Summary statistics for monthly pre-screen loss rates (%).

	January	February	March	April
No. of Release Groups	13	16	16	12
Minimum	66	46	73	46
Mean	84	83	86	76
Median	86	83	86	73
Standard Deviation	10	13	10	17
Maximum	100	100	100	100

Although there were no differences in monthly pre-screen loss rate estimates, time to salvage by month of release may vary. The first observation of a salvaged PIT tagged steelhead occurred on January 12, two days after release at the radial gates. The last observation of a salvaged PIT tagged steelhead occurred on April 30, seventeen days after release at the radial gates. Time to salvage (number of days) was calculated for each PIT tagged steelhead released. Time to salvage ranged from 1 day to 84 days with a mean of 12.5 ±3 days.

For statistical analysis, time to salvage was pooled for each release month. Mean monthly time to salvage estimates for January and February appear different from March and April (Figure 49). However, median monthly time to salvage estimates for January, March and April appear different from February. This discrepancy can be explained by several outliers observed in January (Figure 49). The outliers observed may be due to the difference in the number of observation days. PIT tagged steelhead released in April did not have an equal number of observation days compared to other months. The time between April's last radial gate release to the last possible observation day (June 15) was 63 days. Therefore, months were also compared where "observation days" was set at a maximum such that any PIT tagged steelhead salvaged at more than 63 days was removed from the dataset. Based on this criteria, four steelhead released during the month of January were removed for statistical comparison. Monthly time to salvage means and medians still appear to be different (Table 16) (Figure 50).

A Kruskal-Wallis One Way ANOVA on Ranks test was used to determine if median time to salvage significantly differed by month of release, as data was not normally distributed. The median time to salvage significantly differed ($H = 15.364$; $df = 3$; $p = 0.002$) between release months. To determine which months differed a multiple comparison procedure (Dunn's Method) was employed. Steelhead released at the radial gates in February had a different time to salvage than those released in April or January; but not for those released in March (Table 17). Steelhead released at the radial gates in March did not have a different time to salvage than those released in April. No comparison was made between January and March or January and April.

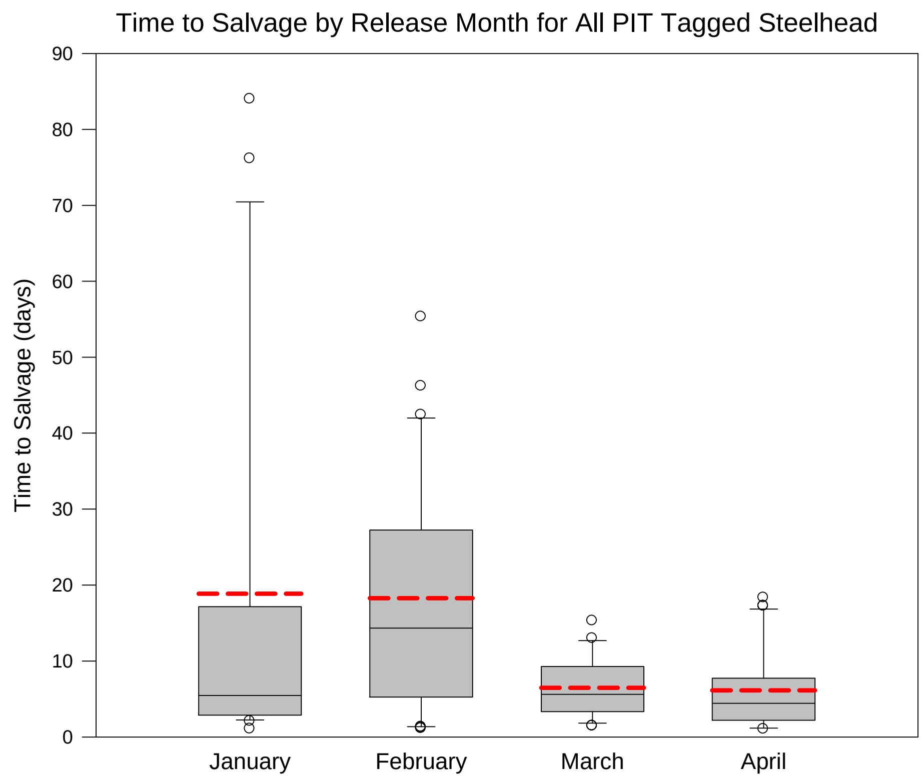

Figure 49. Box plot of monthly time to salvage for all salvaged PIT tagged steelhead released at the radial gates. The red dashed lines indicate the monthly means.

Table 16. Summary statistics for time to salvage in days for PIT tagged steelhead released at the radial gates salvaged in less than 63 days.

	January	February	March	April
No. Steelhead Salvaged	22	33	24	33
Minimum	1	1	1	1
Mean	9	18	6	6
Median	5	14	6	4
Standard Deviation	12.5	14.9	4.0	5.2
Maximum	60	55	15	18

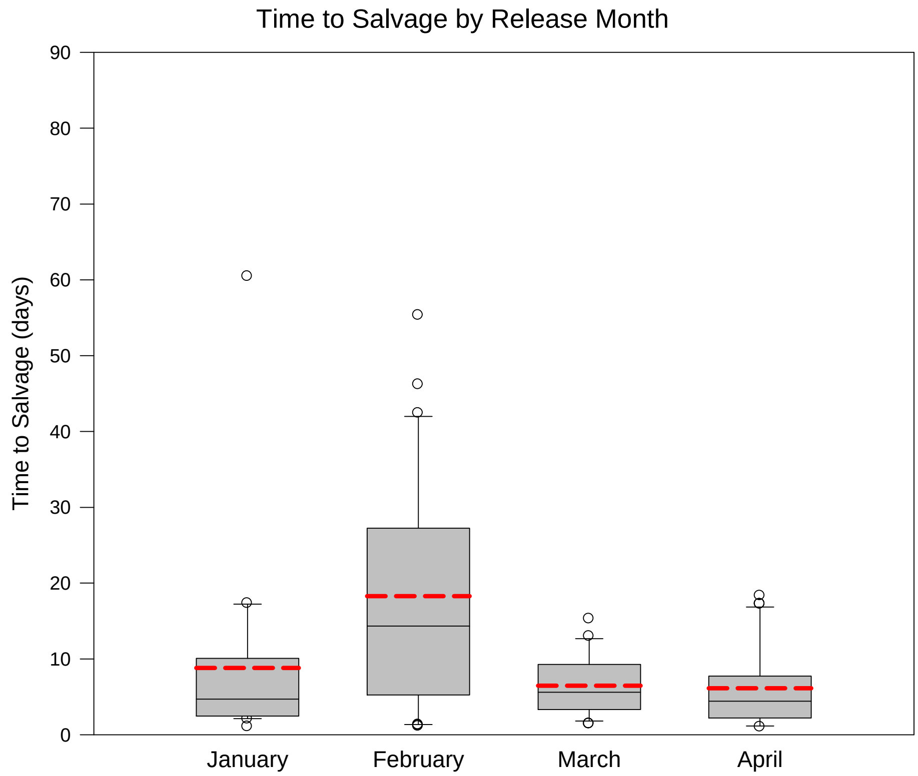

Figure 50. Box plot of monthly time to salvage for PIT tagged steelhead released at the radial gates salvaged in less than 63 days. The red dashed lines indicate the monthly means.

Table 17. Summary of multiple comparison procedure (Dunn's Method) to determine differences in time to salvage by release month.

Comparison	Difference of Ranks	Q	$p < 0.05$
February vs April	29.318	3.667	Yes
February vs January	24.000	2.685	Yes
February vs March	22.536	2.587	No
March vs April	6.782	0.778	No
January vs March	1.464	0.153	Not Tested*
January vs April	5.318	0.595	Not Tested*

* A result of not tested appears for those comparison pairs whose difference of rank means is less than the differences of the first comparison pair which is found to be not significantly different.

8.2.9 Effect of Temperature on Pre-screen Loss Rate of PIT Tagged Steelhead

To test the effect of the water temperature observed at time of release of PIT tagged steelhead on the pre-screen loss rate (PSL_P), a Spearman Rank Order Correlation was used as data were not normally distributed. Water temperature at time of release was found to have no significant effect on pre-screen loss rate ($R_S = -0.087$; $n = 57$; $p = 0.517$).

8.2.10 Effect of Light on Pre-screen Loss Rate of PIT Tagged Steelhead

To test the effect of light intensity observed at time of release for PIT tagged steelhead on the pre-screen loss rate (PSL_P) a Spearman Rank Order Correlation was used as data were not normally distributed. Light intensity at time of release was found to have no significant effect on pre-screen loss rate (R_S = 0.069; n = 57; p = 0.608). In addition, light intensity measurements were categorized into night or day according to the 2007 full-scale light methods section of this report. To test if there was a significant difference in pre-screen loss rate (PSL_P) between night and day releases, a Mann-Whitney Rank Sum test was used as data were not normally distributed. There was no significant difference (U = 248.5; T = 441.5; p = 0.469) in median pre-screen loss rates between night (n = 38) and day (n = 15) releases of PIT tagged steelhead at the radial gates (Figure 51). This result could occur if the initial release period, and predation during that period, did not drive the pre-screen loss rate for a steelhead release group.

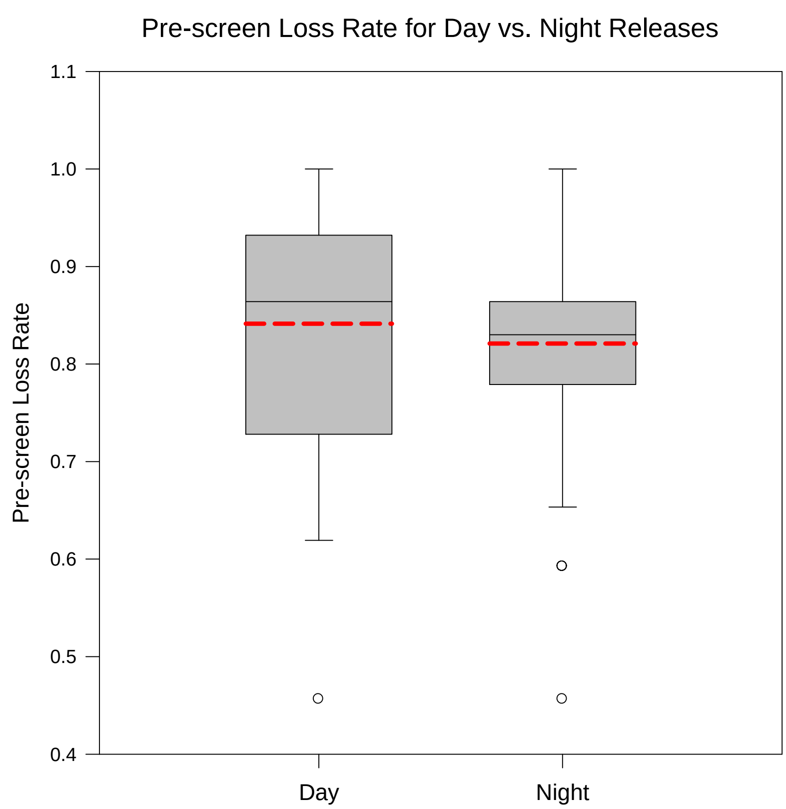

Figure 51. Box plot of pre-screen loss rates for day and night radial gate releases of PIT tagged steelhead. The red dash lines indicate the day and night means.

8.2.11 Avian Predation

Clifton Court Forebay is located along a major migratory pathway for many waterfowl species and harbors thousands of birds at a time during the winter and spring. When the full-scale study began in January 2007, waterfowl of various species were estimated to be in the thousands. Based on their published feeding habits, only a few of these bird species were considered predators of juvenile steelhead. Observational data for bird species that not only exhibited signs of foraging, but were large enough to prey on fish from 200 to 300 mm (7.8 to11.8 in) in length was summarized (Table 18). Western Grebes and Clarke's Grebes were difficult to differentiate at times, so they were grouped as "grebes" for the analyses. For this study period, only Double Crested Cormorants (cormorants), gulls, and Great Blue Herons (herons) had sufficient numbers to perform any statistical analysis.

Cormorants, grebes, gulls, herons, and Great Egrets were present in the Forebay prior to and during the 2007 study. Monthly indices of abundance of these avian predators were calculated for the point-count surveys conducted January through June 2007 (Table 19). Birds were most abundant in zones 1 and 2. Zone 3 consistently had the overall lowest abundance of birds (Table 19). Cormorants were the only species in relatively high total numbers that foraged consistently (Table 18). The mean monthly abundance of cormorants peaked in January, declined through March, and was at a low level for the remainder of the study (Figure 52). Zone 1 had higher numbers of cormorants than zones 2 and 3 for the entire study period (Figure 52). Cormorants were observed consistently foraging in the area near the radial gates, i.e. zone 1. During observations, some cormorants would fly away while others would rest on a nearby tree branch or "snag". Herons presence was much more sporadic and they occurred in relatively low numbers during the 2007 study (Figure 53). Unlike cormorants, herons are solitary fishers. Also, grebes were not common. Gulls were extremely abundant with numbers consistently in the hundreds for a single zone (Figure 54). Gull abundance was markedly higher at zone 1 (Figure 54) during January, followed by higher numbers in zone 3 during February and March. Gulls were almost completely absent from April through June. Gulls were observed briefly poking their heads below the water's surface and pecking at floating objects. It could not be determined if these gulls were feeding.

Table 18. Occurrence and behavior of predatory birds within Clifton Court Forebay.

Species Observed	**No. Observed**	**No. Observations**	**% Behavior Observed**			
			Foraging	Floating	Roosting	Flying
Double Crested Cormorant	2337	264	11.1	13.7	54.8	20.2
Great Blue Heron	552	188	32.4	0.0	48.9	18.3
Gulls	20214	99	0.1	77.5	15.5	6.9
Great Egret	62	37	16.1	0.0	37.1	46.8
Western Grebe	196	77	51.5	50.0	0.0	0.5
Clarke's Grebe	40	18	67.5	32.5	0.0	0.0
White Pelican	2	1	0.0	100.0	0.0	0.0

Table 19. Monthly indices of relative abundance (monthly count/number of surveys) of avian predators within Clifton Court Forebay.

Species	Zone	Jan	Feb	Mar	Apr	May	Jun
Double Crested Cormorant	1	0.0	22.1	19.4	11.2	12.7	11.5
Double Crested Cormorant	2	11.0	14.5	12.8	3.5	3.5	5.2
Double Crested Cormorant	3	0.0	0.9	1.4	0.8	0.6	1.3
Gulls	1	0.0	56.0	241.2	0.2	1.5	8.7
Gulls	2	0.0	7.4	6.4	1.7	0.9	1.3
Gulls	3	27.3	391.0	287.2	7.4	2.5	0.0
Great Blue Heron	1	0.0	1.3	4.4	1.5	2.4	3.3
Great Blue Heron	2	1.3	1.9	4.4	2.7	2.7	7.8
Great Blue Heron	3	0.3	0.7	1.4	0.5	0.6	0.3
Grebes	1	0.0	1.6	0.2	0.2	0.4	0.3
Grebes	2	4.3	0.7	0.1	0.4	1.0	1.2
Grebes	3	0.7	0.2	0.2	0.3	4.0	3.5
Egrets	1	0.0	0.2	0.1	0.0	0.1	0.5
Egrets	2	1.7	0.2	0.8	0.5	0.3	0.2
Egrets	3	0.0	0.1	0.1	0.1	0.1	0.3

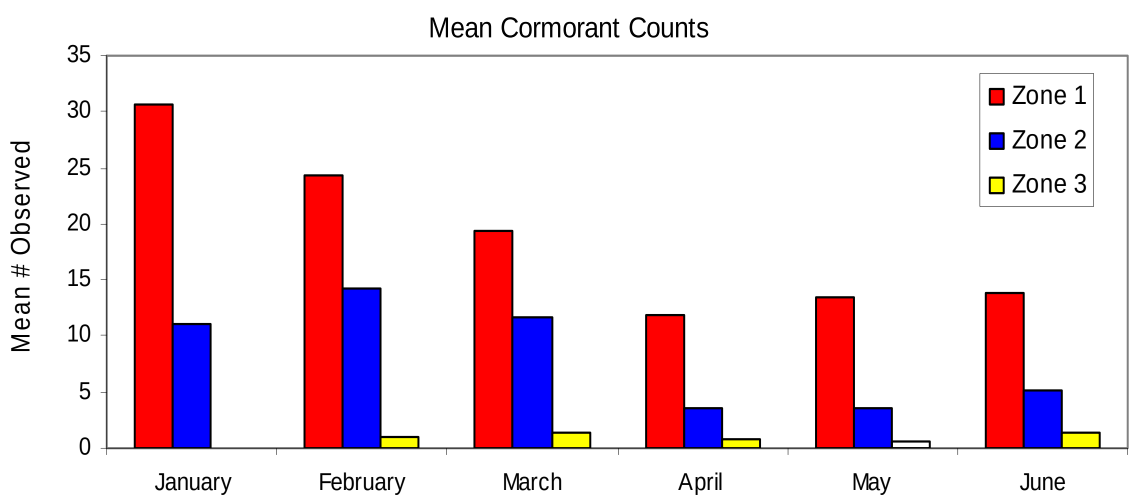

Figure 52. Mean monthly counts of Double Crested Cormorants by Clifton Court Forebay zone.

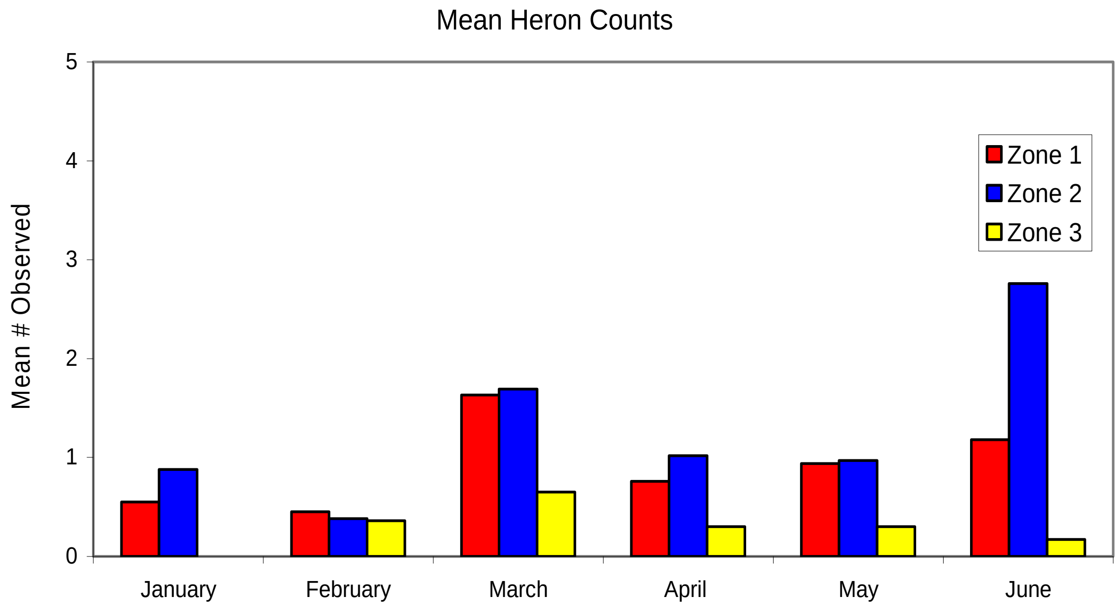

Figure 53. Mean monthly counts of herons by Clifton Court Forebay zone.

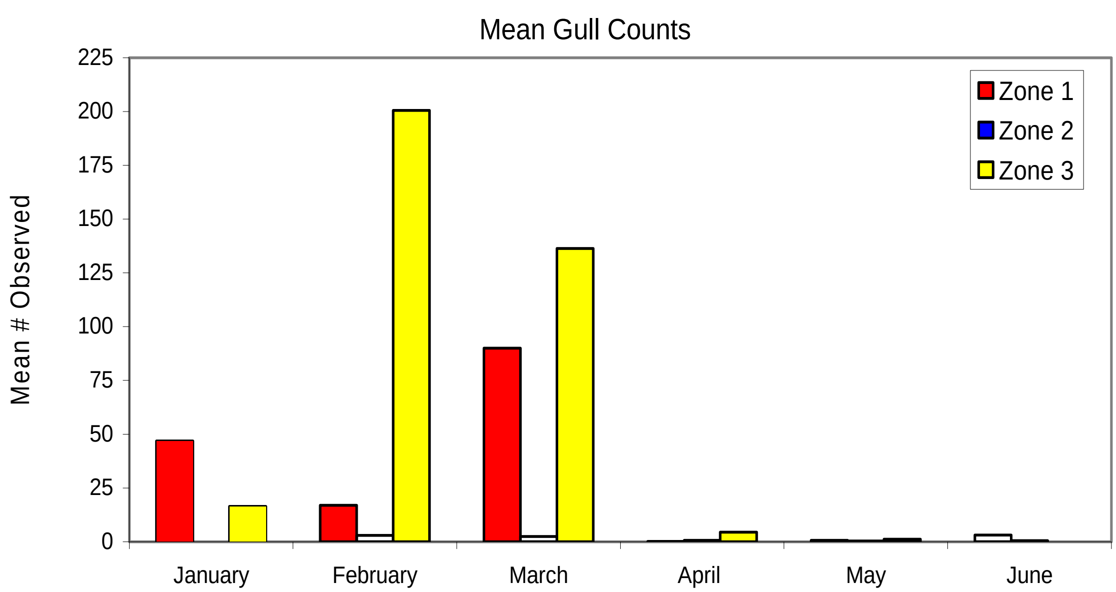

Figure 54. Mean monthly counts of gulls by Clifton Court Forebay zone.

The percentage of cormorants foraging near the radial gates could be influenced by radial gate operations seeing that cormorants were consistently foraging in the area and cormorant distribution was centered near the radial gates (Zone 1). This study was designed to be descriptive and the study design was not sufficient for rigorous statistical analysis. However, to test the null hypothesis that radial gate operations had no effect on the percentage of cormorants foraging in zone 1, a Mann-Whitney Rank Sum test was used. Results of the Mann-Whitney Rank Sum test (U = 479.0; T = 1302.0; p = 0.014) suggests that radial gate operations influenced the percentage of cormorants foraging near the radial gates (Figure 55).

The amount of time the radial gates were either opened or closed at the time of observations could act as a covariate on percent foraging. For example, a survey taking place ten hours after the gates had been opened could have low bird numbers and foraging percentages due to the fact that satiated birds left the Forebay. Because radial gate operations and their temporal proximity to an observation could affect the presence and/or behavior of birds, a logistic regression was performed on percent foraging. However, a logistic regression showed that the amount of hours the radial gates were opened or closed had no significant affect (p = 0.182) on percent foraging.

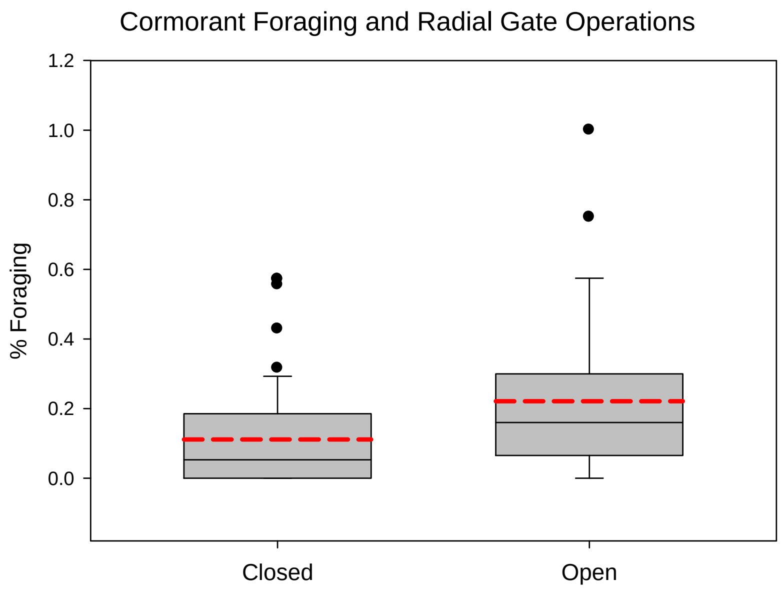

Figure 55. Percent foraging of Double Crested Cormorants located in Zone 1 as a function gate operations. The red dashed lines indicate the closed and open means.

8.3 Discussion and Conclusions

8.3.1 Steelhead Pre-screen Loss

Results of the 2007 full-scale study are consistent with the results of the 2005 and 2006 pilot studies. Steelhead appear to be moving throughout the entire Forebay with only a few steelhead making it from the radial gates into the SFPF salvage holding tanks. Predation by striped bass and piscivorous birds appears to be the primary cause for such losses. Steelhead pre-screen loss rate within Clifton Court Forebay is greater than 74% which is within the range of pre-screen loss rates (63 to 99%) found in other studies for other marked fishes released into the Forebay (Gingras, 1997). The juvenile steelhead released as part of the steelhead pre-screen loss studies were larger and had a higher swimming capacity than the juvenile salmon released in previous studies. Thus, the steelhead might be expected to have a higher predatory avoidance ability than the juvenile salmon released in the previous studies. However, even with these advantages, juvenile steelhead are still being lost at a very high rate within Clifton Court Forebay.

Steelhead pre-screen loss rate within the Forebay is substantially greater than the SFPF loss rate. This is not surprising as the SFPF has a relatively high capture efficiency for juvenile salmonids (Skinner, 1974, Odenweller and Brown, 1982). The SFPF is operated to maximize louver efficiency for salmonids during the times of the year that salmon or steelhead are usually present. Also, the amount of predation occurring within the SFPF is assumed low given the low likelihood of the presence of predators capable of consuming a 200+ mm (7.8+ in) juvenile steelhead. Pre-screen loss rate (> 74%) is much greater than SFPF loss rate (26%). Therefore, efforts to reduce predation within Clifton Court Forebay, rather than improvements within the SFPF, are likely to a produce a greater number of steelhead salvaged. Although the relative losses suggest that DWR management may want to focus on reductions in pre-screen loss rather than facility loss, SFPF improvements may be more feasible. For example, many steelhead were detected within the intake canal and yet were not salvaged. These results may indicate that there is an attraction problem at the SFPF or that the trash rack is perceived as a barrier by the fish. Perhaps changes to SFPF operations or changes in the design of the trash rack may yield higher salvage of steelhead.

Food intake by fishes, including striped bass, increases with water temperature (Brett, 1979; cited in Kestemont and Baras, 2001). Therefore, one would expect pre-screen loss rate to increase with increasing water temperature. However, water temperature at the time of PIT tagged steelhead release had no significant effect on steelhead pre-screen loss rate. Likewise light observed at the time release had no significant effect on steelhead pre-screen loss rate. Striped bass and piscivorous birds located in the Forebay are visual predators and should have increased prey capture success during the crepuscular and day than at night. It is possible that pre-screen loss rate did not change with water temperature or light observed because the number of predators within Clifton Court Forebay is great enough that the majority of juvenile steelhead are consumed regardless of water temperature or light intensity. On the other hand, water temperature and light intensity at the time of release may not influence pre-screen loss if most of the tagged steelhead survived the initial entrainment period. If predation is not immediate, environmental factors would be more relevant at or near the time of death and not at the time of entrainment. Many other factors could influence steelhead pre-screen loss rate. With many variables potentially influencing steelhead pre-screen loss rate such as radial gate operations, barometric pressure, etc, a large variance in that rate may occur and mask the influence of any single factor. Thus, the influence of only one variable may be difficult to detect statistically, but could be important biologically.

In 2007 there was no significant difference in monthly pre-screen loss estimates. However, there was a difference in time to salvage by month of release for PIT tagged steelhead. Steelhead released in February had greater times to salvage than steelhead released in January and April. SWP operational conditions were different in January and April than in February and March. In January, the Harvey Banks Pumping Plant was generally pumping continuously which led to higher average daily pumping rates than in February, March, and April. The Harvey Banks Pumping Plant was not continuously pumping and there was a reduction in average daily pumping rate during those months in comparison to January. Additionally, beginning at the end of April operational conditions changed in response to Vernalis Adaptive Management Plan (VAMP). The Harvey Banks Pumping Plant had significant pumping rate reductions or a zero pumping rate in early May. Perhaps because of this, no PIT tagged steelhead released at the radial gates were salvaged after April 30, 2007, even though water temperatures did not become lethal until June. Thus, operational conditions, such as pumping rate and duration of pumping, may effect the time it takes for steelhead to move from the radial gates to the SFPF. However, analysis of the movement rates of acoustic tagged steelhead did not show any statistical differences in steelhead movement rates that could be attributed to SWP operational conditions.

Steelhead movement rates were not related to changes in water temperature, turbidity level, light intensity level, radial gate operational conditions, or export rate. However, the acoustic telemetry equipment used was not designed to quantify movement rates of tagged fish. Generally movement rate information requires faster pinging tags with specialized 3D tracking equipment or 2D mobile monitoring equipment. Even with the equipment limitations steelhead movement rate was shown to be negatively correlated with time since release, or entrainment, for acoustic tagged steelhead. The longer steelhead remained in the Forebay the slower the movement rate. It is hypothesized that steelhead may become residualized within the Forebay. Residualism occurs when steelhead juveniles do not outmigrate as smolts with the rest of their cohort (McMichael and others, 1997; Sharpe and others, 2007). The water flow entering the Forebay through the radial gates may provide a consistent food supply for steelhead. However, this hypothesis is counter intuitive to what one would expect given that the steelhead used in the study appeared to be smolts and thus, should be looking to move downstream. Perhaps there is no directional flow for steelhead to detect within the Forebay and therefore no motivation to move toward the SFPF.

Results of the 2007 full-scale study and the 2005 and 2006 pilot studies show that steelhead emigrate from Clifton Court Forebay through the radial gates. A few steelhead observed emigrating in 2007 were also observed moving downstream towards the Pacific Ocean. However, a few of the steelhead observed emigrating in 2007 were also observed moving rapidly upstream following a similar movement pattern to that of striped bass seen emigrating from the Forebay. Thus, it is likely that some of the steelhead seen emigrating from the Forebay through the radial gates were actually in the stomach of a striped bass and were not actual steelhead movements. Without further information, it is difficult to say how many of the steelhead observed emigrating were actually steelhead. The method used for trimming steelhead detections may not have been adequate to remove all confounding striped bass movements. Given the uncertainty in the number of live steelhead emigrating from the Forebay, NMFS recommended that the pre-screen loss rate not be adjusted for the percentage of steelhead acoustic tags observed emigrating from Clifton Court Forebay into Old River. Regardless of the confounding results, steelhead possess the swimming capacity to effectively navigate the water velocities at the radial gates. At least one PIT tagged steelhead emigrated and was recovered at the TFCF.

8.3.2 Striped Bass Contributions to the Steelhead Pre-screen Loss Rate

Although there were many striped bass captured less than 550 mm (22 in) in length, it was difficult to capture large numbers of striped bass greater than 550 mm (22 in) in length. Those striped bass that were tagged and released had movement patterns that included multiple trips to the radial gates and the intake canal. Striped bass spent considerable time at both locations and a few striped bass made multiple trips between the radial gates and the intake canal. These results may be biased given that the striped bass were only collected in two locations: near the radial gates and within the intake canal. However, Bolster (1986) also found that striped bass utilized the area near the radial gates predominantly during the winter and spring when the density of prey in the Forebay is low. Even though striped bass spent considerable time near the radial gates and within the intake canal, neither radial gate operations nor Harvey Banks Pumping Plant operations had a significant effect on the proportion of time spent in those locations. Thus, striped bass may not be cuing in on the direct operations, but rather have learned that if they stay long enough a meal will become available. Pikeminnow exhibit a similar behavior on the Columbia River as they are commonly observed immediately downstream of dams (Beamsederfer and Rieman, 1991, Gadomski and Hall-Griswold, 1992). Furthermore, the occurrence of striped bass may be more dictated by prey abundance than by short term changes in water operations.

Striped bass movement rates were not related to changes in water temperature, turbidity level, or light intensity level. However, the acoustic telemetry equipment used was not designed to quantify movement rates of tagged fish. Even with the equipment limitations it is likely that water temperature and turbidity did not influence the movement rates of striped bass as most of Clifton Court Forebay is not stratified and the frequent winds observed at the Forebay keep the water well mixed. However, temperature stratification was measured on a non-windy day in the 18.3+ m (60+ ft) deep hole adjacent to the radial gates during the 2007 full-scale study. Given the frequency of windy days observed during the 2007 study period it is unlikely that a thermal refuge persisted.

Although this study focused on striped bass as the primary predator fish species, other predators were captured within the Forebay during striped bass sampling. A small number of white catfish were captured by gill netting near the radial gates. However, the white catfish were likely too small to consume a juvenile steelhead. Additionally, a small number of largemouth bass were captured in the intake canal during hook and line sampling events, but like the white catfish were likely too small to consume juvenile steelhead. Thus, other predatory fish species are residing within the Forebay, but may or may not be contributing to steelhead pre-screen loss. As the predatory fish sampling methods were designed specifically to capture striped bass, it is impossible to quantify the effect that these other predator fish species may be having on steelhead entrained within the Forebay.

8.3.3 Avian Predation

Avian predation on fishes was observed in the Forebay and can be linked to SWP operations. The avian predation component of this study showed that Double Crested Cormorants tend to feed when the radial gates are open. This is not surprising, given the large numbers of fish entering the Forebay through the radial gates as shown via historical fish salvage data. When the radial gates are open, a turbulent plume of water extends from the opening of the radial gates into zone 1 (Figure 38). As fish pass through this area, they could be disoriented and become more susceptible to predation. Furthermore, cormorants are efficient, deep water predators. This area of turbulence near the gates is approximately 15.2 m to 18.3 m (50 to 60 ft) deep and cormorants appear to be exploiting this area effectively.

Interestingly, cormorant abundance decreased as steelhead abundance increased in the Forebay. SWP operations may have been a reason for this discontinuity between abundance of cormorants and steelhead. Water exports in late April decreased substantially due to implementation of the Vernalis Adaptive Management Plan (VAMP), which may have contributed to decline of entrained and salvaged steelhead (DFG, 2008) (Figure 56). However, this reduction in pumping and the resulting decrease in steelhead occurred well after the cormorants' abundance decline (Figure 52).

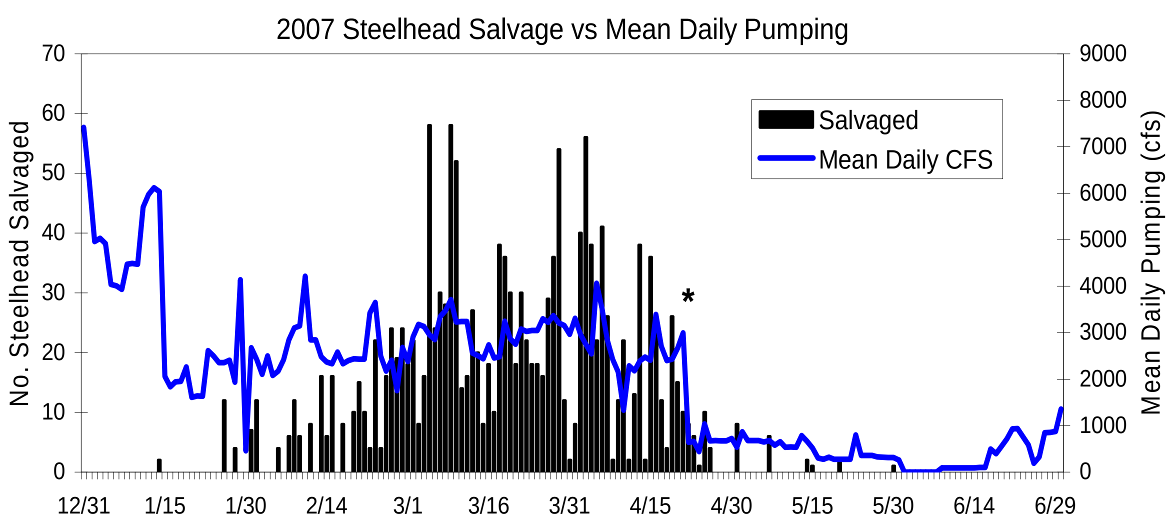

Figure 56. Relationship between 2007 daily total salvage of juvenile steelhead and mean daily pumping exports from the Harvey Banks Pumping Plant. The asterisk denotes the beginning of pumping restrictions during VAMP.

Cormorant life history may explain the lack of overlap in abundance between cormorants and steelhead in the Forebay. Double Crested Cormorants are opportunistic predators (Tommy King, Personal Communication), prey on an array of different fish species, and are able to shift between species based on availability. Fish collection data (DFG, 2008) from the SFPF showed that juvenile striped bass and American shad were the most abundant fishes entrained into the Forebay and salvaged during January and February 2007 (Figure 57). Salvage numbers for these two species dropped considerably in February and they were in negligible numbers for the rest of the 2007 study period. Declines in American shad and striped bass coincided with the cormorant abundance decline (Figure 52). Therefore, it is plausible that these birds were preying on more abundant fishes, American shad and striped bass, entering the Forebay and moved when these fishes became relatively scarce.

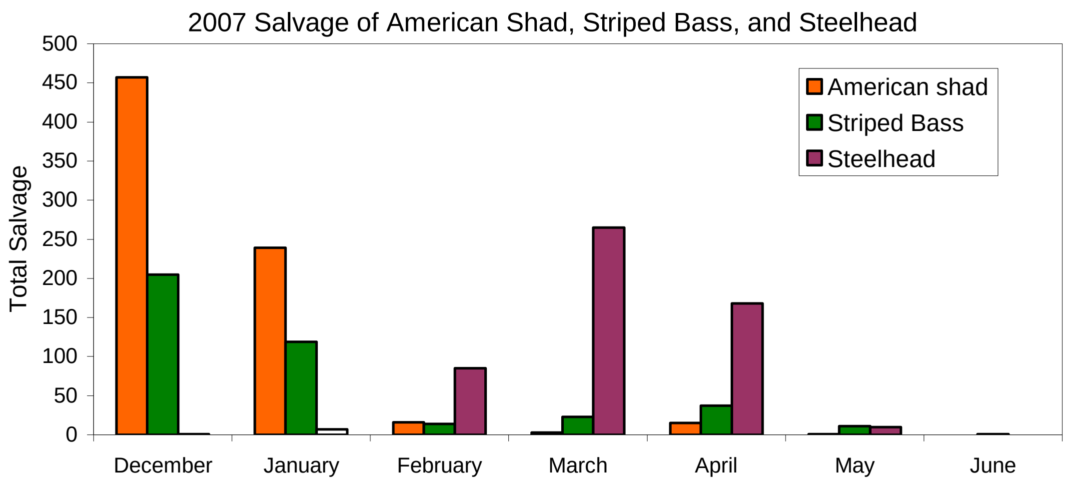

Figure 57. Monthly total salvage for American shad, striped bass and steelhead (100-300 mm fork length) at the John E. Skinner Delta Fish Protective Facility.

Another plausible reason for the difference in timing of cormorant and steelhead abundances in the Forebay is the migratory nature of the birds themselves. Double Crested Cormorants usually arrive at their wintering grounds in November and remain there until April, then move back to their home range (Aderman and Hill, 1995). In this case, much of the cormorant decline may be due the birds migrating from the area. The few cormorants observed during April and May might have been a residential population (Dan Anderson, UC Davis, Personal Communication).

Cormorants are widely recognized as being an efficient avian piscivore. In aquaculture, many fish farms suffer major losses of their stocks due to cormorant predation. People have capitalized on their proficiency as a piscivore by domesticating them in Southeast Asia to catch fish for human consumption. In the wild, cormorants can have large negative impacts on local fish numbers. These birds are capable of consuming up to 1/3 of their body weight per day (Robertson, 1974). One study estimated the number of subadult trout taken by cormorants during their 8 month study to be greater than the number of fish observed during a 12 month creel census nearby (Modde and Wasowicz, 1996). The same study found that cormorants' strong affinity for salmonids is exhibited by distributing themselves wherever trout fingerlings were in a reservoir and by consuming mostly trout despite presence of many other fish. Based on the relevant literature and our observations, we conclude that cormorants almost certainly consume steelhead in Clifton Court Forebay. However, the magnitude of this consumption has not been established. Without stomach content analyses or bioenergetics modeling, determination of the magnitude of juvenile steelhead consumption would be a difficult task. Evidence of avian predation on fishes belonging to the juvenile steelhead size range comes from approximately 10 occasions during this study where cormorants were observed swallowing fish that were estimated to be between 200 to 300 mm (7.8 to 11.8 in) long (Figure 58). There was additional evidence of possible avian predation, as a few acoustic tagged steelhead were only detected for a short time near the radial gates with no subsequent detections. It could be possible for an avian predator to consume a steelhead and fly away with the tag in the bird's stomach, thus, accounting for no subsequent detections. However, the possibility remains that the tags simply malfunctioned and the steelhead were not consumed by a bird.

Figure 58. Photograph of a Double Crested Cormorant with an unidentified fish in its mouth taken after the radial gates were open and immediately following an acoustic tagged steelhead release in 2007.

Low numbers of herons made it difficult to test for any effects or observe any trends or patterns in their abundance and distribution in the Forebay. With regards to radial gate operations, it is unlikely that percent foraging in herons would be affected due to their life history. Herons are wading birds and would not be able to take forage in the deep and often turbulent water near the radial gates. Opening the radial gates nevertheless provides an influx of water and presumably prey to even the shallow portions of the Forebay. As steelhead were shown to utilize the majority of the Forebay, it may be possible for herons to consume steelhead in the shallows.

It was difficult to determine what factor(s) may be contributing to the vulnerability of fish to avian predation within the Forebay. However, one such factor was identified. The presence of stationary debris in the Forebay (e.g., tree branches called 'snags') provides refuge for cormorants. Snags allow cormorants to rest after foraging and remain nearby to forage when the radial gates are open again. A search effort was conducted for acoustic tags that may have been excreted by cormorants close to snags, but no tags were found.

9.0 Findings

The following findings are based on the results from the pilot studies conducted in 2005 and 2006 and the 2007 full-scale study:

Steelhead

1. Many entrained steelhead remained within the Forebay for extended periods of time, i.e. greater than 60 days.
2. Steelhead utilized much of the Forebay and exhibited random movement patterns.
3. Steelhead were shown to emigrate from the Forebay through the radial gates.
4. Many steelhead, 19% of the acoustic tagged steelhead released at the radial gates in 2007, were detected within the intake canal leading to the SFPF.
5. 3% of the acoustic tagged steelhead released at the radial gates in 2007 were salvaged.
6. In 2007, the PIT tagged steelhead pre-screen loss rate within Clifton Court Forebay was between 78 ±4% and 82 ±3% (Mean ±95% Confidence Interval).
7. PIT tagged steelhead pre-screen loss rate estimates were not significantly different by month in 2007.
8. Time to salvage changed by month of entrainment with increased time to salvage by PIT tagged steelhead entrained in February.
9. Acoustic tagged steelhead movement rates were not related to water temperature, turbidity, export rate, radial gate water velocity, or light intensity.
10. Water temperature or light observed at the time of release had no significant effect on PIT tagged steelhead pre-screen loss rate.
11. The large amount of variability in acoustic tagged steelhead movement rates may indicate a great number of variables influence steelhead movement behavior.
12. As time since entrainment increased, acoustic tagged steelhead movement rates decreased.

Striped Bass

1. Striped bass were captured in areas with the highest water velocity, the intake canal and near the radial gates.
2. Striped bass spent long periods of time near the radial gates and in the intake canal. However, the time spent at these locations was not related to SWP operations.
3. Striped bass were observed to make several trips between the radial gates and the trashboom.
4. Striped bass movement rates were not related to water temperature, turbidity, or light intensity.
5. Striped bass were observed to emigrate from Clifton Court Forebay through the radial gates and then re-enter the Forebay again at a later time.

Avian Predation

1. Of the numerous bird species that frequent the Forebay from January-June, the following species or taxa were thought to be capable of eating 200 to 300 mm (7.8 to 11.8 in) sized fish: Double Crested Cormorant, Western Grebe, Clarke's Grebe, Great Blue Heron, gulls, Great Egret, and White Pelicans.
2. The west side of Clifton Court Forebay had consistently lower bird densities.
3. Cormorants were the second most numerous predatory bird species observed.
4. Cormorant counts were higher near the radial gates.
5. Cormorants were observed preying on fish approximately 200 to 300 mm (7.8 to 11.8 in) long.
6. Cormorants displayed a higher percent of foraging behavior in the area adjacent to the radial gates when the radial gates were open.

10.0 Recommendations for Future Work

Central Valley Steelhead are listed as threatened under the Endangered Species Act. A population risk analysis should be completed for these fish that takes into account this pre-screen loss rate. In addition, a management action plan (MAP) should be created that includes the steps to be taken to reduce the pre-screen loss rate of Central Valley steelhead within Clifton Court Forebay. One step could include a predator removal program. Predator removals could reduce pre-screen loss within Clifton Court Forebay. When survival is low (< 25%) due to predation by high numbers of predators, a reduction in predator numbers (> 50%) can yield a doubling in survival rate (Ricker, 1952). Predator removals along with other steps should be explored as part of the MAP.

Steelhead and striped bass movement rate information was inconclusive in the 2007 study. Steelhead may use water flow patterns to determine where and when to move. However, water flow patterns within the Clifton Court Forebay were not investigated. Collecting hydrodynamics data within the Forebay may give insight into the uncertainty of steelhead movements within the Forebay. The hydrodynamics data could be used to construct a hydrodynamics model to test different hypothesis regarding water flow and fish movement patterns within the Forebay. SWP operational changes could be modeled to see if any changes in SWP operations result in beneficial flow patterns within the Forebay.

The employed acoustic telemetry equipment for these studies had limitations that made interpretation of results difficult. Future studies should evaluate the use of other telemetry technologies e.g. three-dimensional tracking systems. Also, future telemetry studies would highly benefit from a striped bass gut evacuation rate experiment. Gut evacuation rate studies have been conducted to determine the rate at which organic material is evacuated. However, studies have not been performed to determine the evacuation rates for inorganic materials, such as acoustic tags. A striped bass gut evacuation experiment should be conducted to determine the time it takes to evacuate an acoustic tag after consuming an acoustic tagged steelhead. Results from a gut evacuation study would provide a better gut evacuation estimate, than the estimate used for the 2007 full-scale study data analysis, to back calculate the date and time that acoustic tagged steelhead were consumed given a tag deposition date and time.

Feasibility studies should be conducted to determine if changes to the configuration of Clifton Court Forebay could reduce the entrainment of fishes. Feasibility studies could also determine if the configuration of Clifton Court Forebay could be changed to shorten the time it takes entrained fish to reach the SFPF.

Although there was not any conclusive evidence that any birds preyed upon tagged steelhead, the 2007 study observations suggest that avian predation is occurring and can be traced to the operation of the radial gates. To achieve greater certainty of avian predation, diet composition and consumption-rate analyses would be necessary. A bioenergetics approach may provide useful information in those regards. Furthermore, a radio telemetry study would help characterize movement of predatory birds. Further investigations should characterize the benefit of removing bird refuges from Clifton Court Forebay and the installation of a non-lethal bird deterrent system.

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13.0 Appendices

A.1 VEMCO Acoustic Tag Specifications

Table A- 1. VEMCO acoustic tag specifications for tags used to tag either steelhead or striped bass.

Tag	Battery Option	Submap ID	Length (mm)	Weight in Air (g)	Power Output (dB)	Min. Off Time (s)	Max. Off Time (s)
V8SC	6L	B	21	2.9	142	20	60
V9	6L	B	21	2.9	142	20	60
V13	1L	B	36	11.0	147	20	60
V16	3H	B	64	25.0	165	20	60

A.2 Acoustic Tagged Fish Released

Table A- 2. Acoustic tag identification numbers and release information for acoustic tagged steelhead and striped bass.

Tag ID	Species	Date Released	Release Location
1236	Steelhead	22-Mar-07	Radial Gates
1246	Steelhead	28-Apr-07	Radial Gates
1260	Steelhead	28-Apr-07	Radial Gates
1285	Steelhead	23-Mar-07	Radial Gates
1286	Steelhead	22-Mar-07	Radial Gates
1288	Steelhead	28-Apr-07	Radial Gates
1292	Steelhead	23-Mar-07	Trash Rack
1293	Steelhead	22-Mar-07	Radial Gates
1294	Steelhead	23-Mar-07	Radial Gates
1296	Steelhead	23-Mar-07	Radial Gates
1297	Steelhead	8-Feb-07	Radial Gates
1298	Steelhead	7-Feb-07	Trash Rack
1299	Steelhead	7-Feb-07	Radial Gates
1300	Steelhead	7-Feb-07	Radial Gates
1301	Steelhead	8-Feb-07	Radial Gates
1302	Steelhead	7-Feb-07	Radial Gates
1303	Steelhead	7-Feb-07	Radial Gates
1304	Steelhead	8-Feb-07	Radial Gates
1305	Steelhead	7-Feb-07	Radial Gates
1306	Steelhead	7-Feb-07	Radial Gates
1307	Steelhead	7-Feb-07	Trash Rack
1308	Steelhead	7-Feb-07	Trash Rack
1309	Steelhead	7-Feb-07	Radial Gates
1310	Steelhead	7-Feb-07	Radial Gates
1311	Steelhead	7-Feb-07	Radial Gates
1312	Steelhead	7-Feb-07	Radial Gates

1313	Steelhead	7-Feb-07	Trash Rack
1314	Steelhead	7-Feb-07	Radial Gates
1315	Steelhead	8-Feb-07	Radial Gates
1316	Steelhead	7-Feb-07	Radial Gates
1317	Steelhead	7-Feb-07	Radial Gates
1318	Steelhead	7-Feb-07	Trash Rack
1319	Steelhead	7-Feb-07	Trash Rack
1320	Steelhead	7-Feb-07	Trash Rack
1321	Steelhead	8-Feb-07	Radial Gates
1322	Steelhead	8-Feb-07	Radial Gates
1323	Steelhead	7-Feb-07	Trash Rack
1324	Steelhead	8-Feb-07	Radial Gates
1325	Steelhead	7-Feb-07	Radial Gates
1326	Steelhead	7-Feb-07	Radial Gates
1327	Steelhead	7-Feb-07	Radial Gates
1328	Steelhead	8-Feb-07	Radial Gates
1329	Steelhead	7-Feb-07	Radial Gates
1331	Steelhead	8-Feb-07	Radial Gates
1332	Steelhead	7-Feb-07	Radial Gates
1333	Steelhead	7-Feb-07	Trash Rack
1334	Steelhead	7-Feb-07	Radial Gates
1335	Steelhead	7-Feb-07	Radial Gates
1336	Steelhead	8-Feb-07	Radial Gates
1339	Steelhead	23-Mar-07	Radial Gates
1340	Steelhead	28-Apr-07	Radial Gates
1341	Steelhead	23-Mar-07	Radial Gates
1342	Steelhead	23-Mar-07	Radial Gates
1343	Steelhead	22-Mar-07	Trash Rack
1346	Steelhead	23-Mar-07	Radial Gates
1347	Steelhead	22-Mar-07	Radial Gates
1348	Steelhead	23-Mar-07	Radial Gates
1349	Steelhead	23-Mar-07	Radial Gates
1350	Steelhead	22-Mar-07	Radial Gates
1351	Steelhead	23-Mar-07	Trash Rack
1352	Steelhead	23-Mar-07	Radial Gates
1353	Steelhead	22-Mar-07	Radial Gates
1354	Steelhead	22-Mar-07	Radial Gates
1357	Steelhead	23-Mar-07	Radial Gates
1358	Steelhead	23-Mar-07	Trash Rack
1359	Steelhead	23-Mar-07	Radial Gates
1360	Steelhead	23-Mar-07	Radial Gates
1361	Steelhead	22-Mar-07	Trash Rack
1363	Steelhead	23-Mar-07	Radial Gates
1364	Steelhead	23-Mar-07	Radial Gates
1365	Steelhead	22-Mar-07	Trash Rack
1366	Steelhead	23-Mar-07	Radial Gates
1367	Steelhead	22-Mar-07	Radial Gates
1368	Steelhead	23-Mar-07	Radial Gates
1369	Steelhead	22-Mar-07	Radial Gates
1370	Steelhead	23-Mar-07	Radial Gates

1371	Steelhead	22-Mar-07	Radial Gates
1372	Steelhead	23-Mar-07	Radial Gates
1373	Steelhead	23-Mar-07	Radial Gates
1374	Striped Bass	5-Apr-07	Intake Canal
1375	Striped Bass	13-Apr-07	Intake Canal
1376	Striped Bass	13-Apr-07	Intake Canal
1377	Striped Bass	24-May-07	Radial Gates
1378	Striped Bass	3-Apr-07	Radial Gates
1379	Striped Bass	25-May-07	Radial Gates
1380	Striped Bass	16-Mar-05	Radial Gates
1381	Striped Bass	18-Mar-05	Radial Gates
1381	Striped Bass	24-May-07	Radial Gates
1382	Striped Bass	18-Mar-05	Radial Gates
1382	Striped Bass	24-May-07	Radial Gates
1383	Striped Bass	18-Mar-05	Radial Gates
1383	Striped Bass	24-May-07	Radial Gates
1384	Striped Bass	16-Mar-05	Radial Gates
1384	Striped Bass	25-Apr-07	Intake Canal
1385	Striped Bass	18-Mar-05	Radial Gates
1387	Striped Bass	18-Mar-05	Radial Gates
1388	Striped Bass	16-Mar-05	Radial Gates
1388	Striped Bass	13-Apr-07	Intake Canal
1389	Striped Bass	17-Mar-05	Radial Gates
1390	Striped Bass	18-Mar-05	Radial Gates
1391	Striped Bass	18-Mar-05	Radial Gates
1394	Striped Bass	17-Mar-05	Radial Gates
1395	Striped Bass	18-Mar-05	Radial Gates
1396	Striped Bass	18-Mar-05	Radial Gates
1398	Striped Bass	17-Mar-05	Radial Gates
1399	Striped Bass	17-Mar-05	Radial Gates
1409	Striped Bass	19-Dec-06	Radial Gates
1410	Striped Bass	21-Dec-06	Intake Canal
1411	Striped Bass	21-Dec-06	Intake Canal
1412	Striped Bass	9-Jan-07	Radial Gates
1413	Striped Bass	9-Jan-07	Intake Canal
1414	Striped Bass	9-Jan-07	Intake Canal
1415	Striped Bass	18-Jan-07	Radial Gates
1416	Striped Bass	18-Jan-07	Radial Gates
1417	Striped Bass	18-Jan-07	Radial Gates
1418	Striped Bass	18-Jan-07	Radial Gates
1420	Striped Bass	8-Mar-07	Radial Gates
1421	Striped Bass	8-Mar-07	Radial Gates
1422	Striped Bass	8-Mar-07	Radial Gates
1424	Striped Bass	8-Mar-07	Radial Gates
1425	Striped Bass	9-Mar-07	Intake Canal
1426	Striped Bass	8-Mar-07	Radial Gates
1427	Striped Bass	9-Mar-07	Intake Canal
1428	Striped Bass	3-Apr-07	Intake Canal
1671	Steelhead	22-Mar-06	Radial Gates
1672	Steelhead	28-Mar-06	Radial Gates

1673	Steelhead	28-Mar-06	Radial Gates
1674	Steelhead	22-Mar-06	Radial Gates
1675	Steelhead	28-Mar-06	Radial Gates
1676	Steelhead	28-Mar-06	Radial Gates
1677	Steelhead	23-Mar-06	Radial Gates
1678	Steelhead	22-Mar-06	Radial Gates
1679	Steelhead	22-Mar-06	Radial Gates
1680	Steelhead	22-Mar-06	Radial Gates
1681	Steelhead	23-Mar-06	Radial Gates
1683	Steelhead	28-Mar-06	Radial Gates
1684	Steelhead	22-Mar-06	Radial Gates
1685	Steelhead	23-Mar-06	Radial Gates
1686	Steelhead	22-Mar-06	Radial Gates
1687	Steelhead	22-Mar-06	Radial Gates
1688	Steelhead	23-Mar-06	Radial Gates
1689	Steelhead	23-Mar-06	Radial Gates
1690	Steelhead	23-Mar-06	Radial Gates
1691	Steelhead	22-Mar-06	Radial Gates
1692	Steelhead	22-Mar-06	Radial Gates
1693	Steelhead	23-Mar-06	Radial Gates
1694	Steelhead	28-Mar-06	Radial Gates
1695	Steelhead	23-Mar-06	Radial Gates
1696	Steelhead	23-Mar-06	Radial Gates
1697	Steelhead	28-Mar-06	Radial Gates
1698	Steelhead	28-Mar-06	Radial Gates
1699	Steelhead	23-Mar-06	Radial Gates
1700	Steelhead	28-Mar-06	Radial Gates
1961	Steelhead	5-Apr-05	Radial Gates
1962	Steelhead	5-Apr-05	Radial Gates
1963	Steelhead	5-Apr-05	Radial Gates
1964	Steelhead	5-Apr-05	Radial Gates
1965	Steelhead	5-Apr-05	Radial Gates
1966	Steelhead	5-Apr-05	Radial Gates
1967	Steelhead	7-Apr-05	Radial Gates
1968	Steelhead	5-Apr-05	Radial Gates
1969	Steelhead	5-Apr-05	Radial Gates
1970	Steelhead	5-Apr-05	Radial Gates
1971	Steelhead	7-Apr-05	Radial Gates
1972	Steelhead	7-Apr-05	Radial Gates
1973	Steelhead	7-Apr-05	Radial Gates
1974	Steelhead	5-Apr-05	Radial Gates
1975	Steelhead	6-Apr-05	Radial Gates
1976	Steelhead	6-Apr-05	Radial Gates
1977	Steelhead	6-Apr-05	Radial Gates
1978	Steelhead	7-Apr-05	Radial Gates
1979	Steelhead	7-Apr-05	Radial Gates
1980	Steelhead	6-Apr-05	Radial Gates
1981	Steelhead	6-Apr-05	Radial Gates
1982	Steelhead	6-Apr-05	Radial Gates
1983	Steelhead	6-Apr-05	Radial Gates

1984	Steelhead	6-Apr-05	Radial Gates
1985	Steelhead	6-Apr-05	Radial Gates
1986	Steelhead	6-Apr-05	Radial Gates
1987	Steelhead	7-Apr-05	Radial Gates
1988	Steelhead	7-Apr-05	Radial Gates
1989	Steelhead	7-Apr-05	Radial Gates
1990	Steelhead	7-Apr-05	Radial Gates

A.3 CIMIS Light Data

The "Brentwood #47" weather station in the CIMIS database has been in operation since Nov. 18, 1985 and is located at 37.93 North Latitude and -121.66 West Longitude (NAD83). This weather station is approximately 8.06 miles (using Google Earth version 4.2.0196.2018, Mountain View, CA., 2007) from the CHTR Study Facility. The Brentwood #47 CIMIS weather station operates on Pacific Standard Time (PST) and records hourly solar radiation in Langley's as an average of the previous 60 minute-by-minute readings whereas daily solar radiation is an average of the previous 1,440 minute-by-minute readings. The CIMIS data is an average of the previous hour also known as a trailing average. For example, if you have 561 Ly/d at 10:00, this value is an average of 60 minute-by-minute readings between 09:00 and 10:00 (Bekele Temesgen, Personal Communication).

The Langley data from the Brentwood #47 CIMIS website was used to estimate PAR for the period of December 19, 2006 01:00 to January 11, 2007 11:00. The CIMIS Langley data was converted to PAR using the following formula (Fisher and others, 2003):

$$\frac{\text{Lagley}}{\text{day}} \times \frac{\text{day}}{24\,\text{hr}} \times \frac{\text{hr}}{60\,\text{min}} \times \frac{698\ \text{Watts/m}^2}{\text{Langley/min}} \times \frac{4.57\ \mu\text{mol/m}^2\text{/sec}}{\text{Watt/m}^2} \times 50\% = \text{PAR}$$

Therefore, Langley/day x 1.1076 = PAR (mol/m^2/sec)

PAR estimates were converted from a trailing average to a leading average by moving each hourly estimate back one hour. Once converted to a leading average, the December 19, 2006 through January 11, 2007 estimates were added to the hourly light dataset recorded at the CHTR Study Facility.

State of California
California Natural Resources Agency
Department of Water Resources

RELEASE SITE PREDATION STUDY

MAY 2010

ARNOLD SCHWARZENEGGER	**LESTER A. SNOW**	**MARK W. COWIN**
Governor State of California	Secretary California Natural Resources Agency	Director Department of Water Resources

State Of California
California Natural Resources Agency
Department of Water Resources

RELEASE SITE PREDATION STUDY

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List of Abbreviations

ANOVA	Analysis of Variance
CDEC	California Data Exchange Center
CHTR	Collection, Handling, Transport, Release
Consortium	California Fish Tracking Consortium
CPUE	Catch Per Unit Effort
CVP	Central Valley Project
CWT	Coded Wire Tag
DIDSON	Dual Frequency Identification Sonar
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
DO	Dissolved Oxygen
EC	Electrical Conductivity
FCCL	UC Davis Fish Conservation and Culture Laboratory
FL	Fork Length
GPS	Global Positioning System
NMFS	National Marine Fisheries Service
HPR	Heading, Pitch, and Roll
PVC	Polyvinyl Chloride
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project
TFCF	Tracy Fish Collection Facility
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
UTM	Universal Transverse Mercator
VAMP	Vernalis Adaptive Management Plan
VUE	VEMCO User Environment
WAAS	Wide Area Augmentation System

Executive Summary

The State Water Project (SWP) John E. Skinner Delta Fish Protective Facility (SDFPF; Figure 1) and federal Central Valley Project (CVP) Tracy Fish Collection Facility (TFCF) were constructed in the late 1950's and 1960's to salvage fish entrained at the southern Sacramento-San Joaquin Delta (Delta) water export facilities. These facilities protect fish by using a series of behavioral dewatering louvers to concentrate fish into holding tanks where they are held for later transport back into the Delta away from the zone of influence of the water export facilities. Fish are held in these facilities until they are collected by draining each holding tank into a haul-out bucket (collection), transferred to a water tanker truck (handling), transported to release sites in the central Delta near the confluence of the Sacramento and San Joaquin Rivers (transport), and released back into the Delta at fixed release points (release; Figures 2 & 3).

In response to concerns about the survival of sensitive fish species exposed to the Collection, Handling, Transport, and Release (CHTR) processes at the state and federal delta water export facilities, the California Department of Water Resources (DWR) in collaboration with the California Department of Fish and Game (DFG) and U.S. Bureau of Reclamation (USBR) conducted a series of focused investigations on the CHTR phase of the salvage process. These investigations were developed to provide useful information that could serve to reduce the potential vulnerability of sensitive fish species including delta smelt (*Hypomesus transpacificus*) and Chinook salmon (*Oncorhynchus tshawytscha*) to injury and mortality during the salvage process. The results of these investigations will be used to reduce overall mortality and stress during the salvage process by making recommendations and providing baseline information for the improvement of existing salvaged fish release sites and construction of new release sites.

The Department of Water Resources' contribution to this effort was to conduct a focused investigation into the release stage of the fish salvage process at the SDFPF. The release phase investigation was composed of three separate elements, each investigating a different aspect of the release phase. Element 1: an investigation of the far-field survival of salvaged fish following release, Element 2: an investigation of release site predation, and Element 3: an investigation of the physical factors influencing mortality and injury during release. The Element 1 investigation was subsequently eliminated based on peer review comments, while the results of the Element 3 investigation will be available as a separate technical report. The results of the Element 2- Release Site Predation Study are the focus of this report.

Element 2- Release Site Predation

Fish released at the salvaged fish release sites into the Delta may experience high mortality because of predation by piscivorous fish and birds. The concentration of fish at the release sites may attract and concentrate predators in the receiving waters at the release locations. Anecdotal observations by

recreational anglers have also indicated that predatory fish are concentrated near the release locations, and field observations have documented the attraction of predatory birds to the areas during the release of salvaged fish.

The experimental design, methods, and approach for evaluating predator abundance and behavior within the receiving waters at the existing release sites included five different, but interrelated, study methods: predator sampling (electrofishing and avian predation observations), mark-recapture (acoustic & Floy tagging), Dual Frequency Identification Sonar (DIDSON) acoustic camera observations, hydroacoustics, and a hypothetical predation risk analysis driven by bioenergetics. Monitoring was conducted during five different periods (from August 2007 until April 2008) at the SWP fish release site at Horseshoe Bend on the Sacramento River and two reference/control sites along Horseshoe Bend. Monitoring consisted of using the DIDSON camera, electrofishing, avian predator observations, and Floy/acoustic tagging. These monitoring techniques were also conducted to varying degrees at other salvaged fish release sites in the Delta.

Electrofishing showed that the predator composition at the Horseshoe Bend release site included various fish species, notably largemouth bass (*Micropterus salmoides*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone saxatilis*). Catch per unit effort (CPUE) in the vicinity of the release site was highest for largemouth bass, though they were predominantly captured near the shoreline and not directly at the end of the fish release pipe. Given their piscivorous nature and substantial population near the release site, it is possible that while they may not feed directly on fish exiting the release pipe, the largemouth bass may feed on salvaged fish that disperse following release. Conversely, Sacramento pikeminnow and striped bass were the predominant piscivores captured directly at the end of the release pipe. CPUE for Sacramento pikeminnow was generally lower than that of largemouth bass, but higher than striped bass numbers at all sites.

Floy and acoustic tags were used to determine site fidelity. Largemouth bass were Floy tagged and through recapture were shown to exhibit strong site fidelity. Although largemouth bass were not tagged with acoustic tags, several striped bass and Sacramento pikeminnow were tagged with acoustic telemetry tags to examine their site fidelity and coarse scale movements. Striped bass did not exhibit strong site fidelity, remaining near a release site for only a few days or less. Conversely, some Sacramento pikeminnow showed strong site fidelity, remaining nearby a release site for as long as four months. Individuals of both species were recorded making long migrations up and down the Sacramento-San Joaquin watershed with striped bass generally detected moving downstream towards San Pablo Bay and Sacramento pikeminnow generally moving upstream in the Sacramento River. Sacramento pikeminnow were detected as far upstream as the Ord Ferry Road Bridge, and striped bass were detected as far downstream as Mare Island in San Pablo Bay.

The DIDSON camera, which provides video imagery in dark or turbid water, was used to record observations of near-field predatory fish relative abundance and behavior at three of the release sites and two control sites. The DIDSON observations showed aggregations of fish at the SWP Horseshoe Bend release site during the summer, fall, late-fall, and early spring when salvage was highest. Conversely, fewer predatory fish were observed during the winter when few fish were being salvaged and released. Observations at the SWP Curtis Landing and CVP Emmaton release sites revealed similar aggregations of predatory fish, though the aggregations were often smaller than at the SWP Horseshoe Bend release site. While the reason for the smaller aggregations was unclear, it was most likely a function of pipe designs and locations. Conversely, the two control sites located along Horseshoe Bend consistently had few if any predator sized fish present during DIDSON monitoring.

DIDSON observations revealed that predatory fish effectively exploit salvaged fish releases by holding at the end of the release pipe and capturing prey fish as they exited the pipe. DIDSON observations however, did not reveal any evidence of attraction to specific components of the release process (e.g. flushing pump activation). Rather, predators were seen remaining aggregated for long periods during non-release periods and exhibiting milling behavior. This may have been a result of some salvaged fish being trapped in the release pipe from prior releases, and slowly trickling out of the pipe over an extended period of time. Predatory fish were also observed utilizing debris trapped on the pier pilings at the release site as cover/refuge. Observations showed predatory fish rapidly dart out of the trapped debris and feed on salvaged fish a short distance away. As remedial measures for these observations, efforts are currently underway to remove the trapped debris and increase the capacity of the flushing pump in an effort to reduce predator habitat and prevent salvaged fish from becoming entrapped in the release pipe.

Hydroacoustic sonar data revealed that the reach of river including the SWP Horseshoe Bend release site did not have substantially more predators than similar control sites located further upstream in Horseshoe Bend. In fact, one of the control sites had substantially more predator sized fish than the release site. The reason for this disparity with DIDSON observations might be due to the sampling range of the two types of equipment and the numbers of fish being released at the release site. The DIDSON has a very small field of view and samples only a small volume of water, while the hydroacoustics has a much longer range and samples a large volume of water. As a result, the DIDSON was able to detect only the presence or absence of predatory fish within a couple meters of the sites, while the hydroacoustics equipment detected predatory fish abundance over a larger area. Nevertheless, the hydroacoustic data and DIDSON observations indicate that when releases are consistently large, a group of predatory fish is consistently observed near the fish release pipe. The predators observed using the DIDSON were likely fish that were actively feeding, as confirmed by the hydroacoustics. In addition, the hydroacoustics data was able to show seasonal differences in predator abundance. This was likely a result of few fish being salvaged and released, and a corresponding inconsistent food supply for predatory fish. Instead the predatory fish dispersed into the nearby area where they were sampled with the hydroacoustics but not the DIDSON.

When coupled with a bioenergetics model, the hydroacoustic data was used to determine the potential ratio of salvaged fish biomass released to salvaged fish biomass potentially consumed (by predatory fishes) occurring at the SWP Horseshoe Bend release site. Based on the bioenergetics approach, when few salvaged fish are released (<2,000, assuming 13-grams each), the predatory fish population can theoretically consume more than 10% of the fish being released. Conversely, when salvaged fish numbers are highest during the summer, the amount of biomass released is sufficient to effectively exceed the predatory fish population food demand potentially resulting in less predation. These results suggest that the magnitude of predation mortality at the release sites is strongly dependent upon the season and amount of biomass being salvaged and released. Furthermore, these results suggest that the practice of making relatively small and frequent releases of salvaged fish to reduce the stress and mortality associated with holding may have the unintended consequence of resulting in an increased rate of predation mortality.

The results of the avian predation survey showed that cormorants and gulls are the predominant avian predators on salvaged fish. Both species were observed feeding on salvaged fish at the SWP Horseshoe Bend release site including DIDSON footage of cormorants actively chasing and capturing salvaged fish as they exited the release pipe. Gull populations were highest earlier during the study (summer/fall), while cormorants were more common near the end of the study (winter/spring). Significantly more avian predators were observed at the SWP Horseshoe Bend release site and CVP Emmaton release site than at either of the control sites. Piscivorous birds were generally rare and were not observed feeding at the control sites or at the SWP Curtis Landing release site. At the SWP Horseshoe Bend release site, birds were routinely observed exploiting an elevated agricultural intake structure as a resting and observation spot before and after salvaged fish releases. Consequently, as a remedial measure to reduce avian predation on salvaged fish, bird deterrents were placed on the agricultural intake structure to prevent further exploitation of the structure for feeding purposes. At the CVP Emmaton site, birds were also observed perched on the railing for the catwalk extending out to the end of the pipe. Given their large metabolic demands, even a few piscivorous birds may be capable of having a substantial predation effect by potentially consuming large numbers of salvaged fish.

Results of the release site predation monitoring suggest that predation at the release site by several species of fish and birds could have a substantial effect on the number of fish surviving the release phase of the salvage process depending on the season and amount of biomass being salvaged and released. Since salvage rates may vary dramatically from day to day, no attempt was made to estimate an exact rate of predation mortality. Rather a series of estimates of potential prey consumption by predators based on predator species and time of year (bioenergetics) was developed. These estimates could be used to calculate the potential vulnerability to predation of a specific amount of biomass being salvaged and released. A series of recommendations and future research questions are also outlined in this report with the goal of reducing release site predation through modifications of the existing release sites and guidelines for the site selection and design of new release sites. Efforts are currently under development to implement these recommendations in compliance with the 2009 National Marine Fisheries Service Biological Opinion for SWP/CVP operations which calls for a reduction of release site predation by 50 percent.

1.0 Introduction

The John E. Skinner Delta Fish Protective Facility (Figures 1 & 2) was built in the 1960s and designed to protect fish in the Sacramento-San Joaquin Delta from entrainment into the California Aqueduct. The fish facility was designed with a maximum louver screening capacity of 291 m^3/s (10,300 cfs). Screened fish are bypassed into holding tanks from which they are loaded into tanker trucks for transport to release sites outside the zone of influence of the South Delta water diversions. Water and fish diverted from Old River enter Clifton Court Forebay, which is used as a regulating reservoir for the pumping plant. The water and fish drawn from the forebay first travel by an intake channel to a floating trash boom designed to intercept floating debris and guide it to a trash conveyor. Water and fish then flow through a trash rack to a series of louvers arranged in a Vee pattern. The louvers create a disturbance in the water to guide fish into the SDFPF. In the final stage of the fish salvage process, salvaged fish are then collected, handled, transported away from the influence of the export pumps, and released back into the Delta in a process known as Collection, Handling, Transport and Release (CHTR).

Figure 1-Aerial view of the John E. Skinner Delta Fish Protective Facility (SDFPF) including the Primary Louvers arranged in a Vee configuration

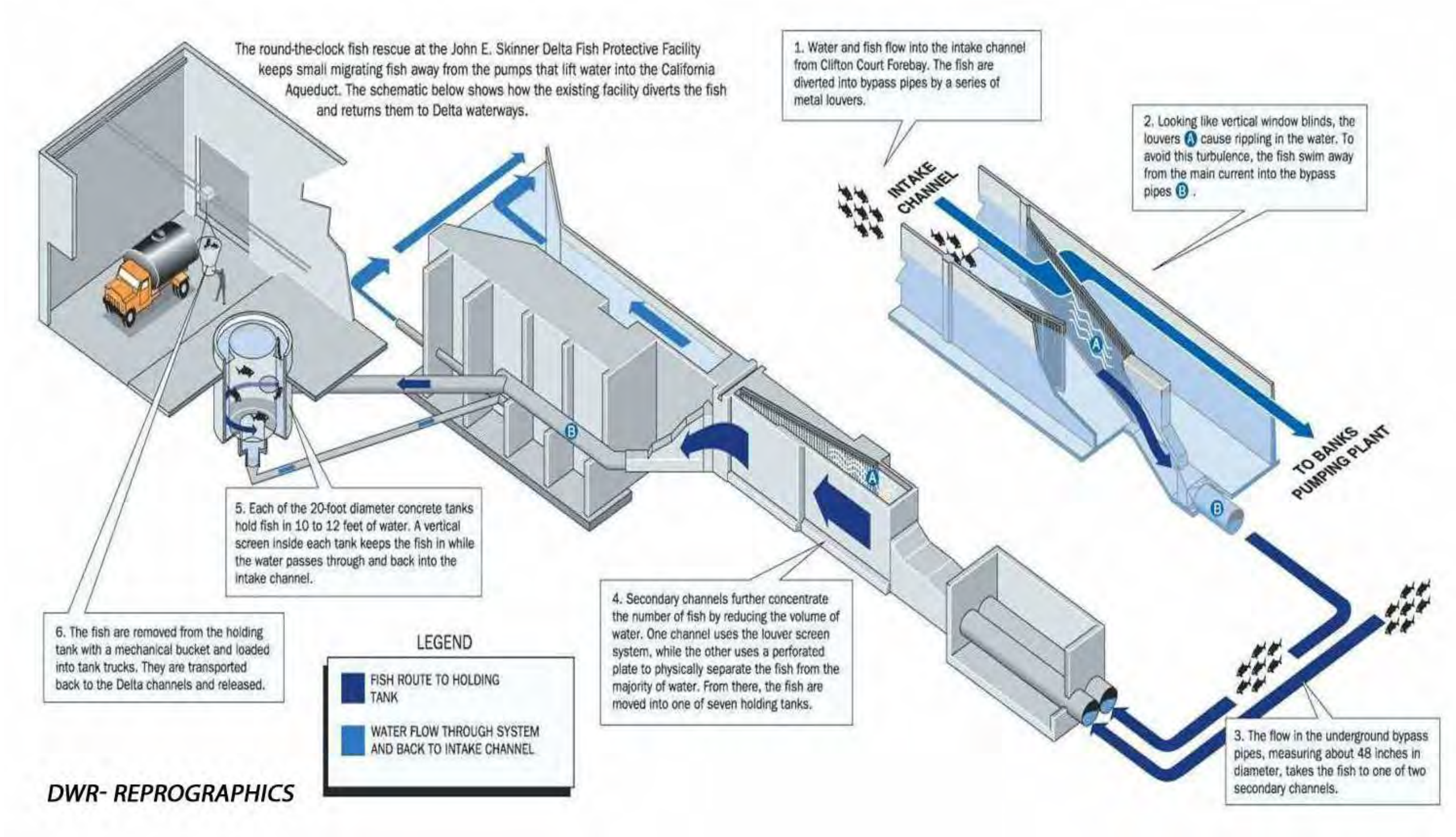


Figure 2-The fish salvage process at the SDFPF

Fish released at the salvaged fish release sites (Figure 3) into the Delta may experience high mortality because of predation by piscivorous fish and birds. During the salvage process, fish are concentrated in a relatively small area immediately after release and may be disoriented by hydraulic turbulence as water and fish are released at a relatively high velocity through the release pipe (DWR 2005). The concentration of dead or injured fish at the release sites may attract and concentrate predators in the receiving waters at the release locations. Anecdotal observations by recreational anglers have indicated that predatory fish are concentrated near the release locations, and field observations have documented the attraction of predatory birds to the areas during the release of salvaged fish (DWR 2005). Several studies have also documented predation mortality associated with the fish salvage operations at both the SWP and CVP (Delta Fish Facilities Technical Coordinating Committee 1980, Kano 1987, DFG 1984, Fausch 2000, Willis and others 1994) and at locations in the Delta receiving waters (Pickard and others 1982). However, actual losses resulting from predation mortality by both fish and birds following release at the salvaged fish release sites are uncertain.

The 2000 CALFED Record of Decision identified the improvement or replacement of the existing fish salvage facilities of the State and Federal export facilities as a major objective to restore and protect fisheries resources (CALFED 2000a, 2000b). However, while proposed new screening facilities would have significant design improvements, a new or modified CHTR process may still be required to move salvaged fish away from the influence of the export facilities. Concerns that these CHTR processes may decrease survival of salvaged delta smelt and other sensitive fish species, which would limit the benefits of new fish screening facilities, led to a comprehensive program designed to investigate the impacts of the CHTR process and assess the potential benefits of new CHTR technologies at the state and federal water export facilities. The Interagency Ecological Program (IEP) and Central Valley Fish Facilities Review Team (CVFFRT) coordinated a series of collaborative studies designed to investigate the effectiveness of the existing fish salvage process and assess the potential benefits of new CHTR technologies at the state and federal water export facilities. The Department of Water Resources' contribution to this effort was to conduct a focused investigation into the release stage of the fish salvage process at the SDFPF. The objective of this investigation, funded by Proposition 13 bond funds and conducted with support from DFG and USBR, was to determine the survival of salvaged fish being released at the existing fish release sites and to gather the necessary scientific and engineering information for the design and operation of improved fish release facilities. The investigations focused on:

1. A comprehensive evaluation of the effects of specific components of the release stage of the salvage process on the survival of delta smelt and other species of concern including physical aspects of the release procedure
2. Collecting necessary scientific information for use in evaluating potential

alternative technologies designed to reduce stress and improve survival throughout the release stage of the salvage process

3. Developing criteria for the design of new facilities or large-scale improvements to the existing release facilities

Originally, the release stage investigation had three separate elements. Element 1– an assessment of the far-field survival of salvaged fish released at both the SWP and CVP releases sites; Element 2 – examination of the abundance, composition, and behavior of predators in the receiving waters at the release sites; and Element 3 – an evaluation of the physical factors influencing mortality and injury of fish during release. The following provides a brief description of these investigations:

- Element 1 was proposed as an assessment of the far-field survival of salvaged fish following release. It was designed to develop quantitative estimates of survival of juvenile fish experimentally released at both the SWP and CVP release sites and at control sites. The experimental design of Element 1 included mass releases of Coded Wire Tagged juvenile Chinook salmon at each salvaged fish release site and at control sites with subsequent recapture downstream using a Kodiak Trawl. Element 1 was subsequently eliminated based on IEP Management Team and peer reviewer concerns about potentially low recovery rates of marked fish using the proposed or existing trawl sampling methodology.

- Element 2, the Release Site Predation Study presented in this report, examined the abundance, composition, and behavior of predators in the receiving waters at the release sites. This study involved using multiple survey methods including electrofishing and avian point counts to determine predator composition. The study included mark-recapture using Floy and acoustic tagging to determine site fidelity along with DIDSON and hydroacoustic sonar observations to determine predator behavior and abundance. In addition, a hypothetical predation risk analysis was performed using a bioenergetics approach.

- Element 3 was designed to assess the physical factors influencing mortality of fish during release. This study assessed the survival and injury of salvaged fish as they exited the release truck and traveled down a near full scale replica release pipe. It included an evaluation of the hydraulic forces and debris loads associated with the release stage including release pipe hydraulics, release pipe design, and the effect of debris on sensitive salvaged fish species. The results of the Element 3 investigation are presented in a separate report, but generally concluded that survival of sensitive fish (adult delta smelt and juvenile Chinook salmon) through the release stage is high and was not significantly different from control treatments regardless of debris loading (DWR 2010).

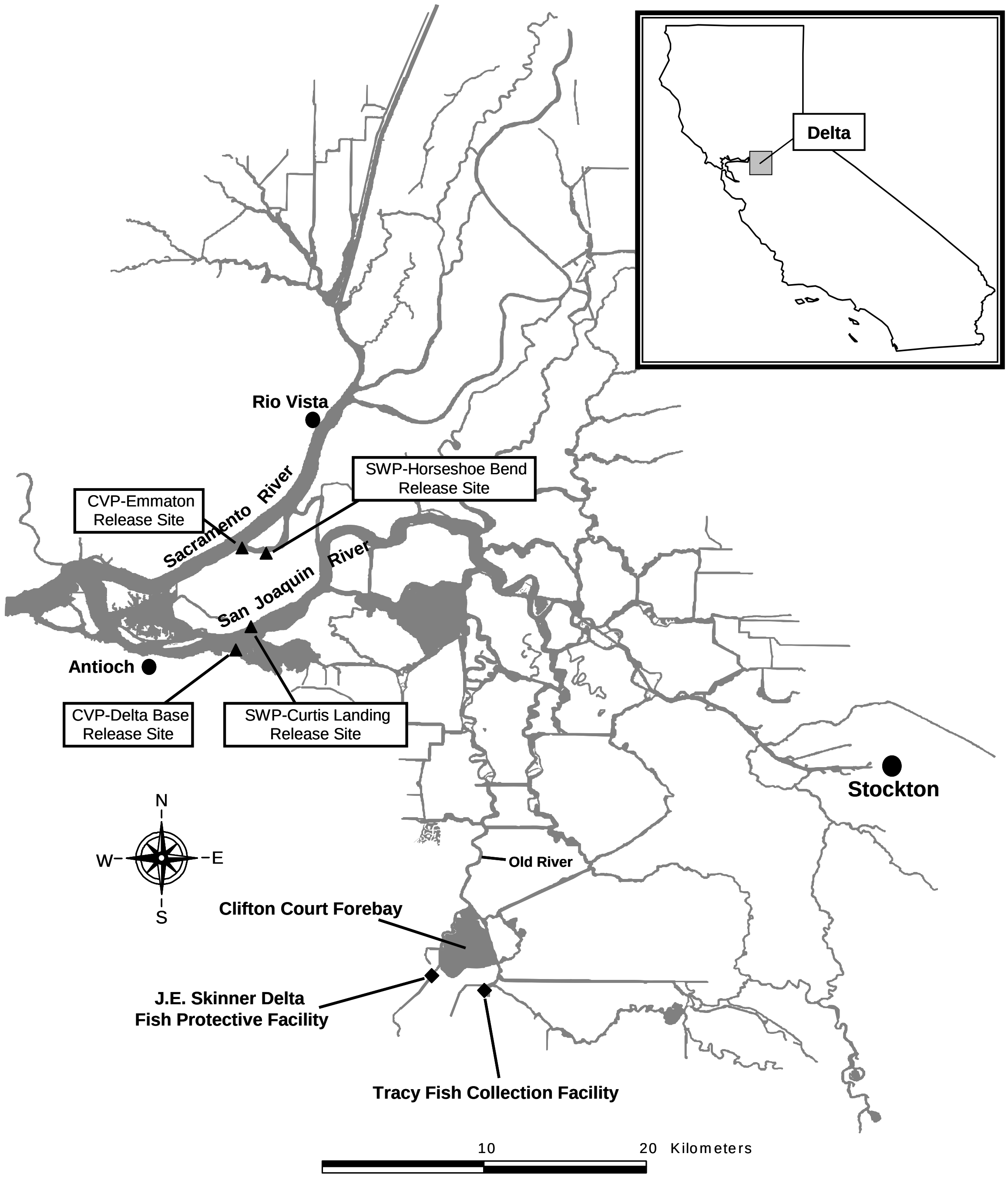


Figure 3- Map of the SWP and CVP fish salvage facilities and release sites. The release sites are a 45- to 60-minute drive from the salvage facilities.

1.1 Objective

The primary objective of the Release Site Predation Study was to develop quantitative and qualitative information for use in assessing the potential magnitude of predation mortality in the receiving waters at the release sites. The study was intended to provide additional information on the distribution and behavior of predatory fish at the release sites. However, the field studies focused primarily on the SWP Horseshoe Bend release site. Another intention of the study was to provide the necessary scientific and technical information for assessing predation as a factor affecting survival of salvaged fish. In the event that predation mortality was identified as a significant factor, the results would provide a foundation of information useful in identifying and evaluating potential alternative technologies designed to reduce or avoid predation mortality of released fish.

1.1.1 Research Questions in Detail

A number of questions exist regarding the potential magnitude and severity of predation mortality as a factor influencing overall survival of fish salvaged at the SWP and CVP and returned to the Delta estuary. These research questions include:

- Is predation mortality in the receiving waters a biologically significant contribution to overall mortality of salvaged fish?
- What are the species of predatory fish and birds inhabiting the Delta estuary, on a seasonal basis, at each of the designated release sites?
- What is the density and geographic distribution of predatory fish in the receiving waters at each release site and does the abundance and distribution of predators change before, during, and after the release of salvaged fish?
- How does predation on salvaged fish vary in response to environmental conditions?
- Are predatory fish behaviorally attracted to the receiving waters at one or more of the designated release sites, and is there evidence of learned behavior contributing to the attraction of predators?

1.2 Experimental Design and Approach

The experimental design and approach for evaluating predation within the receiving waters at the existing release sites includes five different, but interrelated, study methods including:

1) Sampling to determine predator species composition (electrofishing and piscivorous bird surveys)

2) DIDSON camera observations of near-field predator behavior
3) Hydroacoustic determination of predator abundance, distribution, and behavioral attraction
4) Mark recapture using Floy and Acoustic tagging to examine predator movement (e.g., site fidelity, behavioral attraction) in response to releases
5) A hypothetical predation risk analysis using a bioenergetics model

1.2.1 Study Area

There are four active sites for the release of salvaged fish in the Delta (Figure 4). The active release sites include the SWP release sites on Sherman Island, one at Horseshoe Bend (SWP Horseshoe Bend) and one on the lower San Joaquin River (SWP Curtis Landing). The CVP release sites are at the bifurcation between Horseshoe Bend and the Sacramento River (CVP Emmaton) and on the lower San Joaquin River at the Antioch Bridge (CVP Delta Base). The frequency of releases vary based on a number of factors including the seasonal densities and patterns of fish collected in salvage operations, debris loading, maximum fish holding times as specified in federal biological opinions, and diversion operations. The frequency of releases per site also varies, but generally does not exceed twice per day per site during routine operations. For the purposes of this study we also selected two reference or “control” sites, both on Horseshoe Bend in the Sacramento River (Figure 4). We selected two water intake structures because they are ubiquitous structures in the delta. These two specific sites were also chosen based on their proximity to the SWP Horseshoe Bend release site (both are within Horseshoe Bend) and similar habitat and underwater structure (pilings and underwater pipes).

Hydroacoustic surveys were conducted at the SWP Horseshoe Bend release site and the control sites. DIDSON surveys were conducted at all the sites with the exception of the CVP Delta Base site which was deemed unsafe for monitoring due to significant underwater hazards (fishing line). For the acoustic telemetry aspect of this study, a grid of receivers was maintained that included all the release and control sites in addition to several other monitors up and down the Sacramento River (see acoustic telemetry section). Additionally, data from receivers maintained by the various agencies of the California Fish Tracking Consortium (californiafishtracking.ucdavis.edu), including several receivers maintained by the study team at the SWP export facilities, were available to analyze large scale movement of tagged fish.

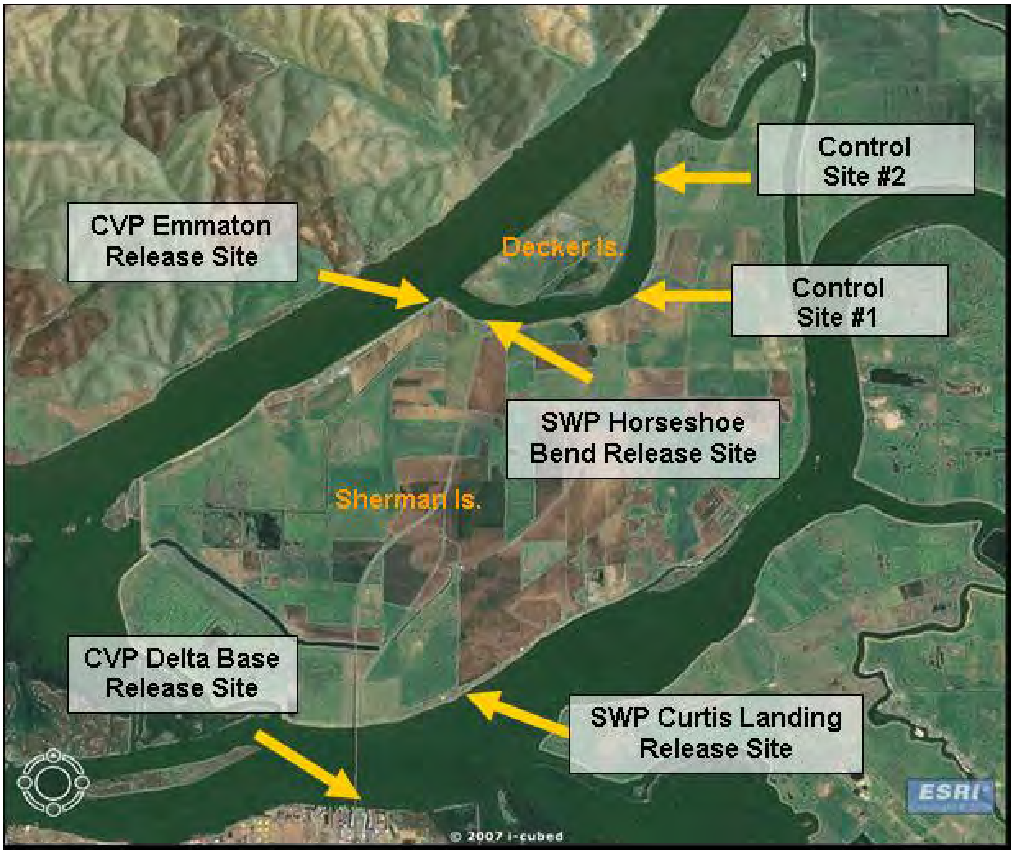


Figure 4- Map of Horseshoe Bend and the surrounding areas with study sites indicated

SWP Horseshoe Bend Release Site

The SWP Horseshoe Bend release site is located within Horseshoe Bend on Sherman Island, approximately 11 km (6.8 mi) downstream of the city of Rio Vista along highway 160. The release facility consists of two 30.5-cm (12-in) diameter steel pipes (Figure 5). One pipe is approximately 54.3 m (178 ft) long and is used for the release of fish. The other pipe houses a submersible pump which feeds flushing water at 0.005 m^3/s (0.18 cfs) into the release pipe through a four inlet manifold. The pipelines are fixed to the top of the Sherman Island levee at approximately a 16% slope with a straight trajectory into the water and are supported by a series of steel piles. The end of the release pipeline extends 2 m (6 ft) beyond the last set of piles and is suspended 1.8 m (6 ft) above the channel bottom to prevent blockage due to sediment buildup. At the mean high water level, the pipe is submerged 3.7 m (12 ft). The flushing system and other release components of the release stage during the CHTR process are discussed in detail in the Element 3 investigation report. The SWP Horseshoe Bend site is operated on an alternative basis with the SWP Curtis Landing site.

Figure 5- SWP Horseshoe Bend release site on Sherman Island

SWP Curtis Landing Release Site

The SWP Curtis Landing release site is on the San Joaquin River side of Sherman Island, immediately upstream of the Antioch Bridge. The mean water depth at the end of the release pipe is approximately 4.5 m (15 ft) and the pipe extends approximately 9 m (29.5 ft) from the shoreline into the river channel (Figure 6). This site is unique in that it has a 162° elbow after the first 4.5 m (15 ft) of pipe, changing the slope of the pipe from a shallow 4.8% to a much steeper 22.5%. Like the SWP Horseshoe Bend release site, the Curtis Landing release site is equipped with a pipe flushing system with a flow rate of 0.005 m^3/s (0.18 cfs). There is an abandoned line of pilings adjacent to the shoreline that are mostly submerged as well as a small tree growing on a small island just upstream (~20 m) of the release pipe. Additionally there is a private dock with pilings ~30 m (98.5 ft) downstream of the release pipe and extending ~10 m (33 ft) into the river. The SWP Curtis Landing release site is operated on an alternative basis with the SWP Horseshoe Bend release site, unless the release occurs at night as this site is unfenced and deemed unsafe for night time operations. The site includes a single inlet flushing manifold and rinse down system that is operated similarly to the SWP Horseshoe Bend release system.

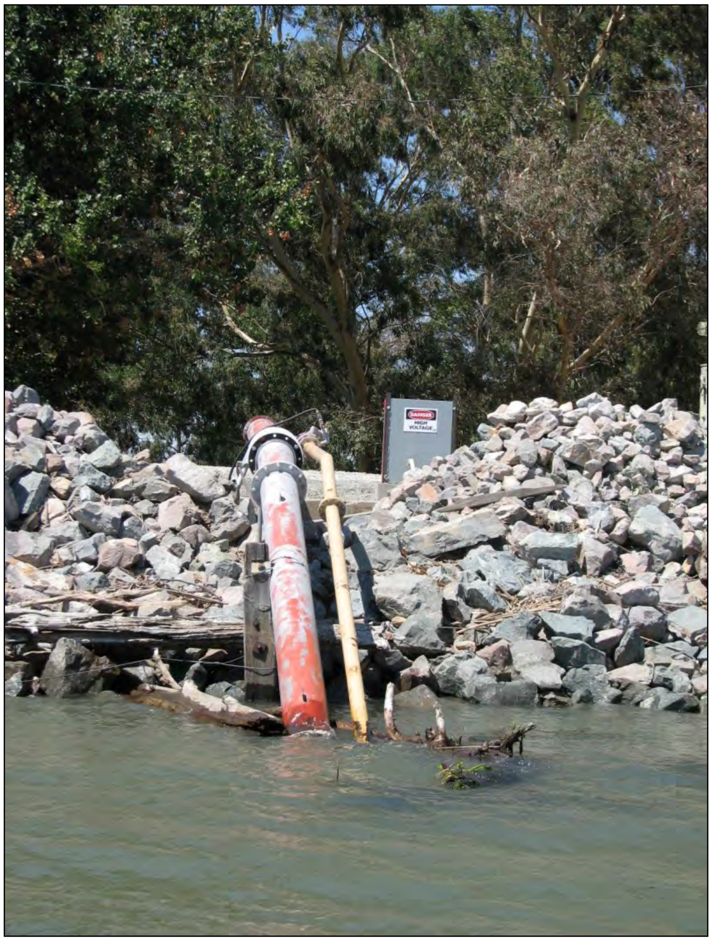


Figure 6- The SWP Curtis Landing Release Site with the release pipe extending down into the water. The smaller pipe on the right is the pipe and pump system supplying the flushing flow.

CVP Emmaton Release Site

The CVP Emmaton release site is located on the Sacramento R. side of Sherman Island at the downstream mouth of Horseshoe Bend (Figure 7). It is located 0.8 km (0.5 mi) downstream of the SWP Horseshoe Bend release site. The release site consists of four pipes that extend to various depths in the channel with a catwalk and piling structure that extends to the end of the longest pipe. There is a permanent water quality station housed in a small shed at the end of the catwalk. Two of the four pipes at the release site are pump/water supply lines that provide a flushing/rinsing flow of 0.045 m^3/s (1.6 cfs). The flushing system is equipped with a timer that randomly turns the pump on and off 4 times each day for 10 minutes each time. The remaining two pipes are the fish release pipes situated at approximately a 36% slope. The longer of the two fish release pipes extends approximately 25 m (82 ft) into the river and has a mean depth at the pipe outlet of about 7.3 m (24 ft), while the other shorter pipe extends roughly half that length and depth and is operated in order to reduce clogging problems when high debris levels are present in the transport truck. The shoreline consists of sparsely vegetated riprap on both sides. The CVP

Emmaton site is operated on an alternative basis with the CVP Delta Base Site.

Figure 7- The CVP Emmaton release site

CVP Delta Base

The second CVP release site is on the south bank of the San Joaquin River near the Antioch Bridge. It is in a park behind an East Bay Regional Parks maintenance yard in a fenced compound. This site is similar in detail to the CVP Emmaton release site including the same flushing system (0.045 m^3/s pump with timer). The San Joaquin River is much shallower and wider at the Antioch Bridge site than the channel at the CVP Emmaton release site. Consequently, the release pipe is longer (58 m [190 ft]), has a shallower slope (18%, Figure 8), and has a mean depth at the pipe outlet of approximately 4.5 m (15 ft).

Figure 8- The CVP Delta Base Release Site

Control Site 1

Control Site 1 is located within Horseshoe Bend on the Sacramento River 0.8 km (0.5 mi) upstream of the SWP Horseshoe Bend release site. The site consists of a water intake structure with pilings and a cylindrical fish screen that serves as the primary water intake for Sherman Island. The shoreline is heavily vegetated with tules and overhanging trees (Figure 9).

Figure 9- Control Site 1, a screened water diversion on Sherman Island

Control Site 2

Control Site 2 is also located within Horseshoe Bend on the Sacramento River. It is 0.8 km (0.5 mi) upstream from Control Site 1 and 1.6 km (1 mi) upstream from the SWP Horseshoe Bend release site. The site consists of an unscreened water intake structure with pilings and a pump platform. The shoreline is heavily vegetated with tules and submerged aquatic vegetation extending out to the platform (Figure 10).

Figure 10- Control Site 2, an unscreened water diversion on Sherman Island

1.2.2 Study Period

The Release Site Predation Study involved periodic monitoring throughout the year to cover a range of seasonal and operational conditions. As per the original plan, monitoring was to commence in the late spring of 2007. However, due to export restrictions imposed by the presence of listed delta smelt in the South Delta, the first scheduled monitoring period in late May/early June was cancelled. The export restrictions included a 10 day halt in pumping which resulted in a cessation of salvage operations. As a result, monitoring commenced in August 2007 and ended in early April 2008 (Table 1). Each monitoring event typically consisted of two to three weeks of DIDSON, Hydroacoustic, and avian predation monitoring. Ten full days of monitoring were scheduled in the study plan, but due to weather resulting in missed monitoring days, each 10-day DIDSON/Hydroacoustic monitoring period took as long as three weeks. Each two-to-three-week monitoring event was followed by one week of electrofishing and fish tagging. Telemetry receivers were deployed beginning in May of 2007 and were periodically serviced and downloaded for the duration of the study (see Acoustic Tagging section).

Table 1- Monitoring schedule for the Release Site Predation Study

Monitoring Period	Date
1	August 1, 2007– August 31, 2007
2	October 3, 2007 – October 29, 2007
3	November 26, 2007 – December 21, 2007
4	January 28, 2008 – February 26, 2008
5	March 10, 2008 – April 2, 2008

Note: An additional monitoring period was planned for May/June 2007, but was cancelled due to SWP export restrictions due to delta smelt salvage

1.3 Assumptions of the Study Plan

Fundamental assumptions of the predation study included, but were not limited to:

- The receiving waters were defined as within 50-m (165-ft) of the end of the release pipe. This area was arbitrarily set based on sampling gear limitations and lack of previous information on the spatial distribution of predator fish in the study area.
- Preliminary field pilot observations at the release sites using the DIDSON camera suggested that predatory fish aggregate near the end of the release pipe.
- Field data collection efforts as part of this investigation did not change or alter the density or distribution of predatory fish or birds in the receiving waters.
- For this investigation, control locations were selected that were assumed to be representative of the habitat conditions, baseline food availability, and structural components of a release site. The control locations are both water intake structures, including multiple pipes, and surrounding pilings approximately 1.6 km (1 mi) and 0.8 km (0.5 mi) upstream of the SWP release site within Horseshoe Bend, respectively.
- The study assumed that the control sites were far enough away from the release sites that the release sites would not affect the local abundance of predators at the control sites. Since predators can move upstream and downstream their abundance could be elevated over distant areas. However, a desire to select sites with similar habitat conditions and structural components resulted in limiting selection of control sites within Horseshoe Bend.

- The experimental study assumed that predator response and distribution at the control sites was representative of conditions occurring at the SWP Horseshoe Bend release site and can be used on a comparative basis to evaluate the results of field studies and observations at other release sites. Based on similarities in water depths and velocities, the control locations and the SWP Horseshoe Bend release site habitat and environmental conditions appeared to be similar. Water depths and velocities, at the control sites, however, differed from environmental conditions occurring at the CVP Sacramento River (Emmaton) release site and SWP and CVP San Joaquin River sites (Curtis Landing and Delta Base).

1.4 Limitations of the Study Plan

Fundamental limitations of the predation study included:

- Given the difficulties of field data collection and observations, the differential vulnerability, predation, or mortality of salvaged fish cannot be readily determined by this study because the data collection methods do not differentiate between predation on different prey species or between live, dying, or dead fish.
- A wide variety of environmental and biological variables influence predator dynamics in the receiving waters. However, the experimental field investigations were simplified to focus on specific parameters and biological responses in order to keep the study at a manageable scale.
- This study was not intended to address any potential ecological effects resulting from salvage operations (e.g. the long-term survival of listed species), but rather focused on assessing the survival of all salvaged fish.
- Measurements of fish lengths were only conducted using the hydroacoustics system and electroshocking. While the DIDSON includes a software measuring tool, no published literature was located documenting the accuracy of measurements attained using this software.

1.5 Project Responsibilities and Coordination

This study was conducted as a collaborative effort between biologists and engineers of the California Department of Water Resources (DWR), U.S. Bureau of Reclamation (USBR), and California Department of Fish and Game (DFG). The following describes each agency's role and responsibilities:

- The California Department of Water Resources was the lead agency. The DWR Fishery Improvements Section was responsible for project management, coordinating with the multi-agency technical teams, completing the DIDSON and avian predation components of this study, and writing the final report.

- The USBR Fisheries and Wildlife Resources Group provided technical support and was responsible for the hydroacoustics component of this study, data analysis and interpretation, and report writing.
- The DFG Fish Facilities Research Unit provided technical support and was responsible for electrofishing/sampling at the release and control sites, tagging predatory fish, operating and maintaining the acoustic tracking receiver network, data analysis and interpretation, and report writing.

2.0 Predator Composition and Mark-Recapture

Several techniques were employed to determine species composition and behavior at the SWP salvaged fish release sites at Horseshoe Bend and Curtis Landing and two control sites located upriver of the Horseshoe Bend site (Figure 4). These techniques included electrofishing and mark-recapture using acoustic telemetry and Floy tagging.

Sampling at the SWP salvaged release sites and two control sites using an electrofishing boat occurred once every two months during each of the monitoring periods. Typically, sampling was performed at the end of each monitoring period, so as not to interfere with other data collection methods (DIDSON and Hydroacoustics).

2.1 Materials and Methods

2.1.1 Electrofishing

Electrofishing was used to collect fish in the receiving waters and surrounding shoreline areas to determine species composition and relative abundance (catch per unit effort: CPUE) for each location. Sampling was performed using an electrofishing vessel (model SR-18EH) built by Smith-Root, Inc. (Vancouver, WA). This vessel was configured with a 5.0 Generator Powered Pulsator (5.0 GPP) Electrofisher. This system was powered using a Smith-Root modified Honda generator with a rated output power of 5,000 watts and a direct current output peak of 1,000 volts. Current was applied to the water using two Smith-Root anodes (model SAA-6). The anode design featured six stainless steel dropper cables that were submersible to about 0.9 to 1.2 m (3–4 ft) of water. Each anode was clipped to a boom arm on the vessel's port and starboard sides. The boom arms were approximately 2 m (6.5 ft) in length and pivoted 180 degrees, allowing the anodes to suspend directly in front of the bow. The boat's hull acted as the cathode. Electrofisher controls were mounted on the center console and electrofisher output was controlled by footswitches on the work deck located on the bow. Also on the center console was a counter that logged, in seconds, electrofisher on-time. A 250–L (65–gallon) livewell was positioned in the center of the boat.

The electrofisher settings for current type, voltage range, amperage, pulses per second, and percent of selected pulse frequency were selected prior to sampling and adjusted occasionally during sampling, as needed, by the boat operator. Direct current and low voltage range (50 to 500 VDC) were used exclusively during this study. Current was maintained at 14 ± 1 amps. Pulse per second was set at 120 DC, with three exceptions when it was set at 60 DC. Percent of range varied between 20 and 45%. Total time spent electrofishing (shocking time) and total shocking distance were recorded for each location at the completion of sampling. Distance was calculated from waypoints taken with a handheld Global Positioning System (GPS) unit. Shocking time ranged from 1,023–6,166 seconds and distance ranged from 129–644 m (423–2,113 ft).

Electrofishing at the SWP Horseshoe Bend release site typically was timed to coincide with the scheduled release of fish regardless of the tidal stage, while Control Sites 1 and 2 were always sampled on the same day. Each site was sampled only once during each sampling period for a minimum number of five samplings per site. The SWP Curtis Landing release site was sampled six times: once in early September in an attempt to collect and tag additional predatory fish. The species composition data were used to interpret data collected during the Hydroacoustic and DIDSON surveys.

Sampling was constrained to a predetermined sampling area that included the littoral zone at each site. The area immediately surrounding the release pipe or pier structure (control sites) were also carefully sampled to ensure sufficient coverage. Upriver and downriver sampling boundaries were established at approximately 200 m (656 ft) on either side of the release pipe (release sites) or piling structure (control sites). A total of 400 m (1312 ft) was sampled at each site. No greater than 6–meter (20–ft) sections of the shoreline were sampled at any one time, due to the range of effectiveness of the electrofisher unit. Typically, each site was sampled beginning at the upriver or downriver boundary, depending on wind and current conditions. A GPS handheld receiver (iFinder Expedition C®, Lowrance, Tulsa, OK) was used to describe the site locations. GPS waypoints were recorded at the beginning and ending of sampling to ensure consistency in maintaining site boundaries. All waypoint coordinates were recorded in Universal Transverse Mercator (UTM) units.

Technicians applied current for approximately 10 seconds, followed by 2- to 5-second intervals of no shocking. This process was repeated several times per section depending on how quickly and how many fish surfaced. The technicians used nets with long fiberglass handles to scoop stunned fish from the water. Netted fish were deposited into the live-well for recovery. At the completion of sampling a location, all fish were identified to species and enumerated. The fork lengths (FL) in mm of up to twenty fish of each species were also measured. All fish, with the exception of adipose fin-clipped Chinook salmon and dead listed (endangered or threatened) species, were returned to the water. Adipose fin-clipped Chinook salmon were euthanized, bagged, and brought back to Stockton for coded wire tag (CWT) analysis by US Fish and Wildlife Service (USFWS). Dead listed species were brought back to Stockton and saved for future analysis.

Readings of water temperature, conductivity, dissolved oxygen, clarity, and depth along with wind speed, air temperature, tide, and time were recorded at the beginning and ending of each sampling session. Water temperature (°C), conductivity (µS/cm), and dissolved oxygen (% and mg/L) were measured using a multi-probe meter (YSI Models MPS 556 and 85, YSI Incorporated, Yellow Springs, OH). Water clarity was measured in centimeters using a Secchi disc.

Water depth was recorded in meters from the depth logger on the boat. Wind speed in kilometers per hour was obtained from posted data on http://cdec.water.ca.gov and air temperature (°C) was obtained from posted data on www.wunderground.com. Tidal conditions were observed in the field and confirmed from posted data at www.saltwatertides.com.

2.1.2 Floy Tags and Telemetry

To examine predatory fish movement and behavior at release sites, Floy tags (mark and recapture) were employed to obtain information on predator site fidelity for predatory fish collected during electrofishing, including largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus)*, striped bass (*Morone saxatilis*), and Sacramento pikeminnow (*Ptychocheilus grandis)*. Largemouth bass and black crappie were Floy tagged. Striped bass and Sacramento pikeminnow not used for the acoustic tag study were also Floy tagged. Each Floy tag was applied to the fish on the left-dorsal area using the Avery Dennison Mark II™ pistol L. Tagging was performed in such a way as to minimize stress to the fish. Fish tagging was discontinued if a fish was not tagged after two attempts. Each Floy tag had a unique identification number and a phone number for DWR. Predatory fish that were recaptured during electrofishing were measured and weighed; the tag number was recorded and the fish was released.

Acoustic telemetry data was used to determine if the tagged fish remained at the release site, were attracted to the release site during a fish release, moved to another location (for example, a control site or other release site), or moved seasonally to and from the release site. Sacramento pikeminnow and striped bass collected during electrofishing were fitted with acoustic transmitters. These two species were selected based on their larger size, habitat preferences, and occurrence in previous field studies (Orsi 1967, Pickard and others 1982). Largemouth bass were not selected for acoustic telemetry tracking because they sometimes remain in a restricted area (Moyle 2002) and the detections from such individuals could have quickly filled the receiver's data storage capacity. Most black crappie were not large enough for use with the smallest acoustic tags purchased for this study, and were too small for Floy tags per the minimum length requirement (predatory fish ≥ 150 mm [5.9 in] FL) (DWR 2005). Most striped bass and Sacramento pikeminnow greater than approximately 400 mm [15.7 in] FL (weighing 450 g [1 lb] or more) caught during electrofishing were fitted with acoustic transmitters. Only fish in good condition with no sores, hemorrhages, or badly frayed fins were selected for acoustic tagging. Movement of acoustically tagged fish was continuously monitored throughout the study using an array of fixed receivers deployed in and around the receiving waters of the release sites. Additionally, fish movement was periodically monitored using a mobile receiver and a hydrophone.

Acoustic telemetry products made by VEMCO, a division of AMIRIX Systems, Inc. (Halifax, Nova Scotia), were used exclusively during this study. Refer to

Appendix 11.1 for information on VEMCO technology, tag, and receiver information. All tags used were less than 2% of the weight of the fish (largest tag weighed 6 g [0.013 lb] and the lightest fish weighed 454 g [1 lb]). The use of an appropriate-sized transmitter ensured minimal impact on swimming performance (Winter 1983 and 1996). The largest tags (Vemco V13-1L) used in the study had an estimated life of 325 days, while the smallest tags (Vemco V9-1L) had an estimated life of 115 days.

The transmitters were designed for surgical implantation. Therefore, each tag had to be modified for external mounting. A 25–cm (10–in) piece of galvanized-steel wire (0.41 mm diameter or 28-gauge) was affixed to the transmitter using polyolefin heat shrink tubing. Two pieces of shrink tubing were cut slightly smaller than the length of the transmitter. One piece was placed over the transmitter and the wire was placed between the shrink tubing and the transmitter. A Ronson® butane lighter (Somerset, NJ) was used to heat the shrink tubing. As the tubing warmed, it shrank around the transmitter, securing the wire to the transmitter. The second piece of shrink tubing was applied in the same fashion for reinforcement.

Each fish, before receiving a transmitter, was measured and weighed (BogaGrip® Model 130, Eastaboga Tackle, Eastaboga, AL) and the appropriate transmitter number was recorded. Securing the transmitter to the fish was performed in a similar manner to the method described by Chadwick (1963), Gray and Haynes (1979), and Gingras and McGee (1997). Hypodermic needles were pushed through the fish below the dorsal fin, starting on the left side of the fish. Through the needle openings, now on the right side of the fish, the wire from the transmitter was threaded. The needles were quickly pulled from the fish, thus pulling the wire through the body of the fish. The two ends of the wire were pulled tightly, twisted several times, cut, and the excess pushed against the fish towards the posterior. During the tagging process, the fish was secured in a cradle and water was pumped across its gills. Once tagging was complete, the fish was released to the water and its condition noted.

VEMCO VR2 receivers were deployed at seven separate locations in the study area (Figure 11 and Table 2). The receivers were situated as close as possible to the release pipe or piling structure at all four release sites and the two control sites. Two additional receivers were deployed in December 2006 as part of another study: in Horseshoe Bend at Decker Island (DI) and in the Sacramento River at Sherman Island (SAC). The same mooring method was used to secure all receivers. Each receiver was secured to the middle section of a 3-meter (10 ft) long piece of nylon rope using zip-ties (36.83 cm length x 0.76 cm width [14.5 in x 0.3 in]). Zip-ties were fastened in accordance with the VEMCO VR2 Receiver Operating Manual (VEMCO 2004). A float was tied to the end of the rope above the receiver's transducer. A 5–kg (11–lb) weight was tied to the other end of the rope. This setup allowed the receiver to orient nearly vertically in the water column, with the transducer pointed towards the surface.

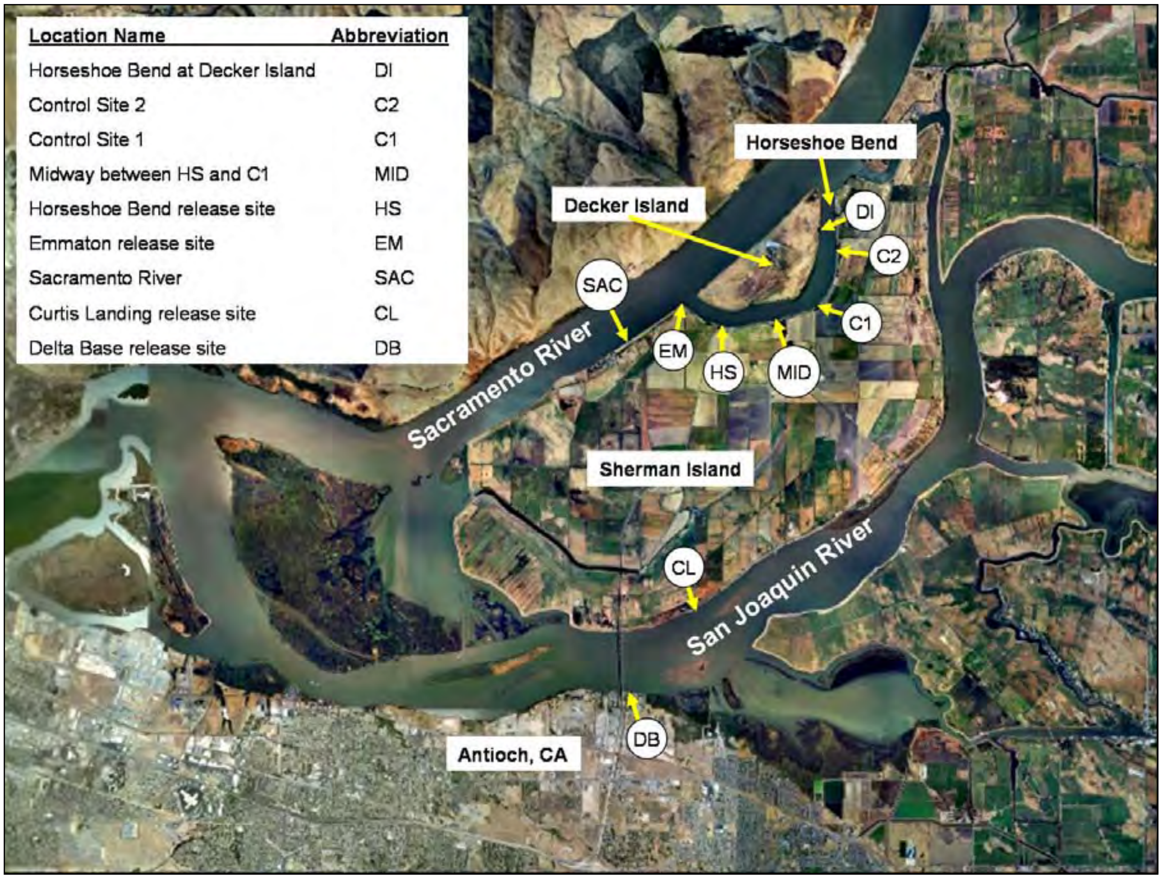


Figure 11- VR2 receiver deployment locations

At all locations, except midway between Control Site 1 and the SWP Horseshoe Bend release site, a first-generation VR2 receiver was deployed along with a second-generation unit. These redundant receivers provided a backup in case of malfunction, damage, or loss of either receiver. The older units were fastened to the line in the same manner as the new units. The data from the newer receivers was used for data analysis purposes since they generally recorded more tag detections than the older units. Based on some range testing using similar tags, 100% tag detection was observed at a maximum range of 160 m (525 ft). Actual detection ranges were expected to vary with depth, channel profile, submerged vegetation, and surface conditions.

Table 2- VR2 receiver deployment locations with GPS waypoints

Location Name	Location Abbreviation	Date Deployed	Time Deployed	Receiver Serial Number	Easting (UTM)	Northing (UTM)	Approximate depth (m)
Control Site 1	C1	06/27/07	0806	6324C	613008	4215897	10.6
		07/11/07	0847	3185C			
Control Site 2	C2	06/27/07	0849	6342C	613381	4216929	4
		07/11/07	0907	3174C			
SWP Horseshoe Bend release site	HS	07/02/07	1015	6320C	611374	4215554	4
		07/05/07	1235	3201C			
CVP Emmaton release site	EM	07/02/07	1058	6335C	610813	4215878	15.2
		07/09/07	0822	3183C			
SWP Curtis Landing release site	CL	07/02/07	1223	6336C	610876	4210182	9.4
		07/10/07	1143	3186C			
CVP Delta Base release site	DB	07/16/07	0828	6309C	609699	4208756	3.3
		07/16/07	0828	3187C			
Midway between HS and C1	MID	07/23/07	1100	6345C	612169	4215653	9.7
		10/11/07	1140	6345C	612122	4215625	7.3

Relocated MID receiver on October 11, 2007; original position too accessible from shoreline
Lost 3183C on a snag and replaced with 6317C on March 7, 2008

Detection data from the receivers was downloaded about once every three weeks. This process required removing the receiver from the water for a short time. The VEMCO VR-PC computer interface was used to download data from the receiver to a laptop. VEMCO VR2 Windows Software, version 1.0.21.0, was used to download data files to the computer. A backup copy of each file was created on a flash drive for precautionary purposes. While downloading, the mooring cable and line, zip-ties, weight, float, and the receiver were inspected for wear. Items were replaced or mended, if necessary. When the downloading process was completed and after the receiver had been initialized, the receiver was checked for proper performance. A “test” transmitter was placed next to the receiver’s hydrophone. The receiver was deemed functional and returned to the water upon a positive detection of the “test” transmitter. Downloading all receivers for all locations was accomplished in one to two days, depending on the weather and the amount of data on each receiver.

In addition to the fixed receivers, remote tracking, or mobile monitoring (MM), was performed one or two times per month using a VEMCO VR100 acoustic tracking receiver. Three locations within Horseshoe Bend were chosen for mobile monitoring (Figure 12). All three locations were accessed from a boat. At each location, an omni-directional hydrophone (VEMCO model VH165) was lowered into the water. The VR100 was programmed with the code map and frequency appropriate for transmitters used for this study. If a transmitter was present in the area, the transmitter code, signal strength, and time of detection were displayed on the screen of the VR100. This information was recorded only once for each transmitter. After approximately 5 minutes, if no additional transmitters were detected, the hydrophone was pulled from the water and the next location was monitored.

Mobile monitoring was used primarily to check for “dead zones”, areas of no detection, within the array of receivers in Horseshoe Bend. When compared to the fixed receiver data, no dead areas were observed during the mobile monitoring and the results validated the detection areas of the fixed receivers. Based on these results, mobile monitoring data was not used in the telemetry data analysis.

VEMCO User Environment (VUE) software (version 1.2.1) was used to maintain and analyze all VR2 receiver data. Downloaded receiver files stored on the laptop were copied to a desktop computer for analysis with the VUE software. Each receiver file was imported into VUE and was assigned a location based upon the location of the receiver in the field.

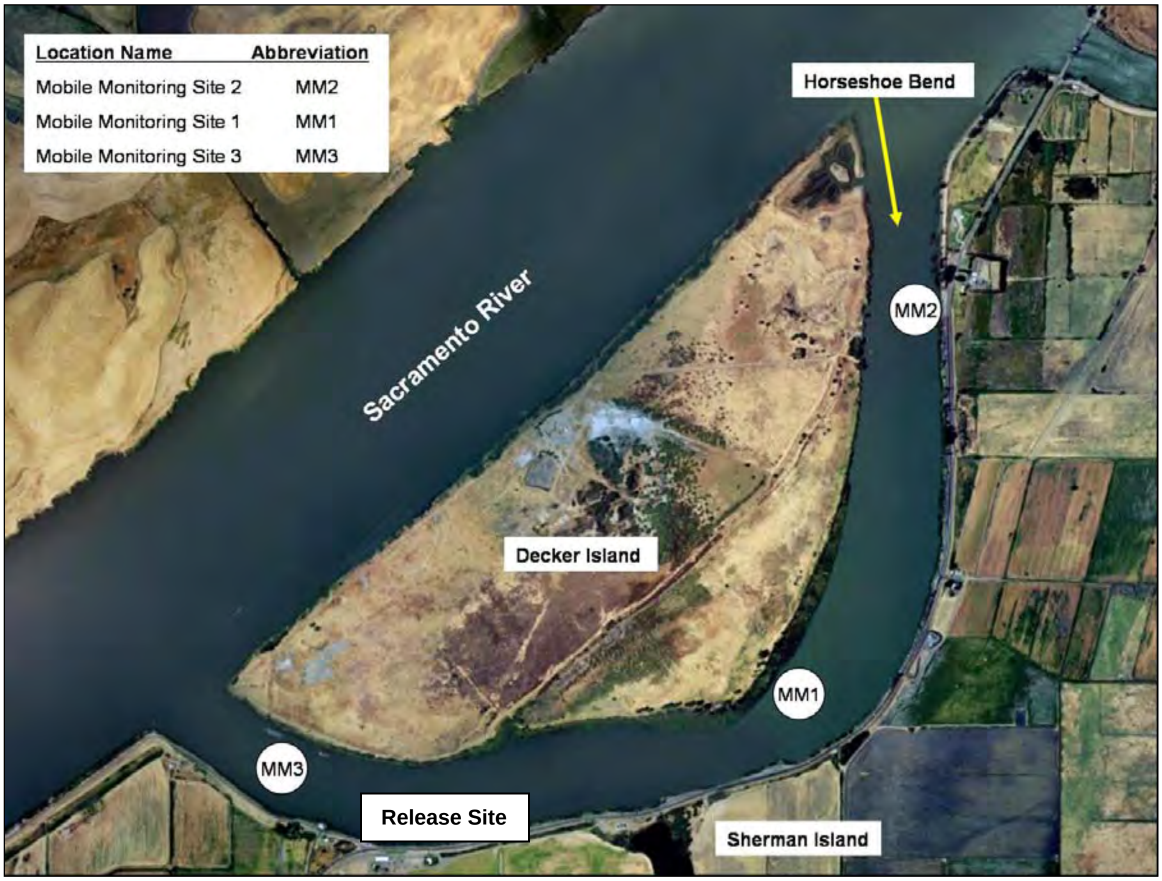


Figure 12 -Map showing location of mobile monitoring locations

From VUE, data for each tag used in this study was exported to Microsoft Excel (Redmond, WA). Data in Excel was imported into Microsoft Access (Redmond, WA). A table was created in Access with the following fields: receiver serial number, tag number, detection date, and detection time. This table contained only the tags used and detected for this study. Additionally, telemetry detections from the California Fish Tracking Consortium (Consortium) database were added to this table (http://californiafishtracking.ucdavis.edu). The Consortium is a collaboration of researchers from several academic, government, and private organizations working together to better understand the life histories of anadromous fish species of California. The Consortium uses a large array of underwater acoustic receivers to monitor the movement of acoustically-tagged fish which ranges from the Sacramento River below Lake Shasta down to the Golden Gate Bridge in San Francisco Bay. Queries summarized data for (1) number of detections of each tag number per receiver by hour and (2) number of detections of each tag number per receiver by day. The location of the receiver with the greatest detections per hour for a specific tag (fish) was deemed to be the location for that fish during that time period. Hourly detections of ≤ 2 per receiver were considered false detections. False detections were not considered when assigning tag (fish) location.

Hourly detection data filtered from the Access database were copied into individual Excel spreadsheets by fish (tag number). Each spreadsheet contained column headings showing the location and serial number of each VR2 receiver that detected the specific tag number. The columns were arranged (left to right) according to increasing distance (river miles) away from the Horseshoe Bend study area. The rows contained the tag number, fish species, detection date, and detection time from the first detection to the last detection. Setting up the spreadsheet in this manner allowed for examining the pattern of detections for logical signs of reasonable fish movement. This design also allowed for excluding simultaneous valid detections from receivers more than a mile apart whose pattern of detections was not a logical sign of reasonable fish movement.

2.1.3 Telemetry Data Analysis

The telemetry detection data was summarized based on the percentage of days monitored that fish resided at a salvage release site using the formula:

% Time at Release Site= (# Days detected at a Release Site / # Days Monitored) X 100.

A Mann-Whitney Rank Sum Test was used to compare the percentage of time spent at a release site for Sacramento pikeminnow and Striped Bass.

2.2 Quality Assurance

Regularly scheduled maintenance was performed, per operations manual, on the YSI 556 multi-probe meter and the YSI 85. Each field-day, the YSI 556 and 85 were calibrated for dissolved oxygen (mg/L and %). The YSI 556 was calibrated using barometric pressure value (mm Hg). Barometric pressure (in millibars) was obtained from the handheld GPS unit and converted to mm Hg by multiplying by the constant, 0.750064. The YSI 85 was calibrated using local altitude in hundreds of feet. Local altitude was considered to be zero in the area of fieldwork during this study. No attempt was made to determine the accuracy of Secchi disc or water depth.

All field personnel received training in proper fish identification. Additionally, the field lead biologist reminded staff of key characteristics for which to check when identifying fish to species. No attempt was made to determine the accuracy of the measuring boards or BogaGrip® used to measure the length and weight of fish, respectively.

The field lead checked all datasheets for completeness at the end of each day. The field lead entered all field data into a Microsoft Access database. Scientific aides checked entries line-by-line (printed copy of data) against the field datasheets. Aides circled any errors on the printout; the field lead corrected the errors in the database.

2.3 Results

2.3.1 All Species

Twenty-six different fish species were collected during electrofishing (Table 3), including eight native species and 18 introduced species. This ratio of native to introduced species is consistent with other studies in the region which have shown that macrophyte dominated shorelines, such as those sampled during this study, are primarily inhabited by introduced species adapted to these littoral habitats (Feyrer and Healy 2003, Grimaldo and others 2004, Nobriga and others 2005). Species composition was most diverse at Control Site 2; this location exhibited 23 of the 26 species collected during this study (Table 3). Eighteen fish species were collected at Control Site 1. Seventeen fish species were collected each at the SWP Curtis Landing and Horseshoe Bend release sites.
The most abundant species was redear sunfish (*Lepomis microlophus*), followed by tule perch (*Hysterocarpus traskii*) and largemouth bass. These three species were collected at all sampling locations throughout the entire sampling period (Table 4). Bluegill (*L. macrochirus*), golden shiner (*Notemigonus crysoleucas*), and inland silverside *(Menidia beryllina*) were also collected frequently. Least abundant were the following 6 species: brown bullhead (*Ameiurus nebulosus*), goldfish (*Carassius auratus*), red shiner (*Cyprinella lutrensis*), smallmouth bass (*M. dolomieu*), steelhead (*O. mykiss*), and yellowfin goby (*Acanthogobius flavimanus*). These 6 species were only collected once during the entire study.

The total number of fish collected for the entire study was 3,100. The total number of fish collected at the SWP Horseshoe Bend and Curtis Landing release sites and Control Site 2 were comparable (Table 3). For Control Site 1, the total number of fish collected was noticeably lower than the other three sampling sites. The most common species by location was: Control Site 1 = largemouth bass; Control Site 2 = redear sunfish; SWP Curtis Landing release site = tule perch; and SWP Horseshoe Bend release site = redear sunfish (Table 3).

2.3.2 Predatory Species

We collected 10 species of predatory (piscivorous) fish. Largemouth bass, bluegill, black crappie, Sacramento pikeminnow, and striped bass were the top five predatory species, in order of highest to lowest abundance. Length and weight ranges and averages were calculated for each predatory species (Table 5).

At all locations, centrarchids were caught primarily near shore, in tules and woody (root) areas. Based on field observations, none of the centrarchids or ictalurids were collected while sampling (electrofishing) at or near (within about 3 m [10 ft]) of the end of the SWP release pipes at Horseshoe Bend or Curtis Landing. Striped bass and large (>390 mm [15.3 in] FL) Sacramento pikeminnow typically were caught when sampling at or near (within 5 m [15 ft]) the end of the SWP Horseshoe Bend release pipe. Pikeminnow collected at the control sites were typically caught near shore, sometimes near piling structures.

Pikeminnow collected at SWP Curtis Landing were collected near shore in the tules. Striped bass collected at the control sites were less than 200 mm (7.9 in) FL, with the exception of one fish (551 mm [21.7 in] FL) collected at Control Site 1. Striped bass collected at the SWP Horseshoe Bend release site were greater than 400 mm (15.7 in) FL.

Collection numbers varied among the top five predators. Largemouth bass were collected fairly consistently at all sampling locations for the entire study period. No fewer than 10 and no greater than 63 were collected at any one time, at any location (Table 4). On some sampling days no bluegill, black crappie, or Sacramento pikeminnow were collected (Table 4).

Twenty-two striped bass were collected in the sampling. Of these, 15 were collected at the SWP Horseshoe Bend release site, and only during August and October 2007 (Table 4). No striped bass were collected at the SWP Horseshoe Bend release site from December 2007 through March 2008. Four of the 22 striped bass were collected at Control Site 1 during October 2007 and March 2008. Only one striped bass collected at Control site 1 in March 2008 was greater than 200 mm (7.8 in) FL (Table 6). Three of the 22 striped bass were collected at Control Site 2, and only during the March 2008 sampling period. None was greater than 175 mm (6.9 in) FL (Table 6). No striped bass were collected at the SWP Curtis Landing release site (Table 6).

Table 3- Species collected while electrofishing. C1=Control 1, C2=Control 2, CL=SWP Curtis Landing release site, and HSB= SWP Horseshoe Bend release site

Common Name	**Scientific Name**	**Catch by sampling location**				**Total**
		C1	**C2**	**CL**	**HSB**	
Black crappie	*Pomoxis nigromaculatus*	1	20	14	38	73
Bluegill	*Lepomis macrochirus*	10	47	46	92	195
Brown bullhead	*Ameiurus nebulosus*		1			1
Carp	*Cyprinus carpio*	9	6	2	2	19
Chinook salmon*	*Oncorhynchus tshawytscha*	2	9		2	13
Delta smelt*	*Hypomesus transpacificus*		2			2
Golden shiner	*Notemigonus crysoleucas*	11	54	47	32	144
Goldfish	*Carassius auratus*			1		1
Hitch*	*Lavinia exilicauda*	6	29	26	17	78
Inland silverside	*Menidia beryllina*	37	64	6	37	144
Largemouth bass	*Micropterus salmoides*	92	202	120	153	567
Red shiner	*Cyprinella lutrensis*		1			1
Redear sunfish	*Lepomis microlophus*	62	300	190	318	870
Sacramento blackfish*	*Orthodon microlepidotus*	1	25	1	42	69
Sacramento pikeminnow*	*Ptychocheilus grandis*	15	16	11	29	71
Sacramento sucker*	*Catostomus occidentalis*	26	8	3	4	41
Shimofuri goby	*Tridentiger bifasciatus*		2			2
Smallmouth bass	*Micropterus dolomieu*		1			1
Spotted bass	*Micropterus punctulatus*	3	3	1	1	8
Steelhead*	*Oncorhynchus mykiss*			1		1
Striped bass	*Morone saxatilis*	4	3		15	22
Threadfin shad	*Dorosoma petenense*	6	1		7	14
Tule perch*	*Hysterocarpus traskii*	36	117	401	192	746
Warmouth	*Lepomis gulosus*		3	4	3	10
White catfish	*Ameiurus catus*	1	2	3		6
Yellowfin goby	*Acanthogobius flavimanus*	1				1
	Sum of Catch =	**323**	**916**	**877**	**984**	**3,100**
	Count of Species =	**18**	**23**	**17**	**17**	**26**

*Native species

Table 4- Species collected by sampling date and sampling location

Sampling date	Sampling location	Black crappie	Bluegill	Brown bullhead	Carp	Chinook salmon	Delta smelt	Golden shiner	Goldfish	Hitch	Inland silverside	Largemouth bass	Red shiner	Redear sunfish	Sacramento blackfish	Sacramento pikeminnow	Sacramento sucker	Shimofuri goby	Smallmouth bass	Spotted bass	Steelhead	Striped bass	Threadfin shad	Tule perch	Warmouth	White catfish	Yellowfin goby
08/23/07	HS	2	9		1							20		5	33	11	4			1		8		10			
08/24/07	C1	1			2					3		10		2	1		8							7			
08/24/07	C2	3	4		2							22	1	4	8	3	5		1					9		2	
08/28/07	CL	1	2					3		2		18		7	1	3								14			
09/05/07	CL	1	3		1			5		5		13		11		2				1				17	1	1	
10/25/07	C1		6					1			1	17		21		1	7			3		3	6	5		1	1
10/25/07	C2	5	6		1			10		3	52	43		25	6	1	1			3			1	27			
10/26/07	HS	2						1			15	11		4	2	11						7	7	5			
10/29/07	CL	1						1		1		17		8										16		2	
12/13/07	C1		2					8		3	36	16		17		5	10							9			
12/13/07	C2	1	6	1				5			12	15		61	2		1							13			
12/14/07	HS	12	22					2		3	21	39		100	4	2								38			
12/21/07	CL		1								1	11		4		3	3							2			
02/19/08	CL	8	28		1			34	1	11	4	35		128		2					1			332	3		
02/20/08	HS	17	36			1		22		10	1	63		169	3	4								126	1		
02/26/08	C1		1			2		2				23		9		8								13			
02/26/08	C2	8	11			9		29		15		63		138	5	5		1						34	3		
03/26/08	C1		1		7							26		13		1	1					1		2			
03/26/08	C2	3	20		3		2	10		11		59		72	4	7	1	1				3		34			
03/27/08	CL	3	12					4		7	1	26		32		1								20			
03/28/08	HS	5	25		1	1		7		4		20		40		1								13	2		
	Total =	**73**	**195**	**1**	**19**	**13**	**2**	**144**	**1**	**78**	**144**	**567**	**1**	**870**	**69**	**71**	**41**	**2**	**1**	**8**	**1**	**22**	**14**	**746**	**10**	**6**	**1**

Table 5- Fork length (mm) and weight (kg) of piscivorous fish collected. Number measured and number weighed denoted by "N"

Species	Fork Length (mm)				Weight (kg)			
	N	Min	Max	Avg	N	Min	Max	Avg
Largemouth bass	419	41	550	237	96	0.45	4.31	1.11
Bluegill	160	22	240	115	0	N/A	N/A	N/A
Black crappie	73	45	260	106	0	N/A	N/A	N/A
Sacramento pikeminnow	71	61	651	362	34	0.23	3.86	1.99
Striped bass	22	119	711	406	11	1.13	4.54	2.10
Warmouth	10	46	160	122	0	N/A	N/A	N/A
Spotted bass	8	68	356	135	0	N/A	N/A	N/A
White catfish	6	237	372	293	0	N/A	N/A	N/A
Brown bullhead	1	230	230	230	0	N/A	N/A	N/A
Smallmouth bass	1	143	143	143	0	N/A	N/A	N/A

Table 6- Striped bass collected per sampling date and sampling location

Sampling date	Sampling location	Number collected	Min FL (mm)	Max FL (mm)
08/23/07	HS	8	416	711
10/25/07	C1	3	166	193
10/26/07	HS	7	406	636
03/26/08	C1	1	551	551
03/26/08	C2	3	119	174

2.3.3 Catch per Unit Effort

Catch per unit effort (CPUE) was calculated for time (per hour of applied current) and distance (per meter of shoreline shocked); (Table 7). CPUE was calculated using total catch of all species per sampling date per sampling location. Catch per hour and per meter fished were highest at the SWP Curtis Landing release site on February 19, 2008. We collected 588 fish in 4,522 shocking seconds or 400 m (1,312 ft), which equated to 468 fish for every hour of electrofishing or 1.461 fish for every meter (0.44 fish/ft) Catch per hour and per meter were lowest at the SWP Curtis Landing release site on December 21, 2007. Twenty-five fish were collected in 2,271 shocking seconds or 400 m (1,312 ft), which equated to 40 fish for every hour of electrofishing or 0.062 fish for every meter (0.019 fish/ft) of shoreline. The highest and lowest CPUE values coincided with the near-lowest and highest average river conductivity values, respectively (Table 7).

Table 7- Catch per unit effort by sampling date and sampling location. River conductivity is average of start and end sampling values

Sampling date	Sampling location	Total catch	Catch per hour	Catch per meter	Conductivity (µS/cm)
08/23/07	HS	104	357	0.130*	456
08/24/07	C1	34	113	0.085	1,442
08/24/07	C2	64	211	0.159	1,339
08/28/07	CL	51	179	0.106	1,630
09/05/07	CL	61	178	0.095	1,577
10/25/07	C1	73	165	0.174	406
10/25/07	C2	184	408	0.440	654
10/26/07	HS	65	174	0.238	1,403
10/29/07	CL	46	87	0.114	2,271
12/13/07	C1	106	165	0.263	423
12/13/07	C2	117	183	0.291	450
12/14/07	HS	243	208	0.604	1,444
12/21/07	CL	25	40	0.062	3,033
02/19/08	CL	588	468	1.461	206
02/20/08	HS	453	264	1.126	203
02/26/08	C1	58	89	0.144	191
02/26/08	C2	321	392	0.798	197
03/26/08	C1	52	86	0.129	220
03/26/08	C2	230	290	0.572	214
03/27/08	CL	106	166	0.263	259
03/28/08	HS	119	243	0.924	235

*Electrofishing distance was not recorded, estimated at 800 m

Catch per hour and per meter were also calculated for three predatory species: largemouth bass, Sacramento pikeminnow, and striped bass (Table 8). Catch per hour and catch per meter were always greatest for largemouth bass at all four sites sampled. CPUE was generally lower for Sacramento pikeminnow with fewer caught at all sites, and in general few striped bass were captured (none were caught at the SWP Curtis Landing release site). At the SWP Horseshoe Bend release site, CPUE for Sacramento pikeminnow and striped bass was generally highest during the summer and spring monitoring periods then gradually decreased as the study progressed. In contrast, CPUE for largemouth bass was highest during the summer monitoring period then lower and relatively constant for the rest of the study.

Table 8 - Catch per unit effort by sampling date and location of three predatory fishes: Largemouth bass, Sacramento pikeminnow, and striped bass. Missing values indicate no catch.

		Largemouth bass			Sacramento pikeminnow			Striped bass		
Sampling date	**Sampling location**	**Total catch**	**Catch per hour**	**Catch per meter**	**Total catch**	**Catch per hour**	**Catch per meter**	**Total catch**	**Catch per hour**	**Catch per meter**
08/23/07	HS	20	69	0.025*	11	38	0.014*	8	27	0.010*
08/24/07	C1	10	33	0.025						
08/24/07	C2	22	73	0.055	3	10	0.007			
08/28/07	CL	18	63	0.037	3	11	0.006			
09/05/07	CL	13	38	0.020	2	6	0.003			
10/25/07	C1	17	38	0.041	1	2	0.002	3	7	0.007
10/25/07	C2	43	95	0.103	1	2	0.002			
10/26/07	HS	11	29	0.040	11	29	0.040	7	19	0.026
10/29/07	CL	17	32	0.042						
12/13/07	C1	16	25	0.040	5	8	0.012			
12/13/07	C2	15	24	0.037						
12/14/07	HS	39	33	0.097	2	2	0.005			
12/21/07	CL	11	17	0.027	3	5	0.007			
02/19/08	CL	35	28	0.087	2	2	0.005			
02/20/08	HS	63	37	0.157	4	2	0.010			
02/26/08	C1	23	35	0.057	8	12	0.020			
02/26/08	C2	63	77	0.157	5	6	0.012			
03/26/08	C1	26	43	0.065	1	2	0.002	1	2	0.002
03/26/08	C2	59	74	0.147	7	9	0.017	3	4	0.007
03/27/08	CL	26	41	0.065	1	2	0.002			
03/28/08	HS	20	41	0.155	1	2	0.008			

*Electrofishing distance was not recorded, estimated at 800 m

2.3.4 Acoustic and Floy Tagged Predators

Twenty-eight predators (7 striped bass and 21 Sacramento pikeminnow) were fitted with acoustic tags (Table 9). Only legal-sized (greater than or equal to 457 mm [18 in] total length or 420 mm [16.5 in] FL) striped bass were fitted with acoustic tags. Only adult Sacramento pikeminnow were tagged.

Table 9- Fork length (mm) and weight (kg) of tagged predators

Tag Method	Species	Fork Length (mm)				Weight (kg)			
		N	Min	Max	Avg	N	Min	Max	Avg
Acoustic Tag	Striped bass	7	465	711	554	7	1.36	4.54	2.49
	Sacramento pikeminnow	21	397	645	534	21	0.45	3.63	2.05
Floy Tag	Largemouth bass	76	215	550	363	57	0.45	4.31	1.27
	Sacramento pikeminnow	15	249	651	490	10	0.23	3.86	1.77
	Striped bass	6	406	525	461	4	1.13	1.81	1.42
	Black crappie	1	260	260	260	0	N/A	N/A	N/A

Ninety-eight predators were tagged with Floy tags (Table 9). No fish were Floy tagged in March 2008 as this was the final sampling event and there was no possibility of recapture by electrofishing. Largemouth bass were Floy tagged during each sampling effort. At least one Sacramento pikeminnow was Floy tagged during each sampling period. Six were tagged at the SWP Horseshoe Bend release site on October 26, 2007 after eight fish had already been fitted with acoustic tags. Striped bass were Floy tagged only at the SWP Horseshoe Bend release site. One black crappie was Floy tagged at the SWP Horseshoe Bend release site.

2.3.5 Recaptured Fish

Eight of the 98 Floy tagged predators were recaptured in subsequent sampling periods. Seven of these recaptured fish were largemouth bass; the other was a Sacramento pikeminnow (Table 10). All fish were recaptured at the location at which they were tagged/released and were only recaptured once. The longest time between tagging and subsequent recapture was for a Sacramento pikeminnow tagged/released in the August 2007 sampling period and recaptured four months later in the December 2007 sampling period.

Table 10- Recapture information of floy-tagged predators

Species	Floy tag Number	Tagged or Recaptured	Date	Location	Fork Length (mm)	Weight (kg)
Largemouth bass	024	Tagged	10/25/07	C2	378	1.13
Largemouth bass	024	Recaptured	03/26/08	C2	390	0.91
Largemouth bass	105	Tagged	12/13/07	C1	336	1.13
Largemouth bass	105	Recaptured	03/26/08	C1	348	0.68
Largemouth bass	116	Tagged	12/14/07	HS	388	0.91
Largemouth bass	116	Recaptured	02/20/08	HS	389	1.13
Largemouth bass	145	Tagged	02/26/08	C2	350	0.91
Largemouth bass	145	Recaptured	03/26/08	C2	361	0.91
Largemouth bass	153	Tagged	02/26/08	C2	396	0.91
Largemouth bass	153	Recaptured	03/26/08	C2	no data	no data
Largemouth bass	157	Tagged	02/26/08	C1	386	1.13
Largemouth bass	157	Recaptured	03/26/08	C1	390	1.13
Largemouth bass	468	Tagged	08/28/07	CL	314	no data
Largemouth bass	468	Recaptured	09/05/07	CL	327	no data
Sacramento pikeminnow	494	Tagged	08/23/07	HS	621	no data
Sacramento pikeminnow	494	Recaptured	12/14/07	HS	630	3.63

2.3.6 Environmental Parameters

Environmental parameters (water and air temperature, river conductivity, dissolved oxygen, Secchi disk depth, and wind speed) were measured at each sampling (electrofishing and mobile monitoring); (Table 11). Parameter values were recorded at the start and end of each electrofishing sample location. During mobile monitoring, parameters were recorded only once, upon arrival at the location. The time at which parameters were taken was recorded. Dissolved oxygen (% saturation) was not recorded during the August 2007 electrofishing period. Additionally, parameters were recorded only for the start of sampling for electrofishing performed on August 23, 24, and 28, 2007. GPS coordinates were not recorded for mobile monitoring performed on January 17, 2008 due to instrument malfunction. Depth values were not consistently recorded during mobile monitoring surveys. Only river conductivity data and water temperature data were used for analysis of fish movement.

Water temperatures changed expectedly between sampling periods (seasons); the lowest and highest temperature values were recorded in December 2007 and August 2007, respectively (Figure 13). Dissolved oxygen (both % and mg/L) levels remained fairly constant throughout the study period, never dropping below 7.50 mg/L or 80.2% saturation. Water clarity, measured as Secchi disk depth, trended downward during the study period, though values were highly variable during October 2007 and December 2007. Wind speeds were also highly variable throughout the study. Air temperature trended downward from the first sampling period to the last; the coldest temperatures were recorded during the December 2007. Tidal fluctuations were compared with river conductivity values. Higher conductivity readings were not always associated with a high slack or flood tide. Some conductivity values were less than 500 μS/cm during a high slack or flood tide. In general, river conductivity was variable, but highest during the late-fall and winter (Figure 14).

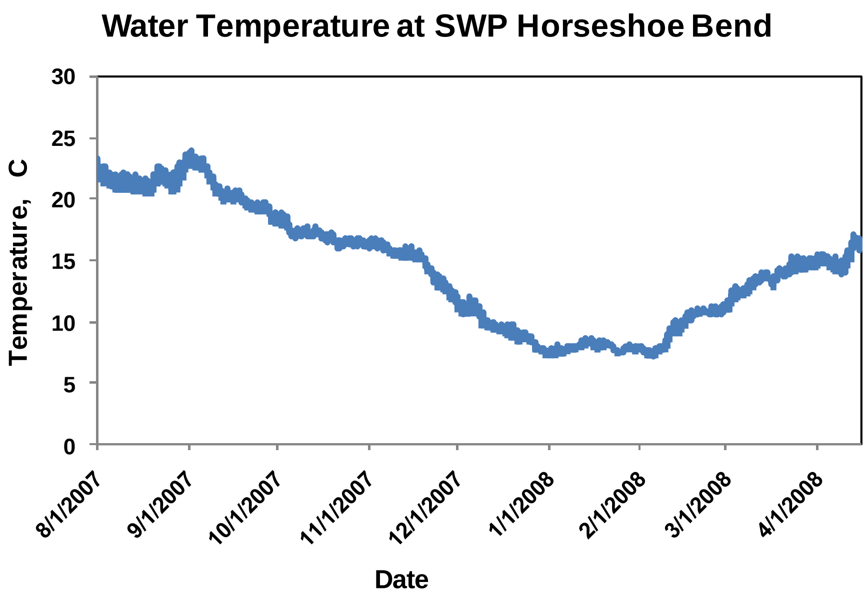


Figure 13-Water temperature at the SWP Horseshoe Bend release site for the duration of the study period.

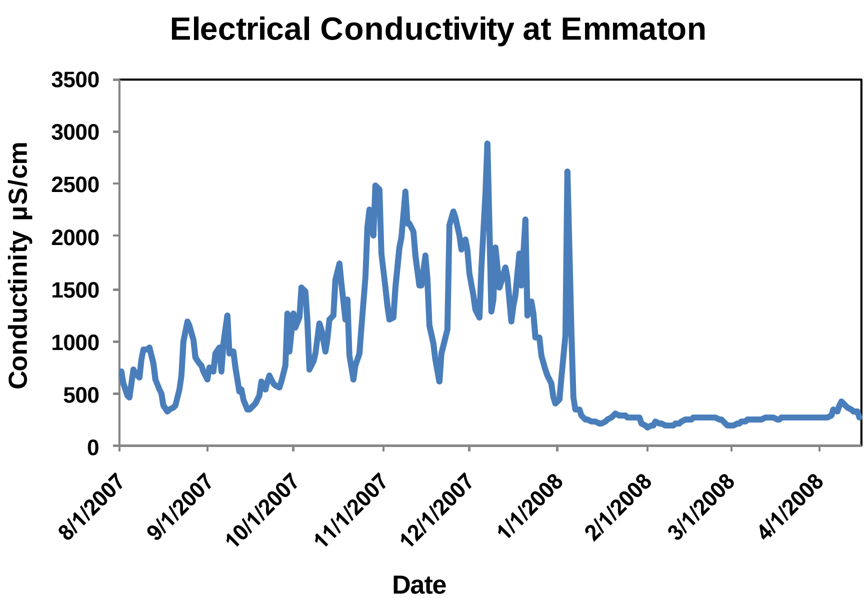


Figure 14-Electrical conductivity at Emmaton during the study period.

Table 11- Environmental parameters values for: (A) electrofishing and mobile monitoring data combined, (B) electrofishing data only, and (C) mobile monitoring data only

A	Water Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Secchi Disc (cm)	Depth (m)	Wind Speed (km/h)	Air Temperature (°C)
Average	13.87	725	94.85	9.79	59	4	12	16.76
Minimum	7.64	132	80.20	7.50	14	1	3	-0.60
Maximum	23.10	3,725	106.60	12.43	110	14	31	33.70
N	63	63	53	63	63	58	46	46

B	Water Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Secchi Disc (cm)	Depth (m)	Wind Speed (km/h)	Air Temperature (°C)
Average	14.36	832	95.05	9.69	64	5	11	16.69
Minimum	9.36	190	83.10	7.50	31	2	3	-0.60
Maximum	23.10	3,470	106.60	11.90	110	14	31	33.70
N	38	38	32	38	38	38	42	42

C	Water Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Secchi Disc (cm)	Depth (m)	Wind Speed (km/h)	Air Temperature (°C)
Average	13.12	563	94.55	9.94	51	4	24	17.50
Minimum	7.64	132	80.20	7.93	14	1	18	15.50
Maximum	20.70	3,725	105.80	12.43	73	8	29	20.10
N	25	25	21	25	25	20	4	4

2.3.7 Fish Telemetry

Twenty-eight predators were tagged with acoustic transmitters between August 23, 2007, and March 26, 2008 (Table 12), comprised of 21 adult Sacramento pikeminnow and seven adult striped bass. Adult striped bass with acoustic transmitters from the SWP Horseshoe Bend release site were generally detected moving away from the vicinity of the release site (Table 13). Only one tagged striped bass remained exclusively at the initial tagging location. However, this fish's tag was detected for a period of only two days after tagging (Table 12). This particular fish may have been caught and removed by an angler or the acoustic tag may have failed. One striped bass was tagged at the SWP Horseshoe Bend release site in October 2007 and was detected at both SWP release sites as well as at both CVP release sites. Between August 2007 and April 2008, acoustic-tagged striped bass were detected on the array of Consortium receivers as far north and east as Snodgrass Slough (Sacramento Co.), as far south as Antioch (Contra Costa Co.), and as far west as Mare Island (Solano Co.; Figure 15). One tagged striped bass was detected moving back and forth twice between the Sacramento River just downstream of Decker Island and the Carquinez Bridge between November 2007 and February 2008. Figure 16 shows the movement of a striped bass that was tagged at the SWP Horseshoe Bend release site in October 2007 and was last detected at Mare Island in March 2008.

Table 12- Predatory fish species tagged with acoustic transmitters

Species	Tag #	Location tagged	Date tagged	Last date Detected	Location of last detection (see Figure 8)
Striped bass	3283	HS	8/23/2007	8/24/2007	Sac R. SW of Decker Is.
Striped bass	3420	HS	8/23/2007	8/25/2007	HS
Sacramento pikeminnow	3290	HS	8/23/2007	11/3/2007	Rio Vista Br.
Sacramento pikeminnow	3288	HS	8/23/2007	4/2/2008	CS2
Sacramento pikeminnow	3292	HS	8/23/2007	4/17/2008	HS
Sacramento pikeminnow	3286	HS	8/23/2007	10/3/2007	EMM
Sacramento pikeminnow	3426	HS	8/23/2007	12/1/2007	CS2
Sacramento pikeminnow	3284	HS	8/23/2007	2/27/2008	Sac R. SW of Decker Is.
Sacramento pikeminnow	3291	HS	8/23/2007	4/17/2008	EMM
Sacramento pikeminnow	3424	CL	8/23/2007	9/3/2007	CL
Striped bass	3419	HS	10/26/2007	3/3/2008	SAC
Striped bass	3287	HS	10/26/2007	3/25/2008	SAC
Striped bass	3423	HS	10/26/2007	11/8/2007	Three Mile Slough
Striped bass	1387	HS	10/26/2007	3/3/2008	Mare Island
Sacramento pikeminnow	1385	HS	10/26/2007	4/17/2008	EMM
Sacramento pikeminnow	3425	HS	10/26/2007	3/7/2008	HS
Sacramento pikeminnow	3293	HS	10/26/2007	2/10/2008	Sac R. Mouth
Sacramento pikeminnow	1386	HS	10/26/2007	2/11/2008	Sac R. above Ord Br.
Sacramento pikeminnow	3417	CS1	12/13/2007	4/17/2008	CS1
Sacramento pikeminnow	3418	CS1	12/13/2007	1/4/2008	Rio Vista Br.
Sacramento pikeminnow	3415	HS	12/14/2007	3/19/2008	Georgiana Sl.
Sacramento pikeminnow	3296	CL	12/13/2007	1/8/2008	DB
Sacramento pikeminnow	3416	CL	12/21/2007	3/6/2008	DB
Sacramento pikeminnow	3305	CL	12/21/2007	4/16/2008	CL
Sacramento pikeminnow	3367	CL	2/19/2008	3/24/2008	EMM
Sacramento pikeminnow	3371	CS1	2/26/2008	4/17/2008	CS2
Sacramento pikeminnow	3369	CS1	2/26/2008	4/17/2008	CS1
Striped bass	3375	CS1	3/26/2008	4/3/2008	Georgiana Sl.

Table 13- Site fidelity of adult striped bass tagged with acoustic transmitters at the SWP Horseshoe Bend release site in 2007 and 2008

Tag ID	Date tagged	Last date of detection	No. of days detected at release site post tagging	No. of days monitored	% of total monitoring days detected at release site post tagging
1387	10/26/2007	3/3/2008	1	175	0.6
3283	8/23/2007	8/24/2007	1	239	0.4
3287	10/26/2007	3/25/2008	2	175	1.1
3419	10/26/2007	3/3/2008	2	175	1.1
3420	8/23/2007	8/25/2007	3	239	1.3
3423	10/26/2007	11/10/2007	3	175	1.7
					Mean= 1%

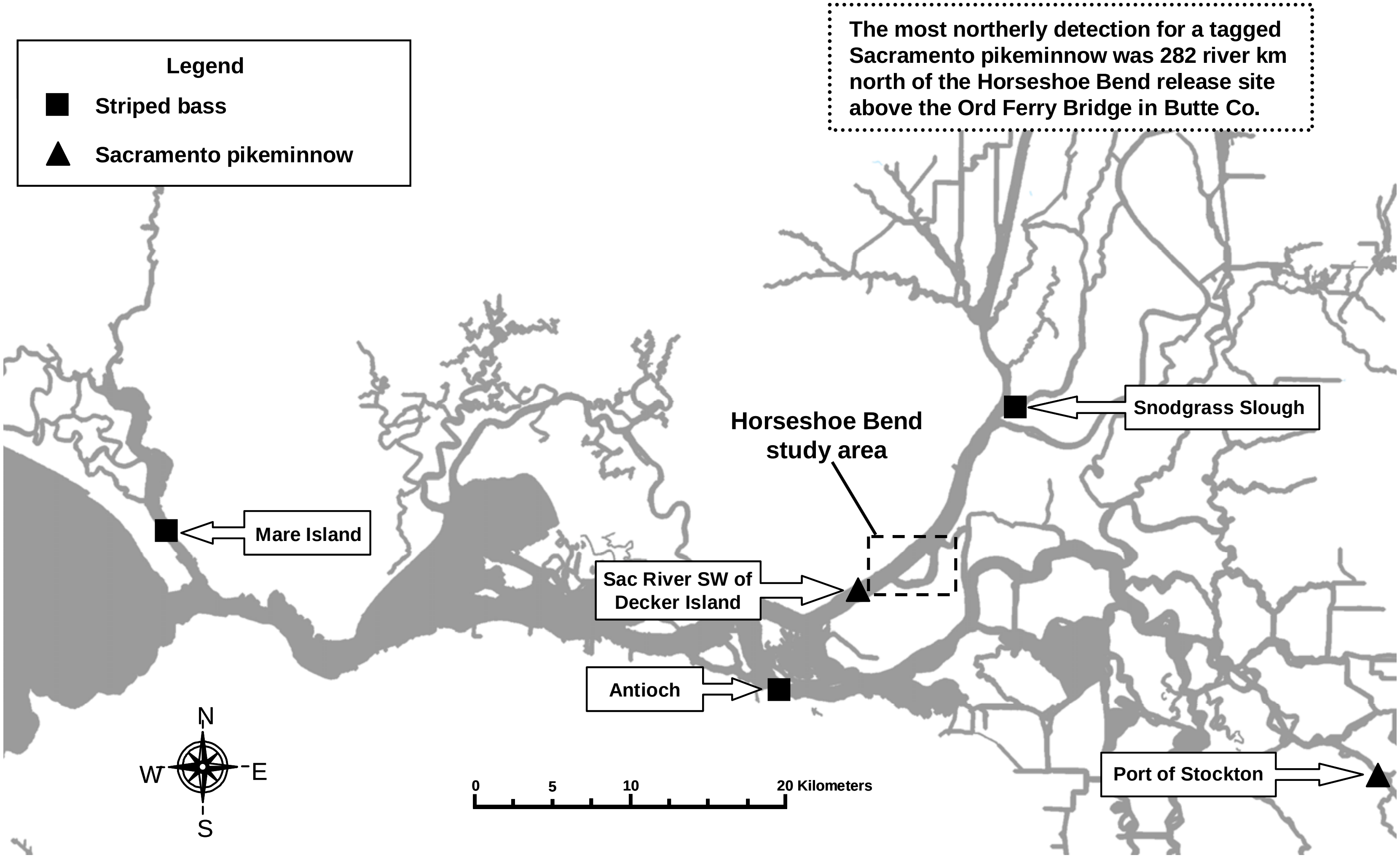


Figure 15- Detections outside of the Horseshoe Bend study area for acoustic-tagged adult striped bass and Sacramento pikeminnow between August 2007 and April 2008. Fish were detected as far north as the Sacramento River at river km 282, as far west as Mare Island, and as far east as the Port of Stockton.

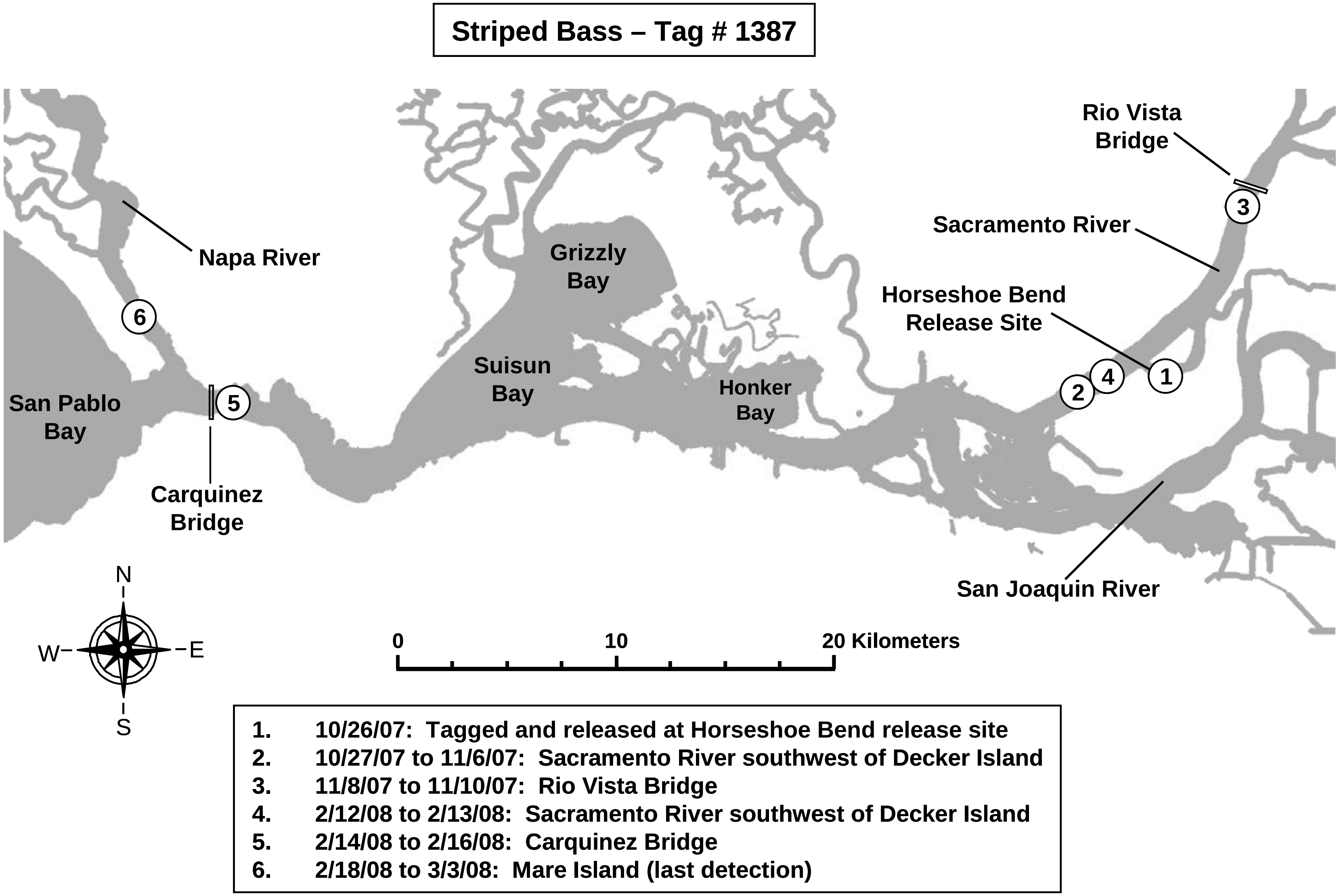


Figure 16- Movement of striped bass #1387 after being acoustic-tagged and released at the SWP Horseshoe Bend release site

Adult Sacramento pikeminnow with acoustic transmitters captured and released at the SWP release sites were generally observed to have more site fidelity than striped bass. Those tagged at the Horseshoe Bend site were detected between < 1% and 85% of the days monitored in the vicinity of the release site (Table 14). Those pikeminnow tagged at the SWP Curtis Landing release site were detected between 1.7% and 51% of the time in the vicinity of the release site (Table 14). Unlike many of the tagged striped bass that moved westerly towards San Pablo Bay, the majority of tagged Sacramento pikeminnow left the Horseshoe Bend area and were detected on the Consortium receivers moving up the Sacramento River. Five pikeminnows tagged at the SWP Horseshoe bend release site eventually left the study area and were detected in Steamboat Slough (Sacramento Co.). One of these pikeminnows returned to the Horseshoe Bend area after traveling to Steamboat Slough. Between August 2007 and April 2008, acoustic-tagged pikeminnow were detected as far north as above the Ord Ferry Bridge (Butte Co.), as far south and east as the port of Stockton (San Joaquin Co.), and only as far west as Antioch and the Sacramento River just downstream of Horseshoe Bend (Sacramento Co.; Figure 15). The pikeminnow that traveled upstream of the Ord Ferry Bridge was last detected at that location in mid-February 2008 (Figure 17).

Four Sacramento pikeminnow were tagged outside of the release sites at Control Site 1. Although these fish were detected at each of the receivers within Horseshoe Bend, all of these fish spent the highest percentage of time within the Control Site 1 area.

Based on Mann-Whitney Rank Sum analysis results, the proportion of time that Sacramento pikeminnow resided at a release site was not the same as for striped bass (U=87.500, p=0.012). Tagged striped bass typically spent very little time at the release site before moving out of the area (Table 13).

The number of predators large enough (>300 g [0.66 lb]) for tagging with acoustic transmitters declined at both the SWP Horseshoe Bend and Curtis Landing release sites, during the course of the study. This may have been due to the number of fish salvaged at the state and federal fish salvage facilities, which normally tend to decline during the late-fall and winter months. Figure 18 shows a declining trend of total fish released at the SWP release sites during the study period. DWR staff at the SDFPF provided fish release data used in the figure.

Table 14- Site fidelity of adult Sacramento pikeminnow tagged with acoustic transmitters at the SWP Horseshoe Bend and Curtis Landing release sites in 2007 and 2008

Tag ID	Tag location	Date tagged	Last date of detection	No. of days detected at release site post-tagging	No. of days monitored	% of monitoring days detected at release site post-tagging
1385	Horseshoe Bend Release Site	10/26/2007	4/17/2008	10	175	6
1386	Horseshoe Bend Release Site	10/26/2007	2/11/2008	24	175	14
3284	Horseshoe Bend Release Site	8/23/2007	2/27/2008	88	239	37
3286	Horseshoe Bend Release Site	8/23/2007	10/3/2007	24	239	10
3288	Horseshoe Bend Release Site	8/23/2007	4/2/2008	1	239	0.4
3290	Horseshoe Bend Release Site	8/23/2007	11/7/2007	16	239	7
3291	Horseshoe Bend Release Site	8/23/2007	4/17/2008	2	239	0.8
3292	Horseshoe Bend Release Site	8/23/2007	4/17/2008	202	239	85
3293	Horseshoe Bend Release Site	10/26/2007	2/10/2008	1	175	0.6
3415	Horseshoe Bend Release Site	12/14/2007	3/19/2008	93	126	74
3425	Horseshoe Bend Release Site	10/26/2007	3/11/2008	136	175	78
3426	Horseshoe Bend Release Site	8/23/2007	12/4/2007	24	239	10
3296	Curtis Landing Release Site	12/13/2007	1/8/2008	10	127	8
3305	Curtis Landing Release Site	12/21/2007	4/16/2008	42	119	35
3367	Curtis Landing Release Site	2/19/2008	3/24/2008	30	59	51
3416	Curtis Landing Release Site	12/21/2007	3/6/2008	23	119	19
3424	Curtis Landing Release Site	8/23/2007	9/3/2007	4	239	1.7
						Mean= 25.7%

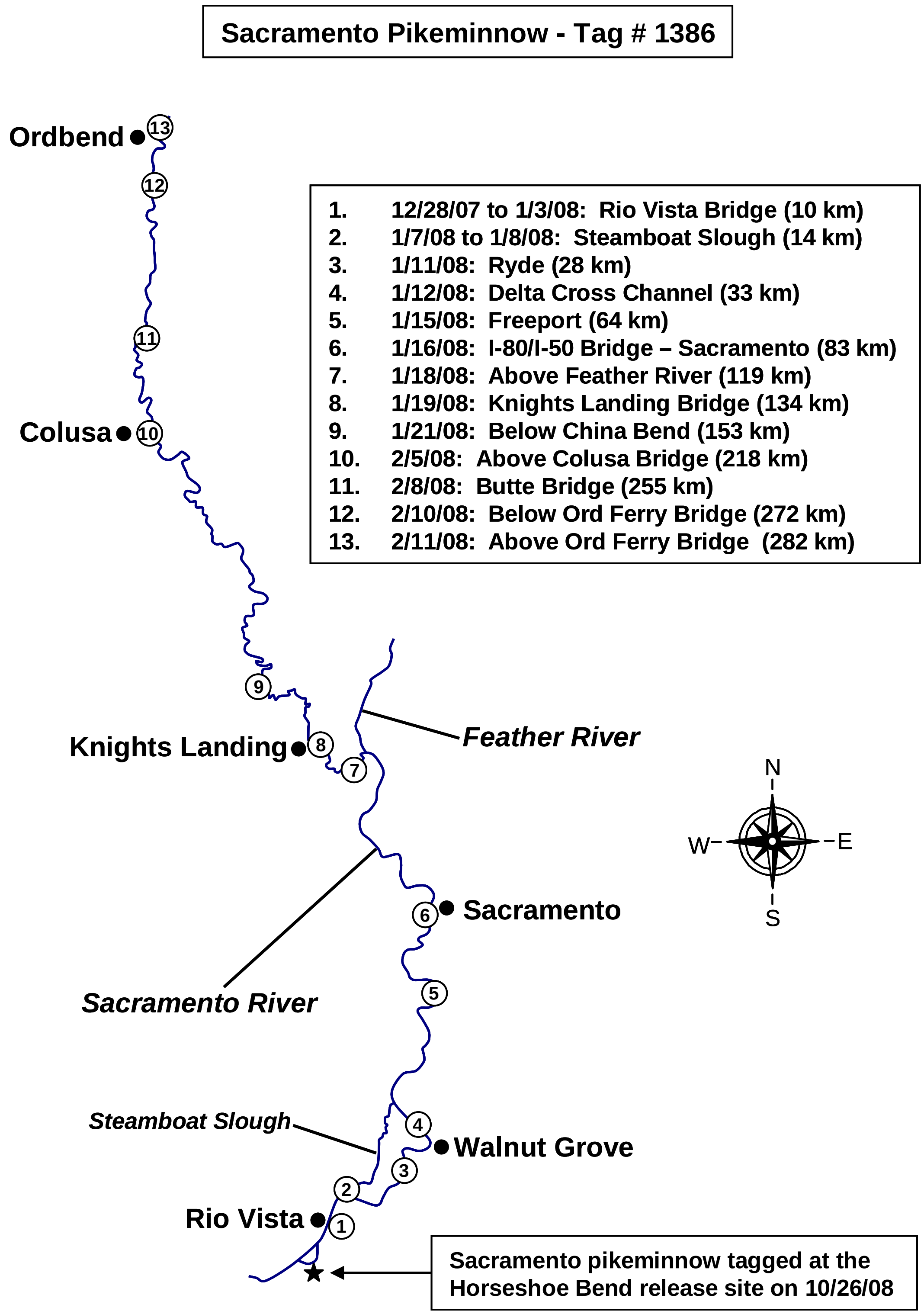


Figure 17- Movement of Sacramento pikeminnow #1386 in the Sacramento River and distances traveled from the SWP Horseshoe Bend release site

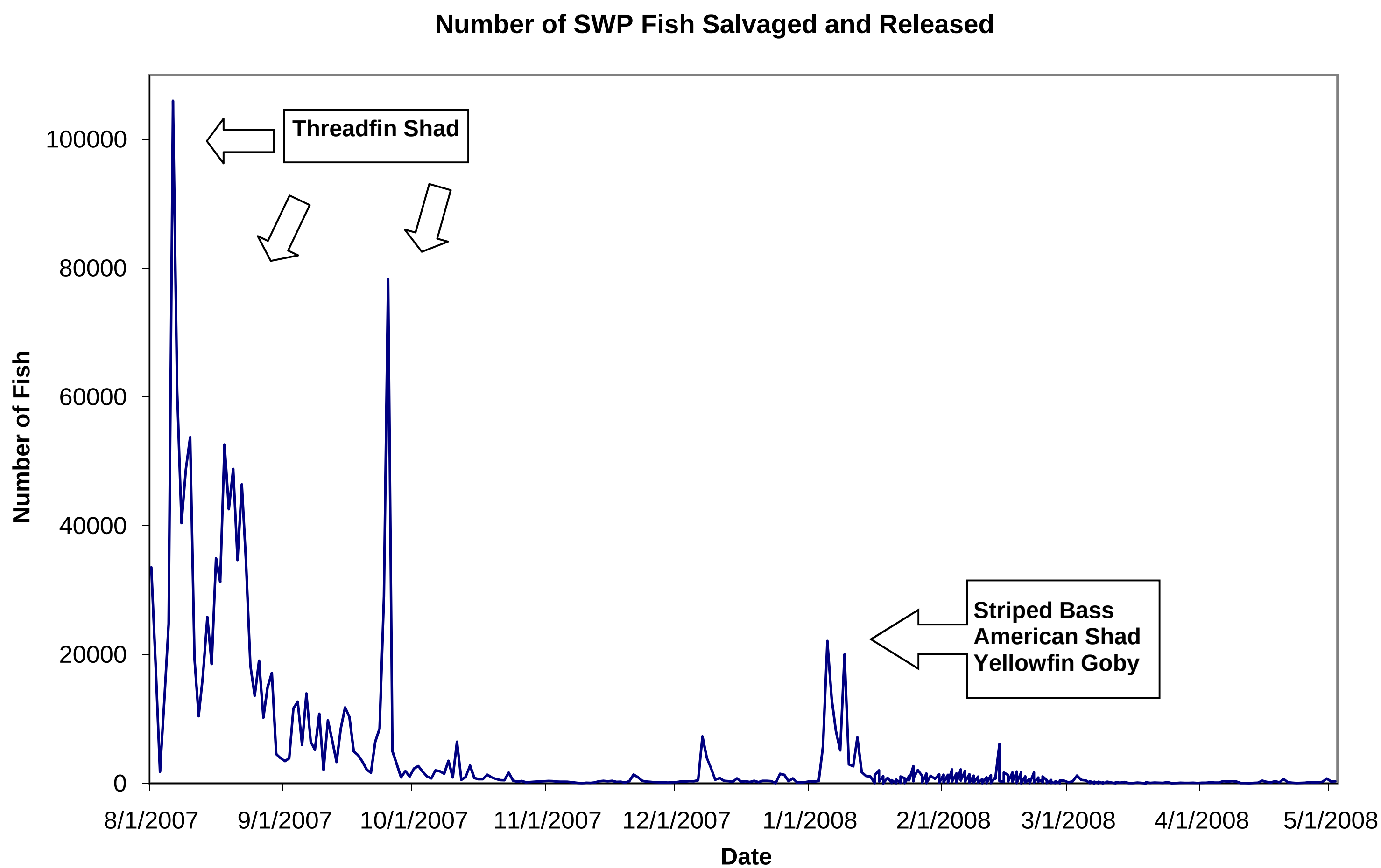


Figure 18- Numbers of salvaged fish transported from the SDFPF and released at the SWP release sites from August 1, 2007, to May 1, 2008. Predominant species being salvaged during peak events are shown in boxes with arrows.

Hourly water temperature and conductivity readings for the Emmaton CDEC site were used to observe whether water quality affected the movement of acoustic-tagged Sacramento pikeminnow (Appendices 11.3 & 11.4). Many of the pikeminnow were sedentary and did not move from near their release points. Although many of the pikeminnow showed a slight tendency to move upstream when water conductivity increased, movement in relation to water temperature was quite variable. Striped bass movement was not compared to Emmaton water quality readings as the striped bass tagged with acoustic tags during the study tended to leave the Horseshoe Bend area within days of tag and release.

2.4 Discussion

Sacramento pikeminnow, striped bass, and some members of the centrarchid family (largemouth bass, bluegill, and black crappie) were the predominant predatory fish species collected during electrofishing. Pickard and others (1982) found striped bass and Sacramento pikeminnow to be the most numerous predators in the Horseshoe Bend area from 1976 to 1978. Unlike the 1976 study, this study did not capture any channel catfish (N=0) and only a handful of white catfish (N=6). This disparity was largely due to the different sampling types used for both studies. This study used electrofishing, which is generally ineffective at capturing catfish in deep water, while Pickard and others used gill netting, a gear type that is more effective at catching the bottom oriented catfish species. Other studies (Orsi 1967) showed black crappie to be more abundant and slightly larger (most fish greater than 160 mm [6.3 in] FL) at their test site (SWP Horseshoe Bend release site) than this study. Again, the different sampling gear used in this study (electrofishing) versus Orsi's (gill netting) might have explained the variation in number and size of black crappie. Another explanation for the differences in species abundance and size of black crappie might be due to the changes in the local population during the 40 years separating these studies.

Catch data for largemouth bass showed that among piscivorous fish, this species had the greatest presence at the SWP Horseshoe Bend release site. Recapture data suggested site fidelity for this species, as all largemouth bass recaptures were made at the same location of tagging and releasing. Moyle (2002) stated adults were mostly piscivorous and considered them a keystone predator, whose foraging could alter the ecosystem and the population of its desired prey. Although no largemouth bass were caught in the immediate vicinity of the release pipe, the pilings supporting the pipe and submerged trees in the area provides habitat that is highly desired by this species. Largemouth bass might also be a major source of predation on salvaged fish as the salvaged fish disperse up and downstream from the release sites and potentially move into the near shore habitat characterized by extensive largemouth bass habitat. The available habitat, abundance data, site fidelity data, and adult selectivity for prey fish, suggest this predator could potentially contribute to the predation of released salvaged fish. Higher spatial resolution telemetry studies are needed to determine its contribution to post-release predation.

Telemetry results indicated that many of the Sacramento pikeminnow tagged at the SWP Horseshoe Bend release site remained in the vicinity of the release site for some period of time (less than a month to several months) before either moving into the main stem of the Sacramento River or elsewhere within Horseshoe Bend. Acoustic-tagged striped bass did not demonstrate much site fidelity to the SWP Horseshoe Bend release site as these fish only spent one to three days at the release site before moving out of the area. The tag detection data showed that striped bass would tend to migrate within a few days of tagging to the main river and travel as far downstream as Carquinez Strait before returning to the release sites in the early spring

Due to inherent limitations of the tagging technology used, this study could not determine if predatory fish are attracted to the release sites from the surrounding area when salvaged fish are released. Attempts made before the start of the study to attenuate the VR2 receivers and compress the range of detection were unsuccessful. Therefore, although acoustic-tagged predators were detected at the Horseshoe Bend receivers during the time of a fish release, we could not determine how close these predatory fish were to the release pipe during fish releases.

Each of the acoustic-tagged predatory fish eventually moved out of the area where they were tagged. Some of the tagged fish tended to move short distances away from their tagging location, while others moved as far away as San Pablo Bay and the upper reaches of the Sacramento River. Moyle (2002) reported that Sacramento pikeminnow are capable of living either a sedentary life style or migrating long distances. Both types of life strategies were observed in our release site study. A few pikeminnow stayed in close proximity to the location they were tagged for up to four months while others traveled as far as 282 km (175 mi) up the Sacramento River. Striped bass tended to leave the area where they were tagged within a few days.

Movement of Sacramento pikeminnow appeared to be slightly influenced by water temperature and conductivity around the Horseshoe Bend area. Most of the pikeminnow showed a slight tendency to move upstream with an increase in conductivity, which was expected for this species of fish. Pikeminnow response to water temperature was inconsistent as some fish had a tendency to move slightly upstream when temperatures increased while others would move slightly downstream. Movement of striped bass in the Horseshoe Bend area in relation to water quality could not be examined due to their lack of site fidelity.

Unfortunately, the monitoring schedule (August 2007-April 2008) did not incorporate the late spring and early summer. Therefore, the hypothesis that predators would congregate at the release site during a period which often the highest densities of prey fish are released could not be tested for this time period.

2.5 Conclusions

The results of the predatory fish tagging and sampling component of the study suggest that while striped bass have traditionally been the predatory species of greatest concern, Sacramento pikeminnow and largemouth bass should also be considered as potential predators on salvaged fish. Both the large number collected and site fidelity of both of these species suggests that they may be major contributors to losses of salvaged fish. Given this finding, future modifications to the release sites or design of new release sites should take these two species and their respective life histories into consideration. For example, efforts should be taken to place release sites at locations that lack extensive centrarchid habitat (ie. aquatic vegetations beds, submerged structure).

3.0 Avian Predation

Predation by birds may represent a large source of mortality of salvaged fish. Birds have high metabolic rates and require large quantities of food relative to their body size (Ruggerone 1986). Most piscivorous birds that have been observed within the study area are colonial nesting birds including, but not limited to Great Blue Heron (*Ardea herodias*), Western Grebe (*Aechmophorus occidentalis*), Clark's Grebe (*Aechmophorus clarkia*), Great Egret (*Ardea albus*), Snowy Egret (*Egretta thula*) Double-crested Cormorant (*Phalacrocorax auritus*), and several species of gulls (*Larus californicus, L. delawarensis, L. smithsonianus, L. occidentalis*). These species are particularly suited to the exploitation of fluctuating prey fish densities (Alcock 1968, Ward and Zahavi 1973). Such prey fish density fluctuations can result from large migratory accumulations, hatchery releases, physical obstructions that concentrate or disorient fish, and other natural features and events which occur in complex river systems (Stephenson and Fast 2004). Therefore the potential for salvaged fish releases, which are similar to hatchery releases, to be exploited by piscivorous birds is high.

In order to examine the magnitude of avian predation occurring at the salvaged fish release sites, a piscivorous bird survey was conducted in conjunction with DIDSON monitoring of piscivorous fishes. This survey had the following objectives:

- Document the presence, abundance, and behavior of predatory birds at the salvaged fish release sites and two control sites.
- Determine if predatory bird abundance is elevated at the salvaged fish release sites in contrast with two reference sites.
- Determine what factor(s) may be contributing to increased salvaged fish vulnerability to avian predation at the release sites.

Knowing the level of avian predation on salvaged fishes would help determine the need to reduce such predation as part of any predator reduction solutions at the salvaged fish release sites.

3.1 Methodology

A minimum of five bird surveys were planned at each release site during each of the five monitoring periods (Table 1) for a total of 25 surveys/site. Bird surveys at the SWP Horseshoe Bend release site were conducted at three times during the release process: 30 minutes before the release-truck arrival, during the release from the time that the truck arrived until its departure, and 30 minutes after the release. Surveys consisted of identifying (to family) and enumerating all piscivorous birds in the immediate vicinity of the release pipe, defined as the area in a 50-m (164 ft) radius of the release pipe. In addition, we noted predatory behavior such as diving, feeding, floating or hovering. A pair of 8 x 42 power binoculars was used for all observations. We conducted surveys in conjunction with fixed DIDSON monitoring at the SWP Horseshoe Bend release site, therefore the timing of surveys corresponded to the timing of releases as dictated by SWP pumping and salvage operating procedures. During the study, survey events typically occurred from 8 a.m. to noon.

Bird surveys at all other sites (CVP Emmaton, SWP Curtis Landing, Control Sites 1 & 2) were conducted immediately before DIDSON mobile monitoring at each site. As the boat approached the site, the boat operator stopped the boat well away from the site and the survey was conducted to avoid scaring away any birds. Surveys consisted of identifying (to family) and enumerating all piscivorous birds present and noting any predatory or foraging behavior. A pair of 8 x 42 power binoculars was used for all observations. The timing of these surveys was random and typically occurred anywhere from 8 a.m. to 1 p.m.

All data were entered into a Microsoft Access database and checked line by line for any data entry errors. For the purpose of comparisons between sites, the “30 minutes prior to release” observations for the SWP Horseshoe Bend site were used to compare to the other sites since those observations represented the maximum possible amount of time since the previous release event. The release period and 30 minutes after release count data were used only for analyses of behavior and distribution during releases. Of the birds observed during our monitoring, only cormorants and gulls had sufficient numbers for any discussion of behavior.

3.2 Results

3.2.1 Species Composition and Abundance

Cormorants, grebes, gulls, herons, and egrets were the piscivorous bird families present in the study area (Table 15). Most birds were at the SWP Horseshoe Bend release site or at the CVP Emmaton release site. The control sites and the SWP Curtis Landing release site consistently had few if any birds present (Figure 19). Gulls were very abundant during the first two monitoring periods (August and October) then slowly tapered off as the study progressed. Cormorants were abundant at the SWP Horseshoe Bend release site only, with exception of the first monitoring period. Grebes, herons, and egrets were sporadically present at several of the release sites, but were never consistently observed.

Table 15- Mean numbers of various avian predators in the study area for each of the 5 monitoring periods (Table 1).

		Monitoring Period				
Species	**Site**	**1**	**2**	**3**	**4**	**5**
Cormorants	Control 1	0	0	0	0	0
	Control 2	0	0	0	0	0
	Curtis	0	0	0	0	0
	Emmaton	0	0	0	0.4	0
	HSB	0	1.4	9.2	3.4	9
Gulls	Control 1	0	0.2	0	0	0
	Control 2	0	0	0	0	0
	Curtis	0	0	0	0	0
	Emmaton	0	18	4.16	2	0
	HSB	10.2	4.2	0.4	0.4	0.25
Grebes	Control 1	0	0	0	0	0
	Control 2	0	0.2	0	0	0
	Curtis	0	0	0	0.25	0.2
	Emmaton	0	0	0	0.6	0.25
	HSB	0	0	0	0	0
Egrets	Control 1	0.2	0.2	0	0	0
	Control 2	0	0.2	0	0	0
	Curtis	0	0	0	0.25	0
	Emmaton	0	0.8	0	0.2	0.25
	HSB	0	0	0	0	0
Herons	Control 1	0	0	0	0	0
	Control 2	0	0	0	0	0
	Curtis	0.2	0	0	0.25	0
	Emmaton	0	0	0	0	0
	HSB	0.2	0	0	0	0

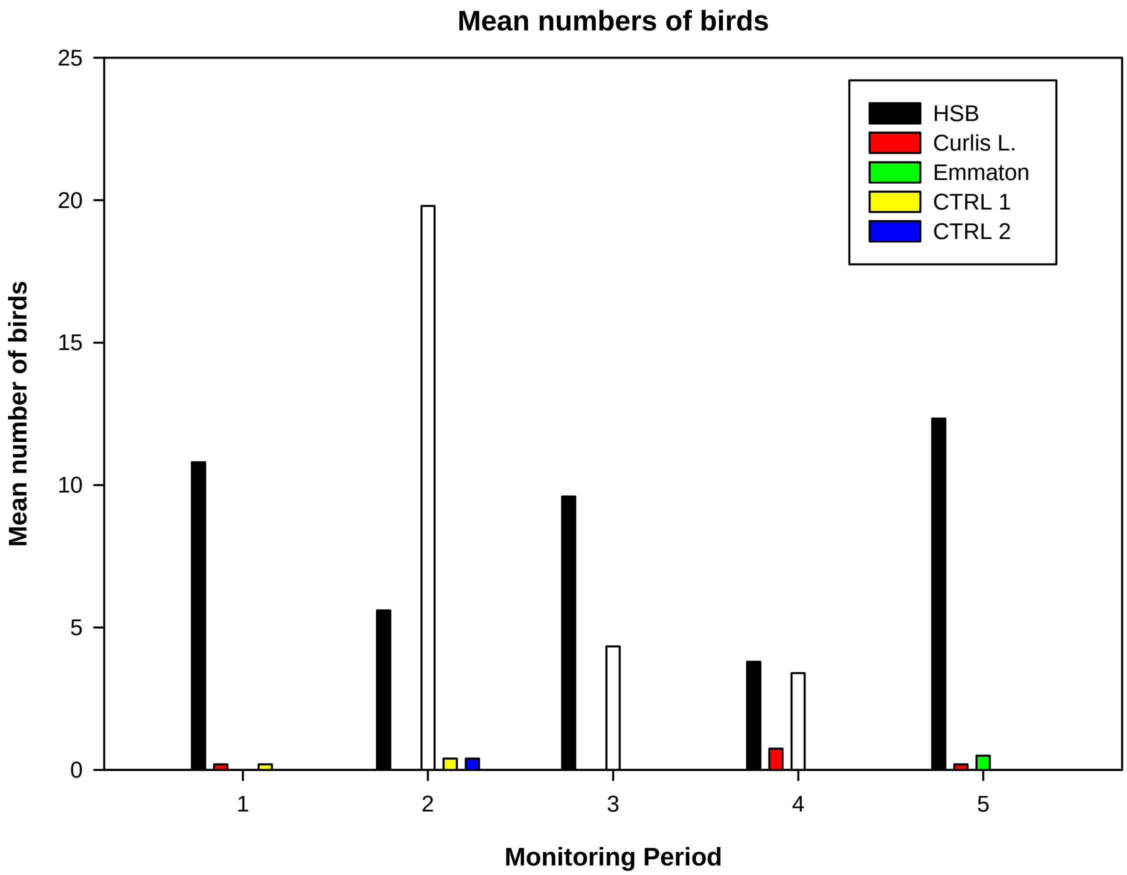


Figure 19-Mean numbers of piscivorous birds present at each of the five survey sites during the study

Control Site 1

Twenty-five surveys were conducted at Control Site 1, five surveys during each monitoring period (Table 1). Birds were generally rare and only present at Control Site 1 during the first two monitoring periods. Three birds were observed consisting of an egret during monitoring period 1 which was wading in the tules adjacent to the intake structure, 1 gull observed hovering high above the site and an Egret wading in the tules adjacent to the intake during monitoring period 2.

Control Site 2

Twenty-five surveys were conducted at Control Site 2, five surveys during each monitoring period (Table 1). Birds were rarely observed and only present during the second monitoring period. Two birds were observed including a grebe swimming on the surface approximately 20 m (65 ft) away from the shoreline, and an egret perched on the intake structure.

SWP Curtis Landing Release Site
Twenty-four surveys were conducted at the SWP Curtis Landing release site, five surveys during each monitoring period (Table 1) except monitoring period 4 when only four surveys were conducted due to poor weather conditions. Birds were generally rare at Curtis Landing.

SWP Horseshoe Bend Release Site
We did 24 surveys at the SWP Horseshoe Bend release site, five surveys during each monitoring period (Table 1) except monitoring period 5 when only four surveys were conducted due to poor weather. The Horseshoe Bend release site consistently had the highest number of total birds of all the study sites and was the only site where Cormorants were consistently observed. As many as 13 cormorants (3/26/08) and 22 gulls (8/9/2007) were observed feeding during releases at the Horseshoe Bend release site. Birds of all other species were generally rare at the Horseshoe Bend release site with the exception of several herons observed during the first monitoring period.

CVP Emmaton Release Site
Twenty-three surveys were conducted at the CVP Emmaton release site, five surveys during each monitoring period (Table 1) except monitoring period 1 when consistently high winds only allowed for three surveys. The CVP Emmaton release site on occasion had large numbers of gulls present. As many as 35 gulls (10/18/07) were observed within the vicinity of the site. However, the presence of large numbers of gulls was often associated with nearby sea lion feeding activity. Interestingly, cormorants were only observed on one occasion, January 29, 2008, even though they were commonly observed just upstream at the SWP Horseshoe Bend release site.

3.2.2 Behavior during Releases

Gulls
At both the SWP Horseshoe Bend and CVP Emmaton release sites, true predatory behavior by gulls was difficult to differentiate from scavenging behavior during releases. In addition to live salvaged fish, the fish release truck typically has many dead or dying fish and various other debris (ie. Aquatic weed, trash, woody debris). Gulls were observed pecking and diving at floating objects. They were often observed fighting over floating fish, but it was unclear whether these fish were dead, injured, or simply disoriented. Anecdotal observations from the Element 3 experiments indicate that on occasion, salvaged fish may exit the release pipe and become disoriented. On several occasions, fish in experimental releases were observed swimming in circles at the surface for several minutes after the release but were shown to recover. If fish are simply injured or disoriented, they conceivably could survive if not for predation by the gulls. At both sites, birds typically followed the plume of salvaged debris/fish as it dispersed up or downstream (depending on the tide) from the release site until it was ~100 meters (328 ft) away from the release site, at which time the gulls either dispersed or returned to their perches.

At the SWP Horseshoe Bend release site, gulls (when present) consistently perched on the support structure of an agricultural water intake located adjacent to the release pipe (Figure 20). The support structure provides an elevated resting and vantage point that gulls utilized to observe release activities and to rest between releases. A sunken dock just downstream of the release pipe was rarely used as a perch, possibly due to its limited elevation above the water line.

At the CVP Emmaton release site, gulls were often observed perched on the hand rails of the catwalk above the release pipe before, during, and after releases. During the second monitoring period, on several occasions large aggregations of gulls (15-20) were also observed shadowing the movements of sea lions present in the area and presumably scavenging. The presence of the sea lions may explain why birds were so abundant at the CVP Emmaton site during the second monitoring period.

Figure 20-Piscivorous birds (gulls) perched on a pump intake structure adjacent to the SWP Horseshoe Bend release site

Cormorants

Active feeding by cormorants was only observed at the SWP Horseshoe Bend release site. Successful predation on salvaged fish was confirmed by DIDSON observations of cormorants catching fish as they exited the release pipe (Figure 21). The same video footage also showed that while the cormorants often momentarily scared away any nearby predatory fish, they did not appear to be actively pursuing the predatory fish but rather were focused on capturing salvaged fish. Any predatory fish displaced by the cormorants quickly returned to their position near the release pipe once the cormorant was gone. Several cormorants were also observed surfacing near the release pipe with prey of appropriate size for salvaged fish. Active feeding by cormorants at the release site was characterized by cormorants floating near the end of the pipe then making long (~30 second) dives in the vicinity of the pipe. When releases occurred during strong tides and correspondingly higher water velocities, cormorants were observed positioning themselves farther upstream or downstream from the pipe in an effort to compensate for the additional sweeping flow.

As with the gulls, cormorants (when present) used the agricultural intake structure adjacent to the SWP Horseshoe Bend release site as a perch. Observations of 12–13 cormorants perched on the structure were common. As with the gulls, cormorants did not use the partially sunken dock downstream of the release site. Interestingly, cormorants were rarely observed at the CVP Emmaton release site even though they were so common at the SWP Horseshoe Bend release site which is located just upstream.

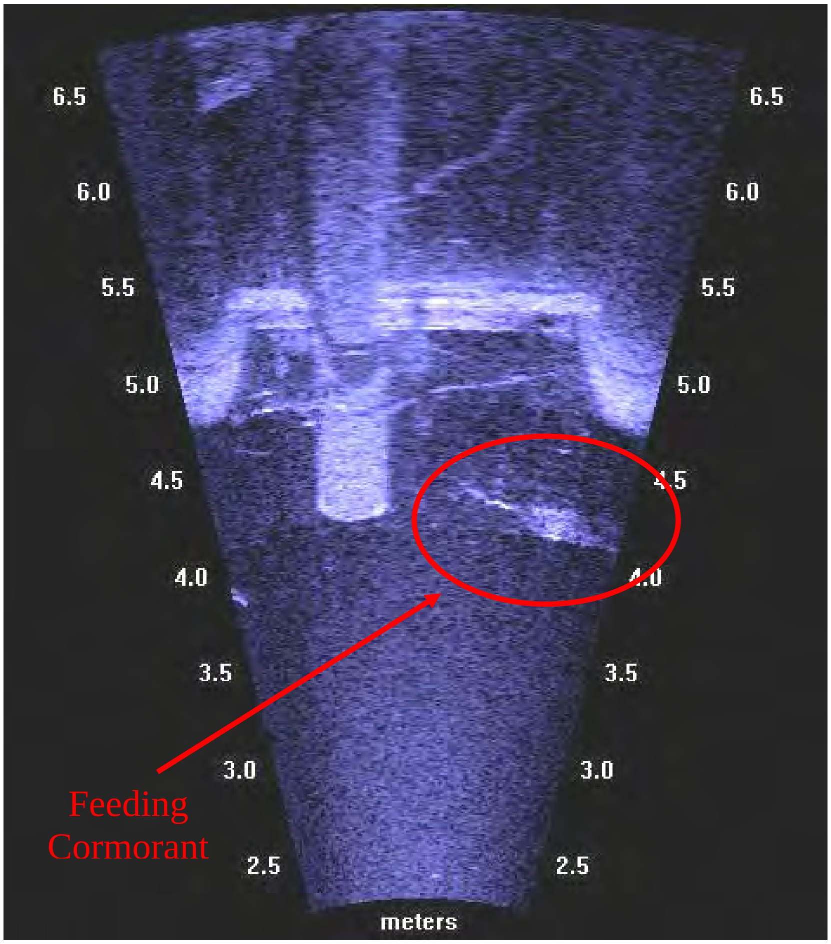


Figure 21- DIDSON image showing a cormorant feeding at the end of the SWP Horseshoe Bend release pipe

3.2.3 Learned Behavior and Behavioral Attraction

For both gulls and cormorants, many birds used the agricultural intake structure adjacent to the SWP Horseshoe Bend release site as a perch at some point before, during, or after a release. Typically, as the release truck arrived at the site, some if not all of the birds would leave their perch and either hover above the site (gulls) or float on the water's surface near the end of the pipe (cormorants and some gulls), suggesting that the arrival of the truck was a visual cue for the birds. When the salvage operator climbed aboard the top of the truck to rinse the tank, in most cases birds still perched on the intake structure used this as another cue to leave their perch and begin searching for prey. Actively feeding birds were not encountered at the SWP Curtis Landing release site or at either of the control sites.

3.3 Discussion

Elevated numbers of avian predators were observed at two of the three release sites monitored, and were directly linked to predation on salvaged fishes through visual and DIDSON observations. The avian predation component of this study showed that cormorants and gulls were the primary avian predators of salvaged fishes at the time of release. This is not surprising, because bird species of both families are known to take advantage of artificially created aggregations of prey fishes such as hatchery releases and dam spillways (Alcock 1968, Ward and Zahavi 1996). When a release is conducted, a turbulent plume of water extends from the point within the submerged pipe that the released water impacts the receiving water to near the terminus of the release pipe, possibly extending to beyond the end of the pipe. As fish pass through this area, they could be disoriented and become more susceptible to predation by both fish and avian predators. Furthermore, cormorants are efficient, subsurface predators and gulls are efficient surface scavengers on disoriented or injured fish.

Interestingly, cormorant abundance increased as numbers of salvaged fish decreased (Table 15). Seasonal abundance of cormorants and seasonal migration may have been a reason for this discontinuity between abundance of cormorants and salvaged fish. Double Crested Cormorants usually arrive at their wintering grounds, including the Delta, in November and remain there until April, then move back to their home range (Aderman and Hill 1995, DWR 2009). This suggests that the cormorants observed feeding at the release sites were not permanent residents of the area, but rather a transient population. This also explains the absence of cormorants from the study area during the first (August) monitoring period. Another possibility is that cormorant predation was tied to the species composition at that location in the Delta and that they may have been there based on the presence of particular prey species. For example, the period that most cormorants were observed (winter/early spring) corresponds to the period of highest juvenile salmonid abundance in the Delta (steelhead and Chinook salmon smolts). In the Columbia River basin, Double-crested Cormorants have been shown to feed heavily on out-migrating salmonids (Collis and others 2001). Another study found that cormorants' strong affinity for salmonids is exhibited by distributing themselves wherever trout fingerlings were located in a reservoir and by consuming mostly trout despite presence of many other fish (Modde and Wasowicz 1996).

Cormorants are widely recognized as being an efficient avian piscivore. Cormorants are capable of consuming up to a third of their body weight per day (Robertson 1974). At the SWP Horseshoe Bend release site, predation by cormorants on salvaged fish was confirmed by DIDSON observations of several cormorants chasing and/or capturing small fish as they exited the release pipe. In addition, cormorants were often observed surfacing near the release pipe with fish in their mouths. While the total number of fish eaten by the cormorants is unknown, the proportion of salvaged fish eaten could be substantial. During the period that cormorant abundance is highest, salvaged fish releases often consist of only a few hundred fish, therefore even a seemingly modest number of salvaged fish lost to avian predation may be a substantial proportion of the total number of salvaged fish.

3.4 Conclusions

The results of the avian predation component of the study show that predation by birds on salvaged fish could potentially have a major impact on salvaged fish survival. Most cormorants were observed feeding on salvaged fish during a season when the fewest numbers of the salvaged fish are released, coinciding with the critical juvenile salmon and steelhead outmigration season. As a result, even only a few birds could have a substantial impact on the percentage of salvaged fish surviving release.

The results of the avian predation component also showed that birds were adept at taking advantage of any structures at or around the release sites as roosting sites or perches. The various structures at the SWP Horseshoe Bend release site and CVP Emmaton release site appeared to make ideal perches for a number of birds. Conversely, the lack of any perches at the SWP Curtis Landing release site, resulted in few birds being observed there even though the number of salvaged fish being released was similar. As a guideline for the construction and placement of new or refurbished release sites, all possible roosting sites or perches near the release sites should be either removed or equipped with bird deterrent devices, such as bird spikes. Similarly, release sites should not be placed near any partially submerged structures, such as snags or agricultural intakes, that might provide roosts/perches for piscivorous birds. Efforts should also be made to remove any exposed snags that get lodged near the release sites.

4.0 DIDSON Observations

The **D**ual frequency **ID**entification **SON**ar, or DIDSON™, is a high-definition imaging sonar designed by the University of Washington's Applied Physics Lab for military applications such as diver detection and underwater mine identification and marketed by the Sound Metrics Corporation (Lake Forest Park, WA). The DIDSON camera system provides a valuable observational tool that can be used to assess changes in predator behavior and density at the study sites. DIDSON operates at two frequencies, 1.8 MHz for close range observations of less than 12 m (40 ft) and 1.0 MHz for detecting targets at ranges up to 40 m (130 ft). At close ranges, this sonar gives near video quality images for identifying objects underwater. The camera emits 48 beams of sound in the low frequency mode and 96 beams of sound in high frequency mode for a 29 degree field of view for both frequencies. The camera uses the sound waves to detect acoustic echoes of objects in the water and then converts them into digital images, which can be viewed on a computer. These same sound waves give DIDSON the ability to produce clear images in dark or turbid waters, unlike standard underwater cameras that rely on a light source to produce an image. The images produced by DIDSON are very similar to an ultrasound image (Figure 22).

The DIDSON camera was used to document predator behavior and abundance at the exit of the salvaged fish release pipes at the SWP Horseshoe Bend, SWP Curtis Landing, and CVP Emmaton release sites. In addition, DIDSON observations were conducted at the two control sites to compare predator abundance and behavior to submerged underwater structures without the added attraction of fish releases. As a result of the DIDSON camera’s limited field of vision, the use of the camera was intended to complement the greater range capability of the split beam hydroacoustic system also used in the study.

The DIDSON was also used to make detailed observations of the release process at the SWP Horseshoe Bend release site. These observations included predator behavior in response to specific events during the release process including the arrival of the release truck, activation of the flushing system, and the exit of salvaged fish into the receiving water. Measurements of fish length, while possible using the DIDSON software, were not conducted due to the absence of any literature on the accuracy or error associated with these measurements.

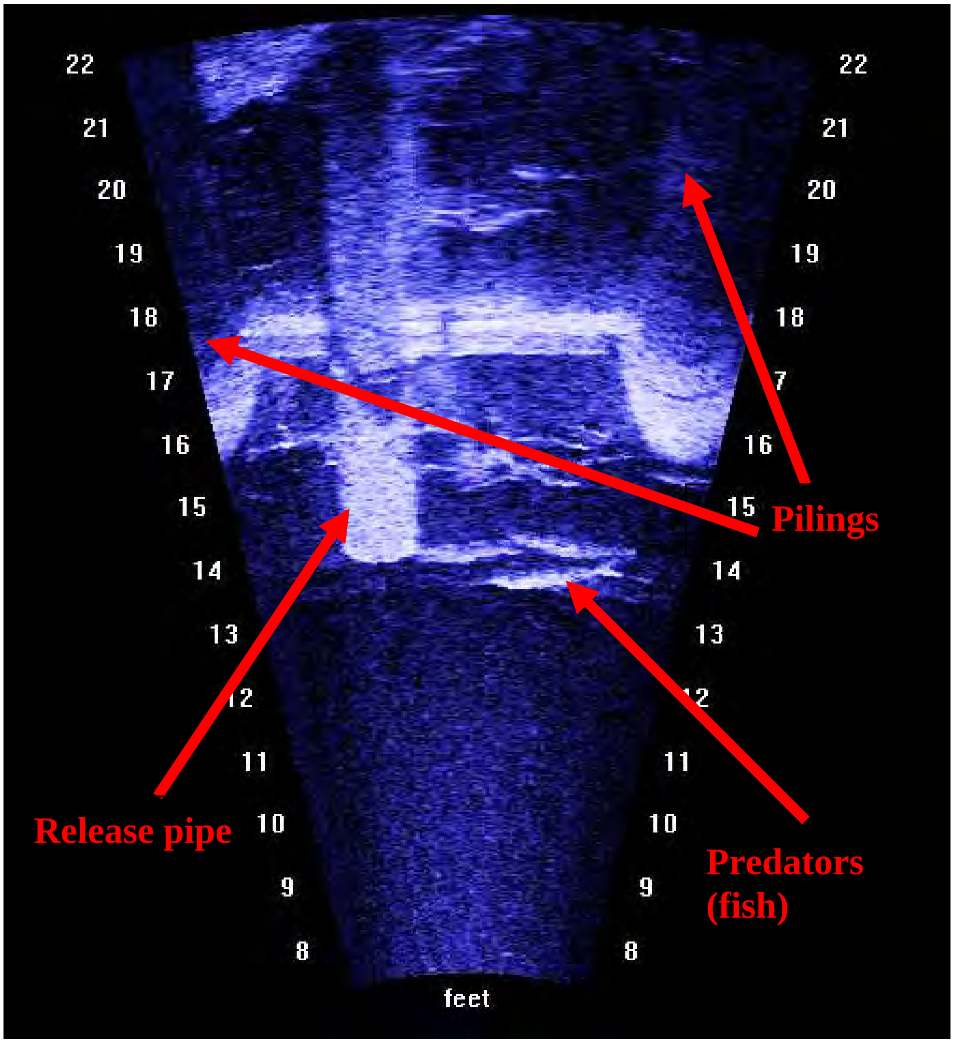


Figure 22- Example of imagery produced by the DIDSON camera with important features pointed out.

4.1 Methodology

DIDSON monitoring was conducted as a combination of "Fixed Site" monitoring at the SWP Horseshoe Bend release site and "Mobile" monitoring at all other sites. The installation of permanent camera deployment facilities at the SWP Horseshoe Bend release site allowed for detailed observation of salvaged fish released at the site.

4.1.1 Fixed Site Monitoring

Monitoring at the SWP Horseshoe Bend release site was conducted five times during each monitoring period (Table 1). Permanent DIDSON deployment equipment was installed at this site that allowed the DIDSON camera to be positioned at a fixed location to determine predator behavior in the immediate vicinity of the release pipe. The field of view for the DIDSON camera was fixed at one location throughout the observational period to determine changes in predator behavior before, during, and after releases. With a fixed field view, relative predator abundance was measured and observations were also used to assess changes in predator behavior and behavioral attraction to the release pipe discharge location.

The permanent DIDSON mounting equipment installed at the SWP Horseshoe Bend release site consisted of a galvanized steel boom that could be lowered and raised with a winch. At the end of the boom, a 3 m (10 ft) steel pole with a mounting bracket for the DIDSON camera on one end was attached (Figures 23 & 24). This configuration placed the DIDSON camera at a range of 4.25 m (14 ft) from the end of the release pipe and at an optimal viewing angle. A data/power cable for the DIDSON camera was also deployed that allowed for operation of the DIDSON camera from onshore within the release site compound. During each monitoring event, the camera was mounted and activated well before the arrival of the release truck and recorded video footage until a minimum of 30 minutes following the truck's departure.

An attempt was also made to collect water velocity information of the channel from near the terminus of the release pipe. An upward facing Acoustic Doppler Velocimeter (ADV) was deployed on the channel bottom near the end of the release pipe. However, during initial testing, it became evident that due to rapid biofouling of the instrument (mostly *Corbula* clams); constant cleaning of the device by a diver would be required to ensure accurate data collection. Due to safety concerns, a diver would not be allowed to clean the ADV, therefore water velocity measurements were not recorded by the upward facing ADV. As an alternative, the ADV instrument was mounted and operated in a downward facing configuration from the side of the research vessel during each sampling effort. This method was also used to collect water velocity data at each of the other monitoring sites. Since the model of ADV (Sontek Argonaut-SW, Sontek/YSI San Diego, CA) used in this study was not manufactured for operation in a downward facing configuration, an effort was made to calibrate and validate the data collected from the device using an alternative method (propeller driven velocimeter). The calibration/validation evaluation demonstrated that accurate measurements could be attained from the ADV in this configuration using an empirically determined data transformation. The ADV adjusted velocity readings correlated well with the propeller probe true velocity readings. If water velocities ranged from 0.3 m/s to 0.6 m/s (0.98 ft/s to 1.97 ft/s), the difference between the propeller and adjusted ADV readings was between 0 m/s to 0.03 m/s (0.0 ft/s to 0.1 ft/s). The methods and results of this evaluation are available in Appendix 11.2. During each monitoring event, water velocity data was collected for 15 minutes following each release. To avoid disturbing fish being observed using the DIDSON, the velocity measurements were not taken until after the camera had been removed, typically 45 minutes after the release.

Figure 23-The fixed mount system being lowered into the water at the SWP Horseshoe Bend release site. Note the DIDSON camera at the end of the mount.

Figure 24-The DIDSON camera mount system in its fully deployed position.

4.1.2 Mobile Monitoring

Mobile DIDSON monitoring was conducted at the two control sites on Horseshoe Bend, the SWP Curtis Landing release site on the San Joaquin River and the CVP Emmaton release site on the Sacramento River. Each site was monitored five times during each monitoring period (the CVP Emmaton release site was only monitored three times during the first monitoring period due to bad weather). Mobile monitoring was conducted from a boat equipped with the side mounted DIDSON camera. The side mount system consisted of a 3 m (10 ft) long pivoting aluminum boom that could be attached to the gunwhale of the boat, with a plate on one end for DIDSON attachment and handle bars on the other end for manual manipulation of the camera orientation (Figures 25 and 26). The design of the mobile monitoring boom allowed the user to rotate laterally 270 degrees and vertically 180 degrees; the boom also included a mechanism to adjust the depth of the camera in order to optimize the DIDSON beam angle on the target to provide the best possible image. To the best of our abilities, the camera was positioned at the same orientation to the target for all mobile monitoring episodes. Once the boat was positioned into place, DIDSON data was recorded for 10 minutes. Water velocity data was concurrently recorded using the same method described for fixed site monitoring. Monitoring at the CVP Emmaton site was limited to observations of the longer of the two release pipes because the shorter of the two pipes is rarely used and because the view of the shorter pipe was obstructed by pilings. Monitoring at the CVP Emmaton and SWP Curtis Landing release sites was conducted during non-release periods.

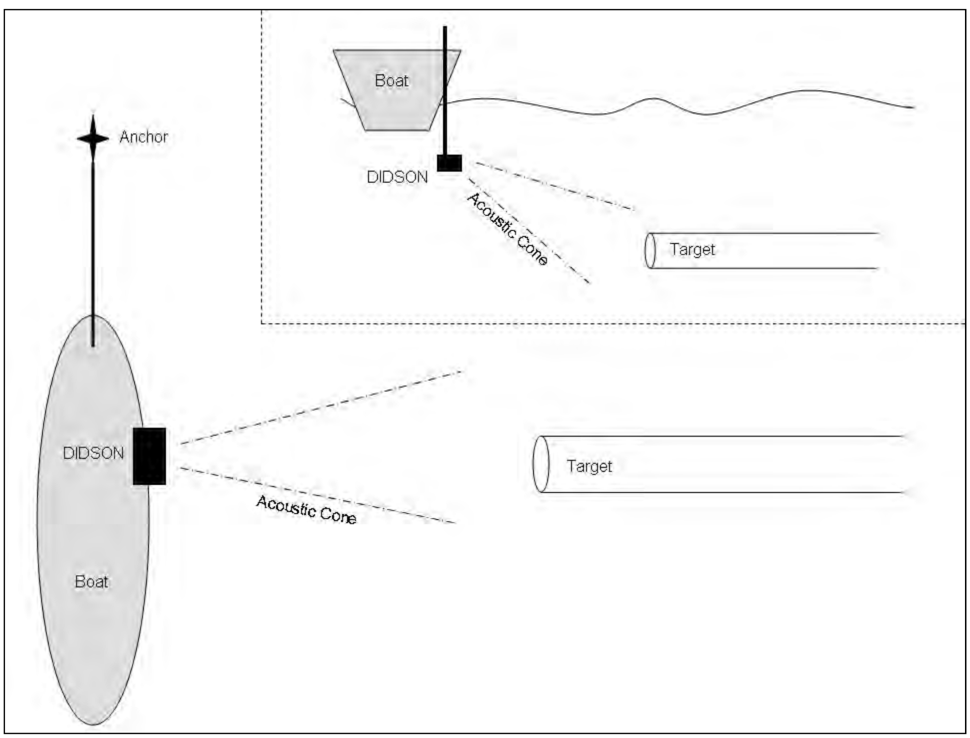


Figure 25- Overhead and side-views of DIDSON mobile monitoring boat positioning.

Figure 26- The DIDSON being used for mobile monitoring. The direction that the camera was pointed could be manipulated using the handle bars shown in the photo.

4.1.3 Side-view Monitoring

Side-view DIDSON monitoring of the SWP Horseshoe Bend release was conducted a limited number of times during monitoring periods two, three, and five. The main purpose of this monitoring was to gain further insight on fish behavior and movement during a release and to examine fish activity near the support structures for the pipe that were not visible from the fixed DIDSON field of view. Side-view monitoring was conducted using the same boat mounted DIDSON system that was used for mobile DIDSON monitoring; however the boat was positioned so that the DIDSON operator could sweep the length of the release pipe from the end of the pipe to near the shoreline. Video footage was collected before, during, and after release as with the fixed footage, however unlike the fixed DIDSON monitoring, only 15 minutes of video before and after release was recorded.

4.1.4 Water Quality

A water quality probe (YSI model 85) calibrated daily, was used to record water temperature (°C), dissolved oxygen (DO, mg/L), and specific conductance (µS/cm) at each of the monitoring sites. Water quality data was recorded during DIDSON observations at each of the mobile monitoring sites and 30 minutes after releases at the SWP Horseshoe Bend release site. Electrical conductivity data was also taken from the Emmaton water quality station in the California Data Exchange Center (CDEC) database. Only conductivity data from the CDEC station was used for analyses since it provided a more comprehensive data set. Water temperature loggers (HOBO® Pro v2 Water Temperature Logger, Onset Computer Corporation, Bourne, MA) were also deployed at each of the monitoring sites for the duration of the study and their data downloaded after the study ended. Only data from the HOBO loggers was used for temperature data analyses because it provided more precise temperature readings due to their placement at the release sites.

4.1.5 Data Analysis

Fixed site DIDSON footage was analyzed post-collection. Video footage from each sampling event was trimmed at 30 minutes before the recorded truck arrival and 30 minutes after the truck departure. The footage was then divided into three segments: pre-release (30 minutes before the truck arrival until 10 minutes before the release), release (10 minutes before release until 10 minutes after truck departure), and post-release (10 minutes after truck departure until 30 minutes after truck departure). During the pre-release segment, a count of all fish visible on the screen was made every five minutes and all notable behavior (feeding, schooling, etc.) was noted. During the release segment, a fish count was made every minute to gather more detailed information about fish behavior during the release. During the post-release segment, fish counts were again made every 5 minutes and all notable behavior was noted.

Mobile monitoring DIDSON footage was analyzed post-collection. The footage was sub- sampled by dividing each 10-minute clip into 30-second intervals. Fish counts were made at the start of each interval, and observations were made of any notable fish behavior or aggregations that occurred within each interval.

All predator counts were converted to an abundance index using the scoring system shown in Table 16 for both fixed and mobile DIDSON monitoring due to difficulty attaining accurate fish counts when more than 50 fish were present in a count. When greater than 50 fish were present on screen, the fish would essentially obstruct each other and could not be differentiated from each other. For comparative purposes, the counts from the “30 minutes prior to release” time period for fixed releases were used for comparison with the mobile sites.

Table 16- Scoring system used to develop a predator abundance index

# of Fish counted	Abundance Score
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
>50	6

Given the limited nature of side-view monitoring at the SWP Horseshoe Bend release site, no statistics were performed on this data, nor was it analyzed for enumerable characteristics such as fish abundance. Each clip was analyzed by noting general fish behavior and movement and observing any unusual underwater structure or behavior within the viewable area.

Statistical analyses were performed using SigmaStat 3.5® (Systat Software, Inc., San Jose, CA), SigmaPlot 10.0.1® (Systat Software, Inc., San Jose, CA), and Microsoft Excel® software packages. Descriptive statistics were used to characterize samples. For hypotheses tests, the following procedure was followed: determine if the data met the assumptions of parametric statistical testing procedure including independence of observations, normality, and homogeneity of variance. If the data met these assumptions a parametric hypothesis test was used. If the data did not meet these assumptions the appropriate non-parametric test was used.

4.1.6 Quality Assurance

The YSI model 85 multi-probe was calibrated daily for dissolved oxygen before use using the instrument's calibration routine. No attempt was made to calibrate the meter for temperature or conductivity because data from the CDEC water quality station at Emmaton and from HOBO temperature loggers were used for all data analysis. HOBO temperature logger accuracy was checked before deployment using a glass thermometer.

Water Velocity measurements from the ADV Argonaut were calibrated using the procedure outlined in Appendix 11.2. Raw ADV data was converted to corrected values post collection. Calibrated water velocity data was within 0.03 m/s (0.1 ft/s) at the velocities tested during calibration efforts. Data was checked line by line for errors.

DIDSON counts for all observations were performed independently by a minimum of two trained personnel. Any discrepancy in counts was resolved by two observers viewing the video together and coming to a consensus. All count data was checked line by line for data entry errors.

4.2 Assumptions and Limitations of DIDSON Observations

The DIDSON camera system is a powerful tool for fisheries observations in dark or turbid water. However, there are several assumptions and limitations that are inherent to the system:

1. The DIDSON camera has a limited field of view. During the sampling for this study, typically an area of about 3 m x 4.5 m (10 ft x 15 ft) was viewable. Therefore, significant numbers of predatory fish may have been present outside the field of view of the camera, which may have resulted in under estimations of abundance.
2. The DIDSON camera provides 2-D observations, which might result in large aggregations of fish being underestimated since the fish nearest the camera would obstruct others from view.
3. The footage from the DIDSON camera is not clear enough to allow species identification. All fish counted from video footage were assumed to be piscivorous species. However, results from the electro-shocking aspect of the study showed that several non-piscivorous species including Sacramento blackfish, Sacramento sucker, splittail, and hitch were located within the study area.
4. The DIDSON could not be operated during nighttime releases or during severe weather conditions due to safety reasons. Predator behavior and abundance could potentially be different during these periods.

4.3 Results and Discussion

4.3.1 Overall Predator Abundance

A one-way ANOVA analysis showed that predator abundance based on DIDSON estimates was significantly higher ($p<0.001$, $n=24$) at the SWP Horseshoe Bend release site in comparison with the control sites during all monitoring periods except monitoring period 4 (February, $p=0.152$) when abundance was low at all the sampling sites. The SWP Curtis Landing release site and CVP Emmaton release site also had significantly higher predator abundance during the second (CL $p=0.003$, Emm $p=0.017$) and third (CL $p=0.014$, Emm $p<0.001$) monitoring periods. Both control sites had consistently low predator abundance. No greater than 7 fish were ever observed at either control site at any one time. Typically no fish were observed at the control sites (Figure 27).

Although near-field predator abundance at the release sites does appear to be high, our observations suggest that this is a seasonal occurrence. Figures 28 and 29 illustrate the greatest predator abundance occurring during the summer and early fall, tapering off into the winter and increasing again in the early spring. Hydroacoustic data discussed in the next section reveals that this is in fact a near field phenomenon and that predator abundance in the open waters of the study area actually revealed the opposite pattern. This difference in near field abundance and far field abundance suggests that the release is in fact an attractant, more so than simply the release site structure itself.

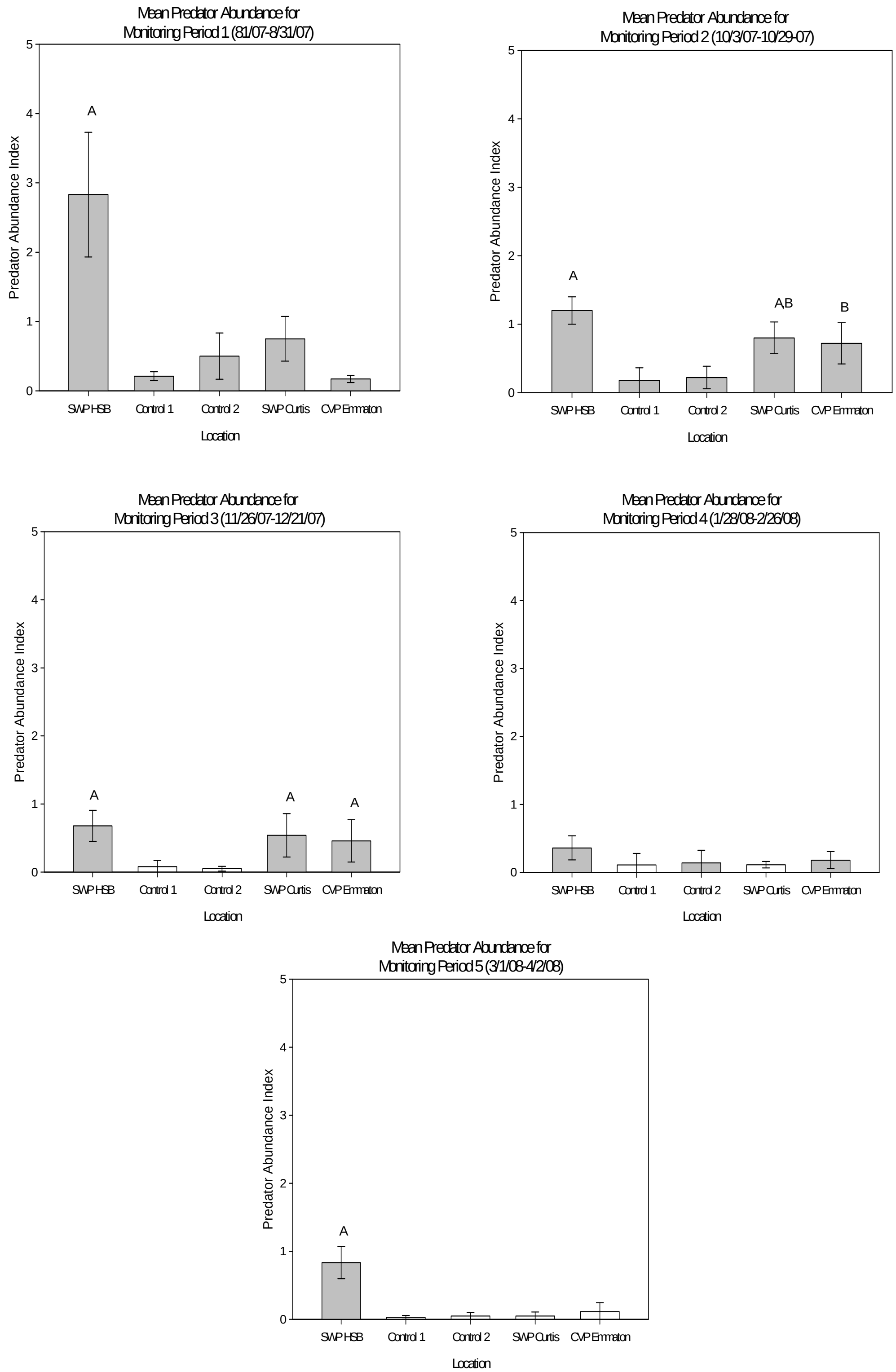


Figure 27- Mean predatory fish abundances during each of the five monitoring periods. Statistically significant groups are denoted by letters.

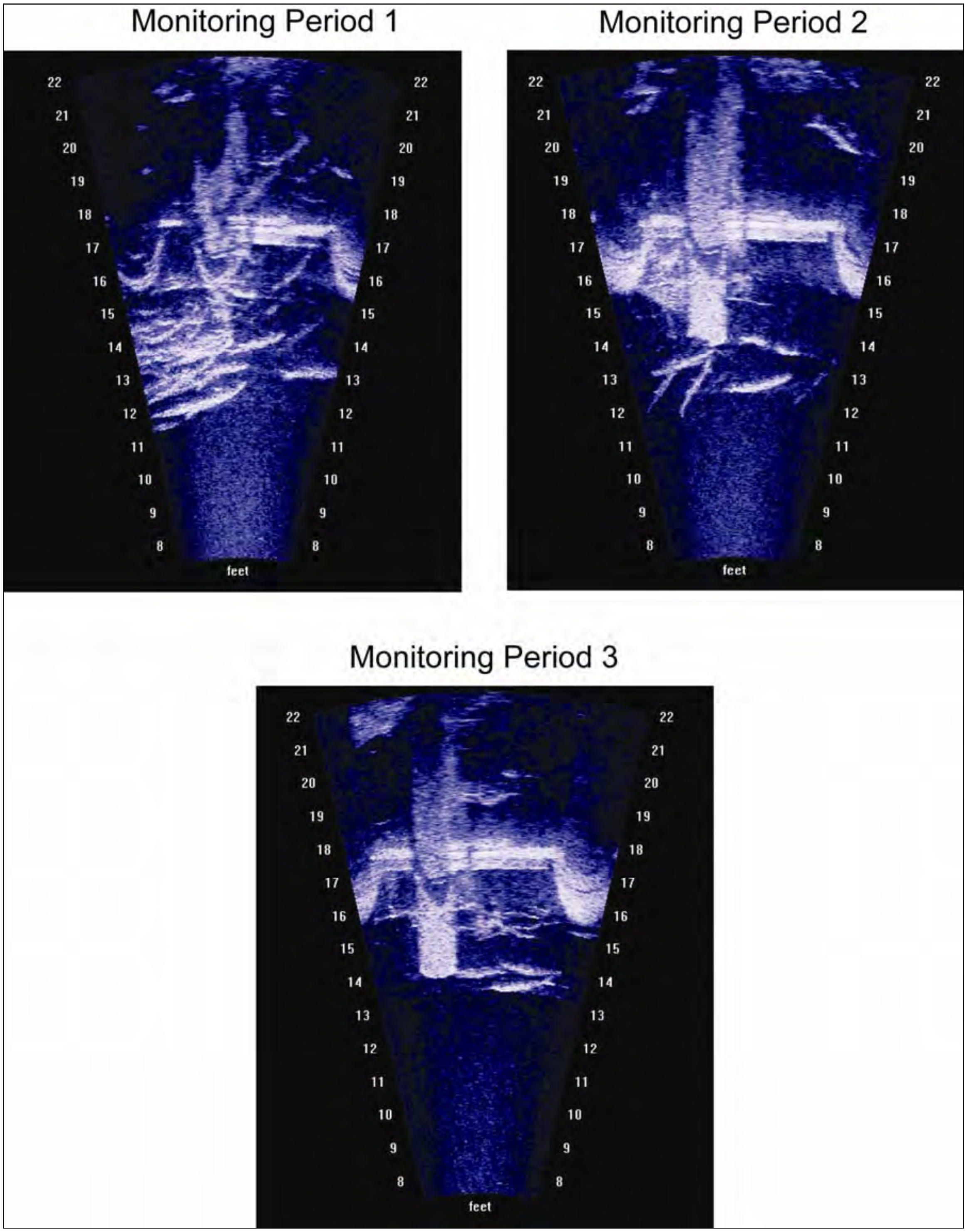


Figure 28- Typical DIDSON views of pre-release activity at the SWP Horseshoe Bend release site for monitoring periods 1-3. Note the large aggregation of fish during monitoring period 1 obstructing the release pipe.

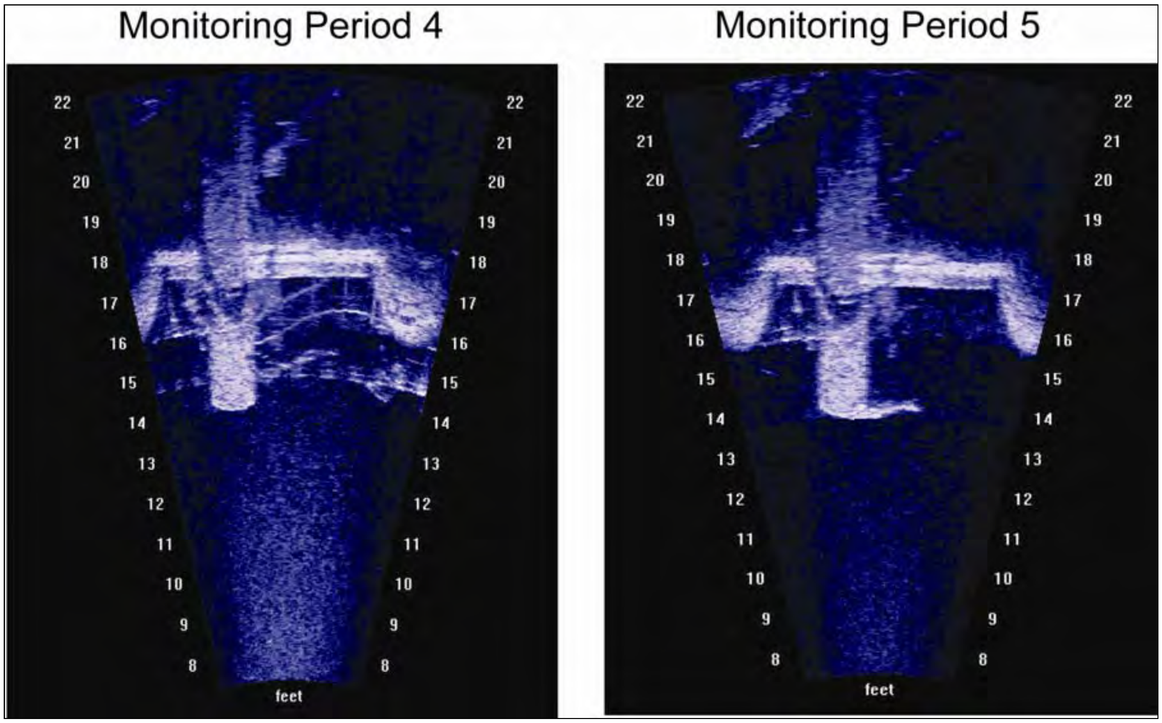


Figure 29- Typical DIDSON views of pre-release activity at the SWP Horseshoe Bend release site for monitoring periods 4-5. Note the absence of fish during the 4th monitoring period.

4.3.2 SWP Horseshoe Bend Release Site

4.3.2.1 Predator Abundance in Response to Numbers of Salvaged Fish

A Pearson Product Moment Correlation test (R=0.808, $p<0.001$, n=23) and a Regression analysis (R^2=0.652, n=23) showed that the number of fish salvaged at the SDFPF was correlated with predator abundance at the SWP Horseshoe Bend release site (Figure 30). The strong positive correlation indicated that as the number of fish salvaged increases, the number of predators holding within the immediate vicinity of the release pipe also increases.

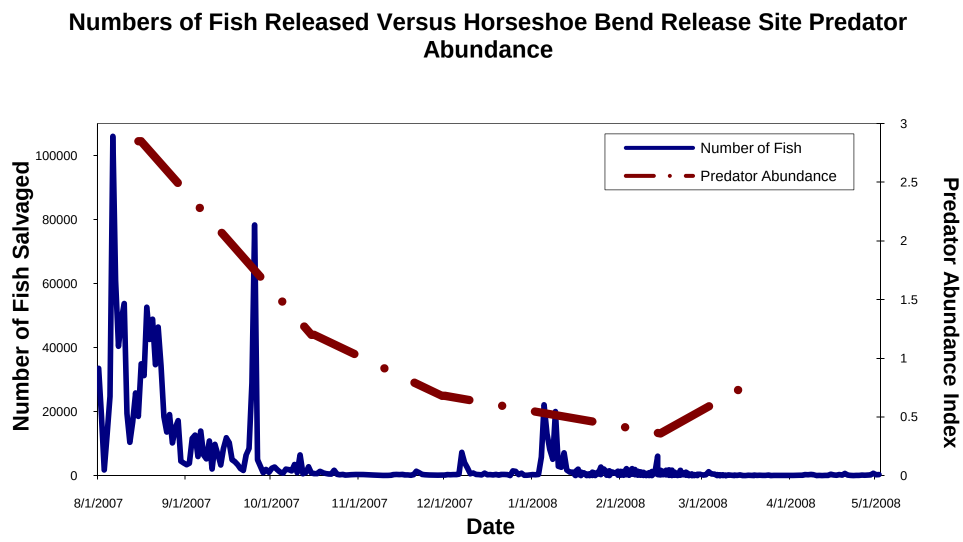


Figure 30- Relationship between the number of SWP fish salvaged and released and SWP Horseshoe Bend release site predator abundance. Salvage from 8/1/07 to 10/1/07 consisted largely of threadfin shad, while the small peak in salvage in mid-January 2008 was a combination of striped bass, American shad, and yellowfin goby.

4.3.2.2 Behavior During Releases

During all DIDSON monitoring when fish were present, predatory fish at the SWP Horseshoe Bend release pipe were characterized by similar behavior. Prior to release, several fish would typically line up near the end of the release pipe positively rheotaxic to the flow of the channel (Figure 31). Many fish also appeared to swim amongst the piles and support structure, intermittently orienting to the flow when large numbers of predators were present (monitoring periods 1 and 2). For 1–2 minutes before the release, the fish would become agitated and dart around quickly, presumably in response to operation of the release facilities (corrugated pipe connection, flushing pump activation, etc), though this behavior was inconsistent and lasted for only a few seconds. As the release occurred, a white plume was visible in the DIDSON image, which was most likely caused by entrainment of air bubbles in the water exiting the release pipe (Figure 32). This plume made close observation and quantification of strikes by predators difficult, but the predators were clearly feeding on prey coming out of the pipe.

During periods when predatory fish abundance was highest (monitoring periods 1 and 2) predatory fish were typically seen forming a large aggregation at the end of the pipe with predatory fish darting in and out of the center of the aggregation, presumably feeding. Occasionally, salvaged fish could also be seen successfully escaping (within the DIDSON's field of view) and swimming away from the pipe. Interestingly, predators were rarely seen chasing these fish, but rather stayed aggregated at the immediate end of the pipe. During periods of low predator abundance, salvaged fish could usually be seen swimming out of the plume/pipe and swimming away from the area.

Once the release was completed, predator abundance at the end of the pipe remained elevated at least up until the time the DIDSON was removed and observations were stopped (typically 45 minutes to 1 hour post-release). This extended elevation in predatory fish abundance suggests that predators attracted to a release may stay at or near the release site for extended periods of time following releases. A notable observation in many releases was that salvaged fish appeared to exit from the pipe for an extended period after the release was over. This observation suggests that at least some fish became trapped or delayed within the pipe. This observation is further supported by pilot efforts to examine the release pipe after a release using an underwater camera. During these pilot efforts, video footage was recorded showing trapped fish and debris in the pipe long after a release. Additionally, the results of the Element 3 study showed that significant debris and potentially salvaged fish remain in the pipe after release, due to the lack of a sufficient flushing flow in the release pipe.

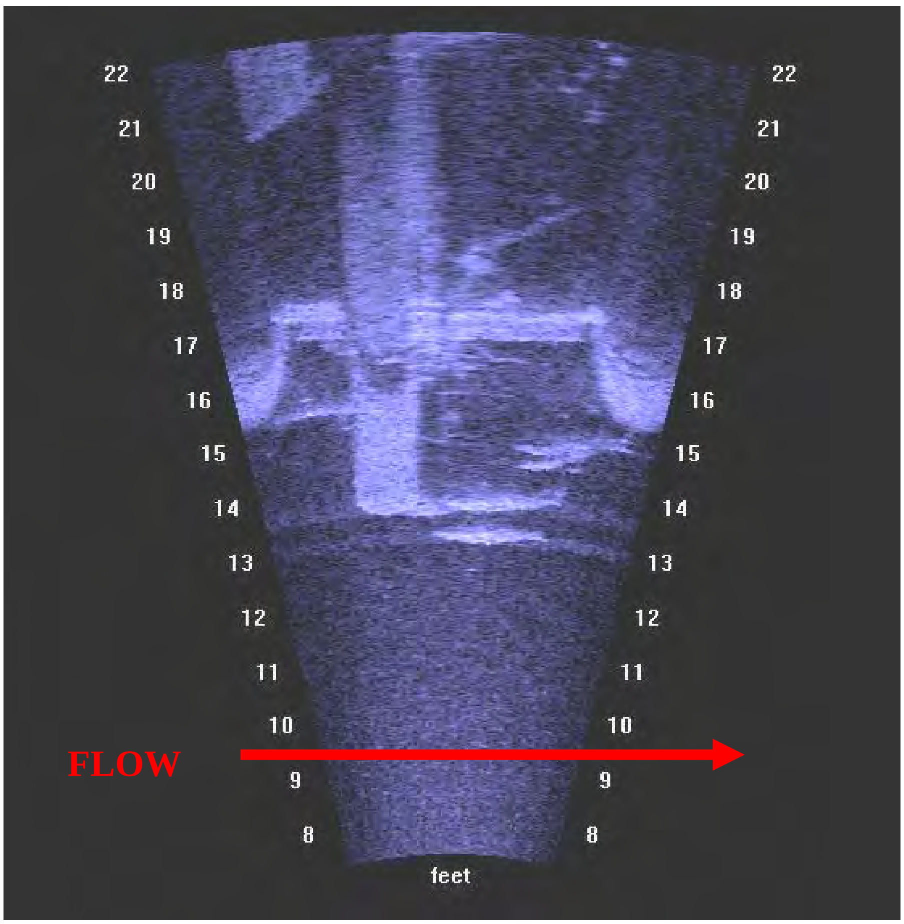


Figure 31- Typical view of predator behavior before releases. The predators in this image are oriented into the flow, holding near the end of the pipe.

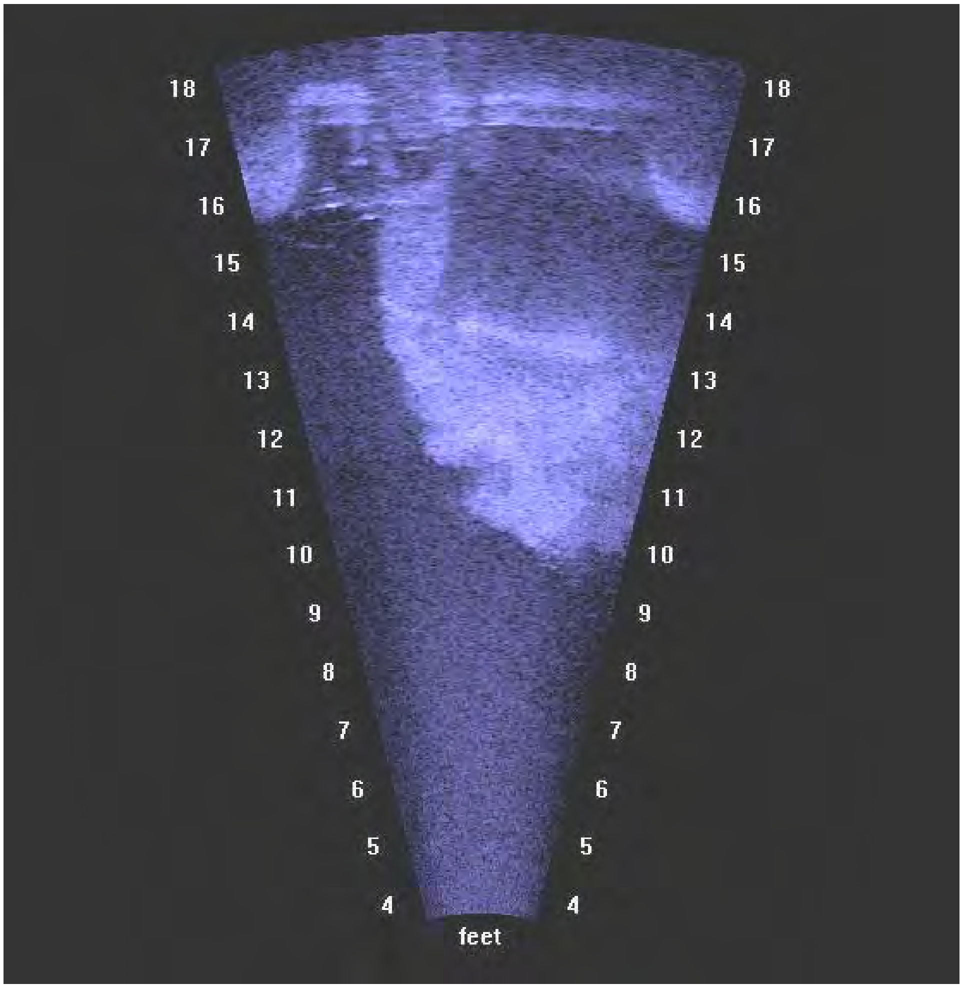


Figure 32- DIDSON image captured during a release. Note the plume extending out from the release pipe. The plume was presumably caused by bubbles entrained in the water being released and often obscured observations of release activity.

4.3.2.3 Response to Release Events

Predator response to individual release events including the release truck arrival, corrugated pipe connection, and flushing system activation was inconsistent. During monitoring periods 1 and 2 when elevated numbers of fish were present,, no correlation between release truck arrival (R_S = 0.064; n = 10; p = 0.700) or flushing pump activation (R_S = 0.088; n = 10; p = 0.454) and fish abundance during the corresponding time period was detected using a Spearman Rank Order Correlation Analysis (corrugated pipe connection time was not recorded during monitoring periods 1 or 2). During some sampling events, fish near the end of the pipe did appear to become agitated and dart away rapidly, but this occurred intermittently and lasted for only a few seconds each time. Predator abundance also remained relatively constant up until the time of release.

4.3.3 Predator Abundance and Behavior at Mobile Monitoring Sites

4.3.3.1 Abundance

As shown in Figure 27, predatory fish abundance at the release sites was generally comparable during three of the monitoring periods, but significantly higher at SWP Horseshoe Bend during the first (August) and last (March/April) monitoring periods versus all other sites. The reason for this disparity is unknown, but may be a result of several factors. At the SWP Curtis Landing release site, there is much less pipe support structure as a result of the channel bathymetry and height of the levee. At this site, the channel quickly drops off to a deep depth (~4 m [13 ft]) within only a short distance(<2 m [6.5 ft]) from shore (steeper pipe slope). The result is that the site design required much less pipe to reach an appropriate depth according to the original design requirements (recommended depth of 6 m, DFG unpublished document). Additionally, the levee at this location is roughly half as tall as at the SWP Horseshoe Bend release site, further minimizing the amount of pipe support structure required to achieve the desired depth of the pipe outlet, per the original design requirements. This lack of support structure eliminates the problem of debris being trapped that was observed at the SWP Horseshoe Bend release site.

At the CVP Emmaton release site the reduced number of predators cannot be attributed to the lack of pipe support structure as at the SWP Curtis Landing release site. The extensive pipe support structure and catwalk out to the water quality station are clearly visible in Figure 7. At this site, the decreased number of predators as compared to the SWP Horseshoe Bend release site might be attributed to several different factors. First, the CVP release sites include a higher output flushing system that operates on a timer. The greater amount of flushing water may result in fewer salvaged fish being trapped in the pipe. Additionally, the timer on the flushing system randomly turns the flushing flow on four times per day, potentially desensitizing predatory fish to the release site. Another reason for lower predator abundance may be that the depth at the outlet of the longer of the release pipes is ~2 m (6.5 ft) deeper than at the SWP Horseshoe Bend release site. This difference in depth might result in a different species composition shifted away from littoral species to more pelagic species that might not associate as strongly with structure. The difference in depth might also result in different hydraulics that might make the site more energetically costly to maintain position at in comparison to the Horseshoe Bend site. The ADV Argonaut velocimeter used in this study has a range limitation of five meters, as a result the CVP Emmaton site might not have been effectively sampled since depths at this site were typically >6 meters (20 ft) even at the lowest river stages. Similarly, since the CVP Emmaton release site is located at the confluence of Horseshoe Bend and the mainstem Sacramento River, as the two channels come together they might create additional complex hydraulic forces as was evident from the debris lines and water movement patterns observed during data collection.

Predators were rarely observed at the control sites throughout the study. This suggests that the salvaged fish releases at the release sites were the principal attractants of predators as opposed to some other factor such as the presence of a man-made structure. In fact Control Site 1 had some of the most complex underwater structure of any of the sites sampled, consisting of a series of pipes, piles, and two large cylindrical fish screens, yet there were few predators observed.

4.3.3.2 Behavior

Predator behavior at the CVP Emmaton and SWP Curtis Landing release sites was similar to that observed at the SWP Horseshoe Bend release site. Predators could typically be observed oriented into the flow of the channel near the outlet of the release pipe. At the SWP Curtis Landing, unlike at the SWP Horseshoe Bend release site, predators were not observed using the length of the pipe between the outlet and the shoreline as cover but instead were aggregated loosely near the pipe outlet. This is, as stated earlier, most likely a result of the decreased complexity of habitat and cover caused by the different release site design.

At the CVP Emmaton release site, predator behavior was difficult to observe because the DIDSON was at the limit of its range due to the depth of the site and because the DIDSON's view was obstructed by the pilings and support structure. However, predators could be seen milling near the outlet of the release pipe and orienting into the flow of the channel.

While few predators were observed in general at the control sites, there were some notable differences in their behavior as compared to release site predators. The majority of observations at the control sites were of predatory fish simply swimming past or through the site and not holding position. On occasion some fish were observed holding position at the control sites, but it was usually solitary fish rather than aggregations of fish seen at the release sites.

4.3.4 Response to Environmental Parameters

4.3.4.1 Water Velocity

Mean water velocity at each of the study sites was lowest at the SWP Horseshoe Bend release site (Table 17). However, due to the limited number of sampling events during each monitoring period, there was insufficient data to perform any meaningful analyses of predator abundance in response to water velocity. Typically during any one monitoring period, only a small range of water velocities were observed; therefore there was no opportunity to examine predator behavior and abundance in response to different water velocities during an individual monitoring period. It is of interest to note, however, that mean water velocity at all sites was highest during the fourth and fifth monitoring periods when predator abundance was generally low for all sites (Table 18). Given the tidal nature of this area, however, the daily fluctuations in water velocity would seem to negate any meaningful influence of water velocity on predatory fish holding behavior at the release site. Regardless of what the daily peak water velocity at a given release site is, at some point over a tidal cycle, the water velocity will decrease to the point that it will not have an energetic cost for predatory fishes. Both striped bass and Sacramento pikeminnow are common in the upper Sacramento River where typical water velocities are several times greater than in the Delta. Therefore, the highest water velocities possible at the release sites would be well below the swimming performance capabilities of the larger predatory fish present at the release sites.

Table 17-Mean, maximum, and minimum Delta water velocities observed at each of the survey sites.

Location	Mean Water Velocity (ft/s)	Maximum Water Velocity (ft/s)	Minimum Water Velocity (ft/s)
SWP HSB	0.620	1.369	0.083
SWP Curtis Landing	0.843	1.978	0.007
CVP Emmaton	0.889	1.766	0.133
Control 1	0.873	1.890	0.085
Control 2	0.937	1.422	0.095

Table 18- Mean water velocities ± SE (ft/s) during each monitoring period for each of the 5 survey sites.

	Location				
Monitoring Period	SWP HSB	SWP Curtis Landing	CVP Emmaton	Control 1	Control 2
1	0.393 ± 0.132	0.661 ± 0.209	0.975 ± 0.060	0.980 ± 0.239	0.671 ± 0.155
2	0.435 ± 0.120	0.734 ± 0.355	0.653 ± 0.214	0.550 ± 0.166	0.728 ± 0.236
3	0.385 ± 0.132	0.555 ± 0.249	0.566 ± 0.135	0.897 ± 0.227	0.934 ± 0.284
4	0.886 ± 0.192	0.907 ± 0.226	1.186 ± 0.290	0.886 ± 0.282	1.190 ± 0.052
5	0.993 ± 0.133	1.312 ± 0.160	1.238 ± 0.227	1.054 ± 0.317	1.161 ± 0.086

4.3.4.2 Temperature

Water temperature at the SWP Horseshoe Bend Release site was tested for correlation with predator abundance at the SWP Horseshoe Bend release site. A Pearson Product Moment Correlation test (R=0.819, P<0.001, n=23) and a Regression analysis (R^2=0.681, n=23) showed that temperature and predator abundance were positively correlated (Figure 33). This trend of decreased predator abundance correlated with decreased temperature is not unexpected and is likely a result of the decreased need of the predators to feed when water temperatures are colder as a result of their decreased metabolic demand (Brett and Groves 1979). Interestingly this trend was not observed with hydroacoustic data, and in fact the opposite trend was observed with increased numbers of predators in the area during the winter months observed with the hydroacoustic equipment. This may be a result of the different ranges and coverage areas inherent to each technique. While the DIDSON was able to capture predators holding tightly to the release pipe/site, the hydroacoustics had a longer range and effectively sampled the open water areas surrounding the release sites. The predators observed using the DIDSON were more than likely fish that were actively feeding or searching for prey, thus their attraction to the release site, whereas the hydroacoustics was able to show seasonal differences in striped bass abundance in the area, but not necessarily feeding because the water temperatures were low.

Temperature may have also had an effect on the populations of prey fish in the open water areas surrounding the release site. If prey densities in the area were substantial, while concurrently the number of fish released decreases, it may be that the release sites no longer represent a better feeding opportunity.

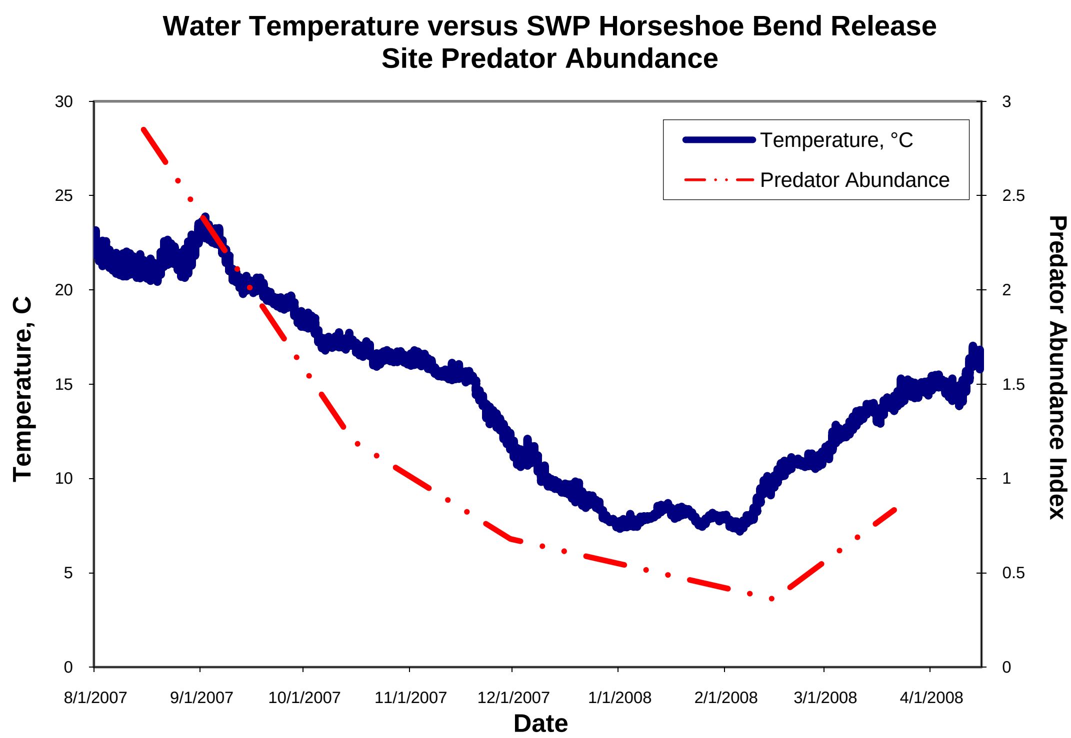


Figure 33- Relationship between water temperature during the study and mean predator abundance at the SWP Horseshoe Bend release site. Water temperature at all other sites was within 1ºC.

4.3.4.3 Electrical Conductivity

Electrical conductivity at Emmaton (monitoring station is located at CVP Emmaton release site) was generally lowest during the fourth and fifth monitoring periods (min= 167.91 µS/cm on 2/1/2008) and highest during the second and third monitoring periods (max=2889.79 µS/cm on 12/7/2007). This coincides with the periods of typically the highest and lowest net Delta outflow.

SWP Horseshoe Bend release site predator abundance was tested for correlation with daily average electrical conductivity at Emmaton. A Pearson Product Moment Correlation analysis showed no significant relationship between electrical conductivity and predator abundance (R=-0.119, n=23, p=0.587). This suggests that at this location and within the range of conductivity values observed, electrical conductivity is not a limiting factor for any of the predator species observed.

4.3.4.4 Dissolved Oxygen

Dissolved Oxygen remained relatively high and relatively constant for the duration of the study (min=7.23 mg/L on10/5/2007, max=10.68 mg/L on 2/15/2008). A Pearson Product Moment Correlation test with Dissolved Oxygen and predator abundance showed no significant relationship (R=-0.316, n=22, p=0.152). This is not unexpected since the Dissolved Oxygen values observed were well above the minimum requirements of the principal predatory species in the area.

4.3.5 Sideview Monitoring

Sideview monitoring was conducted three times during the first monitoring period, once during the third monitoring period, and twice during the fifth monitoring period. Statistical examination of sideview DIDSON footage was not performed due to the limited number of samples, so a more descriptive approach to the observations was employed. The limited footage collected was instrumental in examining how the geographic distribution of predators at the release site changed during a release and in examining habitat utilization in the vicinity of the SWP Horseshoe Bend release pipe. While the fixed mounted viewing angle provided imagery of only a small area near the end of the pipe, sideview monitoring allowed the entire submerged length of release pipe and the surrounding area to be examined. During all sampling except during the 5th monitoring period, when few or no fish were present, most fish were observed not swimming very far beyond the end of the pipe towards the center of the river channel. At times during the second monitoring period, >50 fish could be observed swimming near the pipe, but very few were observed only a few feet out (<1.5 m [5 ft]) from the end of the pipe. Most of the fish appeared to be either lined up at the end of the pipe positively rheotaxic to the channel flow, or aggregating tightly amongst the piles and pipe support structure closer to the shoreline. Sideview monitoring revealed that the pipe support structure and piling captured/trapped a large amount of debris (branches and logs); (Figure 34).

As the release was conducted, the geographic distribution of predators at the release site changed rapidly. As described earlier, predators were seen aggregating at the end of the release pipe. However, during several observations, predators were observed swimming in and out from the debris trapped along the length of the pipe, often swimming towards the end of the pipe to feed. The presence of this trapped debris effectively negates one of the principal reasons that the pipe was designed with such a long length: to release fish away from the litoral zone where they may be subject to predation by a wider variety of predators. This is especially concerning as the electroshocking data showed that largemouth bass and other centrarchids were very abundant in the vicinity of the release site. Largemouth bass and many other centrarchids are commonly known to associate strongly with any sort of structure. Periodic removal of this debris might therefore, reduce release site predation associated with predators utilizing this trapped debris as refuge.

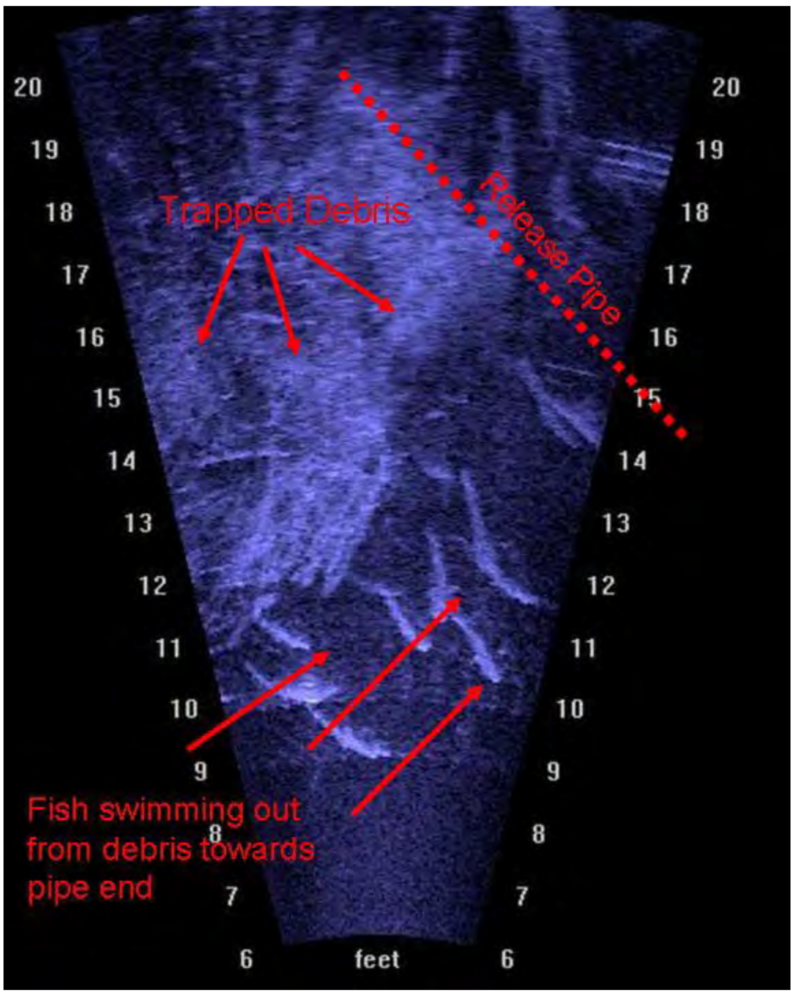


Figure 34- Sideview DIDSON image of predators swimming amongst submerged debris trapped by the release pipe support structure.

4.4 Conclusions

The results of the DIDSON monitoring showed that predatory fish abundance at the SWP Horseshoe Bend release site was generally highest when greater numbers of salvaged fish were being released. However, this was in contrast to the results of the hydroacoustics monitoring, discussed in the next section, which showed the opposite trend. This difference probably is a result of the differing ranges for the equipment (longer range for hydroacoustics, shorter for DIDSON), but also demonstrates the differing magnitude of attraction of predatory fish to the release site during different seasons or operational conditions. During seasons when many fish were being consistently released, many predators were observed aggregating very close to the release pipe even though the hydroacoustics showed there were generally fewer predators in the region during these seasons. Similarly, when very few fish were being released, very few predators were observed near the release site in contrast with the large regional population of predators observed with the hydroacoustics equipment.

Observations with the DIDSON camera failed to reveal any aspects of the release process that might be serving as behavioral attractants (i.e. pump activation, truck arrival). Rather, the driving reason for predators remaining at the release site appeared to be the delayed rate at which many salvaged fish exited the release pipe. Salvaged fish were observed slowly trickling out of the pipe over many hours. This constant source of food might continually attract predators to the site.

Observations with the DIDSON camera also revealed inherent problems with the existing release site design. The observations showed that the underwater structure of the release sites trapped excessive amounts of debris within the immediate vicinity of the release pipes that appeared to serve as predatory fish cover or habitat. To reduce this problem, the debris around the release sites should be periodically removed, and future release site designs should minimize the potential for entrapment of underwater debris by incorporating less pipe support structure.

5.0 Hydroacoustics and Bioenergetics

The objectives of this study component were to further describe the behavior of predators near the SWP Horseshoe Bend release site, and to attempt to quantify the potential magnitude of predation. This study component employed a two tiered approach of both fixed station acoustics and mobile surveys for collecting acoustic data. Fixed station data was used to describe behavioral aspects of potential predators in the immediate vicinity of the release pipes as defined by the effective sampling range of the transducers. Population level estimates of potential predatory fish were determined using mobile acoustic surveys of Horseshoe Bend. The potential magnitude of predation was determined using a simple bioenergetics approach of computing consumption based on water temperature and growth rates of predatory fish species known to be present in the area.

5.1 Methods

The hydroacoustics part of the study focused on the Horseshoe Bend region of the study area. Since hydroacoustics cannot be used to speciate the fish observed, data collected from electro-shocking surveys, DIDSON observations, and the literature was used to determine which species were likely present near the release site.

5.1.1 Data Collection

5.1.1.1 Fixed Site

The fixed site refers to those transducers affixed near the outlet of the release pipe at the SWP Horseshoe Bend release site. These units were used to examine behavior of fishes in the local vicinity of the release pipe. In this case it represented a semi-circular area approximately 25 m (82 ft) in radius (Figure 35). In the initial proposal one acoustic unit was to be placed away from the release pipe looking towards the pipe, however, because of DWR restrictions on diving activities, the units could not be deployed to directly look at the release pipe. Funding constraints prevented use of a similar fixed station at a control site but DIDSON Camera operations at those sites yielded sufficient data for a comparison.

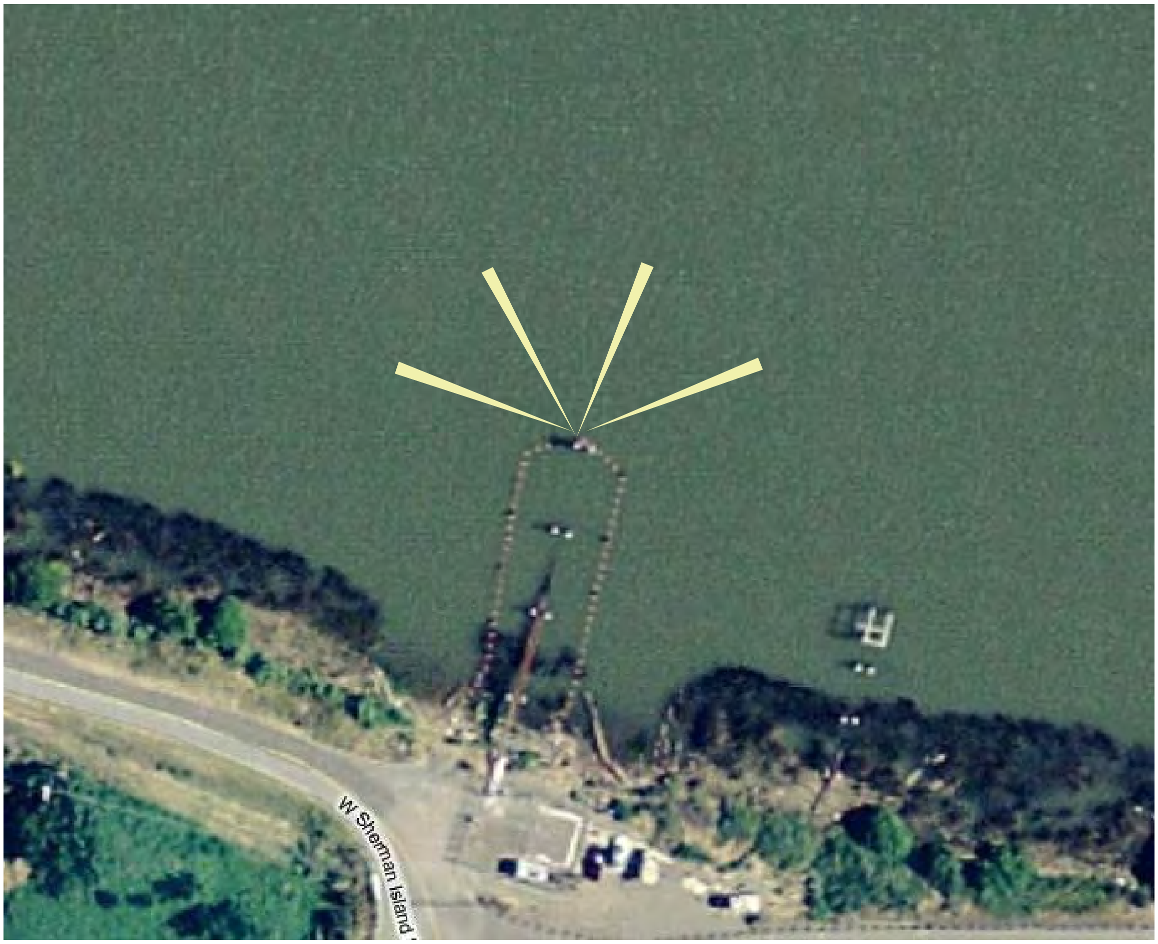


Figure 35- Location of four transducer beams as they sample near the outlet pipe location. Beams and beam spreads are approximately to scale, with a range of 25 m (82 ft) and a beam angle of 6.5°.

To maximize the amount of data collected, a fan shaped array of four transducers mounted to a semi-circular metal plate which could be raised and lowered to a given depth was employed (Figure 36). This plate was mounted to a 2.5 inch (6.35 cm) standard conduit slid through a metal collar attached just above the waterline of the most outboard support piling for the release pipe. Bolts attached to the collar held the array fixed in position. By releasing several bolts the pipe could then be lowered to the approximate depth of the release pipe. At the end of each study period the array was removed from the water to prevent accidental damage or vandalism. Large amounts of fishing line primarily from shore anglers was hung up around the piling, and it had to be cut loose every time the array was deployed.

Figure 36- The four-transducer assembly used for this study. The knobs on the mounting brackets could loosen to allow assembly to be raised and lowered. The transducer on the left points almost directly in front of the release pipe. This picture was taken before attaching shore cables to each transducer.

The acoustics units employed for fixed station work were a pair of Biosonics® DT6000 split-beam systems (Biosonics, Inc., Seattle, WA), each connected to two transducers, one 420 khz, the other 200 khz. Transducers were alternated on the array (420,200,420 200) to prevent cross talk between similar frequency transducers. During the first placement, HPR (Heading, Pitch, and Roll) sensors were used in two of the transducers to orient them. Subsequent damage to the underwater cables, likely from stress breaks due to debris and fishing line, resulted in contact with the sensors being lost. This was not an issue following the first deployment as the pole had been marked to allow replicate placement of the equipment each trip.

A pair of surface control units (Biosonics DT 6000) were placed in a climate controlled utility trailer located within the fenced enclosure of the release site. Each unit operated two of the transducers. Connection to the transducers was provided through four, 152–m (500–ft) cables, run through a PVC conduit down to the water line then hung free in the water out to the transducers. Pentium Class laptop computers were connected to each surface unit and used to record data, via Biosonics Visual Acquisition Version 4 (Biosonics, Inc., Seattle, WA). Data was downloaded to a back up hard drive following the completion of each sampling trip. There was on site power provided to the trailer, which was channeled through a battery backup to ensure continued operation during intermittent power failures. When operating, data was collected at a rate of 5 pings/sec, pulse width was set to 0.4 ms, and the data collection threshold at -70dB. Maximum sampling range was typically set to about 40 m (131 ft), but during analysis much of the long range data was removed, because of debris issues (logs etc. stuck near the pilings that blocked the transducer image. Final analysis ranges for the fixed site data were set to 20 m (65.6 ft) for the two HPR transducers and 25 m (82 ft) for the two non-HPR transducers. Each unit was operated 24 hrs a day for the duration of the study period, typically ten days.

5.1.1.2 Mobile Survey

Mobile survey data was used to determine density differences in potential predatory fish populations between the release site and two reference sites located further upstream in Horseshoe Bend (Figure 37). A boat was equipped with an AC inverter to provide electrical power for the computer and surface unit. When conducting surveys the boat was kept at a constant speed of about 7.2 km/hour (4.5 mph). Mobile survey data was collected using the same type of acoustic equipment used for fixed surveys. The only exception was the unit employed 2-200 khz transducers. The surface unit was also a Biosonics DT6000. One transducer was mounted looking vertically down into the water column, the other mounted to aim laterally off to the side. When collecting data the unit was set at 5 pings/sec, 0.4 ms pulse with a data threshold of -70 dB. Maximum range for the downward looking unit was set to 15 m (50 ft), and 40 m (131 ft) for the side oriented transducer. A WAAS enabled E-Trex Vista™ (Garmin International, Inc., Olathe, KS) GPS unit was connected to the surface unit and a location recorded for each target.

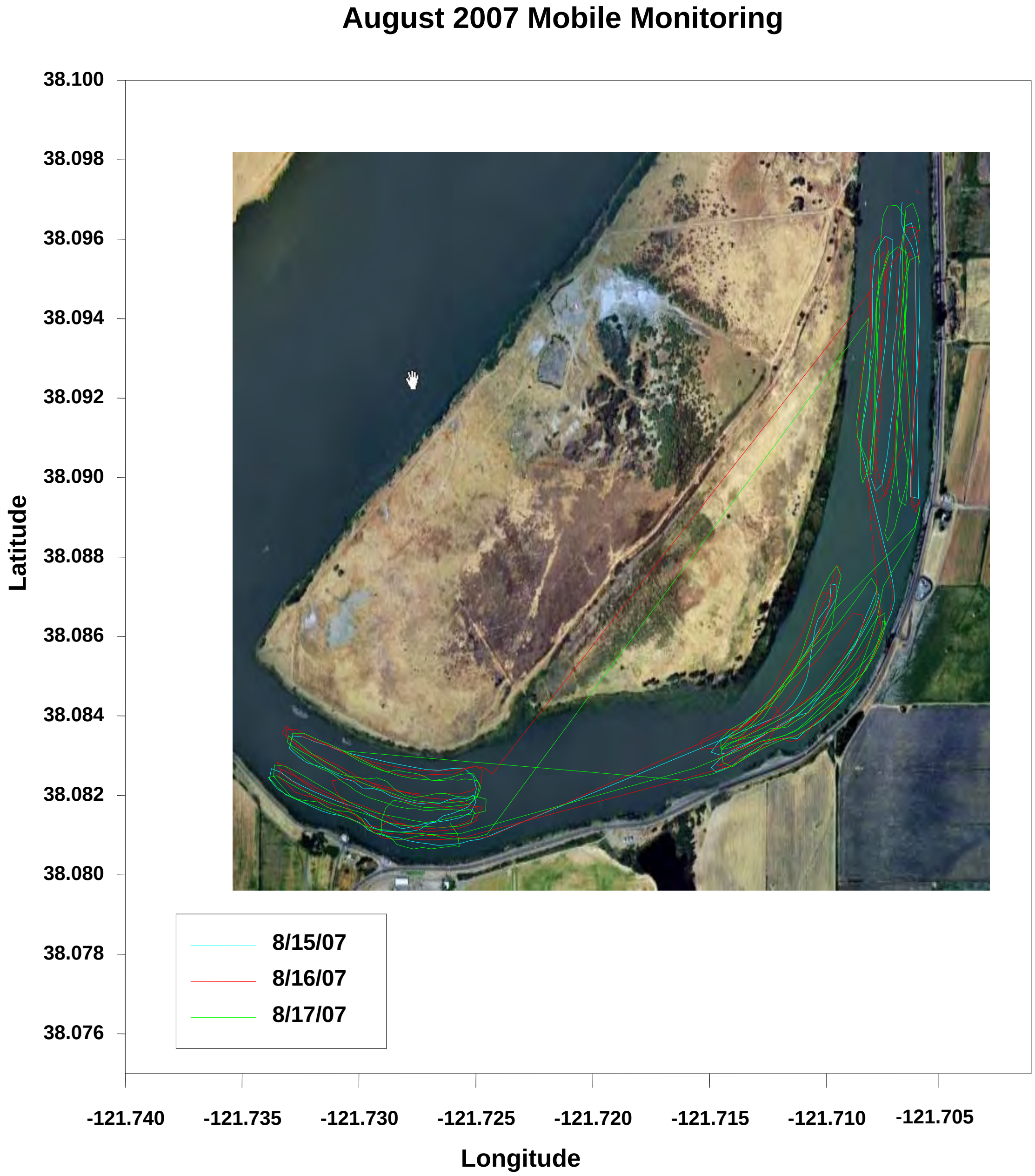


Figure 37- A typical set of transects during mobile surveys. August 2007 is shown as an example. The SWP Horseshoe Bend release site is the lower left set of transects, while the other two sets of transects are the two control sites.

A central point was selected for each control site and transects extended 0.4 km (0.25 mi) upstream and downstream of this point (Figure 37). At the release site the survey was extended 0.4 km (0.25 mi) upstream and downstream of the outlet. Transects were run parallel to the flow of the river, with five transects of data collected at each site every sampling period. Moving into or with the wind resulted in the least amount of impact imparted due to wave action. When moving perpendicular to the waves, i.e. across the channel, rocking of the boat made acoustic data analysis difficult, as the unit alternated between looking skyward, then into the river bottom. Wind was only an issue in August. As the season progressed winds died down, and conditions were relatively calm for the majority of the sampling days.

During each sampling period efforts were made to obtain at least 4–5 days of mobile transects. Winds, and occasional periods of heavy rain were the limiting factors as to how often data could be collected. Both wind and rain significantly degrade the quality of collected data, effectively making analysis impossible. Each sample day typically consisted of an afternoon sampling period, then re-sampling all three sites after dark. The order the sites were sampled changed each time. If Control Site 2 was sampled first one trip, the SWP Horseshoe Bend release site was sampled first the next trip. Control Site 1 was always sampled second as it was the middle site. One complete set of transects for all three sites typically took about 2 hours.

5.1.2 Data Analysis

Echo counting methods were used to measure acoustic target strength (fish size) and direction of movement. Target strengths were measured using split-beam analysis techniques for all sample locations. The target strength of a fish is generally related to the size of the fish, and is a measure of the capacity of a fish to reflect sound energy. Target strength, measured in units of decibels (dB), is calculated from the energy reflected from the target, and is a function of the cross-sectional area of the target and the density difference between water and the component parts of the target (bones, scales, flesh, gas bladder and others).

Fish orientation, and to an extent species, can play a significant role in estimation of target size. The decibel scale used to measure fish size is logarithmic and referenced in negative numbers where the larger the negative number, the smaller the fish. For example, a small, -56 dB fish varies in length from 2.7 to 2.8 cm (1.06 to 1.1 in) and a larger -46 dB fish varies from 8.9 to 9.2 cm (3.5 to 3.6 in) length; a -36 dB fish is approximately 25 cm (9.8 in) length. These sizes assume a transducer is looking down on a perfectly oriented fish from above. This is typically the case when looking down on a fish. When looking from the side, however, fish may not be perfectly oriented parallel to the transducer. When this occurs, a fish target will appear smaller than it actually is due to the reduced cross sectional area of the target. It does not affect the overall population estimate, but likely causes biases where fish are estimated to be smaller than they actually are. Unfortunately, little can be done to rectify this problem. Oftentimes the presence of strong current in the river did help minimize this effect as fish typically orient themselves into the current, and transducers are oriented to look perpendicular to the current.

The direction of travel is calculated as an angle varying between 0 and 360º. The split-beam coordinate system may be considered as a compass, with north oriented in the direction opposite the cable connector on the transducer. This direction would represent 0 degrees. A clockwise rotation of 90 degrees would indicate a direction corresponding to East. Depending on how the transducer was mounted, the direction column indicates the vector direction in a plane normal to the acoustic axis, with zero degrees opposite the connector. Thus a fish with direction of between 0.1 degrees and 179.99 degrees would be considered as going from left to right across the transducer face. For this study any graphics where direction of travel is indicated, 0–179.99 degrees indicate fish are moving upstream in the direction of Rio Vista. Typically observations for a fish are near 90 or near 270 degrees (straight upstream, or straight downstream. An average movement near 180 degrees is indicative of no directional preference.

The SonarData software package, Echoview v4.x® (Myriax Software, Hobart, Tasmania) was used to analyze all data. The echogram was reviewed to locate individual fish targets, which were acquired and logged to data files. An amplitude threshold was used to reject echoes smaller than a predetermined voltage, and areas of high acoustic noise were manually removed from the raw echogram data prior to analysis, by defining a line or region below for which any data is ignored during the analysis phase (Figure 38).

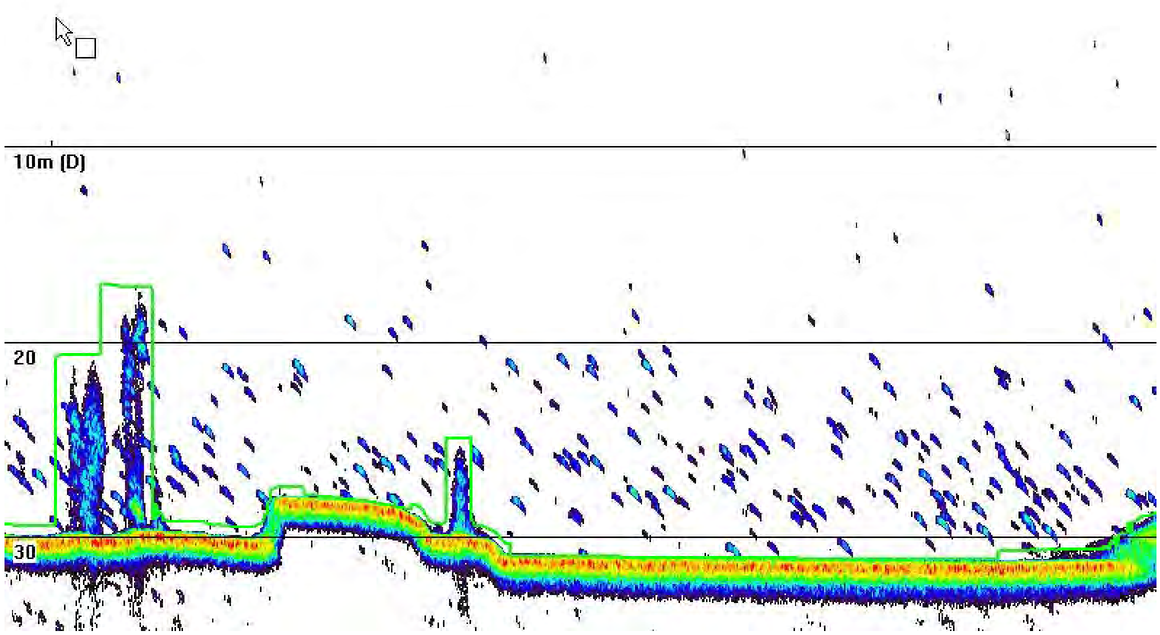


Figure 38- Example of downward looking target data showing fish targets, noise, and bottom. A light green line is shown in going up and around the noise on the lower left and then following the trace of the bottom for the rest of the echogram. During analysis, all data below this line is excluded.

Analyses of acoustic data consisted of a series of post-processing steps, designated as

a) Observation
b) Calibration and Thresholding
c) Regions for Exclusion (Noise)
d) Echo Extraction
e) Trace Formation (Fixed Station)
f) Output Formatting/Quality Assurance

These steps are described in detail in Appendix 11.5.

5.1.2.1 Fixed Station Analyses

Analysis of fixed station data was primarily designed to assess behavior of fishes in and around the location of the release pipe. Units collected data continuously during each sample period. Data was then sub-sampled, into four 24–hr periods during each period for analysis. Raw target data was collected and analyzed as per the preceding section. The collection threshold filtered out all targets smaller than -45 dB or about 9.5 cm (3.7 in). This effectively removed a lot of the smaller debris as well. All the remaining data was analyzed as fish tracks for this portion of the study.

All data was presented graphically using Sigmaplot 10®. For presentation and analysis data were organized into one-hour time bins. Hourly movement was analyzed by examining changes in numbers of fish observed passing each transducer over time. A similar approach was taken to map out the average target strength of fish in the area, direction of movement, and average range from the release pipe. This data was examined seasonally, tidally, in relation to day-night, and in response to releases of fish.

5.2.2.2 Mobile Survey Analyses

Mobile survey data was used to compare fish densities of predator sized targets between the release and two control sites, as well as to estimate total population biomass of smaller fishes in the area to help estimate the contribution of fish from the release site. Population estimates of large fish were used to estimate potential predation in the area.

Analysis of individual targets was used to determine abundance of fishes. Fish targets were output in 100 ping bins. A density (fish/m^3) was calculated by taking the number of targets and dividing it by the sum of the volume sampled by the acoustic beam each period. For one sampling event (set of transects) the number of targets of a given size class was summed up and divided into the total volume of water sampled. To determine a population estimate for each site, this number (fish/m^3) was then multiplied by the number of cubic meters of water in a given area. The volume of each area was determined by determining the surface area of the reach (Figure 39) and multiplying it by the average depth of the set of transects for that site. This was adjusted each sampling period to account for depth differences due to tidal stages. This technique assumes a uniform fish distribution and may result in population estimates biased high, but comparisons between sites are still relevant.

Fish were binned out to two size classes, those > -36 dB (25 cm [9.8 in]), and all fish larger than -45dB (9.5 cm [3.7 in]), for down looking data and -36 dB (25 cm [9.8 in]) and -40 dB (18 cm [7.1 in]) for side looking data. A more restrictive threshold was used for the side looking data due to the amount of noise in the water column due to air bubbles from the almost constant winds in the area.

Figure 39- Surface area (SA) and approximate region of coverage used in fish population estimates for the release and two control sites. Note the left side of the middle site does not come near shore. The map is based on the shoreline. This section of the river averages only about 0.3 m (1 ft) in depth and is weed choked. It was felt this area did not contribute to the available habitat.

5.1.3 Bioenergetics

The bioenergetics approach employed in this study is based on an energy balance equation. For this portion of the study the *Fish Bioenergetics 3.0* (Hanson and others 1997), commonly called the Wisconsin fish model, was employed. The model has been used for a wide variety of applications and has been parameterized for a number of common species, making for a relative ease of use. Consumption shown as grams of prey consumed per gram of predator per day is the output of the model used for this study. This estimate is based on species and age specific metabolic processes, energy density of the prey, proportion of prey in the diet, and growth rate of the predator.

Model results were developed for common predatory species in the study area, including striped bass, largemouth bass, and Sacramento pikeminnow. Initially electrofishing data was to be used to determine the types of predatory species present, but electrofishing data was heavily biased to fish closely associated with the shoreline. Observations from the DIDSON camera, and other referenced studies (Pickard and others 1982) were used to determine the likely makeup up the predator community. The model results were outputted for a variety of potential configurations of which species dominated the community.

Bioenergetics parameters for the striped bass were those provided with the model and were developed by Hartman and Brandt (1995). Largemouth bass data were derived from Rice and others (1983). Data specifically for the Sacramento pikeminnow was not available, and for the purpose of this study the coefficients obtained from studies on Northern pikeminnow (*Ptychocheilus oregonensis*) in the Columbia River basin (Peterson and Ward 1999) were used. Swimming speed can have a significant impact on consumptions estimates in the model, and therefore was held as a constant.

Size ranges of predators potentially impacting the release site were based on the results of both the fixed and mobile acoustic surveys. Water temperature data was collected daily using a temperature logger at the site. Employing temperature data also allows for the calculation of seasonal variation in daily consumption rates as a function of water temperature. Based on fish count data from the SDFPF, an assumption was made that the majority of fish present in releases were predominately threadfin and American shad since they typically dominate the fish salvage for most of the year. For these species an average energy density of 5,600 joules/gram wet weight was used and assumed not to vary over the course of the study. Average growth rates for predatory species were obtained from studies reported in the literature though specific growth data was not available for this area (Kimmerer and others 2005, Brown 1990, Hasler 1988, Vondracek and Moyle 1982, Scofield 1931, Tucker and others 1998).

The approach taken here is rather simplistic in that several assumptions are made: (1) that predators are eating only fish, (2) that the different species are opportunists and do not differentiate between prey species instead consuming them in proportions relative to what is being released, and (3) that the predator assemblage is known. If growth rates are different, or the predator species assemblage proportions used are different from what truly exists, the model will have bias. However, as a broad generalization the model will provide an initial estimate of predation mortality.

5.2 Results and Discussion

5.2.1 Releases

Review of SDFPF salvage data shows increases in the numbers of fish released beginning in June and July, with a peak in August. The number of fish being released decreased significantly by October, and then continued at low levels through the winter, with the exception of a pulse observed in mid-December (Figure 30, Table 19). Salvage data indicate that, over a typical year, the bulk of fish biomass is composed of threadfin and American shad. Other species typically comprise only a small proportion of the total. Based on the assumption shad compose the majority of the release, the total biomass for each release was estimated using an average sized shad as a starting point. Therefore, assuming that an average shad is about 90–110 mm (3.54–4.53 in) in length and weighs about 13g (0.028 lb), for every 1,000 fish released, about 13 kg (28.6 lb) of biomass is released into the river at the SWP Horseshoe Bend release site.

Correlating releases to predator behavior was a central tenet of this study, however, when compiling release dates, times and locations from the SDFPF data sheets, numerous inconsistencies in the data became apparent. Time of release was not difficult to estimate as it reliably was one to one and a half hours following the time the truck left the SDFPF, which was recorded on data sheets. This assumption is based on typical travel time and observations of release truck operations at Horseshoe Bend. However, records for location of release did not agree with observations of releases conducted during DIDSON monitoring. As a result, there was no way to determine where a release occurred on days during which no DIDSON monitoring was conducted. To test hypotheses associated with predator response to releases of fish, a comparison of behavior for release and non-release periods was planned, but without complete records of where fish were released, the analysis could not be conducted.

Table 19- Numbers of fish released, and time of release during study periods.

Date	# of Fish Released	Location *	Time
8/10/2007	53756	Horseshoe Bend	1000
8/11/2007	19377	Horseshoe Bend	1000
8/12/2007	10428	Curtis Landing	1200
8/13/2007	16863	Horseshoe Bend	1200
8/14/2007	25808	Curtis Landing	1200
8/15/2007	18535	Horseshoe Bend	1100
8/16/2007	34917	Curtis Landing	1100
10/13/2007	972	Horseshoe Bend	1100
10/14/2007	2790	Horseshoe Bend	1200
10/15/2007	825	Horseshoe Bend	0900
10/16/2007	639	Horseshoe Bend	1100
10/17/2007	651	Curtis Landing	1100
10/18/2007	1338	Horseshoe Bend	1000
12/4/2007	341	Curtis Landing	1030
12/5/2007	319	Horseshoe Bend	1100
12/6/2007	486	Horseshoe Bend	1000
12/7/2007	7299	Curtis Landing	1230
12/8/2007	3973	Horseshoe Bend	1200
12/9/2007	2526	Curtis Landing	1100
12/10/2007	560	Horseshoe Bend	0430
12/11/2007	826	Curtis Landing	1030
12/12/2007	388	Horseshoe Bend	1030
2/2/2008	1324	Curtis Landing	1100
2/2/2008	128	Horseshoe Bend	2000
2/3/2008	2156	Curtis Landing	0800
2/3/2008	276	Horseshoe Bend	2000
2/4/2008	1560	Curtis Landing	0800
2/4/2008	118	Horseshoe Bend	1400
2/5/2008	2168	Curtis Landing	0800
2/5/2008	436	Horseshoe Bend	1630
2/6/2008	272	Horseshoe Bend	1500
2/7/2008	1404	Curtis Landing	0700
2/7/2008	124	Horseshoe Bend	1800
2/8/2008	1184	Curtis Landing	0700
2/8/2008	108	Horseshoe Bend	1500
3/12/2008	188	Horseshoe Bend	0800
3/12/2008	16	Curtis Landing	1200
3/13/2008	84	Horseshoe Bend	0800
3/14/2008	216	Curtis Landing	0800
3/15/2008	42	Horseshoe Bend	0815
3/16/2008	48	Curtis Landing	0800
3/17/2008	122	Horseshoe Bend	0900
3/18/2008	64	Curtis Landing	0800
3/19/2008	172	Horseshoe Bend	0800
3/19/2008	8	Curtis Landing	1300

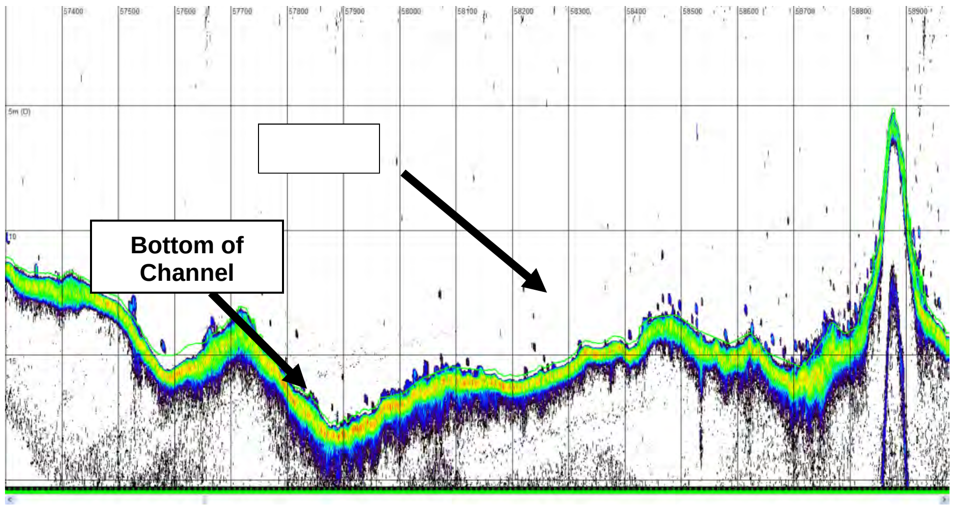
* Location may not represent actual release site

5.2.2 Acoustic Data

When examining the data, numbers of fish observed by each transducer do not necessarily agree in number as Figure 41 illustrates. The orientation of each transducer can cause this type of disagreement in estimated numbers of fish. As an example, using Figure 41, CH1 HPR is the most Westerly facing transducer. This transducer points almost directly downstream, away from the release site. CH2 HPR is oriented slightly more north (approx. 30°), CH1 NHPR more so, and finally CH2 NHPR is the transducer aimed almost across the front of the release pipe, and therefore would be expected to see fish most directly suspended near the release pipe.

Differences in mobile data stem from how each transducer samples the water column. In an ideal setting (eg. fish are randomly distributed in the water column and there are a sufficient number of targets detected to produce meaningful density calculations) both down looking and side looking data should produce the same estimated fish density. However, an ideal setting is rarely the case. Fish population estimates obtained at night also tend to differ from those obtained during the day. This is a common phenomenon, and the primary reason most acoustic surveys are done at night. Typically many species of fish will seek cover during the day or associate closely with bottom structure (Figure 40). When they do this, visualizing fish targets is difficult. The 0.4 ms pulse width used in this study prevents identification of individual targets closer than 28 cm (1 ft) from structure such as the bottom, or from each other. Aside from the differences mentioned above, trends are typically the same or similar for each transducer for either the fixed station or mobile survey data.

Day time distribution, most fish are near the substrate.



Night time distribution, fish have moved up into the water column.

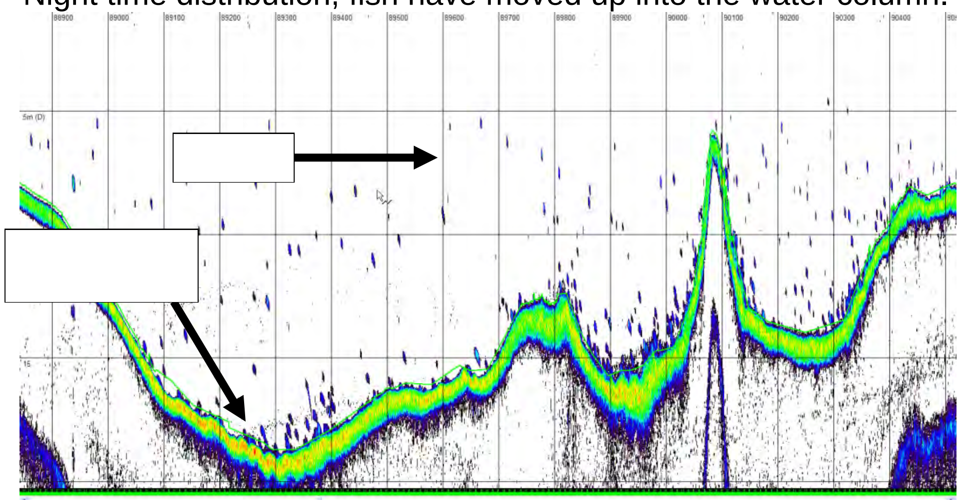


Figure 40- Echogram snapshot showing differences in day and night distribution of fishes.

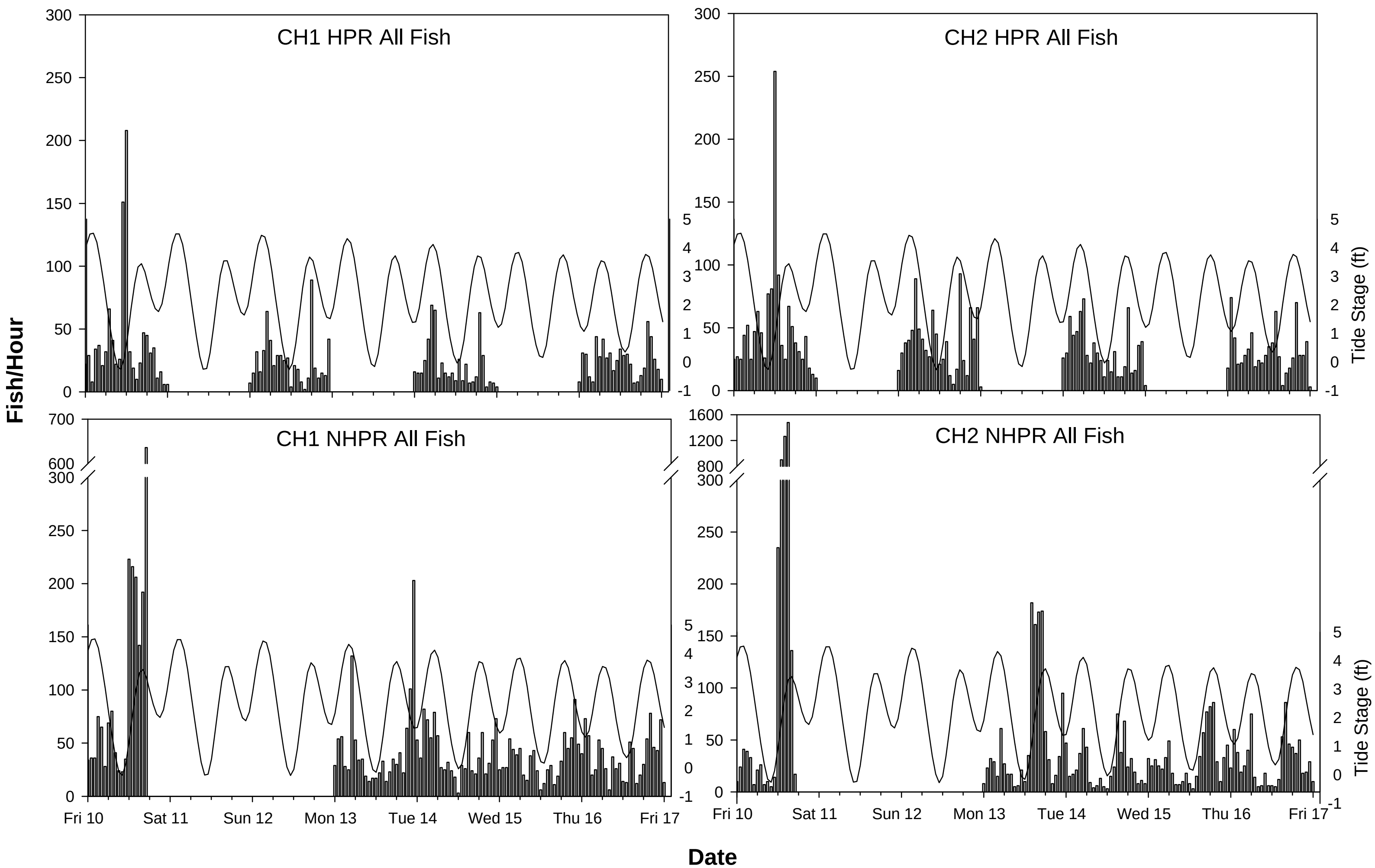


Figure 41- August 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45dB or 9.5cm (3.7 in)

On average, activity of large fish (>-36 dB or 25–26 cm [9.8–10.2 in]) in the local vicinity of the release site peaks in August and October then declines through the rest of the study period (Figure 42). By March the numbers have declined to very low levels and on average only 4-5 large fish per hour or fewer, depending on the transducer, are observed. The pattern for smaller fish shows more consistent numbers through December then a decrease in February and March (Figure 43). This pattern differs from the population trends observed during the mobile surveys, where pelagic densities of fish tended to peak in December and be lower both prior to, and after that time period (Figures 44–47). The December peak also coincides with an increase in numbers of fish being captured at the SDFPF during the second week of December (Table 19).

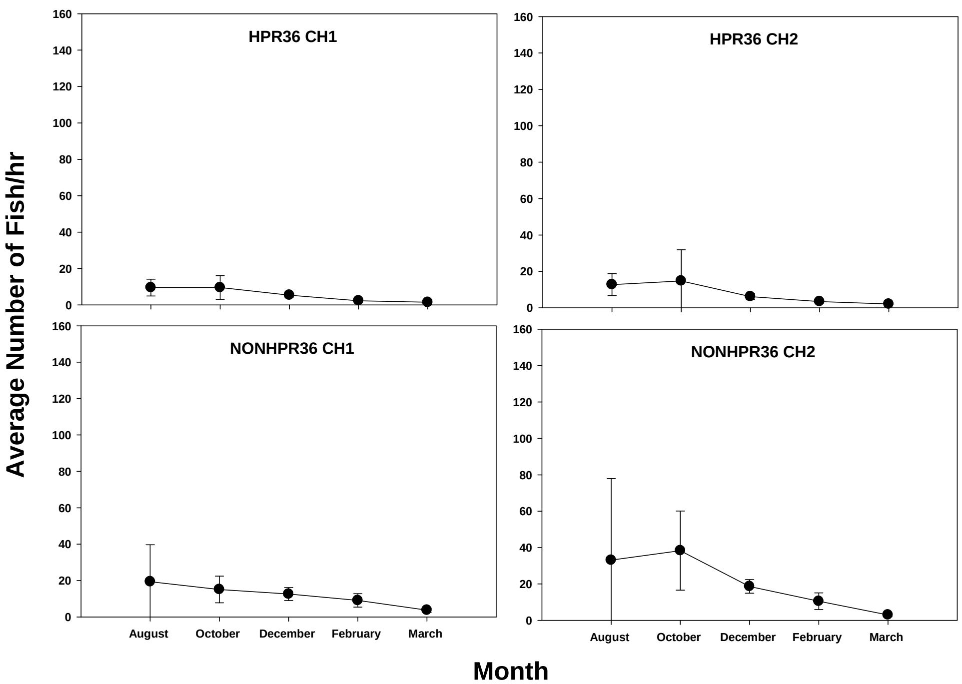


Figure 42- Average number of fish per hour larger than -36 dB (25–26 cm [9.8–10.2 in]) encountered at the release site based on **fixed transducer** data. Bars are plus or minus 1 standard deviation.

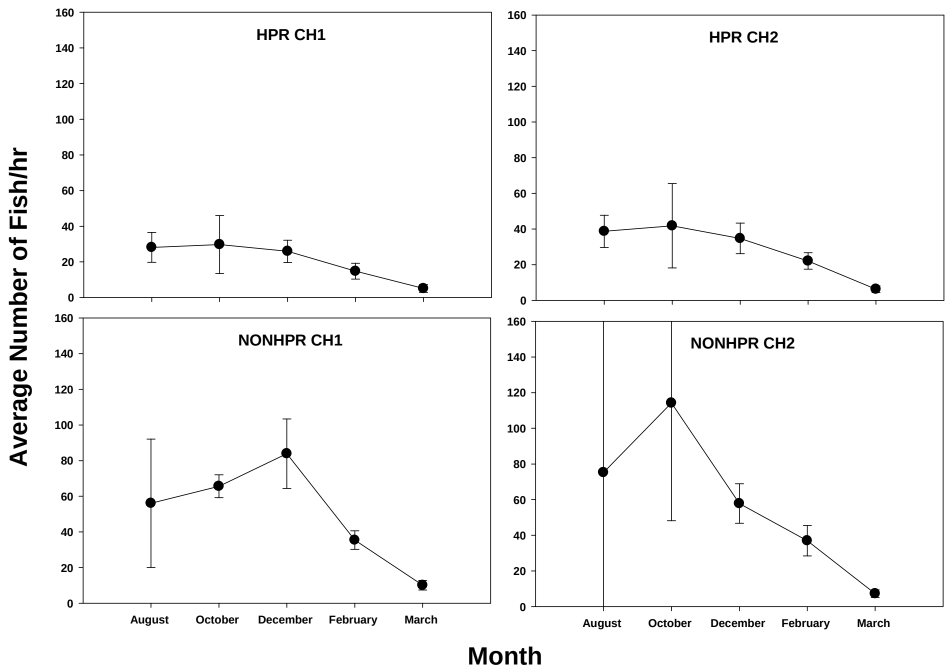


Figure 43- Average number of fish per hour larger than -45 dB (9.5 cm [3.7 in]) encountered at the release site based on **fixed transducer** data. Bars are plus or minus 1 standard deviation.

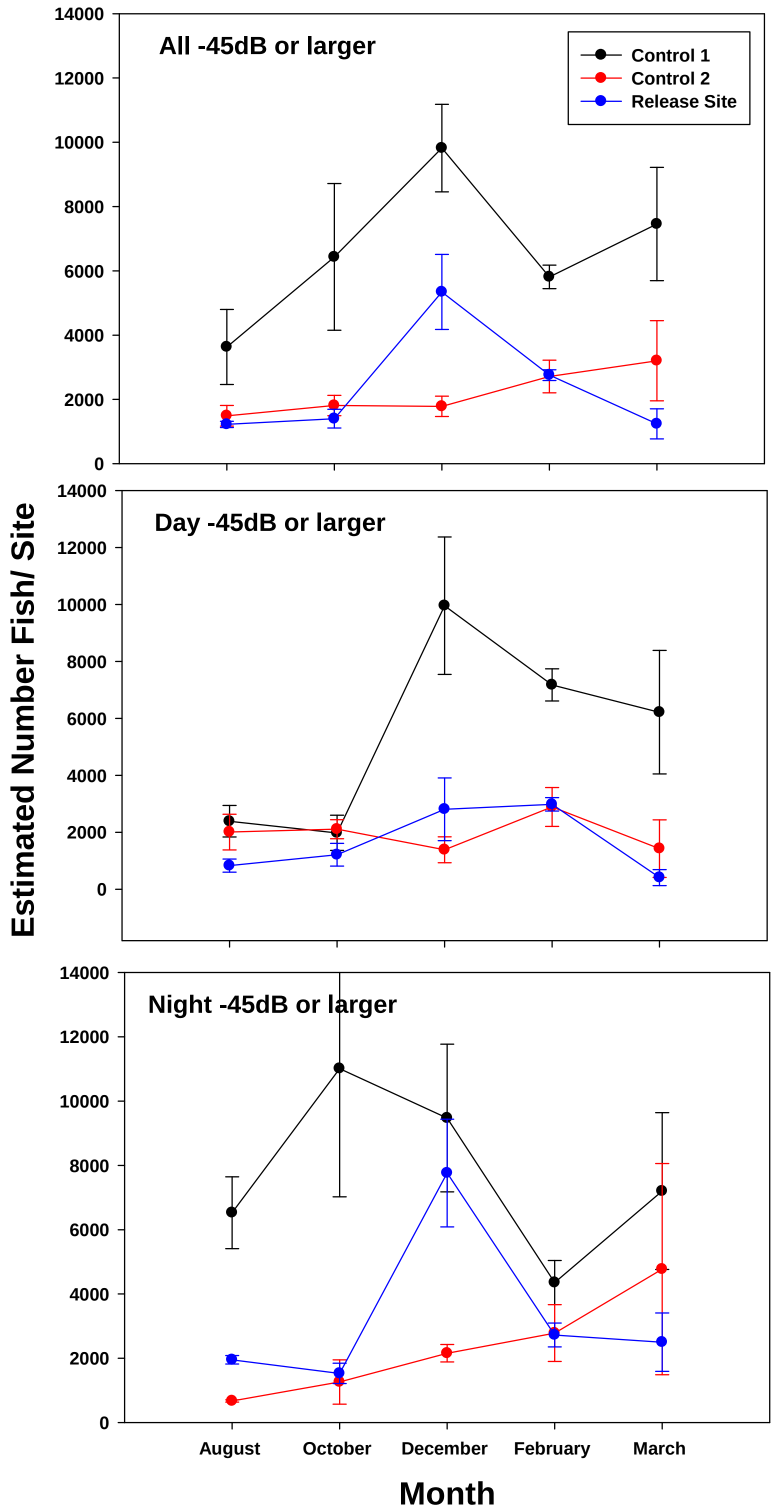


Figure 44- Estimated fish populations (day and night, day only, and night only) for fish larger than -45 dB (9.5 cm [3.7 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **down looking transducer**. Error bars are ± 1 SE.

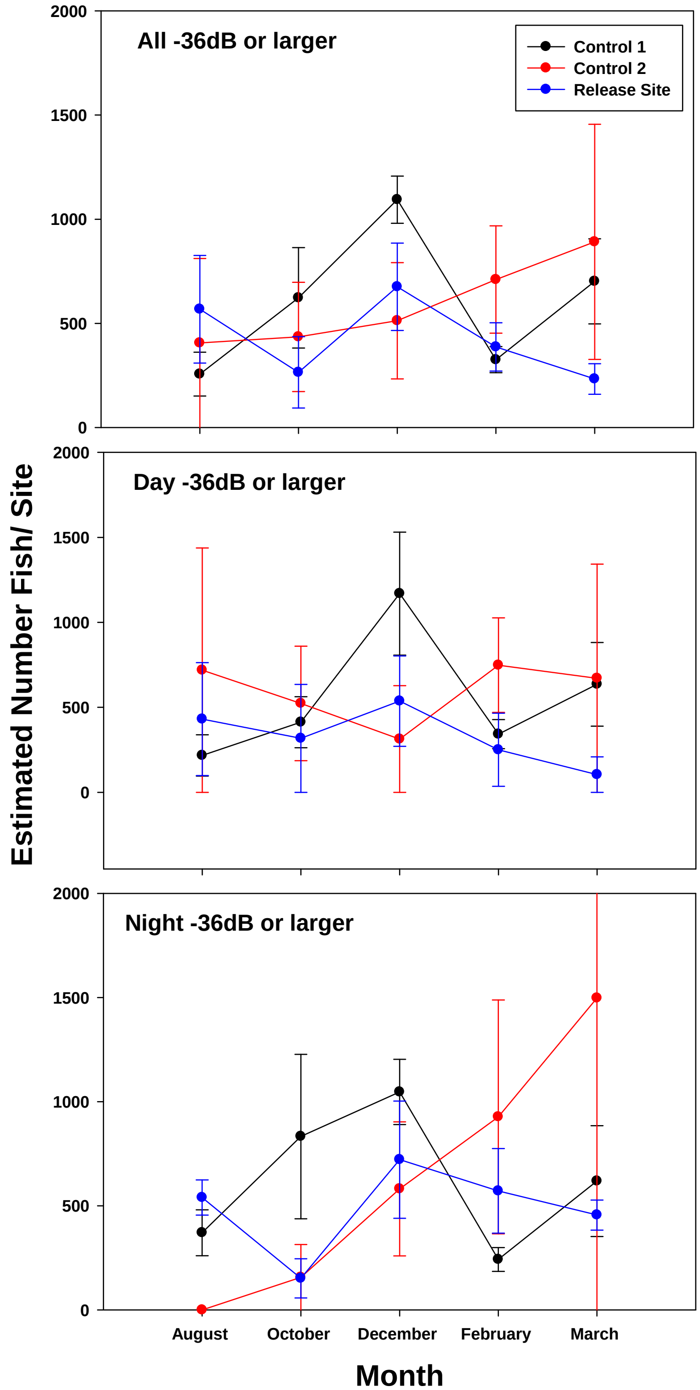


Figure 45- Estimated fish populations (day and night, day only, and night only) for fish larger than -36 dB (~25 cm [9.8 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **down looking transducer**. Error bars are ± 1 SE.

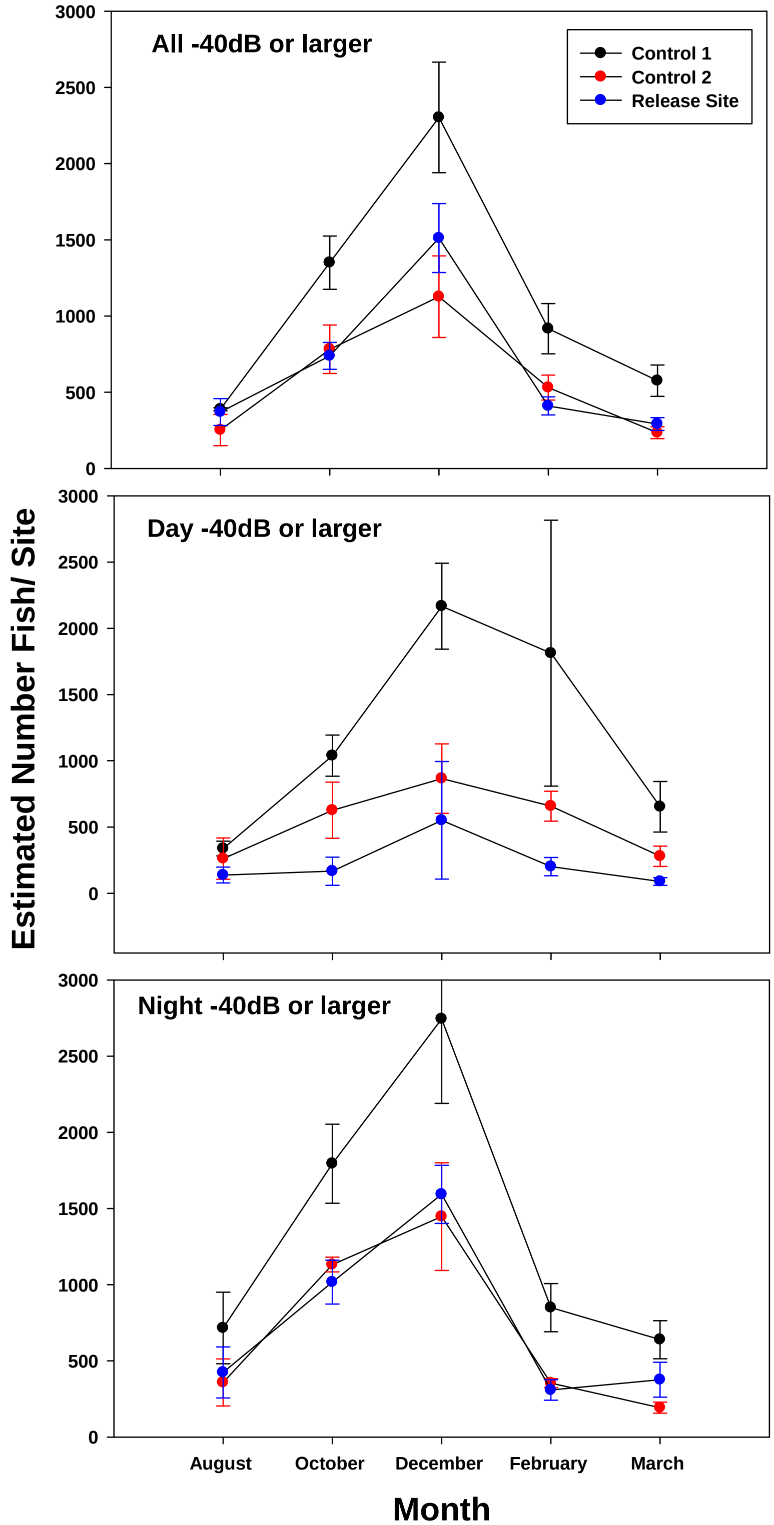


Figure 46- Estimated fish populations (day and night, day only, and night only) for fish larger than -40 dB (~18 cm [7 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **side looking transducer**. Error bars are ± 1 SE.

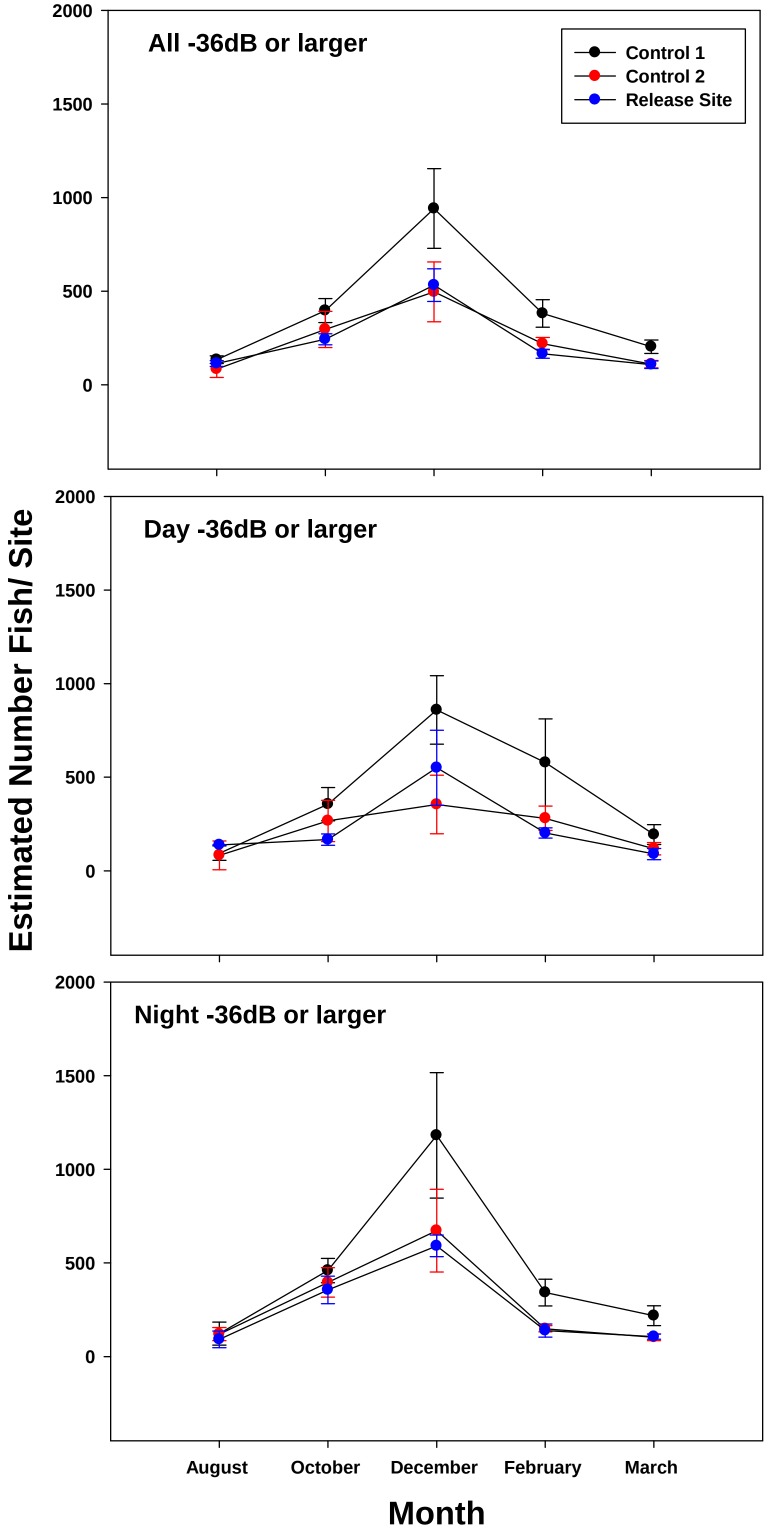


Figure 47- Estimated fish populations (day and night, day only, and night only) for fish larger than -36 dB (~25 cm [9.8 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **side looking transducer**. Error bars are ±1 SE.

Using sidescan acoustic data, densities at the release and control sites were higher during December 2007 than at any other times when comparing populations of both small and large fish (Figures 43–47). Although the data was much noisier, downlooking acoustic samples revealed the same general trend. The less defined pattern associated with the downlooking data is a function of the volume of water sampled. For a 100 ping block the average summed volume of water sampled is approximately 55 m^3 (1,942 ft^3), the same 100 ping block using sidescan data samples about 3,000 m^3 (105,944 ft^3). The relatively small volume of water sampled using the down looking transducer means a small change in number of targets has a large impact on calculated densities of fish. With sidescan, the volume sampled is more than an order of magnitude larger, consequently small variation in the number of targets observed has little impact on the overall population estimate. The size of the error bars for the population estimates are indicative of the effect the different sampling volumes have (Figures 44–47). These differences aside, the average population estimates for large fish are fairly similar, and likely indicate that the population was effectively sampled.

Population estimates for all fish larger than -45 dB, provide a useful starting point to examine the potential impact salvaged fish releases have on the Horseshoe Bend area and why predators might congregate at the release pipe versus feeding in the open channel. In August the populations of fish larger than -45 dB, or 9.5 cm (3.7 in), observed using the downlooking transducer, which for this study provides the most conservative estimate of predatory fish populations, varied between about 1500 fish for the release and Control Site 2, and about 4,000 for Control Site 1 (Figure 44). During this time of year, on a given day, anywhere between 10,000 and 50,000 salvaged fish may have been released into the area; an order of magnitude larger than the local pelagic population (Figure 48). This influx of fish was substantial in relation to the standing predatory fish population in the area. During the other sampling periods the number of fish released tended to approximate the fish populations in each reach, with numbers ranging to slightly above the population estimates to well below. By March, the numbers of fish released were a fraction of the total estimated fish population of any of the sites monitored.

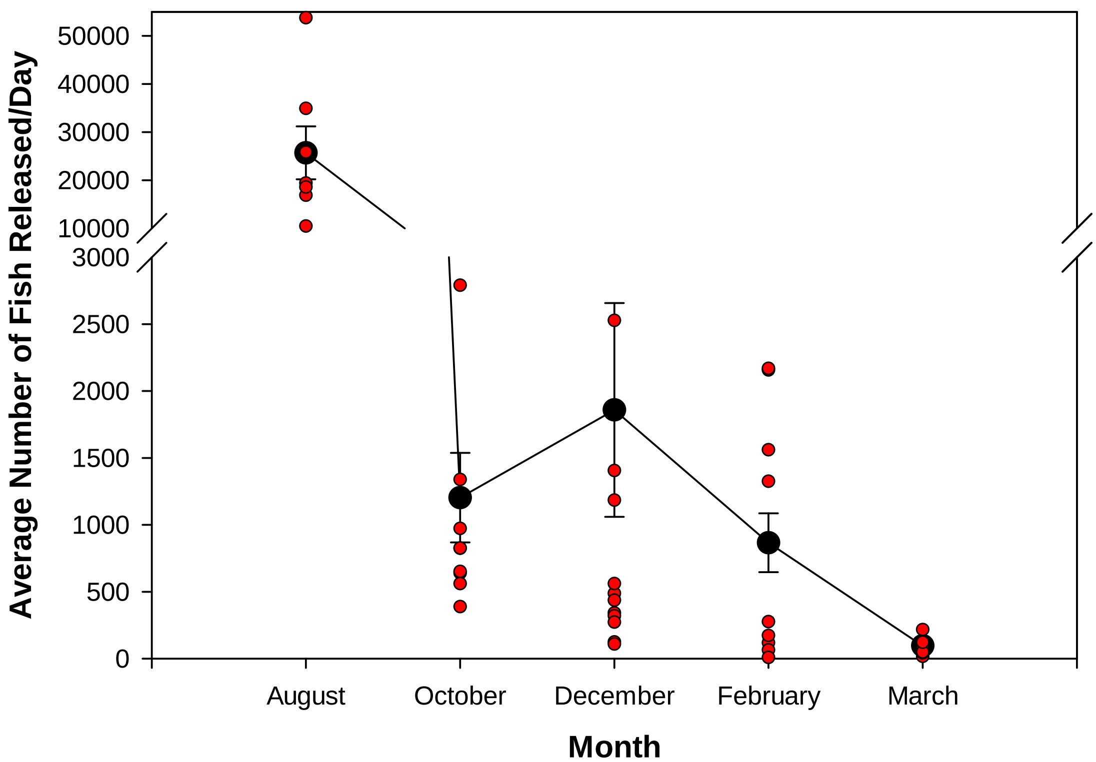


Figure 48- Average number of fish released/day during each study period. Data shows both SWP Horseshoe Bend and Curtis Landing releases since it is not known where the release occurred. Black circles are mean for the time period, red circles represent actual values, and error bars are ± 1 SE.

The observation that fixed site data tend to show an ever decreasing trend for large predator sized fish over time, and do not mimic patterns observed for the mobile surveys is likely indicative of a lessoning response of predators to releases being made. This corresponds to DIDSON observations showing fewer and fewer fish located near the exit of the release pipe as the season progresses. The reason for this decrease is uncertain, as there may be multiple causes. First, the number of fish released each day drops significantly in the winter, when only a couple of hundred small fish are released each day as stated previously. The decrease in numbers of fish being released may result in an unreliable food source such that predators at this time of year no longer associate the site with food. Secondly, at least in December, small fish populations are higher in the open water and may represent a better feeding opportunity than the fish releases. Third and most likely, as water temperatures decrease in the winter, predator species feeding rates, as a function of temperature, drop to only a fraction of summertime rates and there is no real payoff to hold in front of the release site.

Mobile acoustic surveys also reveal that if predators are responding to the release site, it is likely a local grouping. Population estimates of large fish indicate both spatial and seasonal differences in density of large fish among the three sites (Figures 46 & 47; $F_{2,69} = 4.34$, n=70, p=0.01 (location), $F_{4,69} = 14.31$, n=70, p<0.01 (month), $F_{8,69} = 0.79$, n=70, p=0.6 (interaction)). Least squares analysis, however, indicates Control Site 2 and the release site were not different from each other, while Control Site 1 was different from both the other sites. A similar trend was observed when looking at all fish ($F_{2,69} = 9.42$, n=70, p<0.01 (location), $F_{4,69} = 24.64$, n=70, p<0.01 (month), $F_{8,69} = 1.25$, n=70, p=0.28 (interaction), with least squares indicting the release site and Control Site 2 were similar to each other while Control Site 1 held higher fish populations. When these sites were initially selected they were chosen based on their apparent similarities, in that all three have some sort of water structure extending out on pilings, and have fairly similar shoreline topographies. Control Site 1, however, also was found to have a deep hole near the mid-point of the site, making this site somewhat dissimilar from the other two in this respect, and fish tended to congregate in this area. Figure 49 shows the large concentration of targets in the bend of the river where the deep hole is, whereas there is no obvious larger scale association with the area around the release pipe.

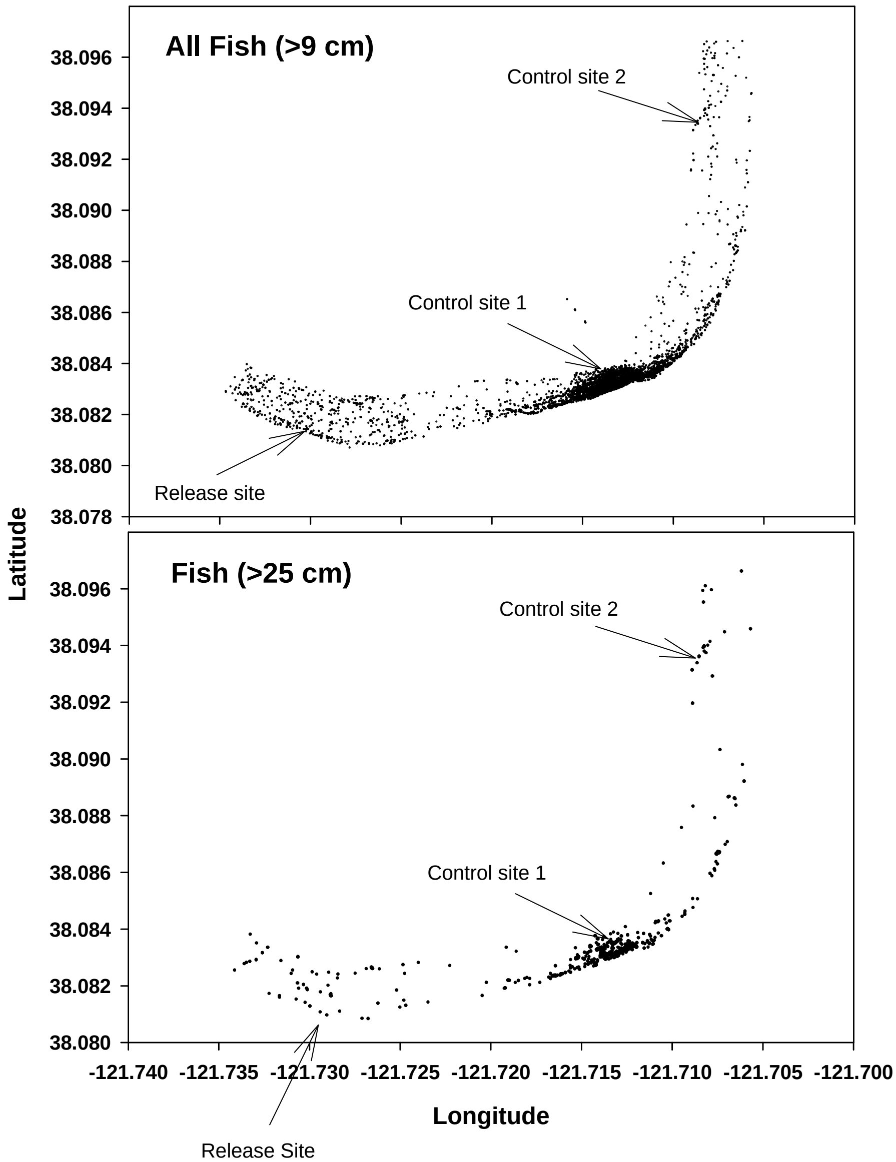


Figure 49- Distribution of fish targets in the Horseshoe Bend Area.

Generalized patterns of movement of fish in the area surrounding the release site show some slightly different patterns when comparing the four transducers. Again transducer CH2 NHPR looked most directly at the release pipe, and predominately saw fish in this vicinity, while the other transducers were not quite as heavily influenced. When lots of fish were present near the release pipe, mainly in August and October, the net direction of movement of fish was often near 180 degrees, indicating as many fish were going down stream as upstream. This can be interpreted as milling behavior in front of the release site, and is supported by the relatively high number of targets observed there. The other three transducers were less impacted by fish immediately in front of the release site, instead looking more at the general fish population in the river. Using Figure 50 as an example, CH2 NHPR and CH1 NHPR show no real pattern of directionality in response to tidal phase, as fish holding near the transducer dominated the signal, while the other transducers do show some tidal response. The tidal response shown is highly variable; however, the trend is for smaller fish to follow the direction of current in the reach (Figures 51 & 52). Large fish are somewhat less likely to follow the tidal flow than small fish, as indicated by the lower r-square values for the plots. Although this relationship is significant, the variability is high and probably extends from the fact the river current in this reach is not particularly strong.

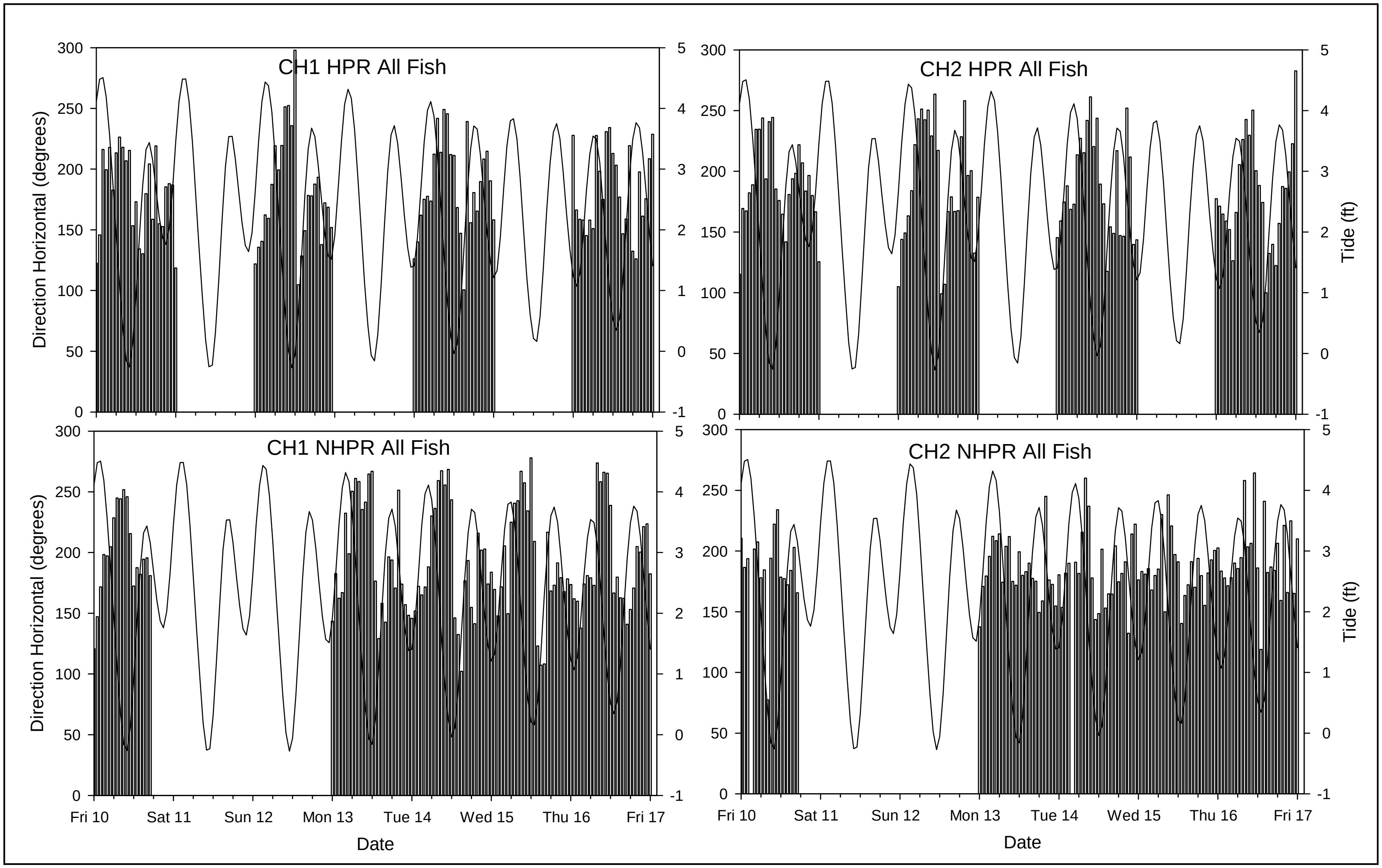


Figure 50- August 2007 fixed site releases, average direction of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

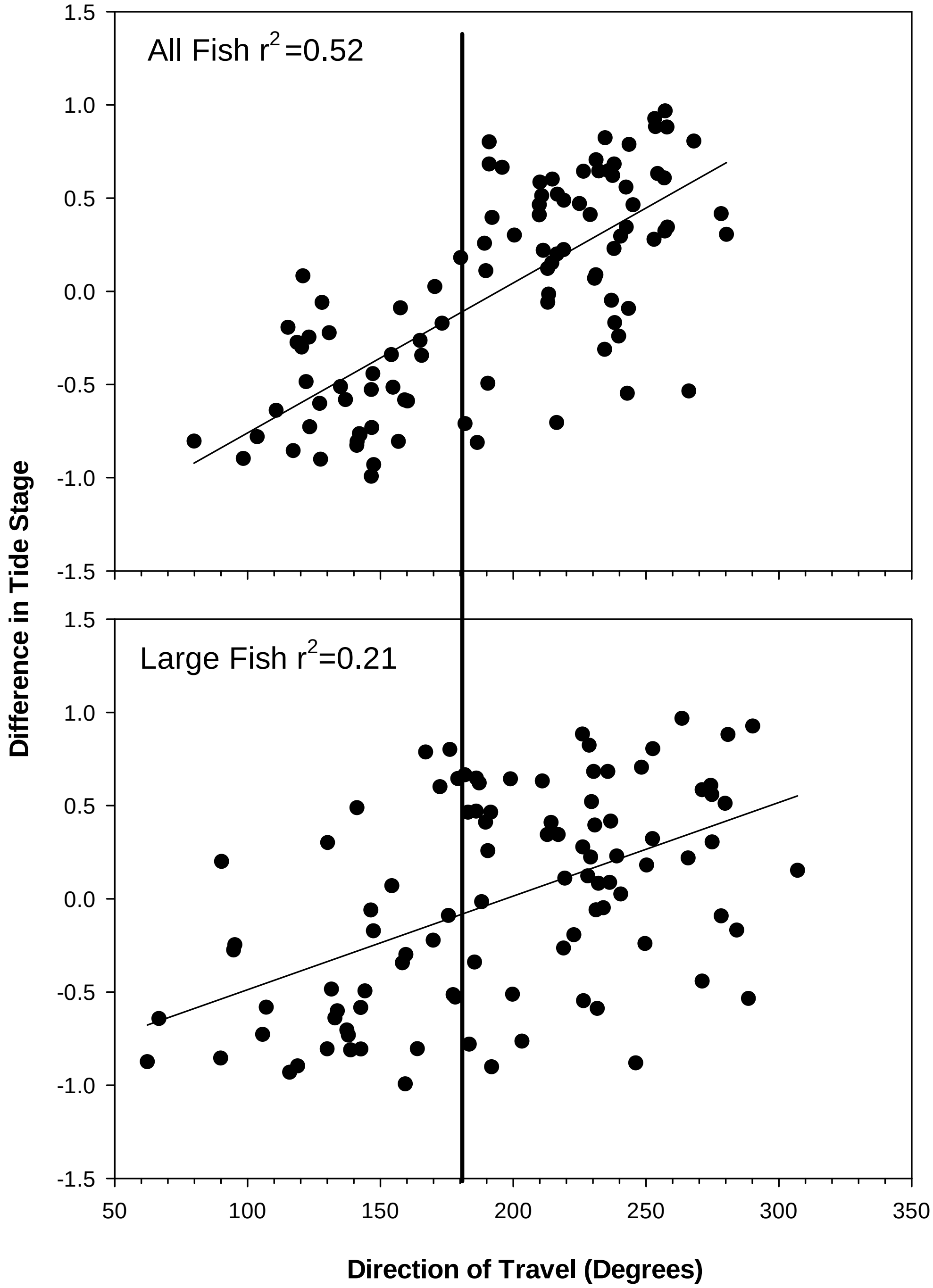


Figure 51- Average direction of movement based on tidal phase. Positive numbers indicate an outgoing tide, negative an incoming tide. Differences are based on hourly stage changes for a study period. In this case data is shown for NHPR CH1, February 2008.

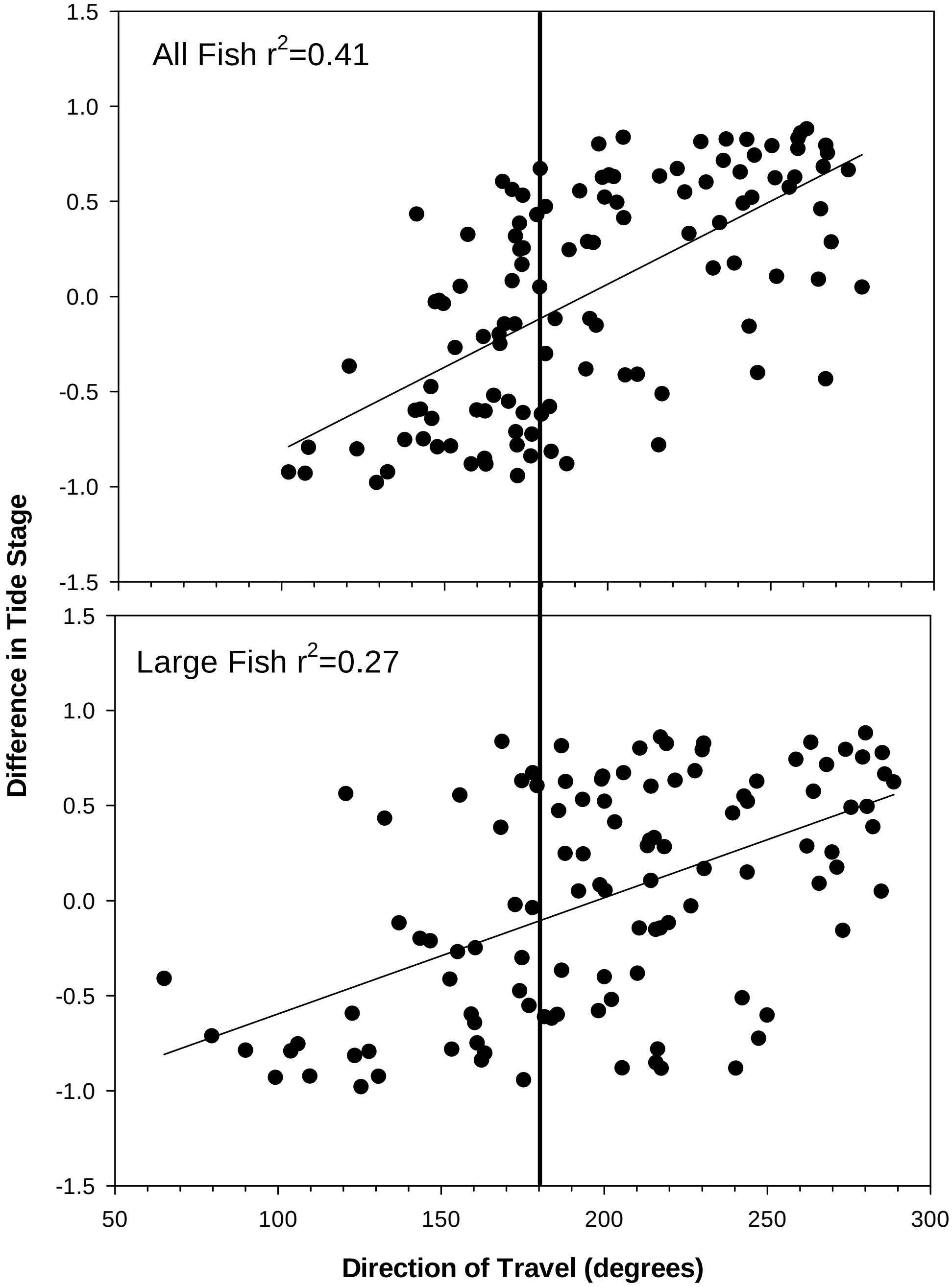


Figure 52- Average direction of movement based on tidal phase. Positive numbers indicate an outgoing tide, negative an incoming tide. Differences are based on hourly stage changes for a study period. In this case data is shown for NHPR CH1, August 2007.

On a diel basis it was difficult to determine if there were any consistent trends in fish behavior that were driven by the light-day cycle. At the release site the largest pulses of fish were typically observed during daylight hours (Figures 53–62). This, however, may simply be a learned response from fish that associate the release site with food. However, in December there tended to be more nocturnal activity (Figure 55). Population estimates in December also showed an overall increase and these two together may indicate something else was occurring during December. There was a shift in the time of releases and this may explain the difference in fish activity and population estimates during this time period. Typical release times at SWP Horseshoe Bend tended to occur twice a day and typically near dawn and dusk during December. This is in contrast to the late morning to mid-day releases that had occurred prior to this time. If predators were responding to releases, this change in observed activity may have been a response to changes in the release schedule.

When trying to describe changes in predator behavior in response to releases, a more descriptive approach was employed instead of applying a rigid statistical analysis. As mentioned previously this largely stems from the fact the correct location of fish releases cannot be reliably determined from the SDFPF data sheets. This aside, there does seem to be a significant increase in the number of fish per hour observed at the release site coinciding with the release of fish at certain times of the year (Figures 53–62). The transducer aimed most directly at the pipe showed the greatest increase in activity at these times. The increase in numbers observed, though, is not necessarily a linear response to the number of fish present in the vicinity of the release pipe. However, this may simply represent an increase in activity of fish already in the area. The same fish can be counted many times when moving back and forth in front of the transducer.

Following release, the length of time an increase in fish movement/activity was observed was highly variable. An increase in fish movement activity was observed to last for 6+ hours following a release on August 10 (Figure 58). Similar observations can be made for releases on August 13 and 15. The length of time activity increases following a release may be a general increased activity, or could be a result of fish being trapped in the pipe following release and slowly exiting the pipe. Observations in 2007 using a remote camera indicated that following a release, numerous fish and pieces of debris remain in the pipe. Over time these “trapped” fish may slowly exit the pipe, resulting in a protracted stream of prey fish being available to predators in the area.

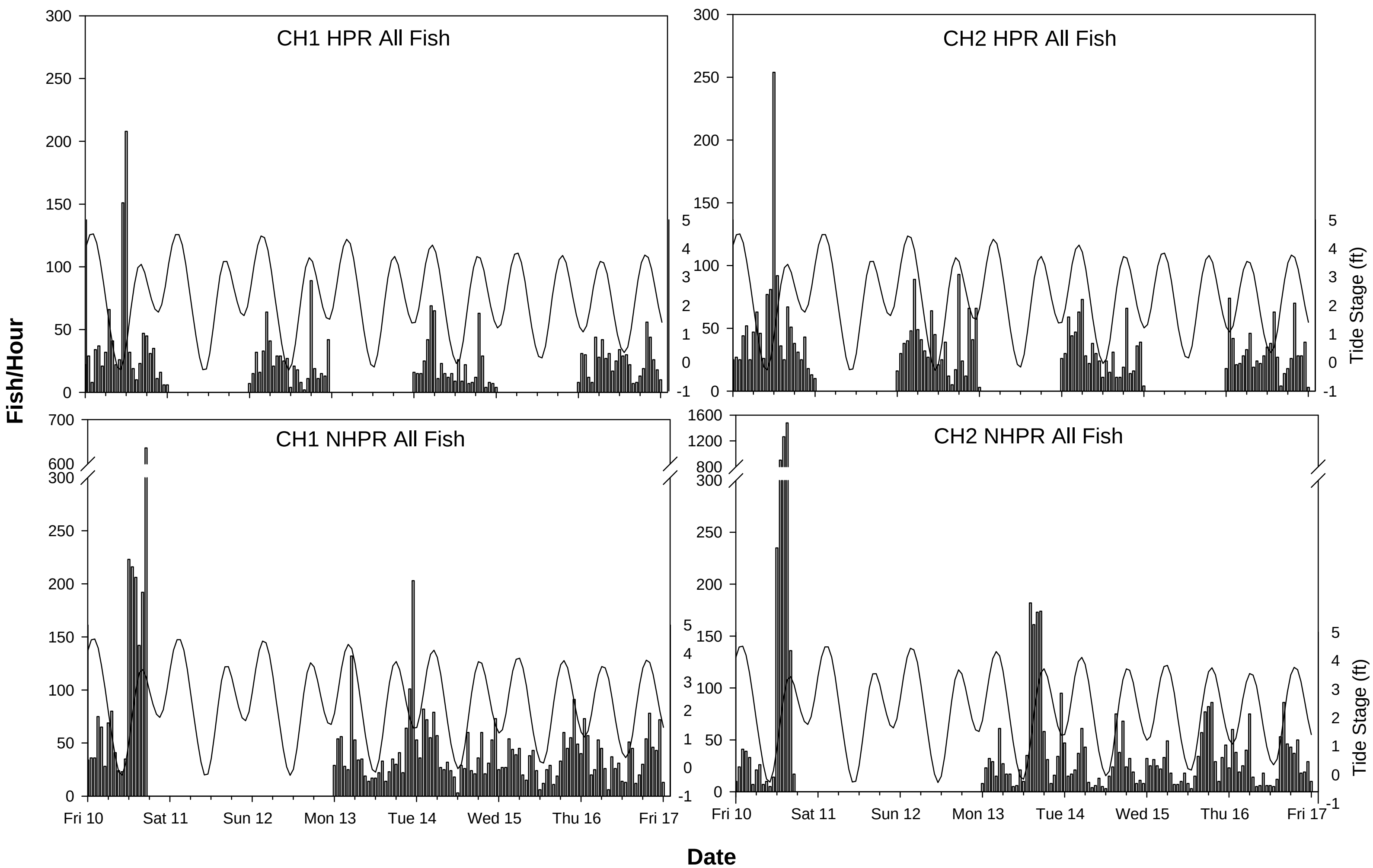


Figure 53- August 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

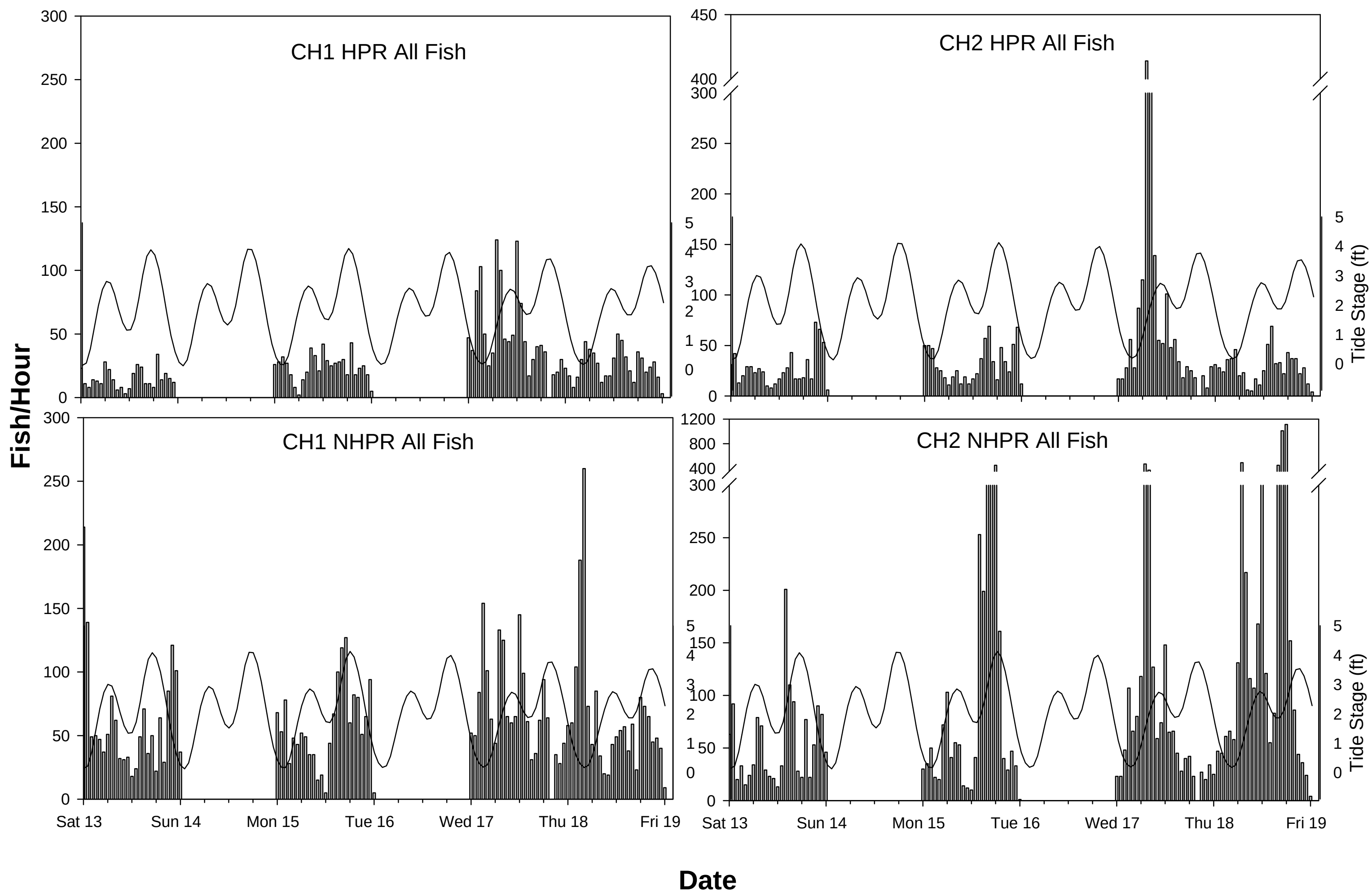


Figure 54- October 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

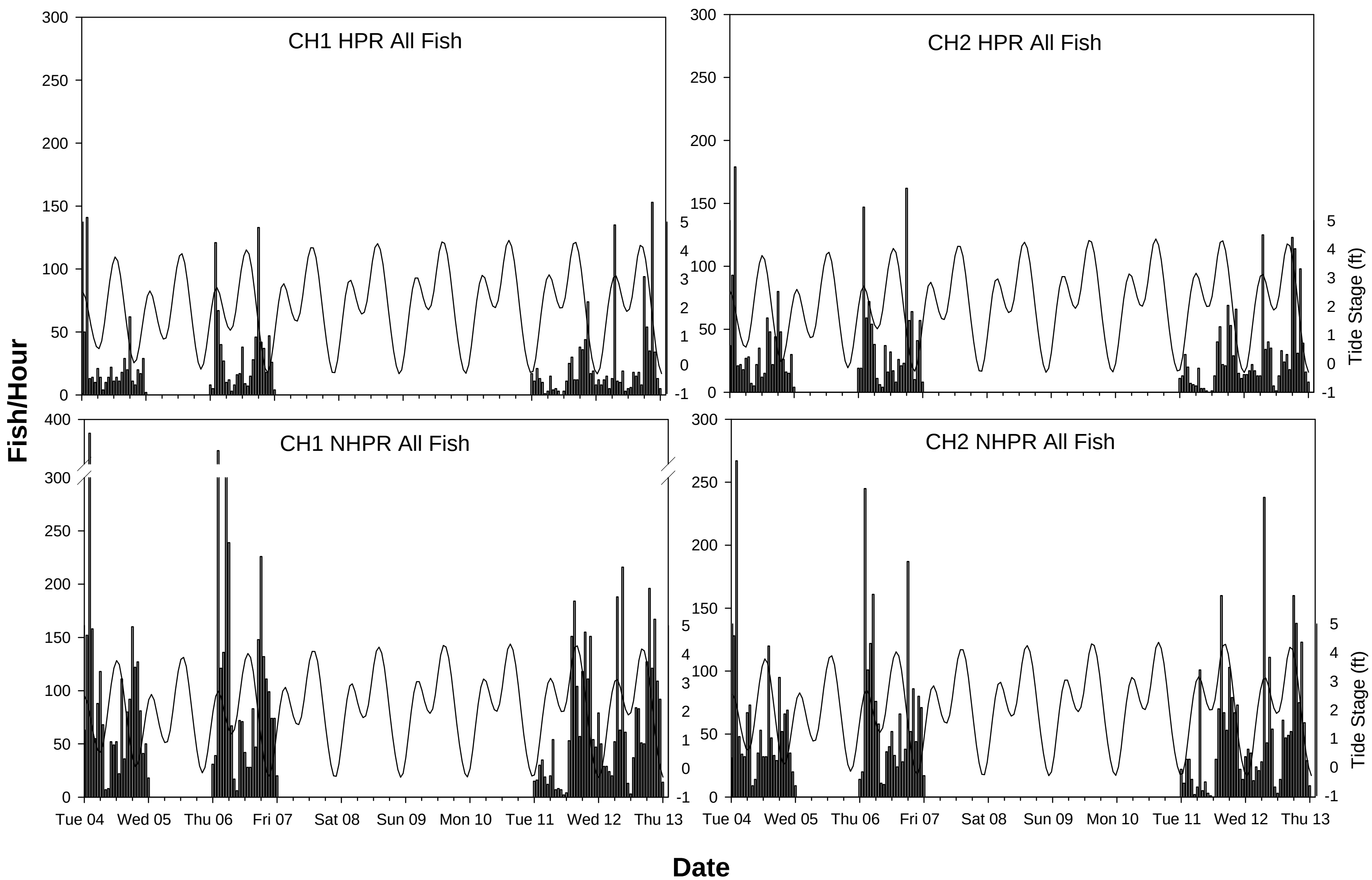


Figure 55- December 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

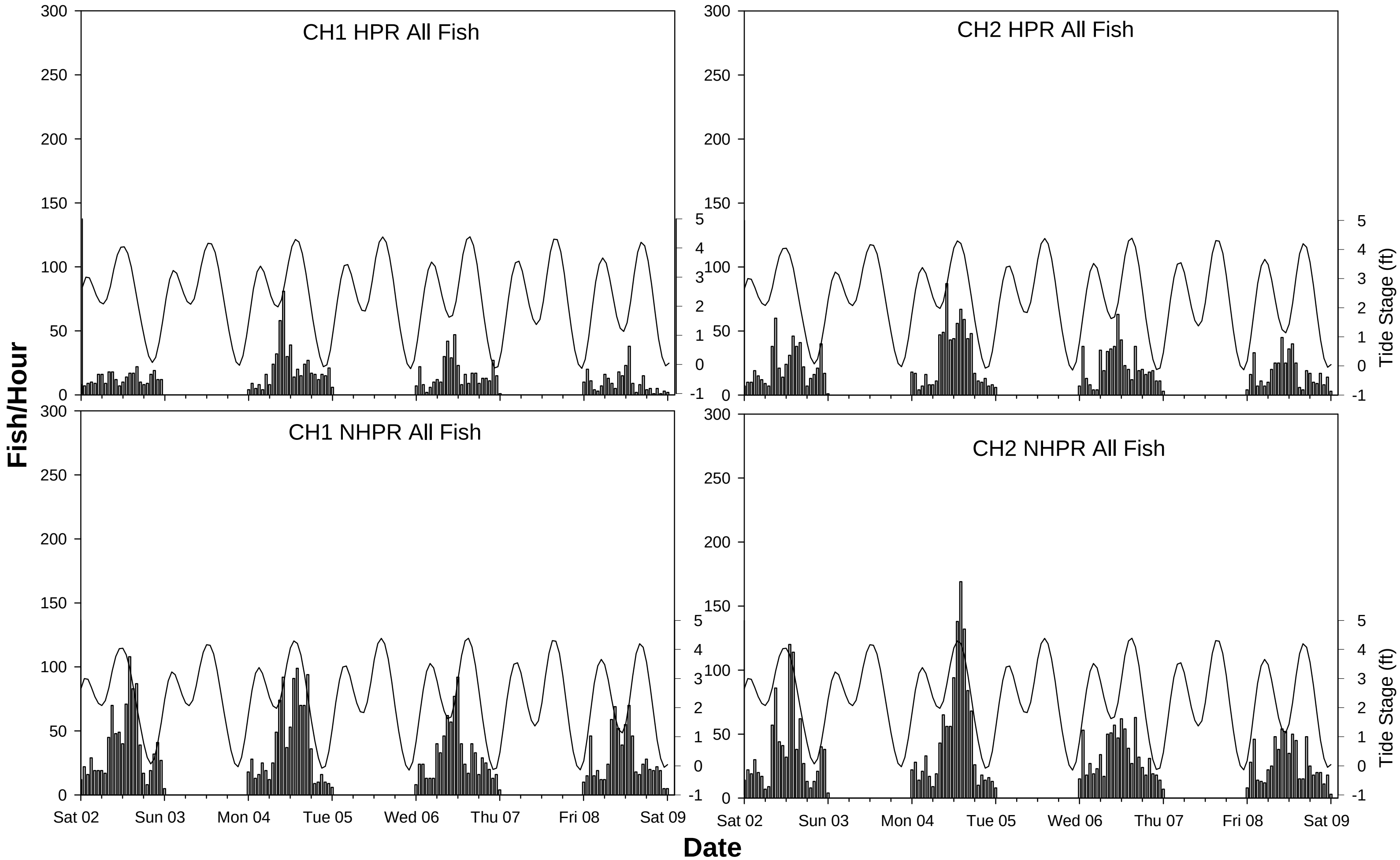


Figure 56- February 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

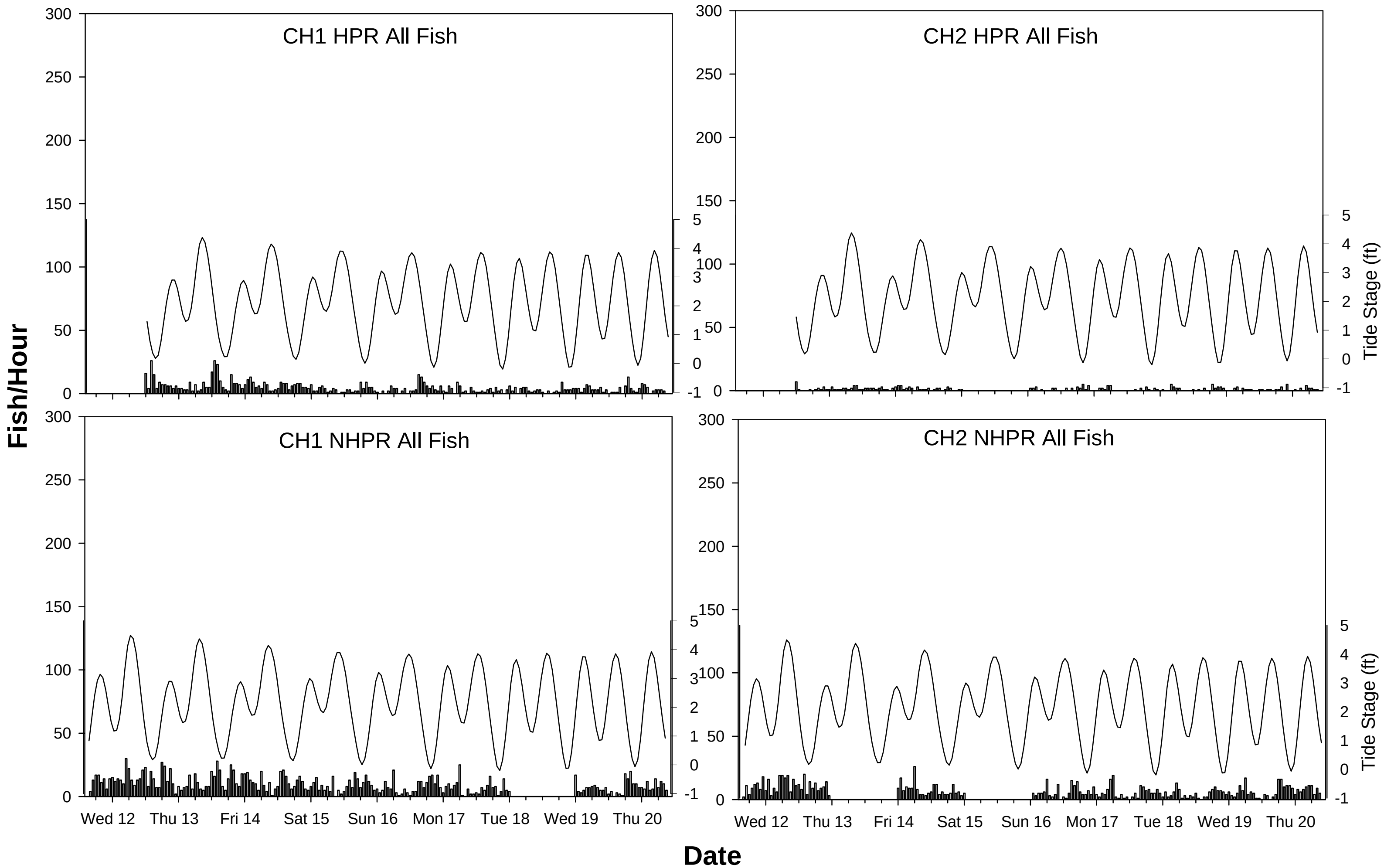


Figure 57- March 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

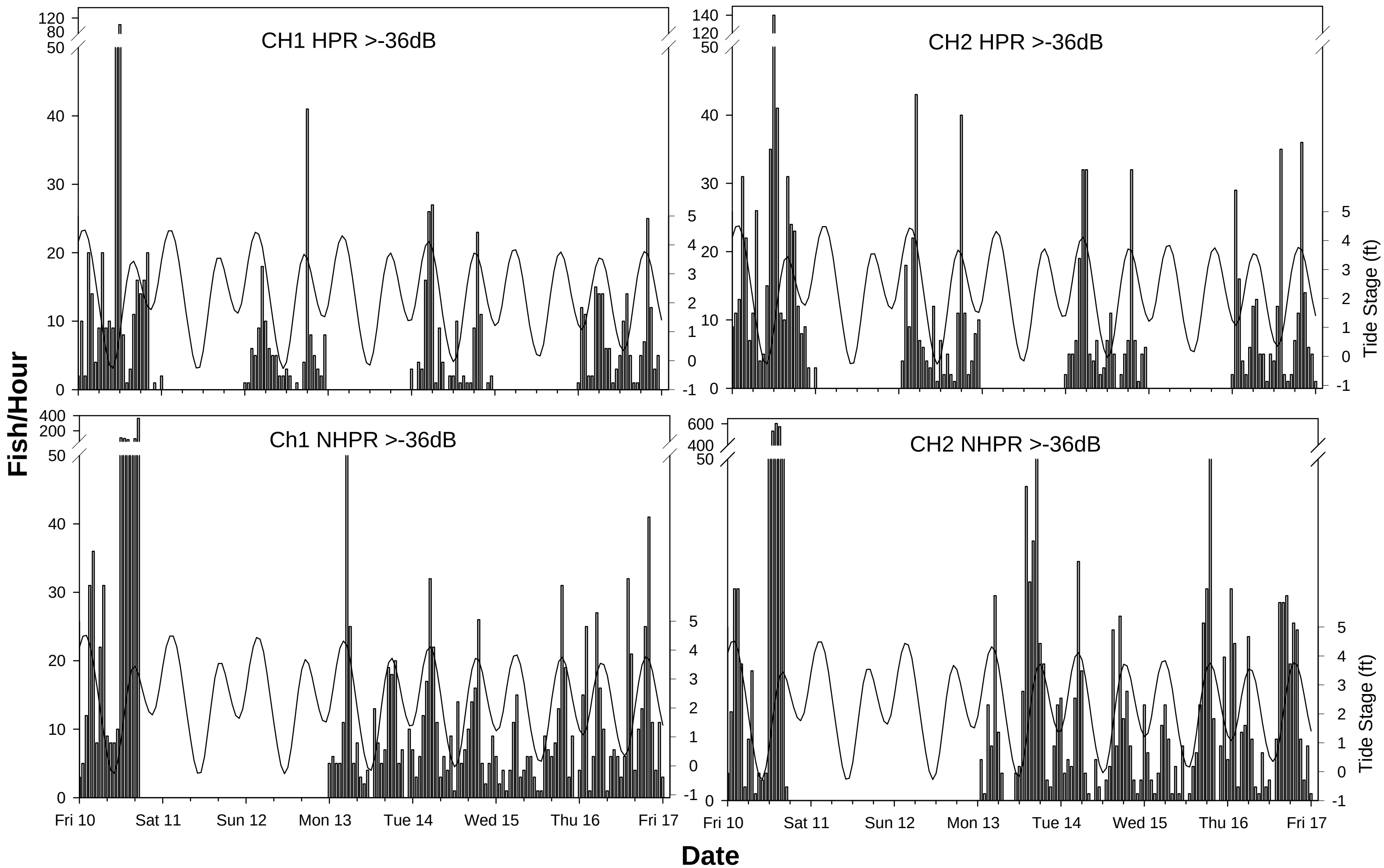


Figure 58- August 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

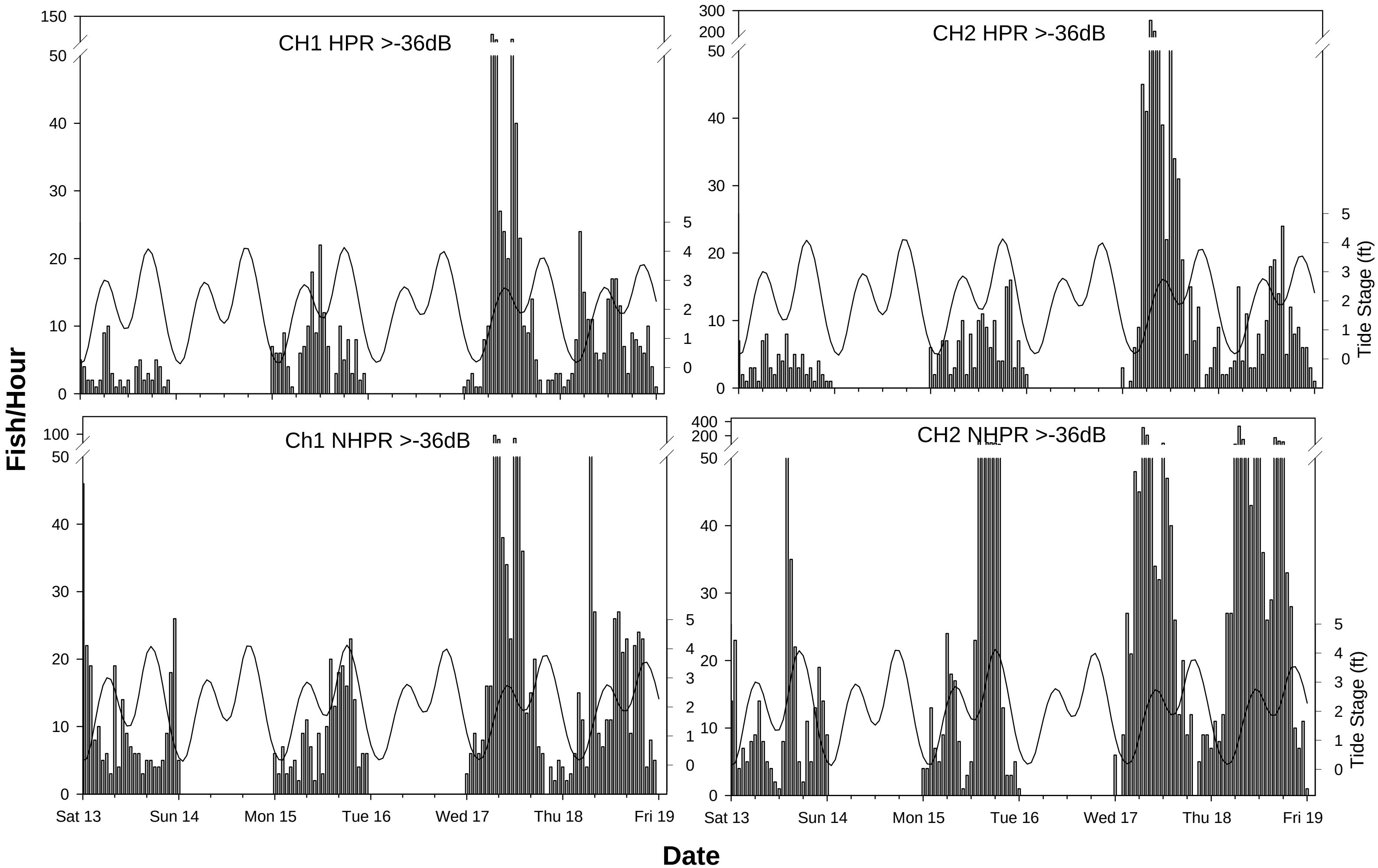


Figure 59- October 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

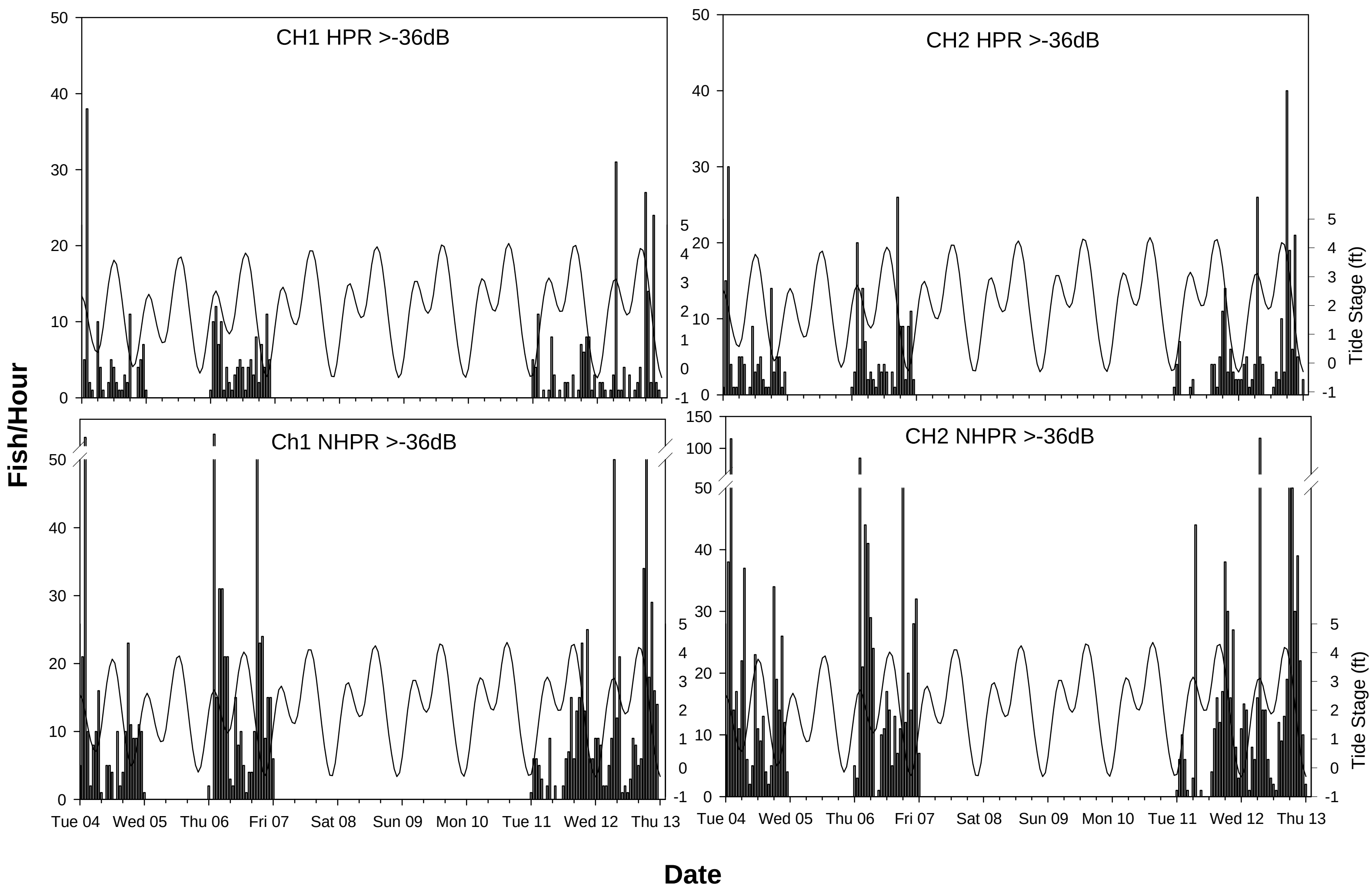


Figure 60- December 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

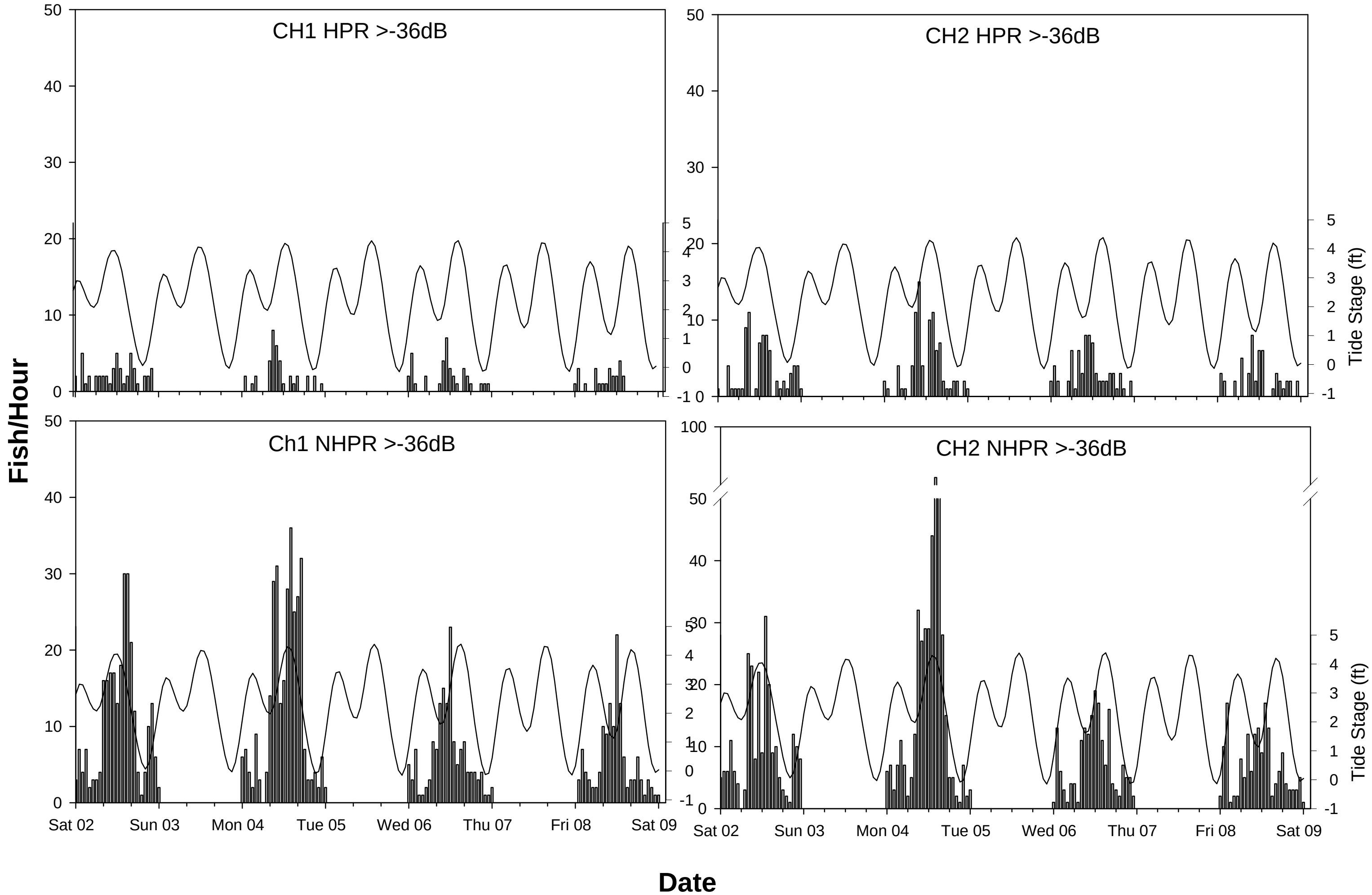


Figure 61- February 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

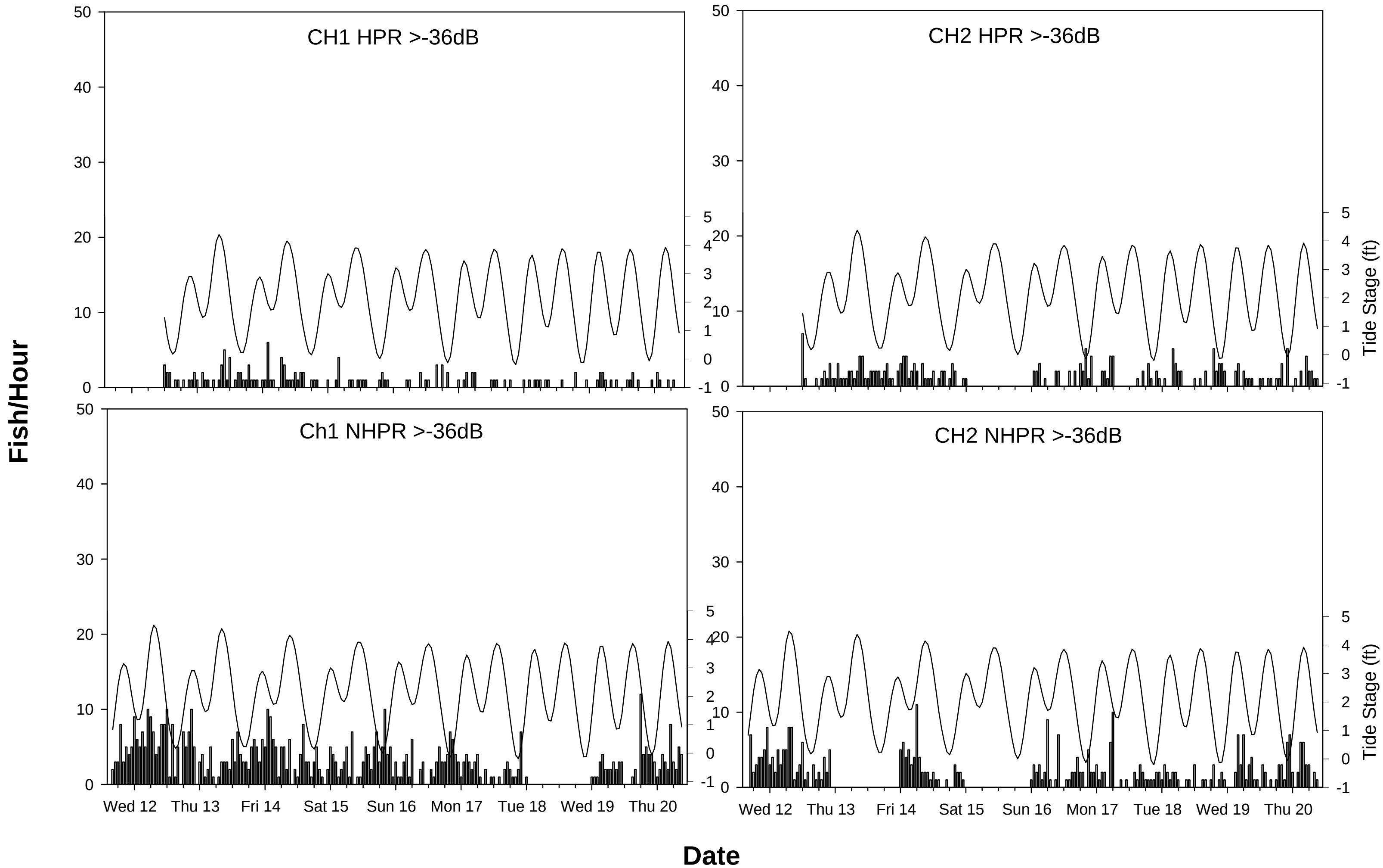


Figure 62- March 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

The apparent strength of the response in fish activity/movement was lower for each of the two latter dates in August. On both these days, however, fewer than half the numbers of fish were released each time than during the August 10 release. However, being several days later, the phase of the tide had shifted forward several hours, which may have impacted our ability to observe the fish. On August 13 and 15 fish were released on an incoming tide whereas on the August 10 it was closer to the peak of the tide. The tidal influence on fish observations may be a function of the direction and strength of flow in the channel. The transducer array sits on the downstream side of the release pipe. On a strong outgoing tide fish tend to congregate on the downstream side of the release pipe, which puts them nearly in front of the transducers. On a strong incoming tide, currents are neutral to slightly upstream. At these times fish are located more directly in front of or slightly upstream of the release pipe and can at times be outside of the zone of detection for the transducers. During October, the pattern was similarly strong and it appears releases were associated with an increase in activity. This was also supported by DIDSON observations.

Changes in apparent fish abundance in front of the transducer array also appear independent of any release. During August and October, this change in abundance is probably a result of the resident group of fish moving their location in front of the release pipe in relation to the tide. DIDSON camera observations indicate that for August and October a large resident group of fish remains at all times in front of the release pipe, this is likely because releases are regular and large enough that fish are conditioned to remain in the area. Such an effect has also been noticed where hatchery trucks stock fish on a regular basis. Fish can learn when “feeding time” is going to occur. While the release may not always occur daily at the release site, the releases occur often enough to keep fish attracted to the area. February still has some fairly well defined peaks of fish indicating some fish may still be remaining in the area, however, by March this pattern is not apparent. March also coincides with lowest numbers of fish being released, and the lowest populations observed in either the release or two control sites.

Graphical data showing all fish, and just fish larger than -36 dB (~25 cm [9.8 in]), show similar trends of increased fish activity. This can mean one of several things; first, some of the fish exiting the release pipe are probably being detected; second, there are probably some smaller predatory fish feeding in the areas as well; and third, and most importantly, the size break we used assumes a fish optimally oriented towards the transducer. If fish are actively moving around back and forth near the transducers their orientation will be constantly changing. What appears as a -32 dB fish in one frame, may be represented as a -40 dB fish in the next frame simply due to orientation. This is not as big a problem in the mobile surveys, particularly with downlooking data where the transducer has a higher probability of seeing a fish in proper orientation most of the time. Even with this orientation issue, there still is a bi-modal distribution of fish observed by the transducers (Figure 63); however, a lot of the smaller targets may also represent larger fish.

By focusing on the larger targets, numerous valid fish may be rejected, but there is also less likelihood of including small fish that happen to be in the vicinity and were observed. This effect would result in any population estimate being biased on the low side, but for behavioral purposes, it might be best to avoid smaller targets. Following release times, fish appear to crowd closer to the location of the release pipe in both August and October, however, during December, February and March, there are so few fish that no real change in the distribution of targets within the receiving water is detected (Figures 64–73). This decrease in range may be correlated to the location of the fish holding in the area as well. On an outgoing tide fish tend to congregate more on the downstream side of the release pipe, and nearer the zone of observation for our system, therefore, part of the decrease in range observed could be a result of this shift in the location of the fish school. Of note, during August and October, the largest pulses of fish observed are also associated with the closest average range measured for a given hourly interval. During February the average range (target distance from transducer) is well out away from the transducers and therefore is more likely to represent activity changes for fish in the open water zone of the channel.

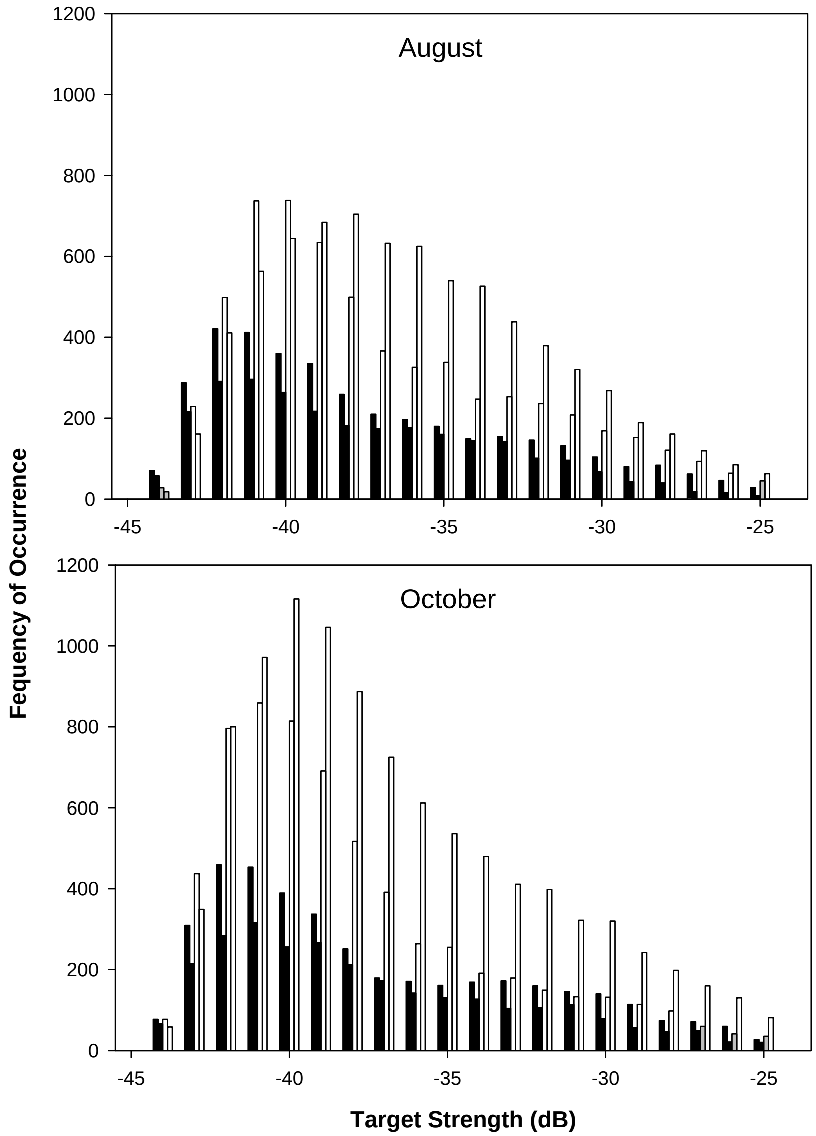


Figure 63- Histogram of fish sizes from fixed station transducers for August and October. Black bars are CH1 and CH2 HPR, gray bars are CH1 and CH2 NHPR. A target strength of -45 dB equals an approximately 9.5 cm (3.7 in) fish while a strength of -25 dB equals an approximately 110 cm (43.3 in) fish.

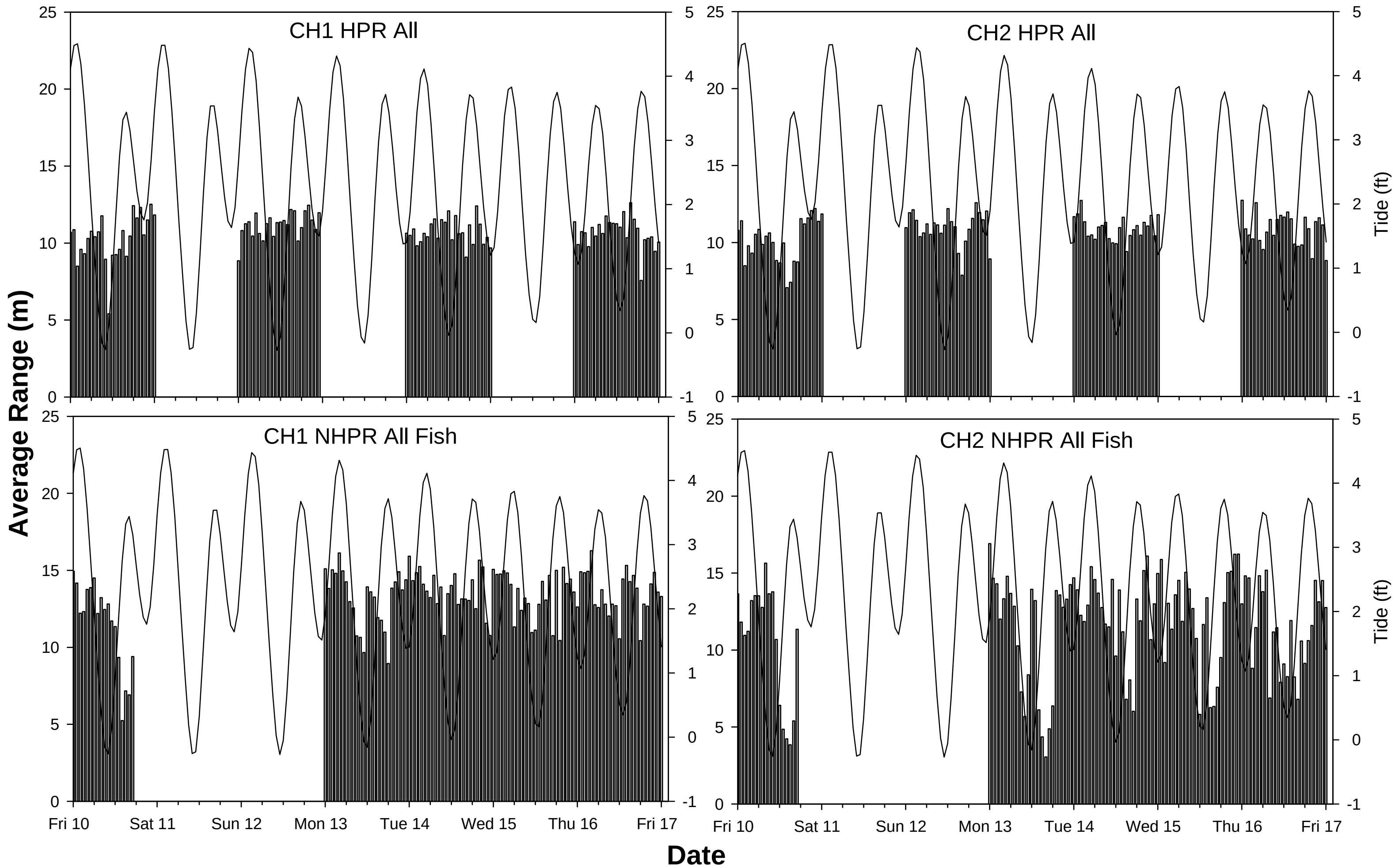


Figure 64- August 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

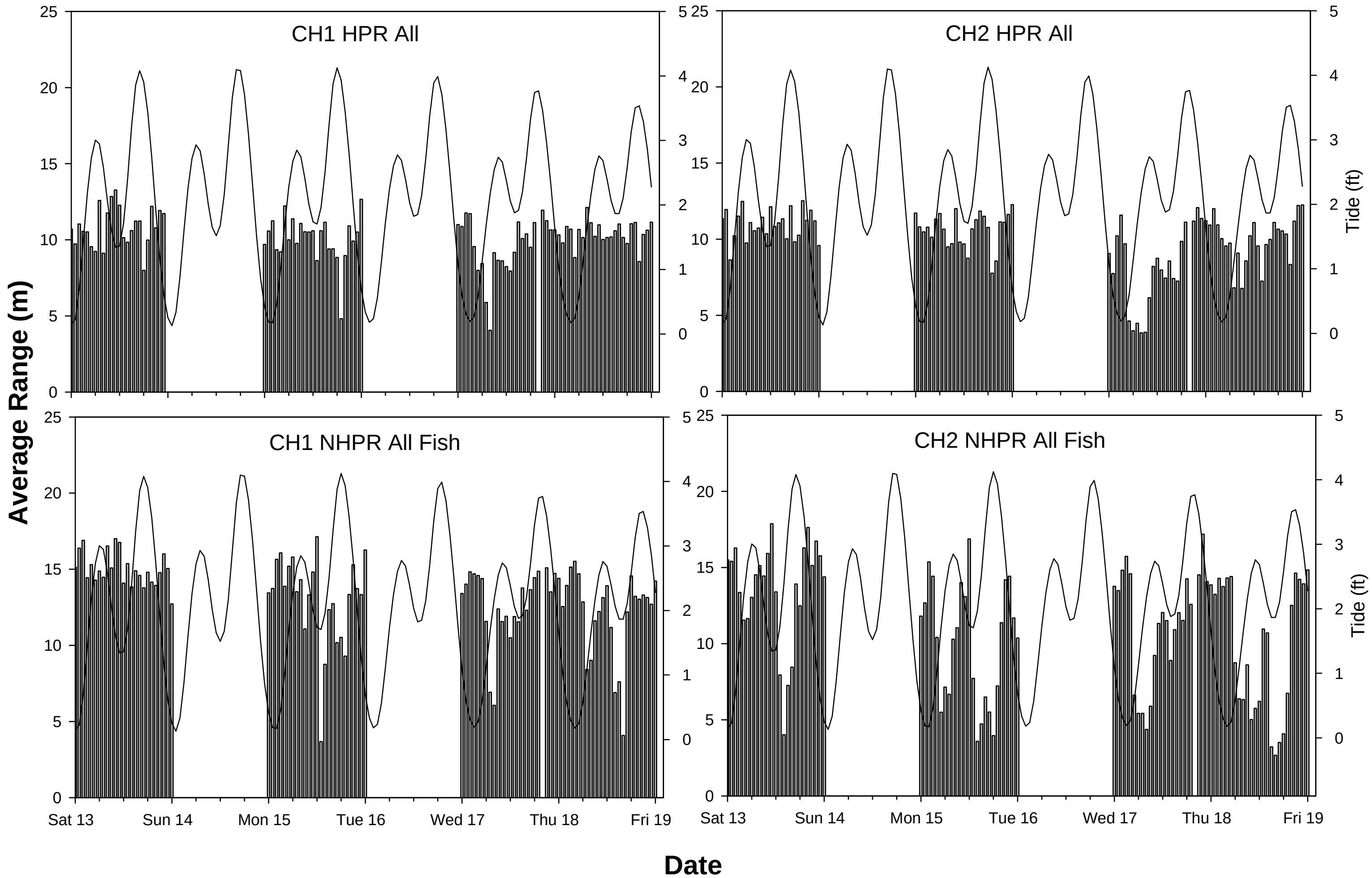


Figure 65- October 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

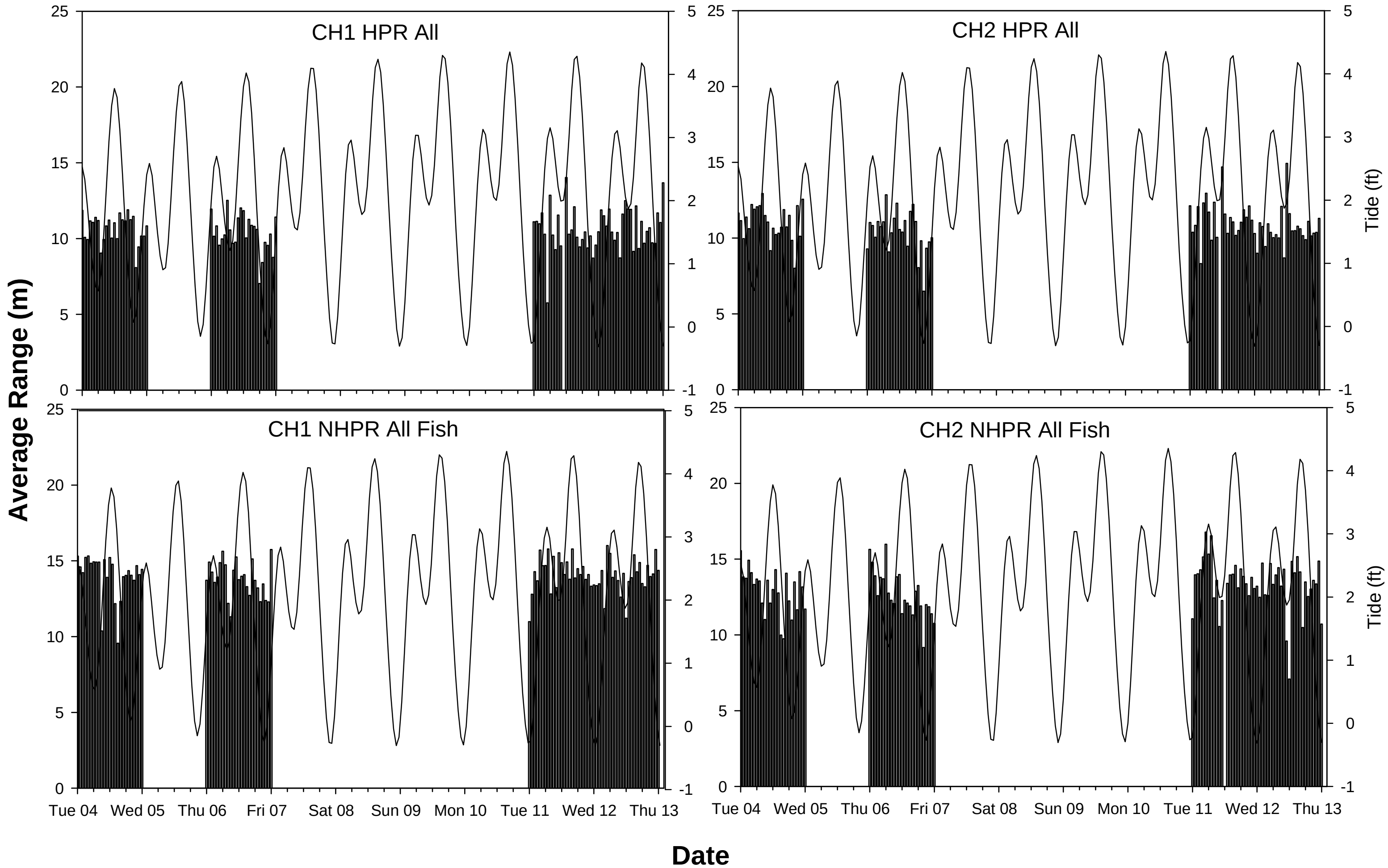


Figure 66- December 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

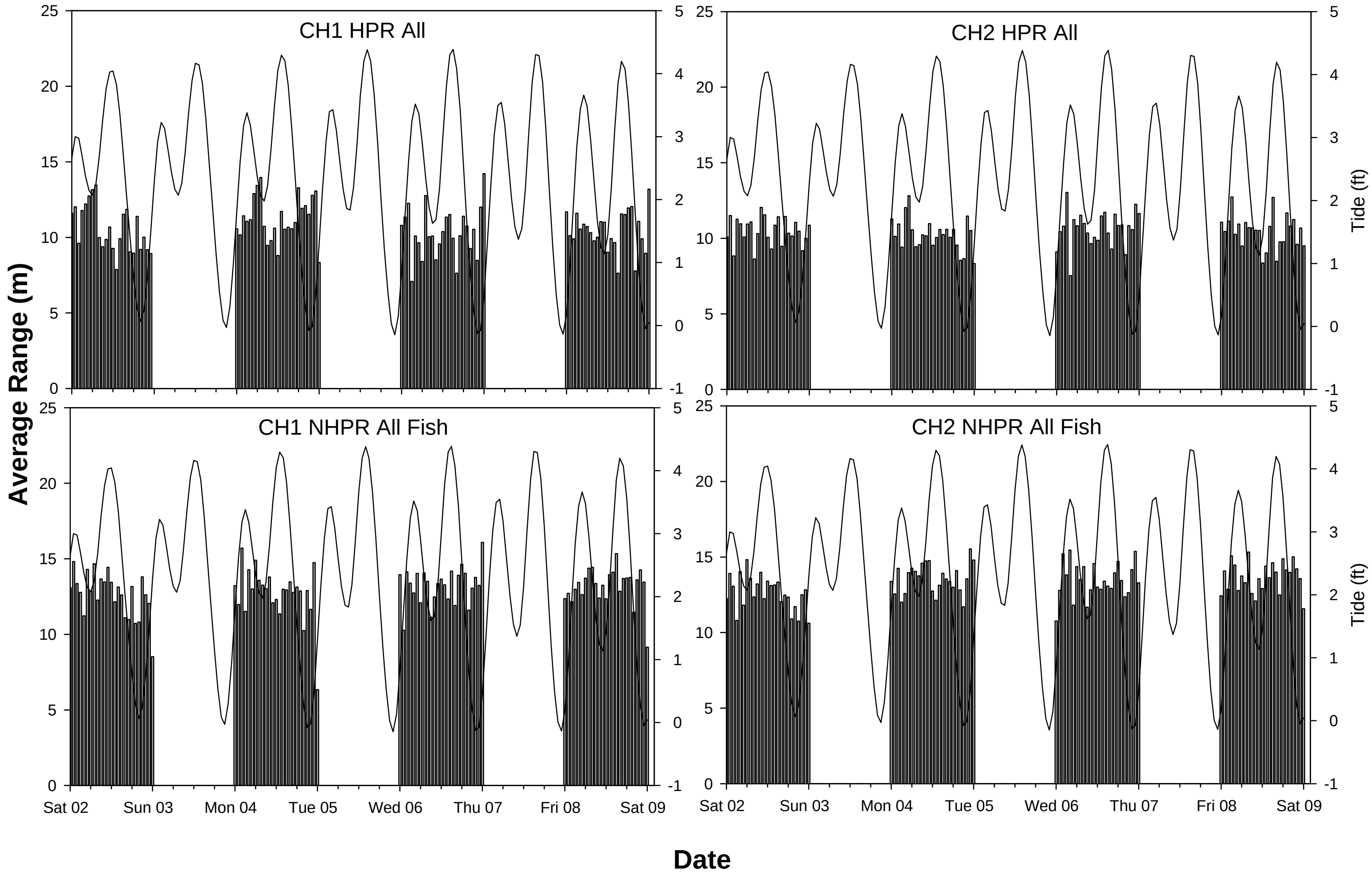


Figure 67- February 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

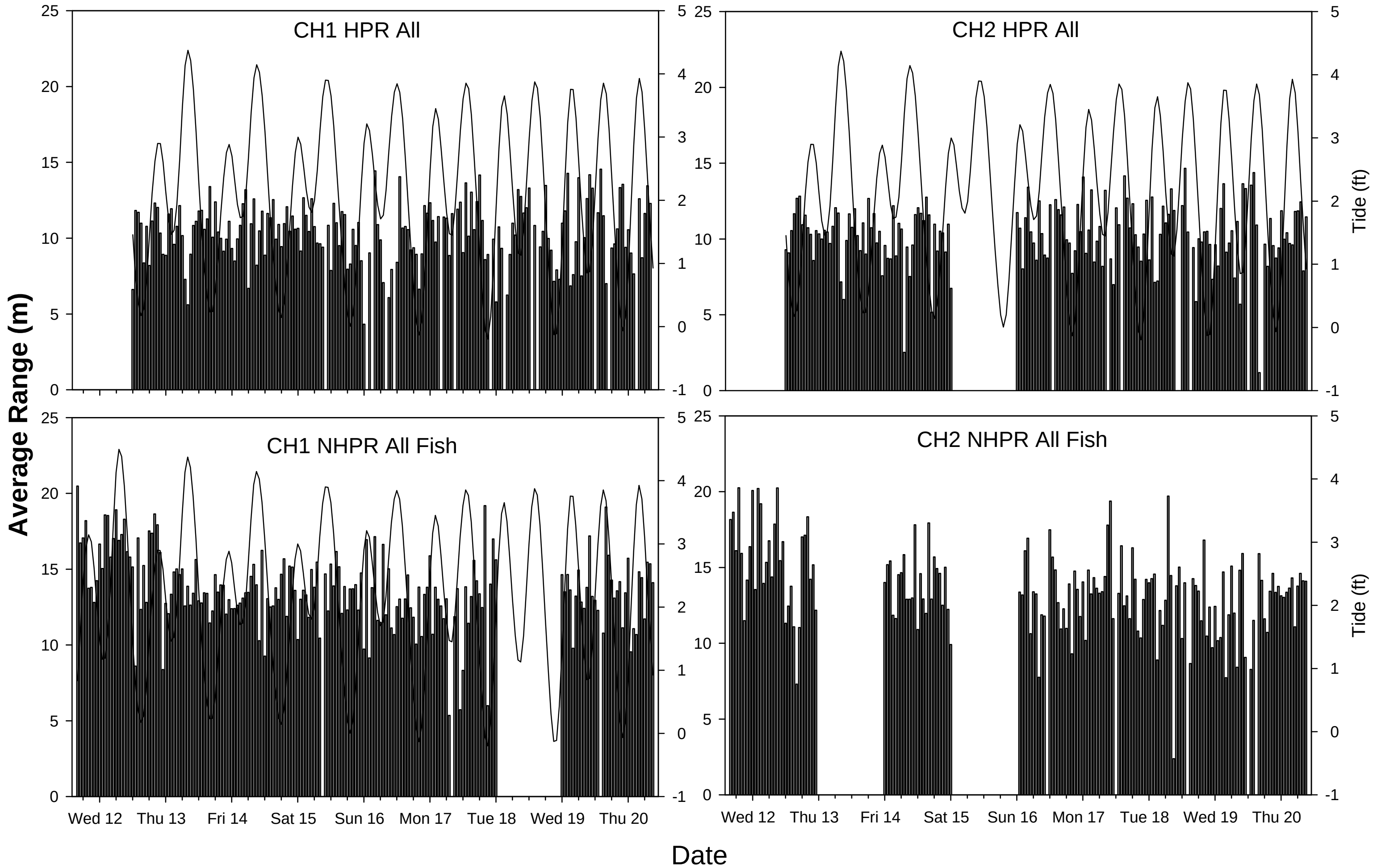


Figure 68- March 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

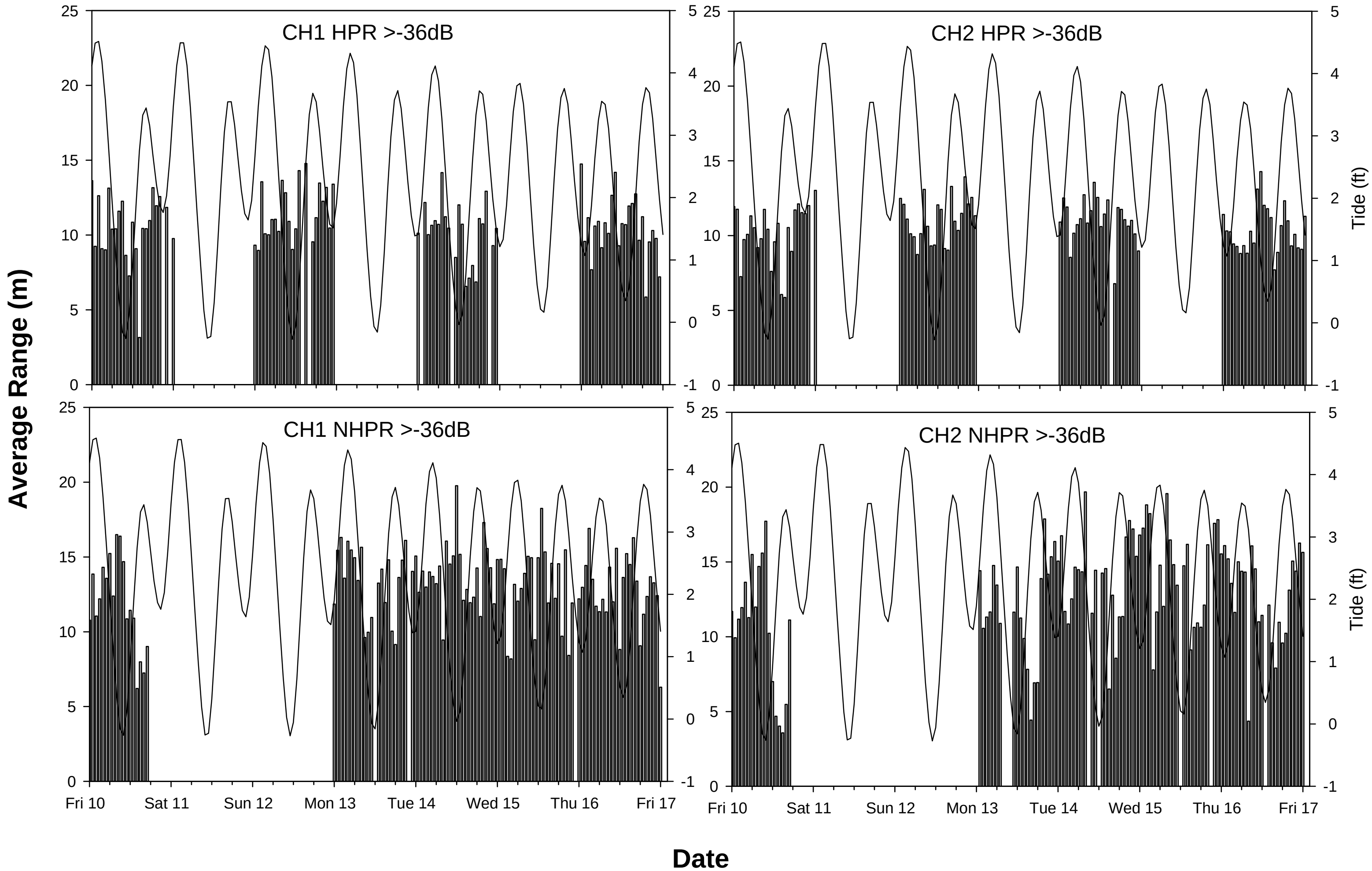


Figure 69- August 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

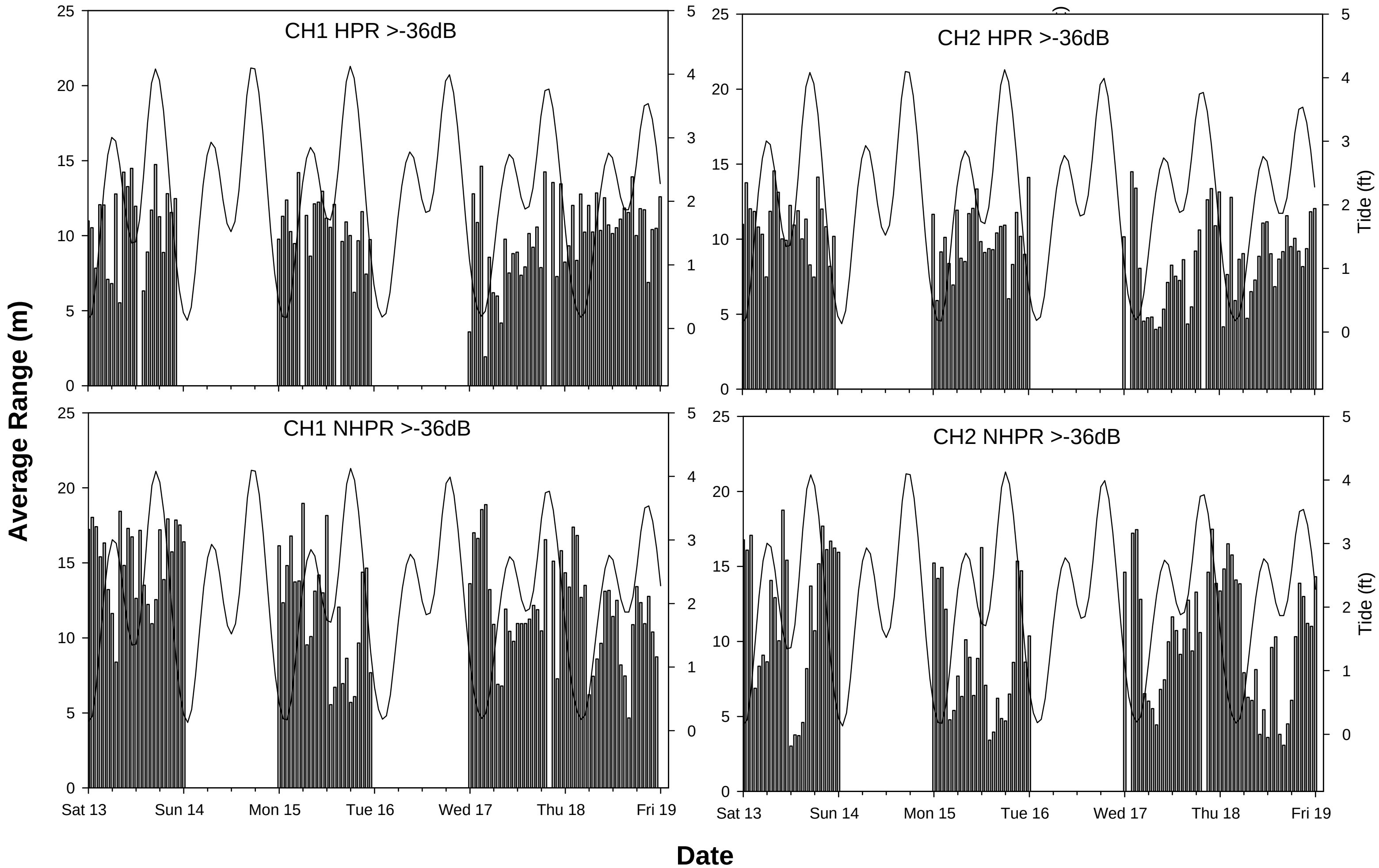


Figure 70- October 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

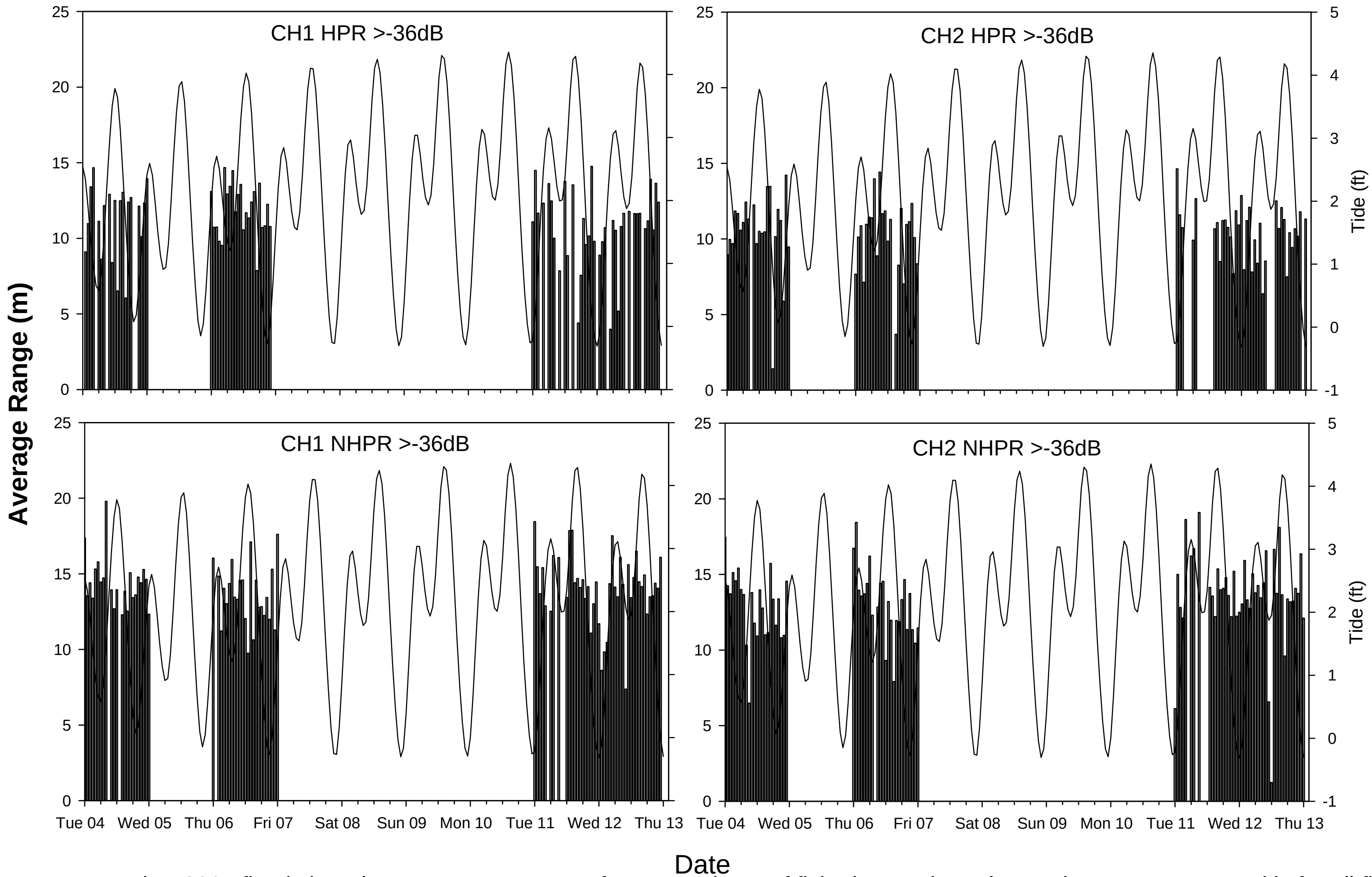


Figure 71- December 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

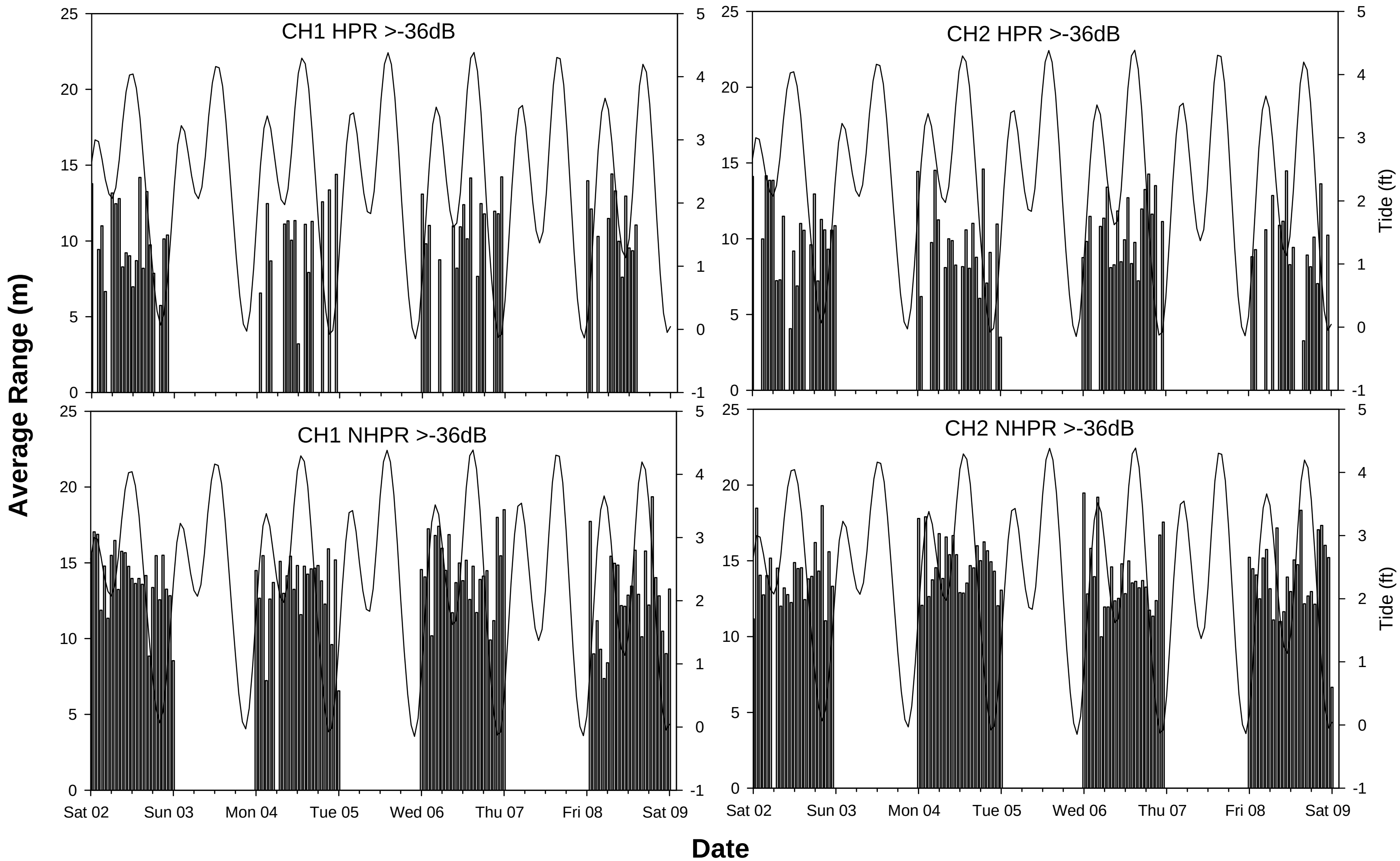


Figure 72- February 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

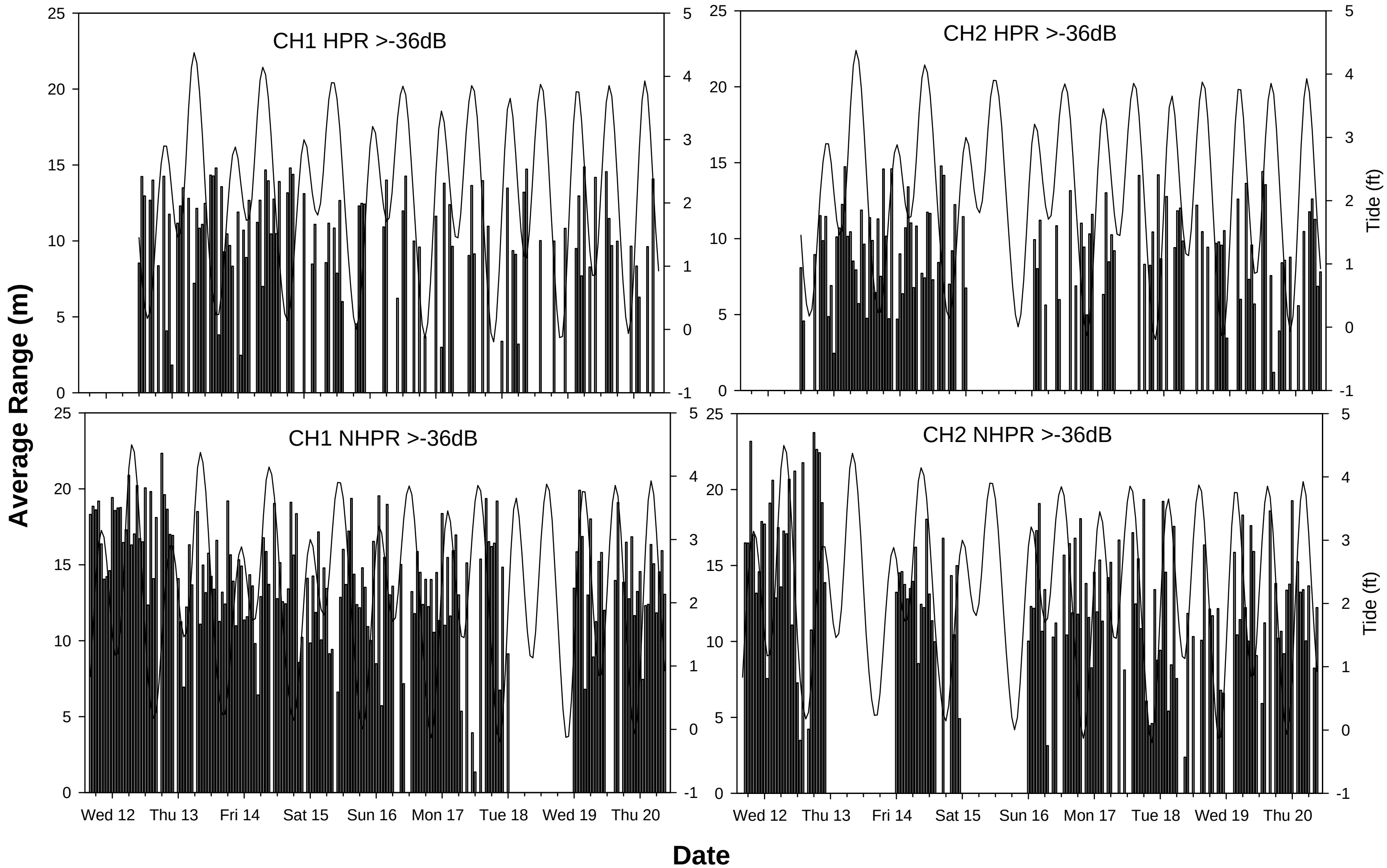


Figure 73- March 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

5.2.3 Bioenergetics

Predation as estimated by an energetics approach is at best only an indirect preliminary estimate of the true predation mortality experienced by fish following their release. However, an energetics approach does provide a good starting point to determine what the magnitude of predation might be. In this model only the average fish are used, there is a slight skew towards smaller fish based on the difference between the median and average values of predators in the river reach. The average size predator as determined acoustically was 36–40 cm (14.2–15.7 in); the median value was slightly smaller at 33–36 cm (13–14.2 in) (Figure 63, Table 20). These values were used as an average size predator, based on literature reported size ranges for each species. Many parameters in the model could impact the overall estimate of predation. The conservative approach presented here would put bounds on the lower limits of predation in the reach.

Table 20- Average size of fish when cutoff is at -36dB for both mobile and fixed station.

Fixed station

Month	Average Target Size	Median Target Size	Num Fish	Average Fish Length (cm)	Median Fish Length (cm)
August	-32.12271	-32.792124	3172	39.4	35.9
October	-31.63473	-32.286958	3593	41.2	38
December	-32.80897	-33.4686255	1711	35.9	33.3
February	-32.86817	-33.604939	1003	35.9	32.8
March	-31.8856	-32.81692	375	40.3	35.9

Mobile Surveys

Date	Down Looking Average Target Size	Date	Side Looking Average Target Size
08/15/2007	-25.00745 n=4	08/11/2007	-32.09790418
08/16/2007	-33.67473	08/13/2007	-33.04348976
08/17/2007	-28.81555	08/14/2007	-30.56966388
10/13/2007	-29.56245	10/13/2007	-31.22754548
10/14/2007	-32.63714	10/14/2007	-31.49582121
10/16/2007	-31.6676	10/16/2007	-31.67973421
10/17/2007	-32.56465	10/17/2007	-31.44935489
10/19/2007	-28.91075	10/19/2007	-32.89688435
12/03/2007	-32.32749	12/03/2007	-31.9461426
12/04/2007	-31.90242	12/04/2007	-32.71206354
12/05/2007	-32.14662	12/05/2007	-31.30880272
12/06/2007	-33.74409	12/06/2007	-32.82576671
12/10/2007	-32.58633	12/10/2007	-32.08910888
12/11/2007	-32.02542	12/11/2007	-32.45410551
12/12/2007	-32.12074	12/12/2007	-33.07093023
02/02/2008	-31.27591	02/02/2008	-32.51561264
02/03/2008	-32.19827	02/03/2008	-32.10073808
02/04/2008	-31.49128	02/04/2008	-32.67942268
02/05/2008	-30.41288	02/05/2008	-32.08486758
02/06/2008	-29.6741	02/06/2008	-31.80554794
02/07/2008	-31.05055	02/07/2008	-32.78003863
02/08/2008	-30.5913	02/08/2008	-32.63821656
02/09/2008	-31.46211	02/09/2008	-32.38522632
03/11/2008	-33.03666	03/11/2008	-29.20937507
03/12/2008	-32.47424	03/12/2008	-32.48826699
03/17/2008	-32.94173	03/17/2008	-32.15747523
03/18/2008	-31.67701	03/18/2008	-30.18602817
03/19/2008	-32.24283	03/19/2008	-30.87523469
		Grand Average	-32.03043919

Of the three predatory species present predation by striped bass has the potential to have the greatest impact on fish at the release site based on average consumption requirements for each species (Figures 74 & 75). For all three species modeled there is a temperature dependent shift in consumption rates, with highest rates occurring in mid-summer. Striped bass show the longest period of time of high consumption, while largemouth bass have the shortest, due to differences in temperature tolerances and preferences between the species.

To convert consumption rates to a per fish and whole population estimate, average weight of each species based, on acoustic size, was calculated using the following length weight relationships: For striped bass $W = 0.0066*(L^{3.12})$ (Kimmerer and others 2005), for pikeminnow log W = 3.12 log L-5.32 (Tucker and others 1998), and for largemouth bass W = 3.2*L-5.35 (Wege and Anderson 1978), where weight is in grams and length is in mm. Assuming an average predator length of 38 cm (15 in), a striped bass should weigh approximately 560 g (1.2 lb), a pikeminnow, 593 g (1.3 lb), and a largemouth 1,210 g (2.6 lb). These numbers are only approximate, as the different body morphometries between the species will impact the acoustic size. Both pikeminnow and striped bass have similar body forms at this size, however largemouth tend to have a much deeper body, and may be biasing the acoustic estimate. Based on average size, at peak consumption striped bass consume the greatest amount of prey on a daily basis followed by largemouth bass, then pikeminnow. Largemouth have the lowest per gram prey requirement, but because of their size total consumption is higher (Figure 75). Figures 76–78 provide an estimate of total population consumption based on population densities as determined using mobile surveys for the SWP Horseshoe Bend release site and two control sites.

Growth rates of individuals near the release pipe outlet may be different from those anywhere else. The data presented is based on average growth rates, indicating fish feed at some percent below their maximum consumption rates. Since fish are opportunistic feeders and the model suggests that on average these species are feeding well below their maximum consumption rates, adjusting this rate in the model can allow exploration of the potential impact of these species if they feed at or near their maximal rate. In the bioenergetics model, the proportion of maximum consumption is adjusted through the use of the p-value, which can be viewed as the amount of food available in a given area of habitat. Average fish growth in this model resulted in p-values for striped bass, largemouth bass and pikeminnow of 0.36, 0.34, and 0.41 respectively. In the case of the release site where large pulses of food items may be entering the water column, a more realistic approach would be to examine a broad range of consumption rates, in this case varying the p-value to look at the potential for consumption given a locally increased availability of food (Figure 79). What constitutes a maximal consumption rate in this field situation is unknown. Also, no assumptions about activity patterns in these fish are made and not doing so will tend to bias the model downward in terms of potential predation effects.

Based on the average p-value calculated by the model the average striped bass probably consumes around 12g/day (0.026 lb/day), or about 2% of its body weight to achieve the average growth observed in the delta. Fish are opportunistic predators however, and given a food source they will consume far greater than this amount. Depending on the time of year, a striped bass nearing maximum consumption rates, may be consuming two or more times this amount of food (Figure 79). Near the release pipe, fish are likely feeding opportunistically and will consume as much food as they can when it is available. Assuming a striped bass is feeding in this mode, the average fish would be expected to consume on the order of 18+ g (0.04 lb) of food per day in August and October. For every 100 striped bass at the release site on average they could consume about 1.8 kg (4 lb) of biomass per day. If for example 20,000 shad (or similar sized fish) were released at the SWP Horseshoe Bend release site, this would equal about 260 kg (573 lb) of biomass, assuming an average weight of 13 g (0.028 lb) for each shad. To consume 10% of the release biomass a population of about 1,450 striped bass would be needed. During October, however, when release numbers are much lower, averaging about 1,000 shad per release or about 13 kg (28.6 lb) of biomass, a very significant impact by predation on salvaged fishes at the release site would be expected.

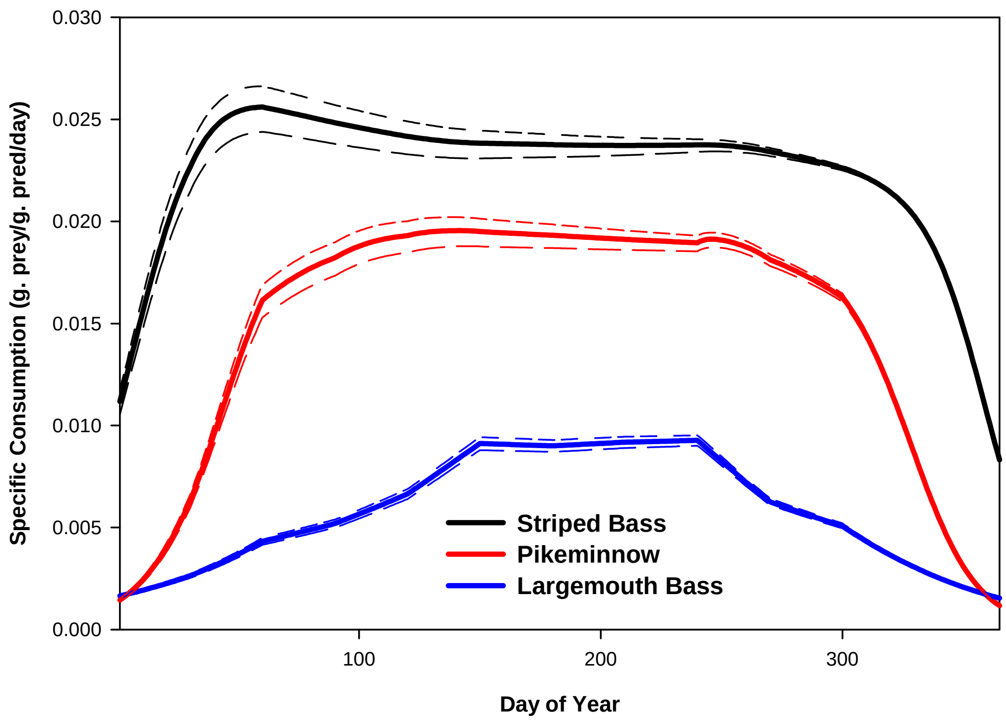


Figure 74- Daily consumption of prey as grams of prey consumed per gram of predator wet body weight. Short and long dashed lines represent the effect on consumption of a ± 30% error in annual growth rate.

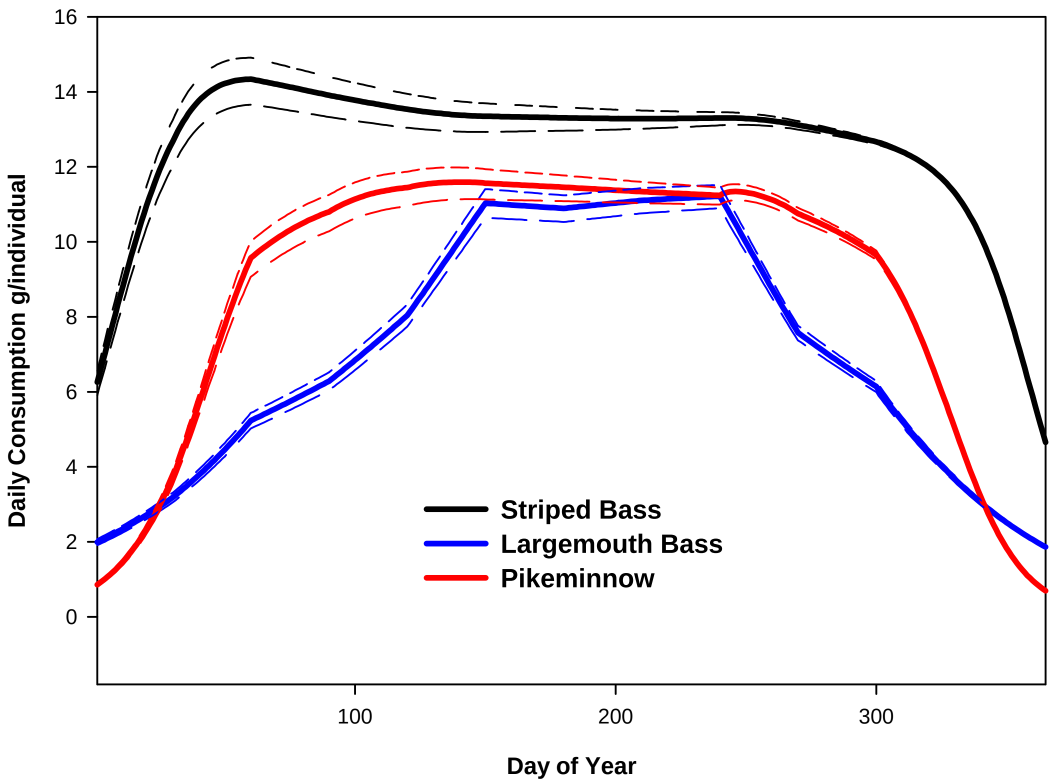


Figure 75- Daily consumption of prey as grams of prey consumed per predator species, assuming an average sized predator as determined using hydroacoustics. Short and long dashed lines represent the effect on consumption of a plus or minus 30% error in annual growth rate of predatory species.

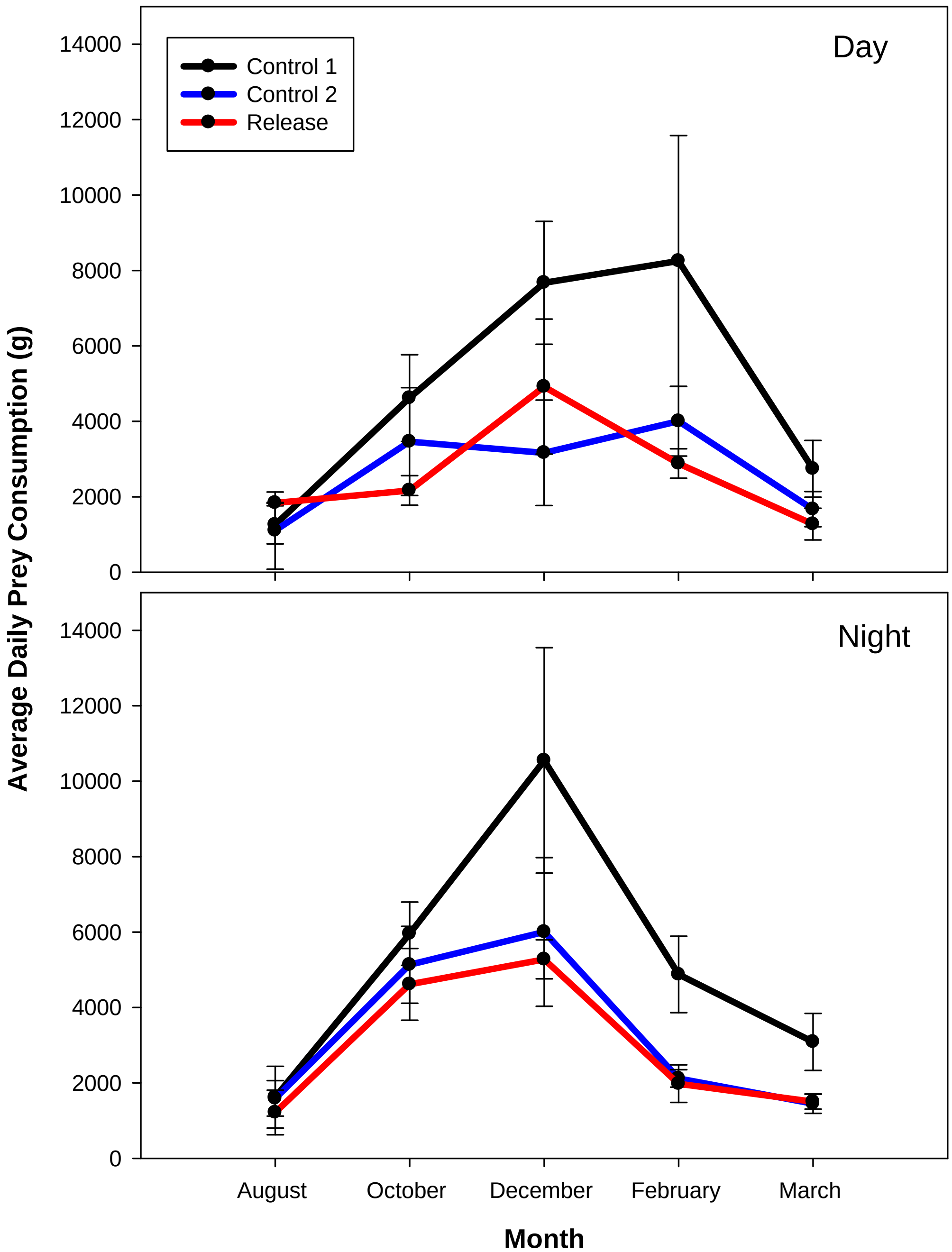


Figure 76- Estimated total daily prey consumption (g) by site, assuming striped bass comprise the population of fish greater than -36 dB (25–26 cm [9.8–10.2 in]).

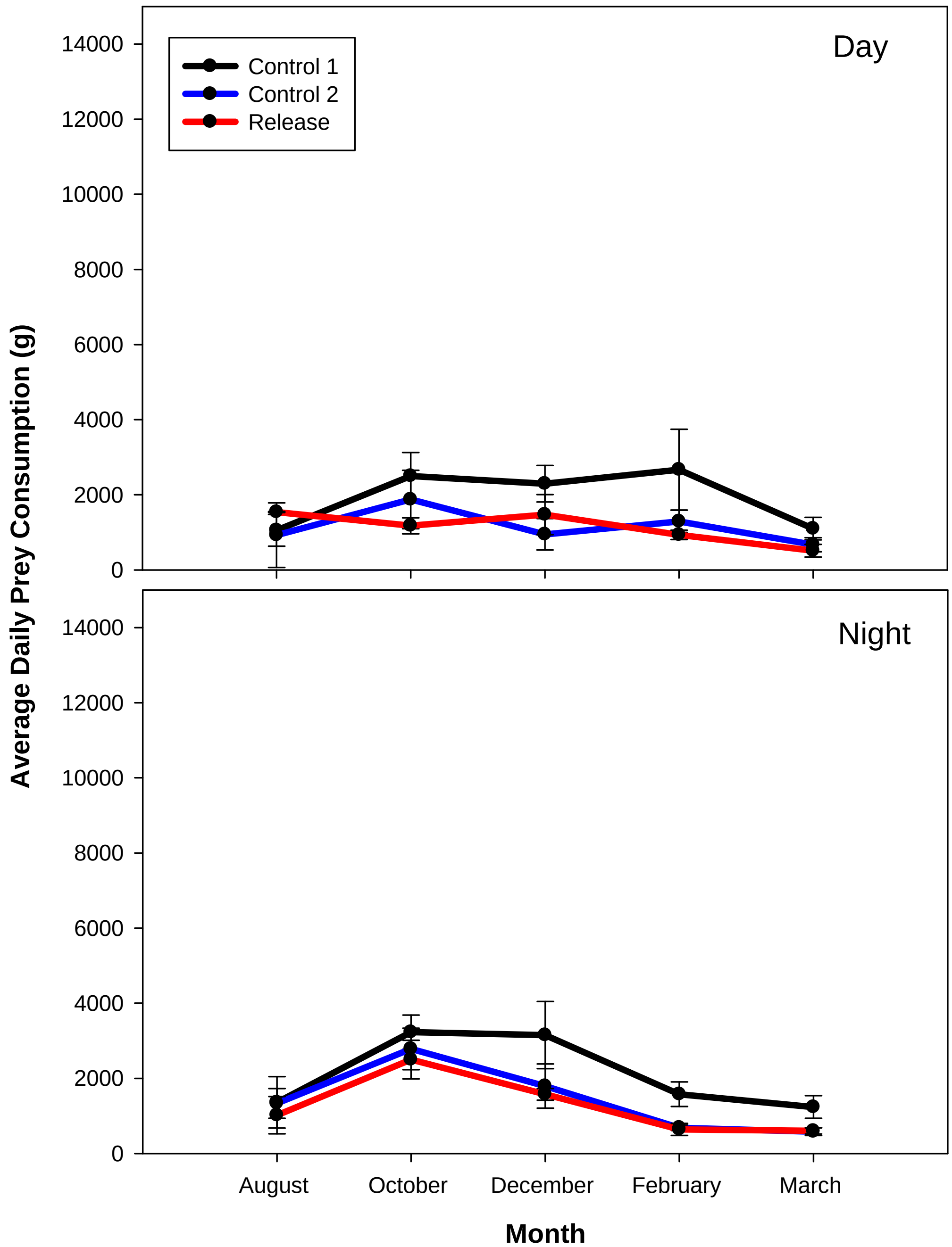


Figure 77- Estimated total daily prey consumption (g) by site, assuming largemouth bass comprise the population of fish greater than -36 dB (25–26 cm [9.8–10.2 in]).

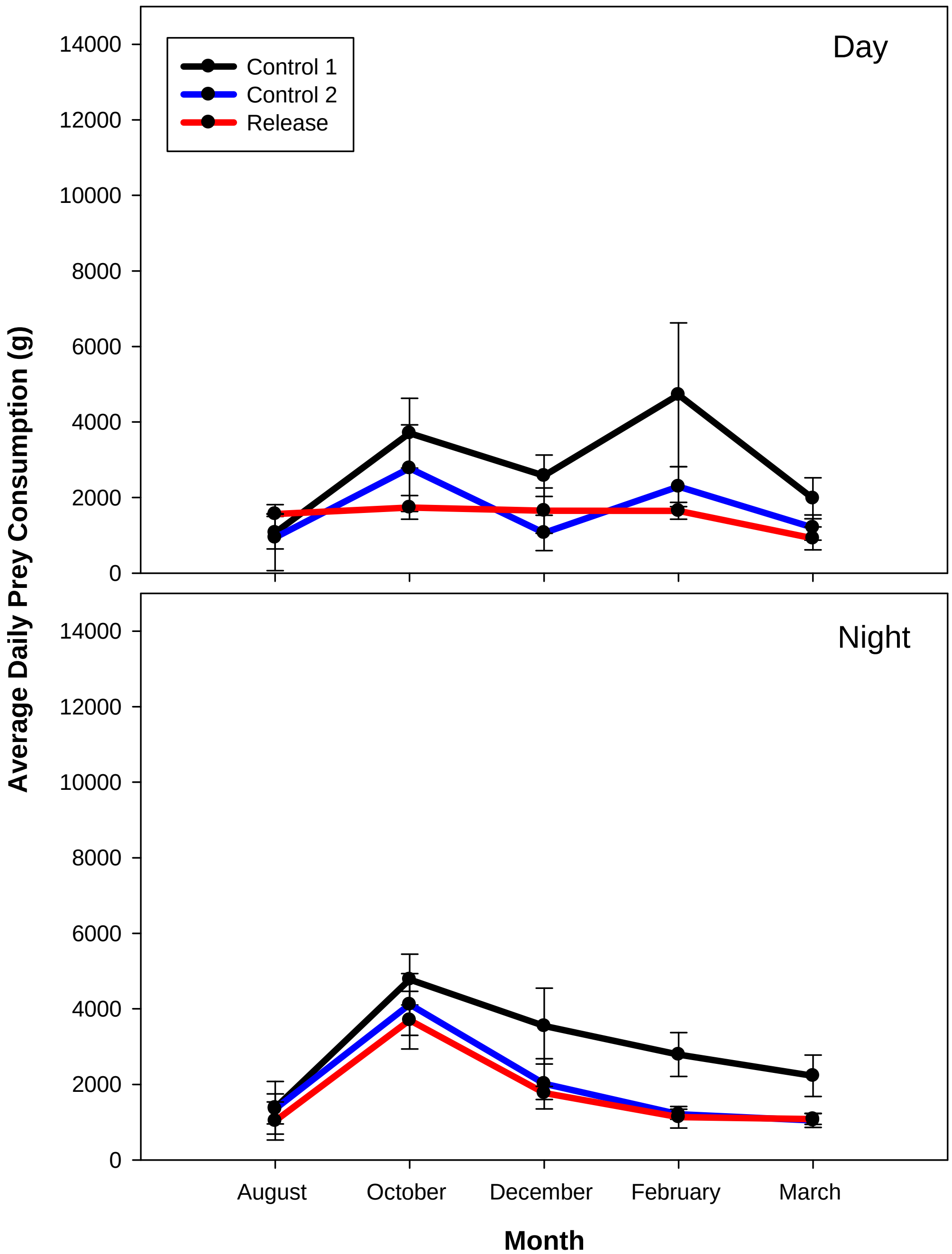


Figure 78- Estimated total daily prey consumption (g) by site, assuming pikeminnow comprise the population of fish greater than -36 dB (25–26 cm [9.8–10.2 in]).

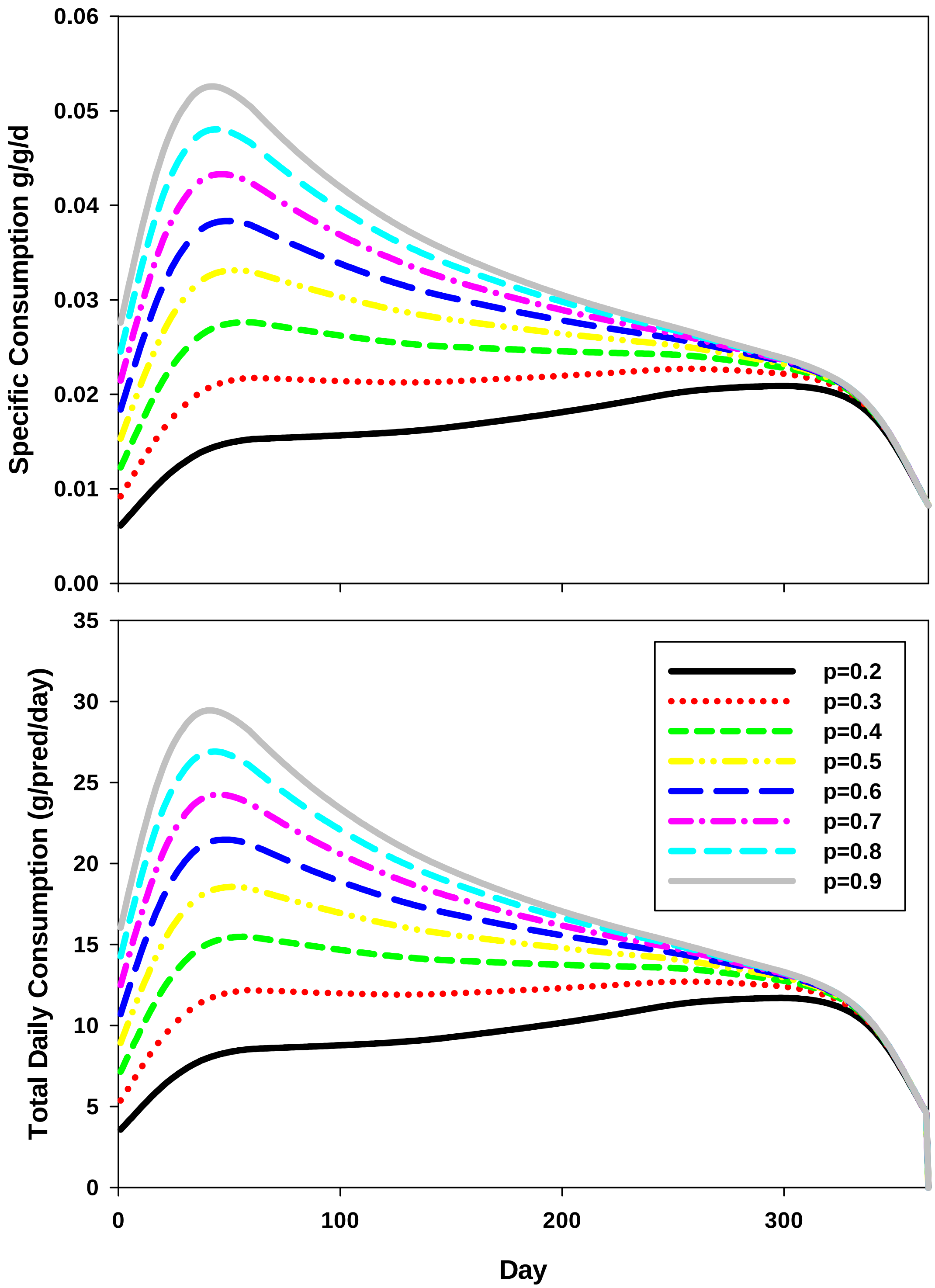


Figure 79- Changes in consumption estimates for an average 560 g (1.2 lb) striped bass in response to varying maximum consumption where the p-value is the amount of food available in a given area of habitat.

5.3 Conclusions

As was shown, predatory fish densities were in fact highest at Control Site 1, while the SWP Horseshoe Bend release site was not dissimilar from the Control Site 2. Thus, at least on the larger scale, changes in density of predators associated with the release of fish do not seem to occur. This suggests any change in predator densities is very localized and occurs at a scale smaller than that used for mobile surveys which is also supported by DIDSON observations.

At the release site there was a continual decrease in predators after the fall as the study progressed. In contrast, December saw the highest populations of fish during the mobile surveys indicating that there is seasonal variation in the density of predatory fish within the local area of the receiving waters. If the same species are being observed in each case, then it appears the predator attraction to the release site decreases faster than does the overall population of fish within the area.

It was difficult to distinguish temporal variation in the density of predatory fish in the local area of the receiving waters from release effects at times. There are times of the year when there are still strong temporal patterns, such as during February, however, since during any given season there is little temporal variability in release times, changes in the time of release cannot be determined to have any impact on predation in the area.

The data showed that fish do move in response to changes in river currents due to the tide. On average fish do tend to follow the flow, although larger fish are less likely to do this than smaller fish. Tidal variation did influence estimates of fish activity at the release site. However, depending on the direction of the current, fish may be oriented more directly in front of our transducer array, and thus numbers would appear higher, than during a tidal phase which may cause fish to orient differently in relation to the release pipe.

Activity of fish at the release site does increase greatly at times following releases, indicative of active feeding. During periods of very high numbers of observed fish, the fish were also at very close range to the transducer as indicated by a decrease in range. This shows fish are congregating near the release pipe at these times. At times of the year when predators do not appear to be congregating near the release site, no such range effect is observed. While the data collected was not sufficient for any analysis of learned behavior, the hydroacoustics data and DIDSON observations indicate that when releases are consistently large, a group of predatory fish is consistently observed near the release pipe. During the summer the number of predatory fish at the release site is significantly greater than the estimated population of predators in the remainder of the Horseshoe Bend area.

The principal hypothesis most important to this study was to test whether predation mortality within the local vicinity of the receiving waters is a significant contributor to overall mortality. A very simple bioenergetics approach was used to attempt to answer this question and suggests that the magnitude of predation on salvaged fish depends on how many salvaged fish are being released. Assuming an average weight of 13 g (0.028 lb) for each salvaged fish, if fish salvage numbers are less than 2,000 fish per release, which for this study occurred for all sampling periods other than August, then significant impacts of predation following release are likely. A group of predators at the release pipe could easily consume a significant portion of the biomass that is released, and certainly populations of fish are high enough in the open water areas around the SWP Horseshoe Bend release site to potentially equal this impact on a slightly longer time scale. Conversely, at certain times of the year (August) very high release numbers may actually swamp the population of predators in the area, and consequently in the short term result in a higher percentage of survivorship.

6.0 Synthesis

This study demonstrates that at the SWP Horseshoe Bend release site, predation on salvaged fishes may have a substantial impact on the number of fish that survive the complete salvage (CHTR) process. While major portions of this study specifically focused on predation at the SWP Horseshoe Bend release site, the study observations and results should still be applicable at the other state and federal release sites even though data collection efforts at these sites were not as intensive.

6.1 Predator Composition

Results of the electrofishing conducted at the SWP Horseshoe Bend release site revealed that various centrarchids and Sacramento pikeminnow were the predominant predators present within the vicinity of the release site. This was somewhat unexpected because anecdotal information and earlier studies (Pickard and others 1982) showed that striped bass were presumed to be the most likely predators at the salvaged fish release sites, but may be due to the fact that electrofishing was not conducted during the late-spring and early summer months when striped bass are common in the area. However, these results are consistent with other more recent studies that have shown centrarchids to be increasingly abundant in the delta and a major predator of juvenile and small adult fishes of the Delta (Brown and Michniuk 2007, Nobriga and Feyrer 2007). The increase in the abundance of centrarchids in the Delta has been attributed to the rapid and widespread colonization of invasive Brazilian waterweed *Egeria densa* and other invasive submerged plants (Brown 2003). This correlation was very clear during our sampling efforts when very few centrarchids were collected near the end of the SWP Horseshoe Bend release pipe, situated in open-water habitat, while centrarchids were collected in great numbers along the release site shoreline which was macrophyte dominated. One implication of this is that while largemouth bass may not be the predominant species aggregating at the release pipe, their sizable population in the region as indicated by our CPUE data suggests that they may still be an important predator on salvaged fish. That is to say, while salvaged fish might survive the initial exit from the release pipe, they may still be at risk of predation by largemouth bass as they disperse from the area. However, results of the bioenergetics modeling showed that striped bass could have a larger predation impact per fish due to their higher metabolic demands and feeding capacity. As a result, to develop a more conservative estimate of predation, one with the highest potential for predation losses, at the salvaged fish release sites, the consumption estimates for striped bass are favored.

Avian predation on salvaged fishes was observed at the SWP Horseshoe Bend release site. The avian predation observations showed that cormorants and gulls were the primary avian predators on salvaged fishes, and that they actively fed or scavenged during salvaged fish releases. When the salvaged fish are released, the water in the pipe is very turbulent. As fish pass through this area of turbulence and exit the pipe, they could be disoriented and become more susceptible to predation even though they may not be directly injured or killed by the release. Gulls were often observed picking at debris and dead or dying fish at the water surface, potentially including salvaged fish that may have become disoriented by the release. Furthermore, cormorants are efficient, deep water predators and were observed with the DIDSON chasing and capturing salvaged fish in the vicinity of the pipe outlet.

6.2 Predator Abundance

Predatory fish abundance based on hydroacoustic data was highest at Control Site 1 where a deep hole was located. Abundance at the SWP Horseshoe Bend release site was similar to Control Site 2. This finding suggests that on a coarse scale, releases at the Horseshoe Bend site do not appear to be influencing the abundance of predators. This is in contrast with the more fine scale DIDSON observations, however, which showed that abundance was typically highest at the SWP Horseshoe Bend release site when compared to the two control sites. Hydroacoustic data also showed peaks in abundance for all sites during the winter (third) monitoring period, with abundance lowest during the summer. Again in contrast, DIDSON observations showed that predatory fish abundance was highest during the summer and tapered off through the winter and early spring monitoring periods. These contrasting results suggest that at certain times of year the release site is not as attractive for predatory fishes even though there are substantial numbers of predatory fish in the area. This may be a result of several factors including a decreased metabolic demand for feeding due to low water temperatures, a more abundant source of food than the release sites (ie. a large population of bait fish in the area), or a small enough number of fish being released as to not make aggregating at the site energetically attractive.

Electrofishing catch data showed that the SWP Horseshoe Bend release site had a substantial population of largemouth bass. While the authors of this paper doubt that they represent a major source of the immediate predation on salvaged fish exiting the release pipe, their impact on the long term survival of salvaged fish cannot be discounted. Largemouth bass have been shown to be effective piscivores even at very small sizes (<110mm [4.3 in]; Nobriga and Feyrer 2007). Given their piscivorous nature and substantial population near the release site it is possible that while they may not feed directly on fish exiting the release pipe, the largemouth bass may feed on salvaged fish as the salvaged fish disperse following release.

Avian predators were consistently more abundant at the SWP Horseshoe Bend and CVP Emmaton release sites than either of the control sites or the SWP Curtis Landing release site. Interestingly, avian predator abundance increased during the winter and early spring periods even as the number of salvaged fish being release declined to very low levels.

Avian predation observations further supported the argument that even though predatory fish populations are lowest during the winter and early spring periods as indicated by DIDSON observations, the abundance of avian predators and relatively low salvage during this period results in the highest impact of predation on salvaged fish survival. Given the enormous food requirements of many avian predators (up to 1/3 body weight/day for cormorants), even a relatively small number of birds might have a substantial impact on the number of salvaged fish being lost to predation. Therefore, efforts should be taken to try and reduce predation by birds in addition to predatory fishes since even a minor reduction in avian predation may have a substantial effect on the number of salvaged fish being consumed.

6.3 Predator Behavior

Using acoustic telemetry, striped bass were shown to exhibit very little site fidelity. Tagged striped bass spent a very short amount of time near their location of tagging and migrated from the area rapidly. Sacramento pikeminnow, however, showed stronger site fidelity with some individuals remaining near a release site for months at a time. This is expected since Sacramento pikeminnow are known for their exploitation of artificial aggregations of prey fish such as those created by the release sites. While largemouth bass were not tagged with acoustic tags, they had the highest number of floy tagged fish recaptured, suggesting that they too exhibited strong site fidelity. This is consistent with other studies on largemouth bass which have shown that they have relatively limited ranges and do not have a life history (like that of striped bass) including long migrations to spawning, rearing, or feeding grounds.

Unfortunately, the acoustic telemetry equipment used in this study limited the ability to track the fine scale movement of predatory fish near the release sites, and limited the resolution to coarse scale presence or absence. Future studies should consider utilizing equipment with finer resolution to examine predator movement and behavior around the release sites which could potentially reveal predator utilization of particular habitat, structure, or areas which could be targets of management action for predator control. For example, DIDSON observations were able to reveal predators utilizing trapped debris around the Horseshoe Bend pipe support structure being used as refuge and cover.

DIDSON observations showed that predatory fish, when present, remain aggregated near the end of the release pipe for long periods of time. This was further supported by hyroacoustics data which showed many targets near the release site even during non-release periods. The DIDSON revealed that these prolonged aggregations were potentially a result of salvaged fish slowly exiting the release pipe long after the release was completed. Since predators remain aggregated in large numbers at the release site during non-release periods, efforts to detect any actions during the release process that might potentially serve as behavioral attractants (ie. a feeding bell) were unsuccessful. However, predators were occasionally observed becoming agitated or more active in response to various events during the release process such as the connection of the truck outlet to the release pipe or flushing pump activation.

Visual and DIDSON observations of avian predation confirmed that avian predators were effectively exploiting salvaged fish releases. On numerous occasions, gulls and cormorants were observed both visually and with the DIDSON, successfully capturing prey fish. DIDSON observations of cormorants showed that they actively chased and fed on salvaged fish, searching for prey near the end of the release pipe with ease. While the feeding cormorants were observed to occasionally scare predatory fish away, they were never observed actively pursuing the predatory fish, instead concentrating on capturing salvaged fish. Avian predators were also observed using a nearby agricultural intake as a resting site or perch between releases. As a result, a bird deterrent device at this site was installed as a potential way to reduce avian predation.

6.4 Magnitude of Predation of Salvaged Fish

The magnitude of potential predation occurring at the SWP Horseshoe Bend release site was strongly tied to the numbers of salvaged fish being released. DIDSON observations showed a strong positive correlation between the numbers of fish being salvaged and the predator abundance within the immediate vicinity of the release pipe. Furthermore, the results of bioenergetics modeling demonstrated that when the number of salvaged fish being released is <2,000 (assuming 13 g [0.028 lb] per fish), then the predatory fish population is capable of consuming a considerable portion of the biomass being released. Conversely, when the number of fish being released is very high, the predatory fish are effectively swamped relative to the number of released fish and their impact on salvaged fish mortality is consequently diminished. The presence of avian predators during the winter months further amplifies the magnitude of potential predation during the winter and early spring. One solution to this problem might be to release salvaged fish into net pens and accumulate a large number of fish prior to releasing them (assuming that salvaged predatory fish could be segregated from other salvaged fish). This might also be an effective way to reduce stress effects from the CHTR process as a whole (Portz 2007). By accumulating a large enough number of fish, the predator population might be swamped with the added benefit of less stressed and healthier fish.

The results of the bioenergetics modeling and hydroacoustics revealed an inherent weakness of DIDSON observations. Examination of DIDSON observations alone would most likely lead to an interpretation of significant predation during the summer when salvage is highest, and lower predation during other periods. This interpretation is a direct result of the DIDSON camera's very limited field of view and the resulting difficulty in accurately quantifying fish in a given area. The DIDSON failed to reveal, as the hydroacoustics did, that predator abundance in the region was actually highest at times of year when few if any predators were aggregated at the release pipe.

7.0 Recommendations

Based on the results of the various components of this study, the following actions and guidelines are recommended for improving current release operations and building new release sites:

1. Given the prevalence of centrarchids, especially largemouth bass, in the delta, all possible efforts should be taken to place release sites at locations that lack extensive centrarchid habitat (i.e., aquatic vegetations beds, submerged structure).

2. Releases during dawn and dusk, when predator activity was shown to be at its highest, should be avoided.

3. All possible roosting sites or perches near release sites should be either removed or equipped with bird deterrent devices (e.g., bird spikes). This measure, which has already been completed at the SWP Horseshoe Bend release site, would prevent avian predator species such as cormorants and gulls from perching on top of manmade structures near the release sites.

4. Release sites should be equipped with a screened flushing system pump to avoid entraining recently released fish.

5. Periodic removal of underwater debris in the immediate vicinity of the release pipes should be conducted. This measure, which is being planned for the SWP Horseshoe Bend release site, would prevent the creation of predatory fish habitat. Release site designs should also minimize the amount of underwater structure such as support pilings to reduce debris accumulation.

6. Release pipes should be flushed more effectively to prevent predators from aggregating at the pipe to feed on fish slowly trickling from the release pipe. Modifications to the SWP release sites are currently underway to address this issue using hydraulic guidelines developed from the Element 3 investigation.

8.0 Future Research Questions

This study uncovered a number of topics that could benefit from further research. Research on these topics could lead to further recommendations or guidelines to reduce predation on salvaged fish.

1. What is the feasibility of using net pens or an alternate holding and release process to release salvaged fish?
    - The use of net pens or an alternate holding strategy might reduce the effects of predation by allowing releases of larger numbers of fish, effectively overwhelming the receiving water predator pool. This additional acclimation time would also have the benefit of reducing salvaged fish stress.

2. What is the efficacy of various behavioral deterrent measures such as strobe lights, sound barriers, bubble curtains and electrical barriers in preventing aggregations of predators at the salvaged fish release sites? How do various species of predators respond to these different measures?
    - Behavioral deterrent devices could help to reduce near-field predation on salvaged fish and give salvaged fish a chance to disperse from the immediate vicinity of the release site (reducing their short term susceptibility to predation at release). Any investigations on behavioral deterrents should be targeted at all the major predatory fish species encountered during the study (striped bass, largemouth bass, Sacramento pikeminnow).

3. How long do predators remain aggregated near release sites after regular releases are stopped? How would alternate release site rotations influence the buildup of predators at a release site?
    - By determining how long predators remain aggregated at a release site post release, it might be possible to determine an appropriate "resting" period for release sites. This could also lead to a recommendation for the total number of release sites necessary to use release site rotation as a predation management measure.

4. What is the impact of predation by centrarchids on the mortality of salvaged fish?
    - While centrarchids were captured in substantial numbers at each of the sites monitored, their actual impact on salvaged fish survival was difficult to determine because they were typically captured along the shoreline near the release sites, not at the end of the release pipes. By examining their gut contents versus the gut contents of centrarchids at other areas in the delta, it may be possible to determine if the centrarchids at the release sites display a higher level of piscivory indicative of predation on salvaged fish.

Alternatively, modern acoustic tags and 2d or 3d telemetry tracking systems could be used to determine how centrarchids respond to salvaged fish releases.

5. What would the impact of increased predatory fish harvest at a release site be on the release site predator population? Would improved public fishing access at release sites be an effective method of controlling predatory fish accumulation?
    - Improved public fishing access at the release sites could be a way to minimize predator accumulation by direct harvest and removal of predatory fish.

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WEBSITE REFERENCES

Central Valley Fish Tracking Consortium
http://californiafishtracking.ucdavis.edu/

Department of Water Resources California Data Exchange Center
http://cdec.water.ca.gov/

Tide, moon, and sun predictions US West Coast
http://www.saltwatertides.com/

Weather Underground
http://www.wunderground.com/

11.0 Appendices

11.1 VEMCO Technology

VEMCO VR2 monitoring receivers and VEMCO coded transmitters were used 1) for their relatively low cost and 2) because of the wide array of VR2 receivers deployed throughout the Delta for other studies. The latter made possible tracking Element 2-tagged fish beyond the study's boundaries. Two different sizes of VEMCO transmitters were used for this study: the V9-1L and the V13-1L. The V9-1L transmitter dimensions were 9 mm (0.35 in) in diameter by 21 mm (0.82 in) length. The tags weighed 2.2 g (0.08 oz) in water (3.6 g [0.13 oz] in air) and produced a power output of 142 dB re 1μPa at 1 meter. The larger V13-1L transmitter dimensions were 13 mm (0.5 in) in diameter by 36 mm (1.4 in) length. The tag weighed 6 g (0.2 oz) in water (11 g [0.4 oz] in air) and produced a power output of 147 dB re 1μPa at 1 meter. Each transmitter was powered by an internal silver-oxide battery that was turned on or off by a magnetic switch. The magnetic switch was controlled by a small magnet that adhered to the surface of the tag. The tags became active when the user removed the magnet. Transmitter parameters were set and secured at the factory. Each transmitter (battery and electronics) was sealed with epoxy in a cylindrical casing. Battery life varied with transmitter size and custom parameters, such as delay between signal transmission.

When a transmitter was turned on by removing its external magnet, it emitted 3 rapid pings. Then the transmitter entered a start-up phase, which contained 16 strings of 7 pings each. The transmitter pinged 7 times, waited about 2 seconds, pinged 7 times, waited 2 seconds, and repeated this process 16 times. After this start-up phase, the 2-second delay was replaced by the factory-set delay.

Each transmitter had a unique code and emitted acoustic pulses or pings at a frequency of 69 kHz. Transmitter identification was coded as binary data into the intervals between a burst of pulses (Pincock 2008). Pulse width and interval were controlled by a microprocessor within the transmitter. The number of intervals and pulses required to contain the entire identification varied depending on the transmitter-coding scheme. The first pulse in the series or group had a fixed width and was for synchronizing with the receiver (Ryan Mayfield, personal communication). Additional pulses and intervals followed, completing the transmission.

VEMCO created a variety of different transmitter coding schemes in an effort to produce more, unique identifying codes. Transmitters used in this study were of the coding scheme R04K, which contained 6 intervals and was referred to as code space A69-1206. The code (identification) was contained within the 7 pings. The first ping was of fixed-length and was provided for synchronization purposes. The remaining 6 pings encoded the transmitter identification and error checking capabilities.

The group of intervals and pulses were followed by a period of delay, or silence. The delay period was random and was not less than the minimum off time and not more than the maximum off time, parameters that were set at the time of manufacture. For all but 3 tags used in this study, the delay was 40 to 120 seconds. For tag numbers 1385, 1386, and 1387, the delay was 20 to 60 seconds. The purposes of the delay were to 1) conserve battery life and 2) make possible for complete detection of multiple transmitters near a single receiver. The random delay also ensured that 2 or more tag signals would not continuously collide with each other. Collisions between tag signals might have occurred when two or more tags transmitted its signal simultaneously.

VEMCO VR2 receiver parameters and components were created and sealed in a cylindrical casing at the factory. Receiver noise-filtering and tag detection algorithms were set by VEMCO and cannot be adjusted by the user. VEMCO VR2 receivers were designed with detection algorithms to measure the time interval between transmitted pulses. Valid detections occurred when the receiving algorithm detected pulses with intervals of those used in the coding scheme. The receiver was designed to reject transmission intervals smaller or larger than expected. However, a false detection might have occurred if (1) the pulse intervals were valid lengths (time intervals) or (2) the error detection algorithm failed to detect the transmission error. Pincock (2008b) stated that a single detection of a transmitter could indicate a false detection. As a conservative approach during this study, detections of ≤ 2 per receiver per hour were considered to be false detections.

Receivers were deployed during this study in areas where detection capabilities might have been affected by broadband noise. The VR2's preamplifier could have been affected by noise within the bandwidth of the preamplifier, around 20 kHz to 100 kHz (Pincock 2008a). As a result, VR2 detection performance could have been affected by ambient noise and by biological or man-made sounds. The effects of weather also may have altered the detection range of this study's receivers. Therefore, the detection range could have varied throughout the study period. Specifically, receiver performance could have decreased in conditions of poor weather or significant noise.

The VR2 receiver produced a file output (statistics) with every download. This file output contained the following information:

1. *Checksum invalid*: number of almost-complete detections rejected by the receiver's algorithm
2. *Total syncs*: number of correct sync values received (sync = time between the first 2 pings of a coded tag's transmission

3. *Total detections*: number of complete coded ping trains received and accepted.
4. *Total pulses received*: number of every acoustic ping detected by the receiver

The information above may be used to calculate detection efficiency of the receiver. A low efficiency may indicate a lot of noise in the environment or collisions from multiple tags.

11.2 Validation of Acoustic Doppler Velocimeter

On July 19, 2007 a comparison test of flow velocity using a propeller and an ADV velocity meter was performed. The comparison test was conducted to determine if an upward viewing ADV could be used in a downward orientation and still maintain instrument accuracy. The calibrated propeller meter was used as an accuracy check for the ADV. The ADV was not tested in the calibration flume because the size of the flume did not facilitate testing. It was too shallow to allow for proper operation of the ADV unit.

Methodology

Calibration of Propeller Velocimeter

Prior to the comparison test, the Swoffer 2100 velocimeter was tested for accuracy at the UCD Hydraulics lab small instrument calibration facility. The velocimeter was positioned inside a calibration chamber and a series of flows with water velocities (30.5, 45.7, 61, 76.2, and 91.4 cm/s [1, 1.5, 2.0, 2.5, and 3.0 ft/s]) were introduced into the chamber. For each type of flow, ten propeller velocity readings were recorded. These test velocities were selected because they are representative of velocities in the field. The duration interval for each propeller reading was set for 90 seconds.

Field Test Using ADV and Propeller Velocimeter

Equipment

- Argonaut-ADV SW in downward viewing position
- Swoffer 2100 propeller velocimeter
- 3.35 m (11 ft) aluminum mounting pole for swoffer velocimeter
- Aluminum Jet Boat
- Lowrence depth finder

Test Sites

Velocity readings were taken at three different locations at and near Horseshoe Bend just off of Sherman Island. The three sites are as follows: CHTR element 2 control site number two, the SWP Horseshoe Bend fish release site, and the CVP Emmaton fish release site. The sites were selected as test sites because they will be used as monitoring sites during the CHTR element 2 studies.

Test Set-Up

The ADV unit was deployed over the side of the boat and suspended by two chains. The Unit was set horizontal to channel bottom. The distance from the water surface to the ADV viewable depth was approximately 1 m (3.2 ft) (viewable depth is the initial point away from the face of the unit that velocity readings are taken). Water depth at all locations was attained using the boat mounted Lawrence sonar/gps system. The Swoffer 2100 velocimeter was mounted to a 3–meter (10–foot) length of aluminum pipe for elongation of the unit and structural support. The total length of the pipe w/velocity probe was 3.35 m

(11 ft). The pipe was labeled in 0.3 m (1 ft) increments and the orientation of the propeller marked at the distal end of the pipe. Both the ADV and Swoffer units were set to sample over a 90 second interval (max interval for the Swoffer).

At each site the boat was stationed parallel to the shoreline by attaching to two piles, placing the boat was reasonably parallel to the flow. The tide was outgoing for all sampling.

Data Collection

Water depth at the test sites varied. At each site the depth to the channel bottom was determined using the boat mounted sonar unit. The ADV was then set to scan this water depth minus 1 m, to account for the depth of the ADV unit and the distance at which it begins to scan for data. The propeller probe was deployed at the midway point of the ADV scanning distance for each individual site. At the CVP Emmaton release site the ADV was set to a scanning distance of 4.8 m (15.7 ft) (the maximum range for the unit). This site is much deeper than the other test sites. The Swoffer and ADV units were set to the same sampling orientation. Then 10 velocities were recorded using each of the unit simultaneously.

Data/Results

Calibration Data

Calibration Data for Swoffer Propeller Velocimeter
U.C. Davis Hydraulics Facility **6/13/07**
90 s sample interval

Flume velocity (Vf)	Measured Velocity (Vm)
(Target velocity = 1.0ft/sec)	
0.99	1.1
0.99	1.11
0.99	1.1
0.99	1.1
0.99	1.1
(Target velocity = 1.5ft/sec)	
1.51	1.72
1.51	1.73
1.51	1.72
1.51	1.73
1.51	1.72
(Target velocity = 2ft/sec)	
2.01	2.33
2.01	2.33
2.01	2.33
2.01	2.33
2.01	2.32
2.01	2.32
(Target velocity = 2.5ft/sec)	
2.5	2.98

2.5	2.98
2.5	2.97
2.5	2.98
2.5	2.96
.52	2.96
(Target velocity = 3ft/sec)	
3.01	3.61
3.01	3.61
3.01	3.61
3.01	3.61
3.01	3.6

Results of the comparison test at the UCD Hydraulics Lab showed a difference in velocity readings between the velocimeter and calibration flume. An equation was developed to account for the difference in velocity between the two instruments. This equation would then be used to correct field data collected with the propeller probe. The equation is as follows:

$$y = 0.8021(x) + 0.1222 \qquad \text{Eq. (A.1)}$$

Where y = corrected velocimeter reading
x = measured velocimeter reading

Data collected in the field with the ADV unit was compared to velocity propeller probe readings for accuracy. The velocity readings were first corrected using equation A.1. The corrected velocity readings were then compared to the ADV readings for accuracy. Results showed logarithmic relationship in the velocity readings between the velocimeter and ADV unit. An equation was developed to account for the difference in velocity readings and obtain an adjusted ADV velocity. The formula is as follows:

$$y = 0.9944*\ln(x) + 0.983 \qquad \text{Eq. (A.2)}$$

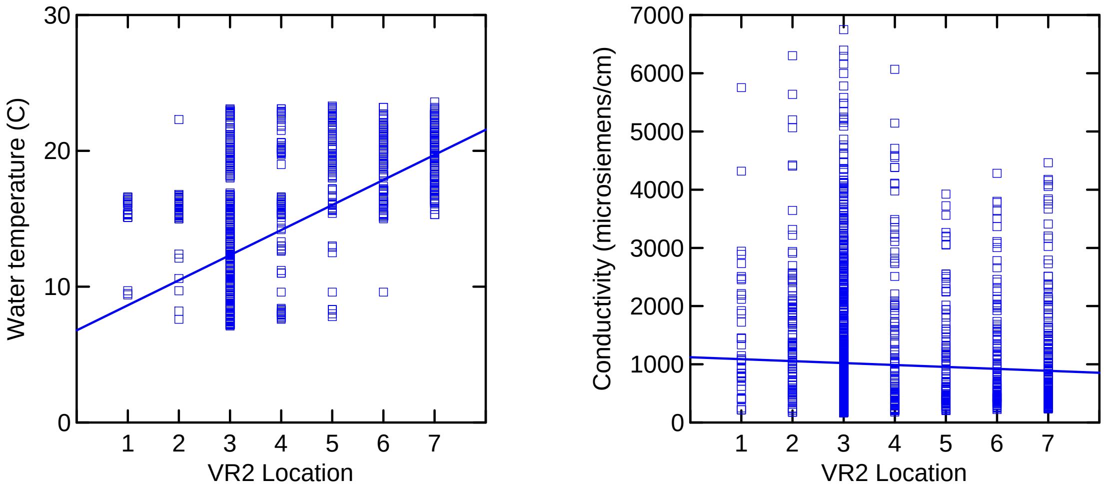
Where y = adjusted ADV velocity
x = measured ADV velocity

All field ADV data was corrected using this equation.

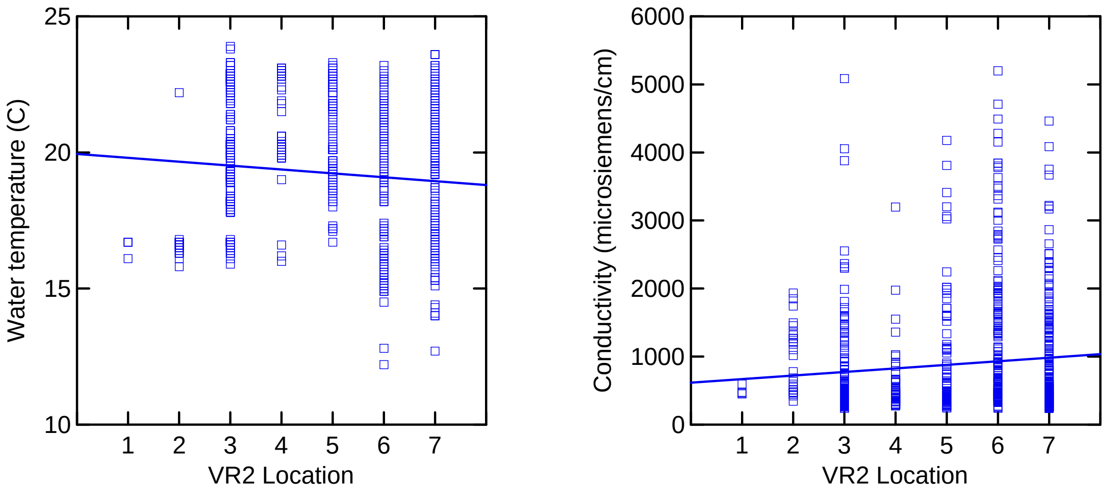
Results
The ADV adjusted velocity readings (using eq. A.2) correlated well with the propeller probe true velocity readings. In water velocities ranging from 29.87 cm/s to 60 cm/s (0.98 ft/s to 1.97 ft/s), the difference between the propeller and adjusted ADV readings was between 0.0 cm/s to 3.05 cm/s (0.0 ft/s to 0.1 ft/s).

11.3 Movement of acoustic-tagged Sacramento pikeminnow plotted against water temperature

Sacramento pikeminnow Tag # 3425



Sacramento pikeminnow Tag # 3426



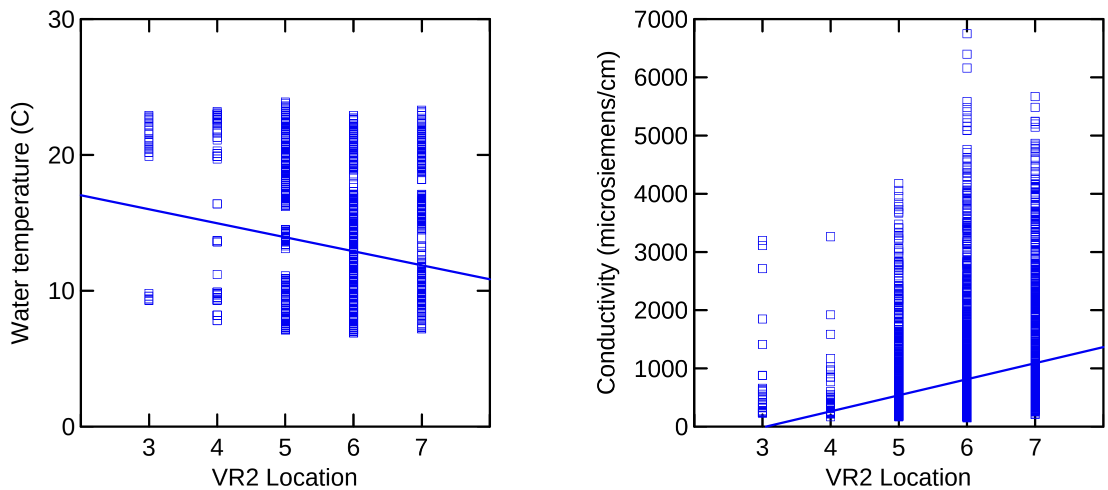
VR2 Location

1 Sacramento River downstream of Emmaton release site
2 USBR Emmaton release site
3 DWR Horseshoe Bend release site
4 Midway between Horseshoe Bend release site and Conrol Site 1
5 Control Site 1
6 Control Site 2
7 Decker Island north of Control Site 2

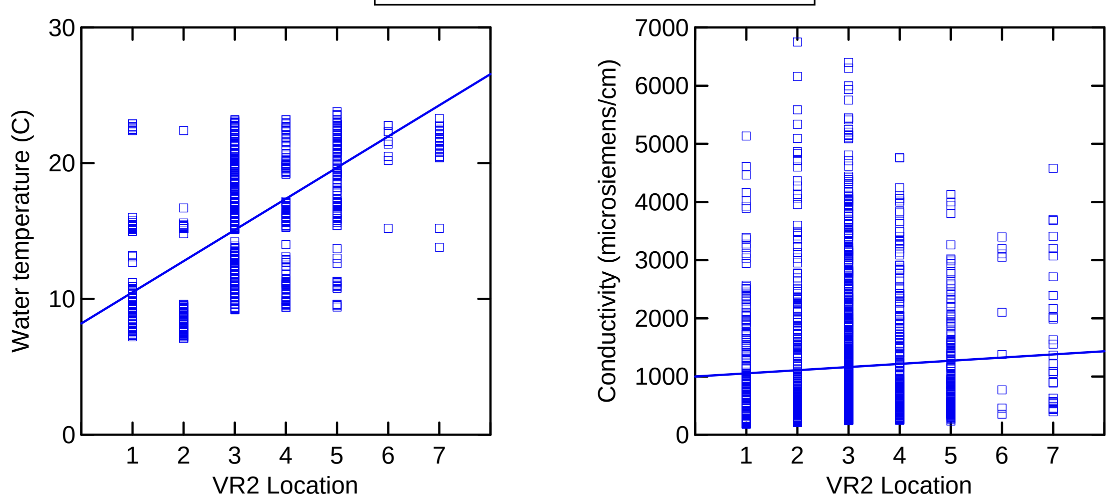
1 = Furthest downstream site 7 = Furthest upstream site

11.4 Movement of acoustic-tagged Sacramento pikeminnow plotted against water temperature and conductivity

Sacramento pikeminnow Tag # 3288



Sacramento pikeminnow Tag # 3284



<u>VR2 Location</u>

1 Sacramento River downstream of Emmaton release site
2 USBR Emmaton release site
3 DWR Horseshoe Bend release site
4 Midway between Horseshoe Bend release site and Conrol Site 1
5 Control Site 1
6 Control Site 2
7 Decker Island north of Control Site 2

1 = Furthest downstream site 7 = Furthest upstream site

11.5 Acoustic data analyses and processing

Analyses of acoustic data consisted of a series of steps, designated as

a) Observation
b) Calibration and Thresholding
c) Regions for Exclusion (Noise)
d) Echo Extraction
e) Trace Formation (Fixed Station)
f) Output Formatting/Quality Assurance

a) Observation

Acoustic files were 1 hour in length, for the fixed site and 30 minutes in length during mobile surveys. Files were broken down in this manner to avoid complete data loss should a computer system crash. Files were visualized by "play-back" in Echo View, providing a high-resolution color echogram of the file. Comments were recorded on presence of fish targets, as well as regions overshadowed by acoustic interference. The primary source of acoustic interference was volume reverberation from bubbles produced by wind generated waves, boat wakes, small debris in the water, and interference as one edge of the acoustic beam contacts the river substrate or surface air-water interface (Figure A1).

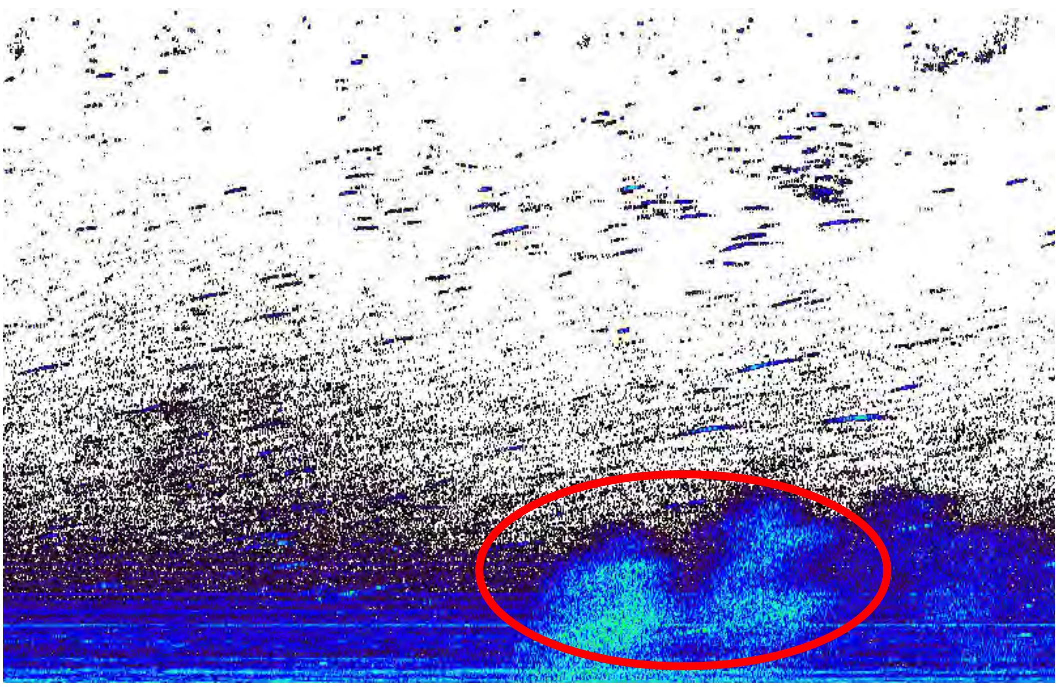


Figure A1- Snapshot of acoustic echogram showing two sources of noise. The light blue bands across the bottom of the picture represent range limitation with the edge of the transducer beam contacting either the surface or bottom. The blue cloud, circled in red, represents the wake from a passing boat.

b) Calibration and Thresholding

Calibration consisted of entering data on water temperature (used for speed of sound calculation), and acoustic system information including, beam angle, frequency, and range gates for analysis. Thresholding was used to limit as much noise as possible. Much of the volume reverberation was observed at a relatively low level. Data files were collected using a -70 dB. Since this level is considerably less than the acoustic size of fish targets the data was Thresholded further for analysis, setting a lower limit for targets at -45 dB for fixed site and down looking mobile data and -40 dB for side looking mobile data. Side looking mobile data had a higher threshold due to almost continuous wave action in the area entraining micro-bubbles near the surface, this was not a problem for the fixed side looking units due to their depth below the water surface. This Thresholding process removed a considerable amount of the acoustic interference, allowing a more rigorous evaluation of the acoustic data. The above parameters, once set, were then saved as a template to automate importation of additional data sets.

c) Exclusion of Bad Data

Even with the increased threshold, some regions were masked by high noise events, and no fish data could be recovered from these regions. Polygons can be drawn on the data field screen with the mouse to denote areas of exclusion, or as is the case with the side-looking mobile data the maximum data range was adjusted throughout the file by manually placing a line in the file, beyond which all data is excluded. For mobile data, boat wakes, wave action, and the impact of varying water depths impacted the range to which data could be analyzed. Fixed site data was typically only range limited due to bottom intrusion, or a large piece of debris fixed in the river bottom

d) Echo Extraction

Pulse width was used as a primary filter to test the returning wave shape. Echoes from reverberation should have corrupted wave shapes in comparison to point-source target echoes (small fish). The pulse width was measured at the half amplitude (endpoint criteria = -6 dB). The pulse width measurement was compared to the nominal transmitted shape (0.4 ms). Echoes with pulse width measurements less than 0.5 times the nominal or greater than 1.5 times the nominal were rejected. The next filter is the maximum allowable beam compensation. This puts a limit on how far off the center axis of the transducer beam a target can be. For these analyses the level was set to 10 dB. A target could be 10 db off peak and still be included in the analysis. The further off the beam axis a target is past a certain point, the less reliable the estimate of size and position are. The final step is to examine the standard deviation of the angles of the samples in both the x and y range. Samples that fall outside the specified range were be rejected.

Once a target has been defined and accepted, the target is utilized in one of two ways. For mobile surveys the targets are the primary mode of analyses, whereas with fixed stations targets are then subject to the formation of fish tracks in the following section.

e) Trace Formation (Release site only)

This process is often called fish tracking. Trace formation is 4-dimensional, using time and the X/Y/Z position produced by a split-beam system. EchoView's ˜ Fish Tracker implements a fixed coefficient filtering method as presented in Blackman (1986). The filtering process selects out single targets as candidates for a track. The algorithm is applied to data from a single target detection process. These are implemented as the 4D and 2D algorithms for split beam data (i.e. targets with range, angles and time). The sensitivity of the tracker to unpredicted changes in position and velocity is controlled by the Alpha and Beta gains respectively. Each fish echo that has passed the echo extraction tests is characterized by a ping number (time) and range. These provide X and Y coordinates. When a candidate echo is received, the algorithm "opens" a new trace. The range of this first seed echo is projected horizontally. A "tracking window" is centered about this position to provide a range window in the following ping. Any echo inside this range window must by definition be correlated to the seed echo. If multiple echoes fall inside the window, a best fit is calculated and that echo is linked to the original seed echo, providing a fish trace containing two echoes. Again, the echo that is closest to the center of the window is selected to be linked to the growing fish trace. A maximum range can be specified, outside of which echoes will not be included. This is useful when fish are close together to avoid the track jumping from fish to fish. A "ping gap" value is entered by the user to define when the trace is completed. If a gap of four is entered, then an active fish trace may miss three echoes and still search for candidate echoes. When the fourth echo is missed, the trace is completed and passed on to the trace filtering processes. In the final stage the length of the track is specified. Having more targets in a track generally results in a more reliable track. Fish tracking can further be used as a way to ignore some background noise as well, as only accepted fish tracks are used in the analysis thus eliminating some of the single targets generated due to noise.

f) Output Formatting and Quality Assurance

For target analyses only each target, instead of trace, is recorded as a date, location range and size. The trace formation process produces a data file with a line (record) for each fish trace accepted by the trace filtering. Each trace is coded by date, time, and contains some trace information such as mean target strength and range, and number of echoes. For split-beam, in addition, angular data such as off axis distances, velocity, and direction of travel are acquired. The direction of travel is calculated as an angle varying between 0 and 360º. The split-beam coordinate system may be considered as a compass, with north oriented in the direction opposite the cable connector on the transducer. This direction would represent 0 degrees. A clockwise rotation of 90 degrees would indicate a direction corresponding to East. Depending on how the transducer was mounted, the direction column indicates the vector direction in a plane normal to the acoustic axis, with zero degrees opposite the connector. Thus a fish with direction of between 0.1 degrees and 179.99 degrees would be considered as going from left to right across the transducer face. For this study any graphics where direction of travel is indicated, 0–179.99 degrees indicate fish are moving upstream in the direction of Rio Vista. Typically observations for a fish are near 90 or near 270 degrees (straight upstream, or straight downstream. An average movement near 180 degrees is indicative of no directional preference.

State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predation Study: 2013 Annual Progress Report

September 2015

Edmund G. Brown, Jr.
Governor
State of California

John Laird
Secretary for Natural Resources
California Natural Resources Agency

Mark W. Cowin
Director
Department of Water Resources

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State of California
Edmund G. Brown. Jr., Governor

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Abbreviations

AADAP	Aquatic Animal Drug Approval Partnership
ACC	Area Control Center
BDO	Department of Water Resources, Bay-Delta Office
BiOP	Biological Opinion
CCFFF	Clifton Court Forebay Fishing Facility
CCFPS	Clifton Court Forebay Predator Study
CEQA	California Environmental Quality Act
CHTR	Collection, Handling, Transport, and Release Facility
CPUE	Catch per Unit Effort
CVP	Central Valley Project (Federal)
CWT	Coded Wire Tag
Delta	Sacramento-San Joaquin Delta
DFD	Department of Water Resources, Delta Field Division
DFW	California Department of Fish and Wildlife
DWR	California Department of Water Resources
EROF	Equipment Request Order Form
ESA	Endangered Species Act
FDA	Food and Drug Administration
Forebay	Clifton Court Forebay
HTI	Hydroacoustic Technology Incorporated
INAD	Investigational New Animal Drug
ITP	Incidental Take Permit
MBTA	Migratory Bird Treaty Act
MOCC	Motorboat Operator Certification Course
MS-222	Tricaine -S
NEPA	National Environmental Policy Act
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
OP-2	Operations Procedure 2 – Lock-out/Tag-out
PCR	Polymerase Chain Reaction
PIT	Passive Integrated Transponder
PSL	Pre-screen Loss
QA/QC	Quality Assurance/Quality Control
RPA	Reasonable and Prudent Alternative
SAV	Sub-aquatic Vegetation
SCP	DFW Scientific Collecting Permit
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project (California State)
TEP	Temporary Entry Permit
USFWS	U.S. Fish and Wildlife Service
WCA	Work Clearance Authorization

Executive Summary

This report details the implementation, issues, and results of the first year of the Clifton Court Forebay Predation Study (CCFPS). Specific study elements implemented as pilot level investigations in 2013 include salmonid survival studies, predatory fish sampling, biotelemetry, avian studies and creel surveys. Additional detail regarding the regulatory history and overall study design and methodology is available in the report entitled *Clifton Court Forebay Predation Study* (Wunderlich 2015).

A total of 410 juvenile Chinook salmon, with average weights from 7.5 g to 15.9 g, and average total length from 87 mm to 108 mm, were PIT tagged and released at the radial gates and Skinner Delta Fish Protective Facility (SDFPF) primaries in April and May of 2013. The percentage of fish entrained into the SDFPF that subsequently are successfully salvaged and taken to the release sites determines the facility efficiency. Facility efficiency was calculated to be 74%, for all releases combined, 76%, for Aqui-S 20E releases, and 71% for MS-222 releases. Using the average facility efficiency calculated for the release period in 2013, a PSL of 81.14% was calculated for all radial gates releases, and a PSL of 86% and 82%, respectively, was calculated for Aqui-S 20E treated Passive Integrated Transponder (PIT) tagged salmon and MS-222 treated PIT tagged salmon released at the radial gates. Due to unforeseen problems, no salmon were acoustically tagged during the pilot season.

A total of 67 predator sampling days were conducted between March 12, 2013 and December 31, 2013, resulting in the capture of 5 non-target fish and 579 predatory fish; 514 Striped Bass, 51 Largemouth Bass and 14 catfish. Striped Bass captured were grouped into four size categories, and total catch was found to be 2% for fish under 0.49 lbs, 55% for fish between 0.5 lbs and 1.49 lbs, 35% for fish between 1.5 lbs and 2.9 lbs, and 8% for fish over 3.0 lbs. Catch per unit effort (CPUE) was calculated for each month, for all species combined, and was found to be highest in September, at 1.13 fish per hour sampled, and lowest in May, at 0.27 fish per hour sampled. A single Striped Bass originally captured on June 11, 2013 was recaptured on October 25, 2013.

A total of 149 predatory fish were acoustically tagged, eight catfish, 18 Largemouth Bass, and 123 Striped Bass. Of the 149 total tagged fish, 10 were never detected by any of the receivers in the array, including two Largemouth Bass and eight Striped Bass. Of the 139 tagged fish that were detected, 29 were only detected in the intake channel, 32 were only detected at the radial gates, 14 were detected moving from the intake channel to the radial gates, 13 were detected moving from the radial gates to the intake channel, 35 were detected moving back and forth between the intake channel and the radial gates, and 16 were detected outside of the Forebay.

A total of 80 angler (creel) surveys were conducted between April 26, 2013 and December 31, 2013. During these surveys, a total of 1,191 anglers were observed fishing at the Clifton Court Forebay. Anglers fished a total of 2,806 hours and captured a total of 807 fish during the survey period. Anglers caught 632 Striped Bass, 104 catfish (not identified to species), and 27 Largemouth Bass, which made up 78%, 13%, and 3% of total catch, respectively. A single adult Chinook salmon was caught in October. Catch per unit effort (CPUE) for all species ranged from 0.15 in July to 0.37 in June, and averaged 0.29 for the entire survey period. When calculated for individual species, CPUE was found to range from 0.05 to 0.30 for Striped Bass, 0.00 to 0.10 in catfish, and 0.00 to 0.04 in Largemouth Bass.

A total of 89 avian surveys were conducted between April 5, 2013 and December 31, 2013. During these surveys, a total of 6,166 piscivorous birds were observed using the Forebay. The highest numbers of avian species were observed in the month of November. Of those 6,166 birds, the most common species observed at the Forebay were gulls (*Larus* sp.), double-crested cormorants (*Phalacrocorax auritus*), and American white pelicans (*Pelecanus erythrorhynchos*). Feeding behavior peaked in September at 67% of total birds observed actively feeding.

Bioenergetics modelling will be undertaken in 2015, following the collection of an appropriate amount of data to be used in the calculations. Genetics was initiated in December of 2013, but the bulk of the work was completed in 2014 for the pilot level effort, and as such it is included in the 2014 annual report. Subsequent annual reports will be compiled for each year that the study is undertaken. At the conclusion of the study a synthesis report, with more in depth analysis will be prepared.

1.0 Introduction

The Clifton Court Forebay Predation Study (CCFPS) is a multi-year effort comprised of experimental investigations that have been designed to gather as much information as possible to understand predation upon juvenile salmonids in the Clifton Court Forebay (Forebay). This report covers the first year pilot level effort conducted to help better define the full-scale study, beginning in 2014, and designed to further the understanding of behavior and movement of predatory fishes, salmonids, and piscivorous birds in the Forebay. The CCFPS includes the following elements: salmonid survival studies, predatory fish sampling, biotelemetry, genetics, creel surveys, avian studies and bioenergetics. CCFPS design and methodology is further discussed in the report titled Clifton Court Forebay Predation Study (2015).

The first year was planned as a pilot level effort to gather information on logistics, study needs, and feasibility of specific elements before launching a full-scale study.

The CCFPS will provide the opportunity to evaluate the effects of any Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) of the Biological Opinion (BiOp) and Conference Opinion on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) (NMFS 2009) undertaken to reduce predation of ESA protected salmon and steelhead within the Forebay.

2.0 CCFPS Study Elements

2.1 Issues

The Forebay and S John E. Skinner Delta Fish Protective Facility (SDFPF) are State Water Project (SWP) facilities managed and operated by the DWR Delta Field Division (DFD), and as such, all CCFPS work conducted at these facilities is done in close coordination with DFD. However, SWP coordination protocols and call-in procedures, which had been in place historically, were changed significantly on the morning of January 25, 2013. All work on the CCFPS was suspended pending dissemination of the new SWP procedural requirements, as well as staff orientation and certification for the new procedures. The new SWP procedures were initiated to improve worker safety and included several elements that required significant lead time to prepare, prior to reinitiating work on the CCFPS. These procedures included successful completion of the Operational Procedure -2 (OP-2) eight hour course and exam for DWR staff and a four hour OP-2 Awareness course for contractors. The OP-2 course is only offered once per month, which prolonged successful completion by the DWR project team. The OP-2 Awareness course is offered on an as-needed basis in coordination with DFD. Additionally, an OP-2 certified DWR staff member was required to file an Equipment Request Order Form (EROF) to obtain an Okay to Work and associated Work Clearance Application (WCA) number for each task to be undertaken and an OP-2 certified DWR staff member was required to be present during field work at SWP facilities. The EROFs were required to be submitted a minimum of four weeks prior to initiation of work.

DFD provided a final procedural guide was provided to DWR Bay-Delta Office (BDO), and EROF’s for elements within the CCFPS were filed with DFD in March and April 2013.

2.2 Salmonid Survival

2.2.1 Methods

For the 2013 pilot study, 1,600 Late-Fall and 550 fall run Chinook Salmon were requested from the Coleman National Fish Hatchery (NFH) for pick-up in January and April, respectively. A total of 100 salmon were scheduled to be acoustically tagged, and up to 1,500 salmon (a combination of fall and Late-Fall run) were scheduled to be tagged with passive integrated transponder (PIT) tags. Due to unforeseen complications, which are discussed in more detail below, no salmon were acoustically tagged. Fish releases, originally planned to begin mid-January 2013 and continue through May 2013, and did not begin until April 2013. No steelhead releases were planned for the 2013 field season, as data from previous studies were more recent for steelhead than for Chinook salmon, and it was determined that beginning with only Chinook salmon would be more useful and informative for refining the balance of the study years.

As part of the 2013 pilot study, two anesthetics, Tricaine-S (MS-222) and AQUI-S 20E (Eugenol), were used to compare relative efficacies. MS-222, when used as an anesthetic for fish, requires a 21 day holding period in any fish that could potentially be used for human consumption and the Food and Drug Administration (FDA) states that its use should be restricted to Ictaluridae, Salmonidae, Esocidae, and Percidae (FDA ANADA 200-226, 1997). AQUI-S 20E was developed in New Zealand as an anesthetic for use on food-fish without the holding period that is needed for drugs such as MS-222. AQUI-S 20E is currently being evaluated for efficacy as an anesthetic for fish species via an Investigational New Animal Drug (INAD) Exemption sponsored by the USFWS Aquatic Animal Drug Approval Partnership (AADAP) Program. The AADAP sponsored INAD allows investigators to use AQUI-S 20E as part of the clinical field trials to determine efficacy as an anesthetic for use in a variety of fish species (USFWS 2010). Data on the use of AQUI-S 20E for the salmon tagging and releases conducted within the CCFPS were compiled for inclusion in the 2013 INAD on December 13, 2012 (Study # 11-741-13-257F).

General data including start and end time, date, water temperature, source and destination tank, staff, anesthesia, and the electronic data file name were recorded by hand for each tagging event. All individual fish data including PIT tag number, fork length to the nearest mm, weight to the nearest 0.1 gram (g), and adipose fin clip status was recorded on a Panasonic Toughbook, into the “df direct” Microsoft Excel spreadsheet (by Destron Fearing) that is connected to a Biomark Destron Fearing FS2001-ISO data logger with hoop style antennae (Figure 1).This spreadsheet was set up to autofill the PIT tag number to avoid transcription errors. Discreet datasheets were maintained for each anesthesia method for each tagging event. In addition to the above data, time to reach the ”surgical plane”, defined as loss of equilibrium and reactivity to most external stimuli, for tagging and time to recover was recorded for fish that were anesthetized. Data on these fish was entered into the online data reporting forms for the AADAP INAD for AQUI-S 20E as part of the reporting requirements for participation in the INAD program.

Figure 1: PIT Tagging Station at CHTR 2013

A total of 886 juvenile fall run Chinook salmon were obtained from the Coleman NFH and transported to the DWR Collection Handling Transport and Release Facility (CHTR) located adjacent to the Forebay in Byron, California on December 20, 2012. They were held at CHTR until tagging and releases could begin. PIT tagging was conducted twice per week on Monday and Friday. Fish were PIT tagged in groups of 80 from April 15, 2013 through April 22, 2013. The number of fish PIT tagged was reduced beginning April 26, 2013 until May 10, 2013, to reflect a lower number of fish released at the SDFPF primaries. During each tagging event, an equal number of fish were anesthetized using MS-222 and AQUI-S 20E. Fish were randomly selected from numbered holding tanks and anesthetized to ”surgical plane”. Each fish was weighed to the nearest 0.1 g, total length was measured to the nearest millimeter (mm), and the adipose fin was removed immediately prior to tagging. Fish were tagged with Biomark HPT6 PIT tags, and placed in holding tanks based upon treatment and tagging date, so that they were released in the proper group and order (Table 1).

Table 1: Tagging and Holding Tank Protocol

Tagging Date	Source Tank #	Release tank # (AQUI-S)	Release tank # (MS-222)
4/15/2013	8	2	1
4/19/2013	8	4	3
4/22/2013	8	2	1
4/26/2013	8	4	3
4/29/2013	8	2	1
5/10/2013	8	4	3

Tagging on April 15th, 19th, and 22nd consisted of two taggers and one data recorder, with each tagger tagging an equal number of fish from each anesthetic group to minimize tagger effect between treatment groups. Tagging on April 26th, 29th and May 10th consisted of a single tagger and data recorder, due to the reduced number of fish.

Table 2: Tagging and Release Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
Tagging	PIT tag up to 80 fish				PIT tag up to 80 fish
Releases	Release ½ of previous Friday's tagged fish (20 at the radial gates; up to 20 at the SDFPF primaries)	Release ½ of previous Friday's tagged fish (20 at the radial gates; up to 20 at the SDFPF primaries)		Release ½ of Mondays tagged fish (20 at the radial gates; up to 20 at the SDFPF primaries)	Release ½ of Mondays tagged fish (20 at the radial gates; up to 20 at the SDFPF primaries)

Fish that were tagged on Monday were released on the following Thursday and Friday, and fish tagged on Friday were released on the following Monday and Tuesday, to reduce variance in the amount of time lapse between tagging and release to no less than 48 and no more than 72 hours. For each release, 20 fish from each anesthetic treatment group were randomly selected, scanned to confirm and record the PIT tag number, and placed into green[1] five gallon buckets, in groups of five fish per bucket, for transport to the release sites. Initially, a total of 10 fish from each anesthetic treatment group was released at the radial gates, and 10 fish from each anesthetic group was released at the SDFPF primaries (Figure 2), for a total of 40 fish released per day (Table 2).The number of fish released at the primaries was reduced to 5 from each treatment, to total 10 per release, following consultation with Javier Miranda regarding facility efficiency calculations.

[1] Green buckets were selected to reduce stress on the fish during transport.

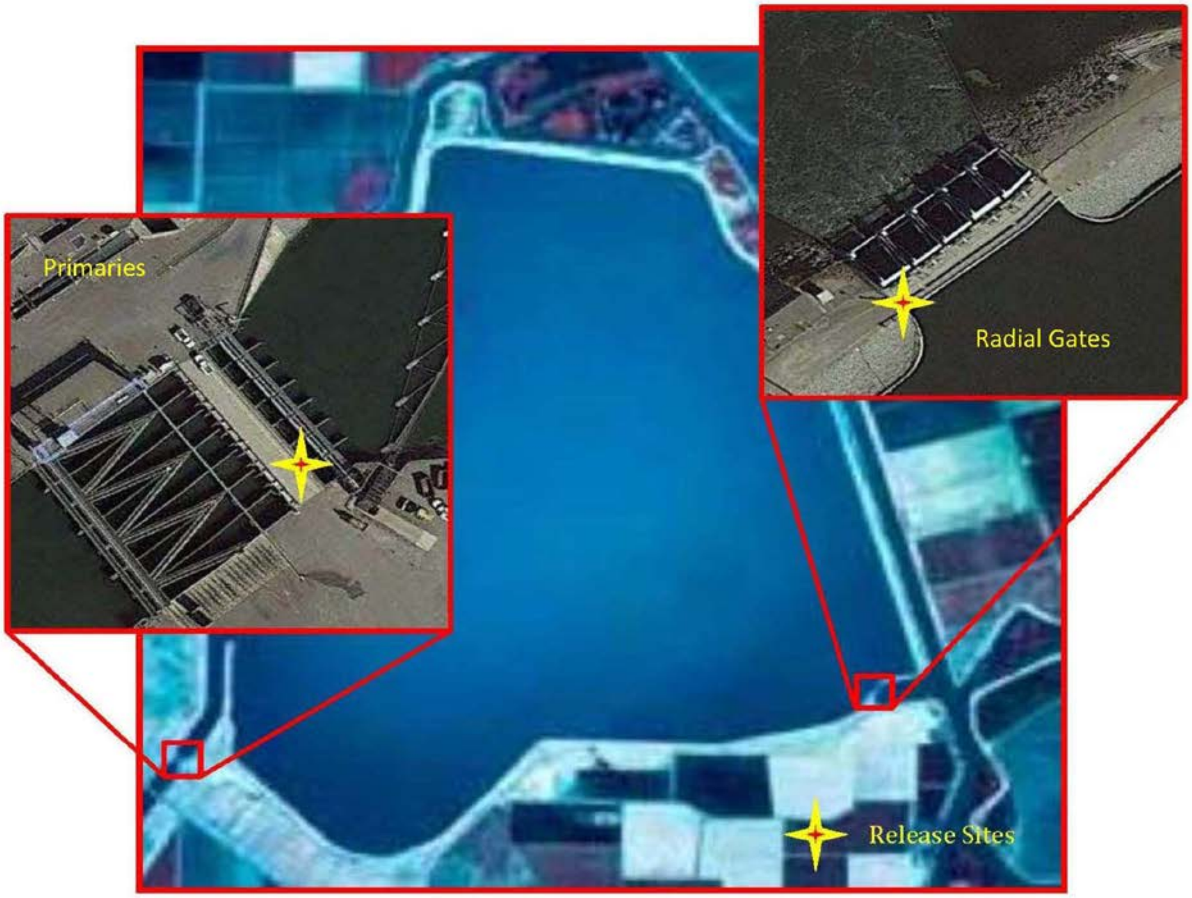

Figure 2: 2013 Release Sites

Releases were always done at the radial gates first, followed by the SDFPF primaries. Releases at the radial gates were planned to coincide with the earliest period of the day that the radial gates were open on the release day (Table 3). The area control center (ACC) was called to confirm the gate status prior to placing the fish into the buckets for transport.

Table 3: Radial Gates Scheduled Opening 2013

Date	Gates Open	Begin Release Time*	End Release Time	Gates Close
4/19/2013	0001	0645	0708	1230
4/22/2013	0115	0145	0230	1500
4/23/2013	0600	0540	0714	1145
4/25/2013	0700	0630	0750	1300
4/26/2013	0745	0752	0840	1345
4/29/2013	0016	0605	0620	0715
4/30/2013	0001	0555	0702	1230
5/3/2013	0105	0410	0510	1030
5/4/2013	0001	0530	0623	1330
5/13/2013	0001	0504	0602	0700
5/14/2013	0001	0504	0537	0745

* Release times were recorded from the time fish were loaded into buckets for transport, and are on average 20 minutes before actual arrival at gates. Gate schedule information was obtained from publicly accessible DWR reports (DWR 2013)

At the radial gates, fish were released by lowering the release bucket via a Spitzlift® hand-operated winch to just above the surface of the water immediately upstream of the open gate (Figure 3). Releases at the SDFPF primaries were done in the same manner, and bay selection was based upon which of the bays was actively flowing water, and was coordinated with the SDFPF Efficiency Studies to reduce resource requirements of both studies.

Figure 3: Fish Release at the Radial Gates

Following the releases, data regarding SDFPF Operational Criteria was recorded, as shown in Table 4. Data was only collected for five releases: April 26, April 29, April 30, May 3, and May 14, due to restrictions in access resulting from heightened security concerns.

Table 4: Types of Operational Criteria Collected in 2013

Date	Begin Release Time	End Release Time	Time Data Recorded	Temperature (°F)	Primary Head (Feet)	Secondary Head (Feet)
Velocity Ratios						
Primary Pipe A	**Primary Pipe B**	**Primary Pipe C**	**Primary Pipe D**	**Secondary Pipe 1**	**Secondary Pipe 2**	
Velocity (FPS)						
Bay 1	**Bay 2**	**Bay 3A**	**Bay 3B**	**Bay 4A**	**Bay 4B**	**Bay 5**
Sec. Channel 1	**Sec. Channel 2L**	**Sec. Channel 2R**				
Depth						
Primary Channel Upstream	**Primary Channel Downstream**	**Bay 1**	**Bay 2**	**Bays 3A & 3B**	**Bays 4A & 4B**	**Bay 5**
Sec. Channel 1 Downstream	**Sec. Channel 2 Downstream**	**Sec. Channel 2L Upstream**	**Sec. Channel 2R Upstream**			
Flow						
Primary Pipe A	**Primary Pipe B**	**Primary Pipe C**	**Primary Pipe D**	**Secondary Pipe 1**	**Secondary Pipe 2**	**Sec. Channel 1**
Sec. Channel 2	**Primary Channel (BAPP)**	**Holding Tank 1**	**Holding Tank 2**	**Holding Tank 3**	**Holding Tank 4**	**Holding Tank 5**
Holding Tank 6	**Holding Tank 7**					

2.2.2 Issues

Salmon releases are conducted at the radial gates which are located at the mouth of the Forebay and are operated remotely by senior operators at the DWR ACC, located at the Banks Pumping Plant. Since releases must be conducted when the gates are open and water is flowing into the Forebay, close coordination with the ACC is needed.

The initiation of salmon releases was originally planned for January 25, 2013. However, as described above SWP coordination protocols and call-in procedures, which had been in place historically, were changed significantly on the morning of January 25, and all work on the CCFPS was suspended pending dissemination of the new SWP procedural requirements.

DFD provided a final procedural guide to DWR Bay-Delta Office (BDO), and following submittal and approval of EROF's for salmon releases approval for the salmon releases was received on April 8, 2013, and the first salmon release occurred on April 19, 2013.

The salmon release plan included placing acoustic tags in 10 fish per week to be released in conjunction with the PIT tagged fish (Table 2). The acoustic tags selected for this project were HTI model 800 micro acoustic tags with integrated Biomark HPT9 PIT tags, which weigh 0.5g +/- 10% in air. To ensure that the weight of the acoustic tag did not exceed 5% of the total weight of the fish, a minimum weight threshold of 12 g was set for acoustic tagging. As of the April 29, 2013 tagging event, no fish had reached the minimum weight threshold, and acoustic tagging was not initiated.

SDFPF Operational Criteria was only collected for five of the releases due to miscommunications early in the process and DFD security concerns which severely restricted access.

2.2.3 Data Analysis

Estimates of pre-screen loss (PSL) were calculated using equations from Clark et al (2009) to maintain comparability to prior efforts. Salmonid PSL was calculated for Chinook salmon as:

$$PSL = \left[1 - \left(\frac{Rec_{rg}}{Rel_{rg} \times A \times F}\right)\right] \times 100$$

Recrg = # PIT tagged salmon recovered from radial gate releases

Relrg = # PIT tagged salmon released at the radial gates

A = PIT antennae detection efficiency

F = Facility efficiency estimated by trash rack releases

SDFPF salvage efficiency (*F*), defined as the proportion of PIT tagged salmon released within the SDFPF primaries that are successfully salvaged and released, was calculated for Chinook Salmon as:

$$F = \left[\frac{Rec_{tr}}{Rel_{tr} \times A}\right] \times 100$$

Rectr = # PIT tagged salmonids recovered from trash rack releases

Reltr = # PIT tagged salmonids released at the trash rack

A = PIT antennae detection efficiency

2.2.4 Results

A total of 410 fish were PIT tagged in groups of 25 to 40 fish per anesthesia method for each tagging day (Table 5). Average weights ranged from 7.5 g to 15.9 g, and average total length ranged from 87 mm to 108 mm.

Table 5: Tagging Efforts in 2013

Date	Number of Fish	Anesthesia Method	Average Weight (g)	Average Total Length (mm)
15-Apr-2013	40	AQUI-S 20E	7.5	87
15-Apr-2013	40	MS-222	7.5	87
19-Apr-2013	40	AQUI-S 20E	8.3	90
19-Apr-2013	40	MS-222	7.7	88
22-Apr-2013	40	AQUI-S 20E	8.5	90
22-Apr-2013	40	MS-222	8.9	91
26-Apr-2013	25	AQUI-S 20E	8.9	88
26-Apr-2013	25	MS-222	8.8	92
29-Apr-2013	30	AQUI-S 20E	10.0	96
29-Apr-2013	30	MS-222	10.0	95
10-May-2013	30	AQUI-S 20E	15.9	108
10-May-2013	30	MS-222	15.7	107

A total of 129 PIT tagged salmon were released at the SDFPF primaries to evaluate facility efficiency (Table 6). Of those 129 salmon, 91 PIT tagged salmon were determined to be recovered based upon detection by the PIT antennae located at the release sites.

Table 6: Fish Releases at the Radial Gates and SDFPF Primaries in 2013

Date	Fish Released at Radial Gates	Fish Released at SDFPF primaries
19-Apr-2013	20	0
22-Apr-2013	20	20
23-Apr-2013	20	20
25-Apr-2013	20	20
26-Apr-2013	20	10
29-Apr-2013	20	10
30-Apr-2013	20	9
3-May-2013	20	10
4-May-2013	20	10
13-May-2013	20	10
14-May-2013	19	10

The PIT tag detection efficiency was determined to be 0.96, or 96%, at the time of release (pers. Comm. J. Miranda). Facility efficiency (F_{all}) was calculated to be 0.74, or 74%, for all releases using the equation below.

$$F_{all} = \left[\frac{Rec_{tr}}{Rel_{tr} \times A}\right] \times 100$$

$$F_{all} = \left[\frac{91}{129 \times 0.96}\right] \times 100$$

$$F_{all} = \left[\frac{91}{123.8}\right] \times 100$$

$$F_{all} = 0.74 \times 100$$

$$F_{all} = 74\%$$

Using the facility efficiency, a PSL (for all treatment types combined, defined as PSL_{all}) of 81.14% was calculated based upon the release of 219 PIT tagged salmon at the radial gates. Of those 219 salmon, 29 PIT tagged salmon were determined to be recovered based upon detection by the antennae located at the release sites.

$$PSL_{all} = \left[1 - \left(\frac{Rec_{rg}}{Rel_{rg} \times A \times F}\right)\right] \times 100$$

$$PSL_{all} = \left[1 - \left(\frac{29}{219 \times 0.74 \times 0.96}\right)\right] \times 100$$

$$PSL_{all} = \left[1 - \left(\frac{29}{155.58}\right)\right] \times 100$$

$$PSL_{all} = [1 - (0.19)] \times 100$$

$$PSL_{all} = 0.81 \times 100$$

$$PSL_{all} = 81\%$$

Facility efficiency ($F_{Aqui\text{-}S}$) was calculated to be 0.76, or 76%, for Aqui-S 20E releases using the equations below.

$$F_{Aqui-S} = \left[\frac{Rec_{tr}}{Rel_{tr} \times A}\right] \times 100$$

$$F_{Aqui-S} = \left[\frac{46}{63 \times 0.96}\right] \times 100$$

$$F_{Aqui-S} = \left[\frac{46}{60.48}\right] \times 100$$

$$F_{Aqui-S} = 0.76 \ \times 100$$

$$F_{Aqui-S} = 76\%$$

Using the facility efficiency, a $PSL_{Aqui\text{-}S}$ of 86% was calculated based upon the release of 111Aqui-S 20E treated PIT tagged salmon at the radial gates. Of those salmon, 11 PIT tagged salmon were determined to be recovered based upon detection by the PIT antennae located at the release sites.

$$PSL_{Aqui-S} = \left[1 - \left(\frac{Rec_{rg}}{Rel_{rg} \times A \times F}\right)\right] \times 100$$

$$PSL_{Aqui-S} = \left[1 - \left(\frac{11}{111 \times 0.76 \times 0.96}\right)\right] \times 100$$

$$PSL_{Aqui-S} = \left[1 - \left(\frac{11}{80.98}\right)\right] \times 100$$

$$PSL_{Aqui-S} = [1 - (0.14)] \times 100$$

$$PSL_{Aqui-S} = .86 \times 100$$

$$PSL_{Aqui-S} = 86\%$$

Facility efficiency (F_{MS222}) was calculated to be 0.71, or 71% for MS-222 releases using the equations below.

$$F_{MS222} = \left[\frac{Rec_{tr}}{Rel_{tr} \times A}\right] \times 100$$

$$F_{MS222} = \left[\frac{45}{66 \times 0.96}\right] \times 100$$

$$F_{MS222} = \left[\frac{45}{63.36}\right] \times 100$$

$$F_{MS222} = 0.71 \times 100$$

$$F_{MS222} = 71\%$$

Using the facility efficiency, a PSL_{MS222} of 82% was calculated based upon the release of 108MS-222 treated salmon at the radial gates. Of those salmon, 13 PIT tagged salmon were determined to be recovered based upon detection by the PIT antennae located at the release sites.

$$PSL_{MS222} = \left[1 - \left(\frac{Rec_{rg}}{Rel_{rg} \times A \times F}\right)\right] \times 100$$

$$PSL_{MS222} = \left[1 - \left(\frac{13}{108 \times 0.71 \times 0.96}\right)\right] \times 100$$

$$PSL_{MS222} = \left[1 - \left(\frac{13}{73.6}\right)\right] \times 100$$

$$PSL_{MS222} = [1 - (.18)] \times 100$$

$$PSL_{MS222} = .82 \times 100$$

$$PSL_{MS222} = 82\%$$

Facility efficiency and PSL were calculated for each individual release (Table 7). Transit time for fish that were successfully salvaged ranged from one day to 46 days, so the facility efficiency for all release dates was used to calculate the PSL for each individual release date.

Table 7: PSL for Each Release by Treatment

Date	Treatment	RECtr	RELtr	A	F	RECgate	RELgate*	PSL
4/22/13	Aqui-S 20E	9	10	0.96	.76	3	10	59%
4/23/13	Aqui-S 20E	8	10	0.96	.76	3	10	59%
4/25/13	Aqui-S 20E	9	10	0.96	.76	2	10	73%
4/26/13	Aqui-S 20E	5	5	0.96	.76	1	10	86%
4/29/13	Aqui-S 20E	3	5	0.96	.76	1	7	80%
4/30/13	Aqui-S 20E	3	3	0.96	.76	0	15	100%
5/3/13	Aqui-S 20E	0	5	0.96	.76	0	10	----
5/4/13	Aqui-S 20E	3	5	0.96	.76	0	10	100%
5/13/13	Aqui-S 20E	3	5	0.96	.76	0	10	100%
5/14/13	Aqui-S 20E	3	5	0.96	.76	1	8	83%
4/22/13	MS-222	4	10	0.96	.71	3	10	56%
4/23/13	MS-222	10	10	0.96	.71	2	10	71%
4/25/13	MS-222	7	10	0.96	.71	1	10	85%
4/26/13	MS-222	2	5	0.96	.71	1	10	85%
4/29/13	MS-222	4	5	0.96	.71	2	13	77%
4/30/13	MS-222	6	6	0.96	.71	2	5	41%
5/3/13	MS-222	0	5	0.96	.71	1	10	------
5/4/13	MS-222	4	5	0.96	.71	0	10	100%
5/13/13	MS-222	5	5	0.96	.71	0	10	100%
5/14/13	MS-222	3	5	0.96	.71	2	10	71%

T-test comparisons were run within each treatment group as well as between AQUI-S 20E and MS-222 to determine if the variance in PSL was significant (Figure 4). For the AQUI-S 20E treatment, the difference between releases was determined to be significant (P = <0.001). Likewise, for the MS-222 treatment, the difference between releases was determined to be significant (P = <0.001). When compared to one another, however, there was no statistical difference between the MS-222 and AQUI-S 20E treatment groups (P = 0.600).

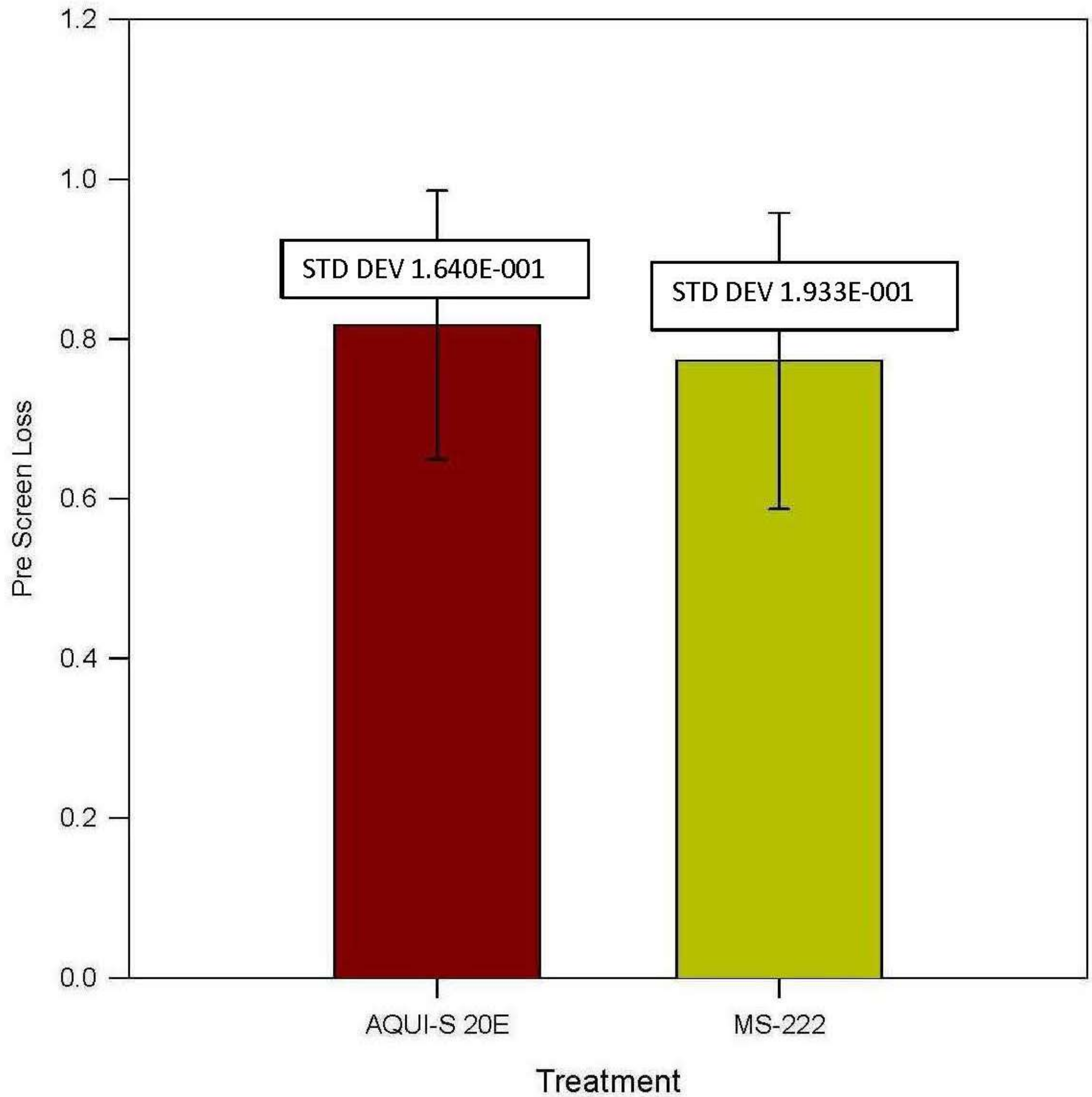

Figure 4: Pre Screen Loss for all Releases by Treatment

2.2.5 Discussion and Recommendations

PSL was estimated by releasing tagged juvenile Chinook salmon at the radial gates and comparing the numbers of Chinook salmon released to the numbers that are successfully detected at the release sites. The simultaneous release of large numbers of juvenile salmonids could potentially swamp the predator population inhabiting the study area, resulting in a biased (high) estimate of survival as a result of a reduction in predation mortality. Alternatively, releases of large numbers of juvenile salmonids could potentially attract predatory fish resulting in a biased (low) estimate of survival as a result of an increase in predation mortality. To avoid biases such as these, releases were conducted with small groups of fish over several weeks, from April through May 2013. PSL was then calculated for all fish released over the release period, as well as separately for each of the two anesthesia techniques used for side by side comparison. PSL was calculated to be 81.14 ± 0.19% for all fish, which is within the range of PSL found in prior studies, which ranged from 63% to 99% for Chinook salmon (Gingras 1997) and 82% for steelhead (Clark et al 2009). When PSL was calculated for AQUI-S 20E and MS-222, it was found to be 86 ± .16% and 82 ± .20%, respectively, and, based upon the t-test comparison there was not a significant effect resultant from anesthetic treatment.

While the PSL found in this study was not outside of the range of prior studies, it may not be indicative of total PSL for the entire time period that juvenile Chinook Salmon would be moving through the system, as releases were only conducted during the months of April and May, which represents just the latter portion of that time period. The study was originally planned to be conducted from January until May, however, issues that were discussed above resulted in significant delays in the initiation of the study. Therefore, limited conclusions can be drawn from this dataset.

It is recommended that these releases be repeated in coming years, for the entire span of the time period during which juvenile Chinook salmon could be encountered in the area, so that PSL is more representative. It is also recommended that future releases be conducted using steelhead in addition to Chinook salmon. No steelhead releases were conducted for the 2013 field season, as data from previous studies were more recent for steelhead than for Chinook salmon, and it was determined that beginning with only Chinook salmon would be more useful and informative for refining the balance of the study years.

2.3 Predatory Fish Sampling

2.3.1 Methods

For the 2013 Pilot Study, predators such as Striped Bass, Largemouth Bass, White Catfish, and Channel Catfish, were collected by either gill netting or hook and line sampling in the Forebay. Predatory fish were sampled twice weekly throughout the year, beginning in March 2013, to supply predatory fish for various study elements. Predatory fish were either sacrificed and preserved for use in the genetic analysis study element, or tagged as part of the mark-recapture and biotelemetry study element (discussed in detail in the Biotelemetry Section) and released at the location of capture. Temperature and dissolved oxygen, and location(s) of capture were noted for each sampling effort. Scale samples were collected from Striped Bass and Largemouth Bass, to be examined at a future date, to determine the age of the predatory fish sampled.

Collection of predators occurred primarily during the day, between the hours of 0600 and 1500, however, three of the sampling efforts were undertaken at night, between the hours of 1900 and 2400 (May 23, August 21 and September 19, 2013). All incidental species caught alive were measured, recorded, and immediately released at the location caught. Field staff were trained to quickly identify listed species and release live fish to minimize handling stress. Incidental take information was detailed in a supplemental report as part of the reporting requirements of the DFW Scientific Collecting Permits (SCP; SCP #'s 7744 and 10286).

The Forebay was split into sampling sections, following the same map as Gingras and McGee (1997; Figure 5). Sampling was conducted from a boat, when possible, to allow for coverage of a greater portion of the Forebay. Sampling locations were determined based upon accessibility and Forebay conditions. On sampling days when the boat was not available for use, sampling was conducted from the shoreline, primarily along the intake canal (Area 2) or adjacent to the radial gates (Area 1).

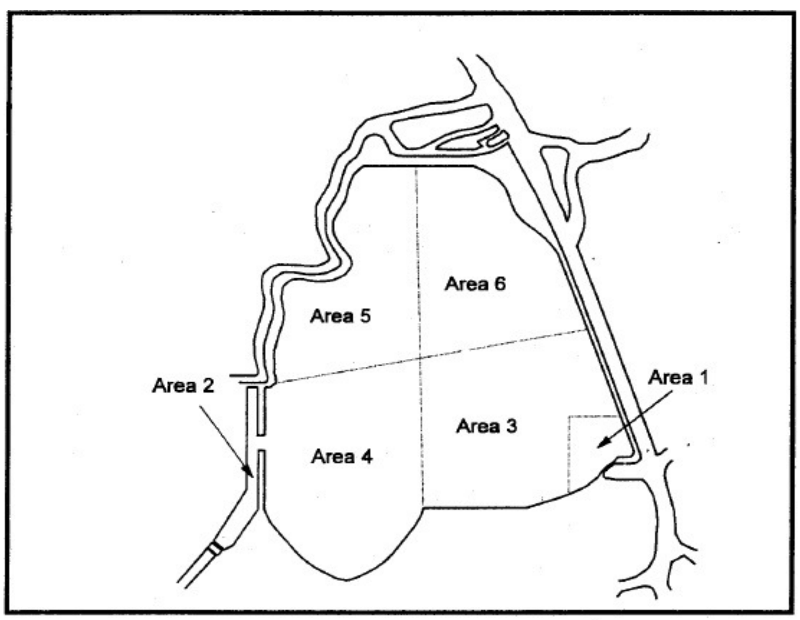

Figure 5: Sampling Map (Gingras and McGee 1997)

Hook and line sampling was conducted using standard rod and reel fishing equipment in accordance with standard DFW regulations for hook and line fishing, and employed a wide variety of bait and lure selections to maximize catch. Hook and line sampling was conducted on 67 sampling days, at various times during the day from March 12, 2013 until December 31, 2013. Gill netting was conducted on five sampling days within Forebay, from March 27, 2013 until October 25, 2013, using a monofilament gill net, measuring 30 meters (m) or less, with variable mesh sizes ranging from five centimeters (cm) to 15.25 cm. Gill netting was determined to have too great an impact upon the condition of fish to be useful for mark/recapture studies, and was suspended following the October 25th effort.

2.3.2 Issues

As stated above, the initiation of predator sampling was planned for January 30, 2013, but was delayed due to a change in SWP procedures/requirements. An EROF for predator sampling was filed with DFD on February 15, 2013, and the first predator sampling survey occurred on March12, 2013. Initially, EROF paperwork was filed on a monthly basis and restricted sampling days to those specifically requested on each monthly submission. However, due to the likelihood of unanticipated scheduling changes that could occur based upon inclement weather, equipment failure or staffing changes, and the long term nature of the project, in April 2013 DFD agreed to issue a WCA number which included no specific sampling dates that was valid for the balance of 2013. The WCA for predator sampling required the presence of an OP-2 certified DWR staff member at all times.

Predator sampling was conducted pursuant to the requirements of the DFW as outlined in SCP #7744. This permit is an individual permit issued solely to Veronica Wunderlich. This restricted staffing for sampling activities in that it required the SCP holder to be present during all sampling efforts. To allow for sampling when the SCP holder was not available, predator collection activities were temporarily conducted under a pre-existing SCP (SCP # 10286) issued to Javier Miranda that was not project specific but allowed for the same activities. A second entity wide permit which replaced the individual permit of the same number (SCP # 10286) was issued on November 27, 2013, which gave more scheduling flexibility for sampling efforts.

Predator sampling efforts were additionally constrained by availability of boats as well as qualified and approved boat operators. BDO has a clearly defined boat operator policy outlined in Section 2.6 of the Safety Guidelines, Policies, and Procedures for DCB Field Operations (January 2013 revision) that requires that each operator complete a multi-day field based Motorboat Operator Certification Course (MOCC) and demonstrate necessary skills on the BDO vessel in the presence of designated approved BDO operators. As many staff members on the CCFPS were not yet approved BDO operators, all predator sampling efforts needed to be scheduled around the availability of qualified boat operators, as well as OP-2 certified staff and the SCP holder. This required the careful coordination of multiple schedules across multiple ongoing projects.

In addition to the availability of boat operators, the availability of boats that could negotiate the variable conditions encountered in the Forebay proved to be a challenge. During a portion of the year, the Forebay becomes inundated with thick, and in some cases unnavigable, patches of submerged aquatic vegetation (SAV). When the SAV becomes thick, it is not possible to use the BDO jet drive boat. The second boat is a prop driven boat, and can be used in SAV to a greater extent; however this boat is borrowed from another group, and is not always available during the year. On June 30, 2013, the BDO jet boat was taken out of service. The second boat was acquired on August 11, 2013, and was used full time until November 30, when it was returned to the group from which it was borrowed.

2.3.3 Data Analysis

Data sheets were scanned and data was initially compiled into an excel spreadsheet to ensure that no data was lost while a database was under development. A database for acoustic tagged fish was completed in June 2014, and the acoustic tag data portion of the predator sampling data was transferred from the excel spreadsheet for analysis. A more comprehensive database for all predatory fish captured was completed in December 2014. Total catch, catch by species, and catch by size for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(q = catchability (fish caught per hours of sampling), C = catch, f = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE per month for all species combined was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and d = number of sampling days in the month)

Mean CPUE per month was then calculated for each species using the equation

$$q_{sp} = \frac{\Sigma\left(\frac{Csp}{f \times a}\right)_i}{d}$$

Seasonal CPUE was calculated for the four seasons defined as Winter (Jan 1 – March 19 and December 21-December 31), Spring (March 20 – June 20), Summer (June 21 – September 21), and Fall (September 22 – December 20), based upon the published[2] equinox/solstice dates for 2013.

Seasonal CPUE for all species combined was calculated by:

$$q_s = \frac{\sum q_i}{d}$$

(q_s = seasonal catchability, q_i = catchability for each day sampled in the season, and d = number of sampling days in the season)

2.3.4 Results:

A total of 67 sampling days were conducted between March 12, 2013 and December 31, 2013, resulting in the total catch of 584 fish, including 579 predatory fish and five non-target fish (Table 8, Figure 6). Of the 579 predatory fish, the majority were Striped Bass, at 514, followed by Largemouth Bass at 51. Catfish were only caught in May, June and July, and totaled only 14 fish for the year. Non-target fish species captured included Bluegill (*Lepomis macrochirus*) and Threadfin Shad (*Dorosoma petenense*), and were only caught during the gill net efforts. Only one fish, a Striped Bass, was recaptured during the 2013 predator sampling effort. The single recapture was a Striped Bass originally captured on June 11, 2013 and recaptured on October 25, 2013, having increased in size from 0.75pounds (lbs) (0.34 kilograms (kg)) to 1.0 lbs (0.45 kg) between captures.

Table 8: 2013 Predatory Fish Captures by Month

Month	Monthly Total	Striped Bass	Largemouth Bass	Catfish Sp	Other
March	101	96	5	0	0
April	25	23	2	0	0
May	25	17	3	3	2
June	34	26	1	7	0
July	43	37	2	4	0
August	82	81	1	0	0
September	82	80	2	0	0
October	69	50	16	0	3
November	38	33	5	0	0
December	85	71	14	0	0
All 2013	584	514	51	14	5

[2] Equinox/solstice dates from http://wwp.greenwichmeantime.com/longest-day/equinox-solstice-2010-2019.htm

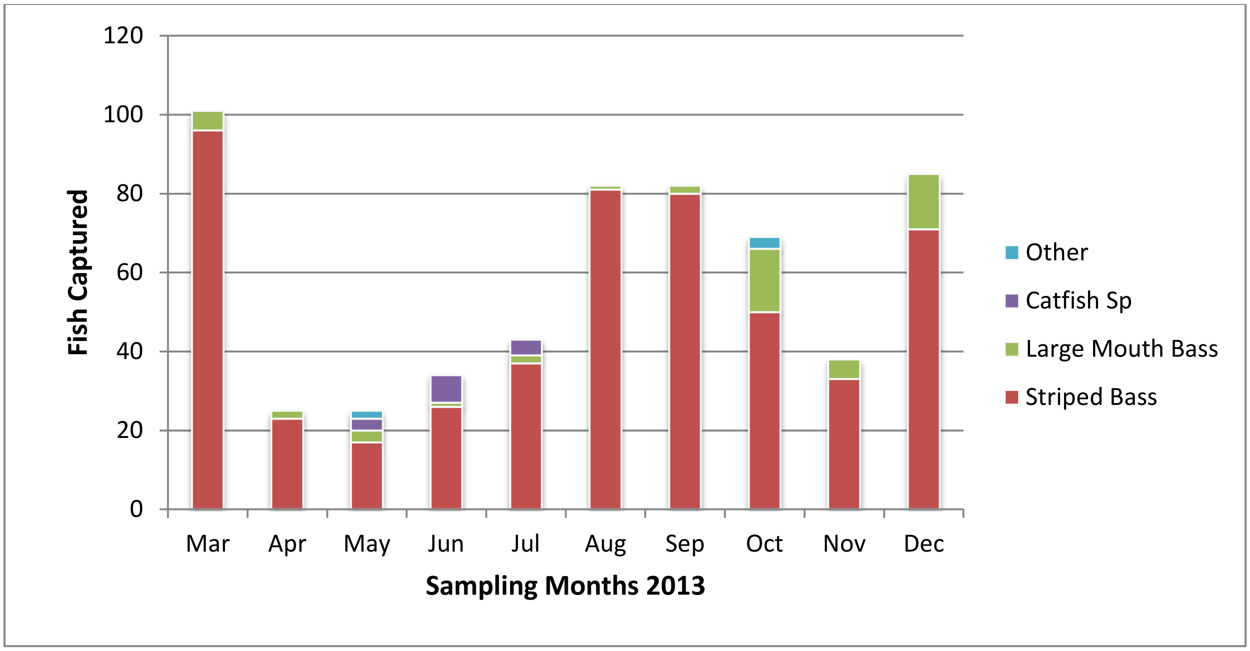

Figure 6: 2013 Predatory Fish Captures by Month

Fish captured during the 2013 effort ranged from 0.20 lbs (0.09 kg) to 10.05 lbs (4.56 kg) for Striped Bass, 0.40 lbs (0.18 kg) to 8.30 lbs (3.76 kg)for Largemouth Bass and 0.90 lbs (0.41 kg) to 7.05 lbs (3.20 kg) for catfish (Figure 7).

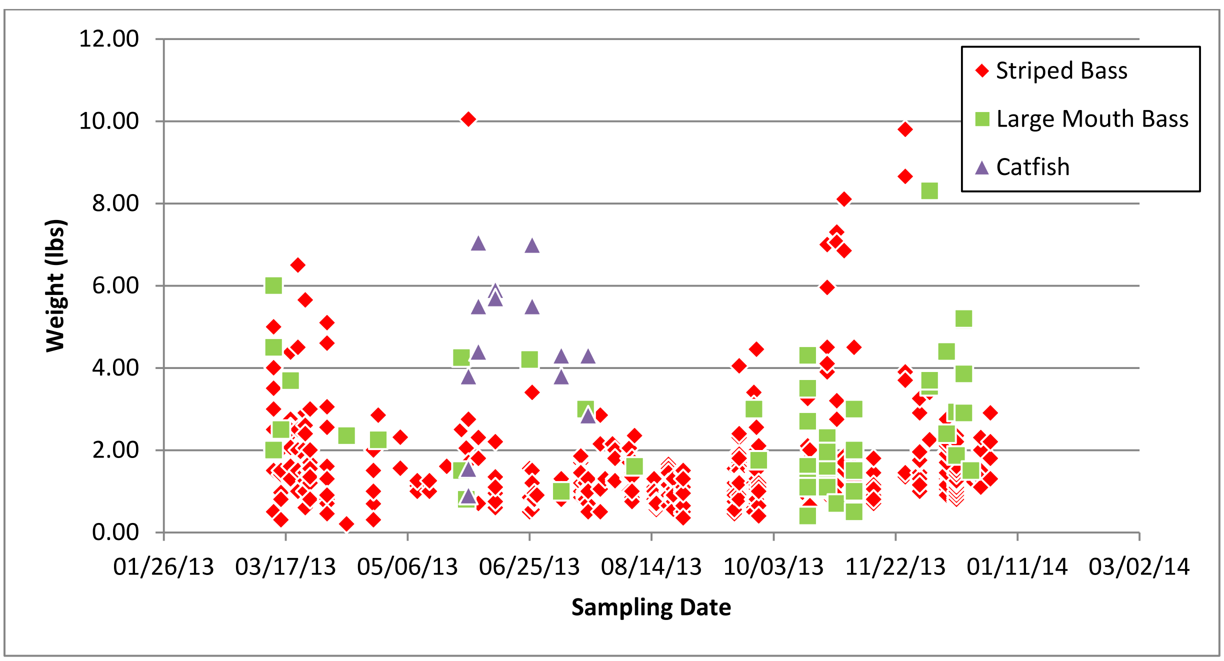

Figure 7: 2013 Predatory Fish Captures by Weight and Species

The majority of Striped Bass captured in 2013 at 55% of total catch, were in the 0.5 lbs (0.23 kg) to 1.5 lbs (0.68 kg) size class, with the highest catch of those fish occurring in August and September, at 65 and 52 fish respectively (Table 9, Figure 8). Fish in the 1.5 lbs (0.68 kg) to 3 lbs (1.36 kg) size class represented 35% of total Striped Bass catch, with the highest number captured in March at 55 fish, with the second highest catch occurring in December, at 32 fish. Fish over 3 lbs (1.36 kg) represented 8% of the total Striped Bass catch, with the bulk captured in March, at 14 fish, with the second highest catch occurring in October, at 10 fish.

Table 9: 2013 Striped Bass Captures by Size Class

Month	Fish <.5 lbs (0.23 kg)	Fish >.5 lbs(0.23 kg) and <1.5 lbs(0.68 kg)	Fish >1.5 lbs (0.68 kg) and <3.0 lbs (1.36 kg)	Fish >3.0 lbs (1.36 kg)
March	1	26	55	14
April	3	9	8	3
May	0	7	9	1
Jun	0	19	6	1
Jul	0	26	10	0
Aug	4	65	11	0
Sept	2	52	22	4
Oct	0	26	14	10
Nov	0	15	9	8
Dec	0	38	32	1
Total for Year	10	283	176	42

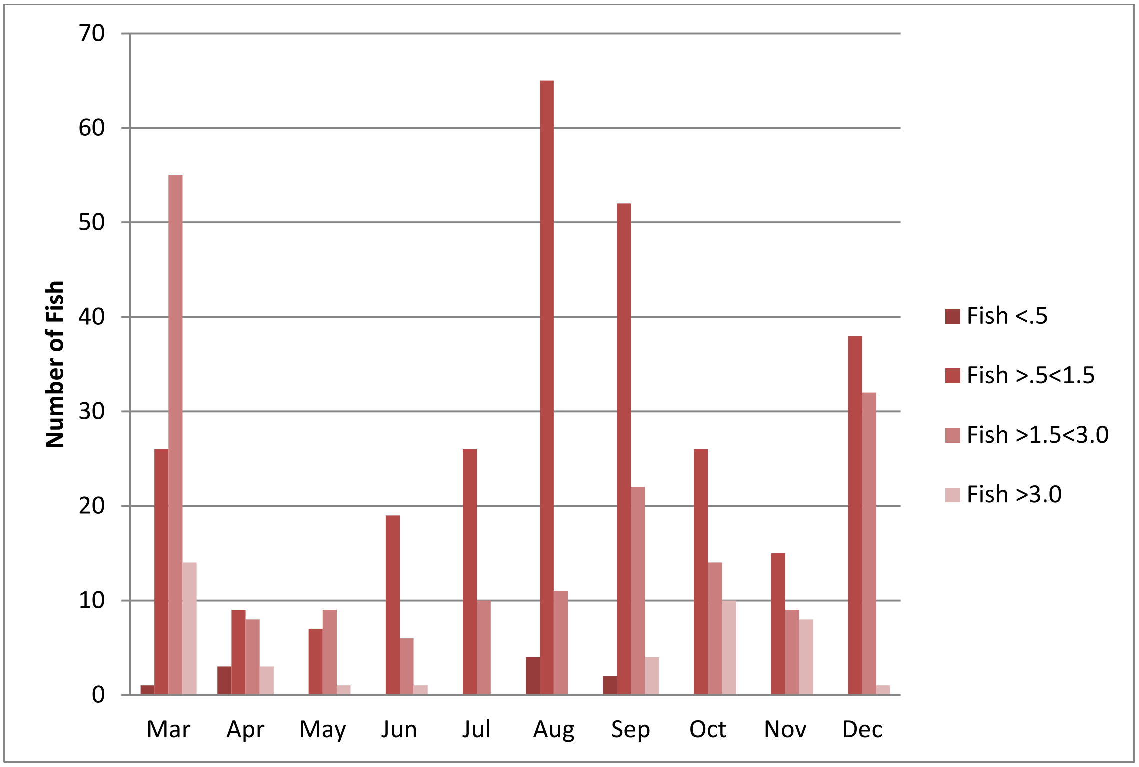

Figure 8: 2013 Striped Bass Captures by Size Class (lbs)

The August peak in capture of small (0.5 lbs/0.23 kg to 1.5 lbs/0.68 kg) Striped Bass coincided with a peak in temperature (Figure 9).

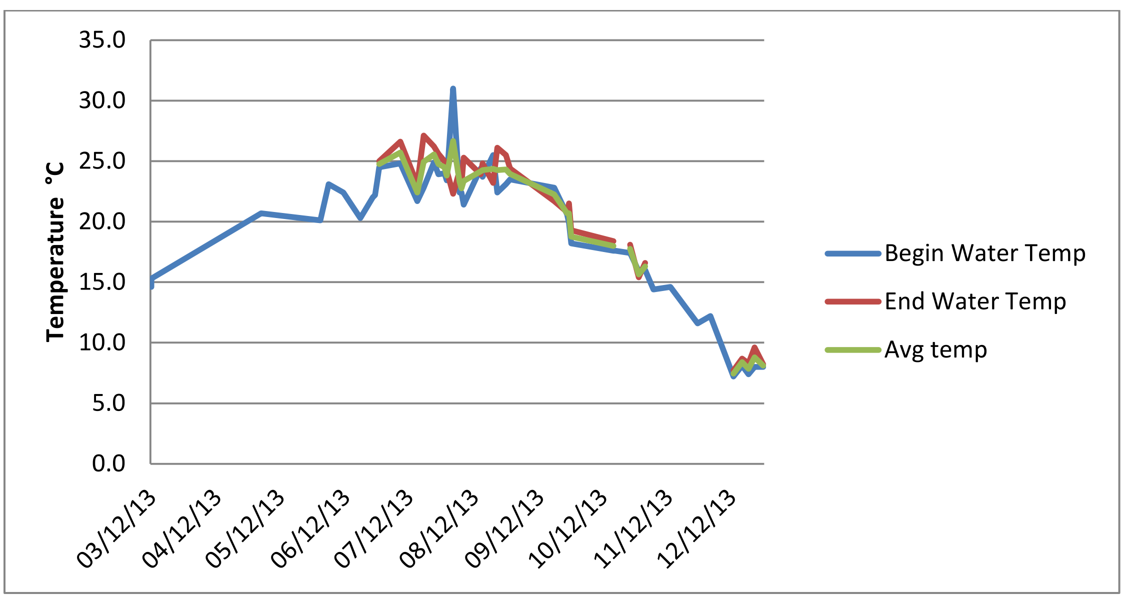

Figure 9: 2013 Sampling Effort Temperatures (°C)

Predatory fish were caught in Areas 1, 2 and 4 during the winter sampling period (Figure 10), with the bulk being caught in Area 2, at 53 fish.

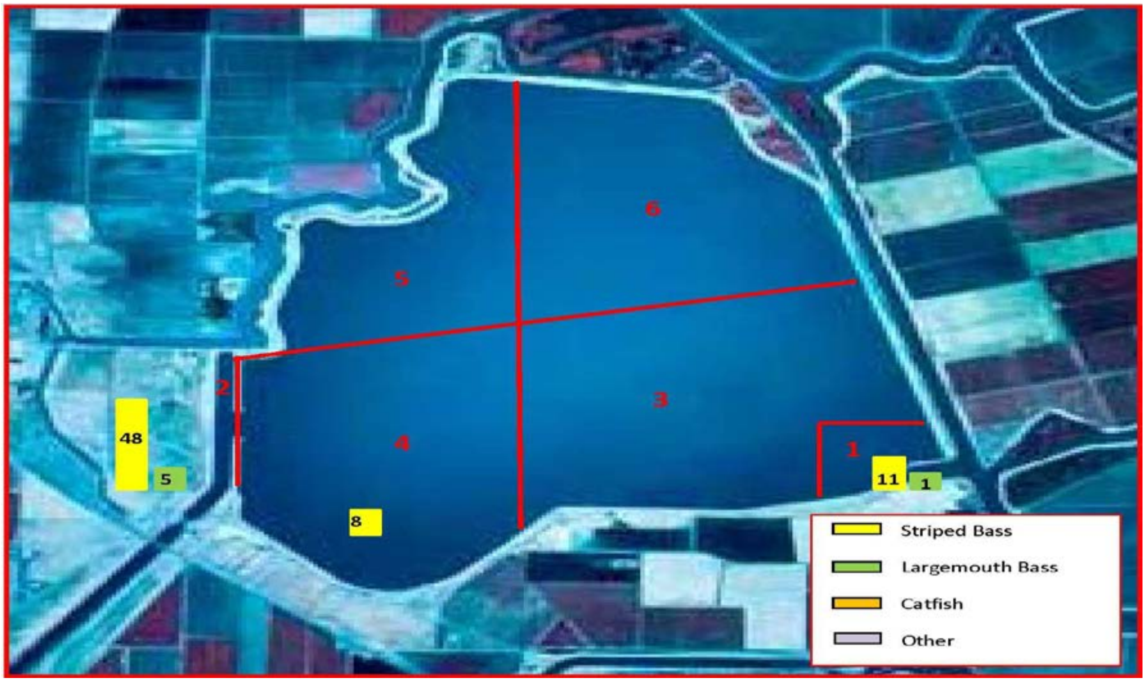

Figure 10: Winter 2013 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3 and 4 during the spring sampling months of April through June (Figure 11), with the bulk being caught in Area 2, at 49 fish.

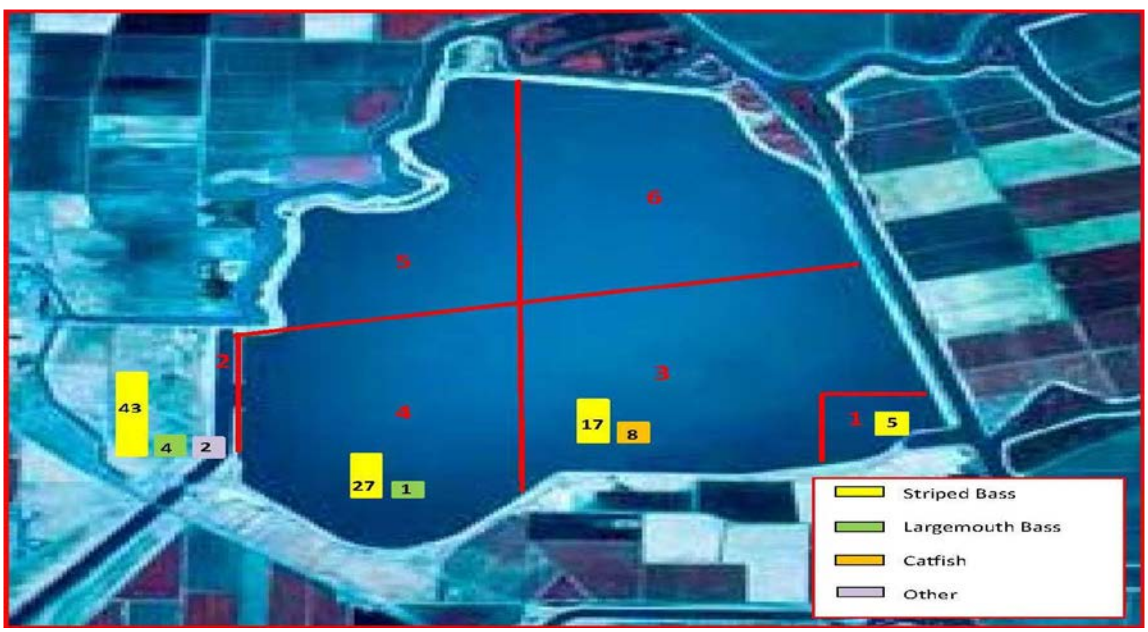

Figure 11: Spring 2013 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, 4 and 5 during the summer sampling months of July through September (Figure 12), with the bulk being caught in Area 2, at 98 fish.

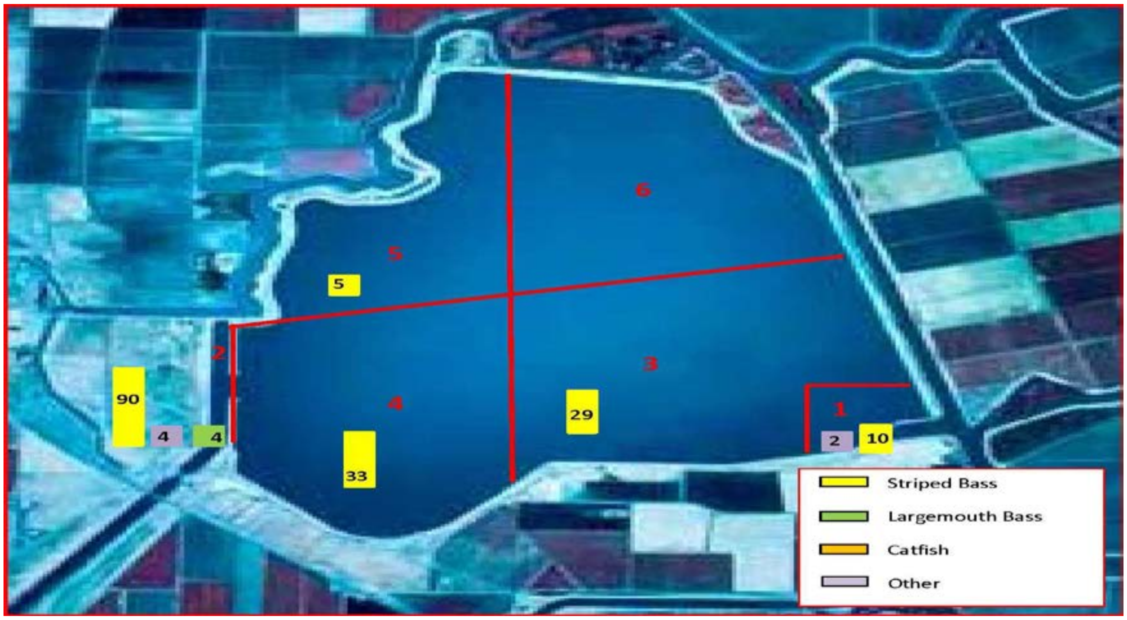

Figure 12: Summer 2013 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, and 4 during the fall sampling months of October through December (Figure 13), with the bulk being caught in Area 1, at 104 fish.

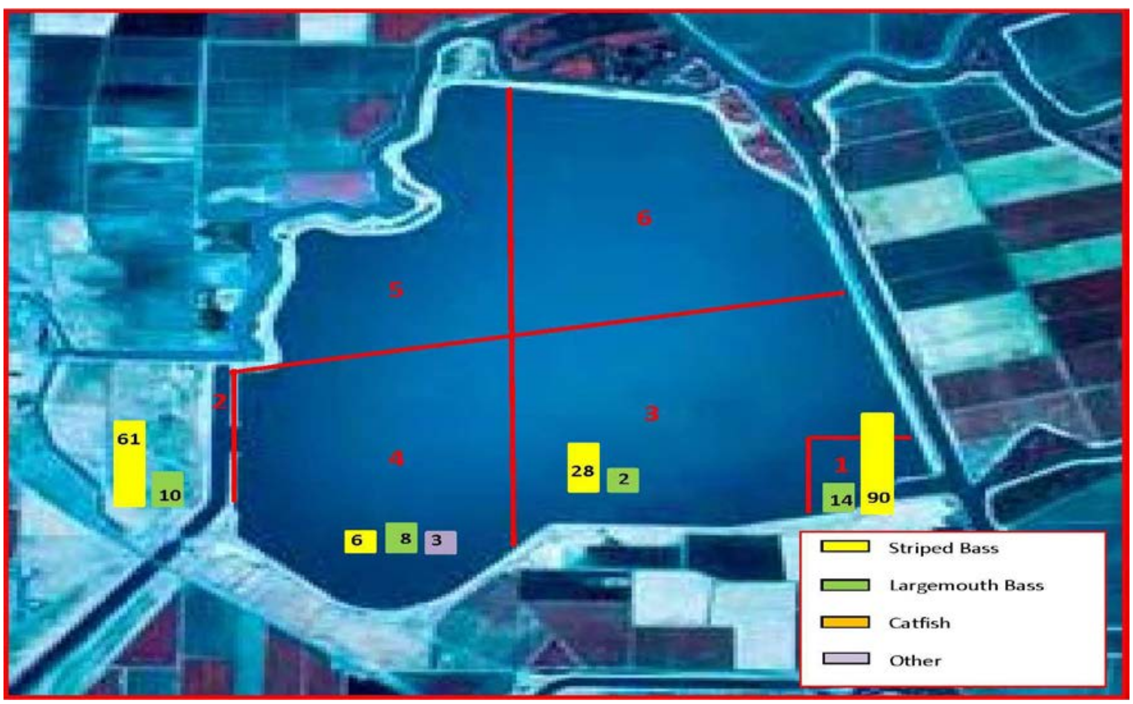

Figure 13: Fall 2013 Catch by Location and Species

CPUE per sampling day was calculated using the equation: $q = \frac{c}{f \times a}$. Mean CPUE per month was then estimated by: $q_m = \frac{\sum q_i}{d}$ (Table 10).

Table 10: Catchability (CPUE) for all Species Combined

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean	0.85	0.62	0.27	0.39	0.5	0.77	1.13	1.04	0.79	0.99
Single Sample Day	0.64	1.43	0.4	0.61	0.67	0.67	1.17	1.16	0.62	0.78
	1.10	0	0.19	0.71	0.65	0.58	1.00	1.10	0.89	0.51
	1.50	0.87	0.12	0	0.23	2.1	0.52	0.90	1.09	2.03
	0.95	0.19	0	0.46	0.22	1.87	2.14	1.02	0.58	0.85
	0.89	-	0.35	0.15	0.74	1.23	0.81	-	-	1.70
	-	-	0.3	-	-	1.35	-	-	-	1.79
	-	-	0.53	-	-	1.02	-	-	-	0.2
	-	-	-	-	-	0	-	-	-	0.62
	-	-	-	-	-	-	-	-	-	0.44

Seasonal CPUE was calculated for the four seasons (Table 11) defined as Winter (Jan 1 – March 19; December 21-31), Spring (March 20 – June 20), Summer (June 21 – September 21), and Fall (September 22 – December 20).

Table 11: Catchability (CPUE) for all Species by Season

Season	Sampling Days	Seasonal CPUE
Winter (Dec 21 – 31 and Jan 1 - Mar 19)	5	1.07
Spring (Mar 20 - Jun 20)	16	0.59
Summer (Jun 21 - Sep 21)	19	0.72
Fall (Sep 22 - Dec 20)	16	1.05

Mean monthly CPUE was then calculated for each species using the equation[3]:

$$q_{sp} = \frac{\Sigma\left(\frac{Csp}{f \times a}\right)_i}{d}$$

CPUE was found to be highest for Striped Bass in March, at 1.18 fish per hour, followed by September and August at 1.10 and 0.98 respectively (Table 12). For Largemouth Bass, CPUE peaked in October, at 0. 08 fish per hour, and for catfish, CPUE peaked in July at 0.22 fish per hour.

Table 12: Monthly Catchability (CPUE) By Species

Monthly CPUE	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Striped Bass	1.18	0.80	0.23	0.36	0.40	0.98	1.10	0.90	0.74	0.88
Largemouth Bass	0.04	0.03	0.07	0.03	0.03	0.02	0.02	0.08	0.07	0.06
Catfish	0.00	0.00	0.00	0.13	0.22	0.00	0.00	0.00	0.00	0.00

[3] See Section 2.3.3 for a full explanation of the CPUE calculation.

2.3.5 Discussion and Recommendations

The 2013 predator sampling effort in the Forebay served multiple purposes, including providing fish for the acoustic tagging studies discussed below, mark/recapture studies using non-acoustic tags such as PIT and Floy tags to investigate population size and gather basic data for future bioenergetics modelling, and to investigate species catchability and seasonal distribution in the Forebay.

The largest numbers of predatory fish were captured in March, with a second peak in total catch occurring in the months of August and September. This pattern was mirrored in total Striped Bass catch, but the distributions were shifted for the three primary size classes investigated. The largest size class of Striped Bass (over 3.0 lbs/1.36 kg) was captured in all sampling months except July and August, with total numbers caught peaking in October and November, indicating that the largest Striped Bass may be leaving the Forebay in the summer months, then returning in the Fall and Winter. The next smaller size class Striped Bass, between 1.51 lbs (0.68 kg) and 2.99 lbs (1.36 kg), were caught in every month sampled, peaking in March and then again in September and December. The size class Striped Bass, between 0.5 lbs (0.23 kg) and 1.5 lbs (0.68 kg) were caught in every month sampled, with a peak in August and September. Striped Bass under 0.5 lbs (0.23 kg) were only captured in March, April, August and September. Throughout the year this size class dominated all but two of the sampling months, March and May, and represented 56% of the total Striped Bass catch for the year. This may be indicative of a thriving population of smaller Striped Bass, including fish less than 3.0 lbs (1.36 kg), which remains in the Forebay year round. While there appear to be some trends in seasonality and residency, due to the variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, and gear selection, these trends need more robust examination before a strong conclusion can be drawn. Residency can be more thoroughly investigated using biotelemetry, as described below.

The overall catch and peak catch for Largemouth Bass and catfish were different than those of Striped Bass, with Largemouth Bass caught in every month sampled, peaking from October through December, with an increase noted in March as well. Catfish were only caught during the months of May, June and July, and very few catfish were caught during the sampling effort. This, however, is not necessarily indicative of a small or strongly seasonal catfish population. Kano (1990) showed a very large population of White Catfish present throughout the year in 1983-1984, and catfish continued to be caught by anglers interviewed for creel throughout 2013. It is likely that variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, gear selection, and limitations in other available capture methods that are known to target catfish significantly affected ability to catch catfish. Kano (1990) employed hoop nets that were deployed for long periods of time, and greatly increased his ability to capture catfish. This technique is not currently available to this project.

It is important to note that sampling was not conducted during the first two months of the year, due to issues discussed in the above issues section, and as such, the data for the winter months is incomplete. March of 2013 had the highest Striped Bass catch of the study period, with a CPUE of 1.18 for Striped Bass, and a CPUE of 0.85 for all species. The following December had a comparable all-species CPUE at 0.99, and a Striped Bass CPUE of 0.88. It is not possible to know what January and February of 2013 would have shown for catch and CPUE, but those two months are important for collecting and analyzing data as they are within the outmigration season for juvenile Chinook salmon and steelhead.

While there do appear to be some seasonal trends in catch by species and size class, the lack of data for January and February, as well as limitations with sampling access due to a variety of issues, including boat access and SAV, it is important to collect more data over several years to determine if these trends are significant. Additionally, the apparent seasonal shift in location of the catch was biased by the limited accessibility during times when a boat could not be used due to poor conditions on the Forebay or the lack of access to a boat. Shore sampling is restricted in access to primarily area 2, with some limited access to areas 1 and 4. Although other areas, including 3, 5 and 6 can technically be reached via the shore, in general those areas are not fishable due to the extent of the shallow water, thickness of weeds and prevailing wind direction making casting very difficult and limited in distance. As such the bulk of the fish that are captured during shore sampling efforts were in area 2, which may bias the catch in species and size class availability. We recommend that shore sampling and boat sampling continue to be indicated within the data taken in future years so that the level of effort can be better addressed for differential catch. Additionally, sampling should be conducted consistently throughout all months of the year, as originally proposed in the study plan, to adequately evaluate the seasonality of the catch. In addition, angling methods to target catfish should be reevaluated for future study years to maximize catfish capture. It is also recommended that additional sampling techniques be pursued, such as electro-fishing, or use of other styles of nets and/or seines.

We also recommend that use of the gill net be reevaluated as a tool for gathering additional population size and distribution information, in conjunction with study elements that are not adversely affected by the resulting condition of the fish. We recommend that the gill net be employed at least twice per month for the genetics study planned to begin in 2014, as the study element will not be adversely affected by injuries sustained using this method of collection. .

2.4 Biotelemetry

2.4.1 Methods

Placement of an acoustic receiver array was initiated in 2012 to track the tagged predators (and salmon) described in previous sections of this report. Due to the amount of lead time anticipated for temporary entry permit (TEP) acquisition for units planned on properties not owned by DWR, the array was designed to be deployed in phases. The initial phase consisted of nine units within and immediately adjacent to the Forebay. These nine units were placed at the following locations IC1, IC2, IC3, RGD1, RGU1, WC1, WC2, WC3 and ORS1 (Figure 14). These locations were selected to provide data regarding directionality of movement relative to the radial gates as well as for determining immigration and emigration into and out of the Forebay, and movement toward and away from the SDFPF. The first nine units were installed between January and March 2013.

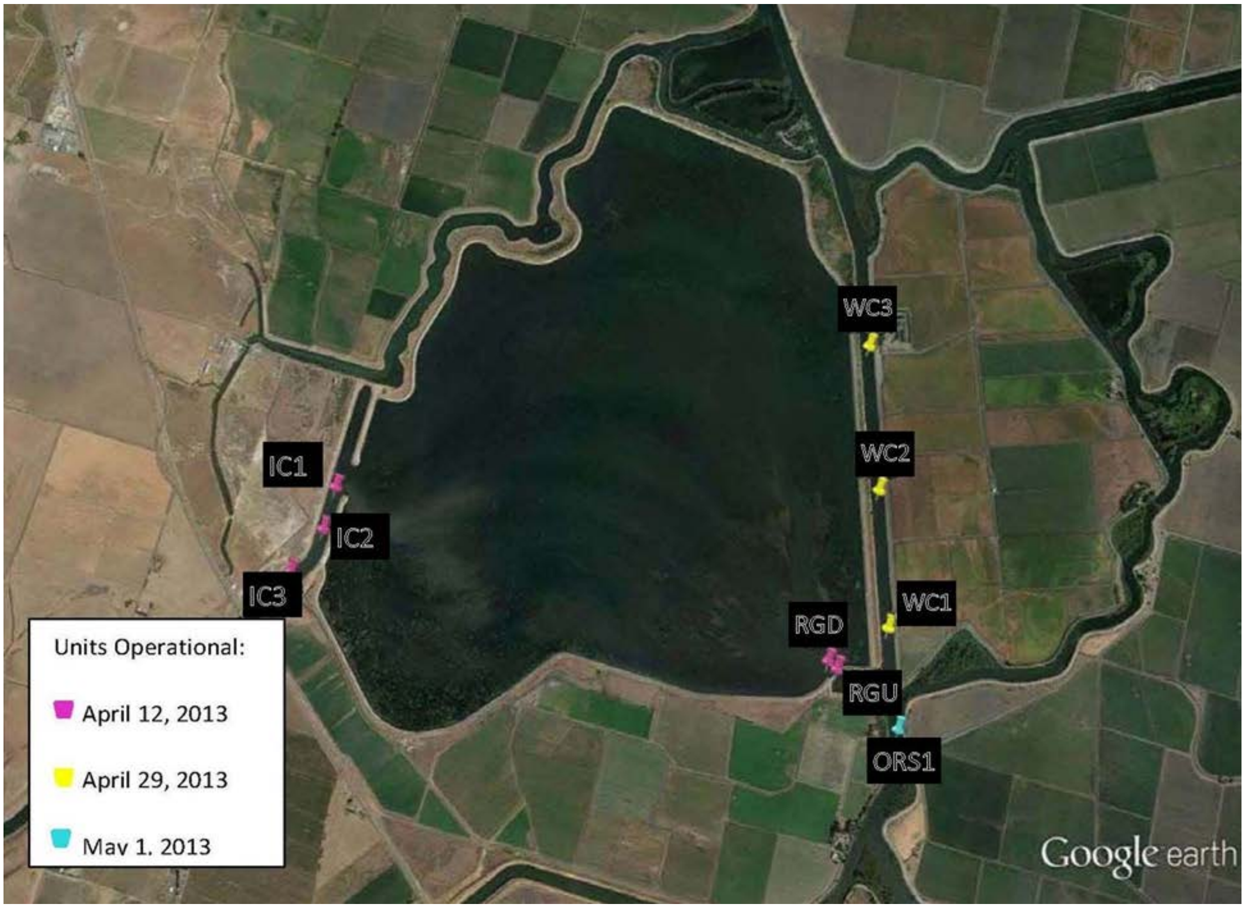

Figure 14: Receiver Array Deployed in 2013

Each of these units was deployed using an HTI Model 295x datalogger, powered by a 12-volt (two six-volt sealed deep cycle batteries wired in series) connected to a solar panel to ensure continued operation (Figure 15). A beacon tag was deployed near each hydrophone to document ongoing functionality of the unit.

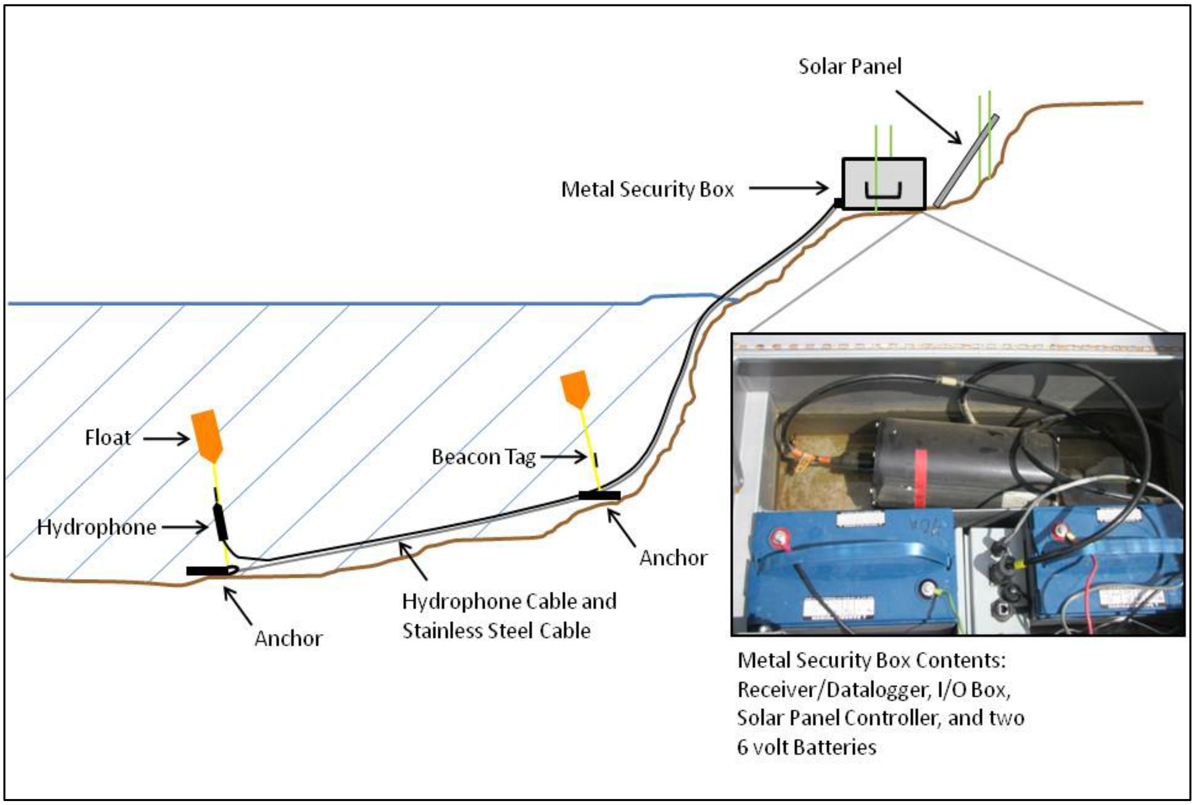

Figure 15: Model 295x Receiver Site Schematic

The phase one locations were all fully operational by May 1, 2013, with the first five (IC1, IC2, IC3, RGU1, and RGD1) collecting data beginning on April 12, 2013, the second three (WC1, WC2, and WC3) on April 29, 2013, and the last location (ORS1) on May 1, 2013(Depicted in pink, yellow and blue respectively; Figure 14). Once all locations were operational and collecting data, daily maintenance visits were initiated with data downloaded once per week, when possible.

Tag codes for 2013 were predetermined by HTI, with sub code 22 for Striped Bass less than 1.5 lbs (0.68 kg), sub code 6 Striped Bass over 1.5 lbs (0.68 kg), and sub code 1 for non-Striped Bass (catfish and black bass species). At the beginning of each month, up to seven HTI 795LG/ Biomark HPT9, 17 HTI 795LY/ Biomark HPT9, and seven HTI 795LZ/ Biomark HPT9 acoustic/PIT combination tags were programmed with codes from the lists provided by HTI. Tags that were not used the prior month were rolled forward into the new month. Following tag programming, each tag was checked for functionality via a tag “sniffer” or a hydrophone attached to an HTI 395 mobile data logger. Up to 31 predatory fish captured during the sampling efforts that were larger than 0.5 lbs (0.23 kg) were tagged with HTI/ Biomark combination acoustic/PIT tags as well as a secondary external Floy tag (Table 13).

Table 13: Maximum Number of Predatory Fish to be Acoustically Tagged Each Month.

HTI Tag Type	Fish Size Range lbs(kg)	Striped Bass	Black Bass	Catfish	Total Tags per Month
795LG – sub code 22	>0.5 (0.23) to <1.5 (0.68)	7	0	0	7
795LY – sub code 1 (non-Striped Bass); sub code 6 (Striped Bass)	>1.5 (0.68) to <3.0 (1.36) (Striped Bass) >1.5 (0.68) (non-Striped Bass)	7	5	5	17
795LZ – sub code 6	>3.0 (1.36)	7	0	0	7
Total Fish per Month		21	5	5	31

Internal tagging followed procedures based on methods described in Wingate and Secor 2007, and incorporated the use of new anesthesia methods as part of the INAD for Aqui-S 20E (USFWS 2011; Study #'s 11-741-13-243E, 11-741-13-177F, 11-741-13-176F, 11-741-13-175F, 11-741-13-174F, 11-741-13-039, 11-741-13-013, 11-741-13-040, and 11-741-13-012). All captured predatory fish that were not acoustic tagged, were tagged with Biomark HPT9 PIT tags so that they could be identified in the event of recapture or salvage.

Acoustic tagging was conducted on 33 predator sampling days, at various times during the day from May 3, 2013 until December 27, 2013. Initially, only acoustically tagged fish were fitted with secondary external Floy tags (model FM-84 Laminated Internal Anchor Tags) applied via a small incision placed on the opposite side of the abdomen from the surgical incision. However, following the discovery of a PIT tagged fish (in this case a salmon) within a captured predator and subsequent investigation into the potential for PIT tag signal collision resulting in false negatives, secondary external Floy tags were applied to all captured fish.

To minimize invasiveness of the external marking procedures, the Floy tag model was switched from a single FM-84 Laminated Internal Anchor Tag to the less invasive FD-68B T-Bar Anchor (applied to the dorsal side of the fish via injection). To minimize the potential loss of visible tags from tag shedding, two Floy tags were applied to each fish, one on either side of the dorsal fin. After the fish was tagged, scale samples were taken, and the fish was placed into a recovery net at the point of capture, and monitored until swimming normally. Once the fish was deemed fully recovered it was released.

2.4.2 Issues

Installation of phase one of the receiver array was initially planned to begin on January 9th, 2013, however due to scheduling conflicts, limitations in available trained and qualified boat crews, and the changes in SWP coordination protocols and call-in procedures, installs were delayed significantly. Once the new SWP procedures were in place, EROF's for the receiver install work were submitted, and WCA's were received on March 25th, 2013. Installation of the first nine receivers was initiated on April 5th, 2013.

Acoustic tagging required surgical technique training and at the inception of the project, only one fully trained and experienced tagger was available, making scheduling of tagging efforts challenging. Training sessions to bring additional taggers onto the project were initiated in March.

A comprehensive list of tag codes for the acoustic tags was provided by HTI at the beginning of the sampling year. This code list included specific sub codes that were pre-designated to differentiate the categories of fish receiving tags as part of the CCFPS. These sub codes allow for quick identification of the fish from different studies and expand the number of unique codes that can be used in the greater Delta for concurrent studies. During initial tag programming, a group of 22 tags were coded without the sub code and subsequently placed in fish that were released into the system. The mistake was identified, procedures for programming and double checking tags were refined, and a glitch in the software was identified and corrected to prevent further release of tags without sub codes. Unfortunately, for the life of the 22 tags released, the main tag codes have been rendered unusable by any other studies in the Delta region.

The initial receiver array was made up of older model HTI 295 dataloggers, which were not sync-able to one another, required physical visits to check, download data, and conduct maintenance. Several of the units also experienced multiple failures, which resulted in limited data loss and gaps in the overall data set. Furthermore, access problems resulting from a significant structural failure resulting in one of the radial gates becoming dislodged and subsequent construction, as well as boat access problems such as loss of navigability during times of high SAV load, and lack of access to qualified boat operators, led to some units not being checked and downloaded as often as was preferred and caused delays in correcting problems when identified.

2.4.3 Data Analysis

All tagging data were recorded onto Rite-in-Rain datasheets that were scanned onto the DWR server and transcribed into an excel spreadsheet. Release dates and times for each acoustic tagged fish were sent to HTI on a weekly basis. Tags were identified by tag type so that they can be removed from the search list as their batteries, which have different lifespans based upon type, reach the end of life. Data downloaded from the acoustic receivers was transferred to HTI staff via jump drive and analyzed when they returned to their office in Seattle.

Data was analyzed by uploading each hour long file from each receiver into the MarkTags® software and identifying tags that had been detected by the hydrophone. Each tag signature identified by the software has a visual beginning and end which are marked via electronic bookmarks and show which tag and what time it was detected (Figure 16). This information was initially processed by an automated program and then verified by trained technicians.

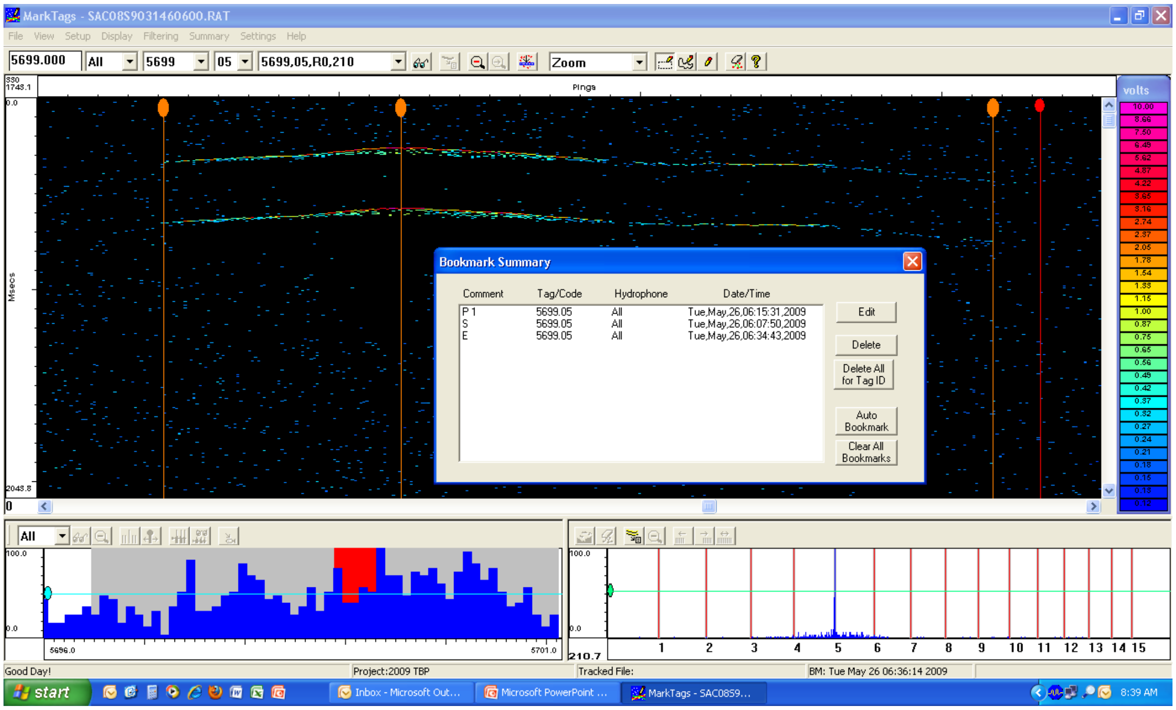

Figure 16: MarkTag Screenshot Displaying a Tagged Fish (2009 K. Clark)

Once analysis via MarkTags® was complete, the acoustic data was placed into a database which allowed for a secondary quality control phase, consisting of checking for tags that appeared to be detected by any hydrophone prior to release. Following verification of the data, the database was fully populated and returned to DWR. The database allowed for determination of the first and last detection of each tagged fish at each receiver location. By looking at all of the receiver stations chronologically, a tagged fish can be “observed” as it moves through the array over time. This can be further visualized using programs such as EON fusion (Figure 17).

A list of acoustic tags released into the Forebay was compiled and compared to a list of acoustic tags detected by the receivers in the array. Then each tag confirmed as being detected in the array was analyzed for first and last detection at each receiver, so that gross movement through the array as well as movement across, into and out of the Forebay, could be identified.

Figure 17: ScreenShot of EONFusion tracks showing Acoustically Tagged Fish at the Tracy Fish Facility

2.4.4 Results

A total of 149 predatory fish were acoustically tagged; eight catfish, 18 Largemouth Bass, and 123 Striped Bass (Table 14). The target number of 31 acoustically tagged fish per month was never achieved during 2013 tagging efforts. The highest number of acoustically tagged fish occurred in October and the lowest number occurred in May, at 26 and 12 fish, respectively. Of the 149 total tagged fish, 10 were never detected by any of the receivers in the array, including two Largemouth Bass and eight Striped Bass. As these fish were not necessarily tagged and released within range of the deployed receivers, it is possible that a fish could be active in the Forebay, but never be detected. Since no mobile monitoring was conducted in 2013, it was not possible to detect fish outside of the range of the array.

Table 14: Acoustic Tagged Fish in 2013

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass	1	1	1	1	2	5	2	5	18
Catfish Species	1	5	2	0	0	0	0	0	8
Striped Bass (LG)	2	8	7	7	7	7	6	7	51
Striped Bass (LY)	7	3	7	7	7	7	7	7	52
Striped Bass (LZ)	1	0	0	0	4	7	7	1	20
All Species	12	17	17	15	20	26	22	20	149

Of the remaining 139 acoustically tagged fish, 16 were detected on receivers inside and outside of the Forebay, indicating that they emigrated from the Forebay. Of those 16 fish that emigrated, two returned to the Forebay at a later date in 2013 (Table 15).

Table 15: Acoustic Tagged Fish Detected Outside of Forebay

				Date Detected Inside Forebay				Date Detected Outside Forebay				
Species	Tag Number	Location Captured/ Released	Date Released	Intake Canal 3	Intake Canal 2	Intake Canal 1	Radial Gates Downstream	Radial Gates Upstream	West Canal 1	West Canal 2	West Canal 3	Old River South 1
Largemouth Bass	9015.01	Area 2	5/28/2013	5/28/2013	5/29/2013	5/31/2013	6/28/2013	6/30/2013				6/30/2013
Striped Bass (LY)	6221.06	Area 4	5/30/2013	6/5/2013	6/5/2013	6/5/2013	6/2/2013	6/28/2013	6/28/2013	6/28/2013	6/28/2013	7/9/2013
Striped Bass (LG)	7909.22	Area 3	5/30/2013	**11/2/2013**	9/16/2013	9/16/2013	5/30/2013	9/17/2013	9/17/2013			
Striped Bass (LY)	6529.06	Area 3	5/31/2013	6/19/2013	6/9/2013	6/9/2013	5/31/2013	9/23/2013	11/4/2013	11/4/2013		
White Catfish	8119.01	Area 3	5/31/2013		6/17/2013	6/17/2013	5/31/2013	6/28/2013	6/28/2013	6/28/2013	6/28/2013	6/28/2013
White Catfish	6523.01	Area 3	6/4/2013				6/5/2013			10/14/2013		
Channel Catfish	6775.01	Area 3	6/11/2013				6/11/2013	7/1/2013	7/1/2013	7/1/2013	7/1/2013	7/1/2013
Striped Bass (LG)	9785.22	Area 3	6/11/2013				6/11/2013	7/2/2013	10/12/2013	10/14/2013	10/12/2013	7/2/2013
Striped Bass (LY)	6501.06	Area 2	6/11/2013	6/21/2013	6/19/2013	6/19/2013	6/15/2013	6/29/2013	6/30/2013			6/30/2013
Striped Bass (LY)	6025.06	Area 1	6/26/2013	6/27/2013	6/27/2013	6/27/2013				6/29/2013		
Striped Bass (LG)	6845*	Area 3	8/6/2013	8/16/2013	8/13/2013	8/12/2013	8/17/2013	8/26/2013	8/26/2013			
Striped Bass (LG)	7097*	Area 3	8/6/2013				8/6/2013	8/13/2013	8/13/2013			
Striped Bass (LZ)	9525.06	Area 3	9/25/2013		9/27/2013	9/27/2013	9/28/2013	10/30/2013	10/30/2013	10/30/2013	10/30/2013	
Striped Bass (LZ)	5857.06	Area 3	10/17/2013	10/19/2013		10/19/2013	10/17/2013	11/4/2013	11/4/2013	11/4/2013	11/7/2013	
Striped Bass (LY)	6165.06	Area 1	10/18/2013	10/30/2013	10/30/2013	10/30/2013	10/24/2013	11/2/2013	11/30/2013	11/30/2013	12/3/2013	
Striped Bass (LY)	7481.06	Area 1	11/5/2013			**11/23/2013**	11/5/2013	11/10/2013	11/10/2013	11/11/2013	11/13/2013	

*Tags programmed without subcode; bold red type and grey highlight indicates fish that returned to the Forebay

Of the 139 tagged fish that were detected, 29 were only detected in the intake channel, 32 were only detected at the radial gates, 14 were detected moving from the intake channel to the radial gates, 13 were detected moving from the radial gates to the intake channel, 35 were detected moving back and forth between the intake channel and the radial gates, and 16 were detected outside of the Forebay. The single recaptured Striped Bass was caught in the vicinity of the radial gates, which is the same general location of its original capture, although the fish was detected in the intake canal as well, indicating that it moved back and forth across the Forebay.

2.4.6 Discussion and Recommendations

Of the 149 tagged predatory fish, ten remained undetected by the receiver array. Based upon the fish that were detected, several behavioral patterns are beginning to emerge as the acoustic data is compiled and analyzed. Of the 139 tagged fish, approximately 44%, 61 fish, were only detected in a single location, either the intake channel or the vicinity of the radial gates, and approximately 44%, 62 fish, were detected moving between the intake channel and the radial gates, in either one direction or back and forth. The remaining approximately 12%, 16 fish, were detected leaving the Forebay. Of this 16 fish, two returned to the Forebay.

The 2013 data set shows immigration and emigration as well as residency, both localized, remaining in a specific portion of the Forebay, as well as more broad roving behavior, moving multiple times across the Forebay. The tags employed in this project will continue to provide data for up to three years per individual fish, allowing for a much better picture of these behaviors over time. The data set expressed in this interim report shows a limited picture in that the fish detected have not all been in the system for the same amount of time, and no tags have been in the system for more than eight months. For instance, fish tagged in November or December have only been detectable for one to two months, not long enough to discern their short-term or ultimate behavioral strategies. It is important to note that currently this data set is very limited in its scope as these tags are intended to provide long term data on individual fishes, allowing for a better understanding of movement behaviors over multiple seasons and years.

The current receivers deployed within and adjacent to the Forebay will be upgraded to units that can be remotely monitored and time synced for improved accuracy, and the balance of the array will be deployed in subsequent years. A sub-set of predatory fish should be held in the lab for the purposes of tag retention studies and tagger quality control, to ensure that the data collected is as accurate as possible. Ten of the 149 fish tagged were never detected following release. It is likely that a fish can remain undetected in the Forebay throughout the study period, if it remains in the central portion of the Forebay, which is outside of the range of the currently deployed array. Therefore, mobile monitoring surveys should be instituted to cover areas of the Forebay that are not currently covered by the array.

2.6 Creel Surveys

2.6.1 Methods

Roaming angler (creel) surveys were planned for three days a week, two week days and one weekend day, and were conducted either in the morning (0900 until noon) or the afternoon (noon until 1600). While anglers can access the Forebay throughout the evening hours as well, no surveys were conducted at night, due to safety concerns. Survey days and time periods were randomly selected by rolling dice, with each side of the die associated with a day or time (Table 19).

Table 16: Creel Survey Selection

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Weekend Day	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday
Time	Morning	Morning	Morning	Afternoon	Afternoon	Afternoon

A total of 80 roaming surveys from the tip of the Fisherman's Point peninsula to the Radial Gates along the public access pathway (Figure 20) were conducted between April 26, 2013 and December 31, 2013.

Figure 18: Creel Survey Route

2.6.2 Issues

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay were changed significantly on the morning of January 25, and all work on the CCFPS was suspended. DFD provided a final procedural guide to the DWR Bay-Delta Office (BDO), and the EROF for creel surveys was filed with DFD in March 2013. Approval for creel surveys was received on March 20, 2013, and the first creel survey did not occur until April 26, 2013 due to logistical complications with initiating the surveys.

Creel surveys were planned to continue year-round from the radial gates to the tip of fisherman's point, however, on July 8, 2013 the radial gates suffered a significant structural failure resulting in one of the gates becoming dislodged. As a result of this structural failure, the area in the vicinity of the radial gates was closed to recreational anglers, while DFD worked to evaluate the extent of the damage and make repairs. Access to the area did not reopen in 2013, and may have resulted in fewer anglers using the Forebay. Surveys were also limited to daylight hours due to safety concerns.

Additional issues with the 2013 effort included a map (Figure 21) that was too divergent from the map used for predator sampling, making the CPUE's incomparable to a great extent. Additionally, the landmarks on the map are hard to distinguish, reducing accuracy of angler placement.

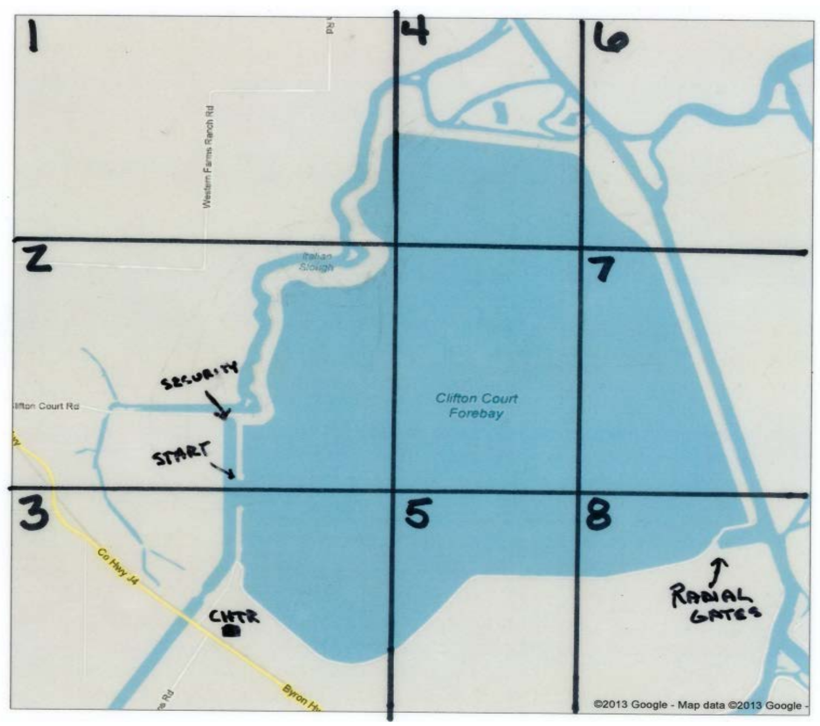

Figure 19: Creel Map 2013

2.6.3 Data Analysis

Data sheets were scanned and data was initially compiled into an excel spreadsheet to ensure that no data became lost while a database was under development. A database for creel surveys was completed in May 2014, and the creel data was transferred from the excel spreadsheet for analysis. Total catch, catch by species, and catch by location for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(*q* = catchability (fish caught per hours of sampling), *C* = catch, *f* = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE for all species per month was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and d = number of sampling days in the month)

Mean CPUE per month was then calculated for each species using the equation

$$q_{sp} = \frac{\Sigma\left(\frac{Csp}{f \times a}\right)_i}{d}$$

2.6.4 Results

A total of 1,191 anglers were observed fishing at the Clifton Court Forebay in 2013. Anglers were found to fish in the greatest numbers on Saturdays and Sundays (Figure 22) and averaged 14 anglers per day throughout the year, with the highest numbers of anglers present in June (Figure 23).

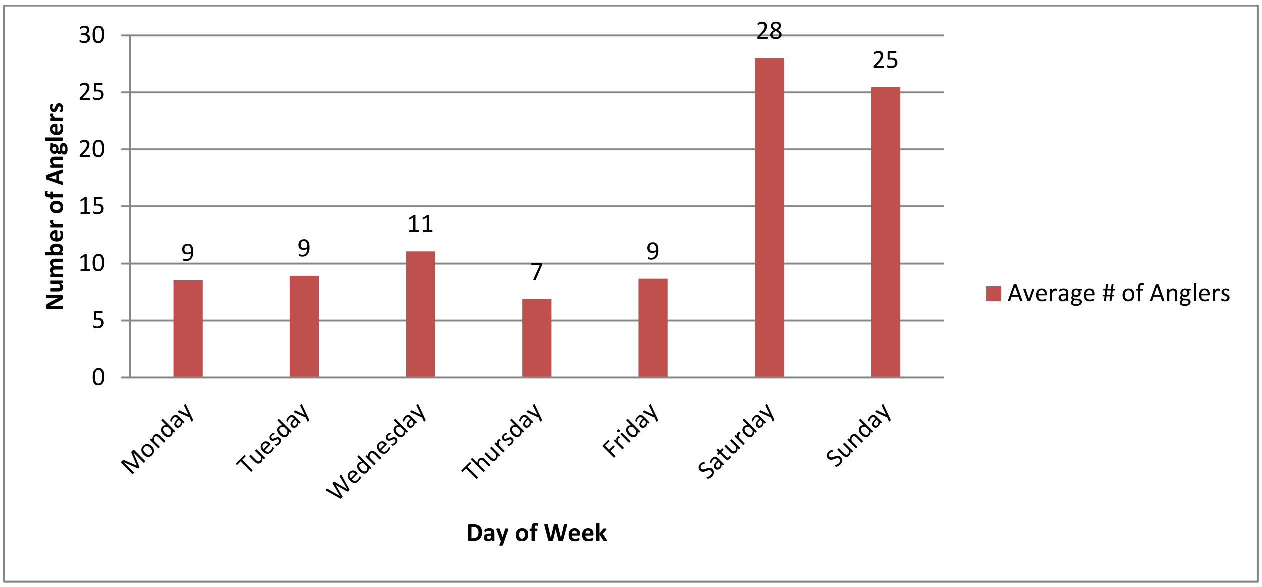

Figure 20: Average Number of Anglers by Day of Week in 2013

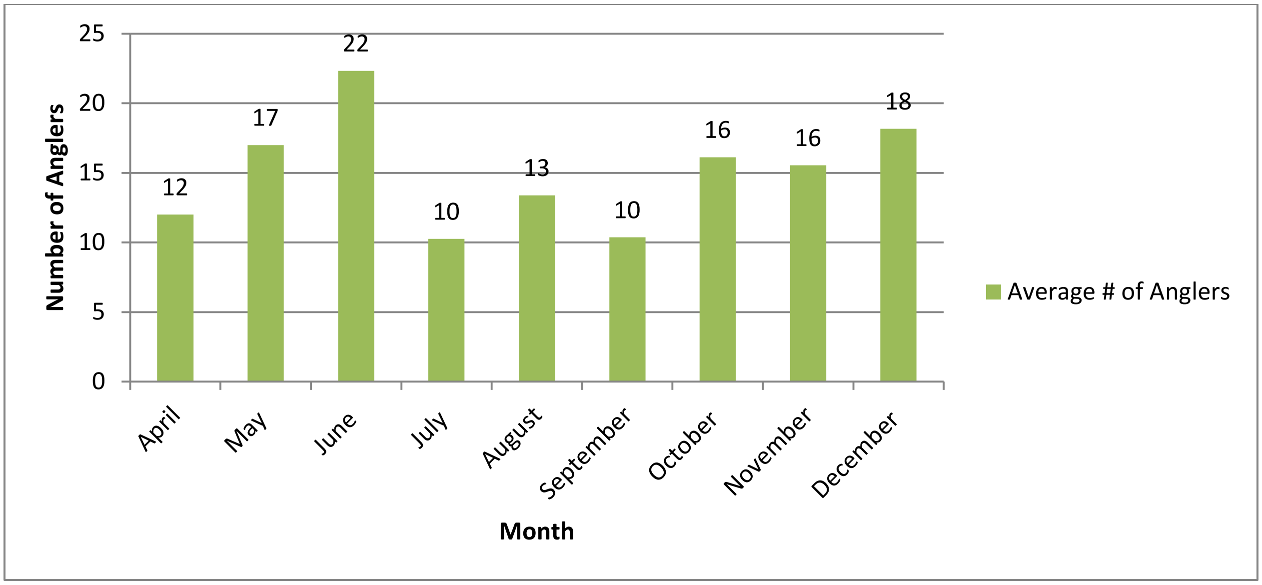

Figure 21: Average Number of Anglers by Month in 2013

Anglers fished a total of 2,806 hours over the survey period, with the greatest number of hours spent in Area 2 and the least number of hours spent in Area 5, at 2,068 and 47 hours respectively (Table 20). The second most frequented fishing location was area 8, at 337 hours. This area was closed to the public during the radial gate repairs, which likely shifted the effort to Area 2. During months when access was available to both areas, such as May and June, hours spent in Area 8 were similar to hours spent in Area 2. Note that although Area 5 is technically closed to the public, there were fishermen observed and surveyed in the area. Five months had eight or fewer surveys conducted, while the remaining four months had greater than 12 surveys conducted (Figure 24).

Table 17: Hours Fished by Month and Location in 2013

Month	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 4 North Center	Area 5 South Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity
Apr	0	3.25	0	0	0	0	30.5
May	0	101.34	0	6	0.66	0	100.57
Jun	4	129.04	0	33.5	0	0	157
Jul	0	78.32	0	4	3	9	40
Aug	12	391.56	14.5	0	0	55.5	5.5
Sep	11.92	234.14	39.75	3.5	36	16	0
Oct	0	246.15	17	0	10	11.5	0
Nov	23.75	492.53	0	0	18	9	3
Dec	0.25	391.4	0	0	0	3	0
Year	51.92	2067.73	71.25	47	67.66	104	336.57

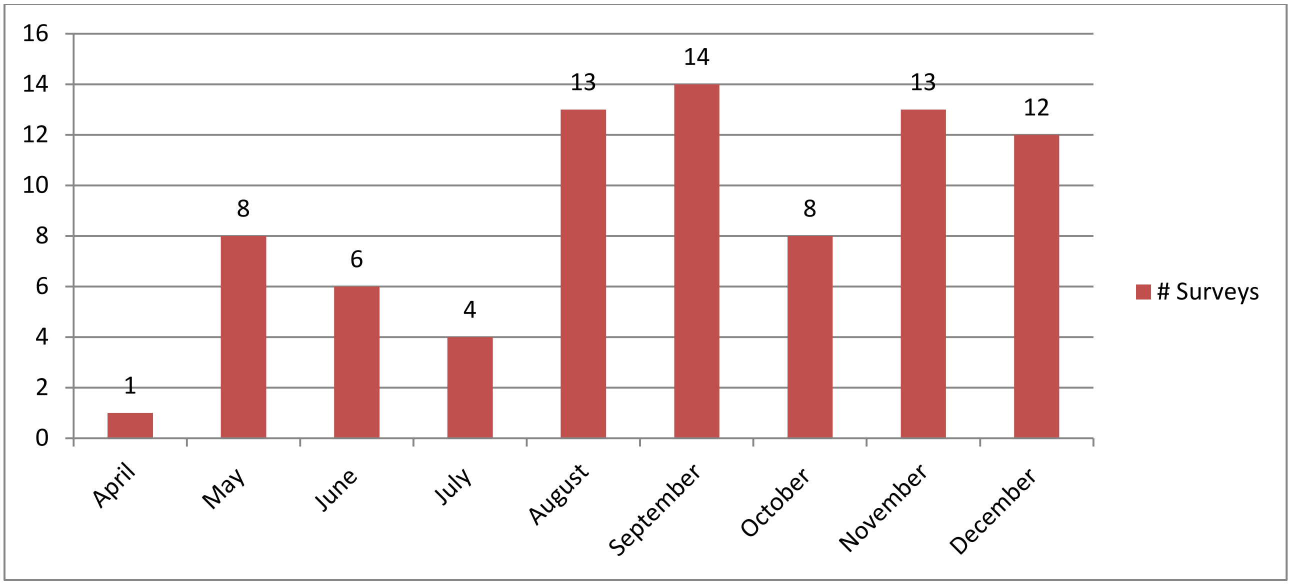

Figure 22: Number of Surveys per Month in 2013

Anglers that were interviewed captured a total of 807 fish during the survey period, with the catch ranging from 11 fish in April to 195 fish in November (Table 21). None of these fish were recaptures.

Table 18: Total Catch by Location and Month in 2013

Month	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 4 North Center	Area 5 South Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity	All Sites Total
Apr	0	0	0	0	0	0	11	11
May	0	18	0	2	0	0	43	63
Jun	2	21	0	8	0	0	88	119
Jul	0	15	0	0	3	1	1	20
Aug	11	70	8	0	0	16	0*	105
Sep	13	65	10	0	3	8	0*	99
Oct	0	87	4	0	0	9	0*	100
Nov	38	154	0	0	3	0	0*	195
Dec	0	95	0	0	0	0	0*	95
Year	64	525	22	10	9	34	143	807

* Radial gate outage and access limited

CPUE was calculated for total catch captured at each location by month, and was found to range from 0.15 in July to 0.37 in June for all sites combined (Table 22). CPUE was highest for Area 1 in September and November, at 1.09 and 1.60, respectively, and Area 6 in July at 1.00 (Figure 25).

Table 19: CPUE by Location and Month in 2013

Month	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 4 North Center	Area 5 South Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity	All Sites Total
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.33
May	0.00	0.18	0.00	0.33	0.00	0.00	0.43	0.30
Jun	0.50	0.16	0.00	0.24	0.00	0.00	0.56	0.37
Jul	0.00	0.19	0.00	0.00	1.00	0.11	0.03	0.15
Aug	0.92	0.18	0.55	0.00	0.00	0.29	0.00*	0.22
Sep	1.09	0.28	0.25	0.00	0.08	0.50	0.00*	0.29
Oct	0.00	0.35	0.24	0.00	0.00	0.78	0.00*	0.35
Nov	1.60	0.31	0.00	0.00	0.17	0.00	0.00*	0.36
Dec	0.00	0.24	0.00	0.00	0.00	0.00	0.00*	0.24
Year	1.23	0.25	0.31	0.21	0.13	0.33	0.42	0.29

*Radial gate outage and access limited

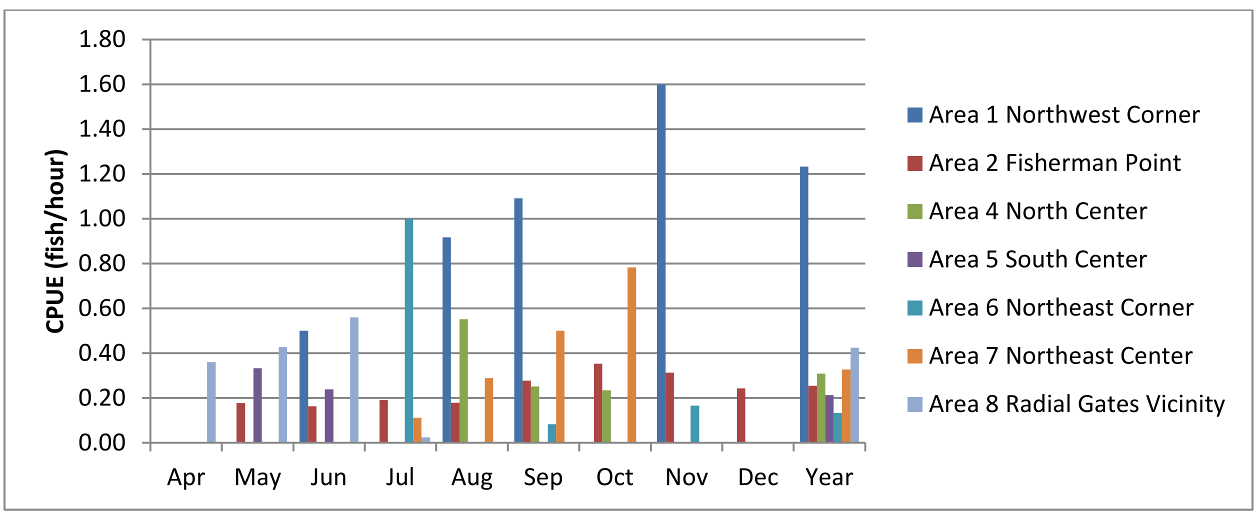

Figure 23: CPUE by Location and Month in 2013

Anglers caught 632 Striped Bass during the survey period, which made up 78% of the total catch of 807 fish. The second most commonly caught fish was catfish[4], at 104 fish, followed by Largemouth Bass, at 27 fish, or 13% and 3% of the total catch, respectively (Table 23). A single adult Chinook salmon was caught in October.

[4] Catfish were not identified to species during the creel surveys, unless the survey crew was able to see the fish caught. Often, anglers did not specify the species. For this reason all catfish were pooled into a single group.

Table 20: Total Catch by Species and Month in 2013

Month	Hours Fished	Unknown	American Shad	Bluegill	Carp	Chinook Salmon (Adult)	Crappie	Perch	Small Mouth Bass	Largemouth Bass	Catfish (Any)	Striped Bass	Total Catch
Apr	33.8	0	0	0	4	0	0	0	0	0	1	6	11
May	208.6	1	0	0	0	0	0	1	0	8	11	42	63
Jun	323.5	0	0	3	1	0	0	0	0	4	31	80	119
Jul	134.3	0	0	0	0	0	0	0	0	0	13	7	20
Aug	479.1	0	0	0	0	0	0	0	2	3	37	63	105
Sep	341.3	1	0	0	0	0	0	0	0	5	4	89	99
Oct	284.7	1	1	6	0	1	0	0	2	2	2	85	100
Nov	606.8	20	7	9	0	0	1	0	0	0	5	153	195
Dec	394.7	0	0	3	0	0	1	0	0	5	0	86	95
Year	2806.6	23	8	21	5	1	2	1	4	27	104	632	807

Angler catch of Striped Bass peaked in November at 153 fish, while Largemouth Bass catch peaked in May, and catfish peaked in August, with 8 and 37 fish, respectively (Figure 26).

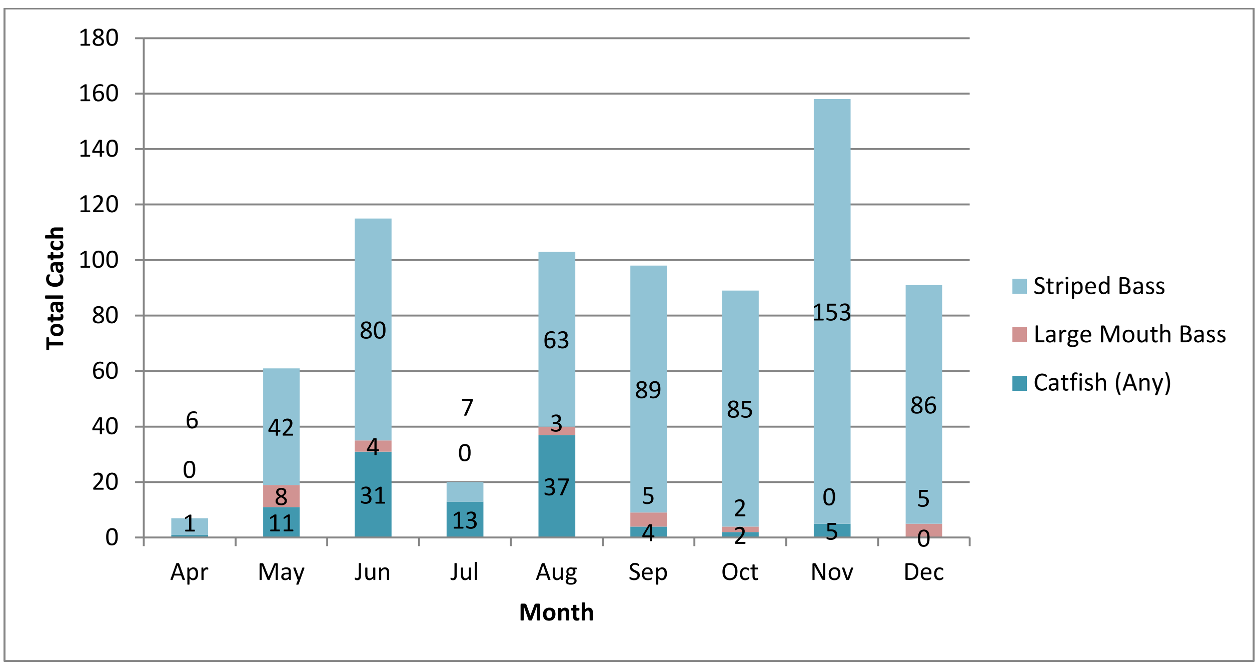

Figure 24: Total Striped Bass, Largemouth Bass and Catfish by Month in 2013

CPUE for total catch ranged from 0.15 in July to 0.37 in June and averaged 0.29 for the entire survey period. When calculated for individual species, CPUE was found to range from 0.05 to 0.30 for Striped Bass, 0.00 to 0.10 in catfish, and 0.00 to 0.04 in Largemouth Bass (Table 24, Figure 27). CPUE for Striped Bass peaked in October at 0.30, which does not correspond with the November peak in numerical catch However hours fished in November were nearly double those fished in October, which accounts for that difference.

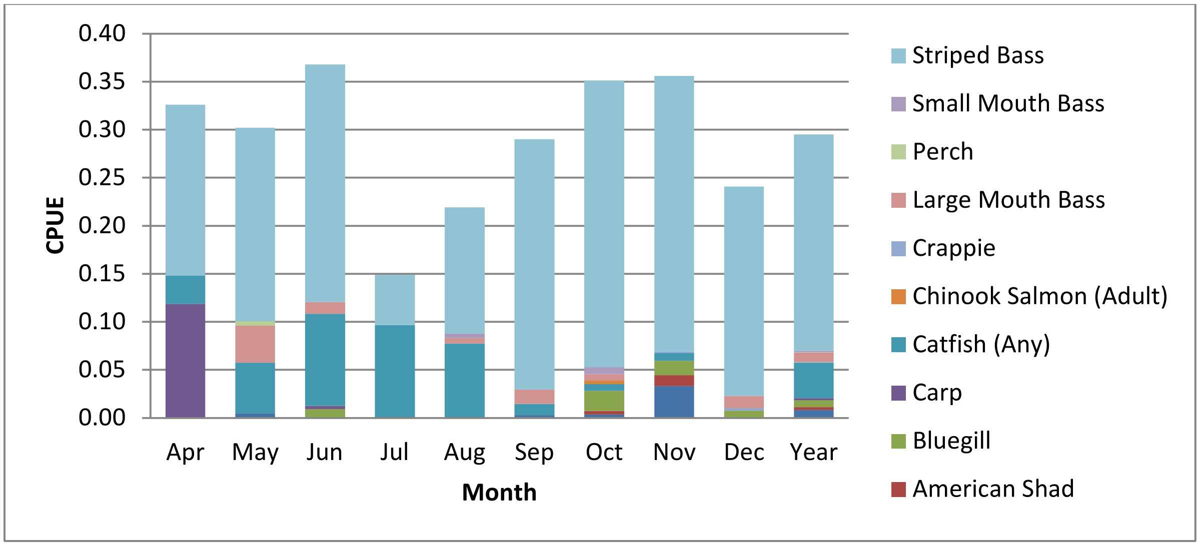

Figure 25: CPUE by Species and Month in 2013

Table 21: CPUE by Species and Month in 2013

Month	Hours Fished	Unknown	American Shad	Bluegill	Carp	Chinook Salmon (Adult)	Crappie	Perch	Small Mouth Bass	Largemouth Bass	Catfish (Any)	Striped Bass	Total Catch
Apr	33.75	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.03	0.18	0.33
May	208.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.20	0.30
Jun	323.54	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.25	0.37
Jul	134.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.05	0.15
Aug	479.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.13	0.22
Sep	341.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.26	0.29
Oct	284.65	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.30	0.35
Nov	606.78	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.25	0.32
Dec	394.65	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.22	0.24
Year	2806.63	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.22	0.29

When calculated based upon fishing location, the two highest Striped Bass CPUE were found in Area 1 in September and November, at 1.09 and 1.60 respectively (Table 25, Figure 28). The lowest calculated CPUE for Striped Bass was noted in Areas 8 and 2 in July, at 0.03 and 0.05 respectively.

Table 22: CPUE for Striped Bass by Month and Location in 2013

	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 4 North Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity
Apr	0.00	0.00	0.00	0.00	0.00	0.20
May	0.00	0.14	0.00	0.00	0.00	0.28
Jun	0.00	0.09	0.00	0.00	0.00	0.44
Jul	0.00	0.05	0.00	0.67	0.00	0.03
Aug	0.92	0.11	0.14	0.00	0.13	*
Sep	1.09	0.26	0.25	0.00	0.38	*
Oct	0.00	0.29	0.24	0.00	0.78	*
Nov	1.60	0.23	0.00	0.17	0.00	*
Dec	0.00	0.22	0.00	0.00	0.00	*

* Radial gate outage and access limited

It is important to note that access to Area 8, which had the highest CPUE for Striped Bass in comparison to other areas from April through June, was closed to the public for repairs to the radial gates, from mid-July through the end of the year.

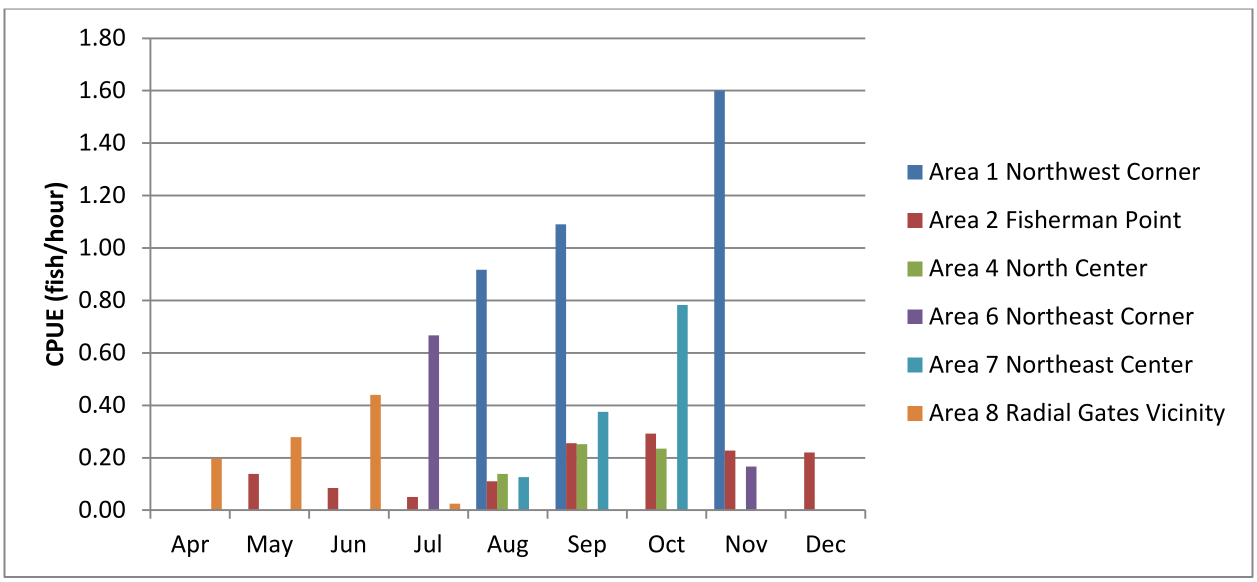

Figure 26: CPUE for Striped Bass by Location and Month in 2013

When calculated based upon fishing location, the Largemouth Bass CPUE was found to be highest in Area 1 in June, at 0.50 and Area 7 in September, at 0.13 (Table 26, Figure 29). CPUE for Largemouth Bass remained at or below 0.05 for the balance of the locations across all months during which they were caught.

Table 23: CPUE for Largemouth Bass by Month and Location in 2013

	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 5 South Center	Area 7 Northeast Center	Area 8 Radial Gates Vicinity
Apr	0.00	0.00	0.00	0.00	0.00
May	0.00	0.03	0.00	0.00	0.05
Jun	0.50	0.00	0.03	0.00	0.01
Jul	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.01	0.00	0.00	*
Sep	0.00	0.01	0.00	0.13	*
Oct	0.00	0.01	0.00	0.00	*
Nov	0.00	0.00	0.00	0.00	*
Dec	0.00	0.01	0.00	0.00	*

* Radial gate outage and access limited

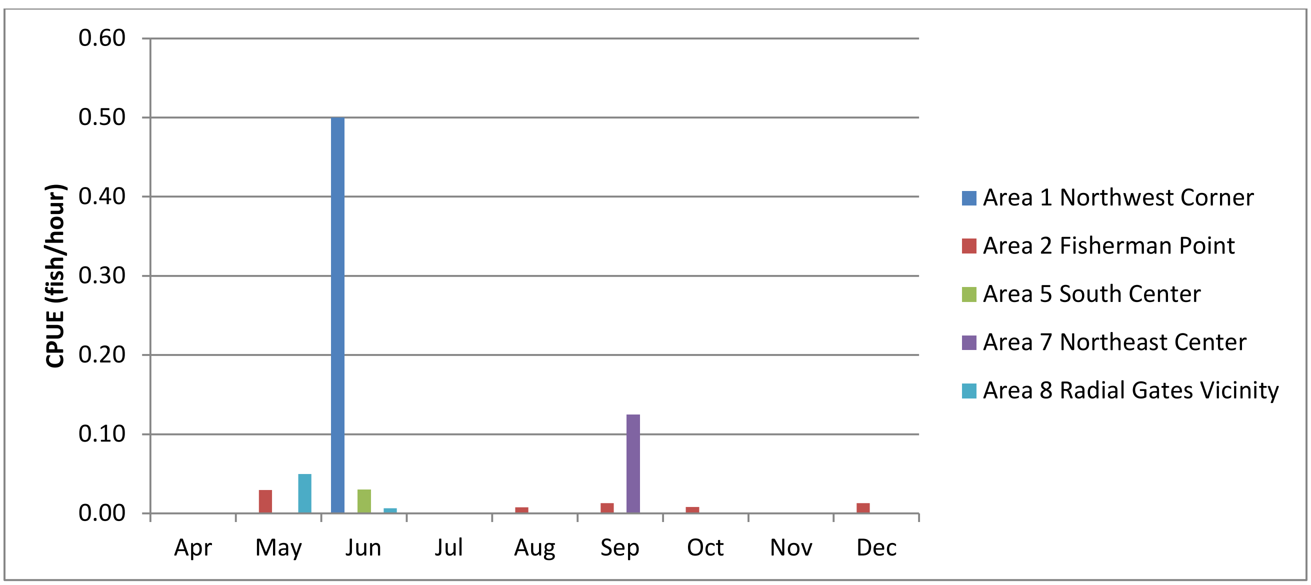

Figure 27: CPUE for Largemouth Bass by Month and Location in 2013

When calculated based upon fishing location, the catfish CPUE was found to be highest in Area 4 in August, at 0.41, followed by Area 5 in May and Area 6 in July, at 0.33 (Table 27, Figure 30). CPUE for catfish was lowest in Area 2 in April, May, and September through November, at or below 0.01.

Table 24: CPUE for Catfish by Month and Location in 2013

	Area 2 Fisherman Point	Area 4 North Center	Area 5 South Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity
Apr	0.00	0.00	0.00	0.00	0.00	0.03
May	0.01	0.00	0.33	0.00	0.00	0.08
Jun	0.05	0.00	0.21	0.00	0.00	0.11
Jul	0.14	0.00	0.00	0.33	0.11	*
Aug	0.06	0.41	0.00	0.00	0.13	*
Sep	0.00	0.00	0.00	0.08	0.00	*
Oct	0.01	0.00	0.00	0.00	0.00	*
Nov	0.01	0.00	0.00	0.00	0.00	*
Dec	0.00	0.00	0.00	0.00	0.00	*

* Radial gate outage and access limited

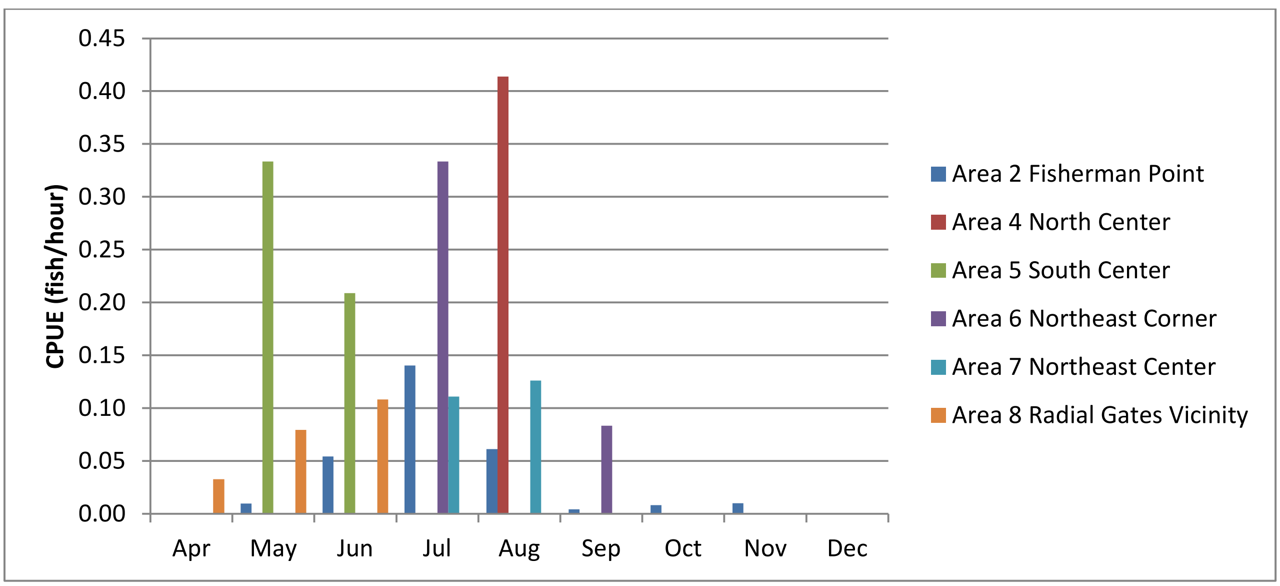

Figure 28: CPUE for Catfish by Month and Location in 2013

2.6.5 Discussion and Recommendations

Fishing at the Forebay by the public is restricted to the shore, from Fisherman Point to the Radial Gates, which reduces an angler's ability to reach the "hot spots" that are accessible by boat. In turn this reduces the portion of the total predatory fish population accessible within the casting envelope of approximately 100 feet from the shore. The bulk of anglers stay within this portion of the shore, however a small number of anglers fish along the portion of the shore that is beyond the Radial Gates, and some anglers have been observed wading into the Forebay in the vicinity of the Radial Gates. Anglers that were observed along the shore were asked to participate in the creel survey, but were not required to do so. Additionally, anglers that were in the water or along the wing walls protruding from the base of the Radial Gate structure were considered inaccessible and not included in the survey, to ensure the safety of the survey team. Most anglers that were encountered were willing to participate in the survey, with only 14 anglers refusing to do so during the 2013 survey effort.

Anglers that were interviewed during creel surveys fished a total of 2,806 hours and captured a total of 807 fish during the survey period. Anglers caught a wide variety of fish including carp, shad, sunfishes, bass and catfish. Striped Bass, catfish and Largemouth Bass were most often targeted and caught, with 632 Striped Bass, 104 catfish, and 27 Largemouth Bass, which made up 76%, 13%, and 3% of the total catch, respectively, caught during the survey period. A single adult Chinook salmon was caught in October.

CPUE for the total catch for all sites combined ranged from 0.15 in July to 0.37 in June and averaged 0.30 for the entire survey period. When calculated for individual species, angler CPUE was found to range from 0.05 to 0.30 for Striped Bass, 0.00 to 0.10 in catfish, and 0.00 to 0.04 in Largemouth Bass. CPUE varied by month and location, with the highest the total catch CPUE being recorded in Area 1 in September and November.

Area 1 is a small area along the Northwest Corner of the Forebay, and is not heavily used. However, due to the restricted access to the radial gates area from August through the end of the year, the fishing pressure shifted to other areas, such as Areas 1, 4 and 6. Restrictions also likely resulted in decreased fishing activity at the Forebay, as the Radial Gates appears to be one of the often selected locations for anglers.

We recommend that surveys continue year round, as originally planned, to gain a better understanding of angler trends before, during and after the restriction to access to the radial gates vicinity. It is also recommended that surveys continue to be conducted on weekdays and weekends to increase the number of anglers included in the survey and to cover a truly representative cross section of anglers including the regular/experienced anglers and the occasional/inexperienced anglers. It is also recommended that the creel map used during 2013 be replaced with the map used for predator sampling so that the CPUE for both efforts can be used together to provide a more complete picture.

2.7 Avian Surveys

2.7.1 Methods

Avian point count surveys, in the vicinity of the radial gates and the vicinity of the trash rack, were initiated on April 5, 2013, and were scheduled three days per week, including two week days and one weekend day. Surveys were conducted during one of three randomly selected time periods, morning (from just before sunrise until 0900), midday (1000 until 1200) or afternoon (from 1300 until 1600). The radial gates area was split into two separate survey areas to ensure adequate coverage on both sides of the structure.

Survey days and time periods were randomly selected by rolling dice, with each side of the die associated with a day or time (Table 28). A total of 89 surveys were conducted between April 5, 2013 and December 30, 2013. Of those 89 surveys, 30 were morning, 39 were midday and 20 were afternoon. Surveys were not conducted at night due to lack of visibility, safety concerns, and the fact that only one of the focal species, black-crowned night heron (*Nycticorax nycticorax*), are nighttime foragers.

Table 25: Randomized Survey Selection Process

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Weekend Day	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday
Time	Morning	Midday	Afternoon	Morning	Midday	Afternoon

Each survey was conducted by a minimum of two biologists for 20 minutes per survey location, using a Kowa TSN-821M spotting scope or Nikon 8x42 Monarch binoculars from predetermined vantage points (Figure 31 and 32) to ensure adequate coverage.

Figure 29: Avian Survey Trash Rack Location

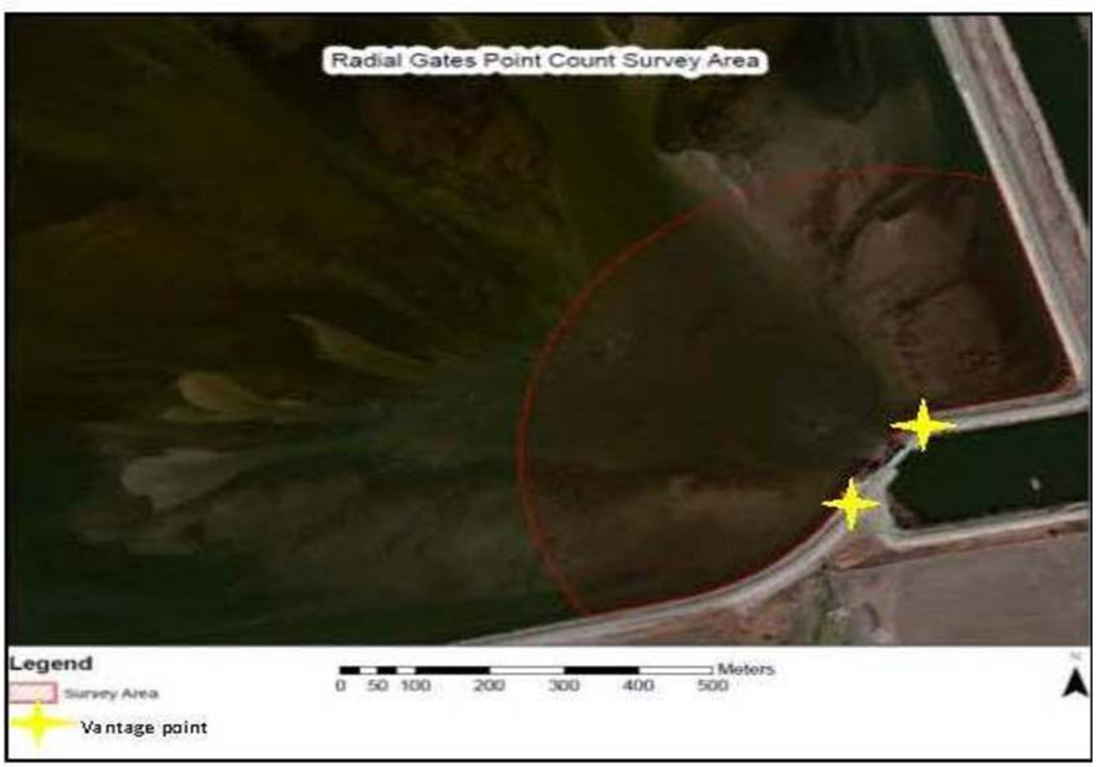

Figure 30: Avian Survey Radial Gates Locations (SW & NE)

2.7.2 Issues

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay were changed significantly on the morning of January 25, and all work on the CCFPS was suspended. DFD provided a final procedural guide to DWR Bay-Delta Office (BDO), and the EROF for avian surveys was filed with DFD in March 2013. Approval for avian surveys was received on March 20, 2013, and the first avian survey occurred on April 5, 2013.

Avian surveys were planned to continue year-round at the radial gates and the trash racks: however, on July 8, 2013 the radial gates structure suffered a significant failure resulting in one of the gates becoming dislodged. As a result of this structural failure, the area in the vicinity of the radial gates was closed to avian survey crews beginning August 1, 2013 while DFD worked to evaluate the extent of the damage and make repairs (Figure 33). This closure limited avian surveys to the trash rack site. Access to the radial gates was regained on November 15, 2013, and surveys were resumed at the radial gates location. Due to this temporary loss of access, 39 of the 89 surveys conducted during 2013 have no data for the radial gates area.

Figure 31: Restricted Access in the vicinity of Radial Gates

2.7.3 Data Analysis

All data was recorded onto Rite-in-Rain data sheets. Data sheets were scanned and data was initially compiled into an excel spreadsheet to ensure that no data became lost while a database was under development. Total numbers of species observed were compiled by month, location and behavior. Time spent feeding versus non-feeding were calculated by species, location and month.

2.7.4 Results

A total of 89 surveys were conducted between April 5, 2013 and December 31, 2013 and bird sightings totaled 6,166 piscivorous birds. Higher numbers of avian species were observed in the month of November and of those 6,166 birds sighted, the most common species observed at the Forebay were gulls (*Larus sp.*), double-crested cormorants (*Phalacrocorax auritus*), and American white pelicans (*Pelecanus erythrorhynchos*) (Table 29). While efforts were made to ensure that birds were not double counted during each survey effort, it is likely that the same birds were often observed at the Forebay on subsequent days.

Table 26: Avian Species Observed at all Locations in 2013

Species	Apr	May	Jun	Jul	Aug*	Sep*	Oct*	Nov	Dec	Total 2013
American White Pelican	93	52	29	3				98	190	465
Belted Kingfisher	1								1	2
Black-Crowned Night Heron									6	6
Caspian Tern		1								1
Clark's Grebe	1	3	4	1				8		17
Common Goldeneye	11							48	31	90
Common Merganser									4	4
Common Tern			1							1
Double-Crested Cormorant	62	63	45	47	13	13	41	279	566	1129
Eared Grebe	3	1					1	20	71	96
Forster's Tern	2									2
Great Blue Heron	2	12	7	2	3	9	15	8	14	72
Great Egret	1	2	2	3	1	11	25	29	131	205
Green Heron				1				1		2
Gull sp.	392	53	21	4	126	2	58	1726	1406	3788
Hooded Merganser								3		3
Horned Grebe									2	2
Osprey		1	1	1			1			4
Pied Billed Grebe	4	1	3	6	2	27	22	30	48	143
Snowy Egret				3	3	25	15	17	25	88
Tern (Unidentified)	4	4	7							15
Western Grebe	2	10	5				1	10	3	31
All species	578	203	125	71	148	87	179	2277	2498	6166

* Radial gate outage and access limited

Gulls were present during all of the months surveyed, however their numbers peaked in November and December, at 1,723 and 1,406 birds respectively (Figure 34), with the bulk of the gulls observed in the vicinity of the Trash Racks in November (Figure 35).

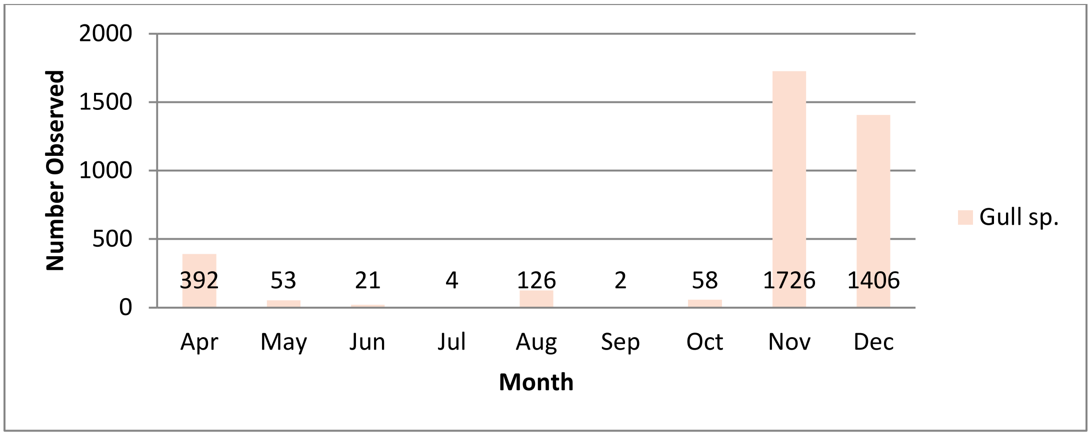

Figure 32: Gull Observed at all locations in 2013

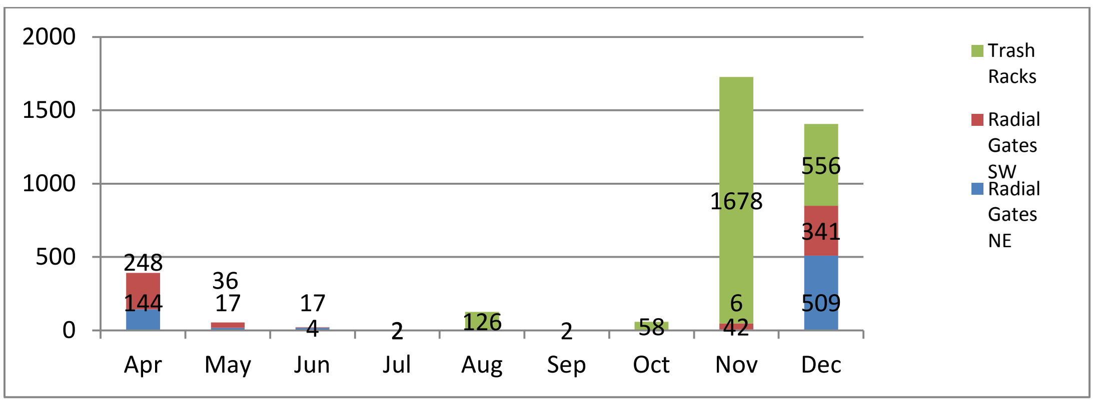

Figure 33: Gulls Observed by Location in 2013

American white pelicans were only present from April until July, and again in November and December (Figure 36), and were only observed in the vicinity of the trash racks in November and December (Figure 37).

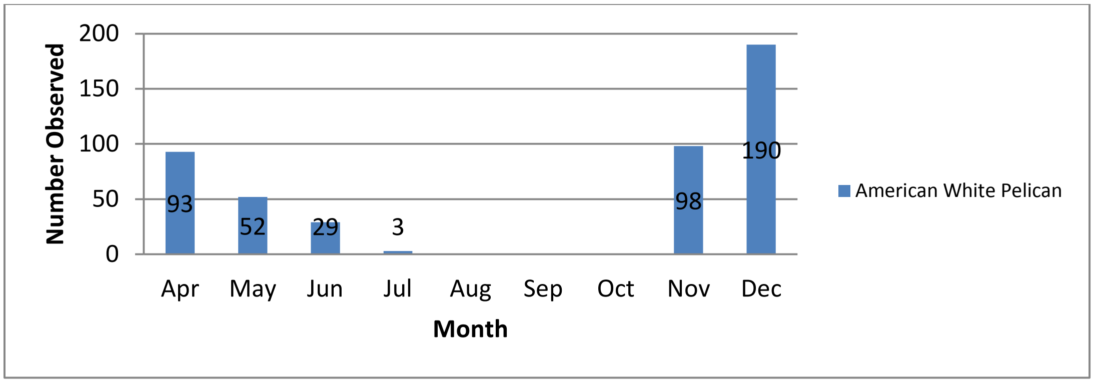

Figure 34: American White Pelicans Observed at all Locations in 2013

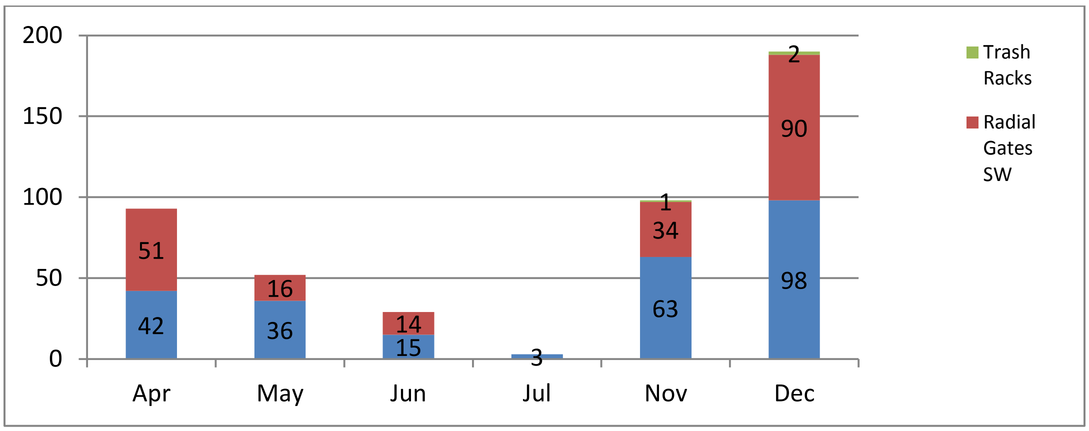

Figure 35: American White Pelicans Observed by Location in 2013

Double-crested cormorants were present during all of the months surveyed (Figure 38), with their numbers peaking in November and December, and were observed at all of the sites throughout the survey period (Figure 39).

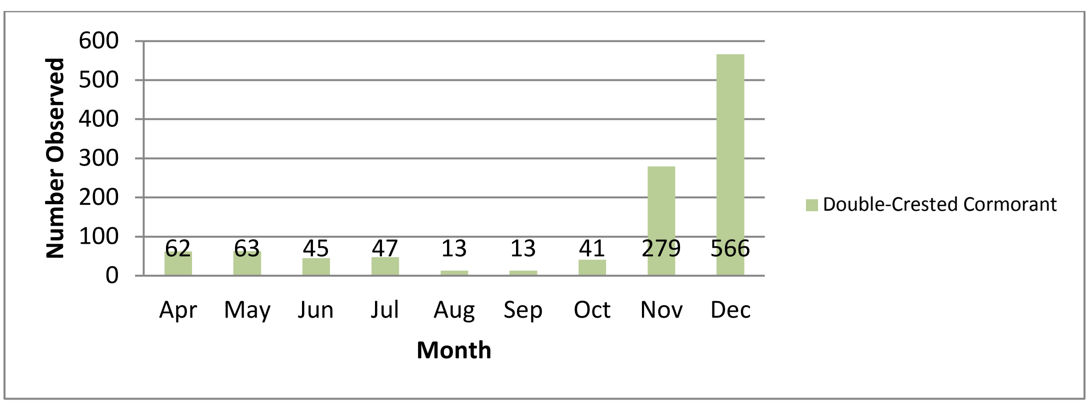

Figure 36: Double-Crested Cormorants observed at all Locations in 2013

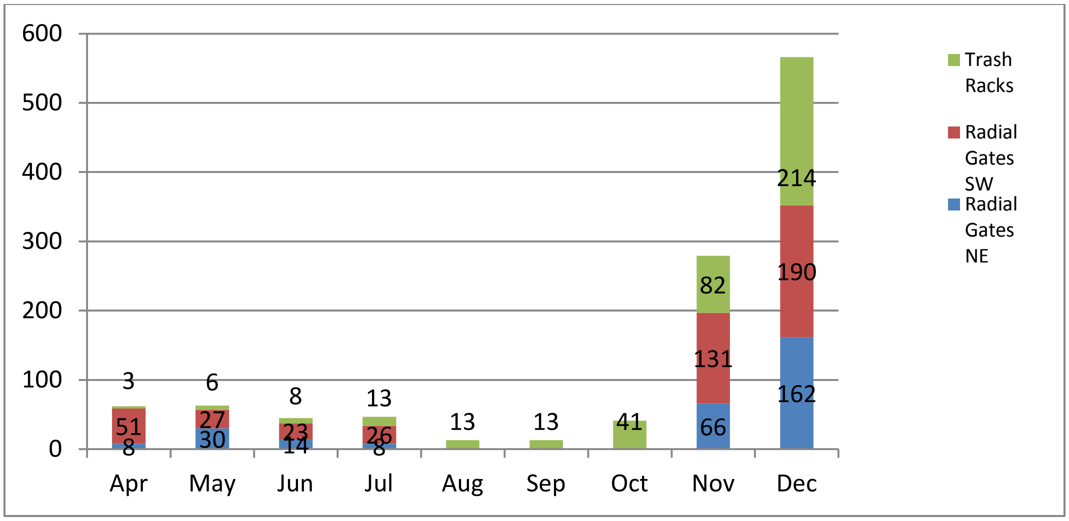

Figure 37: Double-Crested Cormorants Observed by Location in 2013

Several grebe species were observed during the survey, with population of the more commonly observed species, pied billed grebe (*Podilymbus podiceps*) and eared grebe (*Podiceps nigricollis*) peaking from September through December (Figure 40).

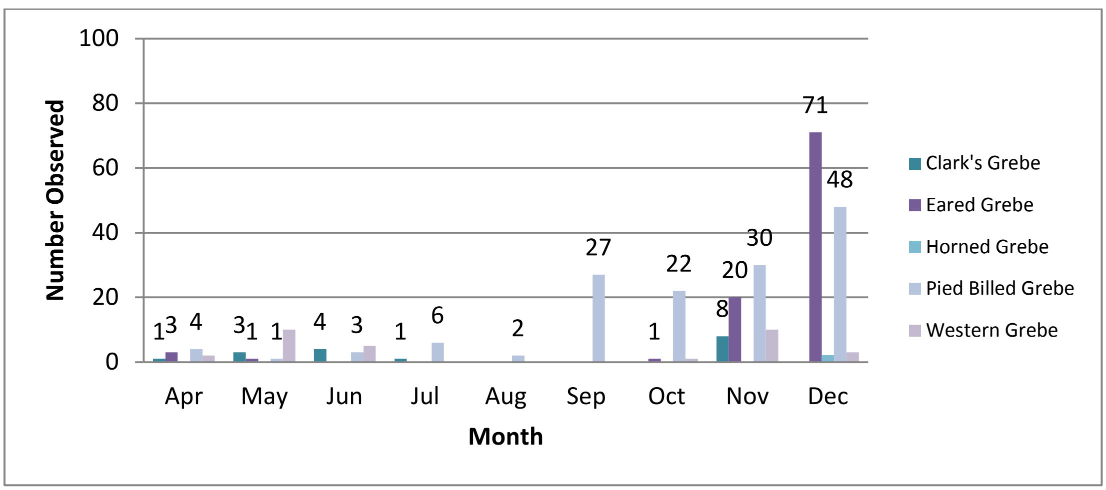

Figure 38: Grebe Species Observed at all Locations in 2013

Multiple heron and egret species were also observed during the survey, with the most commonly observed species, great egret (*Ardea alba*) and snowy egret (*Egretta thula*) peaking from September through December (Figure 41).

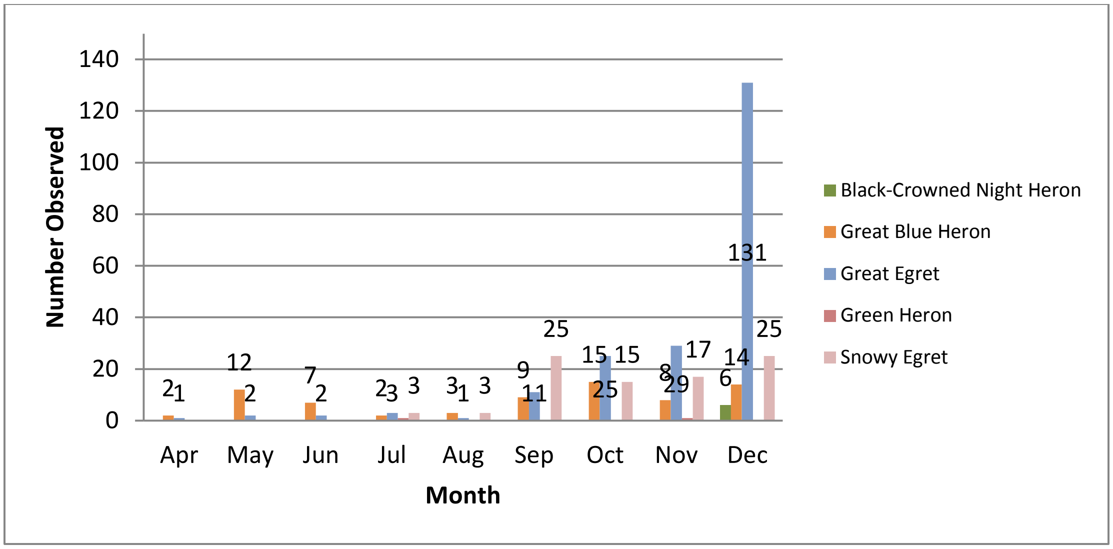

Figure 39: Herons and Egrets Observed at all Locations in 2013

Tern species were only observed from April until June, and were relatively uncommon, with numbers less than ten individuals (Figure 42).

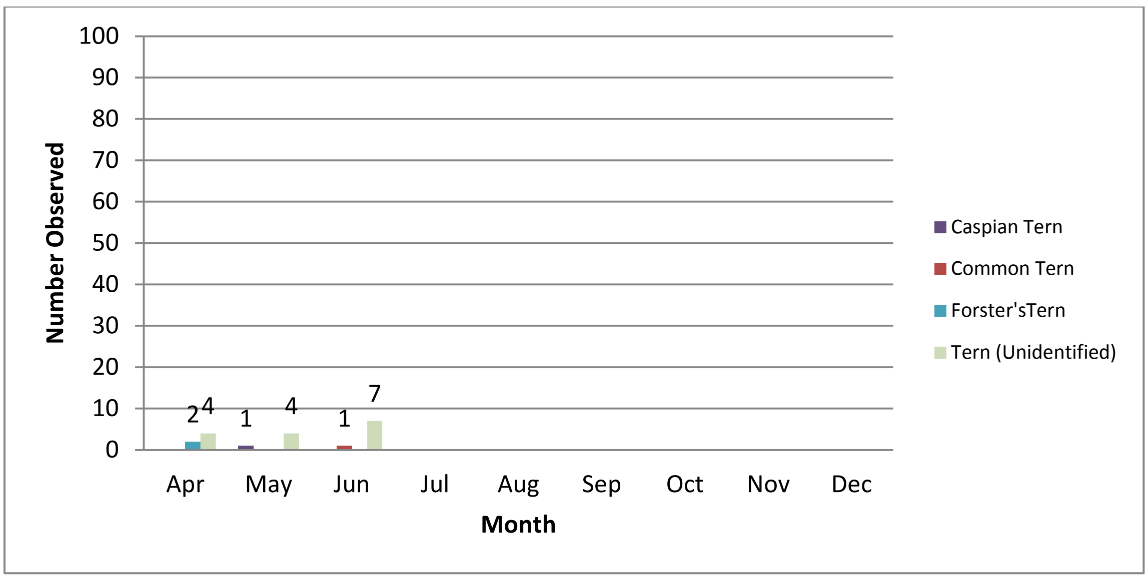

Figure 40: Terns Observed at all Locations in 2013

The most common of the other piscivorous birds observed was the common goldeneye (*Bucephala clangula*), with numbers peaking in November and December (Figure 43).

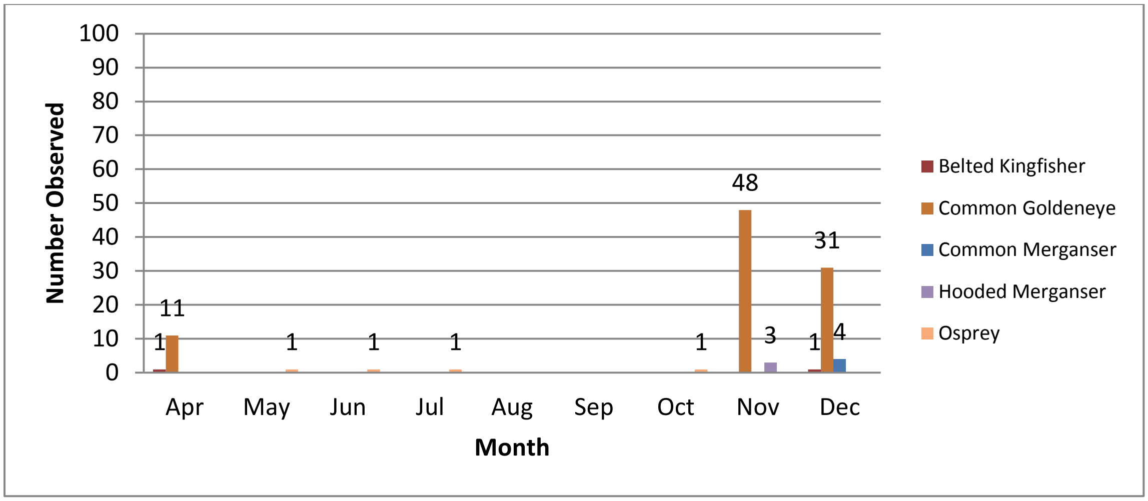

Figure 41: Other Piscivorous Species Observed at all Locations in 2013

At the trash racks, overall bird numbers including gulls peaked in November, with the fewest birds observed in April and May (Table 30).

Table 27: Avian Species Observed at the Trash Racks in 2013

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2013
American White Pelican								1	2	3
Belted Kingfisher	1								1	2
Black-Crowned Night Heron									6	6
Clark's Grebe	1		1					3		5
Common Goldeneye	1							37	18	56
Double-Crested Cormorant	3	6	8	13	13	13	41	82	214	393
Eared Grebe							1	2		3
Great Blue Heron	1		2		3	9	15	5	9	44
Great Egret					1	11	25	29	121	187
Green Heron								1		1
Gull sp.				2	126	2	58	1678	556	2422
Hooded Merganser								2		2
Osprey			1				1			2
Pied Billed Grebe	2		1		2	27	22	20	13	87
Snowy Egret					3	25	15	15	19	77
Western Grebe	2	3	3				1	5	3	17
All Species	11	9	16	15	148	87	179	1880	962	3307

At the radial gates, bird sightings peaked in December and were at their lowest in July (Tables 31 and 32). No observations were made at the gates from August through October, due to lack of access to the site.

Table 28: Avian Species Observed at the Radial Gates NE in 2013

Species	Apr	May	Jun	Jul	Nov	Dec	2013
American White Pelican	42	36	15	3	63	98	257
Clark's Grebe				1	5		6
Common Goldeneye	3				5	11	19
Double-Crested Cormorant	8	30	14	8	66	162	288
Eared Grebe	2				10	55	67
Forster's Tern	2						2
Great Blue Heron		8	3	2	2	2	17
Great Egret	1	2	2	1		6	12
Green Heron				1			1
Gull sp.	144	17	17		6	509	693
Hooded Merganser					1		1
Horned Grebe						2	2
Pied Billed Grebe	2	1	1	4	5	22	35
Snowy Egret				1	1	5	7
Tern (Unidentified)	2	1	4				7
Western Grebe		4			1		5
All Species	206	99	56	21	165	872	1419

Table 29: Avian Species Observed at the Radial Gates SW in 2013

Species	Apr	May	Jun	Jul	Nov	Dec	2013
American White Pelican	51	16	14		34	90	205
Caspian Tern		1					1
Clark's Grebe		3	3				6
Common Goldeneye	7				6	2	15
Common Merganser						4	4
Common Tern			1				1
Double-Crested Cormorant	51	27	23	26	131	190	448
Eared Grebe	1	1			8	16	26
Great Blue Heron	1	4	2		1	3	11
Great Egret				2		4	6
Gull sp.	248	36	4	2	42	341	673
Osprey		1		1			2
Pied Billed Grebe			1	2	5	13	21
Snowy Egret				2	1	1	4
Tern (Unidentified)	2	3	3				8
Western Grebe		3	2		4		9
All Species	361	95	53	35	232	664	1440

During the spring months, April through June, feeding behavior peaked in May at 31% of total birds observed actively feeding (Table 33). Eight species of birds were observed to be feeding during 50% or more of the observations during one or more spring months, including belted kingfisher (*Megaceryle alcyon*), Clark's grebe (*Aechmophorus clarkii*), eared grebe, Forester's tern (*Sterna forsteri*), great blue heron (*Ardea herodias*), great egret, pied billed grebe, and Western grebe (*Aechmophorus occidentalis*).

Table 30: Percent of Observed Birds Feeding at all Locations in Spring 2013

Month	April			May			June		
Species	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican	93	5	5%	52	12	23%	29	2	7%
Belted Kingfisher	1	1	100%						
Caspian Tern				1		0%			
Clark's Grebe	1	1	100%	3	3	100%	4	3	75%
Common Goldeneye	11	4	36%						
Common Tern							1		0%
Double-Crested Cormorant	62	19	31%	63	26	41%	45	15	33%
Eared Grebe	3	2	67%	1		0%			
Forster's Tern	2	2	100%						
Great Blue Heron	2		0%	12	6	50%	7		0%
Great Egret	1		0%	2	1	50%	2		0%
Green Heron									
Gull sp.	392	17	4%	53	3	6%	21		0%
Osprey				1		0%	1	1	100%
Pied Billed Grebe	4	2	50%	1	1	100%	3	1	33%
Tern (Unidentified)	4	1	25%	4	1	25%	7	4	57%
Western Grebe	2	2	100%	10	10	100%	5	1	20%
Grand Total	578	56	10%	203	63	31%	125	27	22%

During the summer months, July through September, feeding behavior peaked in September at 67% of total birds observed actively feeding (Table 34). Seven species of birds were observed to be feeding during 50% or more of the observations during one or more Summer months, including Clarks' grebe, great blue heron, great egret, green heron (*Butorides virescens*), osprey (*Pandion haliaetus*), pied billed grebe, and snowy egret.

Table 31: Percent of Observed Birds Feeding at all Locations in Summer 2013

Month	July			August*			September*		
Species	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican	3		0%						
Clark's Grebe	1	1	100%						
Double-Crested Cormorant	47	12	26%	13		0%	13	3	23%
Great Blue Heron	2	1	50%	3		0%	9	3	33%
Great Egret	3	1	33%	1		0%	11	9	82%
Green Heron	1	1	100%						
Gull sp.	4		0%	126		0%	2		0%
Osprey	1	1	100%						
Pied Billed Grebe	6	5	83%	2	1	50%	27	23	85%
Snowy Egret	3	2	67%	3	3	100%	25	20	80%
Grand Total	71	24	34%	148	4	3%	87	58	67%

* Access to radial gates restricted.

During the fall months, October through December, feeding behavior peaked in October at 17% of total birds observed actively feeding (Table 35). Seven species of birds were observed to be feeding during 50% or more of the observations during one or more fall months, including belted kingfisher, Clark's grebe, eared grebe, great blue heron, green heron, hooded merganser (*Lophodytes cucullatus*), pied billed grebe, and Western grebe.

Table 32: Percent of Observed Birds Feeding at all Locations in Fall 2013

Month	Oct*			Nov			Dec		
Species	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican				98	6	6%	190	33	17%
Belted Kingfisher							1	1	100%
Black-Crowned Night Heron							6		0%
Clark's Grebe				8	7	88%			
Common Goldeneye				48	12	25%	31	11	35%
Common Merganser							4		0%
Double-Crested Cormorant	41	2	5%	279	48	17%	566	16	3%
Eared Grebe	1	1	100%	20	9	45%	71	42	59%
Great Blue Heron	15	9	60%	8	1	13%	14	1	7%
Great Egret	25	4	16%	29	9	31%	131	1	1%
Green Heron				1	1	100%			
Gull sp.	58		0%	1726	4	0%	1406	1	0%
Hooded Merganser				3	3	100%			
Osprey	1		0%						
Pied Billed Grebe	22	12	55%	30	15	50%	48	28	58%
Snowy Egret	15	3	20%	17	5	29%	25	3	12%
Western Grebe	1		0%	10	8	80%	3	2	67%
Grand Total	179	31	17%	2277	128	6%	2498	141	6%

* Access to radial gates restricted.

Feeding behavior was observed in double-crested cormorants during eight of the months surveyed (Figure 44). Feeding was most often observed in May when 41% of double-crested cormorants observed were feeding (Table 33).

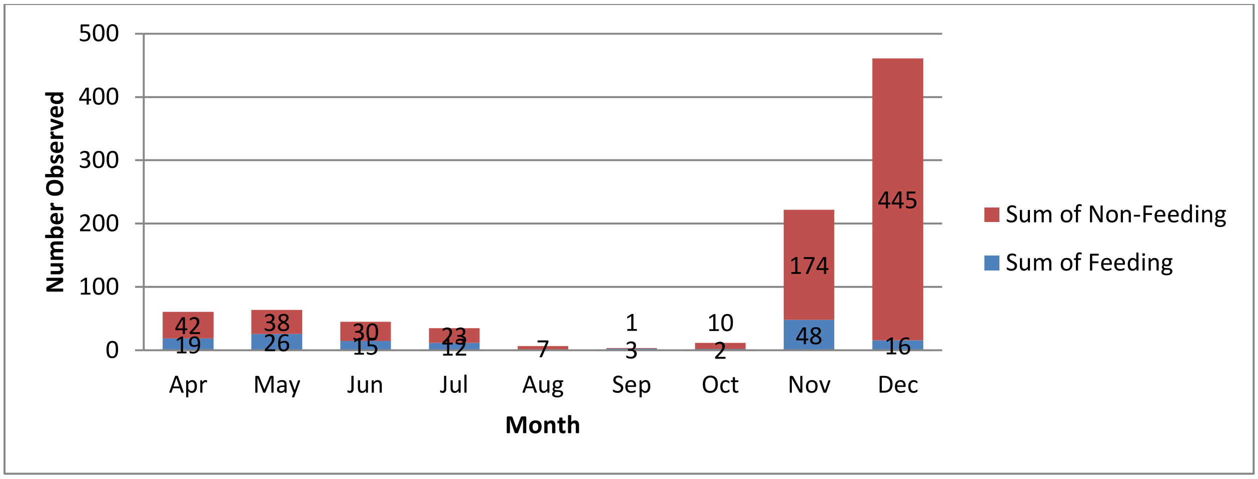

Figure 42: Double Crested Cormorant Feeding Behavior in 2013

American white pelicans were observed feeding during five of the months in which they were present during surveys (Figure 45). Often the feeding behavior observed consisted of stealing from other birds in the vicinity of the radial gates.

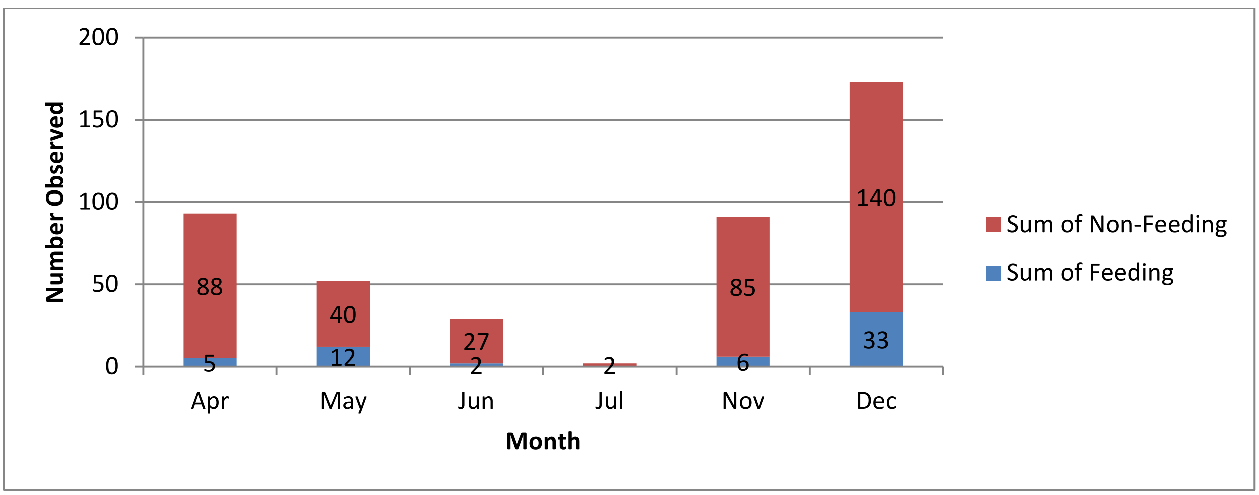

Figure 43: American White Pelican Feeding Behavior in 2013

Gulls were present in large flocks during several of the months surveyed, but were very rarely observed feeding during surveys (Figure 46).

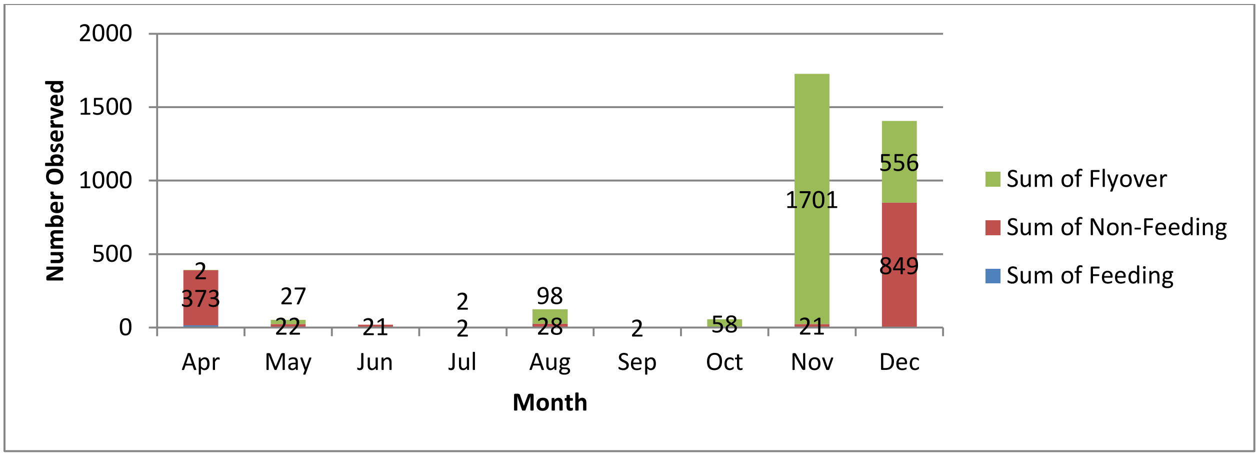

Figure 44: Gull Behavior in 2013

Feeding behavior was primarily observed in the vicinity of the trash racks from September through December (Figure 47), and flyovers of large numbers of birds were observed in November and December. In the vicinity of the radial gates, feeding behavior was observed in all months surveyed (Figure 48) and fewer flyovers were observed than at the trash rack.

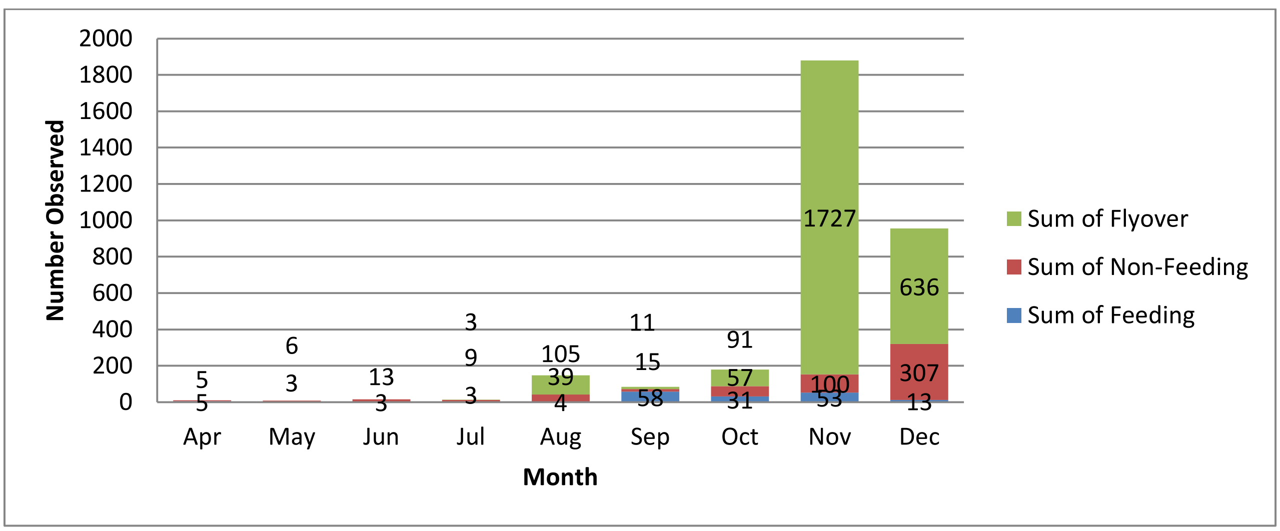

Figure 45: Behavior at the Trash Racks in 2013

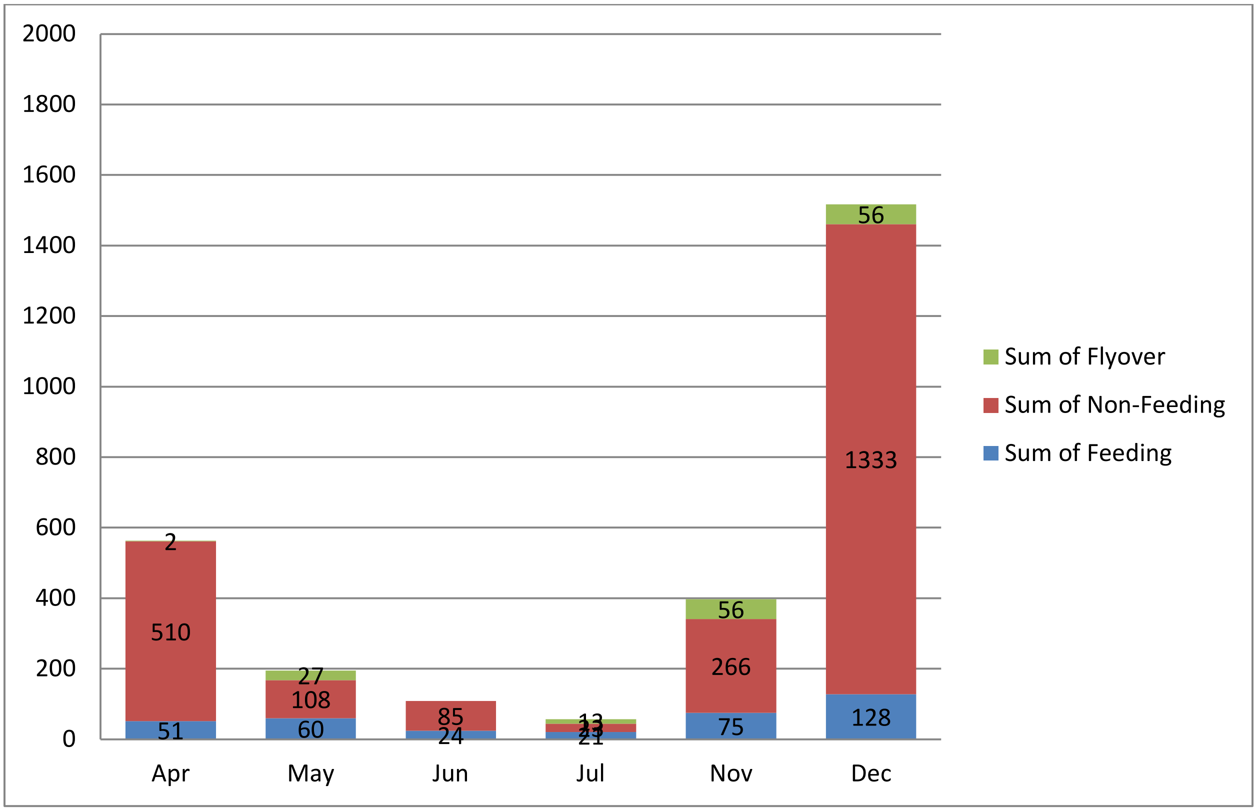

Figure 46: Behavior at the Radial Gates Sites in 2013

2.7.5 Discussion and Recommendations

Double-crested cormorants, gulls and American white pelicans were the most commonly observed birds during avian surveys. All three of these species were most abundant in the months of November and December. Gulls and double-crested cormorants were present throughout the survey period, with the lowest numbers observed in July and September, and August and September, respectively. Pelicans showed stronger seasonal patterns, and were only present six of the nine months surveyed at the radial gates. However, they may still have been present in the three other months and have gone undetected due to the loss of access to the radial gates sites from August through October. Undetected cormorants and gulls were also likely in that time period.

Grebes and herons were the second most commonly observed group of birds, with an apparently strong seasonal trend of increasing populations from September through December. Terns were only observed from April to June, in very small numbers. Goldeneyes were observed primarily in November and December, with some birds also observed in April. A single osprey was observed from May through July and another sighting was made in October. Mergansers and kingfishers were observed infrequently.

Overall seasonal trends appeared to indicate increased population sizes, primarily in the fall months. The data set, however, is incomplete as no surveys were conducted from January through March, and surveys were restricted to the trash racks from August through October.

Feeding behavior was observed throughout the year, with up to 31% of birds observed feeding in the Spring, up to 67% of birds observed feeding in the Summer, and up to 17% of birds observed feeding in Fall. Cormorants were observed feeding during all but one of the survey months. It is likely that they would have been observed feeding in all months had the radial gates been accessible. Pelicans were observed feeding in all months that they were present. Gulls were rarely observed feeding, and were often observed flying over the sites in November and December. General feeding behavior for all species was most often observed from September through November. This indicates that cormorants and pelicans may be having a greater predatory impact on fish than gulls; however, additional data is needed to determine relative predation pressure from these species. Grebes, herons and egrets often displayed high percentages of feeding behavior, often more than 50%, and may also represent a significant level of predation pressure on fishes in the Forebay. Identification of prey species was not possible during the surveys, and could include any of the fish species present at the time of the feeding event, including common species such as Striped Bass, as well as listed species such as Chinook salmon.

While the data collected during 2013 indicates some possible seasonal trends in presence and feeding behavior, no strong conclusion can be drawn at this time, due to a number of factors. These factors include; lack of surveys in the winter months, when juvenile salmon would be coming through the system and the limited access to the radial gates from August through October. Surveys will continue year round at all three sites to see if these trends become more apparent.

2.8 Bioenergetics Modelling

2.8.1 Background

A bioenergetics model is a mass-based equation that can analyze how food consumed by an animal is either used for growth or metabolic processes, or excreted as waste (Ney 1993, Brandt and Hartman 1993). This can be a powerful tool in that it can allow for an understanding of the quantitative impacts of predation upon a population of prey given existing information on metabolic needs, digestion rates and predation habits of a predator species. This approach has been used to better understand the predator-prey dynamics between fish species such as Striped Bass and Threadfin Shad (*Dorosoma petenense*) in Lake Powell (Vatland et al 2008), and Lake Trout (*Salvelinus namaycush*) and Rainbow Smelt (*Osmerus mordax*) in Lake Champlain (LaBar 1993), as well as predation by piscivorous birds such as double-crested cormorants (Seefelt and Gillingham 2008) in northern Lake Michigan.

The relative impact of predation upon salmonids by fish and birds in the Forebay is an important factor in addressing pre-screen loss. These impacts can be evaluated in a quantitative manner using bioenergetics modeling. Work on the bioenergetics modeling was not undertaken in 2013.

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State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predation Study: 2014 Annual Progress Report

August 2016

Edmund G. Brown, Jr.	**John Laird**	**Mark W. Cowin**
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State of California	California Natural Resources Agency	Department of Water Resources

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Abbreviations

BDO	Bay-Delta Office
BiOP	Biological Opinion
CALFED	CALFED Bay-Delta Science Program
CCFPS	Clifton Court Forebay Predator Study
CPUE	Catch per Unit Effort
CVP	Central Valley Project (Federal)
Delta	Sacramento-San Joaquin Delta
DFD	Delta Field Division
DFW	California Department of Fish and Wildlife
DWR	California Department of Water Resources
EROF	Equipment Request Order Form
ESA	Endangered Species Act
Forebay	Clifton Court Forebay
HTI	Hydroacoustic Technology Incorporated
IEP	Interagency Ecological Program
INAD	Investigational New Animal Drug
MOCC	Motorboat Operator Certification Course
NMFS	National Marine Fisheries Service
OP-2	Operations Procedure 2 – Lock-out/Tag-out
PCR	Polymerase Chain Reaction
PIT	Passive Integrated Transponder
RPA	Reasonable and Prudent Alternative
SAV	Sub-aquatic Vegetation
SCP	DFW Scientific Collecting Permit
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project (California State)
USFWS	U.S. Fish and Wildlife Service

Executive Summary

This report details the implementation, issues, and results of the second year of the Clifton Court Forebay Predation Study (CCFPS). Specific study elements undertaken in 2014 include predatory fish sampling, acoustic telemetry, genetics, avian studies, and creel surveys. Additional detail regarding the regulatory history and overall study design and methodology is available in the report entitled *Clifton Court Forebay Predation Study* (Wunderlich 2015). The primary purpose of this report is to report data collected and findings based upon preliminary analysis, and does not include detailed conclusions regarding predation of listed fish species. A more in depth analysis will be undertaken in the synthesis report, following the completion of field studies.

A total of 104 predator sampling days were conducted at various times during the day from January 6, 2014 until December 30, 2014, resulting in the capture of 1,301 target predatory fish, and three non-target fish. Of those predatory fish, 1,178 were Striped Bass, 110 Largemouth Bass, and 13 catfish. Non-target fish species captured included one Sacramento Splittail, one Black Bullhead, and one White Sturgeon. Striped Bass captured in 2014 were grouped into four size categories, and total catch was found to be 5% for fish under 0.49 lb. (0.22 kg), 69% for fish between 0.5 lb. (0.23 kg) and 1.49 lbs. (0.67 kg), 20% for fish between 1.5 lbs. (0.68 kg) and 3 lbs. (1.36 kg), and 6% for fish over 3 lbs.

Mean catch per unit effort (CPUE) for the predator sampling effort was calculated for each month, for all species combined, and was found to be highest in August, at 1.29 fish per hour sampled and lowest in February, at 0.57 fish per hour sampled.

Of the fish used in the acoustic and mark/recapture element, 508 were passive integrated transponder (PIT) tagged, 219 were acoustically tagged, and 72 were not tagged at all, usually due to poor fish condition. Three previously tagged Striped Bass and 11 previously tagged Largemouth Bass were recaptured during the 2014 sampling effort. Recaptures of PIT tagged fish were not analyzed further during 2014 due to the small sample size of recaptures to date.

A total of 219 predatory fish were acoustically tagged; six Channel Catfish, 35 Largemouth Bass, and 178 Striped Bass. Of the 219 total acoustic tagged fish, 14 were not detected by any of the receivers in the array, including one Largemouth Bass, two Channel Catfish, and nine Striped Bass. Of the 205 tagged fish that were detected, 34 were only detected in the intake channel, 40 were only detected at the radial gates, nine were detected moving from the intake channel to the radial gates, five were detected moving from the radial gates to the intake channel, 61 were detected moving back and forth between the intake channel and the radial gates, and 56 were detected outside of the Clifton Court Forebay. When 2013 acoustically tagged fish data were combined with the data from 2014, the number of fish detected outside of the Forebay (emigrating fish) increased to 117 fish, representing 32% of the fish tagged in 2013 and 2014. The majority of the fish that emigrated were Striped Bass, at 106 (91%), with the balance being made up of Largemouth Bass, Channel Catfish and White Catfish, at seven, three and one, respectively.

Pilot level mobile monitoring was conducted beginning in June of 2014, but it was inconsistent, and did not provide enough coverage of the Clifton Court Forebay to accurately detect fish that may be located outside the range of the static array.

A total of 27 genetics sampling days to investigate Striped Bass gut content were conducted from December 2013 through May 2014. During the sample effort, 264 Striped Bass were collected, including

30 in December, 73 in January, one in February, ten in March, 54 in April, and 96 in May. The average fork length of Striped Bass analyzed was 36.09 cm and the average weight was 1.26 lbs. (0.57 kg). A variety of species were detected in the gut tract samples taken from these collected fish, including White Sturgeon, Largemouth Bass, Threadfin Shad, Inland (Mississippi) Silverside, Chinook Salmon, and Delta Smelt.

A total of 139 angler (creel) surveys were conducted between January 4, 2014 and December 31, 2014. During these surveys, a total of 1,419 anglers were observed fishing at the Clifton Court Forebay. Anglers fished a total of 3,554 hours and captured a total of 1,690 fish during the survey period. Anglers caught 1,354 Striped Bass, 19 catfish (not identified to species), and 122 Largemouth Bass, which made up 80%, 1%, and 7% of total catch, respectively. One adult Steelhead was caught in May, and one Green Sturgeon was caught, and immediately released, in August. The sampling map was changed during the 2014 effort so that the results of the creel surveys could more easily be compared with results of the predator sampling efforts. Catch per unit effort (CPUE) was found to range from 0.00 in February to 2.79 in September.

A total of 415 avian surveys were conducted between January 4, 2014 and December 31, 2014. During these surveys, a total of 12,689 piscivorous birds were observed using the Forebay. The highest numbers of avian species were observed in the winter months of January and February. Of those 12,689 birds sighted, the most commonly observed at the Forebay were gulls, double-crested cormorants, and American white pelicans. Feeding behavior was observed throughout the year at all of the locations, peaking in September at 55%. February was the month with the lowest rates of feeding at 8%.

1.0 Introduction

The Clifton Court Forebay Predation Study (CCFPS) is a multi-year effort comprised of several study elements that have been designed to gather as much information as possible to understand predation upon juvenile salmonids in the Clifton Court Forebay (Forebay). This report covers the second year of the CCFPS, which marked the initiation of the full-scale study, conducted in 2014. This study was designed to further the understanding of behavior and movement of predatory fishes, salmonids, and piscivorous birds in the Forebay. The CCFPS includes the following elements: predatory fish sampling, mark-recapture and biotelemetry, genetics, creel surveys, avian studies and bioenergetics. CCFPS design and methodology is further discussed in the Clifton Court Forebay Predation Study Report (2015). For the 2013 reporting period, salmon survival studies were also included within the CCFPS, but that portion of the study was consolidated with efficiency studies at the John E. Skinner Delta Fish Protective Facility (SDFPF) beginning with the data collected in 2014, and is not discussed here.

The CCFPS will provide the opportunity to evaluate the effects of any Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) of the Biological Opinion (BiOp) and Conference Opinion on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) (National Marine Fisheries Service (NMFS) 2009) undertaken to reduce predation of Endangered Species Act (ESA) protected salmon and steelhead within the Forebay.

2.0 CCFPS Study Elements

2.1 Issues

Due to the drought conditions experienced during 2014, some elements were reduced in duration and effort.

2.2 Predatory Fish Sampling

2.2.1 Methods

Predators such as Striped Bass (*Morone saxatilis*), Largemouth Bass **(***Micropterus salmoides*), White Catfish (*Ameiurus catus*), and Channel Catfish (*Ictalurus punctatus*), were collected by either gill netting or hook and line sampling in the Forebay. Predatory fish were sampled twice weekly throughout the year to supply predatory fish for various study elements. Predatory fish capable of consuming juvenile salmonids were either sacrificed and preserved for use in the genetic analysis study element, or tagged as part of the mark-recapture and biotelemetry study element and released at the location of capture. Temperature and dissolved oxygen, and location(s) of capture were noted for each sampling effort. Scale samples were collected from Striped Bass and Largemouth Bass, to be examined at a future date, to determine the age of the predatory fish sampled.

Collection of predators occurred primarily during the day, between the hours of 0600 and 1500; however, 29 of the sampling efforts were undertaken at night, between the hours of 1900 and 2400. All incidental species caught alive were measured, recorded, and immediately released at the location caught. Field staff were trained to quickly identify listed species and release live fish to minimize handling stress. Take information was detailed in a supplemental report as part of the reporting requirements of the California Department of Fish and Wildlife (DFW) Scientific Collecting Permits (SCP; SCP #'s 7744 and 10286).

The Forebay was split into sampling sections, following the same map as Gingras and McGee (1997; Figure 1). Sampling was conducted from a boat, when possible, to allow for coverage of a greater portion of the Forebay. On sampling days when the boat was not available for use, sampling was conducted from the shoreline, primarily along the intake canal (Area 2) or adjacent to the radial gates (Area 1). Hook and line sampling was conducted using standard rod and reel fishing equipment in accordance with standard DFW regulations for hook and line fishing. Hook and line sampling employed a wide variety of bait and lure selections to maximize catch.

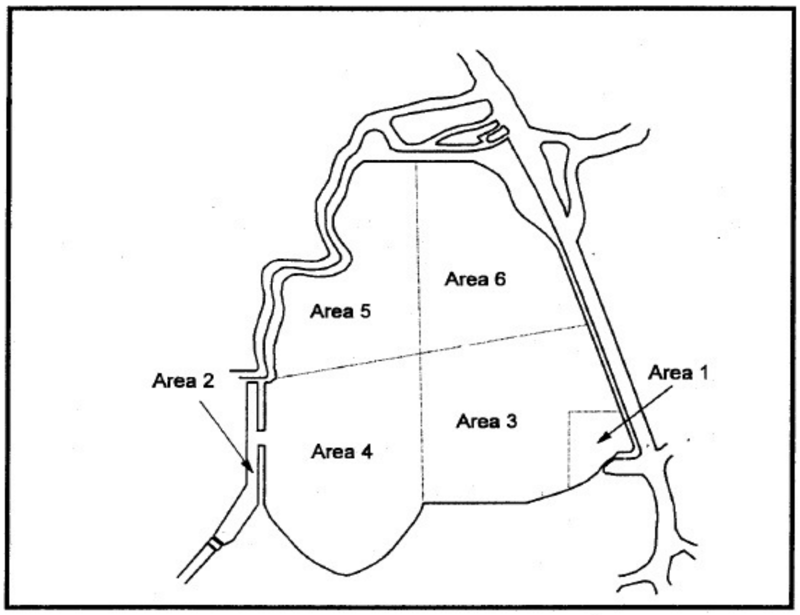


Figure 1: Sampling Map (Gingras and McGee 1997)

Hook and line sampling was conducted on 104 sampling days, at various times during the day from January 6, 2014 until December 30, 2014. Gill netting was conducted on three sampling days within the Forebay, December 22, 23 and 30, 2014, using a monofilament gill net, measuring 30 meters (m) or less, with variable mesh sizes ranging from five centimeters (cm) to 15.25 cm. Gill netting was determined to have too great an impact upon the condition of fish to be useful for mark/recapture studies, and was only used for fish captured specifically for use in the genetics portion of the study where the fish were sacrificed.

2.2.2 Issues

Predator sampling was conducted pursuant to the requirements of the DFW as outlined in SCP #7744 (an individual permit issued to Veronica Wunderlich) and SCP # 10286, an entity permit, which limited sampling efforts to days when approved staff were available.

Predator sampling efforts were additionally constrained by availability of boats as well as qualified and approved boat operators. The DWR Bay-Delta Office (BDO) has a clearly defined boat operator policy that requires that each operator complete a multi-day field based Motorboat Operator Certification Course (MOCC) and demonstrate necessary skills on the BDO vessel in the presence of designated approved BDO operators. As many staff members on the CCFPS were not yet approved BDO operators, all predator sampling efforts needed to be scheduled around the availability of qualified boat operators, as well as Operations Procedure 2 – Lock-out/Tag-out (OP-2) certified staff and the SCP holder. This required the careful coordination of multiple schedules across multiple ongoing projects.

In addition to the availability of boat operators, the availability of boats that could negotiate the variable conditions encountered in the Forebay proved to be a challenge. During a portion of the year, the Forebay becomes inundated with thick, and in some cases unnavigable, patches of submerged aquatic vegetation (SAV). With heavy infestations of SAV, it was not possible to operate the jet drive boat. (One of the two boats used for the project is a jet drive boat.) The second prop driven boat was loaned to DWR by DFW and was operable in heavier SAV infestations yet was not available throughout the year. On August 28, 2014, the borrowed boat was taken out of service, and the jet drive was not usable due to extensive SAV. A contractor boat and operator were secured for use requiring additional coordination.

2.2.3 Data Analysis

Data sheets were scanned and data was initially compiled into an excel spreadsheet to ensure that no data was lost while a database was under development. A database for acoustic tagged fish was completed in June 2014, and the acoustic tag portion of the predator sampling data was transferred from the excel spreadsheet for analysis. A more comprehensive database for all predatory fish captured was completed in December 2014. Total catch, catch by species, and catch by size for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(q = catchability (fish caught per hours of sampling), C = catch, f = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE per month for all species combined was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and d = number of sampling days in the month)

Mean CPUE per month was then calculated for each species using the equation

$$q_{sp} = \frac{\sum \left(\frac{Csp}{f \times a}\right)_i}{d}$$

Seasonal CPUE was calculated for the four seasons defined as winter (Jan 1 – March 19 and December 21-December 31), spring (March 20 – June 20), summer (June 21 – September 21), and fall (September 22 – December 20), based upon the equinox/solstice dates for 2014.

Seasonal CPUE for all species combined was calculated by:

$$q_s = \frac{\sum q_i}{d}$$

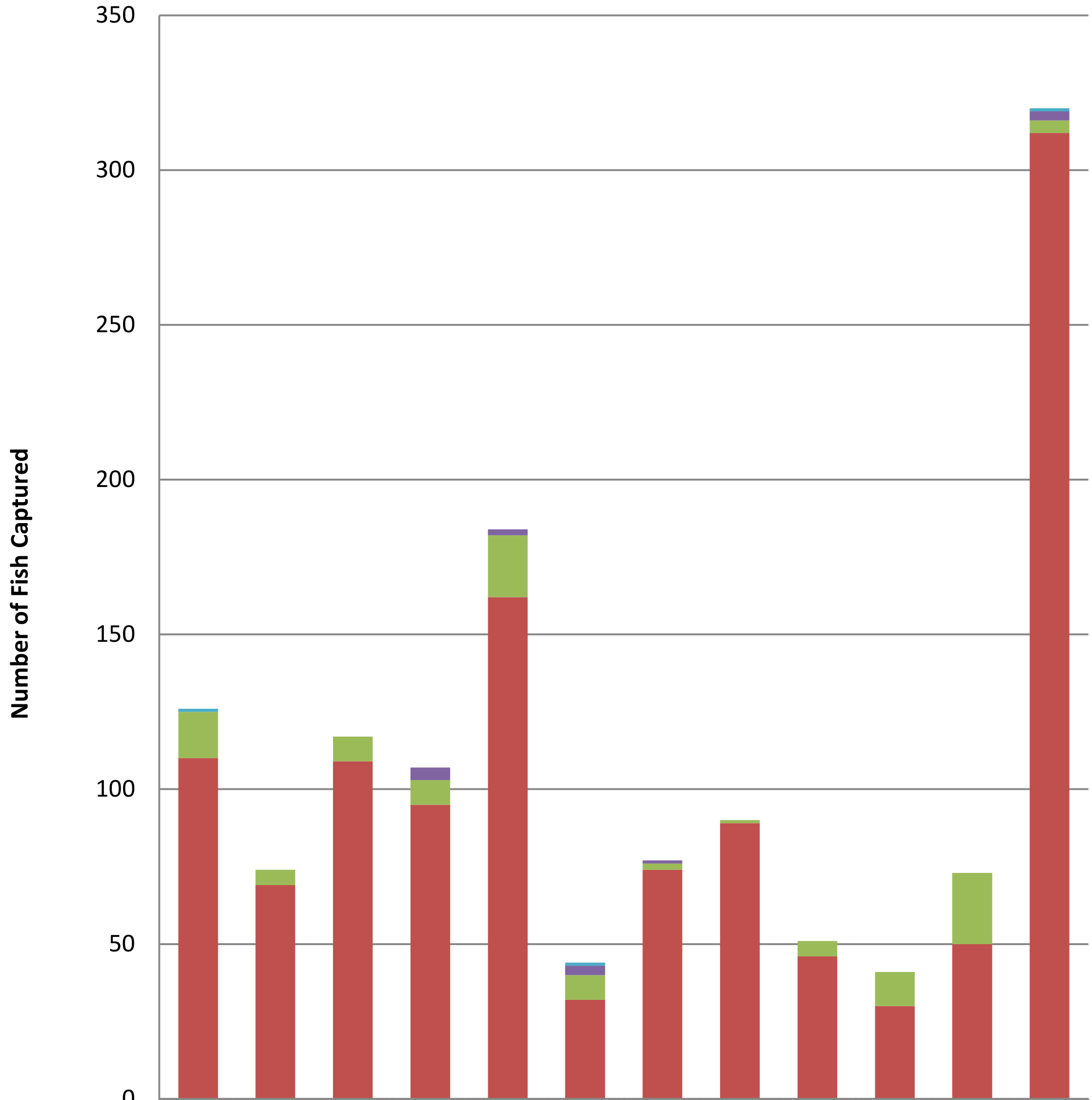
(q_s = seasonal catchability, q_i = catchability for each day sampled in the season, and d = number of sampling days in the season)

2.2.4 Results:

A total of 104 sampling days were conducted from January 6, 2014 until December 30, 2014, at various times during the day, resulting in the capture of 1,301 target predatory fish (Table 1, Figure 2) including Striped Bass, Largemouth Bass and multiple species of catfish, and three non-target fish.

Table 1: 2014 Predatory Fish Captures by Month

Month	Monthly Total	Striped Bass	Largemouth Bass	Catfish Sp	Non-Target Fish
January	126	110	15	0	1
February	74	69	5	0	0
March	117	109	8	0	0
April	107	95	8	4	0
May	184	162	20	2	0
June	44	32	8	3	1
July	77	74	2	1	0
August	90	89	1	0	0
September	51	46	5	0	0
October	41	30	11	0	0
November	73	50	23	0	0
December	320	312	4	3	1
Total	1304	1178	110	13	3



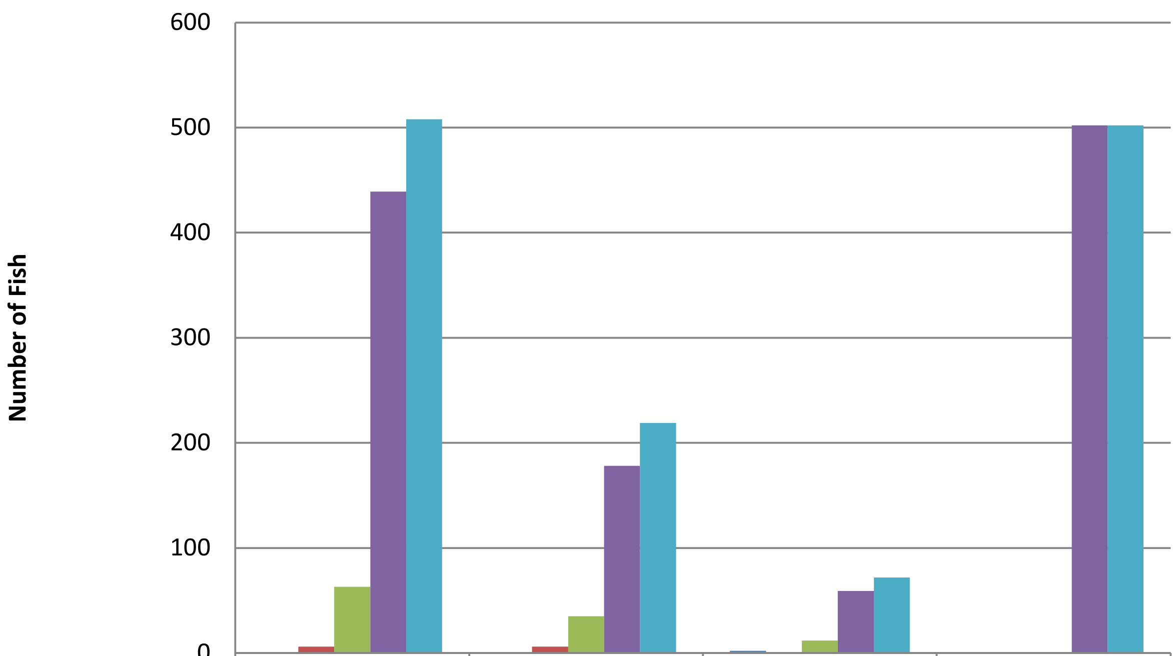
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Other	1	0	0	0	0	1	0	0	0	0	0	1
Catfish Sp	0	0	0	4	2	3	1	0	0	0	0	3
Largemouth Bass	15	5	8	8	20	8	2	1	5	11	23	4
Striped Bass	110	69	109	95	162	32	74	89	46	30	50	312

Figure 2: 2014 Predatory Fish Captures by Month

Of those target predatory fish, 234 Striped Bass were used in the 2013-2014 genetics element of the study conducted from December 2013 through May 2014 and discussed in more detail in section 2.4 of this report. An additional 268 Striped Bass were used in the 2014-2015 genetics[1] portion of the study

[1] Thirty Striped Bass captured in December 2013 were also included in the 2013-2014 genetics analysis. The 268 Striped Bass captured in December 2014 as part of the genetics effort will be discussed in more detail in the 2015 CCFPS Progress Report.

conducted from December of 2014 until May of 2015. The balance of the predatory fish captured was used for the acoustic and mark/recapture elements of the study, and consisted of 676 Striped Bass, 110 Largemouth Bass, and 13 catfish. Non-target fish species captured included one Sacramento Splittail **(***Pogonichthys macrolepidotus*) on December 22, one Black Bullhead (*Ameiurus melas*) on June 6, and one White Sturgeon (*Acipenser transmontanus*) on January 30, 2014. Of the fish used in the acoustic and mark/recapture element, 508 were passive integrated transponder (PIT) tagged, 219 were acoustically tagged, and 72 were not tagged at all, usually due to poor fish condition (Figure 3). All tagged fish were also secondarily tagged with Floy tags, allowing for a quick visual way to identify tagged fish, and to provide anglers with contact information so that they were able to report tagged fish that they may have caught. PIT tags are easily detected with handheld scanners and static antennas, allowing for identification of recaptures both in hand, as well as any time they pass by a PIT tag antennae. Without the use of PIT tags, recaptures would go undetected, and it would not be possible to get any kind of estimate of population. During the 2014 sampling effort three previously tagged Striped Bass and 11 previously tagged Largemouth Bass were recaptured. Due to the low sample size of recaptures, recapture data based upon PIT tags was not analyzed further during 2014. Gill net efforts resulted in the capture of 12 Striped Bass and the single Sacramento Splittail.



	PIT Tagged	Acoustic Tagged	Untagged	Sacrificed for Genetics
Other	1	0	2	0
Catfish Sp.	6	6	1	0
Largemouth Bass	63	35	12	0
Striped Bass	439	178	59	502
Total	508	219	72	502

Figure 3: 2014 Predatory Fish Captures by Treatment

Fish captured during the 2014 effort ranged in length from 17 cm to 93 cm for Striped Bass, 19.5 cm to 65 cm for Largemouth Bass, 29 cm to 68.5 cm for Channel Catfish, and 22.5 cm to 35 cm for White Catfish (Figure 4).

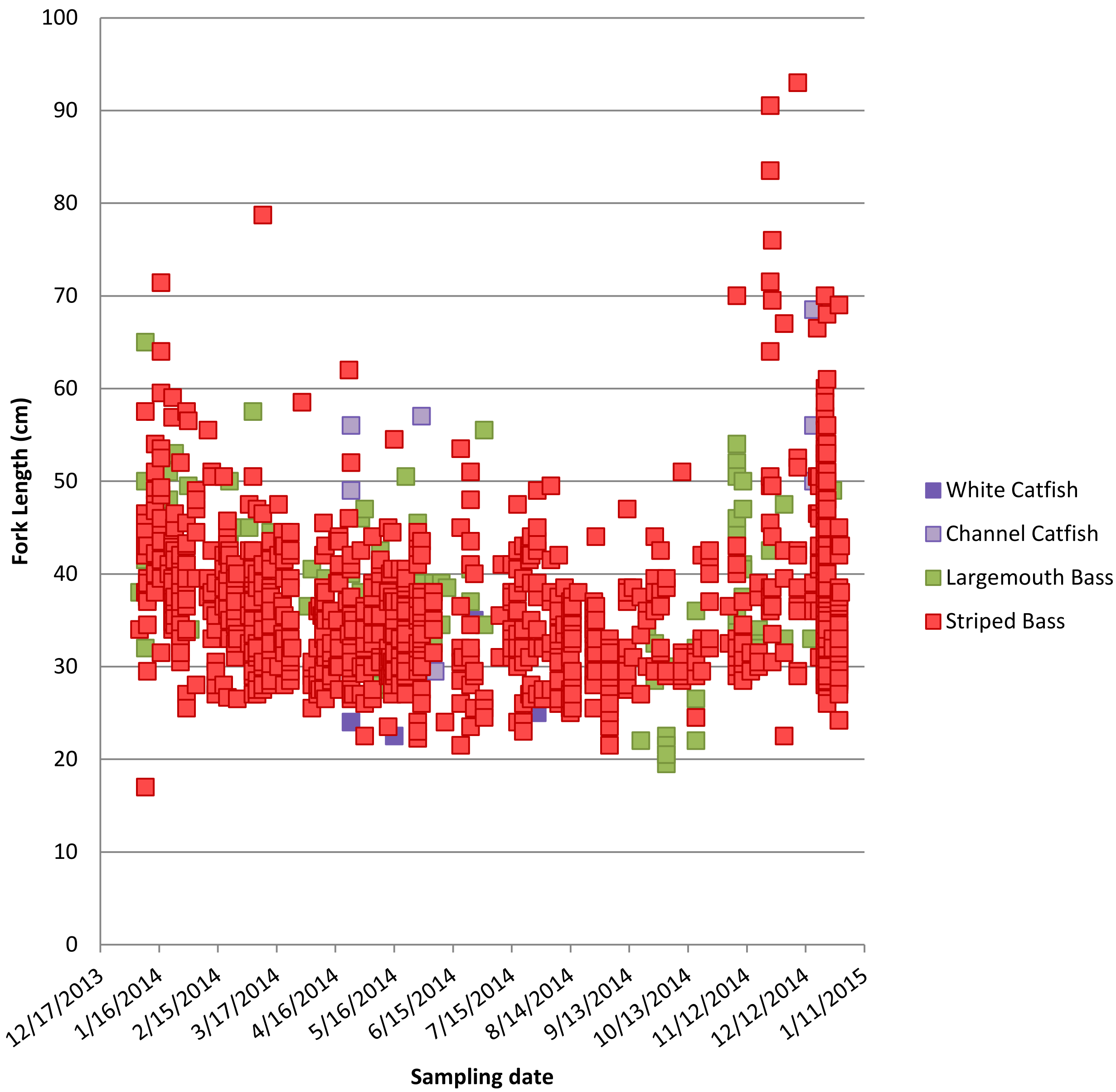


Figure 4: 2014 Predatory Fish Captures by Fork Length and Species

Striped Bass fork lengths converted into inches ranged from 6.69 to 36.61 inches (Figure 5). Striped Bass over 18 inches, which can be harvested legally by recreational anglers, were found to make up only 9 % of the total Striped Bass catch in 2014 (Figure 6).

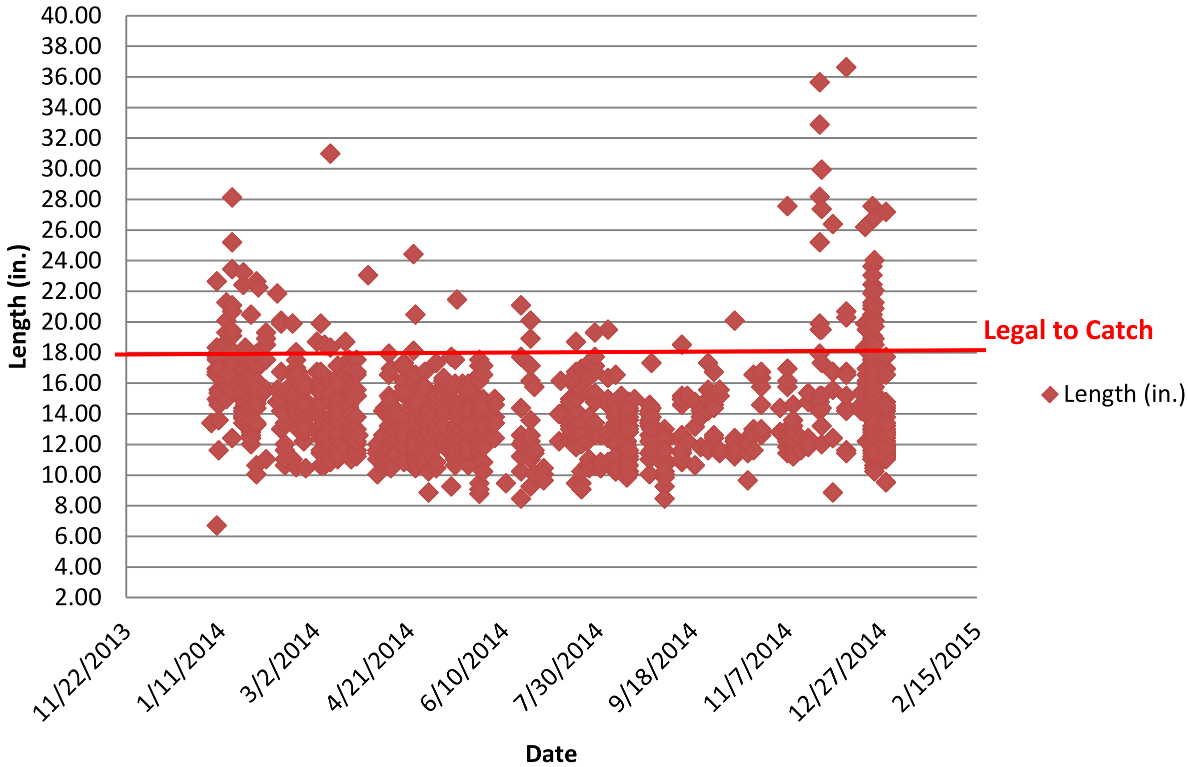


Figure 5: 2014 Striped Bass Captures by Fork Length (Inches)

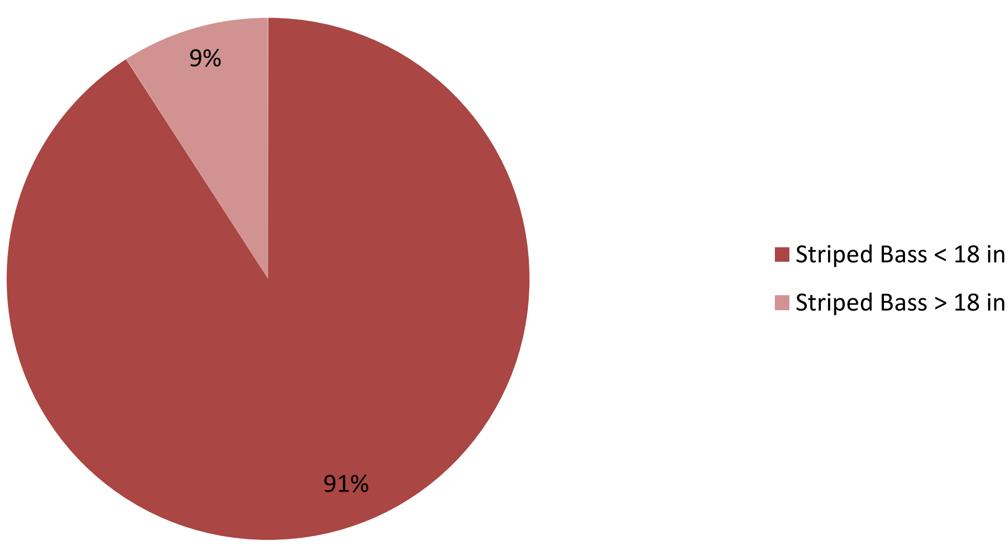


Figure 6: Percent of 2014 Striped Bass Captures of Legal Harvest Length

The majority of Striped Bass captured in 2014 at 69% of total catch, were in the 0.5 lb. (0.23 kg) to 1.5 lb. (0.68 kg) size class, with the highest catch of those fish occurring in May and December, at 131 and 192 fish respectively (Table 2, Figure 7). Fish in the 1.5 lb. (0.68 kg) to 3 lb. (1.36 kg) size class represented 20% of total Striped Bass catch, with the highest number captured in December at 82 fish, and the second highest catch occurring in January, at 38 fish. Fish over 3 lbs. (1.36 kg) represented 6% of the total Striped Bass caught, with the bulk captured in December, at 33 fish, and the second highest catch occurring in January, at 15 fish (Figure 8).

Table 2: 2014 Striped Bass Captures by Size Class

Month	Fish <.5 lbs. (0.23 kg)	Fish >.5 lbs.(0.23 kg) and <1.5 lbs.(0.68 kg)	Fish >1.5 lbs. (0.68 kg) and <3.0 lbs. (1.36 kg)	Fish >3.0 lbs. (1.36 kg)
January	2	55	38	15
February	3	41	22	5
March	2	81	25	4
April	10	78	13	2
May	12	131	17	1
Jun	5	21	3	2
Jul	9	52	12	0
Aug	8	74	5	0
Sept	6	35	5	0
Oct	0	24	4	1
Nov	0	35	8	7
Dec	5	192	82	33
Total for Year	62	819	234	70

*Weight was not recorded for nine Striped Bass during the 2014 sampling season.

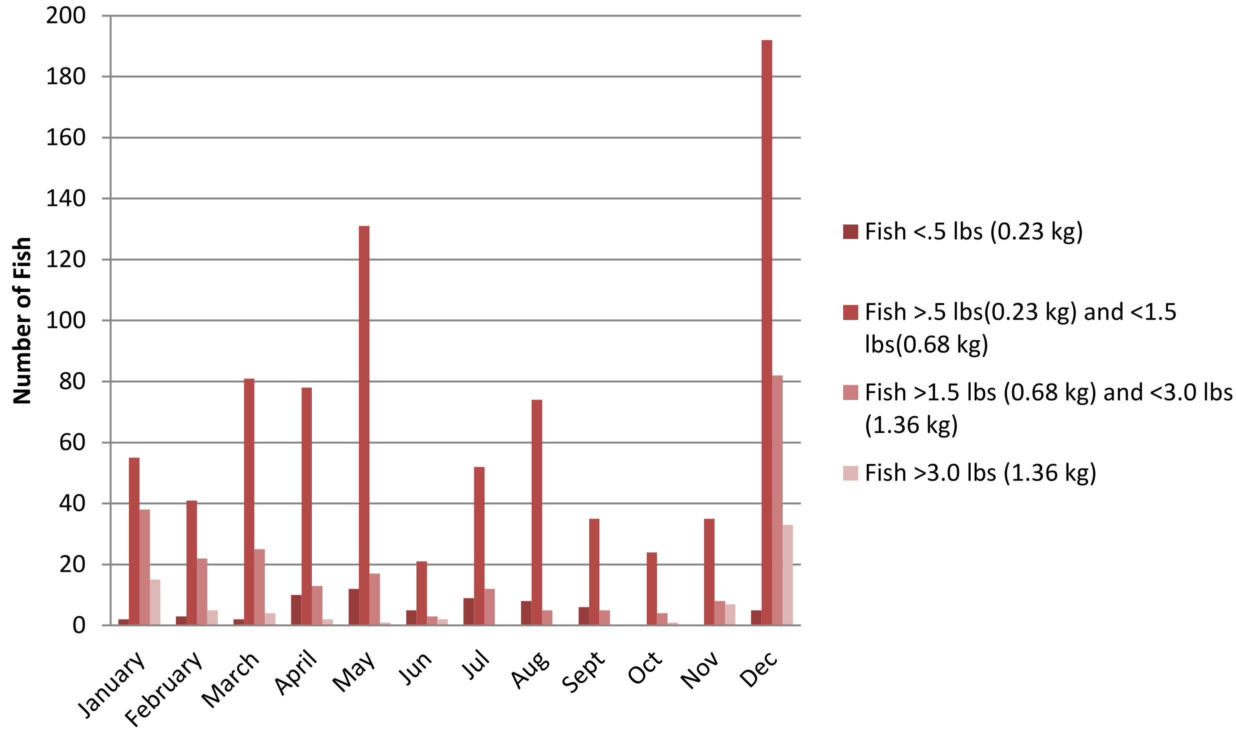


Figure 7: 2014 Striped Bass Captures by Size Class

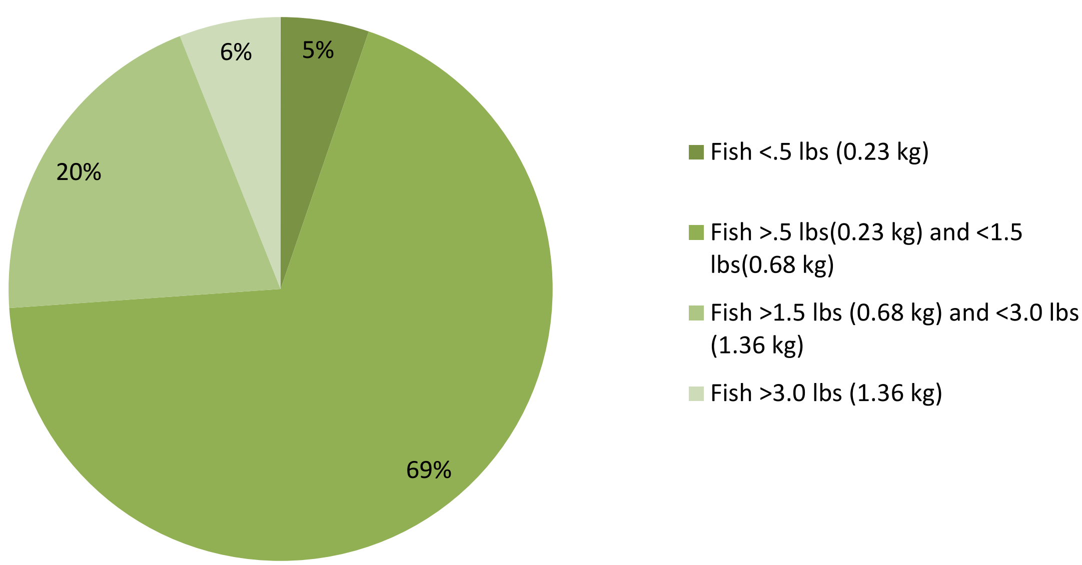


Figure 8: Percent Striped Bass Captures by Size Class in 2014

Sampling was more frequent during the months of January through May, and December, due to the additional crews fielded for the genetics effort. As a result of this increased sampling, catch was highest in the months that had both sampling crews working. The genetics crew catch made up for a large percentage of the total Striped Bass caught during these months (Table 3 and 4).

Table 3: 2014 Striped Bass Captures by Size Class Attributed to the Genetics Crew*

Month	Fish <.5 lbs. (0.23 kg)	Fish >.5 lbs.(0.23 kg) and <1.5 lbs.(0.68 kg)	Fish >1.5 lbs. (0.68 kg) and <3.0 lbs. (1.36 kg)	Fish >3.0 lbs. (1.36 kg)
January	1	39	21	11
February	0	0	1	0
March	0	6	4	0
April	5	41	7	1
May	9	81	6	0
Dec	3	174	70	21
Total for Year	18	341	109	33

* Weight was not recorded for one fish in January

Table 4: 2014 Percentage of Striped Bass Catch Attributed to Genetics Crew

Month	Fish <.5 lbs. (0.23 kg)	Fish >.5 lbs.(0.23 kg) and <1.5 lbs.(0.68 kg)	Fish >1.5 lbs. (0.68 kg) and <3.0 lbs. (1.36 kg)	Fish >3.0 lbs. (1.36 kg)
January	50%	71%	55%	73%
February*	0%	0%	5%	0%
March	0%	7%	16%	0%
April	44%	48%	50%	50%
May	75%	62%	35%	0%
Dec	60%	91%	85%	95%

*The genetics crew only sampled one day in February 2014.

Predatory fish were caught in all six Areas during the winter sampling period (Figure 9), with the bulk being caught in Area 1, at 257 fish, followed closely by 244 in Area 2.

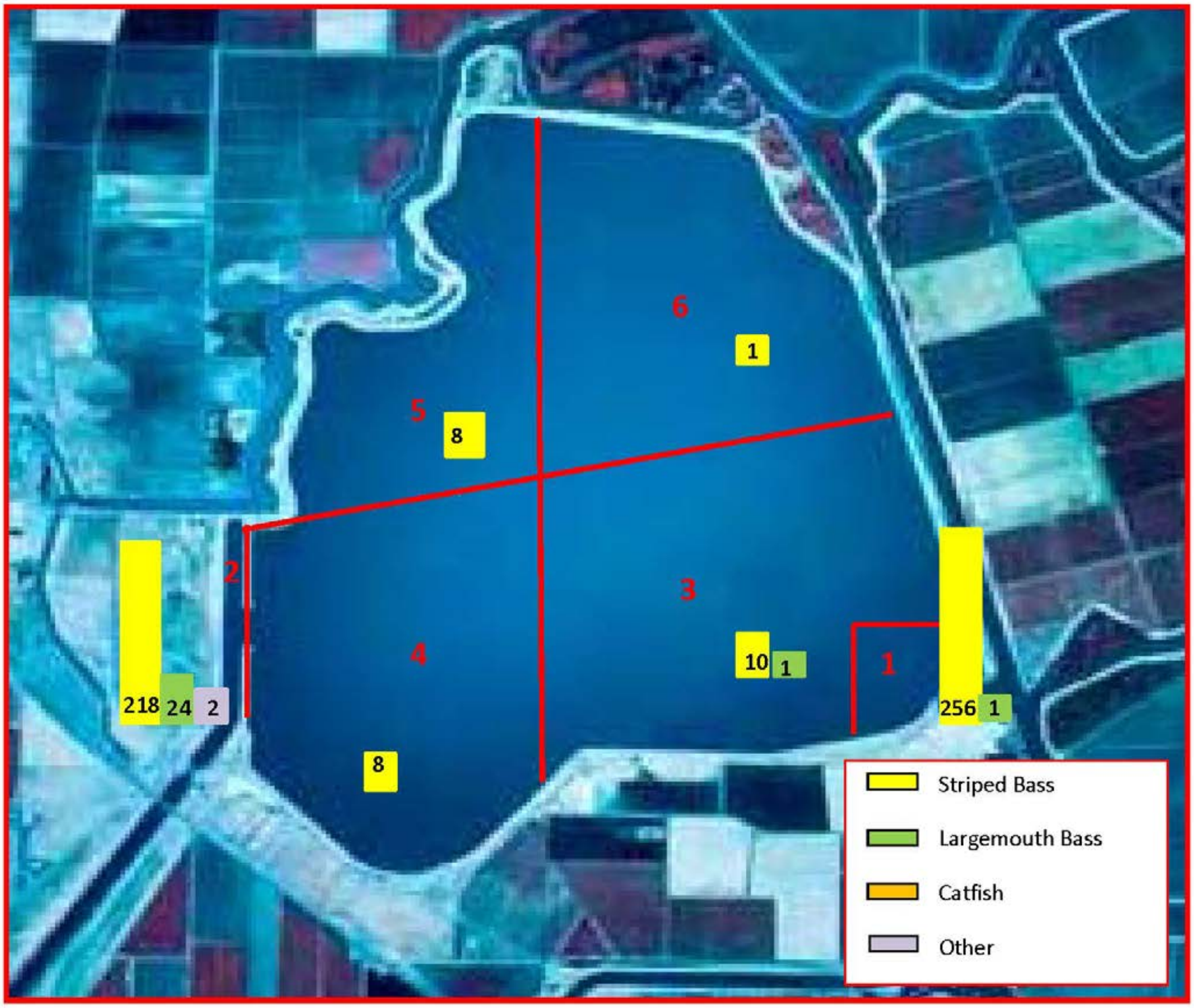


Figure 9: Winter 2014 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, and 4 during the spring sampling period (Figure 10), with the bulk being caught in Area 2, at 251 fish.

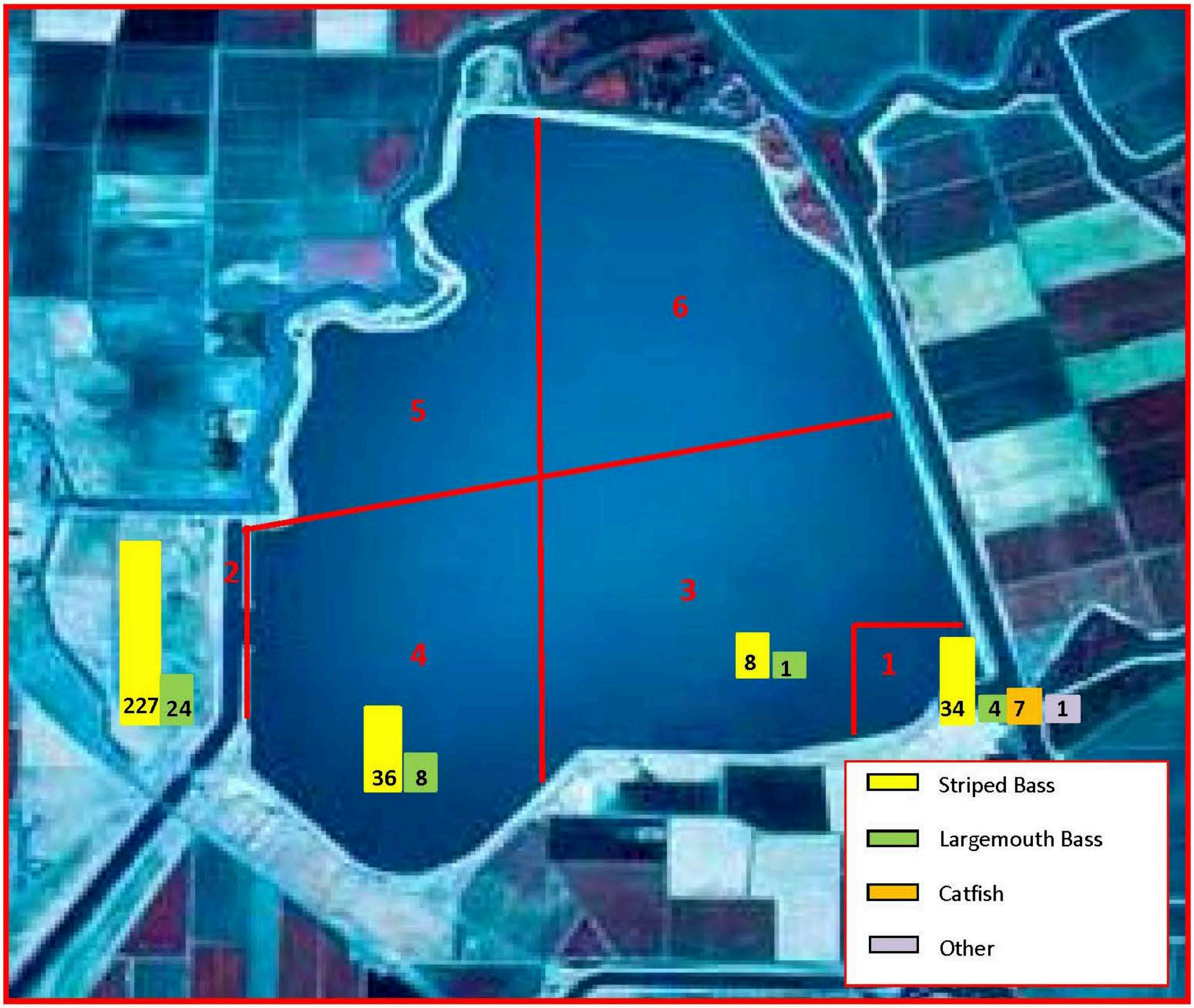


Figure 10: Spring 2014 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, and 4 during the summer sampling period (Figure 11), with the bulk being caught in Area 2, at 132 fish.

Figure 11: Summer 2014 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 4, and 5 during the fall (Figure 12), with the bulk being caught in Area 2, at 117 fish.

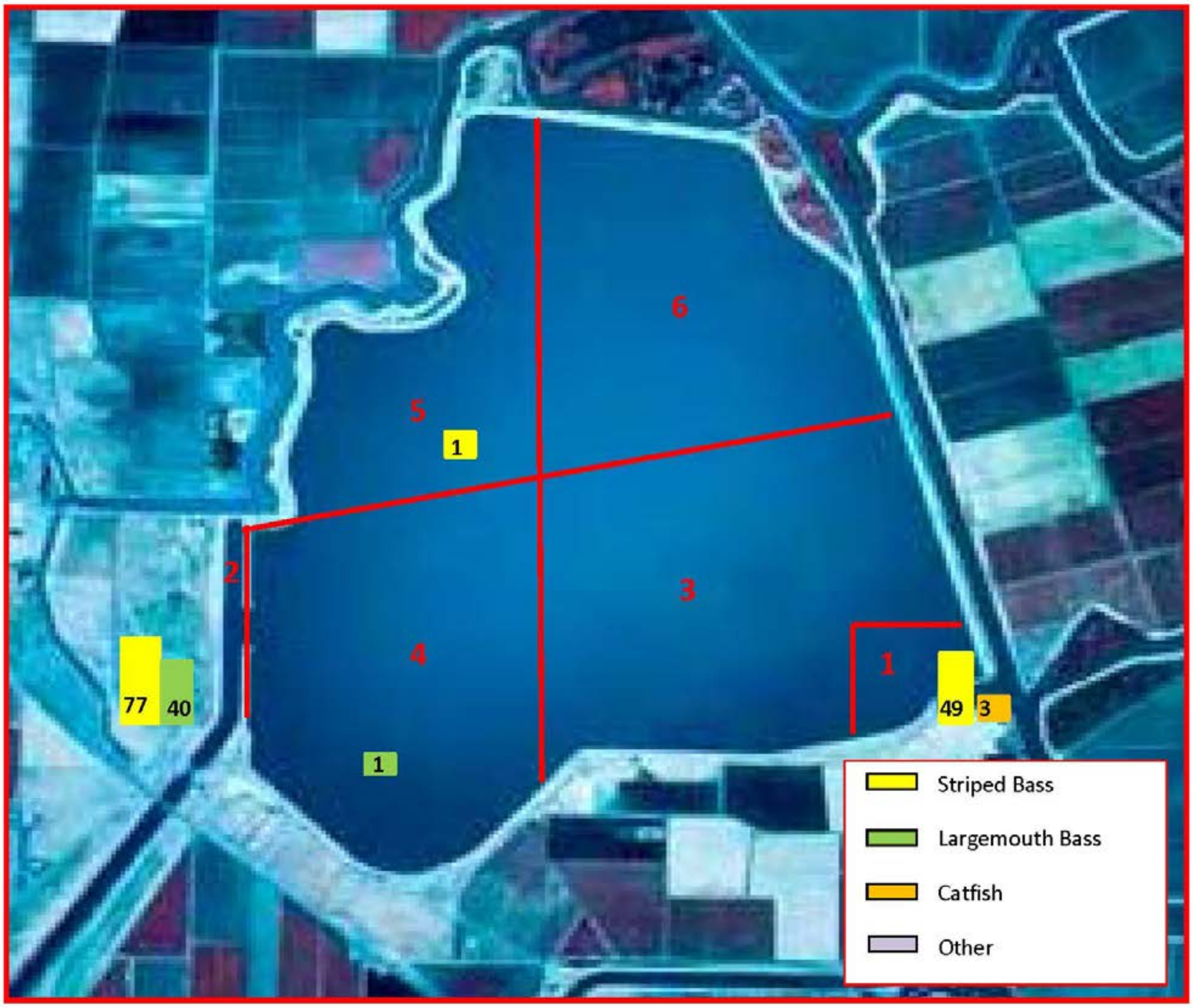


Figure 12: Fall 2014 Catch by Location and Species

CPUE per sampling day was calculated using the equation: $q = \frac{c}{f \times a}$. Mean CPUE per month was then estimated by: $q_m = \frac{\sum q_i}{d}$ (Table 5).

Table 5: 2014 Catchability (CPUE) for all Species Combined Non-Genetics Efforts

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean	0.75	0.57	0.97	0.81	1.09	0.77	0.91	1.29	1.01	0.75	1.29	0.86
Sample Day 1	0.32	0.35	0.29	0.37	1.91	2.33	0.48	0.57	0.75	0.00	0.73	0.95
Sample Day 2	0.13	1.07	0.98	1.00	1.00	1.22	0.71	2.29	1.13	0.93	1.37	0.46
Sample Day 3	0.89	0.86	1.05	0.85	0.76	0.31	1.29	0.20	0.38	0.44	1.60	0.48
Sample Day 4	0.73	0.55	0.00	1.38	1.53	1.14	2.60	2.22	0.62	1.38	0.00	2.00
Sample Day 5	0.89	0.50	1.70	0.50	2.40	0.20	1.16	0.94	0.44	0.00	0.89	0.35
Sample Day 6	0.50	0.86	1.19	0.55	0.00	0.13	1.11	0.91	2.00	1.20	3.33	0.75
Sample Day 7	1.40	0.30	1.23	1.00	0.32	0.38	1.63	2.50	1.75	1.29	2.00	1.00
Sample Day 8	1.43	0.27	1.60		0.83	0.36	0.00	0.67			0.40	0.88
Sample Day 9	0.50	0.42	0.67			0.82	0.33					
Sample Day 10							0.31					
Sample Day 11							0.38					

While mean monthly CPUE peaked in August at 1.29 fish per hour, variability between daily efforts is too great to indicate a true trend (Figure 13).

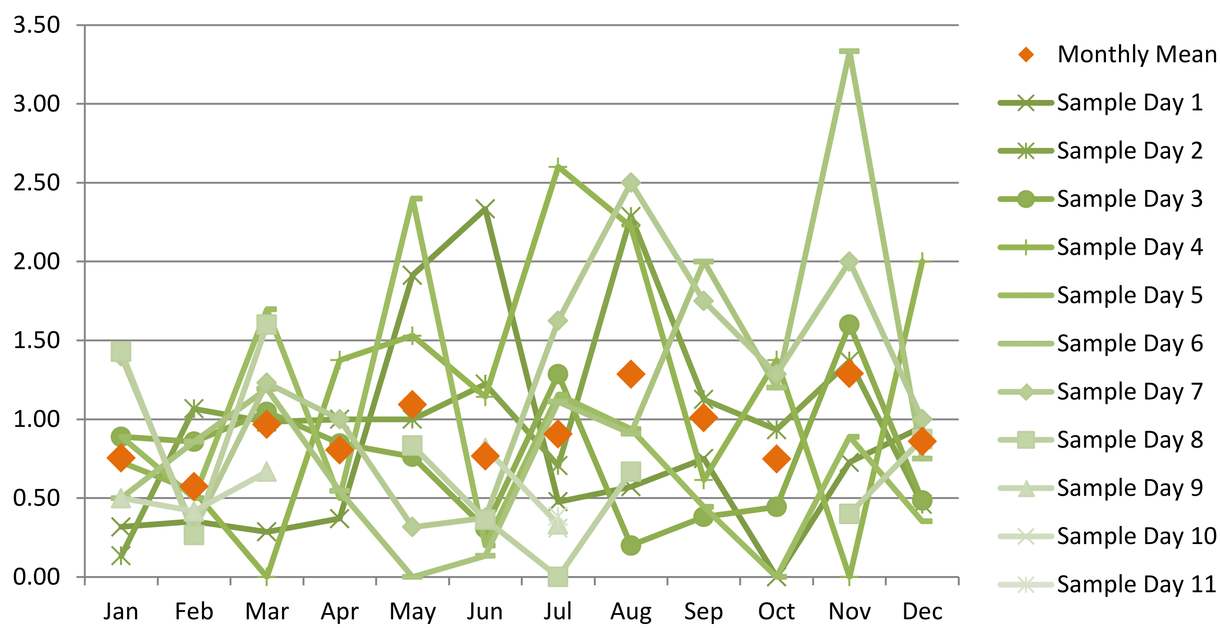


Figure 13: 2014 CPUE for all Species Combined Excluding Genetics Efforts

Seasonal CPUE was calculated for the four seasons (Table 6) defined as Winter (Jan 1 – March 19; December 21-31), Spring (March 20 – June 20), Summer (June 21 – September 21), and Fall (September 22 – December 20)[2].

Table 6: 2014 Catchability (CPUE) for all Species by Season (Including Genetics Efforts)

Season	Sampling Days	Seasonal CPUE
Winter (Jan 1 - Mar 19)	33	0.76
Spring (Mar 20 - Jun 20)	41	0.87
Summer (Jun 21 - Sep 21)	25	1.15
Fall (Sep 22 - Dec 20)	23	0.99
Winter (Dec 21 – 31)	6	2.82

CPUE per sampling day and mean monthly CPUE were calculated for Striped Bass caught by the genetics crew using the equations $q = \frac{C}{f \times a}$ and $q_m = \frac{\sum q_i}{d}$, respectively.

Beginning in December of 2014, genetics collection methods were modified to allow for reduced processing during sampling efforts. This resulted in more efficient fishing efforts and a significant increase in catch, which is shown in the increase in CPUE experienced following the initiation of the new methods (Table 7).

Table 7: 2014 Catchability (CPUE) for Striped Bass (Genetics Efforts Only)

	Jan	Feb	Mar	Apr	May	Dec*
Monthly Mean	**0.87**	**0.11**	**0.47**	**0.63**	**1.14**	**4.98**
Single Sample Day	**1.05**	**0.11**	**0.67**	**0.75**	**1.11**	**4.08**
	0.67		**0.27**	**0.80**	**3.20**	**7.93**
	0.89			**0.35**	**0.58**	**2.94**
	1.33			**0.25**	**0.60**	
	0.70			**0.48**	**0.86**	
	0.59			**0.82**	**0.82**	
	0.88			**0.96**	**0.64**	
				0.60	**1.28**	

*December CPUE is inflated compared to other months due to a change in genetics collection methods.

Mean monthly CPUE, excluding the fish caught during genetics efforts, was then calculated for each species using the equation: $q_{sp} = \frac{\sum \left(\frac{Csp}{f \times a} \right)_i}{d}$

[2] Seasons determined based upon published Equinox/Solstice for 2014.

CPUE was found to be highest for Striped Bass in August, at 1.27 fish per hour, followed by May and September at 0.94 and 0.92 respectively (Table 8). For Largemouth Bass, CPUE peaked in November, at 0.43 fish per hour, and for catfish, CPUE peaked in April at 0.14 fish per hour.

Table 8: Monthly Catchability (CPUE) By Species (Excluding Genetics Efforts)

Monthly CPUE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Striped Bass	0.54	0.53	0.89	0.60	0.94	0.56	0.89	1.27	0.92	0.54	0.86	0.87
Catfish	0.01	0.00	0.00	0.14	0.03	0.09	0.01	0.00	0.00	0.00	0.00	0.05
Largemouth Bass	0.21	0.04	0.08	0.06	0.13	0.11	0.01	0.02	0.09	0.21	0.43	0.06

Temperatures began to meet or exceed 20° C in April 2014 and remained mostly above this temperature until early October, peaking in July and August (Figure 14), however no clear correlation between temperatures and CPUE were identified..

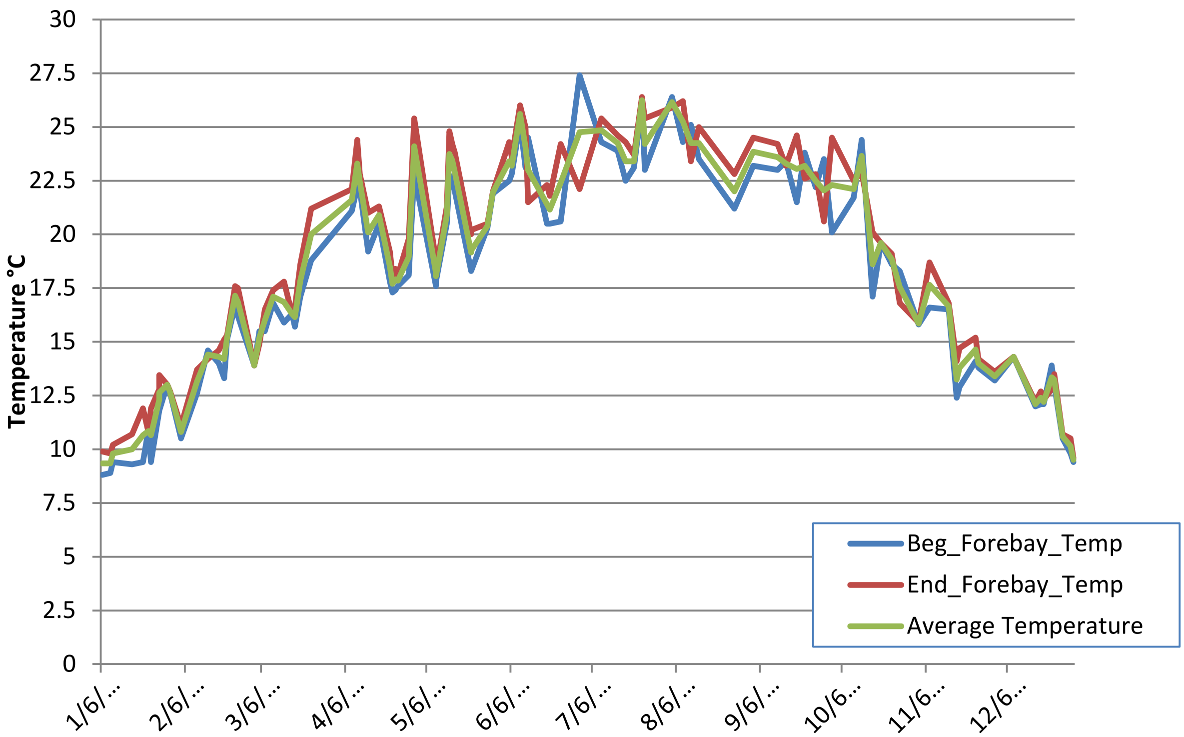


Figure 14: 2014 Sampling Effort Temperatures (°C)

2.2.5 Discussion and Recommendations

The 2014 predator sampling effort in the Forebay served multiple purposes, including providing fish for the acoustic tagging studies, genetic gut diet analysis, and mark/recapture studies using non-acoustic tags such as Passive Integrated Transponder (PIT) and Floy tags, to investigate population size and gather basic data. Data from these various efforts will be used for future bioenergetics modelling, and to investigate species catchability, immigration and emigration rates, dietary habits, and seasonal distribution in the Forebay.

The largest numbers of predatory fish were captured during months that had concurrent sampling for the genetics and tagging efforts, with the peak months being January, May and December at 126, 184, and 320 respectively. Three previously captured and tagged Striped Bass and 11 previously tagged Largemouth Bass were recaptured during the 2014 sampling effort. It should be noted that December 2014 had an unusually high catch that resulted from a significant change in the methods used by the genetics crew, which allowed them to spend more time catching fish and less time processing fish. As the high catch rates were driven in part by the genetics efforts, which focused on catching Striped Bass, the peak months for Striped Bass mirrored those of overall catch.

Within the Striped Bass catch, the largest size class of Striped Bass (over 3.0 lbs./1.36 kg) was captured in all sampling months except July, August and September, with total numbers caught peaking in December and January. The next smaller size class Striped Bass, between 1.51 lbs. (0.68 kg) and 2.99 lbs. (1.36 kg), were caught in every month sampled, peaking in January through March, and again in December. The size class Striped Bass, between 0.5 lbs. (0.23 kg) and 1.5 lbs. (0.68 kg) were caught in every month sampled, with a peak from March through May and again in December. Striped Bass under 0.5 lbs. (0.23 kg) were captured in every month except October and November, with a peak in April and May.

Throughout the year the 0.5 lbs. (0.23 kg) to 1.5 lbs. (0.68 kg) size class dominated all of the sampling months, and represented 69% of the total Striped Bass catch for the year. This may be indicative of a thriving population of smaller Striped Bass, including fish less than 3.0 lbs. (1.36 kg), which are present in the Forebay year round. When captured striped bass were examined based upon length, only 9% of the total catch was found to be over 18 inches, of legal harvestable length. While there appear to be some trends in seasonality and residency, due to the variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, gear selection, and time required to process each fish caught, these trends need more robust examination before a strong conclusion can be drawn. Residency can be more thoroughly investigated using biotelemetry, as described below.

The overall catch and peak catch for Largemouth Bass and catfish were different than those of Striped Bass, with Largemouth Bass caught in every month sampled, peaking in January, May and November. Catfish were only caught during five months, April, May, June, July, and December, and very few catfish were caught during the sampling effort. This, however, is not necessarily indicative of a small or strongly seasonal catfish population. Kano (1990) showed a very large population of White Catfish present throughout the year in 1983-1984, and catfish continued to be caught by anglers interviewed for creel throughout 2014. It is likely that variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, gear selection, and limitations in other available capture methods that are known to target catfish significantly affected ability to catch catfish. Kano (1990) employed hoop nets that were deployed for long periods of time, and greatly increased his ability to capture catfish. This technique is not currently available to this project, as it is not allowed within the terms of the SCPs.

While there may be some seasonal trends in catch by species and size class, due to limitations with sampling access resulting from a variety of issues, including boat access and SAV, and changes in conditions and angling efficiency, it is important to collect more data over several years to determine if these trends are significant. In addition, angling methods to target catfish should be reevaluated for future study years to maximize catfish capture. It is also recommended that additional sampling techniques be pursued, such as electro-fishing, or use of other styles of nets and/or seines.

Gill net sets resulted in the catch of 12 Striped Bass during the December genetics effort, and was shown to be a useful tool for collecting fish for this effort. We recommend the use of the gill net be continued as a tool for gathering additional population size and distribution information, in conjunction with study elements that are not adversely affected by the resulting condition of the fish, such as the genetics effort.

2.3 Biotelemetry

2.3.1 Methods

The initial phase of the biotelemetry receiver array, installed between January and March 2013, consisted of nine units within and immediately adjacent to the Forebay. These nine units included the IC1, IC2, IC3, RGD1, RGU1, WC1, WC2, WC3 and ORS1 (Figure 15).

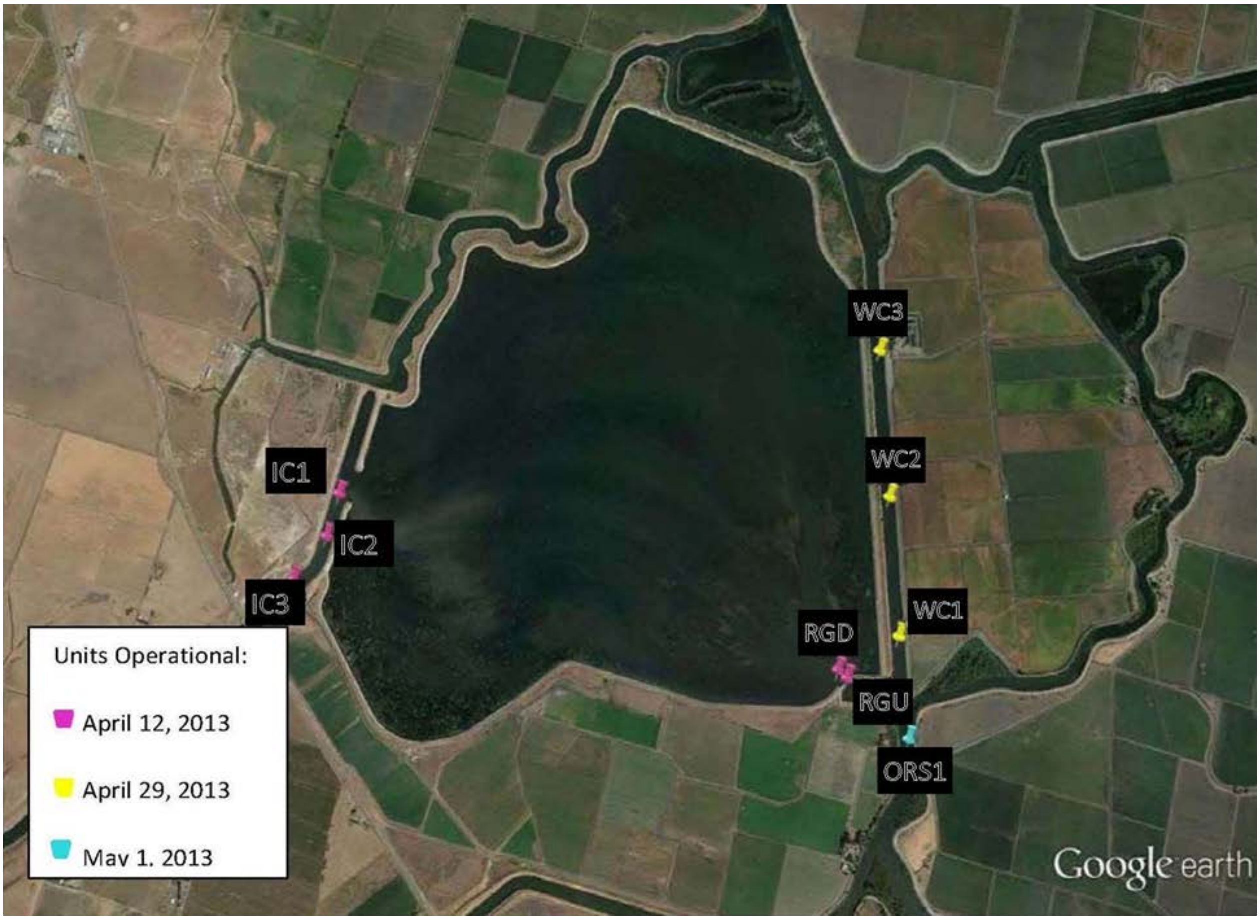


Figure 15: 2014 Receiver Array (Deployed in 2013)

Each of these sites was initially made up of an Hydroacoustic Technology Incorporated (HTI) Model 295x datalogger/ hydrophone combination, powered by a 12-volt (two six-volt sealed deep cycle batteries wired in series) power source connected to a solar panel via a solar charge controller to ensure continued operation. A beacon tag with a predetermined code was deployed near each hydrophone to document ongoing functionality of the unit. These units were upgraded to HTI Model 395 dataloggers in December of 2013 (Figure 16), allowing for remote monitoring and data downloads, as well as gps linking of the entire array.

Figure 16: Deployed Model 395 Datalogger/Hydrophone Unit with Solar Panel

In addition to the static array, pilot level mobile monitoring was conducted, using a mobile version of the Model 395 datalogger/hydrophone unit, beginning in June of 2014, but it was inconsistent, and did not provide enough coverage of the Forebay to accurately detect fish that may be located outside the range of the array.

Tag codes for 2014 were predetermined by HTI, with sub code 7 for Striped Bass less than 1.5 lbs. (0.68 kg), sub code 24 for Striped Bass over 1.5 lbs. (0.68 kg), and sub code 4 for non-Striped Bass (catfish species and black bass species such as Largemouth Bass, Spotted Bass, and Smallmouth Bass). At the beginning of each month, up to seven HTI 795LG/ Biomark HPT9, 17 HTI 795LY/ Biomark HPT9, and seven HTI 795LZ/ Biomark HPT9 acoustic/PIT combination tags were programmed with codes from the lists provided by HTI. Tags that were not used the prior month were rolled forward into the new month. Following tag programming, each tag was checked for functionality via a tag "sniffer" or a hydrophone attached to an HTI 395 mobile data logger. Up to 31 predatory fish captured each month during the sampling efforts that were larger than 0.5 lbs. (0.23 kg) were tagged with HTI/ Biomark combination acoustic/PIT tags as well as secondary external Floy tags (Table 9).

Internal tagging followed procedures based on methods described in Wingate and Secor 2007, and incorporated the use of anesthesia methods as part of the INAD for Aqui-S 20E (US Fish and Wildlife Service (USFWS) 2011; Study #'s 11-741-14-007F, 11-741-14-008F, 11-741-14-009F, 11-741-14-010F). All captured predatory fish that were not acoustic tagged, were tagged with internal Biomark HPT9 PIT and external Floy tags so that they could be identified in the event of recapture or salvage.

Table 9: Maximum Number of Predatory Fish to be Acoustically Tagged Each Month.

HTI Tag Type	Fish Size Range lbs.(kg)	Striped Bass	Black Bass	Catfish	Total Tags per Month
LG – sub code 7	>0.5 (0.23) to <1.5 (0.68)	7	0	0	7
LY – sub code 4 (non-Striped Bass); sub code 24 (Striped Bass)	>1.5 (0.68) to <3.0 (1.36) (Striped Bass) >1.5 (0.68) (non-Striped Bass)	7	5	5	17
LZ – sub code 24	>3.0 (1.36)	7	0	0	7
Total Fish per Month		21	5	5	31

Acoustic tagging was conducted on 66 predator sampling days, at various times during the day from January 6, 2014 until December 19, 2014. Secondary external Floy tags were applied to all captured fish. After the fish was tagged, scale samples were taken, and the fish was placed into a recovery net at the point of capture, and monitored until swimming normally. Once the fish was deemed fully recovered it was released.

2.3.2 Issues

Boat access problems such as loss of navigability during times of high SAV load, and lack of access to qualified boat operators, and scheduling conflicts resulted in a slower than desired response time when datalogger/hydrophone units required maintenance, which caused delays in correcting problems when identified, and potential gaps in data collection.

2.3.3 Data Analysis

All tagging data was recorded onto Rite-in-Rain datasheets that were scanned onto the DWR server and transcribed into an excel spreadsheet. Data including release dates and times for each acoustic tagged fish was sent to HTI on a weekly basis, and tags were identified by tag type so that they can be removed from the search list as their batteries, which have different lifespans based upon type, reach the end of life. Data was downloaded via modem directly from the acoustic receivers by HTI staff and analyzed at their office in Seattle, Washington.

Data was analyzed by uploading each hour long file from each receiver into the MarkTags® software and identifying tags that had been detected by the hydrophone. Each tag signature identified by the software has a visual beginning and end which are marked via electronic bookmarks and show which tag and what time it was detected (Figure 17). This information was initially processed by an automated program and then verified by trained technicians.

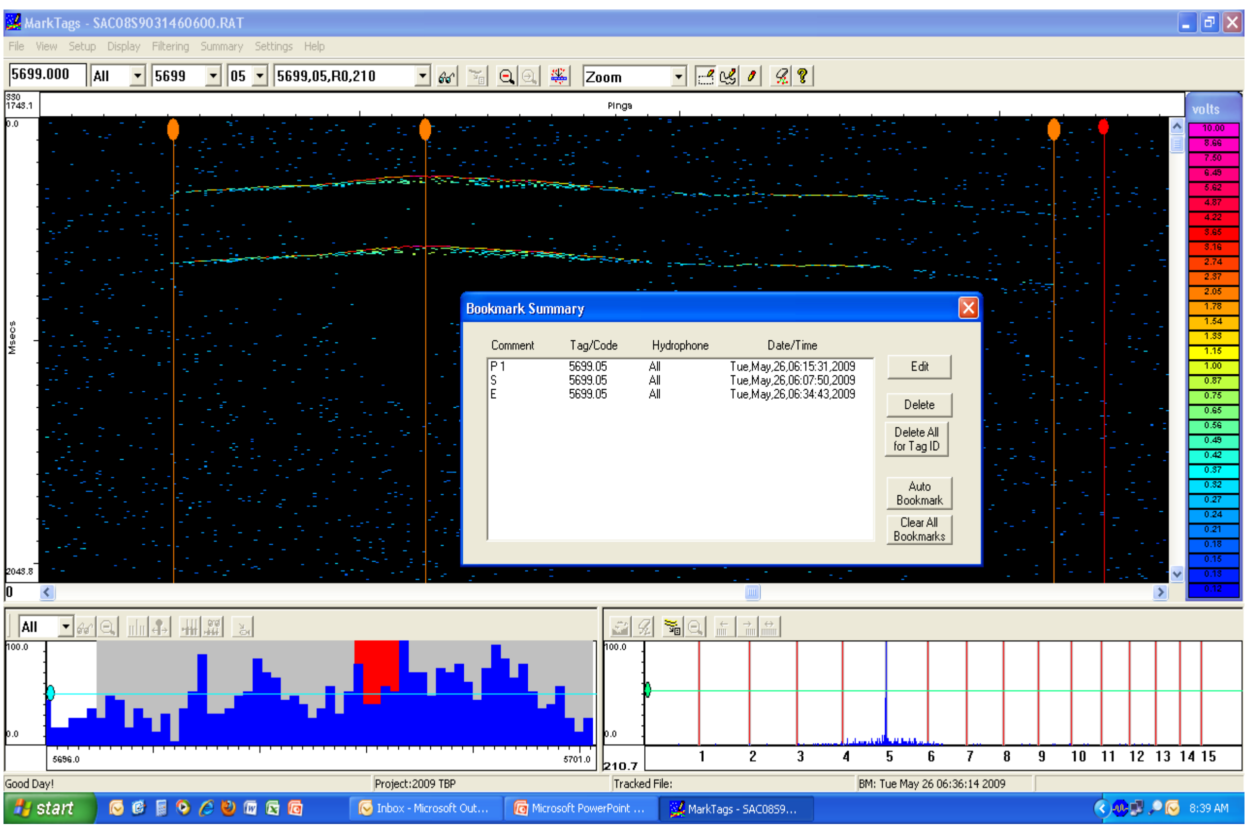


Figure 17: MarkTag Screenshot Displaying a Tagged Fish (2009 K. Clark)

Once analysis via MarkTags® was complete, the acoustic data was imported into a database which allowed for a secondary quality control phase, consisting of checking for tags that appeared to be detected by any hydrophone prior to release. Following verification of the data, the database was fully populated and returned to DWR. The database allowed for determination of the first and last detection of each tagged fish at each receiver location. By looking at all of the receiver stations chronologically, a tagged fish can be "observed" as it moves through the array over time. This can be further visualized using programs such as EON fusion (Figure 18). For instance, in the figure below, the detection of an acoustically tagged catfish is indicated by the appearance of a color-coded polygon. The hydrophones are color-coded by location to make the image easier to decipher, with the intake channel in green, West Canal in blue, radial gates downstream in yellow, radial gates upstream in red, and Old River south in pink. The image in Figure 13 shows a span of time from June 27, 2013 through August 1, 2013, for an overview of the fish's detections throughout this period, and shows that the fish was detected both inside and outside of the Forebay during this period.

A list of acoustic tags released into the Forebay was compiled and compared to a list of acoustic tags detected by the receivers in the array. Then each tag confirmed as being detected in the array was analyzed for first and last detection at each receiver, so that gross movement through the array as well as movement across, into and out of the Forebay, could be identified.

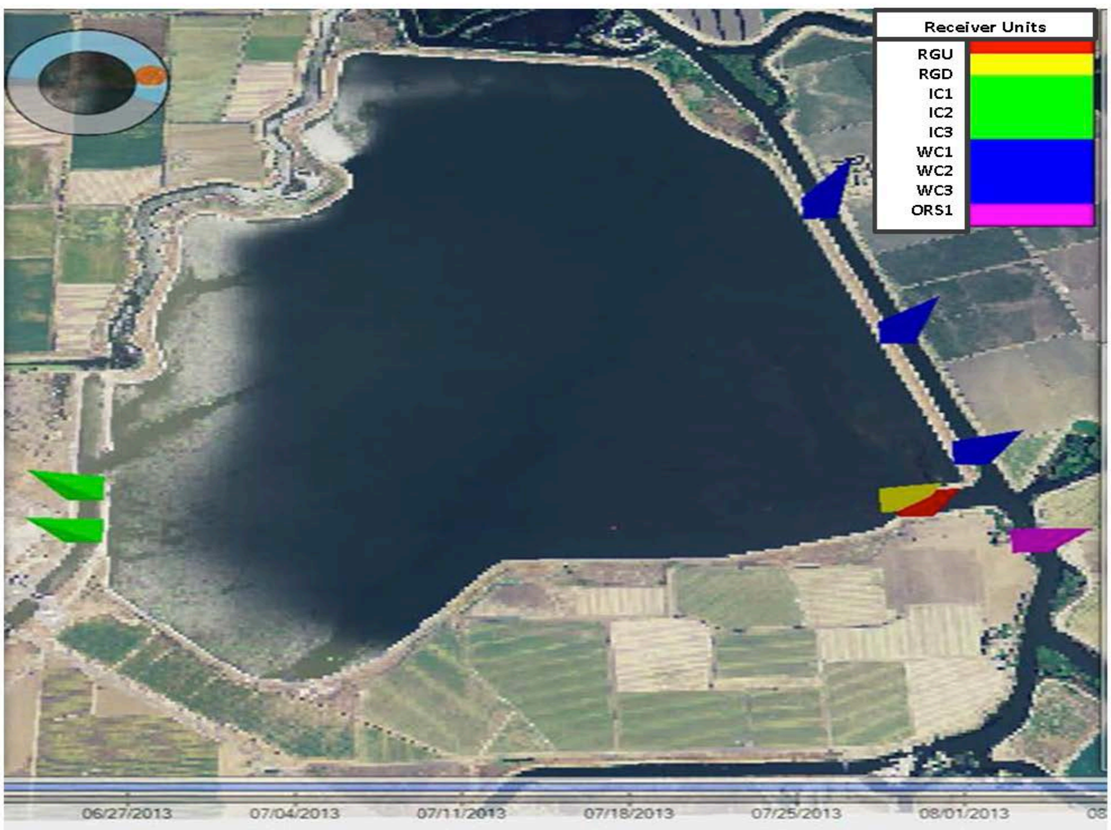


Figure 18: Screenshot of EONFusion showing Acoustically Tagged Catfish in and around Clifton Court Forebay during 2013

2.3.4 Results

A total of 219 predatory fish were acoustically tagged in 2014; six Channel Catfish, 35 Largemouth Bass, and 178 Striped Bass (Table 10). The target number of 31 acoustically tagged fish per month was never achieved during 2014 tagging efforts. The highest number of acoustically tagged fish occurred in November and the lowest number occurred in August, at 26 and 9 fish, respectively. Of the 219 total tagged fish, 14 were never detected by any of the receivers in the array, including one Largemouth Bass, two Channel Catfish and 11 Striped Bass. This represented 6% of the total number of tagged fish. As these fish were not necessarily tagged and released within range of the deployed receivers, it is possible that a fish could be active in the Forebay, but never detected.

Table 10: Acoustic Tagged Fish in 2014

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass	5	4	5	2	5	5	0	0	1	3	5	0	35
Catfish Species	0	0	0	2	1	0	0	0	0	0	0	3	6
Striped Bass (LG)	6	7	7	7	6	7	7	7	7	7	7	7	82
Striped Bass (LY)	7	7	7	6	7	3	5	2	4	4	7	7	66
Striped Bass (LZ)	5	5	3	1	1	1	0	0	0	0	7	7	30
All Species	23	23	22	18	20	16	12	9	12	14	26	24	219

Of the 205 acoustically tagged fish detected by the receivers, 56 fish (27% of the detected fish), were detected on receivers outside as well as inside of the Forebay, indicating that they emigrated from the Forebay (Table 11). Four of these emigrating fish were Largemouth Bass, one was a Channel Catfish, and 51 were Striped Bass.

Table 11: Acoustic Tagged Fish Released in 2014 Detected Outside of Forebay

Species	Tag Number	Release Date	Detected Inside Forebay				Detected Outside Forebay				
			IC1	IC2	IC3	RGD1	RGU1	WC1	WC2	WC3	ORS1
Striped Bass	6068.24	9-Jan-14	31-Aug-14			12-Feb-14	12-Feb-14	15-Feb-14	14-Feb-14	14-Feb-14	14-Feb-14
Striped Bass	9876.24	9-Jan-14	23-Oct-14	25-Oct-14	27-Nov-14	23-Dec-14	11-Aug-14	01-Aug-14	12-Jun-14	30-Jul-14	01-Aug-14
Striped Bass	8112.24	9-Jan-14	26-Jan-14	17-Mar-14	10-Jan-14	18-Feb-14	24-Feb-14	24-Feb-14	24-Feb-14	24-Feb-14	20-Feb-14
Striped Bass	6859.07	10-Jan-14	29-Apr-14	29-Apr-14	29-Apr-14	23-Sep-14	28-May-14	28-May-14	06-Oct-14	14-May-14	23-May-14

Species	Tag Number	Release Date	Detected Inside Forebay				Detected Outside Forebay				
			IC1	IC2	IC3	RGD1	RGU1	WC1	WC2	WC3	ORS1
Striped Bass	9232.24	10-Jan-14				03-Nov-14		17-Feb-14	17-Feb-14	17-Feb-14	
Striped Bass	8231.07	10-Jan-14	08-Mar-14	08-Mar-14	08-Mar-14	16-Mar-14	16-Mar-14	16-Mar-14	16-Mar-14	16-Mar-14	
Striped Bass	7468.24	10-Jan-14	14-Oct-14	13-Oct-14	14-Oct-14	10-Dec-14	24-May-14	24-May-14	24-May-14	08-Apr-14	24-May-14
Striped Bass	8063.07	10-Jan-14	22-Aug-14	23-Jun-14	10-May-14	09-Sep-14	15-Mar-14	15-Mar-14	15-Mar-14	15-Mar-14	
Striped Bass	9008.24	17-Jan-14	24-Oct-14	26-Oct-14	03-Jul-14	06-Nov-14	01-May-14	30-Mar-14	30-Mar-14	30-Mar-14	17-Mar-14
Striped Bass	5683.07	17-Jan-14	13-May-14	13-May-14	13-May-14	19-Aug-14	18-Mar-14	18-Mar-14	18-Mar-14	18-Mar-14	16-Mar-14
Striped Bass	8028.24	17-Jan-14	13-Oct-14		13-Oct-14	31-Dec-14	26-Sep-14	25-Sep-14	25-Sep-14	24-Feb-14	
Striped Bass	7076.24	27-Jan-14	29-Jan-14	29-Jan-14		16-Mar-14	16-Mar-14	16-Mar-14			
Striped Bass	5928.24	31-Jan-14	02-Sep-14	18-Jul-14	18-Jul-14	23-Jul-14	31-Aug-14	31-Aug-14		02-Aug-14	31-Aug-14
Striped Bass	9792.24	4-Feb-14	26-Feb-14	07-Mar-14	07-Mar-14	16-Mar-14	11-Oct-14	29-Oct-14	29-Oct-14	29-Oct-14	29-Oct-14
Striped Bass	9372.24	4-Feb-14				15-Mar-14	15-Mar-14	15-Mar-14	15-Mar-14	15-Mar-14	
Striped Bass	7440.24	10-Feb-14	21-Sep-14	19-Sep-14	01-Sep-14	21-Aug-14	07-Jul-14	07-Jul-14	06-Jul-14	16-Mar-14	
Striped Bass	7888.24	10-Feb-14	20-Feb-14	20-Feb-14	20-Feb-14	31-Mar-14	31-Mar-14	31-Mar-14	31-Mar-14	31-Mar-14	
Striped Bass	7328.24	10-Feb-14		04-Mar-14	04-Mar-14	22-Dec-14	15-Mar-14	15-Mar-14	15-Mar-14	15-Mar-14	
Striped Bass	7531.07	12-Feb-14	28-Aug-14	12-Mar-14	08-May-14	17-Aug-14	15-Mar-14				

Species	Tag Number	Release Date	Detected Inside Forebay				Detected Outside Forebay				
			IC1	IC2	IC3	RGD1	RGU1	WC1	WC2	WC3	ORS1
Striped Bass	6040.24	12-Feb-14	14-Mar-14			31-Dec-14	12-Dec-14	11-Dec-14	11-Dec-14	11-Dec-14	
Striped Bass	9939.07	12-Feb-14	02-Sep-14			17-Aug-14	13-Jul-14	13-Jul-14	07-Jul-14		12-Jul-14
Striped Bass	9064.24	12-Feb-14				03-Aug-14	03-Aug-14	03-Aug-14	07-Jul-14	10-Jul-14	12-Jul-14
Striped Bass	6663.07	14-Feb-14	15-Feb-14			07-Mar-14	07-Mar-14	17-Dec-14	08-Mar-14	08-Mar-14	
Striped Bass	5487.07	14-Feb-14	16-Apr-14	23-Jun-14	16-Apr-14	18-Sep-14	09-Oct-14	07-Oct-14	07-Oct-14	07-Oct-14	09-Oct-14
Striped Bass	7916.24	18-Feb-14	24-Aug-14	26-Aug-14	24-Aug-14	31-Dec-14	17-Mar-14	17-Mar-14	17-Mar-14	17-Mar-14	
Striped Bass	6768.24	18-Feb-14	01-Mar-14			11-Mar-14	11-Mar-14	11-Mar-14	11-Mar-14	11-Mar-14	
Largemouth Bass	6998.04	21-Feb-14				23-Nov-14	23-Nov-14	17-Nov-14			22-Nov-14
Striped Bass	9988.24	3-Mar-14	24-Apr-14	09-Mar-14	08-Mar-14	25-Apr-14	25-Apr-14	30-Apr-14	30-Apr-14	30-Apr-14	
Striped Bass	5760.24	5-Mar-14	31-Dec-14	20-Dec-14	20-Dec-14	24-Dec-14	11-Sep-14	11-Sep-14	18-Mar-14	11-Sep-14	
Striped Bass	8224.24	5-Mar-14	24-Aug-14	24-Aug-14	24-Aug-14	16-Oct-14	13-Oct-14	13-Oct-14	13-Oct-14	06-Apr-14	07-Oct-14
Striped Bass	6852.24	10-Mar-14	30-May-14	30-May-14	30-May-14	01-Dec-14	22-May-14	22-May-14	22-May-14	22-May-14	22-May-14
Striped Bass	5900.24	10-Mar-14	26-May-14	28-May-14	27-May-14	18-Jun-14	18-Jun-14	27-Jun-14	27-Jun-14		27-Jun-14
Striped Bass	6012.24	18-Apr-14	10-Jul-14	11-Jul-14	11-Jul-14	27-Aug-14	05-Oct-14	06-Oct-14	05-Oct-14		06-Oct-14

Species	Tag Number	Release Date	Detected Inside Forebay				Detected Outside Forebay				
			IC1	IC2	IC3	RGD1	RGU1	WC1	WC2	WC3	ORS1
Striped Bass	7524.24	24-Apr-14				25-Apr-14	25-Apr-14	26-Apr-14	26-Apr-14	25-Apr-14	
Channel Catfish	9070.04	24-Apr-14	25-May-14			08-Sep-14	30-Apr-14	30-Apr-14	09-Oct-14	30-Apr-14	09-Oct-14
Striped Bass	9659.07	5-May-14	10-Jul-14	11-Jul-14	11-Jul-14	29-Dec-14	10-Aug-14	10-Aug-14		10-Aug-14	10-Aug-14
Striped Bass	9407.07	5-May-14	26-Dec-14	16-Dec-14	16-Dec-14	06-Oct-14	05-Oct-14	05-Oct-14	05-Oct-14	05-Oct-14	04-Oct-14
Striped Bass	7412.24	9-May-14	01-Sep-14	09-Jun-14	09-Jun-14	21-Aug-14	30-Jun-14				
Largemouth Bass	5374.04	9-May-14				18-Sep-14	03-Nov-14	03-Nov-14	03-Nov-14	03-Nov-14	03-Nov-14
Striped Bass	8147.07	9-May-14	23-Jul-14	05-Aug-14	31-Jul-14	02-Sep-14	05-Sep-14	06-Sep-14		07-Sep-14	06-Sep-14
Striped Bass	9316.24	9-May-14	01-Nov-14	08-Dec-14	08-Dec-14	23-Dec-14	06-Dec-14	06-Dec-14	05-Dec-14	05-Dec-14	
Striped Bass	6607.07	5-Jun-14	23-Aug-14	23-Aug-14	23-Aug-14	03-Nov-14	02-Sep-14				03-Sep-14
Largemouth Bass	6858.04	12-Jun-14				23-Sep-14	23-Sep-14	22-Oct-14	22-Oct-14	18-Dec-14	23-Sep-14
Largemouth Bass	9742.04	24-Jun-14		29-Aug-14	29-Aug-14	02-Sep-14	02-Sep-14				02-Sep-14
Striped Bass	8140.24	24-Jun-14				10-Jul-14	12-Jul-14			15-Jul-14	15-Jul-14
Striped Bass	8371.07	3-Sep-14				10-Sep-14	10-Sep-14			13-Sep-14	
Striped Bass	8987.07	3-Sep-14				10-Sep-14	12-Oct-14	26-Oct-14	26-Oct-14	26-Oct-14	26-Oct-14
Striped Bass	9911.07	3-Sep-14	28-Oct-14	28-Oct-14	28-Oct-14	13-Nov-14	21-Sep-14	20-Sep-14		19-Sep-14	21-Sep-14

Species	Tag Number	Release Date	Detected Inside Forebay				Detected Outside Forebay				
			IC1	IC2	IC3	RGD1	RGU1	WC1	WC2	WC3	ORS1
Striped Bass	8392.24	26-Sep-14				04-Oct-14	27-Dec-14	19-Dec-14	16-Dec-14	16-Dec-14	26-Dec-14
Striped Bass	5004.24	29-Sep-14	29-Sep-14		05-Nov-14	30-Dec-14	23-Dec-14	23-Dec-14	18-Dec-14	17-Dec-14	22-Dec-14
Striped Bass	6747.07	17-Oct-14	30-Oct-14	30-Oct-14	28-Oct-14	27-Nov-14	03-Nov-14				
Striped Bass	7615.07	17-Oct-14	26-Oct-14			06-Nov-14	09-Nov-14	09-Nov-14	09-Nov-14		06-Nov-14
Striped Bass	5431.07	17-Oct-14	28-Oct-14			01-Nov-14	01-Nov-14	01-Nov-14	01-Nov-14	01-Nov-14	
Striped Bass	8812.24	20-Oct-14	22-Oct-14	21-Oct-14		27-Oct-14	03-Nov-14	03-Nov-14	03-Nov-14	01-Nov-14	02-Nov-14
Striped Bass	7776.24	7-Nov-14				31-Dec-14	28-Nov-14			26-Nov-14	26-Nov-14
Striped Bass	6915.07	1-Dec-14				03-Dec-14	03-Dec-14	12-Dec-14	13-Dec-14	13-Dec-14	11-Dec-14

Of those 56 fish that emigrated, 35 fish (63% of emigrating fish) returned to the Forebay at a later date in 2014. Of the remaining 149 fish that were not observed outside of the Forebay, 34 (23%) were only detected in the intake channel, 40 (27%) were only detected at the radial gates, nine (6%) were detected moving from the intake channel to the radial gates, five (3%) were detected moving from the radial gates to the intake channel, 61 (41%) were detected moving back and forth between the intake channel and the radial gates.

In addition to the fish tagged in 2014, many fish tagged in 2013 are still able to be detected due to the time of tagging and battery life of the tags. The combined number of tagged fish from 2013 and 2014 was 368 fish (Table 12). Based upon expected battery life, it is anticipated that LG tags will last from 220 – 400 days, LY tags from two and a half to four years, and LZ tags from four to five years. Assuming minimum battery life, potentially all of the tagged fish released in 2013 would be detectable at least part of 2014. Of the ten fish that were undetected during 2013, only four remained undetected in 2014.

When 2013 fish were included, the total number of fish detected leaving the Forebay rose from 56 to 117, which is 32% of the tagged fish to date. Of those 117 fish, 76 (65% of emigrating fish) were subsequently detected back in the Forebay (Figure 19).

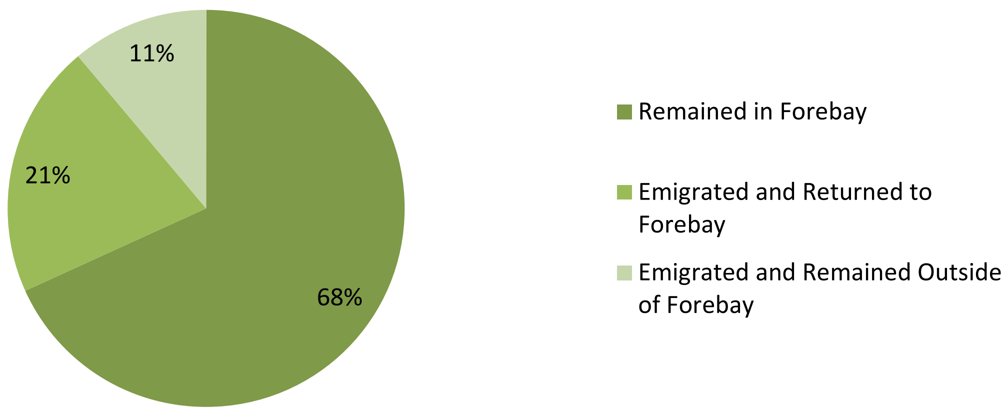


Figure 19: Percent of Striped Bass Remaining, Emigrating and Returning to Forebay

Two of the fish that left the Forebay were removed from the system by anglers. Fish 6068.24 and 8140.24, both Striped Bass, were captured at Mossdale on November 24, 2014 and at one of the temporary rock barriers (the specific barrier was not reported by the angler that caught the fish) on July 28, 2014, respectively.

Table 12: Acoustic Tagged Fish Released in 2013 and 2014 Combined

2013	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass	1	1	1	1	2	5	2	5	18
Catfish Species	1	5	2	0	0	0	0	0	8
Striped Bass (LG)	2	8	7	7	7	7	6	7	51
Striped Bass (LY)	7	3	7	7	7	7	7	7	52
Striped Bass (LZ)	1	0	0	0	4	7	7	1	20
All Species	12	17	17	15	20	26	22	20	149

2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass	5	4	5	2	5	5	0	0	1	3	5	0	35
Catfish Species	0	0	0	2	1	0	0	0	0	0	0	3	6
Striped Bass (LG)	6	7	7	7	6	7	7	7	7	7	7	7	82
Striped Bass (LY)	7	7	7	6	7	3	5	2	4	4	7	7	66
Striped Bass (LZ)	5	5	3	1	1	1	0	0	0	0	7	7	30
All Species	23	23	22	18	20	16	12	9	12	14	26	24	219
Both Years Combined	23	23	22	18	32	33	29	24	32	40	48	44	368

The majority of the fish that emigrated were Striped Bass, at 106 (91%), with the balance being made up of Largemouth Bass, Channel Catfish and White Catfish, at seven, three and one, respectively. The emigrating Striped Bass ranged in weight, at the time of tagging, from 0.5 lbs. (0.23 kg) to 9.8 lbs. (4.45 kg), with the smaller fish, 0.5 lbs. (0.23 kg) to 1.99 lbs. (0.90 kg), representing bulk of the fish detected (Figure 20).

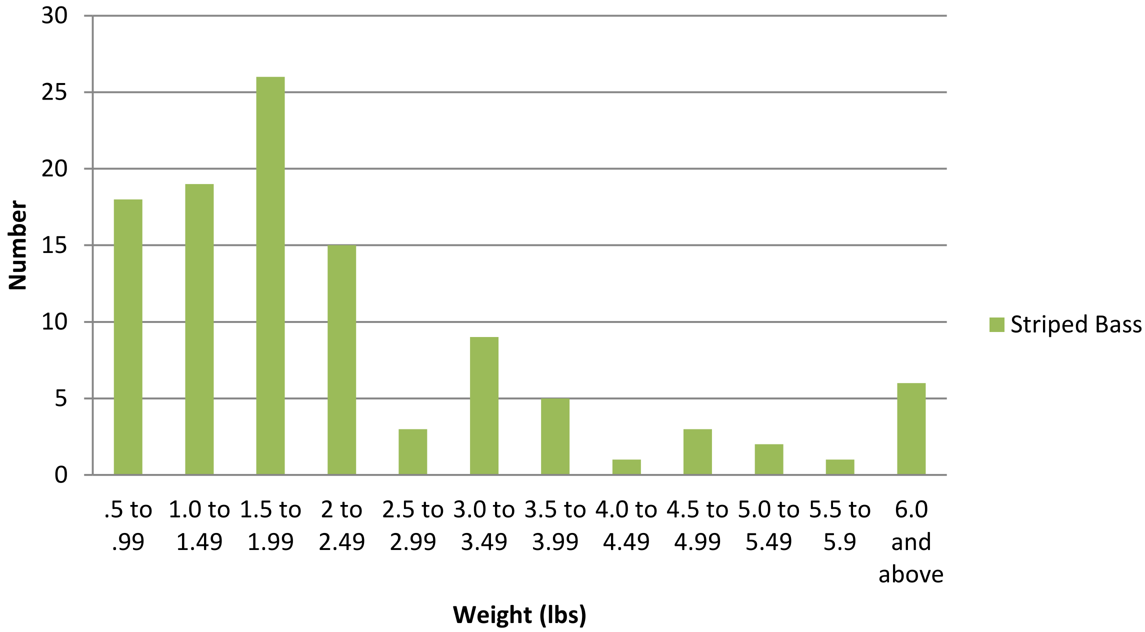


Figure 20: Striped Bass Emigration by Weight Class

The largest percentage of Striped Bass detected outside of the Forebay was within the 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) weight class at 41%. When the weight classes are broken down into increments of 0.5 lbs. (0.23 kg), Striped Bass weighing between 1.5 lbs. (0.68 kg) and 1.99 lbs. (0.90 kg) represented the largest group at 24, followed by 0.5 lbs. (0.23 kg) to 0.99 lbs. (0.45 kg) and 1.00 lbs. (0.45 kg) to 1.49 lbs. (0.68 kg), and 17% each (Figure 21).

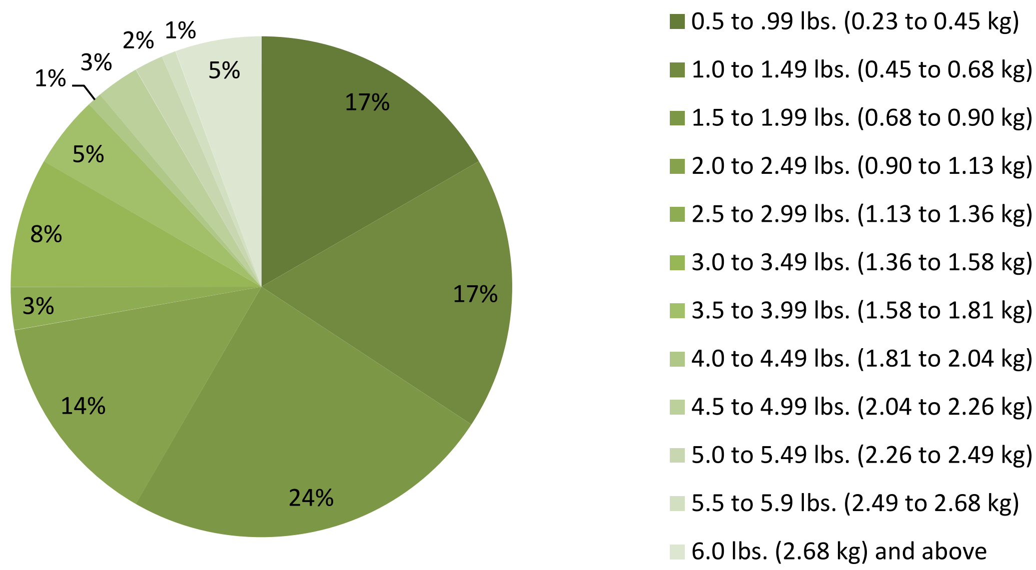


Figure 21: Percentage of Striped Bass Emigration by Weight Class

Of the 50 Striped Bass over 3.0 lbs. (1.36 kg) tagged in 2013 and 2014, 27 (54%) were subsequently detected outside of the Forebay, whereas only 44 of the 118 fish weighing 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) and 37 of the 133 fish weighing less than 1.5 lbs. (0.68 kg) were detected outside of the Forebay, representing 37% and 28% of those weight classes respectively (Figure 22).

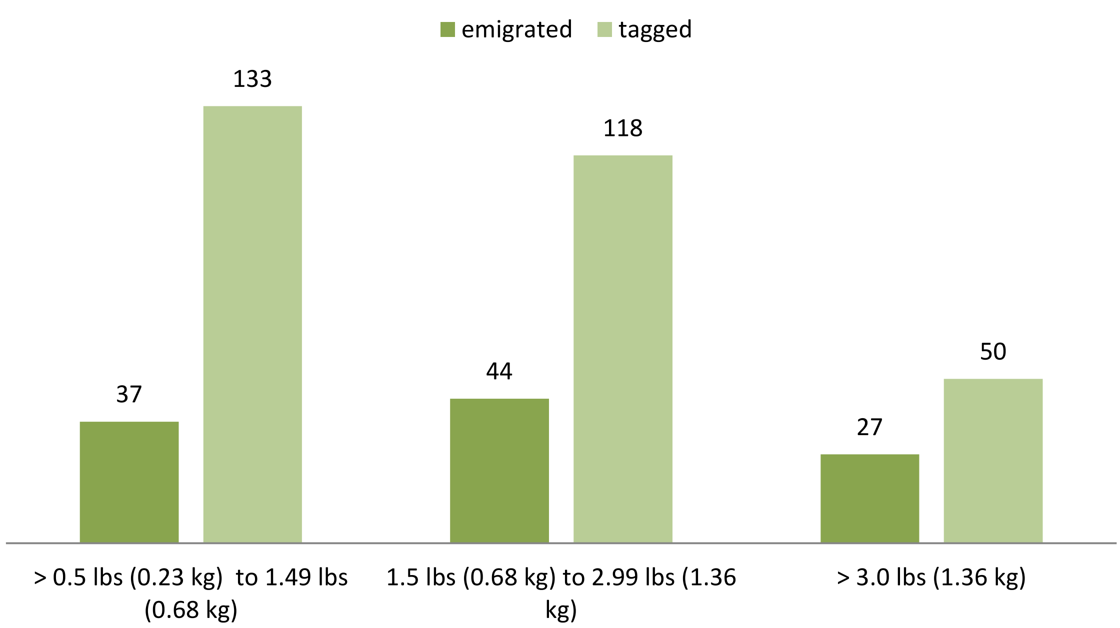


Figure 22: Proportion of Tagged Striped Bass Emigration by Weight Class

All weights were taken at the time of tagging, and growth likely occurred between tagging and detection outside of the Forebay. This elapsed time varied from one to 206 days (Figure 22).

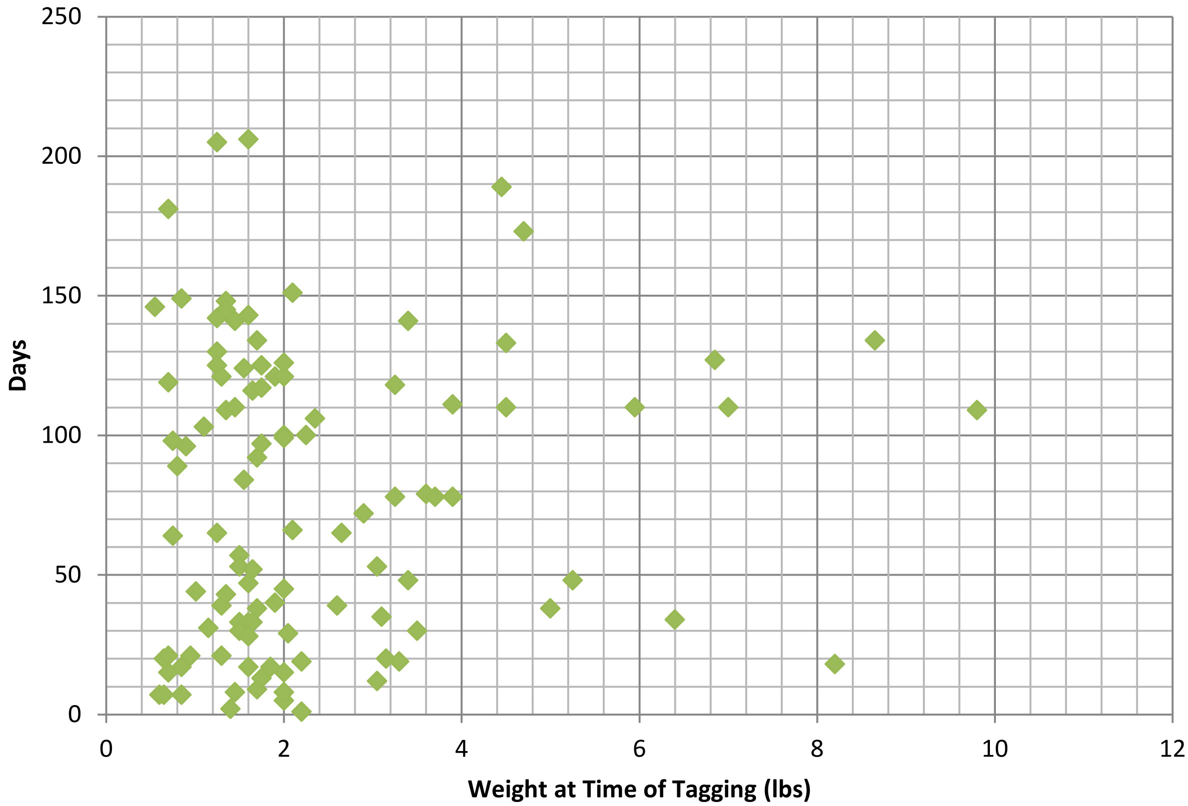


Figure 23: Days Elapsed Between Tagging and First Detection Outside of the Forebay

Striped Bass in the 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) weight class were detected for the first time outside of the Forebay most frequently in March and September, with 37% and 29% of the fish moving during those months respectively (Figure 23, 24). Striped Bass in the 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) weight class were detected for the first time outside of the Forebay most frequently in February and March, at 19% and 37% respectively (Figure 23, 25), and Striped Bass over 3.0 lbs. (1.36 kg) were detected for the first time outside of the Forebay most frequently in February and March at 38% and 35% respectively (Figure 23, 26).

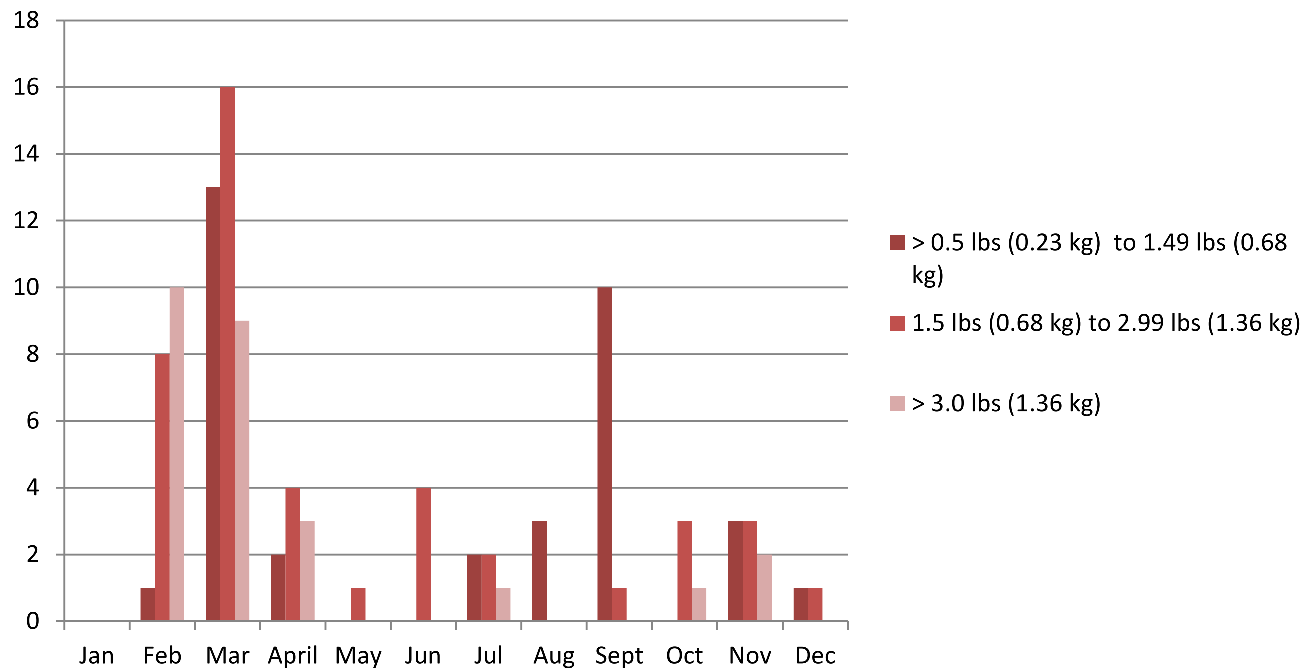


Figure 24: Month of First Detection Outside of Forebay by Weight Class

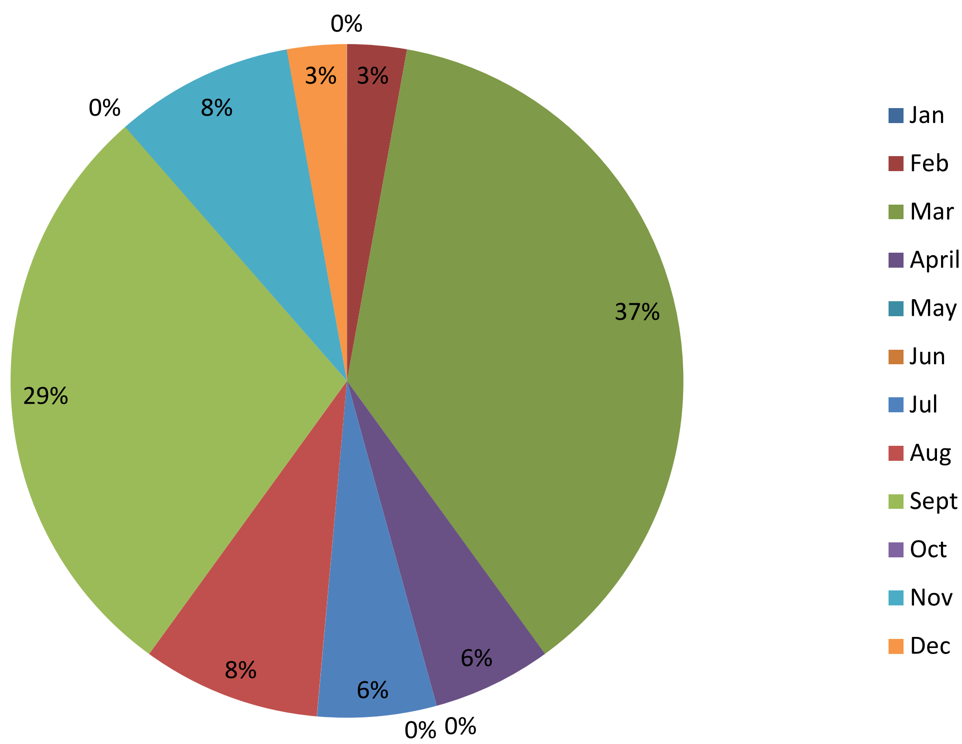


Figure 25: Percentage of 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) Striped Bass First Detection Outside of the Forebay by Month

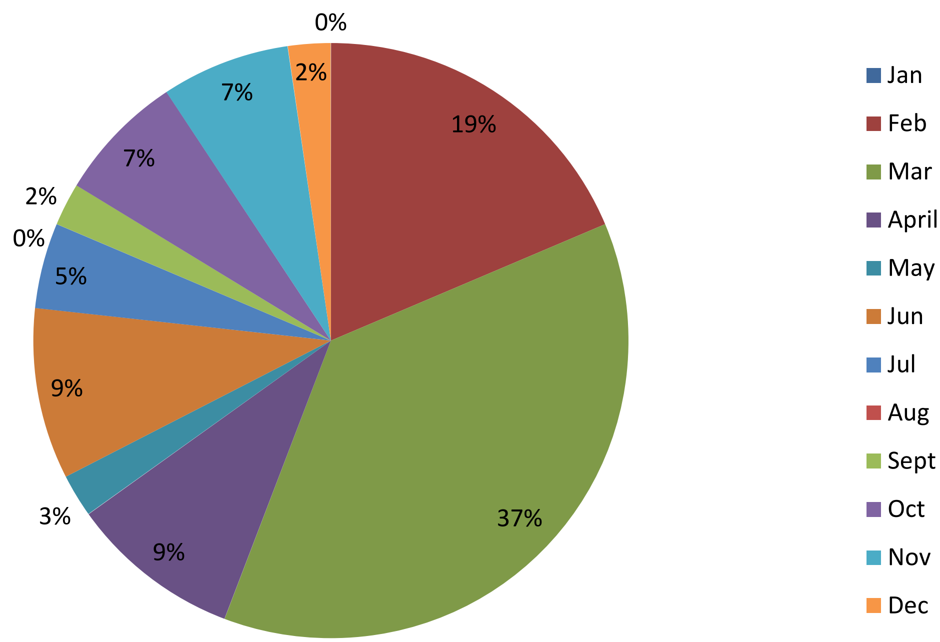


Figure 26: Percentage of 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) Striped Bass First Detection Outside of the Forebay by Month

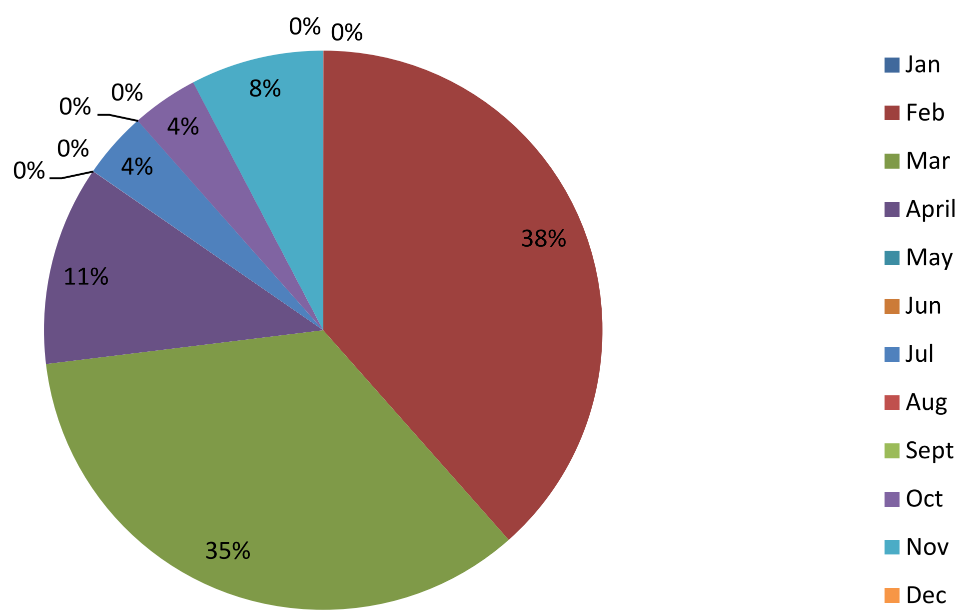


Figure 27: Percentage of 3.0 lbs. (1.36 kg) and larger Striped Bass First Detection Outside of the Forebay by Month

2.3.5 Discussion and Recommendations

Of the 217 predatory fish tagged in 2014, 14 (5%) remained undetected by the receiver array. Approximately 34%, (74 fish) were only detected in a single location, either the intake channel or the vicinity of the radial gates, and approximately 41% (61 fish) were detected moving between the intake channel and the radial gates. The remaining approximately 9% (56 fish) were detected leaving the Forebay. Of this 56 fish, 40 returned to the Forebay in 2014. While only 16 tagged fish were initially detected leaving the Forebay during 2013, once the fish tagged in 2013 were included in the detections through the end of 2014, that number rose to 61. When all of the fish tagged in 2013 were included, the total number of fish detected leaving the Forebay through the end of 2014 rose from 56 to 117, which is 32% of the tagged fish through the end of 2014. Of those 117 fish, 76 were subsequently detected back in the Forebay.

Seven Largemouth Bass, three Channel Catfish, one White Catfish, and 106 Striped Bass emigrated during 2013 and 2014. Of the 106 Striped Bass, 34% were between 0.5 lbs. (0.23 kg) and 1.49 lbs. (0.68 kg), 41% were between 1.5 lbs. (0.68 kg) and 2.99 lbs. (1.36 kg), and the remaining 25% were over 3.0 lbs. (1.36 kg). While this appears to indicate that the smaller Striped Bass are leaving the Forebay at a higher rate than the larger Striped Bass, when each weight class is looked individually, we find that 54% of the largest tagged Striped Bass emigrated from the Forebay, whereas only 37% and 28% of the 1.5lbs. (0.68 kg) to 2.99lbs (1.36 kg) and 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) sized tagged fish emigrated, respectively. This indicates that at least half of the larger, over 3.0 lbs. (1.36 kg), fish are likely to leave the Forebay at some point. The rates at which the smaller fish are leaving, however, is still significant, indicating that smaller fish, that would have been thought to be more resident based upon studies conducted for other Striped Bass populations (Able 2007), are also leaving at roughly the same proportion as all of the fish combined, near 30%.

The 2014 data set continues to show immigration and emigration as well as residency, both localized, remaining in a specific portion of the Forebay, as well as more broad roving behavior, moving multiple times across the Forebay. The tags employed in this project will continue to provide data for up to five[3] years per individual fish, allowing for a much better picture of these behaviors over time. The data set expressed in this interim report shows a limited picture in that the fish detected have not all been in the system for the same amount of time. For instance, fish tagged in November or December of 2014 have only been detectable for one to two months, not long enough to discern their short-term or ultimate behavioral strategies. This limitation is well illustrated by the reduction in number of 2013 tags that were undetected from ten to four with the addition of the longer detection data set.

We recommend that the balance of the array be deployed as soon as feasible to expand the understanding of movements by fish that have left the Forebay. A sub-set of predatory fish should be held in the lab for the purposes of tag retention studies and tagger quality control, to ensure that the data collected is as accurate as possible. Fourteen of the 217 fish tagged in 2014 and four of the ten undetected fish from 2013 were never detected in 2014. It is likely that a fish can remain undetected in the Forebay throughout the study period, if it remains in the central portion of the Forebay, which is outside of the range of the

[3] A revised estimate of potential tag life was received from HTI on January 25, 2016, which is longer than originally anticipated.

currently deployed array. Therefore, mobile monitoring surveys should be expanded to a full scale effort to cover areas of the Forebay that are not currently covered by the array.

2.4 Genetics[4]

2.4.1 Methods

Specific prey species consumed by predatory Striped Bass were identified using genetic methods that target species-specific DNA sequences, as described in the Clifton Court Forebay Predation Study Report (2015). This allows for the positive identification of consumed prey that visual inspection may miss due to digestion. Sampling for predatory fish to be used in the genetics portion of the project was conducted from December 2013 through May 2014 at the Forebay, as outlined in Section 1.3, above. Once fish were captured, they were administered an appropriate amount of EtOH to arrest the digestion of prey located in the gut tract, and placed on ice for preservation until the fish could be processed at the lab. While piscivore-prey dynamics are typically size structured, Striped Bass digestive tracts were pooled among all size classes sampled during the 2013-2014 pilot level effort. The target sample size was 480 Striped Bass to be sampled evenly over a five month period (initially planned to take place from January through May), equating to an average of 24 Striped Bass per week. Striped Bass were captured using hook-and-line with artificial lures. Field sampling was conducted on 29 days from December 2013 through May 2014.

2.4.2 Issues

Due to drought-related water operation changes, sampling was suspended most of February 2014, resulting in a reduced effort for the season. Additionally, due to constraints in on-water time, collection methods employed, and the amount of processing required by each fish, collection numbers fell below the target sample size of 480 Striped Bass.

2.4.3 Data Analysis

All catch data were recorded in the field on a Microsoft Surface RT tablet and transferred to a flash drive for uploading into a CFS - Genidaqs database and to the DWR data portal. Data was then downloaded onto the DWR network and filed into the appropriate project folders. Datasheets were also printed and filed into appropriate binders.

Once fish were brought back to the laboratory for further processing, samples were extracted and quantitative polymerase chain reaction (qPCR) was performed using all assays simultaneously on a 192.24 Gene Expression Integrated Fluidic Circuit (Fluidigm) and BioMark System (Fluidigm) following manufacturer’s protocols. Fluorescent output was analyzed using the Fluidigm Real-Time PCR analysis v4.0.1 software.

2.4.4 Results

A total of 264 Striped Bass were collected during the 2013-2014 pilot year effort. Of those Striped Bass, 30 were collected in December 2013, 74 Striped Bass in January 2014, one in February 2014, ten in March 2014, 54 in April 2014, and 96 in May 2014.

The average fork length (length from the tip of the snout to the edge of the fork at the centerline of the fish) of Striped Bass collected was 36.09 cm and the average weight was 1.26 lbs. (0.57 kg) (Table 13).

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[4] Portions of this section are adapted from the stand alone report entitled “Draft Genidaqs qPCR Diet Analysis Report Year 1 Pilot Study May 2013 – June 2014” (Blankenship and Brodsky 2015).

No Striped Bass were caught at areas 5 or 6 from December 2013 to May 2014, as low water level generally prevented boat access to these areas of the Forebay. Therefore, areas 5 and 6 were omitted from Table 13.

Table 13: Striped Bass Captured by Month and Location in 2013-2014

Month	Area 1	Area 2	Area 3	Area 4	Average Fork Length cm)	Standard Deviation Fork Length(cm)	Average Weight (kg)	Standard Deviation Weight (kg)
December	0	27	0	3	38.11	5.32	0.69	0.26
January	5	68	0	0	41.20	8.17	0.88	0.71
February	0	1	0	0	44.50		0.99	
March	7	0	0	3	38.25	5.72	0.61	0.30
April	2	50	0	2	33.62	6.40	0.45	0.42
May	0	88	6	2	32.66	4.65	0.35	0.20
Total	**14**	**234**	**6**	**10**	**36.09**	**7.23**	**0.57**	**0.47**

Each individual Striped Bass that was captured and analyzed will be referred to herein as "sample". Prey detection, which indicates presence of prey species, but not quantity present, was compiled by sample and partitioned by sampling location and season. Sample days from December 13 through December 17, 2013 were designated Fall, December 31, 2013 through March 20, 2014 were designated Winter, and April 7 through May 28, 2014 were designated Spring.

Of the 14 samples collected at Area 1, only one sample, captured during winter, contained a positive detection of a prey species, White Sturgeon (Table 14, 15; Figure 28, 29). Twenty samples from the 234 collected from Area 2 contained positive detections of prey species. Of these 20 samples, ten contained positive detections of Largemouth Bass, one contained White Sturgeon, two contained Threadfin Shad **(***Dorosoma petenense*), five contained Inland (Mississippi) Silversides (*Menidia beryllina*), and two contained Chinook Salmon (*Oncorhynchus tshawytscha*). At Area 2, Largemouth Bass were detected during all seasons, the White Sturgeon was detected in spring, Threadfin Shad were detected in fall, Inland (Mississippi) Silversides were detected in fall and spring, and the Chinook Salmon were detected in fall and winter. No target prey species were detected in samples obtained from Area 3. Area 4 included one sample containing Threadfin Shad, two containing Inland (Mississippi) Silversides, one containing Delta Smelt **(***Hypomesus transpacificus*) , and one containing Chinook Salmon. In Area 4, the Threadfin Shad, Inland (Mississippi) Silversides, and Chinook Salmon were detected in winter, and the Delta Smelt was detected in fall.

Table 14: Number of Samples with Positive Detections by Species and Area in 2013-2014

Collection Site	Sample Count	Green Sturgeon	Longfin Smelt	Largemouth Bass	Steelhead	Sacramento Pike minnow	Sacramento Splittail	White Sturgeon	Threadfin Shad	Inland (Mississippi) Silverside	Delta Smelt	Chinook Salmon
Area 1	14	0	0	0	0	0	0	1	0	0	0	0
Area 2	234	0	0	10	0	0	0	1	2	5	0	2
Area 3	6	0	0	0	0	0	0	0	0	0	0	0
Area 4	12	0	0	0	0	0	0	0	1	2	1	1

Figure 28: Number of Samples with Prey Species Detected in 2013-2014

Table 15: Number of Samples with Prey Species Detected by Season in 2013-2014

Collection Site	Sample Count	Fall	Winter	Spring
Area 1	14	0	1	0
Area 2	234	5	6	9
Area 3	6	0	0	0
Area 4	12	1	4	0

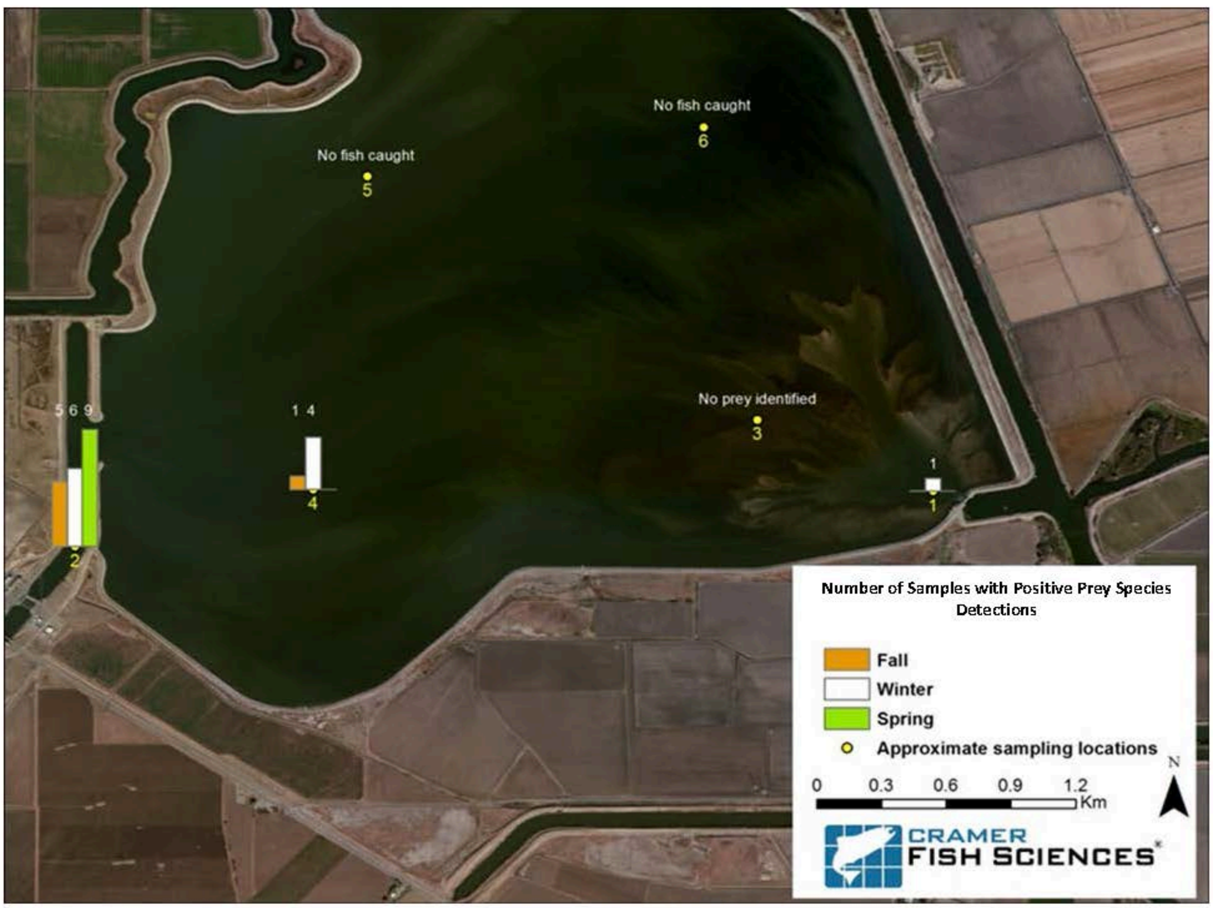


Figure 29: Number of Samples with Prey Species Detected by Season in 2013-2014

2.4.5 Discussion and Recommendations

While planned field days were generally realized in full, the number of Striped Bass captured was below the target. Although the sample size in 2014 was well below the target sample size, the resulting detections showed that special status species such as Chinook Salmon and Delta Smelt are subject to predation from Striped Bass. We recommend field staff implement strategies and alternative methods to increase the collection rate within sample days. Using nets in Clifton Court Forebay to capture fish may be difficult due to submerged debris and permitting restrictions; however, nets are extremely efficient. Further, Striped Bass do not appear to be captured randomly across Clifton Court Forebay. Therefore, targeted netting may be a useful alternative to hook-and-line sampling under certain situations. Electrofishing may also be a possible alternative method of Striped Bass capture under certain conditions.

2.5 Creel Surveys

2.5.1 Methods

Roving angler (creel) surveys were planned for three days a week, two week days and one weekend day, and were conducted either in the morning (0900 until noon) or the afternoon (noon until 1600). While anglers can access the Forebay throughout the evening hours as well, no surveys were conducted at night, due to safety concerns. Survey days and time periods were randomly selected by rolling dice, with each side of the die associated with a day or time (Table 16).

Table 16: Creel Survey Selection

Die Side	1	2	3	4	5	6
Time	Morning	Morning	Morning	Afternoon	Afternoon	Afternoon
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Weekend Day	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday

2.5.2 Issues

Creel surveys were planned to continue year-round from the radial gates to the tip of fisherman's point (Figure 30), however, on July 8, 2013 the radial gates suffered a significant structural failure resulting in one of the gates becoming dislodged. As a result of this structural failure, the area in the vicinity of the radial gates was closed to recreational anglers, while DWR Delta Field Division (DFD) worked to evaluate the extent of the damage and make repairs. Access remained limited into 2014, and may have resulted in fewer anglers using the Forebay.

Figure 30: Creel Survey Route

Surveys were also limited to daylight hours, and anglers standing on the wing-walls, or wading into the Forebay, were not interviewed, due to safety concerns.

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay continued to be followed according to the final procedural guide provided by DFD to BDO. The 2014 Equipment Request Order Form (EROF) for creel surveys was filed with DFD on December 19, 2013. Approval for 2014 creel surveys was confirmed on January 10, 2014. Beginning in mid-August, all weekend surveys were cancelled as a cost saving measure.

The 2014 effort began with the map used in 2013 (Figure 31) that was too divergent from the map used for predator sampling, to make the CPUE's easily comparable. In May of 2014, the original creel map was abandoned and replaced with the map used for predator sampling (Figure 32). Additionally, the landmarks on both of the maps are hard to distinguish, reducing accuracy of angler placement.

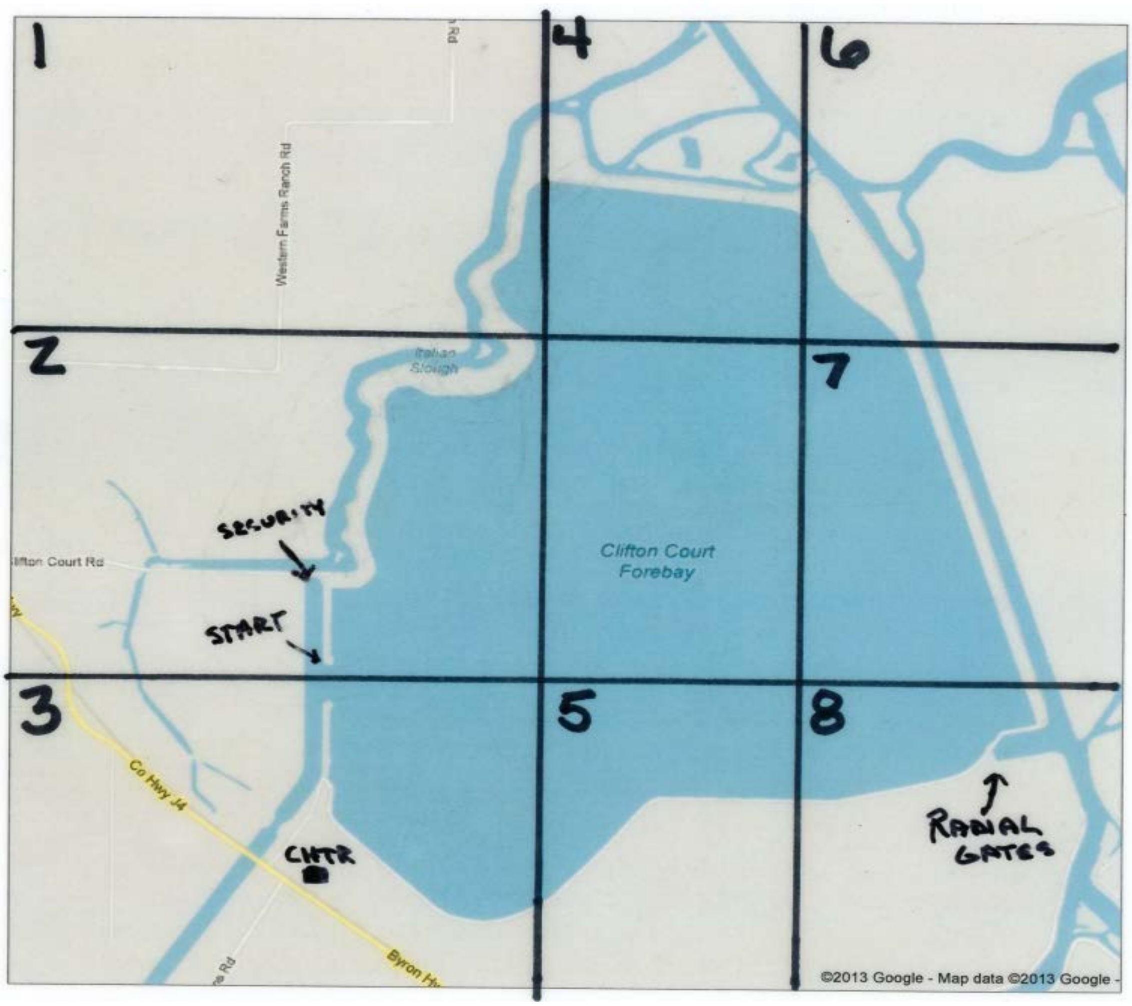


Figure 31: Old Creel Map January 2014 - April 2014

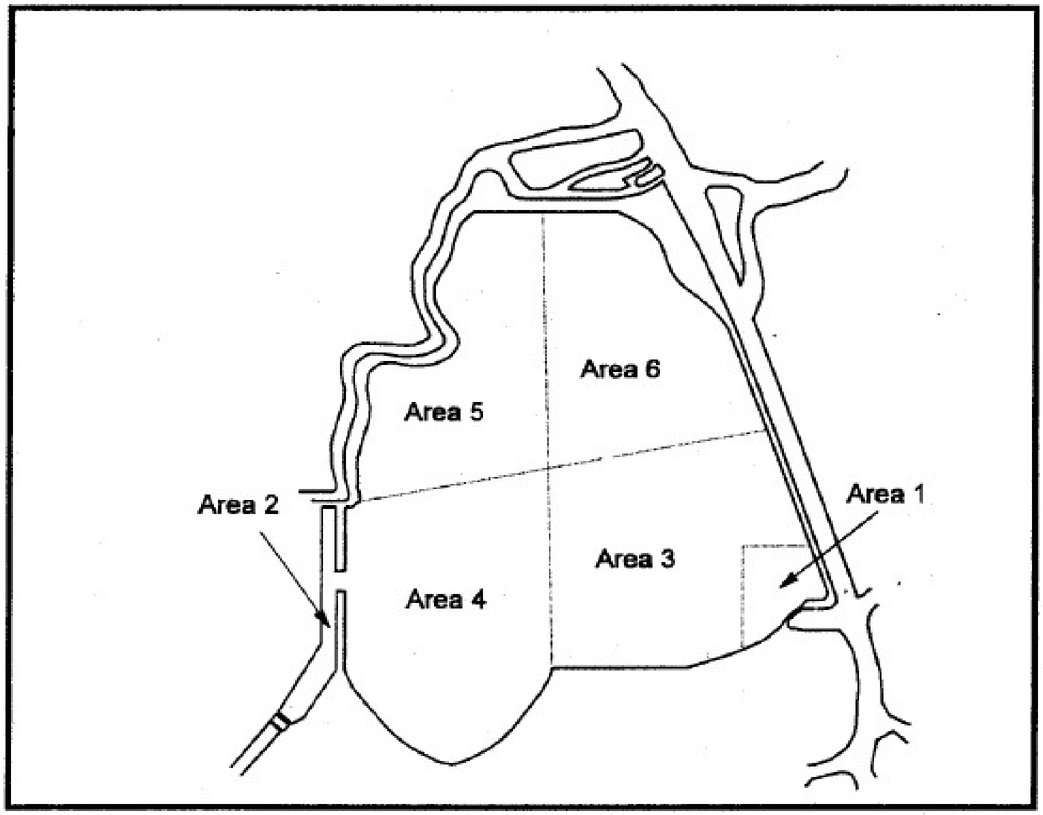


Figure 32: New Creel Map May 2014 - December 2014

2.5.3 Data Analysis

Data sheets were scanned and data was entered into an Excel spreadsheet until it could be transferred into a database for creel surveys that was completed in May 2014. Total catch, catch by species, and catch by location for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(q = catchability (fish caught per hours of sampling), C = catch, f = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE for all species per month was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and d = number of sampling days in the month)

2.5.4 Results

A total of 139 roving surveys from the tip of the Fisherman's Point peninsula to the Radial Gates along the public access pathway (Figure 30) were conducted between January 4, 2014 and December 31, 2014.

A total of 1,419 anglers were observed fishing at the Clifton Court Forebay in 2014. Anglers were found to fish in the greatest numbers on Saturdays and Sundays (Figure 33) and averaged 11 anglers per day throughout the year, with the highest numbers of anglers present in January (Figure 34).

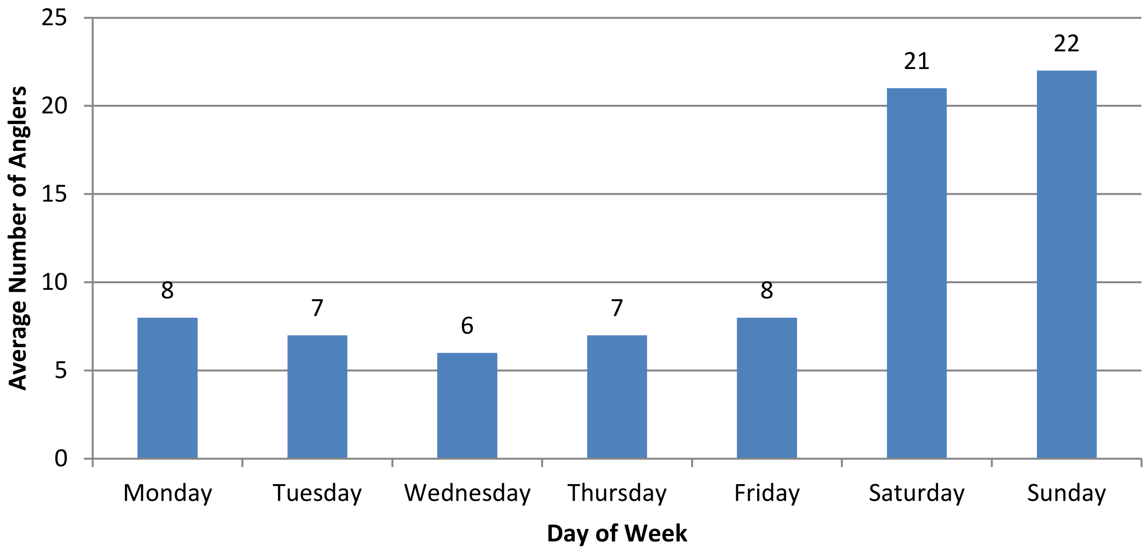


Figure 33: Average Number of Anglers by Day of Week in 2014

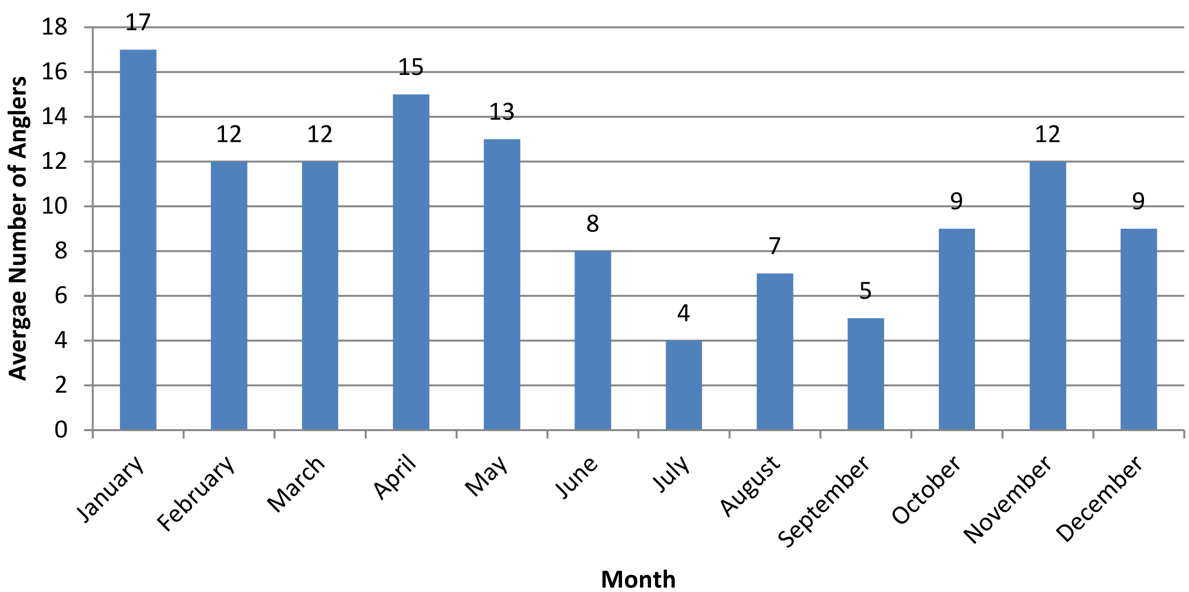


Figure 34: Average Number of Anglers by Month in 2014

Anglers fished a total of 3,554 hours over the survey period, with the greatest number of hours spent in Area 2 of both the old and new maps (Area 2 of the old map fully encompasses Fisherman's Point, whereas Area 2 of the new map only includes the portion of Fisherman's Point that does not face into the main body of the Forebay) with a total of 2,204 hours. The least number of hours were spent in Area 5 of the old map, and Area 3 of the new map at four and 14 hours respectively (Table 17, 18). The second most frequented fishing location was Area 4 of the old map, at 96.3 hours and Area 4 of the new map with 501.2 hours. Although Area 5 of the old map is technically closed to the public, there were fishermen observed and surveyed in the area.

Table 17: Hours Fished by Month and Location (Old Map) from January to April 24 2014

Month	1 Northwest Corner	2 Fisherman Point	3 State Point	4 North Center	5 South Center	6 Northeast Corner	7 Northeast Center	8 Radial Gates Vicinity
January	22	529.2	0.5	2	0	0	5	0
February	7.5	342.9	0	15	0	0	0	4
March	16	299.3	0	10	0	6	14.5	44.7
April	29	272.1	13	69.3	4	3.2	8	32
Year*	74.5	1443.5	13.5	96.3	4	9.2	27.5	80.7

*Ten hours were accounted for with no known location indicated.

Table 18: Hours Fished by Month and Location (New Map) from April 25 to December 2014

Month	1 Radial Gates Vicinity	2 Intake Canal	3 Southeast Corner	4 Southwest Corner	5 Northwest Corner	6 Northeast Corner
April	0.0	18.5	0.0	26.7	0.0	0.0
May	35	116.3	2.0	190.5	32.5	0.0
June	4.0	126.1	0.0	13.8	15.5	13.5
July	0.0	89.1	6.0	2.5	2.0	0.0
August	115.8	84.6	0.0	10.5	8.0	1.0
September	15.7	34.3	6.0	21.0	1.5	2.5
October	93.5	107.2	0.0	49.4	10.5	0.0
November	90.0	83.0	0.0	136.1	36.8	7.0
December	23.3	102.2	0.0	50.8	8.8	2.0
Year	377.2	761.3	14.0	501.2	115.5	26.0

A total of 139 surveys were conducted in 2014 with an average of 11 or more surveys done each month. Only December had less than the average with nine surveys conducted (Figure 35).

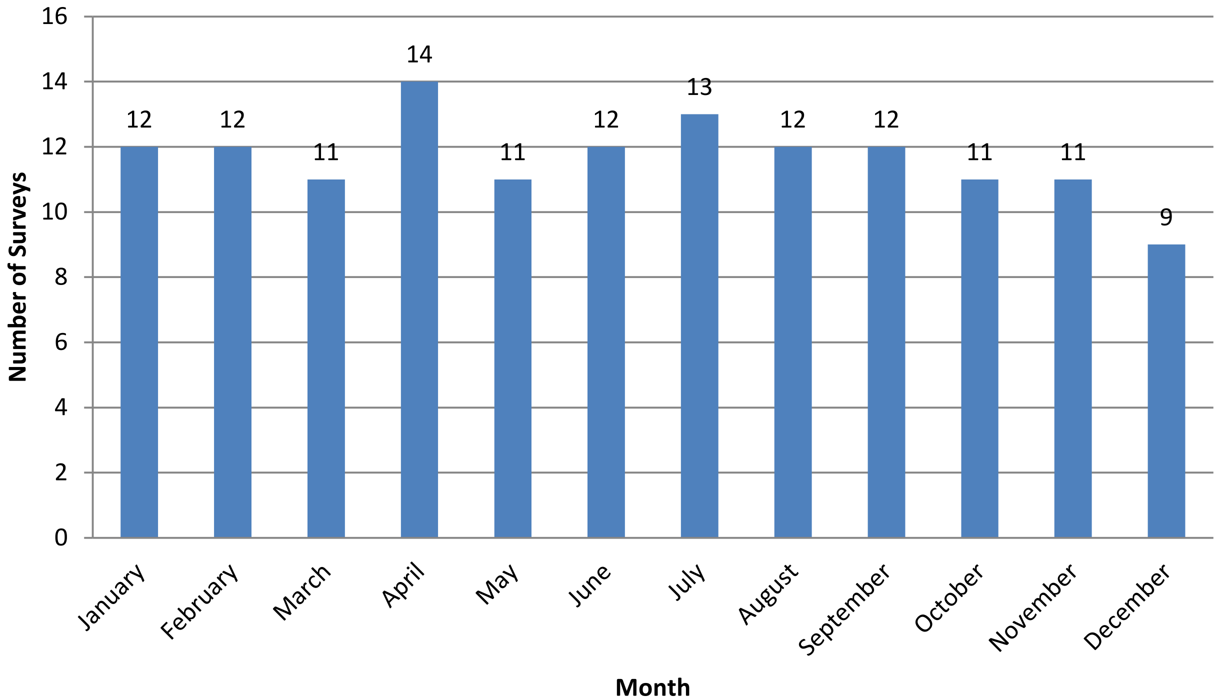


Figure 35: Number of Surveys per Month in 2014

Anglers that were interviewed captured a total of 1,690 fish during the survey period, with the catch ranging from 29 fish in February to 332 fish in May (Tables 19, 20). Three of these fish were recaptures from the predator sampling effort, with PIT tags present.

Table 19: Total Catch by Location and Month (Old Map) from January 1 to April 24, 2014

Month	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 3 State Point	Area 4 North Center	Area 5 South Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity	All Sites Total
January	0	86	0	0	0	0	0	0	86
February	0	28	0	1	0	0	0	0	29
March	4	101	0	0	0	4	1	8	118
April	4	159	0	0	0	0	5	31	199

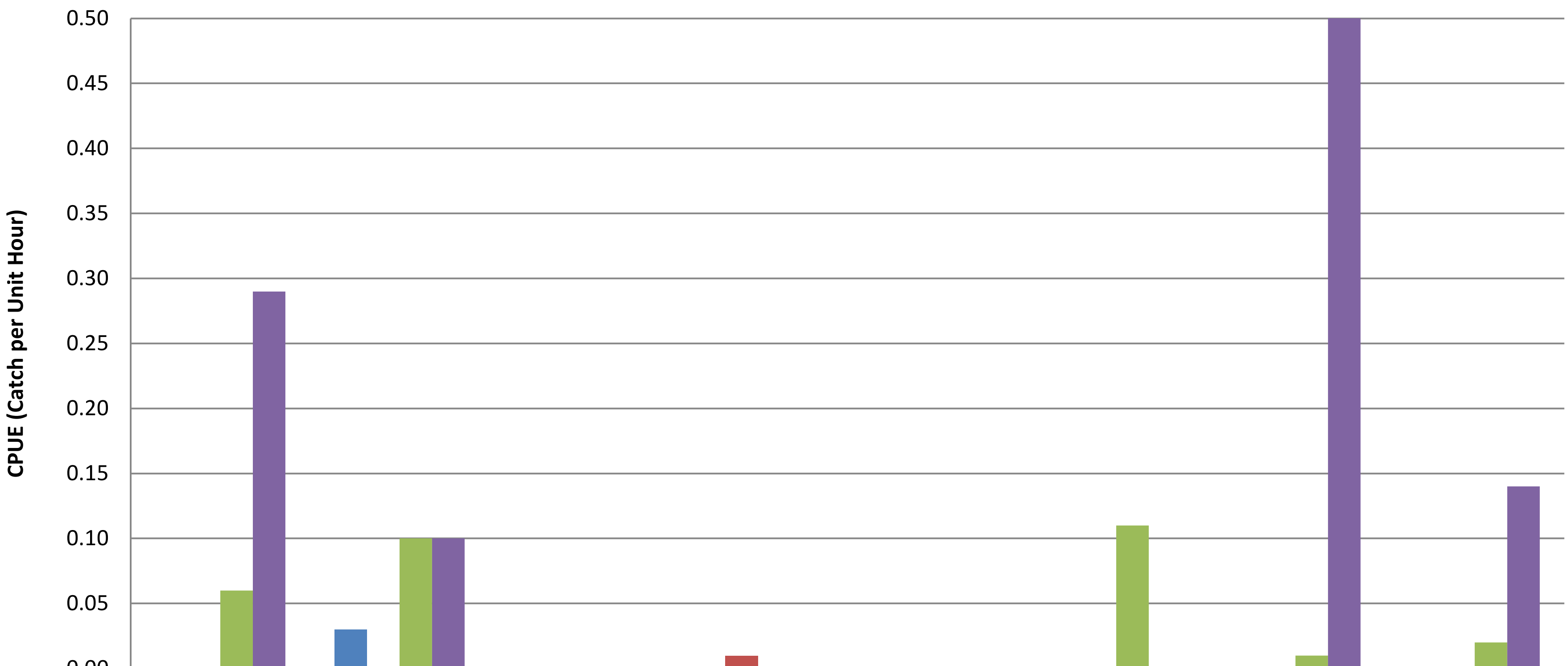
Table 20: Total Catch by Location and Month (New Map) from April 25 to December 31, 2014

Month	Area 1- Radial Gates Vicinity	Area 2- Intake Channel	Area 3- Southeast Corner	Area 4- Southwest Corner	Area 5- Northwest Corner	Area 6- Northeast Corner	All Sites Total
April	15	4	1	17	1	0	38
May	47	150	0	115	21	0	333
June	22	119	0	12	2	5	160
July	0	92	1	0	0	0	93
August	11	28	0	1	0	0	40
September	23	16	10	3	15	6	73
October	71	70	0	43	49	0	233
November	59	44	0	88	30	2	223
December	3	14	0	42	5	1	65

CPUE was calculated for total catch at each location by month. Overall CPUE was found to range from 0.00 in February to 2.79 in September. (Table 21, 22 and Figure 36, 37). The highest CPUE was at Area 5 of the new map during September, at 10.00.

Table 21: CPUE by Location and Month (Old Map) in 2014

Month	Area 1 Northwest Corner	Area 2 Fisherman Point	Area 3 State Point	Area 4 North Center	Area 5 South Center	Area 6 Northeast Corner	Area 7 Northeast Center	Area 8 Radial Gates Vicinity	All Sites
Jan	0.00	0.03	0.00	0.00	-	-	0.00	-	0.01
Feb	0.00	0.00	-	0.01	-	-	-	0.00	0.00
Mar	0.06	0.10	-	0.00	-	0.11	0.01	0.02	0.05
Apr	0.29	0.10	-	0.00	0.00	-	0.87	0.14	0.23

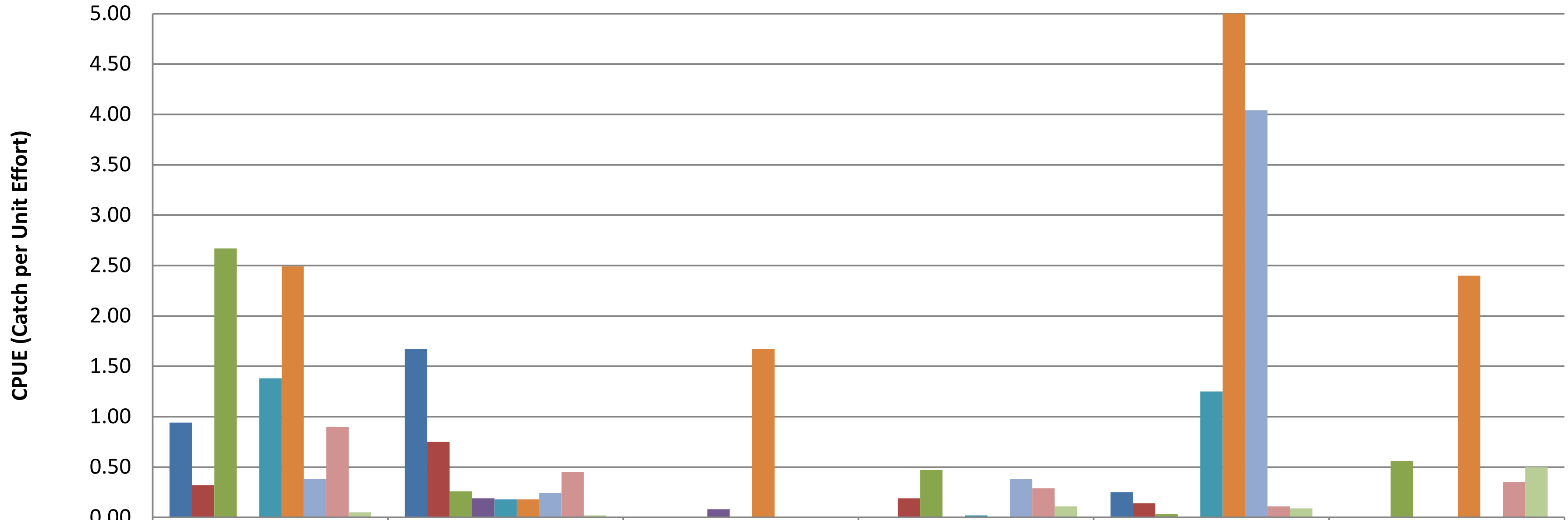


	1 NW Corner	2 Fisherman Point	3 State Point	4 North Center	5 South Center	6 NE Corner	7 NE Center	8 Radial Gates
January	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
March	0.06	0.10	0.00	0.00	0.00	0.11	0.01	0.02
April	0.29	0.10	0.00	0.00	0.00	0.00	0.87	0.14

Figure 36: CPUE by Location and Month (Old Map) in 2014

Table 22: CPUE by Location and Month (New Map) in 2014

Month	Area 1- Radial Gates Vicinity	Area 2- Intake Channel	Area 3- Southeast Corner	Area 4- Southwest Corner	Area 5- Northwest Corner	Area 6- Northeast Corner	All Sites
Apr	0.94	1.67	0.01	1.01	0.25	0.00	0.48
May	0.32	0.75	0.00	0.19	0.14	-	0.28
Jun	2.67	0.26	-	0.47	0.03	0.56	0.80
Jul	-	0.19	0.08	0.00	0.00	-	0.07
Aug	1.38	0.18	-	0.02	1.25	0.00	0.57
Sep	2.49	0.18	1.67	0.01	10.00	2.40	2.79
Oct	0.38	0.24	-	0.38	4.04	-	1.26
Nov	0.90	0.45	-	0.29	0.11	0.35	0.30
Dec	0.05	0.02	-	0.11	0.09	0.50	0.18



	1 (New) Radial Gates	2 (New) Intake Canal	3 (New) SE Corner	4 (New) SW Corner	5 (New) NW Corner	6 (New) NE Corner
April	0.94	1.67	0.01	0.01	0.25	0.00
May	0.32	0.75	0.00	0.19	0.14	
June	2.67	0.26		0.47	0.03	0.56
July		0.19	0.08	0.00	0.00	
August	1.38	0.18		0.02	1.25	0.00
September	2.49	0.18	1.67	0.01	10.00	2.40
October	0.38	0.24		0.38	4.04	
November	0.90	0.45		0.29	0.11	0.35
December	0.05	0.02		0.11	0.09	0.50

Figure 37: CPUE by Location and Month (New Map) in 2014

Anglers caught 1,354 Striped Bass during the survey period, which made up 80% of the total catch of 1,690 fish. The second most commonly caught fish was Bluegill **(***Lepomis macrochirus*), at 157 fish, followed by Largemouth Bass, at 122 fish, and then catfish[5], at 19 fish, or 9%, 7%, and 1% of the total catch, respectively (Table 23). One adult Steelhead was caught in May and one Green Sturgeon was caught, and immediately released, in August.

Table 23: Total Catch by Species and Month in 2014

Month	Hours Fished	Unknown	American Shad	Bluegill	Carp	Chinook Salmon (Adult)	Crappie	Red Ear Sunfish	Steelhead	Perch	Small Mouth Bass	Large Mouth Bass	Green Sturgeon	Catfish (Any)	Striped Bass	Total Catch
January	558.68	3	0	42	0	0	0	5	0	0	0	0	0	0	36	86
February	369.39	4	0	2	0	0	0	0	0	0	0	3	0	1	19	29
March	390.48	8	0	2	0	0	0	0	0	0	0	3	0	2	103	118
April	476.76	0	0	0	0	0	0	0	0	0	0	8	0	4	225	237
May	385.35	0	0	1	0	0	0	0	1	0	0	8	0	8	315	333
June	172.95	5	0	0	0	0	0	0	0	0	0	3	0	0	152	160
July	99.61	0	0	6	0	0	0	0	0	0	0	0	0	0	87	93
August	219.83	0	0	0	0	0	0	0	0	0	0	3	1	0	36	40
September	80.94	0	0	0	0	0	0	0	0	0	2	11	0	0	60	73
October	260.56	0	0	22	0	0	0	0	0	1	3	52	0	1	154	233
November	352.83	0	1	82	0	0	0	2	0	2	0	29	0	3	104	223
December	186.91	0	0	0	0	0	0	0	0	0	0	2	0	0	63	65
Year	3554.29	20	1	157	0	0	0	7	1	3	5	122	1	19	1354	1690

Angler catch of Striped Bass peaked in May at 315 fish, while Large Mouth Bass catch peaked in October, and catfish peaked in May, with 52 and 8 fish, respectively (Figure 38).

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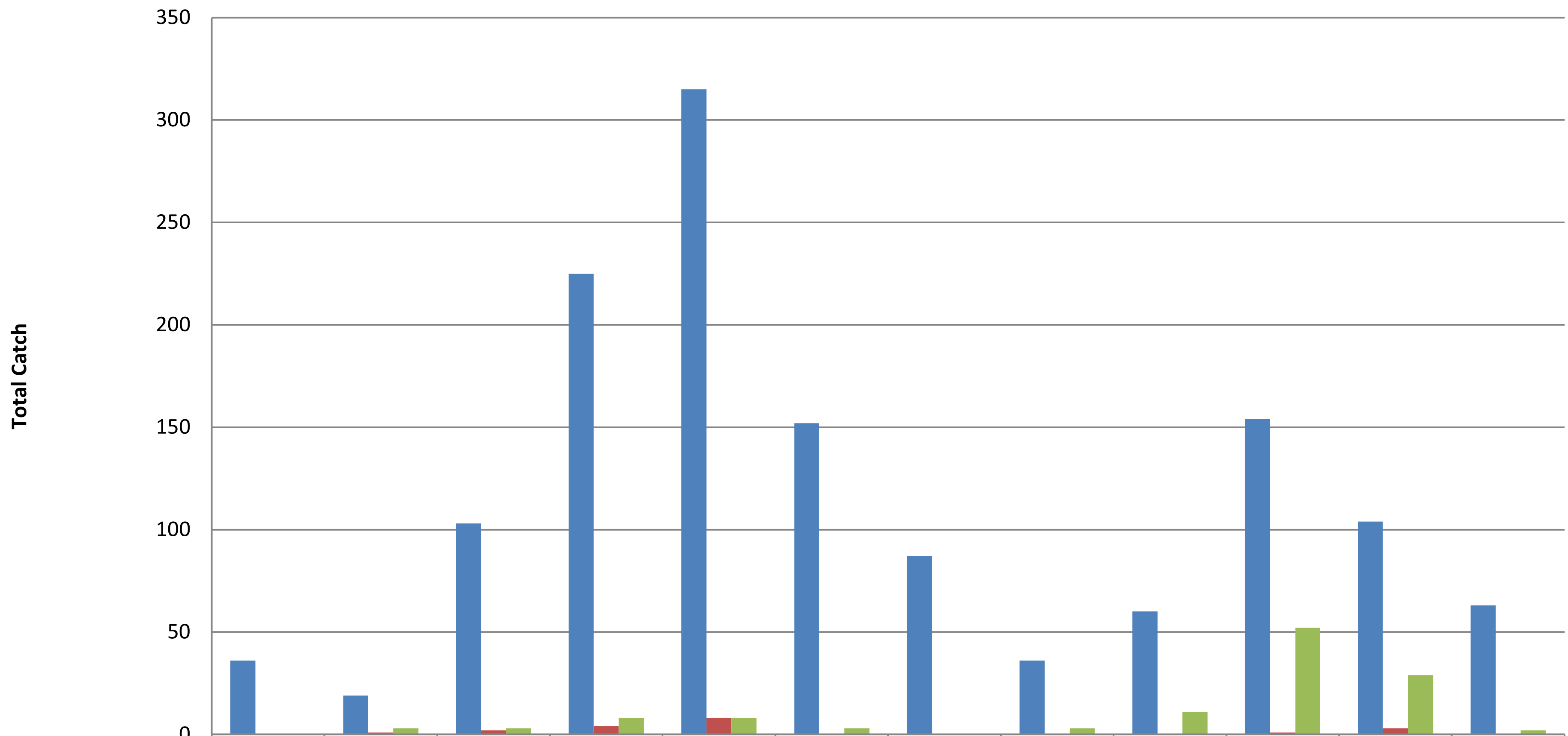
5 Catfish were not identified to species during the creel surveys, unless the survey crew was able to see the fish caught. Often, anglers did not specify the species. For this reason all catfish were pooled into a single group.



	January	February	March	April	May	June	July	August	September	October	November	December
Striped Bass	36	19	103	225	315	152	87	36	60	154	104	63
Catfish	0	1	2	4	8	0	0	0	0	1	3	0
Large Mouth Bass	0	3	3	8	8	3	0	3	11	52	29	2

Figure 38: Total Striped Bass, Largemouth Bass and Catfish by Month in 2014

2.5.5 Discussion and Recommendations

Public fishing at the Forebay is restricted to the shore, from Fisherman Point to the Radial Gates, which reduces an angler's ability to reach the "hot spots" that are accessible by boat. In turn this reduces the portion of the total predatory fish population accessible within the casting envelope of approximately 100 feet from the shore. The bulk of anglers stay within this portion of the shore, however a small number of anglers fish along the portion of the shore that is beyond the Radial Gates, and some anglers have been observed wading into the Forebay in the vicinity of the Radial Gates. Anglers that were observed along the shore were asked to participate in the creel survey, but were not required to do so. Additionally, anglers that were in the water or along the wing walls protruding from the base of the Radial Gate structure were considered inaccessible and not included in the survey, to ensure the safety of the survey team. Most anglers that were encountered were willing to participate in the survey, with only 12 anglers refusing to do so during the 2014 survey effort.

Anglers that were interviewed during creel surveys fished a total of 3,554 hours over the survey period, with the greatest number of hours spent in Area 2 of both the old and new maps (known commonly as Fisherman's Point). Anglers caught a wide variety of fish including carp, shad, sunfishes, bass and catfish. Anglers caught 1,354 Striped Bass during the survey period, which made up 80% of the total catch of 1,690 fish. The second most commonly caught fish was Bluegill, at 157 fish, followed by Largemouth Bass, at 122 fish, and then catfish, at 19 fish, or 9%, 7%, and 1% of the total catch, respectively. One adult Steelhead was caught in May and one Green Sturgeon was caught in August and immediately released.

The map used for the creel surveys was changed in late April so that the surveys were more easily compared to other elements of the study, such as predator sampling. CPUE was calculated for each of the two maps separately, for total catch captured at each location by month. During the first portion of the year, when the old map was still in use, CPUE was found to range from 0.00 in February to 0.23 in April. The highest CPUE was at Area 7 during the month of April, at 0.87. During the balance of the year, when the new map was employed, CPUE was found to range from 0.07 in July to 2.79 in September. The highest CPUE was at Area 5 during September, at 10.00.

Area 7 (Old Map Northeast Center) is an area adjacent to the radial gates area, and is not heavily used. However, due to the restricted access to the radial gates area from the end of 2013, the fishing pressure was shifted away from the immediate vicinity of the radial gates for a portion of 2014. The very high CPUE experienced in Area 5 (New Map Northwest corner), which is located just past the Fisherman's point area, along the access road, was likely an artifact of a small number of anglers with high success on one day, and is not indicative of average conditions in that area.

We recommend that surveys continue year round, with the new map in use, to gain a better understanding of angler trends. It is also recommended that surveys continue to be conducted on weekdays and weekends to increase the number of anglers included in the survey and to cover a truly representative cross section of anglers including the regular/experienced anglers and the occasional/inexperienced anglers.

2.6 Avian Surveys[6]

2.6.1 Methods

Avian point count surveys, in the vicinity of the radial gates and the vicinity of the trash rack, were scheduled three days per week, including two week days and one weekend day. Surveys were conducted during one of three randomly selected time periods, morning (from just before sunrise until 0900), midday (1000 until 1200) or afternoon (from 1300 until 1600). The radial gates area was split into two separate survey areas to ensure adequate coverage on both sides of the structure.

Survey days and time periods were randomly selected by rolling dice, with each side of the die associated with a day or time (Table 24). A total of 415 surveys were conducted between January 4, 2014 and December 31, 2014. Of those 415 surveys, 146 were morning, 165 were midday, and 104 were afternoon.

Table 24: Randomized Survey Selection Process

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Weekend Day	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday
Time	Morning	Midday	Afternoon	Morning	Midday	Afternoon

Each survey was conducted by a minimum of two biologists for 20 minutes per survey location, using a Kowa TSN-821M or a Leupold SX-1 Ventana spotting scope and/or Nikon 8x42 Monarch binoculars from predetermined vantage points (Figure 39, 40) to ensure adequate coverage. Piscivorous birds were counted if they approached within, or flew above, the predetermined survey areas. No border of a survey area was more than 500 meters (m) from the established vantage point of the survey, so all birds were observed at relatively close range. All counted individuals were identified to species whenever possible. Additionally, behavioral observations were also made of all individuals. Behaviors were categorized as feeding, non-feeding, and flyover. An individual that was observed performing multiple behaviors was categorized under the behavior that it was performing a majority of the time observed.

[6] This section co-written by Aaron Haimen, Scientific Aide, DWR Bay-Delta Office

Figure 39: Avian Survey Trash Rack Location

Figure 40: Avian Survey Radial Gates Locations (SW & NE)

2.6.2 Issues

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay continued to be followed according to the final procedural guide provided by DFD to BDO. The 2014 EROF for avian surveys was filed with DFD on December 19, 2013. Approval for 2014 avian surveys was confirmed on January 10, 2014, and backdated to January 1. Avian surveys were conducted year-round at the radial gates and the trash racks.

Beginning in mid-August, all weekend surveys were cancelled as a cost saving measure.

2.6.3 Data Analysis

All data was recorded onto Rite-in-Rain data sheets. Data sheets were scanned and data was initially compiled into an excel spreadsheet to ensure that no data became lost while a database was under development. A database for avian surveys was completed in March 2014, and all of the avian sampling data was transferred from the excel spreadsheet into the database for analysis. Total numbers of species observed were compiled by month, location and behavior. Behavioral observations were compiled by month, location and species.

2.6.4 Results

A total of 415 surveys were conducted between January 4, 2014 and December 31, 2014 and bird sightings totaled 12,689 piscivorous birds (Table 25); 3,856 at the Trash Racks (Table 26), 4,893 at the Radial Gates SW (Table 27) and 3,954 at Radial Gates NE (Table 27). The highest numbers of avian species were observed in the winter months of January and February. Of those 12,689 birds sighted, the most commonly observed at the Forebay were gulls (*Larus sp.*), double-crested cormorants (*Phalacrocorax auritus*), and American white pelicans (*Pelecanus erythrorhynchos*) (Table 25). While efforts were made to ensure that birds were not double counted during each survey effort, it is likely that the same birds were often observed at the Forebay on subsequent days.

Table 25: Avian Species Observed at all Locations in 2014

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 2014	Percentage of Observed
American White Pelican	262	148	125	92	44	67	42	69	69	66	21	103	1108	9%
Black-Crowned Night-Heron										1	5	2	8	0%
Caspian Tern				22	3	6		2				7	40	0%
Cattle Egret	1						1						2	0%
Clark's Grebe		1	1	1	10	18	51	4	34	59	41	12	232	2%
Common Goldeneye	47	82	58	12							34	32	265	2%
Common Merganser	3	1	1								1	5	11	0%
Double-Crested Cormorant	368	323	304	153	95	165	210	225	301	313	342	190	2989	24%
Eared Grebe	92	102	21							8	17	15	255	2%
Great Blue Heron	17		7	14	10	17	34	28	30	22	22	7	208	2%
Great Egret	24	4	4	3	1	54	61	54	87	31	24	12	359	3%
Green Heron	1				2	1	1	5	14	2	2		28	0%
Gull sp.	1900	2515	301	78	66	142	294	87	129	158	116	298	6084	48%
Horned Grebe	2		1			2					1	7	13	0%
Osprey					2	4		2		1			9	0%
Pied Billed Grebe	32	27	20	18	13	21	42	4	124	97	108	34	540	4%
Red-breasted Merganser	2										18	1	21	0%
Snowy Egret	4	1	10	2		5	36	123	108	36	24	10	359	3%
Tern (Unidentified)		10	2	35	6	4	1	12	1			4	75	1%
Western Grebe	1	2	2	3	3	36	30	1	1	2		2	83	1%
Monthly Totals	2756	3216	857	433	255	542	803	616	898	796	776	741	12689	

At the trash racks, overall bird numbers peaked in January and February. This peak was driven largely by gull numbers, which represented 65% of the birds observed. The lowest numbers were observed in May (Table 26).

Table 26: Avian Species Observed at the Trash Racks in 2014

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Species Totals	Percentage of Observed
Black-Crowned Night-Heron										**1**	**5**	**2**	**8**	**0%**
Caspian Tern							**1**						**1**	**0%**
Cattle Egret	**1**												**1**	**0%**
Clark's Grebe		**1**			**3**				**6**	**12**	**15**		**37**	**1%**
Common Goldeneye	**32**	**27**	**33**	**6**							**24**	**10**	**132**	**3%**
Common Merganser	**3**											**1**	**4**	**0%**
Double-Crested Cormorant	**59**	**58**	**54**	**39**	**2**	**10**	**10**	**11**	**31**	**59**	**139**	**71**	**543**	**14%**
Eared Grebe	**3**	**6**	**3**							**1**	**1**	**1**	**15**	**0%**
Great Blue Heron	**9**		**2**	**8**	**5**	**7**	**14**	**11**	**21**	**17**	**18**	**5**	**117**	**3%**
Great Egret	**23**	**1**		**1**		**5**	**1**	**3**	**70**	**18**	**16**	**6**	**144**	**4%**
Green Heron	**1**				**2**	**1**			**14**	**1**			**19**	**0%**
Gull sp.	**767**	**470**	**284**	**4**	**46**	**118**	**272**	**9**	**87**	**154**	**104**	**206**	**2521**	**65%**
Horned Grebe	**2**					**1**						**1**	**4**	**0%**
Pied Billed Grebe	**8**	**11**	**9**	**7**	**3**			**1**	**39**	**32**	**33**	**6**	**149**	**4%**
Snowy Egret	**4**	**1**	**1**	**1**		**1**	**1**		**102**	**7**	**15**	**5**	**138**	**4%**
Western Grebe		**2**	**2**		**1**	**17**						**1**	**23**	**1%**
Monthly Totals	**912**	**577**	**388**	**66**	**62**	**160**	**299**	**35**	**370**	**302**	**370**	**315**	**3856**	

At the radial gates, bird sightings peaked in January and February, and were at their lowest in May (Tables 27 and 28).

Table 27: Avian Species Observed at the Radial Gates SW in 2014

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Species Totals	Percentage of Observed
American White Pelican	**133**	**35**	**41**	**21**	**25**	**28**	**10**	**47**	**35**	**30**	**9**	**77**	**491**	**10%**
Caspian Tern												**6**	**6**	**0%**
Cattle Egret													**0**	**0%**
Clark's Grebe					**4**	**10**	**14**		**4**	**12**	**1**	**5**	**50**	**1%**
Common Goldeneye	**8**	**39**	**11**	**5**							**5**	**5**	**73**	**1%**
Common Merganser		**1**									**1**		**2**	**0%**
Double-Crested Cormorant	**161**	**112**	**105**	**76**	**56**	**82**	**78**	**111**	**176**	**183**	**131**	**88**	**1359**	**28%**
Eared Grebe	**39**	**51**	**8**							**1**	**4**	**3**	**106**	**2%**
Great Blue Heron	**6**		**4**		**4**	**5**	**7**	**10**	**4**	**4**	**3**		**47**	**1%**
Great Egret	**1**	**1**	**2**	**1**	**1**	**25**	**14**	**19**	**7**	**5**	**2**	**3**	**81**	**2%**
Green Heron							**1**	**2**					**3**	**0%**
Gull sp.	**955**	**1196**	**10**	**18**	**6**	**12**	**11**	**29**	**26**	**2**	**6**	**77**	**2348**	**48%**
Horned Grebe						**1**					**1**	**6**	**8**	**0%**
Osprey					**2**	**4**				**1**			**7**	**0%**
Pied Billed Grebe	**11**	**9**	**7**	**6**	**4**	**12**	**25**	**1**	**35**	**28**	**25**	**7**	**170**	**3%**
Red-breasted Merganser	**1**										**18**		**19**	**0%**
Snowy Egret			**1**			**1**	**21**	**46**	**3**	**12**	**7**	**1**	**92**	**2%**
Tern (Unidentified)				**2**	**3**		**3**	**1**	**1**				**10**	**0%**
Western Grebe	**1**			**3**		**5**	**11**		**1**				**21**	**0%**
Monthly Totals	**1316**	**1444**	**189**	**132**	**105**	**185**	**195**	**266**	**292**	**278**	**213**	**278**	**4893**	

Table 28: Avian Species Observed at the Radial Gates NE in 2014

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Species Totals	Percentage of Observed
American White Pelican	129	113	84	71	19	39	32	22	34	36	12	32	623	16%
Caspian Tern				22	3		5	2				1	33	1%
Cattle Egret							1						1	0%
Clark's Grebe			1	1	3	8	37	4	23	35	25	7	144	4%
Common Goldeneye	7	16	14	1							5	17	60	2%
Common Merganser			1									4	5	0%
Double-Crested Cormorant	148	153	145	38	37	73	122	103	94	71	72	31	1087	27%
Eared Grebe	50	45	10							6	12	11	134	3%
Great Blue Heron	2		1	6	1	5	10	7	5	1	1	2	41	1%
Great Egret		2	2	1		24	46	32	10	8	6	3	134	3%
Green Heron								3		1	2		6	0%
Gull sp.	178	849	7	56	14	12	11	49	16	2	6	15	1215	31%
Horned Grebe			1										1	0%
Osprey								2					2	0%
Pied Billed Grebe	13	7	4	5	6	9	17	13	50	37	50	21	232	6%
Red-breasted Merganser	1											1	2	0%
Snowy Egret			8	1		3	14	77	3	17	2	4	129	3%
Tern (Unidentified)		10	2	33	4	4	1	8				4	66	2%
Western Grebe					2	14	19	1		2		1	39	1%
Monthly Totals	528	1195	280	235	89	191	315	323	235	216	193	154	3954	

Species Richness

During the 2014 survey period numerous species of piscivorous birds were identified. The number of species was not constant over the course of the year with an overall peak in diversity in the winter months (November to January) and a low in September (Figure 41). Some species were observed every month, while others showed distinct seasonality to their occurrence patterns.

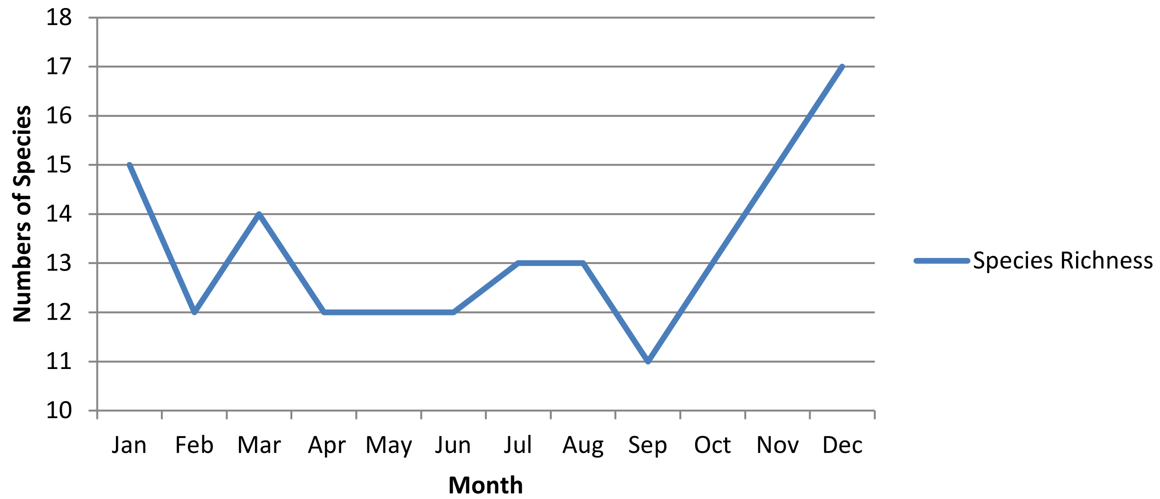


Figure 41: Total Species Richness of Piscivorous Birds at all Survey Locations in 2014

Species richness was not uniform across all survey locations. Generally, the trash rack location had lower species richness than the radial gates locations (Figure 42).

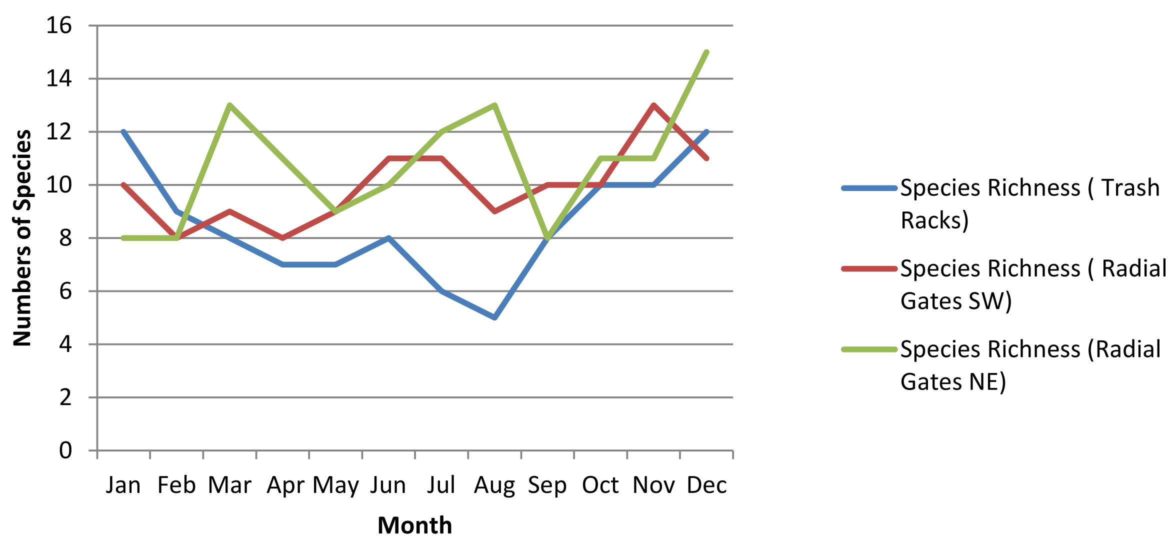
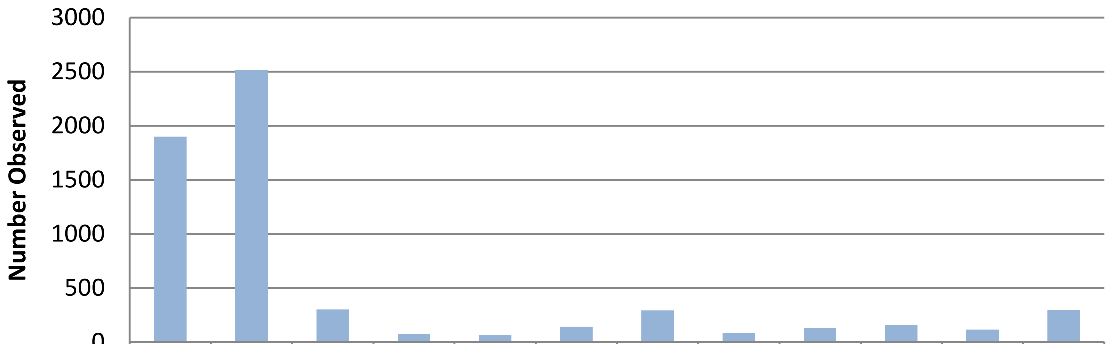


Figure 42: Species richness of piscivorous birds at each survey location in 2014

An ANOVA was performed on the species richness at the Trash Racks and Radial Gates survey sites. The Radial Gates site received high sampling effort compared to the Trash Racks site due to two counts performed on the different sides of the gates. To control for this unbalanced sampling effort, Radial Gates site species totals were randomly chosen for each month. After controlling for sampling effort the ANOVA showed that the differences between the sites are statistically significant ($p = 0.025$) with the numbers of species observed at the trash racks being overall lower than the numbers of species observed at the radial gates across the year.

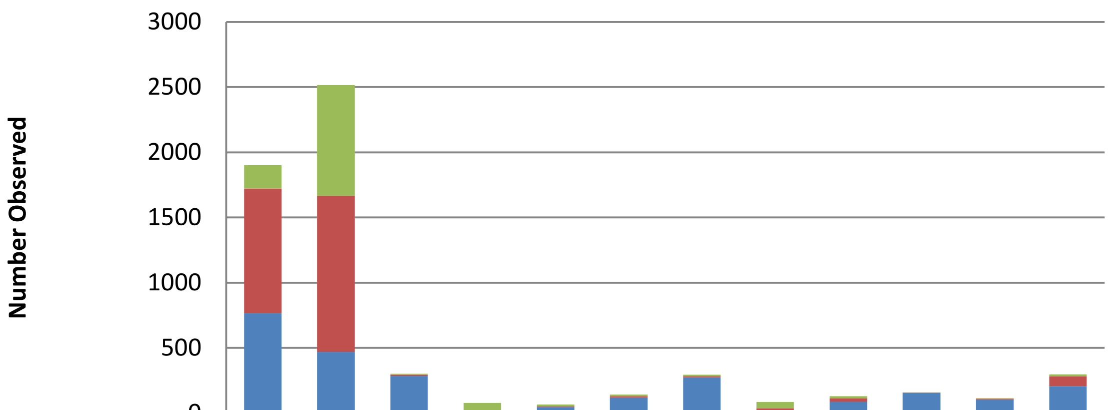
Species Numbers

Gulls were present during all of the months surveyed, however their numbers peaked dramatically in January and February at 1,900 and 2,515 birds respectively (Figure 43). Gulls occurred at all locations in all months of the survey period (Figure 44).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gull sp.	1900	2515	301	78	66	142	294	87	129	158	116	298

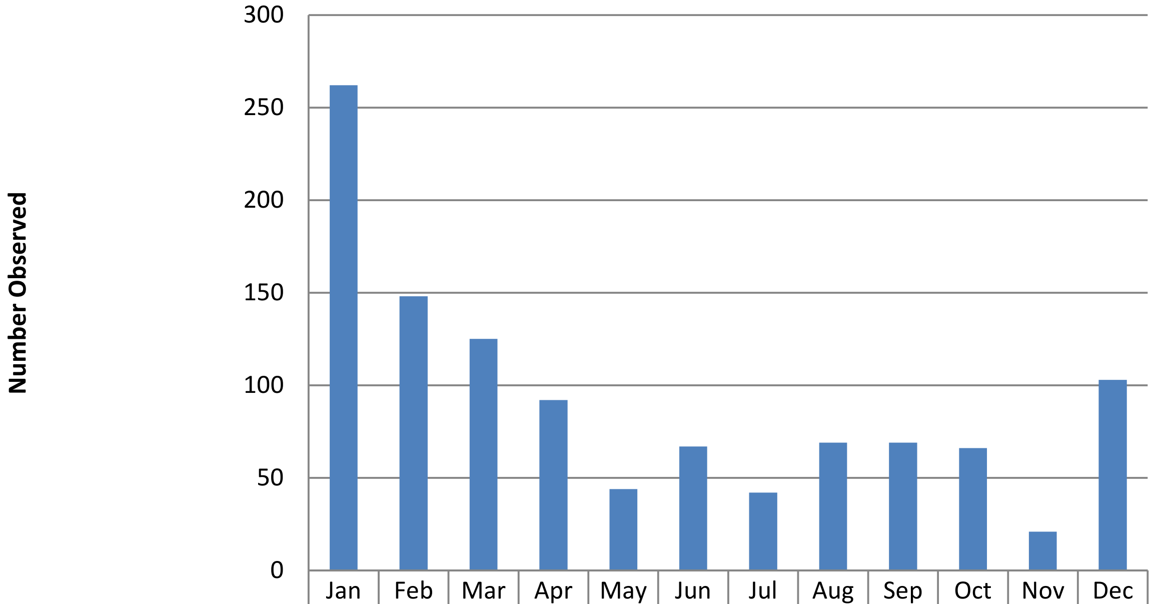
Figure 43: Gulls Observed at all locations by month in 2014



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radial Gates NE	178	849	7	56	14	12	11	49	16	2	6	15
Radial Gates SW	955	1196	10	18	6	12	11	29	26	2	6	77
Trash Racks	767	470	284	4	46	118	272	9	87	154	104	206

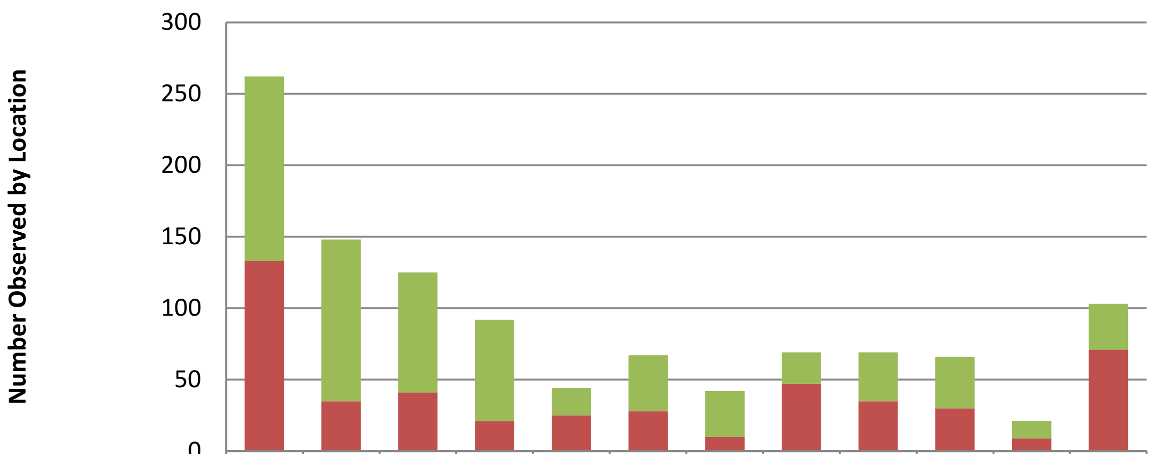
Figure 44: Gulls Observed by Location in 2014

American white pelicans were present in all of the months surveyed, with numbers peaking in January (Figure 45). This species was only observed in the vicinity of the radial gates during the entire survey period (Figure 46).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American White Pelican	262	148	125	92	44	67	42	69	69	66	21	103

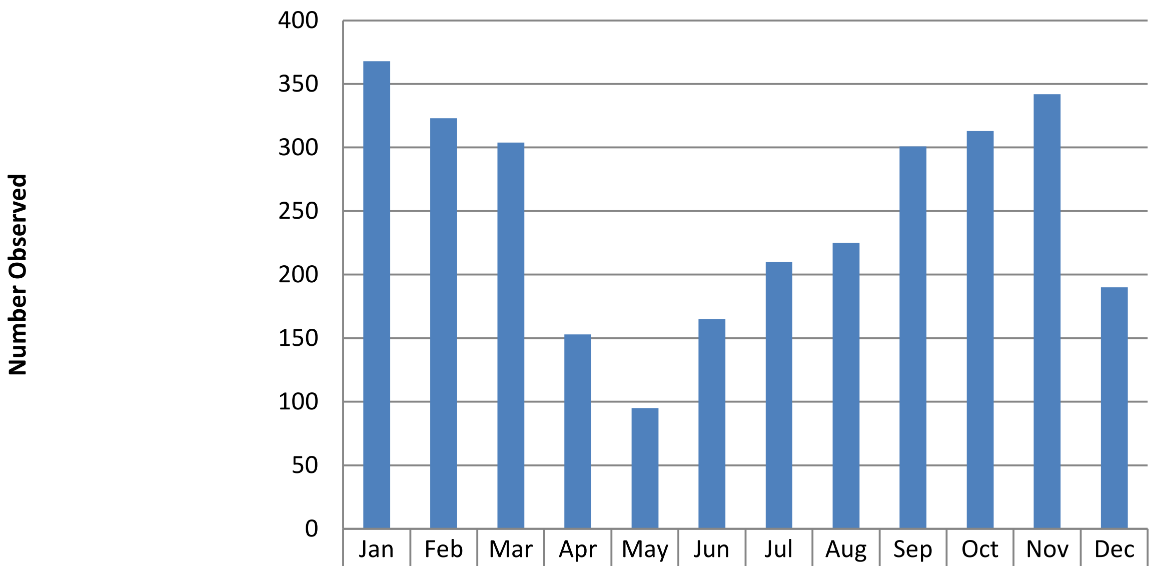
Figure 45: American White Pelicans Observed at all Locations in 2014



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radial Gates NE	129	113	84	71	19	39	32	22	34	36	12	32
Radial Gates SW	133	35	41	21	25	28	10	47	35	30	9	71
Trash Racks												

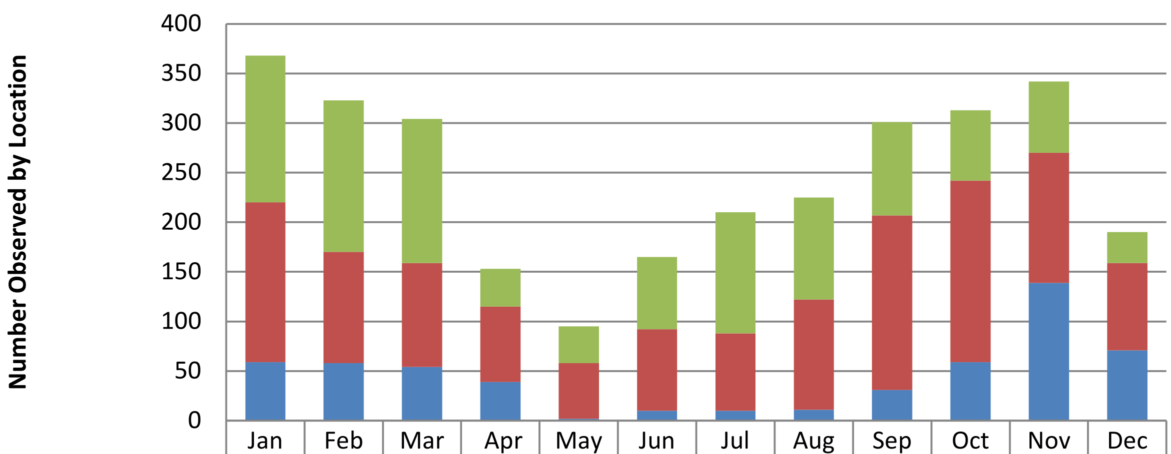
Figure 46: American White Pelicans Observed by Location in 2014

Double-crested cormorants were present during all of the months surveyed (Figure 47). Numbers peaked in the winter months (November to February) and dropped during the summer months (April to August). Double-crested cormorants were observed at all of the sites throughout the survey period with generally higher numbers at the radial gates (Figure 48).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Double-Crested Cormorant	368	323	304	153	95	165	210	225	301	313	342	190

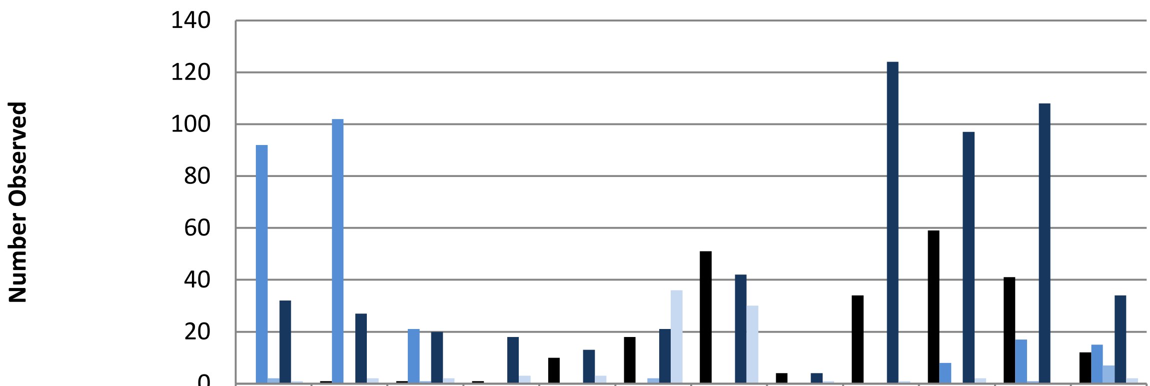
Figure 47: Double-Crested Cormorants observed at all Locations in 2014



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radial Gates NE	148	153	145	38	37	73	122	103	94	71	72	31
Radial Gates SW	161	112	105	76	56	82	78	111	176	183	131	88
Trash Racks	59	58	54	39	2	10	10	11	31	59	139	71

Figure 48: Double-Crested Cormorants Observed by Location in 2014

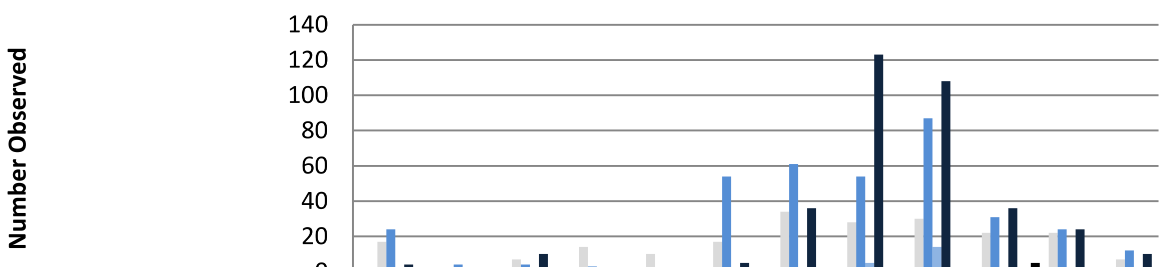
Five grebe species were observed during the survey, with numbers of some species, including pied-billed grebe (*Podilymbus podiceps*), Western grebe (*Aechmophorus occidentalis*) and Clark's grebe (*Aechmophorus clarkii*) peaking from July to November, while numbers of eared grebe (*Podiceps nigricollis*) peaked in January and February. Horned grebes were uncommon on the Forebay (Figure 49).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clark's Grebe		1	1	1	10	18	51	4	34	59	41	12
Eared Grebe	92	102	21							8	17	15
Horned Grebe	2		1			2					1	7
Pied Billed Grebe	32	27	20	18	13	21	42	4	124	97	108	34
Western Grebe	1	2	2	3	3	36	30	1	1	2		2

Figure 49: Grebe Species Observed at all Locations in 2014

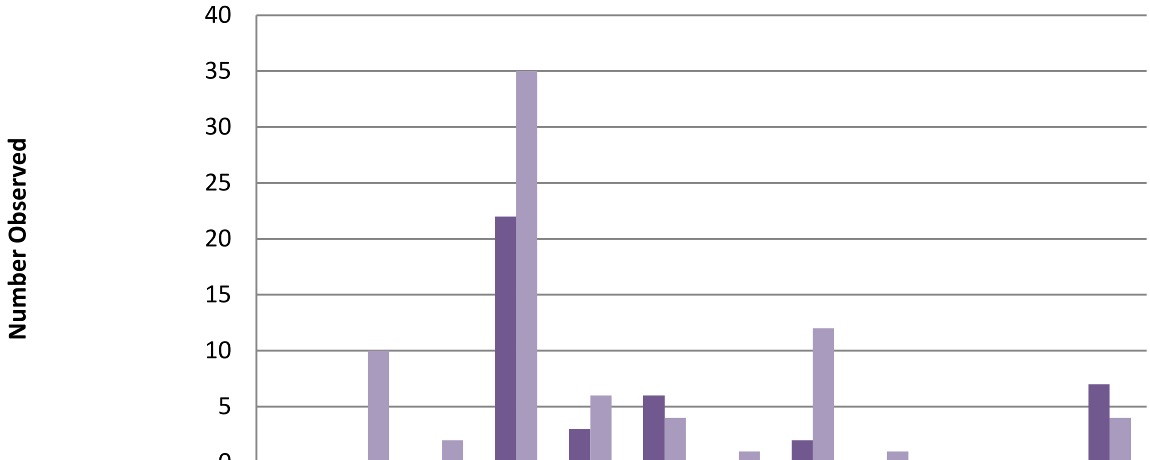
Six species of heron and egret were observed during the survey, with the most commonly observed species, great egret (*Ardea alba*), snowy egret (*Egretta thula*), and great blue heron (*Ardea herodias*) peaking from June through September (Figure 50).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black-Crowned Night-Heron										1	5	2
Cattle Egret	1						1					
Great Blue Heron	17		7	14	10	17	34	28	30	22	22	7
Great Egret	24	4	4	3	1	54	61	54	87	31	24	12
Green Heron	1				2	1	1	5	14	2	2	
Snowy Egret	4	1	10	2		5	36	123	108	36	24	10

Figure 50: Herons and Egrets Observed at all Locations in 2014

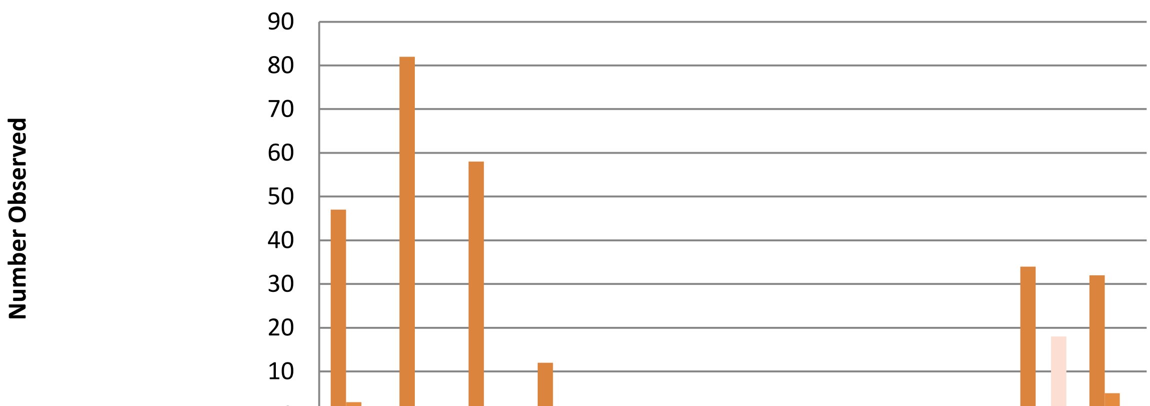
Tern species identification was divided into Caspian tern and unidentified tern due to the difficulty in distinguishing smaller tern species in the field. Numbers for all terns observed peaked in April (Figure 51).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Caspian Tern				22	3	6		2				7
Tern (Unidentified)		10	2	35	6	4	1	12	1			4

Figure 51: Terns Observed at all Locations in 2014

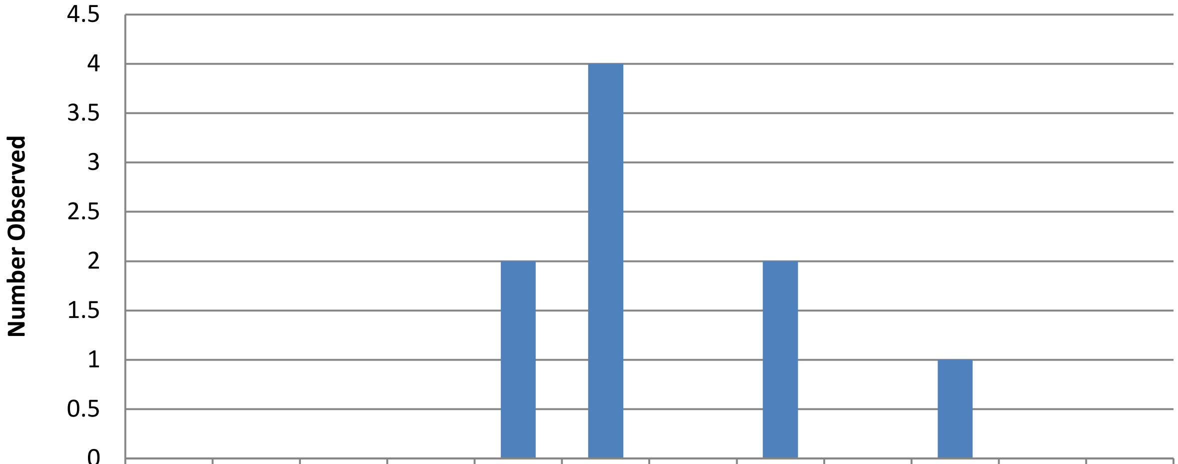
A number of piscivorous waterfowl species were observed during the survey period. The most common species was the common goldeneye (*Bucephala clangula*). Numbers of all species of piscivorous duck followed the same pattern, peaking in the winter months and completely absent in the summer months (Figure 52).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Common Goldeneye	47	82	58	12							34	32
Common Merganser	3	1	1								1	5
Red-breasted Merganser	2										18	1

Figure 52: Piscivorous Waterfowl Species Observed at all Locations in 2014

Osprey numbers were generally low, but peaked from May through June. Ospreys were not observed during the winter months of November through April (Figure 53).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Osprey					2	4		2		1		

Figure 53: Osprey Observed at all Locations in 2014

Seasonality

During the winter months of January, February and December, feeding behavior was relatively low as compared to other seasons (Tables 30, 31, and 32), ranging from 8% to 22%. The species of birds that were observed to be feeding during 50% or more of the observations during one or more winter months included all species of grebes observed on Clifton Court Forebay as well as several other species. Grebes with high observed feeding rates included the pied-billed grebe (*Podilymbus podiceps*), eared grebe (*Podiceps nigricollis*), horned grebe (*Podiceps auritus*), Western grebe (*Aechmophorus occidentalis*), and Clark's grebe (*Aechmophorus clarkii*). Other piscivorous species with high observed feeding rates included common goldeneye (*Bucephala clangula*), common merganser (*Mergus merganser*), Caspian tern (*Hydroprogne caspia*), and snowy egret (*Egreta thula*) (Table 29).

Table 29: Percent of Observed Birds Feeding at all Locations in Winter 2014

Month	Jan			Feb			Dec		
	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
Species									
American White Pelican	262	36	14%	148	8	5%	103	9	9%
Black-Crowned Night-Heron							2	0	0%
Caspian Tern							7	6	86%
Cattle Egret	1	0	0%						
Clark's Grebe				1	1	100%	12	9	75%
Common Goldeneye	47	15	32%	82	53	65%	32	17	53%
Common Merganser	3	0	0%	1	0	0%	5	3	60%
Double-Crested Cormorant	368	36	10%	323	36	11%	190	42	22%
Eared Grebe	92	71	77%	102	94	92%	15	12	80%
Great Blue Heron	17	1	6%				7	2	29%
Great Egret	24	4	17%	4	1	25%	12	3	25%
Green Heron	1	0	0%						
Gull sp.	1900	433	23%	2515	50	2%	298	0	0%
Horned Grebe	2	0	0%				7	7	100%
Osprey									
Pied Billed Grebe	32	21	66%	27	15	56%	34	28	82%
Red-breasted Merganser	2	0	0%				1	0	0%
Snowy Egret	4	2	50%	1	0	0%	10	6	60%
Tern (Unidentified)				10	0	0%	4	0	0%
Western Grebe	1	1	100%	2	1	50%	2	1	50%
Grand Total	2756	620	22%	3216	259	8%	741	145	20%

During the spring months of March, April and May, feeding behavior was relatively low compared to summer and fall months, (Tables 29, 31 and 32), ranging from 22 % to 33% of all birds observed feeding. The species of birds that were observed to be feeding during 50% or more of the observations during one or more spring months included many species of grebe observed on Clifton Court Forebay as well as several other species. Grebes with high observed feeding rates included pied-billed grebe (*Podilymbus podiceps*), eared grebe (*Podiceps nigricollis*), Western grebe (*Aechmophorus occidentalis*), and Clark's grebe (*Aechmophorus clarkii*). Other piscivorous species with high observed feeding rates included American white pelican (*Pelecanus erythrorhynchos*), common goldeneye (*Bucephala clangula*), common merganser (*Mergus merganser*), snowy egret (*Egreta thula*), and unidentified tern species (*Sterna sp.*) (Table 30).

Table 30: Percent of Observed Birds Feeding at all Locations in Spring 2014

Month	Mar			Apr			May		
	Total	**Feeding**	**% Feeding**	**Total**	**Feeding**	**% Feeding**	**Total**	**Feeding**	**% Feeding**
Species									
American White Pelican	**125**	**45**	**36%**	**92**	**20**	**22%**	**44**	**22**	**50%**
Black-Crowned Night-Heron									
Caspian Tern				**22**	**1**	**5%**	**3**	**0**	**0%**
Cattle Egret									
Clark's Grebe	**1**	**1**	**100%**	**1**	**0**	**0%**	**10**	**8**	**80%**
Common Goldeneye	**58**	**33**	**57%**	**12**	**8**	**67%**			
Common Merganser	**1**	**1**	**100%**						
Double-Crested Cormorant	**304**	**58**	**19%**	**153**	**36**	**24%**	**95**	**35**	**37%**
Eared Grebe	**21**	**17**	**81%**						
Great Blue Heron	**7**	**2**	**29%**	**14**	**5**	**36%**	**10**	**4**	**40%**
Great Egret	**4**	**1**	**25%**	**3**	**1**	**33%**	**1**	**0**	**0%**
Green Heron							**2**	**0**	**0%**
Gull sp.	**301**	**1**	**0%**	**78**	**3**	**4%**	**66**	**5**	**8%**
Horned Grebe	**1**	**0**	**0%**						
Osprey							**2**	**0**	**0%**
Pied Billed Grebe	**20**	**15**	**75%**	**18**	**14**	**78%**	**13**	**6**	**46%**
Red-breasted Merganser									
Snowy Egret	**10**	**9**	**90%**	**2**	**2**	**100%**			
Tern (Unidentified)	**2**	**2**	**100%**	**35**	**7**	**20%**	**7**	**2**	**29%**
Western Grebe	**2**	**2**	**100%**	**3**	**3**	**100%**	**3**	**2**	**67%**
Grand Total	**857**	**187**	**22%**	**433**	**100**	**23%**	**256**	**84**	**33%**

During the summer months of June, July and August, feeding behavior was higher than winter and spring, ranging from 28% to 40%, (Tables 29, 30 and 32). The species of birds that were observed to be feeding during 50% or more of the observations during one or more summer months included fewer species of grebe observed on Clifton Court Forebay and more species of egret as well as several other species. Grebes with high observed feeding rates included pied-billed grebe (*Podilymbus podiceps*), horned grebe (*Podiceps auritus*), Western grebe (*Aechmophorus occidentalis*) and Clark's grebe (*Aechmophorus* *clarkii*). Other piscivorous species with high observed feeding rates included American white pelican (*Pelecanus erythrorhynchos*), cattle egret (*Bubulcus ibis*), snowy egret (*Egreta thula*), great egret (*Egreta alba*), great blue heron (*Ardea herodias*), green heron (*Butorides virescens*), osprey (*Pandion haliaetus*), and unidentified tern species (*Sterna sp.*) (Table 31).

Table 31: Percent of Observed Birds Feeding at all Locations in Summer 2014

Month	Jun			Jul			Aug		
	Total	**Feeding**	**% Feeding**	**Total**	**Feeding**	**% Feeding**	**Total**	**Feeding**	**% Feeding**
Species									
American White Pelican	**67**	**35**	**52%**	**42**	**8**	**19%**	**69**	**49**	**71%**
Black-Crowned Night-Heron									
Caspian Tern				**6**	**0**	**0%**	**2**	**0**	**0%**
Cattle Egret				**1**	**1**	**100%**			
Clark's Grebe	**18**	**16**	**89%**	**51**	**50**	**98%**	**4**	**2**	**50%**
Common Goldeneye									
Common Merganser									
Double-Crested Cormorant	**165**	**45**	**27%**	**210**	**42**	**20%**	**225**	**62**	**28%**
Eared Grebe									
Great Blue Heron	**17**	**9**	**53%**	**34**	**14**	**41%**	**28**	**5**	**18%**
Great Egret	**54**	**38**	**70%**	**61**	**38**	**62%**	**54**	**21**	**39%**
Green Heron	**1**	**1**	**100%**	**1**	**0**	**0%**	**5**	**1**	**20%**
Gull sp.	**142**	**1**	**1%**	**294**	**3**	**1%**	**87**	**20**	**23%**
Horned Grebe	**2**	**2**	**100%**						
Osprey	**4**	**3**	**75%**				**2**	**1**	**50%**
Pied Billed Grebe	**21**	**16**	**76%**	**42**	**30**	**71%**	**15**	**12**	**80%**
Red-breasted Merganser									
Snowy Egret	**5**	**3**	**60%**	**36**	**19**	**53%**	**123**	**70**	**57%**
Tern (Unidentified)	**4**	**0**	**0%**	**1**	**0**	**0%**	**12**	**9**	**75%**
Western Grebe	**37**	**31**	**84%**	**30**	**22**	**73%**	**1**	**1**	**100%**
Grand Total	**537**	**200**	**37%**	**809**	**227**	**28%**	**627**	**253**	**40%**

During the fall months of September, October and November, feeding behavior was relatively high compared to winter and spring (Tables 29, 30, and 31), ranging from 35% to 55%. Species of bird that were observed to be feeding during 50% or more of the observations during one or more fall months included all species of grebe observed on Clifton Court Forebay as well as several other species. Grebes with high observed feeding rates included pied-billed grebe (*Podilymbus podiceps*), eared grebe (*Podiceps nigricollis*), horned grebe (*Podiceps auritus*), Western grebe (*Aechmophorus occidentalis*), and Clark's grebe (*Aechmophorus clarkii*). Other piscivorous species with high observed feeding rates included American white pelican (*Pelecanus erythrorhynchos*), common goldeneye (*Bucephala clangula*), common merganser (*Mergus merganser*), great blue heron (*Ardea herodias*), great egret (*Egreta abla*), snowy egret (*Egreta thula*), and green heron (*Butorides virescens*)(Table 32).

Table 32: Percent of Observed Birds Feeding at all Locations in Fall 2014

Month	Sep			Oct			Nov		
	Total	**Feeding**	**% Feeding**	**Total**	**Feeding**	**% Feeding**	**Total**	**Feeding**	**% Feeding**
Species									
American White Pelican	**69**	**38**	**55%**	**66**	**38**	**58%**	**21**	**4**	**19%**
Black-Crowned Night-Heron				**1**	**0**	**0%**	**5**	**1**	**20%**
Caspian Tern									
Cattle Egret									
Clark's Grebe	**34**	**31**	**91%**	**59**	**53**	**90%**	**41**	**32**	**78%**
Common Goldeneye							**34**	**26**	**76%**
Common Merganser							**1**	**1**	**100%**
Double-Crested Cormorant	**301**	**111**	**37%**	**313**	**55**	**18%**	**342**	**90**	**26%**
Eared Grebe				**8**	**6**	**75%**	**17**	**14**	**82%**
Great Blue Heron	**30**	**15**	**50%**	**22**	**8**	**36%**	**22**	**2**	**9%**
Great Egret	**87**	**70**	**80%**	**31**	**21**	**68%**	**24**	**10**	**42%**
Green Heron	**14**	**11**	**79%**	**2**	**1**	**50%**	**2**	**0**	**0%**
Gull sp.	**129**	**16**	**12%**	**158**	**0**	**0%**	**116**	**0**	**0%**
Horned Grebe							**1**	**1**	**100%**
Osprey				**1**	**0**	**0%**			
Pied Billed Grebe	**124**	**120**	**97%**	**97**	**92**	**95%**	**108**	**82**	**76%**
Red-breasted Merganser							**18**	**0**	**0%**
Snowy Egret	**108**	**81**	**75%**	**36**	**11**	**31%**	**24**	**7**	**29%**
Tern (Unidentified)	**1**	**0**	**0%**						
Western Grebe	**1**	**1**	**100%**	**2**	**2**	**100%**			
Grand Total	**898**	**494**	**55%**	**796**	**287**	**36%**	**776**	**270**	**35%**

Behavioral Observations

The percentage of behavior accounted for as feeding, pooled across all survey locations, peaked in September and dropped to a low point in February (Figure 54).

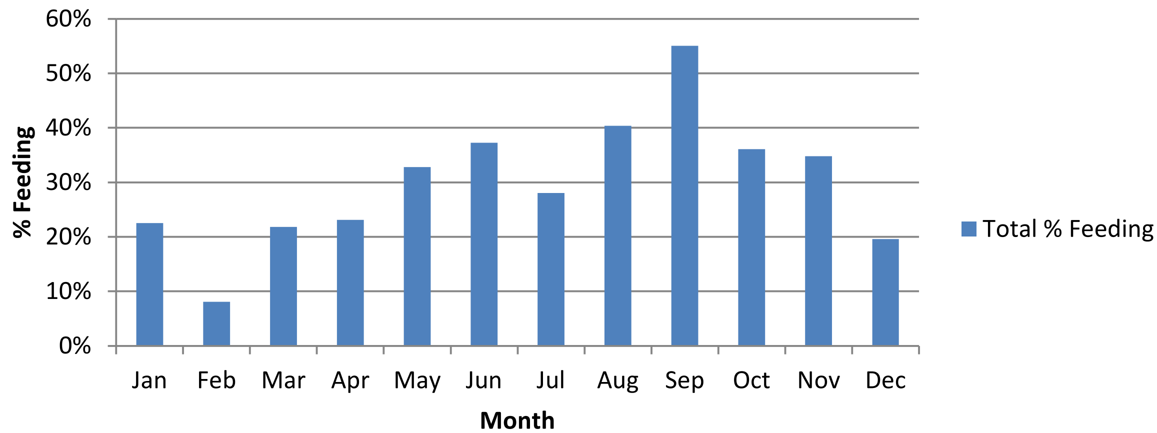
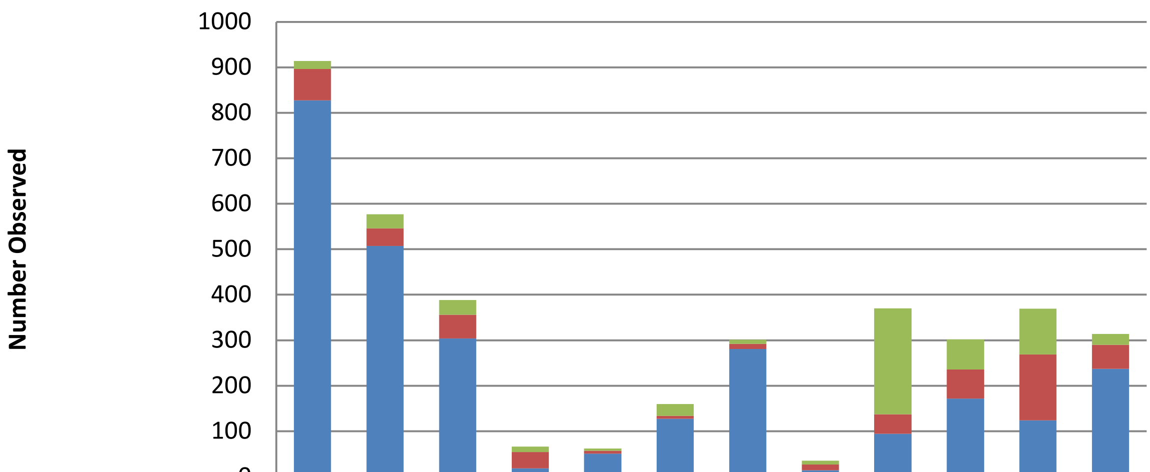


Figure 54: Feeding Behavior at all Locations in 2014

All behavioral categories were observed in all months at the trash racks in 2014 (Figure 55). In most months, flyovers were the most common behavior observed in the vicinity of this location due to large flocks of gulls flying over the site. Feeding behavior was observed to peak in the vicinity of the trash racks from September through November (Figure 56).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sum of Feeding	18	31	32	12	5	26	9	8	233	66	100	24
Sum of Non-Feeding	69	39	52	36	6	7	11	13	43	64	145	53
Sum of Flyover	827	507	304	18	51	127	281	14	94	172	124	237

Figure 55: Behavior at the Trash Racks in 2014

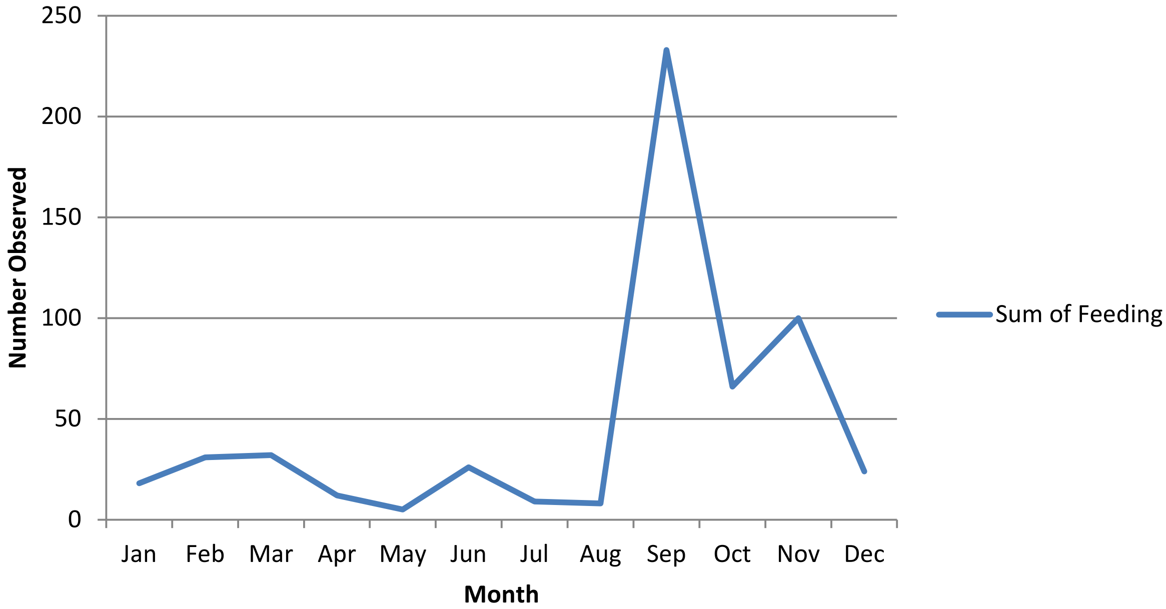
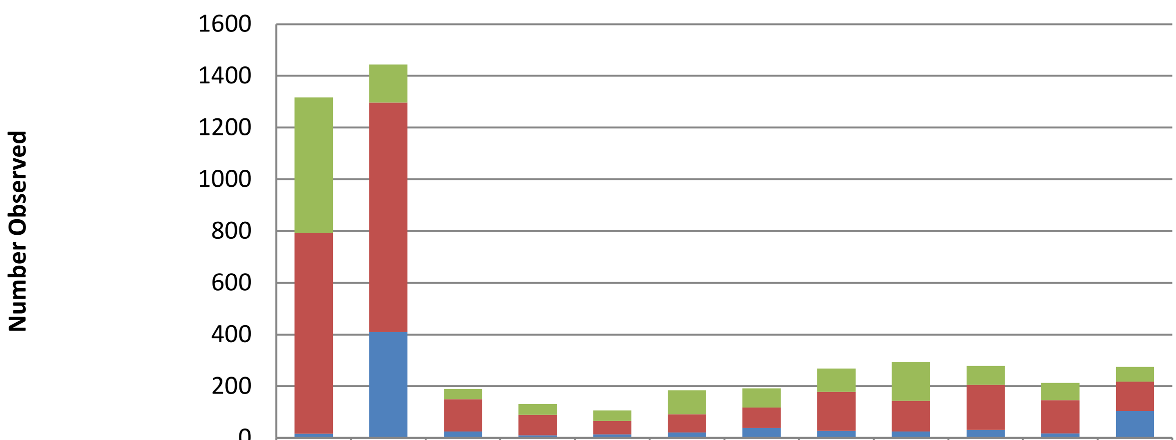


Figure 56: Numbers of Feeding Piscivorous Birds at the Trash Racks in 2014

All behavioral categories were observed in all months at both radial gate locations in 2014. Fewer flyovers were observed at the radial gates locations than at the trash rack location (Figures 57 and 59). Feeding behavior was observed to peak in the vicinity of the radial gates NE from July through October (Figure 60). A notable observation was in the numbers of feeding piscivorous birds in the vicinity of the radial gates SW location in January where a very large number of feeding birds was observed (Figure 58).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sum of Feeding	524	147	39	41	41	93	74	91	149	73	67	57
Sum of Non-Feeding	776	887	125	80	52	71	79	151	119	174	128	114
Sum of Flyover	16	410	25	10	14	21	39	27	25	31	18	104

Figure 57: Behavior at the Radial Gates SW in 2014

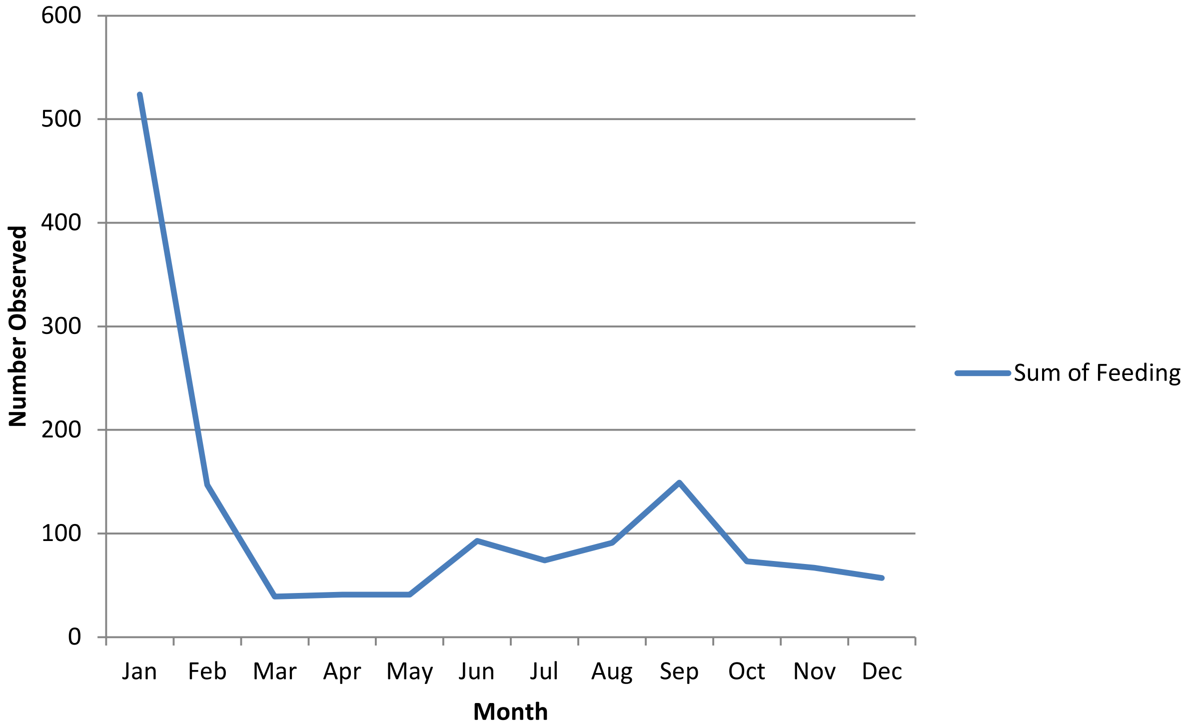
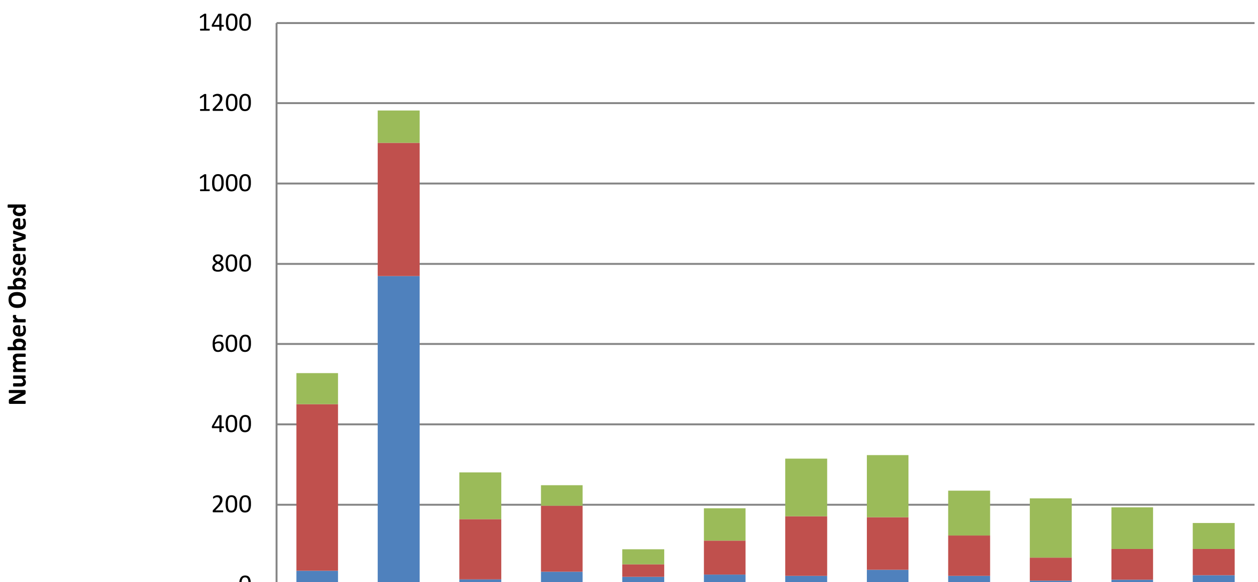


Figure 58: Numbers of Feeding Piscivorous Birds at the Radial Gates SW in 2014



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sum of Feeding	78	81	116	51	38	81	144	154	112	148	103	64
Sum of Non-Feeding	415	332	150	164	31	84	148	131	100	57	77	66
Sum of Flyover	35	769	14	33	20	26	23	38	23	11	13	24

Figure 59: Behavior at the Radial Gates NE in 2014

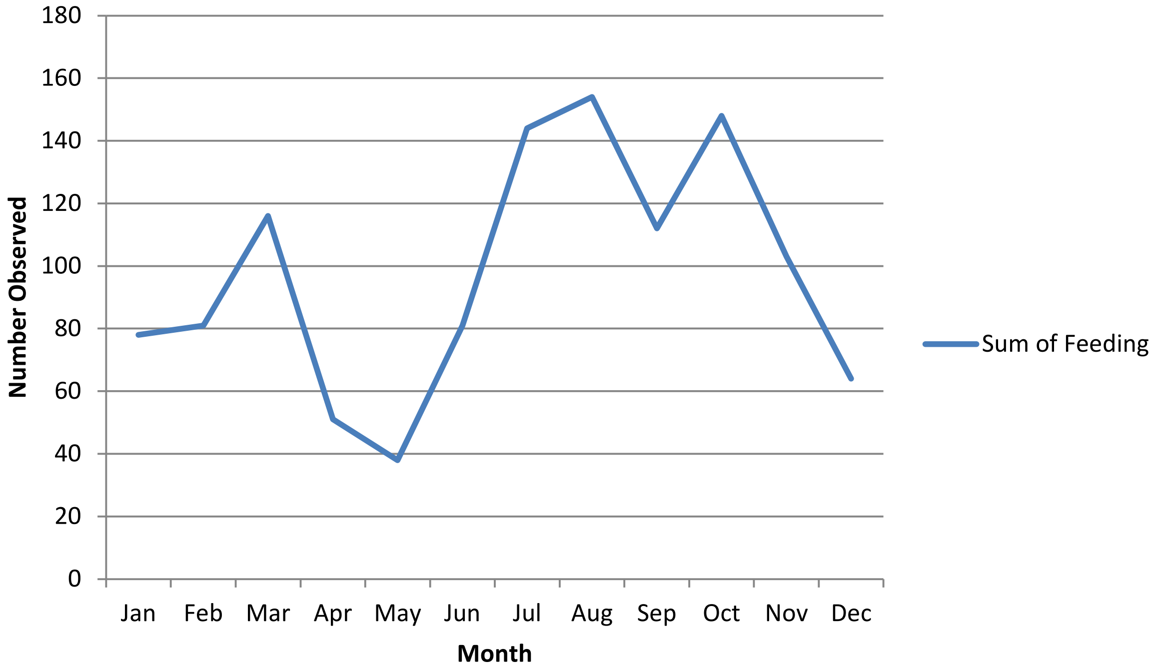
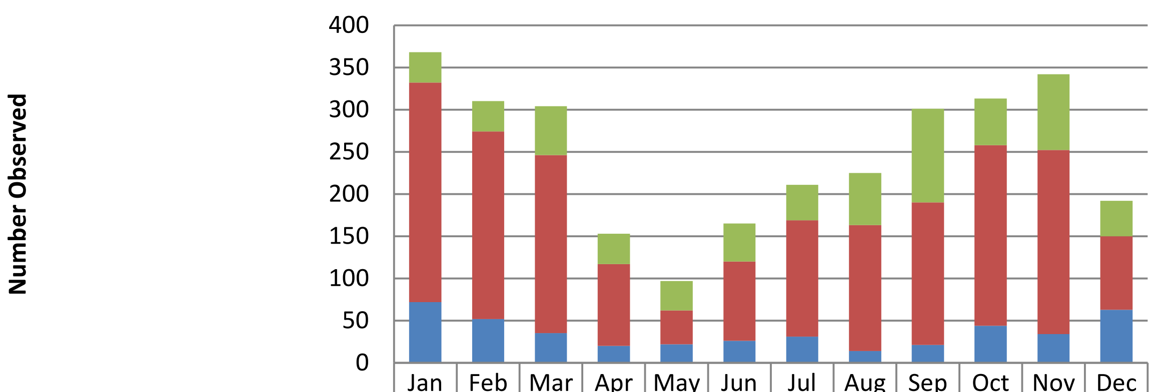


Figure 60: Numbers of feeding piscivorous birds at the Radial Gates NE location in 2014

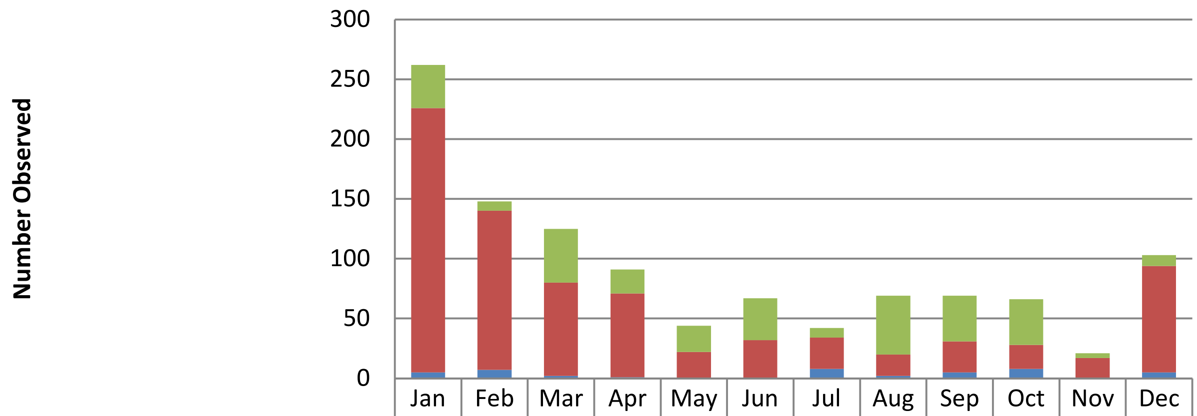
Double-crested cormorants were observed feeding during all of the months in which they were present during surveys (Figure 61). Often the feeding behavior observed consisted of stealing from other cormorants or birds of other species in the vicinity of the radial gates.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Double-crested Cormorant Sum of Feeding	36	36	58	36	35	45	42	62	111	55	90	42
Double-crested Cormorant Sum of Non-Feeding	260	222	211	97	40	94	138	149	169	214	218	87
Double-crested Cormorant Sum of Flyover	72	52	35	20	22	26	31	14	21	44	34	63

Figure 61: Double Crested Cormorant Behavior in 2014

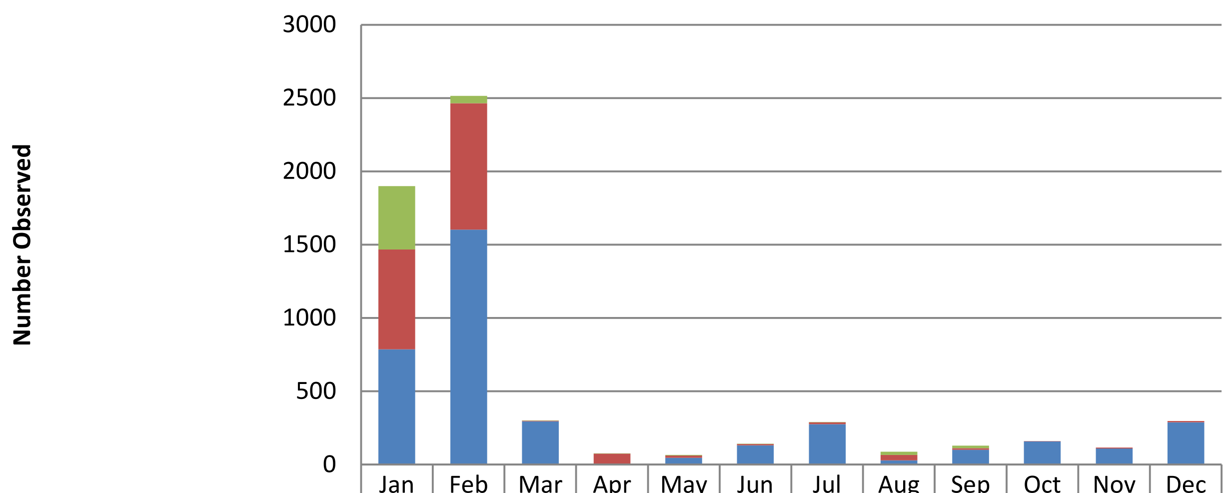
American white pelicans were observed feeding during all months of the survey (Figure 62). Often the feeding behavior observed consisted of stealing from other birds in the vicinity of the radial gates.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American White Pelican Sum of Feeding	36	8	45	20	22	35	8	49	38	38	4	9
American White Pelican Sum of Non-Feeding	221	133	78	70	22	32	26	18	26	20	17	89
American White Pelican Sum of Flyover	5	7	2	1	0	0	8	2	5	8	0	5

Figure 62: American White Pelican Behavior in 2014

Gulls were present in large flocks during several of the months surveyed, but were very rarely observed feeding during surveys (Figure 63).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gull sp. Sum of Feeding	433	50	1	3	5	1	3	20	16	0	0	0
Gull sp. Sum of Non-Feeding	681	863	4	68	15	9	13	38	11	1	6	9
Gull sp. Sum of Flyover	786	1602	296	7	46	132	276	29	102	157	110	289

Figure 63: Gull Behavior in 2014

2.6.5 Discussion and Recommendations

The higher species richness at the radial gates than at the trash racks is likely attributable to the concentration of prey around the radial gates and the wetlands habitat that has been created in the southeast corner of Forebay. All survey locations show the same general trends of higher species diversity in the winter and lower species diversity in the summer. Overall, observed numbers of particular species followed one of three patterns over the course of 2014. Some species, such as double-crested cormorant and great blue heron, were present all year long at relatively constant rates. Some species were present in relatively high numbers in winter and low numbers, or absent, in summer such as all species of piscivorous waterfowl. Some species were present in relatively high numbers in summer and low numbers, or absent in winter such as osprey and most species of egrets and herons.

Of the species observed during avian surveys, double-crested cormorants, American white pelicans, and gulls were the most commonly observed. Double-crested cormorants showed the broadest peak in abundance with relatively higher numbers observed in the months of September to March. American white pelicans and gulls showed a narrower peak in abundance with relatively high numbers observed in the months of January, February, and December. Undetected cormorants, pelicans, and gulls are likely due the large size of the Forebay.

Five species of grebes were observed during the avian surveys. Of them, Clark's grebe, western grebe, and pied-billed grebe numbers all peaked in early fall. These three species also all breed in the floating vegetation within the Forebay. Eared grebe numbers were high from January to March and also from October to December, but were completely absent from April to September. Horned grebe numbers peaked slightly in December, but were never very numerous during any month.

Six species of heron and egret were observed during the avian surveys. Great blue herons were present at fairly constant numbers throughout the study period with a modest peak from July to September. Great egret and snowy egret numbers peaked in July to October and July to December, respectively. The remaining three species (black-crowned night heron, cattle egret, and green heron) were observed at low to very low numbers.

Three species of piscivorous waterfowl were observed during avian surveys. Numbers of all three followed the same general pattern of high numbers from January to March, completely absent from May to October, and then high numbers again from November to December. Two species of tern were counted during the avian surveys. Caspian tern numbers peaked from April to August, while all other species (categorized as Unidentified Tern sp.) peaked from February to August. Osprey numbers peaked from May to October, but were always relatively low.

Feeding behavior was observed throughout the year. Feeding rates across all sites were relatively high from June through November, peaking in September at 55%. February was the month with the lowest rates of feeding at 8%. Looking at seasons overall, the percentages of birds feeding varied across the year. In winter, 17% of birds observed were feeding. In spring, 26% percent of birds observed were feeding. In summer, 35% of birds observed were feeding. In fall, 42% of birds observed were feeding. This indicates that overall predation pressures on fish populations have a degree of seasonality with higher pressure in summer and fall, and reduced predation pressure in winter when combining all species of birds present.

Cormorants and pelicans were observed feeding during all of the survey months; however, gulls were observed feeding in all months except October, November and December. Even in months in which gulls were observed feeding, they were observed to be much less frequent than cormorants and pelicans. This indicates that cormorants and pelicans may be having a greater predatory impact on fish populations than gulls; however, additional data is needed to determine relative predation pressure from these species. Grebes, herons and egrets often displayed high percentages of feeding behavior, often more than 50%, and may also represent a significant level of predation pressure on fishes in the Forebay. Identification of prey species was not possible during the surveys, and could include any of the fish species present at the time of the feeding event, including common species such as Striped Bass, as well as listed species such as Chinook Salmon.

Data collection in 2014 is the first full year of surveys completed for this project. The data collected during 2014 indicates seasonal trends in presence and feeding behavior of piscivorous birds. In order to increase confidence and predictive power of the 2014 avian surveys, we recommend that surveys continue year round at all three sites in 2015 to see if these trends are consistent.

2.7 Bioenergetics Modelling

2.7.1 Background

A bioenergetics model is a mass-based equation that can analyze how food consumed by an animal is either used for growth or metabolic processes, or excreted as waste (Ney 1993, Brandt and Hartman 1993). This can be a powerful tool in that it can allow for an understanding of the quantitative impacts of predation upon a population of prey given existing information on metabolic needs, digestion rates and predation habits of a predator species. This approach has been used to better understand the predator-prey dynamics between fish species such as Striped Bass and Threadfin Shad (*Dorosoma petenense*) in Lake Powell (Vatland et al 2008), and Lake Trout (*Salvelinus namaycush*) and Rainbow Smelt (*Osmerus mordax*) in Lake Champlain (LaBar 1993), as well as predation by piscivorous birds such as double-crested cormorants (Seefelt and Gillingham 2008) in northern Lake Michigan.

The relative impact of predation upon salmonids by fish and birds in the Forebay is an important factor in addressing pre-screen loss. These impacts can be evaluated in a quantitative manner using bioenergetics modeling. Work on the bioenergetics modeling was not undertaken in 2014.

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State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predation Study

September 2015

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Governor
State of California

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Abbreviations

AADAP	Aquatic Animal Drug Approval Partnership
ACC	Area Control Center
BDO	Department of Water Resources, Bay-Delta Office
BiOP	Biological Opinion
CALFED	CALFED Bay-Delta Science Program
CCFPS	Clifton Court Forebay Predator Study
CEQA	California Environmental Quality Act
CHTR	Collection, Handling, Transport, and Release Facility
CNDDB	California Natural Diversity Database
CPUE	Catch per Unit Effort
CVP	Central Valley Project (Federal)
CWT	Coded Wire Tag
Delta	Sacramento-San Joaquin Delta
DFD	Department of Water Resources, Delta Field Division
DFW	California Department of Fish and Wildlife
DIDSON	Dual Frequency Identification Sonar
DWR	California Department of Water Resources
EROF	Equipment Request Order Form
ESA	Endangered Species Act
FDA	Food and Drug Administration
FFAS	Clifton Court Forebay Fishing Facility Access Structure Project
Forebay	Clifton Court Forebay
GPS	Global Positioning System
HTI	Hydroacoustic Technology Incorporated
IEP	Interagency Ecological Program
INAD	Investigational New Animal Drug
ITP	Incidental Take Permit
MBTA	Migratory Bird Treaty Act
MOCC	Motorboat Operator Certification Course
MS-222	Tricaine -S
NEPA	National Environmental Policy Act
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
OP-2	Operations Procedure 2 – Lock-out/Tag-out
PCR	Polymerase chain reaction
PI	Principal Investigator
PIT	Passive Integrated Transponder
PSL	Pre-screen Loss
QA/QC	Quality Assurance/Quality Control
RPA	Reasonable and Prudent Alternative
SAV	Sub-aquatic Vegetation
SCP	DFW Scientific Collecting Permit
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project (California State)
TEP	Temporary Entry Permit
USFWS	U.S. Fish and Wildlife Service
WCA	Work Clearance Authorization

1.0 Introduction

National Marine Fisheries Service (NMFS) has required that the Department of Water Resources (DWR) implement the Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) of the Biological Opinion (BiOp) and Conference Opinion on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) (NMFS 2009) to reduce pre-screen loss of Endangered Species Act (ESA) protected salmon and steelhead within the Forebay to no more than 40 percent. Previous studies have shown pre-screen losses (PSL) of federal and State ESA listed salmonids ranging from 63% to 99%. The Clifton Court Forebay Predation Study (CCFPS) includes experimental investigations that have been designed to gather as much information as possible, both pre- and post-project for the RPA action undertaken. The CCFPS will provide the opportunity to evaluate the effects of the selected action on PSL of salmonids to help guide future management decisions. Specific study elements have been implemented as part of the CCFPS to further the understanding of behavior and movement of predatory fishes, salmonids, and piscivorous birds in the Forebay. These study elements include salmonid survival studies, predatory fish sampling, biotelemetry, genetics, creel surveys, avian studies, and bioenergetics.

1.1 Background

Clifton Court Forebay (Forebay) located near the town of Byron, in Contra Costa County, was constructed in 1969 by utilizing a 2,200 acre tract of land approximately 4.18 kilometers long and 3.38 kilometers across (Kano 1990). The Forebay is operated as a regulating reservoir within the tidally influenced region of the Sacramento-San Joaquin Delta (Delta) to improve operations of the SWP Harvey O. Banks Pumping Plant and water diversions to the California Aqueduct (Figure 1). During high tide cycles when the elevation of water in Old River is greater than that in the Forebay, up to five radial gates located in the southeast corner of the Forebay are opened to allow water to be diverted from Old River into the Forebay. Daily operation of the gates depends on scheduled water exports, tides, and storage availability within the Forebay (Le, 2004). Diversion of water from Old River through the radial gates results in the entrainment of numerous species of fish, including Central Valley steelhead (*Oncorhynchus mykiss*), winter and spring-run Chinook Salmon (*O. tshawytscha*), Delta Smelt (*Hypomesus transpacificus*), and Green Sturgeon (*Acipenser medirostris*; Southern Distinct Population Segment), which have all have been listed under the ESA, as well as the Longfin Smelt (*Spirinchus thaleichthys*) which is currently a candidate species for future listing. Therefore, operation of the SWP is performed in compliance with the terms and conditions of the NMFS 2009 BiOp, U.S. Fish and Wildlife Service (USFWS) 2008 BiOp, and California Department of Fish and Wildlife (DFW) 2009 Longfin Smelt incidental take permit (ITP).

Juvenile out-migrating Chinook salmon and steelhead must navigate from their natal streams through a network of Delta channels to eventually reach the Pacific Ocean (Figure 2.) Several studies have been conducted in recent years in an effort to understand the impact to salmon and steelhead survival that results from the selection of different routes such as the Delta Cross Channel, Sutter Slough, Steamboat Slough and Georgiana Slough (Perry et al 2010, 2012, Delaney et al 2014). Several of these routes can lead salmonids through the South Delta, where they can be entrained in the Forebay.

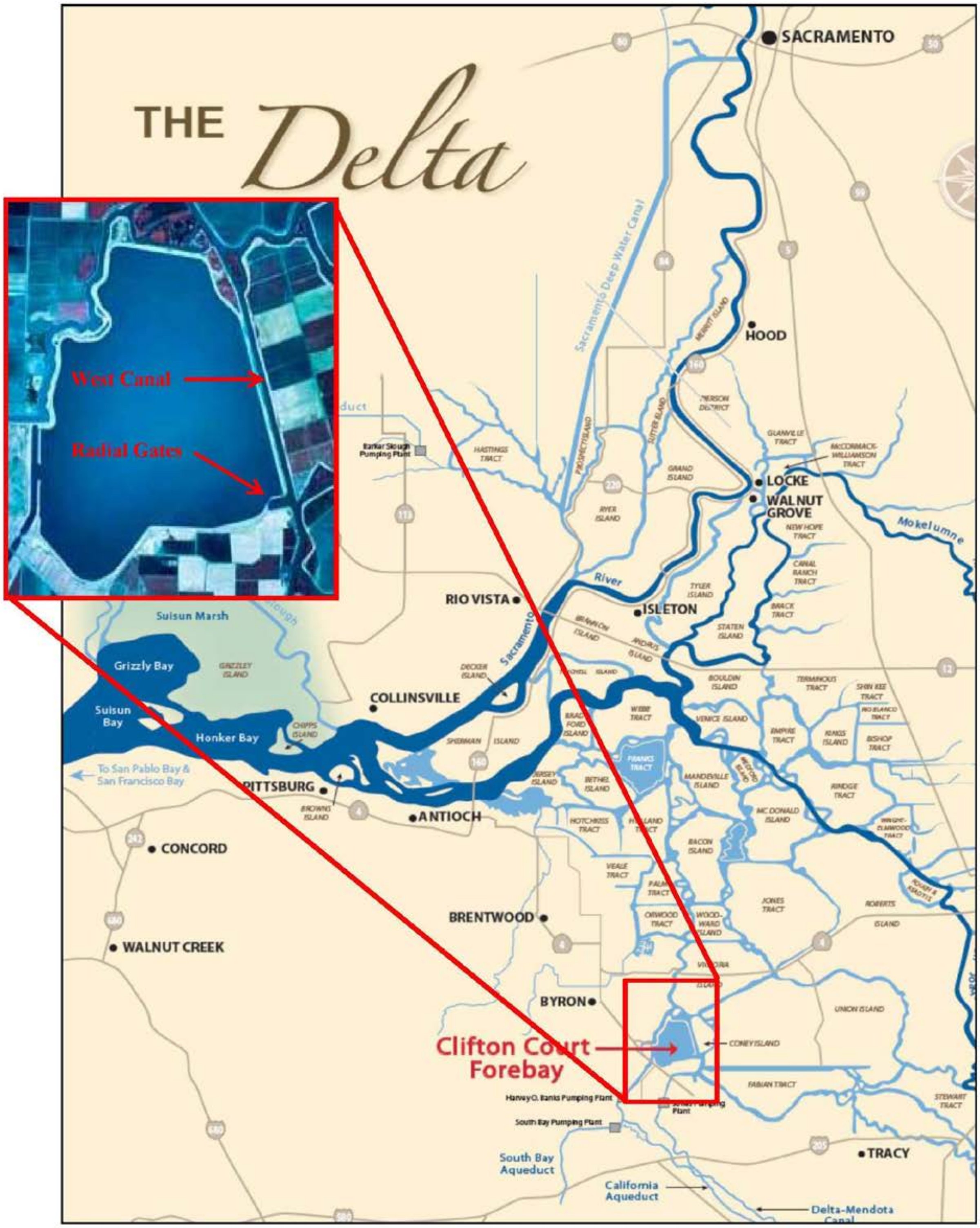

Figure 1: Clifton Court Forebay

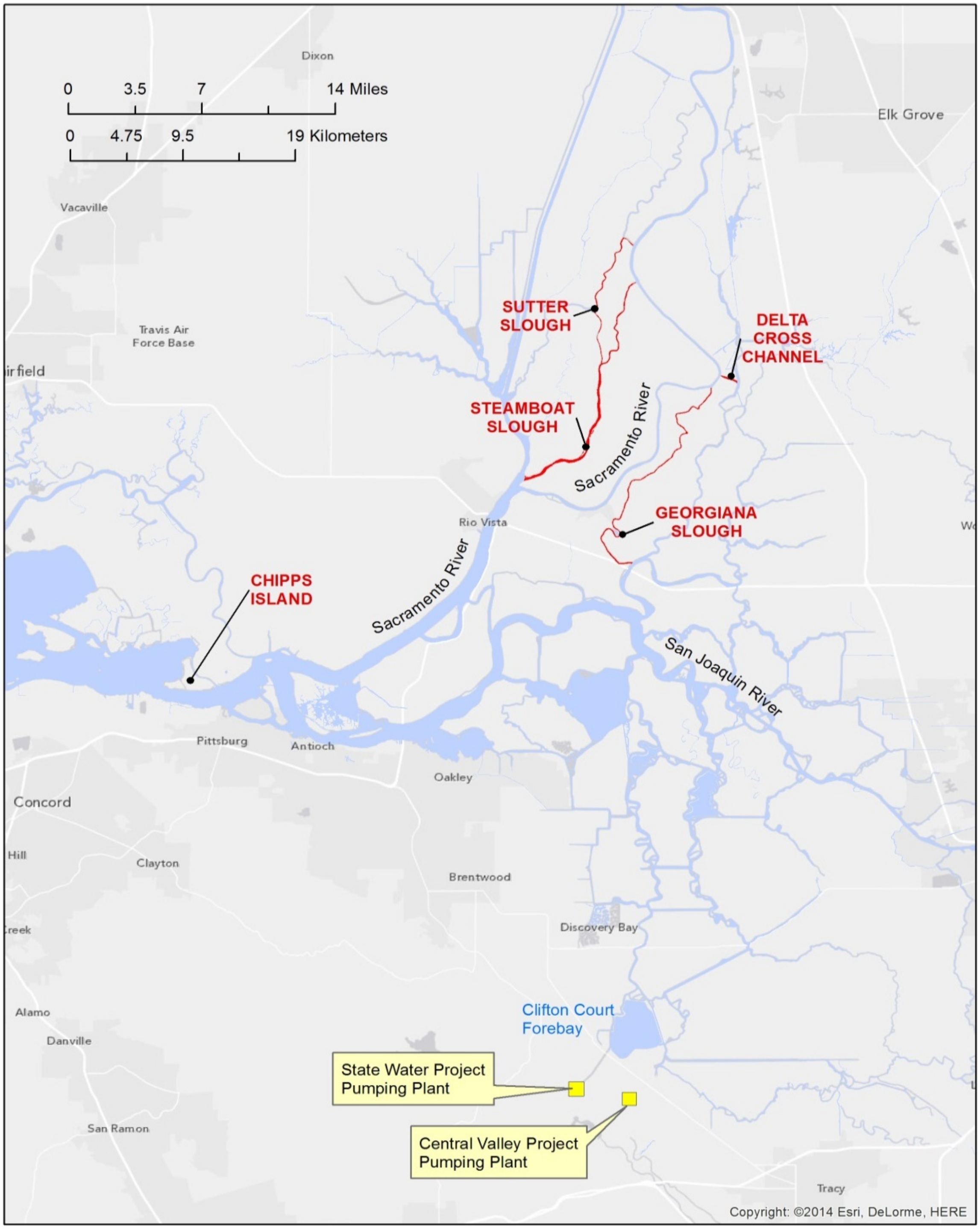

Figure 2: Delta Channels

Once fish have entered the Forebay, they must travel 3.4 kilometers across the Forebay to reach the John E. Skinner Delta Fish Protective Facility (SDFPF). The SDFPF was designed to protect fish from entrainment into the California Aqueduct, by diverting them into holding tanks where they can be salvaged and safely returned to the western Delta. Water is drawn to the SDFPF from the Forebay via the intake canal, and past a floating trash boom. The trash boom is designed to intercept floating debris and guide it to a trash conveyor on shore. Water and fish then flow through a trash rack, equipped with a trash rake, to a series of louvers arranged in a Vee pattern. Fish are behaviorally guided via the louvers, and directed to salvage holding tanks, where they remain until transported and released into the Delta (Figure 3).

Figure 3: Intake Canal and Trash Boom

Losses of fish entrained within the Forebay during their movement to the SDFPF, termed pre-screen loss (PSL), include predation by fish, birds, and occasionally marine mammals. Scientific studies conducted by the DWR and the DFW, including series of mark/recapture experiments conducted within the Forebay to determine PSL of juvenile Chinook Salmon and steelhead, have indicated that losses are likely primarily due to predation by a non-native predatory fish, Striped Bass (*Morone saxatilis*). These studies indicated that the range of PSLs of juvenile Chinook salmon were 63-99% and the losses of juvenile steelhead were 82 ±3% (Kano 1985, Gingras 1997, Clark et al 2009). Kano (1990) and Brown et al (1995) have further described PSL as being synonymous with predation by Striped Bass. In 2007, DWR conducted a study to quantify the PSL of juvenile steelhead within the Forebay. The 2007 study determined that only about 20% of steelhead that initially enter the Forebay successfully cross to the intake canal, ultimately to be salvaged at SDFPF, with the remaining 80% lost, most likely to predation, with Striped Bass being one of the significant predators (Clark et al 2009). Gingras summarized several studies regarding Chinook Salmon in the Interagency Ecological Program (IEP) technical report Mark/Recapture Experiments at Clifton Court Forebay to Estimate Pre-Screening Loss to Juvenile Fishes: 1976-1993 (Gingras 1997), stating "Predation by adult and sub-adult Striped Bass may account for much of the pre-screen loss.".

In 2005, a predation workshop was held by the CALFED Bay-Delta Science Program (CALFED) and DWR to examine questions associated with the losses of Chinook salmon, steelhead, Delta Smelt and other fish at the SWP and Central Valley Project (CVP) south Delta export facilities. At this workshop, an expert panel was convened and the panel concluded that "a more mechanistic understanding of the predation process and predator/prey interactions is required to address the problem" (Kimmerer and Brown 2006) The expert panel's recommendations included:

> The spatial overlap of predators and prey must be quantified at various temporal (seasonal, diel) and spatial (within the Forebay) scales.
>
> Size and time-specific diet data must be collected for predator populations in the Forebay.
>
> Size and growth rate data must be collected for both predators and prey to determine temporal and spatial variability in prey susceptibility to predators in the Forebay and the SWP facility, and to inform bioenergetics models for predicting predation potential.
>
> The degree to which predators and especially prey are free to move into and out of the Forebay must be evaluated, along with residence time of prey within the Forebay.
>
> Begin to build integrated models, including bioenergetics models, that will combine data and information on the effects of systems hydraulics, predator and prey behaviors as it affects species-specific vulnerability to predation, and predation potential.

As a result of previous PSL studies, NMFS has required that DWR implement the RPA action (IV 4.2(2)) of the 2009 BiOp to reduce pre-screen loss of ESA protected salmon and steelhead within the Forebay to no more than 40 percent. The Bay-Delta Office proposed the Clifton Court Forebay Fishing Facility (CCFFF) to provide a fixed structure to increase angler access to a predator "hotspot" in the Forebay as one effort to decrease predation and increase the survival of ESA listed fishes, including Chinook salmon, steelhead, and Green Sturgeon, within Clifton Court Forebay. Ancillary benefits of the proposed CCFFF may also include increased survival of Delta Smelt and Longfin Smelt. The Clifton Court Forebay Predation Study (CCFPS), includes experimental investigations that have been designed to gather as much information as possible, both pre- and post- installation of the proposed CCFFF. It will provide the opportunity to evaluate the effects of the proposed CCFFF on PSL of salmonids to help guide future management decisions. Field studies evaluating sturgeon survival in the Forebay cannot be performed as there is no viable source of Green Sturgeon for use in survival experiments. Sturgeon predation risk may be assessed through laboratory studies, but not as part of CCFPS.

In 2014, DWR and NMFS suspended work on the proposed CCFFF due to conflicts with the anticipated changes to the Bay-Delta Conservation Plan Conservation Measure 1. These changes would limit public access to the proposed CCFFF and significantly reduce any benefit originally anticipated from construction of the facility. Both DWR and NMFS are currently working on several alternatives to reduce predation in the Forebay. While the proposed CCFPS may need to be altered to address the final selection of which alternatives are implemented, the initial study results provide an excellent baseline to evaluate the success of any selected alternative.

1.2 CCFPS Study Objectives

Specific study elements have been implemented as part of the CCFPS to further the understanding of behavior and movement of predatory fishes, salmonids, and piscivorous birds in the Forebay. These study elements seek to address many of the CALFED expert panel recommendations above and answer several key questions regarding each of the topics below:

<u>Movements and behavior of predatory fishes in the Forebay</u>:

> What is the residence time and abundance of Striped Bass of different age/size classes in Forebay?
>
> What is the percentage of Striped Bass that emigrate, return to the Forebay, and what is the duration of time spent away from the Forebay?
>
> What are the seasonal demographics of Striped Bass?
>
> What are the relative densities of other (other than Striped Bass) piscivorous fish in the Forebay, and how do they influence predation upon salmonids?
>
> What is the recreational angler harvest of Striped Bass, and other piscivorous fishes, pre- and post- project?
>
> What are Striped Bass consuming in the Forebay?

<u>Survival of Salmonids in the Forebay</u>:

> What is survival pre- and post- project?

<u>Predatory bird foraging habits</u>:

> What is the abundance of predatory bird species pre- and post- project within 1,000 feet (300 meters) of the radial gates and within the vicinity of the trash rack?
>
> How does the predatory bird population change seasonally?
>
> What is the maximum consumption of salmonids by predatory birds?

Salmonid survival and predator (avian and fish) behavior and population demographics are being studied and documented to provide the baseline information needed to evaluate the impacts of any selected predation reduction alternative on fish populations, PSL, and predator-prey dynamics. Results of these studies can also guide future management decisions to assist in further reducing PSL at the Forebay by providing the information necessary to model predation potential.

Predation has been identified as having a significant impact on the survival of native salmonid smolts near water diversion structures in many systems including the Merrimack River in Massachusetts (Blackwell and Juanes 1998), Columbia and Snake River System (Willis 1994, Beamesderfer et al 1996), Mokelumne River (Merz 2003, Boyd 2007), and Sacramento-San Joaquin Delta (Clark et al 2009).

Numerous studies have documented the abundance of predatory fishes in Clifton Court Forebay, with the density of predatory fishes found to be higher in the California Aqueduct intake than in adjacent Delta channels (Brown et al 1996). Kano (1990) found White Catfish (*Ameiurus catus*) and Striped Bass to be the two most abundant predators in the Forebay, with population estimates ranging from 35,000 to 118,000 and 67,000 to 246,000, for Striped Bass and White Catfish respectively. Kano (1990) assumed that the Forebay was a closed system when generating these population estimates, however multiple other studies showed that the Forebay is an open system (Clark et al 2009, Gingras and McGee 1997, Bolster 1986). Therefore, these population estimates are likely inaccurate.

Striped Bass have been implicated as the primary predator affecting salmonid survival within the Forebay. Striped Bass are estimated to consume as much as 9% of out migrating winter-run Chinook Salmon in the Sacramento River (Lindley and Mohr 2003), and may account for as much as 28% of the loss of natural salmonid production in the Mokelumne River System (Merz 2003). In the Merrimack River in Lawrence, Massachusetts, Blackwell and Juanes (1998) found that over 48% of Striped Bass with stomach contents had consumed Atlantic Salmon (*Salmo salar*) smolts. Hall (1980b) showed losses of as much as 88% of late fall-run Chinook at the Forebay entrance. Johnson et al (1992) indicated that a decline in fall run Chinook Salmon in Coos Bay, Oregon, coincided with an increase in Striped Bass populations, and that a subsequent recovery in salmon populations also coincided with a reduction in the local Striped Bass population. The presence of other predatory fish such as White Catfish and black bass species (*Micropterus sp.*) may be a contributing factor in predation success of Striped Bass. Specifically, Carey and Wahl (2011) demonstrated that the presence of ambush style predators in a system with cruising predators can actually enhance predation success of the cruising predators. The numbers of black bass species present in the Forebay are unknown.

Predatory fish populations and diet composition have been shown to fluctuate seasonally with prey abundance in the Sacramento-San Joaquin Delta (Bolster 1986, Norbriga and Feyrer 2007, Thomas 1967). Additionally, predatory fish populations and diet composition have been shown to fluctuate seasonally with prey abundance in other systems such as the Chesapeake Bay (Walter and Austin 2003). Seasonal feeding movements of Striped Bass have been documented in the Chesapeake Bay System (Walter and Austin 2003) and in the Sacramento-San Joaquin Delta (Norbriga and Feyrer 2007). Predatory fish population estimates within the Forebay may change seasonally and may be associated with prey abundance within the Forebay.

In addition to piscivorous fishes, migrating smolts are subject to predation by a variety of bird species. Collis et al (2001) found 50,221 PIT tags from consumed juvenile Chinook Salmon and steelhead in Caspian tern (*Sterna caspia*) and double crested cormorant (*Phalacrocorax auritus*) colonies on Rice Island in the Columbia River Estuary, and Salmonids were found to make up as much as 74% and 46% of the total diet of these two avian species, respectively (Collis et al 2002) based upon gut content analysis and bill load observations. Similarly, over 2,000 coded wire tags (CWT) from Chinook Salmon were found in a sub-sample of nesting substrate in a colony of Caspian terns on Brooks Island in the San Francisco Bay (Evans et al 2011).

There is a strong likelihood that predation is the primary cause of PSL in the Forebay based on the numbers of predatory fish captured and birds observed inhabiting the Forebay, the demonstrated predatory habits and seasonal movements of Striped Bass and other piscivores in the Delta, and the demonstrated losses of marked hatchery salmonids crossing the Forebay (Brown et al 1996, Clark et al 2009). The relationship between loss of salmon and predation in the Forebay is such that the term PSL is generally accepted to be synonymous with predation (Kano 1990, Brown et al 1996). The predation pressures that exist for salmonids in the Forebay are multivariate, and include avian predation as well as predation from a variety of piscivores that demonstrate differing predation strategies. Additionally, in recent years the spread of invasive Submerged Aquatic Vegetation (SAV), such as Brazilian waterweed (*Egeria densa*) and several species of pondweed (*Potamogeton sp.*), has reached the Forebay, adding a new variable to the system. Several studies have shown that the presence of SAV in a system can alter predator-prey dynamics (Gotcietas and Colgan 1987, Brown and Michniuk 2007).

Predation upon juvenile salmonids in the Forebay is a complex problem; therefore, several concurrent study elements have been undertaken as part of the CCFPS to better define the existing threats and quantify the effects of any RPA action taken regarding predation reduction. These study elements include salmonid survival evaluation, predatory fish sampling, biotelemetry, genetics, creel surveys, avian surveys, and bioenergetics modeling.

2.0 CCFPS Study Elements

2.1 Salmonid Survival

2.1.1 Background

Mark/recapture studies using hatchery salmon and steelhead have been conducted numerous years, from 1976 through 2007, within the Forebay. Experiments conducted using Chinook Salmon from 1976 through 1993 were summarized by Gingras (1997), and estimated PSL to be between 63% and 99% for Chinook Salmon. Mark/recapture studies undertaken by Clark et al (2009) showed a PSL of 82% for steelhead. As part of the CCFPS, pilot level mark/recapture experiments using acoustic tagged (HTI Model 800 with integrated Biomark HPT9 PIT tags) and PIT (Biomark HPT6 or HPT9) tagged hatchery salmonids as surrogates for wild salmonids was planned for multiple years to evaluate the efficacy of the CCFFF on reducing PSL of salmonids in the Forebay. As described above, these experiments will now provide baseline information for any selected predation reduction alternative currently being considered for implementation.

2.1.2 Methods

This element of the study consists of requesting steelhead and Chinook Salmon (Fall and Late Fall) from the Mokelumne River Fish Hatchery and Coleman National Fish Hatchery (NFH), respectively. A total of 100 salmon are planned to be acoustically tagged, and up to 1,500 salmon (a combination of Fall and Late-Fall run) are planned to be PIT tagged, annually. In addition, up to 1,000 steelhead are planned to be PIT-tagged in select years.

Chinook Salmon and steelhead are transported from the hatcheries to the DWR fish laboratory facility located adjacent to the Forebay in Byron, California. The fish are held until tagging and releases can begin, after which fish are PIT tagged in groups of up to 80, twice per week on Monday and Friday. Fish are randomly selected from holding tanks, and anesthetized to handleable, defined as loss of equilibrium and reactivity to most external stimuli. Each fish is weighed to the nearest 0.1 gram (g), total length is measured to the nearest millimeter (mm), and the adipose fin is removed immediately prior to tagging. Fish are tagged with Biomark HPT6 or HPT9 PIT tags, and placed in holding tanks based upon treatment and tagging date, so that they are released in the proper group and order.

The release plan also includes placing acoustic tags in up to 10 fish per week to be released in conjunction with the PIT tagged fish (Table 3). The acoustic tags selected for this project were HTI model 800 micro acoustic tags with integrated Biomark HPT9 PIT tags, which weigh 0.5g +/- 10% in air. To ensure that the weight of the acoustic tag did not exceed 5% of the total weight of the fish, a minimum fish weight threshold of 12 grams was set for acoustic tagging.

Fish that are tagged on Monday are released on the following Thursday and Friday, and fish tagged on Friday are released on the following Monday and Tuesday, to reduce variance in the amount of time lapse between tagging and release to no less than 48 and no more than 72 hours. For each Chinook Salmon release, 40 fish are randomly selected, scanned to confirm and record the PIT tag number, and placed into green[1] five gallon buckets, in groups of five fish per bucket, for transport to the release sites, the primaries

[1] Green buckets were selected to reduce stress on the fish during transport.

and the radial gates (Figure 4, Table 1). For steelhead releases, 10 fish are released per day, two per bucket, at the radial gates. Releases of both salmon and steelhead are also conducted at the SDFPF primaries for purposes of calculating facility efficiency for the time periods during which the radial gates releases are conducted.

Releases at the radial gates are planned to coincide with the earliest period of the day that the radial gates were open on the release day. The gates are opened according to a monthly schedule that is determined based upon the tidal cycle and the amount of water allotted for the SWP.

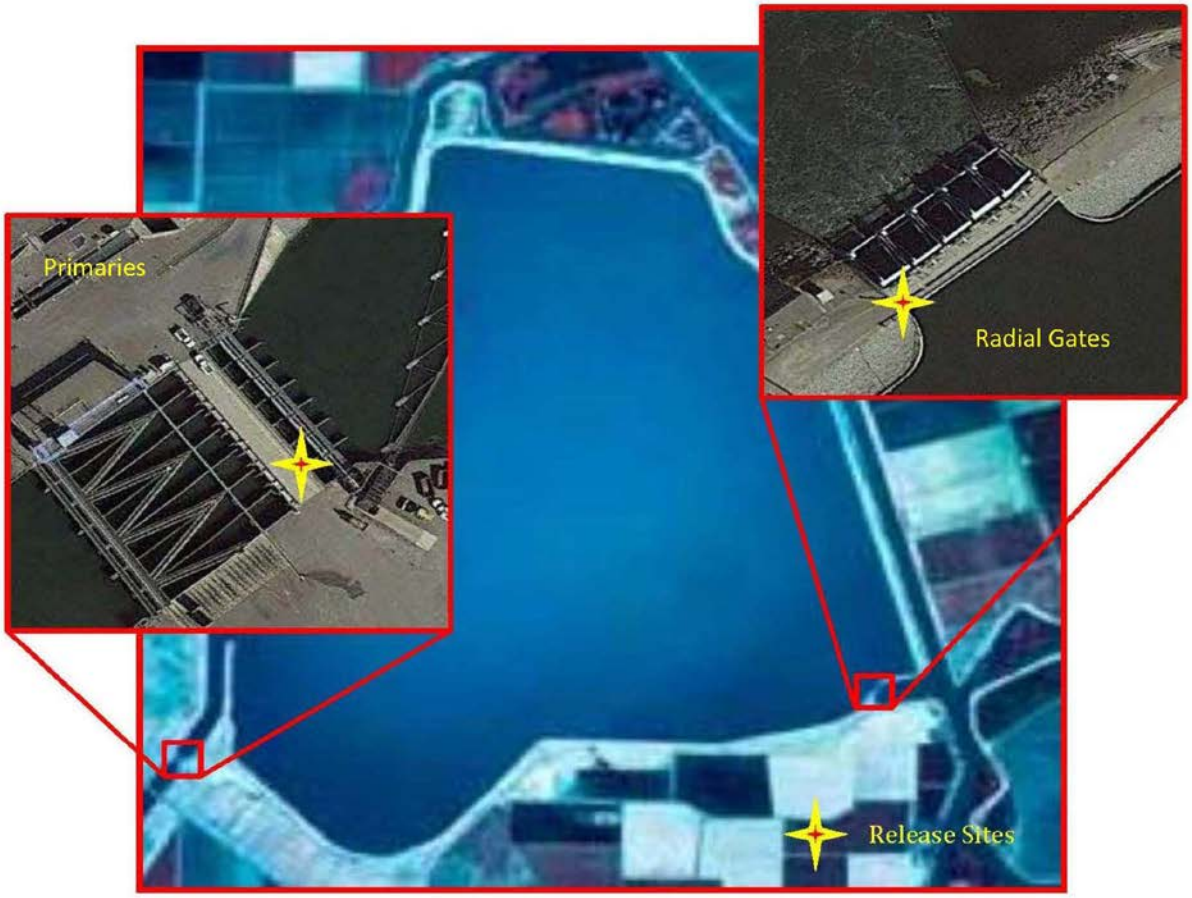

Figure 4: CCFPS Release Locations

Releases at the SDFPF primaries are based upon which of the bays was actively flowing water, and is coordinated with the SDFPF Efficiency Studies to reduce resource requirements of both studies. Following the releases, data regarding SDFPF Operational Criteria is recorded.

Table 1: Tagging and Release Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
Tagging	PIT tag up to 80 Chinook Salmon and 10 steelhead	Acoustically Tag up to 10 fish			PIT tag up to 80 Chinook Salmon and 10 steelhead
Releases	Release ½ of previous Friday's tagged fish	Release ½ of previous Friday's tagged fish		Release ½ of Mondays tagged fish	Release ½ of Mondays tagged fish and all of Tuesday's tagged fish

Figure 5: Fish Release at the Radial Gates

Following release, the salmon that are successfully salvaged would be detectable at the SWP fish salvage release sites located at Horseshoe Bend and Curtis Landing (Figures 7 and 8). Each release site is fitted with two separate PIT tag detection antennas, each connected to its own data logger. Prior to initiation of the releases each year, the PIT tag detectors and data loggers at each release site are checked by tagging and releasing fish directly into the fish hauling trucks immediately prior to the trucks leaving for designated release sites. During regularly scheduled fish counts at the SDFPF, operators check adipose fin clipped salmonids for PIT tags using a handheld PIT tag detector. Those salmonids found to have a PIT tag during the SDFPF counts are placed into the SDFPF holding tank and transported to one of the SDFPF fish release sites during the routine transport and release process.

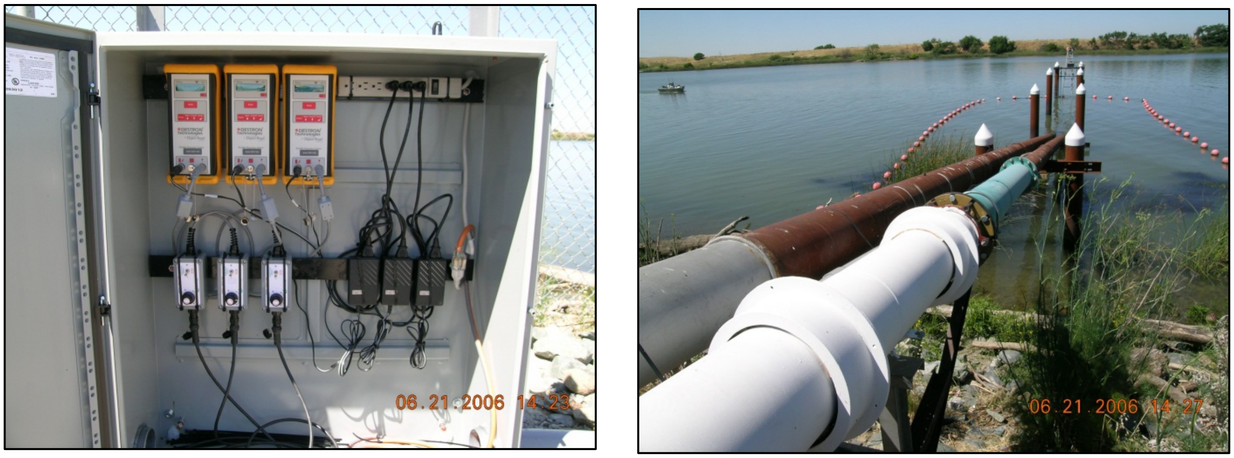

Figure 6: SDFPF Fish Salvage Data Loggers and Release Pipe (Horseshoe Bend)

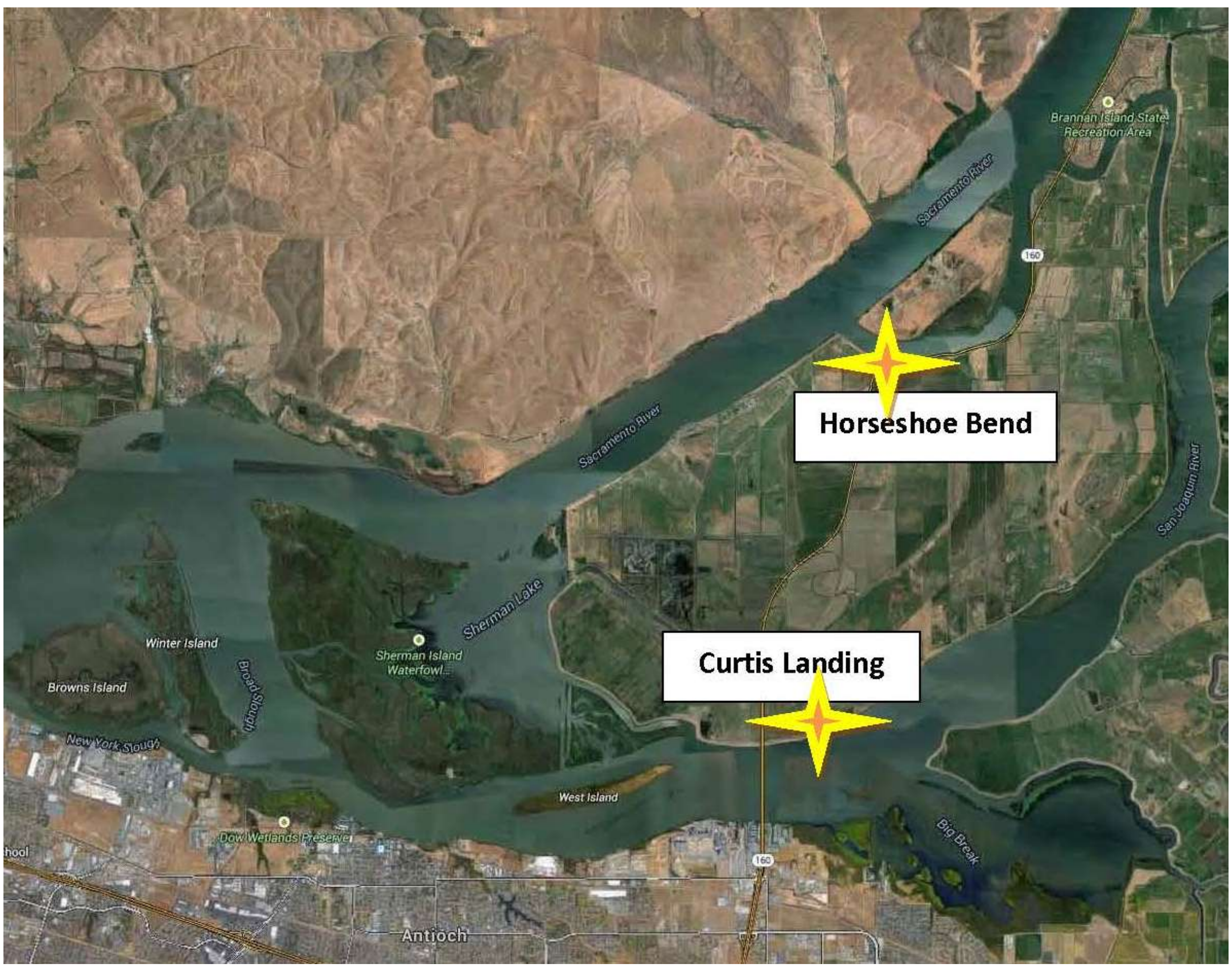

Figure 7: Location of Curtis Landing and Horseshoe Bend Release Sites on Sherman Island

2.2 Predatory Fish Sampling

2.2.1 Background

A variety of studies have been conducted in the Forebay since inundation of the site in 1969. Those studies have documented the presence of a wide variety of potential predatory fish species in the Forebay, including White Catfish (*Ameiurus catus*), Channel Catfish (*Ictalurus punctatus*), Blue Catfish (*Ictalurus furcatus*), Striped Bass (*Morone saxatilis*), Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Sacramento Pikeminnow (*Ptychocheilus grandis*), Black Crappie (*Pomoxis nigromaculatus*), and Brown Bullhead (*Ameiurus nebulosus*)(Kano 1990, Brown et al 1996). These species are known to demonstrate a variety of foraging strategies including roving, ambushing, and nocturnal feeding.

Striped Bass have been shown to not only move in and out of the Forebay, but also to traverse the Forebay itself (Gingras and McGee 1997). Striped Bass, after emigrating from the Forebay, have been shown to travel great distances (Clark et al 2009). Within the confines of the Forebay, they have shown a tendency to move back and forth between the radial gates and the trash racks. Striped Bass have been shown to spend a lot of time near the radial gates as well as near the trash racks, presumably consuming the juvenile fish that pass by these locations. However, there is uncertainty as to the individual site fidelity of Striped Bass to the Forebay and how long individual Striped Bass reside in the Forebay. Although site fidelity has not been definitively identified at the Forebay, Striped Bass have shown a variety of behavioral strategies in other areas, with clear evidence of site fidelity over multiple years in a New Jersey estuary (Ng et al 2007). Nevertheless, Able and Grothues (2007) have shown a variance in site fidelity and length of residency demonstrated by different individual Striped Bass in a single location, indicating that a population of Striped Bass may have subsets of individuals with very different behavioral strategies. This behavioral flexibility indicates that localized site fidelity can be an important demographic element in understanding predator-prey dynamics within the Forebay and could be just one of a suite of behavioral strategies employed by Striped Bass, depending upon the size and age of the fish.

While presence of all of the above listed predatory species has been documented, little is known about the behavior, population structure, and seasonal demographics of predatory fishes in the Forebay. To gain a more complete picture of the behavior and composition of the predator population year round, seasonal changes in the demographics of predatory fishes in the Forebay are being investigated. Field sampling is conducted throughout the year to capture predatory fishes for use in several specific study elements, including mark/recapture and genetic analysis of prey base. All field sampling is conducted in a manner that avoids or minimizes the potential take of listed species.

2.2.2 Methods

Predators such as Striped Bass, Largemouth Bass, White Catfish, and Channel Catfish, are collected by either gill netting or hook and line sampling in the Forebay. Predatory fish are sampled twice weekly throughout the year, to supply predatory fish for various study elements. Predatory fish capable of consuming juvenile salmonids are either sacrificed and preserved for use in the genetic analysis study element, or tagged as part of the mark-recapture and biotelemetry study element (discussed in detail in the Biotelemetry Section) and released at the location of capture. Temperature and dissolved oxygen, and location(s) of capture are noted for each sampling effort. Scale samples are collected from Striped Bass and Largemouth Bass, to be examined at a future date, to determine the age of the predatory fish sampled.

Collection of predators occur primarily during the day, between the hours of 0600 and 1500; however, some of the sampling efforts are also undertaken at night, between the hours of 1900 and 2400. All incidental species caught alive are measured, recorded, and immediately released at the location caught. Field staff are trained to quickly identify listed species and release live fish to minimize handling stress. Incidental take information is detailed in a supplemental report as part of the reporting requirements of the DFW Scientific Collecting Permits (SCP; SCP #'s 7744 and 10286).

The Forebay was split into sampling sections, following the same map as Gingras and McGee (1997; Figure 9) for use to identify the catch location of the predators sampled. Sampling is conducted from a boat, when possible, to allow for coverage of a greater portion of the Forebay. On sampling days when a boat is not available for use, sampling is conducted from the shoreline, primarily along the intake canal (Area 2) or adjacent to the radial gates (Area 1). Hook and line sampling is conducted using standard rod and reel fishing equipment in accordance with standard DFW regulations for hook and line fishing, and employs a wide variety of bait and lure selections to maximize catch. Gill netting is conducted on limited sampling days within the Forebay, using a monofilament gill net, measuring 30 meters (m) or less, with variable mesh sizes ranging from five centimeters (cm) to 15.25 cm, and is used primarily to support the genetics effort.

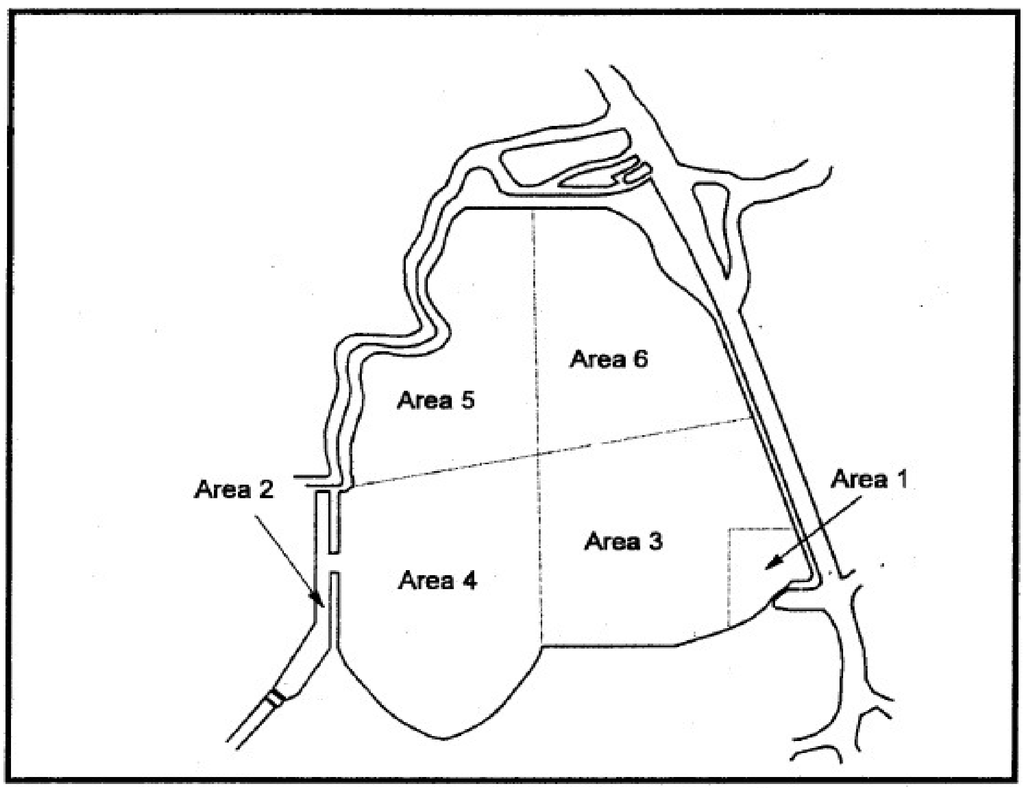

Figure 8: Sampling Map (Gingras and McGee 1997)

2.3 Biotelemetry

2.3.1 Background

Understanding the way in which fish use the Forebay is critical to understanding the local predator-prey dynamics. In combination with predator population estimates and other parameters, this will help in determining the impact that predation by piscivorous fishes is having on the survival of listed salmonids. One of the best tools currently available to assist in answering questions about fish residency and behavior is biotelemetry.

To gather more detailed information on the movements of predators as well as salmonids in the Forebay and nearby waterways, Hydroacoustic Technology Incorporated (HTI) acoustic receivers (consisting of an acoustic receiver, datalogger and hydrophone assembly) and acoustic tags were used. Biotelemetry is an effective method for documenting the spatial and temporal distribution of fish (Dux et al 2011), and can provide information on movement and residency. Conducting studies utilizing long-lived tags should allow for a better understanding of any site fidelity demonstrated via return of individual fish to the Forebay.

2.3.2 Methods

Beginning in late 2012, placement for the acoustic receiver array was determined through a series of reconnaissance level site visits to assess accessibility and suitability for placement. Following the site reconnaissance, a draft placement map was compiled (Figure 9), and each site was assigned a designation based upon location. Due to the amount of lead time anticipated for temporary entry permit (TEP) acquisition for units planned on properties not owned by DWR, the array was designed to be deployed in phases.

Figure 9: Planned Receiver Array for CCFPS

The initial phase consists of nine units within and immediately adjacent to the Forebay. These nine units include the IC1, IC2, IC3, RGD1, RGU1, WC1, WC2, WC3 and ORS1 (Figure 10). These locations were selected to provide data regarding directionality of movement relative to the radial gates as well as for determining immigration and emigration into and out of the Forebay, and movement toward and away from the SDFPF.

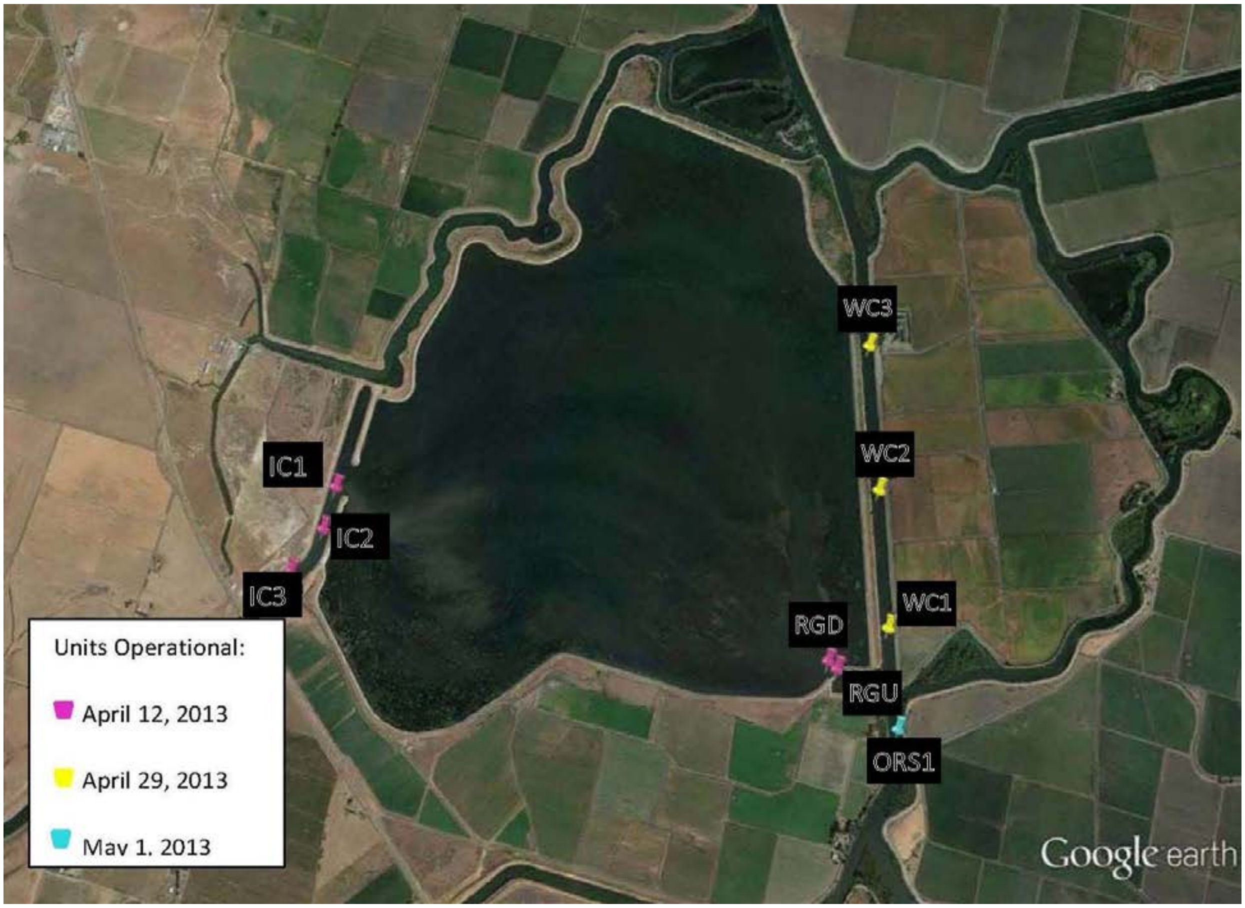

Figure 10: Receiver Array Deployed in 2013

Each of these sites will initially employ an HTI Model 295x dataloggers, and be powered by a 12-volt (two six-volt sealed deep cycle batteries wired in series) connected to a solar panel to ensure continued operation (Figure 11). A beacon tag is deployed near each hydrophone to document ongoing functionality of the unit. Once each site is operational and collecting data, daily maintenance visits will be initiated with data downloaded once per week, when possible.

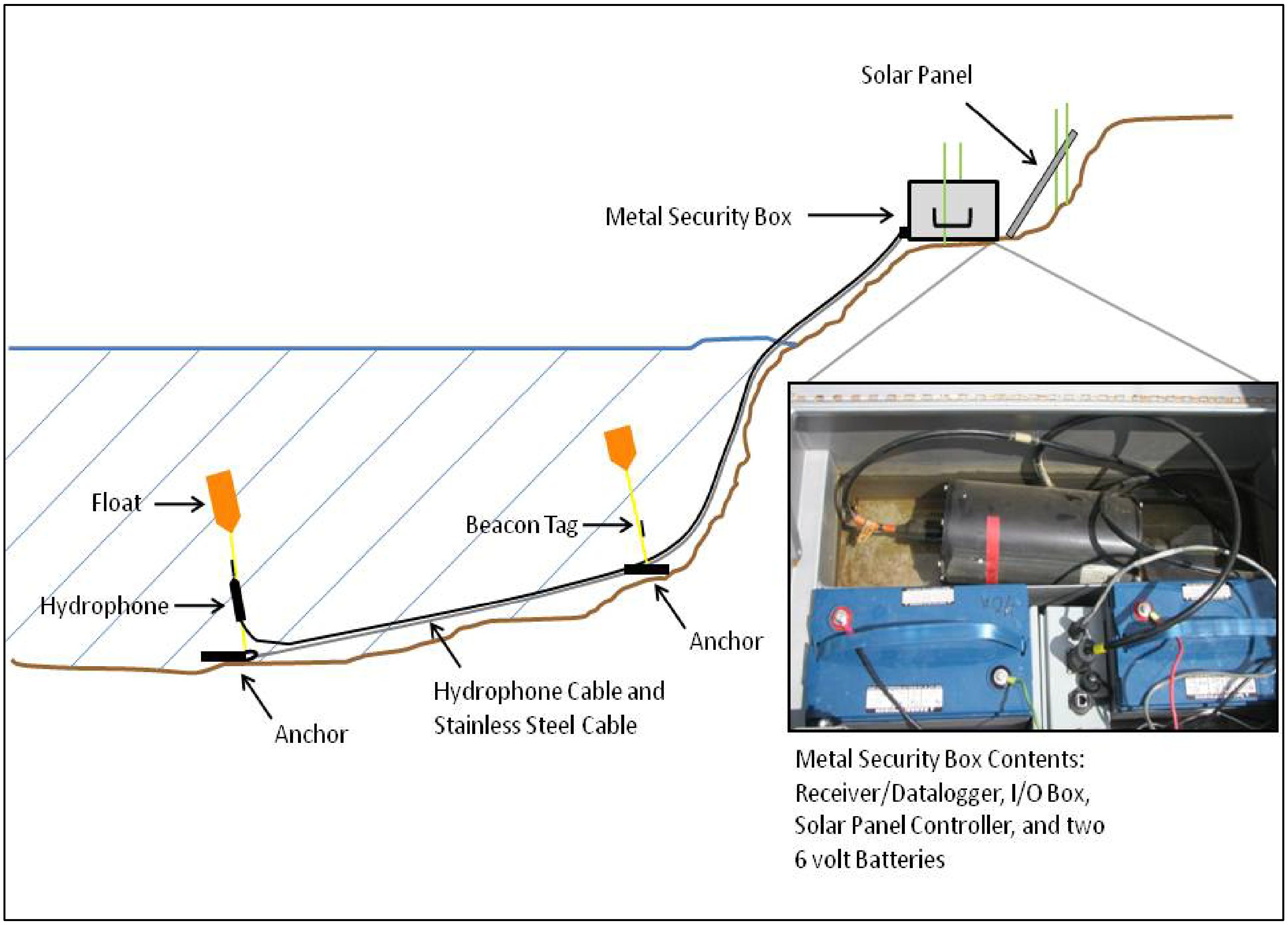

Figure 11: Model 295x Receiver Site Schematic

All nine of the initial units will be upgraded to model 395 micro dataloggers as they become available, which adds the ability to remotely check and download each unit, gps link the entire array, and reduce maintenance needs through lower power requirements. The second phase of the array will be installed after the 395 model dataloggers have become available, bringing the total number of dataloggers to 16 (Figure 9).

Tag codes for each year of the study are predetermined by HTI, with different sub codes for Striped Bass less than 1.5 pounds (lbs; 0.68 kg), Striped Bass over 1.5 lbs (0.68 kg), and non-Striped Bass (catfish and black bass species). At the beginning of each month, up to seven HTI 795LG/ Biomark HPT9, 17 HTI 795LY/ Biomark HPT9, and seven HTI 795LZ/ Biomark HPT9 acoustic/PIT combination tags were programmed with codes from the lists provided by HTI. Following tag programming, each tag is checked for functionality via a tag "sniffer" or a hydrophone attached to an HTI 395 mobile data logger. Up to 31 predatory fish captured during the sampling efforts larger than 0.5 lbs (0.23 kg) are tagged with HTI/ Biomark combination acoustic/PIT tags as well as a secondary external Floy tag in accordance with Table 2 below.

Table 2: Maximum Number of Predatory Fish to be Acoustically Tagged Each Month

HTI Tag Type	Fish Size Range lbs(kg)	Striped Bass	Black Bass	Catfish	Total Tags per Month
795 LG	>0.5 (0.23) to <1.5 (0.68)	7	0	0	7
795 LY	>1.5 (0.68) to <3.0 (1.36) (Striped Bass) >1.5 (0.68) (non-Striped Bass)	7	5	5	17
795 LZ	>3.0 (1.36)	7	0	0	7
Total Fish per Month		21	5	5	31

Internal tagging of captured predators follows procedures based on methods described in Wingate and Secor 2007, and incorporate the use of new anesthesia methods as part of the INAD for Aqui-S 20E (USFWS 2011). All captured predatory fish that are not acoustic tagged, are tagged with Biomark HPT9 PIT tags so that they can be identified in the event of recapture or salvage.

Each predatory fish captured is scanned using a Biomark 601 handheld reader prior to tagging, to ensure that no fish is double tagged. Once the fish is determined to be a new capture, general data is taken, including capture location, sampler, tagger, weight to the nearest 0 .01 lbs, fork length to the nearest 0 .5 cm, type of tag applied, time to reach "surgical plane"[2]and recover (when applicable), tag numbers, and release time. Fish that meet the species and weight criteria for acoustic tagging are acoustically tagged, unless that category of tags has already been exhausted for the month.

Fish that are acoustically tagged are anesthetized in a bath of 35mg/L AQUI-S 20E until the fish reaches the surgical plane. The fish is then placed in the surgical sling, and an incision appropriate to the size of the tag is made in the abdomen. The acoustic tag is placed into the abdominal cavity and the incision is sutured shut using two to four sutures depending upon the length of the incision (Figure 13).

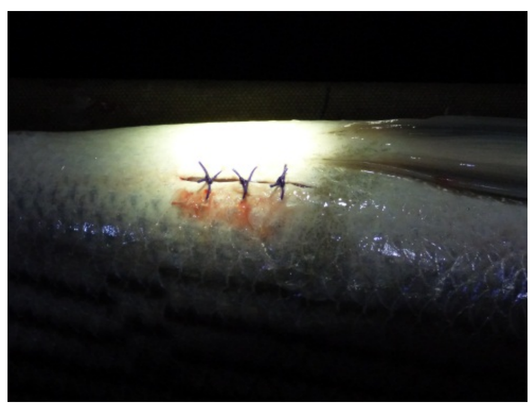

Figure 12: Acoustic Tagging of a Striped Bass

[2] Defined as the point at which the fish is still gilling but does not react to external stimuli.

Fish that are only PIT tagged are not anesthetized. All tagged fish are also fitted with secondary external Floy tags (model FM-84 Laminated Internal Anchor Tags, or FD-68B T-Bar Anchor) (Figure 14). After the fish is tagged, scale samples are taken, and the fish is placed into a recovery net at the point of capture, and monitored until swimming normally.
Once the fish is deemed fully recovered it is

released.

Figure 13: FM-84 Laminated Internal Anchor (left) and FD-68B T-Bar Anchor (right) Floy Tags

2.4 Genetics[3]

2.4.1 Background

While numerous studies have been conducted to estimate PSL and the influences of various factors such as predator catch-per-unit-effort (CPUE) or water export rate on survival, there is no direct evidence of piscivorous species consuming listed species in the Forebay. To address this, Cramer Fish Science (CFS)-Genidaqs (as part of the AECOM Team) has been tasked with identifying fish species in the digestive tracts of Striped Bass using genetic methods that target species-specific DNA sequences (King et al. 2008). Data are being gathered on other important listed species such as Delta Smelt in addition to Chinook salmon, steelhead, and Green Sturgeon. This analysis will provide direct observations of Striped Bass prey, which may include federally-listed fish species. The specific methodologies used follow quantitative polymerase chain reaction (qPCR) protocols (Baerwald et al. 2012; Brandl et al. in press). Genetic analyses will provide the specific identity of fish species consumed by Striped Bass and help with understanding the contribution of predation to pre-screen loss.

2.4.2 Methods

Sampling at the Forebay is conducted annually, from December through May, to overlap with presence of listed fish species. The target sample size is 480 Striped Bass during the pilot effort and 1,000 Striped Bass during subsequent years, sampled evenly over the six month sampling period. All Striped Bass analyzed are captured using hook-and-line with artificial lures or gill nets, as described in the predator sampling section above. Hooked fish are netted with a clean-handled net and hooks removed using a clean multi-tool or by nitrile-gloved hand. Captured Striped Bass are euthanized via blunt force and placed on a clean measuring board where fork length is measured. Based on fish length, the appropriate amount of ethanol is inserted into the stomach through the mouth using a motorized pipet filler/dispenser and a sterilized disposable pipet.

Following digestive tract stabilization using ethanol, the Striped Bass is placed into a pre-labeled bag and weight measured using a digital hanging scale that was tared for the weight of the bag. Each bagged Striped Bass is then placed in a cooler and packed in ice.

After processing each Striped Bass, all equipment used is washed in a 10 percent bleach solution. A YSI Pro-DO instrument is used to measure dissolved oxygen and water temperature of each polygon sampled. A water sample also is taken from each polygon (using the same map as the predator sampling effort) sampled on each sample day. The ancillary environmental data associated with captured Striped Bass will be used to inform predation effects modeling.

Quality control of field data is performed at the end of each sample day before leaving the facility. All data are recorded on a Microsoft Surface RT tablet and transferred to a flash drive for uploading into a CFS - Genidaqs database and to the DWR data portal. After the field crew returns to the CFS - Genidaqs laboratory, the fish are transferred from the cooler to a freezer where they remain until further processing is initiated.

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[3] Excerpt from “Draft Genidaqs qPCR Diet Analysis Report Year 1 Pilot Study May 2013 – June 2014” (Blankenship and Brodsky 2015).

Collected fish transported to the CFS-Genidaqs lab facilities are dissected and the stomach contents isolated following strict protocols. Each stomach content sample is incubated overnight at 56°C in a proteinase K-buffered ATL solution. Following overnight digestion, DNA is extracted from each solution using QIAGEN DNeasy Blood and Tissue Kit affinity columns following manufacturer's protocols.

Extracted DNA from each diet sample is used as a template for each laboratory reaction, with species-specific molecular assays for twelve species (including six special-status species) applied to each sample (Table 3). The molecular assays used for this study were developed previously (Baerwald et al. 2012; Brandl et al. in press). The assays took the form of a sequence-specific oligonucleotide hybridization (i.e., 5′ exonuclease TaqMan™) interrogated using qPCR. This procedure uses conventional forward and reverse polymerase chain reaction (PCR) primers to amplify a specific region of DNA, but incorporates a fluorescently-labeled probe that hybridizes (i.e., targets) to the conserved sequence diagnostic for each species. For each template, qPCR is performed using all assays simultaneously on a 192.24 Gene Expression Integrated Fluidic Circuit and BioMark System following manufacturer's protocols[4]. Fluorescent output is analyzed using the Fluidigm Real-Time PCR analysis v4.0.1 software.

Table 3: Prey Species for DNA Testing

State and Federal Special-Status Species	Other Species
Chinook Salmon	Largemouth Bass
Green Sturgeon	Sacramento Pikeminnow
Steelhead	Striped Bass
Delta Smelt	White Sturgeon
Longfin Smelt*	Threadfin Shad
Sacramento Splittail*	Inland (Mississippi) Silverside

* Protected under California Endangered Species Act only

An electronic data form was developed to minimize process error, with field data verification prior to inclusion into the database. Staff is well trained and follow sample management protocols so that tissue samples and meta data are linked accurately. Genetic analyses are communicated using standard results format. Laboratory controls are added for each step of tissue processing and analysis to provide quality assurance, including the following:

Negative Controls: Negative samples consist of H_20 "blanks" that are processed in parallel with regular samples. The following negative controls guard against false positives or issues with contamination.

1. Dissection control (DC)
2. Extraction control (EC).
3. PCR negative control or No Template Control (NTC)

All negative controls are analyzed for the presence of predator and prey DNA in parallel.

[4] Fluidigm is the manufacturer of the 192.24 Gene Expression Integrated Fluidic Circuit and BioMark System.

Positive Controls: Striped Bass DNA is assayed for on each integrated fluidic circuit (i.e., chip) as a positive control, as Striped Bass is the predator sampled, and as such all samples should test positive for Striped Bass. The Striped Bass positive control is used to ensure that DNA extraction step was successful, and to verify the DNA amplification (i.e., PCR) was successful on the Fluidigm BioMark system. It is not possible to genetically differentiate from the predator itself and any same species prey it has consumed, so it is not possible to identify the individual Striped Bass who have consumed other Striped Bass.

Process Controls: An internal fluorescent standard is included in each of the 4,608 chambers on each 24.192 integrated fluidic circuit used so that the chip pressurizes properly and the reaction mixture loads properly in each chamber. In addition, each tissue sample is analyzed in quadruplicate to verify fluorescent output.

2.5 Creel Surveys

2.5.1 Background

Often, one of the greatest resources for information regarding behavior and population dynamics of popular sport fish comes from the recreational anglers spending countless hours in their pursuit. The ability to accurately determine a relative exploitation rate, pre- and post- construction, for the predatory game fishes within the Forebay will be critical to future management decisions regarding predator control at the Forebay, and will be accomplished in part via creel surveys to determine Catch Per Unit Effort (CPUE).

2.5.2 Methods

Roaming creel surveys are conducted three days a week, two week days and one weekend day, either in the morning (0900 until noon) or the afternoon (noon until 1600). While anglers can access the Forebay throughout the evening hours as well, no surveys are conducted at night, due to safety concerns. Survey days and time periods are randomly selected by rolling dice, with each side of the die associated with a day or time (Table 3).

Table 4: Creel Survey Selection

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Weekend Day	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday
Time	Morning	Morning	Morning	Afternoon	Afternoon	Afternoon

The roaming creel surveys begin with a total angler count from the tip of the Fisherman's Point peninsula to the Radial Gates along the public access pathway (Figure 15). Once the anglers are counted, the crew works back towards the start point and each angler is asked a series of questions including target fish species, species and number of fish caught, species and number of fish released, fish length, fish weight, duration of fishing effort, and frequency of fishing at the Forebay. Weather conditions, including wind speed and temperature, are measured using a Kestrel 3000 wind meter. Angler location is determined based upon a location map, which splits the Forebay into distinct polygons (Figure 16). Scale samples are collected from Striped Bass and black bass, when possible, and will be examined to determine the age of the fish harvested by anglers. Following the 2013 pilot effort, the creel survey map was altered to be the same as the predator sampling map to make the two efforts more comparable.

Figure 14: Creel Survey Route

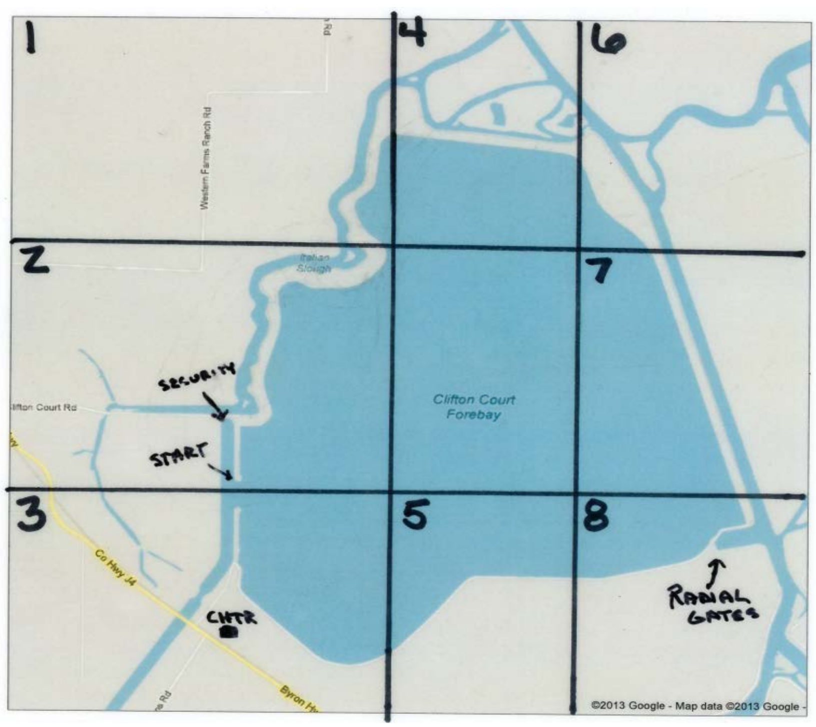

Figure 15: 2013 Creel Map

2.6 Avian Surveys

2.6.1 Background

Predation by piscivorous birds upon juvenile salmonids has been well documented in several systems including the Columbia River (Collis et al 2001, 2002), and San Pablo Bay (Evans et al 2011). Salmonids have been identified as one of the prey items consumed by double-crested cormorants, various gull species, and Caspian terns via the recovery and identification of coded wire tags (CWT) and PIT tags (Collis et al 2001, Evans et al 2011), direct observation (Ruggerone 1986), and stomach content analysis of birds in several studies (Modde et al 1996, Collis et al 2002). Double-crested cormorants and Western grebes (*Aechmophorus occidentalis*) have been shown to consume as much as 31% and 8% respectively, of planted fingerling Rainbow Trout (*Oncorhynchus mykis*s) in Minersville Reservoir, Utah (Modde et al 1996). Determining the extent of avian piscivory at the Forebay is important in determining the best approaches to improving pre-screen survival of salmonids.

Avian predation upon juvenile fishes within the Forebay has been observed (Clark et al 2009), but the extent of the impact on overall survival and PSL is unknown. To further evaluate the impact of avian predation on Chinook Salmon and steelhead in the Forebay, studies are being conducted to quantify the population of avian piscivores and identify behavior patterns as well as seasonality of population trends. A wide variety of piscivorous birds has been observed foraging at the Forebay (eBIRD 2011, Clark et al 2009). Species observed onsite include double-crested cormorants (*Phalacrocorax auritus*), herring gull (*Larus argentatus*), California gull (*Larus californicus*), mew gull (*Larus canus*), ring-billed gull (*Larus delawarensis*), American white pelican (*Pelecanus erythrorhynchos*), Forster's tern (*Sterna forsteri*), Western grebe, Clark's Grebe (*Aechmophorus clarkii*), Western gull (*Larus occidentalis*), and Thayer's gull (*Larus thayeri*), amongst others. Populations and species composition varies by season, with some species being observed year-round, and others only present during a portion of the year.

Studies of bird predation at the Forebay have been designed to ensure that no take of listed species and no harm to species protected by the Migratory Bird Treaty Act (MBTA) occurs.

2.6.2 Methods

Avian point count surveys were designed following methods similar to those used by the Point Reyes Bird Observatory (PRBO)[5]. The Forebay was scouted for suitable survey vantage points in January 2013. Two locations at the Forebay were identified as target locations for modified point count surveys based upon accessibility and the proximity to predatory fish "hot spots", the vicinity of the radial gates and the vicinity of the trash rack (Figure 17). The survey areas were delineated to include all of the aquatic habitat and adjacent levee slope for a distance of 500 meters from the vantage point. Because of the large size of the area to be covered at the radial gates, that location was split into two separate survey areas.

Surveys are conducted three days per week, including two week days and one weekend day, during one of three randomly selected time periods, morning (from just before sunrise until 0900), midday (1000 until 1200) or afternoon (from 1300 until 1600).

[5] As of June 5, 2013 PRBO has changed its name to Point Blue Conservation Science.

Survey days and time periods are randomly selected by rolling dice, with each side of the die associated with a day or time (Table 5).

Table 5: Randomized Survey Selection Process

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Weekend Day	Saturday	Sunday	Saturday	Sunday	Saturday	Sunday
Time	Morning	Midday	Afternoon	Morning	Midday	Afternoon

Each survey is conducted by a minimum of two staff for 20 minutes per survey location, using a Kowa TSN-821M spotting scope or Nikon 8x42 Monarch binoculars from predetermined vantage points (Figure 17 and 18) to ensure adequate coverage. A list of target piscivorous species known to occur in the vicinity of the Forebay was compiled using sources including bird observation lists available on eBIRD[6], anecdotal staff observation, and species range information from the Sibley Field Guide to Birds of Western North America (2003). All staff are trained to identify target species, and provided with Sibley guides for additional species identification.

Figure 16: Avian Survey Trash Rack Location

[6] eBIRD is an online database of bird observations, abundance, and spatial distribution that was made available on the internet in 2002 by the Cornell Lab of Ornithology and National Audubon Society.

Figure 17: Avian Survey Radial Gates Locations

Piscivorous birds observed within the survey area during the 20 minute survey are counted and recorded to genus (as with gulls), or when possible, species. All birds observed are classified as feeding, non-feeding, or flying over. Environmental data including wind, temperature, and humidity are measured using a Kestrel 3000 wind meter, and cloud cover, and precipitation determined by visual observation. Beginning and ending time for each survey as well as presence or absence of any potential disturbance factor such as anglers or any work activities in the vicinity is also recorded.

2.7 Bioenergetics Modelling

2.7.1 Background

A bioenergetics model is a mass-based equation that can analyze how food consumed by an animal is either used for growth or metabolic processes, or excreted as waste (Ney 1993, Brandt and Hartman 1993). This can be a powerful tool in that it can allow for an understanding of the quantitative impacts of predation upon a population of prey given existing information on metabolic needs, digestion rates and predation habits of a predator species. This approach has been used to better understand the predator-prey dynamics between fish species such as Striped Bass and Threadfin Shad (*Dorosoma petenense*) in Lake Powell (Vatland et al 2008), and Lake Trout (*Salvelinus namaycush*) and Rainbow Smelt (*Osmerus mordax*) in Lake Champlain (LaBar 1993), as well as predation by piscivorous birds such as double-crested cormorants (Seefelt and Gillingham 2008) in northern Lake Michigan.

The relative impact of predation upon salmonids by fish and birds in the Forebay is an important factor in addressing pre-screen loss. These impacts can be evaluated in a quantitative manner using bioenergetics modeling. The model for predatory fish will be developed using data input from the predator sampling, predator genetics and creel elements of the project. Specifics will be outlined in the Clifton Court Forebay Predation Study Annual Progress Reports as development progresses.

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State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predation Study: 2015 Annual Progress Report

September 2017

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Abbreviations

BDO	Bay-Delta Office
BiOP	Biological Opinion
CALFED	CALFED Bay-Delta Science Program
CCFPS	Clifton Court Forebay Predator Study
CPUE	Catch per Unit Effort
CVP	Central Valley Project (Federal)
Delta	Sacramento-San Joaquin Delta
DFD	Delta Field Division
DFW	California Department of Fish and Wildlife
DWR	California Department of Water Resources
EROF	Equipment Request Order Form
ESA	Endangered Species Act
Forebay	Clifton Court Forebay
HTI	Hydroacoustic Technology Incorporated
IEP	Interagency Ecological Program
INAD	Investigational New Animal Drug
MOCC	Motorboat Operator Certification Course
NMFS	National Marine Fisheries Service
OP-2	Operations Procedure 2 – Lock-out/Tag-out
PCR	Polymerase Chain Reaction
PIT	Passive Integrated Transponder
RPA	Reasonable and Prudent Alternative
SAV	Sub-aquatic Vegetation
SCP	DFW Scientific Collecting Permit
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project (California State)
USFWS	U.S. Fish and Wildlife Service

Executive Summary

This report details the implementation, issues, and results of the third year of the Clifton Court Forebay Predation Study (CCFPS). Specific study elements undertaken in 2015 include predatory fish sampling, acoustic telemetry, genetics, avian studies, creel surveys, and a feasibility study for the bioenergetics modeling effort. Additional detail regarding the regulatory history and overall study design and methodology is available in the report entitled *Clifton Court Forebay Predation Study* (Wunderlich 2015).

Predator sampling was conducted on 99 days in 2015. The largest numbers of predatory fish were captured during months that had concurrent sampling for the genetics and tagging efforts, with the peak months being January, February and March at 317, 463, and 330 respectively. Individuals in the largest size class of Striped Bass (over 3.0 lbs./1.36 kg) were captured in all sampling months except May, July and August, peaking in February. Individuals in the next smaller size class of Striped Bass, between 1.51 lbs. (0.68 kg) and 2.99 lbs. (1.36 kg), were caught in every month except May, peaking in January and February. Individuals in the size class Striped Bass, between 0.5 lbs. (0.23 kg) and 1.5 lbs. (0.68 kg) were caught in every month sampled, with peaks from January through March and again in September and October. Striped Bass under 0.5 lbs. (0.23 kg) were captured in every month except January, April and December, with a peak in March.

Throughout the year the 0.5 lbs. (0.23 kg) to 1.5 lbs. (0.68 kg) size class dominated all of the sampling months except January, and represented 62% of the total Striped Bass catch for the year. Largemouth Bass were caught in all months except July and August, peaking in November. Catfish were only caught in April, May, June, and September, with a peak in April. One Chinook Salmon was caught and released unharmed in November and one steelhead was caught and released unharmed in December.

Catch per Unit Effort (CPUE) (excluding fish caught by the genetics crew) was found to be highest for Striped Bass in March, at 1.09 fish per hour, followed by February and September at 0.84 and 0.80 respectively. For Largemouth Bass, CPUE peaked in November, at 0.25 fish per hour, and for catfish, CPUE peaked in April at 0.30 fish per hour.

Twenty-seven previously tagged predatory fish were recaptured, ten by anglers outside of the Forebay, eight by anglers interviewed for creel surveys, seven during sampling efforts, one at Curtis Landing release site, and one during a separate study within the Forebay. This represents less than one percent of the available tagged fish as of the end of 2015.

A total of 185 fish were acoustically tagged in 2015. Of those fish, 19 Striped Bass (10%) were never detected by any of the receivers in the array. Of the remaining 166 acoustically tagged fish, 56 fish (34% of the detected fish) were detected on receivers outside as well as inside of the Forebay, indicating that they emigrated from the Forebay. Of the remaining 110 fish that were not observed outside of the Forebay, 16 (15%) were only detected in the intake channel, 48 (44%) were only detected at the radial gates, and 46 (42%) were detected moving between the intake channel to the radial gates. Twenty-six of the 56 fish that emigrated (46%), returned to the Forebay at a later date in 2015. The majority of the fish tagged in 2015 that emigrated were Striped Bass, at 54 with the remaining two being Channel Catfish.

When fish tagged during 2013 and 2014 that remained detectable into 2015 were included, the total number of fish detected leaving the Forebay rose from 56 to 124, which is 25% of the detectable tagged fish to date. Of those 124 fish, 64 (52% of emigrating fish) were subsequently detected back in the Forebay. Of the 72 Striped Bass over 3.0 lbs. (1.36 kg) tagged between 2013 and 2015 that remained detectable, 30 (42%) were subsequently detected outside of the Forebay, whereas only 52 of the 177 fish weighing 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) and 28 of the 153 fish weighing less than 1.5 lbs. (0.68 kg) were detected outside of the Forebay, representing 29% and 18% of those size classes respectively.

A total of 1,141 Striped Bass were collected and analyzed during the 2014-2015 genetics effort. Of those Striped Bass, 269 were collected in December 2014, 286 Striped Bass in January 2015, 350 in February 2015, 217 in March 2015, and 19 in April 2015. The average fork length (length from the tip of the snout to the edge of the fork at the centerline of the fish) of Striped Bass collected was 38.6 cm and the average weight was 1.8 lbs. (0.82 kg), with the largest numbers of Striped Bass captured in Area 1 (adjacent to the Clifton Court Forebay radial gates), representing 90% of the total catch. Nine of the possible 11 prey species that could be identified as present were found during the sample season. The two species not detected were Green Sturgeon (*Acipenser medirostris*) and Longfin Smelt (*Spirinchus thaleichthys*). Positive detections of prey species were found in 270 of the samples collected, representing 23.6 % of the total catch. The most frequently detected prey species in December were Largemouth Bass and Threadfin Shad **(***Dorosoma petenense*), making up 26% and 42% of the positive detections respectively. Steelhead (*Onchorhynchus mykiss*), Delta Smelt **(***Hypomesus transpacificus*) and Chinook Salmon (*Oncorhynchus tshawytscha*), were detected in samples from Area 1 and 2 (within the intake channel to the John E. Skinner Delta Fish Protective Facility; SDFPF). Chinook Salmon were the most frequently detected special-status species, with 18 detections, followed by 17 Delta Smelt detections and seven steelhead detections.

A total of 108 roving creel surveys were conducted between January 5, 2015 and December 29, 2015, during which 1,247 anglers were observed fishing at the Clifton Court Forebay in 2015. Anglers that were interviewed during creel surveys fished a total of 3,384 hours over the survey period, with the greatest number of hours spent in Area 2. Anglers caught a wide variety of fish including carp, shad, sunfishes, bass and catfish. Anglers caught 1,290 Striped Bass during the survey period, which made up 79% of the total catch of 1,635 fish. The second most commonly caught fish was Largemouth Bass at 184, followed by catfish at 67 and Bluegill at 62, representing 11%, 4%, and 4% of the total catch, respectively. One adult Chinook salmon was caught in November. The highest CPUE was at Area 5 (the northwest section of the Clifton Court Forebay) during the month of November, at 5.56. Throughout the year, CPUE was found to range from 0.20 in January to 1.61 in March.

A total of 320 avian surveys were conducted at the three survey locations between January 5, 2015 and December 29, 2015. Bird sightings totaled 10,269 piscivorous (fish eating) birds, with the highest number observed in February and September, at 2,256 and 1,148 respectively. Feeding behavior was observed throughout the year. Feeding rates across all sites were relatively high in January, April, July and November, peaking in January at 38%. September was the month with the lowest rates of feeding at 5%. Feeding peaked at the SDFPF trash racks in October, whereas at the Clifton Court Forebay radial gates, it peaked in July and August.

Using data from the 2013-2015 CCFPS data collection effort, a Bioenergetics Feasibility Study was undertaken in late 2015, by Dana Stroud and Joseph Simonis of Cramer Fish Sciences. The results of this study were compiled into a separate report entitled *DWR Clifton Court Forebay Predator Study 2014-2015: Bioenergetics Feasibility* (Appendix A). A summary of that report is included in Section 2.7 of this report. Preliminary findings of the modelling feasibility study indicate that smaller Striped Bass may consume more grams of prey versus body weight than larger Striped Bass. However, it is important to highlight key assumptions of the standard bioenergetics model that are violated by this system, including the assumption that the system is closed. Additionally, prey identified in the genetic samples are reflections of where the Striped Bass have been in the previous approximately 60 hours, as opposed to where they are when captured. Existing bioenergetics models, including this evaluation, do not account for this distinction, and therefore cannot allow us to distinguish between a listed species consumed in the Delta versus in CCF.

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1.0 Introduction

The Clifton Court Forebay Predation Study (CCFPS) is a multi-year effort comprised of several study elements that have been designed to gather as much information as possible to understand predation upon juvenile salmonids in the Clifton Court Forebay (Forebay). This report covers the third year of the CCFPS, conducted in 2015. This study was designed to further the understanding of behavior and movement of predatory fishes, salmonids, and piscivorous birds in the Forebay. The CCFPS includes the following elements: predatory fish sampling, biotelemetry, genetics, creel surveys, avian studies and bioenergetics. CCFPS design and methodology is further discussed in the Clifton Court Forebay Predation Study Report (2015).

The CCFPS will provide the opportunity to evaluate the effects of any Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) of the Biological Opinion (BiOp) and Conference Opinion on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) (National Marine Fisheries Service (NMFS) 2009) undertaken to reduce predation of Endangered Species Act (ESA) protected salmon and steelhead within the Forebay.

2.0 CCFPS Study Elements

2.1 Issues

Predatory fish sampling was not conducted during the annual John E. Skinner Delta Fish Protective Facility (SDFPF) maintenance shutdown, aquatic weed spraying, and Wednesdays during duck hunting season, from January 1 to 25 and October 24 to December 31. This amounted to approximately four weeks with no sampling. Additionally, avian and creel surveys were not conducted on Wednesdays and weekends during the duck hunting season.

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay (Forebay) continued to be followed according to the final procedural guide provided by Delta Field Division (DFD) to Bay Delta Office (BDO). The 2015 Equipment Request Order Forms (EROF) for predator sampling, creel, avian, mobile monitoring and receiver maintenance were filed with DFD on December 1, 2014. Approval for all 2015 field work was confirmed on December 22, 2014.

2.2 Predatory Fish Sampling

2.2.1 *Methods*

Direct Sampling

Predators such as Striped Bass (*Morone saxatilis*), Largemouth Bass (*Micropterus salmoides*), White Catfish (*Ameiurus catus*), and Channel Catfish (*Ictalurus punctatus*), were collected by either gill netting or hook and line sampling in the Forebay. Predatory fish were sampled twice weekly throughout the year, except as noted above, to supply predatory fish for various study elements. Predatory fish capable of consuming juvenile salmonids were either sacrificed and preserved for use in the genetic analysis study element, or tagged and released at the location of capture as part of the mark-recapture and biotelemetry study element. Temperature, dissolved oxygen, and location(s) of capture were noted for each sampling effort. Scale samples were collected from Striped Bass and Largemouth Bass, to be examined at a future date, to determine the age of the predatory fish sampled.

Collection of predators occurred during the day, between the hours of 0600 and 1500. All incidental species caught alive were measured, recorded, and immediately released at the location of capture. Field staff were trained to quickly identify listed species and release live fish to minimize handling stress. Take information was detailed in a supplemental report as part of the reporting requirements of the California Department of Fish and Wildlife (DFW) Scientific Collecting Permits (SCP; SCP #'s 7744 and 10286).

The Forebay was split into sampling sections, following the same map as Gingras and McGee (1997; Figure 1). Sampling was conducted from a boat, when possible, to allow for coverage of a greater portion of the Forebay. On sampling days when the boat was not available for use, sampling was conducted from the shoreline, primarily along the intake canal (Area 2) or adjacent to the radial gates (Area 1). Hook and line sampling was conducted using standard rod and reel fishing equipment in accordance with standard DFW regulations for hook and line fishing. Hook and line sampling employed a wide variety of bait and lure selections to maximize catch.

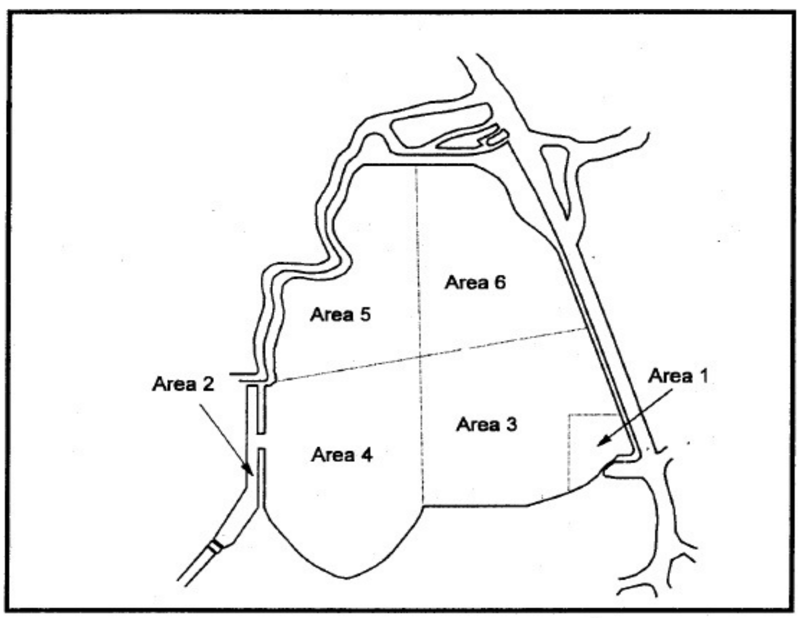


Figure 1: Sampling Map (Gingras and McGee 1997)

Hook and line sampling was conducted on 99 sampling days, at various times during the day from January 8, 2015 until December 18, 2015. Gill netting was conducted on two sampling days within the Forebay, April 20 and November 19, 2015, using a monofilament gill net, measuring 30 meters (m) or less, with variable mesh sizes ranging from five centimeters (cm) to 15.25 cm.

Recapture of Marked Fish (Non-Acoustic)

Tagged fish could potentially be recaptured via multiple methods including direct catch during predator sampling, catch by angler reported during creel survey, catch by angler reported via telephone, or detection of PIT tag by other studies (DWR as well as other Federal and State Agency). When recaptures occurred or were reported by an outside source, efforts were made to collect as much data for each fish as possible, including length, weight, tag numbers, location of capture, and ultimate fate of the fish. Often recaptures by anglers resulted in the fish being kept and likely consumed, whereas fish captured by researchers were generally returned to the waterways.

2.2.2 *Issues*

Predator sampling was conducted pursuant to the requirements of the DFW as outlined in SCP #7744 (an individual permit issued to Veronica Wunderlich) and SCP # 10286, an entity permit which limited sampling efforts to days when approved staff were available.

Predator sampling efforts were additionally constrained by availability of boats as well as qualified and approved boat operators. The DWR Bay-Delta Office (BDO) has a clearly defined boat operator policy that requires that each operator complete a multi-day field based Motorboat Operator Certification Course (MOCC) and demonstrate necessary skills on the BDO vessel in the presence of designated approved BDO operators. As many staff members on the CCFPS were not yet approved BDO operators, all predator sampling efforts needed to be scheduled around the availability of qualified boat operators, as well as Operations Procedure 2 – Lock-out/Tag-out (OP-2) certified staff and the SCP holder. This required the careful coordination of multiple schedules across multiple ongoing projects.

In addition to the availability of boat operators, the availability of boats that could negotiate the variable conditions encountered in the Forebay proved to be a challenge. During a portion of the year, the Forebay becomes inundated with thick, and in some cases unnavigable, patches of submerged aquatic vegetation (SAV). With heavy infestations of SAV, it was not possible to operate the jet drive boat. (One of the boats used for the project is a jet drive boat.) A second DWR boat was acquired in mid-2015 allowing for more flexibility in the scheduling of boat based activities. A contractor boat and operator were also secured for use when DWR boats were unavailable, requiring additional coordination.

2.2.3 *Data Analysis*

Data sheets were scanned and data was entered into a database. Total catch, catch by species, and catch by size for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(q = catchability (fish caught per hours of sampling), C = catch, f = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE per month for all species combined was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and d = number of sampling days in the month)

Mean CPUE per month was then calculated for each species using the equation

$$q_{sp} = \frac{\sum\left(\frac{Csp}{f \times a}\right)_i}{d}$$

Seasonal CPUE was calculated for the four seasons defined as Winter (Jan 1 – March 19 and December 21-December 31), Spring (March 20 – June 20), Summer (June 21 – September 22), and Fall (September 23 – December 20), based upon the equinox/solstice dates for 2015.

Seasonal CPUE for all species combined was calculated by:

$$q_s = \frac{\sum q_i}{d}$$

(q_s = seasonal catchability, q_i = catchability for each day sampled in the season, and d = number of sampling days in the season)

2.2.4 *Results:*

Direct Sampling

A total of 99 sampling days were conducted from January 8, 2015 until December 18, 2015, resulting in the capture of 1,632 target predatory fish (Table 1, Figure 2) including 1,504 Striped Bass, 91 Largemouth Bass and 37 catfish. In addition, 14 non-target fish were captured. Of those target predatory fish, 892 Striped Bass were used in the 2014-2015 genetics portion of the study conducted from December of 2014 until May of 2015. The balance of the predatory fish captured were used for the acoustic and mark/recapture elements of the study. Non-target fish species captured included 11 American Shad (*Alosa sapidissima*) on April 20, one Sacramento Splittail **(***Pogonichthys macrolepidotus*) on May 28, one Chinook Salmon (*Onchorhynchus tshawytscha*) on November 2, and one steelhead (*Onchorhynchus mykiss*) on December 18, 2015. The Chinook Salmon and steelhead were released unharmed. During the 2015 sampling effort, four previously tagged Striped Bass and three previously tagged Largemouth Bass were recaptured. Thirty-two fish, including 26 Striped Bass, two catfish, and four Largemouth Bass, were released untagged, due to injury during capture or other issues. Gill net efforts resulted in the capture of 20 Striped Bass, 11 American Shad, 7 Channel Catfish, and one Largemouth Bass.

Table 1: 2015 Predatory Fish Captures by Month

Month	Striped Bass	Largemouth Bass	Catfish	Non-Target Species	Total
January	316	1	0	0	317
February	449	12	0	0	463
March	320	8	0	0	330
April	27	4	27	11	74
May	42	7	5	1	62
June	35	4	4	0	44
July	31	0	0	0	31
August	19	0	0	0	19
September	84	10	1	0	97
October	87	16	0	0	106
November	70	28	0	1	99
December	24	1	0	1	26
Total for Year	1504	91	37	14	1646

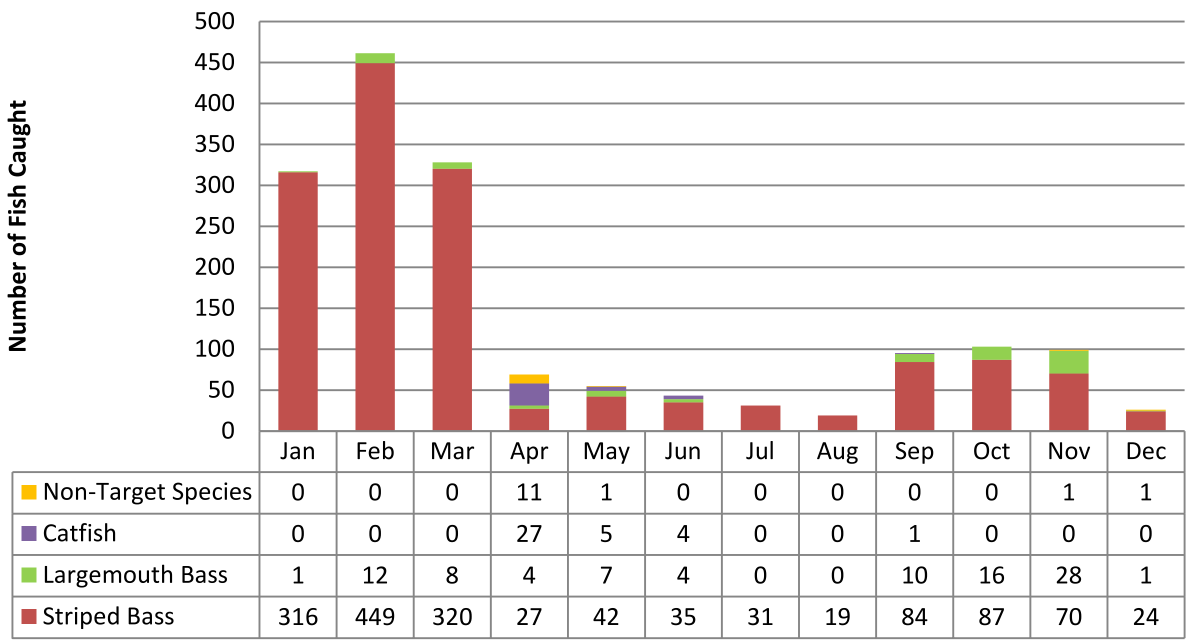


Figure 2: 2015 Predatory Fish Captures by Month

Fish captured during the 2015 effort ranged in length from 21 cm to 108 cm for Striped Bass, 21.5 cm to 58.5 cm for Largemouth Bass, 38 cm to 73 cm for Channel Catfish, and 24 cm to 51 cm for White Catfish (Figure 3).

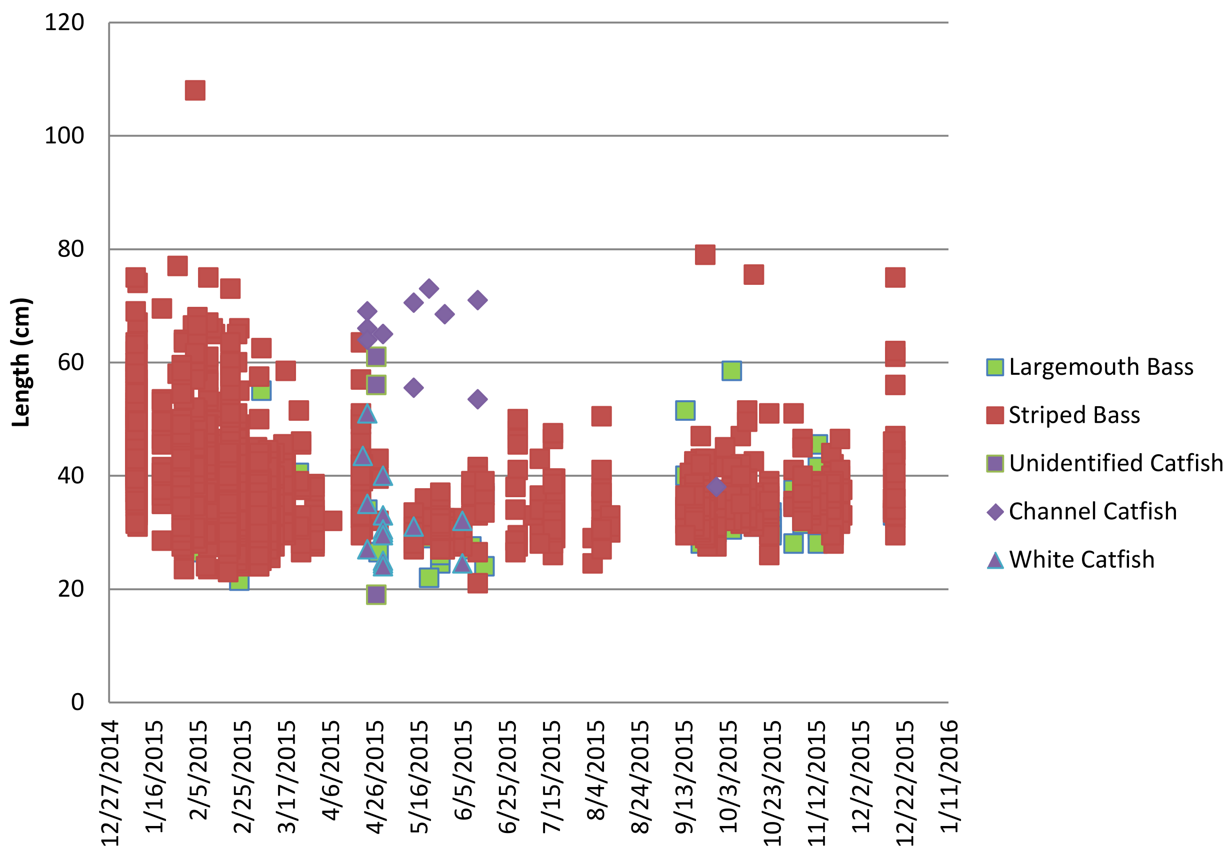


Figure 3: 2015 Predatory Fish Captures by Fork Length and Species

The majority of Striped Bass captured in 2015 at 62% of total catch, were in the 0.5 lb. (0.23 kg) to 1.5 lb. (0.68 kg) size class, with the highest catch of those fish occurring in February and March, at 231 and 260 fish respectively (Table 2, Figure 4, 5). Fish in the 1.5 lb. (0.68 kg) to 3 lb. (1.36 kg) size class represented 24% of total Striped Bass catch, with the highest number captured in February at 148 fish, and the second highest catch occurring in January, at 128 fish. Fish over 3 lbs. (1.36 kg) represented 11% of the total Striped Bass caught, with the bulk captured in January, at 84 fish, and the second highest catch occurring in February, at 56 fish.

Table 2: 2015 Striped Bass Captures by Size Class

Month	Fish <.5 lbs. (0.23 kg)	Fish >.5 lbs.(0.23 kg) and <1.5 lbs.(0.68 kg)	Fish >1.5 lbs. (0.68 kg) and <3.0 lbs. (1.36 kg)	Fish >3.0 lbs. (1.36 kg)
January	0	104	128	84
February	12	231	148	56
March	22	260	33	5
April	0	11	11	5
May	3	40	0	0
Jun	2	24	7	1
Jul	1	27	3	0
Aug	1	17	1	0
Sept	1	72	6	1
Oct	1	72	11	3
Nov	1	56	12	1
Dec	0	14	6	4
Total for Year	44	928	366	160

*Weight was not recorded for seven Striped Bass during the 2015 sampling season.

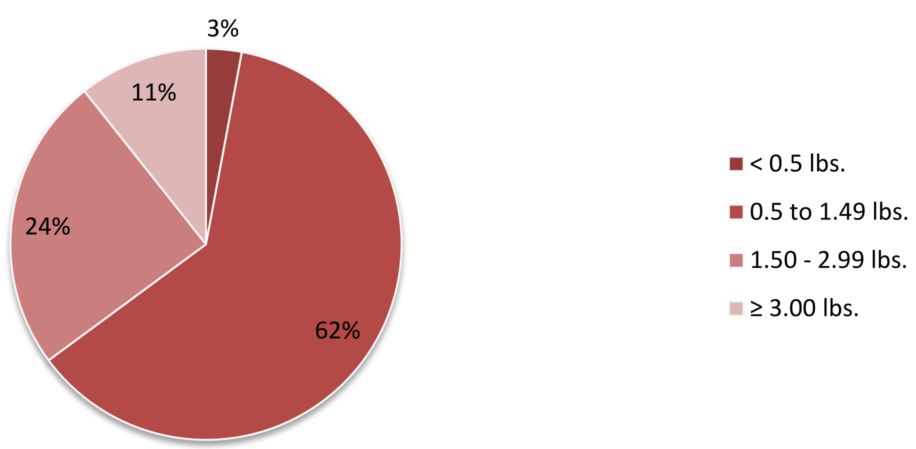
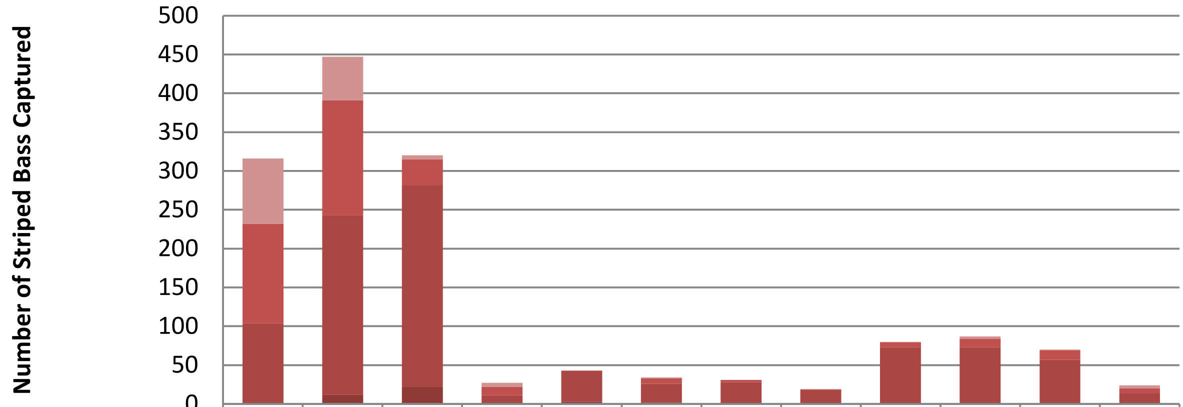


Figure 4: Percentage of 2015 Striped Bass Captures by Size Class



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Striped Bass	316	447	320	27	43	34	31	19	80	87	70	24
≥ 3.00 lbs.	84	56	5	5	0	1	0	0	1	3	1	4
1.50 - 2.99 lbs.	128	148	33	11	0	7	3	1	6	11	12	6
0.5 to 1.49 lbs.	104	231	260	11	40	24	27	17	72	72	56	14
< 0.5 lbs.	0	12	22	0	3	2	1	1	1	1	1	0

Figure 5: 2015 Striped Bass Captures by Size Class

Sampling was more frequent during the months of January through April, due to the additional crews fielded for the genetics effort. As a result of this increased sampling, catch was highest in the months that had both sampling crews working. The genetics crew catch made up for a large percentage of the total Striped Bass caught during these months (Table 3).

Table 3: 2015 Striped Bass Captures by Size Class Attributed to the Genetics Crew

Month	Fish <.5 lbs. (0.23 kg)		Fish >.5 lbs.(0.23 kg) and <1.5 lbs.(0.68 kg)		Fish >1.5 lbs. (0.68 kg) and <3.0 lbs. (1.36 kg)		Fish >3.0 lbs. (1.36 kg)		Total
January	0	0%	94	33%	120	42%	75	26%	289
February	12	3%	176	48%	131	36%	48	13%	367
March	19	9%	183	84%	12	6%	3	1%	217
April	0	0%	6	32%	8	42%	5	26%	19
Total for Year	31	3%	459	51%	271	30%	131	15%	892

Predatory fish were caught in all Areas 1, 2,4 and 5 during the winter sampling period (Figure 6), with the bulk being caught in Area 1, at 1,031 fish.

Figure 6: Winter 2015 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, 4, and 5 during the spring sampling period (Figure 7), with the bulk being caught in Area 1, at 109 fish.

Figure 7: Spring 2015 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, and 4 during the summer sampling period (Figure 8), with the bulk being caught in Area 1, at 36 fish.

Figure 8: Summer 2015 Catch by Location and Species

Predatory fish were caught in all Areas during the fall (Figure 9), with the bulk being caught in Area 1, at 178 fish.

Figure 9: Fall 2015 Catch by Location and Species

CPUE per sampling day was calculated using the equation: $q = \frac{C}{f \times a}$. Mean CPUE per month was then estimated by: $q_m = \frac{\sum q_i}{d}$ (Table 4).

Table 4: 2015 Catchability (CPUE) for all Species Combined Excluding Genetics Sampling Efforts

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean	0.74	0.95	1.15	0.42	0.43	0.4	0.29	0.42	0.9	0.9	0.92	0.8
1st Sample Day	1.17	0.69	1.19	0.13	0	0.37	0.07	0.17	0.44	0.56	0.75	0.54
2nd Sample Day	0.33	0.74	1.8	0.3	0.36	0.29	0	0.67	0.24	1.33	1.25	1.06
3rd Sample Day	0.71	0.53	1.67	0.51	0.32	0.65	0.52	0.42	1.41	0.83	0.58	
4th Sample Day		1.88	1.11	0.26	0.12	0.53	0		1.75	0.88	1.41	
5th Sample Day		1.13	1.33	0.23	0.86	0.36	0.65		1.29	0.6	0	
6th Sample Day		0.72	0.36	1.11	0.91	0.28	0.5		0.72	1.41	1.56	
7th Sample Day			0.79			0.35			0.44	0.69	1.17	
8th Sample Day			0.96								0.67	

While mean monthly CPUE peaked in March at 1.15 fish per hour, variability between daily efforts is too great to indicate a true trend (Figure 10).

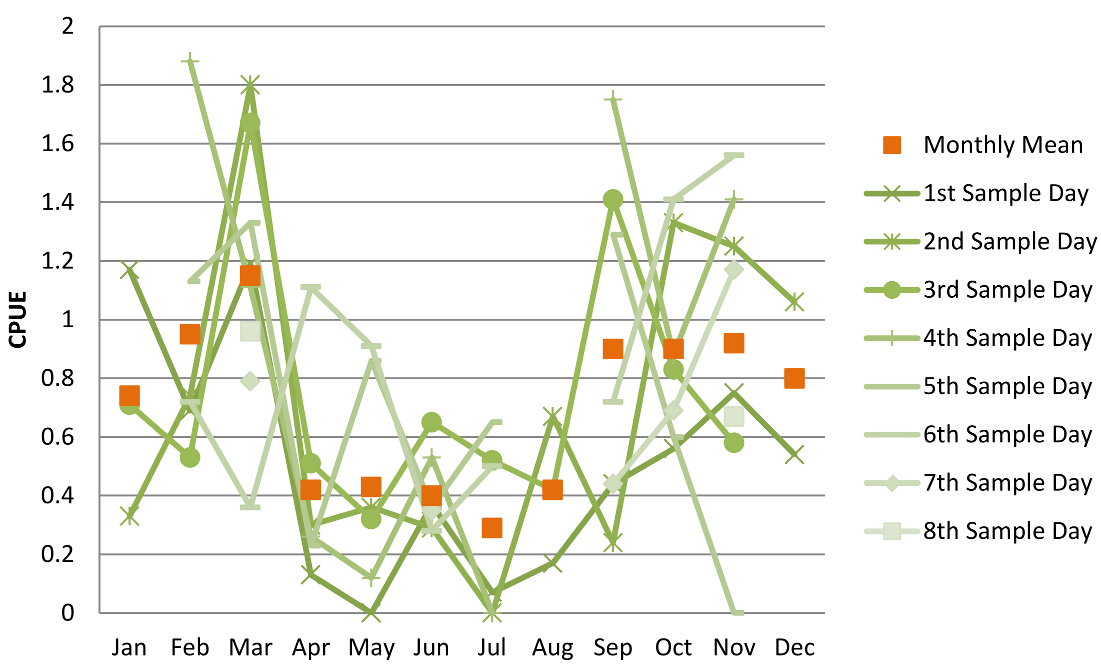


Figure 10: 2015 CPUE for all Species Combined Excluding Genetics Efforts

Seasonal CPUE was calculated for the four seasons (Table 5) defined as Winter (Jan 1 – March 19), Spring (March 20 – June 20), Summer (June 21 – September 21), and Fall (September 22 – December 20).

Table 5: 2015 Catchability (CPUE) for all Species by Season (Including Genetics Sampling Efforts)

Season	Sampling Days	Seasonal CPUE
Winter (Jan 1 - Mar 19)	26	2.10
Spring (Mar 20 - Jun 20)	24	0.90
Summer (Jun 21 - Sep 21)	15	0.50
Fall (Sep 22 - Dec 20)	20	0.89

Genetics collection methods allow for minimal processing during sampling efforts, resulting in more efficient fishing efforts and a significant increase in catch, compared to other predator sampling efforts. For this reason, CPUE was calculated separately for the genetics effort (Table 6) and the balance of the sampling effort.

CPUE per sampling day and mean monthly CPUE were calculated for Striped Bass caught by the genetics crew using the equations $q = \frac{C}{f \times a}$ and $q_m = \frac{\sum q_i}{d}$, respectively.

Table 6: 2015 Catchability (CPUE) for All Species (Genetics Sampling Efforts Only)*

	Jan	Feb	Mar
Monthly Mean	**4.31**	**2.01**	**3.05**
1st Sample Day	**4.90**	**1.17**	**7.94**
2nd Sample Day	**5.60**	**1.79**	**2.00**
3rd Sample Day	**3.10**	**0.6**	**0.91**
4th Sample Day	**3.64**	**2.8**	**1.35**
5th Sample Day		**1.15**	
6th Sample Day		**9.02**	
7th Sample Day		**3.30**	
8th Sample Day		**2.61**	

*Excludes fish captured via gillnet

Mean monthly CPUE, excluding the fish caught during genetics efforts, was then calculated for each species using the equation: $q_{sp} = \frac{\sum\left(\frac{Csp}{f \times a}\right)_i}{d}$

When the genetics effort was excluded, CPUE was found to be highest for Striped Bass in March at 1.09 fish per hour, followed by February and September at 0.84 and 0.80 respectively (Table 7). For

Largemouth Bass, CPUE peaked in November, at 0.25 fish per hour, and for catfish, CPUE peaked in April at 0.30 fish per hour.

Table 7: 2015 Monthly Catchability (CPUE) By Species (Excluding Sampling Genetics Efforts)

Monthly CPUE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Striped Bass	0.71	0.84	1.09	0.09	0.33	0.32	0.29	0.42	0.80	0.72	0.66	0.74
Catfish	0.00	0.00	0.00	0.30	0.04	0.04	0.00	0.00	0.01	0.00	0.00	0.00
Largemouth Bass	0.03	0.11	0.06	0.03	0.05	0.05	0.00	0.00	0.09	0.17	0.25	0.03

Temperatures began to meet or exceed 20° C in April 2015 and remained mostly above this temperature until early November, peaking in June and July (Figure 11), however no clear correlation between temperatures and CPUE were identified.

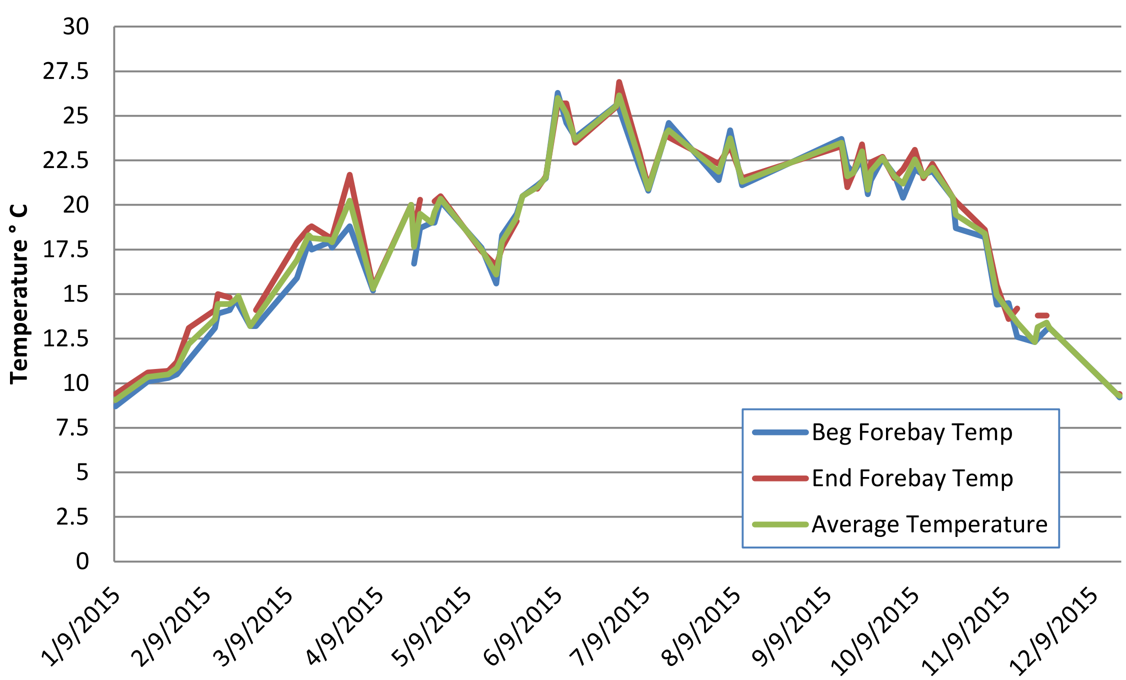


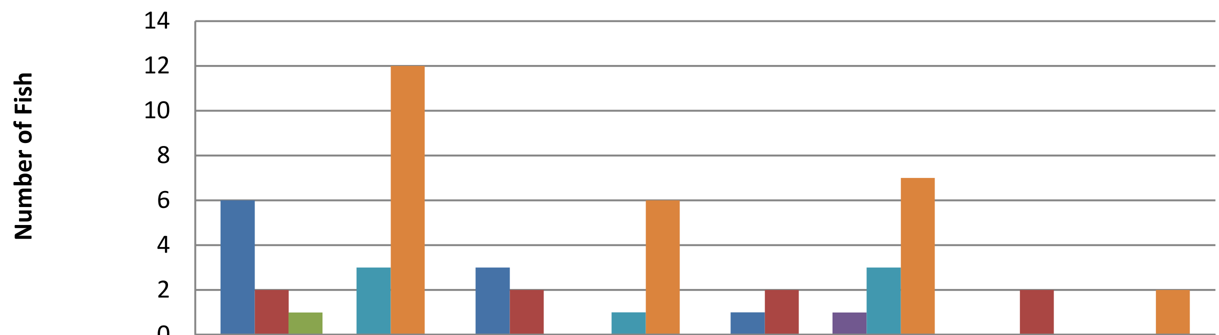
Figure 11: 2015 Sampling Effort Temperatures (°C)

Recapture of Marked Fish (Non-Acoustic)

A total of 27 fish were recaptured during 2015, ten by anglers outside of the Forebay, eight by anglers interviewed for creel surveys, seven during sampling efforts, one at the Curtis Landing release site, and one during a NOAA study within the Forebay (Table 8). Two additional acoustic tags were found at the facility, one in the SDFPF secondary unit, and one in a desiccated fish on the levee road near the radial gates. Of these 27 recaptured fish, 12 were released back into the water at the point of capture. Of those 27 recaptures, eight were acoustic tagged fish, and the remaining were PIT tagged fish.

Table 8: 2015 Recaptured Fish

Recapture Method	Striped Bass	Largemouth Bass	Catfish	Total
Angler	9	1	0	10
Creel Angler	4	4	0	8
Release Site PIT antennae	1	0	0	1
Other Study Researcher	0	1	0	1
Sampling Crew	4	3	0	7
All Methods	18	9	0	27



	Striped Bass (PIT)	Striped Bass (Acoustic)	Largemouth Bass (PIT)	Largemouth Bass (Acoustic)
Angler	6	3	1	0
Creel Angler	2	2	2	2
Release Site PIT antenae	1	0	0	0
Other Study Researcher	0	0	1	0
Sampling Crew	3	1	3	0
All Methods	12	6	7	2

Figure 12: 2015 Recaptured Fish by Tag Type, Species and Method

2.2.5 *Discussion and Recommendations*

The 2015 predator sampling effort in the Forebay served multiple purposes, including providing fish for the acoustic tagging studies, genetic gut diet analysis, and mark/recapture studies using non-acoustic tags such as Passive Integrated Transponder (PIT) and Floy tags, to investigate population size and gather basic data. Data from these various efforts will be used for bioenergetics modeling, and to investigate species catchability, immigration and emigration rates, dietary habits, and seasonal distribution in the Forebay.

The largest numbers of predatory fish were captured during months that had concurrent sampling for the genetics and tagging efforts, with the peak months being January, February and March at 317, 463, and 330 respectively. Within the Striped Bass catch, the largest size class of Striped Bass (over 3.0 lbs./1.36 kg) were captured in all sampling months except May, July and August, with total numbers caught peaking in January. The next smaller size class Striped Bass, between 1.51 lbs. (0.68 kg) and 2.99 lbs. (1.36 kg), were caught in every month except May, peaking in January and February. The size class Striped Bass, between 0.5 lbs. (0.23 kg) and 1.5 lbs. (0.68 kg) were caught in every month sampled, with peaks from January through March and September through October. Striped Bass under 0.5 lbs. (0.23 kg) were captured in every month except January, April and December, with a peak in March.

Throughout the year the 0.5 lbs. (0.23 kg) to 1.5 lbs. (0.68 kg) size class dominated all of the sampling months except January, and represented 62% of the total Striped Bass catch for the year. This may be indicative of a thriving population of smaller Striped Bass, including fish less than 3.0 lbs. (1.36 kg), which are present in the Forebay year round. The overall catch and peak catch for Largemouth Bass and catfish were different than those of Striped Bass, with Largemouth Bass caught in every month except July and August, peaking in November. Catfish were only caught during four months, April, May, June, and September, with the bulk caught in April, at 27 fish. Comparatively few catfish were caught during the sampling effort, representing only 2% of the overall catch.

A total of 27 fish were recaptured during 2015, ten by anglers outside of the Forebay, eight by anglers interviewed for creel surveys, seven during sampling efforts, one at the Curtis Landing release site, and one during a NOAA study within the Forebay . This represents less than one percent of the available fish tagged as part of this study.

Predatory fish were most often captured in Area 1, near the scour hole, which is considered to be a hotspot for predation. CPUE was highest from January through March and September through December, peaking at 1.15, and lowest in July, at 0.29, indicating a possible seasonal trend. While there may be some seasonal trends in catch by species and size class, due to the variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, gear selection, and time required to process each fish caught, these trends need more robust examination before a strong conclusion can be drawn. Residency can be more thoroughly investigated using biotelemetry, as described in Section 2.3, below.

Additionally, the low catch of catfish is not necessarily indicative of a small or strongly seasonal catfish population. Kano (1990) showed a very large population of White Catfish present throughout the year in 1983-1984, and catfish continued to be caught by anglers interviewed for creel. It is likely that variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, gear selection, and limitations in other available capture methods that are known to target catfish significantly affected ability to catch catfish. Kano (1990) employed hoop nets that were deployed for long periods of time, and greatly increased his ability to capture catfish. This technique is not currently available to this project, as it is not allowed within the terms of the SCPs.

2.3 *Biotelemetry*

2.3.1 *Methods*

Receiver Array

The initial phase of the biotelemetry receiver array, installed between January and March 2013, consisted of nine units within and immediately adjacent to the Forebay. These nine units included the IC1, IC2, IC3, RGD1, RGU1, WC1, WC2, WC3 and ORS1 (Figure 13).

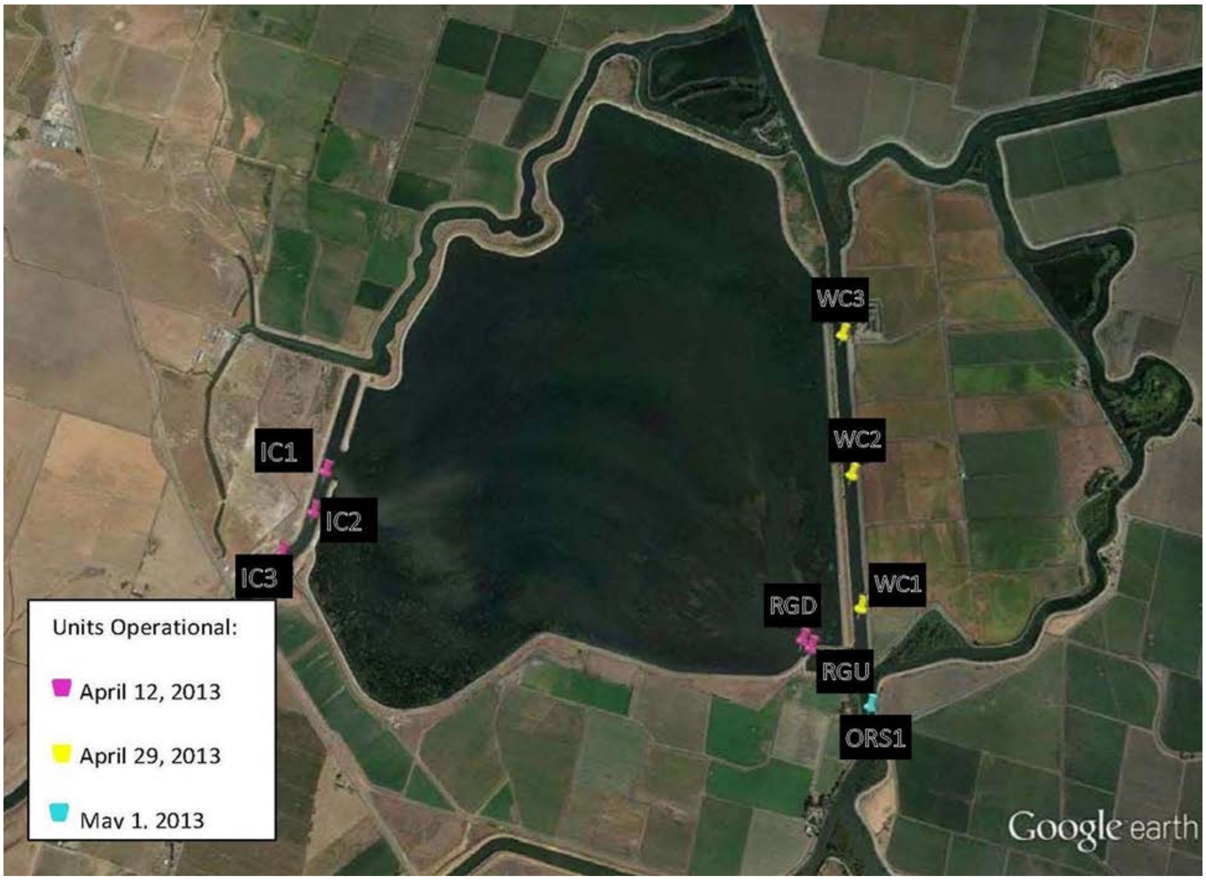


Figure 13: 2014 Receiver Array (Deployed in 2013)

Each of these sites was initially made up of an Hydroacoustic Technology Incorporated (HTI) Model 295x datalogger/ hydrophone combination, powered by a 12-volt (two six-volt sealed deep cycle batteries wired in series) power source connected to a solar panel via a solar charge controller to ensure continued operation. A beacon tag with a predetermined code was deployed near each hydrophone to document ongoing functionality of the unit. These units were upgraded to HTI Model 395 dataloggers in December of 2013 (Figure 14), allowing for remote monitoring and data downloads, as well as global positioning system (GPS) linking of the entire array.

Figure 14: Model 395 Datalogger

The second phase of five additional units was installed outside of the Forebay between April 13 and 15, 2015 (Figure 15, 16) to expand the array's coverage to the main waterways leaving the Forebay.

Figure 15: Receiver Site with Datalogger and Solar Panel Located at Grant Line Canal (GL1)

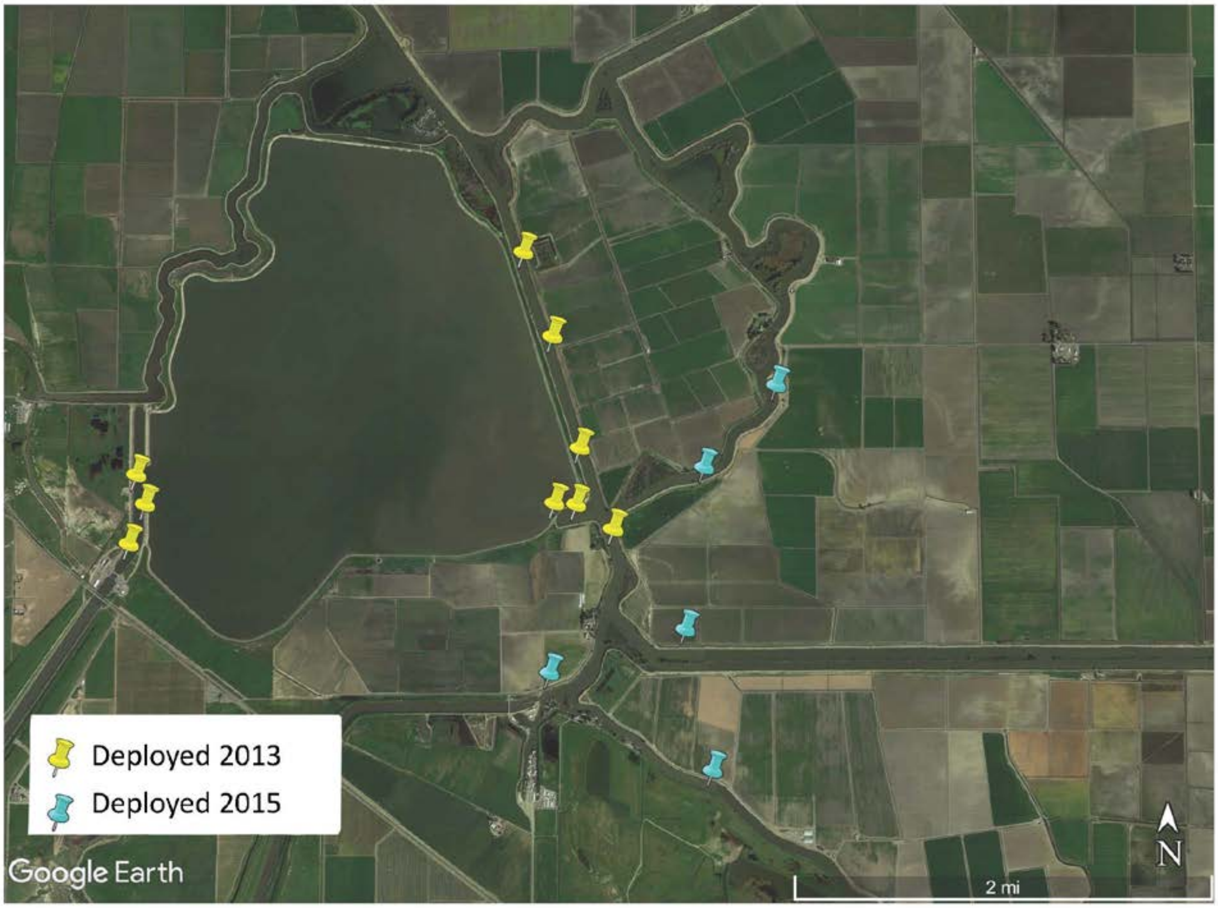


Figure 16: 2015 Expanded Receiver Array

In addition to the static array, a six-month pilot level mobile monitoring effort was conducted, using a mobile version of the Model 395 datalogger/hydrophone unit (Figure 17).

Figure 17: Mobile Datalogger and Laptop Unit and Hydrophone Attachment on Boat

Building off of lessons learned during the initial 2014 mobile monitoring pilot effort, surveys were conducted up to three times per week, using pre-determined transects to cover the portion of the Forebay not covered by the static receiver array (Figure 18).

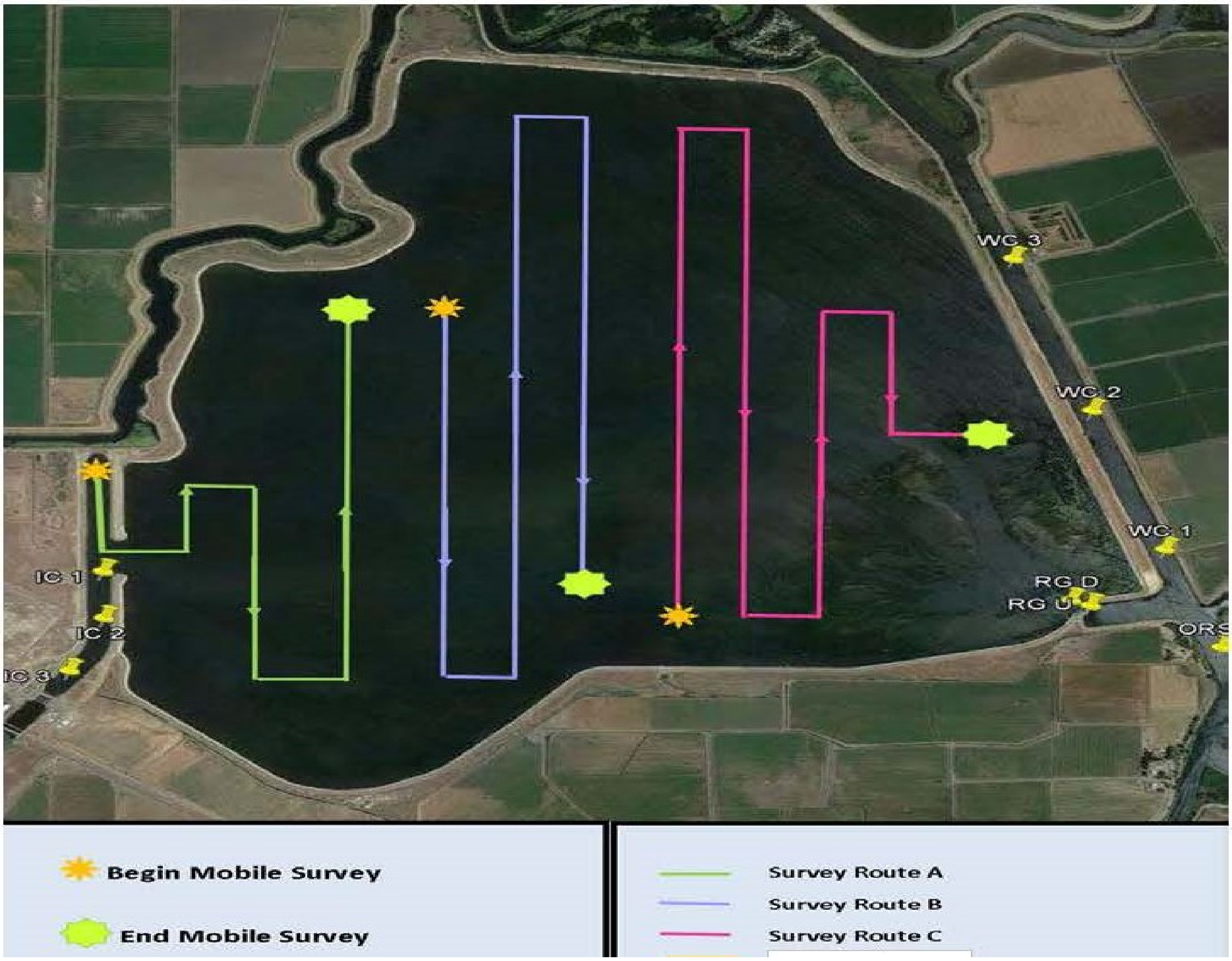


Figure 18: 2015 Mobile Monitoring Transect Map

Acoustic Tagging

Tag codes for 2015 were predetermined by HTI, with sub code 11 for Striped Bass less than 1.5 lbs. (0.68 kg), sub code 31 for Striped Bass over 1.5 lbs. (0.68 kg), and sub code 15 for non-Striped Bass (catfish species and black bass species such as Largemouth Bass, Spotted Bass, and Smallmouth Bass). At the beginning of each month, up to seven HTI 795LG/ Biomark HPT9, 17 HTI 795LY/ Biomark HPT9, and seven HTI 795LZ/ Biomark HPT9 acoustic/PIT combination tags were programmed with codes from the lists provided by HTI. Tags that were not used the prior month were rolled forward into the new month. Following tag programming, each tag was checked for functionality via a tag "sniffer" or a hydrophone attached to an HTI 395 mobile data logger. Up to 31 predatory fish captured each month during the sampling efforts that were larger than 0.5 lbs. (0.23 kg) were tagged with HTI/ Biomark combination acoustic/PIT tags as well as secondary external Floy tags (Table 9).

Internal tagging followed procedures based on methods described in Wingate and Secor 2007, and incorporated the use of anesthesia methods as part of the INAD for Aqui-S 20E (US Fish and Wildlife Service (USFWS) 2011; Study #'s 11-741-15-023F, 11-741-15-022F, 11-741-15-021F, 11-741-15-020F). All captured predatory fish that were not acoustic tagged, were tagged with internal Biomark HPT12 PIT tags and external Floy tags so that they could be identified in the event of recapture or salvage.

Table 9: 2015 Assigned Tag Codes by Species and Size Class

HTI Tag Type	Fish Size Range lbs.(kg)	Striped Bass	Black Bass	Catfish	Total Tags per Month
LG – sub code 11	>0.5 (0.23) to <1.5 (0.68)	7	0	0	7
LY – sub code 15 (non-Striped Bass); sub code 31 (Striped Bass)	>1.5 (0.68) to <3.0 (1.36) (Striped Bass) >1.5 (0.68) (non-Striped Bass)	7	5	5	17
LZ – sub code 31	>3.0 (1.36)	7	0	0	7
Total Fish per Month		21	5	5	31

Acoustic tagging was conducted on 53 predator sampling days, at various times during the day from January 20, 2014 until December 18, 2014. Secondary external Floy tags were applied to all captured fish. After the fish was tagged, scale samples were taken, and the fish was placed into a recovery net at the point of capture, and monitored until swimming normally. Once the fish was deemed fully recovered it was released.

Tag Retention[1]

As part of the quality assurance/quality control (QA/QC) efforts for acoustic tagging, a laboratory based study to examine fish health and tag retention was conducted. For this purpose, a group of 36 Channel Catfish weighing over 1.5lbs (0.68 kg) were acquired from Passmore Ranch and transported to the Fish Science Building (FSB) and held for a two week acclimation period. Once acclimated, each of the five taggers working on the CCFPS surgically implanted acoustic tags (HTI LY) into six individual fish. Tagging followed the standard operating procedures for all CCFPS predator tagging (Wunderlich 2015), and included the application of the Floy tags to the dorsal side of each fish. Following tagging each fish was placed in one of six holding tanks so that each tank contained one fish from each tagger, along with an untagged control fish. Fish were fed a maintenance diet of steelhead feed, and were held for 60 days. At the conclusion of the study, the fish were sacrificed and necropsies were performed. An in-depth evaluation of incision and suture healing, and tagging effects was conducted. Insertion sites for Floy tags and acoustic tags were scored for healing, residual irritation, and scarring. Internally, the fish were examined for position of tag, inclusion of organs in suturing, signs of tag encapsulation, and signs of

[1] Adapted from draft internal report "CCFPS Catfish Health and Tag Retention Study" by Bryce Kozak 2016

disease. All fish evaluations were photo-documented. No indication of tag explusion was found, and tag position, placement of sutures and overall healing indicate consistency across taggers for this species.

2.3.2 *Issues*

Boat access problems such as loss of navigability during times of high SAV load, and lack of access to qualified boat operators, and scheduling conflicts resulted in a slower than desired response time when datalogger/hydrophone units required maintenance, which caused delays in correcting problems when identified, and potential gaps in data collection.

2.3.3 *Data Analysis*

All tagging data was recorded onto Rite-in-Rain datasheets that were scanned onto the DWR server and transcribed into an access database. Data including release dates and times for each acoustic tagged fish was sent to HTI on a weekly basis, and tags were identified by tag type so that they can be removed from the search list as their batteries, which have different lifespans based upon type, reach the end of life. Data was downloaded via modem directly from the acoustic receivers by HTI staff and analyzed at their office in Seattle, Washington.

Data was analyzed by uploading each hour long file from each receiver into the MarkTags® software and identifying tags that had been detected by the hydrophone. A list of acoustic tags released into the Forebay was compiled and compared to a list of acoustic tags detected by the receivers in the array. Each tag signature identified by the software has a visual beginning and end which are marked via electronic bookmarks and show which tag and what time it was detected (Figure 19). This information was initially processed by an automated program and then verified by trained technicians. Once analysis via MarkTags® was complete, the acoustic data was imported into a database which allowed for a secondary quality control phase, consisting of checking for tags that appeared to be detected by any hydrophone prior to release. Following verification of the data, the database was fully populated and returned to DWR.

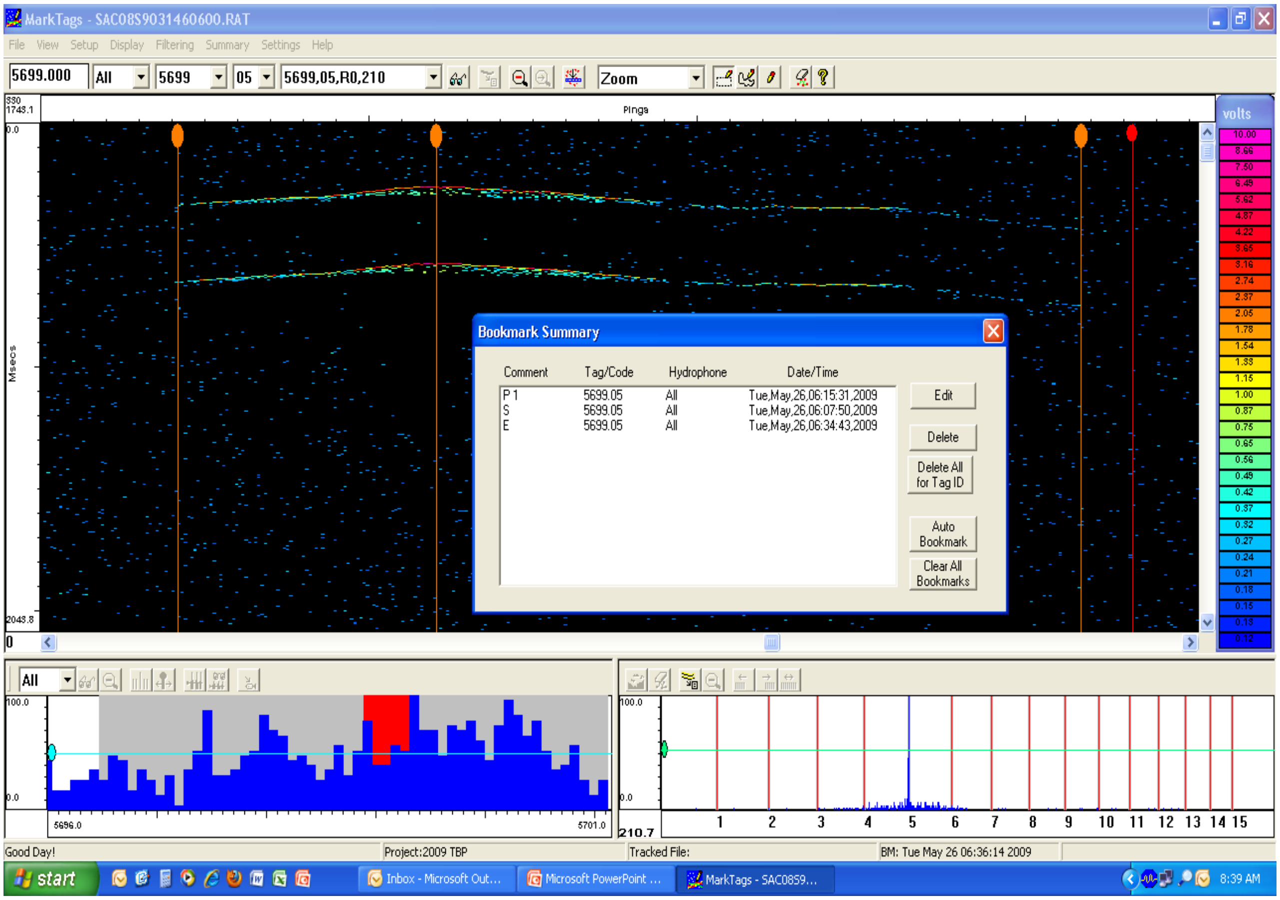


Figure 19: MarkTag Screenshot Displaying a Tagged Fish (2009 K. Clark)

The database allowed for determination of the first and last detection of each tagged fish at each receiver location. By looking at all of the receiver stations chronologically, a tagged fish can be “observed” as it moves through the array over time. This can be further visualized using programs such as EON fusion (Figure 20). For instance, in the figure below, the detection of an acoustically tagged catfish is indicated by the appearance of a color-coded polygon. The hydrophones are color-coded by location to make the image easier to decipher, with the intake channel in green, West Canal in blue, radial gates downstream in yellow, radial gates upstream in red, and Old River south in pink. The image in Figure 20 shows a span of time from June 27, 2013 through August 1, 2013, for an overview of the fish’s detections throughout this period, and shows that the fish was detected both inside and outside of the Forebay during this period.

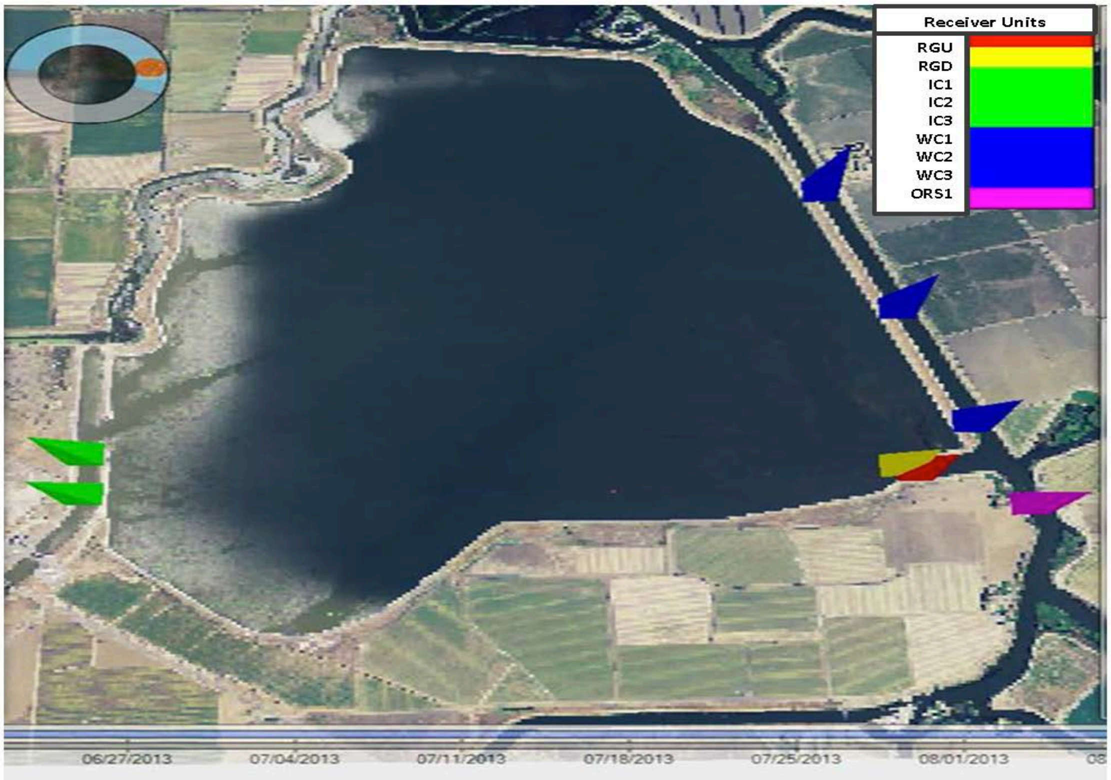


Figure 20: Screenshot of EONFusion showing Acoustically Tagged Catfish in and around Clifton Court Forebay during 2013

2.3.4 *Results*

A total of 185 predatory fish were acoustically tagged in 2015; 12 Channel Catfish, 20 Largemouth Bass, 150 Striped Bass, and three White Catfish (Table 10). The target number of 31 acoustically tagged fish per month was never achieved during 2015 tagging efforts. The highest number of acoustically tagged fish occurred in February and the lowest number occurred in August, at 24 and 8 fish, respectively. Of the 185 total tagged fish, 19 Striped Bass were never detected by any of the receivers in the array. This represented 10% of the total number of tagged fish during 2015. As these fish were not necessarily tagged and released in locations within the Forebay where they would be immediately within range of the deployed receivers, and mobile monitoring was not conducted consistently throughout the year, it is possible that a fish could be active in the Forebay, but never detected. Twenty-five fish were detected during mobile monitoring surveys, all of which had also been detected on at least one stationary receiver.

Table 10: Acoustic Tagged Fish in 2015

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass	1	3	5	0	0	1	0	0	2	3	5	0	20
Catfish Species	0	0	0	8	4	2	0	0	1	0	0	0	15
Striped Bass (LG)	7	7	0	0	7	7	7	7	7	7	6	7	69
Striped Bass (LY)	7	7	7	3	0	4	2	1	6	7	7	6	57
Striped Bass (LZ)	6	7	2	0	0	0	0	0	1	3	1	4	24
All Species	21	24	14	11	11	14	9	8	17	20	19	17	185

Of the 166 acoustically tagged fish detected by the receivers, 56 fish (34% of the detected fish), were detected on receivers outside as well as inside of the Forebay, indicating that they emigrated from the Forebay. Two of these emigrating fish were Channel Catfish, and 54 were Striped Bass (Table 11).

Of those 56 fish that were detected outside of the Forebay, three were detected on only one receiver, 32 were detected on between two and five receivers, 20 were detected on between six and nine receivers, and one was detected on all ten receivers outside of the Forebay.

Table 11: 2015 Acoustic Tagged Fish Detected Outside of Forebay

Species	Tag Code	Release Date	Radial Gates Upstream (RGU1)	Old River South (ORS1)	Old River South (ORS3)	Central Valley Project (CVP1)	Grant Line Canal (GL1)	Old River North (ORN1)	Old River North (ORN2)	West Canal (WC1)	West Canal (WC2)	West Canal (WC3)
Channel Catfish	9519.15	23-Apr-15	26-May	26-May			26-May					
Channel Catfish	5823.15	23-Apr-15	26-May	26-May			26-May			11-Jul	11-Jul	12-Jul
Striped Bass	9434.31	20-Jan-15	20-Mar	20-Mar	6-Oct	6-Oct	7-Oct				21-Mar	27-Mar
Striped Bass	8874.31	20-Jan-15	19-Feb	19-Feb		10-Jun	3-May	14-May	4-Jun	25-Nov	1-May	1-May
Striped Bass	6992.11	20-Jan-15	27-Feb	27-Feb							7-Mar	7-Mar
Striped Bass	8314.31	20-Jan-15	16-Mar	16-Mar								
Striped Bass	8952.11	20-Jan-15	16-Feb	16-Feb	29-Apr		20-Apr	4-Jul	4-Jul		20-Feb	20-Feb
Striped Bass	6438.31	20-Jan-15	10-Mar									
Striped Bass	7188.11	20-Jan-15	3-Mar	3-Mar							10-Mar	10-Mar
Striped Bass	6634.31	20-Jan-15	8-Feb	26-Mar						5-Apr	9-Feb	9-Feb
Striped Bass	8700.11	20-Jan-15				26-Sep						
Striped Bass	9512.11	20-Jan-15	27-May	27-May	30-May	30-May	27-May	19-Jun	19-Jun		18-Jun	20-Jun
Striped Bass	9714.31	20-Jan-15	8-Feb	13-Feb						22-Mar	4-Apr	4-Apr
Striped Bass	6606.31	27-Jan-15	14-Mar	3-Sep		4-Sep				4-Mar	14-Mar	3-Sep
Striped Bass	5816.11	27-Jan-15	8-Feb	13-Mar						14-Mar	14-Mar	14-Mar
Striped Bass	7306.31	27-Jan-15	16-Mar	17-Mar			24-Oct			4-Nov	17-Mar	17-Mar
Striped Bass	7082.31	30-Jan-15	15-Feb	15-Feb						13-Aug		
Striped Bass	8258.31	30-Jan-15	19-Feb	19-Feb						26-May		
Striped Bass	8986.31	30-Jan-15	19-Mar	19-Mar						13-Mar		
Striped Bass	6628.11	3-Feb-15	4-Mar	4-Mar							10-Mar	4-Mar
Striped Bass	7334.31	3-Feb-15	4-Nov	4-Nov		7-Nov	15-Nov					

Species	Tag Code	Release Date	Radial Gates Upstream (RGU1)	Old River South (ORS1)	Old River South (ORS3)	Central Valley Project (CVP1)	Grant Line Canal (GL1)	Old River North (ORN1)	Old River North (ORN2)	West Canal (WC1)	West Canal (WC2)	West Canal (WC3)
Striped Bass	6662.31	12-Feb-15	16-Mar	5-Sep	8-Sep	8-Sep	8-Sep		6-Sep		16-Mar	16-Mar
Striped Bass	8174.31	12-Feb-15	27-May	4-Jun	28-May	28-May	5-Jun	10-Jun	9-Jun	17-Jun	17-Jun	17-Jun
Striped Bass	5626.31	12-Feb-15	19-Mar	11-Aug			11-Aug			19-Mar	19-Mar	19-Mar
Striped Bass	7384.11	12-Feb-15	20-Mar	20-Mar							30-Mar	30-Mar
Striped Bass	9624.11	12-Feb-15	9-Mar	9-Mar						12-Feb	10-Mar	10-Mar
Striped Bass	6690.31	12-Feb-15	1-Apr	1-Apr			24-Jun	24-Jun	24-Jun		25-Jun	
Striped Bass	6936.11	12-Feb-15	20-Mar	23-Mar							23-Mar	23-Mar
Striped Bass	7250.31	14-Feb-15	15-Apr								15-Apr	
Striped Bass	5402.31	14-Feb-15	15-Mar							15-Mar	15-Mar	15-Mar
Striped Bass	5542.31	14-Feb-15	3-Mar	3-Mar			15-May			15-May	15-May	15-May
Striped Bass	8202.31	17-Feb-15	16-Mar	27-Aug		27-Aug	25-Aug			3-Apr	25-Aug	25-Aug
Striped Bass	6578.31	20-Feb-15	15-Apr	17-Jun		15-Jul		14-Jul	14-Jul	2-Mar	15-Apr	15-Apr
Striped Bass	5766.31	3-Mar-15	16-Mar	16-Mar	31-May	26-May	28-Apr	28-May		17-Mar	31-Mar	31-Mar
Striped Bass	8678.31	3-Mar-15	17-Mar	17-Mar							29-Mar	31-Mar
Striped Bass	7194.31	3-Mar-15	16-Mar	16-Mar						6-Aug	23-Mar	23-Mar
Striped Bass	7026.31	4-Mar-15	19-Mar	19-Mar	5-Sep	3-Oct	4-Sep			11-Mar	20-Mar	20-Mar
Striped Bass	5290.31	4-Mar-15	16-Mar	16-Mar	19-Oct	10-Oct	29-Sep			17-Mar	18-Mar	18-Mar
Striped Bass	8286.31	21-Apr-15	26-May	7-Jun			10-Jul	11-Jul	11-Jul	9-Mar	26-May	27-May
Striped Bass	6186.31	28-Apr-15	31-Aug	2-Sep	31-Aug	31-Aug	3-Sep			31-Aug	31-Aug	31-Aug
Striped Bass	8644.11	14-May-15	28-Aug								29-Aug	29-Aug
Striped Bass	7580.11	19-May-15	15-Aug	15-Aug		15-Aug						17-Aug
Striped Bass	6964.11	9-Jun-15	15-Aug									
Striped Bass	9266.31	12-Jun-15	26-Oct			26-Oct						
Striped Bass	9462.31	30-Jun-15	10-Jul	10-Jul			10-Jul	23-Jul	23-Jul		28-Jul	28-Jul

Species	Tag Code	Release Date	Radial Gates Upstream (RGU1)	Old River South (ORS1)	Old River South (ORS3)	Central Valley Project (CVP1)	Grant Line Canal (GL1)	Old River North (ORN1)	Old River North (ORN2)	West Canal (WC1)	West Canal (WC2)	West Canal (WC3)
Striped Bass	6320.11	10-Jul-15	26-Oct	26-Oct			26-Oct					
Striped Bass	7636.11	16-Sep-15	31-Oct	22-Nov	16-Nov	31-Oct	8-Nov					
Striped Bass	6236.11	18-Sep-15	5-Nov	22-Dec		5-Nov				23-Dec	23-Dec	
Striped Bass	8896.11	18-Sep-15	5-Nov	5-Nov		25-Nov					25-Nov	25-Nov
Striped Bass	8818.31	2-Oct-15	25-Oct	25-Oct			25-Oct				26-Oct	26-Oct
Striped Bass	5704.11	2-Oct-15	5-Nov	5-Nov		5-Nov						
Striped Bass	5990.31	5-Oct-15	5-Nov	5-Nov						5-Nov		
Striped Bass	6242.31	5-Oct-15	25-Oct							25-Oct	25-Oct	25-Oct
Striped Bass	8370.31	9-Oct-15	24-Oct	26-Oct			24-Oct			14-Mar	26-Oct	26-Oct
Striped Bass	8846.31	2-Nov-15	24-Dec								24-Dec	24-Dec
Striped Bass	5878.31	6-Nov-15	21-Dec							21-Dec	22-Dec	

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2015 acoustic tagged fish that were detected outside of the Forebay were detected most often at the Radial Gates Upstream site (RGU1), with the least number of fish detected at the Old River North sites (ORN1, ORN2), at 87% and 14% respectively (Figure 21, 22).

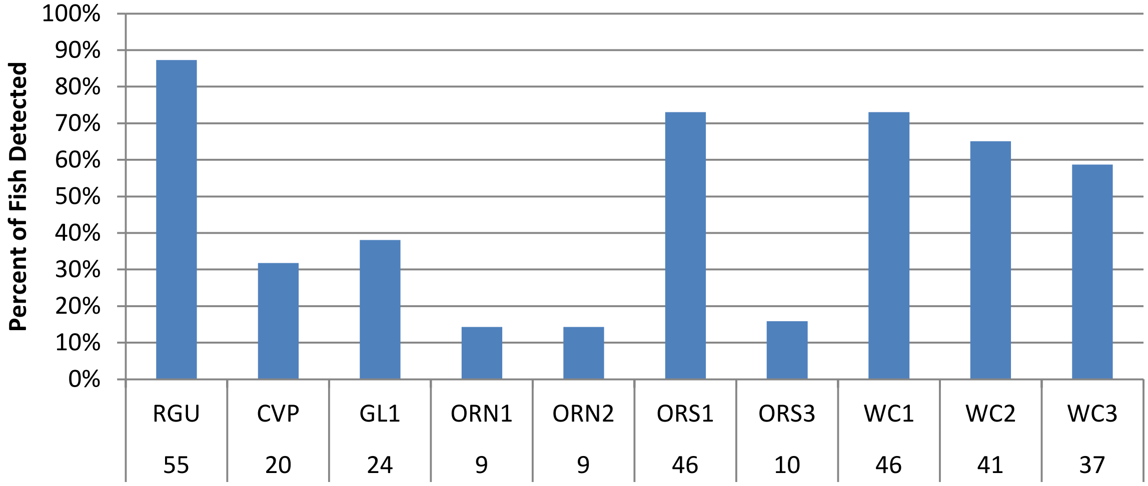


Figure 21: Percent of 2015 Acoustic Tagged Fish Detected outside of Forebay by Site

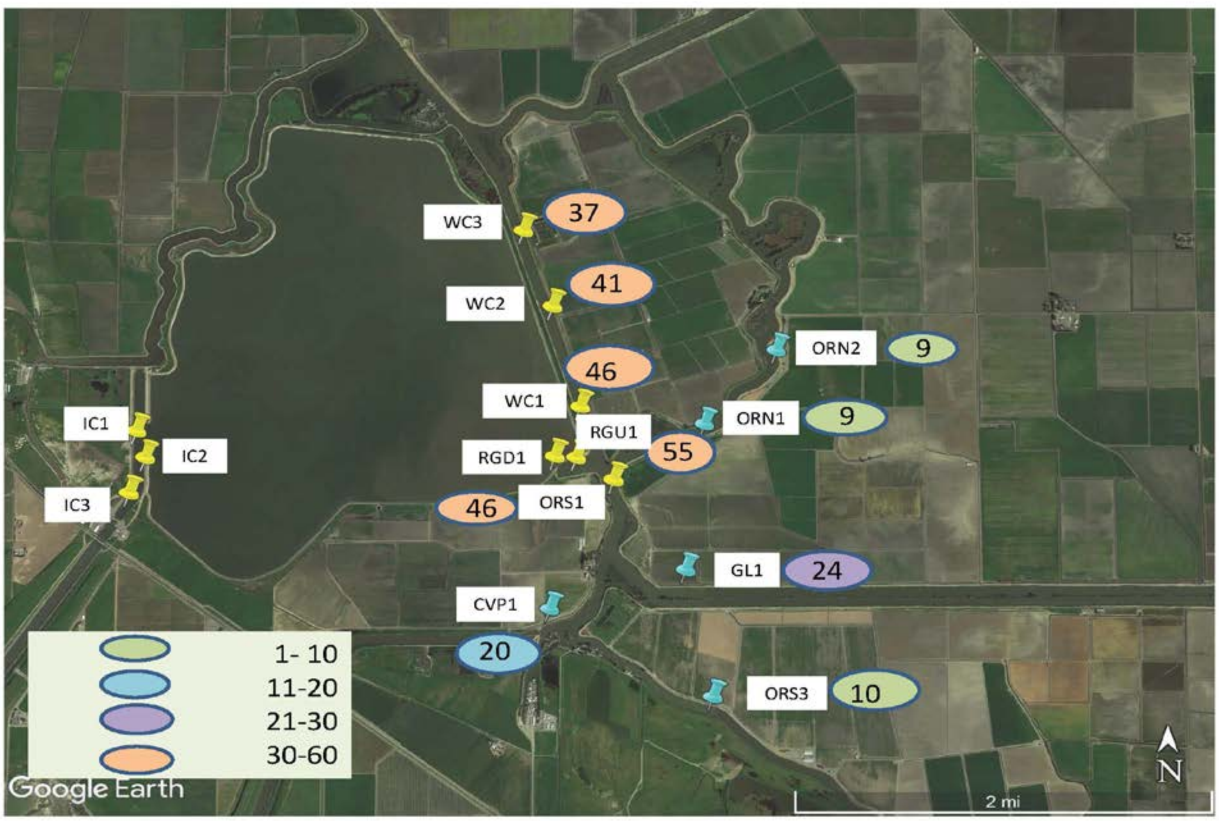


Figure 22: 2015 Acoustic Tagged Fish Detected Outside of Forebay by Site

Of those 56 fish that emigrated, 26 fish (46% of emigrating fish) returned to the Forebay at a later date in 2015. Of the remaining 110 fish that were not observed outside of the Forebay, 16 (15%) were only detected in the intake channel, 48 (44%) were only detected at the radial gates, and 46 (42%) were detected moving between the intake channel and the radial gates.

In addition to the fish tagged in 2015, many fish tagged in 2013 and 2014 were still able to be detected during 2015 due to the time of tagging and battery life of the tags. The combined number of tagged fish from 2013 through 2015 was 553 fish (Table 12).

Table 12: Acoustic Tagged Fish Released in 2013, 2014 and 2015 Combined

2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass					1	1	1	1	2	5	2	5	18
Catfish Species					1	5	2	0	0	0	0	0	8
Striped Bass (LG)					2	8	7	7	7	7	6	7	51
Striped Bass (LY)					7	3	7	7	7	7	7	7	52
Striped Bass (LZ)					1	0	0	0	4	7	7	1	20
All Species					12	17	17	15	20	26	22	20	149
2014	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total**
Largemouth Bass	**5**	4	5	2	5	5	0	0	1	3	5	0	35
Catfish Species	**0**	0	0	2	1	0	0	0	0	0	0	3	6
Striped Bass (LG)	**6**	7	7	7	6	7	7	7	7	7	7	7	82
Striped Bass (LY)	**7**	7	7	6	7	3	5	2	4	4	7	7	66
Striped Bass (LZ)	**5**	5	3	1	1	1	0	0	0	0	7	7	30
All Species	**23**	23	22	18	20	16	12	9	12	14	26	24	219
2015	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total**
Largemouth Bass	1	3	5	0	0	1	0	0	2	3	5	0	20
Catfish Species	0	0	0	8	4	2	0	0	1	0	0	0	15
Striped Bass (LG)	7	7	0	7	7	7	7	7	7	7	6	7	69
Striped Bass (LY)	7	7	7	3	0	4	2	1	6	7	7	6	57
Striped Bass (LZ)	6	7	2	0	0	0	0	0	1	3	1	4	24
All Species	21	24	14	11	11	14	9	8	17	20	19	17	185
All Years Combined	**44**	**47**	**36**	**29**	**43**	**47**	**38**	**32**	**49**	**60**	**67**	**61**	**553**

Based upon expected battery life, it is anticipated that LG tags will last from 220 – 400 days, LY tags from two and a half to four years, and LZ tags from four to five years. Assuming minimum battery life, 99 of the tagged fish released in 2013 would be detectable for at least part of 2015. Of the 14 fish that were undetected during 2014, only seven remained undetected in 2015. Three fish were reported to have been caught and kept by anglers in 2014, and as such were not detectable during 2015. Seven additional angler captured fish were removed from the system in 2015; however, all but one of these fish was detected on at least one receiver prior to removal (Table 13).

Table 13: Acoustic Tagged Fish Removed from System in 2014 and 2015

Acoustic Tag	Date Tagged and Released	Date Removed from system	Date of Last Detection	Site of Last Detection	Left the Forebay?	Returned to Forebay?	Capture Details
8140.24	**6/24/14**	7/28/2014	7/15/2014	ORS1	Y	N	Angler caught at Rock Barrier
8517.06	**9/17/13**	11/1/2014	9/12/2014	RGD1	N		Angler caught at CCF
6068.24	**1/9/14**	11/24/2014	8/31/2014	IC1	Y	Y	Angler caught at Mossdale
8314.31	**1/20/15**	4/1/2015	3/16/2015	ORS1	Y	Y	Angler caught by Grimes Road/ Tracy Blvd
6277.06	**5/3/13**	5/4/2015	6/16/2013	IC3	N		Tag found in SDFPF secondary
6634.31	**1/20/15**	5/9/2015	5/9/2015	IC1	Y	Y	Angler caught at CCF
9882.31	**2/3/15**	5/26/2015	5/22/2015	IC1	N		Angler caught at CCF
5004.24	**9/29/14**	6/11/2015	6/10/2015	RGD1	Y	Y	Found on road near radial gates at CCF
6186.31	**4/28/15**	9/23/2015	9/23/2015	RGD1	Y	Y	Angler caught at CCF
7278.04	**3/3/14**	10/16/2015	3/14/2015	IC1	N		Angler caught at CCF

When fish tagged during 2013 and 2014 that remained detectable into 2015 were included, the total number of fish detected leaving the Forebay rose from 56 to 124, which is 26% of the detectable tagged fish to date. Of those 124 fish, 64 (52% of emigrating fish) were subsequently detected back in the Forebay. Of those 64 fish, three were Channel Catfish, five were Largemouth Bass, 13 were Striped Bass under 1.5 lbs. (at the time of tagging), and 43 were Striped Bass over 1.5 lbs. (at the time of tagging).

The majority of the fish that emigrated were Striped Bass, at 110 (89%), with the balance being made up of Largemouth Bass and Channel Catfish, at eight and six, respectively. The emigrating Striped Bass ranged in weight, at the time of tagging, from 0.6 lbs. (0.27 kg) to 17.8 lbs. (8.07kg), with the smaller fish, 1.0 lbs. (0.45 kg) to 1.99 lbs. (0.90 kg), representing bulk of the fish (Figure 23).

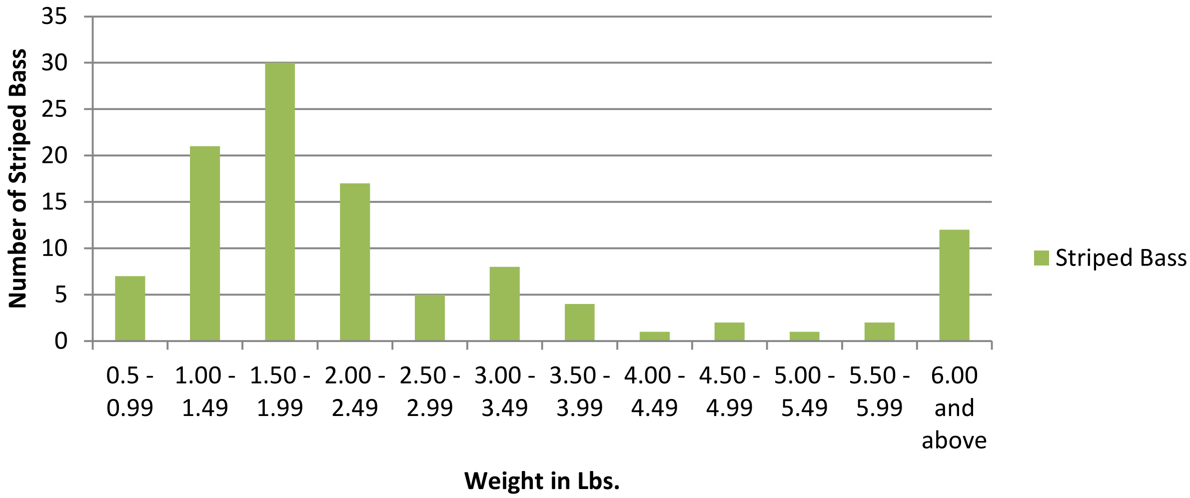


Figure 23: 2013 – 2015 Striped Bass Emigration by Weight Class (lbs.)

The largest percentage of Striped Bass detected outside of the Forebay was within the 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) weight class (Figure 24) at 47%.

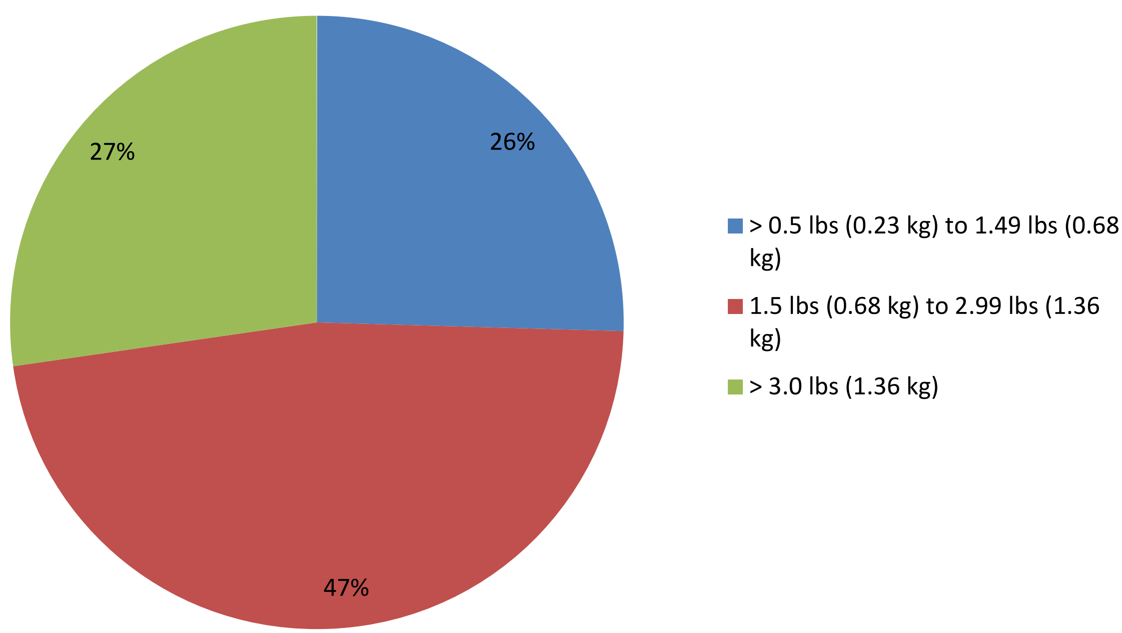


Figure 24: 2013 - 2015 Striped Bass Emigration Percentage by Weight Class

When the weight classes are broken down into increments of 0.5 lbs. (0.23 kg), Striped Bass weighing between 1.5 lbs. (0.68 kg) and 1.99 lbs. (0.90 kg) represented the largest group at 27%, followed by 1.0 lbs. (0.45 kg) to 1.49 lbs. (0.68 kg) at 19% (Figure 25).

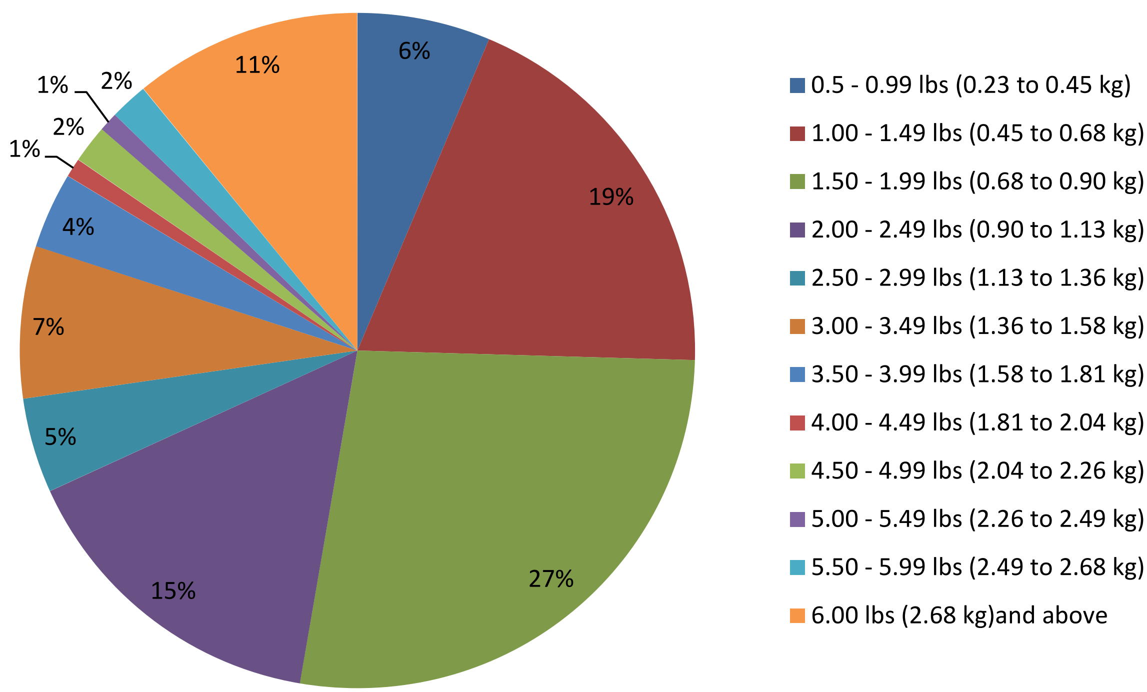


Figure 25: 2013 - 2015 of Striped Bass Emigration Percentage by Weight Class

Of the 72 Striped Bass over 3.0 lbs. (1.36 kg) tagged between 2013 and 2015 that remained detectable based upon battery life estimates, 30 (42%) were subsequently detected outside of the Forebay, whereas only 52 of the 177 fish weighing 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) and 28 of the 153 fish weighing less than 1.5 lbs. (0.68 kg) were detected outside of the Forebay, representing 29% and 18% of those weight classes respectively (Figure 26).

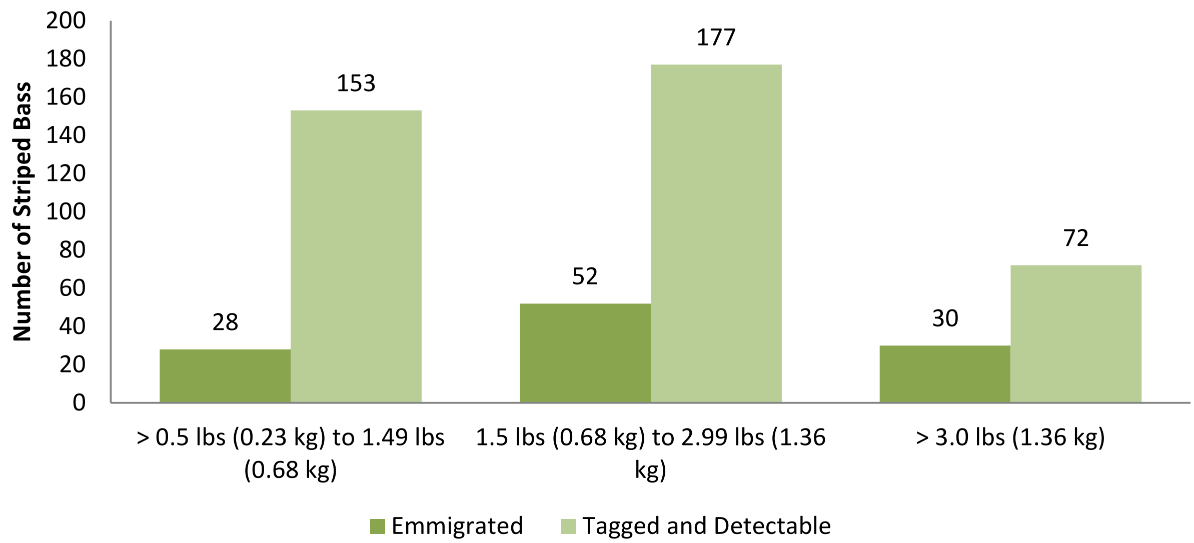


Figure 26: 2013 - 2015 Detectable Tagged Striped Bass Emigration by Weight Class

All weights were taken at the time of tagging, and growth likely occurred between tagging and detection outside of the Forebay. This elapsed time varied from one to 767 days (Figure 27).

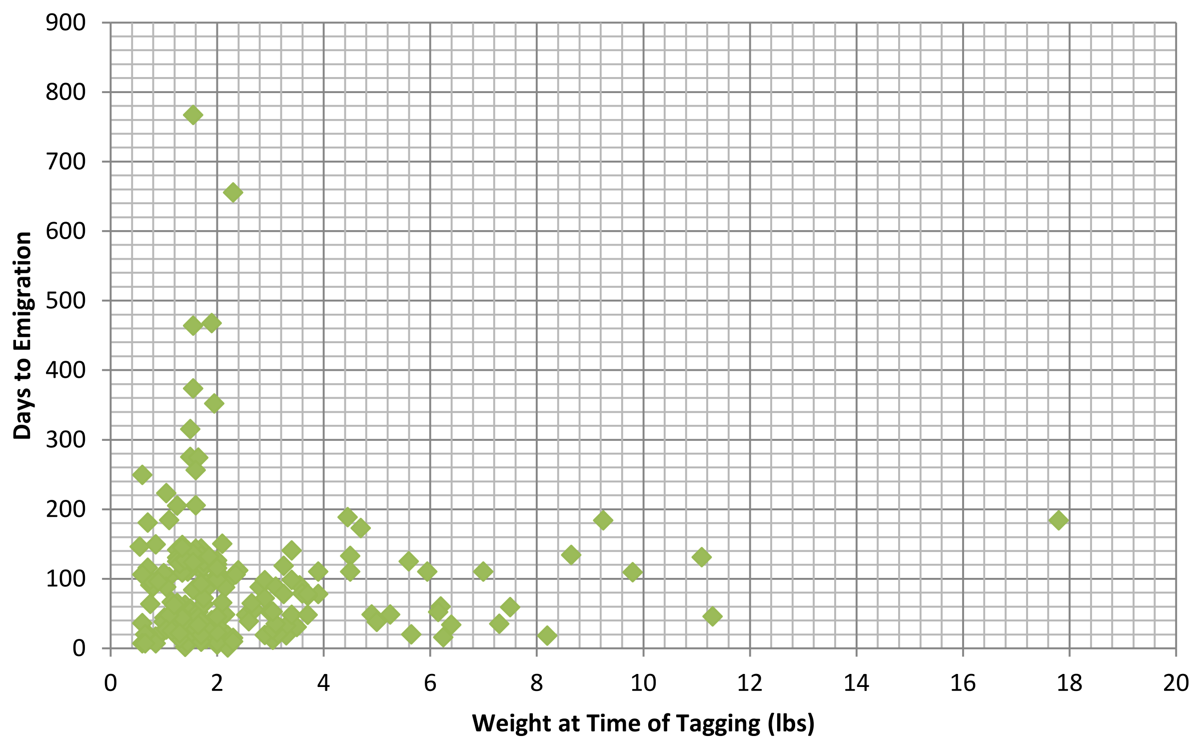


Figure 27: Days Elapsed Between Tagging and First Detection of Emigration by Weight for 2013 - 2015 Striped Bass

Striped Bass in the 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) weight class were detected for the first time outside of the Forebay most frequently in March and September, with 37% and 19% of the fish moving during those months respectively (Figure 28, 29). Striped Bass in the 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) weight class emigrated most frequently in February and March, at 19% and 39% respectively (Figure 28, 30), and Striped Bass over 3.0 lbs. (1.36 kg) emigrated most frequently February and March at 31% and 40% respectively (Figure 28, 31).

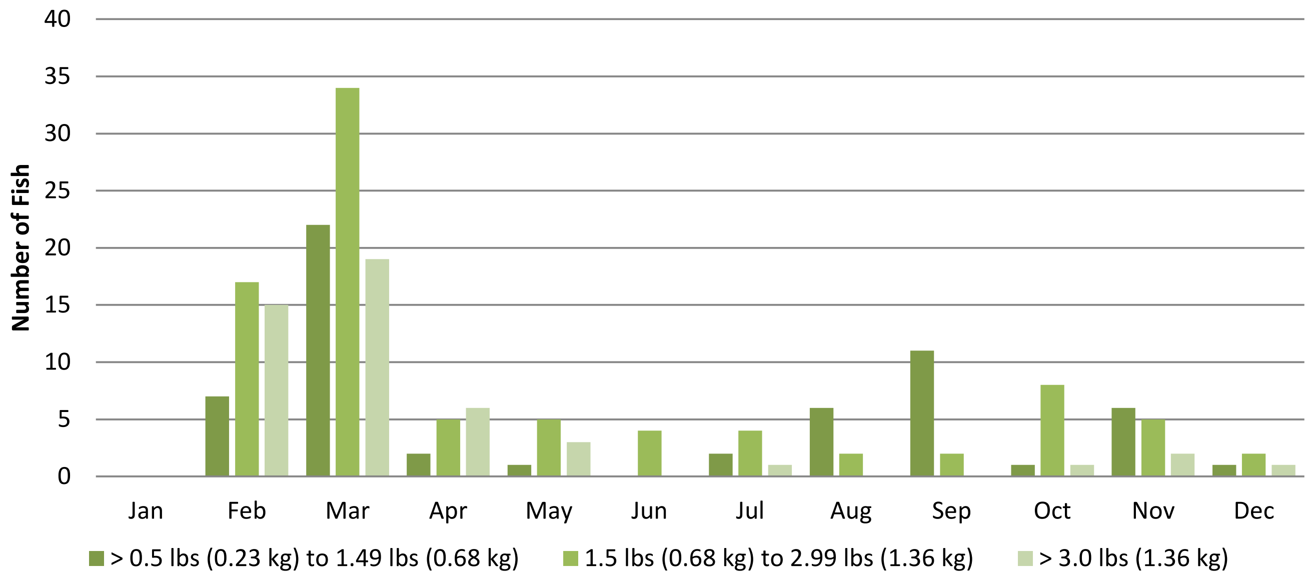


Figure 28: Month of Striped Bass Emigration by Weight Class

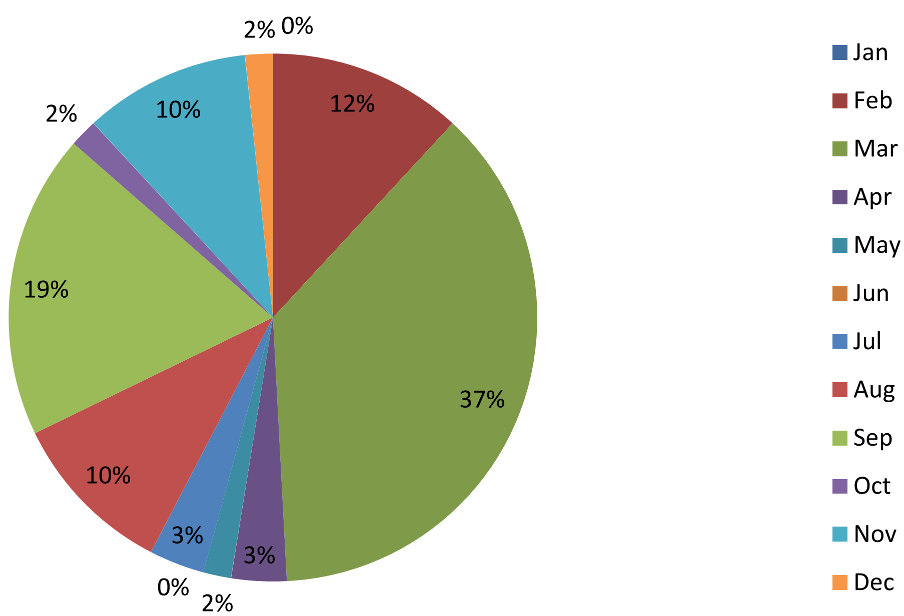


Figure 29: Percentage of 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) Striped Bass Emigration by Month

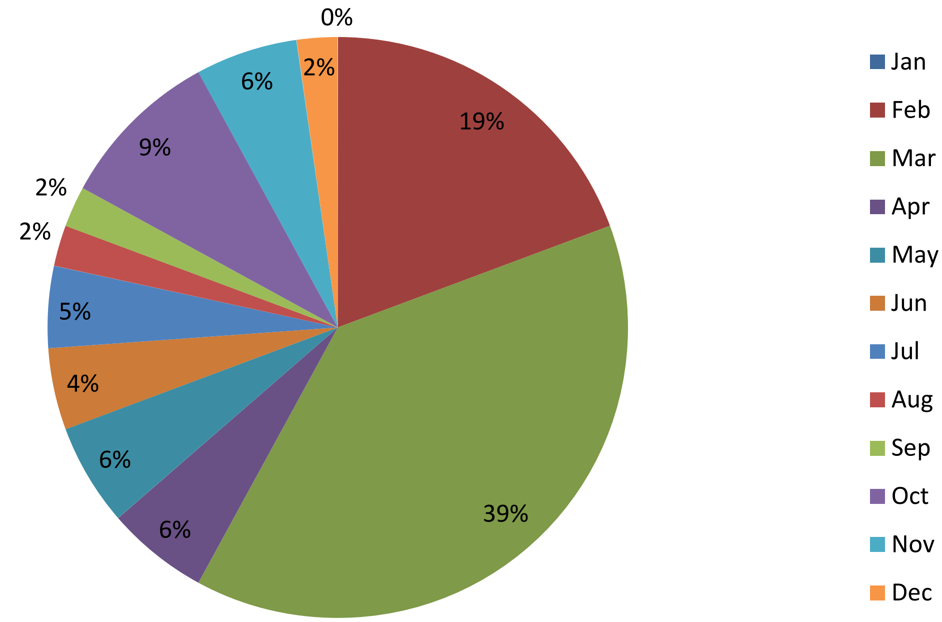


Figure 30: Percentage of 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) Striped Bass Emigration by Month

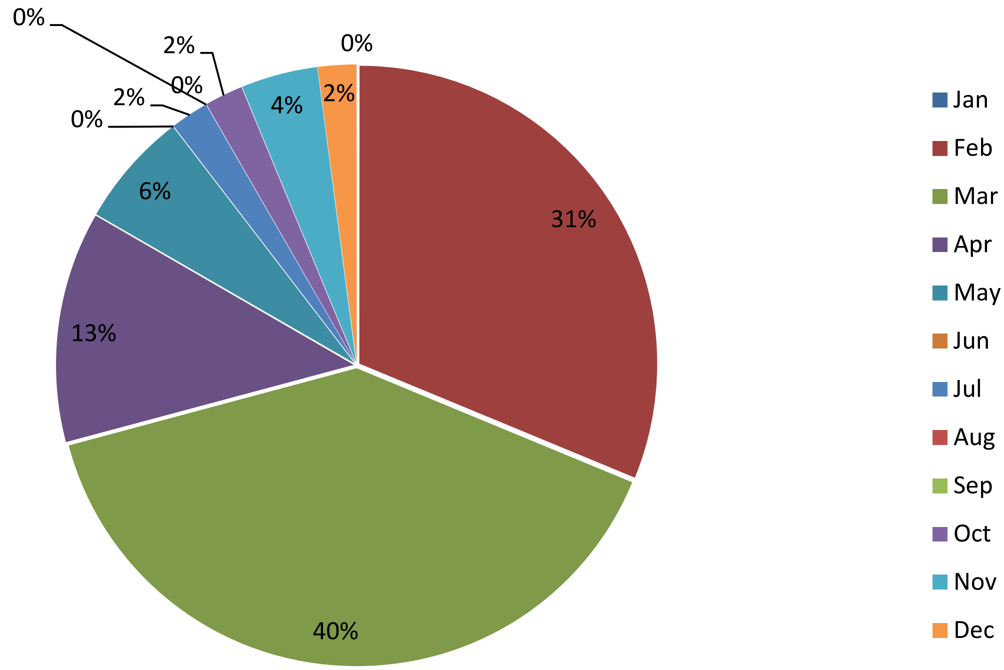
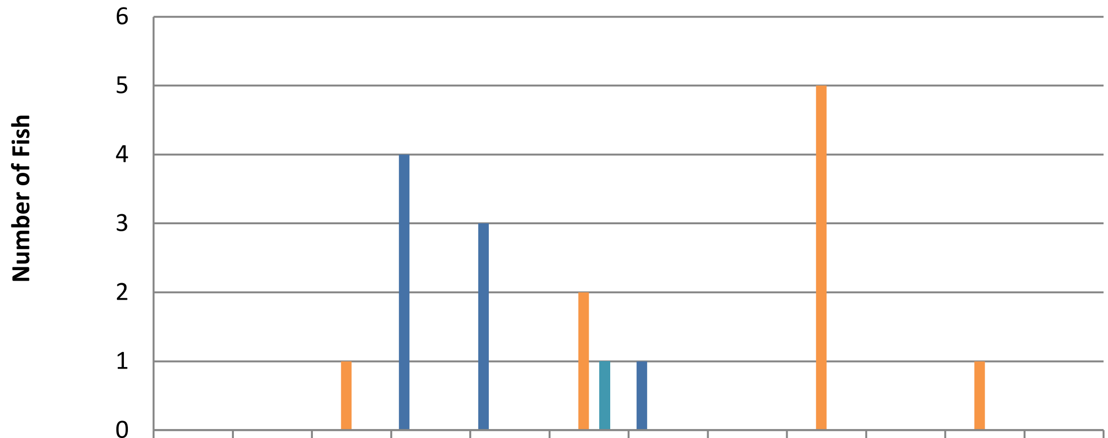


Figure 31: Percentage of 3.0 lbs. (1.36 kg) and larger Striped Bass Emigration by Month

Largemouth Bass emigrated most frequently in September at 56%, while catfish were found to emigrate most often in April and May at 50 % and 38% respectively (Figure 32).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Channel Catfish	0	0	0	4	3	0	1	0	0	0	0	0
	0%	0%	0%	50%	38%	0%	13%	0%	0%	0%	0%	0%
Largemouth Bass	0	0	1	0	0	2	0	0	5	0	1	0
	0%	0%	11%	0%	0%	22%	0%	0%	56%	0%	11%	0%
White Catfish	0	0	0	0	0	1	0	0	0	0	0	0
	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%

Figure 32: Largemouth Bass and Catfish Emigration by Month

When all species were combined, emigration was most frequent in February and March, with 18% and 36% of emigration occurring in these months respectively (Figure 33, 34).

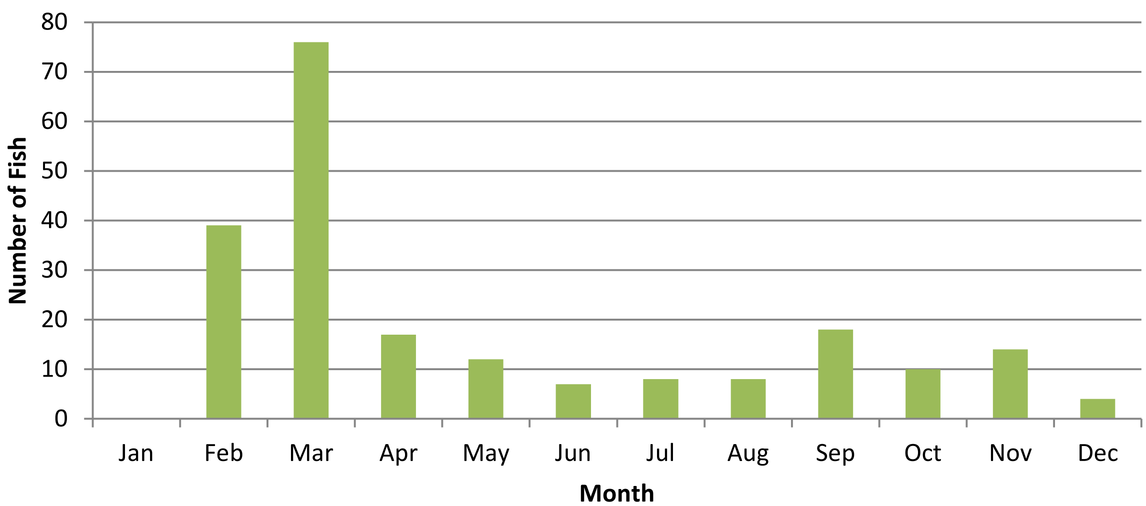


Figure 33: All Species Emigration by Month

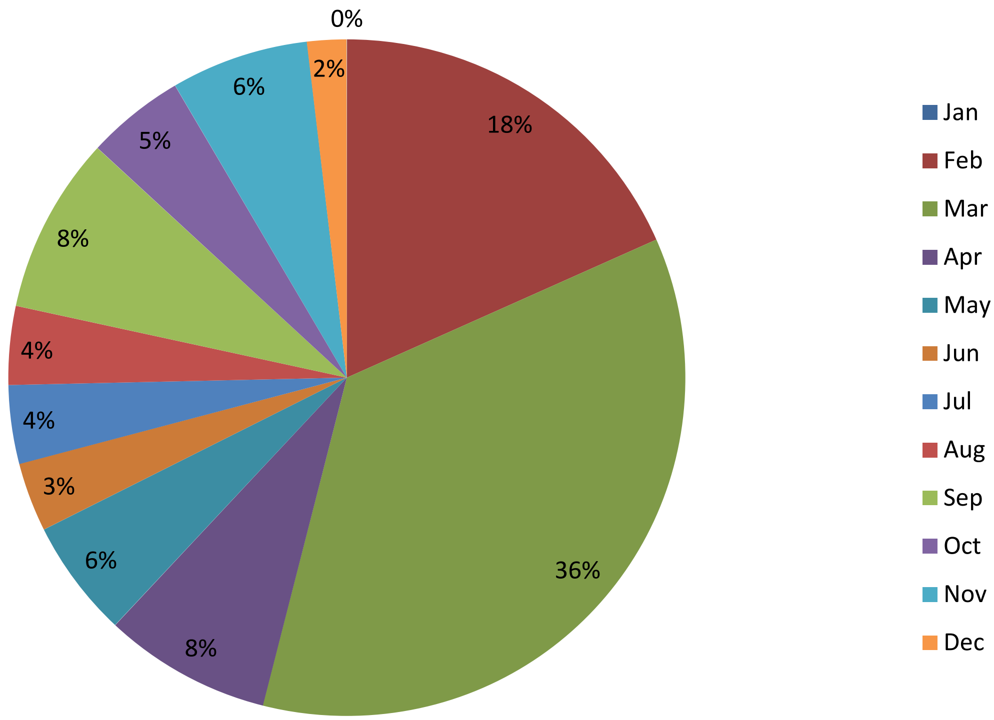


Figure 34: Percentage of Emigration for All Species by Month

2.3.5 *Discussion and Recommendations*

The 2015 acoustic tagging effort contributed an additional 185 tagged fish, comprised of 12 Channel Catfish, 20 Largemouth Bass, 150 Striped Bass, and three White Catfish to bring the total tagged fish in the Forebay to 553. Of the 185 total tagged fish, 19 Striped Bass (10%) were never detected by any of the receivers in the array, leaving 166 detectable fish tagged in 2015. The addition of tagged fish from 2013 and 2014 brings the total number of detectable fish to 477.

Of this 477 detectable fish, 124 have emigrated at some point following tagging, representing 26% of the detectable fish. 64 (52% of emigrating fish) were subsequently detected back in the Forebay. Fish were found to emigrate during every month except January, with the largest number of Striped Bass emigrations occurring in March, Largemouth Bass in September and Catfish in April and May. While this appears to indicate some different movement strategies between species, it should be noted that the number of tagged Largemouth Bass and Catfish is relatively small compared to the number of tagged Striped Bass. As the data set continues to grow over time, trends will likely become more apparent.

Fish that remained within the Forebay also displayed multiple behavioral strategies. When looking solely at the 2015 tagged fish, of the 110 fish that were not observed outside of the Forebay, 16 (15%) were only detected in the intake channel, 48 (44%) were only detected at the radial gates, and 46 (42%) were detected moving between the intake channel to the radial gates. Fine scale movements within the Forebay cannot be ascertained by the current static receiver array, however, as mobile monitoring is increasingly employed, additional information regarding fish moving through, and residing in, the central portion of the Forebay, which has no static receiver sites, is beginning to be compiled.

The 2015 data set continues to show immigration and emigration as well as residency, both localized (remaining in a specific portion of the Forebay) as well as more broad roving behavior (moving multiple times across the Forebay). The tags employed throughout this project will continue to provide data for up to five[2] years per individual fish, allowing for a much better picture of these behaviors over time. The data set expressed in this annual report shows a limited picture, in that the fish detected have not all been in the system for the same amount of time. For instance, fish tagged in November or December of 2015 have only been detectable for one to two months, not long enough to discern their short-term or ultimate behavioral strategies. This limitation is well illustrated by the increased detection of 2013 and 2014 tags with the addition of the longer detection data set.

The Channel Catfish tag retention study showed no explusion of tags over a 60 day holding period, and indicated consistency across taggers for this species. We recommend repeating this type of lab-based QA/QC study for both Largemouth Bass and Striped Bass. We also recommend that mobile monitoring surveys be continued on a regular interval to cover areas of the Forebay that are not currently covered by the static array.

[2] A revised estimate of potential tag life was received from HTI on January 25, 2016, which is longer than originally anticipated.

2.4 Genetics[3]

2.4.1 *Methods*

Specific prey species consumed by predatory Striped Bass were identified using genetic methods that target species-specific DNA sequences, as described in the Clifton Court Forebay Predation Study Report (2015). This allows for the positive identification of consumed prey that visual inspection may miss due to digestion. Twenty-one field sampling days were conducted at the Forebay, as outlined in Section 1.3, above, from December 2014 through April 2015. Striped Bass were captured using hook-and-line with artificial lures. Once fish were captured, they were administered an appropriate amount of EtOH to arrest the digestion of prey located in the gut tract, and placed on ice for preservation until the fish could be further processed at the lab.

2.4.2 *Issues*

Concurrent sampling efforts from multiple boats for both mark/recapture and genetics fish required careful coordination.

2.4.3 *Data Analysis*

All catch data were recorded in the field on a Microsoft Surface RT tablet and transferred to a flash drive for uploading into a CFS - Genidaqs database and to the DWR data portal. Data was then downloaded onto the DWR network and filed into the appropriate project folders. Datasheets were also printed and filed into appropriate binders.

Once fish were brought back to the laboratory for further processing, samples were extracted and quantitative polymerase chain reaction (qPCR) was performed using all assays simultaneously on a 192.24 Gene Expression Integrated Fluidic Circuit (Fluidigm) and BioMark System (Fluidigm) following manufacturer's protocols. Fluorescent output was analyzed using the Fluidigm Real-Time PCR analysis v4.0.1 software.

2.4.4 *Results*

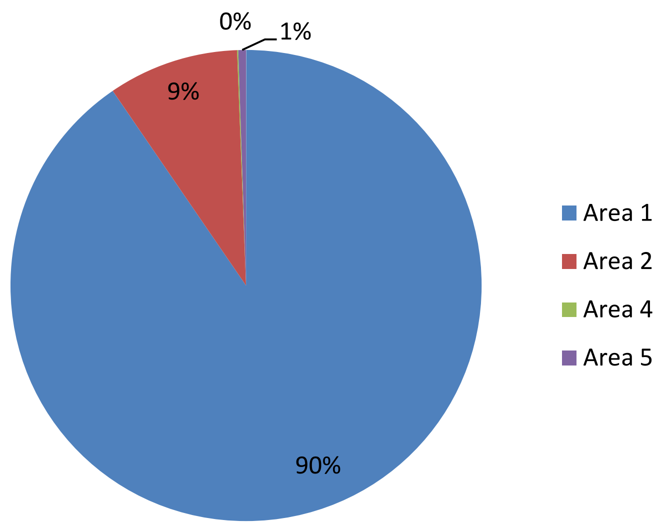
A total of 1,141 Striped Bass were collected and analyzed during the 2014-2015 effort. Of those Striped Bass, 269 were collected in December 2014, 286 Striped Bass in January 2015, 350 in February 2015, 217 in March 2015, and 19 in April 2015.

The average fork length (length from the tip of the snout to the edge of the fork at the centerline of the fish) of Striped Bass collected was 38.6 cm and the average weight was 1.8 lbs. (0.82 kg) (Table 14). No Striped Bass were caught in areas 3 or 6; therefore, these areas were omitted from Table 14. The largest numbers of Striped Bass were captured in Area 1, with 90% of the catch occurring in this area (Figure 35).

[3] Portions of this section are adapted from the stand alone report entitled "Draft Genidaqs qPCR Diet Analysis Report Year 1 Pilot Study May 2013 – June 2014" (Blankenship and Brodsky 2015).

Table 14: Striped Bass Captured by Month and Location in 2014-2015

Month	Area 1	Area 2	Area 4	Area 5	Total	Avg. Length	S.D. Length	Avg. Weight
						(FL)	(FL)	(lbs)
December	174	94	1		269	36.9	8	1.5
January	286				286	43.1	8.8	2.4
February	338	6		6	350	39.6	9.7	1.9
March	215	2			217	32.4	4.9	1.3
April	19				19	43.2	8.6	2.2
Total	1032	102	1	6	1141	38.6	9.1	1.8



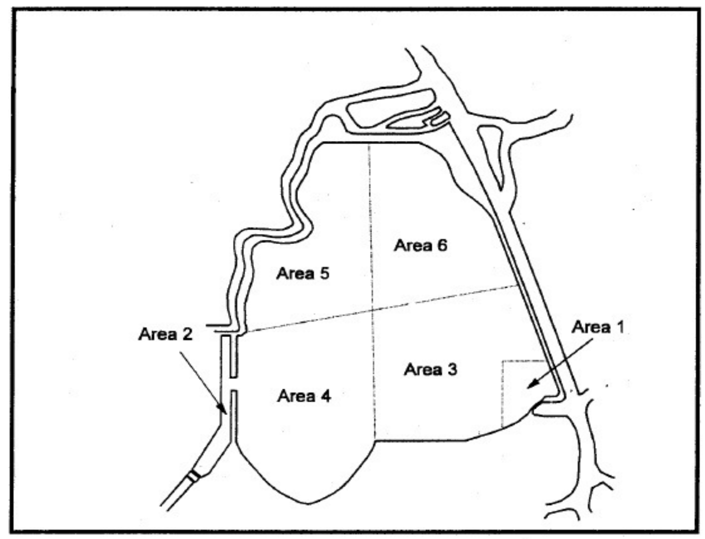
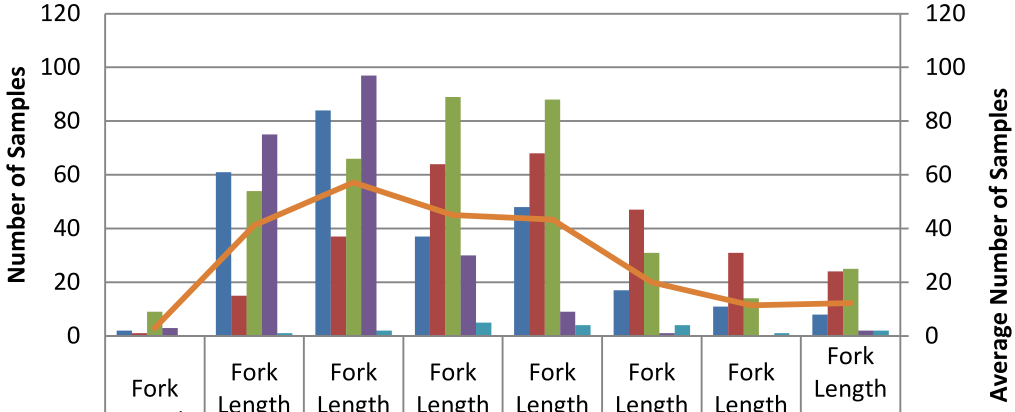


Figure 35: Percentage of Striped Bass Capture by Location

Each individual Striped Bass that was captured and analyzed will be referred to herein as “sample”. Samples were binned into size classes based upon length for comparison across months, with fish in the 30 cm to 35 cm lengths representing the largest portion of the catch (Figure 36). Prey detection, which indicates presence of prey species, but not quantity present, was compiled by sample and partitioned by sampling location and month.



	Fork Length 20-25	Fork Length 25.1-30	Fork Length 30.1-35	Fork Length 35.1-40	Fork Length 40.1-45	Fork Length 45.1-50	Fork Length 50.1-55	Fork Length 55.1 and over
Dec	2	61	84	37	48	17	11	8
Jan	1	15	37	64	68	47	31	24
Feb	9	54	66	89	88	31	14	25
Mar	3	75	97	30	9	1	0	2
Apr	0	1	2	5	4	4	1	2
Average	3	41	57	45	43	20	11	12

Figure 36: Samples Binned by Fork Length (cm) by Month

Nine of the possible 11 prey species that could be identified as present were found during the sample season. The two species not detected were Green Sturgeon (*Acipenser medirostris*) and Longfin Smelt (*Spirinchus thaleichthys*) (Figure 37).

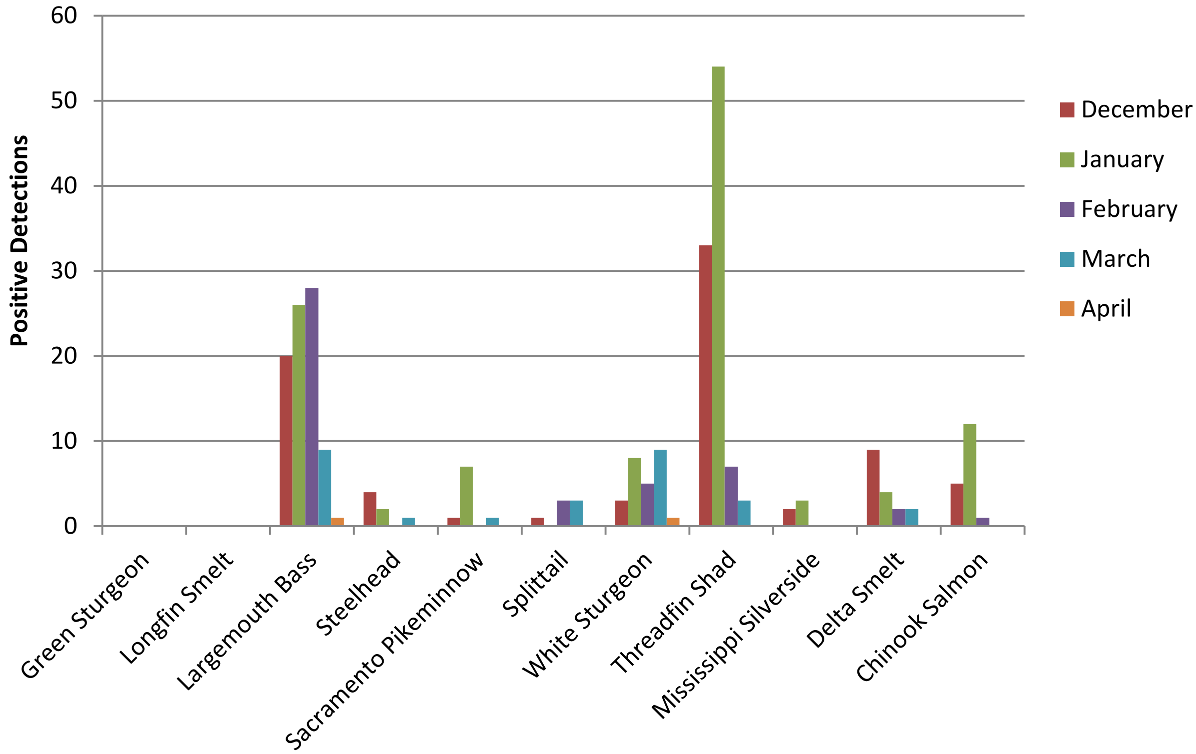


Figure 37: Prey Species Detected by Month in All Locations

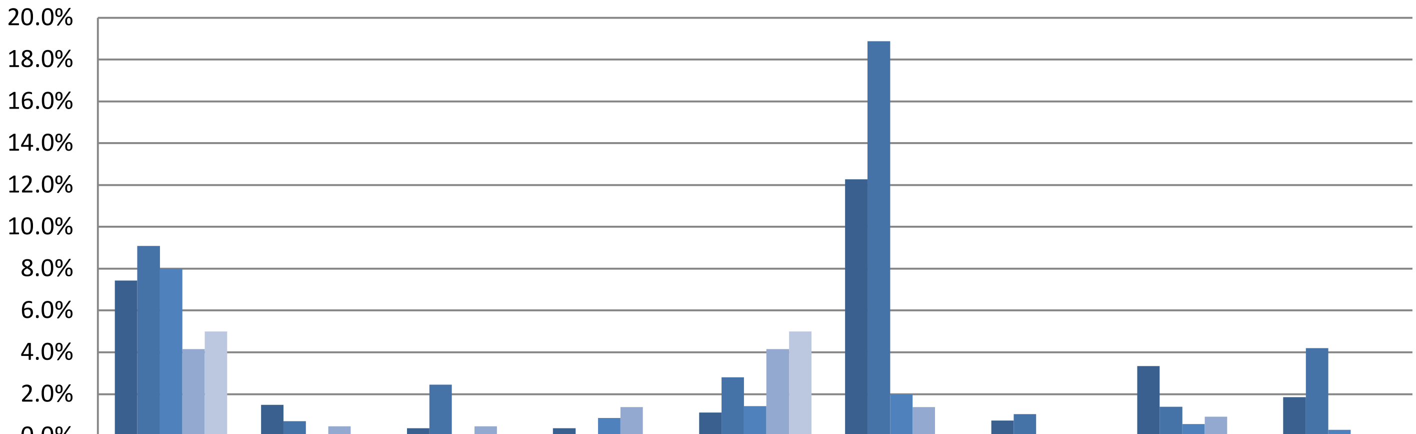
Of the 1,141 samples collected during the 2014-2015 sampling effort, 270 contained positive detections for prey species (Table 15), representing 23.6 % of the total catch (Table 16, Figure 38).

Table 15: Positive Detections by Prey Species and Month in 2014-2015 for All Locations

	Number of Samples	Largemouth Bass	Steelhead	Sacramento Pikeminnow	Splittail	White Sturgeon	Threadfin Shad	Mississippi Silverside	Delta Smelt	Chinook Salmon	All Positive Detections
December	269	20	4	1	1	3	33	2	9	5	78
January	286	26	2	7	0	8	54	3	4	12	116
February	350	28	0	0	3	5	7	0	2	1	46
March	217	9	1	1	3	9	3	0	2	0	28
April	19	1	0	0	0	1	0	0	0	0	2
Annual Total	1141	84	7	9	7	26	97	5	17	18	270

Table 16: Percentage of Samples with Positive Prey Detections by Month in 2014-2015 for All Locations

	Largemouth Bass	Steelhead	Sacramento Pikeminnow	Splittail	White Sturgeon	Threadfin Shad	Mississippi Silverside	Delta Smelt	Chinook Salmon	All Positive Detections
December	7.4%	1.5%	0.4%	0.4%	1.1%	12.3%	0.7%	3.3%	1.9%	29.0%
January	9.1%	0.7%	2.4%	0.0%	2.8%	18.9%	1.0%	1.4%	4.2%	40.6%
February	8.0%	0.0%	0.0%	0.9%	1.4%	2.0%	0.0%	0.6%	0.3%	13.1%
March	4.1%	0.5%	0.5%	1.4%	4.1%	1.4%	0.0%	0.9%	0.0%	12.9%
April	5.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	10.0%
Annual Total	7.4%	0.6%	0.8%	0.6%	2.3%	8.5%	0.4%	1.5%	1.6%	23.6%



	Largemouth Bass	Steelhead	Sacramento Pikeminnow	Splittail	White Sturgeon	Threadfin Shad	Mississippi Silverside	Delta Smelt	Chinook Salmon
December	7.4%	1.5%	0.4%	0.4%	1.1%	12.3%	0.7%	3.3%	1.9%
January	9.1%	0.7%	2.4%	0.0%	2.8%	18.9%	1.0%	1.4%	4.2%
February	8.0%	0.0%	0.0%	0.9%	1.4%	2.0%	0.0%	0.6%	0.3%
March	4.1%	0.5%	0.5%	1.4%	4.1%	1.4%	0.0%	0.9%	0.0%
April	5.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%

Figure 38: Percentage of Samples with Positive Prey Species Detections by Month for All Locations

The most frequently detected prey species in December were Largemouth Bass and Threadfin Shad **(***Dorosoma petenense*), making up 26% and 42% of the positive detections respectively (Figure 39).

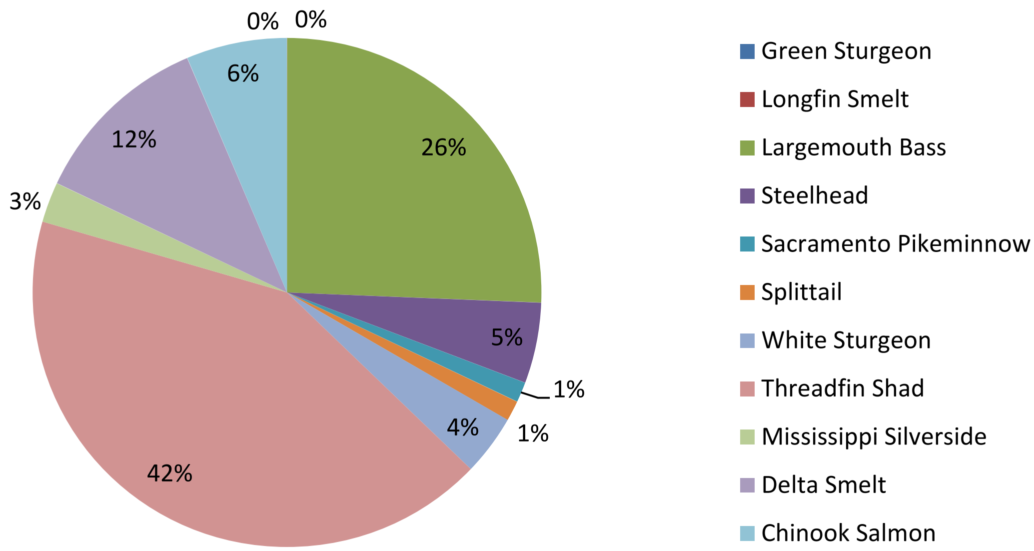


Figure 39: Percentage of Prey Species Detected in December in All Locations

The most frequently detected prey species in January were also Largemouth Bass and Threadfin Shad, making up 22% and 47% of the positive detections respectively (Figure 40).

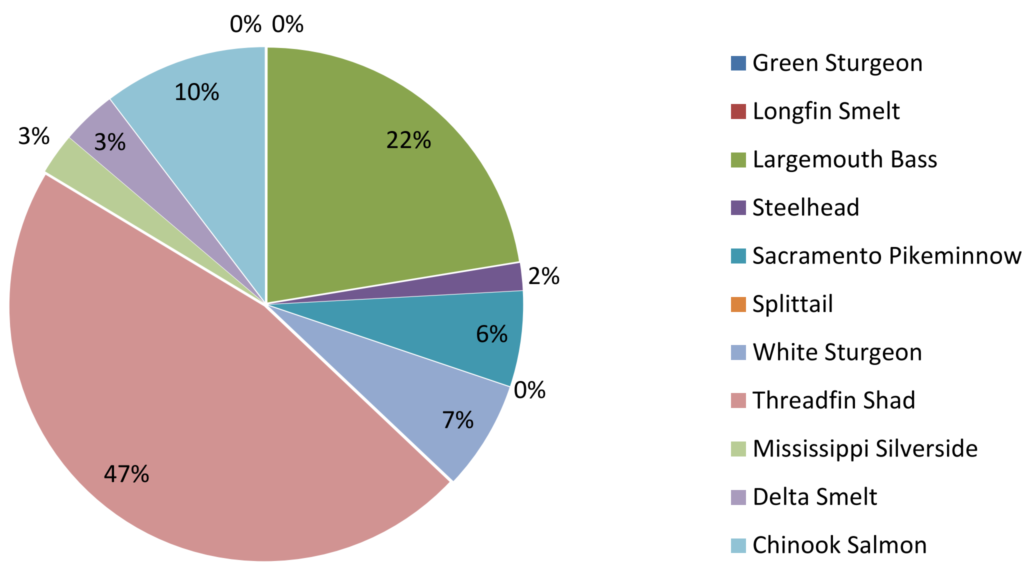


Figure 40: Percentage of Prey Species Detected in January in All Locations

In February, Largemouth Bass made up 61% of the positive detections, followed by Threadfin Shad and White Sturgeon (*Acipenser transmontanus*) at 15% and 11% respectively (Figure 41).

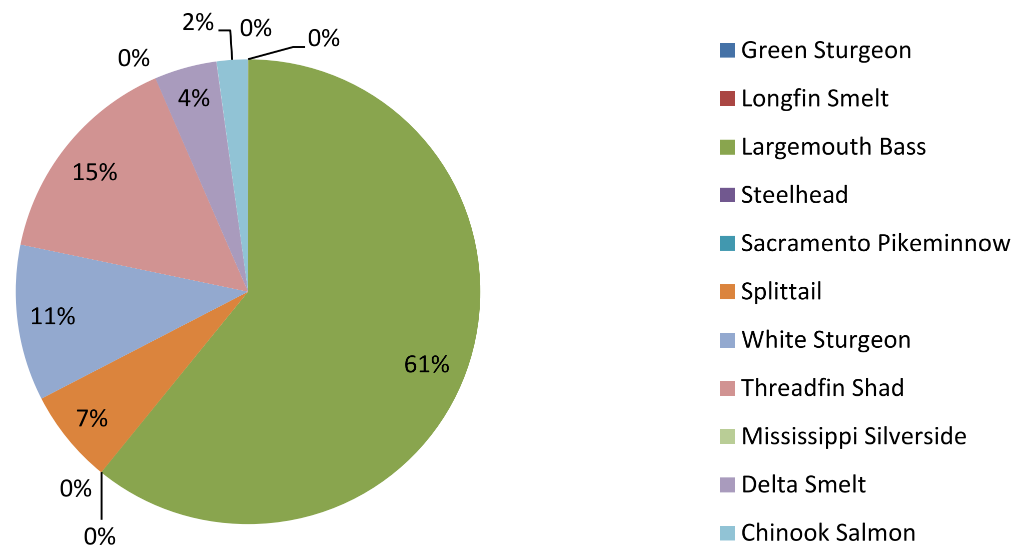


Figure 41: Percentage of Prey Species Detected in February in All Locations

The most frequently detected species in March and April were White Sturgeon and Largemouth Bass, at 32% of the positive detections each for March and 50% each in April (Figure 42, 43).

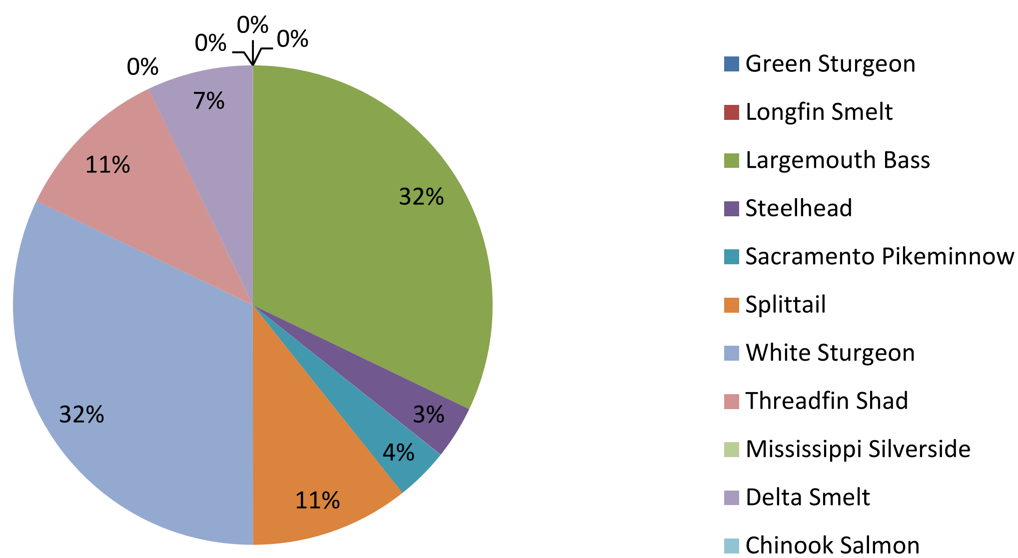


Figure 42: Percentage of Prey Species Detected in March in All Locations

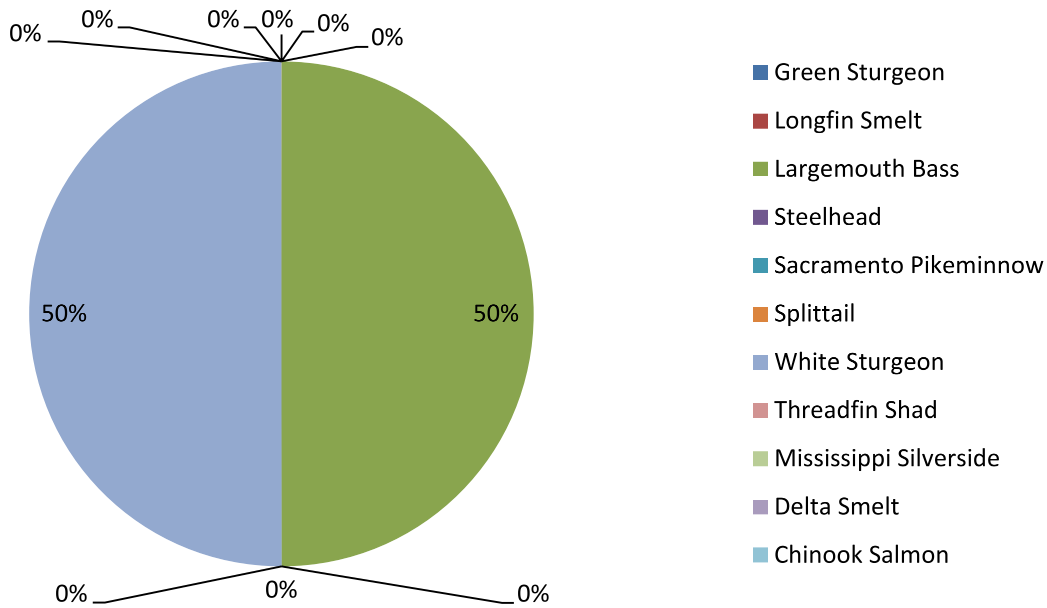


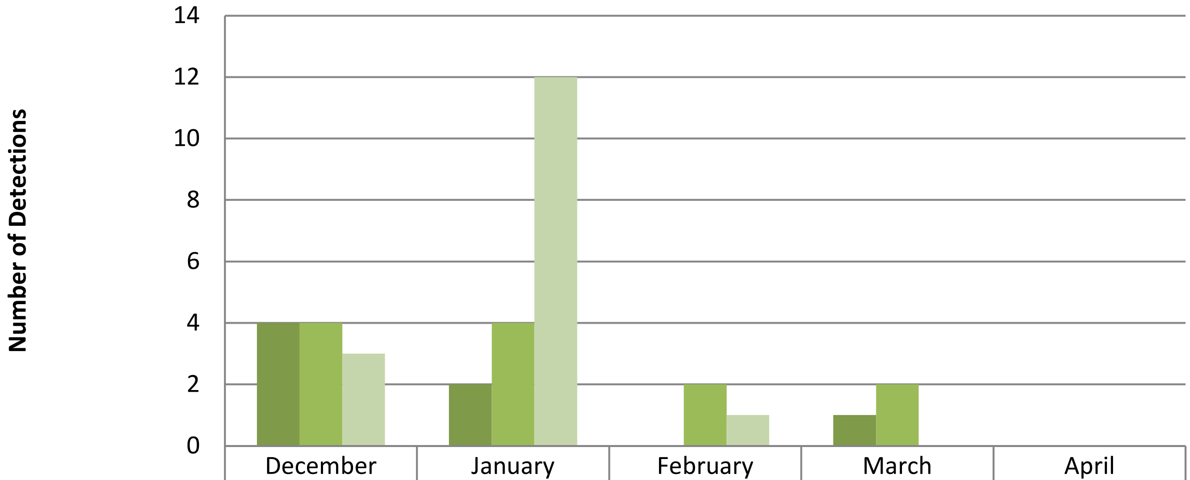
Figure 43: Percentage of Prey Species Detected in April in All Locations

Three of the 11 prey species detected are designated special-status species by USFWS, NOAA-Fisheries or CDFW. These three species, Steelhead (*Onchorhynchus mykiss*), Delta Smelt **(***Hypomesus transpacificus*) and Chinook Salmon (*Oncorhynchus tshawytscha*), were detected in samples from Area 1 and 2 (Table 17).

Table 17: Detections of Special-Status Species by Month and Location in 2014-2015

	Area 1			Area 2		
	Steelhead	Delta Smelt	Chinook Salmon	Steelhead	Delta Smelt	Chinook Salmon
December	4	4	3	0	5	2
January	2	4	12	0	0	0
February	0	2	1	0	0	0
March	1	2	0	0	0	0
April	0	0	0	0	0	0

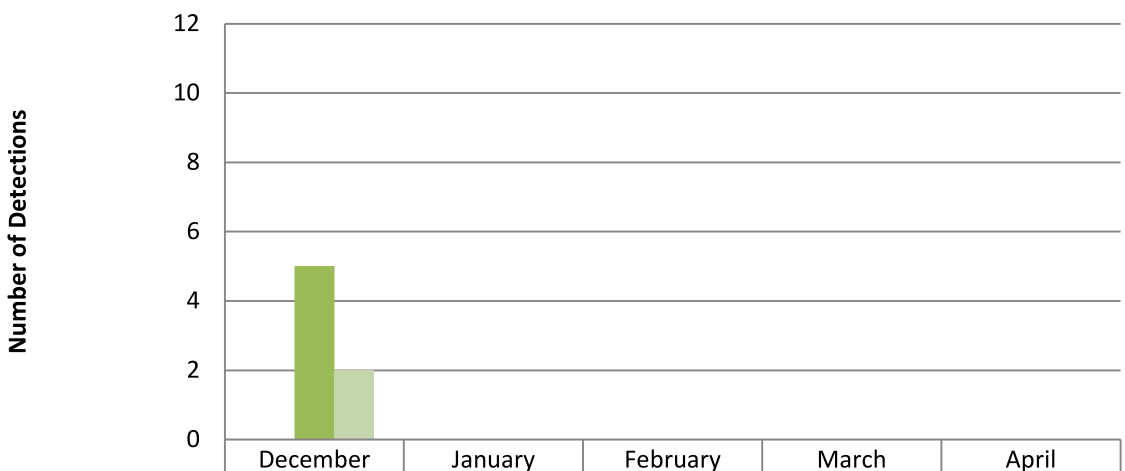
All three of these species were detected in Area 1 in every month sampled except for April (Figure 44). Chinook salmon was detected in December, January and February (Figure 46, 47, 48), with the highest frequency in January, at 12 samples. Steelhead were detected in December, January, and March (Figure 44, 49), peaking in December with 4 samples. Delta Smelt were detected from December through March, peaking in December and January with four samples each of the two months.



	December	January	February	March	April
Steelhead	4	2	0	1	0
Delta Smelt	4	4	2	2	0
Chinook Salmon	3	12	1	0	0

Figure 44: Special-Status Species Detected in Area 1

Chinook Salmon and Delta Smelt were detected in samples from Area 2 in December (Figure 45).



	December	January	February	March	April
Steelhead	0	0	0	0	0
Delta Smelt	5	0	0	0	0
Chinook Salmon	2	0	0	0	0

Figure 45: Special-Status Species Detected in Area 2

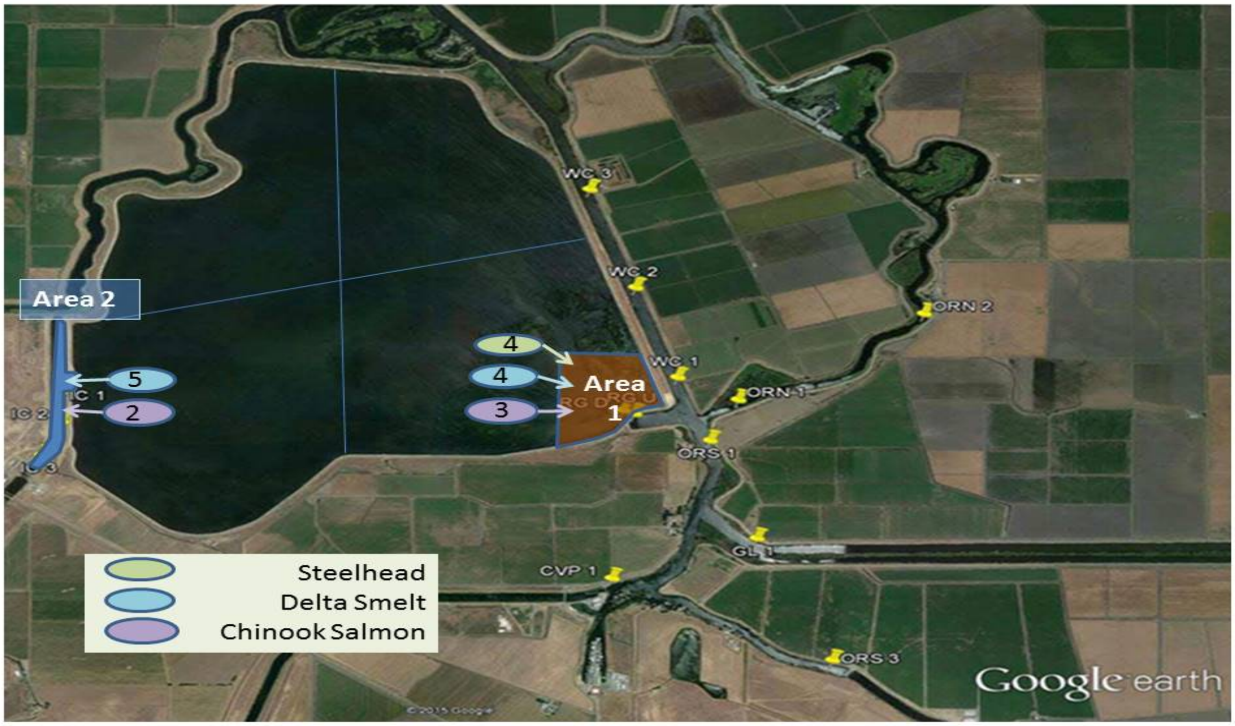


Figure 46: Special-Status Species Detected in December 2014

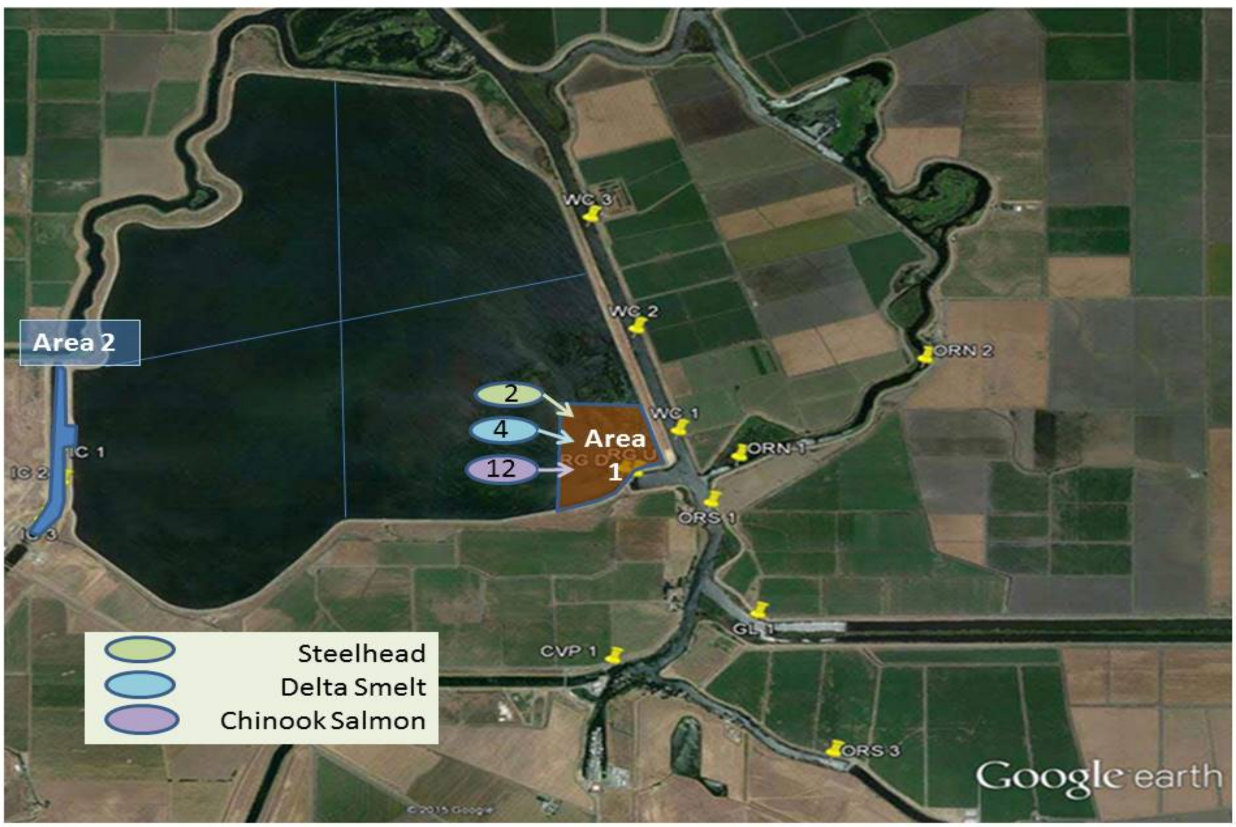


Figure 47: Special-Status Species Detected in January 2015

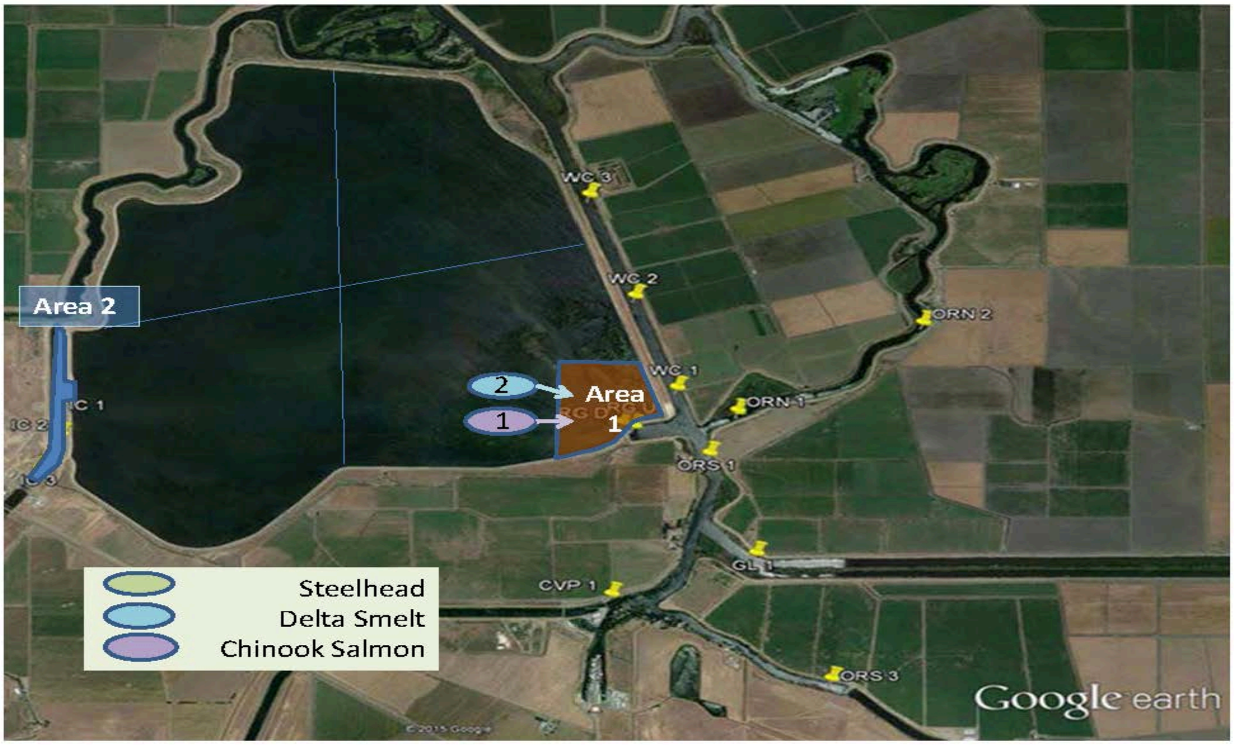


Figure 48: Special-Status Species Detected in February 2015

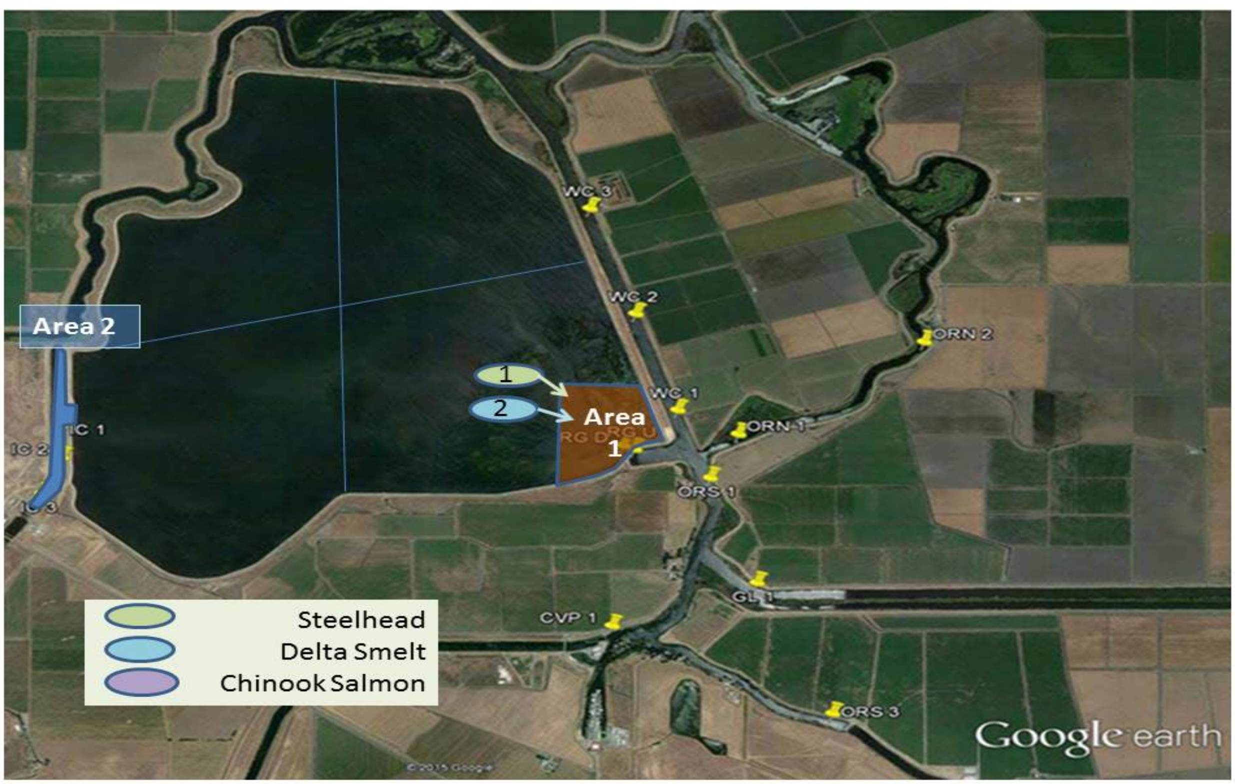
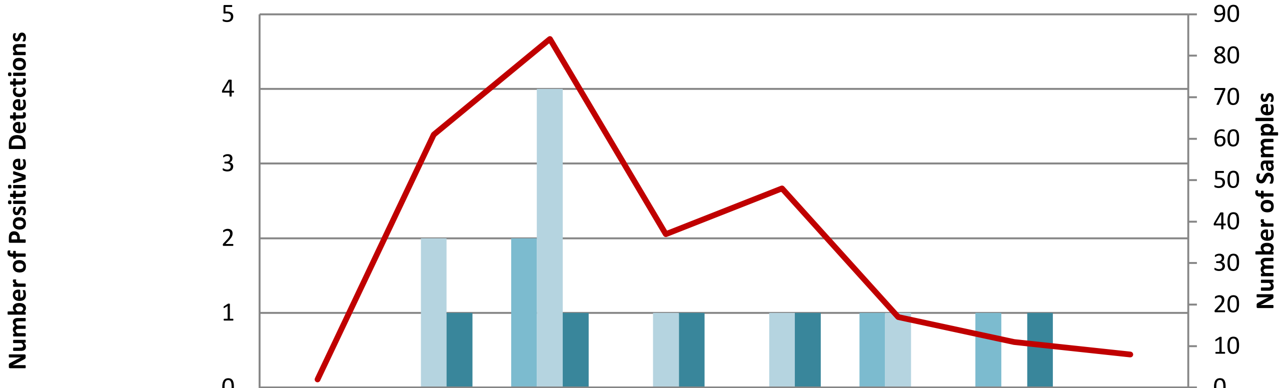


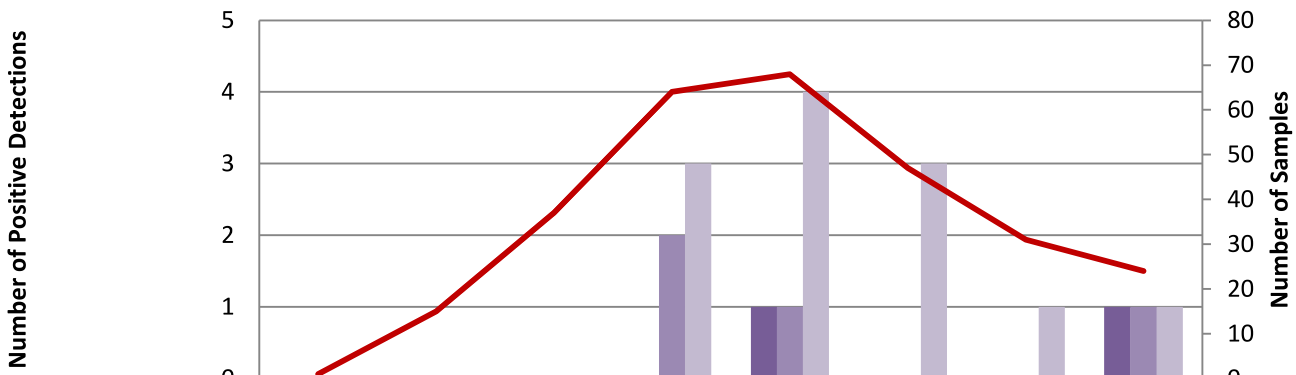
Figure 49: Special-Status Species Detected in March 2015

Samples with positive detections for special-status species were found at higher frequencies in the size groups that had the highest capture rate (Figure 50, 51, 52, 53).



	Fork Length 20-25	Fork Length 25.1-30	Fork Length 30.1-35	Fork Length 35.1-40	Fork Length 40.1-45	Fork Length 45.1-50	Fork Length 50.1-55	Fork Length 55.1 and over
Steelhead	0	0	2	0	0	1	1	0
Delta Smelt	0	2	4	1	1	1	0	0
Chinook Salmon	0	1	1	1	1	0	1	0
Samples	2	61	84	37	48	17	11	8

Figure 50: Special-Status Species Detected by Sample Size Class December 2014

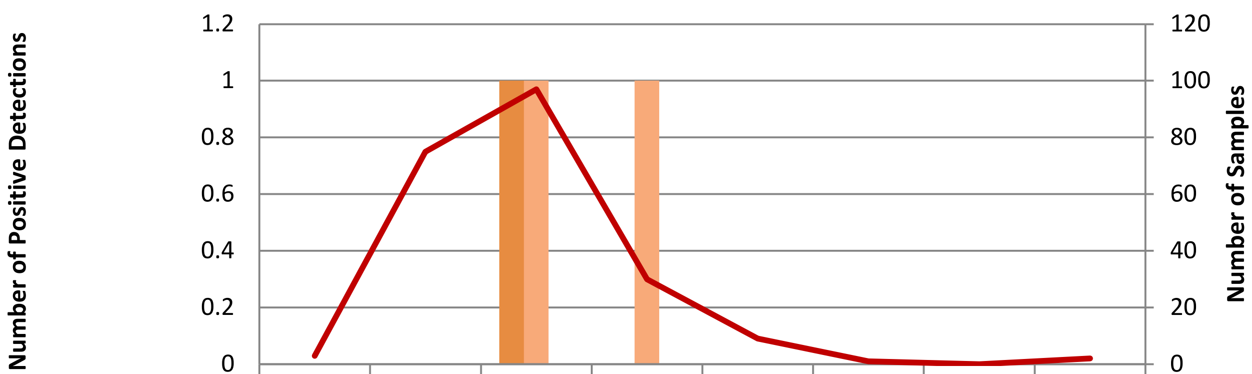


	Fork Length 20-25	Fork Length 25.1-30	Fork Length 30.1-35	Fork Length 35.1-40	Fork Length 40.1-45	Fork Length 45.1-50	Fork Length 50.1-55	Fork Length 55.1 and over
Steelhead	0	0	0	0	1	0	0	1
Delta Smelt	0	0	0	2	1	0	0	1
Chinook Salmon	0	0	0	3	4	3	1	1
Samples	1	15	37	64	68	47	31	24

Figure 51: Special-Status Species Detected by Sample Size Class January 2015

	Fork Length 20-25	Fork Length 25.1-30	Fork Length 30.1-35	Fork Length 35.1-40	Fork Length 40.1-45	Fork Length 45.1-50	Fork Length 50.1-55	Fork Length 55.1 and over
Steelhead	0	0	0	0	0	0	0	0
Delta Smelt	0	0	0	2	0	0	0	0
Chinook Salmon	0	0	1	0	0	0	0	0
Samples	9	54	66	89	88	31	14	25

Figure 52: Special-Status Species Detected by Sample Size Class February 2015



	Fork Length 20-25	Fork Length 25.1-30	Fork Length 30.1-35	Fork Length 35.1-40	Fork Length 40.1-45	Fork Length 45.1-50	Fork Length 50.1-55	Fork Length 55.1 and over
Steelhead	0	0	1	0	0	0	0	0
Delta Smelt	0	0	1	1	0	0	0	0
Chinook Salmon	0	0	0	0	0	0	0	0
Samples	3	75	97	30	9	1	0	2

Figure 53: Special-Status Species Detected by Sample Size Class March 2015

2.4.5 *Discussion and Recommendations*

The 2014-2015 genetics effort used lessons learned from the 2013-2014 effort to streamline sampling protocols, allowing for a much larger overall catch, with enough monthly depth for binning of size classes for more in depth evaluation. The goal for the effort was to catch approximately 200 Striped Bass each month, distributed across the available size classes commonly caught within the Forebay, throughout the time period during which the special status juvenile Chinook Salmon, steelhead and Delta Smelt would have the potential to be present.

A total of 1,141 Striped Bass were collected; 269 in December 2014, 286 in January 2015, 350 in February 2015, 217 in March 2015 and 19 in April 2015. The catch was binned into groups ranging from 20cm to 55cm and over, in 5 cm increments. The largest groups of fish were in the 25 cm to 45 cm bins, with an average fork length of 38.6 cm. The largest numbers of Striped Bass captured were in Area 1, representing 90% of the total catch.

Nine of the possible 11 prey species that could be identified as present were found during the sampling season. The two species not detected were Green Sturgeon (*Acipenser medirostris*) and Longfin Smelt (*Spirinchus thaleichthys*). Positive detections of prey species were found in 270 of the samples collected, representing 23.6 % of the total catch. The most frequently detected prey species in December were Largemouth Bass and Threadfin Shad **(***Dorosoma petenense*), making up 26% and 42% of the positive detections respectively. It is likely that a far larger percentage of fish did have prey in their stomach, but that prey remained undetected as it was either Striped Bass, which would be indistinguishable from the predator, or a species not included in the prey species tested for.

Steelhead (*Onchorhynchus mykiss*), Delta Smelt **(***Hypomesus transpacificus*) and Chinook Salmon (*Oncorhynchus tshawytscha*), were detected in samples from Area 1 and 2. Chinook Salmon were the most frequently detected special-status species, with 18 detections, followed by 17 Delta Smelt detections and seven steelhead detections. In December, detections were found in all Striped Bass bin groups from 25 cm to 55cm. In January, positive detections were only found in bin groups between 35 cm and above. In February and March, positive detections were found in bin groups from 30 cm to 40 cm. Number of detections increased with number of samples across size classes, and the bulk of the detections occurred in December and January. No clear relationship between predator size and prey detection was identified, however, due to the unevenly distributed size binning, there could be trends that are not evident in the current data set.

It is recommended that additional sampling efforts, with an increased emphasis on even distribution of sample size be undertaken to further examine the relationship between predator size and prey selection.

2.5 Creel Surveys

2.5.1 Methods

Roving angler (creel) surveys were planned for three days a week, two week days and one weekend day, and were conducted either in the morning (0900 until noon) or the afternoon (noon until 1600). Surveys were conducted along a set route (Figure 54) from Fisherman's Point to the Radial Gates. While anglers can access the Forebay throughout the evening hours as well, no surveys were conducted at night, due to safety concerns. Survey days and time periods were randomly selected by rolling dice, with each side of the die associated with a day or time (Table 18). Weekend surveys were always conducted on Saturdays in 2015.

Figure 54: Creel Survey Route

Table 18: Creel Survey Selection

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Time	Morning	Morning	Morning	Afternoon	Afternoon	Afternoon

2.5.2 *Issues*

Surveys were limited to daylight hours, and anglers standing on the wing-walls, or wading into the Forebay, were not interviewed, due to safety concerns. Weekend surveys were only conducted on Saturdays, due to the difficulty of staffing Sunday shifts.

2.5.3 *Data Analysis*

Data was recorded onto Rite-in Rain data sheets. Data sheets were scanned and data was entered into an access database. Total catch, catch by species, and catch by location for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(*q* = catchability (fish caught per hours of sampling), *C* = catch, *f* = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE for all species per month was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and *d* = number of sampling days in the month)

2.5.4 *Results*

A total of 108 roving surveys from the tip of the Fisherman's Point peninsula to the Radial Gates along the public access pathway (Figure 54) were conducted between January 5, 2015 and December 29, 2015.

A total of 1,247 anglers were observed fishing at the Clifton Court Forebay in 2015. Anglers were found to fish in the greatest numbers on Saturdays (Figure 55) and averaged 11 anglers per day throughout the year, with the highest numbers of anglers present in April (Figure 56).

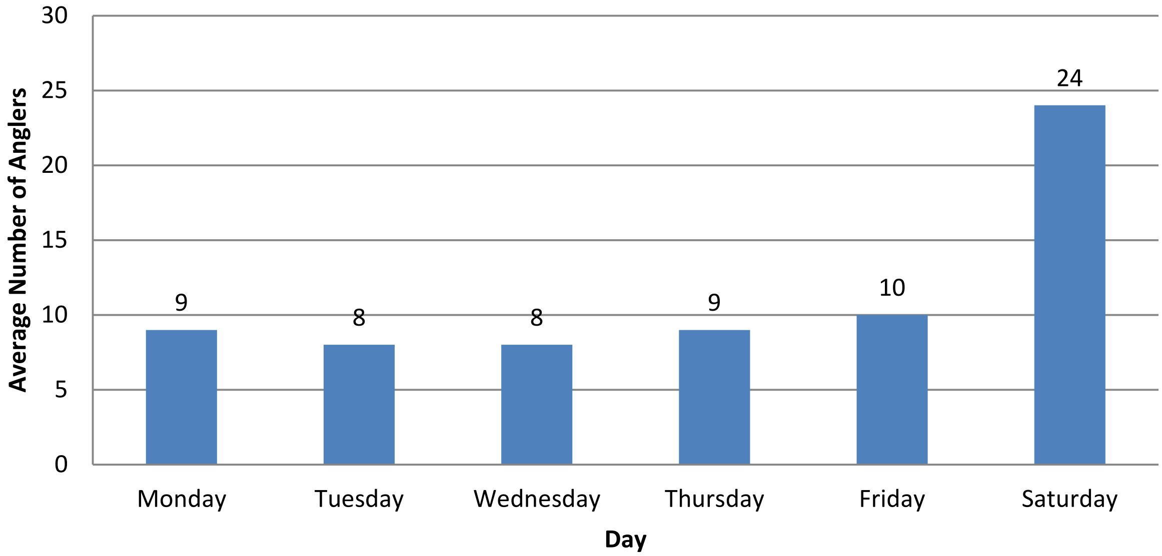


Figure 55: Average Number of Anglers by Day of Week in 2015

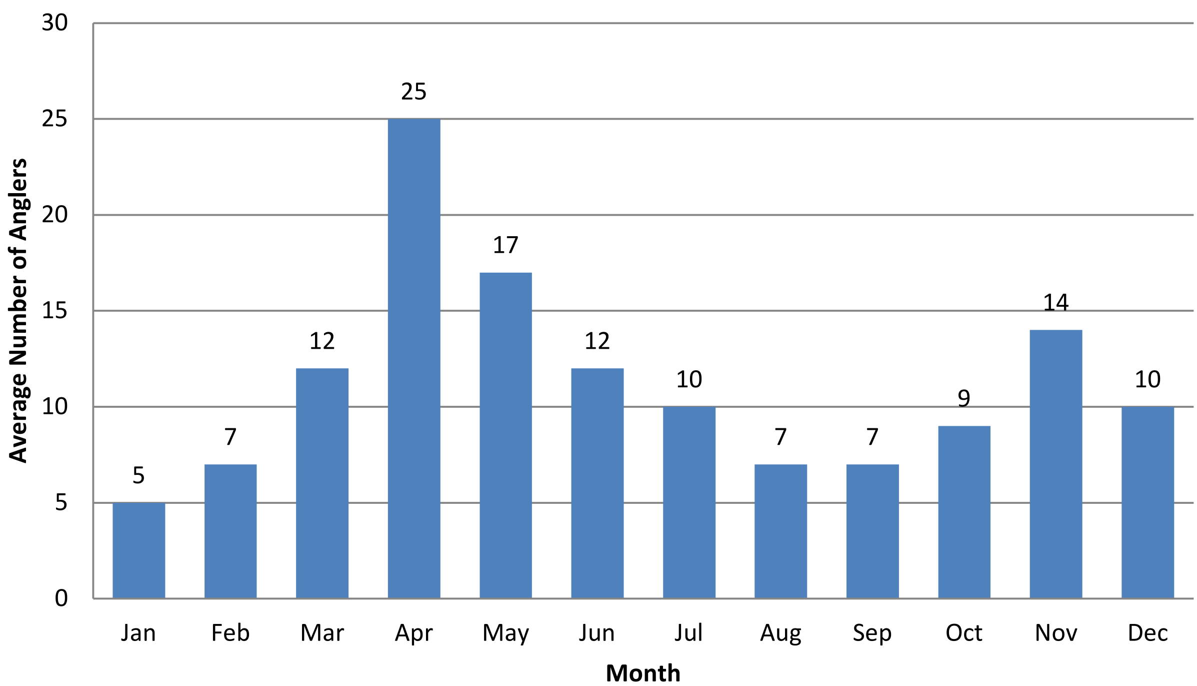


Figure 56: Average Number of Anglers by Month in 2015

Anglers fished a total of 3,384.42 hours over the survey period, with the greatest number of hours spent in Area 2 at 1,391.92 hours followed by Area 4 and Area 1, at 772.97 and 740.52 respectively. The least number of hours were spent in Area 6 at 76.75 hours (Table 19).

Table 19: Hours Fished by Month and Location 2015

Month	1 - Radial Gates Vicinity	2 - Intake Canal	3 - Southeast Corner	4 - Southwest Corner	5 - Northwest Corner	6 - Northeast Corner
Jan	26.92	25.00	0.00	18.13	2.00	0.00
Feb	30.00	28.81	0.00	30.24	7.50	0.00
Mar	37.00	76.50	26.00	70.15	19.00	8.50
Apr	139.00	146.04	19.50	192.40	52.25	6.00
May	117.50	277.90	27.50	77.25	42.75	16.25
Jun	116.50	145.40	15.00	68.46	43.60	0.00
Jul	68.50	115.50	0.00	39.90	19.00	5.00
Aug	74.50	128.30	0.00	11.35	20.00	12.00
Sep	33.00	28.32	2.50	23.25	10.00	0.00
Oct	51.00	166.08	37.00	55.53	44.16	20.00
Nov	36.60	57.57	0.00	128.75	3.00	5.00
Dec	10.00	196.50	0.00	57.56	11.50	4.00
Total	740.52	1391.92	127.50	772.97	274.76	76.75

Of the 108 surveys conducted in 2015, the fewest surveys were conducted in November and December at seven each, and the most in May, at 13 (Figure 57). Surveys were conducted on all days of the week, except Sundays. The day of week with the fewest surveys was Wednesday at nine, and the day with the most surveys conducted was Monday at 24 surveys (Figure 58).

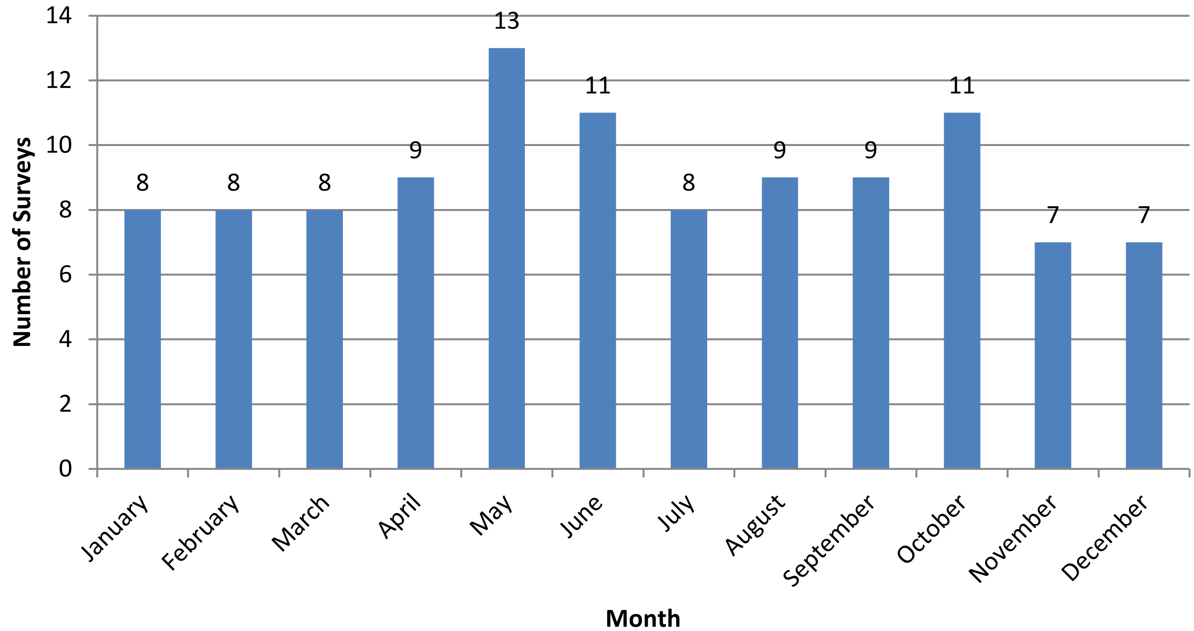


Figure 57: Number of Surveys per Month in 2015

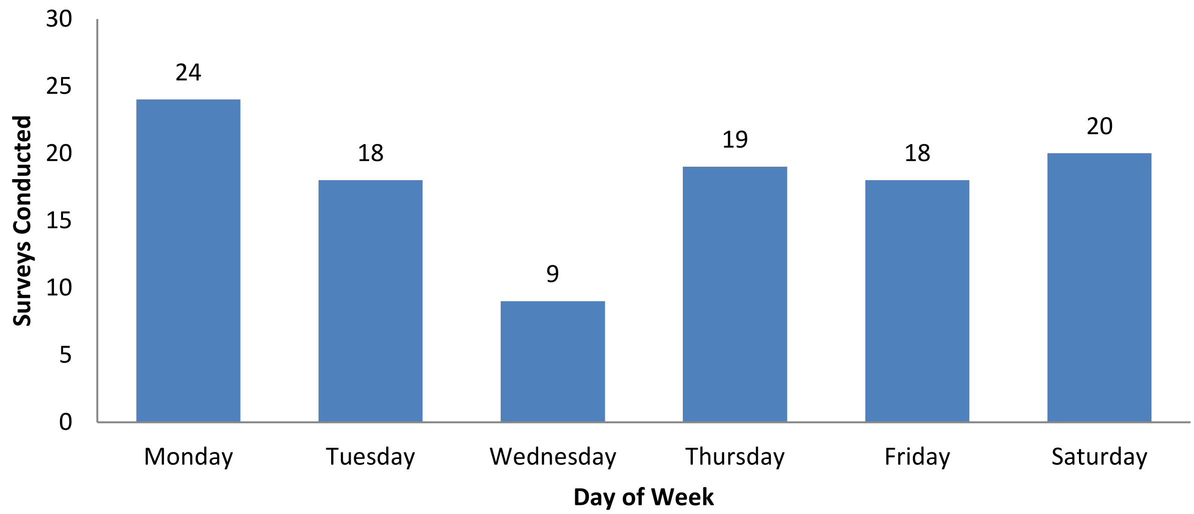


Figure 58: Number of Surveys per Day in 2015

Anglers that were interviewed captured a total of 1,631 fish during the survey period, with the catch ranging from 27 fish in January to 278 fish in April (Table 20). Eight of these fish were recaptures from the predator sampling effort, including four Striped Bass and four Largemouth Bass. Of the 1,631 fish captured, anglers reported releasing 1,271, or 78% of the total catch, back into the Forebay.

Table 20: Total Catch by Location and Month 2015

Month	1 - Radial Gates Vicinity	2 - Intake Canal	3 - Southeast Corner	4 - Southwest Corner	5 - Northwest Corner	6 - Northeast Corner	All Sites
Jan	2	0	0	25	0	0	27
Feb	42	8	0	21	5	0	76
Mar	26	70	12	95	13	6	222
Apr	55	50	10	85	67	11	278
May	75	58	8	21	13	4	179
Jun	78	48	4	28	4	0	162
Jul	47	35	0	7	2	0	91
Aug	31	43	0	3	3	6	86
Sep	25	0	0	5	9	0	39
Oct	55	85	8	30	48	17	243
Nov	23	27	0	105	17	0	172
Dec	2	33	0	15	6	0	56
2015	461	457	42	440	187	44	1631

CPUE was calculated for total catch at each location by month, and was found to range from 0.20 in January to 1.61 in March (Table 21, Figure 59) with all sites combined. The highest CPUE was at Area 5 during November, at 5.56.

Table 21: CPUE by Location and Month in 2015

Month	1 - Radial Gates Vicinity	2 - Intake Canal	3 - Southeast Corner	4 - Southwest Corner	5 - Northwest Corner	6 - Northeast Corner	All Sites
Jan	0.21	0.00	-	0.60	0.00	-	0.20
Feb	1.03	0.24	-	0.39	1.25	-	0.73
Mar	0.57	2.70	0.53	1.16	1.29	3.42	1.61
Apr	0.82	0.32	0.67	1.10	1.52	2.25	1.11
May	0.76	0.23	0.17	0.20	0.94	0.33	0.44
Jun	0.94	0.50	0.38	0.43	0.09	-	0.47
Jul	0.57	0.70	-	0.16	0.10	0.00	0.31
Aug	1.55	0.23	-	0.21	0.21	0.50	0.54
Sep	0.84	0.00	0.00	1.07	3.61	-	1.10
Oct	0.67	1.60	0.43	1.36	1.09	1.95	1.18
Nov	0.55	0.40	-	0.57	5.56	0.00	1.42
Dec	0.17	0.27	-	0.23	0.30	0.00	0.19

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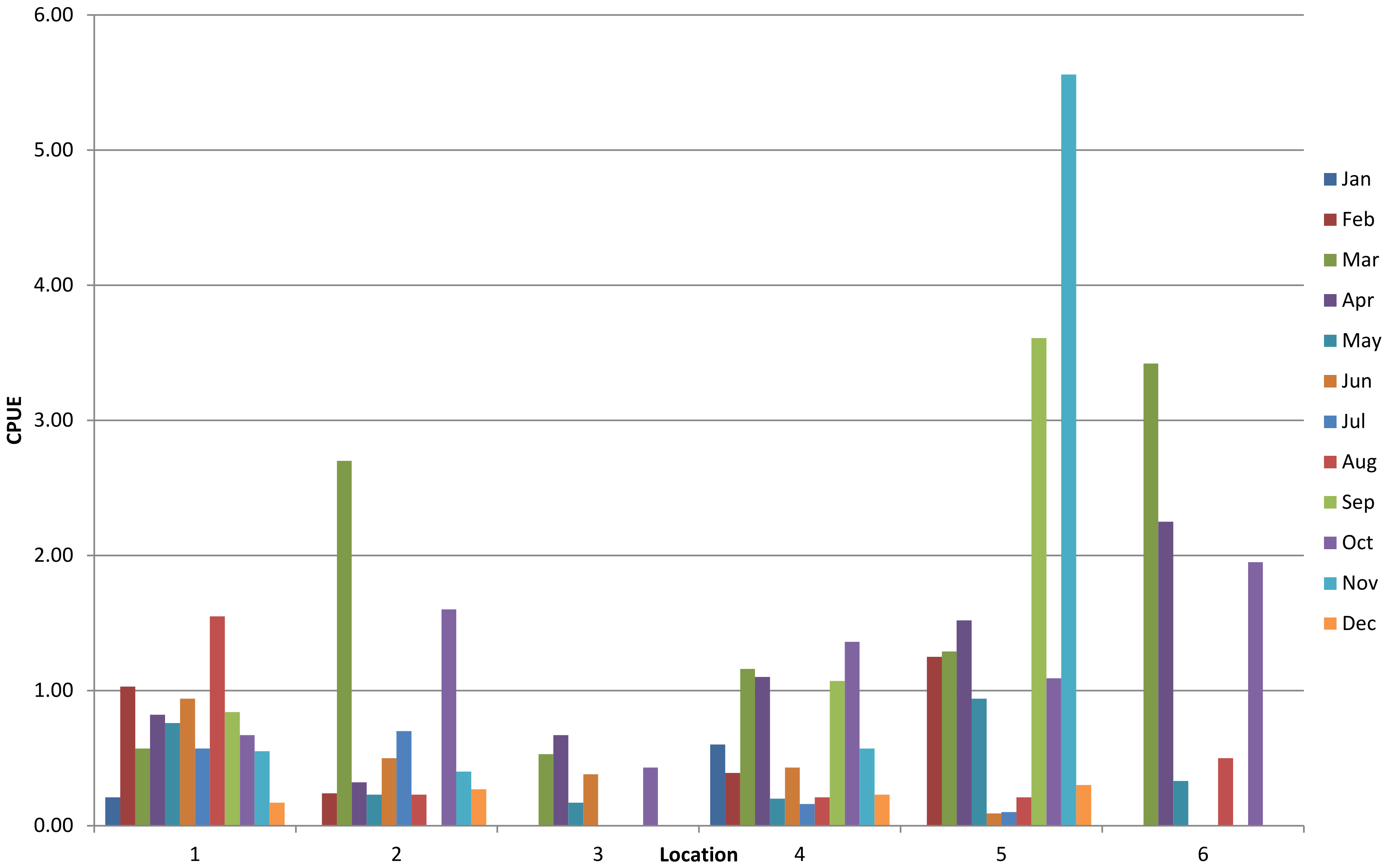


Figure 59: CPUE by Location and Month in 2015

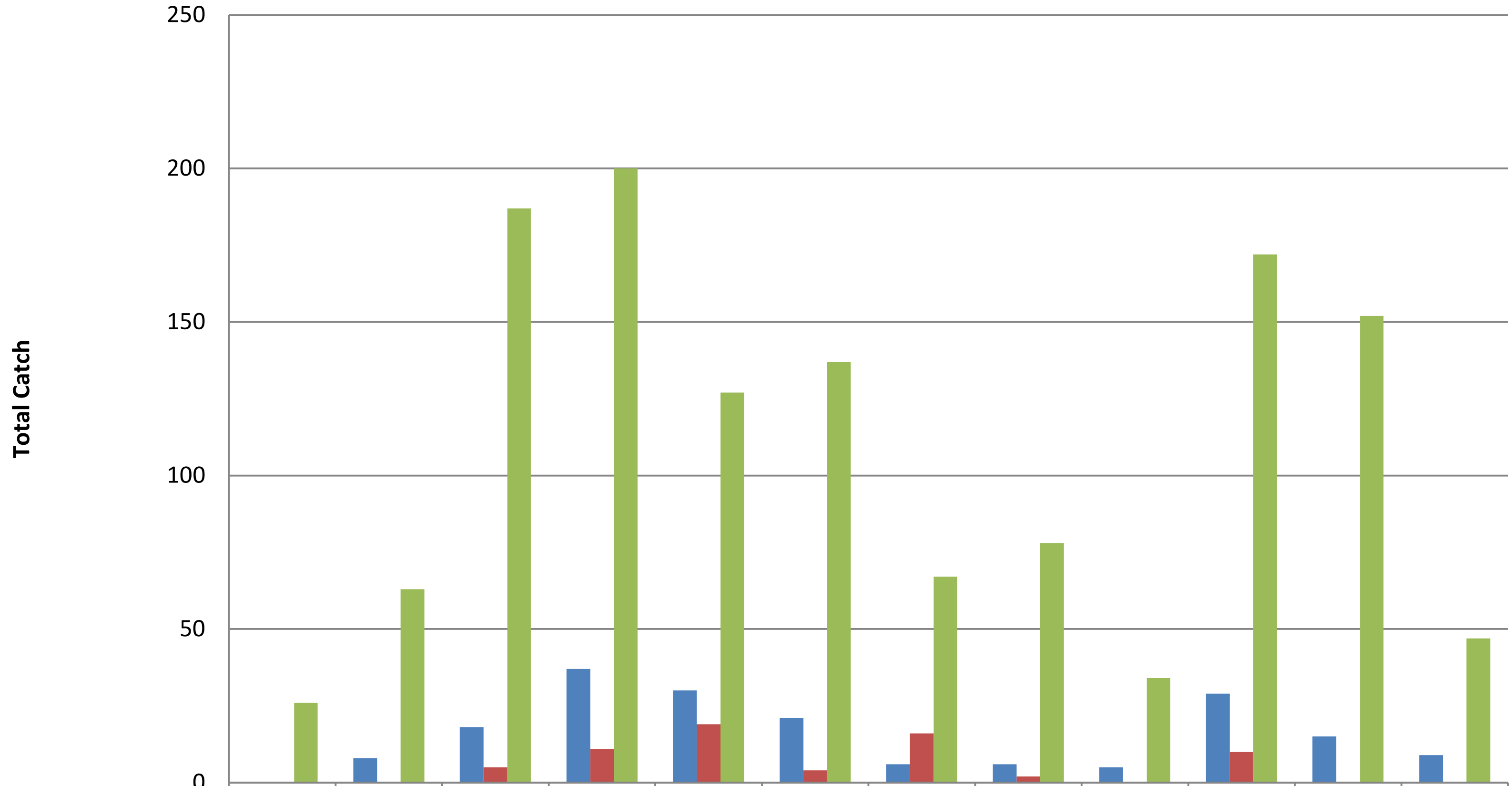
Anglers caught 1,290 Striped Bass during the survey period, which made up 79% of the total catch of 1,631 fish. The second most commonly caught fish was Largemouth Bass, at 184 fish, followed by catfish[4] at 67 fish and then Bluegill **(***Lepomis macrochirus*), at 62 fish, or 11%, 4%, and 4% of the total catch, respectively (Table 22). One adult Chinook Salmon was caught in November.

Table 22: Total Catch by Species and Month in 2015

	Unknown	American Shad	Bluegill	Carp	Chinook Salmon (Adult)	Crappie	Red Ear Sunfish	Steelhead	Perch	Smallmouth Bass	Largemouth Bass	Green Sturgeon	White Sturgeon	Catfish (Any)	Striped Bass	Total Catch
Jan	0	0	1	0	0	0	0	0	0	0	0	0	0	0	26	27
Feb	2	0	1	0	0	1	0	0	0	1	8	0	0	0	63	76
Mar	0	0	0	0	0	0	0	0	0	12	18	0	0	5	187	222
Apr	0	0	30	0	0	0	0	0	0	0	37	0	0	11	200	278
May	0	0	3	0	0	0	0	0	0	0	30	0	0	19	127	179
Jun	0	0	0	0	0	0	0	0	0	0	21	0	0	4	137	162
Jul	0	0	2	0	0	0	0	0	0	0	6	0	0	16	67	91
Aug	0	0	0	0	0	0	0	0	0	0	6	0	0	2	78	86
Sep	0	0	0	0	0	0	0	0	0	0	5	0	0	0	34	39
Oct	10	0	22	0	0	0	0	0	0	0	29	0	0	10	172	243
Nov	0	0	4	0	1	0	0	0	0	0	15	0	0	0	152	172
Dec	0	0	0	0	0	0	0	0	0	0	9	0	0	0	47	56
2015	16	0	62	0	1	1	0	0	0	13	184	0	0	67	1290	1631

Angler catch of Striped Bass and Largemouth Bass peaked in April at 200 and 37 fish, respectively. Catfish peaked in May, with 19 fish (Figure 60).

[4] Catfish were not identified to species during the creel surveys, unless the survey crew was able to see the fish caught. Often, anglers did not specify the species. For this reason all catfish were pooled into a single group.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Largemouth Bass	0	8	18	37	30	21	6	6	5	29	15	9
Catfish (Any)	0	0	5	11	19	4	16	2	0	10	0	0
Striped Bass	26	63	187	200	127	137	67	78	34	172	152	47

Figure 60: Total Striped Bass, Largemouth Bass and Catfish by Month in 2015

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2.5.5 *Discussion and Recommendations*

Public fishing at the Forebay is restricted to the shore, from Fisherman Point to the Radial Gates, which reduces an angler's ability to reach the "hot spots" that are accessible by boat. In turn this reduces the portion of the total predatory fish population accessible within the casting envelope of approximately 100 feet from the shore. The bulk of anglers stay within this portion of the shore, however a small number of anglers fish along the portion of the shore that is beyond the Radial Gates, and some anglers have been observed wading into the Forebay in the vicinity of the Radial Gates. Anglers that were observed along the shore were asked to participate in the creel survey, but were not required to do so. Additionally, anglers that were in the water or along the wing walls protruding from the base of the Radial Gate structure were considered inaccessible and not included in the survey, to ensure the safety of the survey team. Most anglers that were encountered were willing to participate in the survey, with only 22 anglers (less than 2 percent of those surveyed) refusing to do so during the 2015 survey effort.

Anglers that were interviewed during creel surveys fished a total of 3,384 hours over the survey period, concentrated primarily in Area 2 (Intake Canal), which is the easiest area to access. When anglers were asked what fish they were targeting during the creel surveys, they often responded any fish or bass. A wide variety of fish were caught, including carp, shad, sunfishes, bass and catfish. Over 79% of the catch was Striped Bass during the survey period, followed by Largemouth Bass, catfish, and Bluegill. One adult Chinook Salmon was caught in November.

The experience level of anglers varied widely, from first time anglers to seasoned veteran recreational fishermen. This combined with variables such as weather conditions and gear selection led to an extremely variable CPUE. CPUE for the entire Forebay ranged from a low of 0.20 in January to a high of 1.61 in March. The highest localized CPUE was at Area 5 during the month of November, at 5.56. The very high CPUE experienced in Area 5, which is located just past the Fisherman's point area, along the access road, was likely an artifact of a small number of anglers with high success on one day, and is not indicative of average conditions in that area.

2.6 *Avian Surveys*

2.6.1 *Methods*

Avian point count surveys, in the vicinity of the radial gates and the vicinity of the trash rack (Figure 61, 62), were scheduled three days per week, including two week days and one weekend day. Surveys were conducted during one of three randomly selected time periods, morning (from just before sunrise until 0900), midday (1000 until 1200) or afternoon (from 1300 until 1600). The radial gates area was split into two separate survey areas to ensure adequate coverage on both sides of the structure.

Survey days and time periods were randomly selected by rolling dice, with each side of the die associated with a day or time (Table 23). A total of 320 surveys were conducted between January 5, 2015 and December 29, 2015. Of those 320 surveys, 79 were morning, 156 were midday, and 85 were afternoon.

Table 23: Randomized Survey Selection Process

Die Side	1	2	3	4	5	6
Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Re-roll
Time	Morning	Midday	Afternoon	Morning	Midday	Afternoon

Each survey was conducted by a minimum of two biologists for 20 minutes per survey location, using a Kowa TSN-821M or a Leupold SX-1 Ventana spotting scope and/or Nikon 8x42 Monarch binoculars from predetermined vantage points (Figure 61, 62) to ensure adequate coverage. Piscivorous birds were counted if they approached within, or flew above, the predetermined survey areas. No border of a survey area was more than 500 meters (m) from the established vantage point of the survey, so all birds were observed at relatively close range. All counted individuals were identified to species whenever possible. Additionally, behavioral observations were also made of all individuals. Behaviors were categorized as feeding, non-feeding, and flyover. An individual that was observed performing multiple behaviors was categorized under the behavior that it was performing a majority of the time observed.

Figure 61: Avian Survey Trash Rack Location

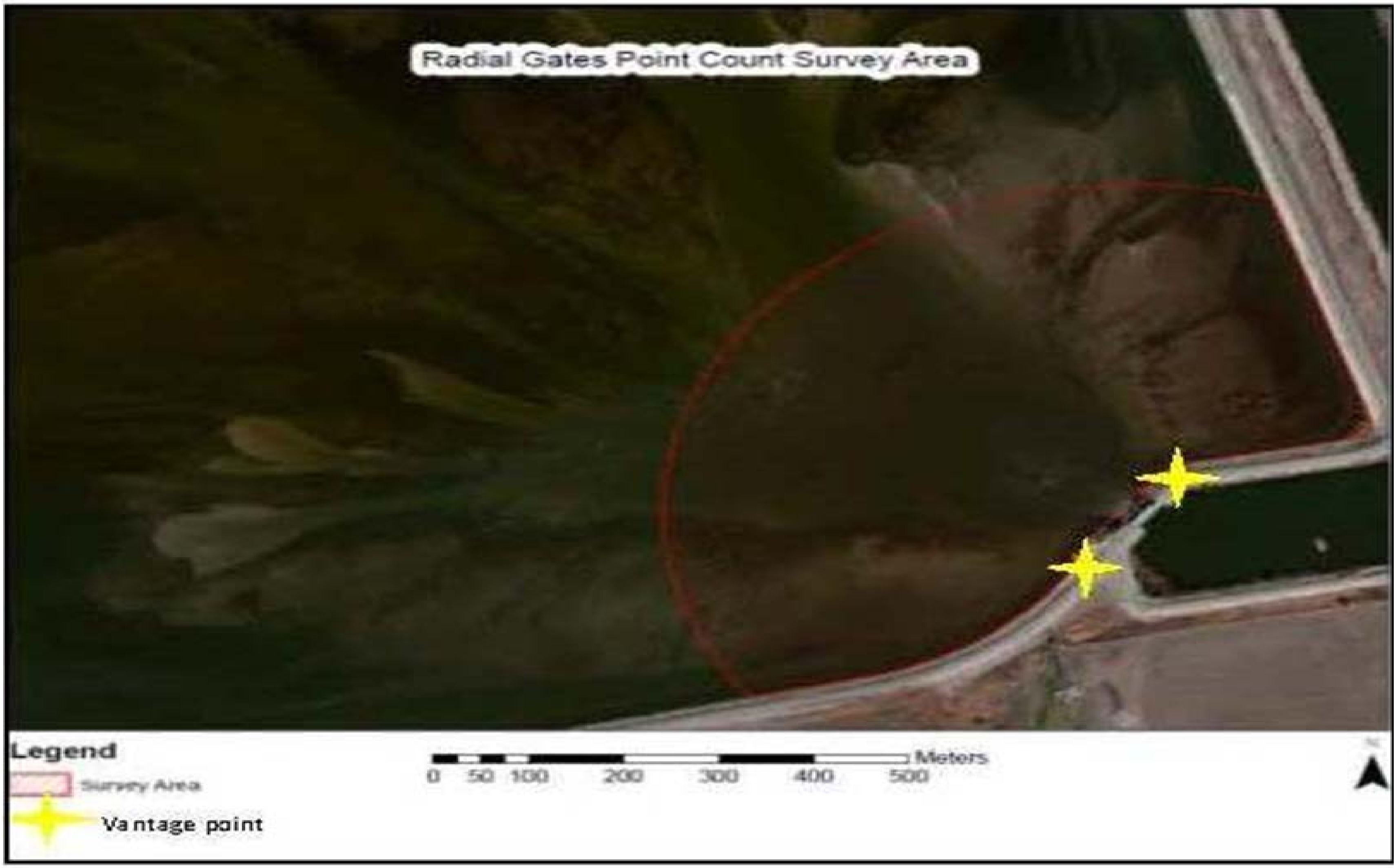

Figure 62: Avian Survey Radial Gates Locations (SW & NE)

2.6.2 *Issues*

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay continued to be followed according to the final procedural guide provided by DFD to BDO. The 2015 EROF for avian surveys was filed with DFD on December 1, 2014. Approval for 2015 avian surveys was confirmed on December 22, 2014. Avian surveys were conducted year-round at the radial gates and the trash racks. The Kowa spotting scope was damaged during a survey resulting in several weeks of surveys being conducted using only binoculars. A replacement scope was procured and used upon receipt.

2.6.3 *Data Analysis*

All data was recorded onto Rite-in-Rain data sheets. Data sheets were scanned and data entered into the database for analysis. Total numbers of species observed were compiled by month, location and behavior. Behavioral observations were compiled by month, location and species.

2.6.4 *Results*

A total of 320 surveys were conducted between January 5, 2015 and December 29, 2015 and bird sightings totaled 10,269 piscivorous birds (Table 24); 5,323 at the Trash Racks (Table 25), 2,907 at the Radial Gates SW (Table 26) and 2,050 at Radial Gates NE (Table 27). The highest numbers of avian species were observed in the months of February and September at 2,256 and 1,148 respectively. Of those 10,269 birds sighted, the most commonly observed at the Forebay were gulls (*Larus sp.*), double-crested cormorants (*Phalacrocorax auritus*), pied-billed grebes (*Podilymbus podiceps*), and American white pelicans (*Pelecanus erythrorhynchos*) (Table 24). While efforts were made to ensure that birds were not double counted during each survey effort, it is likely that the same birds were often observed at the Forebay on subsequent days.

At the Trash Racks, bird sightings peaked in September, March and February, while at the radial gates, bird sightings peaked in July, August and December, when both radial gate sites were combined (Tables 25, 26 and 27).

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Table 24: Avian Species Observed at all Locations in 2015

Species	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 2015	Percentage Observed
American White Pelican	31	55	23	31	44	75	58	100	25	0	7	17	**466**	**5%**
Belted Kingfisher		0	0	0	0	0	0	2	1	0	0	0	**3**	**0%**
Black-Crowned Night Heron		0	0	0	0	0	3	0	3	2	0	2	**10**	**0%**
Caspian Tern		0	0	0	0	0	5	9	5	0	0	0	**19**	**0%**
Cattle Egret	1	1	0	0	0	0	0	1	0	0	0	0	**3**	**0%**
Clark's Grebe		1	1	2	8	17	42	23	22	32	1	0	**149**	**1%**
Common Goldeneye	101	32	17	1	0	0	0	0	1	0	15	84	**251**	**2%**
Common Merganser	4	1	2	0	1	0	0	0	0	0	0	0	**8**	**0%**
Common Tern		0	0	4	26	0	0	0	0	0	0	0	**30**	**0%**
Double-Crested Cormorant	147	123	128	132	102	114	147	193	187	244	178	150	**1845**	**18%**
Eared Grebe	21	18	0	0	0	0	0	1	4	15	37	4	**100**	**1%**
Forster's Tern		0	0	0	0	0	2	0	8	0	0	0	**10**	**0%**
Great Blue Heron	11	5	7	6	21	23	31	35	15	19	9	11	**193**	**2%**
Great Egret	9	5	3	5	5	12	56	31	33	60	26	9	**254**	**2%**
Green Heron		0	0	0	0	2	0	4	5	6	1	0	**18**	**0%**
Gull Sp.	223	895	860	12	92	218	256	309	1817	386	79	715	**5862**	**57%**
Hooded Merganser	3	0	0	0	0	0	0	0	0	2	0	0	**5**	**0%**
Horned Grebe		0	0	0	0	0	0	0	0	1	8	0	**9**	**0%**
Lesser Scaup	12	0	0	0	0	0	0	0	0	0	0	0	**12**	**0%**
Osprey		0	0	0	1	4	3	5	1	3	0	1	**18**	**0%**
Pied Billed Grebe	13	7	12	5	21	36	123	150	106	143	56	17	**689**	**7%**
Snowy Egret	2	2	0	0	6	5	31	68	15	29	5	3	**166**	**2%**
Tern (Unidentified)		1	0	4	2	7	0	0	0	2	0	0	**16**	**0%**
Western Grebe		2	0	0	6	45	36	16	8	14	3	3	**133**	**1%**
All Birds	**578**	**1148**	**1053**	**202**	**335**	**558**	**793**	**947**	**2256**	**958**	**425**	**1016**	**10269**	

Table 25: Avian Species Observed at the Trash Racks in 2015

Species	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 2015	Percentage Observed
American White Pelican	0	2	0	0	1	4	0	0	0	0	0	0	7	0%
Belted Kingfisher	0	0	0	0	0	0	0	1	1	0	0	0	2	0%
Black-Crowned Night Heron	0	0	0	0	0	0	0	0	2	2	0	1	5	0%
Caspian Tern	0	0	0	0	0	0	3	0	0	0	0	0	3	0%
Cattle Egret	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Clark's Grebe	0	0	0	0	2	3	0	0	2	5	0	0	12	0%
Common Goldeneye	89	9	3	1	0	0	0	0	0	0	8	63	173	3%
Common Merganser	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Common Tern	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Double-Crested Cormorant	39	49	35	29	14	9	12	9	5	56	54	44	355	7%
Eared Grebe	0	0	0	0	0	0	0	0	4	1	8	0	13	0%
Forster's Tern	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Great Blue Heron	5	2	3	3	5	6	5	9	7	11	7	4	67	1%
Great Egret	2	2	0	0	1	0	3	10	15	21	20	5	79	1%
Green Heron	0	0	0	0	0	0	0	1	4	4	0	0	9	0%
Gull Sp.	4	601	839	4	47	181	205	250	1762	367	43	117	4420	83%
Hooded Merganser	3	0	0	0	0	0	0	0	0	2	0	0	5	0%
Horned Grebe	0	0	0	0	0	0	0	0	0	0	6	0	6	0%
Lesser Scaup	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Osprey	0	0	0	0	0	0	1	1	0	1	0	0	3	0%
Pied Billed Grebe	3	2	5	2	8	9	3	1	10	44	18	6	111	2%
Snowy Egret	2	1	0	0	2	0	1	0	1	15	3	3	28	1%
Tern (Unidentified)	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Western Grebe	0	1	0	0	1	9	1	2	0	5	3	3	25	0%
All Birds	147	669	885	39	81	221	234	284	1813	534	170	246	5323	100%

Table 26: Avian Species Observed at the Radial Gates SW in 2015

Species	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 2015	Percentage Observed
American White Pelican	18	35	10	15	24	32	35	48	20	0	5	10	**252**	**9%**
Belted Kingfisher	0	0	0	0	0	0	0	1	0	0	0	0	**1**	**0%**
Black-Crowned Night Heron	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0%**
Caspian Tern	0	0	0	4	0	0	2	5	4	0	0	0	**15**	**1%**
Cattle Egret	0	0	1	0	0	0	0	1	0	0	0	0	**2**	**0%**
Clark's Grebe	0	0	1	2	5	9	20	15	16	11	0	0	**79**	**3%**
Common Goldeneye	3	10	8	0	0	0	0	0	1	0	4	8	**34**	**1%**
Common Merganser	2	0	0	0	0	0	0	0	0	0	0	0	**2**	**0%**
Common Tern	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0%**
Double-Crested Cormorant	82	57	63	75	51	75	105	131	160	134	99	82	**1114**	**38%**
Eared Grebe	4	1	0	0	0	0	0	1	0	2	14	1	**23**	**1%**
Forster's Tern	0	0	0	0	0	0	2	0	5	0	0	0	**7**	**0%**
Great Blue Heron	5	1	0	0	8	6	18	13	3	7	0	3	**64**	**2%**
Great Egret	1	1	0	1	0	2	22	8	10	27	2	3	**77**	**3%**
Green Heron	0	0	0	0	0	1	0	1	0	0	0	0	**2**	**0%**
Gull Sp.	148	269	14	3	6	10	38	27	42	15	25	240	**837**	**29%**
Hooded Merganser	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0%**
Horned Grebe	0	0	0	0	0	0	0	0	0	1	0	0	**1**	**0%**
Lesser Scaup	7	0	0	0	0	0	0	0	0	0	0	0	**7**	**0%**
Osprey	0	0	0	0	1	4	2	4	1	2	0	1	**15**	**1%**
Pied Billed Grebe	5	1	3	1	5	12	78	46	50	32	12	2	**247**	**8%**
Snowy Egret	0	0	0	0	1	0	22	16	9	8	0	0	**56**	**2%**
Tern (Unidentified)	0	0	0	1	2	6	0	0	0	1	0	0	**10**	**0%**
Western Grebe	0	0	0	0	2	22	25	9	3	0	0	0	**61**	**2%**
All Birds	275	375	100	102	105	179	370	326	324	240	161	350	**2907**	**100%**

Table 27: Avian Species Observed at the Radial Gates NE in 2015

Species	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total 2015	Percentage Observed
American White Pelican	13	18	13	16	19	39	23	52	5	0	2	7	**207**	**10%**
Belted Kingfisher	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0%**
Black-Crowned Night Heron	0	0	0	0	0	0	2	0	1	0	0	1	**4**	**0%**
Caspian Tern	0	0	0	0	0	0	0	4	1	0	0	0	**5**	**0%**
Cattle Egret	1	1	0	0	0	0	0	0	0	0	0	0	**2**	**0%**
Clark's Grebe	0	1	0	0	1	5	22	8	4	16	1	0	**58**	**3%**
Common Goldeneye	9	13	6	0	0	0	0	0	0	0	3	13	**44**	**2%**
Common Merganser	2	1	2	0	1	0	0	0	0	0	0	0	**6**	**0%**
Common Tern	0	0	0	0	26	0	0	0	0	0	0	0	**26**	**1%**
Double-Crested Cormorant	26	17	30	28	37	30	30	53	22	54	25	24	**376**	**18%**
Eared Grebe	17	17	0	0	0	0	0	0	0	12	15	3	**64**	**3%**
Forster'sTern	0	0	0	0	0	0	0	0	3	0	0	0	**3**	**0%**
Great Blue Heron	1	2	4	3	8	11	8	13	5	1	2	4	**62**	**3%**
Great Egret	6	2	2	4	4	10	31	13	8	12	4	1	**97**	**5%**
Green Heron	0	0	0	0	0	1	0	2	1	2	1	0	**7**	**0%**
Gull Sp.	71	25	7	5	39	27	13	32	13	4	11	358	**605**	**30%**
Hooded Merganser	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0%**
Horned Grebe	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**0%**
Lesser Scaup	5	0	0	0	0	0	0	0	0	0	0	0	**5**	**0%**
Osprey	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0%**
Pied Billed Grebe	5	4	4	2	8	15	42	113	46	67	26	9	**341**	**17%**
Snowy Egret	0	1	0	0	3	5	8	52	6	6	2	0	**83**	**4%**
Tern (Unidentified)	0	1	0	3	0	1	0	0	0	1	0	0	**6**	**0%**
Western Grebe	0	1	0	0	3	14	10	5	5	9	0	0	**47**	**2%**
All Birds	156	104	68	61	149	158	189	347	120	184	94	420	**2050**	**100%**

Species Richness

During the 2015 survey period numerous species of piscivorous birds were identified. The number of species was not constant over the course of the year with an overall peak in diversity from August through Mid- October and a low in March (Figure 63). Some species were observed every month, while others showed distinct seasonality to their occurrence patterns.

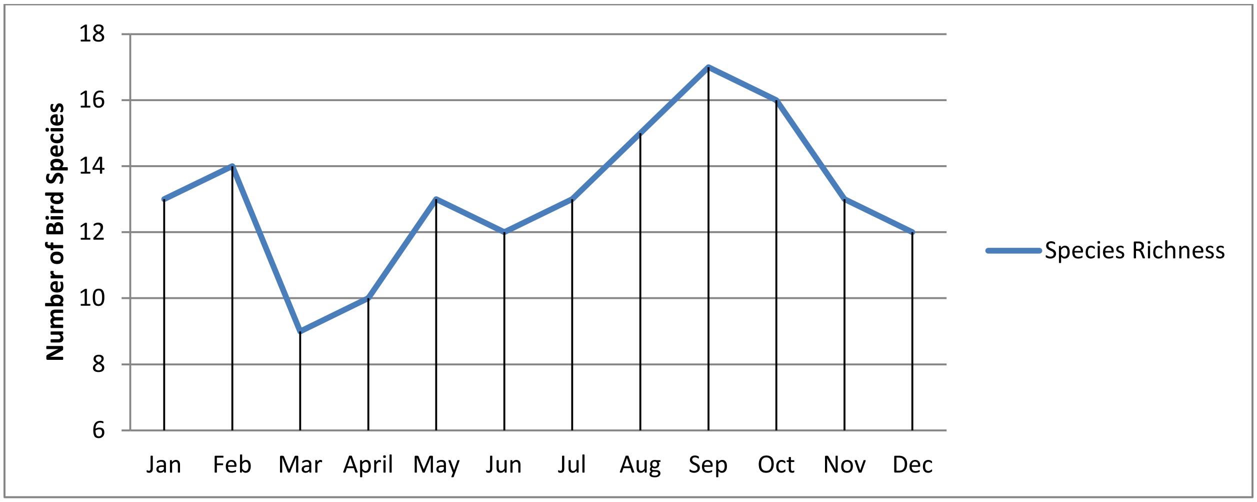


Figure 63: Total Species Richness of Piscivorous Birds at all Survey Locations in 2015

Species richness was not uniform across all survey locations. Generally, the trash rack location had lower species richness than the radial gates locations (Figure 64).

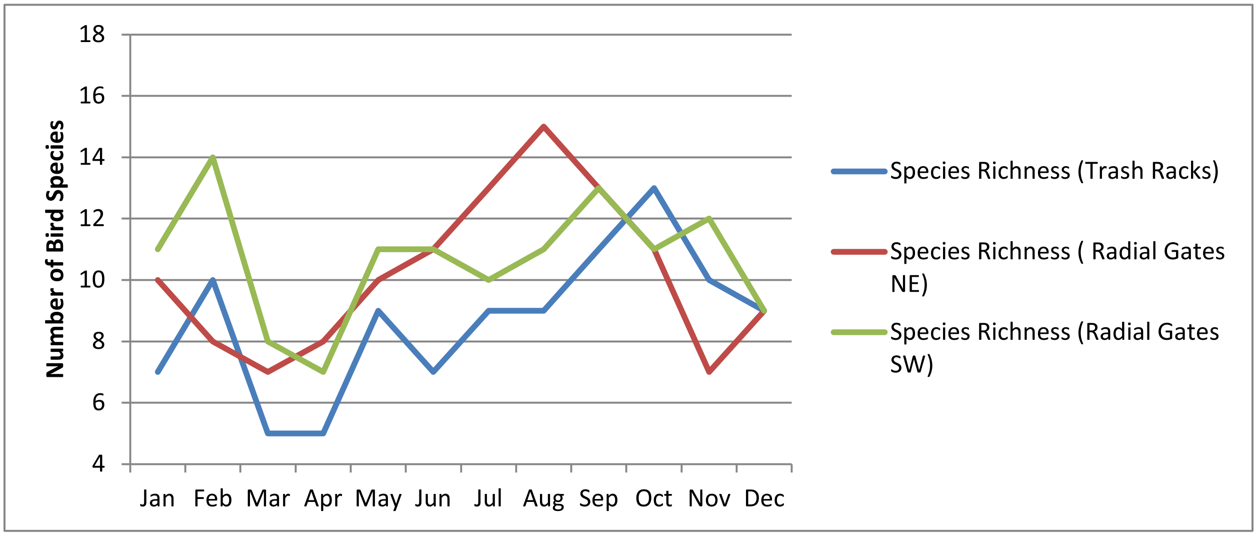
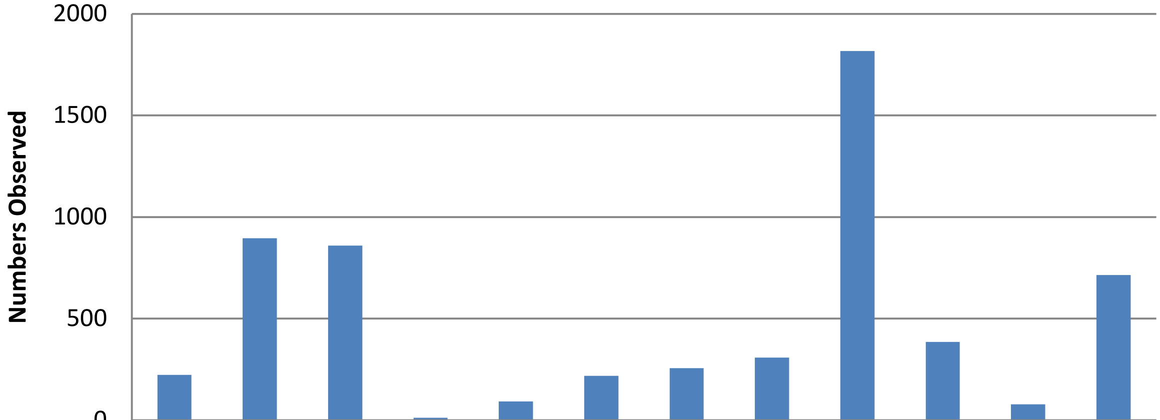


Figure 64: Species Richness of Piscivorous Birds at each Survey Location in 2015

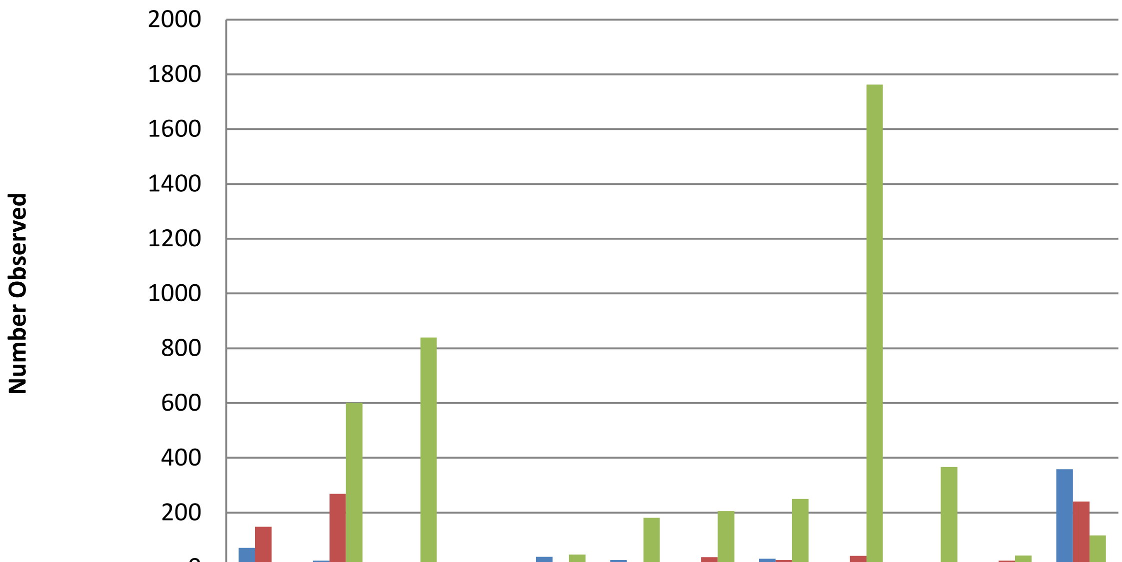
Species Numbers

Gulls were present during all of the months surveyed, however their numbers peaked dramatically in September at 1,817 (Figure 65). Gulls occurred at all locations in all months of the survey period (Figure 66).



	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gull Sp.	223	895	860	12	92	218	256	309	1817	386	79	715

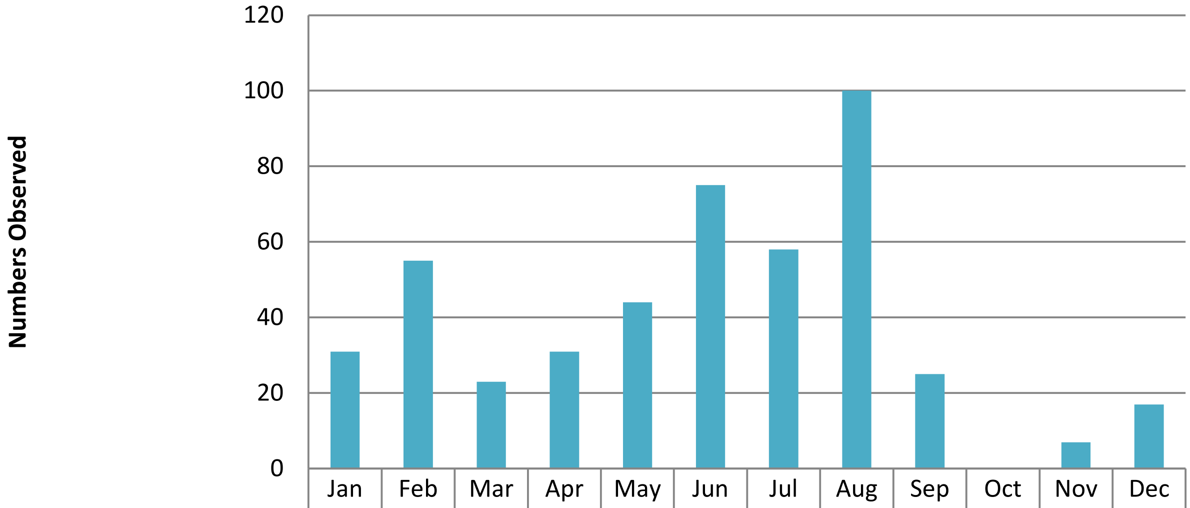
Figure 65: Gulls Observed by Month at all Locations in 2015



	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radial Gates NE	71	25	7	5	39	27	13	32	13	4	11	358
Radial Gates SW	148	269	14	3	6	10	38	27	42	15	25	240
Trash Racks	4	601	839	4	47	181	205	250	1762	367	43	117

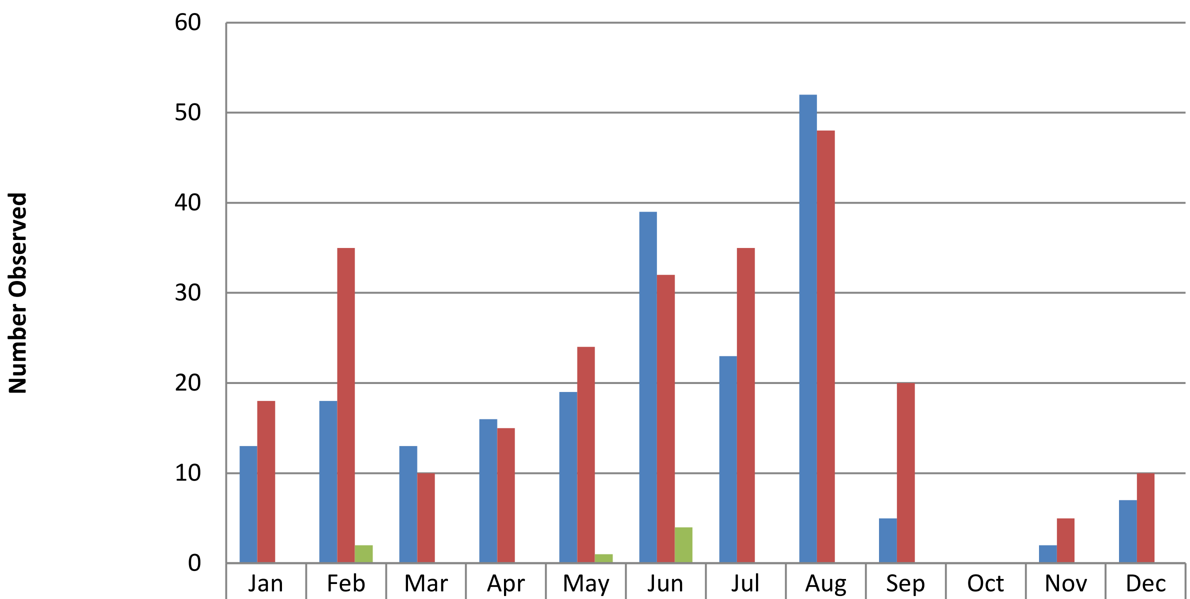
Figure 66: Gulls Observed by Location in 2015

American white pelicans were present in all of the months surveyed except October, with numbers peaking in August (Figure 67). This species was only observed in the vicinity of the trash racks in February, May and June (Figure 68), and when present very few were observed in that location.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American White Pelican	31	55	23	31	44	75	58	100	25	0	7	17

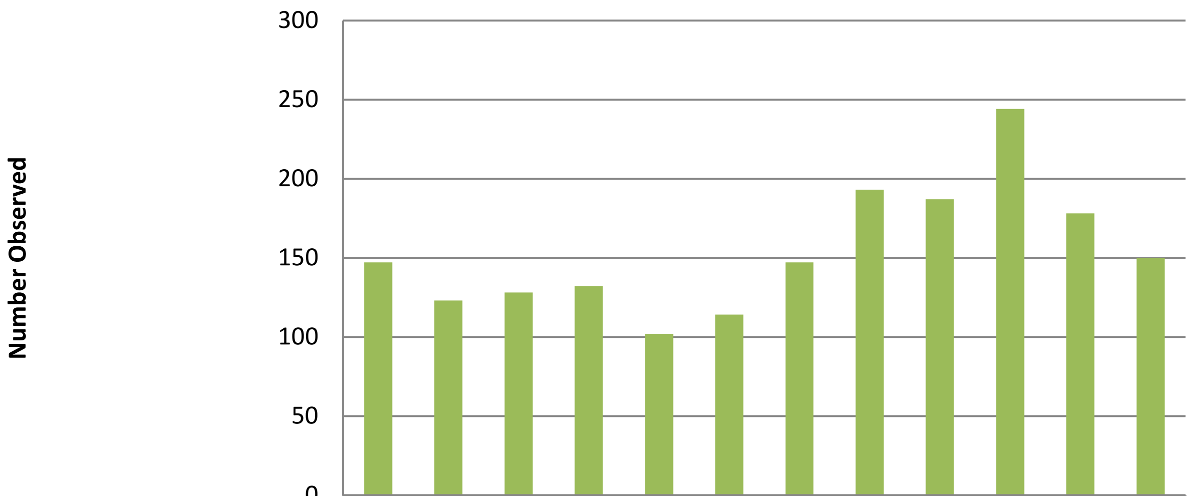
Figure 67: American White Pelicans Observed by Month at all Locations in 2015



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radial Gates NE	13	18	13	16	19	39	23	52	5	0	2	7
Radial Gates SW	18	35	10	15	24	32	35	48	20	0	5	10
Trash Rack	0	2	0	0	1	4	0	0	0	0	0	0

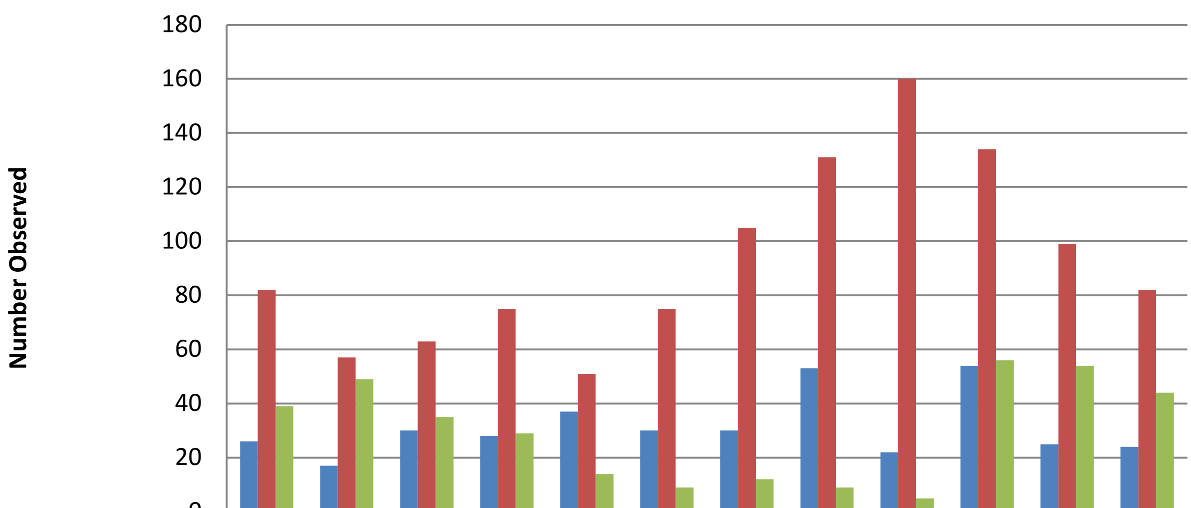
Figure 68: American White Pelicans Observed by Location in 2015

Double-crested cormorants were present during all of the months surveyed (Figure 69). Numbers peaked from August through November and dropped during May and June. Double-crested cormorants were observed at all of the sites throughout the survey period with generally higher numbers at the radial gates (Figure 70).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Double-Crested Cormorant	147	123	128	132	102	114	147	193	187	244	178	150

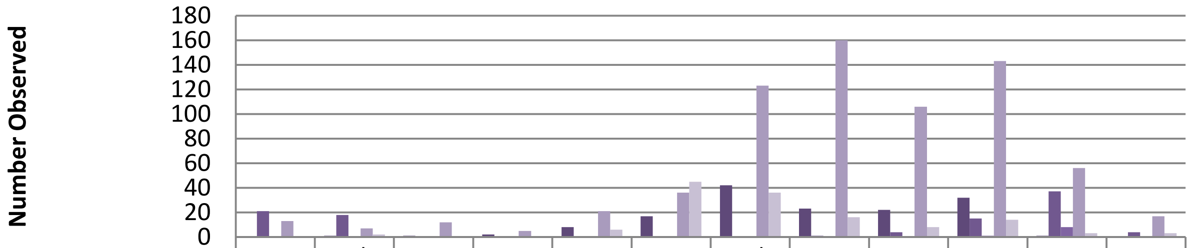
Figure 69: Double-Crested Cormorants Observed by Month at all Locations in 2015



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radial Gates NE	26	17	30	28	37	30	30	53	22	54	25	24
Radial Gates SW	82	57	63	75	51	75	105	131	160	134	99	82
Trash Racks	39	49	35	29	14	9	12	9	5	56	54	44

Figure 70: Double-Crested Cormorants Observed by Location in 2015

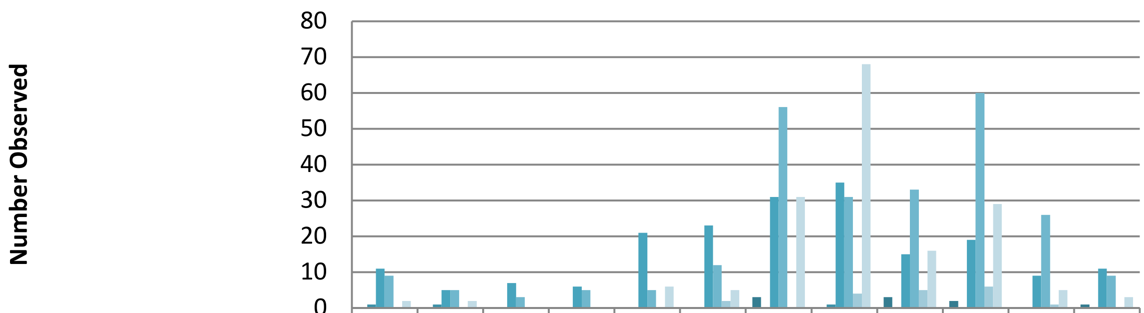
Five grebe species were observed during the survey, with numbers of some species, including pied-billed grebe, Western grebe (*Aechmophorus occidentalis*) and Clark's grebe (*Aechmophorus clarkii*) peaking from June to October, while numbers of eared grebe (*Podiceps nigricollis*) peaked in November. Horned grebes (*Podiceps auritus*) were uncommon on the Forebay, only present in October and November (Figure 71).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clark's Grebe	0	1	1	2	8	17	42	23	22	32	1	0
Eared Grebe	21	18	0	0	0	0	0	1	4	15	37	4
Horned Grebe	0	0	0	0	0	0	0	0	0	1	8	0
Pied Billed Grebe	13	7	12	5	21	36	123	160	106	143	56	17
Western Grebe	0	2	0	0	6	45	36	16	8	14	3	3

Figure 71: Grebe Species Observed by Month at all Locations in 2015

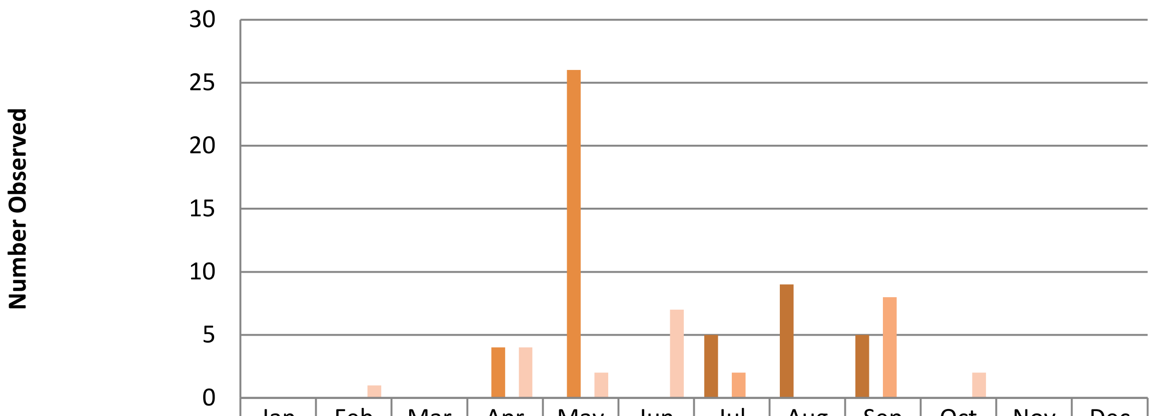
Six species of heron and egret were observed during the survey, with the most commonly observed species, great egret (*Ardea alba*), snowy egret (*Egretta thula*), and great blue heron (*Ardea herodias*) peaking from July through October (Figure 72).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black-Crowned Night Heron	0	0	0	0	0	0	3	0	3	2	0	1
Cattle Egret	1	1	0	0	0	0	0	1	0	0	0	0
Great Blue Heron	11	5	7	6	21	23	31	35	15	19	9	11
Great Egret	9	5	3	5	5	12	56	31	33	60	26	9
Green Heron	0	0	0	0	0	2	0	4	5	6	1	0
Snowy Egret	2	2	0	0	6	5	31	68	16	29	5	3

Figure 72: Herons and Egrets Observed by Month at all Locations in 2015

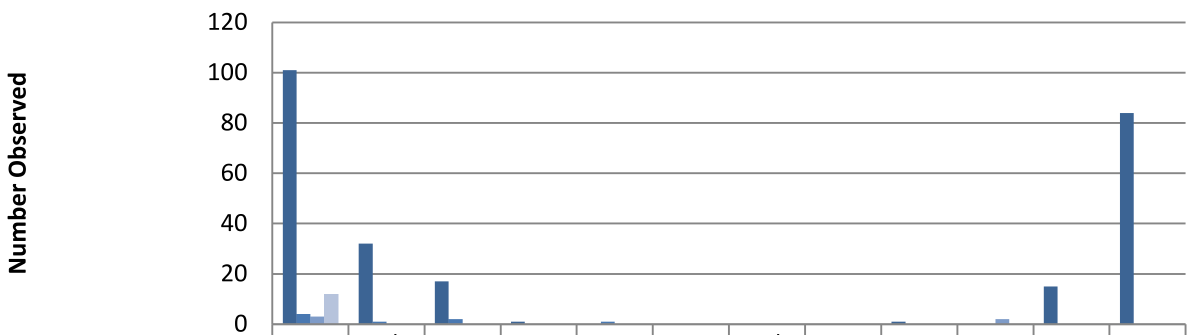
Three species of tern were observed at the Forebay; however, due to the difficulty with identifying some of the smaller species, not all terns were identified to species. Numbers for common terns (*Sterna hirundo*) observed peaked in May (Figure 73).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Caspian Tern	0	0	0	0	0	0	5	9	5	0	0	0
Common Tern	0	0	0	4	26	0	0	0	0	0	0	0
Forester's Tern	0	0	0	0	0	0	2	0	8	0	0	0
Unidentified Tern	0	1	0	4	2	7	0	0	0	2	0	0

Figure 73: Terns Observed by Month at all Locations in 2015

A number of piscivorous waterfowl species were observed during the survey period. The most common species was the common goldeneye (*Bucephala clangula*). Numbers of all species of piscivorous duck followed the same pattern, peaking in the winter months and completely absent in the summer months (Figure 74).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Common Goldeneye	101	32	17	1	0	0	0	0	1	0	15	84
Common Merganser	4	1	2	0	1	0	0	0	0	0	0	0
Hooded Merganser	3	0	0	0	0	0	0	0	0	2	0	0
Lesser Scaup	12	0	0	0	0	0	0	0	0	0	0	0

Figure 74: Piscivorous Waterfowl Species Observed by Month at all Locations in 2015

Osprey (*Pandion haliaetus*) numbers were generally low, but peaked from June through October (Figure 75).

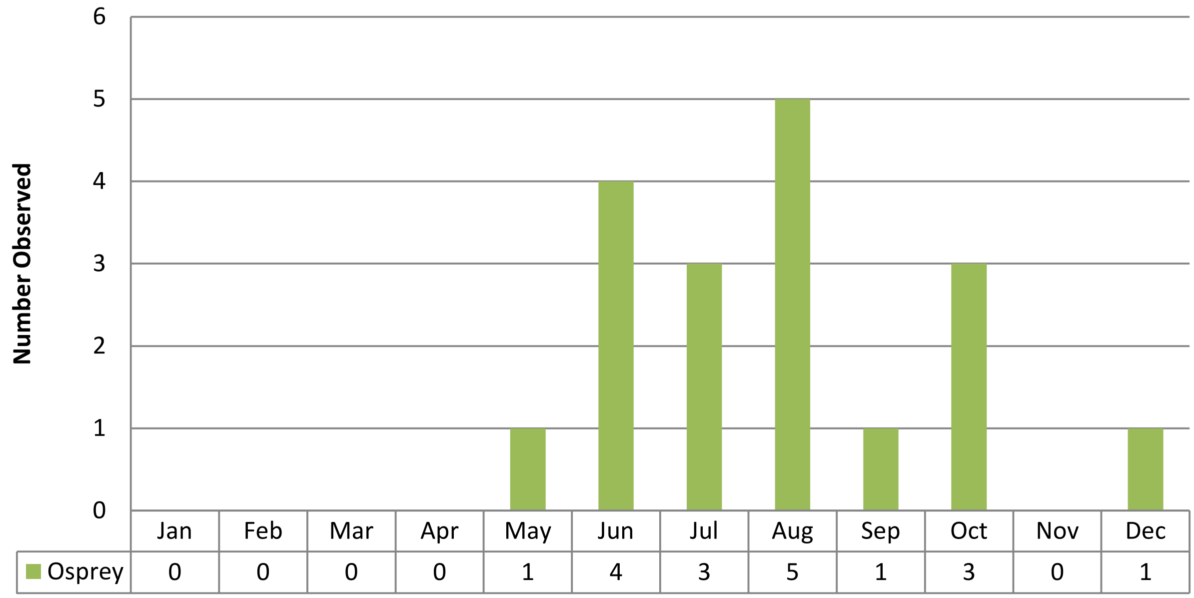


Figure 75: Osprey Observed by Month at all Locations in 2015

Belted kingfishers (*Ceryle alcyon*) were only observed in August and September (Figure 76).

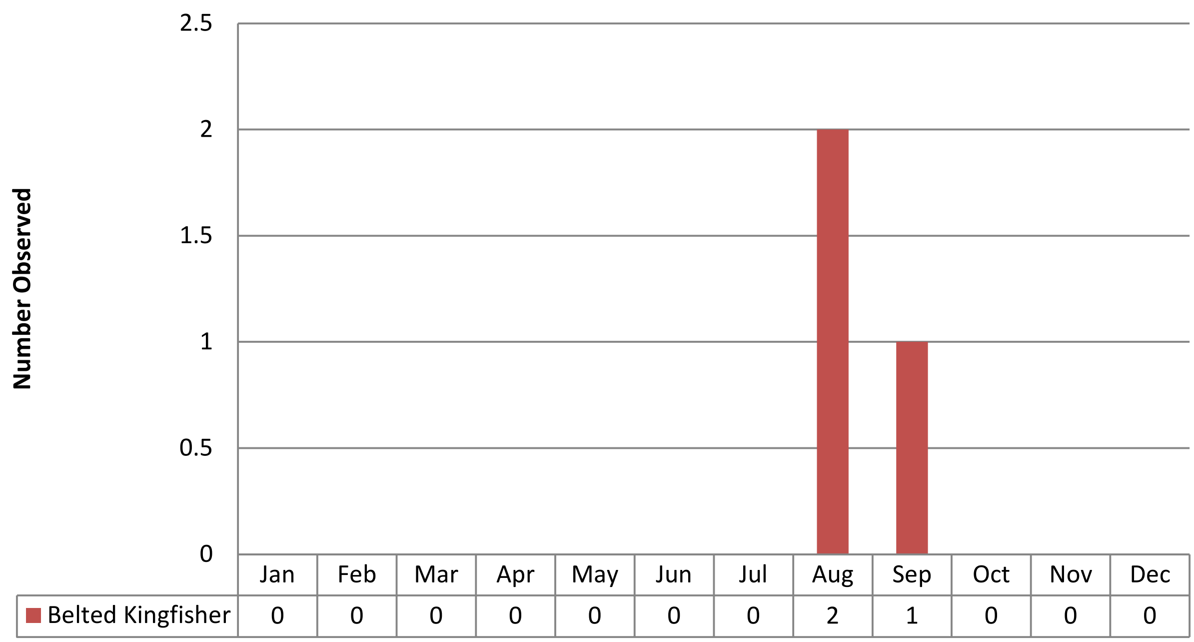


Figure 76: Belted Kingfisher Observed by Month at all Locations in 2015

Seasonality

During the winter months of January, February and December, species of birds that were observed to be feeding during 50% or more of the observations during one or more months included several species of grebe: pied-billed grebe (*Podilymbus podiceps*), eared grebe (*Podiceps nigricollis*), Western grebe (*Aechmophorus occidentalis*), and Clark's grebe (*Aechmophorus clarkii*), as well as several other piscivorous species: American white pelican (*Pelecanus erythrorhynchos*), cattle egret (*Bubulcus ibis*), common goldeneye (*Bucephala clangula*), common merganser (*Mergus merganser*), great egret (*Egreta alba*), great blue heron (*Ardea herodias)*, and snowy egret (*Egreta thula*) (Table 28). Of those species, only American white pelicans and common goldeneyes were also observed in large numbers (over 25 individuals).

During the spring months of March, April and May, species of birds that were observed to be feeding during 50% or more of the observations during one or more months included many species of grebe observed on Clifton Court Forebay as well as several other species. Grebes with high observed feeding rates included pied-billed grebe, Western grebe, and Clark's grebe. Other piscivorous species with high observed feeding rates included American white pelican, common goldeneye, common merganser, great blue heron, great egret, and osprey (*Pandion haliaetus*) (Table 29). Of those species, only American white pelicans were also observed in large numbers (over 25 individuals).

During the summer months of June, July and August, species of birds that were observed to be feeding during 50% or more of the observations during one or more months included several species of grebe observed on Clifton Court Forebay as well as several other species. Grebes with high observed feeding rates included pied-billed grebe, Western grebe, and Clark's grebe. Other piscivorous species with high observed feeding rates included American white pelican, belted kingfisher (*Ceryle alcyon*), black-crowned night heron (*Nycticorax nycticorax*), Forester's tern (*Sterna forsteri*), and snowy egret (Table 30). Of those species, only American white pelicans, pied billed grebes and snowy egrets were also observed in large numbers (over 25 individuals).

During the fall months of September, October and November, species of birds that were observed to be feeding during 50% or more of the observations during one or more months included all species of grebe observed on Clifton Court Forebay as well as several other species. Grebes with high observed feeding rates included pied-billed grebe, eared grebe, horned grebe, Western grebe, and Clark's grebe. Other piscivorous species with high observed feeding rates included American white pelican, common goldeneye, Forester's tern, great blue heron, and green heron (*Butorides virescens*)(Table 31).Of those species, only pied billed grebes, Clark's grebes and eared grebes were also observed in large numbers (over 25 individuals).

Table 28: Percent of Observed Birds Feeding at all Locations in Winter 2015

Month	January			February			December		
	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican	31	21	68%	55	31	56%	17	3	18%
Belted Kingfisher	-	-	-	-	-	-	-	-	-
Black-Crowned Night Heron	-	-	-	-	-	-	2	0	0%
Caspian Tern	-	-	-	-	-	-	-	-	-
Cattle Egret	1	0	0%	1	1	100%	-	-	-
Clark's Grebe	-	-	-	1	1	100%	-	-	-
Common Goldeneye	101	33	33%	32	22	69%	84	41	49%
Common Merganser	4	4	100%	1	1	100%	-	-	-
Common Tern	-	-	-	-	-	-	-	-	-
Double-Crested Cormorant	147	18	12%	123	26	21%	150	9	6%
Eared Grebe	21	20	95%	18	16	89%	4	3	75%
Forster's Tern	-	-	-	-	-	-	-	-	-
Great Blue Heron	11	2	18%	5	3	60%	11	3	27%
Great Egret	9	4	44%	5	4	80%	9	6	67%
Green Heron	-	-	-	-	-	-	-	-	-
Gull Sp.	223	103	46%	895	22	2%	715	45	6%
Hooded Merganser	3	0	0%	-	-	-	-	-	-
Horned Grebe	-	-	-	-	-	-	-	-	-
Lesser Scaup	12	0	0%	-	-	-	-	-	-
Osprey	-	-	-	-	-	-	1	1	100%
Pied Billed Grebe	13	13	100%	7	7	100%	17	10	59%
Snowy Egret	2	2	100%	2	1	50%	3	0	0%
Tern (Unidentified)	-	-	-	1	0	0	-	-	-
Western Grebe	-	-	-	2	1	50%	3	1	33%

Table 29: Percent of Observed Birds Feeding at all Locations in Spring 2015

Month	March			April			May		
	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican	23	12	52%	31	21	68%	44	18	41%
Belted Kingfisher	-	-	-	-	-	-	-	-	-
Black-Crowned Night Heron	-	-	-	-	-	-	-	-	-
Caspian Tern	-	-	-	-	-	-	-	-	-
Cattle Egret	-	-	-	-	-	-	-	-	-
Clark's Grebe	1	1	1	2	1	50%	8	3	38%
Common Goldeneye	17	15	88%	1	1	100%	-	-	-
Common Merganser	2	2	100%	-	-	-	1	0	0%
Common Tern	-	-	-	4	0	0%	26	0	0%
Double-Crested Cormorant	128	27	21%	132	31	23%	102	19	19%
Eared Grebe	-	-	-	-	-	-	-	-	-
Forster's Tern	-	-	-	-	-	-	-	-	-
Great Blue Heron	7	6	86%	6	3	50%	21	2	10%
Great Egret	3	3	100%	5	3	60%	5	0	0%
Green Heron	-	-	-	-	-	-	-	-	-
Gull Sp.	860	5	1%	12	2	17%	92	0	0%
Hooded Merganser	-	-	-	-	-	-	-	-	-
Horned Grebe	-	-	-	-	-	-	-	-	-
Lesser Scaup	-	-	-	-	-	-	-	-	-
Osprey	-	-	-	-	-	-	1	1	100%
Pied Billed Grebe	12	9	75%	5	3	60%	21	5	24%
Snowy Egret	-	-	-	-	-	-	6	0	0%
Tern (Unidentified)	-	-	-	4	1	25%	2	0	0%
Western Grebe	-	-	-	-	-	-	6	3	50%

Table 30: Percent of Observed Birds Feeding at all Locations in Summer 2015

Month	June			July			August		
	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican	75	5	7%	58	48	83%	100	44	44%
Belted Kingfisher	-	-	-	-	-	-	2	1	50%
Black-Crowned Night Heron	-	-	-	3	2	67%	-	-	-
Caspian Tern	-	-	-	5	1	20%	9	1	11%
Cattle Egret	-	-	-	-	-	-	1	0	0%
Clark's Grebe	17	8	47%	42	31	74%	23	11	48%
Common Goldeneye	-	-	-	-	-	-	-	-	-
Common Merganser	-	-	-	-	-	-	-	-	-
Common Tern	-	-	-	-	-	-	-	-	-
Double-Crested Cormorant	114	25	22%	147	29	20%	193	58	30%
Eared Grebe	-	-	-	-	-	-	1	1	100%
Forster's Tern	-	-	-	2	2	100%	-	-	-
Great Blue Heron	23	6	26%	31	6	19%	35	11	31%
Great Egret	12	1	8%	56	11	20%	31	8	26%
Green Heron	2	0	0%	-	-	-	4	1	25%
Gull Sp.	218	0	0%	256	0	0%	309	10	3%
Hooded Merganser	-	-	-	-	-	-	-	-	-
Horned Grebe	-	-	-	-	-	-	-	-	-
Lesser Scaup	-	-	-	-	-	-	-	-	-
Osprey	4	1	25%	3	1	33%	5	1	20%
Pied Billed Grebe	36	22	61%	123	66	54%	160	46	29%
Snowy Egret	5	0	0%	31	21	68%	68	15	22%
Tern (Unidentified)	7	2	29%	-	-	-	-	-	-
Western Grebe	45	28	62%	36	16	44%	16	9	56%

Table 31: Percent of Observed Birds Feeding at all Locations in Fall 2015

Month	September			October			November		
	Total	Feeding	% Feeding	Total	Feeding	% Feeding	Total	Feeding	% Feeding
American White Pelican	25	1	4%	-	-	-	7	7	100%
Belted Kingfisher	1	0	0%	-	-	-	-	-	-
Black-Crowned Night Heron	3	0	0%	2	0	0%	-	-	-
Caspian Tern	5	1	20%	-	-	-	-	-	-
Cattle Egret	-	-	-	-	-	-	-	-	-
Clark's Grebe	22	8	36%	32	25	78%	1	0	0%
Common Goldeneye	1	1	100%	-	-	-	15	15	100%
Common Merganser	-	-	-	-	-	-	-	-	-
Common Tern	-	-	-	-	-	-	-	-	-
Double-Crested Cormorant	187	12	6%	244	28	11%	178	18	10%
Eared Grebe	4	4	100%	15	14	93%	37	31	84%
Forster's Tern	8	8	100%	-	-	-	-	-	-
Great Blue Heron	15	3	20%	19	11	58%	9	4	44%
Great Egret	33	11	33%	60	24	40%	26	12	46%
Green Heron	5	1	20%	6	3	50%	1	1	100%
Gull Sp.	1817	0	0%	386	1	0%	79	2	3%
Hooded Merganser	-	-	-	2	0	0%	-	-	-
Horned Grebe	-	-	-	1	1	100%	8	8	100%
Lesser Scaup	-	-	-	-	-	-	-	-	-
Osprey	1	0	0%	3	1	33%	-	-	-
Pied Billed Grebe	106	62	58%	143	95	66%	56	32	57%
Snowy Egret	16	2	13%	29	12	41%	5	2	40%
Tern (Unidentified)	-	-	-	2	0	0%	-	-	-
Western Grebe	8	4	50%	14	11	79%	3	3	100%

Behavioral Observations

The percentage of behavior accounted for as feeding, pooled across all survey locations, peaked in January and dropped to a low point in September (Figure 77).

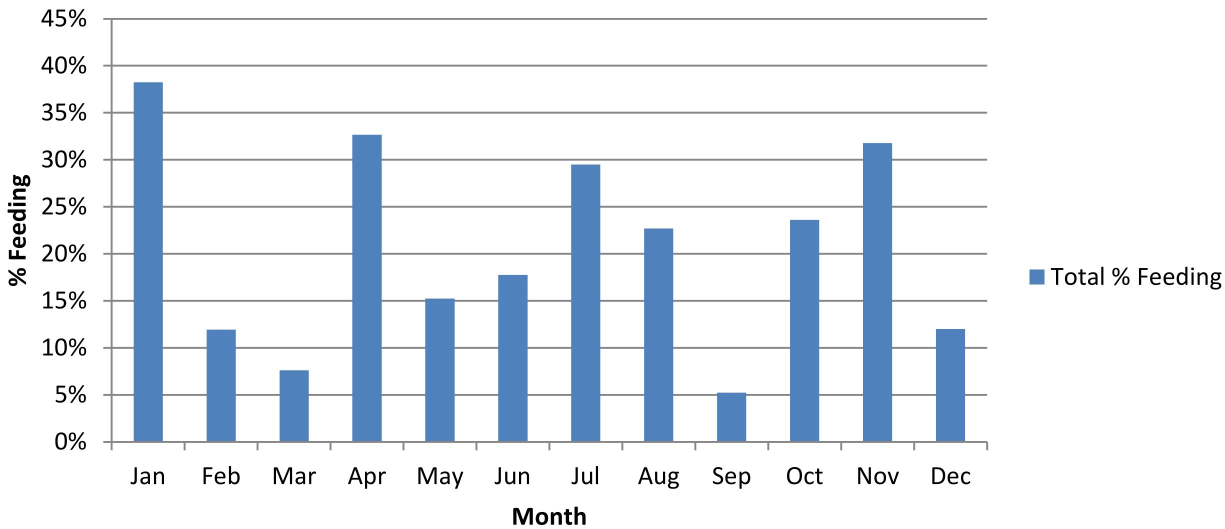
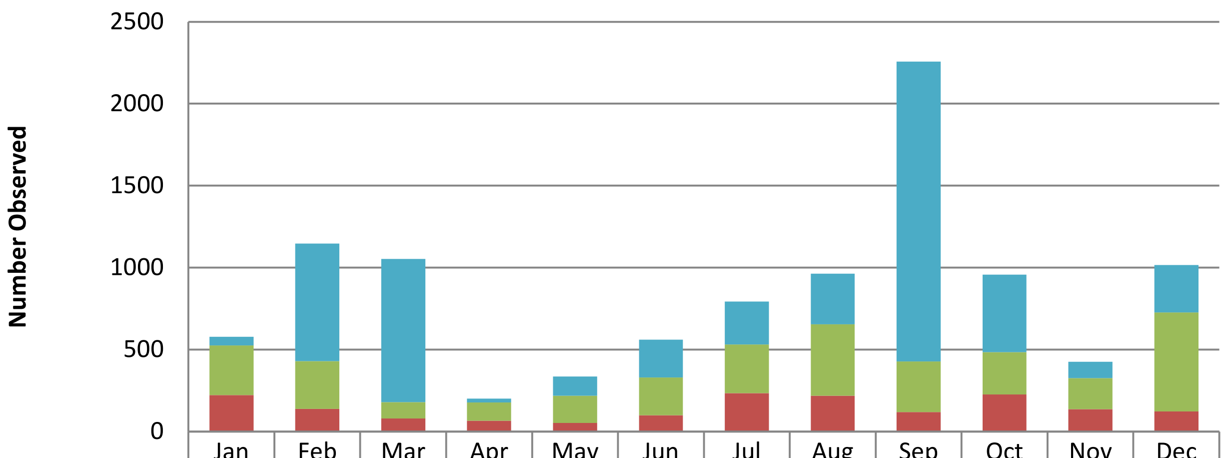


Figure 77: Feeding Behavior at all Locations in 2015

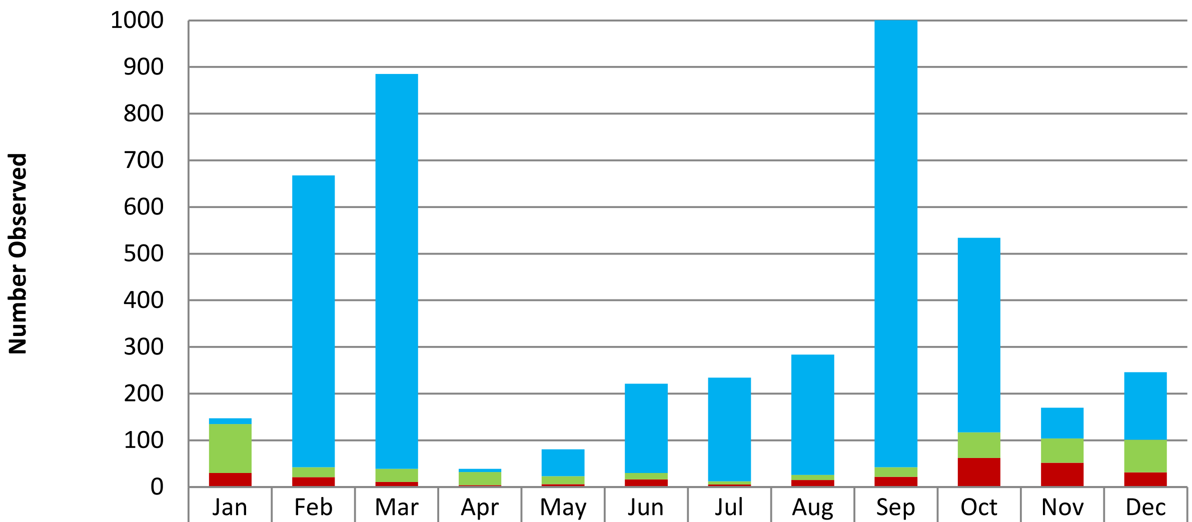
Feeding was observed in all months; however the number of individual birds observed feeding was greatest in July, August, October and January (Figure 78).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fly Over	53	717	873	24	118	231	262	308	1830	474	100	290
Non-Feeding	304	293	99	110	166	231	297	437	309	257	190	604
Feeding	221	137	80	66	51	99	234	217	118	226	135	122

Figure 78: Behavior at all Locations in 2015

All behavioral categories were observed in all months at the trash racks in 2015 (Figure 79). In most months, flyovers were the most common behavior observed in the vicinity of this location due to large flocks of gulls flying over the site. Feeding behavior was observed to peak in the vicinity of the trash racks from October through November (Figure 80).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FlyOver	12	626	846	7	58	191	222	258	1771	417	66	145
Non-Feeding	105	21	28	28	17	14	7	11	20	55	52	70
Feeding	30	21	11	4	6	16	5	15	22	62	52	31

Figure 79: Behavior at the Trash Racks in 2015

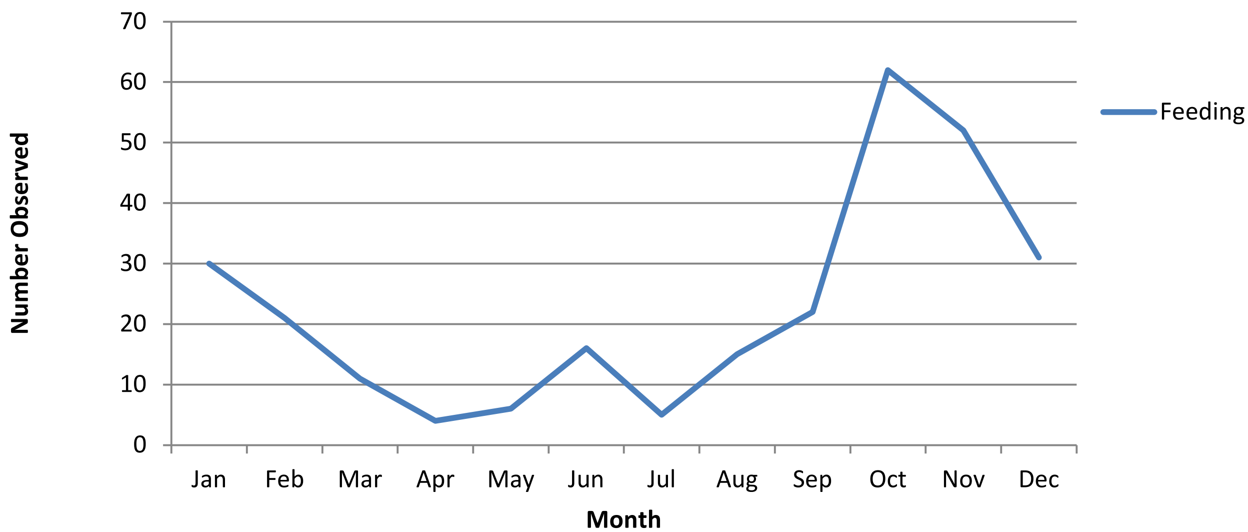
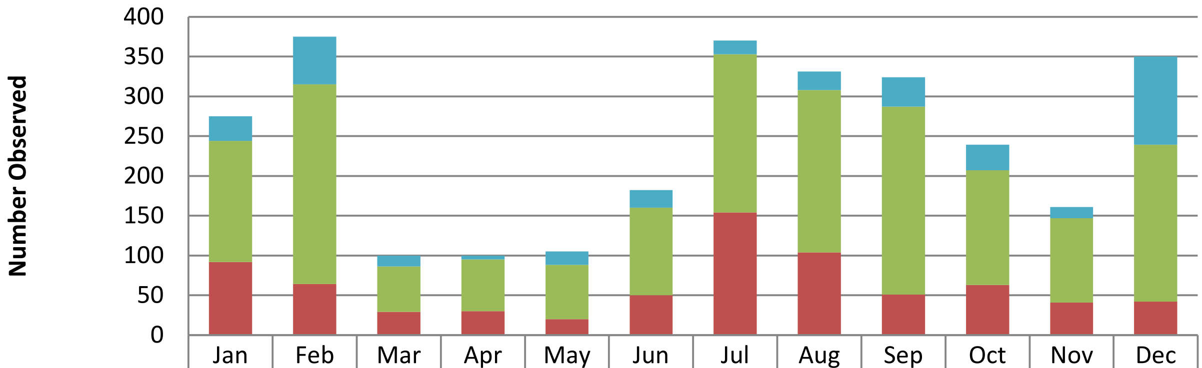


Figure 80: Numbers of Feeding Piscivorous Birds at the Trash Racks in 2015

All behavioral categories were observed in all months at both radial gate locations in 2015. Fewer flyovers were observed at the radial gates locations than at the trash rack location (Figures 81, 83). Feeding behavior was observed to peak in the vicinity of the radial gates SW in July (Figure 82), and January, August and October in the vicinity of the radial gates NE (Figure 84).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FlyOver	31	60	14	5	17	22	17	23	37	32	14	111
Non-Feeding	152	251	57	65	68	110	199	204	236	144	106	197
Feeding	92	64	29	30	20	50	154	104	51	63	41	42

Figure 81: Behavior at the Radial Gates SW in 2015

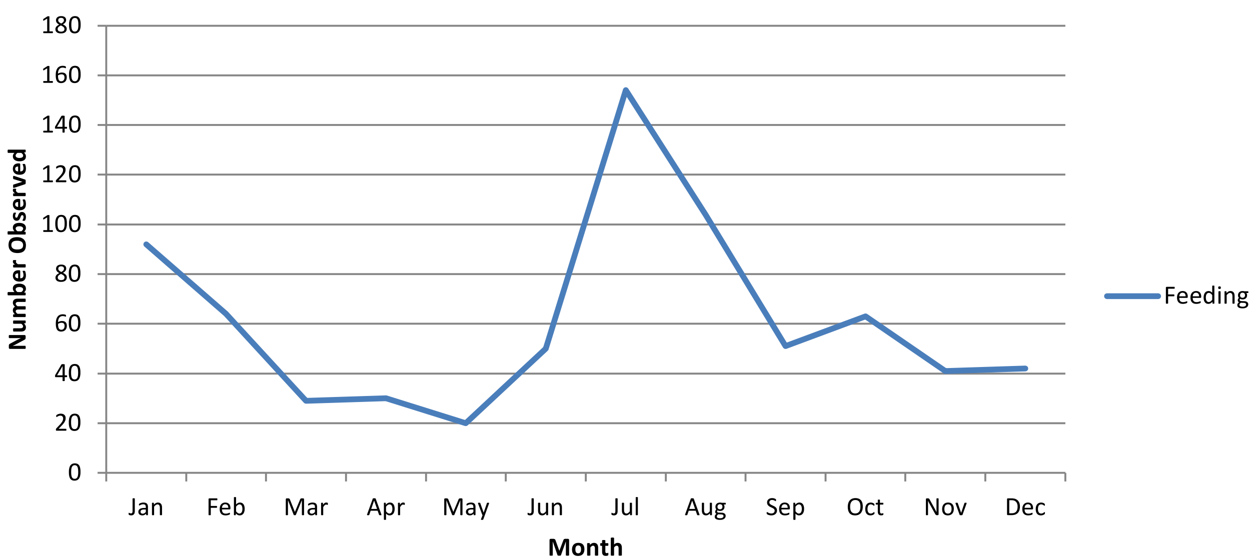
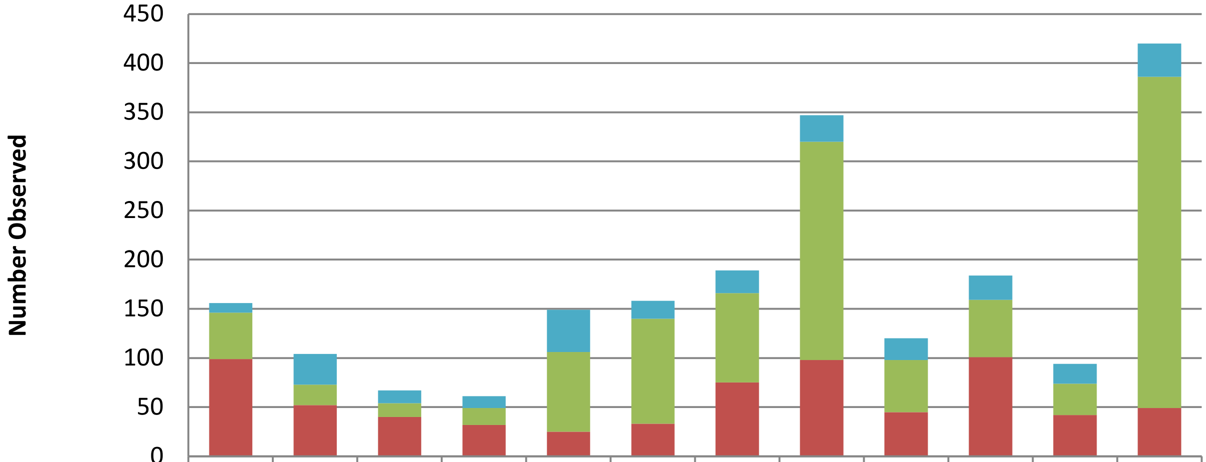


Figure 82: Numbers of Feeding Piscivorous Birds at the Radial Gates SW in 2015



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FlyOver	10	31	13	12	43	18	23	27	22	25	20	34
Non-Feeding	47	21	14	17	81	107	91	222	53	58	32	337
Feeding	99	52	40	32	25	33	75	98	45	101	42	49

Figure 83: Behavior at the Radial Gates NE in 2015

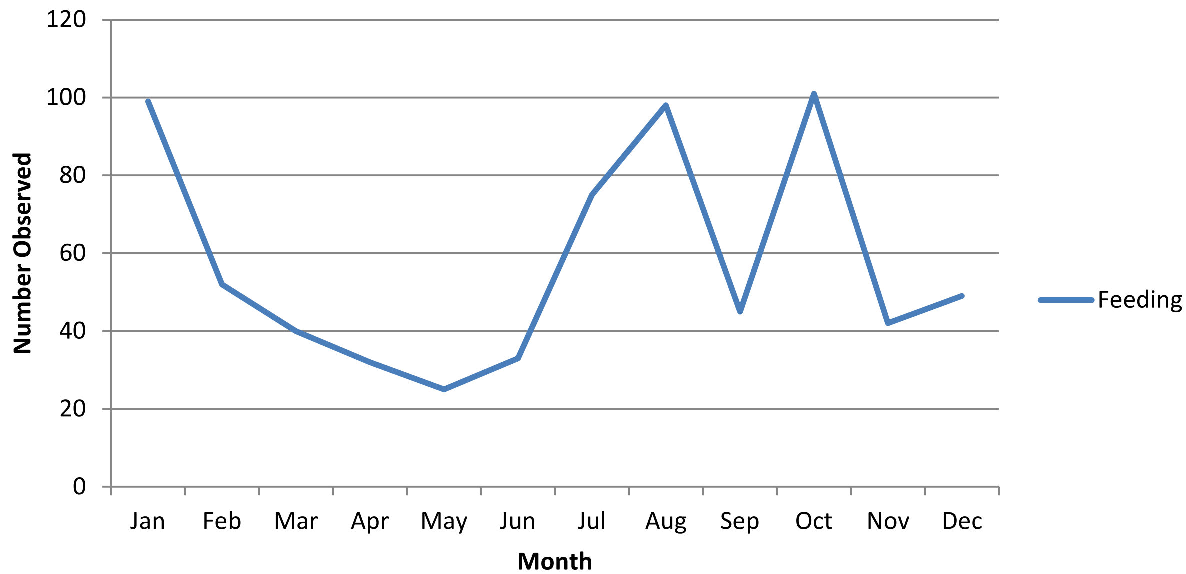
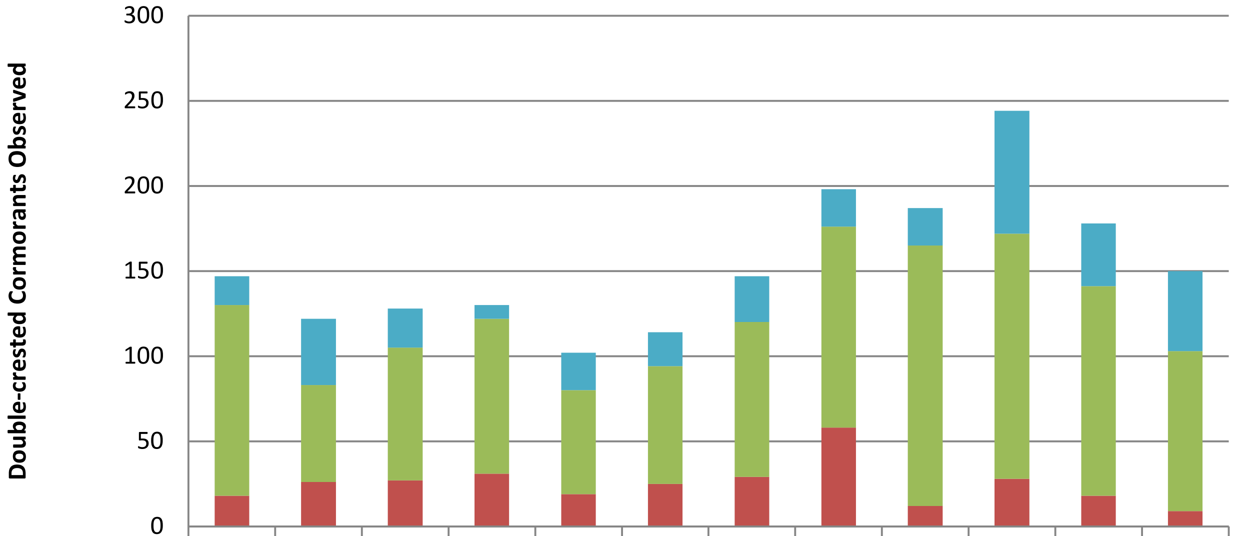


Figure 84: Numbers of feeding piscivorous birds at the Radial Gates NE location in 2015

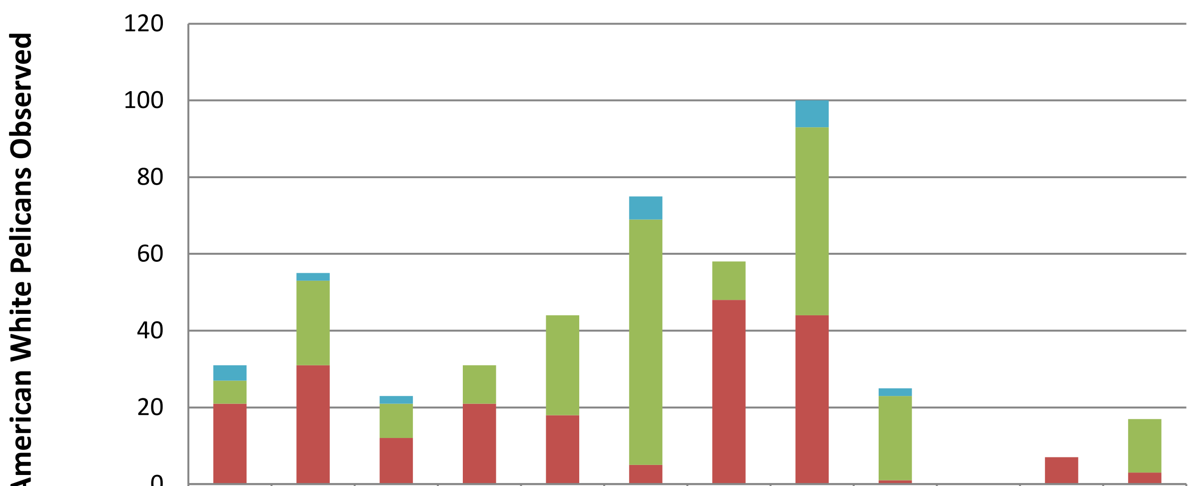
Double-crested cormorants were observed feeding during all of the months in which they were present during surveys (Figure 85). Often the feeding behavior observed consisted of stealing from other cormorants or birds of other species in the vicinity of the radial gates.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fly Over	17	39	23	8	22	20	27	22	22	72	37	47
Non-Feeding	112	57	78	91	61	69	91	118	153	144	123	94
Feeding	18	26	27	31	19	25	29	58	12	28	18	9

Figure 85: Double Crested Cormorant Behavior in 2015

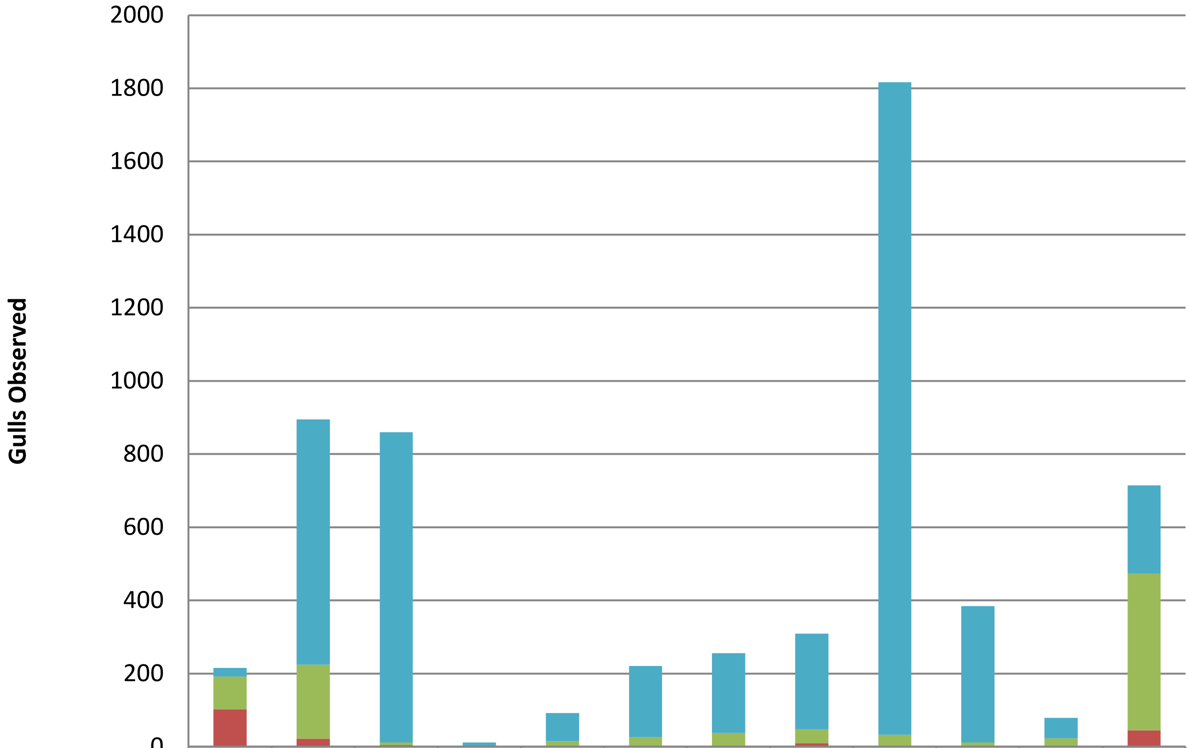
American white pelicans were observed feeding, when present, during all months of the survey (Figure 86). Similar to the Double-crested cormorant, the feeding behavior observed often consisted of stealing from other birds in the vicinity of the radial gates.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Fly Over	4	2	2	0	0	6	0	7	2	0	0	0
Non-Feeding	6	22	9	10	26	64	10	49	22	0	0	14
Feeding	21	31	12	21	18	5	48	44	1	0	7	3

Figure 86: American White Pelican Behavior in 2015

Gulls were present, often in large flocks, throughout the months surveyed, but were only observed feeding during nine of those months, and feeding often has been observed to include scavenging food scraps left by the resident sea lion (Figure 87).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fly Over	24	671	848	10	77	194	218	261	1784	373	56	242
Non-Feeding	89	202	7	0	15	26	38	38	33	11	21	428
Feeding	103	22	5	2	0	1	0	10	0	1	2	45

Figure 87: Gull Behavior in 2015

2.6.5 *Discussion and Recommendations*

Species richness was lowest in March, steadily climbing to a peak in September. Similar to 2014, species richness for most months was greater at the radial gates than at the trash racks, which is likely attributable to the concentration of prey around the radial gates and the wetlands habitat that has been created in the southeast corner of the Forebay. Unlike 2014, species richness at the trash racks did surpass that at the radial gates during one month, October. This could be indicative of a shift in the concentration of prey due to changes in operations, or environmental conditions.

Overall, observed numbers of particular species followed one of three patterns over the course of 2015. Some species, such as double-crested cormorant, were present all year long at relatively constant rates. Some species were present in relatively high numbers in winter and low numbers, or absent, in summer such as piscivorous waterfowl. Some species were present in relatively high numbers in spring and summer and low numbers, or absent in winter such as terns, osprey, herons, egrets and grebes.

Of the species observed during avian surveys double-crested cormorants, American white pelicans, pied-billed grebes, and gulls were the most commonly observed. Double-crested cormorants showed the broadest peak in abundance with relatively higher numbers observed in the months August through November. American white pelicans peaked in August, and gulls in September. Pied-billed grebes peaked from July through October.

Cormorants and pelicans were observed feeding during all of the survey months that they were present. Gulls were observed feeding in all months except May, July and September. Grebes, herons, and common goldeneye often displayed high feeding behavior, and may also represent a significant level of predation pressure on fishes in the Forebay. Identification of prey species was not possible during the surveys, and could include any of the fish species present at the time of the feeding event, including common species such as Striped Bass, as well as listed species such as Chinook Salmon.

2.7 *Bioenergetics Modelling*

2.7.1 *Background*

A bioenergetics model is a mass-based equation that can analyze how food consumed by an animal is either used for growth or metabolic processes, or excreted as waste (Ney 1993, Brandt and Hartman 1993). This can be a powerful tool in that it can allow for an understanding of the quantitative impacts of predation upon a population of prey given existing information on metabolic needs, digestion rates and predation habits of a predator species. This approach has been used to better understand the predator-prey dynamics between fish species such as Striped Bass and Threadfin Shad (*Dorosoma petenense*) in Lake Powell (Vatland et al 2008), and Lake Trout (*Salvelinus namaycush*) and Rainbow Smelt (*Osmerus mordax*) in Lake Champlain (LaBar 1993), as well as predation by piscivorous birds such as double-crested cormorants (Seefelt and Gillingham 2008) in northern Lake Michigan.

The relative impact of predation upon salmonids by fish and birds in the Forebay is an important factor in addressing pre-screen loss. These impacts can be evaluated in a quantitative manner using bioenergetics modeling.

A Bioenergetics Feasibility Study was undertaken in late 2015, by Dana Stroud and Joseph Simonis of Cramer Fish Sciences, using data from the 2013-2015 CCFPS data collection effort. The results of this study were compiled into a separate report entitled *DWR Clifton Court Forebay Predator Study 2014-2015: Bioenergetics Feasibility* (Appendix A). A summary of that report is included here.

2.7.2 *Methods*

Cramer Fish Sciences scientists selected a mass-balanced bioenergetics model (Kitchell et al 1977) to estimate the daily Striped Bass predation of prey species that were detectable during the genetics studies conducted from 2013 through 2015. A monthly index of relative importance values for prey species available in the Forebay incorporating historic diet data from the region, and the genetics data collected, was used to characterize diet habits. All genetics samples were assumed to be positive for Striped Bass as prey, and temperatures experienced by the Striped Bass sampled during the genetics effort were assumed to be the same as ongoing temperatures measured at the SDFPF. Striped Bass growth was based upon the length-at-age data reported by Tucker et al (1998), and age specific growth rates reported by Collins (1980). Energy content for each prey species was determined based upon the existing literature. Model output data was analyzed via 2-way ANOVA’s and Tukey tests.

2.7.3 *Results*

Consumption rates of Chinook Salmon by Striped Bass were determined across days and between water years. The median Chinook consumption rate during the 2013-2014 sampling year varied from 0.007 – 0.074 grams (g) of Chinook per day, depending on predator age. The median Chinook consumption rate during the 2014-2015 sampling year varied from 0.008 – 0.049 g per day, depending on age. The average consumption rate (total grams consumed per predator) increased with Striped Bass age during both sampling years (Figure 88). Consumption rates of Chinook Salmon differed between age-classes and between years. Interaction between age class and year was found to be statistically significant.

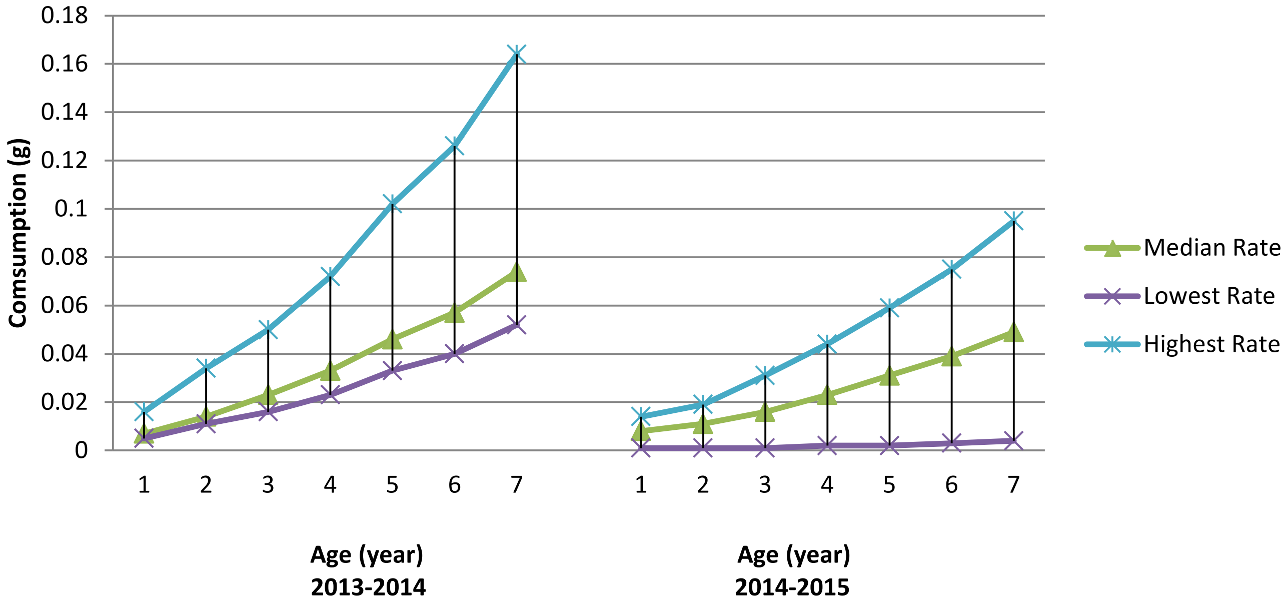


Figure 88: Striped Bass Consumption Rate of Chinook Salmon by Age and Sample Year

However, when mass-specific consumption rates were calculated (e.g. gram consumed of prey per gram of predator body weight), it was found to decrease as age class increased for both years (Figure 89), indicating that smaller bass ate more prey per gram of body weight than their larger peers.

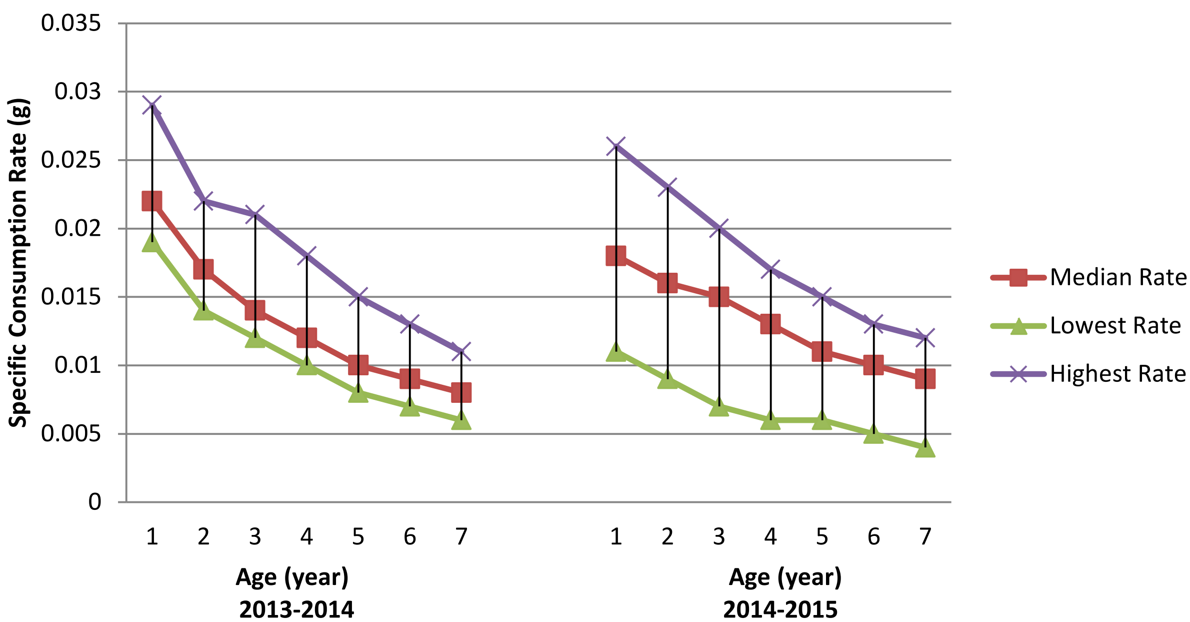


Figure 89: Specific Consumption Rate for Striped Bass by Age and Sample Year

2.7.4 *Discussion and Recommendations*

The bioenergetics model developed for this study translates the presence/absence predation genetics data collected in the Forebay to an estimate of grams a Striped Bass consumes in a 24-hour period. By constructing the bioenergetics model in a feasibility landscape, additional relationships can be developed to describe factors that can potentially impact predation rates, such as temperature and predator size. These relationships and calculations could be used to provide groundwork for future studies on predation by Striped Bass in the Forebay.

It is important to highlight key assumptions of the standard bioenergetics model that are violated by this system, including the assumption that the system is closed. When taking into account the immigration and emigration seen in Section 2.3 (above), in conjunction with the amount of time a prey sample's genetic signal would remain detectable via qPCR, it must be acknowledged that the model includes predation events that are reflections of where the Striped Bass have been in the previous approximately 60 hours, as opposed to where they are when captured. Existing bioenergetics models, including this evaluation, do not account for this distinction, and therefore cannot allow us to distinguish between a listed species consumed in the Delta versus in CCF. Any calculations of predation in CCF will be more refined and robust when movement by predators into and out of the system is accounted for within the structure of the model.

Future modeling would benefit from field studies that specifically evaluate the relationship between predation genetics and prey biomass consumed by the predator, as well as, an analysis of the model's sensitivity to these assumptions.

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Appendix A:
DWR Clifton Court Forebay Predator Study 2014 – 2015: Bioenergetics Feasibility

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DWR Clifton Court Forebay Predator Study 2014-2015: Bioenergetics Feasibility

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Introduction

Fish that enter Clifton Court Forebay (CCF) must traverse 3.4 km from the radial gate entrance, across the Forebay, to reach the John E. Skinner Delta Fish Protective Facility (SFPF) in order to be salvaged and released back to the Sacramento-San Joaquin Delta. Studies indicate most juvenile fish do not survive the crossing. The relative impact of predation on these losses is important to effective short- and long-term management of water project operations. More specifically, the information is needed to evaluate how the Biological Opinion pre-screen loss (PSL) requirement [NMFS 2009; RPA IV 4.2(2)] could best be satisfied. In the current evaluation, our focus was to assess the feasibility of a bioenergetics approach for estimating predation losses of California and/or Federal ESA-listed Central Valley Steelhead Trout (*Oncorhynchus mykiss*), Delta Smelt (*Hypomesus transpacificus*), and Chinook Salmon (*O. tshawytscha*) by Striped Bass within CCF. Data are also being gathered on other regionally significant species including Green Sturgeon (*Acipenser medirostris*).

Model Description

We use mass-balanced bioenergetic modeling (Kitchell et al. 1977), a tool used to assess the tradeoffs of consumption versus growth (Cyterski et al. 2003; Hartman 2003; Uphoff 2003), to estimate the daily predation by Striped Bass on a select group of targeted prey items. Parameters for age-1, age -2 and adult Striped Bass models are borrowed from Hartman and Brandt (1995) for consumption, respiration, egestion and excretion (Table 1). Structures of the equations can be found in Hansen et al (1997).

We use monthly index of relative importance (IRI) values (George and Hadley 1979) to characterize diet habits (Dowd et al. 2006). IRI values incorporate historic diet data from regional studies that reported prey proportions by weight, proportions by number, or provided raw data (Stevens 1966; Thomas 1967; Edwards 1995; Walters and Austin 2003; Nobriga and Feyrer 2007, 2008; Miranda and Raborn 2013). We estimate frequency of occurrence data for targeted prey items (Table 2) with qPCR predation genetics output (Blankenship and Schummer et al. 2014, 2015), methods described below. We fix the remaining frequencies of occurrence for prey items not included in the qPCR analysis (non-targeted items) based on regional historic literature (Stevens 1966; Thomas 1967; Edwards 1995; Walters and Austin 2003; Nobriga and Feyrer 2007, 2008; Miranda and Raborn 2013) as follows: Striped Bass (4.1%), non-targeted fish and non-fish species (62.5%) (annelids, bivalves, crustaceans) (Stevens 1966; Thomas 1967; Edwards 1995; Walters and Austin 2003; Nobriga and Feyrer 2007, 2008; Miranda and Raborn 2013). Fish species that were identified in regional literature that were not included in the qPCR analysis include sculpins (Cottoidea), flounders (Pleuronectidae), catfish (Ictaluridae), bluegill (*Lepomis macrochirus*), lamprey (*Entosphenus tridentatus*), herring (*Clupea pallasii*), goldfish (*Carassius auratus*), perch (Percidae), mosquitofish (Poeciliidae), goby (*Tridentiger bifasciatus, Eucyclogobius newberryi, Acanthogobius flavimanus*), and unspecified fish. Energy content of prey items were based on the literature (Table 2).

Table 1. Parameters used in Bioenergetic Modeling

Parameter	Description	Value	Unit
Consumption Equation 3			
CA	Intercept of the allometric mass function	0.3021	$g\ g^{-1}\ d^{-1}$
CB	Slope of the allometric mass function	-0.2523	
CQ	Temperature for CK_1	6.6, 6.6, 7.4	°C
CTO	Temperature for 0.98 of C_{max} on increasing curve	19, 18, 15	°C
CTM	Temperature for 0.98 of C_{max} on decreasing curve	28, 29, 28	°C
Respiration Equation 1			
RA	Intercept for the allometric mass function	0.0028	$g\ O_2\ g^{-1}\ d^{-1}$
RB	Slope of the allometric mass function	-0.218	
RQ	approximates Q_{10}	0.076	$°C^{-1}$
RTO	Constant swimming speed at reference metabolism	0.5002	$s\ cm^{-1}$
RTM	Maximum (lethal) water temperature	0	
RTL	Cutoff temperature at which activity relationship changes	0	°C
RK_1	Swimming speed intercept above RTL	1	$cm\ s^{-1}$
RK_4	Mass-dependence for swimming speeds	0	
ACT	Intercept for the swimming speed-water temperature function below RTL	1.649	$cm\ s^{-1}$
BACT	Temperature-dependence coefficient for swimming seed-water temperature function below RTL	0	$°C^{-1}$
SDA	Proportion of assimilated energy lost to specific dynamic action	0.172	
Egestion/Excretion Equation 1			
FA	Intercept of proportion of consumed energy egested versus water temperature and ration	0.104	
UA	Intercept of proportion of consumed energy excreted versus water temperature and ration	0.068	
Predator Energy Density Equation 1			
E_{pred}	Energy density of predator	6488	$J\ g^{-1}$

Table 2. Energy Densities and References of Prey Taxa used in Modeling.

Abbreviation	Common Name	Scientific Name	Energy Density (j/g)
CHN	Chinook Salmon	*Oncorhynchus tshawytscha*	5,764[1]
DSM	Delta Smelt	*Hypomesus transpacificus*	4,814[2]
GST	Green Sturgeon	*Acipenser medirostris*	4,990[3]
LMB	Largemouth Bass	*Micropterus salmoides*	4,186[4]
LFS	Longfin Smelt	*Spirinchus thaleichthys*	4,390[5]
MSS	Mississippi Silverside	*Menidia beryllina*	4,766[6,7]
OMY	Steelhead / Rainbow Trout	*Oncorhynchus mykiss*	5,764[8]
SAPM	Sacramento Pikeminnow	*Ptychocheilus grandis*	5,218[9]
SPLT	Sacramento Splittail	*Pogonichthys macrolepidotus*	5,218[9]
SMB	Smallmouth Bass	*Micropterus dolomieu*	4,186[10]
STB	Striped Bass*	*Morone saxatilis*	5,023[11]
TFS	Threadfin Shad	*Dorosoma petenense*	5,536[12]
WAG	Wakasagi Smelt	*Hypomesus nipponensis*	4,766[6,7]
WST	White Sturgeon	*Acipenser transmontanus*	4,990[3]
--	Other fish species	N/A	5,025[7, 12, 13]
--	Other non-fish items	N/A	2,944[14]

*Based on assumption that most Striped Bass that are consumed are age-0 individuals.

[1]Stewart and Ibarra 1991, [2]Lantry and Stewart 1993, [3]Badiani et al. 1997, [4]Rice et al. 1983, [5]Anthony et al. 2000, [6]Miranda and Muncy 1991; [7]Bryan et al. 1996, [8]Rand et al. 1993, [9]Beauchamp and Van Tassell 2001 in Tabor et al. 2007, [10]Shuter and Post 1990, [11]Hartman and Brandt 1995b, [12]Eggleton and Schramm (2002) *in* Vatland et al. 2008, [13]Hewett and Johnson 1992 in Vatland et al. 2008, [14]Cummins and Wuychuck 1971

We utilize diet habit data from genetic evaluations of Striped Bass stomach contents in CCF. We expect that all stomach samples from Striped Bass stomachs would test positive for Striped Bass, and thus samples that tested negative were not included in this analysis. Striped Bass were captured in CCF with hook-and-line sampling. A total of 264 Striped Bass were collected in WY 2013 between 12/13/13 - 5/28/14 and another 1,160 Striped Bass were collected in WY 2014 between 12/22/14 – 4/20/2015 (Blankenship and Schummer et al. 2014, 2015). Stomach contents were homogenized and analyzed with qPCR genetics assays (Baerwald et al. 2012; Brandl et al. 2015; King et al. 2008) based on prey items listed in Table 2. Bioenergetic models perform best when constrained by seasonal estimates of growth (Beauchamp et al. 1989; Brodeur et al. 1992; Ruggerone and Rogers 1992), so the modeling simulation period was based on the range of dates that had a Chinook Salmon, Delta Smelt, or Rainbow Trout / Steelhead positively identified. We assume that the temperatures experienced by Striped Bass were not different than the ongoing water temperatures measured at SFPF collections (ftp://ftp.dfg.ca.gov/salvage/).

Of the 264 stomachs from WY2013, 26 contained targeted prey species (for full details of genetics analysis including other species, see Blankenship et al. 2014, 2015). Of these, there were 3 Chinook Salmon (overall frequency of occurrence, F.O. = 1.1%), 0 Steelhead (F.O. = 0%) and 1 Delta Smelt (F.O. = 0.4%) identified. Remaining detections included Largemouth Bass, White Sturgeon, Threadfin Shad, and Mississippi Silverside. Remaining targeted items from Table 2 were not identified. Chinook Salmon were identified in December and January, and Delta Smelt were identified in December. In WY 2014, there were 1,142 stomachs analyzed, of which 270 contained targeted items. Of these, there were 18 Chinook Salmon (F.O. = 1.6%), 7 Steelhead (F.O. = 0.6%) and 17 Delta Smelt (F.O. = 1.5%) identified. Remaining detections included Largemouth Bass, Sacramento Pikeminnow, Sacramento Splittail, White Sturgeon, Threadfin Shad, and Mississippi Silverside. Chinook were identified in bass stomachs in December through February, Smelt were identified December through March, Rainbow/Steelhead were identified in December, January and March. Green Sturgeon were not identified in any of the bass stomachs during any sampling period. Consumption models for WY2013 were run for the time window of 13 December 2013 to 14 January 2014 (29 d period). WY2014 models were run from 12 December 2014 through 23 February 2015 (63 d period).

We estimate Striped Bass growth based on length-at-age data (Tucker et al. 1998) and apply daily age-specific growth (Collins 1980). We forward-calculate the length for the last day of the simulation period depending on the number of modeled days in the window. We convert fish length to fish weight using historic weight length relationships (Tucker et al. 1998).

Statistical Methods

We analyze model output data (daily consumption of Chinook Salmon by each Striped Bass age class) using 2-way ANOVA's and Tukey tests, and conduct our analyses in Systat 13 (Systat Software Inc., Chicago, Illinois). For ANOVAs found to be significant, we perform post-hoc Tukey tests to determine what factor levels were significantly different from other levels. We also provide the results of post-hoc Tukey tests in tables showing which regions or age-classes are significantly or not significantly different from the other regions or age-classes (assuming an alpha level of 0.05).

Model Results

We determined the consumption rates of Chinook Salmon by Striped Bass across days and between water years. The median Chinook consumption rate in WY2013 varied from 0.007 – 0.074 g of Chinook per day, depending on age (Table 3, Figure 1). The median Chinook consumption rate in WY2014 varied from 0.008 – 0.049 g/d, depending on age (Table 3, Figure 2). The average consumption rate (total grams consumed per predator) increased with Striped Bass age regardless of water year. Consumption rates of Chinook Salmon differed between age-classes (ANOVA, $F_{6,476} = 113.571$, $p < 0.001$, Table 4) and differed between years (ANOVA, $F_{1,476} = 118.166$, $p < 0.001$, Table 4). There was a significant interaction term between age class and year. Central to these results was the observation of a statistically significant interaction between water year and age (ANOVA, $F_{6,476} = 8.917$, $p < 0.001$). This suggests that future efforts to quantify Striped Bass predation levels estimates need to consider how age structure changes and dynamically influences consumption over time.

Table 3. Median, average, and daily range of Chinook Salmon consumed per day (g/d) by Striped Bass.

Bass age	Median	Average	Range
WY 2013			
1	0.007	0.009	0.005 - 0.016
2	0.014	0.018	0.011 - 0.034
3	0.023	0.027	0.016 - 0.050
4	0.033	0.040	0.023 - 0.072
5	0.046	0.056	0.033 - 0.102
6	0.057	0.068	0.040 - 0.126
7	0.074	0.089	0.052 - 0.164
WY 2014			
1	0.008	0.008	0.001 - 0.014
2	0.011	0.011	0.001 - 0.019
3	0.016	0.017	0.001 - 0.031
4	0.023	0.024	0.002 - 0.044
5	0.031	0.033	0.002 - 0.059
6	0.039	0.041	0.003 - 0.075
7	0.049	0.052	0.004 - 0.095

Table 4. Codes that display significant differences in consumption of Chinook Salmon between age classes and water years.

Factor	Code
Bass Age	
1	AB
2	BC
3	C
4	D
5	E
6	F
7	G
Water Year	
2013	H
2014	I

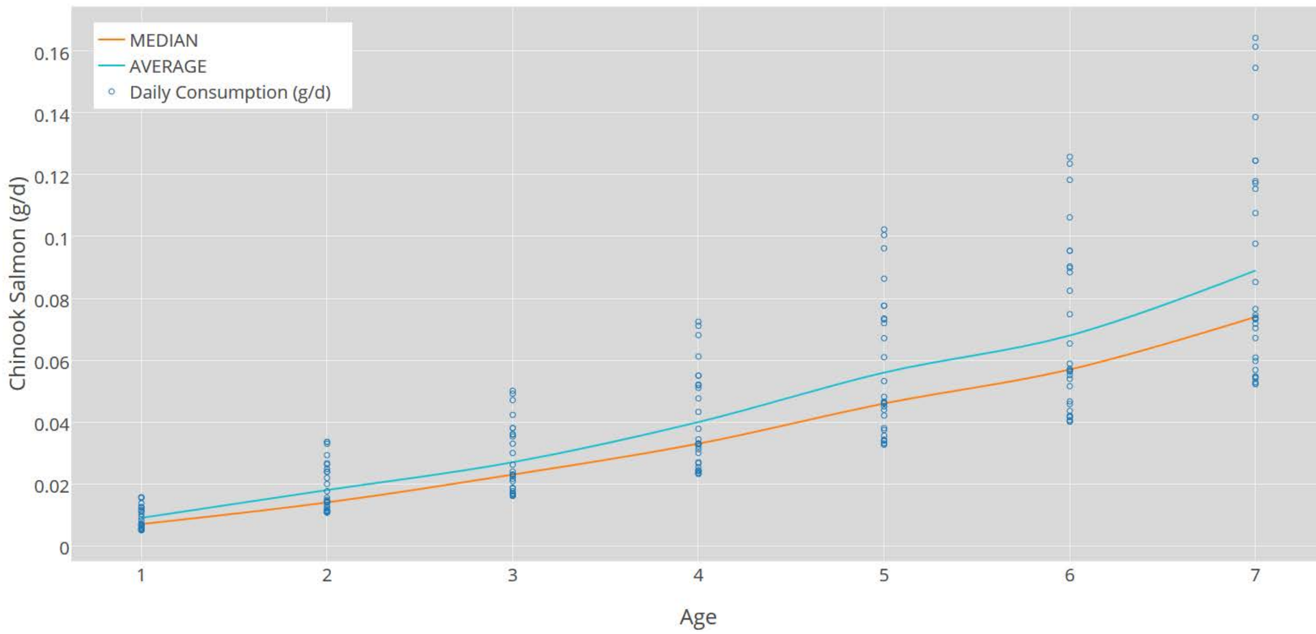

Figure 1. Daily predation rates of Striped Bass on Chinook Salmon, by age class, in a 29 d-period during WY2013.

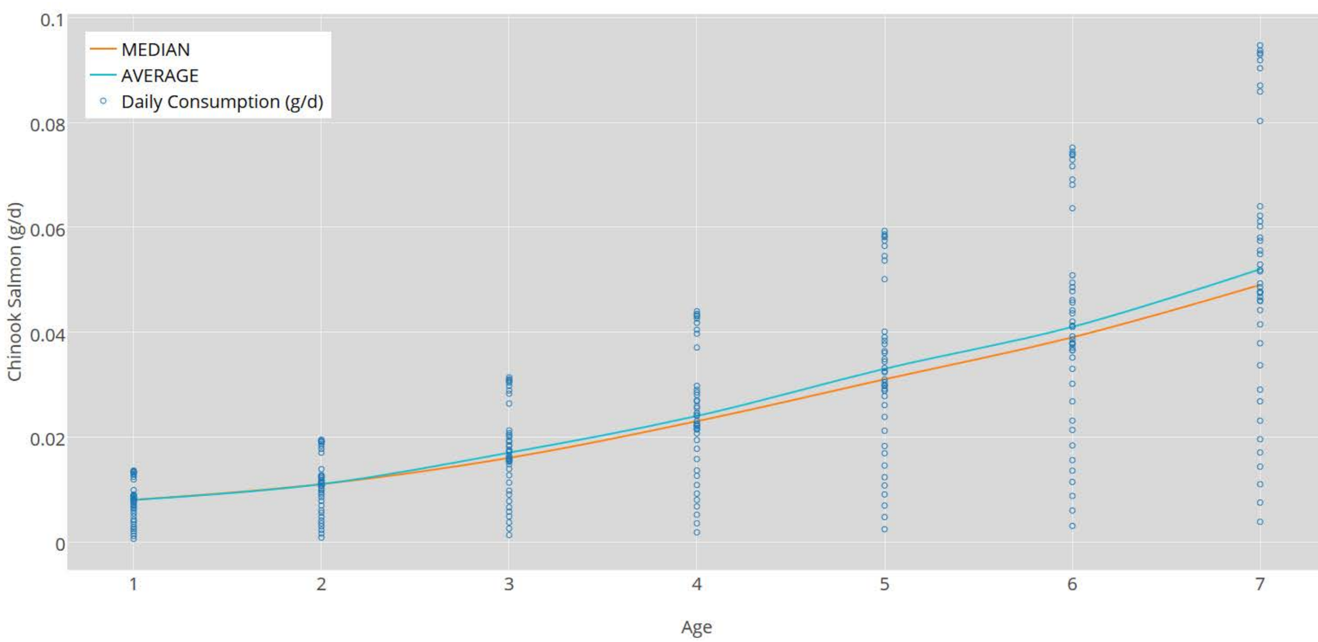

Figure 2. Daily predation rates of Striped Bass on Chinook Salmon, by age class, in a 41-d period during WY2014.

In WY2013, Striped Bass consumed between 3.322 – 34.829 g/d, depending on age class (Table 4). Of the species included in the qPCR analysis (see Table 2), the species most heavily consumed included Chinook Salmon, Mississippi Silverside, and Threadfin Shad. Targeted species that were either not identified with qPCR and/or did not have percent by weight data available for us to utilize included: Striped Bass, Rainbow Trout/Steelhead, Delta Smelt, Green Sturgeon, Longfin Smelt, Largemouth Bass, Sacramento Squawfish and Sacramento Splittail. In WY2014, Striped bass consumed slightly more than the previous year, between 5.614 – 38.893 g/d (Table 5). Consumption ranges for Chinook Salmon varied from a median of 0.008 – 0.049 g/d, depending on Striped Bass age class. In WY2014, Threadfin Shad were preyed on at a higher rate and Mississippi Silverside a lower rate, compared to WY2013 (Table 6).

Striped Bass mass-specific consumption rates (e.g. gram consumed of prey per gram of predator body weight) decreased as age class increased for both years (Table 5), indicating that cohorts of smaller bass ate more prey per gram of body weight than their larger peers. As expected, specific growth rates followed a similar pattern, with the older age classes occasionally experiencing slightly negative growth.

Table 5. Striped Bass daily median (range) consumption rate of all prey items and Striped Bass growth rates.

Age	Specific consumption rate (g/g/d)	Specific growth rate (g/g/d)
2013		
1	0.022 (0.019 - 0.029)	0.003 (0.002 - 0.005)
2	0.017 (0.014 - 0.022)	0.002 (0.001 - 0.004)
3	0.014 (0.012 - 0.021)	0.002 (0.001 - 0.004)
4	0.012 (0.010 - 0.018)	0.001 (0.001 - 0.003)
5	0.01 (0.008 - 0.015)	0.001 (0.000 - 0.002)
6	0.009 (0.007 - 0.013)	0.001 (0.000 - 0.002)
7	0.008 (0.006 - 0.011)	0.000 (0.000 - 0.001)
2014		
1	0.018 (0.011 - 0.026)	0.002 (0.000 - 0.004)
2	0.016 (0.009 - 0.023)	0.002 (0.000 - 0.003)
3	0.015 (0.007 - 0.02)	0.002 (-0.001 - 0.003)
4	0.013 (0.006 - 0.017)	0.001 (-0.001 - 0.002)
5	0.011 (0.006 - 0.015)	0.001 (-0.001 - 0.002)
6	0.010 (0.005 - 0.013)	0.001 (-0.001 - 0.001)
7	0.009 (0.004 - 0.012)	0.001 (-0.001 - 0.001)

Table 6. Median and daily range of prey taxa consumed per day (g/d) by Striped Bass.

Age	CHN	STB	TFS	MISC FISH	MSS	NON FISH	TOTAL
2013	*Median*						
1	0.007	0.051	0.031	1.395	0.000	1.835	3.322
2	0.014	0.109	0.066	2.975	0.001	3.915	7.093
3	0.023	0.163	0.099	4.461	0.001	5.869	10.672
4	0.033	0.235	0.142	6.431	0.002	8.461	15.413
5	0.046	0.331	0.200	9.049	0.002	11.907	21.726
6	0.057	0.406	0.246	11.105	0.003	14.612	26.692
7	0.074	0.529	0.320	14.478	0.003	19.050	34.829
	Range						
1	(0.005 - 0.016)	(0.038 - 0.071)	(0.000 - 0.392)	(1.019 - 1.952)	(0.000 - 0.004)	(1.343 - 2.568)	(2.812 - 4.598)
2	(0.011 - 0.034)	(0.081 - 0.153)	(0.000 - 0.836)	(2.172 - 4.198)	(0.000 - 0.009)	(2.862 - 5.523)	(5.993 - 9.890)
3	(0.016 - 0.050)	(0.116 - 0.248)	(0.000 - 1.224)	(3.102 - 6.787)	(0.000 - 0.013)	(4.086 - 8.930)	(8.558 - 15.989)
4	(0.023 - 0.072)	(0.167 - 0.355)	(0.000 - 1.770)	(4.489 - 9.733)	(0.000 - 0.019)	(5.913 - 12.806)	(12.384 - 22.928)
5	(0.033 - 0.102)	(0.236 - 0.498)	(0.000 - 2.499)	(6.34 - 13.627)	(0.000 - 0.027)	(8.351 - 17.929)	(17.489 - 32.102)
6	(0.04 - 0.126)	(0.29 - 0.609)	(0.000 - 3.074)	(7.8 - 16.665)	(0.000 - 0.033)	(10.274 - 21.926)	(21.516 - 39.259)
7	(0.052 - 0.164)	(0.379 - 0.791)	(0.000 - 4.015)	(10.187 - 21.671)	(0.000 - 0.043)	(13.418 - 28.512)	(28.096 - 51.051)
2014	*Median*						
1	0.008	0.074	0.741	2.022	-	2.664	5.614
2	0.011	0.106	1.033	2.904	-	3.827	8.024
3	0.016	0.173	1.651	4.730	-	6.233	13.076
4	0.023	0.241	2.309	6.632	-	8.739	18.269
5	0.031	0.324	3.104	8.946	-	11.788	24.499
6	0.039	0.411	3.929	11.347	-	14.951	30.964
7	0.049	0.516	4.942	14.295	-	18.836	38.893
	Range						
1	(0.001 - 0.014)	(0.038 - 0.103)	(0.254 - 1.345)	(1.049 - 2.727)	-	(1.383 - 3.589)	(3.215 - 7.538)
2	(0.001 - 0.019)	(0.052 - 0.147)	(0.363 - 1.922)	(1.447 - 3.896)	-	(1.907 - 5.127)	(4.432 - 10.766)
3	(0.001 - 0.031)	(0.074 - 0.236)	(0.585 - 3.022)	(2.05 - 6.279)	-	(2.702 - 8.263)	(6.28 - 16.624)
4	(0.002 - 0.044)	(0.103 - 0.329)	(0.816 - 4.242)	(2.872 - 8.752)	-	(3.786 - 11.517)	(8.798 - 23.346)
5	(0.002 - 0.059)	(0.139 - 0.441)	(1.092 - 5.728)	(3.87 - 11.72)	-	(5.101 - 15.423)	(11.854 - 31.548)
6	(0.003 - 0.075)	(0.176 - 0.557)	(1.379 - 7.27)	(4.905 - 14.8)	-	(6.465 - 19.476)	(15.025 - 40.061)
7	(0.004 - 0.095)	(0.222 - 0.699)	(1.731 - 9.164)	(6.176 - 18.576)	-	(8.141 - 24.446)	(18.918 - 50.52)

*Prey species with no reported consumption: RBT, DS, GST, LFS, LMB, SASQ, SPLT.

Discussion

We built bioenergetic models that translate presence/absence predation genetics data in a quantitative index to estimate the number of grams a Striped Bass consumes in a 24-hour period (e.g. daily meal). This evaluation was useful in identifying key features of predation by Striped Bass on listed species in the CCF and has provided a better understanding of the complexity of the study site, prey populations, and predator population. Constructing the bioenergetics model in a feasibility landscape also allowed us to begin developing relationships describing the factors that impact predation rates, such as temperature and predator size. Some of the component relationships and calculations from this exercise could be used to provide groundwork for future studies on predation by Striped Bass in CCF.

Our evaluation also highlighted key assumptions of the standard bioenergetics model that are not appropriate fits for this system and the current data available on predation within it. For instance, bioenergetics models in standard form assume that the predator and prey populations are closed (items found in the diet must be from the site where they were collected, not elsewhere). However, tracking data of the Striped Bass population that occupies the Forebay suggest that they move frequently in and out of the Forebay through the radial gates (Wunderlich 2015). Laboratory studies designed to evaluate the digestion and qPCR detection time of Chinook in Striped Bass stomachs in temperatures similar to the Central Valley suggest that 50% of stomachs containing Chinook Salmon would fail to detect the species after ~66 hours (Brandl 2016). Thus, Striped Bass diets collected in the Forebay are reflections of where they have been in the previous roughly 3 days, as opposed to where they are when captured. Existing bioenergetics models, including this evaluation, do not account for this distinction, and therefore cannot allow us to distinguish between a listed species consumed in the Delta versus in CCF. Any calculations of predation in CCF will be more refined and robust when movement by predators into and out of the system is taken into account.

In the Central Valley, the target species are rare, particularly in the stomachs of predators since the 1960’s and 70’s, and further, they tend to decay rather quickly precluding visual identification in a short amount of time. Thus, genetics-based assessments of diets are invaluable because they can accurately identify which taxa have been consumed (presence, i.e., qualitative). There is, however, a missing link that allows one to translate from presence to a quantitative relative proportion by biomass, which predation models such as bioenergetics often require (Kitchell et al. 1977; Kooijman 1993).

Translation of the presence of a prey taxon to the relative biomass of that taxon consumed by the predator requires multiple assumptions that introduce uncertainty into model predictions. For example, in this evaluation we made the assumption that historical data would identify consumption by biomass and by total number, however, there were few to no data points describing historic Delta Smelt or Rainbow Trout / Steelhead predation by Striped Bass in the CCF or the Delta. Thus, percent by weight (the percent of total biomass of a stomach sample comprised of a given prey taxa) from historic literature suggests a 0% consumption rate of either of these target prey items in the diets of Striped Bass, so the concluding model was not able to identify Delta Smelt or Rainbow Trout consumption levels. Previous works suggest that juvenile Striped Bass are not highly selective on any given species and instead consume food items based on availability (Heuback et al. 1963; Stevens 1966a; Hester and Stevens 1970; Manooch 1973; Boynton et al. 1981) and the salvage database suggests that both Delta Smelt and Rainbow Trout are available in CCF. Thus, future CCF predation work would benefit from: 1) empirical field studies that evaluate the relationship between prey presence in the predator’s gut (predation genetics) and prey biomass consumed by the predator (total weight of each prey taxa in the stomach), although given the observed rarity of any observations, the degree of improvement provided by this data is uncertain; and 2) an analysis of the model's sensitivity to these assumptions.

A key step in estimating predation by Striped Bass on listed prey species is scaling the amount of prey consumed by an individual predator up to the total amount consumed by the whole population (Blankenship et al. 2015). A individual-based bioenergetic model has been reported here, but ultimately some integration at the population level will be necessary to inform management decisions in CCF (Stewart et al. 1981, 1983; Olson and Mullen 1986; Yule and Luecke 1993; Hansson et al. 1996; Cyterski et al. 2002; Nelson et al. 2006; Tuomikoski et al. 2008; Vatland et al. 2008; Benkwitt et al. 2009; Loboschefsky et al. 2012; Grossman et al. 2013). One way to scale predation from the individual- to the population-level to estimate prey species loss attributable to predation within CCF, would be to build a model that's informed by a population estimate-driven experiment and long term survey program. While some studies indicate that adult Striped Bass have declined in size across the Delta since the 1960s (Lindley and Mohr 2003), other studies show a long-term decline in age-0 fish but a relatively stable adult population since 1980 (Sommer et al. 2011). However, Loboschefsky et al. (2012) suggest that age-0 abundance is likely underestimated and that sub-adult abundance has increased since 1981, ranging from 3 to >12 million individuals. Variance is not unexpected between studies when different methods are used to estimate population size or make inference about the distribution of age classes, and a thoughtfully designed long-term evaluation can go a long way to reduce these uncertainties when field collections are non-biased.

Scaling consumption by individual predators up to the population level also requires acknowledgement of the variation in predation rates among individuals, as well as the environmental context in which predation is occurring, as these can substantially impact consumption rates (Peters 1983, Hairston and Hairston 1997, Brown et al. 2004, Grossman et al. 2013, Simonis 2013). For example, consumption rates and metabolisms of fish typically increase allometrically with body size (Mittelbach 1981, Peters 1983, Kooijman 1993, Brown et al. 2004), such that larger predators eat more and larger prey. However, smaller predators may be more numerous at a population level and typically eat more grams of prey per gram of predator body weight, which may translate to more total consumption by the predator population (Fritts and Pearsons 2006). Also important for predation in CCF, Striped Bass consume other prey species, even engaging in cannibalism, which can certainly influence their impact on listed prey species. Cannibalistic behavior is likely a factor of prey availability, predator body size, and conspecific density (CDFG 1995; Nobriga and Feyrer 2007, 2008), but also influences their rate of predation on listed species. One common way to integrate these factors for quantification of consumption is to develop the relationship between predation rate and prey density, known as the functional response (Holling 1959). Functional responses can be adapted to incorporate impacts of environmental factors like temperature, as well as characteristics of the predators and prey, such as their sizes (McCoy et al. 2011). Functional responses also offer the potential to include variance partitioning and sensitivity analyses to identify key drivers of predation (Hilborn and Walters 1992; Grossman et al. 2013). In relation to the context of CCF where target and listed prey species are in low occurrence already, focused field experiments could be designed to construct linkages between prey biomass availability vs prey biomass consumed by Striped Bass.

The focus of this study was to assess feasibility of quantifying the rate of California and/or Federal ESA-listed Central Valley Steelhead Trout, Delta Smelt, and Chinook Salmon predation by Striped Bass within CCF using individual-level bioenergetic modeling. Our evaluation has shown that while the bioenergetics framework provided useful insight into predation by Striped Bass in CCF, it relies heavily on assumptions that are not appropriate for larger temporal scales and will require a more novel approach to appropriately estimate predation limited to the spatial extent of the Forebay, which limits the utility of the resulting estimations. Given the specificity of the system and management questions of interest, a more customized analytical approach that would allow managers and scientists to incorporate more of the relevant and necessary factors into a single framework and could generate a substantially more robust, precise, and accurate estimation of predation losses in CCF would be suitable.

Many approaches exist for quantifying predation, including controlled experiments, longitudinal observational data collection, and mathematical population or food-web modeling (Werner and Gilliam 1984, Kooijman 1993, de Roos et al. 2003, Simonis 2013). However, it is likely that the most accurate prediction of predation will come from combining multiple lines of inquiry into a synthetic understanding of the system (Peters 1983, Kooijman 1993, Hildrew et al. 2007, Simonis 2013). Regardless of the specific analytical approach taken, the present study highlights important details of predation in the CCF that future work should consider. In particular, the roles of system openness (immigration and emigration through the radial gates, emigration and loss through the salvage facility), multiple available prey types (including cannibalism), and the distributions of prey and predator sizes will likely influence estimations of predation in CCF.

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The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predation Study: 2016 Annual Progress Report

January 2018

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Abbreviations

BDO	Bay-Delta Office
BiOP	Biological Opinion
CALFED	CALFED Bay-Delta Science Program
CCFPS	Clifton Court Forebay Predator Study
CPUE	Catch per Unit Effort
CVP	Central Valley Project (Federal)
Delta	Sacramento-San Joaquin Delta
DFD	Delta Field Division
DFW	California Department of Fish and Wildlife
DWR	California Department of Water Resources
EROF	Equipment Request Order Form
ESA	Endangered Species Act
Forebay	Clifton Court Forebay
HTI	Hydroacoustic Technology Incorporated
IEP	Interagency Ecological Program
INAD	Investigational New Animal Drug
MOCC	Motorboat Operator Certification Course
NMFS	National Marine Fisheries Service
OP-2	Operations Procedure 2 – Lock-out/Tag-out
PIT	Passive Integrated Transponder
RPA	Reasonable and Prudent Alternative
SAV	Sub-aquatic Vegetation
SCP	DFW Scientific Collecting Permit
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project (California State)
USFWS	U.S. Fish and Wildlife Service

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Executive Summary

This report details the implementation, issues, and results of the fourth year of the Clifton Court Forebay Predation Study (CCFPS). Specific study elements undertaken in 2016 include predatory fish sampling, acoustic telemetry, and mark/recapture. Additional detail regarding the regulatory history and overall study design and methodology is available in the report entitled *Clifton Court Forebay Predation Study* (Wunderlich 2015).

Predator sampling was conducted for 91 days in 2016, resulting in the capture of 871 target predatory fish; 773 Striped Bass, 92 Largemouth Bass and 6 catfish. In addition, one non-target fish, a Steelhead (*Onchorhynchus mykiss*), was captured and released unharmed. Striped Bass under 0.5 lbs (0.23 kg) were caught in every month except January, and made up 21% of the Striped Bass catch, with the bulk captured in October and November, at 38 and 37 respectively. Striped Bass in the 0.5 lb. (0.23 kg) to 1.5 lb. (0.68 kg) size class were caught in all months, and represented the largest portion of the total catch at 67%, with the highest catch of those fish occurring in March and November, at 87 and 80 fish respectively. Striped Bass in the 1.5 lb. (0.68 kg) to 3 lb. (1.36 kg) size class were captured in all months except April and June, and made up 10% of the Striped Bass catch, with the highest number captured in December at 21 fish. Striped Bass over 3 lbs. (1.36 kg) were caught in all months except March, May, and June, and represented 2% of the total Striped Bass catch, with the bulk captured in November, at eight fish. Largemouth Bass were caught every month except August, peaking in July at 22, and catfish were caught only in February, March and July.

CPUE was found to be highest for Striped Bass in October at 1.61 fish per hour, followed by September and February at 1.18 and 1.14, respectively. For Largemouth Bass, CPUE peaked in July, at 0.24 fish per hour, and for catfish, CPUE peaked in March at 0.05 fish per hour.

Fish were recaptured a total of 104 times during 2016; Seven fish were recaptured by anglers, 42 during electrofishing efforts in the Forebay, 20 at Curtis Landing Release Site, five at Horseshoe Bend Release Site, 23 during predator sampling, five during other studies within the Forebay and two by NOAA on the San Joaquin River. Twelve of the Largemouth Bass were recaptured multiple times, by multiple methods, leaving only 89 individual fish recaptured.

A total of 181 predatory fish were acoustically tagged in 2016. Of those fish, four Largemouth Bass and 30 Striped Bass were not detected by any of the receivers in the array. Of the 147 acoustically tagged fish detected by the receivers, 29 (20% of the detected fish), were detected on receivers outside as well as inside of the Clifton Court Forebay (Forebay), indicating that they emigrated from the Forebay. Of those 29 fish that emigrated, 13 fish (45% of emigrating fish) returned to the Forebay at a later date in 2016. Of the remaining 118 fish that were not observed outside of the Forebay, 40 (34%) were only detected in the intake channel, 39 (33%) were only detected at the radial gates, and 39 (33%) were detected moving between the intake channel and the radial gates. The majority of the emigrating fish in 2016 were Striped Bass at 24, followed by four Channel Catfish, and one Largemouth Bass.

When fish tagged from prior years that remained detectable into 2016 were included, the total number of fish detected leaving the Forebay rose from 29 to 225, which is 40% of the detectable tagged fish to date. The majority of the 225 fish that emigrated were Striped Bass, at 200 (89%), with the balance being made

up of Largemouth Bass and catfish, at nine and 16, respectively. The emigrating Striped Bass ranged in weight, at the time of tagging, from 0.5 lbs. (0.23 kg) to 17.8 lbs. (8.07kg), with the smaller fish, 1.0 lbs. (0.45 kg) to 2.49 lbs. (1.13 kg), representing bulk of the fish detected. Of the 225 fish that emigrated, 132 (59% of emigrating fish) were subsequently detected back in the Forebay, including seven Channel Catfish, six Largemouth Bass, 14 Striped Bass under 1.5 lbs. (0.68 kg), 78 Striped Bass between 1.5. and 2.99 lbs. (0.68 – 1.36 kg), and 27 Striped Bass over 3.0 lbs. (1.36 kg).

1.0 Introduction

The CCFPS is a multi-year effort comprised of several study elements that have been designed to gather as much information as possible to understand predation upon juvenile salmonids in the Forebay. This report covers the fourth year of the CCFPS, conducted in 2016. This study was designed to further the understanding of behavior and movement of predatory fishes, salmonids, and piscivorous birds in the Forebay. The CCFPS includes the following elements: predatory fish sampling, biotelemetry, genetics, creel surveys, avian studies and bioenergetics. CCFPS design and methodology is further discussed in the Clifton Court Forebay Predation Study Report (2015). This report contains Predatory Fish Sampling and Biotelemetry as the only two elements conducted in 2016.

The CCFPS will provide the opportunity to evaluate the effects of any Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) of the Biological Opinion (BiOp) and Conference Opinion on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) (National Marine Fisheries Service (NMFS) 2009) undertaken to reduce predation of Endangered Species Act (ESA) protected salmon and steelhead within the Forebay.

2.0 CCFPS Study Elements

2.1 Issues

Predatory fish sampling was not conducted during the annual John E Skinner Delta Fish Protective Facility (SDFPF) maintenance shutdown, aquatic weed spraying, and Wednesdays during duck hunting season, from January 1 to 31 and October 22 to December 31. This amounted to approximately four weeks with no sampling.

SWP coordination protocols and call-in procedures for work conducted at the Clifton Court Forebay (Forebay) continued to be followed according to the final procedural guide provided by Delta Field Division (DFD) to Bay Delta Office (BDO). The 2015 Equipment Request Order Forms (EROF) for predator sampling, mobile monitoring and receiver maintenance were filed with DFD on December 9, 2015. Approval for all 2016 field work was confirmed on December 10, 2015.

2.2 Predatory Fish Sampling

2.2.1 Methods

Direct Sampling

Predatory fish such as Striped Bass (*Morone saxatilis*), Largemouth Bass (*Micropterus salmoides*), White Catfish (*Ameiurus catus*), and Channel Catfish (*Ictalurus punctatus*), were collected by either gill netting or hook and line sampling in the Forebay. Sampling was conducted twice weekly throughout the year to supply predatory fish for various study elements. Predatory fish capable of consuming juvenile salmonids were tagged and released at the location of capture as part of the mark-recapture and biotelemetry study element. Temperature, dissolved oxygen, and location(s) of capture were noted for each sampling effort.

Scale samples were collected from Striped Bass and Largemouth Bass to determine the age of the predatory fish sampled.

Collection of predators occurred during the day, between the hours of 0600 and 1500. All incidental species caught alive were measured, recorded, and immediately released at the location of capture. Field staff were trained to quickly identify listed species and release live fish to minimize handling stress. Take information was detailed in a supplemental report as part of the reporting requirements of the California Department of Fish and Wildlife (DFW) Scientific Collecting Permits (SCP; SCP #'s 7744 and 10286).

The Forebay was split into sampling sections, following the same map as Gingras and McGee (1997; Figure 1). Sampling was conducted from a boat, when possible, to allow for coverage of a greater portion of the Forebay. On sampling days when the boat was not available for use, sampling was conducted from the shoreline, primarily along the intake canal (Area 2) or adjacent to the radial gates (Area 1). Hook and line sampling was conducted using standard rod and reel fishing equipment in accordance with standard DFW regulations for hook and line fishing. Hook and line sampling employed a wide variety of bait and lure selections to maximize catch.

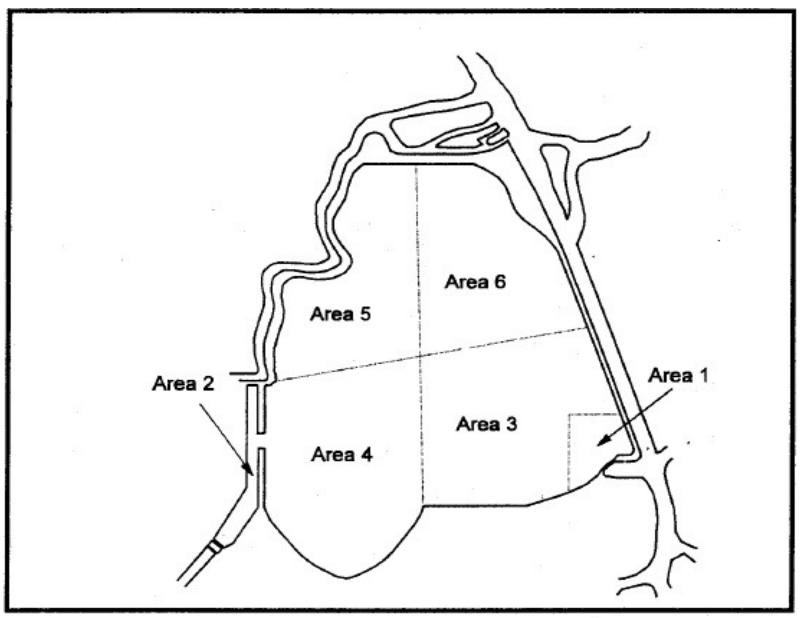


Figure 1: Sampling Map (Gingras and McGee 1997)

Hook and line sampling was conducted on 87 sampling days, at various times during the day from January 7, 2016 until December 30, 2016.

Recapture of Marked Fish (Non-Acoustic)

Tagged fish could potentially be recaptured via multiple methods including direct catch during predator sampling, direct catch by other researchers, catch by angler reported during creel survey, catch by angler reported via telephone, or detection of PIT tag by other studies (DWR as well as other Federal and State Agency). When recaptures occurred, or were reported by an outside source, efforts were made to collect as much data for each fish as possible, including length, weight, tag numbers, location of capture, and ultimate fate of the fish. Often recaptures by anglers resulted in the fish being kept and likely consumed, whereas fish captured by researchers were generally returned to the waterways.

2.2.2 Issues

Predator sampling was conducted pursuant to the requirements of the DFW as outlined in SCP #7744 (an individual permit issued to Veronica Wunderlich) and SCP # 10286, an entity permit which limited sampling efforts to days when approved staff were available.

Predator sampling efforts were additionally constrained by availability of boats as well as qualified and approved boat operators. The DWR Bay-Delta Office (BDO) has a clearly defined boat operator policy that requires that each operator complete a multi-day field based Motorboat Operator Certification Course (MOCC) and demonstrate necessary skills on the BDO vessel in the presence of designated approved BDO operators. As many staff members on the CCFPS were not yet approved BDO operators, all predator sampling efforts needed to be scheduled around the availability of qualified boat operators, as well as Operations Procedure 2 – Lock-out/Tag-out (OP-2) certified staff and the SCP holder. This required the careful coordination of multiple schedules across multiple ongoing projects.

2.2.3 Data Analysis

Data sheets were scanned and data was entered into a database. Total catch, catch by species, and catch by size for each month and the year as a whole were compiled for the entire Forebay, and catchability, defined as catch per unit effort (CPUE) per sampling day was calculated using the equation:

$$q = \frac{C}{f \times a}$$

(q = catchability (fish caught per hours of sampling), C = catch, f = fishing effort which is defined as hours spent fishing per sampling day, and a = number of anglers during the effort)

Mean CPUE per month for all species combined was then estimated by:

$$q_m = \frac{\sum q_i}{d}$$

(q_m = mean monthly catchability, q_i = catchability for each day sampled in the month, and d = number of sampling days in the month)

Mean CPUE per month was then calculated for each species using the equation

$$q_{sp} = \frac{\sum\left(\frac{Csp}{f \times a}\right)_i}{d}$$

Seasonal CPUE was calculated for the four seasons defined as Winter (Jan 1 – March 18; December 21 - 31), Spring (March 19 – June 19), Summer (June 20 – September 21), and Fall (September 22 – December 20), based upon the equinox/solstice dates for 2016.

Seasonal CPUE for all species combined was calculated by:

$$q_s = \frac{\sum q_i}{d}$$

(q_s = seasonal catchability, q_i = catchability for each day sampled in the season, and d = number of sampling days in the season)

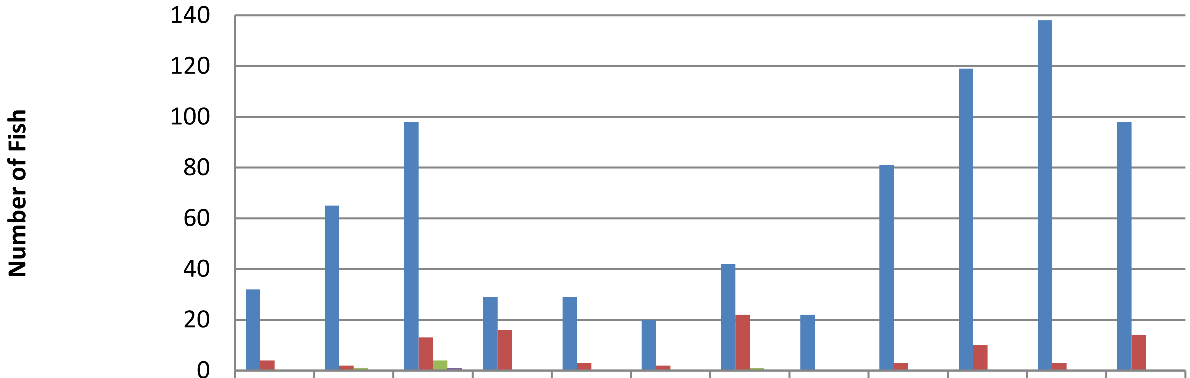
2.2.4 Results

Direct Sampling

A total of 91 sampling days were conducted from January 7, 2016 until December 30, 2016, resulting in the capture of 871 target predatory fish (Table 1, Figure 2) including 773 Striped Bass, 92 Largemouth Bass and 6 catfish. In addition, one non-target fish, a steelhead (*Onchorhynchus mykiss*), was captured on March 25, 2016. The steelhead was released unharmed. During the 2016 sampling effort, four previously tagged Striped Bass and 19 previously tagged Largemouth Bass were recaptured. One Largemouth Bass and 108 Striped Bass were released untagged, due to injury during capture or other issues.

Table 1: 2016 Predatory Fish Captures by Month

Month	Striped Bass	Largemouth Bass	Catfish	Total
January	32	4	0	36
February	65	2	1	68
March	98	13	4	115
April	29	16	0	45
May	29	3	0	32
June	20	2	0	22
July	42	22	1	65
August	22	0	0	22
September	81	3	0	84
October	119	10	0	129
November	138	3	0	141
December	98	14	0	112
Total	773	92	6	871



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Striped Bass	32	65	98	29	29	20	42	22	81	119	138	98
Largemouth Bass	4	2	13	16	3	2	22	0	3	10	3	14
Catfish	0	1	4	0	0	0	1	0	0	0	0	0
Non-Target	0	0	1	0	0	0	0	0	0	0	0	0

Figure 2: 2016 Predatory Fish Captures by Month

Fish captured during the 2016 effort ranged in length from 20 cm to 83.5 cm for Striped Bass, 26 cm to 54.9 cm for Largemouth Bass, 33 cm to 55 cm for Channel Catfish, and 24.5 cm for White Catfish (Figure 3).

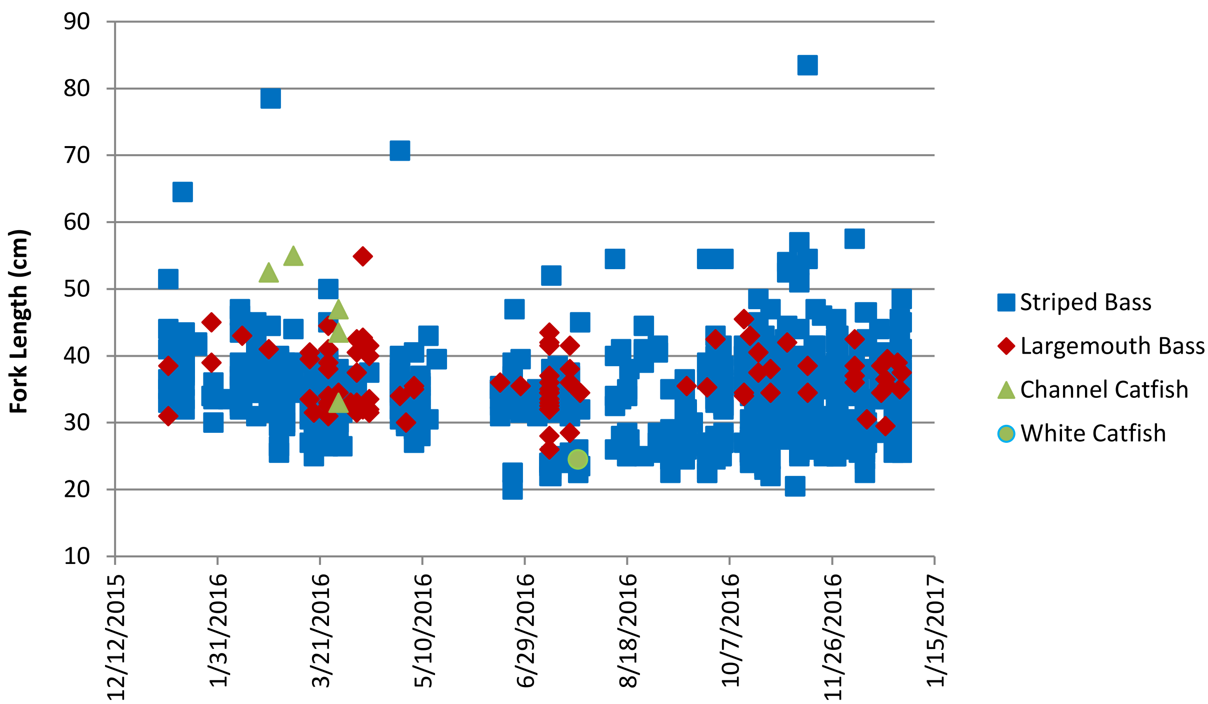


Figure 3: 2016 Predatory Fish Captures by Fork Length and Species

The majority of Striped Bass captured in 2016 at 67% (517) of total catch, were in the 0.5 lb. (0.23 kg) to 1.5 lb. (0.68 kg) size class, with the highest catch of those fish occurring in March and November, at 87 and 80 fish respectively (Table 2, Figure 4, 5). Fish under 0.5 lbs (0.23 kg) made up 21% (161) of the Striped Bass catch, with the bulk captured in October and November, at 38 and 37 respectively. Fish in the 1.5 lb. (0.68 kg) to 3 lb. (1.36 kg) size class represented 10% (73) of total Striped Bass catch, with the highest number captured in December at 21 fish. Fish over 3 lbs. (1.36 kg) represented 2% (17) of the total Striped Bass caught, with the bulk captured in November, at eight fish.

Table 2: 2016 Striped Bass Captures by Size Class

Month	Fish <.5 lbs. (0.23 kg)	Fish >.5 lbs.(0.23 kg) and <1.5 lbs.(0.68 kg)	Fish >1.5 lbs. (0.68 kg) and <3.0 lbs. (1.36 kg)	Fish >3.0 lbs. (1.36 kg)
January	0	21	9	2
February	1	55	8	1
March	6	87	4	0
April	1	27	0	1
May	6	21	2	0
Jun	3	16	0	0
Jul	15	24	1	1
Aug	7	9	5	1
Sept	30	46	3	1
Oct	38	72	7	1
Nov	37	80	13	8
Dec	17	59	21	1
Total for Year	161	517	73	17

*Weight was not recorded for five Striped Bass during the 2016 sampling season.

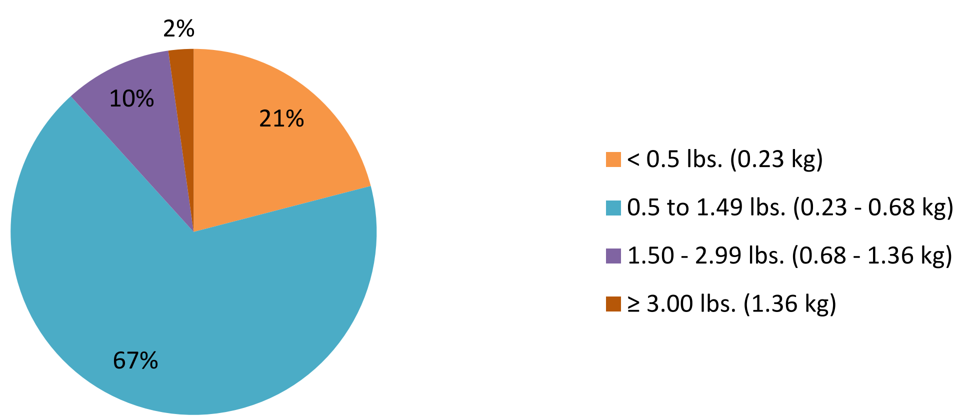
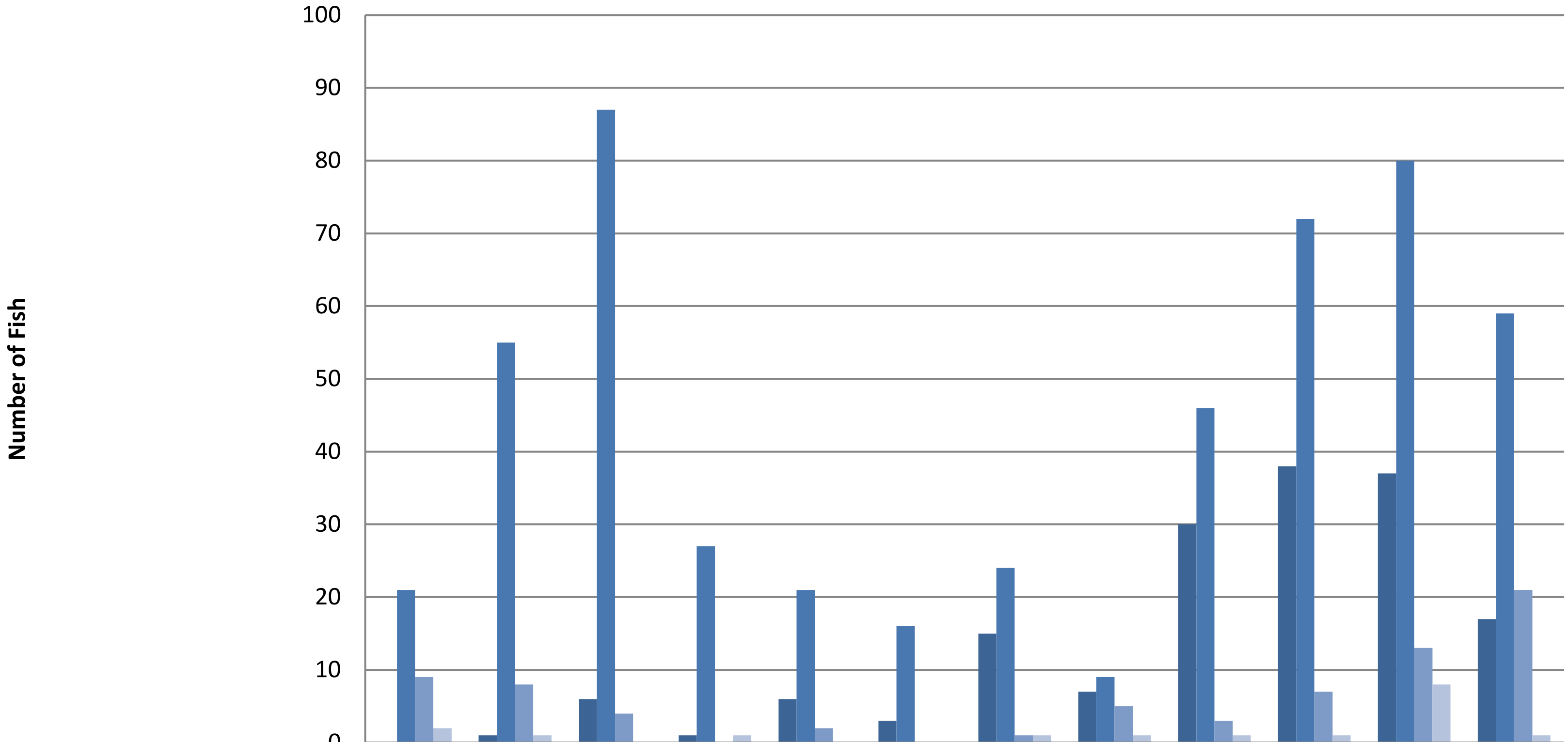


Figure 4: Percentage of 2016 Striped Bass Captures by Size Class



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
< 0.5 lbs. (0.23 kg)	0	1	6	1	6	3	15	7	30	38	37	17
0.5 to 1.49 lbs. (0.23 - 0.68 kg)	21	55	87	27	21	16	24	9	46	72	80	59
1.50 - 2.99 lbs. (0.68 - 1.36 kg)	9	8	4	0	2	0	1	5	3	7	13	21
≥ 3.00 lbs. (1.36 kg)	2	1	0	1	0	0	1	1	1	1	8	1

Figure 5: 2016 Striped Bass Captures by Size Class

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Predatory fish were caught in all Areas 1, 2, and 3 during the winter sampling period (Figure 6), with the bulk being caught in Area 1, at 177 fish.

Figure 6: Winter 2016 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, and 4 during the spring sampling period (Figure 7), with the bulk being caught in Area 1, at 78 fish.

Figure 7: Spring 2016 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3, 4, and 5 during the summer sampling period (Figure 8), with the bulk being caught in Area 2, at 78 fish.

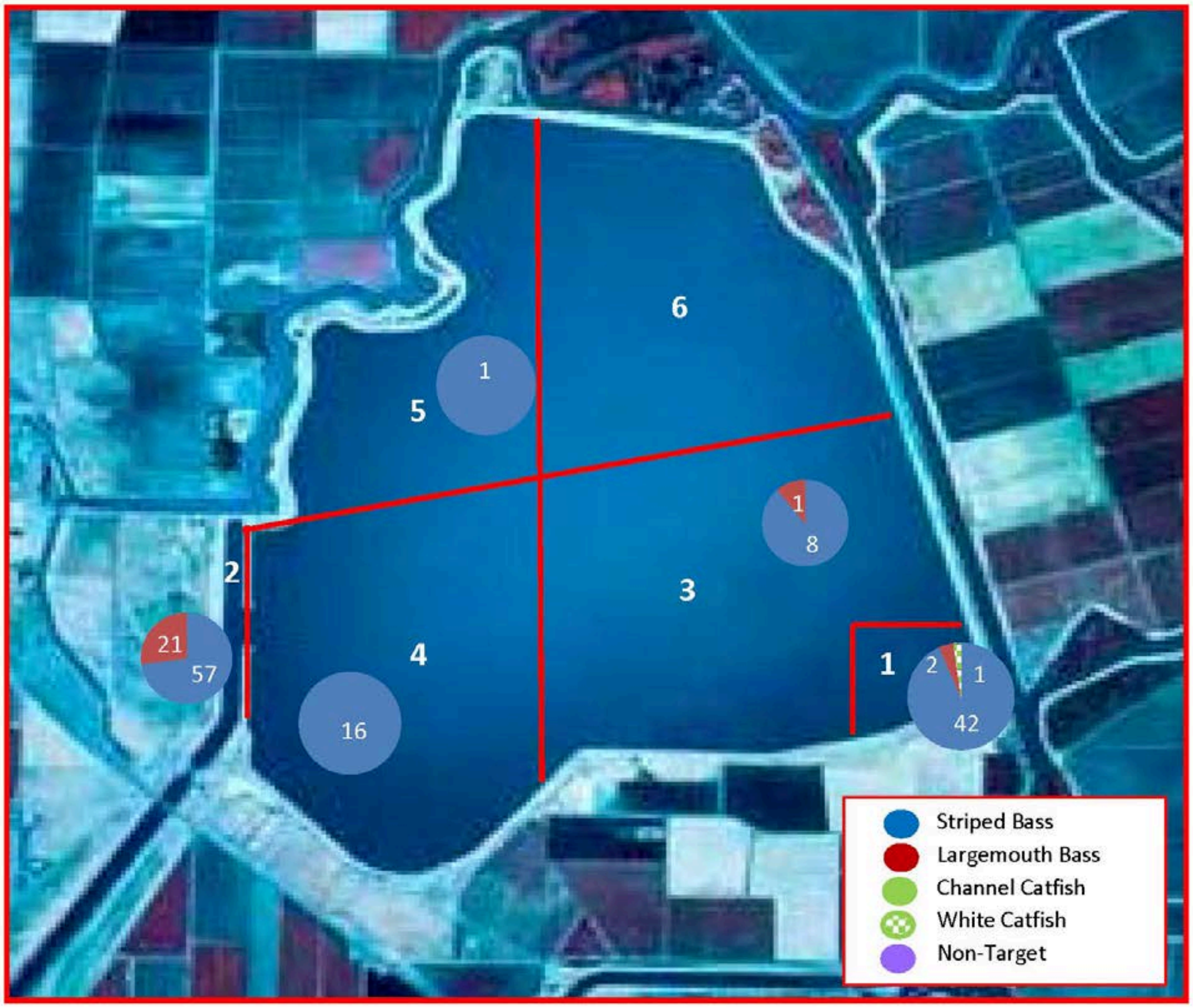

Figure 8: Summer 2016 Catch by Location and Species

Predatory fish were caught in Areas 1, 2, 3 and 4 during the fall sampling period (Figure 9), with the bulk being caught in Area 2, at 186 fish.

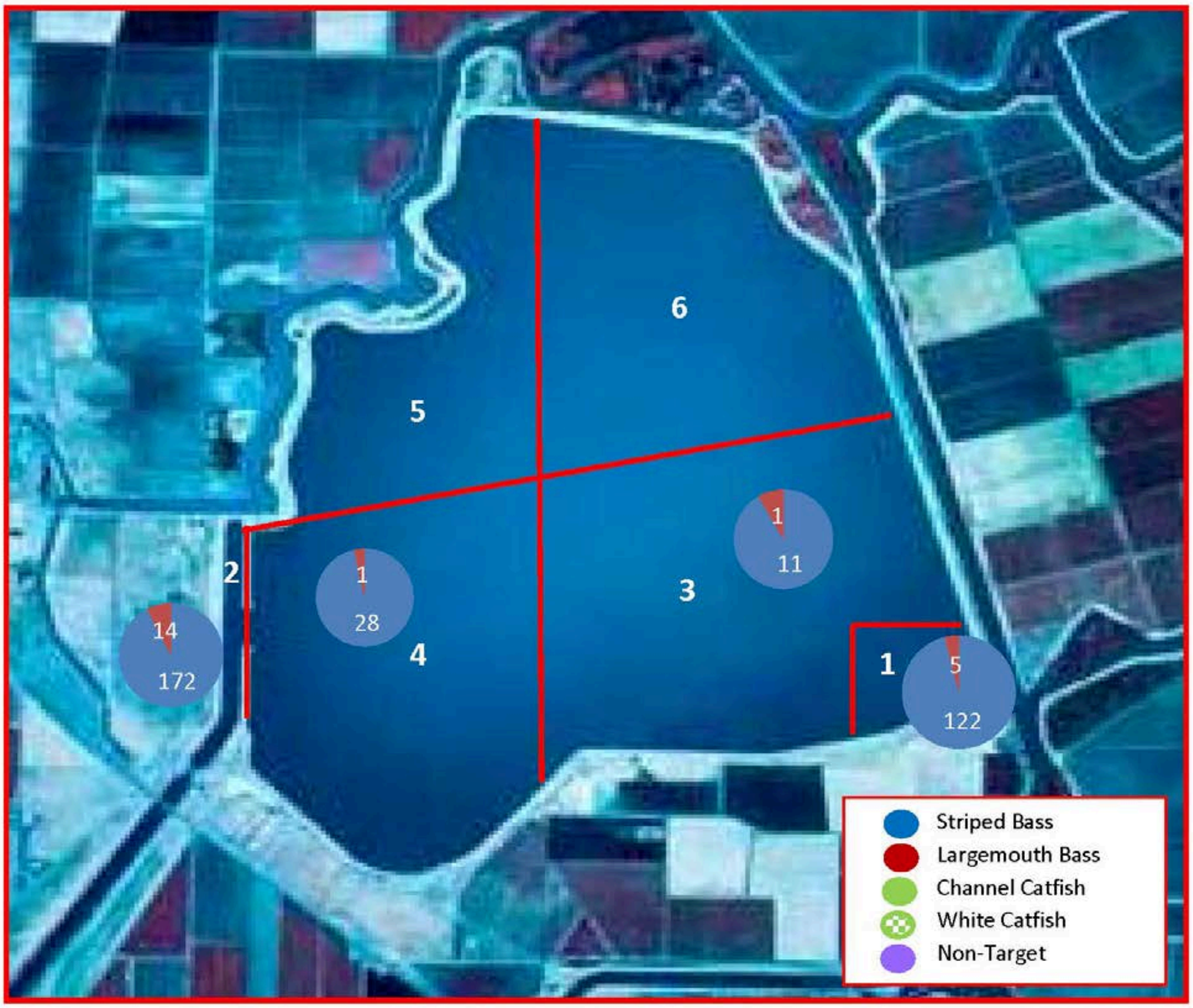

Figure 9: Fall 2016 Catch by Location and Species

CPUE per sampling day was calculated using the equation: $q = \frac{c}{f \times a}$. Mean CPUE per month was then estimated by: $q_m = \frac{\sum q_i}{d}$. CPUE was highest in March and October at 1.59 and 1.68, respectively, and lowest in August at 0.51 (Table 3, Figure 10).

Table 3: 2016 Catchability (CPUE) for all Species Combined

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Mean	**0.53**	**1.19**	**1.59**	**0.9**	**0.87**	**0.67**	**0.81**	**0.51**	**1.22**	**1.68**	**0.89**	**0.66**
1st Sample Day	**0.71**	**0.17**	**3.17**	**0.6**	**0.81**	**0.82**	**0.45**	**0.55**	**0.77**	**1.02**	**0.76**	**1.26**
2nd Sample Day	**0.28**	**1.03**	**1.44**	**0.76**	**1.74**	**0.79**	**1.66**	**0.43**	**0.97**	**1.45**	**0.52**	**0.27**
3rd Sample Day	**0.56**	**1.33**	**0.87**	**0.52**	**1.18**	**0.39**	**1.25**	**0.62**	**0.51**	**2.51**	**1.06**	**1.26**
4th Sample Day	**1.13**	**1.21**	**1.02**	**1.74**	**0.4**		**0.5**	**0.36**	**3.43**	**0.92**	**0.43**	**0.57**
5th Sample Day	**0.26**	**1.43**	**2.1**		**0.24**		**0.92**	**0.6**	**0.78**	**1.76**	**1.55**	**0.8**
6th Sample Day	**0.46**	**1.96**	**3.06**				**0.49**		**0.15**	**1.64**	**0.64**	**0.36**
7th Sample Day	**0.3**		**0.1**				**0.39**		**1.53**	**2.4**	**1.15**	**0.44**
8th Sample Day			**0.95**						**1.63**	**1.73**	**0.69**	**0.33**
9th Sample Day											**0.57**	**0.36**
10th Sample Day											**0.78**	**0.53**
11th Sample Day											**1.18**	**0.96**
12th Sample Day											**1.83**	**0.77**
13th Sample Day											**0.24**	
14th Sample Day											**1.03**	

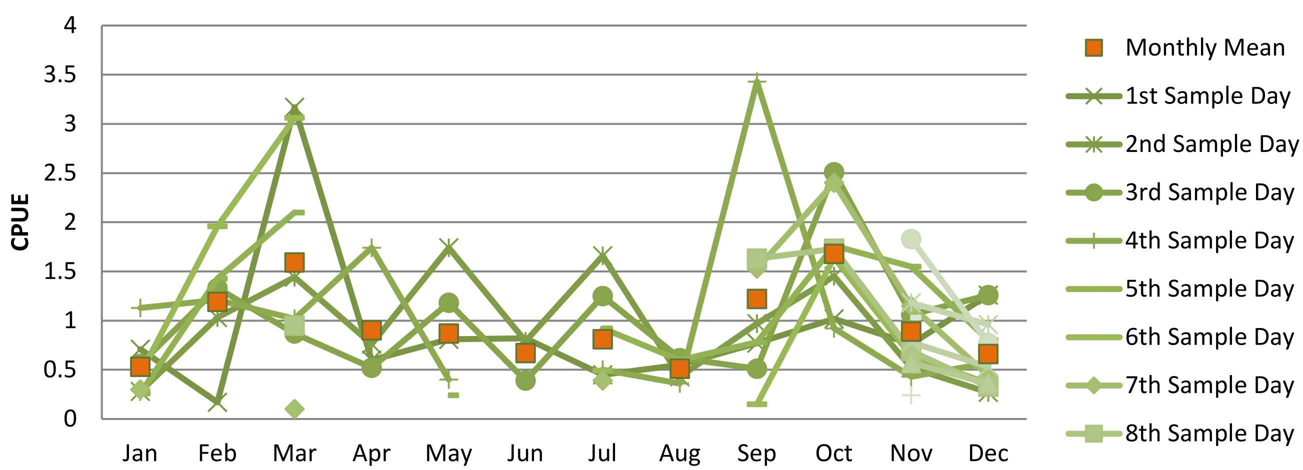

Figure 10: 2016 CPUE for all Species Combined

Seasonal CPUE was calculated for the four seasons defined as Winter (Jan 1 – March 18; December 21 - 31), Spring (March 19 – June 19), Summer (June 20 – September 21), and Fall (September 22 – December 20). CPUE was found to be highest during Fall and Spring at 1.12 and 0.99, respectively (Table 4).

Table 4: 2016 Catchability (CPUE) for all Species by Season

Season	Sampling Days	Seasonal CPUE
Winter	24	0.95
Spring	13	0.99
Summer	19	0.80
Fall	31	1.12

Mean monthly CPUE was calculated for each species using the equation: $q_{sp} = \frac{\Sigma\left(\frac{Csp}{f \times a}\right)_i}{d}$

CPUE was found to be highest for Striped Bass in October at 1.61 fish per hour, followed by September and February at 1.18 and 1.14, respectively (Table 5). For Largemouth Bass, CPUE peaked in July, at 0.24 fish per hour, and for catfish, CPUE peaked in March at 0.05 fish per hour.

Table 5: 2016 Monthly Catchability (CPUE) By Species

Monthly CPUE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Striped Bass	0.47	1.14	1.37	0.67	0.79	0.60	0.56	0.51	1.18	1.61	0.87	0.57
Catfish	0.00	0.02	0.05	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Largemouth Bass	0.06	0.00	0.15	0.23	0.08	0.06	0.24	0.00	0.04	0.07	0.02	0.09

Temperatures began to meet or exceed 20° C in May 2016 and remained mostly above this temperature until the end of September, peaking in June and July (Figure 11), however no clear correlation between temperatures and CPUE were identified.

Figure 11: 2016 Sampling Effort Temperatures (°C)

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Recapture of Marked Fish

A total of 89 individual fish were recaptured during 2016. Twelve of the Largemouth Bass were recaptured multiple times, by multiple methods (Table 6).

Table 6: 2016 Largemouth Bass Recaptured Multiple Times

Fish PIT Tag Number	Date Captured	Recapture Method
3D6.000B320E1A	3/25/2016	Predator Sampling Crew
	4/11/2016	Other Study Researcher (in Forebay)
3D6.000B3AA22E	5/12/2016	Electrofishing (in Forebay)
	5/18/2016	Electrofishing (in Forebay)
	7/11/2016	Predator Sampling Crew
	9/30/2016	Predator Sampling Crew
	10/17/2016	Predator Sampling Crew
3D6.001569BEB5	4/11/2016	Other Study Researcher (in Forebay)
	4/27/2016	Electrofishing (in Forebay)
3D6.001569C02F	7/11/2016	Predator Sampling Crew
	10/14/2016	Predator Sampling Crew
3D9.239F883D1C	4/20/2016	Electrofishing (in Forebay)
	4/27/2016	Electrofishing (in Forebay)
	7/11/2016	Predator Sampling Crew
3D9.239F885247	5/12/2016	Electrofishing (in Forebay)
	10/21/2016	Predator Sampling Crew
3D9.239F885349	5/4/2016	Electrofishing (in Forebay)
	5/12/2016	Electrofishing (in Forebay)
3D9.239F886FC8	3/16/2016	Predator Sampling Crew
	4/14/2016	Predator Sampling Crew
3DD.003BC7F179	5/4/2016	Electrofishing (in Forebay)
	5/12/2016	Electrofishing (in Forebay)
3DD.003BC7F2F5	5/12/2016	Electrofishing (in Forebay)
	5/18/2016	Electrofishing (in Forebay)
	10/14/2016	Predator Sampling Crew
3DD.003BC7F305	5/11/2016	Electrofishing (in Forebay)
	5/18/2016	Electrofishing (in Forebay)
3DD.003BC7F407	4/5/2016	Other Study Researcher (in Forebay)
	4/13/2016	Electrofishing (in Forebay)

Including the multiple recaptures, seven fish were recaptured by anglers, 42 during electrofishing efforts in the Forebay, 20 at Curtis Landing Release Site, five at Horseshoe Bend Release Site, 23 during predator sampling, five during other studies within the Forebay and two by NOAA on the San Joaquin

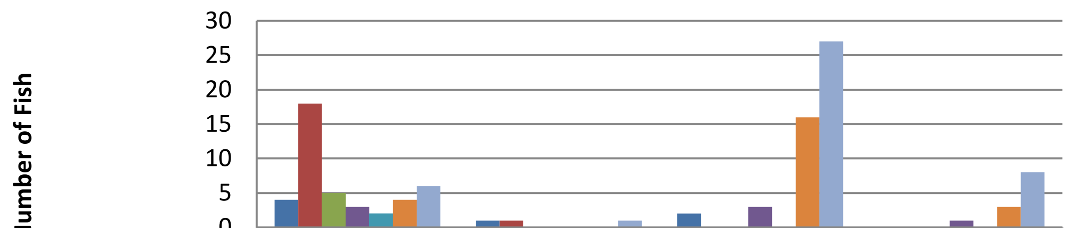
River (Table 7). Of the 89 individual recaptured fish, all but four were released back into the water at the point of capture.

Table 7: 2016 Recaptured Fish

Recapture Method	Striped Bass	Largemouth Bass	Catfish	Total
Angler	5	2	0	7
Curtis Landing Release Site PIT Antennae	19	0	0	19*
Horseshoe Band Release Site PIT Antennae	5	0	0	5
Other Study Researcher (in Forebay)	3	4	0	7
NOAA crew (San Joaquin River)	2	0	0	2
Predator Sampling Crew	4	19	0	23
Electrofishing (in Forebay)	7	35	0	42

*One fish with unknown species due to a transcription error during tagging, was detected at Curtis Landing in December 2016.

Of those 89 recaptures, 15 were acoustic tagged fish, and the remaining were PIT tagged fish (Figure 12).



	Striped Bass (PIT)	Striped Bass (Acoustic)	Largemouth Bass (PIT)	Largemouth Bass (Acoustic)
Angler	4	1	2	0
Curtis Landing Release Site PIT Antennae*	18	1	0	0
Horseshoe Band Release Site PIT Antennae	5	0	0	0
Other Study Researcher (in Forebay)	3	0	3	1
NOAA crew (San Joaquin River)	2	0	0	0
Predator Sampling Crew	4	0	16	3
Electrofishing (in Forebay)	6	1	27	8

Figure 12: 2016 Recaptured Fish by Tag Type, Species and Method

2.2.5 Discussion and Recommendations

The 2016 predator sampling effort in the Forebay provided fish for the acoustic tagging studies as well as mark/recapture studies using non-acoustic tags such as Passive Integrated Transponder (PIT) and Floy tags, to investigate population size and gather basic data. Data from these various efforts will be used for bioenergetics modeling, and to investigate species catchability, immigration and emigration rates, dietary habits, and seasonal distribution in the Forebay, in future synthesis reports.

The largest numbers of predatory fish were captured during months of March, October and November at 116, 129, and 141 respectively. Within the Striped Bass catch, the largest size class of Striped Bass (over 3.0 lbs./1.36 kg) were captured in all sampling months except March, May and June, with total numbers caught peaking in November. The next smaller size class Striped Bass, between 1.50 lbs. (0.68 kg) and 2.99 lbs. (1.36 kg), were caught in every month except April and June, peaking in December. The size class Striped Bass, between 0.5 lbs. (0.23 kg) and 1.5 lbs. (0.68 kg) were caught in every month sampled, with peaks in March, October, and November. Striped Bass under 0.5 lbs. (0.23 kg) were captured in every month except January, with a peak in October and November.

Throughout the year the 0.5 lbs. (0.23 kg) to 1.5 lbs. (0.68 kg) size class dominated all of the sampling months, and represented 67% of the total Striped Bass catch for the year. This may be indicative of a thriving population of small Striped Bass, including fish less than 3.0 lbs. (1.36 kg), which are present in the Forebay year round. The overall catch and peak catch for Largemouth Bass and catfish were different than those of Striped Bass, with Largemouth Bass caught in every month except August, peaking in July. Catfish were only caught during three months, February, March and July, with the bulk caught in March, at four fish. Comparatively few catfish were caught during the sampling effort, representing only 1% of the overall catch. It should be noted that no specific species were targeted, and bait versus lures were used randomly during all sampling efforts from 2013 through 2016.

A total of 89 fish were recaptured during 2016, with 12 of those fish caught between two and five separate times. The bulk of recaptures occurred during electrofishing efforts, at 42 fish. Only seven fish were reported as captured by anglers, 23 were captured during sampling efforts, two during a NOAA study on the San Joaquin River, and five during a separate study in the Forebay. Tagged fish were also detected at the two DWR release sites during 2016, five at Horseshoe Bend and 20 at Curtis Landing.

CPUE was highest in March and October, peaking at 1.68, and lowest in August, at 0.51. When analyzed seasonally, CPUE was higher in Spring and Fall, indicating a possible seasonal trend. While there may be some seasonal trends in catch by species and size class, due to the variables in sampling, such as shore versus boat based angling, a wide range of sampler experience, gear selection, and time required to process each fish caught, these trends need more robust examination before a strong conclusion can be drawn. Residency can be more thoroughly investigated using biotelemetry, as described in Section 2.3, below.

2.3 Biotelemetry

2.3.1 Methods

Receiver Array

The initial phase of the biotelemetry receiver array, installed between January and March 2013, consisted of nine units within and immediately adjacent to the Forebay. These nine units included the IC1, IC2, IC3, RGD1, RGU1, WC1, WC2, WC3 and ORS1 (Figure 13).

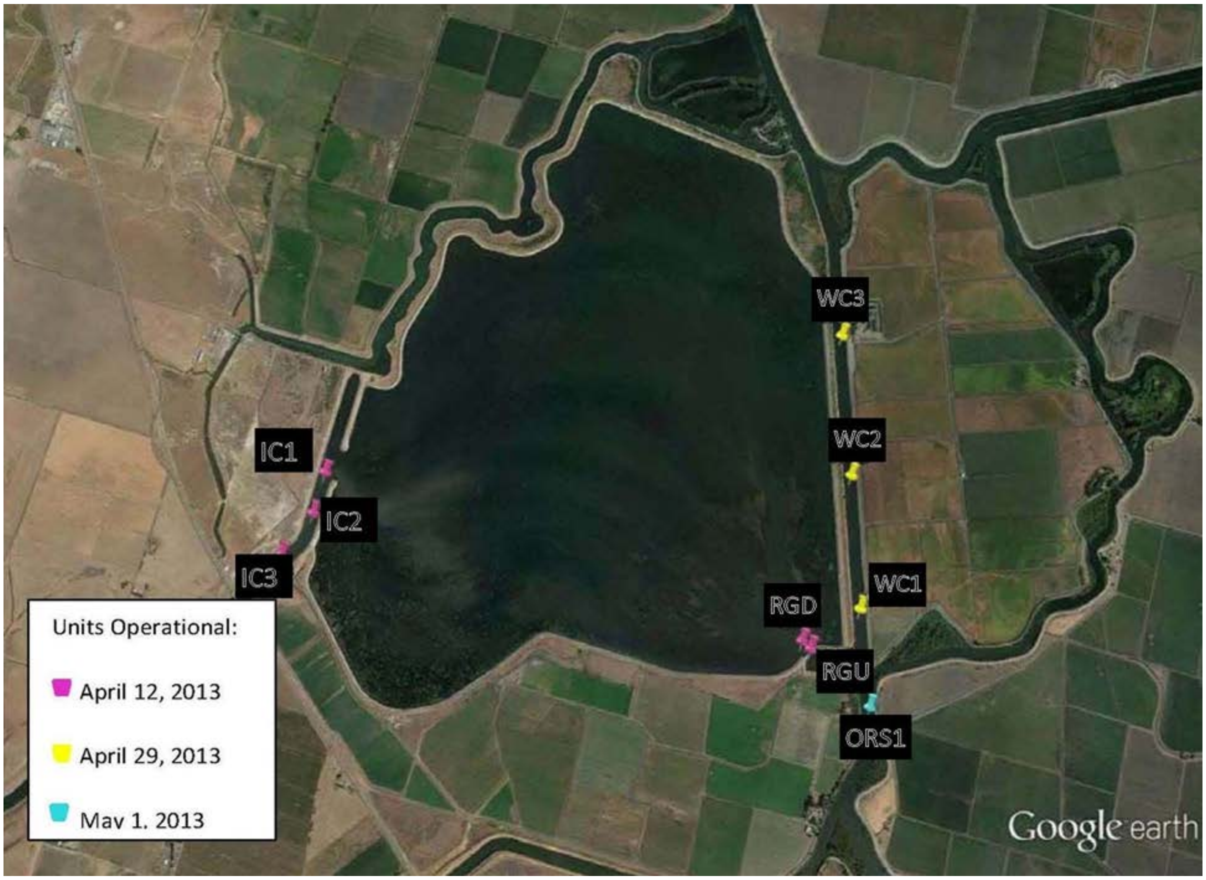


Figure 13: 2014 Receiver Array (Deployed in 2013)

Each of these sites was initially made up of an Hydroacoustic Technology Incorporated (HTI) Model 295x datalogger/ hydrophone combination, powered by a 12-volt (two six-volt sealed deep cycle batteries wired in series) power source connected to a solar panel via a solar charge controller to ensure continued operation. A beacon tag with a predetermined code was deployed near each hydrophone to document ongoing functionality of the unit. These units were upgraded to HTI Model 395 dataloggers in December of 2013 (Figure 14), allowing for remote monitoring and data downloads, as well as gps linking of the entire array.

Figure 14: Model 395 Datalogger

The second phase of five additional units was installed outside of the Forebay between April 13 and 15, 2015 (Figure 15, 16) to expand the array's coverage to the main waterways leaving the Forebay.

Figure 15: Receiver Site with Datalogger and Solar Panel Located at Grant Line Canal (GL1)

Figure 16: 2015 Expanded Receiver Array

An additional site was added at the Curtis Landing Release Site, located on Sherman Island, on June 21, 2016 (Figure 17). A site is planned at Horseshoe Bend Release Site; however, deployment was not possible during the 2016 field season due to high flows in the Sacramento River which created logistical difficulties.

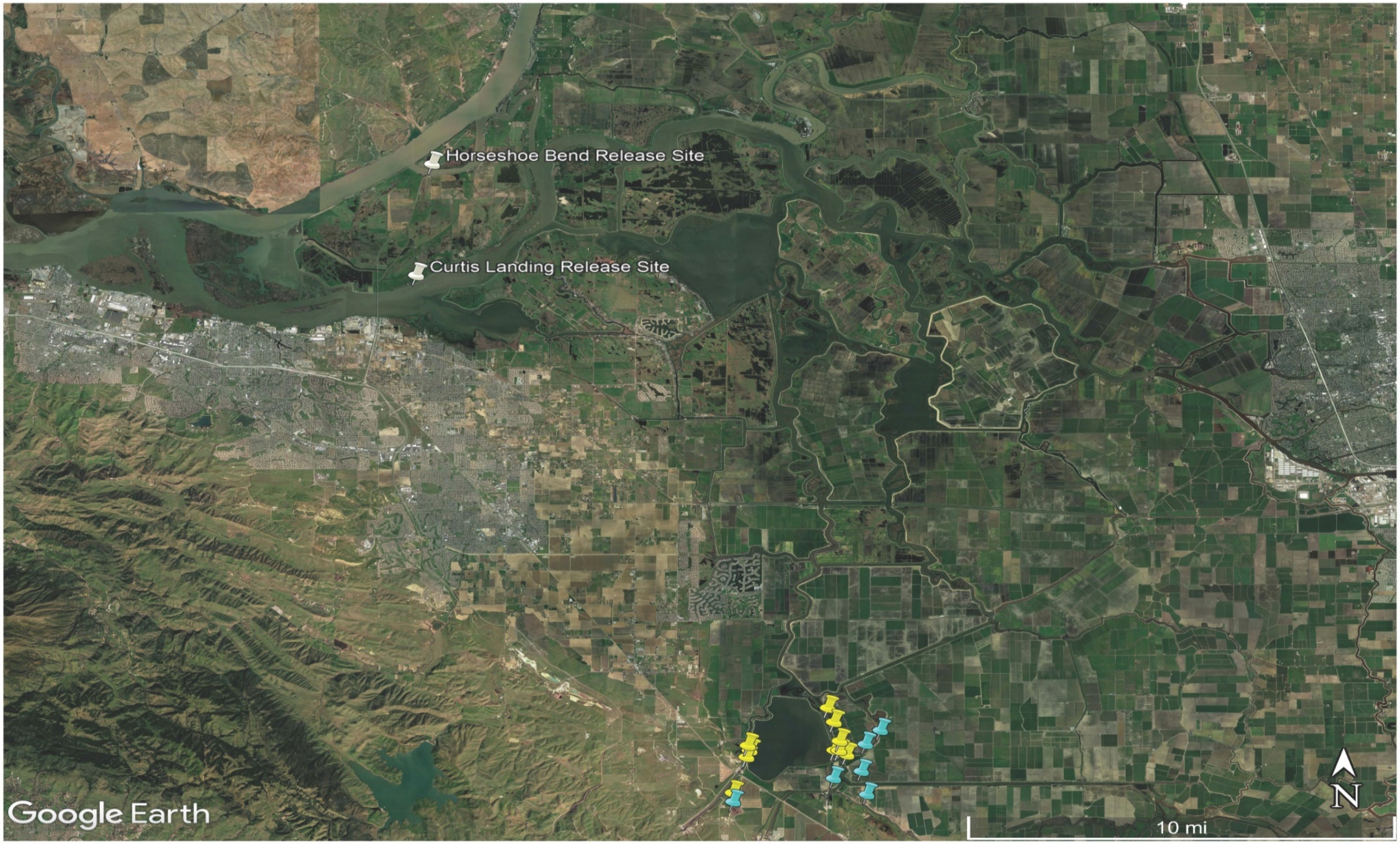


Figure 17: 2016 Receiver Array including Deployed Curtis Landing Release Site and Planned Horseshoe Bend Release Site

In addition to the static array, a mobile monitoring effort was conducted, using a mobile version of the Model 395 datalogger/hydrophone unit (Figure 18).

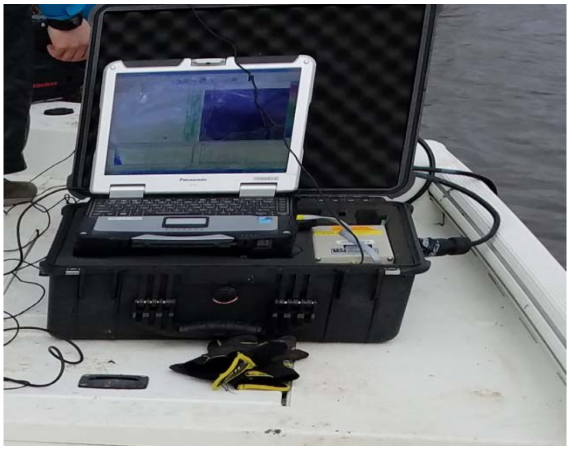


Figure 18: Mobile Datalogger Unit and Hydrophone Attachment

Mobile monitoring surveys were conducted up to three times per week, using pre-determined transects to cover the portion of the Forebay not covered by the static receiver array (Figure 19). These transect were the same as those used in 2015, with the addition of a fourth transect, Survey Route D, covering the perimeter of the Forebay.

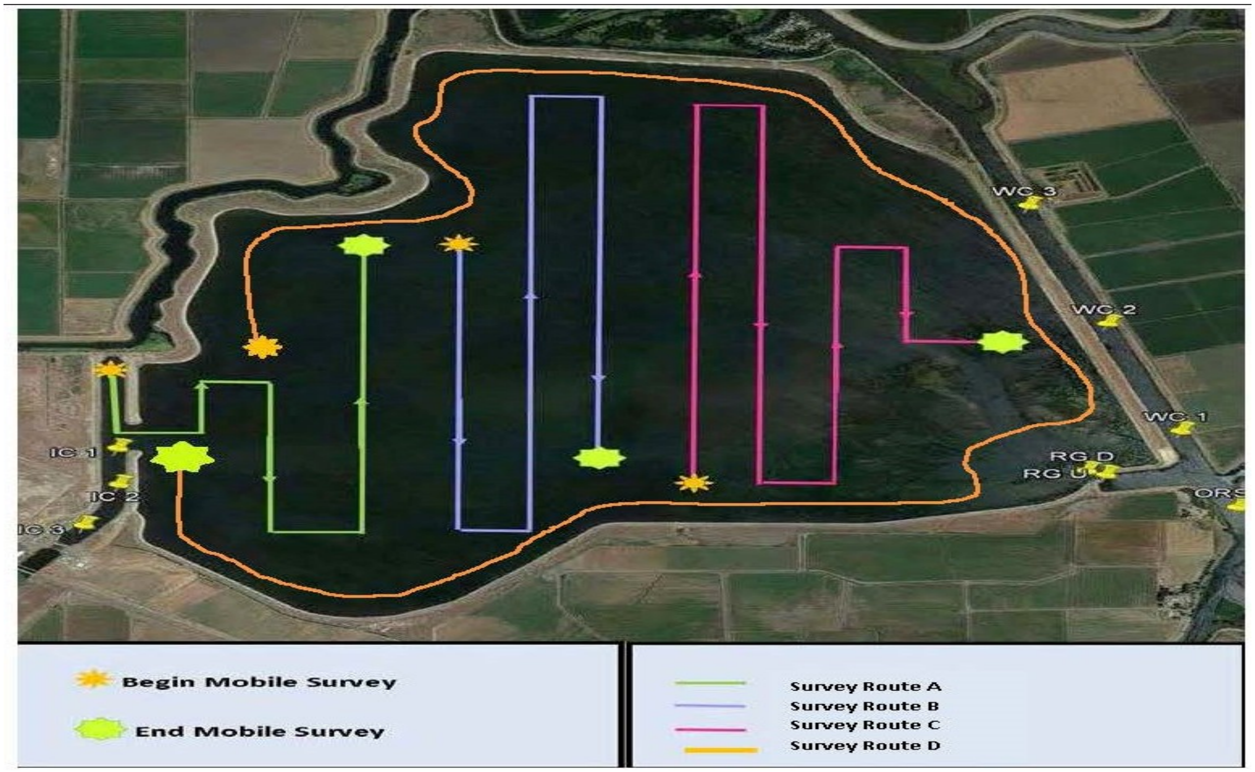


Figure 19: 2015 Mobile Monitoring Transect Map

Acoustic Tagging

Tag codes for 2016 were predetermined by HTI, with sub code 03 for Striped Bass less than 1.5 lbs. (0.68 kg), sub code 16 for Striped Bass over 1.5 lbs. (0.68 kg), and sub code 26 for non-Striped Bass (catfish species and black bass species such as Largemouth Bass, Spotted Bass, and Smallmouth Bass). At the beginning of each month, up to seven HTI 795LG/ Biomark HPT9, 17 HTI 795LY/ Biomark HPT9, and seven HTI 795LZ/ Biomark HPT9 acoustic/PIT combination tags were programmed with codes from the lists provided by HTI. Tags that were not used the prior month were rolled forward into the new month. Following tag programming, each tag was checked for functionality via a tag "sniffer" or a hydrophone attached to an HTI 395 mobile data logger. Up to 31 predatory fish captured each month during the sampling efforts that were larger than 0.5 lbs. (0.23 kg) were tagged with HTI/ Biomark combination acoustic/PIT tags as well as secondary external Floy tags (Table 8).

Internal tagging followed procedures based on methods described in Wingate and Secor 2007, and incorporated the use of anesthesia methods as part of the INAD for Aqui-S 20E (US Fish and Wildlife Service (USFWS) 2011; Study # 11-741-16-017F). All captured predatory fish that were not acoustic tagged, were tagged with internal Biomark HPT12 PIT tags and external Floy tags so that they could be identified in the event of recapture or salvage.

Table 8: 2016 Tag Codes

HTI Tag Type	Fish Size Range lbs.(kg)	Striped Bass	Black Bass	Catfish	Total Tags per Month
LG – sub code 03	>0.5 (0.23) to <1.5 (0.68)	7	0	0	7
LY – sub code 26 (non-Striped Bass); sub code 16 (Striped Bass)	>1.5 (0.68) to <3.0 (1.36) (Striped Bass) >1.5 (0.68) (non-Striped Bass)	7	5	5	17
LZ – sub code 16	>3.0 (1.36)	7	0	0	7
Total Fish per Month		21	5	5	31

Acoustic tagging was conducted on 66 predator sampling days, at various times during the day from January 7, 2016 until December 30, 2016. Secondary external Floy tags were applied to all captured fish. After the fish was tagged, scale samples were taken, and the fish was placed into a recovery net at the point of capture, and monitored until swimming normally. Once the fish was deemed fully recovered it was released.

Tag Retention[1]

As part of the quality assurance/quality control (QA/QC) efforts for acoustic tagging, a laboratory based study to examine fish health and tag retention was conducted. A group of 30 Largemouth Bass weighing over 1.5lbs (0.68 kg) that had been captured in the Forebay for various studies, and had been held at either the Fish Science Building (FSB) or the Tracy Fish Collection Facility (TFCF), were placed into tanks at the FSB. The fish were held for a two-week acclimation period. Once acclimated, four of the five taggers working on the CCFPS surgically implanted acoustic tags (HTI LY) into six individual fish. Tagging followed the standard operating procedures for all CCFPS predator tagging (Wunderlich 2015), and included the application of the Floy tags to the dorsal side of each fish. Following tagging, each fish was placed in one of six holding tanks so that each tank contained one fish from each tagger, along with an untagged control fish. Fish were fed a maintenance diet of steelhead feed, and were held for 87 days. At the conclusion of the study, the fish were sacrificed and necropsies were performed. An in-depth evaluation of incision and suture healing, and tagging effects was conducted. Insertion sites for Floy tags and acoustic tags were scored for healing, residual irritation, and scarring. Internally, the fish were examined for position of tag, inclusion of organs in suturing, signs of tag encapsulation, and signs of disease. All fish evaluations were photo-documented. No indication of tag expulsion was found, and tag position, placement of sutures and overall healing indicate consistency across taggers for this species.

2.3.2 Issues

Lack of access to qualified boat operators and scheduling conflicts resulted in a slower than desired response time when datalogger/hydrophone units required maintenance, which caused delays in correcting problems when identified, and potential gaps in data collection.

2.3.3 Data Analysis

All tagging data was recorded onto Rite-in-Rain datasheets that were scanned onto the DWR server and transcribed into a Microsoft Access database. Data including release dates and times for each acoustic tagged fish was sent to HTI on a weekly basis. Tags were identified by tag type so that they could be removed from the search list as their batteries, which have different lifespans based upon type, reach the end of life. Data was downloaded via modem directly from the acoustic receivers by HTI staff and analyzed at their office in Seattle, Washington.

Data was analyzed by uploading each hour-long file from each receiver into the MarkTags® software and identifying tags that had been detected by the hydrophone. A list of acoustic tags released into the Forebay was compiled and compared to a list of acoustic tags detected by the receivers in the array. Each tag signature identified by the software has a visual beginning and end which are marked via electronic bookmarks and show which tag and what time it was detected (Figure 20). This information was initially processed by an automated program and then verified by trained technicians. Once analysis via MarkTags® was complete, the acoustic data was imported into a database which allowed for a secondary quality control phase, consisting of checking for tags that appeared to be detected by any hydrophone prior to release. Following verification of the data, the database was fully populated and returned to DWR.

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[1] Adapted from internal draft report "CCFPS Largemouth Bass Health and Tag Retention Study" by Bryce Kozak 2017

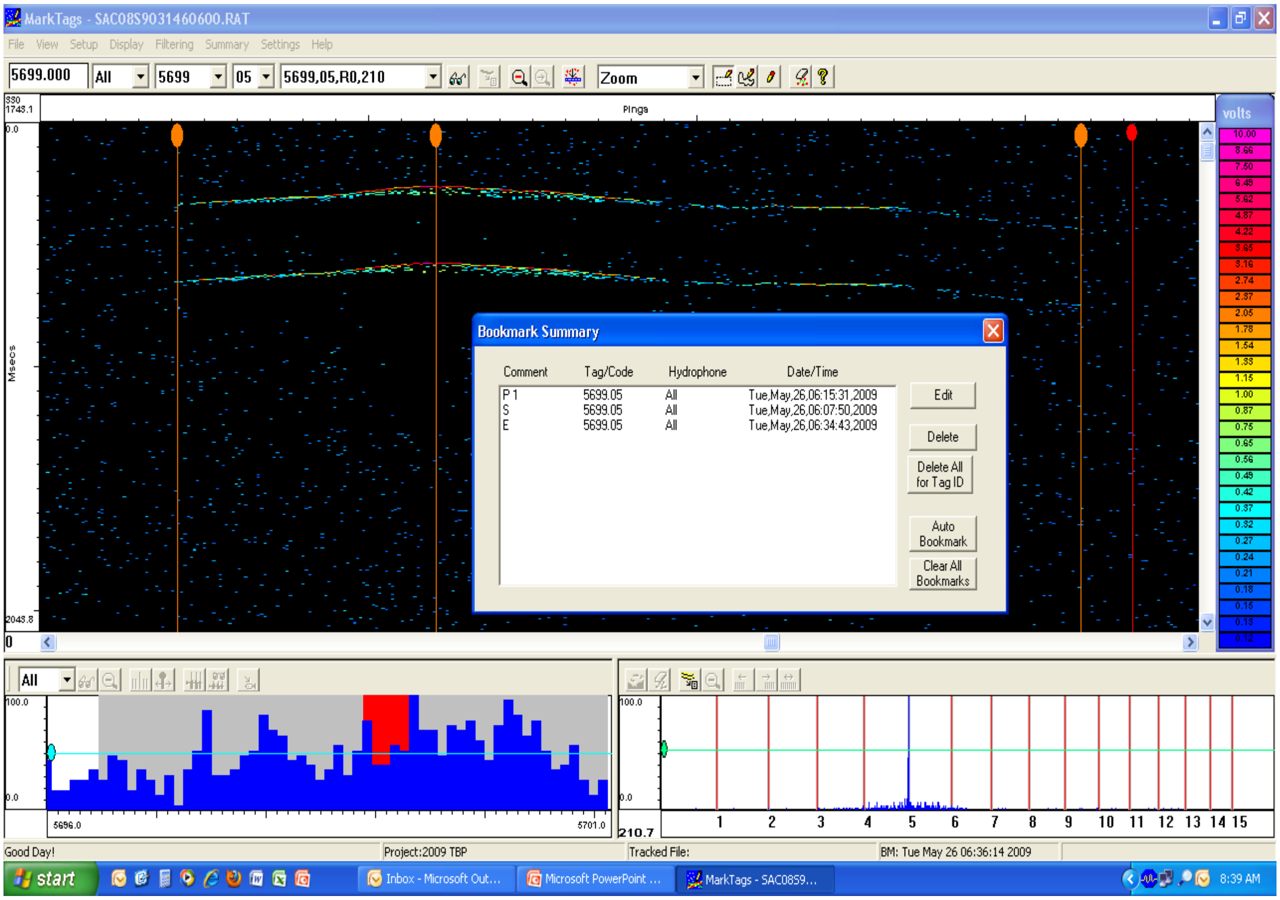


Figure 20: MarkTag Screenshot Displaying a Tagged Fish (2009 K. Clark)

The database allowed for determination of the first and last detection of each tagged fish at each receiver location. By looking at all of the receiver stations chronologically, a tagged fish can be “observed” as it moves through the array over time. This can be further visualized using programs such as EON fusion (Figure 21). For instance, in the figure below, the detection of an acoustically tagged catfish is indicated by the appearance of a color-coded polygon. The hydrophones are color-coded by location to make the image easier to decipher, with the intake channel in green, West Canal in blue, radial gates downstream in yellow, radial gates upstream in red, and Old River south in pink. The image in Figure 21 shows a span of time from June 27, 2013 through August 1, 2013, for an overview of the fish’s detections throughout this period, and shows that the fish was detected both inside and outside of the Forebay during this period.

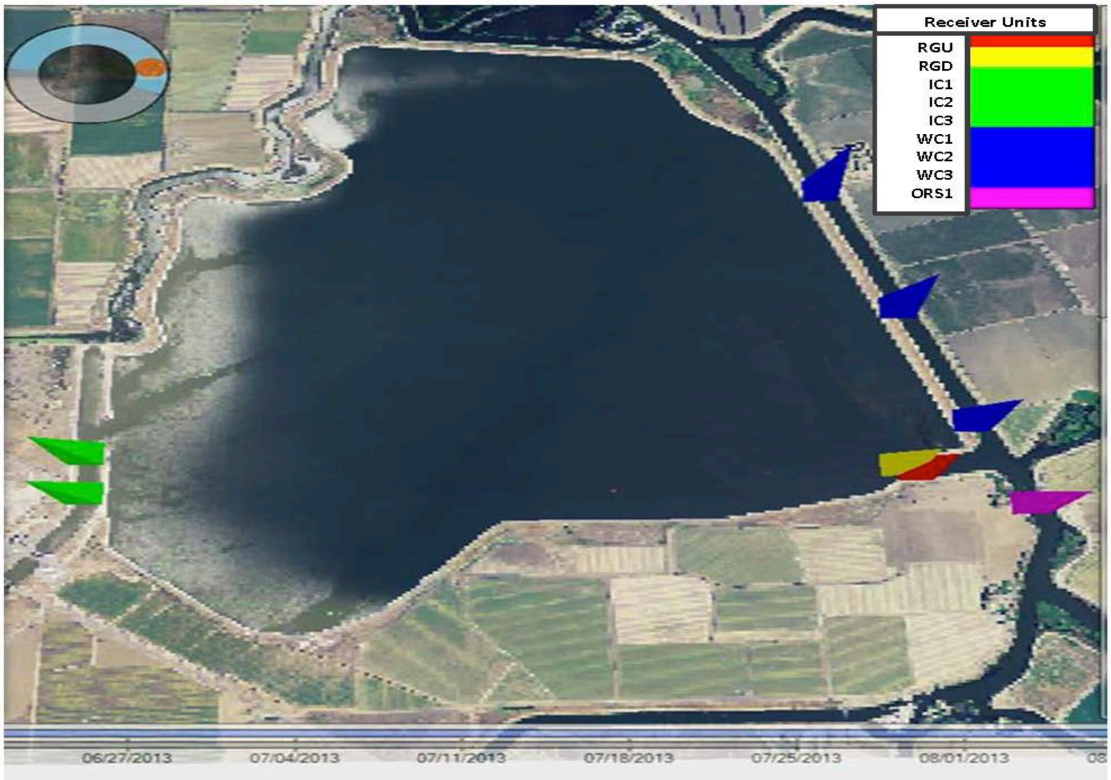


Figure 21: Screenshot of EONFusion showing Acoustically Tagged Catfish in and around Clifton Court Forebay during 2013

2.3.4 Results

A total of 181 predatory fish were acoustically tagged in 2016; seven Channel Catfish[2], 36 Largemouth Bass, and 138 Striped Bass (Table 9). The target number of 31 acoustically tagged fish per month (21 Striped Bass, five Catfish and five Largemouth Bass) was never achieved during 2016 tagging efforts. As 2016 was the last planned year of tagging for the CCFPS, during November and December tagging continued beyond the planned cap for each species and size group when additional fish beyond those tagging caps were captured. No Striped Bass under 1.5 lbs (0.68 kg) were tagged after September, as there was a defect in the remaining LG tags, which made them unusable. The highest number of acoustically tagged fish occurred in December and the lowest number occurred in June, at 31 and 8 fish, respectively. Of the 181 total tagged fish, four Largemouth Bass and 30 Striped Bass were not detected by any of the receivers in the array. This represented 19% of the total number of tagged fish during 2016. As these fish were not necessarily tagged and released within range of the deployed receivers and 12 of the 30 undetected fish were released in December, and mobile monitoring only provides short duration "snapshots" of the center of the Forebay, it is possible that a fish could be active in the Forebay, but never detected. A total of 116 fish were detected during mobile monitoring surveys (Figure 22), 106 of which had also been detected on at least one stationary receiver.

[2] Three Channel Catfish that had been captured for another project within the Forebay, and held at the FSB for several months, were tagged and released into the Intake Channel on January 8, 2016.

Table 9: Acoustic Tagged Fish in 2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass	2	2	4	4	0	0	5	0	2	3	3	11	36
Catfish Species	3	1	3	0	0	0	0	0	0	0	0	0	7
Striped Bass (LG)	7	7	7	7	7	7	7	7	4	0	0	0	60
Striped Bass (LY)	7	5	3	0	2	1	2	5	3	6	11	19	64
Striped Bass (LZ)	2	1	0	1	0	0	0	0	1	1	7	1	14
All Species	21	16	16	12	9	8	14	12	10	10	21	31	181

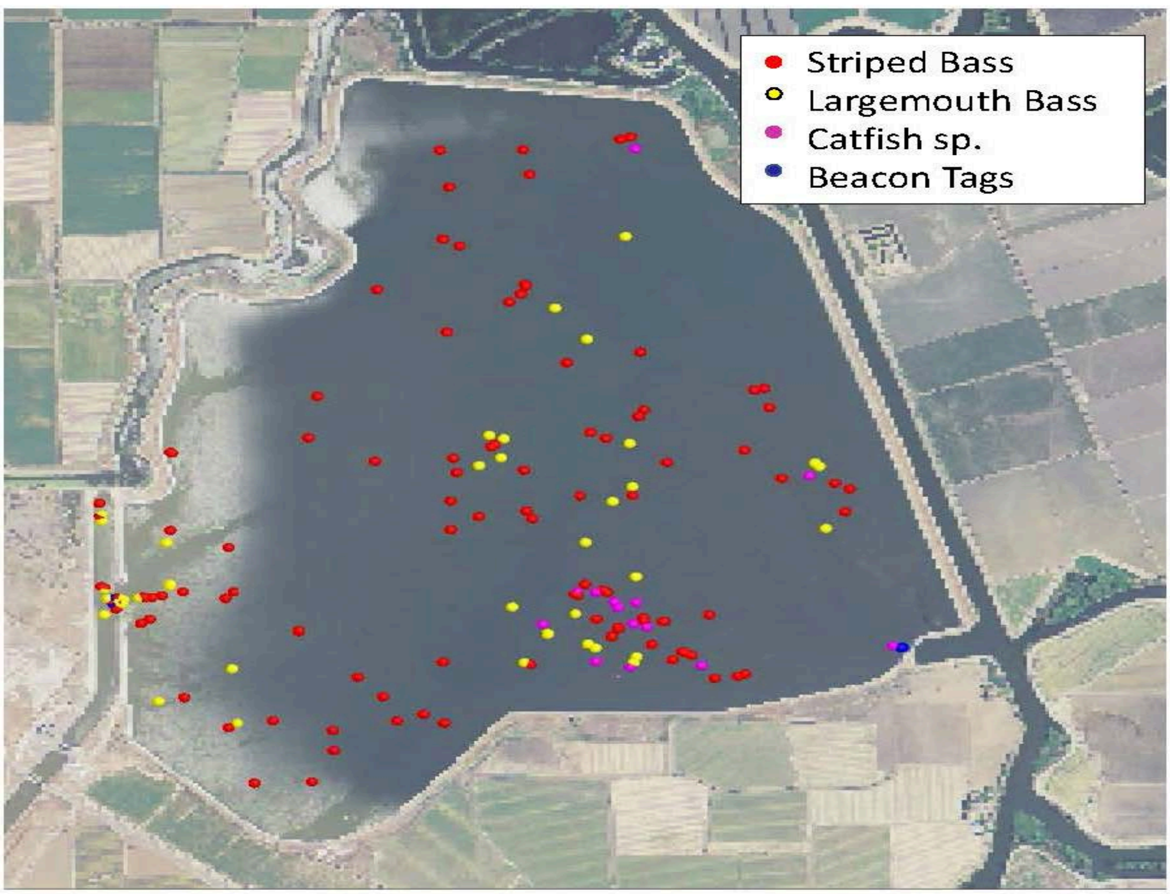


Figure 22: 2016 Mobile Monitoring Detections

Of the 147 acoustically tagged fish detected by the receivers, 29 fish (20% of the detected fish), were detected on receivers outside as well as inside of the Forebay, indicating that they emigrated from the Forebay. Four of these emigrating fish were Channel Catfish, one Largemouth Bass, and 24 were Striped Bass (Table 10).

Of those 29 fish that were detected outside of the Forebay, two were detected by only one receiver, 14 were detected by between two and five receivers, 12 were detected by between six and nine receivers, and one was detected on ten receivers outside of the Forebay.

Table 10: 2016 Acoustic Tagged Fish Detected Outside of Forebay

Species	TagCode	Radial Gates Upstream (RGU1)	West Canal (WC1)	West Canal (WC2)	West Canal (WC3)	Old River South (ORS1)	Old River South (ORS3)	Old River North (ORN1)	Old River North (ORN2)	Central Valley Project (CVP1)	Grant Line Canal (GL1)	Curtis Landing Release Site (CLRS1)
Channel Catfish	6341.26	7-Apr				7-Apr				7-Apr	7-Apr	
Channel Catfish	8133.26	8-Apr	8-Apr	8-Apr	8-Apr	9-Apr	13-Apr	9-Apr	9-Apr	10-Apr	10-Apr	
Channel Catfish	7321.26	27-May	27-May	27-May	2-Jul	28-May					4-Jul	
Channel Catfish	5445.26	27-May	27-May	28-May	28-May						27-May	
Largemouth Bass	6285.26	26-Oct	26-Oct	26-Oct	26-Oct							
Striped Bass	8714.16	14-Feb										
Striped Bass	8938.16	2-Mar	2-Mar	5-Mar	5-Mar	5-Mar	6-Apr					
Striped Bass	6859.03	23-Feb	25-Feb	26-Feb	26-Feb	24-Feb	26-Feb	12-Mar		27-Feb	23-Feb	
Striped Bass	5298.16	26-May	30-May	30-May	30-May	31-May	26-May			27-May	26-May	
Striped Bass	8231.03	23-Feb	26-Feb	26-Feb	26-Feb							
Striped Bass	7118.16	9-Feb	12-Feb	12-Feb	12-Feb	13-Feb	18-Apr	15-Apr		12-Feb	9-Feb	
Striped Bass	5123.03	9-Mar				9-Mar				9-Mar		
Striped Bass	9127.03	9-Mar	16-Apr			9-Mar	10-Apr	28-Apr		9-Mar		
Striped Bass	8882.16	11-Feb	11-Feb	9-Mar	9-Mar	10-Mar	11-Feb			11-Feb	26-Feb	
Striped Bass	8798.16	20-Feb	20-Feb	20-Feb	20-Feb							
Striped Bass	5487.03	9-Mar	9-Mar	9-Mar	9-Mar	9-Mar						
Striped Bass	5074.16	9-Mar	12-Mar	12-Mar	12-Mar	9-Mar					12-Mar	
Striped Bass	7846.16	8-Mar	8-Mar	8-Mar	8-Mar							
Striped Bass	8742.16	2-Apr	2-Apr	2-Apr	2-Apr							
Striped Bass	9302.16	1-Apr	3-Apr	3-Apr	3-Apr	8-Apr					1-Apr	
Striped Bass	8539.03	25-May	17-Jun			25-May					25-May	
Striped Bass	9659.03	17-Jun									17-Jun	

Species	TagCode	Radial Gates Upstream (RGU1)	West Canal (WC1)	West Canal (WC2)	West Canal (WC3)	Old River South (ORS1)	Old River South (ORS3)	Old River North (ORN1)	Old River North (ORN2)	Central Valley Project (CVP1)	Grant Line Canal (GL1)	Curtis Landing Release Site (CLRS1)
Striped Bass	9547.03	17-Jun	22-Jun	19-Jun	19-Jun	25-Jun				18-Jun	17-Jun	
Striped Bass	9407.03	16-Jun	17-Jun	17-Jun	17-Jun						17-Jun	
Striped Bass	9827.03	26-May		26-May								
Striped Bass	8147.03	19-Jun	20-Jun	20-Jun	21-Jun		19-Jun			19-Jun		
Striped Bass	8819.03	22-Jul									22-Jul	
Striped Bass	5326.16	14-Sep	29-Sep			14-Sep	14-Sep	16-Sep		16-Sep	15-Sep	
Striped Bass	7678.16											6-Dec

2016 acoustic tagged fish that were detected outside of the Forebay were detected most often at the Radial Gates Upstream site (RGU1), with the least number of fish detected at the Old River North and Curtis Landing Release Site (ORN2, CLRS1), at 97% and 3% respectively (Figure 23, 24).

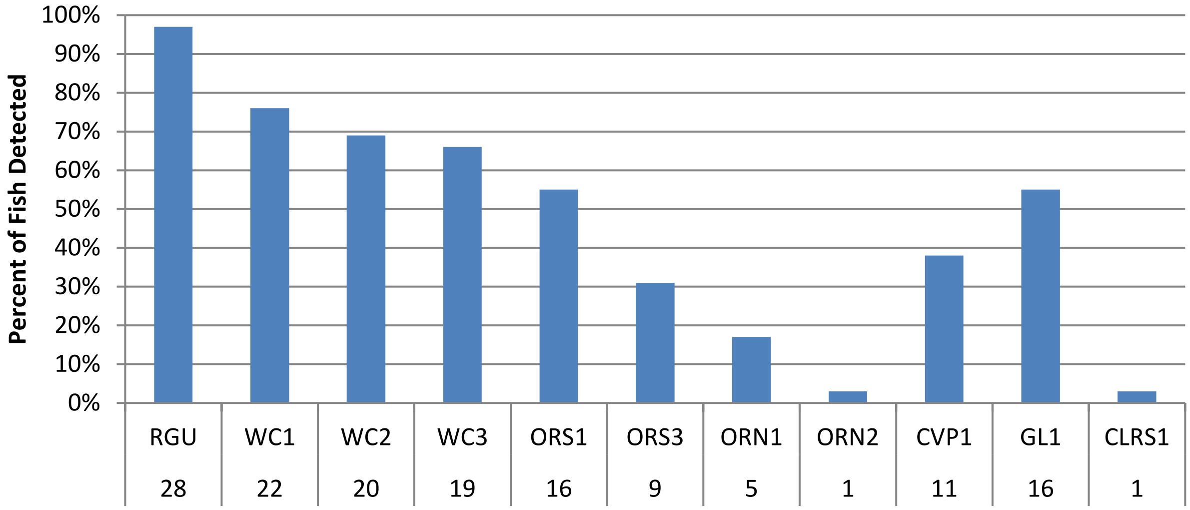


Figure 23: Percent of 2016 Acoustic Tagged Fish Detected by Site

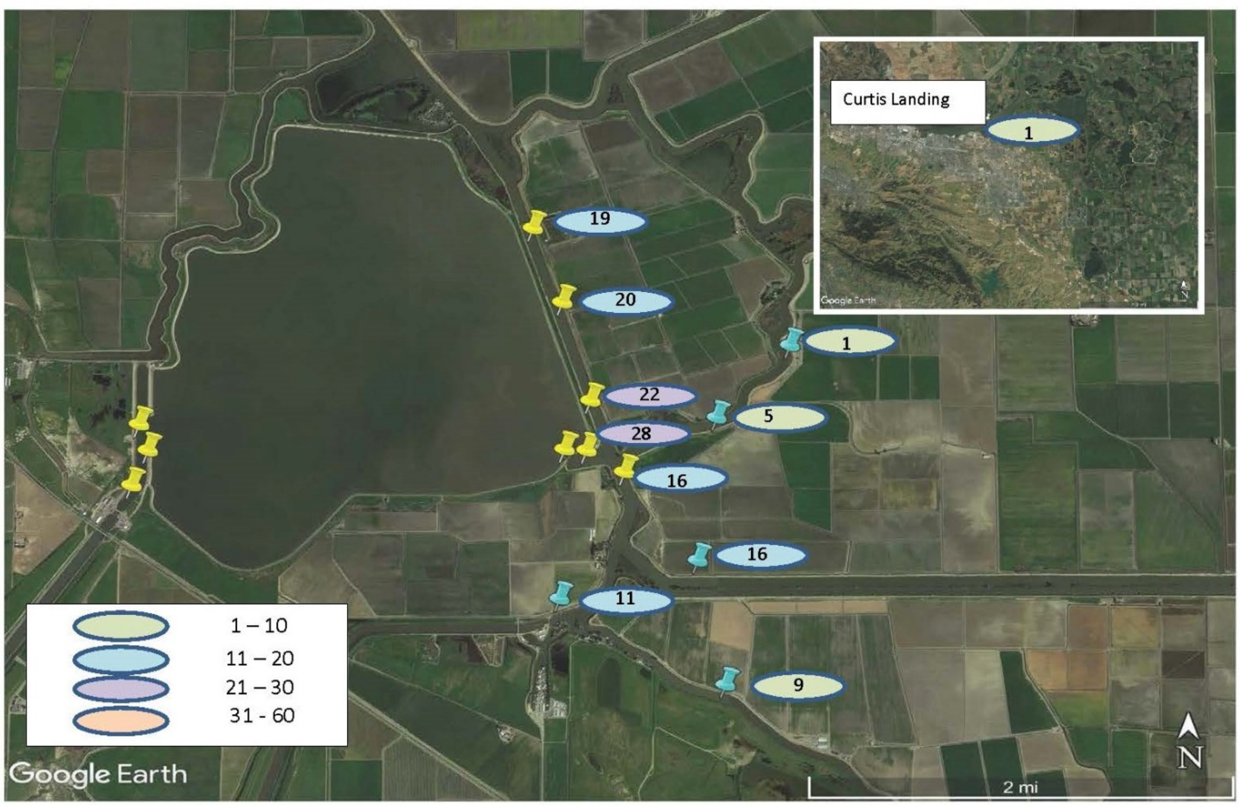


Figure 24: 2016 Acoustic Tagged Fish Detected Outside of Forebay by Site

Of those 29 fish that emigrated, 13 fish (45% of emigrating fish) returned to the Forebay at a later date in 2016. Of the remaining 118 fish that were not observed outside of the Forebay, 40 (34%) were only detected in the intake channel, 39 (33%) were only detected at the radial gates, and 39 (33%) were detected moving between the intake channel and the radial gates.

In addition to the fish tagged in 2016, many fish tagged in 2013 through 2015 were still able to be detected during 2016 due to the time of tagging and battery life of the tags. The combined number of tagged fish from 2013 through 2016 was 734 fish (Table 11).

Table 11: Acoustic Tagged Fish Released in 2013 through 2016 Combined

2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Largemouth Bass					1	1	1	1	2	5	2	5	18
Catfish Species					1	5	2	0	0	0	0	0	8
Striped Bass (LG)					2	8	7	7	7	7	6	7	51
Striped Bass (LY)					7	3	7	7	7	7	7	7	52
Striped Bass (LZ)					1	0	0	0	4	7	7	1	20
All Species					12	17	17	15	20	26	22	20	149
2014	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total**
Largemouth Bass	**5**	4	5	2	5	5	0	0	1	3	5	0	35
Catfish Species	**0**	0	0	2	1	0	0	0	0	0	0	3	6
Striped Bass (LG)	**6**	7	7	7	6	7	7	7	7	7	7	7	82
Striped Bass (LY)	**7**	7	7	6	7	3	5	2	4	4	7	7	66
Striped Bass (LZ)	**5**	5	3	1	1	1	0	0	0	0	7	7	30
All Species	**23**	23	22	18	20	16	12	9	12	14	26	24	219
2015	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total**
Largemouth Bass	1	3	5	0	0	1	0	0	2	3	5	0	20
Catfish Species	0	0	0	8	4	2	0	0	1	0	0	0	15
Striped Bass (LG)	7	7	0	7	7	7	7	7	7	7	6	7	69
Striped Bass (LY)	7	7	7	3	0	4	2	1	6	7	7	6	57
Striped Bass (LZ)	6	7	2	0	0	0	0	0	1	3	1	4	24
All Species	21	24	14	11	11	14	9	8	17	20	19	17	185
2016	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total**
Largemouth Bass	2	2	4	4	0	0	5	0	2	3	3	11	36
Catfish Species	3	1	3	0	0	0	0	0	0	0	0	0	6
Striped Bass (LG)	7	7	7	7	7	7	7	7	4	0	0	0	60
Striped Bass (LY)	7	5	3	0	2	1	2	5	3	6	11	19	64
Striped Bass (LZ)	2	1	0	1	0	0	0	0	1	1	7	1	14
All Species	21	16	16	12	9	8	14	12	10	10	21	31	181
All Years Combined	**65**	**63**	**52**	**41**	**52**	**55**	**52**	**44**	**59**	**70**	**88**	**92**	**734**

Based upon expected battery life, we anticipate that LG tags will last from 220 – 400 days, LY tags from two and a half to four years, and LZ tags from four to five years. Assuming minimum battery life, 97 of the tagged fish released in 2013, 132 of the tagged fish released in 2014, and 181 of the tagged fish released in 2015, would be detectable for at least part of 2016. Of the 33 fish that were undetected during 2015, 24 remained undetected in 2016. Three fish were reported to have been caught and kept by anglers in 2014, seven additional angler captured fish were removed from the system in 2015, and one was removed in 2016, and as such these fish were no longer detectable (Table 12).

Table 12: Acoustic Tagged Fish Removed from System from 2014 through 2016

Acoustic Tag	Date Removed from system	Date of Last Detection	Site of Last Detection	Emigrated from Forebay?	Returned to Forebay Following Emigration?	Capture Details
8140.24	7/28/2014	7/15/2014	ORS1	Y	N	Angler caught at Rock Barrier
8517.06	11/1/2014	9/12/2014	RGD1	N		Angler caught at CCF
6068.24	11/24/2014	8/31/2014	IC1	Y	Y	Angler caught at Mossdale
8314.31	4/1/2015	3/16/2015	ORS1	Y	Y	Angler caught by Grimes Road/ Tracy Blvd
6277.06	5/4/2015	6/16/2013	IC3	N	-	Tag found in SDFPF secondary
6634.31	5/9/2015	5/9/2015	IC1	Y	Y	Angler caught at CCF
9882.31	5/26/2015	5/22/2015	IC1	N		Angler caught at CCF
5004.24	6/11/2015	6/10/2015	RGD1	Y	Y	Found on road near radial gates at CCF
6186.31	9/23/2015	9/23/2015	RGD1	Y	Y	Angler caught at CCF
7278.04	10/16/2015	3/14/2015	IC1	N	-	Angler caught at CCF
7636.11	6/24/2016	11/24/2015	ORS1	Y	N	Angler caught near Alcatraz Island

When fish tagged from 2013 through 2015 that remained detectable into 2016 were included, the total number of fish detected leaving the Forebay rose from 29 to 225, which is 40% of the detectable tagged fish to date. Of those 225 fish, 132 (59% of emigrating fish) were subsequently detected back in the Forebay. Of those 132 fish, seven were Channel Catfish, six were Largemouth Bass, 14 were Striped Bass under 1.5 lbs. (0.68 kg), 78 were Striped Bass between 1.5. and 2.99 lbs. (0.68 – 1.36 kg), and 27 were Striped Bass over 3.0 lbs. (1.36 kg).

The majority of the fish that emigrated were Striped Bass, at 200 (89%), with the balance being made up of Largemouth Bass and catfish, at nine and 16, respectively. The emigrating Striped Bass ranged in weight, at the time of tagging, from 0.5 lbs. (0.23 kg) to 17.8 lbs. (8.07kg), with the smaller fish, 1.0 lbs. (0.45 kg) to 2.49 lbs. (1.13 kg), representing bulk of the fish detected (Figure 25).

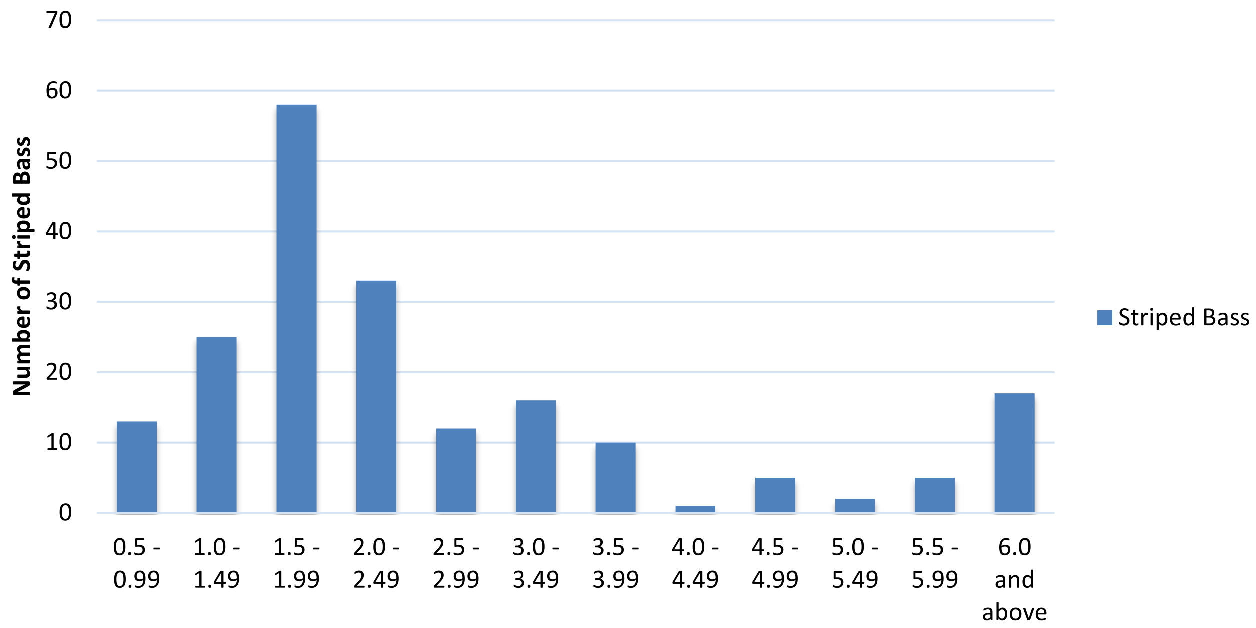


Figure 25: 2013 – 2016 Striped Bass Emigration by Weight Class (lbs.)

The largest percentage of Striped Bass detected outside of the Forebay was within the 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) weight class (Figure 26) at 52%.

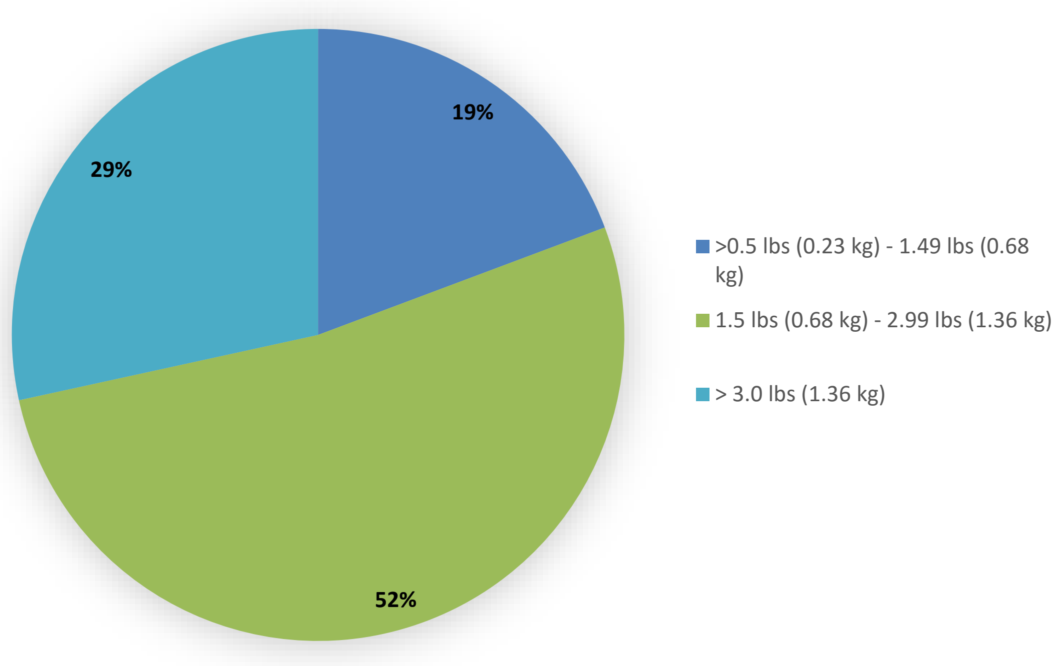


Figure 26: 2013 - 2016 Striped Bass Emigration Percentage by Weight Class

Of the Striped Bass that emigrated, only 35% were over the minimum size required for legal harvest by recreational anglers (Figure 27).

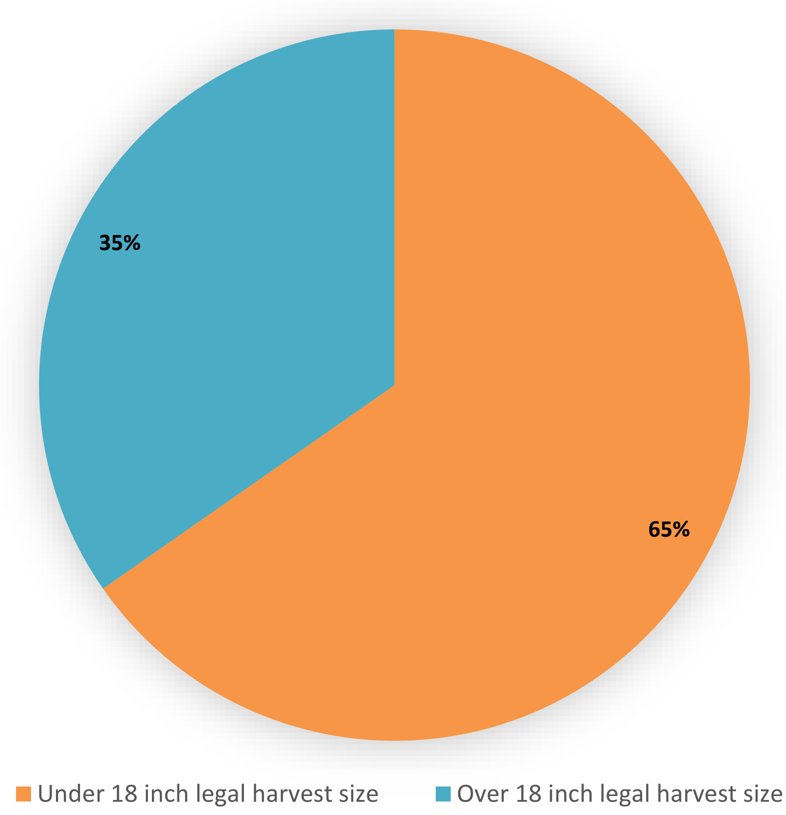


Figure 27: Percentage of Emigrating Striped Bass Legal for Harvest by Anglers

When the weight classes of Striped Bass that emigrated are broken down into increments of 0.5 lbs. (0.23 kg), Striped Bass weighing between 1.5 lbs. (0.68 kg) and 1.99 lbs. (0.90 kg) represented the largest group at 29%, followed by 2.0 lbs. (0.90 kg) to 2.49 lbs. (1.13 kg) at 17% (Figure 28).

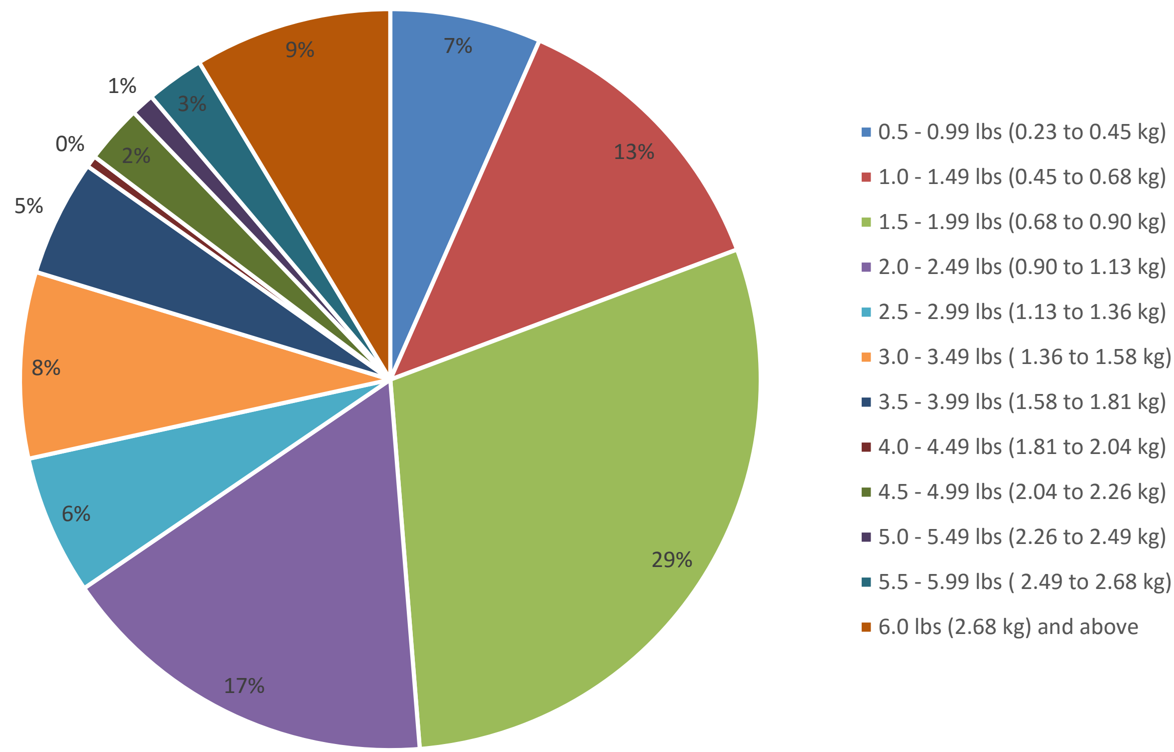


Figure 28: 2013 - 2016 of Striped Bass Emigration Percentage by Weight Class

Of the 77 Striped Bass over 3.0 lbs. (1.36 kg) tagged between 2013 and 2016 that remained detectable, 56 (73%) were subsequently detected outside of the Forebay, whereas only 103 of the 244 fish weighing 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) and 38 of the 132 fish weighing less than 1.5 lbs. (0.68 kg) were detected outside of the Forebay, representing 42% and 29% of those weight classes respectively (Figure 29).

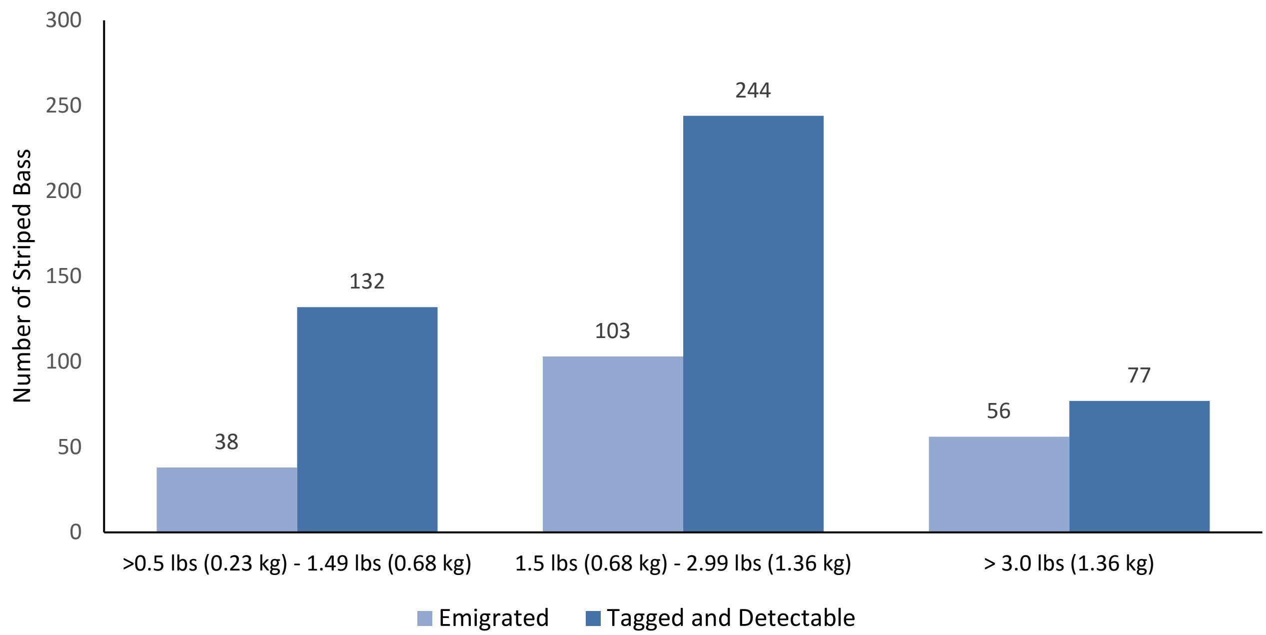


Figure 29: 2013 - 2016 Detectable Tagged Striped Bass Emigration by Weight Class

All weights were taken at the time of tagging, and growth likely occurred between tagging and detection outside of the Forebay. The elapsed time from tagging to emigration varied from one to 937 days (Figure 30).

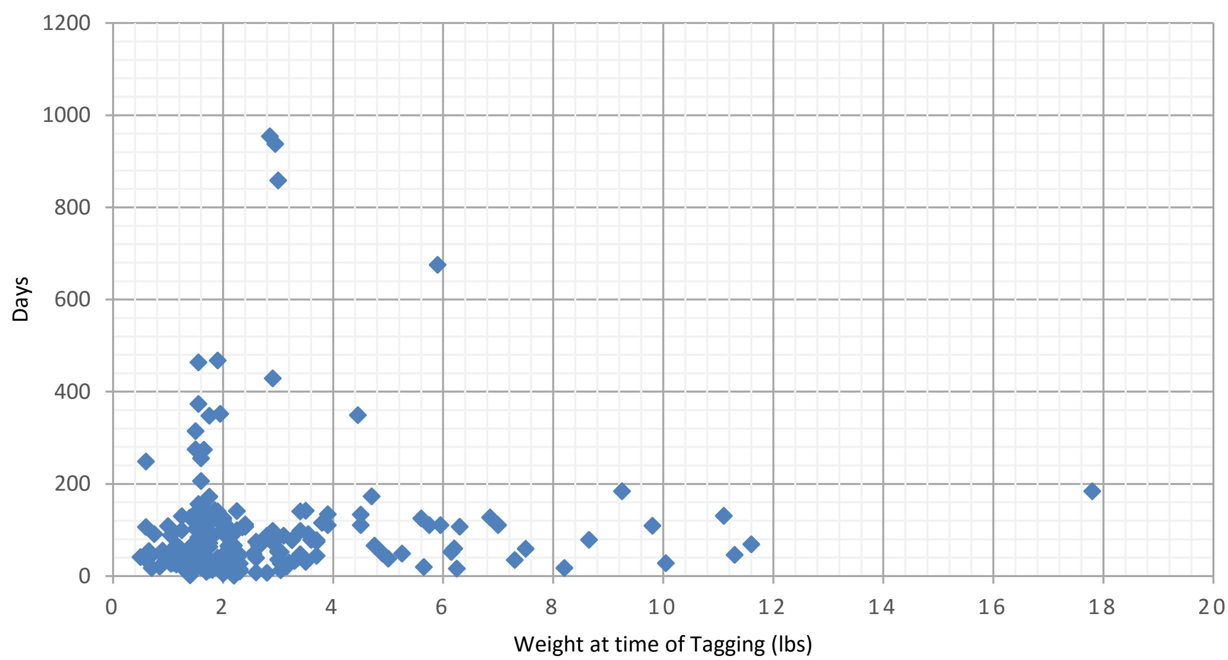


Figure 30: Days Elapsed Between Tagging and First Detection of Emigration by Weight for 2013 - 2016 Striped Bass

Striped Bass in the 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) weight class were detected for the first time outside of the Forebay most frequently in March, with 32% of the fish moving during that month (Figure 31,32). Striped Bass in the 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) weight class emigrated most frequently in February and March, at 30% and 35%, respectively (Figure 31,33), and Striped Bass over 3.0 lbs. (1.36 kg) emigrated most frequently February and March at 31% and 38%, respectively (Figure 31,34).

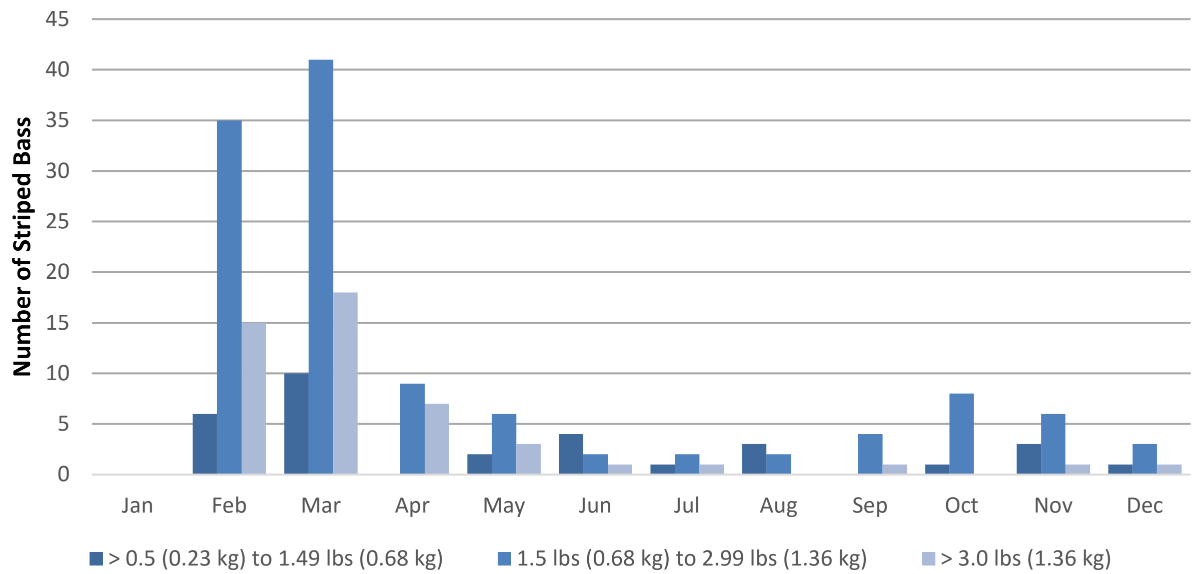


Figure 31: Month of Striped Bass Emigration by Weight Class

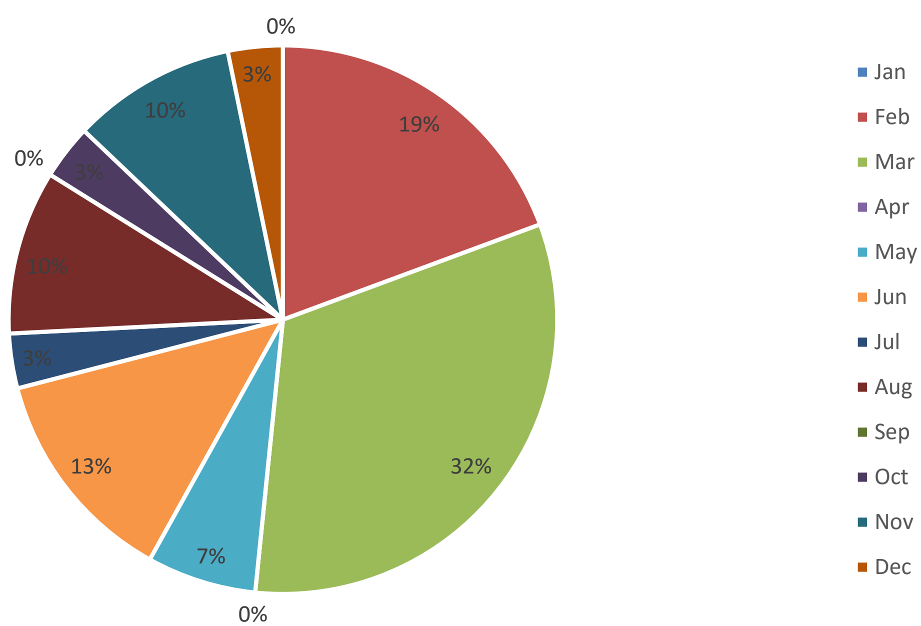


Figure 32: Percentage of 0.5 lbs. (0.23 kg) to 1.49 lbs. (0.68 kg) Striped Bass Emigration by Month

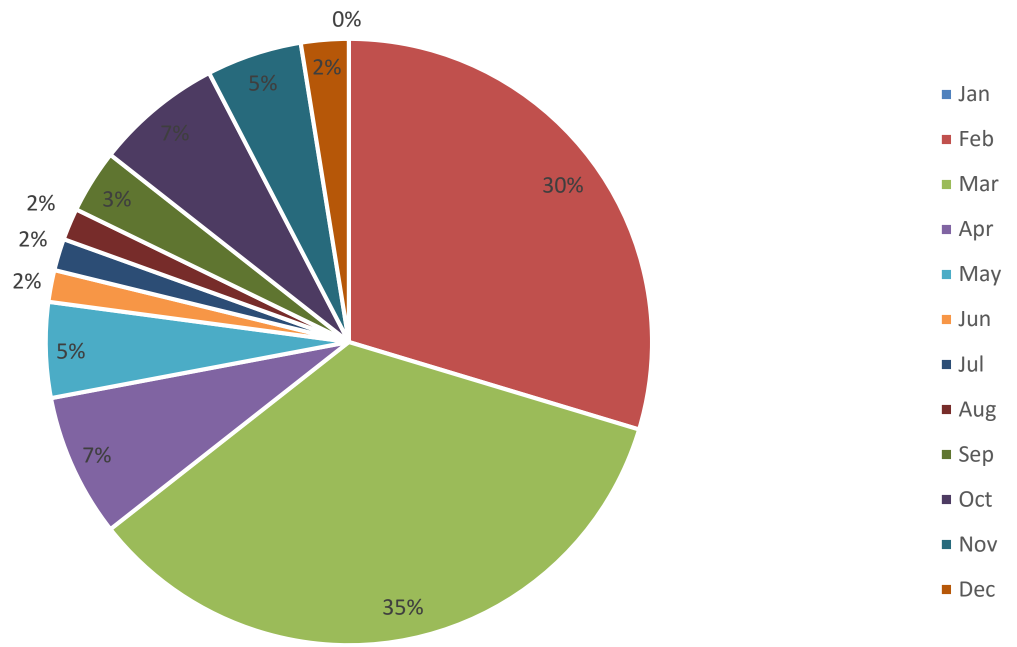


Figure 33: Percentage of 1.5 lbs. (0.68 kg) to 2.99 lbs. (1.36 kg) Striped Bass Emigration by Month

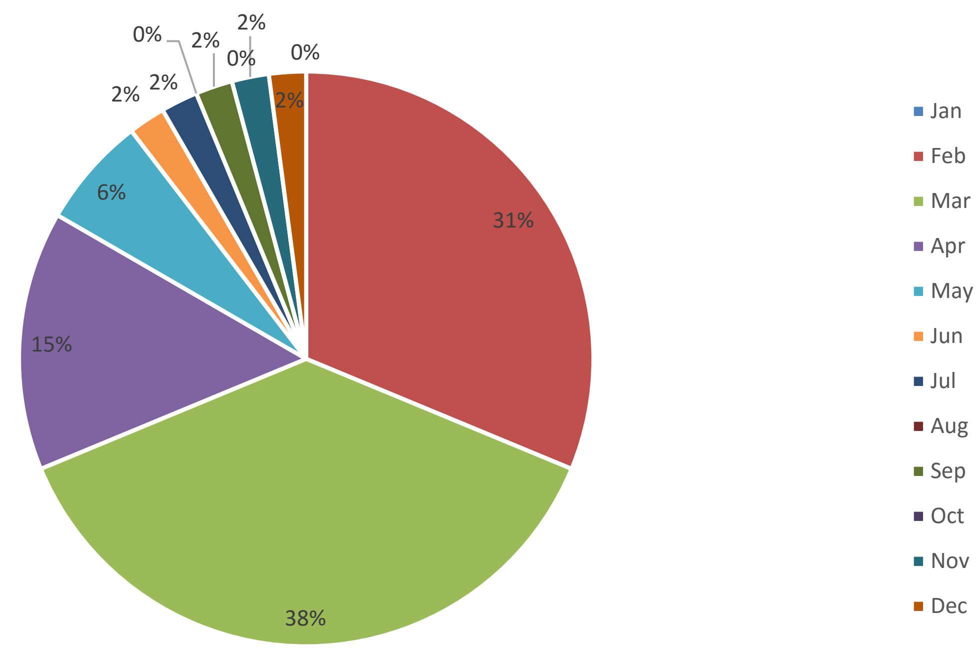
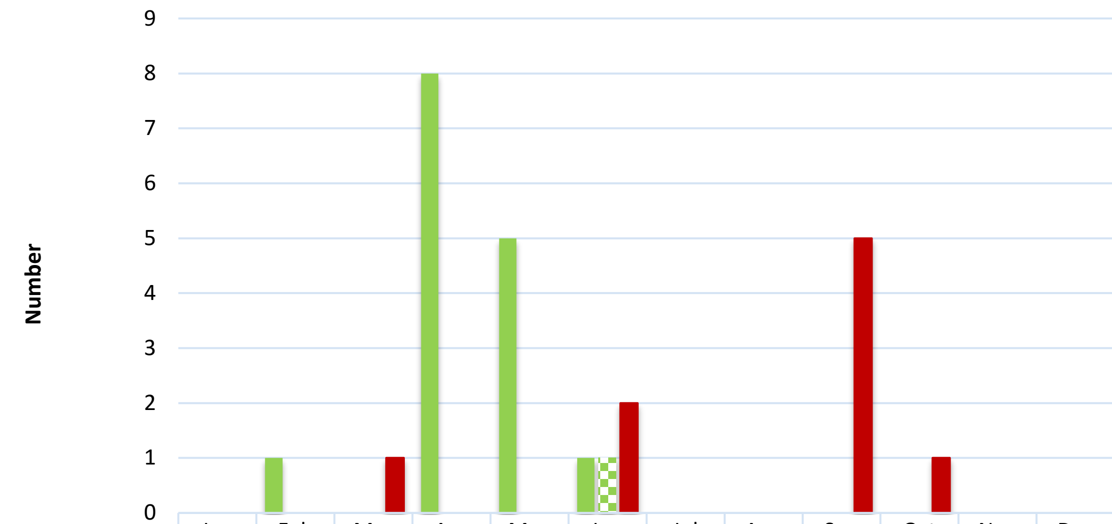


Figure 34: Percentage of 3.0 lbs. (1.36 kg) and larger Striped Bass Emigration by Month

Largemouth Bass emigrated most frequently in September at 56% (35,36), while catfish were found to emigrate most often in April and May at 53 % and 33% respectively (Figure 35,37).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Channel Catfish	0	1	0	8	5	1	0	0	0	0	0	0
Unidentified Catfish	0	0	0	0	0	1	0	0	0	0	0	0
Largemouth Bass	0	0	1	0	0	2	0	0	5	1	0	0

Figure 35: Largemouth Bass and Catfish Emigration by Month

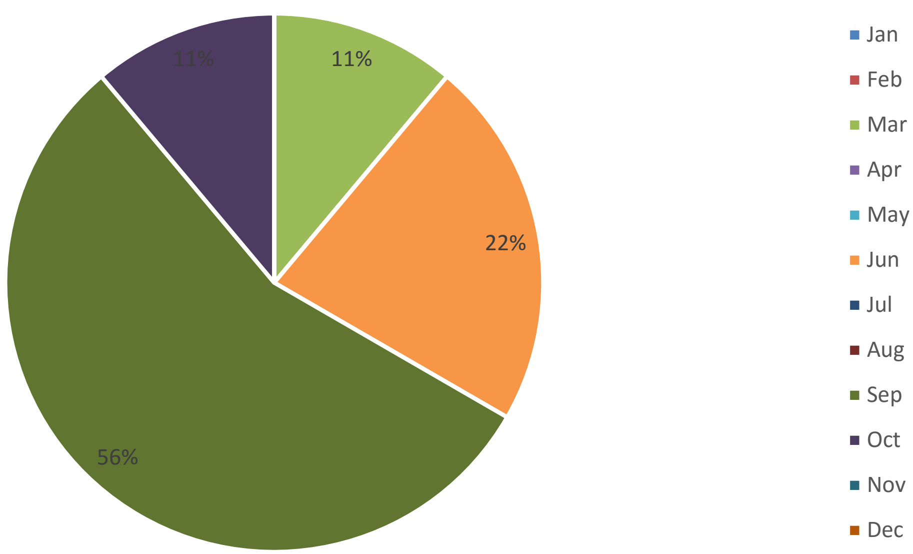


Figure 36: 2016 Largemouth Bass Emigration by Month

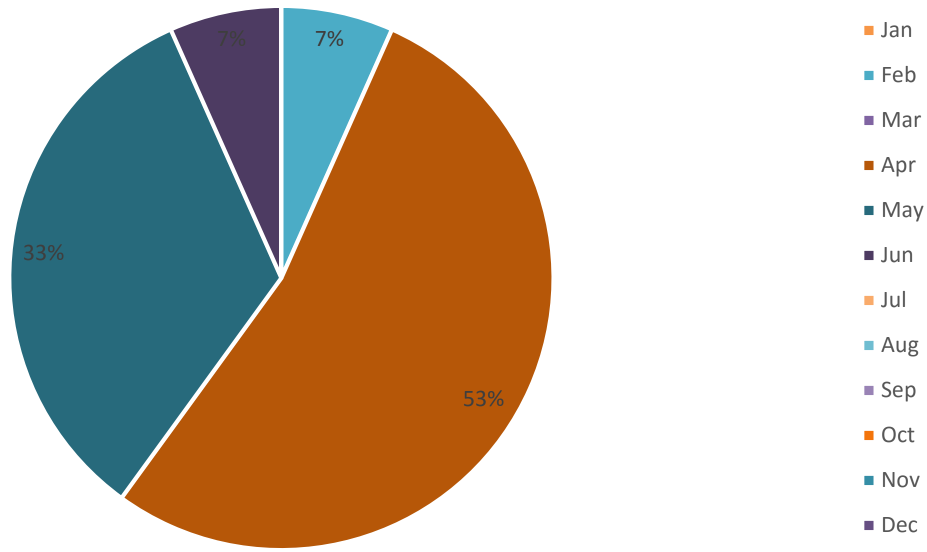


Figure 37: 2016 Catfish Emigration by Month

When all species were combined, emigration was most frequent in February and March, with 26% and 32% of emigration occurring in these months respectively (Figure 38, 39).

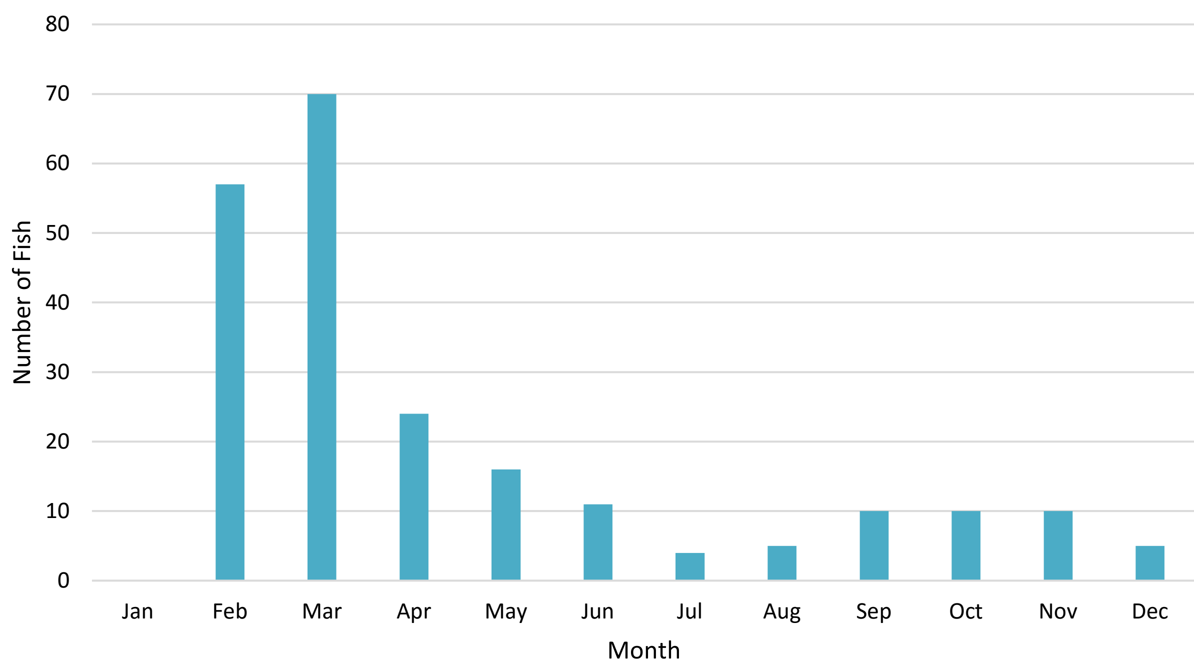


Figure 38: 2016 All Species Emigration by Month

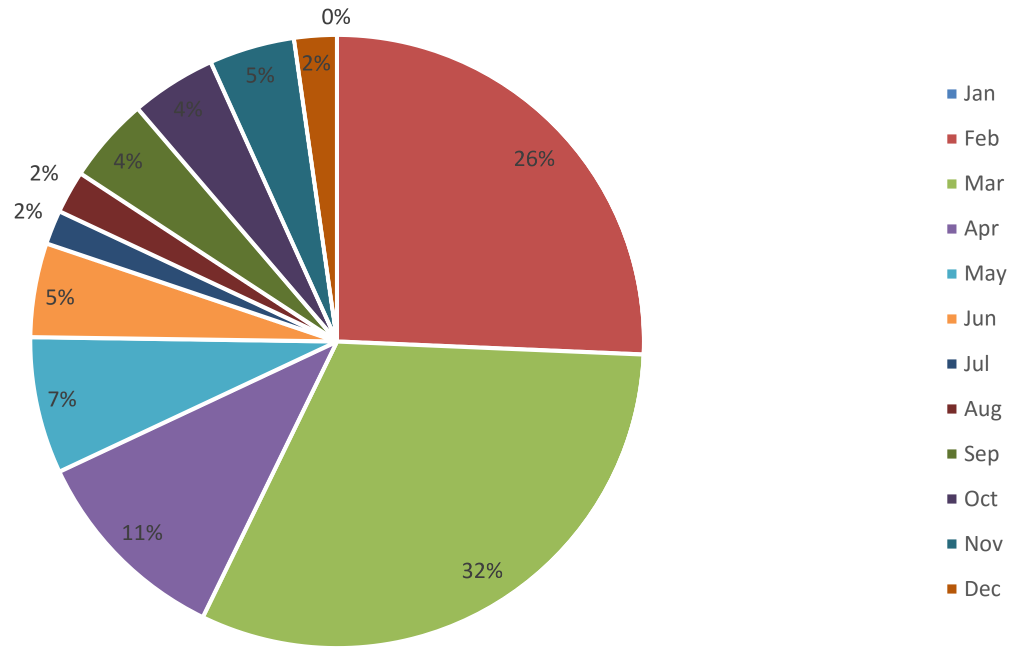


Figure 39: Percentage of Emigration for All Species by Month

2.3.5 Discussion and Recommendations

The 2016 acoustic tagging effort contributed an additional 181 tagged fish, comprised of 7 Channel Catfish, 36 Largemouth Bass, and 138 Striped Bass, to bring the total tagged fish in the Forebay to 734. Of the 181 total tagged fish, 30 Striped Bass and four Largemouth Bass, representing 19% of the 2016 tagged fish, were never detected by any of the receivers in the array, leaving 147 detectable fish tagged in 2016. The addition of detectable tagged fish from 2013 through 2015 brings the total number of detectable fish to 557.

When looking just at fish tagged within the 2016 sampling effort, 29 of the 147 detectable fish (20%) were detected outside of the Forebay, including four Channel Catfish, one Largemouth Bass and 24 Striped Bass. One of these fish, a Striped Bass, was only detected at the Curtis Landing Release Site, having emigrated via the Skinner Delta Fish Protective Facility. The remaining 28 actively emigrated via the Radial Gates, and were detected in greatest numbers on the West Canal receivers, followed by Grant Line Canal and the Central Valley Project receivers. The fewest detections of 2016 fish were noted on the Old River North receivers. As the data set grows over time, it may be possible to see if the differences in frequency of use across channels show any statistically significant trends towards preferred travel corridors.

The 2016 fish that remained in the Forebay showed an equitable distribution across the three main spatial uses examined. Of the 118 fish that remained within the Forebay, 40 (34%) stayed within the intake channel, 39 (33%) stayed near the vicinity of the radial gates, and 39 (33%) moved between the intake channel and the radial gates.

When looking at the combined 557 detectable fish, 225 had emigrated at some point following tagging, representing 40% of the detectable fish. One hundred and thirty-two (59% of emigrating fish) were subsequently detected back in the Forebay. Fish were found to emigrate during every month except January, with the largest number of Striped Bass emigrations occurring in February and March, Largemouth Bass in September and catfish in April. While this appears to indicate some different movement strategies between species, it should be noted that the number of tagged Largemouth Bass and catfish is relatively small compared to the number of tagged Striped Bass.

The 2016 data set continues to show immigration and emigration as well as residency, both localized (remaining in a specific portion of the Forebay) as well as more broad roving behavior (moving multiple times across the Forebay). The tags employed in this project will continue to provide data for up to five[3] years per individual fish, allowing for a much better picture of these behaviors over time. The data set expressed in this interim report shows a limited picture, in that the fish detected have not all been in the system for the same amount of time. For instance, fish tagged in November or December of 2016 have only been detectable for one to two months, not long enough to discern their short-term or ultimate behavioral strategies. This limitation is well illustrated by the reduction in number of prior years' tags that were undetected with the addition of the longer detection data set.

The Largemouth Bass tag retention study showed no explusion of tags over a 87 day holding period, and indicated consistency across taggers for this species. We recommend repeating this type of lab-based QA/QC study for Striped Bass. We also recommend that mobile monitoring surveys be continued on a regular interval to cover areas of the Forebay that are not currently covered by the static array.

[3] A revised estimate of potential tag life was received from HTI on January 25, 2016, which is longer than originally anticipated.

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State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predator Reduction: Electrofishing Annual Report 2016

December 2016

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Executive Summary

The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (Study) was implemented in response to the National Marine Fisheries Service (NMFS) letter dated April 9, 2015, requiring that the California Department of Water Resources (DWR) immediately implement interim measure (a) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative (RPA) Action IV.4.2(2) of the Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and State Water Project (NMFS 2009 BiOp). The Study length will total three years, beginning with a pilot year effort in 2016. The study will electroshock and remove predators from CCF and transport them to Bethany Reservoir with the goal of decreasing pre-screen loss of protected fish species with an emphasis on Chinook Salmon (*Oncorhynchus ishawytscha*) and steelhead (*Onchorhynchus mykiss*). Additionally, concurrent with this Study, releases of Passive Integrated Transponder (PIT) and acoustically tagged Chinook Salmon occurred in an effort to determine rates of pre-screen loss.

During the 2016 pilot study effort, electrofishing was conducted on 11 days during the months of April and May. This effort resulted in the removal of 2,059 striped bass, 594 black bass, and 33 catfish from CCF. Size distribution of predatory fish captures suggest that 98.5 percent of striped bass and 37 percent of black bass are below the minimum legal recreational harvest length limit. There is no minimum harvest length limit for catfish. This length distribution data suggests that attempting to increase fishing pressure in CCF would likely have a limited effect on reducing pre-screen loss without changes to these recreational size limits. During 2016, Chinook Salmon pre-screen loss was estimated at 91 percent based on data collected during the SWP Chinook Salmon Survival Study, which is within the range of loss rates previously documented in CCF (63 to 99 percent). The efficacy of predator relocation efforts in 2016 was inconclusive based on the preliminary results of the State Water Project Chinook Salmon Survival Study. No statistically significant differences in loss were detected when comparing the months during the relocation study to the months prior. The absence of detectable effects of the 2016 predator relocation effort may be due to a variety of reasons. First and foremost, predator relocation efforts in 2016 were limited in nature, occurring only for 11 days near the end of the monitoring season. Additionally, tagged salmon released during this period may have encountered unfavorable conditions, including high water temperatures and low rates of pumping, which may have contributed to mortality.

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List of Figures and Tables

Acronyms and Abbreviations

ANOVA	Analysis of Variance
BiOp	Biological Opinion
BDCP	Bay Delta Conservation Plan
CESA	California Endangered Species Act
CDEC	California Data Exchange Center
cfs	Cubic Feet per Second
CIMIS	California Irrigation Management Information System
CCF	Clifton Court Forebay
C.I.	Confidence Interval
CPUE	Catch per Unit Effort
CVP	Central Valley Project (federal)
˚C	Degrees Celsius
Delta	Sacramento-San Joaquin River Delta
DFW	California Department of Fish and Wildlife
DO	Dissolved Oxygen
df	Degrees of Freedom
DPS	Distinct Population Segment
DWR	California Department of Water Resources
FESA	Federal Endangered Species Act
FSB	Fish Science Building
GPP	Generator Powered Pulsator
GPS	Global Positioning System
Hz	Hertz
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
L	Liter
lb(s)	Pound(s)
mm	Millimeter
MOTC	Motorboat Operator Training Course
µS/cm	Microsiemens per Centimeter
NMFS	National Marine Fisheries Service
NMFS 2009 BiOp	Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project
OCAP	Biological Opinion and Conference Opinion for the Long-Term Operational Criteria and Plan of the Central Valley Project and State Water Project
PIT	Passive Integrated Transponder
PSL	Pre-Screen Loss
RPA	Reasonable and Prudent Alternative
SD	Standard Deviation
SDFPF	John E. Skinner Delta Fish Protective Facility
sp.	Species
Study	Clifton Court Forebay Predator Reduction Electrofishing Study
SWP	State Water Project (California State)
USFWS	United States Fish and Wildlife Service
WY	Water Year

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1. Introduction

The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (Study) was implemented in response to the National Marine Fisheries Service (NMFS) letter dated April 9, 2015, requiring that the California Department of Water Resources (DWR) immediately implement interim measure (a) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative (RPA) Action IV.4.2(2) of the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS 2009 BiOp). The Study length will total three years beginning with a pilot year effort in 2016. The Study will electroshock and remove predators from CCF and transport them to Bethany Reservoir for the goal of decreasing pre-screen loss of protected fish species with an emphasis on Chinook Salmon (*Oncorhynchus ishawytscha*) and steelhead (*Onchorhynchus mykiss*).

1.1 Background

CCF, located near the town of Byron in Contra Costa County, California, was created in 1969 by inundating a 2,200 acre tract of land approximately 2.6 miles long and 2.1 miles across (Kano 1990). CCF is operated as a regulating reservoir within the tidally influenced region of the Sacramento-San Joaquin River Delta (Delta) to improve operations of the State Water Project (SWP), Harvey O. Banks Pumping Plant, and water diversions to the California Aqueduct (Figure 1). During high tide cycles, when the elevation of water in Old River is greater than that in CCF, up to five radial gates that are located in the southeast corner of CCF are opened to allow water to be diverted from the Delta into CCF. Daily operation of the gates depends on scheduled water exports, tides, and storage availability within CCF (Le 2004). Diversion of water from Old River into CCF results in the entrainment of numerous species of fish which have been listed under the California and/or Federal Endangered Species Acts (CESA and FESA, respectively), including California Central Valley steelhead, winter and spring-run Chinook Salmon, Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), and Green Sturgeon (*Acipenser medirostris*; Southern Distinct Population Segment [DPS]). As such, operation of the SWP is performed in compliance with the terms and conditions of the NMFS 2009 BiOp, U.S. Fish and Wildlife Service (USFWS) 2008 Biological Opinion on the Long-Term Operational Criteria and Plan (OCAP), and California Department of Fish and Wildlife (DFW) 2009 Longfin Smelt incidental take permit (ITP) actions.

Fish entering CCF must travel approximately 2.1 miles to reach the John E. Skinner Delta Fish Protective Facility (SDFPF). The SDFPF was designed to protect fish from entrainment into the California Aqueduct by diverting them into holding tanks where they can be salvaged and safely returned to the Delta. Water is drawn to the SDFPF from CCF via the intake canal and past a floating trash boom. The trash boom is designed to intercept floating debris and guide it to an on shore trash conveyor. Water and fish then flow through a trash rack, equipped with a trash rake, to a series of louvers arranged in a V pattern. Fish are behaviorally guided by the louvers and directed to salvage holding tanks where they remain until transported and released back into the Delta.

The loss of fish between the CCF Radial Gates and the SDFPF is termed pre-screen loss (PSL). PSL includes, but is not limited to, predation by fish and birds. Scientific studies conducted by DWR and

DFW, including those conducted within CCF to determine PSL of juvenile Chinook Salmon and juvenile steelhead, have shown that losses are primarily due to predation by Striped Bass (*Morone saxatilis*), a non-native fish. These studies indicated that the range of PSL of juvenile Chinook Salmon was 63 to 99 percent while the PSL of juvenile steelhead was 82 ± 3 percent.

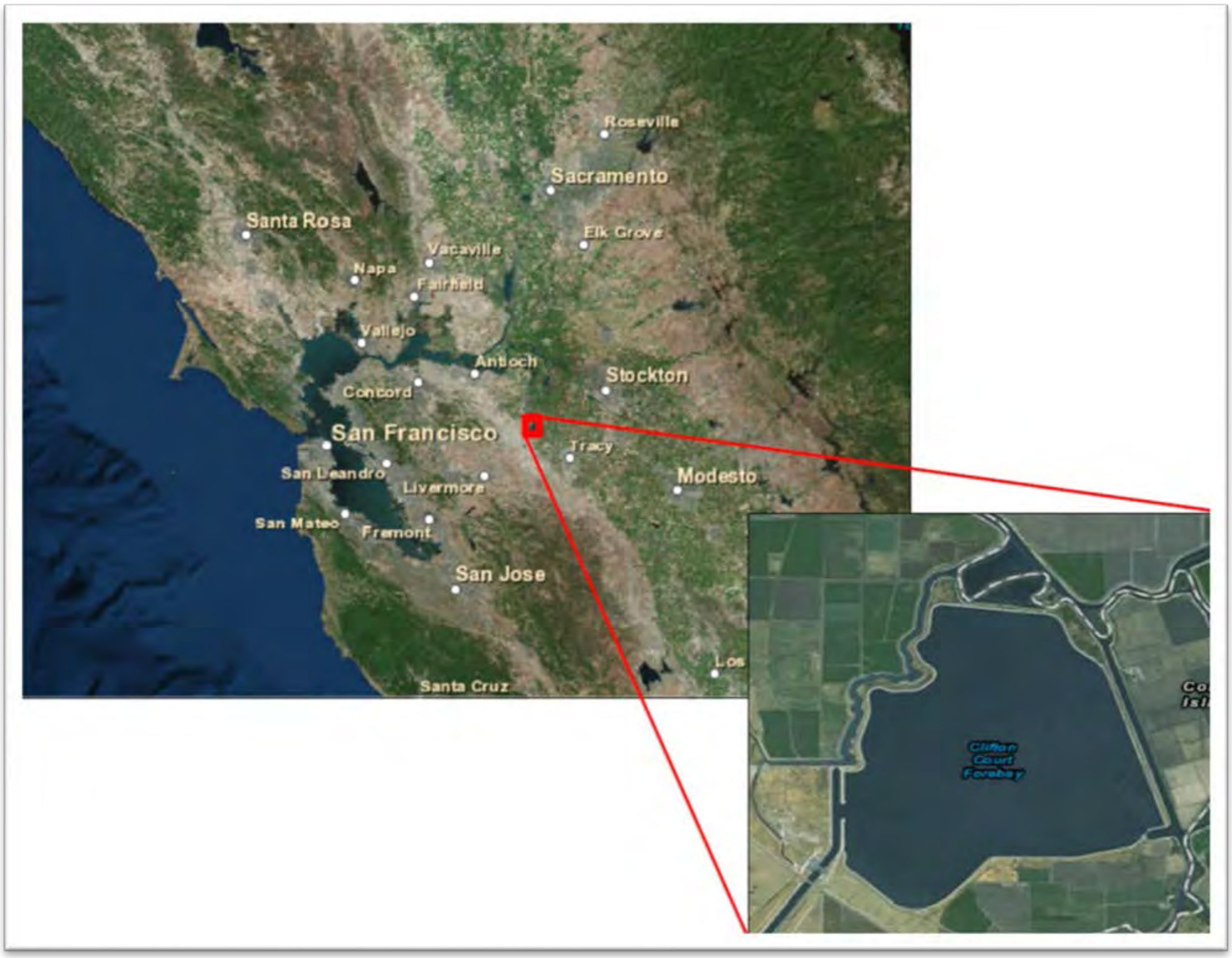

Figure 1 – CCF Location Map.

In the Interagency Ecological Program (IEP) technical report *Mark/Recapture Experiments at CCF to Estimate Pre-Screening Loss to Juvenile Fishes: 1976-1993* (Gingras 1997), which summarized PSL studies, the author stated, "Predation by adult and sub-adult Striped Bass may account for much of the pre-screen loss" Kano (1990); Brown, et al. (1995) further describe PSL as being synonymous with predation by Striped Bass. In 2007, DWR conducted a study to quantify the PSL of juvenile steelhead within CCF. The 2007 study determined that approximately 20 percent of steelhead initially entering CCF successfully cross to the intake canal. Those that successfully cross CCF are salvaged at SDFPF; the remaining 80 percent are presumably lost through predation, primarily by Striped Bass (Clark, et al. 2009).

As a result of these studies, NMFS required DWR to implement the RPA Action IV 4.2(2) of the NMFS 2009 BiOp to reduce predation of ESA protected Chinook Salmon and steelhead within CCF. RPA Action IV.4.2(2) states that DWR must "develop predator control methods for Clifton Court Forebay that will reduce Chinook Salmon and steelhead pre-screen loss in Clifton Court Forebay to no more than 40 percent." It continues that, "Full Compliance (of this RPA) shall be achieved by March 31, 2014" and that "DWR may petition the Fish and Game Commission to increase bag limits on Striped Bass caught in Clifton Court Forebay."

To comply with this RPA, DWR petitioned the Fish and Game Commission to reduce size restrictions and increase bag limits on Striped Bass in CCF on March 24, 2011, December 6, 2011, and March 23, 2015.

Additionally, DWR proposed and planned to construct a public access fishing facility within CCF near the radial gates to increase fishing pressure on legally sized predatory fishes, thereby reducing predation of protected fish species. Since 2011, NMFS has twice approved time extensions of RPA Action IV.4.2(2). First, in a letter dated May 1, 2011, DWR requested extending the timeline for improving predator reduction methods until December 2014, with full compliance by December 2017. NMFS agreed to the extension in a July 2, 2012 response letter, with the understanding that an additional number of actions would be implemented over the next three years. DWR implemented predation surveys and selected a fishing pier as the best alternative to meet the RPA Action IV.4.2(2) requirement. Then, in a letter dated February 7, 2014, DWR requested a one-year extension until December 2015 to complete environmental permitting and ESA Section 7 consultation associated with the construction of a new fishing pier. In a May 15, 2014 letter, NMFS agreed to the second request for a one-year time extension. However, during the consultation process it became apparent that Conservation Measure 1 of the Bay Delta Conservation Plan (BDCP)/California Water Fix would conflict with the fishing pier. Specifically, changes in the design of CCF would limit public access to the proposed fishing pier and reduce the effectiveness of the proposed public access fishing pier.

DWR and NMFS staff met in December 2014 to evaluate alternatives to the fishing pier for reducing predation in CCF. On February 4, 2015, DWR requested another extension until November, 2015 to deliver a final plan, schedule, and formal extension. In a response letter dated April 9, 2015, NMFS granted DWR this extension with conditions. Condition 3 states that, "DWR shall initiate interim measures to improve predator control before December 2015, to reduce predators in the CCF until an acceptable alternative can be implemented. Interim measures agreed to at the March 12, 2015 meeting that could be immediately implemented include: (a) electro-shocking and relocating predators; (b) controlling aquatic weeds; (c) developing a fishing incentives or a reward program for predators; and (d) operational changes when listed species are present (e.g., preferential pumping via the Central Valley Project [CVP] rather than the SWP)."

1.2 Objective

The objective of the 2016 Study was to comply with interim measure (a) from condition 3 of the April 9, 2015 NMFS response letter. The Study focused on determining the numbers and approximate percentages of predatory fishes that can be feasibly removed from CCF. Tagged Chinook Salmon and steelhead were released from the radial gates concurrent with the Study time period. Concurrent tagging and releasing of fish at the radial gates is intended to assist DWR in understanding the relative effects that predatory fish relocation may have on PSL of salmonids entrained in CCF. Information gathered from the Study will also aid DWR in meeting the requirements of RPA Action IV.4.2(2).

1.3 Concurrent Salmon Survival Study

DWR initiated a mark-recapture study in Water Year (WY) 2013 to evaluate losses of marked salmonids from the SWP intake at CCF radial gates to the termination of the fish salvage process (approximately 2.1 miles) at the SDFPF. A Memorandum on the effort for 2016 is included as an attachment to this report (Attachment 1).

2. Methods

The Study consisted of three main components: electrofishing, fish processing, and fish transportation. Two electrofishing boats were used to collect target predatory fish species (Striped Bass, black bass, and all catfish species). The captured target species were transferred from the electro fishing boats to a processing barge once the livewells in the electrofishing boats were full. After processing all target captures, they were transferred to a land based transportation livewell that was secured to a large trailer. Target captures were then transported to and released into Bethany Reservoir. Each project component is described in detail below, as are other project methodologies and details.

2.1 Electrofishing

The Study utilized two electrofishing boats, fishing concurrently, to capture target predatory fish species. Each electrofishing boat was specifically designed and outfitted with equipment necessary to temporarily stun fish and hold them in recirculating livewells. The electrofishing boats were outfitted with Smith-Root® Generator Powered Pulsator (GPP) electrofishing units. The GPPs were energized by a gasoline-powered generator securely attached to the floor of each electrofishing boat. Each electrofishing boat was staffed by four crew members: a boat captain, two netters, and a data collector.

Netters used nine-foot long dip nets to capture stunned fish and transfer them to the livewells. The data recorder used a Trimble® Geo7X handheld Global Positioning System (GPS) unit to record capture location and fish capture data. Point files were collected at each capture location. Fish species, number captured, date and time data were all recorded with each point file. In situations where large numbers of target species were encountered, the number of individuals captured was sometimes estimated. The primary goal was to capture as many individuals as possible; it was not efficient to stop netting and count the number of each species in each net when large numbers of fish were in the net and more were being stunned. Therefore, the capture totals for each target species calculated from the point file data are considered estimates. The boat captain navigated CCF using a Trimble® Geo7X handheld GPS unit that had recent, high resolution bathymetry data downloaded to serve as background coverage on the GPS unit's navigation page. This allowed the boat captain to safely navigate the shallow water and sandbars that characterize CCF. It also allowed the boat captain to locate and electrofish underwater structural features, such as shallow humps and deeper depressions, in an attempt to find the structural features that attracted and held large numbers of target species.

Water quality data were recorded at the beginning and end of each sample day with a YSI® Pro2030 meter and included conductivity (microsiemens per centimeter, μS/cm) and water temperature (degrees celsius, °C). Power output settings were recorded on each sample day and included frequency, duty cycle, percent of range, voltage, current, and power. The amount of time electricity was applied to the water was recorded in seconds. Settings were adjusted as needed based on environmental conditions and observed fish response to the electrical field to ensure high capture efficiency while maintaining minimal injury to fish. Captured fish were transported in livewells to a fish transport barge, as discussed below.

2.2 Fish Processing

Target captures were transported to a 28-foot long, flat bottomed barge after the livewells in the electrofishing boats reached capacity. The barge was positioned in close proximity to the electrofishing boats to minimize travel time and maximize time spent electrofishing. The barge was outfitted with up to four circular recirculating livewells (approximately 660 liters) to hold fish during and after processing. The livewells were securely fastened to the deck of the barge and filled with water from CCF using submersible pumps. Data recorded for each capture included species, fork length (millimeter, mm), and weight (0.00 pounds [lbs.]; Salter-Brecknell SA3N ElectroSamson portable hanging scale 55 lb. max), as well as whether or not the fish was a mortality. Mortalities were placed in secure plastic bags and disposed of at the Fish Science Building at CCF. All captures were checked for external tags and scanned using a Biomark 601 Passive Integrated Transponder (PIT) tag reader. Data from all detected tags were recorded and tagged fish were immediately released after processing. Throughout the course of each day, water temperature and dissolved oxygen (DO) levels in the livewells were monitored with a YSI® Pro2030 meter. Handheld oxygen diffusers were used to increase DO levels in the livewells when necessary. After processing, all target captures were transported to a land-based transportation truck and livewell.

2.3 Fish Transportation

The transportation truck and livewell was strategically positioned on the levee of CCF to minimize barge travel time for fish transfers. A ¾-ton pickup truck towed a flatbed trailer on which an insulated fish transport livewell was securely fastened. The transport livewell had a capacity of 1314 liters and was outfitted with oxygen diffusers and an oxygen tank. Prior to receiving fish, the livewell was filled with water from CCF and the DO level was increased to a range of 90 to 180 percent saturation. Once this range was obtained, captures were transferred from the processing barge to the transportation livewell using short handled dip nets. Fish were then transported to Bethany Reservoir, approximately seven miles from CCF, and released at the public boat ramp. The following data were recorded by transportation staff prior to departing CCF with a load of fish: date, time of departure, DO percent saturation in the livewell (YSI® Pro2030 meter), and water temperature (°C; YSI® Pro2030 meter) in the livewell. The following data were recorded by transportation staff just prior to releasing fish in Bethany Reservoir: time of arrival, DO percent saturation in the livewell, water temperature (°C) in the livewell, DO percent saturation in Bethany Reservoir, water temperature (°C) in Bethany Reservoir, and the number of mortalities by species. Mortalities occurring within the transportation livewell were removed prior to releasing fish, placed in secure plastic bags, and disposed of at the Fish Science Building at CCF.

2.4 Sampling Sections

CCF is operated as a regulating reservoir within the tidally influenced region of the Delta to improve operations of the SWP Harvey O. Banks Pumping Plant and water diversions to the California Aqueduct (Figure 1). CCF was divided into six sampling sections to maintain consistency with previous studies conducted at CCF (Figure 2). The sections and brief summaries of each are provided below:

- *Intake Canal*: This sampling section, located along the southwest border of CCF, is a long, narrow channel that is connected to the main body of CCF by a narrow entrance. The entrance is bounded by long, narrow spits of land on the north (37.8333°N, -121.5931°W) and south (37.8317°N, -121.5931°W). The SDFPF is located at the southern end of the intake canal.
- *Scour Hole*: This sampling section is located in the southeast corner of CCF just to the west of the radial gates. The section is characterized by a deep scour hole created by water rushing into CCF through the radial gates.
- *Northwest Quadrant*: The boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8404°N, -121.5910°W, 2) 37.8404°N, -121.5750°W, and 3) 37.8566°N, -121.5750°W.
- *Southwest Quadrant*: the boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8404°N, -121.5910°W, 2) 37.8404°N, -121.5750°W, and 3) 37.8270°N, -121.5750°W. The public fishing area is located in this quadrant and receives a fair amount of recreational use.
- *Northeast Quadrant*: The boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8566°N, -121.5750°W, 2) 37.8404°N, -121.5750°W, and 3) 37.8404°N, -121.5590°W.
- *Southeast Quadrant*: The boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8270°N, -121.5750°W, 2) 37.8404°N, -121.5750°W, and 3) 37.8404°N, -121.5590°W.

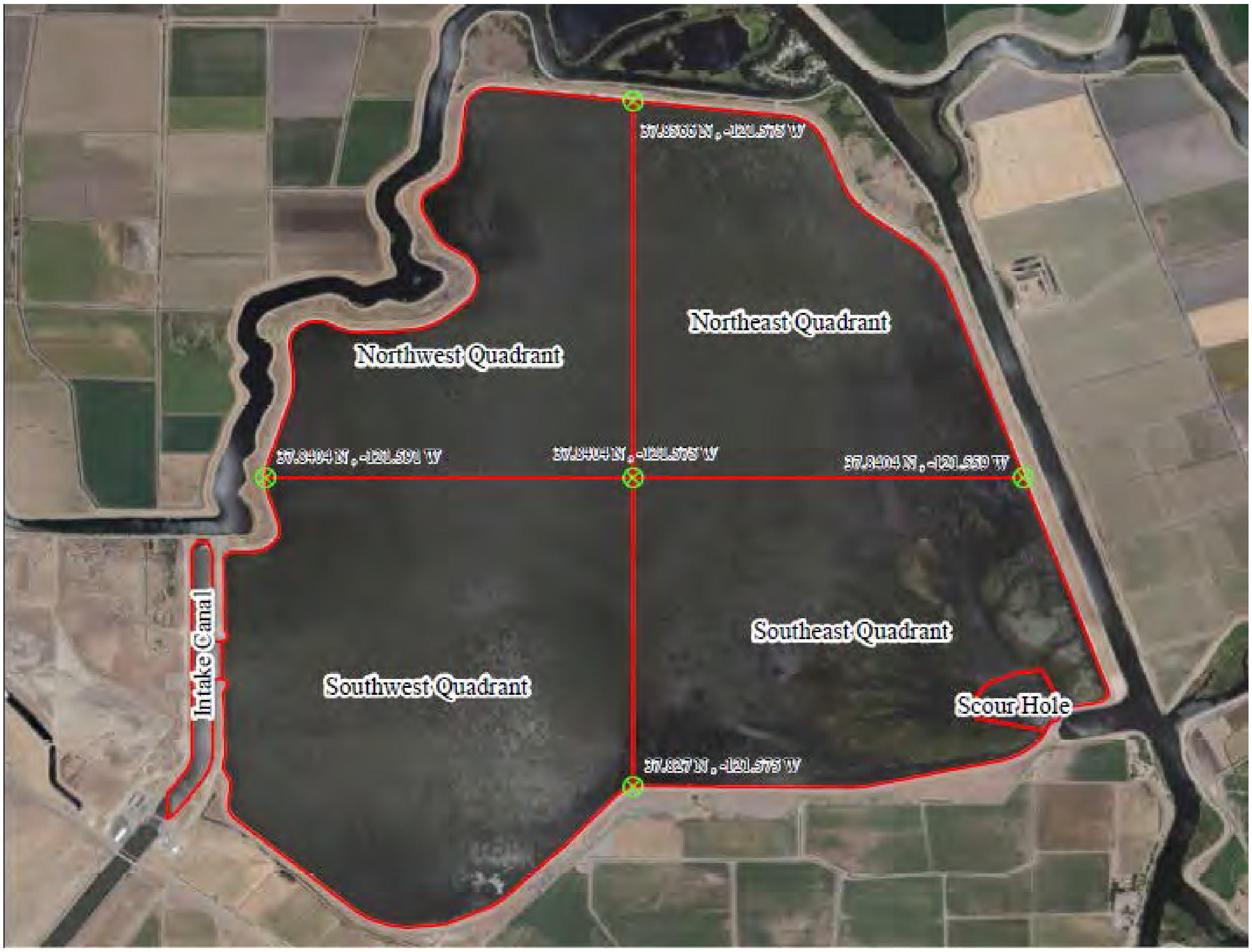

Figure 2 - Map of the study sections used during the 2016 CCF Study.

Sections were selected for sampling on the morning of each sample day. An effort was made to sample each section an equal number of times during the pilot effort; however, site selection was also influenced by multiple environmental and operational variables, including weather, CCF operations (including radial gate schedule), water levels within CCF, and the SWP Harvey O. Banks water pumping schedule. All of these factors impacted the sampling schedule, site selection, and safety of the work environment. As the study progressed, catch rates within each section was also factored into the selection process. An effort was made to sample two sections on each sample day: one morning session and one afternoon session. An effort was also made to have both electrofishing boats sample the same section simultaneously.

2.5 Staff Training

Smith-Root was contracted to provide an on-site electrofishing course for permanent DWR staff working on this project. A classroom session took place in Sacramento and covered basic electrical theory, electrofishing equipment, operation and safety, and applied electrofishing methods. A field session took place at CCF where participants operated electrofishing equipment, including adjusting settings on the control panel, and applied information learned in the classroom. The training focused on the following:

- Minimizing/eliminating potential harm to fish;
- Proper electrofishing settings to maximize capture efficiency;
- Working safely as a team in a variety of environments;
- Techniques and settings for a variety of target species in different life stages;
- Operation and safety, including dangers to humans and fish; and
- Electrofishing techniques as they apply to bioassessments, fisheries characterizations, population estimates, and age and growth studies.

All contractor staff working on this project were required to complete the online U.S. Department of Interior FWS-CSP2202A-OLT Electrofishing Safety course. This course emphasized electrofishing safety to minimize hazards and maximize performance. All project boat operators were required to have Motorboat Operator Training Course (MOTC) certification. The multi-day training course combined classroom sessions and field sessions. The course emphasized safe motorboat operations and included a review of legal requirements, preparations, navigation, operations, emergency procedures, rescue, self-rescue, trailering, fire suppression, and basic seamanship. The course included both classroom and on-the-water instruction. The objectives of the MOTC certification were to:

- Provide attendees with specific skills and knowledge that will allow them to make informed decisions about their own safety, the safety of all crew members, and the safety of the vessel;
- Familiarize attendees with state-of-the-art watercraft safety equipment and other gear, through demonstration and actual use; and
- Allow attendees to demonstrate, through written examination and physical demonstration, that they have an adequate grasp of motorboat handling techniques and knowledge to safely operate a motorboat in a normal work environment.

2.6 Target Species and Sampling Techniques

A variety of non-native predatory fishes are known to inhabit CCF. Target species selected for this study were based on previous studies conducted in the CCF (Kano, 1990) and include:

- Striped Bass (*Morone saxatilis*);
- Largemouth Bass (*Micropterus salmoides*);
- Spotted Bass (*Micropterus punctulatus*);
- Channel Catfish (*Ictalurus punctatus*);
- White Catfish (*Ameiurus catus.*);
- Black Bullhead (*Ameiurus nebulosus*); and
- Brown Bullhead (*Ameiurus melas*).

Scientific observations, including, but not limited to, tagged fish tracking data, have shown differences in habitat selection among species (DWR, 2015). Accordingly, electrofishing efforts were partitioned among broad habitat types available in CCF to ensure all target species were sampled. The main habitat types were shoreline, open water, and deep water.

2.6.1 Shoreline Sampling

Sampling along the shoreline (defined as within 25 meters of the shoreline) was conducted primarily to target black bass. Sampling consisted of moving slowly parallel or at a slight angle to the shoreline to concentrate the electrical field around vegetation, rip-rap, and other likely fish holding features. While moving within the shoreline section between high probability capture locations, electricity was applied to the water at rate of 12 to15 seconds on and 5 seconds off in a searching pattern or continuously as the boat paralleled the shore. The on/off technique was an attempt to minimize continually pushing fish outside of the effective range of the electrofishing boat. When schools of fish were located, the captain of the electrofishing boat would stop forward movement and reposition the bow such that netters could capture as many fish as possible. Once the school dispersed, the electrofishing boat would move from the area in a broadening circular pattern in an attempt to relocate the school of fish.

2.6.2 Open Water Sampling

Open water sampling was conducted beyond 25 meters from the shoreline. This sampling technique was intended to target Striped Bass, which have shown pelagic schooling behavioral tendencies in CCF. Open water sampling typically was conducted at a faster rate of movement than shoreline sampling, with the intention of covering a substantial amount of water in an attempt to locate high densities of target fish species. Sampling in the open water section involved roving in a straight line, searching for fish by applying electricity to the water. When concentrations of fish were encountered, forward movement of the boat was slowed and sampling efforts were increased in that area. Micro-habitats, such as patches of aquatic vegetation and changes in water depth, were often specifically targeted during open water sampling by using bathymetry data as background coverage on the electrofishing boat's GPS navigation page and staff observations.

2.6.3 Deep Water Sampling

Low frequency sampling, a method that has been effective for capturing catfish in reservoirs, was used in deeper areas of CCF, primarily the scour hole. Low frequency sampling consisted of applying a low frequency current (15 pulses per second) to the water by a stationary electrofishing boat for 5 minutes.

2.7 Metrics

Morphological data for all target captures were recorded during processing aboard the barge. These data were used to report project total captures, associated descriptive statistics, and catch per unit effort (CPUE) for the days in which shock time was recorded by both electrofishing boats. It is unknown how much shock time occurred in each sampling section. Therefore, CPUE could only be applied to CCF. The metric could not be used to make inferences among sampling sections, because each electrofishing boat's shock timer was reported as a daily total.

The data that were recorded in each fish capture point file were used to report captures in each sampling section and to make inferences among sampling sections. It is important to note that the data recorded with these point files and metrics derived from these data are estimates as described in section 2.1. The capture point files and associated capture data could be assigned to a sampling section. The metric used to describe captures within sampling sections/quadrants was percent of total captures. For example, the following equation was used to determine the percent of total captures that occurred within the scour hole section:

$$\%\,Total\ Captures\ Scour\ Hole = \frac{Total\ Captures\ Scour\ Hole}{Total\ Captures\ CCF}$$

The percent of total captures that occurred in the northwest quadrant attributed to Striped Bass was calculated as:

$$\%\,Total\ Capture\ Northwest\ Quandrant: Striped\ Bass = \frac{Total\ Captures\ Striped\ Bass\ NW\ Quadrant}{Total\ Captures\ NW\ Quadrant}$$

2.8 Recreationally Harvestable Fish

CCF is within the Delta, as defined in DFW's Freshwater Sport Fishing Regulations (section 1.71). As such, recreational harvest regulations in CCF are consistent with those listed for the Delta in DFW's Freshwater Sport Fishing Regulations. Recreational harvest of Striped Bass is permitted year-round in the Delta with an 18-inch minimum size limit (total length) and a 2 fish daily bag limit. Black bass is a collective term that describes all species in the genus *Micropterus*. In the Delta, the black bass assemblage includes Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Spotted Bass (*Micropterus punctulatus*), and Redeye Bass (*Micropterus coosae*). Recreational harvest of black bass is permitted year-round in the Delta with a 12-inch minimum size limit (total length) and a 5 fish daily bag limit. For the purpose of this report, catfish is a collective term for species in the genus *Ictalurus* and *Ameiurus*. In the Delta, the catfish assemblage includes Channel Catfish (*Ictalurus punctatus*), White Catfish (*Ameiurus catus*), Brown Bullhead (*Ameiurus nebulosus*), and Black Bullhead (*Ameiurus melas*). Recreational harvest of catfish is permitted year-round in the Delta with no size restrictions and no daily bag limit.

Length measurements for this project were recorded in fork length. California recreational harvest regulations are described using total length. Fork length was converted to total length to determine the number of recreationally harvestable fish that were captured during this project. Many studies have demonstrated a relationship between fork length and total length (Carlander 1977). The relationship is species specific and often system specific. System specific conversion factors can be developed from large datasets. In lieu of system specific data, conversion factors are readily available within published literature. Carlander (1977) provides standard conversion factors for most warm-water game species.

Many fisheries studies have been implemented at CCF. The CCF Predation Study began in 2013 and is ongoing. Predatory fishes, including Striped Bass, are sampled for project activities. During the 2013-14 sampling season, all Striped Bass captured were measured in both fork and total length. These data were used to calculate the fork to total length conversion factor used for Striped Bass for this report (Wunderlich 2016, DWR unpublished data). The following conversion factor was used:

$$Total\ Length = Fork\ Length\ x\ 1.068772$$

Carlander (1977) provides fork to total length conversion factors for Largemouth Bass. However, most of the studies reported were conducted prior to 1970 and are from systems well outside of California. In lieu of system specific conversion factors, or those from systems close to the system of interest, Carlander (1977) recommends the following standard conversion factor:

$$Total\ Length = Fork\ Length\ x\ 1.08$$

Pagliughi (2002) studied Largemouth Bass at Freshwater Lagoon, Humboldt County, California, and reported a conversion factor of:

$$Total\ Length = Fork\ Length\ x\ 1.034$$

This conversion factor was used for this study because of its proximity to CCF and because the results are fairly recent.

Fork length to total length conversion factors are not available for Spotted Bass. The one Spotted Bass captured during this project had a fork length of 9.40 inches. Regardless of conversion factor used, this fish would not be recreationally harvestable and was thus determined to be unharvestable.

2.9 Environmental Data

Environmental data were gathered from the California Data Exchange Center (CDEC) and the California Irrigation Management Information System (CIMIS). Water temperature (°C), inflow (cubic feet per second, cfs), and turbidity (NTU) data were downloaded from CDEC from the CLC (Clifton Court) station. This water quality monitoring station is located in Contra Costa County (37.8298°N, -121.5574°W) and is maintained by DWR. Data are presented in daily averages. Air temperature (daily minimum and maximum) were downloaded from CIMIS from the Tracy #167 station. This air quality monitoring station is located in Tracy, San Joaquin County, California (37.7259°N, -121.4755°W), and is maintained by DWR.

3. Results

Results from this study are based on 11 days of electrofishing from April 20 to May 18, 2016.

3.1 Sample Days and Captures

Electrofishing sampling generally occurred two to three times per week during the sampling period. The first sample day was April 20 and the last sample day was May 18. Three sample days occurred in April and eight sample days occurred in May. Data were recorded for target predatory fish species only; all other species captured were released during the processing of target species. A total of 2,686 target predatory fish were captured during 11 sample days. The highest number of predatory fish was sampled on May 12 (476) and the lowest number was sampled on May 17 (76). Total captures included 2,059 Striped Bass (77% of total captures), 594 black bass (22% of total captures), and 33 catfish (1% of total captures). Black bass captures included 593 Largemouth Bass and 1 Spotted Bass. Catfish captures included 1 Brown Bullhead, 1 Black Bullhead, 10 Channel Catfish, and 21 White Catfish. Table 1 shows total predatory fish captures by sample day.

Table 1 - Total number of target predatory fish captured during the 2016 Study.

Species	April			May								
	20	27	28	3	4	5	10	11	12	17	18	*Total*
Striped Bass	247	75	153	149	300	275	85	167	430	60	118	*2,059*
Black Bass sp.	35	15	54	49	74	79	104	74	45	16	49	*594*
Catfish sp.	0	0	1	11	0	5	2	4	1	0	9	*33*
	282	*90*	*208*	*209*	*374*	*359*	*191*	*245*	*476*	*76*	*176*	*2,686*

3.2 Length and Weight of All Target Species

Weights were converted to grams from pounds and fork length was taken in millimeters for all captured target species. Total captures' fork length and weight averaged 294.8 mm and 395 grams, respectively. Minimum, maximum, and average lengths and weights can be found in Table 2. The length frequency distribution for total captures is shown in Figure 3.

Table 2 - Length and weight metrics for target predatory fish captured during the 2016 Study.

Species	Total Captures (n)	% of Total	Min Length (mm FL)	Max Length (mm FL)	Ave Length (mm FL)	Min Weight (grams)	Max Weight (grams)	Ave Weight (grams)
Striped Bass	2,059	77%	89	1,040	289.5	23	17645	327
Black Bass	594	22%	99	625	309.3	45	4899	608
Catfish	33	1%	135	664	363.8	45	4264	1039
Total	*2,686*	*100%*	*89*	*1,040*	*294.8*	*23*	*17645*	*395*

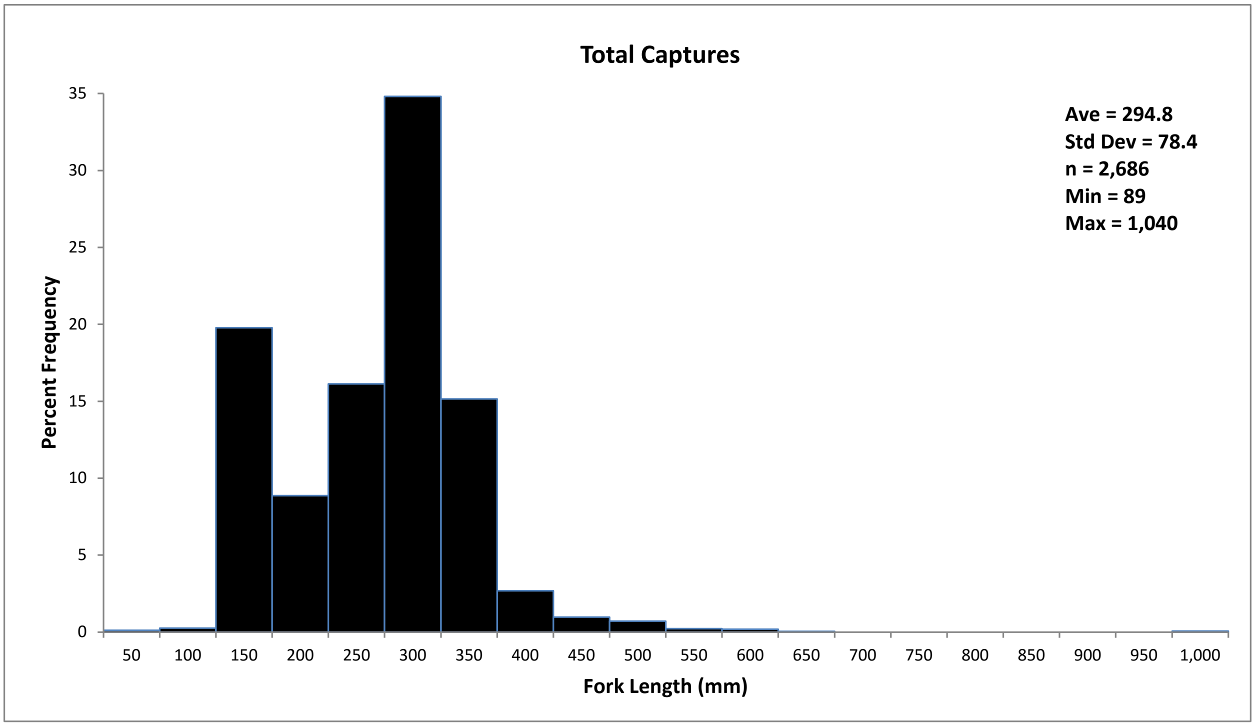

Figure 3 - Length frequency distribution for target predatory fish (total captures) captured during the 2016 Study.

3.3 Catch per Unit Effort

Shock time was available for both electrofishing boats on eight sample days; CPUE for these days is reported as captures per minute of electrofishing time. The CPUE for total captures ranged between 0.54 and 1.97 fish per minute of electrofishing. CPUE summary statistics are shown in Table 3.

Table 3 - CPUE for target predatory fish captured during the 2016 Study.

	Catch Per Unit Effort (minute)								
	3-May	4-May	5-May	10-May	11-May	12-May	17-May	18-May	*Total CPUE*
Total Captures	0.95	1.49	1.36	0.75	0.92	1.97	0.54	0.81	***1.44***
Striped Bass	0.67	1.20	1.04	0.33	0.62	1.78	0.43	0.54	***1.11***
Black Bass	0.22	0.30	0.30	0.41	0.28	0.19	0.11	0.22	***0.32***
Catfish	0.05	0.00	0.02	0.01	0.01	0.00	0.00	0.04	***0.02***

3.4 Recreationally Harvestable vs. Non-Harvestable Captures

The total numbers of recreationally harvestable fish, and the percentage of the total captures recreationally harvestable fish accounted for, are shown in Table 4. A total of 435 captures were recreationally harvestable, which represents 16 percent of total captures. Recreationally harvestable Striped Bass accounted for 1 percent of total captures; black bass accounted for 14 percent; and catfish accounted for 1 percent. A total of 2,059 Striped Bass, 594 black bass, and 33 catfish were captured during this study and 1 percent, 63 percent, and 100 percent of each species were recreationally harvestable, respectively. Length frequency distributions for Striped Bass, black bass, and catfish are shown in Figures 4 through 6, respectively.

Table 4 - Recreationally harvestable metrics for target predatory fish captured during the 2016 Study.

	Total Captures	Recreationally Harvestable	% Harvestable
Striped Bass	2,059	30	1%
Black Bass	594	372	63%
Catfish	33	33	100%
Total	***2,686***	***435***	***16%***

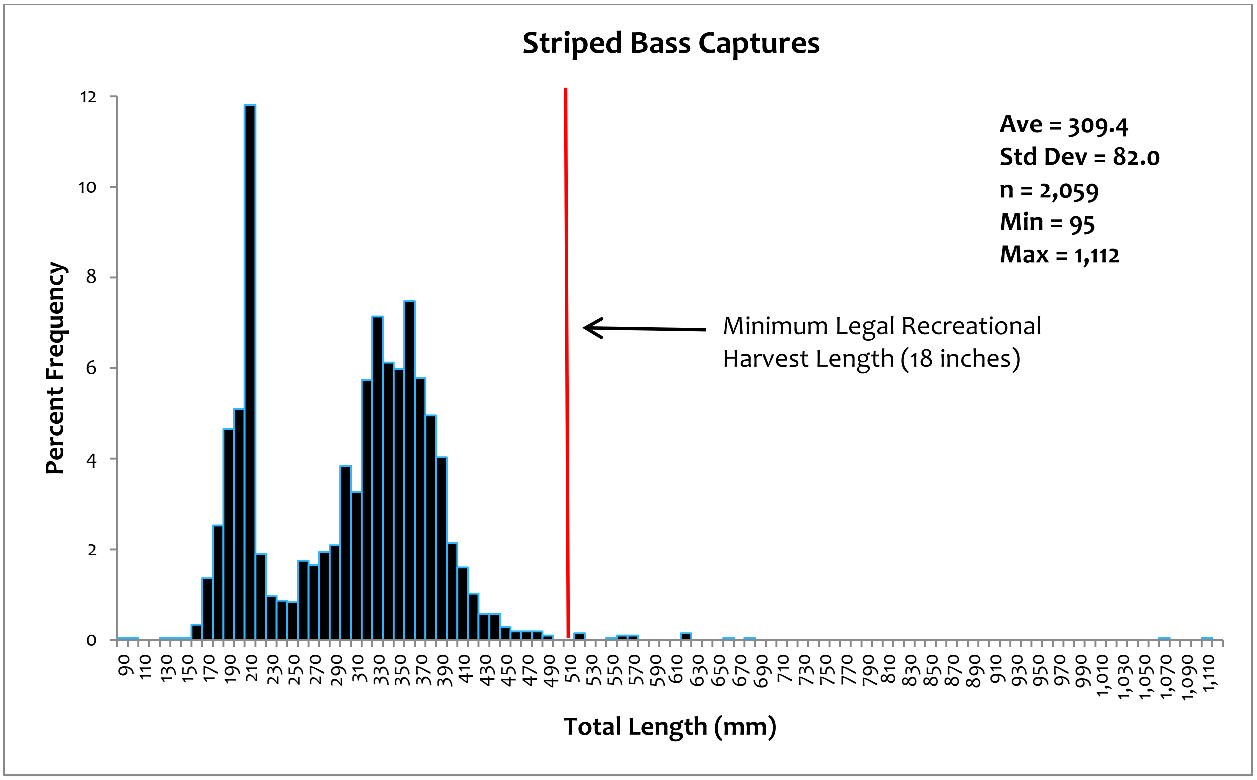

Figure 4 - Length frequency distribution for Striped Bass captured during the 2016 Study.

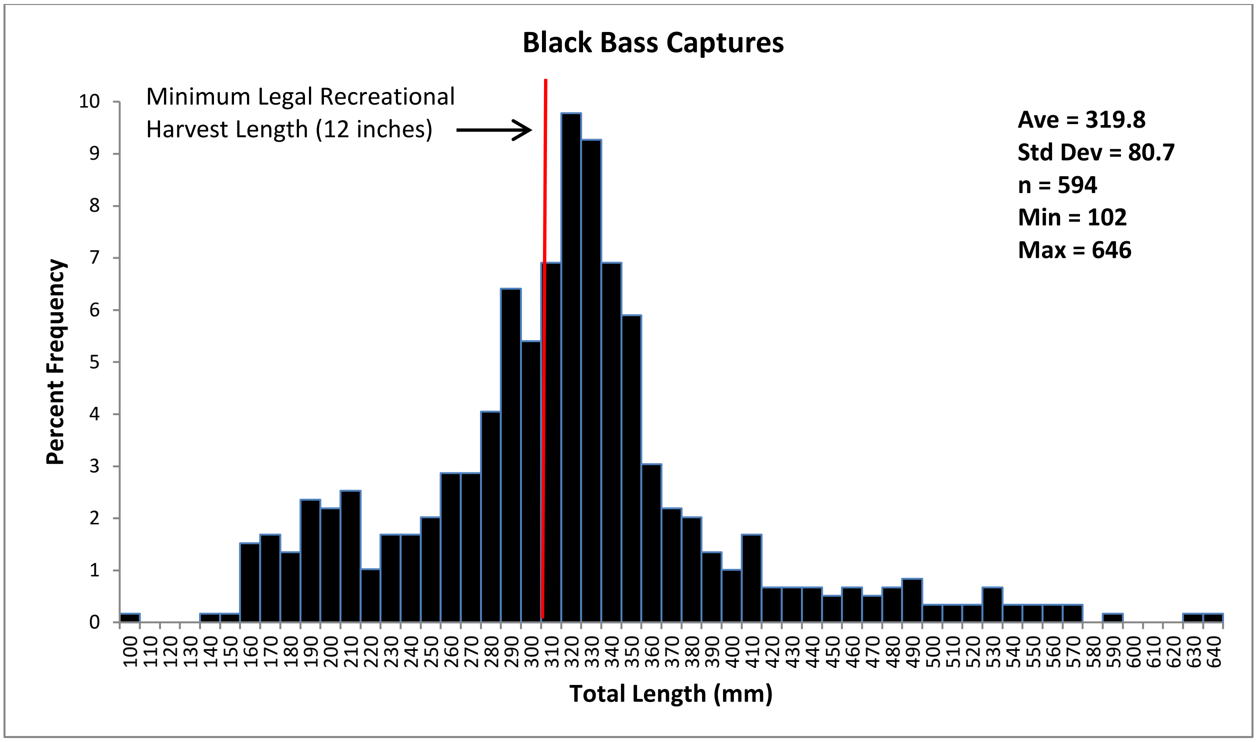

Figure 5 - Length frequency distribution for black bass captured during the 2016 Study.

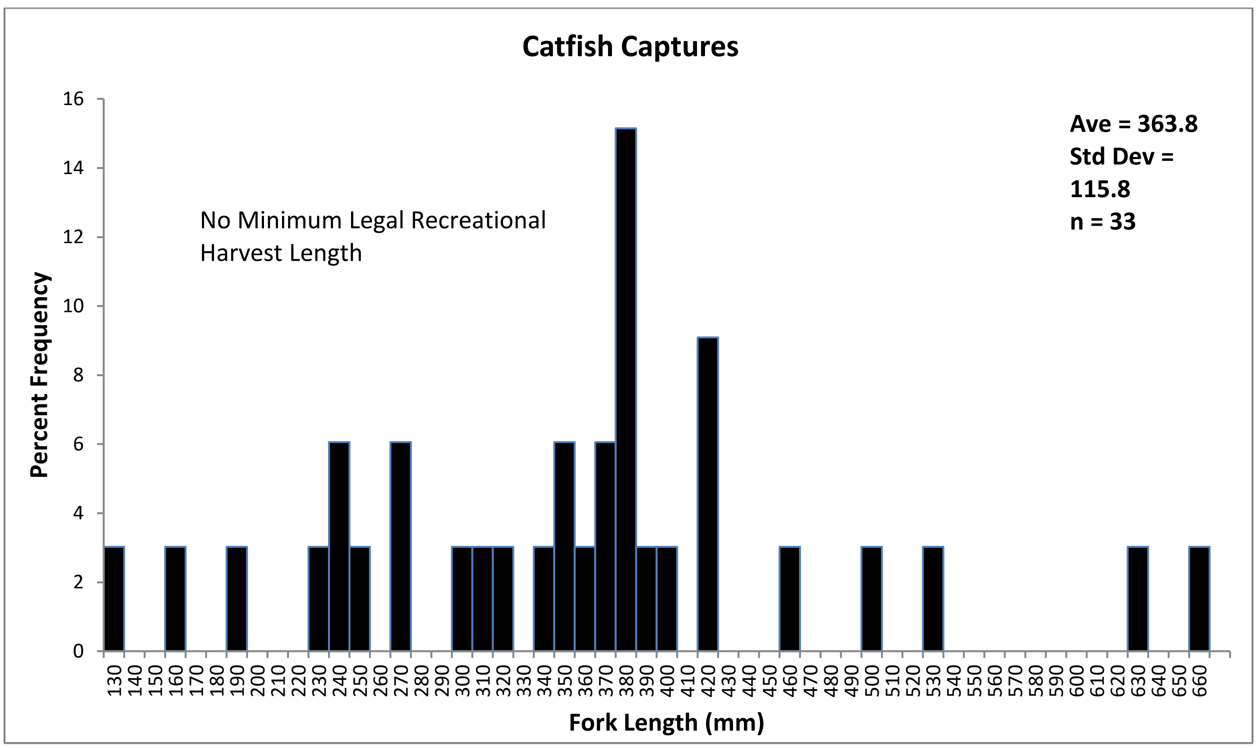

Figure 6 - Length frequency distribution for catfish captured during the 2016 Study.

3.5 Captures by Sampling Section

The metrics used to characterize captures among sampling sections were calculated from capture data in the point files collected from each electrofishing boat's GPS unit. Capture data recorded in the point files were sometimes estimated. However, the percent of total captures was similar between the data collected on sheets during processing and data collected with the point files during capture as show in Table 5.

Table 5 – Comparison of captures per sample day between datasheet and point file datasets. (Note: No point file data was taken on April 20).

		Sample Day												
		April			May									
Species	Dataset	20	27	28	3	4	5	10	11	12	17	18	Total Captures	% Total Captures
Striped Bass	*Datasheet Data*	247	75	153	149	300	275	85	167	430	60	118	2,059	77%
	Point file Data	N/A	68	144	127	282	281	81	169	365	63	119	1,699	72%
Black Bass	*Datasheet Data*	35	15	54	49	74	79	104	74	45	16	49	594	22%
	Point file Data	N/A	26	62	43	96	84	112	77	58	17	56	631	27%
Catfish	*Datasheet Data*	0	0	1	11	0	5	2	4	1	0	9	33	1%
	Point file Data	N/A	1	1	10	0	5	2	4	1	0	9	33	1%
Total	*Datasheet Data*	282	90	208	209	374	359	191	245	476	76	176	2,686	
	Point file Data	0	95	207	180	378	370	195	250	424	80	184	2,363	

Predatory fish captures for each sampling section are shown in Figure 7. The shoreline and open water sections are omitted from this figure, because the captures within these two habitat types overlap the captures of the other sections. The highest number of total captures occurred in the southeast quadrant (578) and the lowest number of total captures occurred in the northeast quadrant (136). Mapped capture locations for all predatory fish, Striped Bass, black bass and catfish can be seen in Figures 8 - 11.

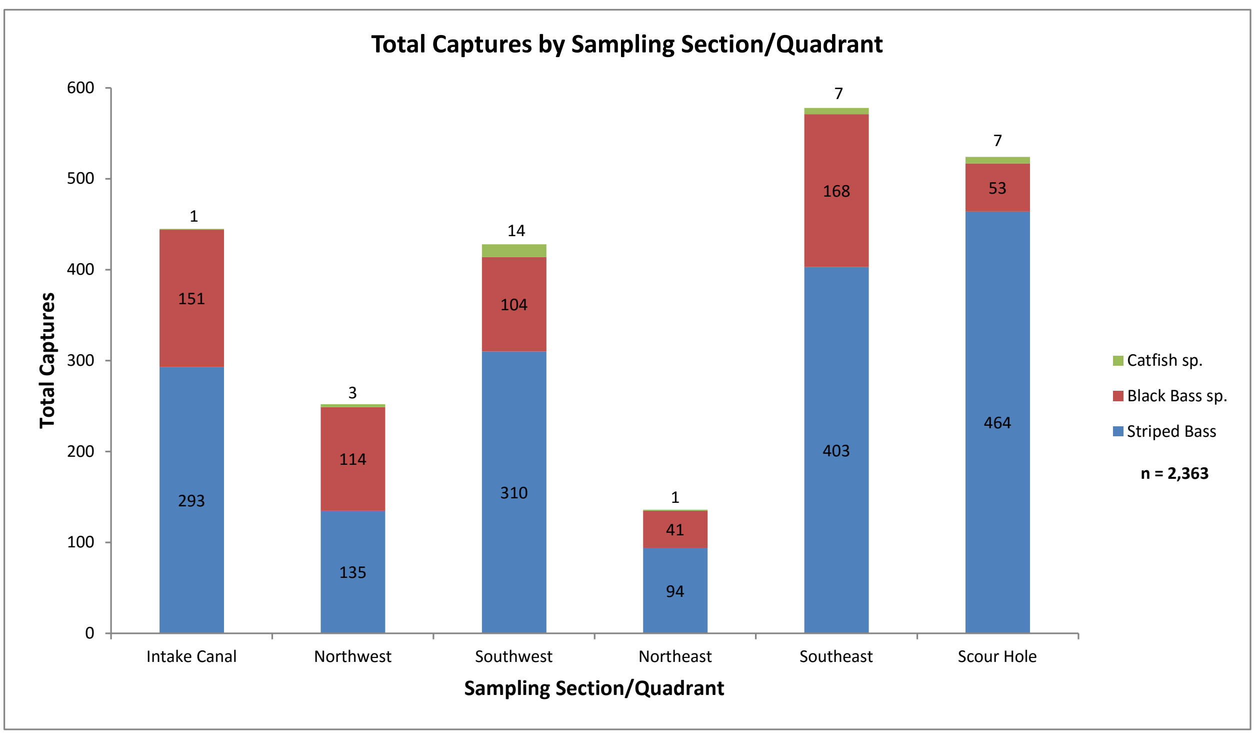

Figure 7 - Total captures by sampling section and species during the 2016 Study.

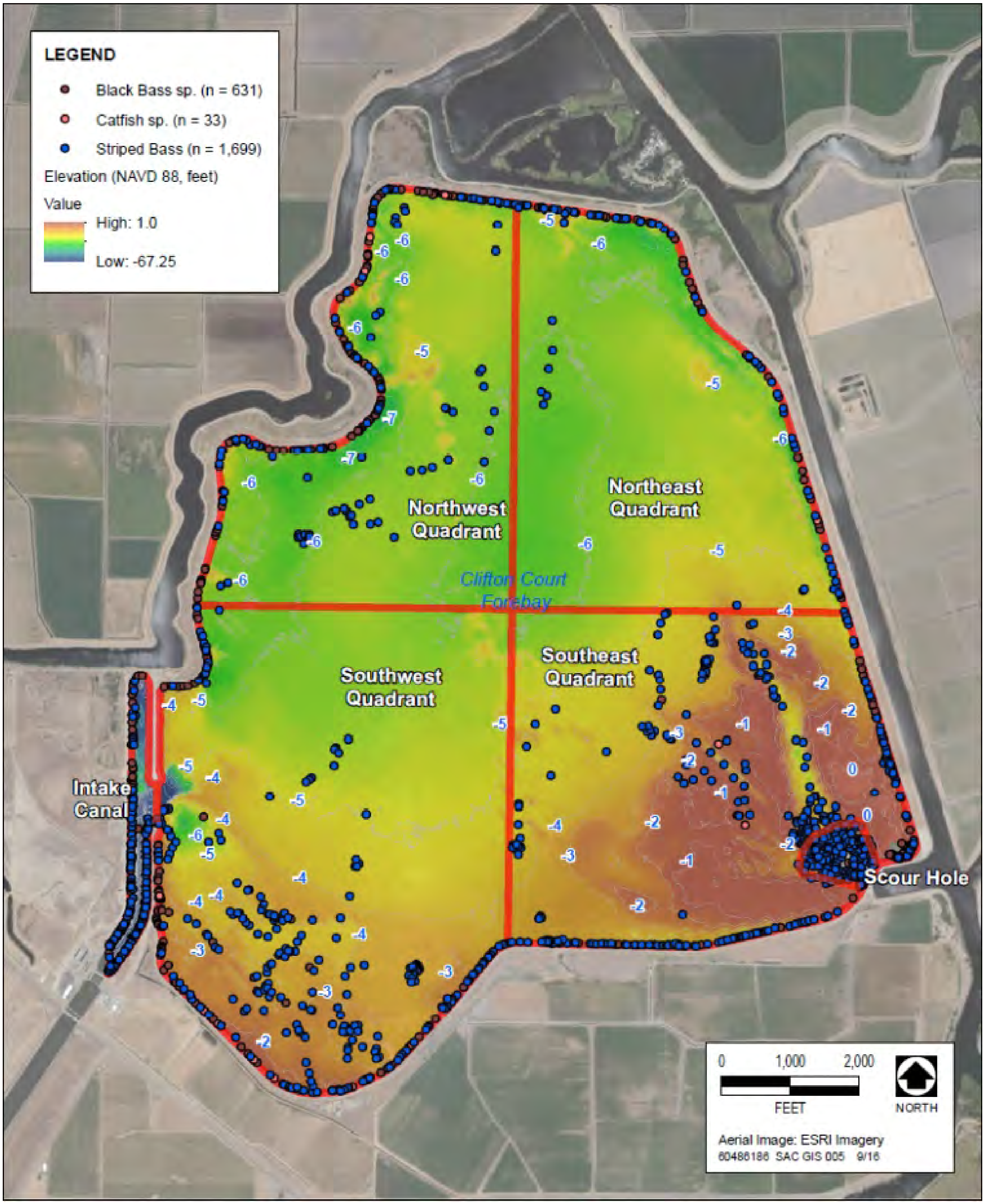

Figure 8 - Capture locations of removed predatory fish combined and by species during the 2016 Study.

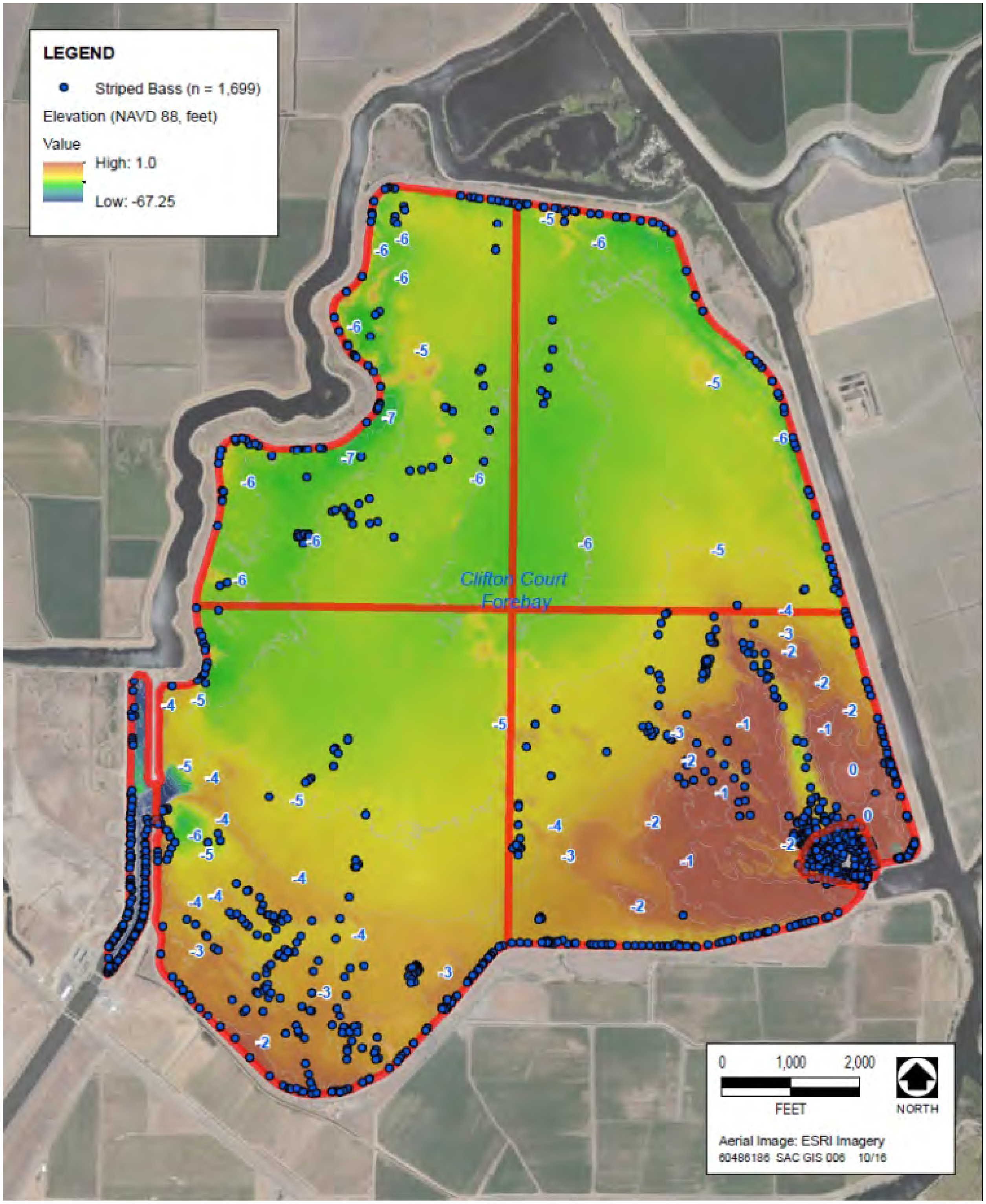

Figure 9 - Capture locations of removed Striped Bass during the 2016 Study.

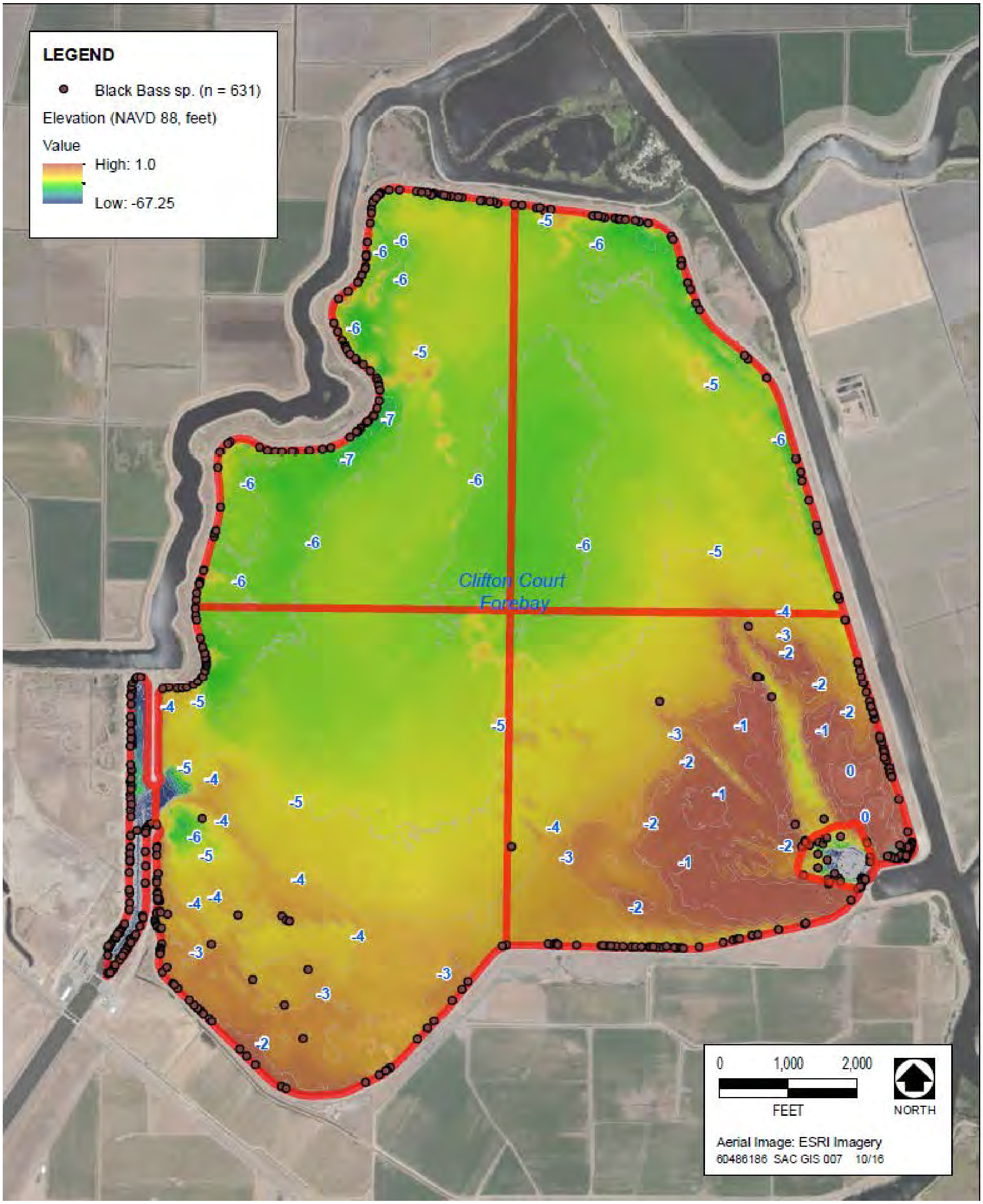

Figure 10 - Capture locations of removed black bass during the 2016 Study.

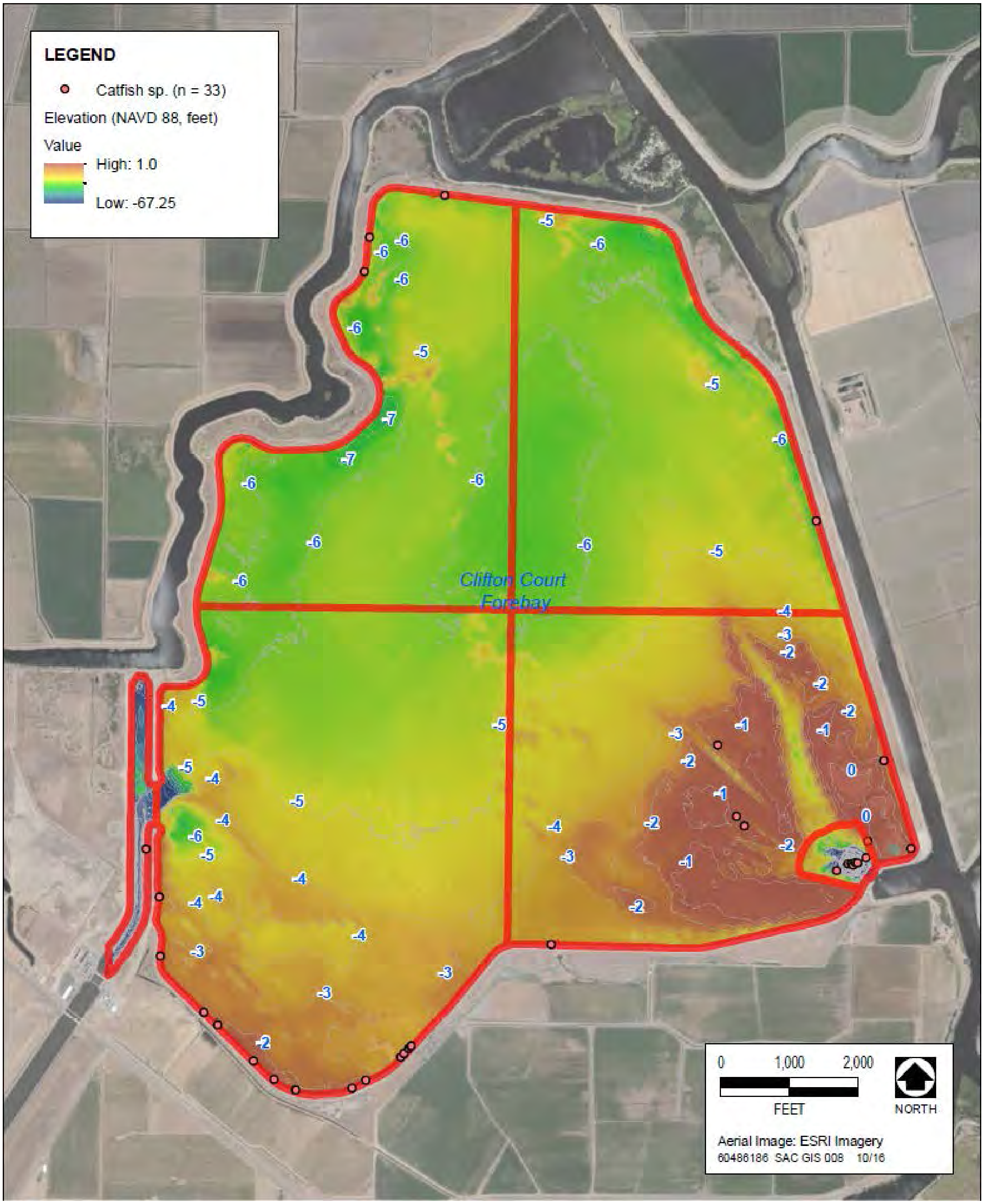

Figure 11 - Capture locations of catfish during the 2016 Study.

3.5.1 Intake Canal

A total of 445 of the 2,363 captures occurred within the intake canal, which represents 19 percent of the total captures recorded in the point files. Striped Bass, black bass, and catfish accounted for 66 percent, 34 percent, and less than 1 percent, respectively, of total captures that occurred in the intake canal section. A total of 293 Striped Bass captures occurred within the intake canal section, which represents 12 percent of total captures and 17 percent of the 1,699 total Striped Bass captures. A total of 151 black bass captures occurred within the intake canal section, which represents 6 percent of total captures and 24 percent of the 631 total black bass captures. One catfish capture occurred within the intake canal section, which represents less than 1 percent of total captures and 3 percent of the 33 total catfish captures.

3.5.2 Scour Hole

A total of 524 of the 2,363 captures occurred within the scour hole, which represents 22 percent of total captures recorded in the point files. Striped Bass, black bass, and catfish accounted for 89 percent, 10 percent, and 1 percent, respectively, of total captures that occurred in the scour hole section. A total of 464 Striped Bass captures occurred within the scour hole section, which represents 20 percent of total captures and 27 percent of the 1,699 total Striped Bass captures. A total of 53 black bass captures occurred within the scour hole section, which represents 2 percent of total captures and 8 percent of the 631 total black bass captures. Seven catfish captures occurred within the scour hole section, which represents less than 1 percent of total captures and 21 percent of the 33 total catfish captures.

3.5.3 Northwest Quadrant

A total of 252 of the 2,363 captures occurred within the northwest quadrant, which represents 11 percent of total captures recorded in the point files. Striped Bass, black bass, and catfish accounted for 54 percent, 45 percent, and 1 percent, respectively, of total captures that occurred in the northwest quadrant. A total of 135 Striped Bass captures occurred within the northwest quadrant, which represents 6 percent of total captures and 8 percent of the 1,699 total Striped Bass captures. A total of 114 black bass captures occurred within the northwest quadrant, which represents 5 percent of total captures and 18 percent of the 631 total black bass captures. Three catfish captures occurred within the northwest quadrant, which represents less than 1 percent of total captures and 9 percent of the 33 total catfish captures.

3.5.4 Southwest Quadrant

A total of 428 of the 2,363 captures occurred within the southwest quadrant, which represents 18 percent of total captures recorded in the point files. Striped Bass, black bass, and catfish accounted for 72 percent, 24 percent, and 3 percent, respectively, of total captures that occurred in the southwest quadrant. A total of 310 Striped Bass captures occurred within the southwest quadrant, which represents 13 percent of total captures and 18 percent of the 1,699 total Striped Bass captures. A total of 104 black bass captures occurred within the southwest quadrant, which represents 4 percent of total captures and 16 percent of the 631 total black bass captures. Fourteen catfish captures occurred within the southwest quadrant, which represents less than 1 percent of total captures and 42 percent of the 33 total catfish captures.

3.5.5 Northeast Quadrant

A total of 136 of the 2,363 captures occurred within the northeast quadrant, which represents 6 percent of total captures recorded in the point files. Striped Bass, black bass, and catfish accounted for 69 percent, 30 percent, and 1 percent, respectively, of total captures that occurred in the northeast quadrant. A total of 94 Striped Bass captures occurred within the northeast quadrant, which represents 4 percent of total captures and 6 percent of the 1,699 total Striped Bass captures. A total of 41 black bass captures occurred within the northeast quadrant, which represents 2 percent of total captures and 6 percent of the 631 total black bass captures. One catfish capture occurred within the northeast quadrant, which represents less than 1 percent of total captures and 3 percent of the 33 total catfish captures.

3.5.6 Southeast Quadrant

A total of 578 of the 2,363 captures occurred within the southeast quadrant, which represents 24 percent of total captures recorded in the point files. Striped Bass, black bass, and catfish accounted for 70 percent, 29 percent, and 1 percent, respectively, of total captures that occurred in the southeast quadrant. A total of 403 Striped Bass captures occurred within the southeast quadrant, which represents 17 percent of total captures and 24 percent of the 1,699 total Striped Bass captures. A total of 168 black bass captures occurred within the southeast quadrant, which represents 7 percent of total captures and 27 percent of the 631 total black bass captures. Seven catfish captures occurred within the southeast quadrant, which represents less than 1 percent of total captures and 21 percent of the 33 total catfish captures.

3.6 Shoreline vs. Open Water

To gain a better understanding of habitat usage variability between species, an analysis of shoreline captures versus open water captures was conducted. Individuals captured within 25 meters of the shore were considered to have been captured along the shoreline and individuals captured further than 25 meters from the shore were considered to have been captured in open water.

3.6.1 Shoreline

A total of 1,368 of the 2,363 captures occurred within 25 meters of the shoreline, which represents 58 percent of total captures recorded in the point files. A total of 782 Striped Bass captures occurred within the shoreline section, which represents 46 percent of the 1,699 total Striped Bass captures. A total of 564 black bass captures occurred within the shoreline section, which represents 89 percent of the 631 total black bass captures. A total of 22 catfish captures occurred within the shoreline section, which represents 67 percent of the 33 total catfish captures.

3.6.2 Open Water

A total of 995 of the 2,363 captures occurred within the open water section, which represents 42 percent of total captures recorded in the point files. A total of 917 Striped Bass captures occurred within the open water section, which represents 54 percent of the 1,699 total Striped Bass captures. A total of 67 black bass captures occurred within the open water section, which represents 11 percent of the 631 total black bass captures. A total of 11 catfish captures occurred within the open water section, which represents 33 percent of the 33 total catfish captures.

3.7 Recaptures

Forty-five of the target predatory fish that were captured were externally tagged with one or two Floy tags, implanted with PIT tags, or tagged with both (Table 6). This represents 1.7 percent of the 2,686 total captures. Striped Bass and black bass accounted for 18 percent and 82 percent of total tagged captures, respectively. No tagged catfish were captured. The highest number of tagged captures occurred in the intake canal section (24, 53 percent) and none were captured in the northeast quadrant. Six of the tagged captures were captured multiple times during the study and all were black bass. Five were captured two times and one was captured three times. The maximum amount of time transpiring between first and last capture of the same tagged individual was 14 days. One tagged individual was captured twice on the same sample day. All but one of the tagged fish that were captured multiple times were captured in the intake canal section. A tagged individual was first captured in the southwest quadrant on May 11 and was captured again in the intake canal section on May 18.

Table 6 - Summary of tagged captures from the 2016 Study.

			Original Capture Data			Recapture Data			
Species	Floy Tag #	Pit Tag #	Date Tagged	Original Weight (lbs)	Original Fork Length (mm)	Date	Capture Quadrant	Weight (lbs 0.00)	Fork Length (mm)
LMB	4234/4235	3PD003B07F4D0	4/14/2016	363	320	20-Apr-16	Intake	386	-
LMB	4148/4149	3D9239F883D1C	3/25/2016	907	380	20-Apr-16	Intake	816	-
LMB	4148/4149	3D9239F883D1C	3/25/2016	907	380	20-Apr-16	Intake	816	-
STB	387/2106	3DD003BC7F281	6/9/2015	522	365	20-Apr-16	Intake	-	-
LMB	-	3DDF003BC7F2AB	3/6/2015	1429	420	27-Apr-16	Intake	1656	463
LMB	-	3D6F001569BEB5	6/25/2013	1905	510	27-Apr-16	Intake	2880	555
LMB	2920/2921	-	11/20/2015	590	340	27-Apr-16	Intake	431	430
LMB	4148	3D9239F883D1C	3/25/2016	907	380	27-Apr-16	Intake	839	368
LMB	337	3DDF003BC7F3D7	5/26/2015	227	260	28-Apr-16	Scour Hole	544	338
STB	-	3DDF003BC7F2FF	3/1/2016	590	375	28-Apr-16	Scour Hole	544	364
LMB	3385	-	11/13/2015	340	280	28-Apr-16	North West	363	280
LMB	4239/4238	3DDF003BC7F4E2	4/14/2016	476	335	3-May-16	South West	522	330
STB	3288	3DDF003BC7F429	10/12/2015	680	395	4-May-16	Scour Hole	635	389
LMB	-	3DDF003BC7F179	9/21/2015	408	315	4-May-16	Intake	386	308
LMB	4234/4235	3DDF003BC7F4D0	4/14/2016	363	320	4-May-16	Intake	408	308
LMB	-	3DDF003BC7F28AB	-	-	-	4-May-16	Intake	1588	460
LMB	4232/4233	3D9F239F885349	4/14/2016	1293	415	4-May-16	Intake	1452	400
STB	4177/4126	3D9F1C2DB8FDE7	4/1/2016	295	315	5-May-16	South West	295	311
LMB	-	3DDF003BC7F42F	-	-	-	5-May-16	South West	590	340
LMB	4243	3DDF003BC7F433	11/13/2015	522	315	5-May-16	South West	408	304
LMB	-	3DDF003BC7F48B	11/14/2014	590	325	5-May-16	South West	703	371
LMB	-	3D6F000B320D37	12/23/2013	680	360	5-May-16	South West	1043	415
LMB	-	3D6000B320E1C	5/15/2014	612	360	5-May-16	South West	998	405
LMB	-	3D9F239F883CCF	2/12/2016	1474	430	4-May-16	Intake	1270	430
STB	3870/3871	3DDF003BC7F31F	3/18/2016	386	345	5-May-16	South West	-	-
LMB	4215/4216	3DDF003BC7F509	4/29/2016	544	340	10-May-16	North West	658	305
LMB	4236/4236	3DD003BC7F4DD	4/14/2016	386	315	10-May-16	North West	431	275
STB	4124	3DD003BC7F320	3/25/2016	590	377	11-May-16	South East	476	377
LMB	4136/4137	3DD003BC7F305	3/25/2016	522	325	11-May-16	South West	567	321
STB	3164/3163	3DD003BC7F27C	9/18/2015	340	320	12-May-16	Scour Hole	272	316
STB	-	3DD003BDET607	-	-	-	12-May-16	Scour Hole	318	300
LMB	3398/3399	3D9239F885247	11/13/2015	703	350	12-May-16	Intake	635	356
LMB	2803	3DD003BC7F179	9/21/2015	408	315	12-May-16	Intake	363	305
LMB	-	3D6000B3AA22E	6/5/2014	431	325	12-May-16	Intake	1179	420
LMB	3518/3517	3DD003BC7F456	10/23/2015	499	310	12-May-16	Intake	499	315
LMB	2850/2849	3DD003BC7FA7	9/21/2015	499	320	12-May-16	Intake	499	321
LMB	3890	3DD003BC7F2F5	3/18/2016	476	315	12-May-16	Intake	499	310
LMB	-	3DD003BC7F270	4/20/2015	-	-	12-May-16	Intake	862	361
LMB	4233/4232	3D9239F885349	4/14/2016	1293	415	12-May-16	Intake	1315	405
LMB	2974/2975	3D9239F885178	1/28/2016	726	390	18-May-16	South East	544	366
LMB	3344	3DD003BC7F400	11/6/2015	544	320	18-May-16	South East	386	312
LMB	3326	3DD003BC7F41F	11/6/2015	567	330	18-May-16	South East	499	320
LMB	3890	3DD003BC7F2F5	3/18/2016	476	315	18-May-16	Intake	476	305
LMB	4136/4137	3DD003BC7F305	3/25/2016	522	325	18-May-16	Intake	499	312
LMB	-	3D6000B3AA22E	6/5/2014	431	325	18-May-16	Intake	1134	406

3.8 Mortalities

The number of total mortalities was 404 representing 15 percent of the 2,686 total captures. The number of mortalities occurring during electrofishing and processing was 195, which represents about 7 percent of total captures; 209 mortalities occurred during transport to Bethany Reservoir, representing 7 percent of total captures. Striped Bass accounted for 99 percent (402), while black bass accounted for the remaining mortalities (2). There were no catfish mortalities. A summary of mortalities from this study can be found in Table 7.

Table 7 - Summary of mortalities from the 2016 Study.

	Efish+Processing		Transport		Combined	
Species	**Total**	**% Total Caps[1]**	**Total**	**% Total Caps[1]**	**Total**	**% Total Caps[1]**
Striped Bass	193	9.37%	209	10.15%	402	19.52%
Black Bass	2	0.34%	0	0.00%	2	0.34%
Catfish sp.	0	0.00%	0	0.00%	0	0.00%
Totals [2]	***195***	***7.26%***	***209***	***7.78%***	***404***	***15.04%***

[1] This metric shows the % of mortalities for total captures per species

[2] This metric shows the % of mortalities for total captures of all species

The amount of time it took to transport captured predatory fish from CCF to Bethany Reservoir was dependent upon the sampling section that was being sampled. The transport truck positioned itself on the levee as close as possible to the processing barge to minimize travel time for the barge. Transport time ranged from 10 to 44 minutes and averaged 22 minutes.

DO levels (percent saturation) for the transport livewell at the time of departure from CCF, the transport livewell at the time of arrival at Bethany Reservoir, and for Bethany Reservoir are shown in Figure 12. DO in the transport livewell at the time of CCF departure ranged from 67 to 350 and averaged 186. DO in the transport livewell upon arrival at Bethany Reservoir ranged from 77 to 283 and averaged 180. DO in Bethany Reservoir at the time of fish release (shortly after arriving at Bethany Reservoir) ranged from 70 to 184 and averaged 92.

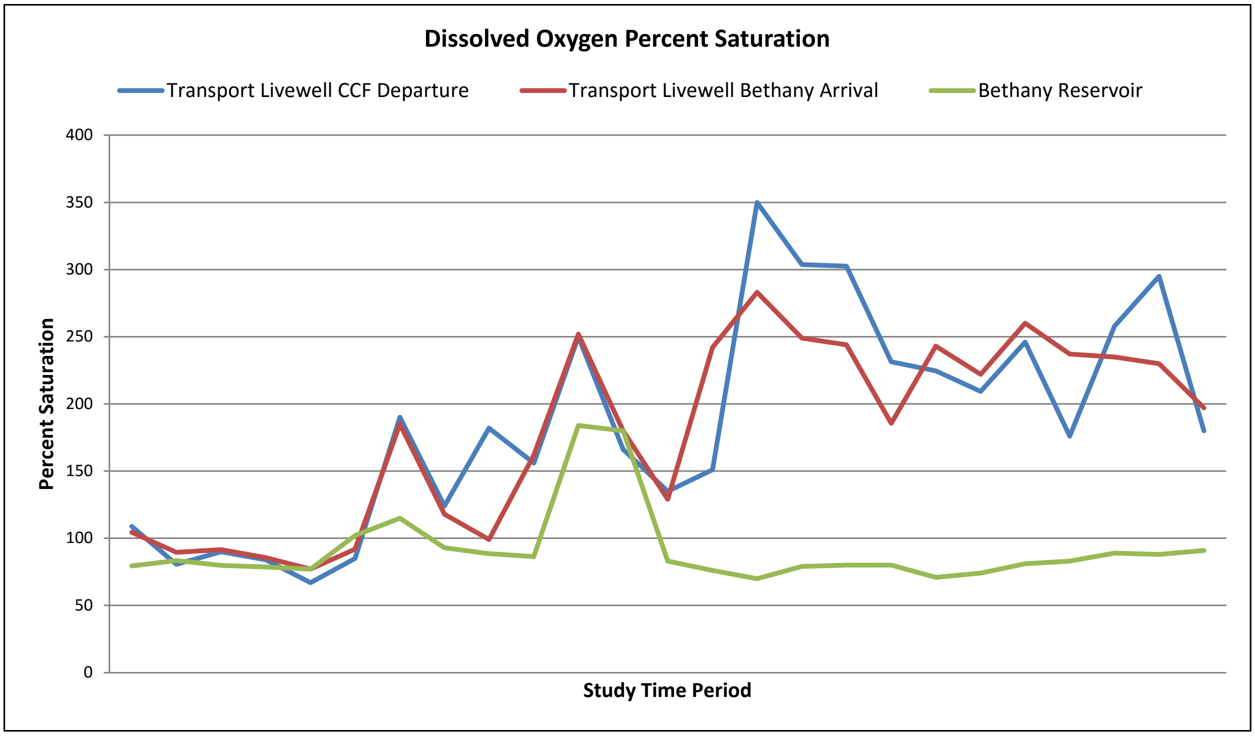

Figure 12 - DO (percent saturation) associated with the transportation of predatory fish during the 2016 Study.

Water temperature (°C) in CCF at time of departure, the transport livewell at the time of departure from CCF, the transport livewell at the time of arrival at Bethany Reservoir, and for Bethany Reservoir is shown in Figure 13. Water temperature at CCF at time of departure ranged from 18.8 to 22.6 and averaged 20.8. Water temperature in the transport livewell at the time of departure from CCF ranged from 17.1 to 22.9 and averaged 20.5. Water temperature in the transport livewell upon arrival at Bethany Reservoir ranged from 17.2 to 23.2 and averaged 20.8. Water temperature in Bethany Reservoir at the time of fish release (shortly after arriving at Bethany Reservoir) ranged from 17.2 to 21.3 and averaged 19.6.

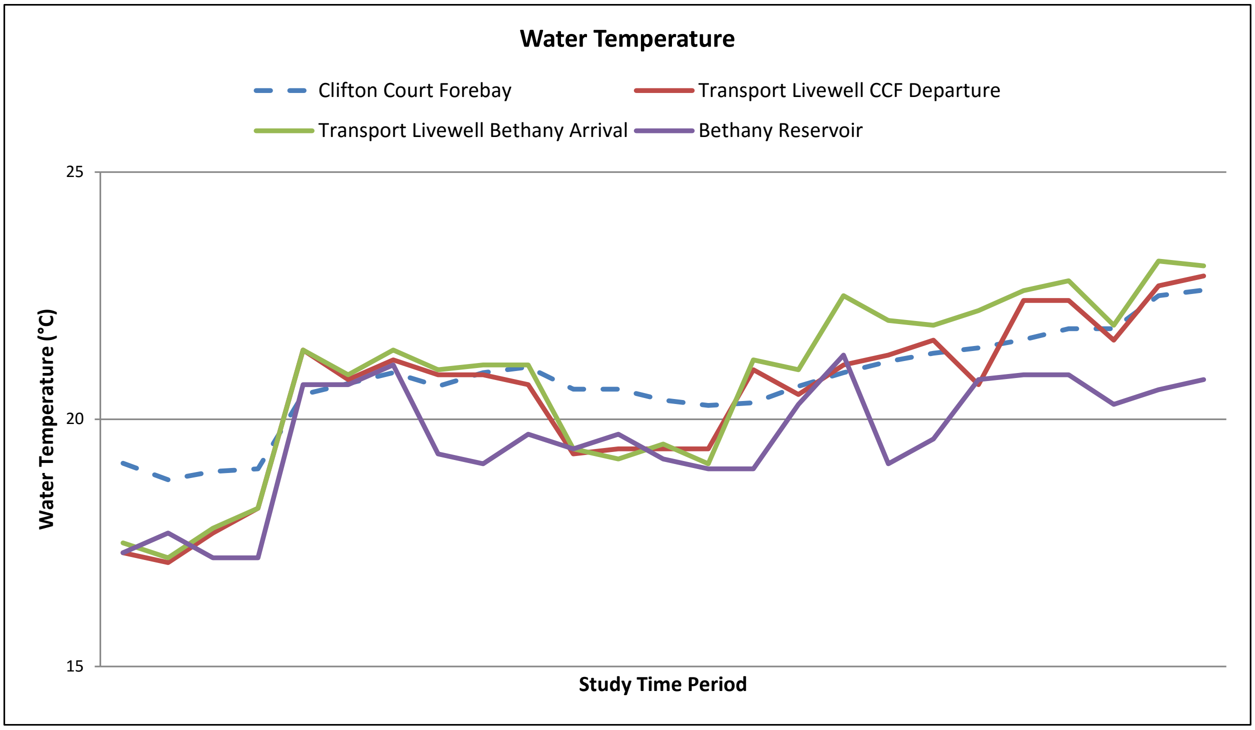

Figure 13 - Water temperature (°C) associated with the transportation of predatory fish during the 2016 Study.

3.9 Sensitive Species

There was the potential for fish protected under FESA and CESA to be shocked during this study. The maximum allowable take for the 2016 pilot study of species listed under FESA and CESA is shown in Table 8. There were no protected species shocked, sampled, or otherwise encountered during project activities.

Table 8 - Maximum allowable take of fish protected under FESA and CESA for the 2016 Study.

Fish Species	Federal Listing Status	State Listing Status	Take Limit	
			Federal	State
Delta Smelt	Threatened	Endangered	1	20
Longfin Smelt	No Listing	Threatened	N/A	20
Green Sturgeon (Southern DPS)	Threatened	No Listing	20	N/A
steelhead (Central Valley DPS)	Threatened	No Listing	50	N/A
Winter-run Chinook Salmon	Endangered	Endangered	50	20
Spring-run Chinook Salmon	Threatened	Threatened	50	20

3.10 Electrofishing Settings

The control boxes on each of the electrofishing boats were slightly different; however, the settings generally were similar. Both boats ran the Pulsed Alternating Current with the pulses mostly set at 30 pulses per second. The settings on the older model 7.5 GPP boat tended to have the Range Switch set to Low and the Percent of Range Knob set between 20 percent and 35 percent. For the newer model 7.5 GPP, the Duty Cycle knob was mainly set to 5 and the Percent of Range knob was set between 20 and 30. There was one occasion when the frequency was set to 60 Hz (15 minute duration on May 4, 2016) and there was one occasion when the frequency was set to 15 Hz (1 hour 28 minute duration on May 8, 2016).

4. Discussion

Predator Removal

Results from the 2016 Pilot Study have shown that electrofishing can work effectively for capturing and removing non-native predatory fish. If capture rates remain similar in 2017 and 2018, then up to 75 days of sampling each year could yield a total catch of over 18,000 non-native predatory fish annually. While immigration and emigration of predatory fish occurs regularly in CCF (Gingras et al., 1997), removals of large numbers of predatory fish could improve the survival of listed species. If a long term removal project is considered after this Study, focused electrofishing efforts and increased pressure could improve the efficacy of electrofishing to reduce PSL. Focused efforts, using the spatial analysis data that will be gathered over this Study, will allow DWR to improve catch rates. Additional electrofishing boats and increases in removal days would also facilitate a reduction in predator density in CCF.

Fish Size Distribution

The fish size distribution data also has confirmed that the size distribution of predatory fish restricts anglers from actively targeting 98.5 percent of the Striped Bass and 37.4 percent of the black bass in CCF. As Striped Bass are the dominant predatory fish in CCF, this would very much limit the efficacy of a fishing incentive program to reduce predation of listed fish species. Changes in recreational harvest catch and length limits must be addressed before any such program could be a viable option for predation reduction.

Spatial Analysis

Based on the data collected in 2016, spatial analysis of predatory fish can and will be a useful tool in improving catch rates, as well as in understanding the spatial distribution of different fish species. Data from the 2016 Study already have shown variations in species distributions and that certain areas harbor greater concentrations of non-native predatory fish than others. This suggests that future targeted electrofishing will likely improve CPUE. Measures are being taken for 2017 to improve data collection, repeatability, and comparability. These improvements include creating a Geographic Information System Collector Application to facilitate the easy collection of capture and track data and creating set transects that allows electrofishing to occur more evenly through open water areas.

Chinook Salmon Survival Estimates

Results of the WY 2016 evaluation appear to be consistent with the results of prior studies evaluating losses of salmonids in CCF. Chinook Salmon pre-screen loss was estimated at 91 percent based on data collected during the SWP Chinook Salmon Survival Study, which is within the range of loss rates previously documented in CCF (63 to 99 percent; Gingras, 1997; Clark, et al. 2009; Wunderlich 2015). Predation by predators, including piscivorous fish, appears to be the primary source of loss and was demonstrated by multiple instances of predators captured with tagged salmon inside of them (V. Wunderlich, personal communication).

The efficacy of predator relocation efforts in 2016 was inconclusive based on the preliminary results of the SWP Chinook Salmon Survival Study. No statistically significant differences in loss were detected when comparing the months during the relocation study to the months prior. The absence of detectable effects of the 2016 predator relocation effort may be due to a variety of reasons. First and foremost, the predator relocation efforts in 2016 were limited in nature, occurring only for 11 days near the end of the monitoring season. Additionally, tagged salmon released during this period may have encountered unfavorable conditions, including high water temperatures and low rates of pumping, which may have contributed to mortality.

Additional discussion on Chinook Salmon survival in CCF during 2016 can be found in Attachment 1.

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Attachment 1

State of California California Natural Resources Agency

Memorandum

Date: December 12, 2016

To: Matthew Reeve, Program Manager II
Bay Delta Office
Department of Water Resources

From: Javier Miranda, Senior Environmental Scientist (Specialist)
Bay Delta Office
Department of Water Resources

Subject: Preliminary SWP Chinook Salmon Survival Estimates for WY 2016

Introduction

In 2009 the National Marine Fisheries Service (NMFS) issued a Biological and Conference Opinion (BiOp) on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) requiring the Department of Water Resources (DWR) to implement Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) to reduce pre-screen losses of Endangered Species Act (ESA) protected salmon and steelhead within Clifton Court Forebay (Forebay) to no more than 40 percent (NMFS 2009). Previous studies have shown pre-screen losses (PSL) of federal and State ESA listed salmonids ranging from 63% to 99%.

Since the issuance of this requirement, DWR has undertaken or has planned a number of proposed actions to comply with this pre-screen loss reduction target. Most recently, in WY 2016, DWR implemented a pilot study (Clifton Court Predator Reduction Study) from April 20, 2016 to May 18, 2016 to relocate predatory fishes collected with electrofishing gear in the Forebay to nearby Bethany Reservoir. In tandem with these actions and to evaluate their effectiveness, DWR initiated a mark-recapture study in WY 2013 to evaluate losses of marked salmonids from the SWP intake at the Forebay radial gates to the termination of the fish salvage process at the John E. Skinner Delta Fish Protective Facility (SDFPF). This memorandum describes the preliminary results from the salmonid mark-recapture study for WY2016 to aid in evaluating and refining the continued implementation of the Clifton Court Forebay Predator Reduction - Electrofishing Study (PRES). Final results from this mark-recapture study will be detailed in a future report documenting WY 2016 survival estimates for the SWP including the Forebay and SDFPF.

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Methods

Chinook Salmon Stock and Husbandry

During WY 2016, a mark-recapture study was conducted from January through June utilizing Passive Integrated Transponder (PIT) tagging technology. Juvenile late-fall run Chinook Salmon and fall run Chinook Salmon for this study were obtained from the Coleman National Fish Hatchery and Mokelumne River Fish Hatchery, respectively. Late-fall run Chinook Salmon were utilized in releases from January through early-April, while fall-run Chinook Salmon were released from early-April through May. The selection of these runs and their respective size classes was intended to be representative of the general seasonal size distribution of Chinook Salmon salvaged at the SDFPF. Plans to utilize steelhead trout for the WY 2016 study year were cancelled due to study fish being unavailable from area fish hatcheries in large part due to ongoing drought conditions.

Juvenile salmon provided by the hatcheries were transported in two separate events using a 1,700-L insulated fish hauling tank and transferred to the Fish Science Building (FSB) at the SDFPF. Upon arrival at the FSB facility, fish were transferred to 1,362-L and 3,558-L circular, aerated fish holding tanks. These tanks were supplied with either "raw" water from the California Aqueduct (flow through water with minimally treated with UV sterilization and mechanical filtration) or "recirculated" water (filtered, recirculated, and temperature controlled water). Use of the recirculated water system was initiated in March 2016 to prevent fish health problems as a result of temperature fluctuations in the California Aqueduct water source. The salmon were fed a sinking, pelleted feed daily except when fasted for 24 hours before tagging and the 48-72 hour period between tagging and release.

PIT Tagging

Juvenile late-fall run Chinook Salmon selected for PIT tag implantation ranged in fork length from 100 to 241 mm, with a mean of 174 ± 23 mm (mean ± SD). Fall run Chinook Salmon selected for PIT tag implantation ranged in fork length from 45 to 140 mm, with a mean of 102 ± 14 mm (mean ± SD). Salmon were tagged following the general guidelines of the PIT tagging procedure manual prepared by the Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee (1999). Each juvenile salmon was netted from the holding tank and placed into an 18.9-L anesthesia bath that contained 35 mg/L of Aqui-S 20E. The salmon was left in the bath for 1-3 minutes until anesthetized. Each salmon was measured for length and weight, evaluated for abnormalities or external signs of disease/injury, and the presence of an adipose fin. If the adipose fin was still present, the tagger clipped the fin using dissection scissors to ensure that the salmon was appropriately identified as a study fish if subsequently captured at the SDFPF. A PIT tag implant gun (Biomark, model MK 25) utilizing pre-loaded needles was used to inject the PIT tag (Biomark HPT 12) into the abdominal cavity. The time to PIT tag each fish was less than one minute. Tagged fish were placed into an 18.9-L aerated container and held for observation to ensure recovery. Once recovered, fish were transferred to a 1,362-L tank supplied with raw water and aeration and held for a 48-72 hour recovery period prior to release.

Tagged Fish Releases

To simulate the exposure to high water velocity and turbulence experienced by run of the river fish entrained into the Forebay, small groups of tagged salmon were released immediately upstream of the Forebay radial gates utilizing specially modified 18.9-L buckets (Clark et al 2009). Prior to transportation of tagged salmon to the Forebay radial gate release site, all salmon were checked individually for presence of an operational PIT tag and their tag identification number recorded. Fish with non-operational PIT tags or shed tags were not released, and the total release group size reduced accordingly. Each group of 20 tagged salmon was transported in their 18.9-L release bucket(s), equipped with aeration, to the release site. No more than 5 late-fall Chinook Salmon, or 10 fall run Chinook Salmon were placed in a single bucket to prevent water quality degradation or stress due to overcrowding.

The timing of the releases varied with the daily routine changes in Forebay radial gate operations. Typically, releases were scheduled for the first hour of scheduled water inflows (gate openings) into the Forebay for each day. Notably in WY 2016, for the majority (63 of 66) of releases, releases occurred from 0700-0900 as a result of operational restrictions limiting the openings during night time hours to reduce entrainment of listed fish species. During each fish release, fish were released by lowering the release bucket secured by two lines, one attached to the bucket handle and one attached to the bucket base, to just above the water surface and pulling on the line attached to the bucket base to invert the bucket. PIT tagged salmon releases began on January 10, 2016, and were generally conducted 4 days per week through May 31, 2016 in release groups of 20 fish. Releases of tagged fish ceased at the end of May when daily mean temperatures in the Forebay approached tolerance limits for salmonids. In total, 1,312 PIT tagged salmon in 66 releases were released upstream of the Clifton Court Forebay radial gates with 11, 13, 15, 14, and 13 releases in January, February, March, April, and May, respectively.

Table 1- Chinook Salmon releases conducted during WY 2016 at the Clifton Court Forebay.

	January	**February**	**March**	**April**	**May**
Late-fall Chinook Salmon	11	13	15	3	
Fall Chinook Salmon				11	13

PIT Tag Detection System

To detect salvaged, PIT tagged salmon released as part of this study, a PIT tag detection system was installed at the two SWP salvage release sites on Sherman Island in the Central Delta. The detection system consisted of three custom made, circular antennae with aluminum shields at the Horseshoe Bend release site (Figure 1) and two custom made, circular antennae at the Curtis Landing release site. Any study fish that were salvaged were trucked to the release sites and released through these pipes outfitted with PIT antennae according to the SDFPF standard operating procedures. All detections of PIT tagged salmon were made post salvage. All PIT tagged salmon detected during the salvage release process were assumed to have been successfully salvaged and alive[1]. Any PIT tagged salmon encountered during routine counts at the SDFPF were immediately released to a holding tank for subsequent detection on the detection system installed at the salvage release sites. This ensured that all fish were subjected to the entire salvage process through release.

Attached to each antenna was a transceiver/datalogger capable of storing tag detections. The Curtis Landing site was equipped with two types of transceivers/dataloggers; a Destron Fearing FS2001F-ISO and a Biomark HPR+. The antennae at the Horseshoe Bend release site were connected to a series of three Biomark IS1001 transceivers/dataloggers equipped with a battery backup system and remote telemetry. The equipment at the Horseshoe Bend was installed by Biomark and monitored remotely as part of a PIT tagging feasibility study being conducted by the NMFS-Southwest Fisheries Science Center and California Department of Fish and Wildlife in collaboration with DWR as part of a Proposition 1 grant.

Ten tag detection efficiency tests were conducted throughout the study with five at each of the two SDFPF salvage release sites. The efficiency tests utilized groups of either 10 or 40 PIT tagged salmon which were placed directly into the SWP fish hauling truck tank. These fish were subsequently taken to the release site during a routine fish haul and were released through the release pipe outfitted with the PIT tag detection system antennae. Results of the tag detection efficiency test indicated that the efficiency of the two systems was a combined 90.5%.

PIT tag detections and subsequent data analyses were limited to detections occurring on or before June 15, 2016. Therefore, any released (tagged?) fish coming through after that date were not included as part of this analysis. Should any of these fish come through after that date, they would be included as part of a future report documenting final WY 2016 survival estimates for the SWP including the Forebay and SDFPF.

[1] Striped Bass and other predatory fishes of the size required to consume the PIT tagged salmon are occasionally encountered within the SDFPF fish hauling truck. However, predatory fishes encountered during counts at the SDFPF during experimental salmon releases in 2015 and 2016 were examined for PIT tags and no PIT tags were encountered during these events indicating that predation rates on study fish are likely low.

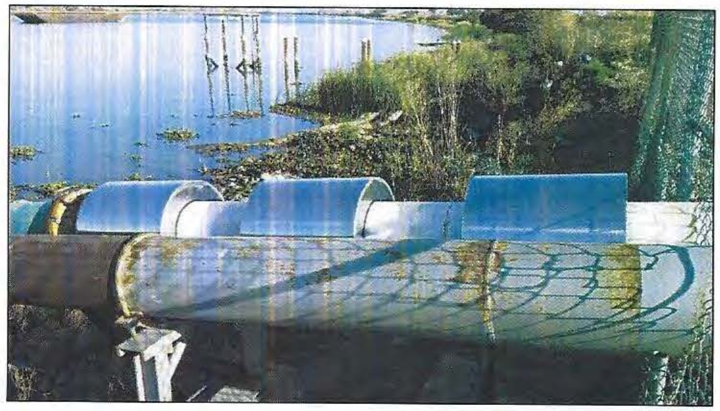

Figure 1- PIT tag detection array installed at the Horseshoe Bend Release Site. Shown are the three Biomark IS1001 transceivers/dataloggers (left) and three custom antennas with their aluminum shields mounted on the salvage release pipe (right).

SWP Water Pumping and Forebay Radial Gate Operations

Forebay hydrodynamics can vary substantially within and among days depending on factors such as water export rates, Forebay radial gate operations, tidal conditions, weather conditions, and water storage within the Forebay (Clark et al 2009). These factors can affect pre-screen loss in the Forebay and salvage at the SDFPF.

Water inflows through the Forebay radial gates were variable during WY 2016, though with marked decreased inflows during April and May. Mean daily inflow ranged from 393 to 4,540 cfs with a season mean of 1,856 cfs (Table 2, Figure 2).

Water exports through Banks Pumping Plant were similar to CCF inflows during WY 2016. Mean daily exports ranged from 0 to 4,528 cfs with a season mean of 1,833 cfs (Table 3).

During the WY 2016 study, atypical Forebay radial gate operations may have also affected pre-screen loss in the Forebay. As indicated earlier, the majority of releases occurred from 0700-0900 as a result of operational restrictions limiting the opening of the gates during nighttime hours to reduce entrainment of listed fish species. While these operations may or may not have affected entrainment into the Forebay, it is notable to point out that historically, under similar seasonal and regulatory conditions, a greater proportion of water would have been exported through the Forebay radial gates during nighttime hours (midnight to 0700). Similarly, some past studies (Clark et al 2009; Wunderlich 2015) conducted the majority of their releases during nighttime hours.

Table 2- Summary statistics for Forebay radial gate water exports from January 1 through June 15, 2016. Data from CDEC.

	January	February	March	April	May	June	Season Total/Mean
Daily CFS min	1,297	1,397	1,164	490	393	1,189	393
Daily CFS max	4,194	2,591	4,540	1,600	1,790	3,992	4,540
Mean	2,224	2,152	2,643	764	957	2,941	1,856

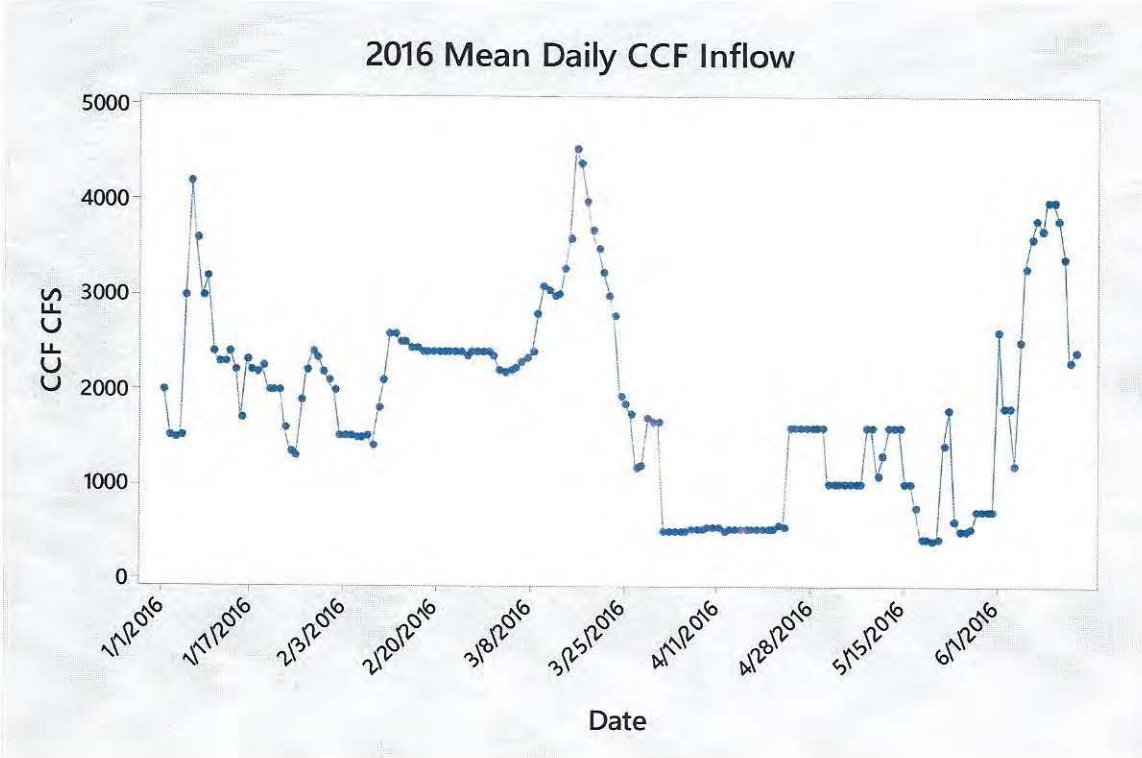

Figure 2- Mean daily inflow (cfs) through the Clifton Court Forebay radial gates from January 1 through June 15, 2016. Data from CDEC.

Table 3- Mean daily exports (cfs) through Banks Pumping Plant from January 1 through June 15, 2016. Data from CDEC.

	January	February	March	April	May	June	Season Total/Mean
Daily CFS min	1,461	1,097	1,276	357	0	729	0
Daily CFS max	4,179	2,782	4,528	1,551	1,707	4,042	4,528
Mean	2,220	2,139	2,633	731	920	2,879	1,833

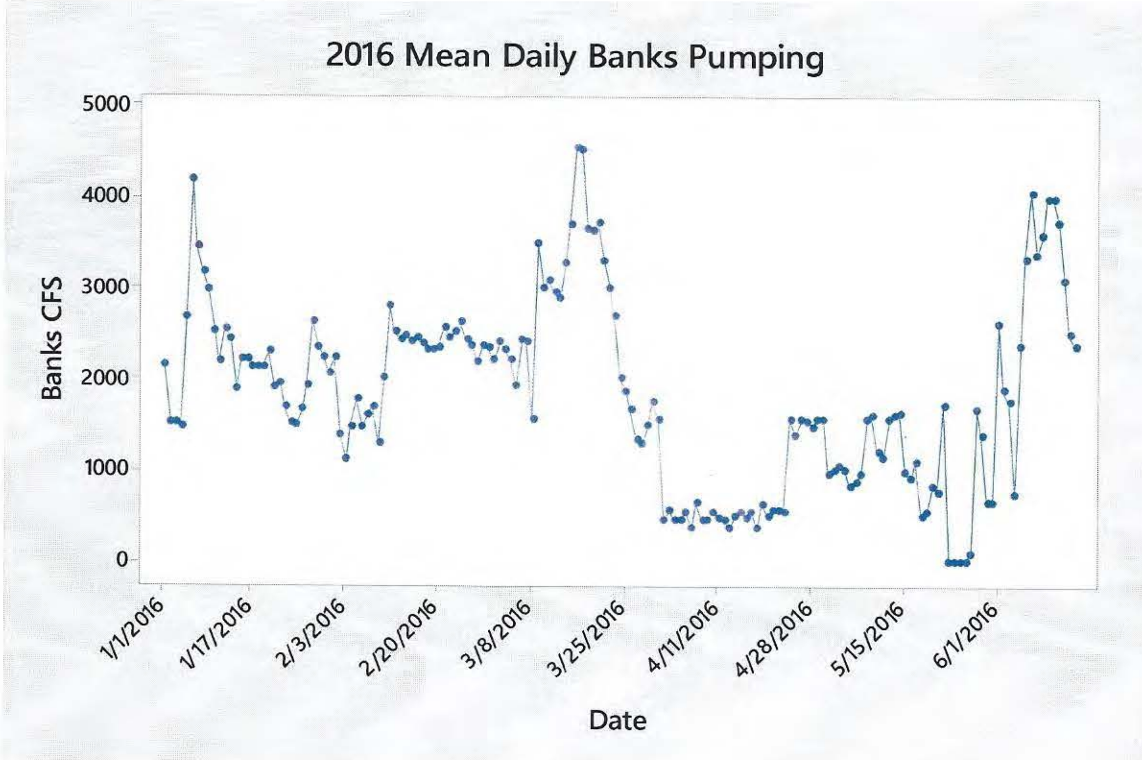

Figure 3- Mean daily water exports (cfs) through Banks Pumping Plant from January 1 through June 15, 2016. Data from CDEC.

Results

Preliminary estimates of Total SWP Loss and Pre-screen Loss (PSL) were calculated using the equations from Clark et al (2009) and Wunderlich (2015) to maintain comparability to prior evaluations. A placeholder value of 78% for SDFPF salvage efficiency was utilized for these analyses (Wunderlich 2015, DWR unpublished data).

Preliminary Total SWP Loss Estimates

Total SWP loss (TL_{SWP}) is defined as the proportion of fish released at the Forebay radial gates that are lost prior to successful salvage at the SDFPF. TL_{SWP} for Chinook Salmon were based upon detections (recaptures) of PIT tagged salmon released at the Forebay radial gates and detected at the SDFPF salvage release sites. TL_{SWP} was calculated for each of the 66 Forebay radial gate release groups as:

$$TL_{SWP} = \left(1 - \left(\frac{Rec_{rg}}{Rel_{rg} \times A}\right)\right) \times 100$$

Rec_{rg} = # PIT tagged Chinook Salmon recovered from Forebay radial gate releases

Rel_{rg} = # PIT tagged Chinook Salmon released at the Forebay radial gates

A = Mean PIT antennae detection efficiency (90.5%)

TL_{SWP} for WY 2016 was estimated to be 93% ± 3% (Mean ± 95% C.I.). TL_{SWP} for each of the 66 release groups ranged from 39% to 100%. Summary statistics for TL_{swp} are shown in Table 4. The percentage of release groups with zero recoveries conducted during WY 2016 ranged from 18% to 77% with a mean of 50% of the releases resulting in 100% loss of the release group (zero recoveries).

Table 4- Summary statistics for Total SWP Loss (TL_{swp}; %) estimates.

	January	February	March	April	May	Annual Total/Mean
No. of Release Groups	11	13	15	14	13	66
TL_{SWP}	80%	90%	96%	97%	98%	93%
S.D.	15%	19%	6%	4%	5%	12%
min	56%	39%	83%	89%	83%	39%
max	100%	100%	100%	100%	100%	100%
% of releases with zero recoveries	18%	54%	53%	50%	77%	50%

Preliminary Pre-screen Loss Estimates

Pre-Screen Loss (PSL) is defined as the proportion of fish released at the Forebay radial gates that were lost within the Forebay prior to the SDFPF trashrack. Due to limitations on the placement of PIT tag detection arrays within the project area, PSL could not be directly determined, but was instead calculated by adjusting the Total SWP loss rate (TL_{swp}) with the SDFPF salvage efficiency rate (E_S).

SDFPF salvage efficiency (E_S) is defined as the proportion of PIT tagged fish released at the head of the primary louver bays that were successfully salvaged and released. E_S is generally calculated as:

$$E_S = \left(1 - \left(\frac{Rec_{tr}}{Rel_{tr} \times A}\right)\right) \times 100$$

Rec_{tr} = # PIT tagged Chinook Salmon recovered from Primary Louver Bay releases

Rel_{rg} = # PIT tagged Chinook Salmon released at the Forebay radial gates

A = Mean PIT antennae detection efficiency

In WY 2016 an evaluation E_S was conducted in tandem with the Total SWP Loss evaluation, however the results of this investigation are still undergoing analysis. In the interim, loss rates for Chinook Salmon developed by Wunderlich (2015; 74%) in WY 2013 were utilized in conjunction with unpublished data collected by DWR in WY 2011 (82%) to establish a place holder value of E_S of 78%. This value is consistent with historical salvage efficiency values established for Chinook Salmon at the SWP (Gingras 1997, Skinner 1974) which range from 65-90%.

PSL was calculated for each of the 66 Forebay radial gate release groups as:

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$$PSL = 1 - \left(\left(\frac{Rec_{rg}}{Rel_{rg} \times E_S \times A} \right) \right) \times 100$$

Rec_{rg} = # PIT tagged Chinook Salmon recovered from Forebay radial gate releases

Rel_{rg} = # PIT tagged Chinook Salmon released at the Forebay radial gates

E_S = SDFPF Salvage Efficiency (78%)

A = Mean PIT antennae detection efficiency

Total PSL for WY 2016 was estimated to be 91% ± 4% (Mean ± C.I.). PSL for each of the 66 release groups ranged from 22% to 100%. Summary statistics for PSL are shown in

Table 5. This PSL estimate assumes that all fish released at the Forebay radial gates were entrained into the Forebay and therefore, because this estimate of PSL does not account for emigration into Old River, PSL may be overestimated.

Monthly PSL estimates were determined by taking the calculated PSL for each release group and pooling them by release month. An ANOVA test was used to determine if there was a significant difference in monthly PSL estimates. There was a significant difference (F=5.05, df=65, p=0.001). To determine which months differed, a multiple comparison procedure (Tukey's test) was used. PSL of salmon released at the Forebay radial gates in January was significantly different that for those released in March through May (Figure 4).

Table 5- Summary statistics for Pre-Screen Loss (PSL; %) estimates.

	January	February	March	April	May	Annual Total/Mean
No. of Release Groups	11	13	15	14	13	66
PSL	75%	87%	94%	96%	97%	91%
S.D.	20%	24%	8%	5%	6%	15%
min	43%	22%	79%	86%	79%	22%
max	100%	100%	100%	100%	100%	100%

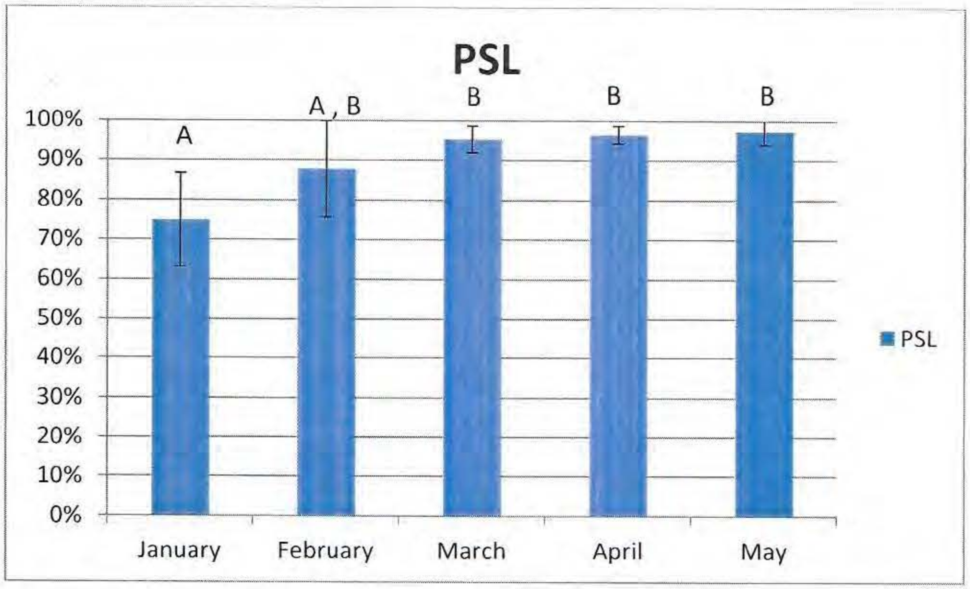

Figure 4- Pre-Screen Loss (PSL) by month in WY 2016. Error bars indicate 95% confidence intervals. Statistically significant groups are indicated by letters above each bar.

Preliminary Time to Salvage for PIT Tagged Chinook Salmon

Time to Salvage (TTS) is defined as the duration of time from the time of release at the Forebay radial gates to the time of detection at the SDFPF. Since all detections at the SDFPF occur post-salvage during the release phase, fish detected at the release sites may have entered the SDFPF from 1-24 hrs prior to the time of detection (note that the SDFPF generally trucks fish every 8, 12, or 24 hours based upon the presence of listed species in the salvage and/or Banks Pumping Plant operations). TTS is a valuable metric for evaluating the effect of Banks Pumping Plant water export on pre-screen losses. A longer TTS likely results in increased exposure of salmonids to predation within the Forebay, and may contribute to increased pre-screen losses.

Mean TTS for WY 2016 was estimated to be 1.9 ± 0.4 days (Mean ± S.D.) TTS ranged from 0.3 to 6.5 days. Summary statistics for TTS are shown in Table 6. Monthly TTS estimates were determined by taking the mean TTS for each release group and pooling them by release month. An ANOVA test was used to determine if there was a significant difference in monthly TTS estimates. There was no significant difference ($F=0.45$, $df=31$, $p=0.774$).

Table 6- Summary Statistics for Time to Salvage (TTS) in days for PIT tagged salmon released at the Forebay radial gates.

	January	February	March	April	May	Annual Total/Mean
TTS (days)	2.5	1.8	1.8	1.9	1.3	1.9

SD	1.8	0.8	1.0	2.1	0.2	0.4
min	0.6	1.1	0.5	0.3	1.0	0.3
max	5.9	3.0	3.3	6.5	1.5	6.5
median	1.8	1.6	1.4	1.0	1.4	1.4

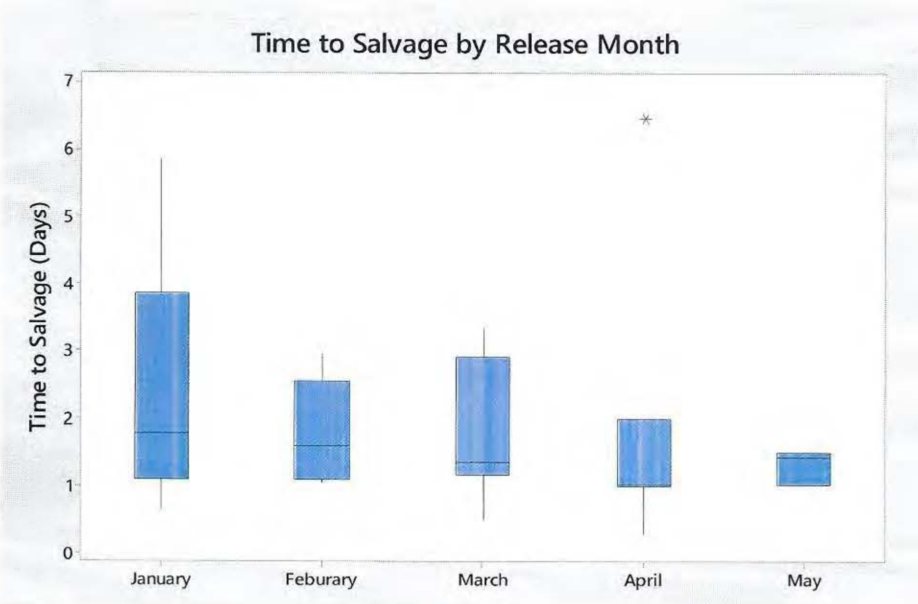

Figure 5- Box plot of Time to Salvage (TTS) by release month. Outliers are denoted by the "*" symbol.

Discussion

Results of the WY 2016 evaluation appear to be consistent with the results of prior studies evaluating losses of salmonids in the Forebay. Chinook Salmon Pre-screen Loss is estimated at 91% which is within the range of loss rates previously documented in the Forebay (63-99%; Gingras, 1997; Clark et al 2009; Wunderlich 2015). Predation by predators, including piscivorous fish, appears to be the primary source of loss and was demonstrated by multiple instances of predators captured with tagged salmon inside of them (V. Wunderlich, Personal Communication). Both this study and Wunderlich (2015) assumed that emigration through the Forebay radial gates was zero, and that all tagged salmon were entrained into the Forebay. Consequently, these estimates of PSL may be biased high if some fish were not entrained or emigrated from the study area. In their 2009 report, Clark et al adjusted their loss estimate to consider possible emigration from the Forebay based upon detections of acoustic tagged steelhead emigrating from the Forebay and a single recovery of a PIT tagged fish at the Tracy Fish Collection Facility. While the likelihood of emigration from the study area is slim, efforts should be taken to document emigration rates during subsequent evaluations, possibly using newly released predation detection tags to differentiate live salmon from predated fish.

The efficacy of predator relocation efforts in WY 2016 was inconclusive based on the preliminary results of this loss monitoring study. No statistically significant differences in loss were detected when comparing the months during the relocation study to the months prior. In addition, there were no statistically significant differences between months for Time to Salvage. One would expect that Time to Salvage would be higher during months with lower total exports (April and May), however this was not observed.

The absence of detectable effects of the WY 2016 predator relocation effort may be due to a variety of reasons. First and foremost, predator relocation efforts in WY 2016 were limited in nature, occurring for only a 3-4 week period at the end of the monitoring season. Tagged salmon released during this period may have encountered unfavorable environmental conditions, including high water temperatures, which may have contributed to mortality. Water temperatures measured in the CA Aqueduct at the Fish Science Building, peaked at 20.6 °C and 22.0°C during April and May respectively, and surface temperatures in the Forebay measured during the predator relocation effort peaked at 21.4°C and 22.4°C during April and May respectively. Furthermore, water temperature in the CA Aqueduct exceeded 24°C in the days following the final release of fish at the Forebay radial gates on 5/31/16. In a laboratory study, Marine and Cech (2004) demonstrated that while Chinook Salmon can grow and survive in temperatures up to 24°C, juveniles reared at 21-24°C experienced significantly decreased, growth rates, impaired smoltification, and higher predation vulnerability compared with fish reared at 13-16°C. Based upon these findings, it is possible that tagged salmon released during April and in particular during May, may have experienced increased mortality rates as a result of temperature stress. This additional mortality could have masked any beneficial effects from a reduction in the predator population, or could have biased the survival of some of the final release groups as they would have experienced lethal temperatures during part of their migration across the Forebay.

In addition to temperature effects, water export operations may have had an effect on salmon survival during April and May that masked reductions in predation losses due to the predator relocation effort. Forebay inflows and Banks pumping were on average 2.5-3 times higher during January through March than they were in April and May. While this did not result in a statistically significant difference in Time to Salvage, similar studies at the nearby Tracy Fish Collection Facility (C. Karp, Personal Communication) have indicated that lower pumping rates may result in delays in salvage as tagged fish appear to be delayed as they approach the facility trashrack. Such delays, even minor, may result in increased predation losses as fish are exposed to predators at this known predator hot spot.

This study utilized two runs and respective size classes of juvenile Chinook Salmon for tagging and release. As a result, fish (fall run) released during the predator relocation effort in late-April through May were generally smaller than fish (late-fall run) released during most of the period prior to the predator relocation period. In their study, Clark et al (2009) found that losses of juvenile steelhead trout were within the range of reported loss rates for smaller Chinook Salmon. Therefore the results of the steelhead study and of prior studies utilizing Chinook Salmon suggest that we would not expect a significant difference in survival between the fall and late-fall run release groups used for our study.

During this study, the Forebay radial gates were operated differently than they have been historically. Under historical operations, the Forebay radial gates are normally opened at the first available tidal window based on south delta water elevation restrictions ("Priority") after midnight each night and water is drawn into the Forebay until the daily allotment is reached or until the tidal window closes. Consequently, since the water allotment resets each day at midnight, the majority of water drawn in through the gates comes during nighttime hours on most days. During this study year, water operations managers placed a restriction on opening of the gates during nighttime hours. This was in an effort to reduce entrainment of run of the river listed fish including salmonids and smelt. While the efficacy of this effort is unknown as there was no monitoring regimen in place to evaluate the effects on entrainment, it is possible that there may have been effects on PSL. Namely, because the majority of tagged salmonid releases occurred during daylight hours, predation by diurnal feeding activity or more visual predators such as avian predators, may have resulted in higher than expected loss rates. Nevertheless, loss during this study was in the same range as loss during prior studies during historical operations.

While unrelated to the efficacy of the predator relocation effort, we did find a significant difference in survival between tagged salmon released in January and those released in March through April. The cause of this significant difference remains unknown and will be evaluated further. It does not appear directly related to total exports, as exports were comparable during January and March.

Lastly, half (50%) of all tagged salmon releases conducted in WY 2016 resulted in zero recoveries of live fish at the SDFPF salvage release sites. This finding could not be attributed to problems with the detection array, as concurrent evaluations of salvage efficiency utilizing the same array resulted in "normal" detections, and because the array was tested throughout the study period. Therefore, the large number of non-detections must be attributed to pre-screen losses and emphasizes the magnitude of mortality within the Forebay. Consequently, because this large number of non-detections may limit our ability to resolve changes in pre-screen losses as a result of predator relocation, efforts should be taken to reevaluate the number of releases and release group sizes for subsequent evaluations of pre-screen losses.

Recommendations for Future Work and/or Analyses

Several analyses and study components are recommended for further investigation and for refinement of loss estimation in the Forebay:

1) The sample sizes employed during this study were developed based upon limited available data for Chinook Salmon and with the specific aim of evaluating predation reduction as a result of a different activity (a fishing pier). A revised power and sample size analysis should be conducted prior to initiation of experimental releases in WY 2017 to determine whether a different release scheme would be more effective in detecting changes in pre-screen losses as a result of planned full-scale implementation of the predator relocation (electrofishing) study.

2) Forebay radial gate operations in WY 2016 were constrained to primarily daytime openings beginning in late January. While the data do not appear to directly support the theory that this may have contributed to increased pre-screen loss, further investigation comparing the survival of fish entrained during the day to those entrained at night is warranted. Similarly, an evaluation of entrainment into the Forebay would be valuable in determining whether or not this operational change is actually beneficial for reducing entrainment into the Forebay.

3) The employed PIT tag methodology, while valuable in that it enables the utilization of large sample sizes, limits the amount of information available about the direct source of fish mortality. New and evolving telemetry techniques such as predation indication tags could be used to assess the location of predatory hot spots within the forebay. Such information could be used to refine predator management efforts including electrofishing.

4) These analyses assumed that all tagged salmon released at the Forebay radial gates were entrained into the Forebay and participated in the experiment. However, past studies (Clark et al 2009) have indicated that some fish may be able to emigrate from the study area under certain operational conditions. To asses this factor, releases of acoustic tagged salmonids in tandem with PIT tagged fish could be used to assess the degree of experimental participation.

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Appendices

Appendix 1- Mark-Recapture data, Pre-screen Loss, and TL_{SWP} for each of the 66 releases of Chinook Salmon at the Clifton Court Forebay radial gates in WY 2016.

Release Date	Recaptured	Released	TLswp	PSL
1/10/2016	2	20	89%	86%
1/12/2016	0	20	100%	100%
1/14/2016	1	20	94%	97%
1/15/2016	0	20	100%	100%
1/19/2016	6	19	65%	55%
1/21/2016	6	20	67%	58%
1/22/2016	4	20	78%	72%
1/25/2016	5	19	71%	63%
1/26/2016	8	20	56%	43%
1/28/2016	2	20	89%	86%
1/29/2016	5	20	72%	65%
2/1/2016	11	20	39%	22%
2/2/2016	7	20	61%	50%
2/5/2016	0	20	100%	100%
2/8/2016	1	20	94%	93%
2/9/2016	0	20	100%	100%
2/11/2016	1	20	94%	93%
2/12/2016	3	20	83%	79%
2/15/2016	0	20	100%	100%
2/18/2016		Cancelled		
2/19/2016	0	19	100%	100%
2/22/2016	1	20	94%	93%
2/23/2016	0	20	100%	100%
2/26/2016	0	20	100%	100%
2/29/2016	0	20	100%	100%
3/1/2016	0	20	100%	100%
3/3/2016	0	20	100%	100%
3/4/2016	0	20	100%	100%
3/7/2016	0	20	100%	100%
3/8/2016	0	20	100%	100%
3/10/2016	1	19	94%	93%
3/11/2016	1	20	94%	93%
3/14/2016	2	20	89%	86%
3/15/2016	0	19	100%	100%
3/17/2016	3	20	83%	79%

3/18/2016	0	20	100%	100%
3/21/2016	0	20	100%	100%
3/22/2016	1	20	94%	93%
3/24/2016		Cancelled		
3/25/2016		Cancelled		
3/28/2016	3	20	83%	79%
3/29/2016	1	20	94%	93%
3/31/2016		Cancelled		
4/1/2016		Cancelled		
4/4/2016		Cancelled		
4/5/2016	1	20	94%	93%
4/7/2016	0	20	100%	100%
4/8/2016	0	19	100%	100%
4/11/2016	0	20	100%	100%
4/14/2016	1	20	94%	93%
4/15/2016	1	20	94%	93%
4/18/2016	0	20	100%	100%
4/19/2016	1	20	94%	93%
4/21/2016	0	20	100%	100%
4/22/2016	0	20	100%	100%
4/25/2016	2	20	89%	86%
4/26/2016	0	20	100%	100%
4/28/2016	1	20	94%	93%
4/29/2016	1	19	94%	93%
5/2/2016	0	20	100%	100%
5/3/2016	0	20	100%	100%
5/5/2016	0	20	100%	100%
5/6/2016	0	20	100%	100%
5/9/2016	0	20	100%	100%
5/10/2016	0	20	100%	100%
5/12/2016	0	19	100%	100%
5/13/2016	3	20	83%	79%
5/16/2016	0	20	100%	100%
5/17/2016	1	20	94%	93%
5/19/2016	1	20	94%	93%
5/20/2016	0	20	100%	100%
5/31/2016	0	20	100%	100%

State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predator Reduction Electrofishing Study Annual Report 2017

December 2017

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Executive Summary

The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (PRES) was implemented in response to the National Marine Fisheries Service (NMFS) letter dated April 9, 2015, requiring that the California Department of Water Resources (DWR) immediately implement interim measure (a) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative (RPA) Action IV.4.2(2) of the 2009 Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and State Water Project (NMFS BiOp). The PRES length is three years, beginning with a pilot year effort in 2016, a 2017 effort to refine methods and determine the main factors affecting predator catch, particularly spatial patterns, and a 2018 effort focused on maximizing predator removal based on knowledge gained during the 2016 and 2017 campaigns. The PRES involves electroshocking and removing predators from CCF and transporting them to Bethany Reservoir with the goal of decreasing pre-screen loss of protected fish species with an emphasis on Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*). Additionally, concurrent with the PRES, releases of Passive Integrated Transponder (PIT) and acoustically tagged juvenile Chinook Salmon are occurring in an effort to determine rates of pre-screen loss in the Skinner Evaluation and Improvement Study (SEIS).

During the 2017 field effort we focused on refining methods based on lessons learned and recommendations from the 2016 effort, determining spatial and temporal patterns in predator catch rates using a standardized electrofishing sampling regime, and assessing environmental variables that may affect catch rates. In addition, we assessed factors contributing to mortality of predators transported to Bethany Reservoir and conducted preliminary analysis to evaluate evidence of black bass depletion in shoreline habitats; it is important to emphasize that predator depletion was not a PRES objective in 2017, but was informative for the 2018 season.

Electrofishing occurred at CCF on 39 days between January 23 and June 15, 2017. Due to damage and subsequent construction to repair the CCF intake radial gates (radial gates), no sampling occurred between March 10 and April 24, 2017. During the 39 field days, a total of 145 unique electrofishing samples, defined as a single electrofishing boat fishing in a single sampling section for a specific period, occurred for a total of 239.27 hours on the water and 167.77 hours of active electrofishing, when electricity was being applied to the water column.

There were 6,151 predatory fish weighing approximately 7,200 lb (3.26 metric tons) caught and removed from CCF during the 2017 field season. The large majority (5,236 fish, or 85.1%) of fish captured during the 2017 field season were Striped Bass, weighing approximately 5,800 lb (2.63 metric tons). Black bass accounted for 14.3% of total removals (879 fish; 1,300 lb or 0.60 metric tons) and 36 catfish (0.6% of total predators; 70 lb) were removed.

Based on the information gathered from the 2016 and 2017 field seasons, the following recommendations are made:

1. **Increase predator removal effort to maximize predator removals.** There was little evidence suggesting that predator depletion occurred or that juvenile Chinook Salmon survival increased during the predator removal period. This suggests that predator removal efforts should be increased to maximize the ability to determine whether predator removal would result in an increase to salmonid survival. Electrofishing effort could be increased by increasing the number of electrofishing days per week, increasing the duration of time on the water, and fishing with more than two electrofishing boats concurrently.

2. **Focus targeted removal efforts on Scour Hole, Intake Canal, and shorelines.** In 2017, statistically significant increases in predatory fish captures were documented higher in the Scour Hole, Intake Canal, and along the shorelines than in open water locations. Therefore, these locations should be the focus for targeted removal efforts and open water locations should be dropped.

3. **Focus targeted removal on other smaller scale locations.** Detailed spatial analysis of 2017 data showed that specific areas in CCF have consistently higher catch rates ("predator hotspots") and could be the focus of future electrofishing. These areas include: (1) just east of the opening of the Intake Canal to the rest of CCF for Striped Bass and black bass; (2) the ring around deeper water within the Scour Hole for Striped Bass; (3) the open water area to the Northeast of the Scour Hole delineation within the Southeast quadrant for Striped Bass; (4) the linear southwest reach of shoreline in the Southwest quadrant for Striped Bass and black bass; (5) the middle reach of the Northeast quadrant shoreline for black bass; and (6) the upper reach of the Northwest quadrant shoreline for black bass.

4. **Consider more effective options for catching catfish.** Electrofishing as undertaken in 2016/2017 does not effectively catch catfish. The dropper cable did not work, likely due to the long distance between the anode and the electrofishing boat, which diffused the electrical field to the point of being ineffective on fish near or at the bottom like catfish. Although not a consideration for the Study, the utilization of other gear types, such as traps and nets, for full diel (24-hour) periods should be strongly considered as part of the upcoming Predator Fish Relocation Study (PFRS).

5. **Continue predator transport to Bethany Reservoir using current methods but with additional trailers.** There were no statistically significant predictors of predator mortality in 2017, and mortality rates were low (4.5%), suggesting transport was generally effective. With the 2018 focus on predator removal, additional transport trailers may be needed to effectively process the anticipated increased predator catch.

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Acronyms and Abbreviations

ANOVA	Analysis of Variance
BiOp	Biological Opinion
BDCP	Bay Delta Conservation Plan
CESA	California Endangered Species Act
CDEC	California Data Exchange Center
cfs	Cubic Feet per Second
CIMIS	California Irrigation Management Information System
CCF	Clifton Court Forebay
C.I.	Confidence Interval
CPUE	Catch per Unit Effort
CVP	Central Valley Project (federal)
˚C	Degrees Celsius
Delta	Sacramento-San Joaquin River Delta
DFW	California Department of Fish and Wildlife
DO	Dissolved Oxygen
df	Degrees of Freedom
DPS	Distinct Population Segment
DWR	California Department of Water Resources
FESA	Federal Endangered Species Act
FSB	Fish Science Building
GPP	Generator Powered Pulsator
GPS	Global Positioning System
Hz	Hertz
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
L	Liter
lb(s)	Pound(s)
mm	Millimeter
MOTC	Motorboat Operator Training Course
µS/cm	Microsiemens per Centimeter
NMFS	National Marine Fisheries Service
NMFS BiOp	Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project
PIT	Passive Integrated Transponder
PRES	Clifton Court Forebay Predator Reduction Electrofishing Study
PSL	Pre-Screen Loss
radial gates	Clifton Court Forebay Intake Radial Gates
RPA	Reasonable and Prudent Alternative
SD	Standard Deviation
SDFPF	John E. Skinner Delta Fish Protective Facility
sp.	Species
SWP	State Water Project (California State)
USFWS	United States Fish and Wildlife Service
USFWS BiOp	2008 Biological Opinion on the Long-Term Operational Criteria and Plan
WY	Water Year

1. Introduction

The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (PRES) was implemented in response to the National Marine Fisheries Service (NMFS) letter dated April 9, 2015, requiring that the California Department of Water Resources (DWR) immediately implement interim measure (a) (Initiate measures to improve predator control in Clifton Court Forebay (CCF) by electroshocking and relocating predators) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative (RPA) Action IV.4.2(2) of the 2009 Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS BiOp). The purpose of the PRES is to electroshock and remove predatory fish from CCF and transport them to Bethany Reservoir to decrease pre-screen loss of protected fish species, particularly juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and California Central Valley Steelhead (*Oncorhynchus mykiss*). The PRES began in 2016 with a pilot effort and will end in 2018 with full-scale implementation of predator removal.

1.1 Background

Located near Byron in Contra Costa County, California, CCF was constructed in 1969 by inundating a 2,200 acre tract of land approximately 2.6 miles long and 2.1 miles across (Kano 1990). CCF is operated as a regulating reservoir within the tidally influenced region of the Sacramento-San Joaquin River Delta (Delta) to improve operations of the State Water Project (SWP), Harvey O. Banks Pumping Plant, and water diversions to the California Aqueduct (Figure 1). During high tide cycles, when the elevation of water in Old River exceeds that in CCF, up to five radial gates that are located in the southeast corner of CCF are opened to allow water to be diverted from the Delta into CCF. Daily operation of the gates depends on scheduled water exports, tides, and storage availability within CCF (Le 2004). Diversion of water from Old River into CCF results in the entrainment of numerous fish species, some of which are listed under the California and/or Federal Endangered Species Acts (CESA and FESA, respectively), including California Central Valley Steelhead, Sacramento River Winter-run and Central Valley Spring-run Chinook Salmon, Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), and North American Green Sturgeon (*Acipenser medirostris*; Southern Distinct Population Segment [DPS]). As such, operation of the SWP is performed in compliance with the terms and conditions of the NMFS BiOp, U.S. Fish and Wildlife Service (USFWS) 2008 Biological Opinion on the Long-Term Operational Criteria and Plan (USFWS BiOp), and California Department of Fish and Wildlife (DFW) 2009 Longfin Smelt incidental take permit (ITP) actions.

Fish entering CCF must travel approximately 2.1 miles across CCF to reach the John E. Skinner Delta Fish Protective Facility (SDFPF). The SDFPF was designed to protect fish from entrainment into the California Aqueduct by diverting them into holding tanks where they can be salvaged and safely returned to the Delta. Water is drawn to the SDFPF from CCF via an intake canal past a floating trash boom. The trash boom is designed to intercept floating debris and guide it to an onshore trash conveyor. Water and fish then flow through a trash rack, equipped with a trash rake, to a series of louvers arranged in a V pattern. Fish are behaviorally guided by the louvers and directed to salvage holding tanks where they remain until transported and released back into the Delta.

Figure 1. Clifton Court Forebay Location Map.

The loss of fish between the CCF Radial Gates and the SDFPF is termed pre-screen loss (PSL). PSL includes, but is not limited to, predation by fish and birds. Studies conducted by DWR and DFW indicate that PSL of juvenile Chinook Salmon varies from 63 to 99 percent (Gingras 1997) and PSL of juvenile steelhead was 82 ± 3 percent (Clark et al. 2009). Predation by Striped Bass is thought to be the primary cause of high PSL in CCF (Brown et al. 1996, Gingras 1997, Clark et al. 2009).

RPA Action IV.4.2(2) of the NMFS BiOp required DWR to “develop predator control methods for Clifton Court Forebay that will reduce Chinook Salmon and steelhead pre-screen loss in Clifton Court Forebay to no more than 40 percent.” Further, “Full Compliance (of this RPA) shall be achieved by March 31, 2014” and “DWR may petition the Fish and Game Commission to increase bag limits on Striped Bass caught in Clifton Court Forebay.”

To comply with this RPA action, DWR petitioned the Fish and Game Commission to remove size restrictions and increase or eliminate bag limits on Striped Bass recreational fishing in CCF on March 24, 2011, December 6, 2011, and March 23, 2015. Additionally, DWR proposed and planned to construct a public access fishing facility within CCF near the radial gates to increase recreational fishing pressure on legally sized predatory fishes in an effort to reduce predation of protected fish species.

Since 2011, NMFS has twice approved time extensions of RPA Action IV.4.2(2). First, in a letter dated May 1, 2011, DWR requested extending the timeline for improving predator reduction methods until December 2014, with full compliance by December 2017. NMFS agreed to the extension in a July 2, 2012 response letter, with the understanding that an additional number of actions would be implemented over the next three years. DWR implemented predation surveys and selected a fishing pier as the best alternative to meet the RPA Action IV.4.2(2) requirement. Then, in a letter dated February 7, 2014, DWR requested a one-year extension until December 2015 to complete environmental permitting and FESA Section 7 consultation associated with the construction of a new fishing pier. In a May 15, 2014 letter, NMFS agreed to the second request for a one-year time extension. However, during the consultation process it became apparent that implementation of the Bay Delta Conservation Plan/California WaterFix would conflict with the fishing pier. Specifically, changes in the design of CCF would limit public access to the proposed fishing pier, thereby reducing the fishing pressure at the proposed fishing pier.

DWR and NMFS staff met in December 2014 to evaluate alternatives to the fishing pier for reducing predation in CCF. On February 4, 2015, DWR requested another extension until November, 2015 to deliver a final plan, schedule, and formal extension. In a response letter dated April 9, 2015, NMFS granted DWR this extension with conditions. Condition 3 states that, “DWR shall initiate interim measures to improve predator control before December 2015, to reduce predators in the CCF until an acceptable alternative can be implemented. Interim measures agreed to at the March 12, 2015 meeting that could be immediately implemented include: (a) electro-shocking and relocating predators; (b) controlling aquatic weeds; (c) developing a fishing incentives or a reward program for predators; and (d) operational changes when listed species are present (e.g., preferential pumping via the Central Valley Project [CVP] rather than the SWP).”

1.2 PRES Objective

Our PRES objective is to evaluate the feasibility of electro-shocking and relocation of predatory fish in CCF to comply with interim measure (a) from condition 3 of the April 9, 2015 NMFS response letter.

Each year of the three-year PRES has a specific focus. During 2016 we conducted a pilot effort, focusing on field logistics, equipment and personnel needs, developing effective sampling methods, and collecting initial data on predator density patterns. During 2017 we focused on refining methods based on lessons learned and recommendations from the 2016 effort, determining spatial and temporal patterns in predator catch rates using a standardized sampling regime, and assessing environmental variables that may affect catch rates. During 2017 we also assessed factors contributing to mortality of predators transported to Bethany Reservoir, conducted two preliminary analyses to evaluate evidence of depletion of black bass in shoreline habitats, and estimated the potential biomass of Chinook Salmon saved from predator consumption through predator removal. It is important to emphasize that predator depletion and reduction of Chinook Salmon consumptive loss were not PRES objectives in 2017, but these analyses are informative for the 2018 season. During the 2018 field season we will utilize the information on factors that affect predator catch rates and recommendations from the 2016 and 2017 efforts provided in this report to maximize predator removal rates. All effort involved with the PRES aims to reduce PSL of juvenile salmonids in CCF to comply with RPA Action IV.4.2(2). As such, the survival of tagged Chinook Salmon and steelhead in CCF was monitored and will continue to be monitored concurrently with the PRES to determine whether predator removal efforts can reduce juvenile salmonid PSL.

1.3 Concurrent Predator Studies in Clifton Court Forebay

1.3.1 Skinner Evaluation and Improvement Study (SEIS)

In Water Year (WY) 2013, DWR initiated the Skinner Evaluation and Improvement Study (SEIS), a mark-recapture study to evaluate losses of tagged salmonids from the SWP intake at CCF radial gates to the termination of the fish salvage process (approximately 2.1 miles) at the SDFPF. Similar to the PRES, the SEIS was developed in response to RPA Action IV.4.2 from the NMFS BiOp, which directs the DWR to reduce pre-screen loss and improve screening efficiency of juvenile salmonids. The two studies coordinate closely to time releases of tagged salmonids with predator removal efforts in CCF.

A Memorandum on the 2017 effort is included as an attachment to this report (Attachment 1, Skinner Evaluation and Improvement Study Annual Report 2017).

1.3.2 Clifton Court Forebay Predation Study (CFPS)

The Clifton Court Forebay Predation Study (CFPS) was initiated in 2013 in response to RPA Action IV.4.2 from the NMFS BiOp to gain a better understanding of predation as a factor in survival of listed salmonids in CCF. One element of CFPS is to tag predatory fish with Passive Integrated Transponder (PIT) and Floy tags and follow their recaptures through time to estimate movement, population size, and prey consumption. Field sampling during the PRES regularly captures predatory fish that were tagged for CFPS and reports all recaptured fish to the CFPS project manager. All recaptured fish are subsequently released back into CCF.

2. Methods

2.1 Overview

In 2017, field work for the PRES comprised systematically of removing of predatory fishes from CCF using a variable sample design that maximized the amount of effort over the bathymetry of CCF. Sampling consisted of three main stages: electrofishing, fish processing, and fish transportation. Two electrofishing boats were used to collect target predatory fish species. The captured target species were regularly transferred from electrofishing boats to a 28 foot, fish processing barge (barge). After all target captures were processed, they were transferred to a land-based transportation livewell secured to a large trailer pulled by a pick-up truck. Target captures were then transported to and released into Bethany Reservoir.

Target species selected for the PRES were based on previous studies conducted in the CCF (Kano 1990):

- Striped Bass (*Morone saxatilis*);
- Largemouth Bass (*Micropterus salmoides*);
- Spotted Bass (*Micropterus punctulatus*);
- Channel Catfish (*Ictalurus punctatus*);
- White Catfish (*Ameiurus catus*);
- Black Bullhead (*Ameiurus nebulosus*); and
- Brown Bullhead (*Ameiurus melas*).

2.2 Study Site

2.2.1 Clifton Court Forebay

CCF is operated as a regulating reservoir within the tidally influenced region of the Delta to improve operations of the SWP Harvey O. Banks Pumping Plant and water diversions to the California Aqueduct (Figure 1). CCF was divided into six sampling sections to maintain consistency with previous studies conducted at CCF (Figure 2). The main portion of the forebay was split into four sampling sections, referred to as quadrants

1. *Northwest Quadrant*: The boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8404°N, 121.5910°W, 2) 37.8404°N, 121.5750°W, and 3) 37.8566°N, 121.5750°W.
2. *Southwest Quadrant*: the boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8404°N, 121.5910°W, 2) 37.8404°N, 121.5750°W, and 3) 37.8270°N, 121.5750°W. A public fishing area is located in this quadrant and receives a fair amount of recreational use.
3. *Northeast Quadrant*: The boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8566°N, 121.5750°W, 2) 37.8404°N, 121.5750°W, and 3) 37.8404°N, 121.5590°W.
4. *Southeast Quadrant*: The boundaries of this quadrant include the levee on the landside and a line running through the following coordinates on the waterside: 1) 37.8270°N, 121.5750°W, 2) 37.8404°N, 121.5750°W, and 3) 37.8404°N, 121.5590°W.

Each quadrant was further divided into open water (>25 meters from shore) or shoreline (≤25 meters from shore) positions.

Two additional sampling sections were located along the periphery of the main forebay and were not further split into open water and shoreline positions:

5. *Intake Canal*: This sampling section, located along the southwest border of CCF, is a long, narrow channel that is connected to the main body of CCF by a narrow entrance. The entrance is bounded by long, narrow spits of land on the north (37.8333°N, 121.5931°W) and south (N 37.8317°N, 121.5931°W). The Skinner Delta Fish Protection Facility (SDFPF) is located at the southern end of the intake canal.
6. *Scour Hole*: This sampling section is located in the southeast corner of CCF just to the west of the radial gates. The section is characterized by a deep scour hole created by water rapidly flowing into CCF through the radial gates due to the head differential between the river and CCF.

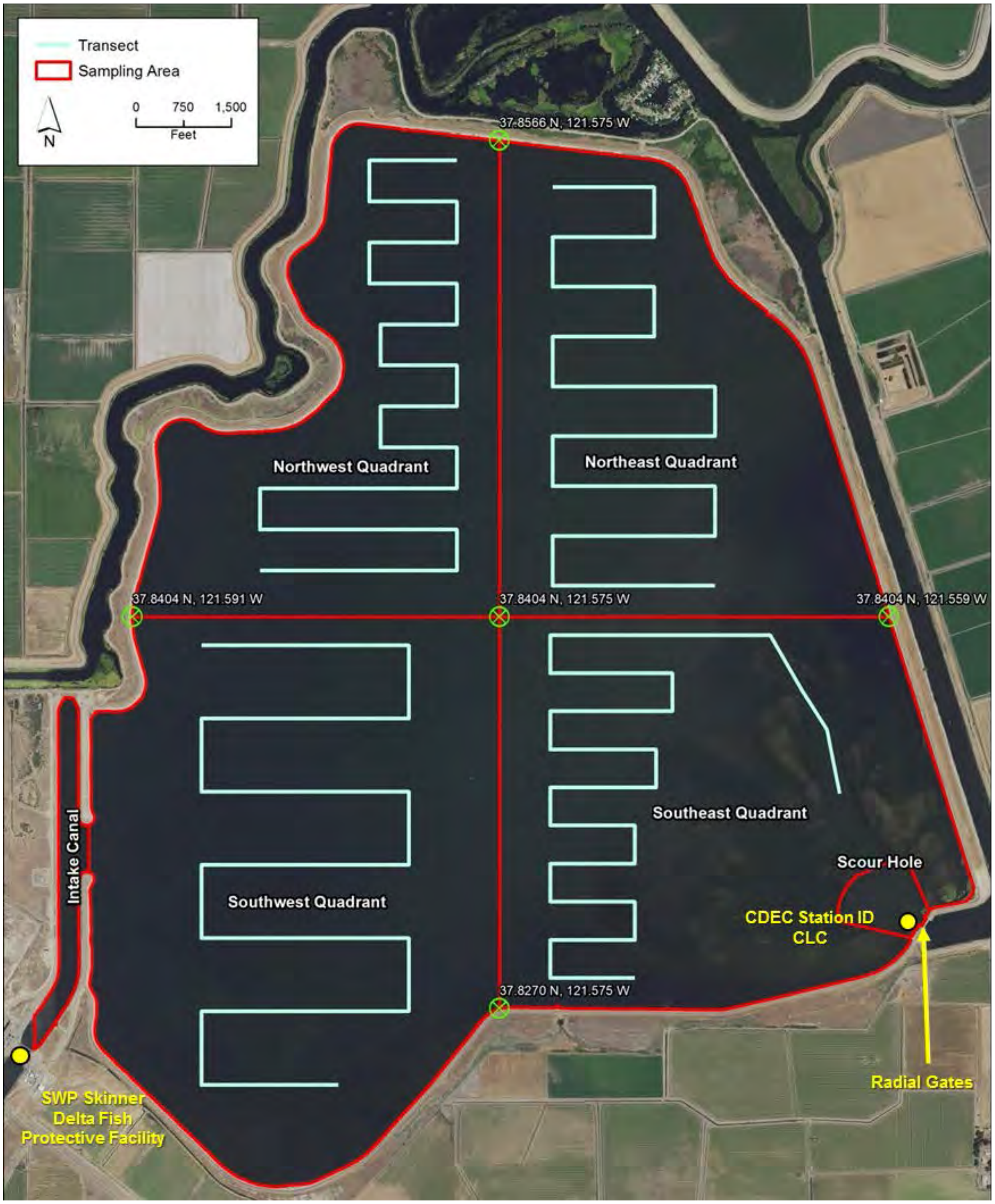


Figure 2. PRES site map indicating the six sampling sections of CCF and Open Water sampling transects (turquoise lines) used by electrofishing boats.

2.2.2 Bethany Reservoir

Bethany Reservoir is a small reservoir (6 miles of shoreline) in northeastern Alameda County (Figure 1). The reservoir is approximately 7 miles from CCF (~15 minute drive) and is the first reservoir along the California Aqueduct after leaving Harvey O. Banks Pumping Plant. It serves as the forebay for the South Bay Pumping Plant. Bethany Reservoir and surrounding area compose the Bethany Reservoir State Recreation Area and is open to the public for boating, fishing, and other forms of recreation.

2.3 Sampling Design

Prior to the start of the field season, transects were drawn over a GIS bathymetry map in offshore areas in approximately equal distances (~13 km) (Figure 2). These transects were added to maps in ArcGIS Collector on iPads and used by boat operators in the field to follow the transect in real time.

An effort was made to sample each sampling section and position within a quadrant an equal number of times over the duration of the project and to sample each sampling section and position at least once per week. In reality, site selection was also influenced by multiple environmental and operational variables, including weather, presence of aquatic vegetation, CCF operations (including radial gate schedule), water levels within CCF, and the Banks Pumping Plant water pumping schedule. All of these factors impacted the sampling schedule, site selection, and safety of the work environment. Sampling section and positions were selected for sampling on the morning of each sample day based on these considerations. An effort was made to sample two sampling sections on each sample day for a total of four samples per day (two electrofishing boats in different sampling sections and/or positions with quadrants). In addition, when sampling a quadrant, an effort was made for both electrofishing boats to sample in the same quadrant concurrently – one in the shoreline position and one in the open water position. In the Scour Hole and Intake Canal, two electrofishing boats sampled a single sampling section concurrently. During June, the growth of aquatic weeds prohibited sampling in quadrants; as a result, only the Intake Canal and Scour Hole were sampled.

Sampling was intended to occur on Tuesday, Wednesday, and Thursday of every week from January until water temperatures exceeded ~21°C, which affected survival of juvenile salmonids being released into CCF as part of the SEIS. The 2017 sampling season lasted from January 23, 2017 through June 15, 2017, when water temperatures became too high to support juvenile salmonids. Due to damage and subsequent construction to repair the radial gates, no sampling occurred between March 10, 2017 and April 24, 2017.

2.4 Electrofishing

For the PRES we utilized two electrofishing boats (with an extra in reserve), fishing concurrently, to capture target predatory fish species. Each electrofishing boat was specifically designed and outfitted with equipment necessary to temporarily stun fish and hold them in recirculating livewells. The DWR electrofishing boat is a North River jet boat outfitted with a Smith-Root® Generator Powered Pulsator (GPP) 7.5 shore unit. The FISHBIO boat is a V hull standard Smith-Root electrofishing boat with a GPP 5.0 electrofishing unit. The GPP for each electrofishing boat is energized by a gasoline powered generator securely attached to the floor (DWR: 7,500 watts; FISHBIO: 5,000 watts). Each electrofishing boat has adjustable front mounted insulated boat booms with umbrella type anodes with an integrated cathode array mounted to the front of the hull. The DWR boat has a control box with a foot pedal that controls the application of power through the front arrays. The FISHBIO boat contains the standard integrated foot switches in the bow deck and operator console.

Each electrofishing boat was staffed by four crew members: two netters, a data collector, and a boat operator. Netters used variable length monorail electrofishing nets to capture stunned fish and transfer them to livewells. The data recorder recorded time, location, and number of fish caught by species with submeter accuracy in ArcGIS Collector on a tablet connected to a mounted Trimble R1 Global Navigation Satellite System (GNSS) receiver. Point files were collected at each capture location. The boat operator navigated CCF with a digital map, and boat position was recorded every 30 seconds, on a separate tablet connected to a mounted Trimble R1 GNSS receiver. The map had 10-foot resolution bathymetry as background to safely navigate the shallow water and sandbars that characterize CCF. The map also had sampling area boundaries and open water transect lines displayed to navigate sampling effort. Boat operators use portable VHF radios and cell phones to communicate start times and electrofisher settings.

Electrofisher settings typically started at 30Hz, 0-500 volts, at 10% range on the GPP 5.0 (FISHBIO boat) and 30Hz, 50-340 volts, 10% range on the 7.5 GPP (DWR boat). If necessary, the range was adjusted upward until fish were caught. Power output settings were recorded for each sampling period and included frequency, percent of range, voltage, and amperage. Settings were adjusted as needed based on environmental conditions and observed fish response to the electrical field to ensure high capture efficiency while maintaining minimal injury to fish. The amount of time electricity was applied to the water was recorded in seconds on the control box and using a separate time-of-use data logger (HOBO UX90, Onset, Bourne, MA) wired to the GPP high voltage indicator light.

An additional electrofishing method was attempted on one day (5/31/17) in the Scour Hole to improve catfish catch efficiency. One electrofishing boat experimented with an anode attached to a cable and dropped into deep water. After 30 minutes of sampling, no fish were caught. Therefore, the sampling method was discontinued. Data on sampling effort in this report do not include this experimental attempt.

Safety equipment for electrofishing boat staff included Coast Guard approved Type II personal flotation devices and, for netters, Class I linesman gloves to protect from electrical current.

2.5 Fish Processing

Target captures were transported to the barge after the livewells in the electrofishing boats reached capacity or at the end of the sampling day. The barge was positioned in close proximity to the electrofishing boats to minimize travel time and maximize time spent electrofishing. The barge was outfitted with two circular recirculating livewells (~660 liter (L)) to hold fish during and after processing. Livewells were securely fastened to the deck of the barge and filled with water from CCF using submersible pumps.

The barge was staffed by four crew members: two fish handlers, a data collector, and a barge operator. Handlers processed fish by scanning for tags, weighing, and measuring.

Fish were first scanned for PIT tags with a Biomark® HPR PLUS PIT tag scanner. If a PIT tag was detected, the fish was further scanned visually for a Floy tag. Fish that contained a PIT tag and/or Floy tag were from other CCF studies conducted by DWR (see Section 1.3). For each tagged fish, the barge crew recorded the species, tag number(s), length as fork length (FL) and total length (TL) to nearest millimeter (mm), weight to nearest tenth or hundredth of a pound (lb) using a Salter-Brecknell SA3N ElectroSamson portable hanging scale (55 lb. max), and whether the fish was alive. All tagged fish were then returned to CCF.

For each untagged fish, the species, FL (mm), and TL (mm), and whether the fish was alive were recorded. For approximately every tenth fish of each species, weight (lb) was recoded to the nearest tenth of a lb. Fish that died ("mortalities") were placed in secure plastic bags and disposed of at the Fish Science Building (FSB). Water quality data were recorded at the beginning and end of each sample day with a YSI® Pro2030 meter and included conductivity (microsiemens per centimeter, μS/cm), dissolved oxygen (DO) percent saturation, and water temperature (°C). In addition, turbidity (Nephelometric Turbidity Units; NTU) was measured using a handheld turbidity meter. Water temperature and DO levels were monitored throughout the day in livewells to ensure acceptable conditions. An oxygen diffuser bar was used in conjunction with an oxygen tank to increase DO levels in livewells when necessary. After processing, all live target captures were transported to a land-based transportation truck and livewell.

Safety equipment for the barge staff included Coast Guard approved Type II personal flotation devices.

2.6 Fish Transportation

To transport fish to Bethany Reservoir, a ¾-ton pickup truck towed a flatbed trailer on which a 1,314 L insulated fish transport livewell with oxygen diffusers and an oxygen tank was securely fastened. Prior to receiving fish, the livewell was filled with water from CCF and, if warranted, DO level was increased to a range of 90 to 120 percent saturation. The transportation truck and livewell was strategically positioned on the levee of CCF to minimize barge travel time for fish transfers. Two staff members were assigned to the transport truck. Fish were transferred from the barge to the transport livewell using short handled monorail nets. Fish were then transported to Bethany Reservoir, approximately seven miles from CCF, and released at the public boat ramp. DO percent saturation and water temperature in the livewell were measured using a YSI® Pro2030 multi-meter just before departure from CCF and just prior to releasing fish into Bethany Reservoir. In addition, DO percent saturation and water temperature in Bethany Reservoir, and the number of mortalities by species during transport, were recorded. Mortalities were removed prior to releasing fish, placed in secure plastic bags, and disposed of at the FSB.

2.7 Sampling Techniques

Electrofishing techniques were generally similar among all sampling locations, although location-specific differences are described here.

2.7.1 Quadrant Shoreline Sampling

Sampling along the shoreline (defined as ≤25 meters to shore) was conducted primarily to target black bass. Sampling consisted of moving slowly parallel or at a slight angle to the shoreline to concentrate the electrical field around vegetation, rip-rap, and other likely fish holding features. While moving within the shoreline section, one of two electricity application strategies was used. First, electricity was applied continuously unless there was a break in sampling. Second, electricity was applied to the water at rate of 12 to 15 seconds on and 5 seconds off as the electrofishing boat moved forward into unsampled water. The on/off strategy was meant to create breaks in the electrical field in front of the electrofishing boat that fish sense and avoid. This allowed the electrical field to get closer to fish when power was reapplied, facilitating capture. Boat operators assigned the two strategies unsystematically among samples, except that each strategy was applied to an approximately equal number of samples.

When schools of fish were located, the electrofishing boat operator would stop forward propulsion, allowing the electrofishing boat to drift over the affected fish so netters could maximize capture. As fish drifted past or away from the electrofishing boat, the boat operator would reposition the electrofishing boat to capture all shocked fish. Once the school dispersed, the electrofishing boat would move from the area in a broadening pattern in an attempt to relocate the school of fish. If the school was not relocated, the boat operator would return to where the school was originally located and continue along the shoreline.

2.7.2 Quadrant Open Water Sampling

Open water sampling (defined as >25 meters from shore) conducted to target Striped Bass, which have shown pelagic schooling behavioral tendencies in CCF. The electrofishing boat followed along a predetermined transect that crossed over a broad swatch of the open water portion of the quadrant (Figure 2). Sampling in the open water section involved using the same two electricity application strategies used for shoreline sampling (continuous and on-off). When schools of fish were encountered, forward movement of the electrofishing boat was slowed and sampling efforts were increased in an unsystematic manner in that area.

2.7.3 Intake Canal Sampling

The Intake Canal was sampled similarly to quadrant shoreline locations. Due to its smaller shoreline length, more than one pass of the same shoreline often occurred within the allotted time.

2.7.4 Scour Hole Sampling

The scour hole was sampled by moving in an unsystematic pattern around the hole until fish were located. Boat operators paid close attention to flow patterns set up by the radial gates and bathymetry at different water levels.

2.8 Environmental Data

In addition to environmental data collected by the barge staff for each sampling day and by the transport staff for each trip to Bethany Reservoir, several sources of environmental data were collected.

Water temperature and turbidity data were gathered from the California Data Exchange Center (CDEC) Water temperature (°C), turbidity (NTU), wind speed (miles per hour; mph), and wind direction (°) data were downloaded for the CLC (Clifton Court) station (37.8298°N, 121.5574°W; Figure 2) maintained by DWR.

A YSI® Model EX02 multiparameter sonde was placed in CCF to collect 15-minute interval data on several water quality parameters, including water temperature (°C), conductivity (uS/cm), turbidity (Formazin Nephelometric Units), and DO (percent saturation). The dataset for the 2017 field season was incomplete due to a large gap in the middle of the season. As a result, these data were not used for this annual report.

Operational data were provided to BDO staff by the DWR Operations and Maintenance (O&M) office. This dataset included each radial gate position (feet), calculated flow through each gate (cfs), stage upstream and downstream of the radial gates (feet), and pumping rates at Banks Pumping Plant (cfs). As part of the QA/QC process, pumping rates at Banks Pumping Plant from O&M were compared to pumping rates reported as part of the salvage process (ftp://ftp.dfg.ca.gov/salvage/). If pumping rates differed by more than 5% between datasets, pumping rates from the salvage data were used.

2.9 Staff Training

Smith-Root provided an on-site electrofishing course for permanent DWR staff and contractors working on this project. A classroom session took place in Sacramento and covered basic electrical theory, electrofishing equipment, operation and safety, and applied electrofishing methods. A field session took place at CCF where participants operated electrofishing equipment, including adjusting settings on the control panel, and applied information learned in the classroom. The training focused on the following:

- Minimizing/eliminating potential harm to fish;
- Proper electrofishing settings to maximize capture efficiency;
- Working safely as a team in a variety of environments;
- Techniques and settings for a variety of target species in different life stages;
- Operation and safety, including dangers to humans and fish; and
- Electrofishing techniques as they apply to bioassessments, fisheries characterizations, population estimates, and age and growth studies.

Contractor staff that had access to the Department of the Interior (DOI) Learn completed the USFWS Electrofishing Safety Course (Course Number FWS-CSP2202A-OLT). This course emphasized electrofishing safety to minimize hazards and maximize performance.

All project boat operators were required to have taken either the U.S. Fish and Wildlife Service (USWFS) Motorboat Operator Certification Course (MOCC) or Scientific Boating Safety Association (SBSA) Motorboat Operator Training Course (MOTC) certification, or have a U.S. Coast Guard captain’s license. Both multi-day training courses combined classroom sessions and field sessions. The courses emphasize safe motorboat operations and include review of legal requirements, preparations, navigation, operations, emergency procedures, rescue, self-rescue, trailering, fire suppression, and basic seamanship. The course included both classroom and on-the-water instruction.

All field staff were required to complete adult cardiopulmonary resuscitation (CPR) with automated external defibrillator (AED) procedures and first aid. All DWR employees were required to complete the 8 hour OP2 certification course and contractor field staff were required to take the 4 hour OP2 Awareness certification course.

2.10 Statistical Analysis

2.10.1 Environmental Influences on Predator Catch

We used generalized linear modeling (GLM) with a negative binomial error distribution and logarithmic link function to model the relationship between environmental variable predictors and the number of predators captured while electrofishing. A negative binomial distribution eliminated overdispersion evident in an initial GLM with Poisson distribution. GLM was conducted separately for total predatory fish, Striped Bass, and black bass. Catfish were not evaluated independently because very few individuals were caught. Effort (hours) was included as an offset in each model. Effort was recorded in two ways: the amount of time the electrofishing boat was outputting electricity and the amount of time on the water (beginning from the start of the sampling period to the end of the sampling period). Analyses were repeated for both effort measures. The set of candidate predictors included electrofishing section of CCF (Figure 2), boat, water temperature, turbidity, wind speed, radial gate flow, Banks pumping rate, and time from sunrise (Table 1). Mean values of continuous variables were calculated for each sampling period. There were no significant correlations ($r > |0.7|$) between predictors.

Table 1. Environmental Variables Included in Generalized Linear Modeling of Predator Catch from Electrofishing in CCF, January-June 2017.

Variable	Unit (continuous; with source) or factor levels	Rationale for Inclusion
CCF Section	Scour Hole, Intake Canal, Northeast Open Water, Northeast Shoreline, Northwest Open Water, Northwest Shoreline, Southeast Open Water, Southeast Shoreline, Southwest Open Water, Southwest Shoreline	Earlier studies showed considerable differences in predator occurrence by section (Clark et al. 2009; DWR 2016); important to know for management purposes in order to plan future studies
Boat	DWR, FISHBIO, FISHBIO-2	Different electrofishing boats could have different sampling efficiency
Water Temperature	°C (CDEC CLC station)	Predator species may have seasonal migrations or increased bioenergetics demand with greater temperature (DWR 2015)
Turbidity	NTU (CDEC CLC station)	Greater turbidity may lower fish boat avoidance through reduced visibility but also may reduce visibility of fish to netters (Reynolds and Kolz 2012)
Wind Speed	Mph (CDEC CLC station)	Wind could affect distribution of fish by physical displacement or make fish difficult for netters to see (Reynolds and Kolz 2012)
Gate Flow	cfs (calculated by DWR Operations staff)	Gate flow could affect availability of prey fish to predators in CCF, particularly near the Scour Hole.
Banks Pumping Rate	cfs (DFW salvage reports, supplemented with calculated values by DWR Operations staff)	Pumping rate could affect the availability of prey fish to predators in CCF, particularly in the Intake Canal.
Time from Sunrise	Hours (United States Naval Observatory 2016)	Predator activity often has a diel component, with peaks of activity during crepuscular periods (e.g., Moyle 2002: p.399).

For each analysis, model averaging was undertaken from all possible model combinations, with weights based on the support for each model (Barton 2016), as assessed from Akaike's Information Criterion corrected for small sample sizes (AIC_c; Mazerolle 2006). Variable importance was assessed by summing the weights of all models in which the variable appeared. A variable was considered "important" if the variable importance was greater than 0.8 and the 95% confidence intervals did not include zero, (after Calcagno and de Mazancourt 2010 and Zeug and Cavallo 2013). The pseudo-r^2 was calculated for each full model to indicate variance explained. Plots of the model-averaged predicted values were created for variables considered important. Differences between factor levels were considered statistically significant when the coefficient 95% confidence intervals did not overlap. GLMs including predictors were assessed to provide a better fit to the data than intercept-only models if the AIC_c of the full model (with all predictors included) was three or more units less than the AIC_c of the intercept-only model (after Zeug and Cavallo 2013).

Two-way interactions between location and gate flow and location and pumping rate were examined. The importance for these interactions was extremely low (<1) so they were removed as candidate predictors. To explore the effect of gate flow and pumping rate at each section, a plot of model-averaged predicted values with separate prediction lines for each section was created.

All GLM analyses were conducted in R (Version 3.4.1; R Core Team 2017).

2.10.2 Small-Scale Spatial Patterns in Predator Capture Rates

To examine small-scale spatial patterns within CCF, we utilized the georeferenced data collected for boat tracks and fish catches using Environmental Systems Research Institute (ESRI) ArcGIS Collector application on iPads, and time-of-use HOBO data loggers to determine when electrofishing boats were actively sampling (power was on). Catch data collected on iPads was strongly correlated with catch data from the barge (Figure 3; $r^2 = 0.99$), indicating that total catch data collection was consistent between the two methods.

Using these data, catch per unit effort was estimated at a small spatial scale, which was chosen to be 50 ft x 50 ft cells in a grid across the entire CCF. Electrofishing boat location data were collected on a 30 second time step, whereas HOBO electrofishing (power on) data were collected every second. Electrofishing boat location was matched temporally with electrofishing data to determine the locations of electrofishing. Desktop ArcGIS software was used to interpolate track position locations between each 30 second track point interval (assuming a constant speed, straight line path between pairs of points) to establish point locations for every second of active fishing. Georeferenced fish catch data were collected whenever a fish was caught. A CPUE was calculated for each cell by dividing total fish catches in that cell by total track seconds when power was on within the cell. CPUE was calculated for Striped Bass, black bass, and total predatory fish separately. Too few catfish were collected to warrant this calculation.

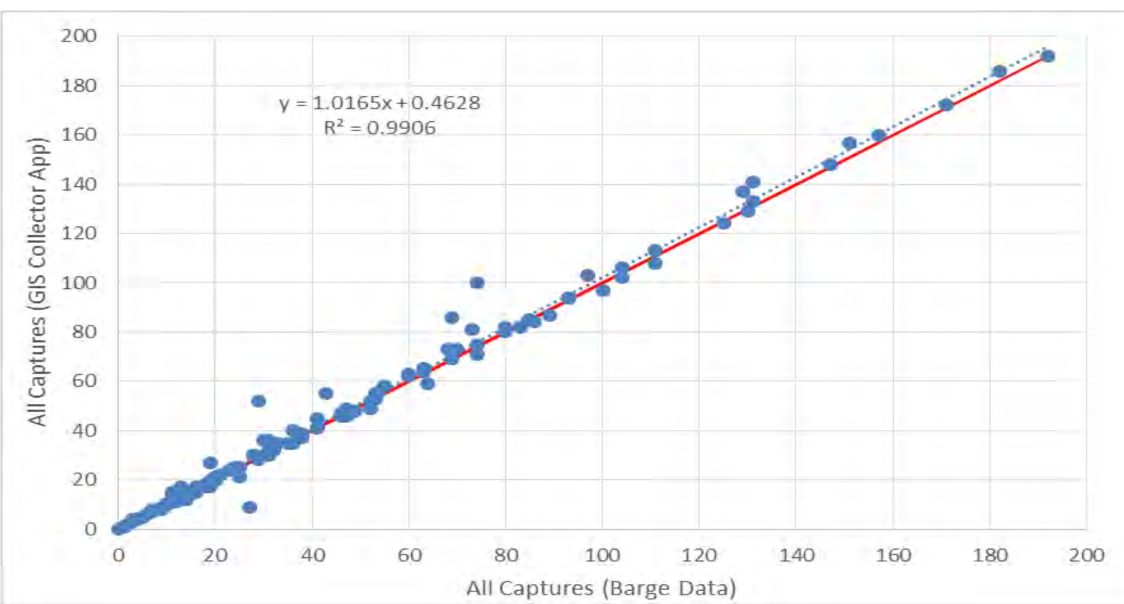


Figure 3. Comparison of Total Predatory Fish Captured by Sampling Session in CCF and Recorded with the GIS Collector Application on the Electrofishing Boat versus Captured Fish Recorded on the Barge. The red line indicates y=x.

Once the CPUE values were developed, spatial statistic tools within ArcGIS were used to analyze distribution patterns for Striped Bass, black bass, and total predatory fish for each month separately (January through June) and for all months combined. The Incremental Spatial Autocorrelation tool (ESRI 2017a), which measures autocorrelation for a series of distances and graphs those distances and their corresponding z-scores, was used for this analysis. Z-score peaks within the graph indicated distances at which clustering of the data was most distinct. The distances chosen which represented the best clustering pattern of CPUE data across the study area were 514 ft for black bass and 415 ft for Striped Bass and total predatory fish. Using these distance bands, “hotspot” analyses were conducted using Getis-Ord Gi* statistic (ESRI 2017b). Grid cells with a z-score > 1.65 were deemed significant hotspots with 90-99% confidence. Maps were developed to show where these significant hotspots occurred throughout CCF (Figures 28 through 39).

2.10.3 Predator Mortality

We used a beta regression (Zeilis et al. 2016) to model the relationship between environmental variables and the proportion of fish that died during each transport trip from CCF to Bethany Reservoir. Beta regression involves predicting the count of events (in this case mortality) while accounting for the total number of events (mortality + survival, i.e., total fish per transport trip), to give a mortality proportion or rate. The covariates included in the analyses were hypothesized to have potential effects on mortality, i.e., dissolved oxygen at the start and end of the transport and at Bethany Reservoir, water temperature at the start of transport, and the amount of biomass removed (as a measure of potential crowding/stress in the transport trailer). The ending temperature and temperature at Bethany Reservoir were not included because of a high correlation with starting temperature ($R > 0.9$). Modeling averaging and assessment of predictor importance were undertaken using the same methods as the negative binomial models for predator capture during electrofishing, as described in Section 2.10.1. The pseudo r^2 for the full model was reported to indicate variance explained.

2.10.4 Predator Depletion

Although predatory fish depletion was not an objective of the PRES, it was felt that an exploratory analysis of evidence for depletion was warranted for black bass in shoreline habitats, for two reasons: first, catch of black bass was considerably higher in shoreline habitat than open water, and second, the species tends to occupy a small home range (DWR 2015, 2016) and, therefore, would be more likely to show evidence of depletion than migratory, open-water species such as Striped Bass.

Two hypotheses for evidence of black bass depletion were tested. The first hypothesis was that black bass CPUE would decrease over time as fish were caught and removed from CCF. This was tested with linear regression of CPUE vs. date. The second hypothesis was that the difference in CPUE between one electrofishing session and the previous session would become more negative as the number of days between the sessions decreased. The second hypothesis was also tested with linear regression.

The hypotheses were tested separately for each shoreline sampling section, as well as the Intake Canal; catches of black bass in open water and Scour Hole sections were too low to justify inclusion. For the first hypothesis, separate analyses were conducted for electrofishing sessions conducted before and after the period of repair of the CCF radial gates. In addition, for the Intake Canal, a separate regression was calculated for the more intensive late May/June electrofishing that occurred toward the end of the PRES. For the second hypothesis, data from before and after the radial gate damage/repair period were combined, although the first session following recommencement of electrofishing in April was excluded as it was felt that too long had elapsed to retain any depletion effects from sampling in January-early March, based on observed patterns elsewhere in the Delta (Cavallo et al. 2013).

To provide context for whether observed patterns were caused by depletion or seasonal migration, the CPUE of recaptured black bass was regressed against date. Given that these fish were returned to the water from the barge following PIT or Floy tag detection and would be expected to return to the site of capture within hours (DWR 2016; see also Section 3.6 *Predator Recapture*), any trends in CPUE would be evidence for seasonal migrations. This analysis was limited to recaptures in the Intake Canal because insufficient recaptures were made from the other study sections.

2.11 Chinook Salmon Consumption (Bioenergetics Modeling)

Bioenergetics modeling was conducted in order to illustrate the potential biomass of Chinook Salmon that was not consumed within CCF during the PRES period as a result of Striped Bass removal by electrofishing.

2.11.1 Approach

The methodology used for the Study was that of Stroud and Simonis (2016). Basically, consumption was calculated as the product of the proportion of maximum daily ration (Loboschefsky, Personal Communication; Loboschefsky et al. 2012); the maximum feeding rate, which is an allometric function of fish mass at the optimal temperature; and an age-specific temperature dependence function (Hanson et al. 1997). Stroud and Simonis (2016: p.12-27) described in more detail the fixed-parameter point-estimate bioenergetics model that was based on the “Wisconsin” Bioenergetics Model developed by Kitchell et al. (1977). The Kitchell et al. (1977) methodology was generalized and documented in Hanson et al. (1997).

Stroud and Simonis (2016) conducted a sensitivity analysis of the fixed-parameter point-estimate Wisconsin bioenergetics model by comparing it to a variable-parameter version of the same bioenergetics model. A key finding of Stroud and Simonis (2016) was that the fixed-parameter point-estimate model produced a downward bias on estimates of consumption rate. Therefore, for the PRES, fixed-parameter point-estimates were calculated in addition to the variable-parameter bioenergetics model being employed to avoid the downward bias; both sets of results are reported here. However, the variable-parameter model results are relied on for interpretation and discussion purposes in the PRES.

The methodology of Stroud and Simonis (2016) was followed except for the inputs described in the following three sections. Temperature data were specific to 2017. Data on number and size of Striped Bass were from those fish removed by electrofishing and relocated to Bethany Reservoir in 2017. No predator diet information was collected in 2017 and therefore various data sets from previous studies were combined to estimate the fraction of the diet comprised of Chinook Salmon. The bioenergetics model was run on a daily time step from 1/23/17 through 6/16/17. January 23 was selected because that was the first day of predator removals to Bethany Reservoir. June 16 was selected for the end date because that was the last full 24 hour period to occur after predator removals ended on June 15.

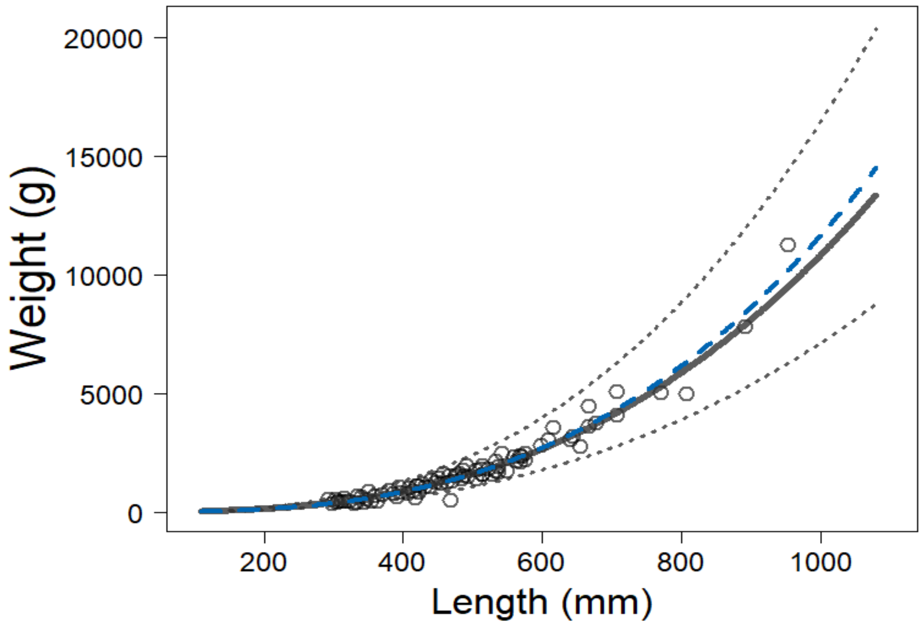
2.11.1.1 Temperature Data

Hourly temperature data were taken from two sources: 1) the majority of the temperature observations were obtained from CDEC station ID CLC; and 2) missing values from the CDEC station were filled in through observations obtained by the YSI multiparameter sonde (located at 37.8403, -121.5748) deployed in CCF in 2017. Because the bioenergetics functions and model operate on a daily time step, hourly temperature data were averaged to generate a single daily temperature.

2.11.1.2 Predator Sizes

For this analysis, fork lengths of captured Striped Bass were translated to weight using a standard allometric relationship ($W=a \times FL ^\wedge b$). The refitted length-weight relationship from Stroud and Simonis

(2016) was used (Figure 4), which is based on Striped Bass collected in the Sacramento River (Tucker et al. 1998). The Striped Bass captured in the PRES ranged in length from 132 to 1194 mm, whereas Tucker et al. (1998) only collected fish ranging in length from 290 to 950 mm. The refit of the data from Stroud and Simonis (2016) produced nearly identical point estimates as the Tucker et al. (1998) relationship, while it also allowed for variances on the length-weight regression (and thus for inclusion of uncertainty in predator weight for the variable-parameter model).



Source: Reprinted with permission from Stroud and Simonis (2016).

Figure 4. Length-Weight Regression Fit to Data from Tucker et al. (1998). Grey lines are associated with the re-fit model: the solid line is the predicted value and the dotted lines show the 95% prediction interval. The blue dashed line shows the predicted value for the original fit model (Tucker et al. 1998).

There were ten individual Striped Bass that did not have lengths recorded. For those fish, it was assumed they were the average length (specifically, the exponentiated mean of log lengths to deal with the right-skew of the length distributions) of the other Striped Bass collected on that day (Table 2.)

Table 2. Mean of Log Lengths of Striped Bass Captured on Dates when Ten Individual Fish Were Not Measured to Length.

Date	Mean Fork Length (mm)	N
2/14/2017	405	154
4/25/2017	347	280
5/9/2017	303	277
5/11/2017	259	165
5/17/2017	319	181
5/17/2017	319	181
5/17/2017	319	181
6/1/2017	308	315
6/8/2017	318	213
6/14/2017	289	212

The bioenergetics calculations are defined by age class (age-1, age-2, age-3, age-4, age-5 and up). Therefore, each predator was placed into an age class (yearly) according to its length (Table 3.)

Table 3. Striped Bass Ages at Length Used for Bioenergetics Calculations.

Age Class	Minimum Length	Maximum Length
1	110	309
2	310	374
3	375	449
4	450	524
5	525	599
6	600	674
7	675	749
8	750	899
9	900	1099
10	1100	1500

2.11.1.3 Predator Diets

Predator diet proportions were calculated following the methods outlined in Stroud and Simonis (2016), but with first condensing the frequency of occurrence data (measured by QPCR assays) across time. This produced a frequency of occurrence data set based on 1,401 Striped Bass (21 of which, 1.5%, had positive detection of Chinook DNA in their gut contents). The calculations of the predator diet proportions (ratio of the total mass of diet that belongs to a particular prey class) included the frequency of occurrence, percent by number, and percent by mass (see Stroud and Simonis 2016 for the data sets included). These metrics were averaged to produce the overall diet proportions used for the fixed-parameter analysis, for which the proportion comprised of Chinook Salmon was 1.95% (Table 4).

Table 4. Striped Bass Diet Proportions Used for Bioenergetics Calculations.

Species	Diet Percent
Chinook Salmon	1.95
Delta Smelt	0.46
Largemouth Bass	2.19
Longfin Smelt	0.06
Mississippi Silverside	0.61
Steelhead/Rainbow Trout	0.36
Sacramento Pikeminnow	0.26
Sacramento Splittail	0.24
Threadfin Shad	25.20
White Sturgeon	0.69
Striped Bass	6.39
Other Fish Species	9.19
Non-Fish Items	32.22

For the variable-parameter analysis, 100,000 iterations were drawn of the diet data from distributions based on the means and standard deviations of the percent by number and by mass metrics and the back-transformed fit of a logistic regression to the QPCR data (following the methods of Stroud and Simonis 2016). This generated a distribution of diet proportions comprised of Chinook Salmon with a mean of 2.1%, a median of 1.9%, a standard deviation of 1.5%, and a range of 0.2% to 12.6%.

2.11.2 Fixed Parameters: Basic Consumption

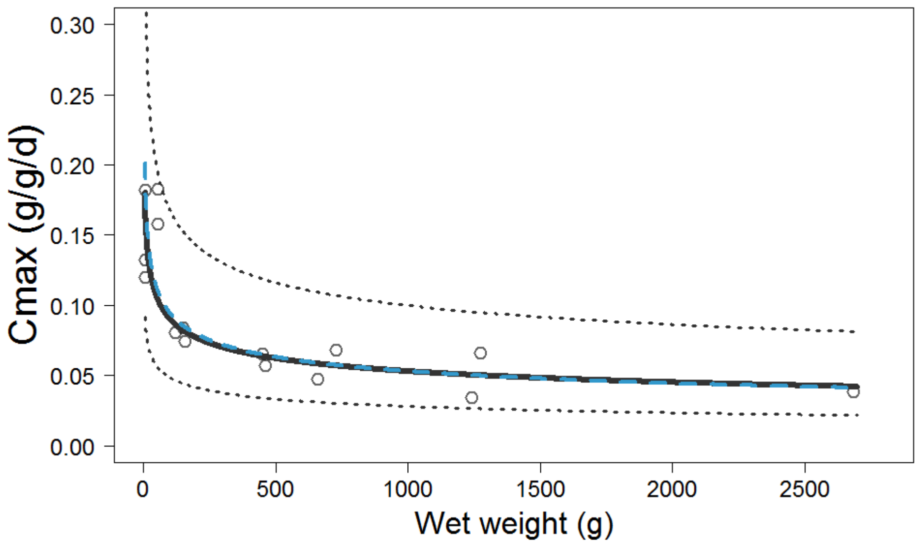
Fixed-parameter analyses were conducted using all parameters following the methodology described in Hanson et al. (1997). For each Striped Bass, the total daily food consumption in CCF was calculated based on the daily average temperatures and assuming a fixed predator size through time (i.e., no growth). It was assumed that Striped Bass were eating the proportions of maximum consumption (p) estimated in the work described by Loboschefsky et al. (2012): p = 0.69 for Striped Bass aged 1-2 years, 0.73 for Striped Bass aged 3 years, 0.68 for Striped Bass aged 4 years, and 0.72 for Striped Bass aged 5 years and up (Loboschefsky personal communication). The bioenergetic consumption function generated a specific consumption rate (C: g prey/g predator/day), and this was converted to the total consumption on that day by multiplying by the mass of the predator to produce the total consumption rate (g prey/day). This was then converted to a rate of Chinook eaten (g Chinook/day) by multiplying by the proportion of the diet made up by Chinook Salmon.

For all analyses including fixed and variable parameters (described in the next section), no growth was assumed in the Striped Bass, after they were captured and removed, through the course of the 2017 field season. The “No Growth” option was selected because if an electrofished Striped Bass had been returned to CCF it could then have left CCF. Other Striped Bass could have entered CCF and no data were collected on the Striped Bass population size or changing size distribution during the 2017 field season. In the absence of these data, the “No Growth” option was selected because it was conservative: estimated consumption must be the estimated value or greater.

On each day, the total possible consumption was calculated as the sum for all 5,236 Striped Bass on that day and the removed consumption was calculated as the sum for the Striped Bass previously removed but based on the temperature on that day.

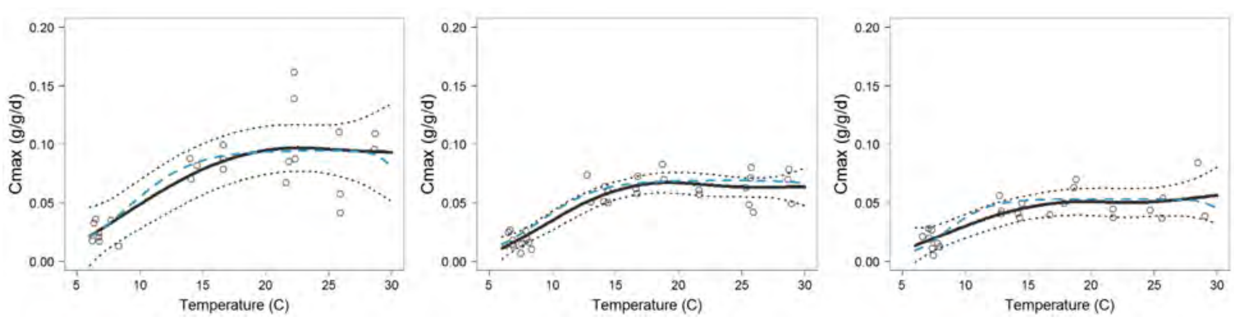
2.11.3 Variable Parameters: Basic Consumption

Variable-parameter model analyses were conducted following the methods of Stroud and Simonis (2016) that allow for uncertainty to be incorporated into the consumption calculations. This included re-fitting the allometric scaling of maximum consumption (Figure 5) and the temperature-dependence of maximum consumption for the three age categories (age-1, age-2, and age-3+) (Figure 6). As a result, unlike the fixed-parameters model, variability was included in the variable-parameters model.



Source: Reprinted with permission from Stroud and Simonis (2016).

Figure 5. Cmax-Weight Regression Fit to Data from Hartman and Brandt (1995). The black line is the predicted value, the dotted lines show the 95% prediction interval, and the blue dashed line is the original fit (Hartman and Brandt 1995).



Source: Reprinted with permission from Stroud and Simonis (2016).

Figure 6. Temperature-Dependence of C_{max} for Age-1, -2, and -3+ Striped Bass (left-to-right). The black line is the predicted value and the dotted lines the 95% prediction interval of the GAM. The blue dashed line is the "by eye" fit (Hartman and Brandt 1995).

Variation was provided in the weight of the predator, by drawing a value from the prediction of the length-weight regression based on the measured length. Then, on each day, the specific maximum consumption and temperature-dependence values were drawn from the statistical distributions generated by the re-fit functions. The total specific consumption rate was then calculated based on the predator size and temperature on that day from these random draws. The resulting total specific consumption rate was multiplied by the mass of that individual Striped Bass to generate the total consumption rate. The total consumption rate was then multiplied by a value of the Chinook diet fraction drawn at random from the 100,000 iterations. This method was repeated 500 times to generate distributions of Striped Bass-specific daily Chinook consumption values.

Similar to the methods of the fixed-parameter analyses (Section 2.11.2 *Fixed Parameters: Basic Consumption*), for the variable-parameter analyses, on each day the total possible consumption was calculated as the sum for all 5,236 predators on that day and the removed consumption as the sum for the predators previously removed but based on the temperature on that day. These calculations were done for each of the 500 iterations. All variable-parameter model results were summarized with means and 95% confidence intervals.

2.11.4 Predator Population Extrapolation

The effect of predator population size on consumption of Chinook Salmon was evaluated graphically. The proportion of maximum consumption (p) was set to 1.0 to estimate the maximum consumption that could have been removed by predator capture and relocation to Bethany Reservoir. As described above (Section 2.11.3 *Variable Parameters: Basic Consumption*), the mean and 95% confidence intervals (CIs) were calculated for consumption removed for each day of the field season. The upper bound of the 95% CI was then used as the numerator to calculate the proportion of maximum consumption avoided. The denominator was the total consumption that would have occurred on a given day if all 5,236 Striped Bass removed in 2017 were present on that day (Equation 1):

Equation 1 $C_P = (C_U/C_T)$

Where,

C_P = proportion of maximum consumption avoided,

C_U = upper bound of the 95% CI of estimated consumption on a given day, and

C_T = total consumption that would have occurred on that day if all 5,236 Striped Bass removed in 2017 were present in CCF on that day.

C_P was calculated for all 145 days in the field season (1/23/17 through 6/16/17) and plotted by date.

To simulate a Striped Bass population size of 52,360, the value of C_P was multiplied by 0.1 for each day. This population size, 52,360, was of similar magnitude to the only available estimates of Striped Bass population size in CCF (Kano 1990, pg. 7). To simulate a Striped Bass population size of 523,600 Striped Bass the value of C_P for population size of 52,360 was multiplied by 0.1 for each day. These population sizes are multiples of the actual number of Striped Bass removed in 2017 (5,236) and are only intended to provide illustrative context. This graphical analysis assumed that Striped Bass consumption of Chinook Salmon would increase in strict proportion to Striped Bass population size. The effects of the three illustrative population sizes on maximum consumption were compared by graphing C_P against date.

3. Results

3.1 Sampling Effort and Environmental Parameters

Electrofishing occurred at CCF on 39 days between January 23 and June 15, 2017. Due to damage and subsequent construction to repair the radial gates, no sampling occurred between March 10 and April 24, 2017. During the 39 field days, a total of 145 unique electrofishing samples occurred for a total of 239.27 hours on the water and 167.77 hours of active electrofishing, when electricity was being applied to the water column (Table 5).

Aside from the Scour Hole and Intake Canal, all sampling sections and positions were sampled relatively evenly over the field season (8 to 10 samples per section). The Scour Hole and Intake Canal were sampled much more often (37 and 33 samples, respectively). The fact that sampling during the last 3 weeks of the field season could occur only at these two sections due to aquatic weed growth in the rest of CCF accounts for some of this increased effort. Also, unlike in the quadrants where one electrofishing boat typically sampled the shoreline while the other electrofishing boat sampled the open water, two electrofishing boats typically sampled concurrently in the Scour Hole and Intake Canal.

The highest number of samples were taken during May (43 samples, 67.28 hours on the water, 51.28 hours of electrofishing) and the lowest number of samples were taken during January (10 samples, 19.25 hours on the water, 12.28 hours of electrofishing). Mean time on the water per sample for all months combined ranged from 1.17 ± 0.43 hours (mean ± SD) in the Intake Canal to 2.02 ± 0.70 hours in the Southwest quadrant, open water position. Mean electrofishing duration per sample ranged from 0.83 ± 0.28 hours in the Intake Canal to 1.47 ± 0.58 hours in the Southwest quadrant, open water position.

Table 5. Electrofishing Sampling Effort during the 2017 Field Season. Note: “Time on Water” represents the total amount of time during an electrofishing session, including time when electrofishing occurred and did not occur (e.g., when fish were being transferred to the barge). “Electrofishing Duration” represents time when electricity was applied to the water column.

Sampling Section	Position	Electro-fishing Sessions	Time on Water		Electrofishing Duration	
			Total (h)	Mean (h; mean ± SD)	Total (h)	Mean (h; mean ± SD)
January						
Scour Hole	--	2	1.43	0.72 ± 0.42	1.13	0.57 ± 0.30
Intake Canal	--	2	1.37	0.68 ± 0.07	1.04	0.52 ± 0.18
Southeast	Open Water	1	2.80	2.80[1]	1.89	1.89[1]
	Shoreline	1	1.45	1.45[1]	0.98	0.98[1]
Southwest	Open Water	1	3.73	3.73[1]	2.85	2.85[1]
	Shoreline	1	3.87	3.87[1]	1.33	1.33[1]
Northeast	Open Water	1	1.97	1.97[1]	1.82	1.82[1]
	Shoreline	1	2.63	2.63[1]	1.23	1.23[1]
Northwest	Open Water	0	--	--	--	--
	Shoreline	0	--	--	--	--
Total		10	19.25	1.93 ± 1.28	12.28	1.23 ± 0.78

Sampling Section	Position	Electro-fishing Sessions	Time on Water		Electrofishing Duration	
			Total (h)	Mean (h; mean ± SD)	Total (h)	Mean (h; mean ± SD)
February						
Scour Hole	--	5	9.43	1.89 ± 0.16	6.21	1.24 ± 0.17
Intake Canal	--	5	7.93	1.59 ± 0.62	4.77	0.95 ± 0.50
Southeast	Open Water	3	5.63	1.88 ± 0.13	3.85	1.28 ± 0.19
	Shoreline	3	6.10	2.03 ± 0.12	3.70	1.23 ± 0.22
Southwest	Open Water	2	3.40	1.70 ± 0.05	2.13	1.06 ± 0.07
	Shoreline	3	4.20	1.40 ± 1.04	2.55	0.85 ± 0.64
Northeast	Open Water	3	5.25	1.75 ± 0.10	3.14	1.05 ± 0.29
	Shoreline	3	6.83	2.28 ± 0.63	3.65	1.22 ± 0.10
Northwest	Open Water	2	3.50	1.75 ± 0.19	2.51	1.25 ± 0.02
	Shoreline	3	5.25	1.75 ± 0.43	3.42	1.14 ± 0.17
Total		32	57.53	1.80 ± 0.47	35.92	1.12 ± 0.31
March						
Scour Hole	--	4	7.52	1.88 ± 0.14	5.09	1.27 ± 0.25
Intake Canal	--	4	5.08	1.27 ± 0.62	3.57	0.89 ± 0.40
Southeast	Open Water	1	1.72	1.72[1]	1.51	1.51[1]
	Shoreline	1	1.75	1.75[1]	1.12	1.12[1]
Southwest	Open Water	2	3.48	1.74 ± 0.18	2.80	1.40 ± 0.09
	Shoreline	2	3.47	1.73 ± 0.07	1.81	0.91 ± 0.05
Northeast	Open Water	1	1.60	1.60[1]	1.48	1.48[1]
	Shoreline	1	1.73	1.73[1]	1.07	1.07[1]
Northwest	Open Water	2	3.27	1.63 ± 0.14	2.39	1.20 ± 0.14
	Shoreline	2	4.13	2.07 ± 0.57	2.15	1.07 ± 0.00
Total		20	33.75	1.69 ± 0.38	22.98	1.15 ± 0.28
April						
Scour Hole	--	2	3.07	1.53 ± 0.00	1.30	0.65 ± 0.11
Intake Canal	--	2	3.70	1.85 ± 0.09	2.43	1.21 ± 0.05
Southeast	Open Water	1	1.73	1.73[1]	1.55	1.55[1]
	Shoreline	1	2.00	2.00[1]	1.11	1.11[1]
Southwest	Open Water	1	1.95	1.95[1]	1.14	1.14[1]
	Shoreline	1	1.3	1.30[1]	0.8	0.80[1]
Northeast	Open Water	1	1.58	1.58[1]	1.57	1.57[1]
	Shoreline	1	1.87	1.87[1]	1.27	1.27[1]
Northwest	Open Water	1	1.85	1.85[1]	1.22	1.22[1]
	Shoreline	1	1.65	1.65[1]	1.11	1.11[1]
Total		12	20.70	1.73 ± 0.21	13.48	1.12 ± 0.30

Sampling Section	Position	Electro-fishing Sessions	Time on Water		Electrofishing Duration	
			Total (h)	Mean (h; mean ± SD)	Total (h)	Mean (h; mean ± SD)
May						
Scour Hole	--	10	16.43	1.64 ± 0.44	12.10	1.21 ± 0.37
Intake Canal	--	6	6.42	1.07 ± 0.23	4.38	0.73 ± 0.21
Southeast	Open Water	3	5.07	1.69 ± 0.02	3.97	1.32 ± 0.17
	Shoreline	4	6.08	1.52 ± 0.26	4.15	1.04 ± 0.12
Southwest	Open Water	2-	3.62	1.81 ± 0.04	2.83	1.42 ± 0.11
	Shoreline	2	3.70	1.85 ± 0.14	2.91	1.46 ± 0.04
Northeast	Open Water	4	6.05	1.51 ± 0.12	5.22	1.31 ± 0.22
	Shoreline	4	6.43	1.61 ± 0.22	5.00	1.25 ± 0.23
Northwest	Open Water	4	6.90	1.73 ± 0.21	5.70	1.43 ± 0.17
	Shoreline	4	6.58	1.65 ± 0.32	5.01	1.25 ± 0.32
Total		43	67.28	1.56 ± 0.34	51.28	1.19 ± 0.32
June						
Scour Hole	--	14	26.80	1.91 ± 0.18	20.76	1.48 ± 0.24
Intake Canal	--	14	13.95	1.00 ± 0.01	11.06	0.79 ± 0.07
Southeast	Open Water	0	--	--	--	--
	Shoreline	0	--	--	--	--
Southwest	Open Water	0	--	--	--	--
	Shoreline	0	--	--	--	--
Northeast	Open Water	0	--	--	--	--
	Shoreline	0	--	--	--	--
Northwest	Open Water	0	--	--	--	--
	Shoreline	0	--	--	--	--
Total		28	40.75	1.46 ± 0.48	31.82	1.14 ± 0.39
2017 Total						
Scour Hole	--	37	64.68	1.75 ± 0.39	46.59	1.26 ± 0.36
Intake Canal	--	33	38.45	1.17 ± 0.43	27.25	0.83 ± 0.28
Southeast	Open Water	10	17.38	1.74 ± 0.31	11.06	1.11 ± 0.16
	Shoreline	9	16.95	1.88 ± 0.36	12.76	1.42 ± 0.24
Southwest	Open Water	8	16.18	2.02 ± 0.70	11.74	1.47 ± 0.58
	Shoreline	9	16.53	1.84 ± 0.95	9.42	1.05 ± 0.42
Northeast	Open Water	10	19.50	1.95 ± 0.50	12.22	1.22 ± 0.15
	Shoreline	10	16.45	1.65 ± 0.17	13.23	1.32 ± 0.31
Northwest	Open Water	10	17.62	1.76 ± 0.37	11.69	1.17 ± 0.21
	Shoreline	9	15.52	1.72 ± 0.17	11.81	1.31 ± 0.16
Total		145	239.27	1.65 ± 0.52	167.77	1.16 ± 0.37

[1] Standard deviation could not be calculated with n = 1

Water temperature gradually increased over the course of the PRES period, from just over 10°C in January to over 21°C in early June (Figure 7), after which the PRES was stopped because the water temperature had exceeded the 21°C threshold above which survival of juvenile salmonids being released into CCF as part of SEIS was affected.

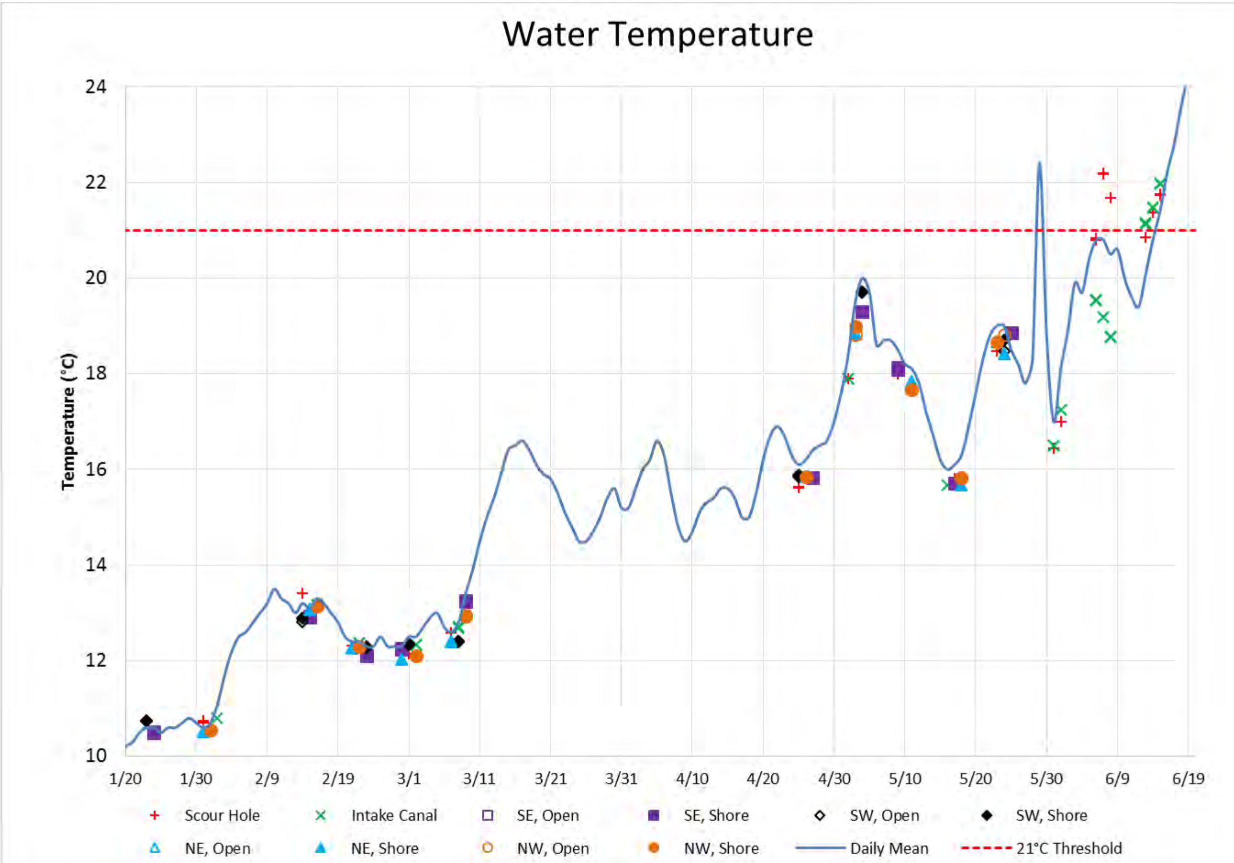


Figure 7. Water Temperature during the 2017 Field Season Measured at CDEC Station CLC. Symbols represent mean water temperatures recorded during individual samples.

Turbidity was variable over the 2017 study period, with two storm-driven events in January and February that resulted in high turbidity of around 60-100 NTU (Figure 8). At other times in the winter, turbidity was generally 30-40 NTU, whereas spring turbidity following the damage and repair to the CCF radial gates was typically 15-30 NTU.

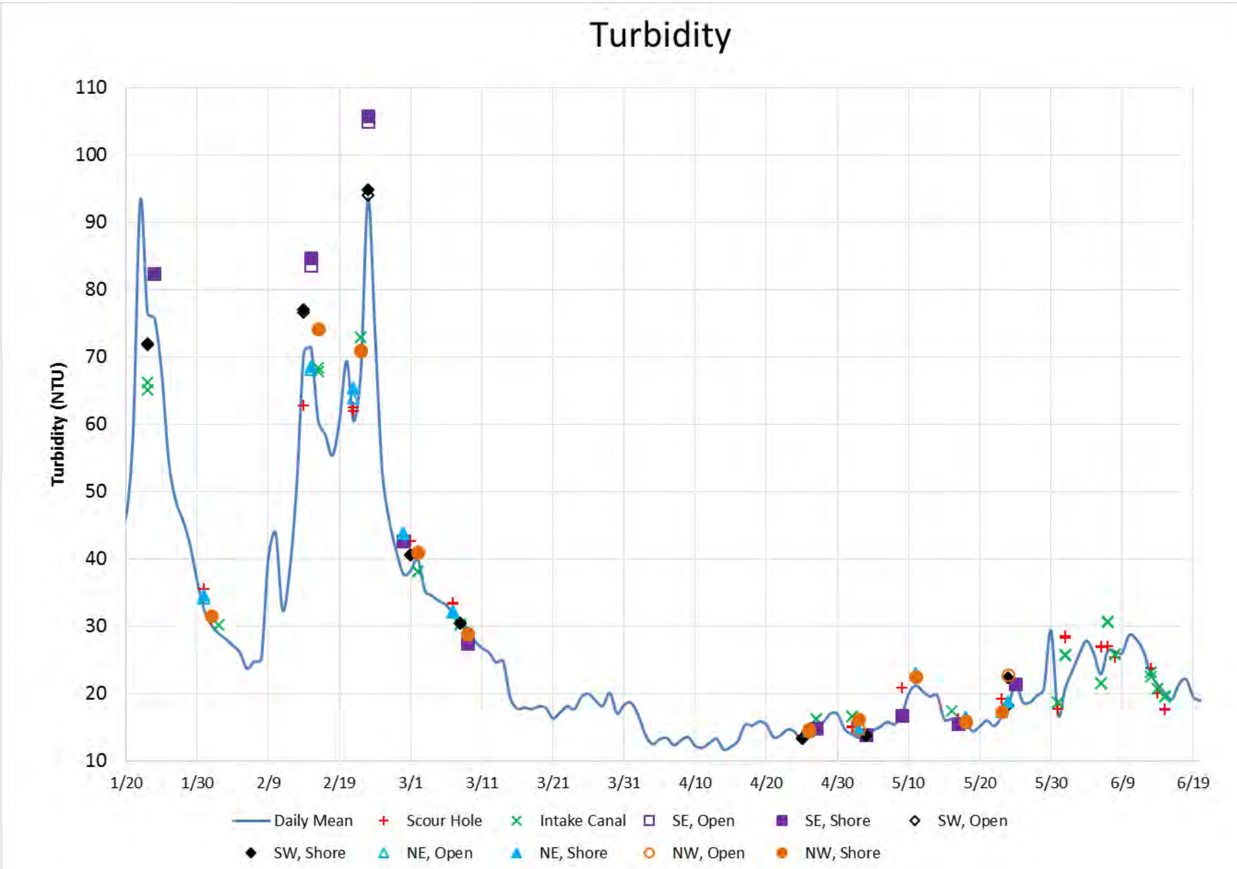


Figure 8. Turbidity During the 2017 Field Season Measured at CDEC Station CLC. Symbols represent mean turbidity recorded during individual samples.

Wind speed was somewhat variable during the 2017 study period (Figure 9). However, wind tended to be stronger in the spring than in the winter.

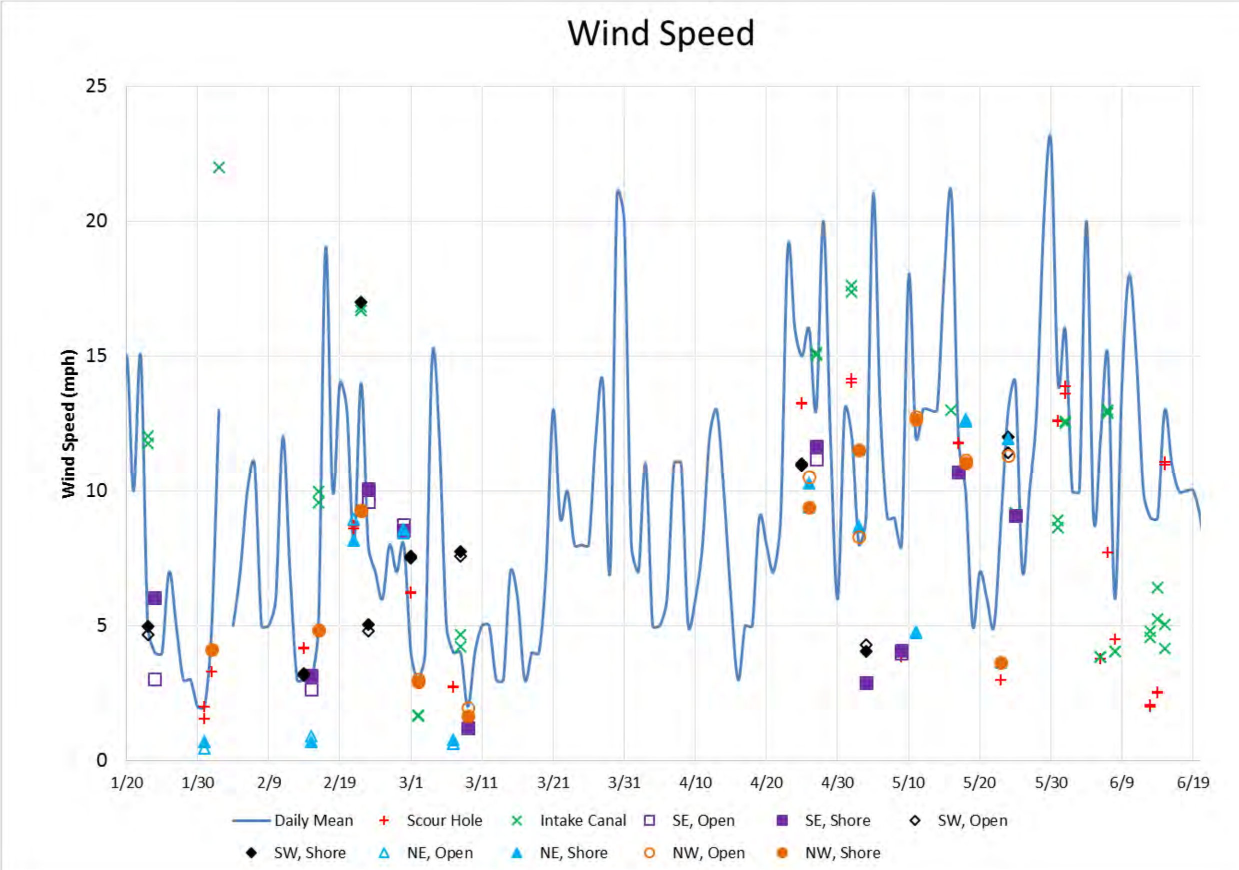


Figure 9. Wind Speed During the 2017 Field Season Measured at CDEC Station CLC. Symbols represent mean wind speed recorded during individual samples.

Flow through the CCF radial gates varied considerably both daily and seasonally (Figure 10). The PRES began during a period of relatively high gate flow, e.g., up to 8,000 cfs in January/February, whereas gate flow in mid-February to mid-March was lower, generally 0-3,000 cfs. Following CCF radial gate damage and repair, sampling tended to coincide with very high gate flow, from around 4,000 cfs to 14,000 cfs. A small proportion of electrofishing sessions occurred with gates closed, and was spread throughout most of the 2017 study period.

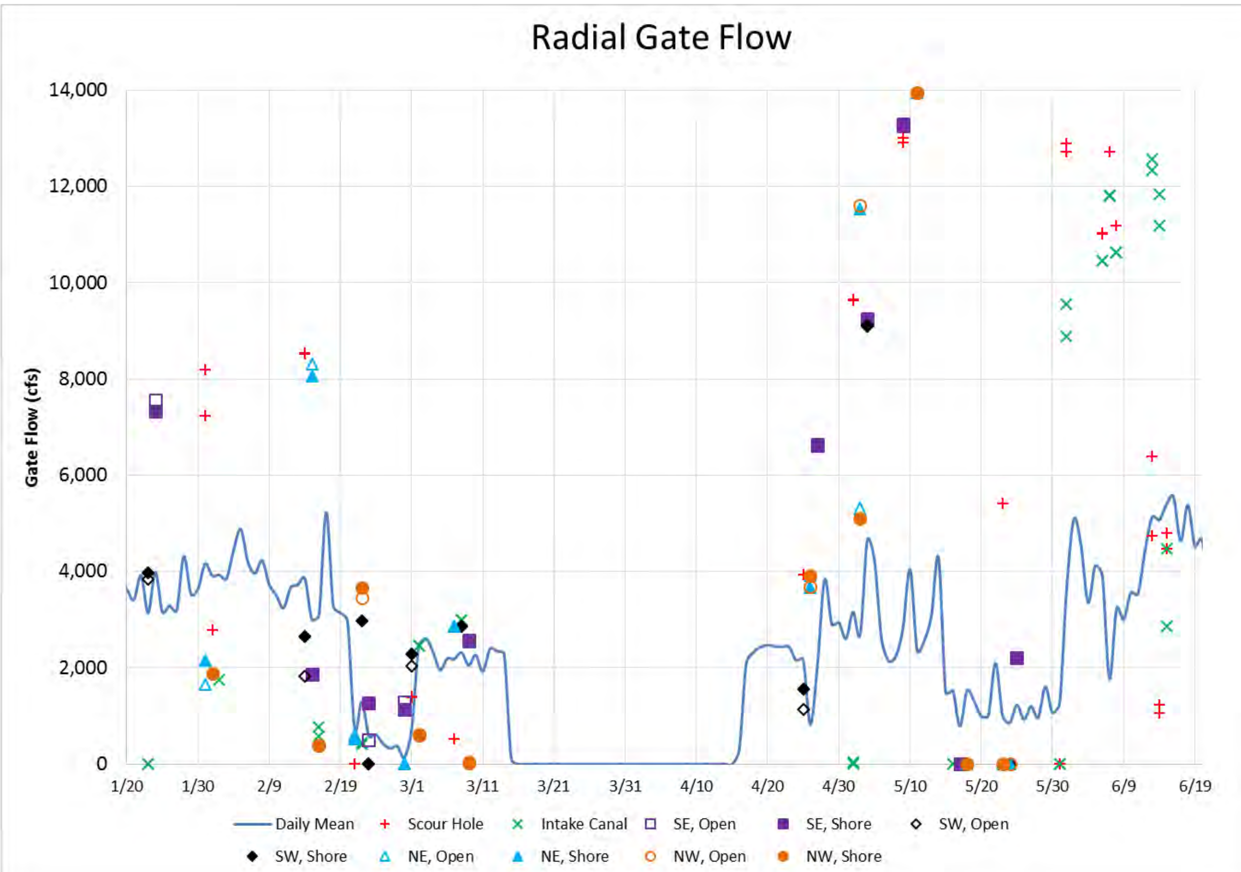


Figure 10. CCF Radial Gate Flow During the 2017 Field Season Measured with Data Obtained from DWR O&M. Symbols represent mean gate flow recorded during individual samples.

Banks pumping was greatest at the start of the 2017 study period (mid-January to mid-February), with mean daily pumping close to 10,000 cfs (8,000-10,500 cfs during electrofishing sessions) (Figure 11). Pumping subsequently decreased in February/March to around 1,500-4,000 cfs, prior to pumping largely ceasing for a month because of CCF radial gate damage and repair. Following radial gate repair, pumping was variable in late April/May, ranging from 0 to >8,000 cfs. Pumping increased to around 6,000-7,000 cfs for the remainder of the field season.

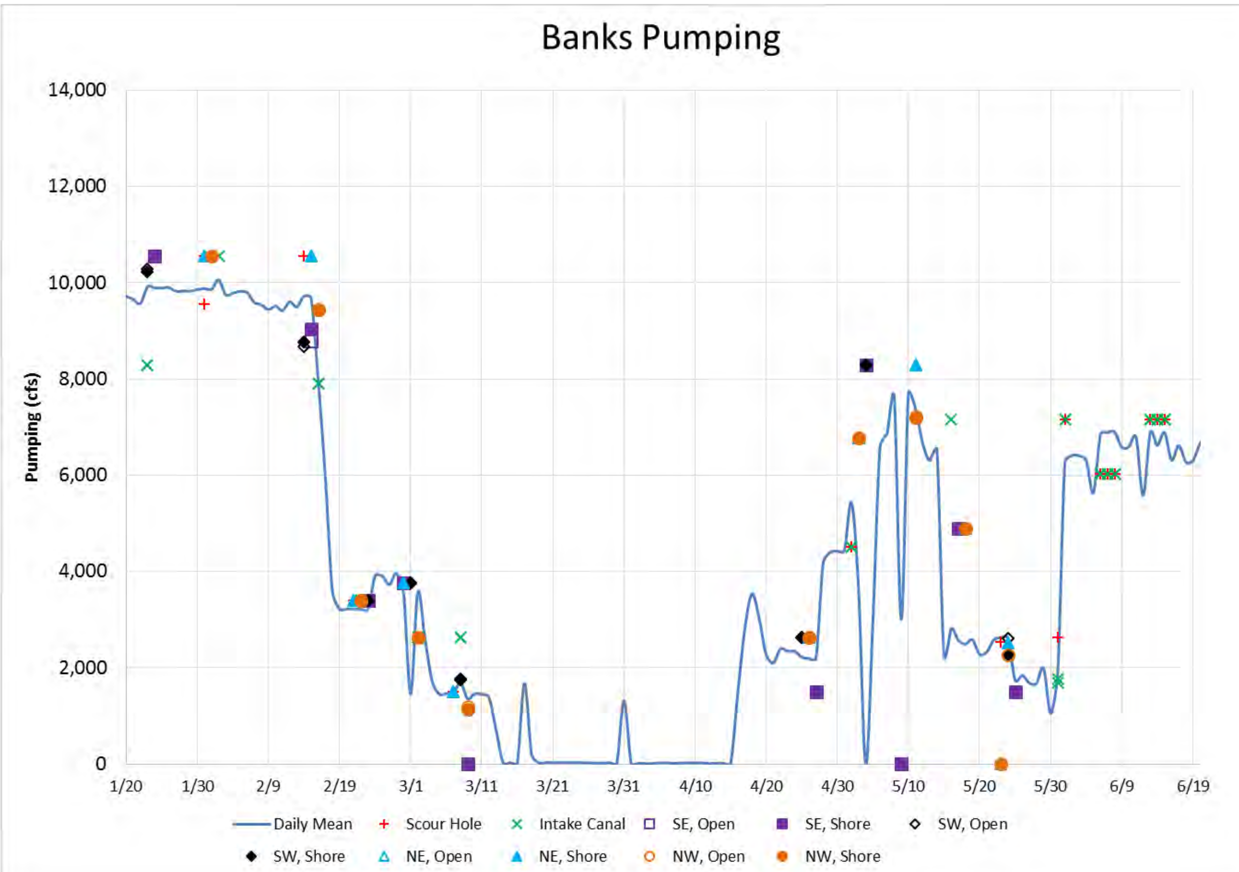


Figure 11. Banks Pumping During the 2017 Field Season Measured with Data Obtained from DWR O&M and DFW Salvage Reports. Symbols represent mean pumping recorded during individual samples.

3.2 Predator Catch Composition

There were 6,151 predatory fish caught and removed from CCF during the 2017 field season (Table 6). An additional 81 fish were caught but not removed from CCF. Of these, 57 fish were recaptured with tags from other CCF studies (for a total of 75 captures because several were recaptured more than once) and released back into CCF (see Section 3.6, Predator Recapture). In addition, 24 fish escaped back into CCF after capture. For simplicity, we refer to "caught" fish in this report as those that were both caught and removed from CCF and, other than here and when reporting tagged predator recaptures, do not mention predatory fish that were captured but returned to CCF.

The large majority (5,236 fish, or 85.1%) of fish captured during the 2017 field season were Striped Bass (Table 6). Black bass accounted for 14.3% of total removals (879 fish) and only 36 catfish (0.6% of total predators) were removed. Early in the field season, ~60-70% of total catches were Striped Bass and ~30-35% were black bass, whereas later in the field season total catches were ~85-90% Striped Bass and 7-15% black bass. Catfish accounted for <2% of total catch in all months.

Mean total lengths (± SD) of Striped Bass, black bass, and catfish for the entire field season were 348.2 ± 93.2 mm, 348.7 ± 96.2 mm, and 403.2 ± 123.7 mm, respectively (Table 6; Figure 12, Figure 13, Figure 14). The largest individual captured was a 1,245-mm (TL), 1,194-mm (FL), 44.3-lb Striped Bass and the smallest individual captured was an 80-mm (TL) white catfish that was too small for a reliable fork length measurement.

Mean total length of Striped Bass decreased by ~50 mm during the field season (Table 6) and only 2 individuals >1,000 mm were caught after March 1. Striped Bass total length distribution was highly skewed because of infrequent captures of very large individuals (Figure 12). Peaks in the length-frequency distribution occurred at ~280-330 mm and ~370-450 mm. This pattern probably indicates multiple year classes. The reduction in mean size of Striped Bass during the field season (Table 6) combined with this length frequency pattern indicates that larger individuals were present early in the season and a group of smaller (~280-300 mm) individuals gained prominence as the season progressed.

Mean total length of black bass was fairly consistent through time, although mean total length dropped during June, possible because of the focus only on the Scour Hole and Intake Canal, or as a result of overall seasonal shifts in size composition of black bass. The black bass size distribution is normally shaped with the large majority of individuals between 260 mm and 460 mm (Figure 13).

Too few catfish were captured to observe any clear patterns in length (Figure 14).

CCF is within the Delta, as defined in DFW's Freshwater Sport Fishing Regulations (section 1.71). As such, recreational harvest regulations in CCF are consistent with those listed for the Delta in DFW's Freshwater Sport Fishing Regulations. Recreational harvest of Striped Bass is permitted year-round in the Delta with an 18-inch (457.2-mm) minimum size limit (total length) and a 2-fish daily bag limit. Recreational harvest of black bass is permitted year-round in the Delta with a 12-inch (304.8-mm) minimum size limit (total length) and a 5-fish daily bag limit. Recreational harvest of catfish is permitted year-round in the Delta with no size restrictions and no daily bag limit. Only 7% of Striped Bass caught were larger than the legal minimum size limit (Figure 12). However, the majority of black bass (72%) were larger than the legal minimum size limit (Figure 13).

Table 6. Number, percent of total, and total length of predatory fish caught in and removed from CCF by species group, all sampling sections combined, 2017 field season.

Species Group	n	% of Total	Mean Total Length (mm; ± SD)	Min Total Length (mm)	Max Total Length (mm)
January					
Black bass	32	28.6	368.3 ± 96.1	152	537
Catfish	1	0.9	341.0[1]	341	341
Striped Bass	79	70.5	397.6 ± 132.9	140	1,144
Total	112	100	388.7 ± 123.2	140	1,144
February					
Black bass	202	34.8	363.8 ± 88.5	127	634
Catfish	9	1.6	462.3 ± 86.1	335	604
Striped Bass	369	63.6	433.9 ± 131.9	184	1,232
Total	580	100	409.9 ± 122.6	127	1,232
March					
Black bass	111	16.2	372.2 ± 87.0	94	620
Catfish	3	0.4	371.3 ± 72.0	300	444
Striped Bass	571	83.4	394.8 ± 92.8	153	1,245
Total	685	100	391.1 ± 92.1	94	1,245
April					
Black bass	107	13.8	374.8 ± 74.5	228	629
Catfish	1	0.1	312.0[1]	312	312
Striped Bass	668	86.1	346.0 ± 79.7	167	1,100
Total	776	100	350.2 ± 79.7	167	1,100
May					
Black bass	291	14.4	353.7 ± 85.0	92	634
Catfish	16	0.8	368.8 ± 148.0	80	568
Striped Bass	1,712	84.8	334.5 ± 91.8	147	1,005
Total	2,019	100	337.5 ± 91.7	80	1,005
June					
Black bass	136	6.9	271.4 ± 113.1	102	582
Catfish	6	0.3	447.8 ± 109.0	320	603
Striped Bass	1,837	92.8	327.9 ± 69.7	177	957
Total	1,979	100	324.6 ± 75.2	102	957
2017 Total					
Black bass	879	14.3	348.7 ± 96.2	92	634
Catfish	36	0.6	403.2 ± 123.7	80	604
Striped Bass	5,236	85.1	348.2 ± 93.2	140	1,245
Total	6,151	100	348.8 ± 94.0	80	1,245

[1] Standard deviation could not be calculated with n = 1

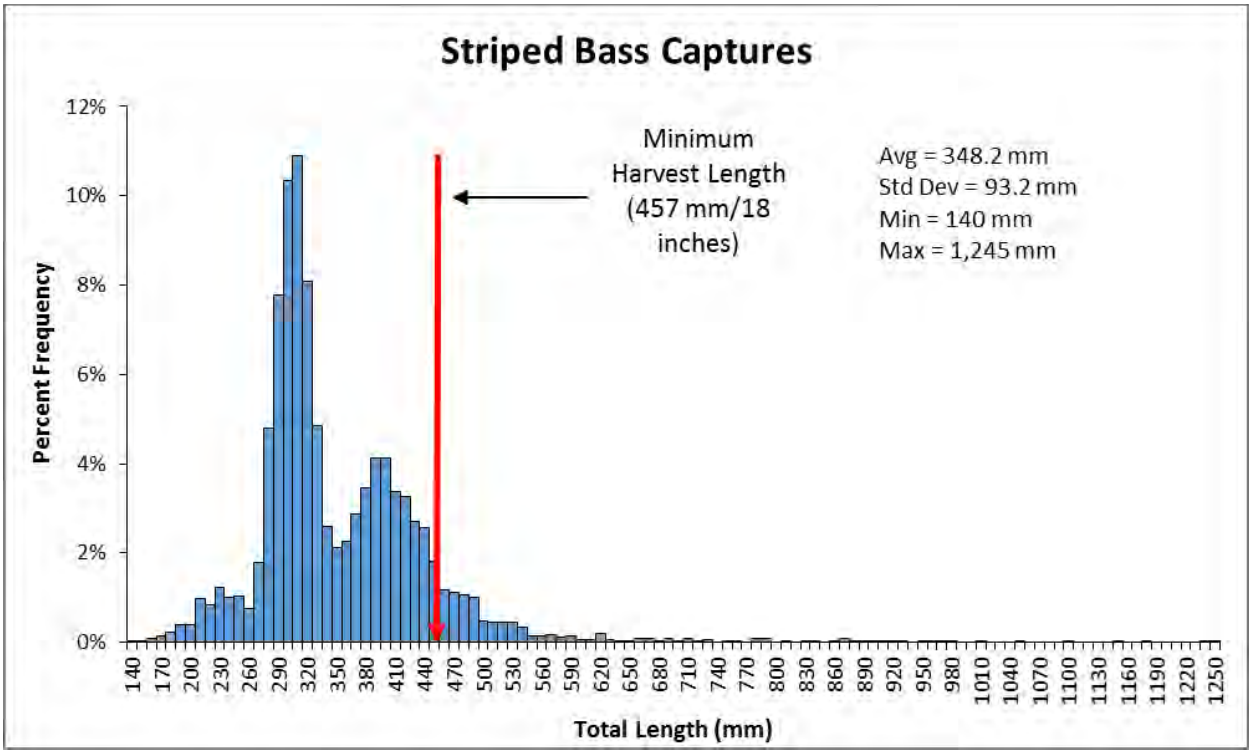


Figure 12. Histogram of Total Lengths of Striped Bass Caught in CCF and Relocated to Bethany Reservoir, 2017 Field Season. Minimum legal harvest length noted by red arrow.

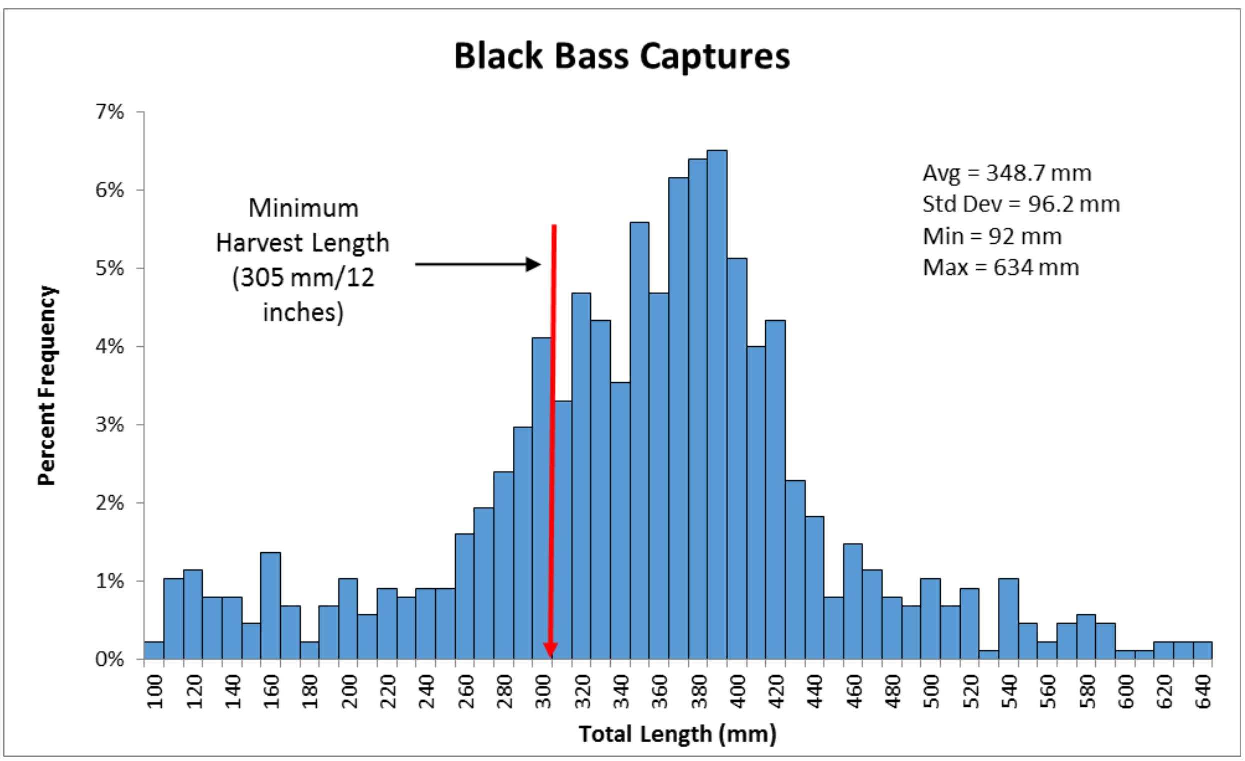


Figure 13. Histogram of Total Lengths of Black Bass Caught in CCF and Relocated to Bethany Reservoir, 2017 Field Season. Minimum legal harvest length noted by red arrow.

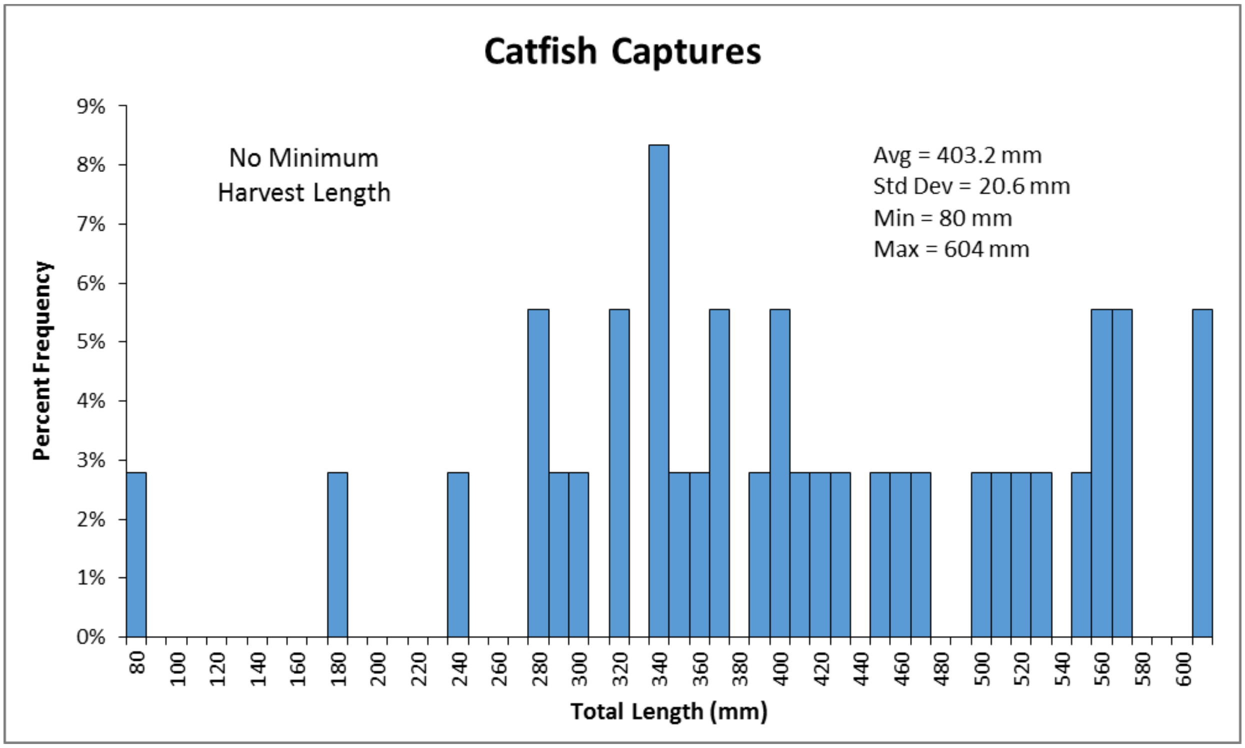


Figure 14. Histogram of Total Lengths of Catfish Caught in CCF and Relocated to Bethany Reservoir, 2017 Field Season.

Length-weight relationships based on FL and TL were calculated by species group from all fish for which both length and weight measurements were recorded (approximately 10 to 20% of individuals). Striped Bass relationships, based on 1,189 individuals, showed strong predictive value (FL: r^2 = 0.955; TL: r^2 = 0.953; Figure 15). Black bass relationships, based on 232 individuals, were also strong (FL: r^2 = 0.9435; TL: r^2 = 0.9444; Figure 16). Although based on only 17 individuals, catfish relationships were fairly strong (FL: r^2 = 0.93; TL: r^2 = 0.90; Figure 17).

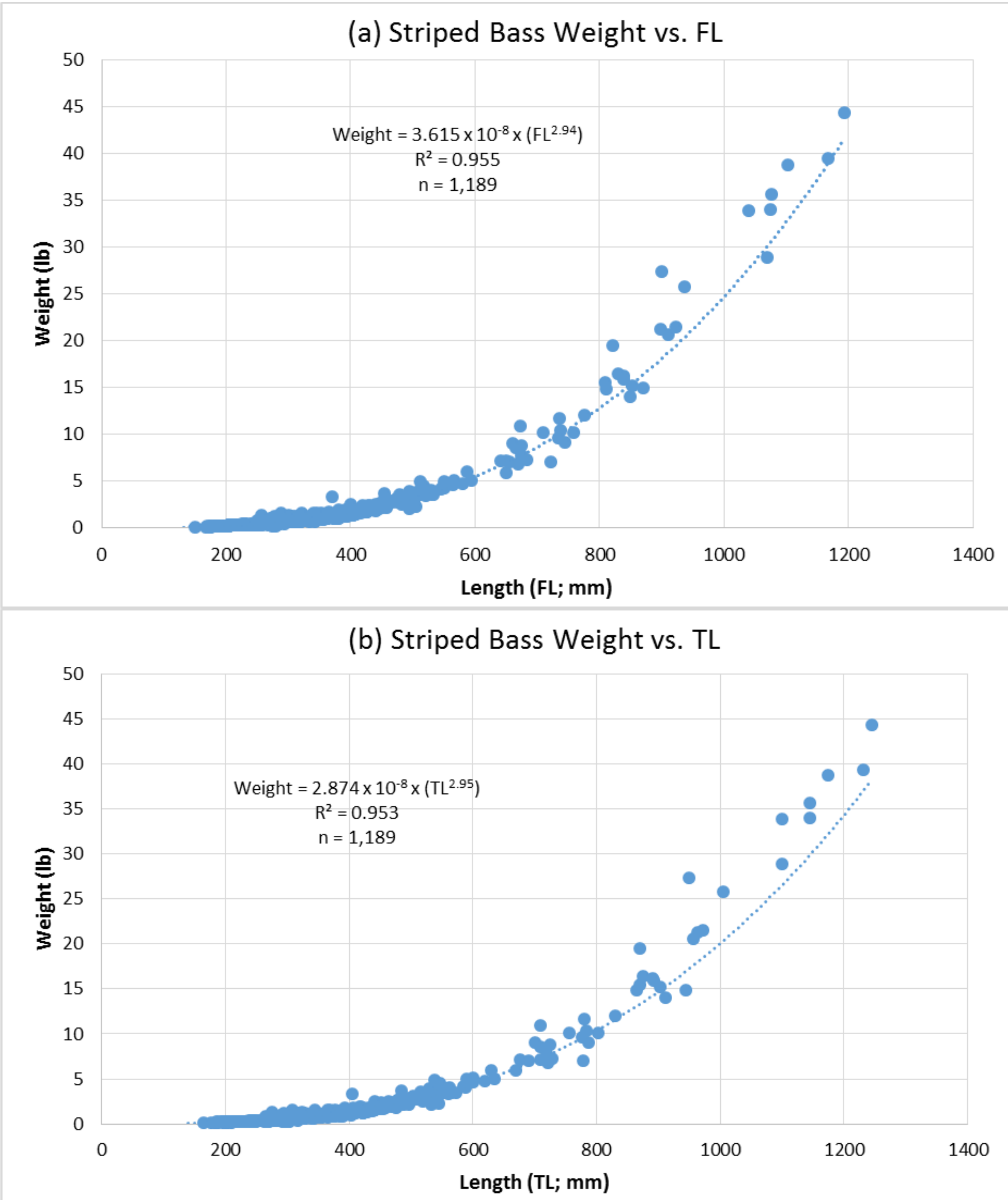


Figure 15. Weight versus (a) Fork Length and (b) Total Length of Striped Bass Caught in CCF and Released into Bethany Reservoir during the 2017 Field Season.

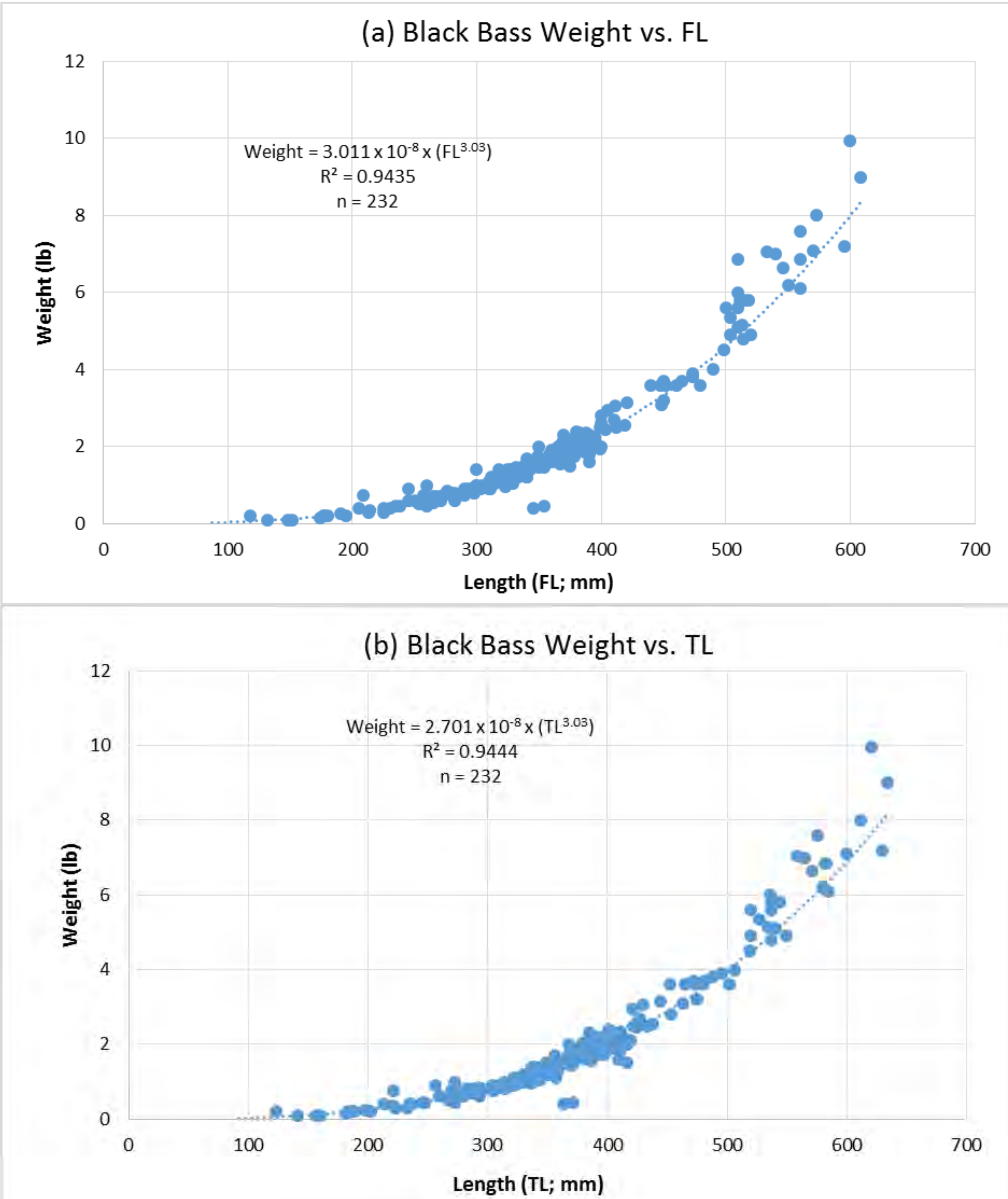
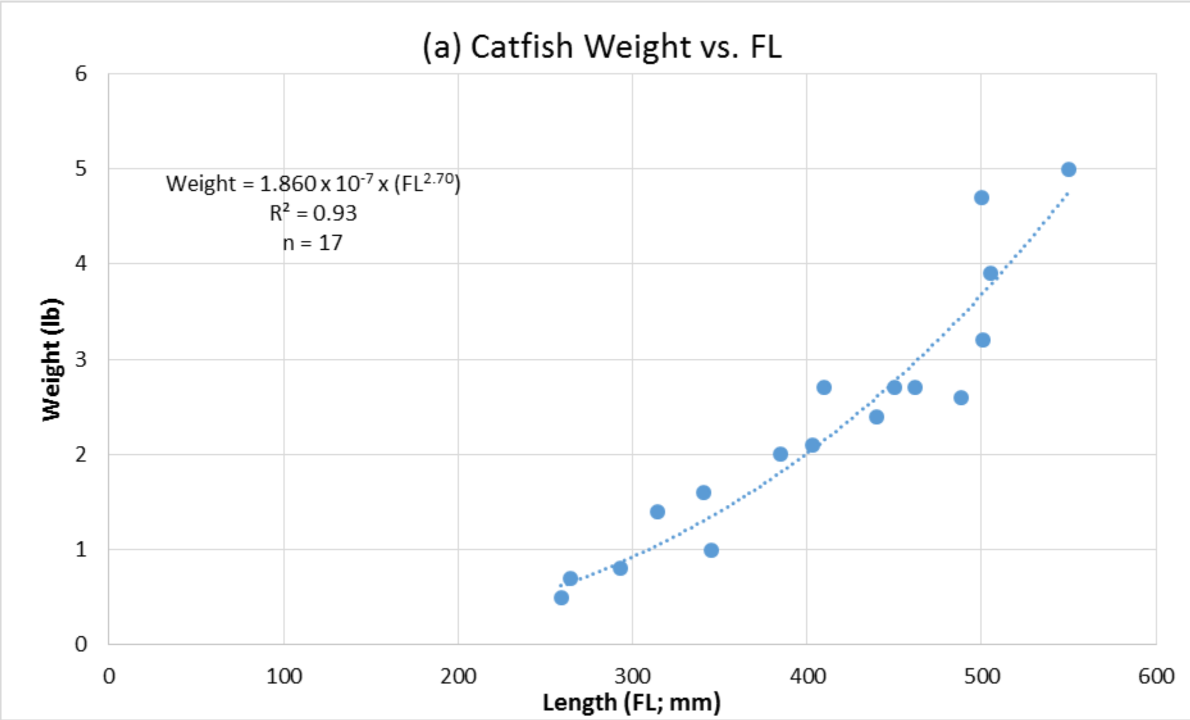


Figure 16. Weight versus (a) Fork Length and (b) Total Length of Black Bass Caught in CCF and Released into Bethany Reservoir during the 2017 Field Season.



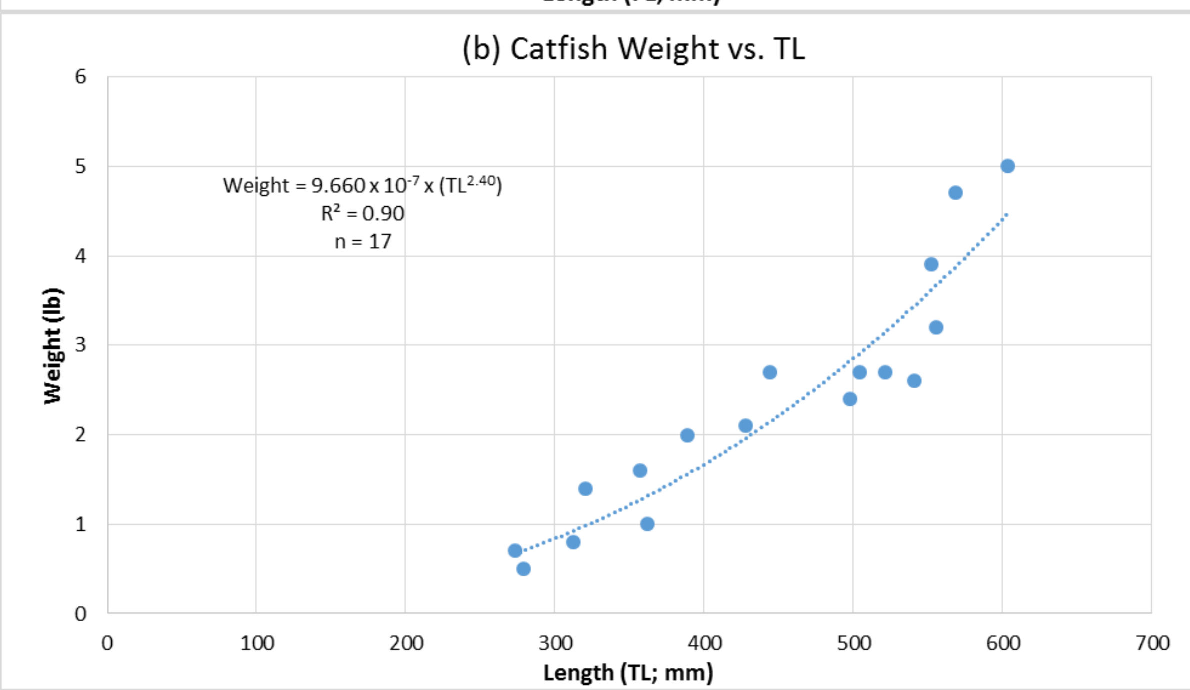


Figure 17. Weight versus (a) Fork Length and (b) Total Length of Catfish Caught in CCF and Released into Bethany Reservoir during the 2017 Field Season.

Length-weight relationships were applied to the 80 to 90% of fish for which weight was not taken in order to calculate total biomass removed from CCF. Because relationships with both TL and FL were available, the strongest relationship (highest r^2) was used preferentially (black bass: TL; Striped Bass: FL; catfish: FL). If the preferred length measurement was missing for a given species but the other length measurement was available, the alternative length and corresponding relationship was used. If neither was available, the fish was excluded. Only 10 total fish were excluded, which, based on total numbers of fish removed (6,151 fish), would represent a negligible proportion of total biomass removed.

A total of 7,190.7 lb (3.26 metric tons) of predatory fish biomass was removed from CCF during the 2017 field season (Table 7; Figure 18). A total of 5,804.9 lb (2.63 metric tons) of Striped Bass were removed, representing 81% of total biomass. The highest amount of predatory fish biomass was removed from the Scour Hole (3368.9 lb; 1.53 metric tons) and the lowest amount was removed from the Northwest quadrant open water transect (26.3 lb). The highest biomass of black bass biomass was removed from the Northwest quadrant (341.0 lb; 0.15 metric tons) and Southeast quadrant (322.5 lb; 0.15 metric tons) shorelines. The highest biomass of catfish was removed from the Southeast quadrant shoreline (31.8 lb).

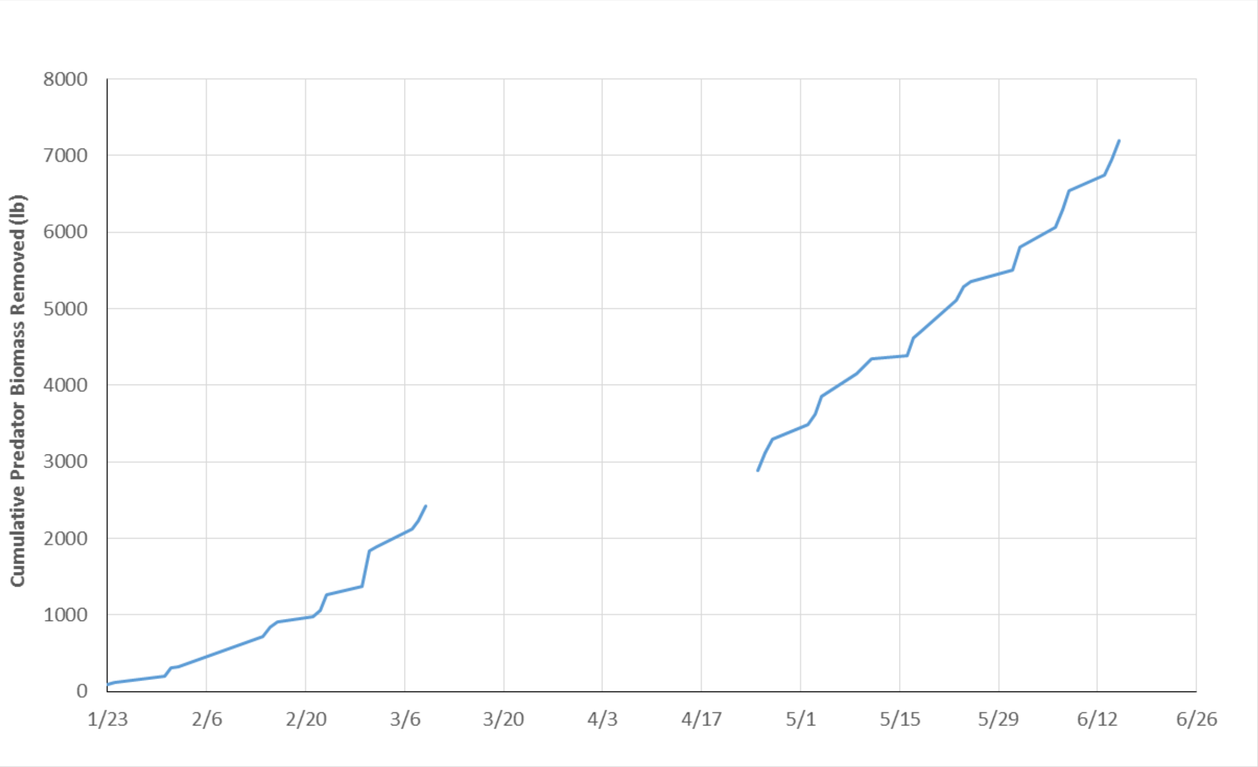


Figure 18. Cumulative biomass of predatory fishes removed from CCF during the 2017 field season. Gap indicates period during which electrofishing was not possible because of radial gate damage and repair. Note: No sampling occurred between 3/10/17 and 4/24/17

Table 7. Total biomass (lb) of predatory fish removed from CCF by species and location during the 2017 field season.

Sampling Section	Position	Striped Bass	Black Bass	Catfish	All Fish
Scour Hole	--	3246.3	103.1	19.5	3,368.9
Intake Canal	--	748.3	222.8	0	971.1
Southeast	Open Water	133.3	5.7	0	139.0
	Shoreline	371.3	322.5	31.8	725.6
Southwest	Open Water	129.9	0	0	129.9
	Shoreline	501.0	171.4	14.2	686.6
Northeast	Open Water	51.5	0.7	0	52.2
	Shoreline	410.4	147.5	1.5	559.4
Northwest	Open Water	26.3	0	0	26.3
	Shoreline	186.5	341.0	4.2	531.7
Total		5804.9	1,314.7	71.2	7,190.7

3.3 Environmental Influences on Predator Catch

3.3.1 CPUE Summary

CPUE is summarized herein in terms of number of fish per hour of electrofishing as well as number of fish per hour spent on the water; the latter provides perspective on the overall yield of fish given the logistics associated with electrofishing in particular sampling sections.

Overall patterns of CPUE by electrofishing hour and by hour on the water were generally similar. For the whole PRES period, the CPUE of total predators was greatest in the Scour Hole, a pattern largely driven by the CPUE of Striped Bass (Table 8). The next highest CPUE for total predators was in the Intake Canal and along shorelines . The open water sections had the lowest CPUE values. The CPUE for black bass was greatest in the Northwest quadrant shoreline and was also relatively high in the Southeast quadrant shoreline, which is also where the catfish CPUE was greatest (although much lower than the other two taxa).

Monthly total predator CPUE by electrofishing hour was greatest in the Scour Hole during January and April, and greatest in the Scour Hole by hour on the water in January and February (Table 8). Other sections with highest monthly total predator CPUE included the Intake Canal in February (by electrofishing hour), the Southeast quadrant shoreline in March (by electrofishing hour and hour on the water), and the Southwest quadrant shoreline (by electrofishing hour and hour on the water). These patterns generally were driven by Striped Bass. Total predator CPUE by both electrofishing hour and hour on the water were very similar for the Scour Hole and Intake Canal in June, again largely due to Striped Bass.

The monthly total predator CPUE across all sections increased from just over 12 fish per electrofishing hour in January to over 60 fish per hour in June, with a small decline to around 40 fish per hour in May (Table 8). This pattern of seasonal change in CPUE generally also was apparent from catch per hour on the water, and both black bass and Striped Bass CPUE exhibited similar seasonal patterns to the total predator CPUE. The low CPUE of catfish resulted in seasonal patterns not being clearly evident. The June CPUE in the Scour Hole was similar to that in May, at around 60 fish per electrofishing hour, whereas the June CPUE in the Intake Canal was appreciably greater than the May CPUE.

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Table 8. Total catch and mean CPUE by location and position using electrofishing duration and total time on water as effort, 2017 Field Season. Gray cells indicate locations with highest catch or CPUE within each month or overall.

Sampling Section	Position	Total Catch (Number of fish)				Mean CPUE ± SD (fish per electrofishing hr)				Mean CPUE ± SD (fish per hr on water)			
		Black Bass	Catfish	Striped Bass	Total	Black Bass	Catfish	Striped Bass	Total	Black Bass	Catfish	Striped Bass	Total
January													
Scour Hole	--	0	0	24	24	0.0 ± 0.0	0.0 ± 0.0	23.1 ± 7.2	23.1 ± 7.2	0 ± 0	0 ± 0	18.9 ± 7.2	18.9 ± 7.2
Intake Canal	--	2	0	15	17	1.5 ± 2.2	0.0 ± 0.0	12.6 ± 10.6	14.1 ± 12.8	1.6 ± 2.2	0 ± 0	11.6 ± 12.6	13.2 ± 14.8
Southeast	Open Water	0	0	7	7	0[1]	0[1]	3.7[1]	3.7[1]	0[1]	0[1]	2.5[1]	2.5[1]
	Shoreline	7	0	3	10	7.2[1]	0[1]	3.1[1]	10.2[1]	4.8[1]	0[1]	2.1[1]	6.9[1]
Southwest	Open Water	0	0	18	18	0[1]	0[1]	6.3[1]	6.3[1]	0[1]	0[1]	4.8[1]	4.8[1]
	Shoreline	8	1	10	19	6.0[1]	0.7[1]	7.5[1]	14.2[1]	2.1[1]	0.3[1]	2.6[1]	4.9[1]
Northeast	Open Water	0	0	1	1	0[1]	0[1]	0.5[1]	0.5[1]	0[1]	0[1]	0.5[1]	0.5[1]
	Shoreline	15	0	1	16	12.2[1]	0[1]	0.8[1]	13.0[1]	5.7[1]	0[1]	0.4[1]	6.1[1]
Northwest	Open Water	--	--	--	--	--	--	--	--	--	--	--	--
	Shoreline	--	--	--	--	--	--	--	--	--	--	--	--
Total		32	1	79	112	2.8 ± 4.3	0.1 ± 0.2	9.3 ± 9.4	12.2 ± 8.9	1.6 ± 2.2	0 ± 0.1	7.4 ± 8.8	9.0 ± 8.6

February													
Scour Hole	--	0	1	173	174	0 ± 0	0.2 ± 0.3	26.9 ± 17.2	27.1 ± 17.2	0 ± 0	0.1 ± 0.2	17.7 ± 11.7	17.8 ± 11.7
Intake Canal	--	38	0	28	66	6.6 ± 7.1	0 ± 0	23.9 ± 46.5	30.5 ± 43.1	4.2 ± 4.6	0 ± 0	6.3 ± 9.6	10.5 ± 8
Southeast	Open Water	2	0	34	36	0.6 ± 1.1	0 ± 0	8.7 ± 2.0	9.3 ± 1.0	0.4 ± 0.7	0 ± 0	6 ± 1.7	6.4 ± 1.1
	Shoreline	81	3	15	99	21.3 ± 9.2	0.9 ± 0.8	4.1 ± 3.6	26.3 ± 12.8	13.1 ± 5.9	0.5 ± 0.5	2.4 ± 2	15.9 ± 7.7
Southwest	Open Water	0	0	37	37	0 ± 0	0 ± 0	17.8 ± 12.5	17.8 ± 12.5	0 ± 0	0 ± 0	10.8 ± 6.8	10.8 ± 6.8
	Shoreline	14	3	34	51	6.4 ± 1.9	0.8 ± 0.8	9.4 ± 9.6	16.6 ± 8.3	3.8 ± 1.0	0.5 ± 0.5	5.7 ± 5.8	10.0 ± 5.0
Northeast	Open Water	0	0	14	14	0 ± 0	0 ± 0	4.6 ± 1.2	4.6 ± 1.2	0 ± 0	0 ± 0	2.7 ± 0.6	2.7 ± 0.6
	Shoreline	32	0	13	45	8.6 ± 3.2	0 ± 0	3.7 ± 2.0	12.3 ± 1.4	4.6 ± 0.8	0 ± 0	2.1 ± 1.3	6.7 ± 0.6
Northwest	Open Water	0	0	4	4	0 ± 0	0 ± 0	1.6 ± 0.0	1.6 ± 0.0	0 ± 0	0 ± 0	1.1 ± 0.1	1.1 ± 0.1
	Shoreline	35	2	17	54	10.4 ± 4.7	0.6 ± 0.6	4.5 ± 5.2	15.6 ± 6.8	7.1 ± 3.8	0.4 ± 0.4	2.8 ± 3.3	10.4 ± 4.6
Total		202	9	369	580	5.5 ± 7.5	0.2 ± 0.5	12.4 ± 20.6	18.1 ± 19.8	3.4 ± 4.7	0.1 ± 0.3	6.5 ± 8.0	10.0 ± 7.8

March													
Scour Hole	--	3	1	320	324	0.7 ± 0.9	0.2 ± 0.4	61.6 ± 23.0	62.5 ± 22.4	0.4 ± 0.5	0.1 ± 0.3	41.7 ± 18	42.2 ± 17.7
Intake Canal	--	23	0	68	91	6.3 ± 1.5	0 ± 0	17.0 ± 8.3	23.3 ± 7.7	4.8 ± 2.4	0 ± 0	11.6 ± 4.8	16.4 ± 4.8
Southeast	Open Water	2	0	21	23	1.3[1]	0[1]	13.9[1]	15.2[1]	1.2[1]	0[1]	12.2[1]	13.4[1]
	Shoreline	19	0	92	111	17.0[1]	0[1]	82.4[1]	99.5[1]	10.9[1]	0[1]	52.6[1]	63.4[1]
Southwest	Open Water	0	0	10	10	0 ± 0	0 ± 0	3.5 ± 1.8	3.5 ± 1.8	0 ± 0	0 ± 0	2.8 ± 1.3	2.8 ± 1.3
	Shoreline	16	1	17	34	8.7 ± 4.2	0.5 ± 0.8	9.5 ± 4.4	18.7 ± 0.6	4.6 ± 2.3	0.3 ± 0.4	4.9 ± 2.2	9.8 ± 0.4
Northeast	Open Water	0	0	7	7	0[1]	0[1]	4.7[1]	4.7[1]	0[1]	0[1]	4.4[1]	4.4[1]
	Shoreline	12	1	15	28	11.3[1]	0.9[1]	14.1[1]	26.3[1]	6.9[1]	0.6[1]	8.7[1]	16.2[1]
Northwest	Open Water	0	0	5	5	0 ± 0	0 ± 0	1.9 ± 2.7	1.9 ± 2.7	0 ± 0	0 ± 0	1.6 ± 2.3	1.6 ± 2.3
	Shoreline	36	0	16	52	16.8 ± 0.1	0 ± 0	7.5 ± 9.3	24.3 ± 9.3	9.0 ± 2.5	0 ± 0	3.3 ± 3.9	12.4 ± 1.4
Total		111	3	571	685	5.4 ± 6.2	0.1 ± 0.3	23.7 ± 27.6	29.3 ± 28.2	3.3 ± 3.8	0.1 ± 0.2	15.8 ± 18.7	19.3 ± 18.9

April													
Scour Hole	--	4	0	247	251	2.9 ± 1.7	0 ± 0	188.2 ± 22.1	191.2 ± 23.8	1.3 ± 0.9	0 ± 0	80.5 ± 22.6	81.8 ± 23.5
Intake Canal	--	21	0	73	94	8.6 ± 1.4	0 ± 0	30.0 ± 4.1	38.7 ± 5.6	5.7 ± 1.4	0 ± 0	19.8 ± 4.5	25.6 ± 5.9
Southeast	Open Water	0	0	15	15	0[1]	0[1]	9.7[1]	9.7[1]	0[1]	0[1]	8.7[1]	8.7[1]
	Shoreline	15	0	70	85	13.5[1]	0[1]	63.1[1]	76.7[1]	7.5[1]	0[1]	35.0[1]	42.5[1]
Southwest	Open Water	0	0	19	19	0[1]	0[1]	16.7[1]	16.7[1]	0[1]	0[1]	9.7[1]	9.7[1]
	Shoreline	23	0	15	38	28.7[1]	0[1]	18.7[1]	47.4[1]	17.7[1]	0[1]	11.5[1]	29.2[1]
Northeast	Open Water	1	0	8	9	0.6[1]	0[1]	5.1[1]	5.7[1]	0.6[1]	0[1]	5.1[1]	5.7[1]
	Shoreline	14	0	168	182	11.0[1]	0[1]	132.4[1]	143.4[1]	7.5[1]	0[1]	90.0[1]	97.5[1]
Northwest	Open Water	0	0	3	3	0[1]	0[1]	2.5[1]	2.5[1]	0[1]	0[1]	1.6[1]	1.6[1]
	Shoreline	29	1	50	80	26.1[1]	0.9[1]	45.0[1]	72.0[1]	17.6[1]	0.6[1]	30.3[1]	48.5[1]
Total		107	1	668	776	8.6 ± 10.0	0.1 ± 0.3	60.8 ± 69.5	69.5 ± 69.4	5.4 ± 6.4	0.1 ± 0.2	32.7 ± 33.1	38.2 ± 33.7

May													
Scour Hole	--	9	4	699	712	0.7 ± 1.0	0.3 ± 1.0	55.8 ± 26.4	56.9 ± 26.3	0.5 ± 0.6	0.2 ± 0.6	41.1 ± 19.0	41.8 ± 18.8
Intake Canal	--	37	0	143	180	9.4 ± 7.7	0 ± 0	31.6 ± 30.1	41.1 ± 30.0	5.9 ± 4.3	0 ± 0	21.0 ± 18.2	27 ± 18.4
Southeast	Open Water	0	0	46	46	0 ± 0	0 ± 0	11.6 ± 8.1	11.6 ± 8.1	0 ± 0	0 ± 0	9.1 ± 6.4	9.1 ± 6.4
	Shoreline	59	9	160	228	14.4 ± 3.0	2.3 ± 1.8	37.1 ± 16.8	53.8 ± 12.8	10.1 ± 3.3	1.6 ± 1.5	26.5 ± 12.4	38.2 ± 12.6
Southwest	Open Water	0	0	15	15	0 ± 0	0 ± 0	5.4 ± 3.9	5.4 ± 3.9	0 ± 0	0 ± 0	4.1 ± 2.7	4.1 ± 2.7
	Shoreline	26	2	201	229	8.9 ± 0.3	0.7 ± 1.0	70.1 ± 78.3	79.7 ± 77.6	7.0 ± 0.5	0.6 ± 0.8	52.2 ± 56.0	59.8 ± 54.7
Northeast	Open Water	0	0	34	34	0 ± 0	0 ± 0	6.1 ± 4.1	6.1 ± 4.1	0 ± 0	0 ± 0	5.4 ± 3.7	5.4 ± 3.7
	Shoreline	28	1	245	274	5.6 ± 2.5	0.2 ± 0.4	50.1 ± 17.7	55.9 ± 16.0	4.5 ± 2.3	0.2 ± 0.4	37.8 ± 8.0	42.6 ± 7.2
Northwest	Open Water	0	0	27	227	0 ± 0	0 ± 0	4.9 ± 3.2	4.9 ± 3.2	0 ± 0	0 ± 0	3.9 ± 2.3	3.9 ± 2.3
	Shoreline	132	0	142	274	23.8 ± 14.2	0 ± 0	24.3 ± 25.2	48.1 ± 36.4	19.0± 11.9	0 ± 0	18.8 ± 20.8	37.7 ± 30.5
Total		291	16	1,712	2,019	6.0 ± 8.9	0.3 ± 0.9	33.1 ± 30.6	39.4 ± 32.6	4.4 ± 6.9	0.2 ± 0.7	24.3 ± 21.9	29.0 ± 23.7

June													
Scour Hole	--	68	6	1,211	1,285	3.5 ± 7.7	0.3 ± 1.1	60.1 ± 29.5	63.9 ± 26.8	2.4 ± 5.2	0.2 ± 0.7	45.8 ± 20.3	48.4 ± 17.8
Intake Canal	--	68	0	626	694	6.3 ± 8.1	0 ± 0	57.2 ± 48.6	63.4 ± 44.4	4.9 ± 6.3	0 ± 0	44.9 ± 36.6	49.8 ± 33.1
Southeast	Open Water	--	--	--	--	--	--	--	--	--	--	--	--
	Shoreline	--	--	--	--	--	--	--	--	--	--	--	--
Southwest	Open Water	--	--	--	--	--	--	--	--	--	--	--	--
	Shoreline	--	--	--	--	--	--	--	--	--	--	--	--
Northeast	Open Water	--	--	--	--	--	--	--	--	--	--	--	--
	Shoreline	--	--	--	--	--	--	--	--	--	--	--	--
Northwest	Open Water	--	--	--	--	--	--	--	--	--	--	--	--
	Shoreline	--	--	--	--	--	--	--	--	--	--	--	--
Total		136	6	1,837	1,979	4.9 ± 7.9	0.2 ± 0.7	58.6 ± 39.5	63.7 ± 36.0	3.7 ± 5.8	0.1 ± 0.5	45.3 ± 29	49.1 ± 26.1

2017 Total													
Scour Hole	--	84	12	2,674	2,770	1.8 ± 4.9	0.2 ± 0.8	59.5 ± 41.5	61.5 ± 41.4	1.2 ± 3.3	0.2 ± 0.5	40.7 ± 22.2	42.1 ± 21.8
Intake Canal	--	189	0	953	1,142	6.8 ± 6.8	0 ± 0	38.3 ± 41.0	45.0 ± 38.6	4.8 ± 4.8	0 ± 0	27.1 ± 29.6	31.9 ± 28
Southeast	Open Water	4	0	123	127	0.3 ± 0.7	0 ± 0	9.8 ± 5.1	10.1 ± 5.1	0.3 ± 0.5	0 ± 0	7.6 ± 4.4	7.9 ± 4.4
	Shoreline	181	12	340	533	15.9 ± 6.5	1.2 ± 1.5	30.9 ± 29.2	48.0 ± 28.4	10.3 ± 4.3	0.8 ± 1.2	20.3 ± 18.8	31.4 ± 19.0
Southwest	Open Water	0	0	99	99	0 ± 0	0 ± 0	9.6 ± 8.3	9.6 ± 8.3	0 ± 0	0 ± 0	6.2 ± 4.5	6.2 ± 4.5
	Shoreline	87	7	277	371	9.9 ± 7.4	0.6 ± 0.6	23.7 ± 38.7	34.3 ± 39.2	6.1 ± 4.7	0.4 ± 0.4	16.2 ± 28.7	22.6 ± 29.5
Northeast	Open Water	1	0	64	65	0.1 ± 0.2	0.0 ± 0.0	4.8 ± 2.9	4.9 ± 2.9	0.1 ± 0.2	0 ± 0	4.0 ± 2.8	4.0 ± 2.8
	Shoreline	101	2	442	545	8.3 ± 3.3	0.2 ± 0.4	35.8 ± 42.0	44.3 ± 41.5	5.2 ± 1.8	0.1 ± 0.3	25.7 ± 28.9	31.0 ± 29.3
Northwest	Open Water	0	0	39	39	0 ± 0	0 ± 0	3.2 ± 2.7	3.2 ± 2.7	0 ± 0	0 ± 0	2.5 ± 2.1	2.5 ± 2.1
	Shoreline	232	3	225	460	18.6 ± 10.6	0.3 ± 0.5	17.1 ± 20.2	36.0 ± 29.0	13.3 ± 9.2	0.2 ± 0.3	12 ± 15.8	25.5 ± 23.5
Total		879	36	5,236	6,151	5.6 ± 7.9	0.2 ± 0.7	32.8 ± 38.3	38.6 ± 38.3	3.8 ± 5.6	0.1 ± 0.5	22.8 ± 25.2	26.7 ± 25.4

[1] Standard deviation could not be calculated with n = 1

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3.3.2 Statistical Analysis

3.3.2.1 Effort as Hours Electrofishing

The statistical analysis of environmental influences on predator catch per electrofishing hour found that the CCF sampling section was the most important predictor of catch in models for total predators, Striped Bass, and black bass, with other variables also being important for total predators and Striped Bass. In all three sets of analyses, addition of environmental predictors to the models improved the prediction of predator catch relative to an intercept-only model with no predictors (i.e., the full models had AIC_c more than 3 units below those of the intercept-only models). The remainder of this section describes results for total predators, Striped Bass, and black bass separately.

3.3.2.1.1 Total Predators

The predictors of highest importance for the analysis of total predator count were sampling section, water temperature, boat, and turbidity (Table 9). Predicted catches of total predators were significantly greater in the Scour Hole than in the Intake Canal, with all four shoreline sections intermediate and not significantly different from the Scour Hole or Intake Canal (Figure 19). That the predicted predator count in the Intake Canal was lower relative to the shoreline sections is nonintuitive because mean CPUE was calculated as higher in the Intake Canal than in shoreline sections (Table 8). It is likely a result of the application of the effort offset combined with an unequal mean effort (1.17 h of electrofishing in the Intake Canal compared to 1.65 to 2.02 h of electrofishing in other locations; Table 5). The statistical result warrants further exploration. Regardless, these statistical outputs indicate that the Intake Canal, along with the Scour Hole and shoreline sections had significantly greater predicted total predator catch than the open water sections.

Predicted total predator catch also increased with increasing water temperature and decreasing turbidity, and the DWR boat had a significantly greater predicted total predator catch than the FISHBIO-2 boat, with the FISHBIO boat intermediate (Figure 19). The relationship between predicted predator catch in each sampling section and CCF radial gate flow and Banks pumping rate had little statistical importance in the modeling (Table 9).

Table 9. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Total Predator Catch per Electrofishing Hour in CCF, January-June 2017 (Full Model Pseudo $r^2 = 0.69$).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Section - NE.openwater	**-1.783**	**-2.271**	**-1.295**	**1.00**
Section - NE.shoreline	**0.429**	**0.015**	**0.844**	**1.00**
Section - NW.openwater	**-2.089**	**-2.617**	**-1.561**	**1.00**
Section - NW.shoreline	**0.299**	**-0.119**	**0.717**	**1.00**
Section - Scour Hole	**0.655**	**0.382**	**0.927**	**1.00**
Section - SE.openwater	**-0.797**	**-1.258**	**-0.337**	**1.00**
Section - SE.shoreline	**0.546**	**0.130**	**0.961**	**1.00**
Section - SW.openwater	**-0.873**	**-1.356**	**-0.390**	**1.00**
Section - SW.shoreline	**0.157**	**-0.279**	**0.594**	**1.00**
Water Temperature	**0.100**	**0.055**	**0.146**	**1.00**
Boat - FISHBIO	**-0.199**	**-0.417**	**0.018**	**1.00**
Boat - FISHBIO-2	**-0.685**	**-1.036**	**-0.334**	**1.00**
Turbidity	**-0.007**	**-0.012**	**-0.001**	**0.80**
Gate flow	0.000	0.000	0.000	0.49
Wind Speed	0.010	-0.013	0.033	0.30
Banks Pumping Rate	0.000	0.000	0.000	0.26
Time from sunrise	-0.009	-0.101	0.083	0.22

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

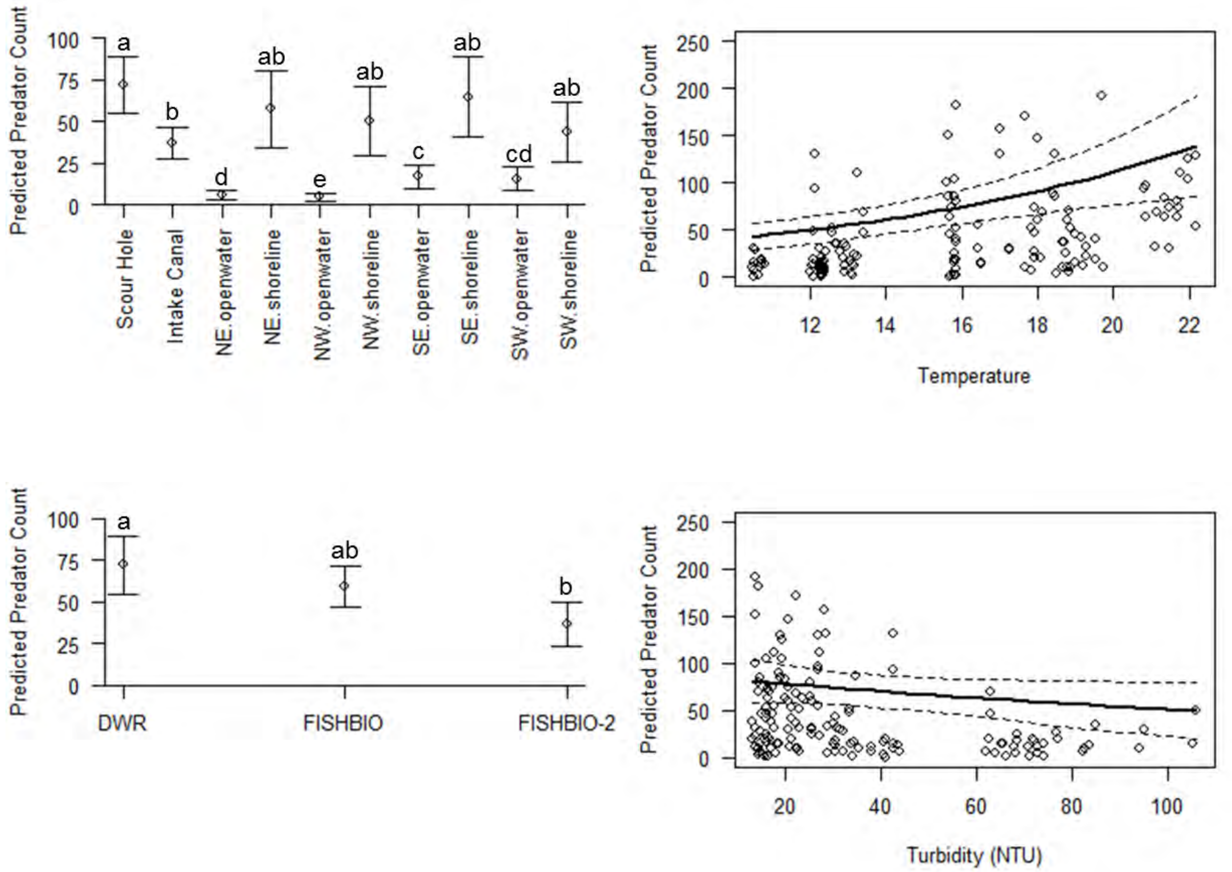

Figure 19. Predicted Total Predator Count (with 95% Confidence Interval) per Electrofishing Hour as a Function of Important Environmental Variables from Generalized Linear Modeling of CCF Catch Data, January-June 2017. Letters Correspond to Groups with Nonoverlapping Confidence Intervals.

3.3.2.1.2 Striped Bass

The statistical relationships between environmental predictors and Striped Bass catch generally were similar to those for total predators (Table 10). Sampling section was the most important predictor, although the relative relationships differed somewhat from those for total predators in that predicted open water catches in the Southeast and Southwest quadrants were not significantly different than all of the shoreline sections and the Intake Canal, and the Scour Hole catch was significantly greater than all other sections except the Northeast, Southeast, and Southwest quadrant shorelines (Figure 20). Otherwise, the relationships to environmental predictors were similar to those for total predators: a positive relationship between catch and temperature, a negative relationship between catch and turbidity, and the DWR boat had significantly greater predicted catch than the FISHBIO-2 boat. As with the total predator analysis, there was no significant relationship between predicted Striped Bass catch and either CCF radial gate flow or Banks pumping rate (Table 10). Compared to the mean CPUE values presented in Table 8, some of these results appear nonintuitive. As discussed in Section 3.3.2.1.1 for total predators, these nonintuitive results are likely a result of the offset data transformation and the shorter electrofishing duration in the Intake Canal relative to other locations (Table 5).

Table 10. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Striped Bass Catch per Electrofishing Hour in CCF, January-June 2017 (Full Model Pseudo r^2 = 0.61).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Section - NE.openwater	**-1.566**	**-2.169**	**-0.962**	**1.00**
Section - NE.shoreline	**0.369**	**-0.171**	**0.908**	**1.00**
Section - NW.openwater	**-1.780**	**-2.418**	**-1.142**	**1.00**
Section - NW.shoreline	**-0.159**	**-0.714**	**0.396**	**1.00**
Section - Scour Hole	**0.919**	**0.559**	**1.278**	**1.00**
Section - SE.openwater	**-0.404**	**-0.990**	**0.183**	**1.00**
Section - SE.shoreline	**0.227**	**-0.315**	**0.770**	**1.00**
Section - SW.openwater	**-0.439**	**-1.048**	**0.170**	**1.00**
Section - SW.shoreline	**0.136**	**-0.433**	**0.705**	**1.00**
Water Temperature	**0.104**	**0.047**	**0.161**	**0.99**
Boat - FISHBIO	**-0.361**	**-0.639**	**-0.082**	**0.99**
Boat - FISHBIO-2	**-0.929**	**-1.380**	**-0.479**	**0.99**
Turbidity	**-0.012**	**-0.019**	**-0.004**	**0.97**
Gate flow	0.000	0.000	0.000	0.59
Wind Speed	0.014	-0.015	0.043	0.31
Banks Pumping Rate	0.000	0.000	0.000	0.24
Time from sunrise	0.003	-0.114	0.120	0.22

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

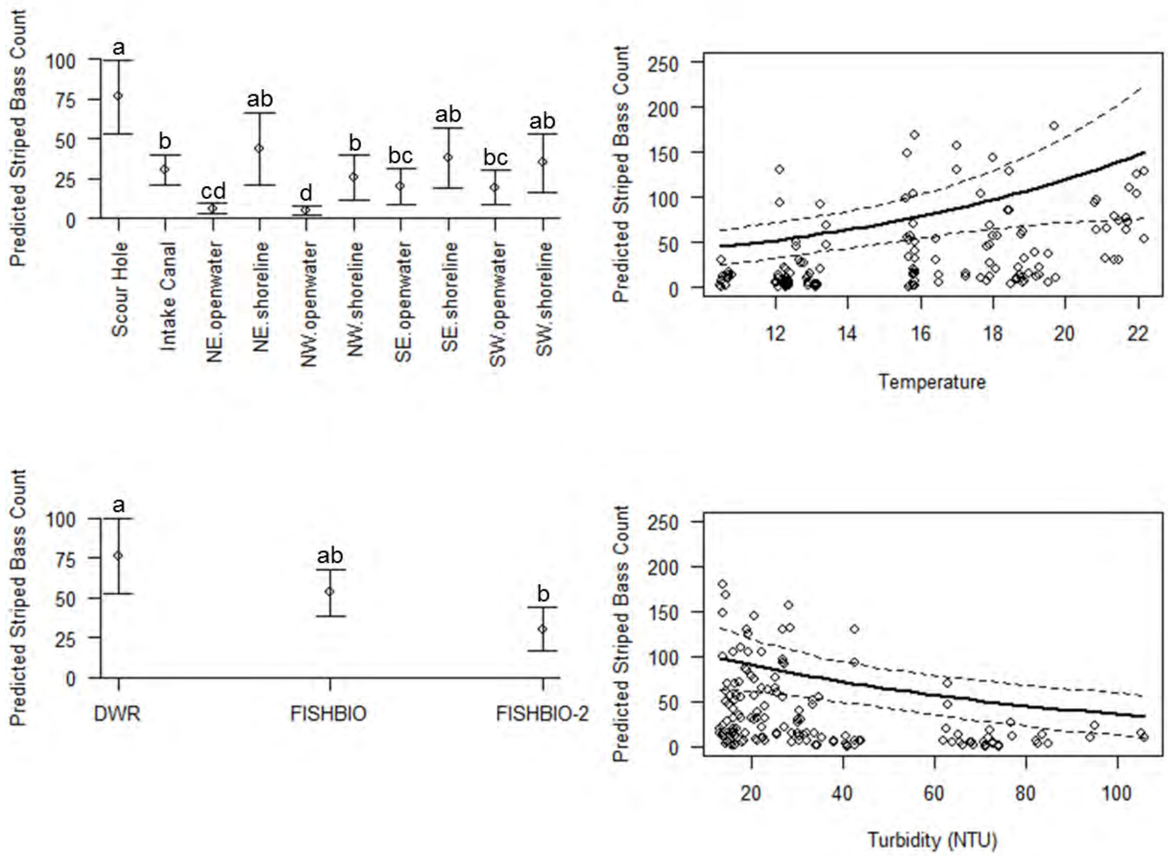

Figure 20. Predicted Striped Bass Count (with 95% Confidence Interval) per Electrofishing Hour as a Function of Important Environmental Variables from Generalized Linear Modeling of CCF Catch Data, January-June 2017. Letters Correspond to Groups with Nonoverlapping Confidence Intervals.

3.3.2.1.3 Black Bass

The statistical analysis of black bass catch as a function of environmental variables found only sampling section to be an important predictor (Table 11). Predicted catches in the shoreline sections and in the Intake Canal were significantly greater than in the Scour Hole and open water sections (Figure 21). As with total predators and Striped Bass, there was no significant relationship to either CCF radial gate flow or Banks pumping rate (Table 11).

Table 11. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Black Bass Catch per Electrofishing Hour in CCF, January-June 2017 (Full Model Pseudo r^2 = 0.61).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Section - NE.openwater	**-4.164**	**-6.314**	**-2.015**	**1.00**
Section - NE.shoreline	**0.249**	**-0.576**	**1.074**	**1.00**
Section - NW.openwater	**-35.645**	**-2.34E+07**	**2.34E+07**	**1.00**
Section - NW.shoreline	**0.988**	**0.167**	**1.809**	**1.00**
Section - Scour Hole	**-1.441**	**-2.103**	**-0.778**	**1.00**
Section - SE.openwater	**-2.980**	**-4.318**	**-1.641**	**1.00**
Section - SE.shoreline	**1.028**	**0.210**	**1.847**	**1.00**
Section - SW.openwater	**-35.487**	**-2.47E+07**	**2.47E+07**	**1.00**
Section - SW.shoreline	**0.372**	**-0.463**	**1.206**	**1.00**
Boat - FISHBIO	0.711	0.213	1.208	0.79
Boat - FISHBIO-2	0.271	-0.513	1.056	0.79
Wind Speed	-0.047	-0.095	0.001	0.61
Turbidity	-0.009	-0.021	0.003	0.48
Gate Flow	0.000	0.000	0.000	0.48
Water Temperature	0.047	-0.039	0.134	0.35
Pumping Rate	0.000	0.000	0.000	0.24
Time from sunrise	-0.007	-0.221	0.208	0.23

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

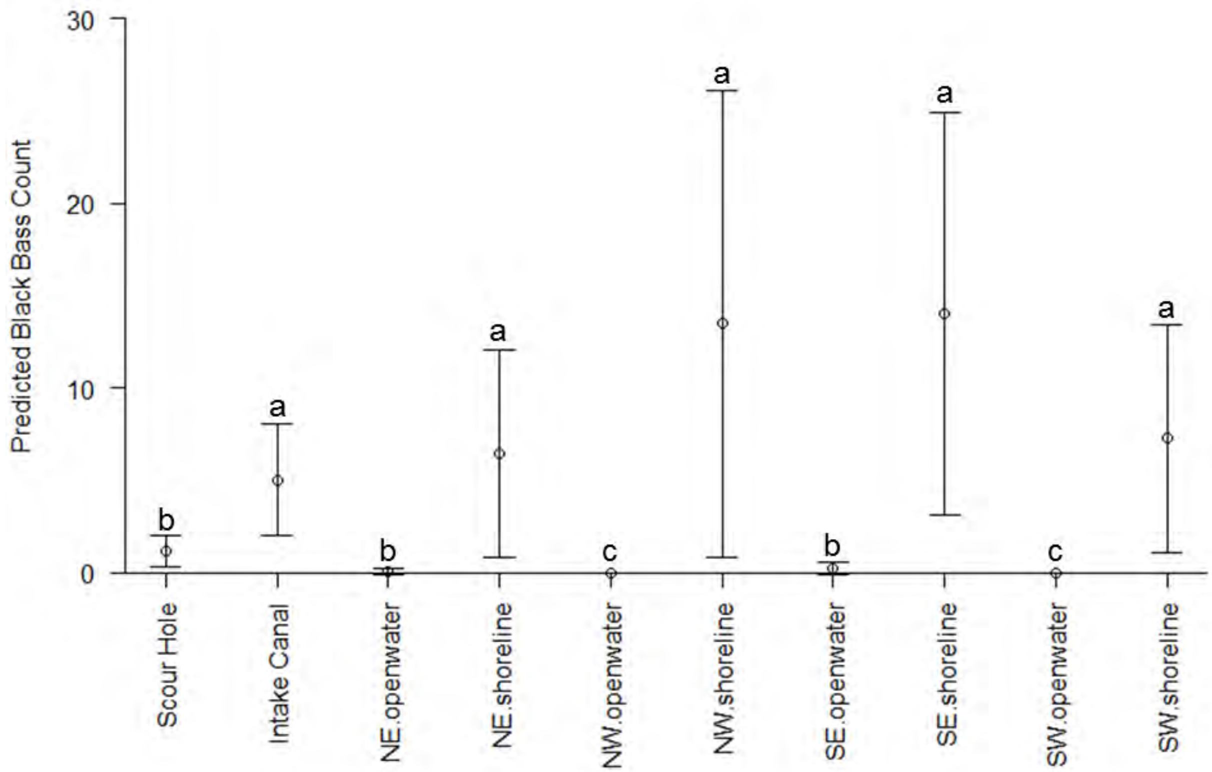

Figure 21. Predicted Black Bass Count (with 95% Confidence Interval) per Electrofishing Hour as a Function of Section, the Only Important Environmental Variable from Generalized Linear Modeling of CCF Catch Data, January-June 2017. Letters Correspond to Groups with Nonoverlapping Confidence Intervals.

3.3.2.2 Effort as Hours on the Water

The statistical analyses based on effort as hours on the water found essentially the same results as the analyses based on electrofishing hours, for total predators (Table 12, Figure 22), Striped Bass (Table 13, Figure 23), and black bass (Table 14, Figure 24).

Table 12. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Total Predator Catch per Hour on the Water in CCF, January-June 2017 (Full Model Pseudo r^2 = 0.70).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Section - NE.openwater	**-1.735**	**-2.217**	**-1.252**	**1.00**
Section - NE.shoreline	**0.368**	**-0.042**	**0.778**	**1.00**
Section - NW.openwater	**-2.072**	**-2.596**	**-1.548**	**1.00**
Section - NW.shoreline	**0.260**	**-0.153**	**0.673**	**1.00**
Section - Scour Hole	**0.609**	**0.340**	**0.878**	**1.00**
Section - SE.openwater	**-0.764**	**-1.219**	**-0.310**	**1.00**
Section - SE.shoreline	**0.481**	**0.070**	**0.891**	**1.00**
Section - SW.openwater	**-0.912**	**-1.391**	**-0.433**	**1.00**
Section - SW.shoreline	**0.053**	**-0.379**	**0.485**	**1.00**
Water Temperature	**0.112**	**0.067**	**0.157**	**1.00**
Boat - FISHBIO	**-0.220**	**-0.436**	**-0.005**	**0.99**
Boat - FISHBIO-2	**-0.689**	**-1.036**	**-0.342**	**0.99**
Turbidity	**-0.007**	**-0.013**	**-0.001**	**0.84**
Gate flow	0.000	0.000	0.000	0.48
Wind Speed	0.009	-0.014	0.031	0.27
Banks Pumping Rate	0.000	0.000	0.000	0.25
Time from sunrise	-0.007	-0.097	0.084	0.22

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

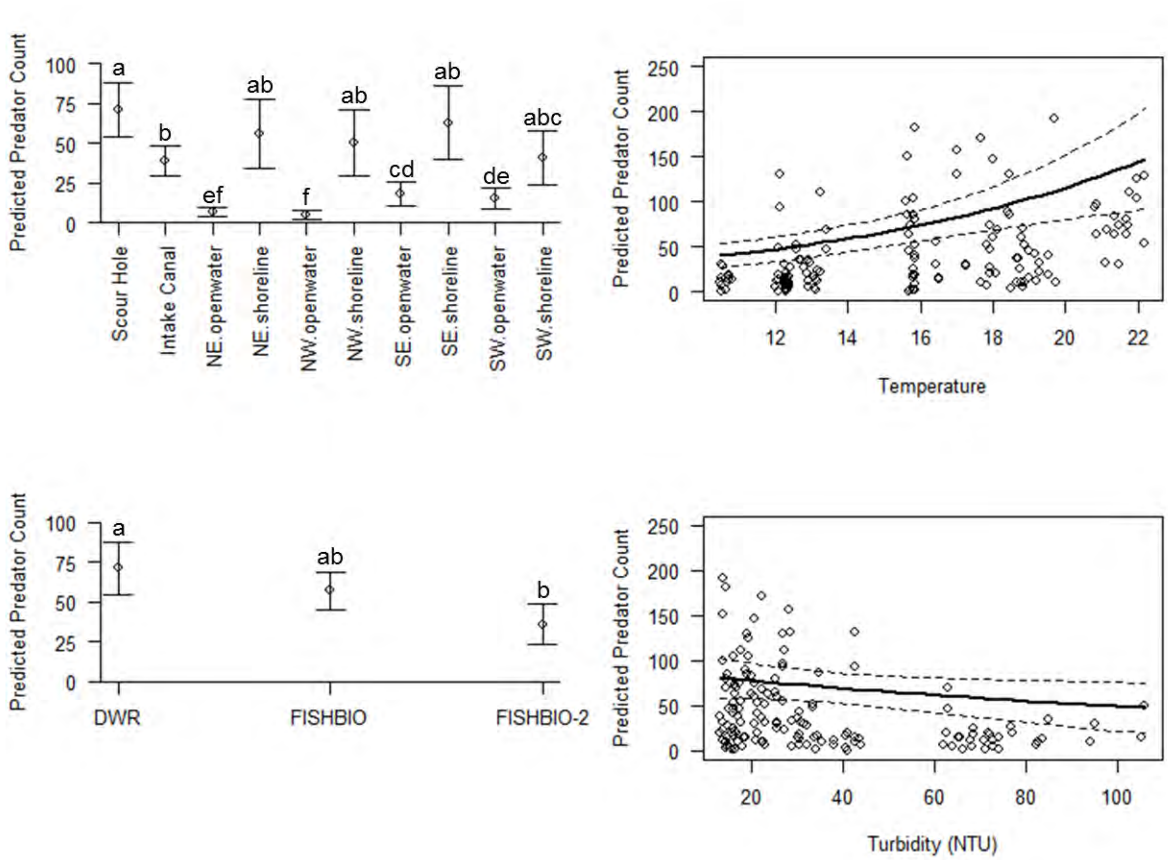

Figure 22. Predicted Total Predator Count (with 95% Confidence Interval) per Hour on the Water as a Function of Important Environmental Variables from Generalized Linear Modeling of CCF Catch Data, January-June 2017. Letters Correspond to Groups with Nonoverlapping Confidence Intervals.

Table 13. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Striped Bass Catch per Hour on the Water in CCF, January-June 2017 (Full Model Pseudo r^2 = 0.62).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Section - NE.openwater	**-1.530**	**-2.125**	**-0.935**	**1.00**
Section - NE.shoreline	**0.322**	**-0.211**	**0.856**	**1.00**
Section - NW.openwater	**-1.770**	**-2.401**	**-1.138**	**1.00**
Section - NW.shoreline	**-0.213**	**-0.763**	**0.336**	**1.00**
Section - Scour Hole	**0.871**	**0.517**	**1.225**	**1.00**
Section - SE.openwater	**-0.381**	**-0.957**	**0.196**	**1.00**
Section - SE.shoreline	**0.156**	**-0.383**	**0.695**	**1.00**
Section - SW.openwater	**-0.485**	**-1.088**	**0.118**	**1.00**
Section - SW.shoreline	**0.026**	**-0.542**	**0.593**	**1.00**
Water Temperature	**0.114**	**0.058**	**0.171**	**1.00**
Boat - FISHBIO	**-0.380**	**-0.657**	**-0.103**	**1.00**
Boat - FISHBIO-2	**-0.931**	**-1.379**	**-0.484**	**1.00**
Turbidity	**-0.012**	**-0.020**	**-0.005**	**0.97**
Gate flow	0.000	0.000	0.000	0.59
Wind Speed	0.012	-0.016	0.041	0.29
Banks Pumping Rate	0.000	0.000	0.000	0.24
Time from sunrise	0.009	-0.107	0.125	0.22

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

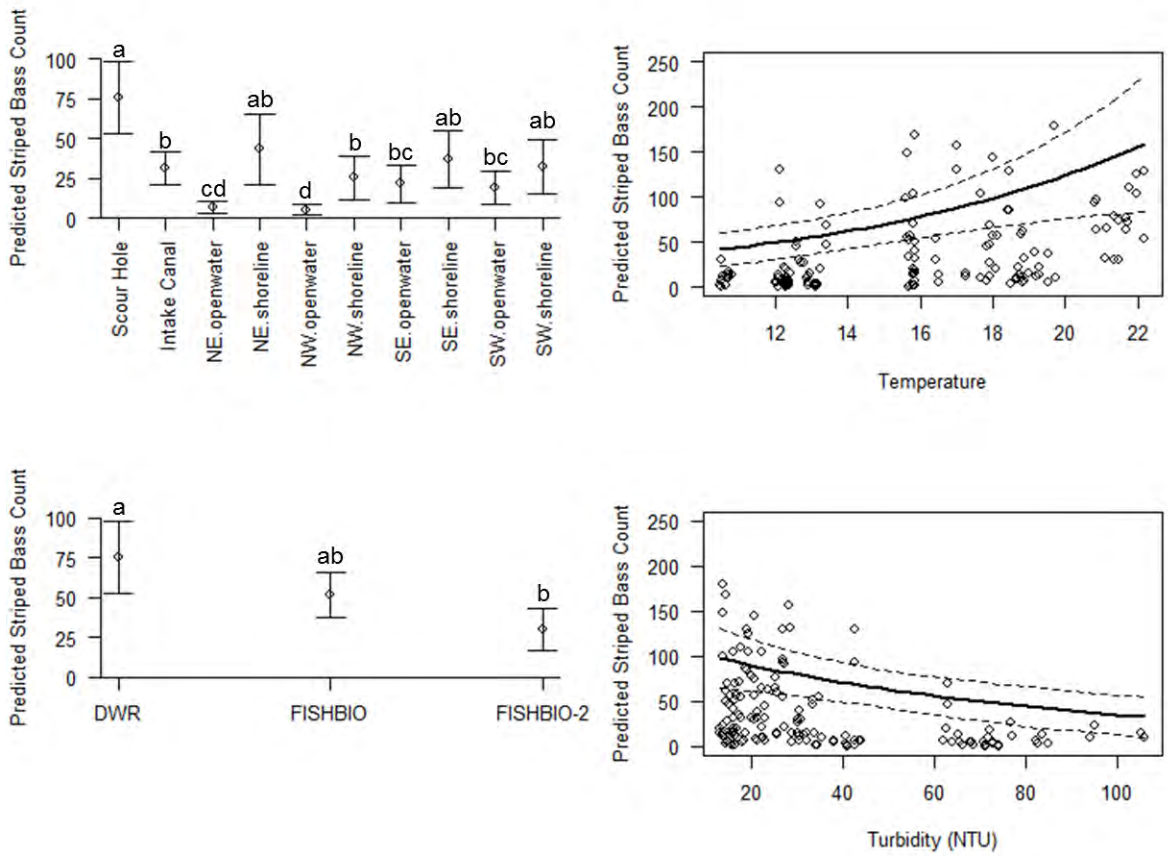

Figure 23. Predicted Striped Bass Count (with 95% Confidence Interval) per Hour on the Water as a Function of Important Environmental Variables from Generalized Linear Modeling of CCF Catch Data, January-June 2017. Letters Correspond to Groups with Nonoverlapping Confidence Intervals.

Table 14. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Black Bass Catch per Hour on the Water in CCF, January-June 2017 (Full Model Pseudo $r^2 = 0.61$).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Section - NE.openwater	**-4.111**	**-6.249**	**-1.973**	**1.00**
Section - NE.shoreline	**0.159**	**-0.660**	**0.977**	**1.00**
Section - NW.openwater	**-35.411**	**-2.13E+07**	**2.13E+07**	**1.00**
Section - NW.shoreline	**0.965**	**0.151**	**1.779**	**1.00**
Section - Scour Hole	**-1.502**	**-2.159**	**-0.845**	**1.00**
Section - SE.openwater	**-2.948**	**-4.276**	**-1.620**	**1.00**
Section - SE.shoreline	**0.961**	**0.148**	**1.773**	**1.00**
Section - SW.openwater	**-35.285**	**-2.25E+07**	**2.25E+07**	**1.00**
Section - SW.shoreline	**0.284**	**-0.545**	**1.114**	**1.00**
Boat - FISHBIO	0.690	0.194	1.186	0.77
Boat - FISHBIO-2	0.261	-0.518	1.040	0.77
Wind Speed	-0.046	-0.094	0.002	0.59
Turbidity	-0.010	-0.022	0.002	0.53
Gate Flow	0.000	0.000	0.000	0.47
Water Temperature	0.058	-0.028	0.145	0.41
Banks Pumping Rate	0.000	0.000	0.000	0.24
Time from sunrise	-0.013	-0.226	0.199	0.23

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

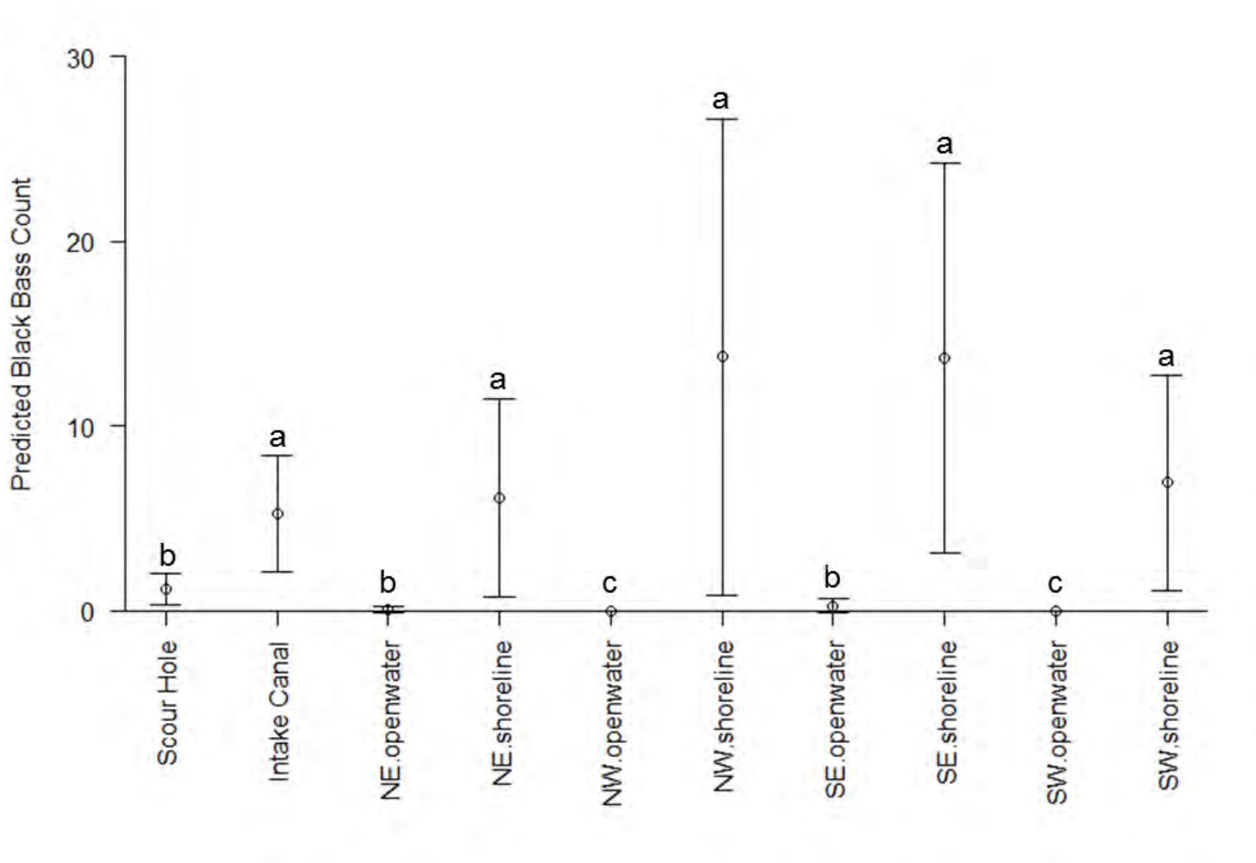

Figure 24. Predicted Black Bass Count (with 95% Confidence Interval) per Hour on the Water as a Function of Section, the Only Important Environmental Variables from Generalized Linear Modeling of CCF Catch Data, January-June 2017. Letters Correspond to Groups with Nonoverlapping Confidence Intervals.

3.4 Small-Scale Spatial Patterns in Predator Capture Rates

3.4.1 Pattern Summary

Figure 25, 26, and 27 present spatial patterns in raw catches (not correcting for effort) of predatory fish during the 2017 field season. These figures indicate that predatory fish were caught along nearly every part of shoreline and Intake Canal. There were larger catch numbers throughout the Intake Canal and Scour Hole (except for the deep center), but these locations were sampled most often (Table 5).

3.4.2 Statistical Analysis

The results of the Getis-Ord Gi* statistical analysis indicate that the Scour Hole and area outside the Scour Hole in the Southeast quadrant open water are fairly consistent hotspots for total predatory fish except for June (Figure 28, 29, 30, 31). This pattern is largely driven by Striped Bass (Figure 32, 33, 34, 35). Because of this limited sampling extent during June and because data are compared only among locations where data were collected, June patterns are not generally comparable to other months. The northern end of the Intake Canal is a consistent hotspot for black bass, except for January and April (Figure 36, 37, 38, 39). In addition, a reach of the Northeast quadrant shoreline consistently appears as a black bass hotspot except during February and June and a reach along the Northwest quadrant shoreline is a black bass hotspot in all months when sampling was conducted there (February through May). Cold spots were rare, although they were primarily located in open water.

Spatial patterns in catch rates tended to be ephemeral at a very small spatial scale, although 6 small-scale predator hotspots were identified from visual inspection of Figures 28 through Figure 39: (1) just east of the opening of the Intake Canal to the rest of CCF for Striped Bass; (2) the ring around deeper water within the Scour Hole for Striped Bass; (3) the open water area to the Northeast of the Scour Hole delineation within the Southeast quadrant for Striped Bass; (4) the linear southwest reach of shoreline in the Southwest quadrant for Striped Bass and black bass; (5) the middle reach of the Northeast quadrant shoreline for black bass; and (6) the upper reach of the Northwest quadrant shoreline for black bass.

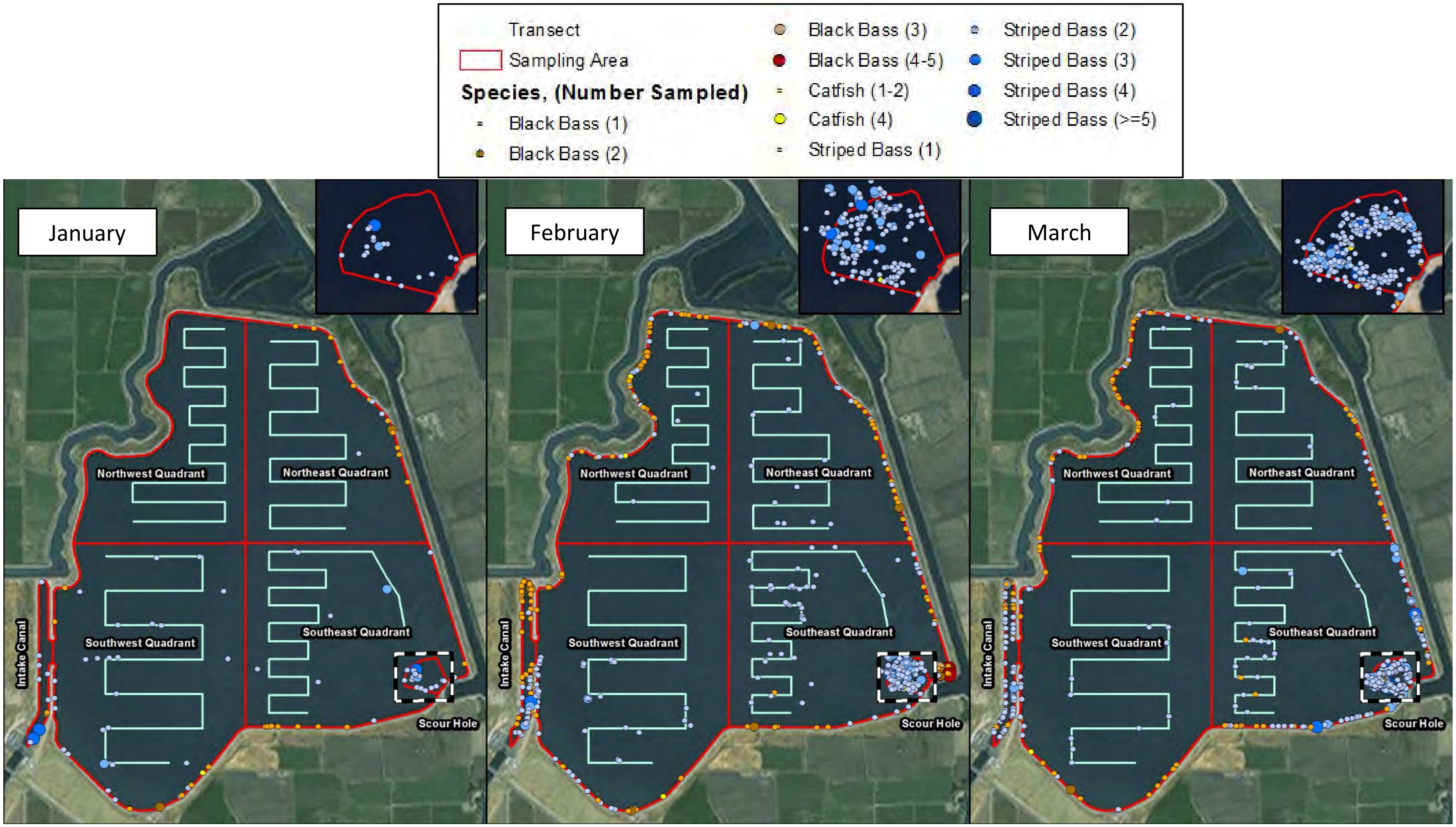

Figure 25. Catch of Predatory Fish in CCF Based on GIS Collector Data by Month, January through March.

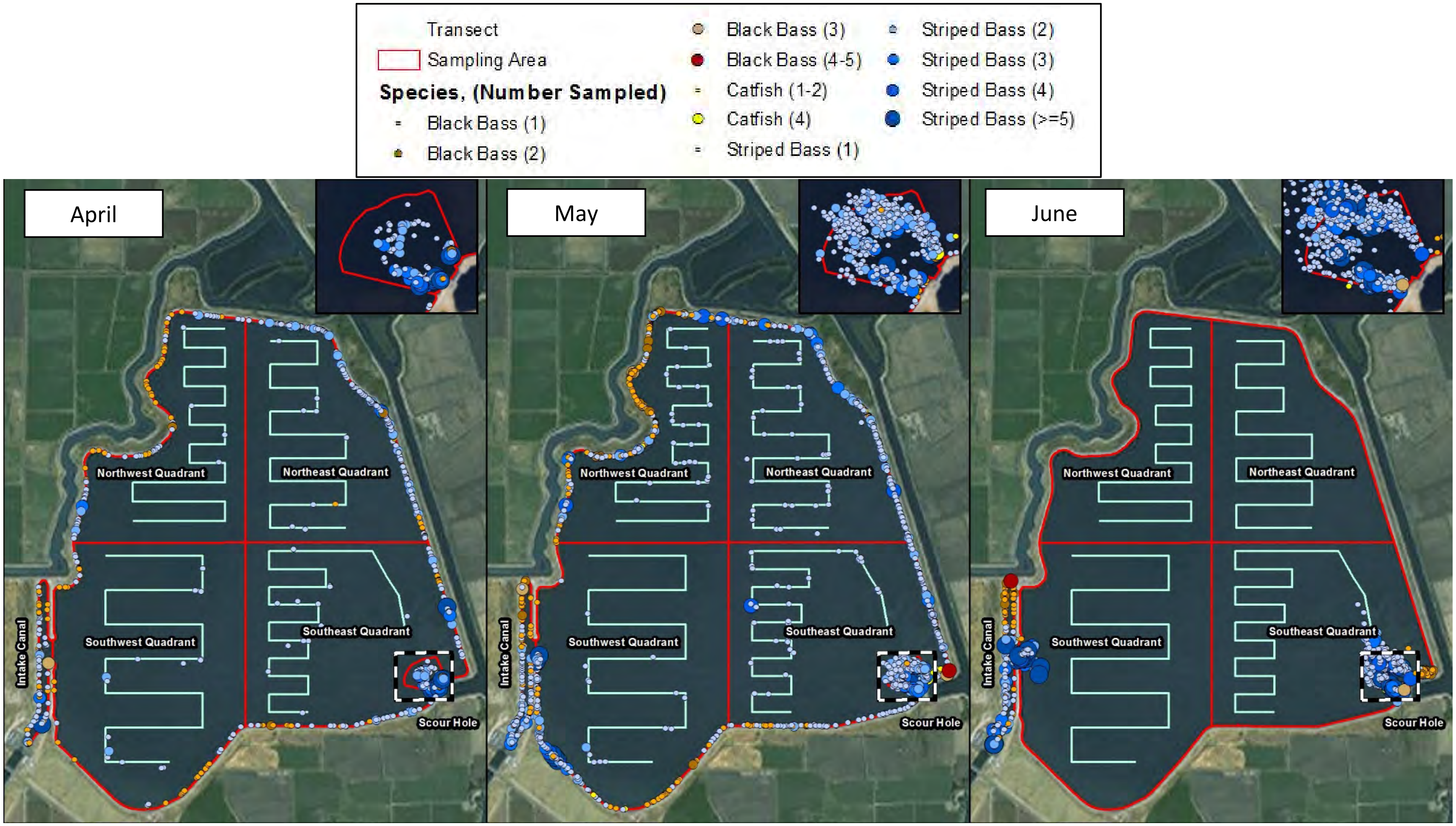

Figure 26. Catch of Predatory Fish in CCF Based on GIS Collector Data by Month, April through June

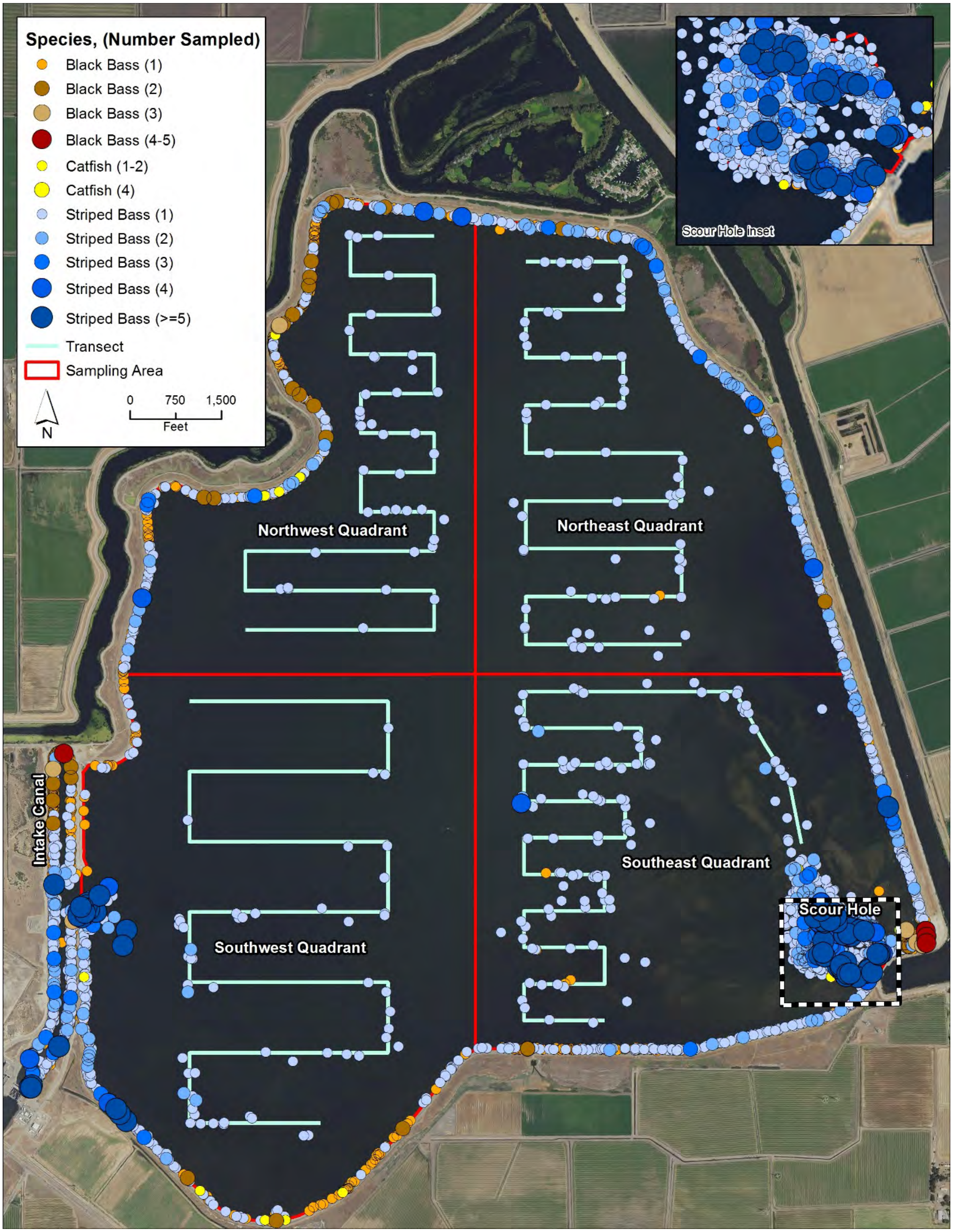

Figure 27. Catch of Predatory Fish in CCF during the 2017 Field Season Based on GIS Collector Data.

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Figure 28. Getis-Ord Gi* Results for Total Predatory Fish CPUE in CCF Based on GIS Collector Data by Month, January through March.

Figure 29. Getis-Ord Gi* Results for Total Predatory Fish CPUE in CCF Based on GIS Collector Data by Month, April through June.

Figure 30. Getis-Ord Gi* Results for All Predatory Fish CPUE in CCF Based on GIS Collector Data, Total 2017 Field Season.

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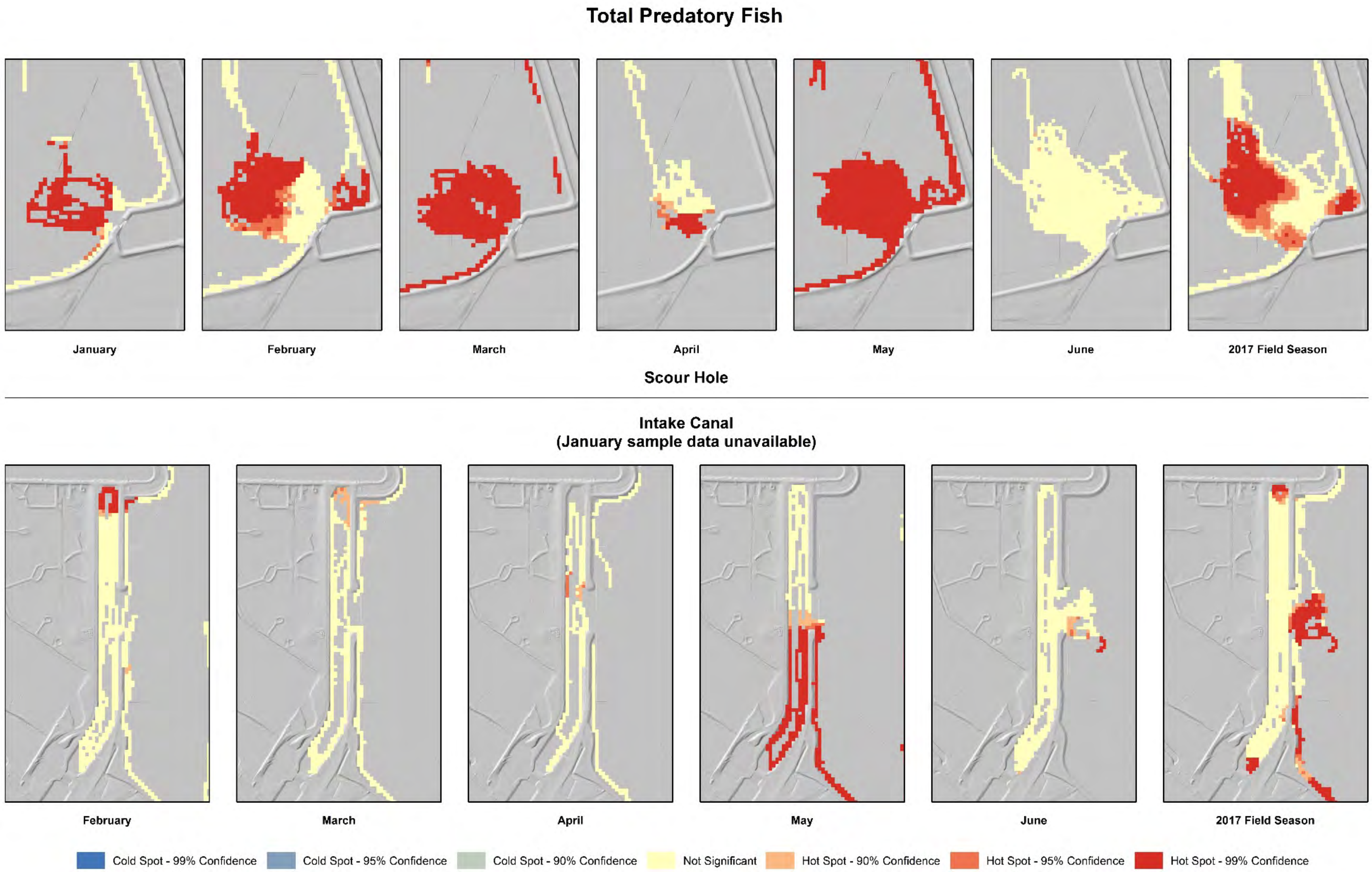

Figure 31. Getis-Ord Gi* Results for Total Predatory Fish CPUE in the Scour Hole and Intake Canal.

Figure 32.Getis-Ord Gi* Results for Striped Bass CPUE in CCF Based on GIS Collector Data by Month, January through March.

Figure 33. Getis-Ord Gi* Results for Striped Bass CPUE in CCF Based on GIS Collector Data by Month, April through June.

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Figure 34. Getis-Ord Gi* Results for Striped Bass CPUE in CCF Based on GIS Collector Data, Total 2017 Field Season.

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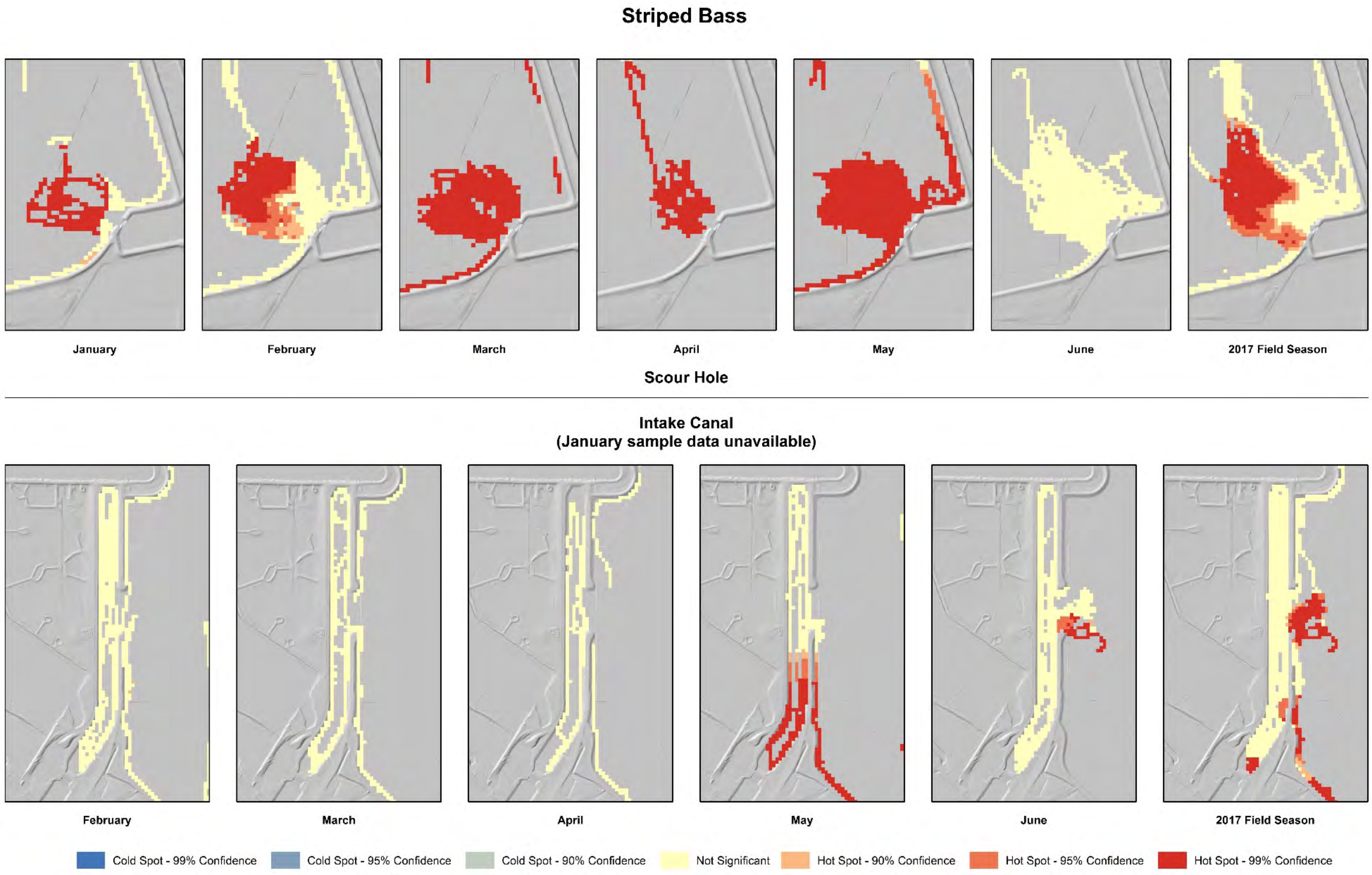

Figure 35. Getis-Ord Gi* Results for Striped Bass CPUE in the Scour Hole and Intake Canal.

Figure 36.Getis-Ord Gi* Results for Black Bass CPUE in CCF Based on GIS Collector Data by Month, January through March.

Figure 37. Getis-Ord Gi* Results for Black Bass CPUE in CCF Based on GIS Collector Data by Month, April through June.

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Figure 38. Getis-Ord Gi* Results for Black Bass CPUE in CCF Based on GIS Collector Data, Total 2017 Field Season.

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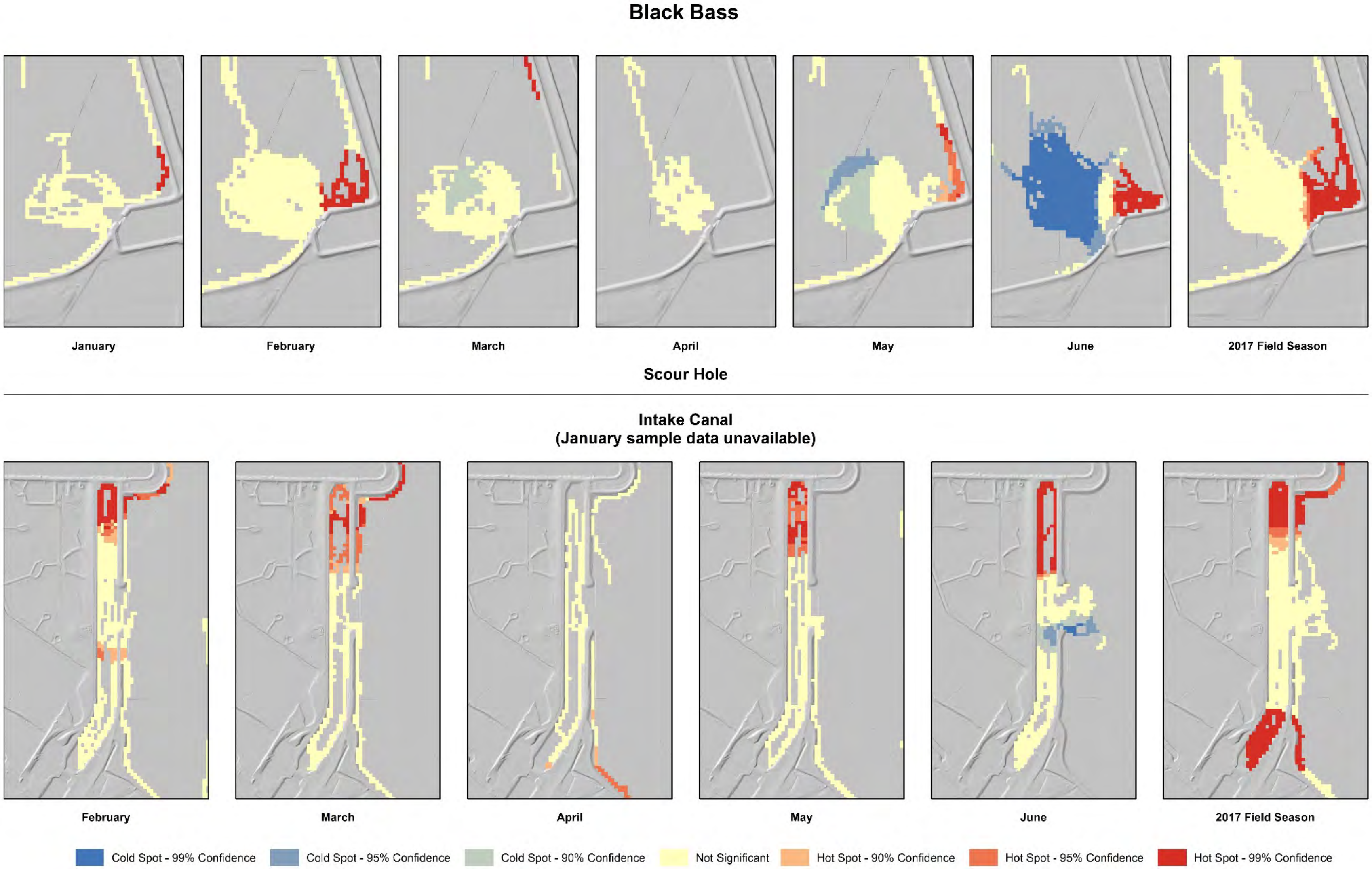

Figure 39. Getis-Ord Gi* Results for Black Bass CPUE in the Scour Hole and Intake Canal

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3.5 Predator Recapture

There were 57 predatory fish previously tagged for other CCF predator studies (see Section 1.3, *Concurrent Predator Studies in Clifton Court Forebay*) that were recaptured during the 2017 field season, accounting for 75 total recapture events (Table 15). There were 34 black bass, all of which were Largemouth Bass, and 23 Striped Bass recaptured, accounting for 52 and 23 recapture events, respectively. The majority of these individuals were recaptured in the Intake Canal (36 fish) and along the shoreline (23 or 24 fish; 1 fish's recapture position was not recorded), although there were 14 Striped Bass recaptured in the Scour Hole and at least one Striped Bass recaptured in open water (Table 16).

Fourteen individuals, all Largemouth Bass, were recaptured more than once during 2017, including one individual (PIT tag # 3D9239F883D1C) that was recaptured four times between February and April. This individual was recaptured in both the Intake Canal and along the Northwest quadrant shoreline. This same individual was recaptured 3 times in the Intake Canal during the 2016 field season, including twice in one day (DWR 2016). Only this individual and two other Largemouth Bass, (PIT Tag #3D9239F888527 and #3DD003BC7F438) were recaptured in different locations within CCF during 2017. PIT Tag #3D9239F888527 was recaptured in the adjoining Southeast and Southwest quadrant shorelines on 4/27 and 5/4, respectively. However, PIT Tag ##3DD003BC7F438 was recaptured along the Northeast quadrant shoreline on March 7 and in the Intake Canal on June 6, indicating that it traveled at least ~3 km (smallest straight line distance between locations) in 3 months, and likely traveled much farther if it did not cross the center of CCF.

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Table 15. Summary of 2017 Recaptures. Gray shading indicates that the fish was also recaptured in 2016.

			Original Capture Data			Recapture Data			
Species	PIT Tag #	Floy Tag #	Date Tagged	Weight (lb)	Fork Length (mm)	Date	Location	Weight (lb)	Fork Length (mm)
Largemouth Bass	3D6000B320 D1F	-	1/21/2014	4.1	425	5/4/2017	SW Shoreline	4.95	531
Largemouth Bass	3D6000B320 D76	-	10/25/2013	1.6	355	1/23/2017	SW Shoreline	4.8	494
Largemouth Bass	3D6000B3A A22E	-	6/5/2014	0.95	325	5/24/2017	SW Shoreline	2.3	411
Largemouth Bass	3D6001569C 095	-	7/21/2016	2.0	380	2/16/2017	Intake Canal	2.5	395
Largemouth Bass	3D91C2DB9 55EC	4860/ 4859	12/7/2016	1.9	370	5/16/2017	Intake Canal	1.7	370
						6/1/2017	Intake Canal	1.7	367
Largemouth Bass	3D9239F883 CCF	-	2/12/2016	3.3	430	5/2/2017	Intake Canal	3.3	464
Largemouth Bass	3D9239F883 D1C	-	3/25/2016	2.0	380	2/16/2017	Intake Canal	2.6	407
						3/2/2017	NW Shoreline	2.7	400
						3/9/2017	NW Shoreline	2.6	410
						4/27/2017	Intake Canal	2.5	398
Largemouth Bass	3D9239F884 DD9	4621/ 4620	11/14/2016	1.8	385	2/15/2017	SE Shoreline	1.8	373
Largemouth Bass	3D9239F884 DE3	-	4/8/2016	2.7	425	2/14/2017	SW Shoreline	3.35	445
Largemouth Bass	3D9239F884 E9A	5366/ 5367	12/20/2016	2.2	385	6/6/2017	Intake Canal	2.0	370
Largemouth Bass	3D9239F885 18C	-	11/13/2015	2.6	415	5/2/2017	Intake Canal	2.8	419
						6/1/2017	Intake Canal	2.55	429
Largemouth Bass	3D9239F885 5C6	5450/ 5449	12/23/2016	2.4	395	4/27/2017	Intake Canal	2.4	380
						5/2/2017	Intake Canal	-	390
Largemouth Bass	3D9239F886 FC8	-	9/14/2015	2.4	400	5/2/2017	Intake Canal	3.0	428
Largemouth Bass	3D9239F888 527	-	1/7/2016	2.0	385	4/27/2017	SE Shoreline	2.5	400
						5/4/2017	SW Shoreline	2.25	406

			Original Capture Data			Recapture Data			
Species	PIT Tag #	Floy Tag #	Date Tagged	Weight (lb)	Fork Length (mm)	Date	Location	Weight (lb)	Fork Length (mm)
Largemouth Bass	3D9239F888 AD4	4036	10/27/2016	1.6	380	1/24/2017	SE Shoreline	1.75	388
						5/4/2017	SE Shoreline	-	375
Largemouth Bass	3D9239F888 C0E	4039	10/27/2016	1.6	345	2/16/2017	Intake Canal	1.6	340
						5/2/2017	Intake Canal	0.5	339
						6/6/2017	Intake Canal	1.5	337
Largemouth Bass	3D9239F888 ED6	2996	3/23/2015	3.5	405	2/16/2017	Intake Canal	4.7	457
Largemouth Bass	3D9239F889 31C	-	10/5/2015	8.3	585	2/1/2017	NW Shoreline	9.85	581
Largemouth Bass	3D9239F889 413	4868/ 4869	12/7/2016	2.1	385	2/23/2017	SW Shoreline	2.0	373
Largemouth Bass	3D9239F889 A62	-	11/13/2015	3.2	455	2/22/2017	Intake Canal	4.05	468
						5/16/2017	Intake Canal	3.4	460
Largemouth Bass	3DD003BC7 416	-				2/22/2017	NW Shoreline	1.2	310
Largemouth Bass	3DD003BC7 F22F	-	11/20/2015	1.7	370	1/31/2017	NE Shoreline	2.0	384
Largemouth Bass	3DD003BC7 F24B	-	11/23/2015	1.1	330	6/6/2017	Intake Canal	1.4	357
						6/7/2017	Intake Canal	1.5	358
Largemouth Bass	3DD003BC7 F270		4/20/2015	-	-	2/22/2017	NW Shoreline	2.7	391
Largemouth Bass	3DD003BC7 F2F5	3642	3/18/2016	1.05	315	1/23/2017	Intake Canal	1.2	321
						2/22/2017	Intake Canal	1.2	323
Largemouth Bass	3DD003BC7 F305	4136	3/25/2016	1.15	325	2/22/2017	Intake Canal	1.7	340
Largemouth Bass	3DD003BC7 F416	-	11/13/2015	0.75	280	3/9/2017	NW Shoreline	1.2	319
						5/11/2017	NW Shoreline	1.05	315
Largemouth Bass	3DD003BC7 F438	-	11/2/2015	0.8	280	3/7/2017	NE Shoreline	1.25	325
						6/1/2017	Intake Canal	1.2	324
Largemouth Bass	3DD003BC7 F48B	-	11/14/2014	1.3	325	3/8/2017	SW Shoreline	1.85	375

			Original Capture Data			Recapture Data			
Species	PIT Tag #	Floy Tag #	Date Tagged	Weight (lb)	Fork Length (mm)	Date	Location	Weight (lb)	Fork Length (mm)
Largemouth Bass	3DD003BC7 F4CF	-	7/11/2016	1.5	345	5/31/2017	Intake Canal	2.2	386
Largemouth Bass	3DD003BC7 F50E	-	7/11/2016	1.2	320	2/22/2017	Intake Canal	1.8	345
						5/2/2017	Intake Canal	1.7	350
Largemouth Bass	3DD003BEA C53B	5396/ 5395	12/13/2016	0.95	305	3/8/2017	Intake Canal	1.0	315
						4/27/2017	Intake Canal	1.1	323
						6/1/2017	Intake Canal	1.15	314
Largemouth Bass	3DD003BEE 87A6	-				4/27/2017	SE Shoreline	1.3	307
Largemouth Bass	3DD00BC7F 4CF	-	7/11/2016	1.45	345	4/27/2017	Intake Canal	2.4	386
Striped Bass	-	5445/ 5446	12/23/2016	0.6	-	3/8/2017	Intake Canal	0.55	274
Striped Bass	-	4781/ 4780	12/30/2016	1.2	370	4/25/2017	SW	1.1	365
Striped Bass	3D6001569C 09C	5355/ 5356	12/19/2016	1.5	400	2/2/2017	Intake Canal	1.4	394
Striped Bass	3D91C2DB8 7DFC	4029/ 4028	10/27/2016	1.8	415	2/23/2017	SW Shoreline	1.7	412
Striped Bass	3D9239F885 1E0	4664/ 4665	11/28/2016	1.9	420	6/1/2017	Scour Hole	1.95	422
Striped Bass	3D9239F885 408	4717/ 4716	11/14/2016	4.8	545	2/23/2017	SE Open Water	4.55	540
Striped Bass	3D9239F885 420	-	7/12/2016	2.2	-	2/23/2017	SW Shoreline	3.45	509
Striped Bass	3DD003BC7 F3E0	-	5/26/2015	0.7	310	5/9/2017	Scour Hole	1.6	400
Striped Bass	3DD003BC7 F51F	-	3/30/2016	0.9	340	3/8/2017	Intake Canal	1.2	366
Striped Bass	3DD003BEA C4F7	4781/ 4780	12/30/2016	1.2	370	6/1/2017	Scour Hole	1.15	370

			Original Capture Data			Recapture Data			
Species	PIT Tag #	Floy Tag #	Date Tagged	Weight (lb)	Fork Length (mm)	Date	Location	Weight (lb)	Fork Length (mm)
Striped Bass	3DD003BEAC556	4882/ 4883	12/12/2016	0.6	260	6/15/2017	Scour Hole	0.6	301
Striped Bass	3DD003BEAC56E	3647/ 3648	10/17/2016	0.4	250	6/13/2017	Intake Canal	0.6	275
Striped Bass	3DD003BEAC5A4	4611	11/14/2016	0.6	305	6/7/2017	Scour Hole	0.5	315
Striped Bass	3DD003BEAC5CA	3653/ 3654	11/10/2016	1.3	375	6/6/2017	Scour Hole	1.4	381
Striped Bass	3DD003BEAC5FC	4500/ 4499	9/12/2016	0.4	260	6/14/2017	Intake Canal	0.6	277
Striped Bass	3DD003BEE8B9C	-				5/9/2017	Scour Hole	1.5	385
Striped Bass	3DD003BEE8BA3	-				5/9/2017	Scour Hole	0.4	249
Striped Bass	3DD003BEE9016	-				5/9/2017	Scour Hole	1.25	379
Striped Bass	3DD003BEE94BF	-				6/6/2017	Scour Hole	1.1	346
Striped Bass	3DD003BEE94DE	-				6/6/2017	Scour Hole	2.6	472
Striped Bass	3DD003BEE9507	-				6/6/2017	Scour Hole	-	-
Striped Bass	3DD003BEE9512	-				6/6/2017	Scour Hole	0.7	298
Striped Bass	-	4733/ 4732	11/21/2016	1.2	375	6/1/2017	Scour Hole	1.4	397

Table 16. Recaptured predatory fish by sampling section and position.

Sampling Section	Position	Striped Bass	Black Bass[1]	All Fish
Scour Hole	--	14	0	14
Intake Canal	--	5	31	36
Southeast	Open Water	1	0	1
	Shoreline	0	5	5
Southwest	Open Water	0	0	0
	Shoreline	2	7	9
	<Not recorded>	1	--	1
Northeast	Open Water	0	0	0
	Shoreline	0	2	2
Northwest	Open Water	0	0	0
	Shoreline	0	7	7
Total		23	52	75

[1] All recaptured black bass were Largemouth Bass

3.6 Predator Mortality

There were 276 predatory fish mortalities representing 4.5% of the 6,151 total captures (Table 17). The vast majority of mortalities were Striped Bass (274 of 276 mortalities). There were two black bass mortalities and no catfish mortalities. The majority of mortality occurred in the transport process (87% of mortalities; just under 4% of total capture).

Table 17. Summary of mortalities from the 2017 field season.

	Efishing and Processing		Transport		Combined	
Species	Total	% of Total Capture	Total	% of Total Capture	Total	% of Total Capture
Striped Bass	35	0.7%	239	4.6%	274	5.2%
Black Bass	0	0.0%	2	0.2%	2	0.2%
Catfish	0	0.0%	0	0.0%	0	0.0%
Total	35	0.6%	241	3.9%	276	4.5%

DO levels (% saturation) in the transport livewell at the time of CCF departure ranged from 75% to 210% and averaged 98% (Figure 40). DO in the transport livewell upon arrival at Bethany Reservoir ranged from 20% to 172% and averaged 103%. DO in Bethany Reservoir at the time of fish release (shortly after arriving at Bethany Reservoir) ranged from 66% to 123% and averaged 96%.

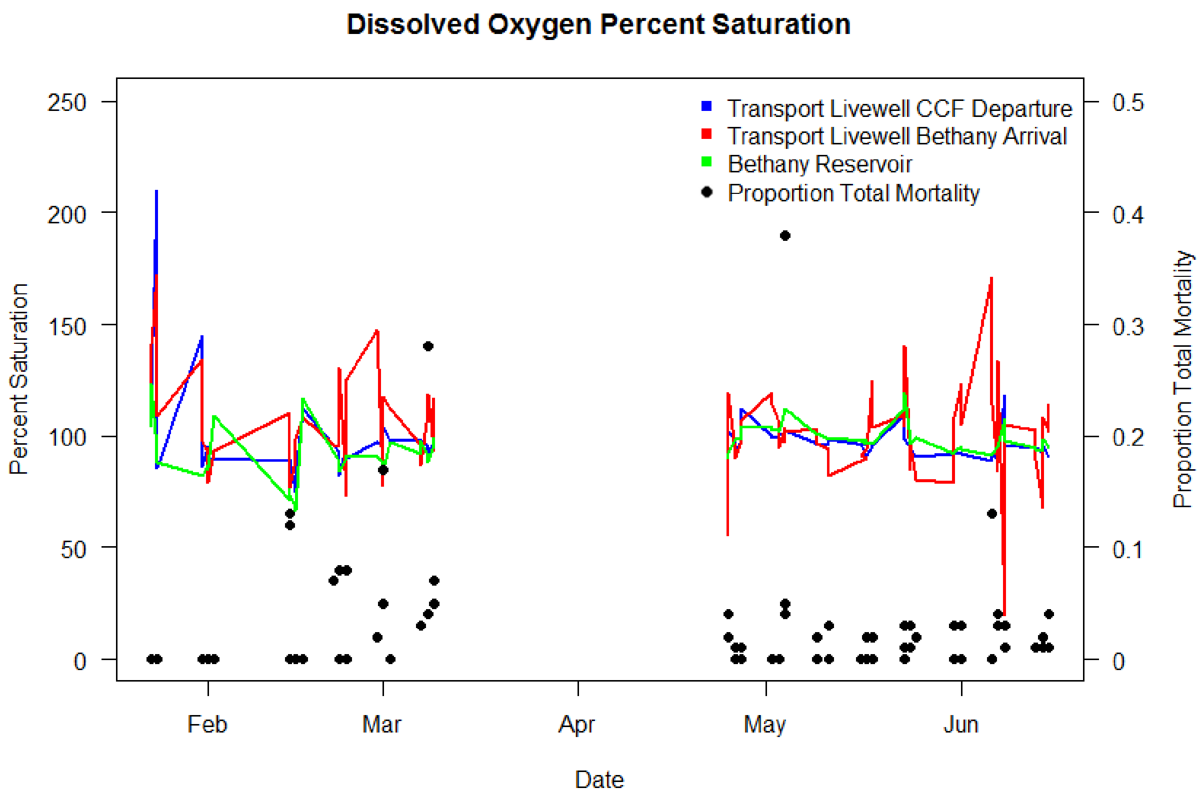
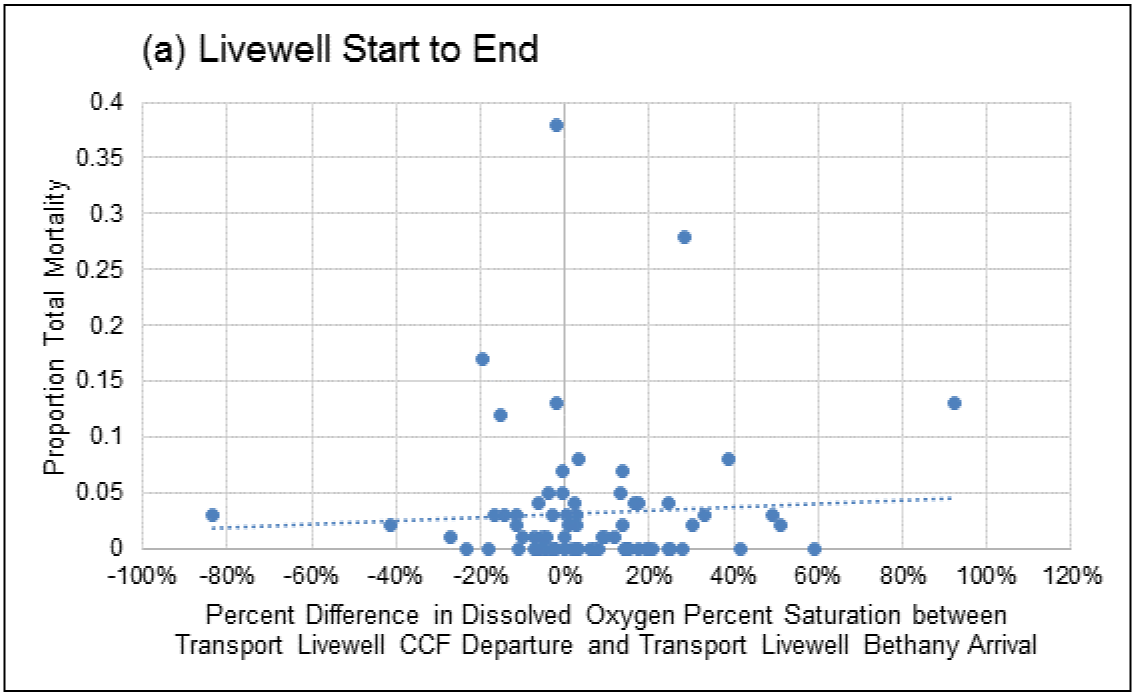


Figure 40. Dissolved Oxygen (Percent Saturation) and Proportion of Predators that Died during the 2017 Field Season.

The effect of change in dissolved oxygen between: (1) transport livewell at the time of departure and upon arrival at Bethany Reservoir, and (2) transport livewell upon arrival at Bethany Reservoir and in Bethany Reservoir, was examined graphically (Figure 41). This figure indicates that there was no clear relationship between mortality and change in dissolved oxygen. In fact, the highest proportion of predator mortality occurred when change in percent dissolved oxygen was within 20-30%.



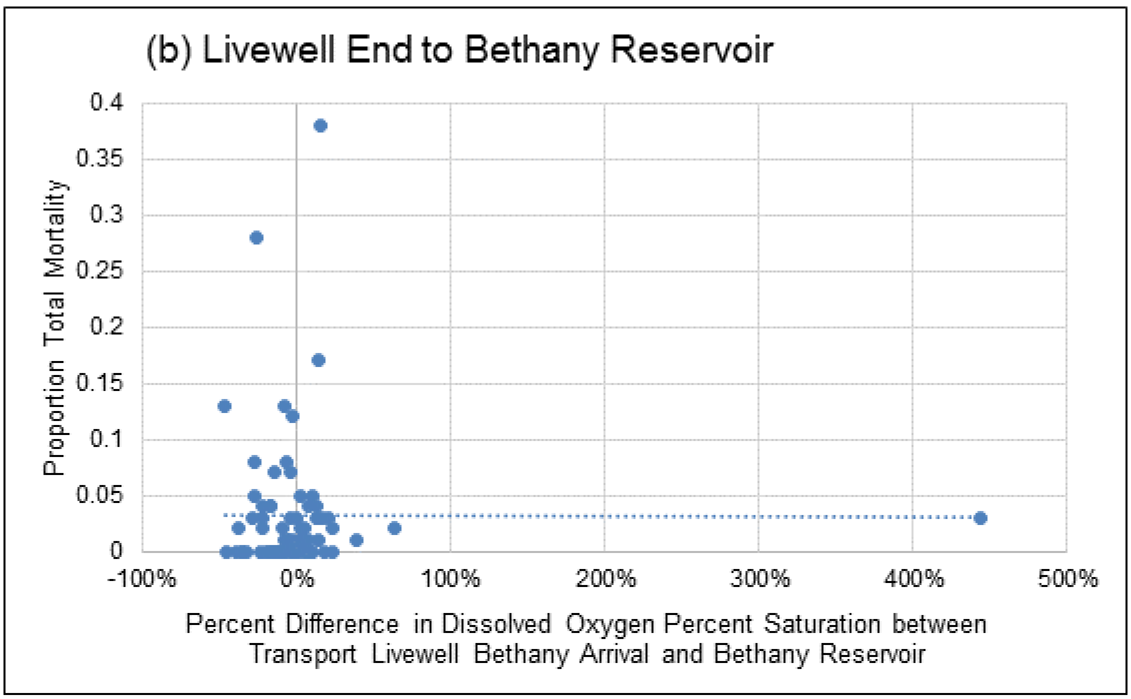


Figure 41. Proportion of Predators that Died during the 2017 Field Season as a function of (a) Percent Difference in Dissolved Oxygen between Transport Livewell CCF Departure and Transport Livewell Bethany Arrival, and (b) Percent Difference in Dissolved Oxygen Percent Saturation between Transport Livewell Bethany Arrival and Bethany Reservoir.

Water temperature in the transport livewell at the time of departure from CCF ranged from 9.4 °C to 22.6 °C and averaged 16.4 °C (Figure 42). Water temperature in the transport livewell upon arrival at Bethany Reservoir ranged from 9.6 °C to 23.1 °C and averaged 16.6 °C. Water temperature in Bethany Reservoir at the time of fish release (shortly after arriving at Bethany Reservoir) ranged from 9.8 °C to 24.0 °C and averaged 16.4 °C.

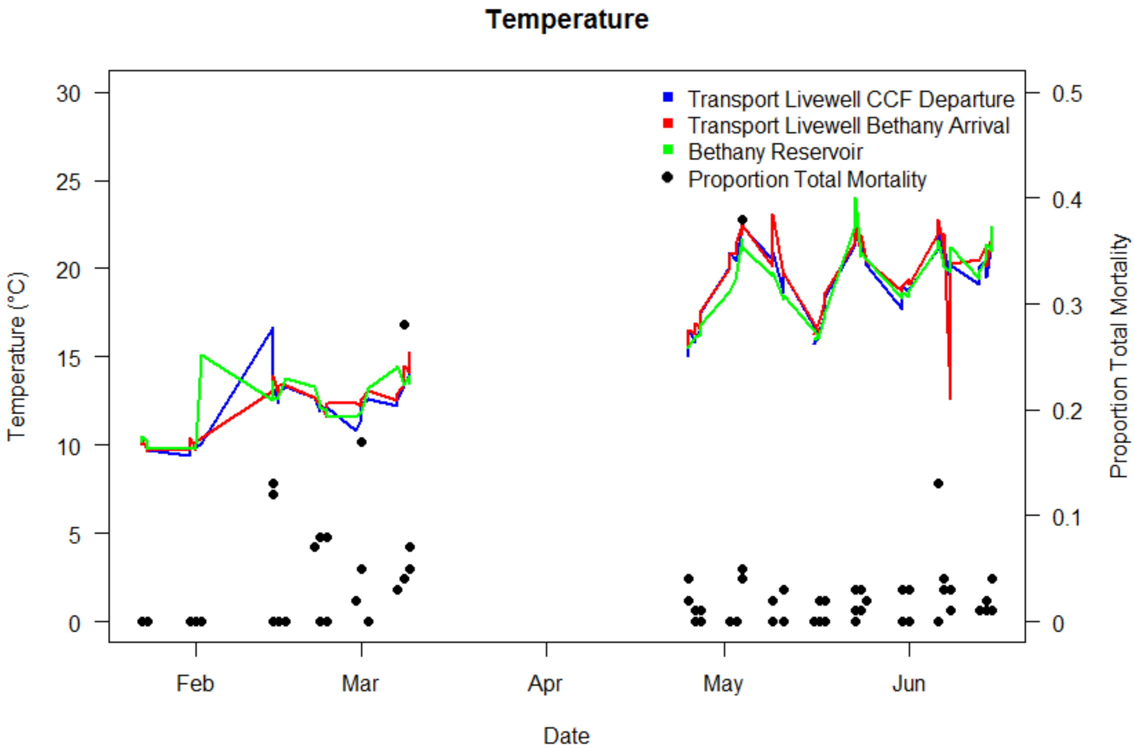


Figure 42. Water Temperature (°C) and Proportion of Predators that Died during the 2017 Field Season.

Predator biomass removed per sample ranged from 5.7 lb to 369.0 lb, and averaged 95.5 lb (Figure 43).

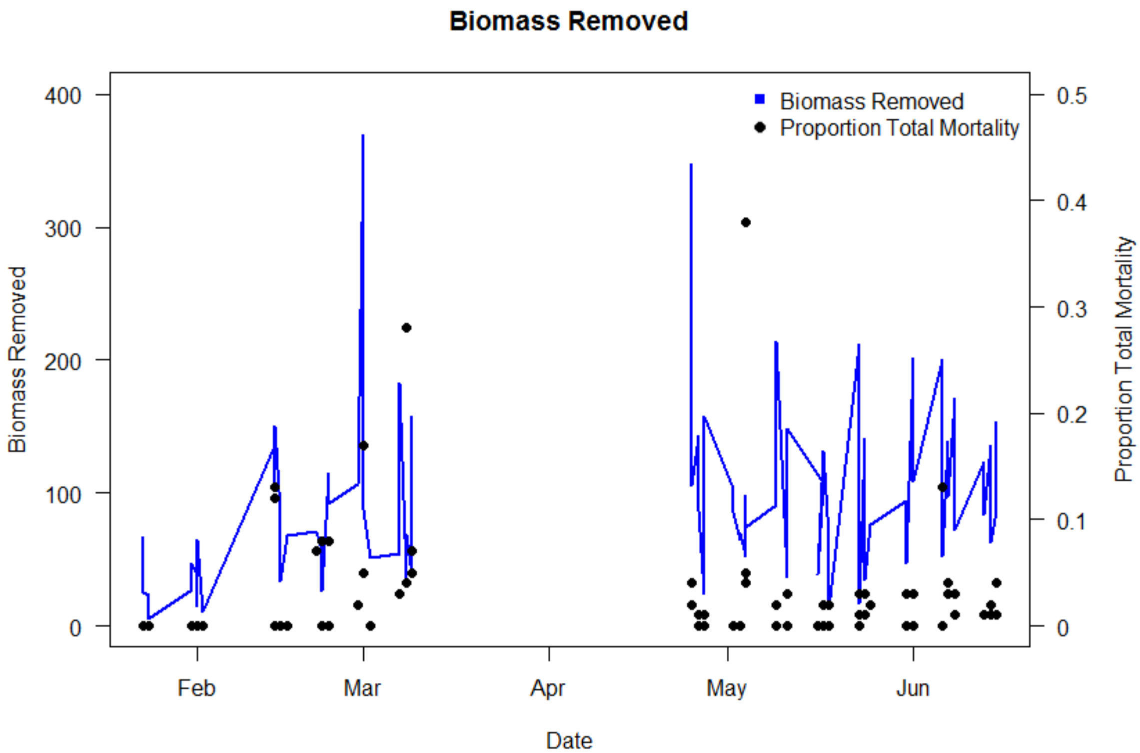


Figure 43. Biomass (lb) of Predatory Fish Removed from CCF and Proportion of Predators that Died during the 2017 Field Season.

None of the environmental predictors of predator mortality during transport were found to be statistically significant. Although predator biomass removed (an indicator of potential crowding/stress during transport or increased processing time and stress) had importance >0.8 and a 95% confidence interval not overlapping zero (Table 18), the intercept-only model was not >3 AIC_c units more than the full model, indicating limited support for the models including predictors over the intercept-only model. This was also indicated by the full model explaining only a modest portion of variation (Full model pseudo r^2= 0.20).

Table 18. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Beta Regression of Total Predator Mortality During Transport from CCF to Bethany Reservoir, January-June 2017 (Full Model Pseudo r^2 = 0.20).

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Biomass Removed	0.004	0.002	0.007	0.97
Ending dissolved oxygen	0.004	-0.005	0.013	0.32
Hour of day	0.048	-0.088	0.184	0.28
Starting dissolved oxygen	-0.004	-0.017	0.009	0.28
Dissolved oxygen at Bethany	-0.003	-0.022	0.015	0.25
Starting temperature	0.001	-0.046	0.048	0.24

Note: Variables in bold have importance ≥ 0.80 and coefficients not overlapping zero.

3.7 Predator Depletion

There was limited statistical evidence for depletion of black bass in CCF during the PRES (Figures 44, 45, 46, 47, 48, 49, 50, 51, 52, 53). The only statistically significant linear regression supporting the hypothesis that black bass CPUE would decrease over time was for the Intake Canal for May 31 to June 15 ($P = 0.01$; Figure 44). Although there was an apparent negative trend in CPUE over time in the Northeast quadrant shoreline in April-May (Figure 46), the relatively few samples led to low statistical power and a non-significant linear regression ($P = 0.12$). The Southeast quadrant shoreline was the only location providing marginal statistical support ($P = 0.052$) for the hypothesis that the difference in CPUE between one electrofishing session and the previous session would become more negative as the number of days between the sessions decreased (Figure 51).

The analysis of recaptured tagged black bass CPUE vs. date in the Intake Canal gave a statistically significant decrease in CPUE from May 31 to June 15 ($P = 0.004$) but the trends in recaptured tagged black bass CPUE for January 23 to March 8 and April 27 to May 25 were not statistically significant ($P > 0.05$; Figure 54).

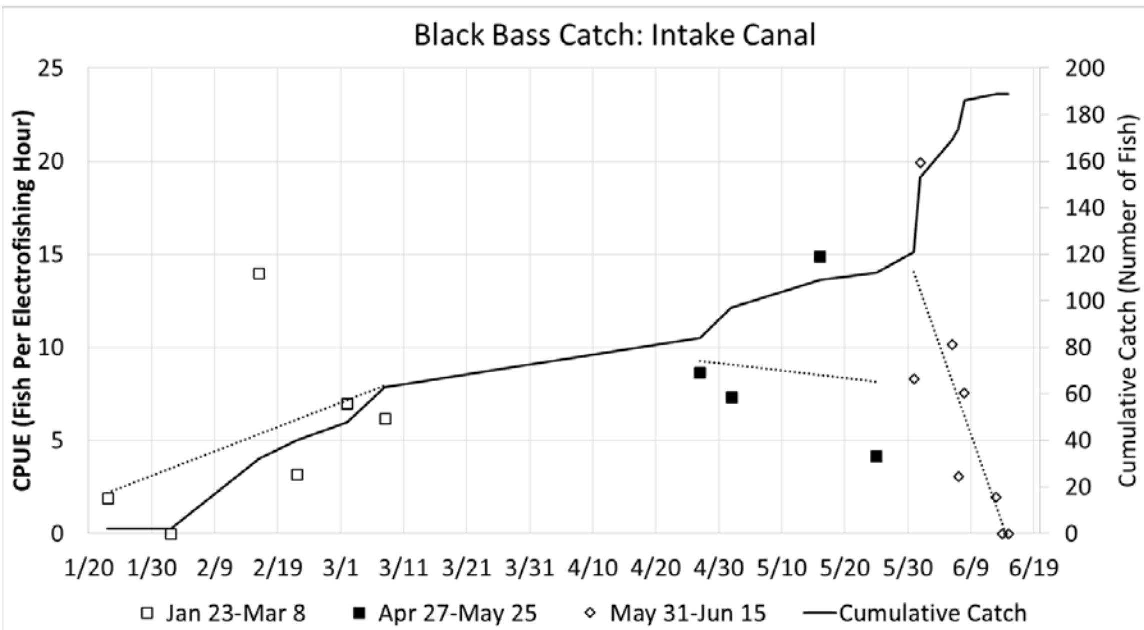


Figure 44. Black Bass Catch Per Unit Effort and Cumulative Catch in the Intake Canal. Note: Linear trendlines are shown for all CPUE vs. date regressions, but only May 31-June 15 was statistically significant.

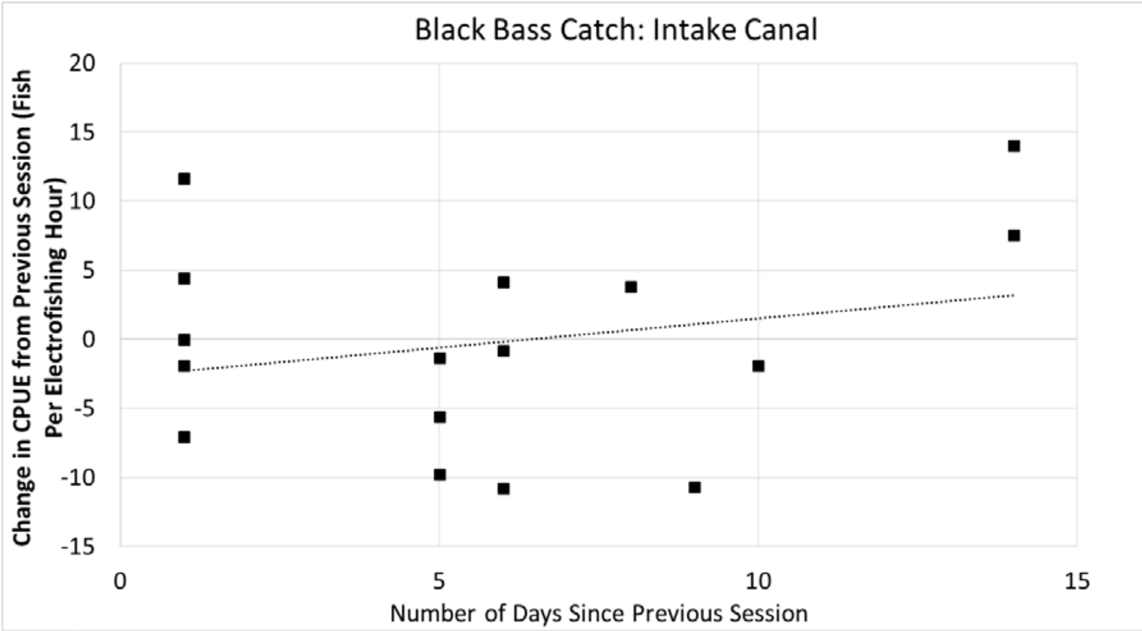


Figure 45. Change in Black Bass Catch Per Unit Effort in the Intake Canal From One Electrofishing Session to the Next, as a Function of Number of Days Between the Sessions. Note: Linear trendline is shown, but was not statistically significant.

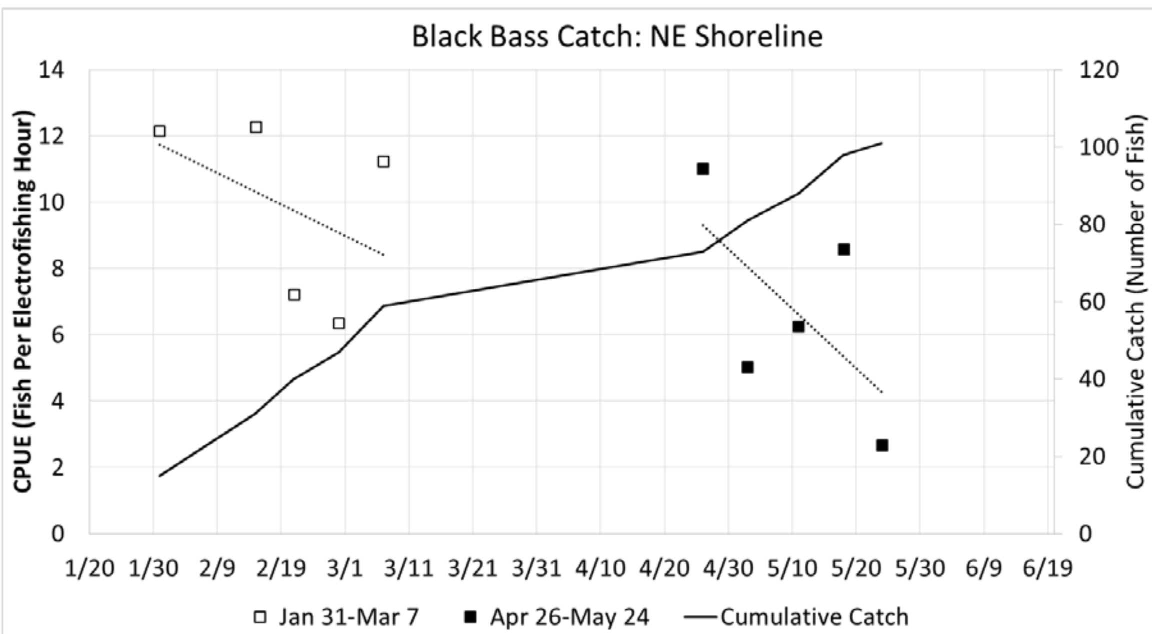


Figure 46. Black Bass Catch per Unit Effort and Cumulative Catch in the Northeast Quadrant Shoreline. Note: Linear trendlines are shown for all CPUE vs. date regressions, but none were statistically significant.

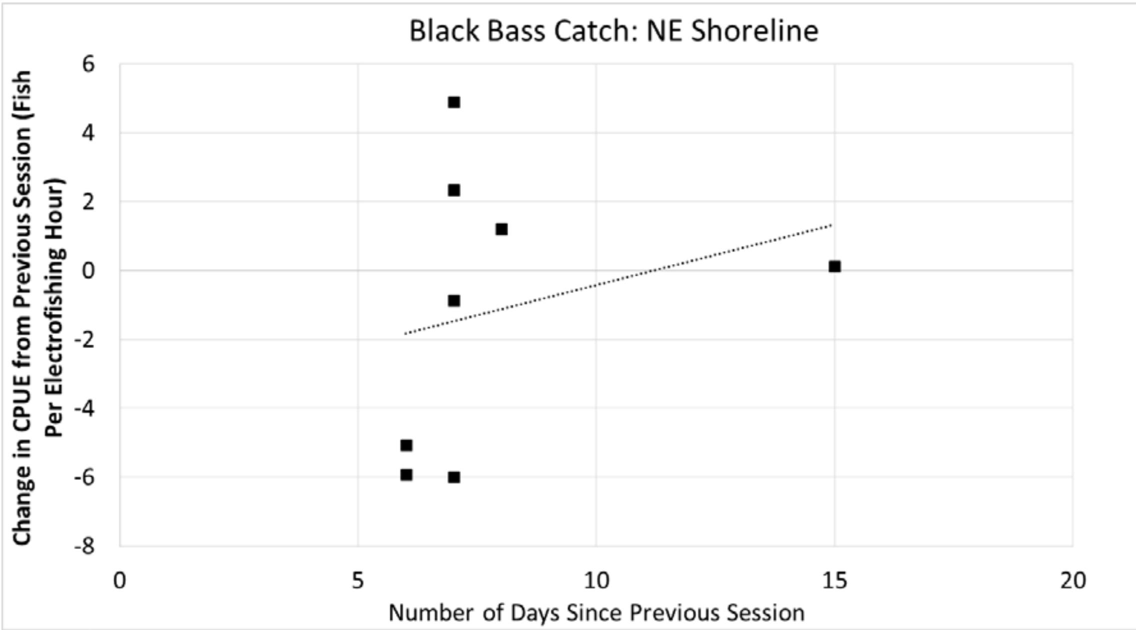


Figure 47. Change in Black Bass Catch per Unit Effort in the Northeast Quadrant Shoreline from One Electrofishing Session to the Next, as a Function of Number of Days between the Sessions. Note: Linear trendline is shown, but was not statistically significant.

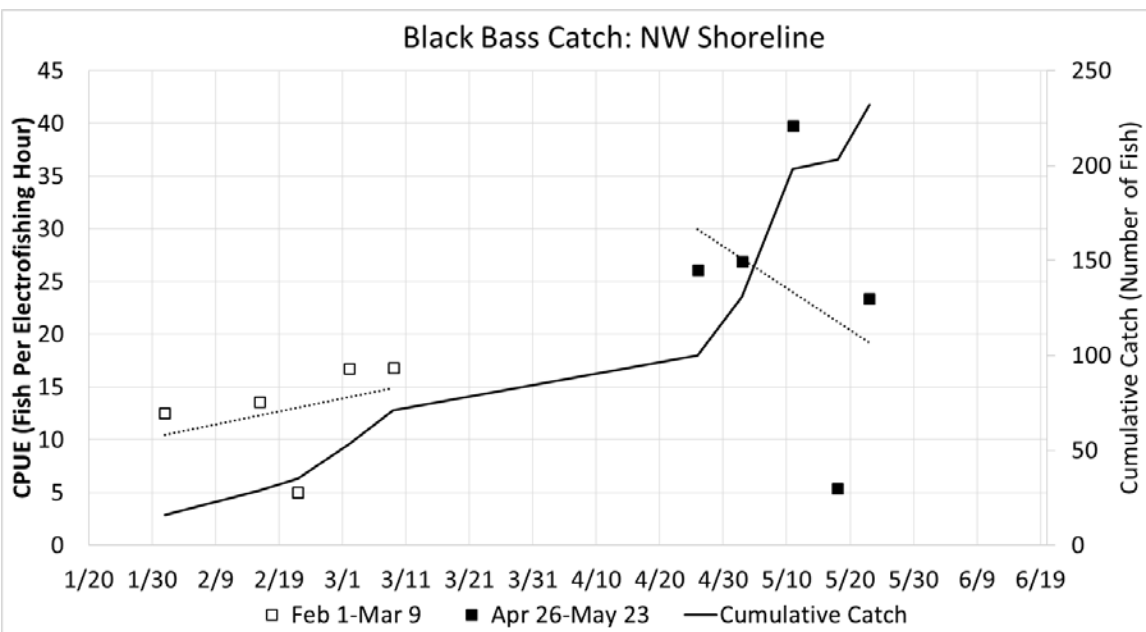


Figure 48. Black Bass Catch per Unit Effort and Cumulative Catch in the Northwest Quadrant Shoreline. Note: Linear trendlines are shown for all CPUE vs. date regressions, but none were statistically significant.

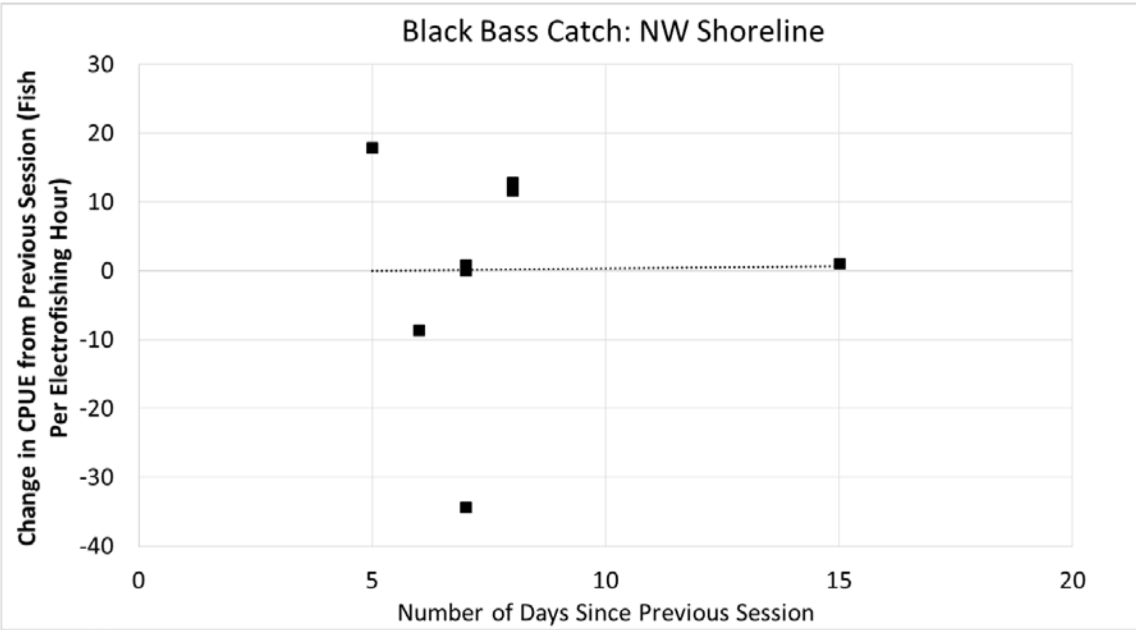


Figure 49. Change in Black Bass Catch per Unit Effort in the Northwest Quadrant Shoreline from One Electrofishing Session to the Next, as a Function of Number of Days between the Sessions. Note: Linear trendline is shown, but was not statistically significant.

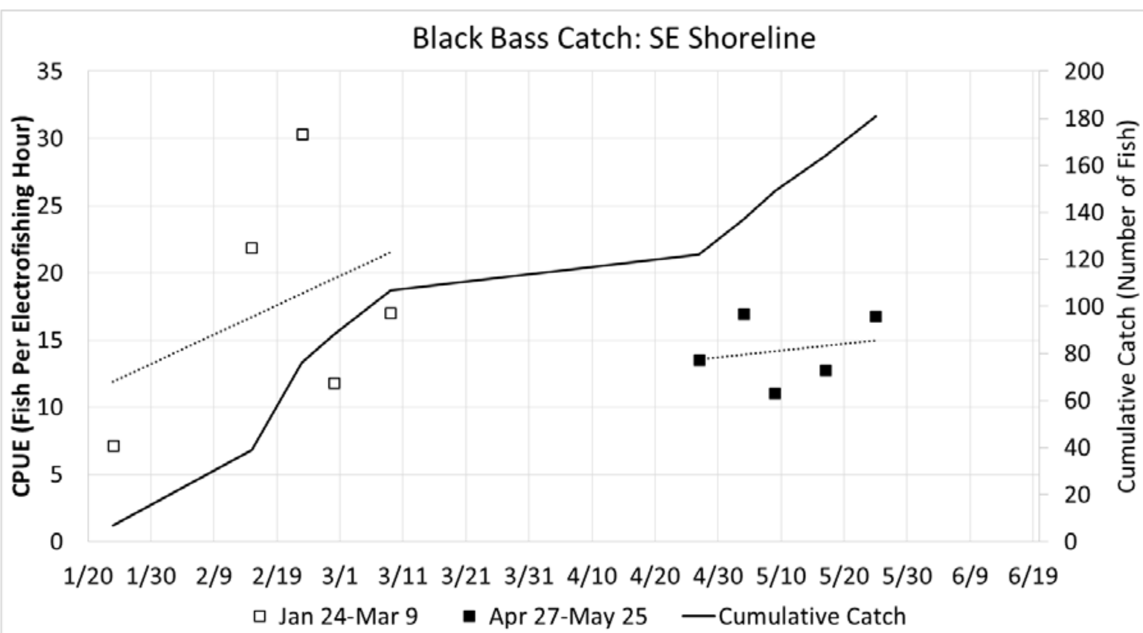


Figure 50. Black Bass Catch per Unit Effort and Cumulative Catch in the Southeast Quadrant Shoreline. Note: Linear trendlines are shown for all CPUE vs. date regressions, but none were statistically significant.

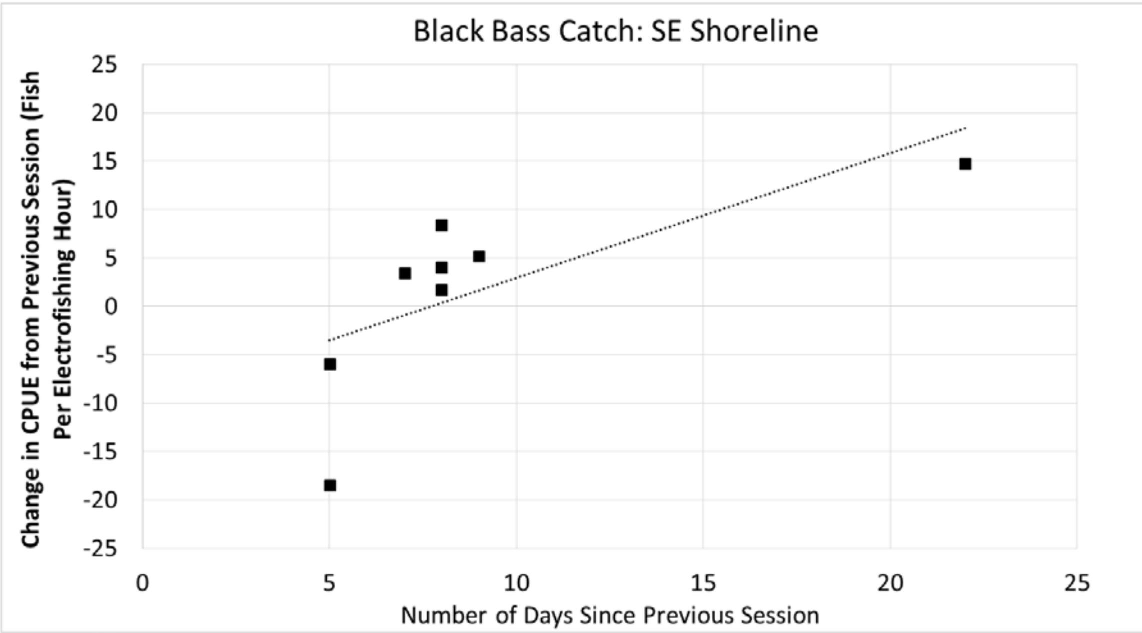


Figure 51. Change in Black Bass Catch per Unit Effort in the Southeast Quadrant Shoreline from One Electrofishing Session to the Next, as a Function of Number of Days between the Sessions. Note: Linear trendline is shown, which was marginally statistically significant (P = 0.052).

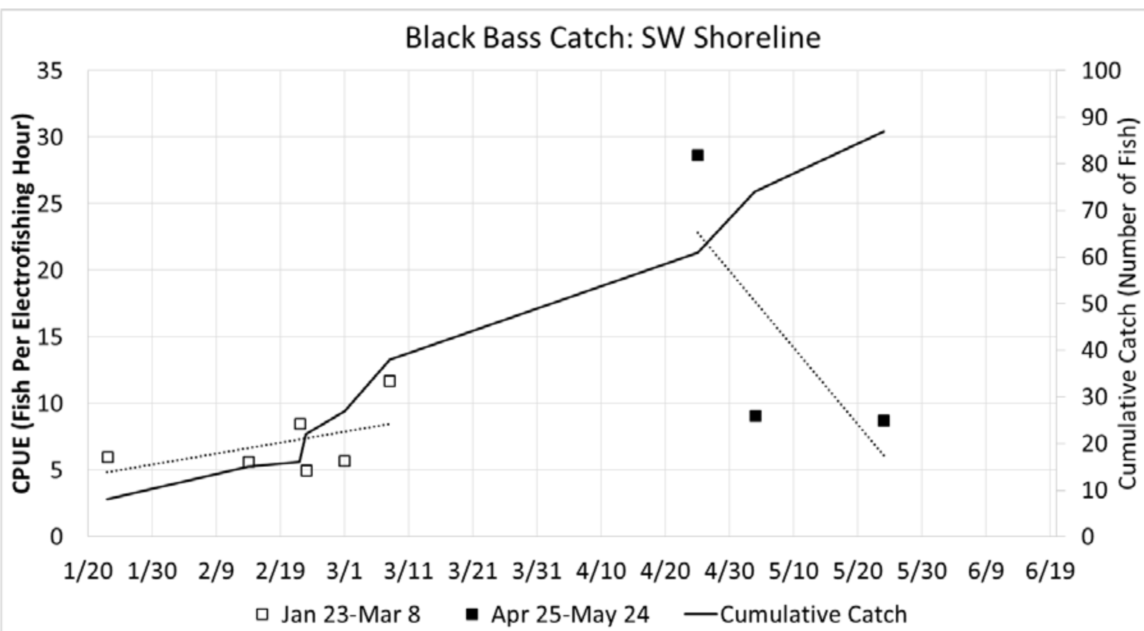


Figure 52. Black Bass Catch per Unit Effort and Cumulative Catch in the Southwest Quadrant Shoreline. Note: Linear trendlines are shown for all CPUE vs. date regressions, but none were statistically significant.

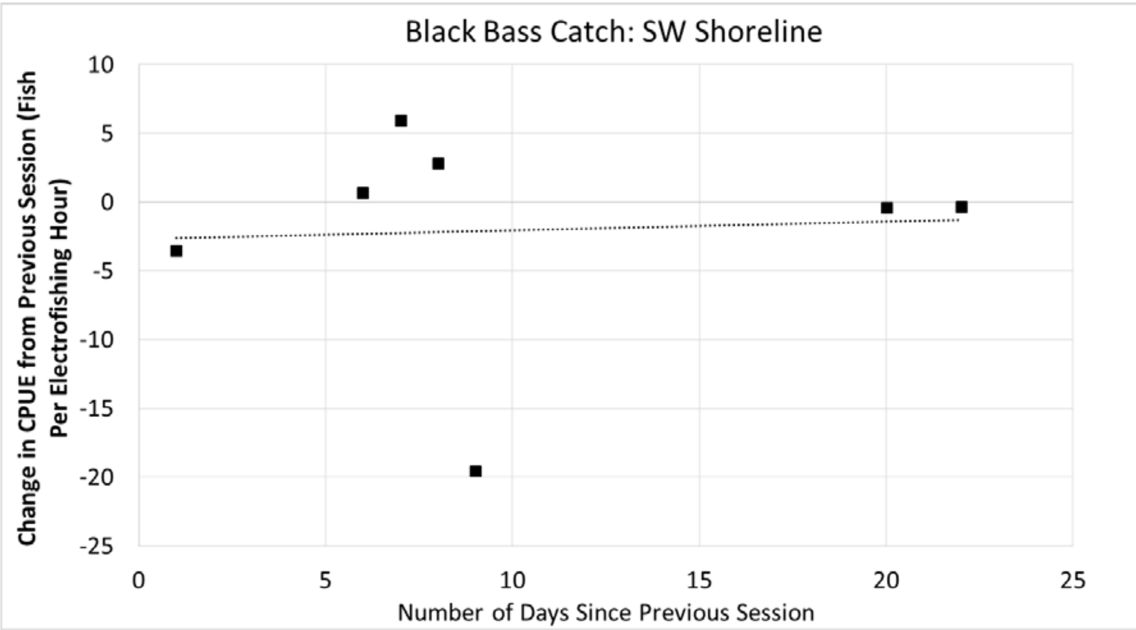


Figure 53. Change in Black Bass Catch per Unit Effort in the Southwest Quadrant Shoreline from One Electrofishing Session to the Next, as a Function of Number of Days between the Sessions. Note: Linear trendline is shown, but was not statistically significant.

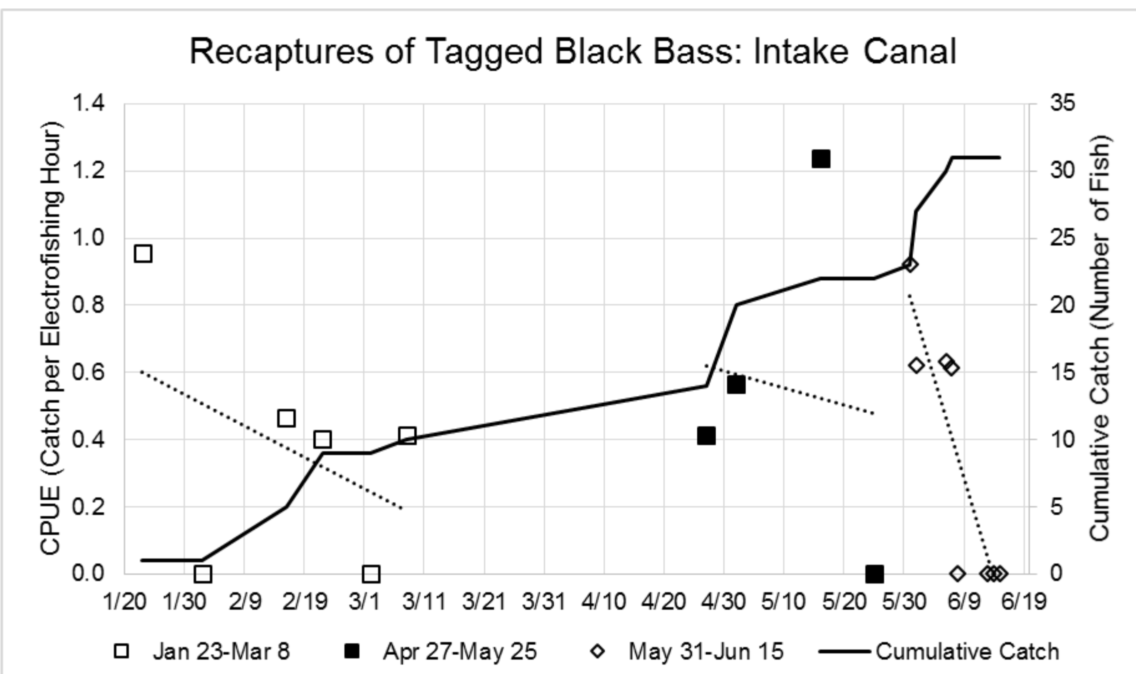


Figure 54. Recaptured Tagged Black Bass Catch Per Unit Effort and Cumulative Catch in the Intake Canal. Note: Linear trendlines are shown for all CPUE vs. date regressions, but only May 31-June 15 was statistically significant.

3.8 Chinook Salmon Consumption (Bioenergetics Modeling)

3.8.1 Total Possible Consumption and Removed Consumption

Similar to the findings of Stroud and Simonis (2016), the classical fixed-parameter bioenergetics model produced a downward-biased estimate of consumption in 2017 (Table 19); thus, the variable-parameter bioenergetics model was relied on for results interpretation. The variable-parameter model estimated 16.99 to 2,733.3 g of cumulative consumption of Chinook Salmon was avoided daily (Figure 55). The sum of these daily values estimated that removal of 5,236 Striped Bass between January 23 (00:00 hr) and June 16 (23:59 hr) potentially avoided 127.6 kg of juvenile Chinook Salmon being consumed in 2017 (Table 19). Assuming a juvenile Chinook Salmon size range of 0.66 g to 22.6 g, which are the 5^{th} and 95^{th} percentiles of mass of juvenile Chinook salmon (CDFW, unpublished data) salvaged at the SWP salvage facility (CDFW, unpublished data) during January 23 (00:00 hr) to June 16 (23:59 hr) that were converted from FL using the relationship in MacFarlane and Norton (2002) of $\text{Weight (g)} = 0.0003 * \text{FL (mm)}^{2.217}$, this biomass translates to between 5,640 and 192,872 juvenile Chinook Salmon individuals that avoided predation from predator removal efforts in 2017. Based on CDFW salvage data, total loss of juvenile Chinook salmon at the SWP facility during this period was calculated as 97,331 individuals.

Bookends were calculated on these daily estimates of daily cumulative consumption avoided. The lower bookend of the estimated total consumption avoided was the lower bound of the 95% CI of variable-parameters model estimates for Striped Bass previously removed and for $p < 1.0$ (Figure 55). When $p < 1.0$, the model simulates the situation in which Striped Bass do not eat their maximum possible ration. Instead, the independent estimate of the proportion of maximum consumption actually realized by Striped Bass in the Delta, obtained by the modeling described by Loboschefsky et al. (2012) (Loboschefsky, Personal Communication), was used to estimate actual consumption by Striped Bass. The values of $p < 1.0$ differed by age class: 0.69 for Striped Bass ages 1-2 years, 0.73 for age 3 years, 0.68 for age 4 years, and 0.72 for ages 5 years and up (Loboschefsky et al. (2012); Loboschefsky (Personal Communication)). The lower bound of the 95% confidence interval on the cumulative consumption avoided at $p < 1.0$ was 126.4 kg (Table 19).

The upper bookend was estimated first by setting $p = 1.0$. This simulates the situation in which every Striped Bass is consuming its maximum daily ration. Then, the variable-parameter model was used to determine the cumulative daily consumption for each day of the 2017 field season and the 95% confidence interval about that mean. The upper bound of the 95% CI of variable-parameters model estimates for $p = 1.0$ was plotted against date (Figure 55). The upper bookend was the upper bound of the 95% confidence interval of the cumulative consumption avoided for the entire 2017 field season with $p = 1.0$, which was 185.7 kg (Table 19).

Table 19. Estimates of Cumulative Juvenile Chinook Salmon Consumption for the 2017 Field Season.

p[1] (Proportion of Max. Consumption)	Type[2]	Fixed-Parameter Model (g)	Variable-Parameter Model		
			Lower Bound 95% CI (g)	Mean (g)	Upper Bound 95% CI (g)
1	Total	458,736.6	495,454.8	498,833.1	502,791.8
1	Removed	165,058.3	182,285.2	183,922.1	185,744.8
< 1	Total	317,516.6	342,831.7	345,230.4	350,844.5
< 1	Removed	114,448.0	126,364.8	127,610.8	128,898.4

Notes: [1]The value of p differed by age class: 0.69 for Striped Bass ages 1-2 years, 0.73 for age 3 years, 0.68 for age 4 years, and 0.72 for ages 5 years and up (Loboschefsky et al. 2012); Loboschefsky, Personal Communication). [2]Type is Total consumption that would have occurred if all 5,236 Striped Bass removed were present in the CCF every day of the field season and Removed is consumption avoided by those predators removed up to and including the previous day.

The estimated daily cumulative consumption avoided (Figure 55) climbed from the first day of predator removals (1/23/17) through the final day that was modeled (6/16/17). This increase was not linear because Striped Bass catch increased in a nonlinear way through time and estimated consumption rises exponentially with temperature.

In Figure 55, the lower bookend was much closer to the estimated cumulative consumption avoided than was the upper bookend. This was because consumption cannot be less than zero for a given day. However, in the variable-parameter model on some days consumption could be considerably higher than the estimated cumulative consumption by random chance of the draw of multiple variable parameters. This reflected a situation where an individual Striped Bass consumed a large amount of food, a relatively large proportion of which was Chinook Salmon. Thus, the upper bound was further from the estimated cumulative consumption because its value was not bound on the positive side while there was such a constraint on the lower bound of consumption.

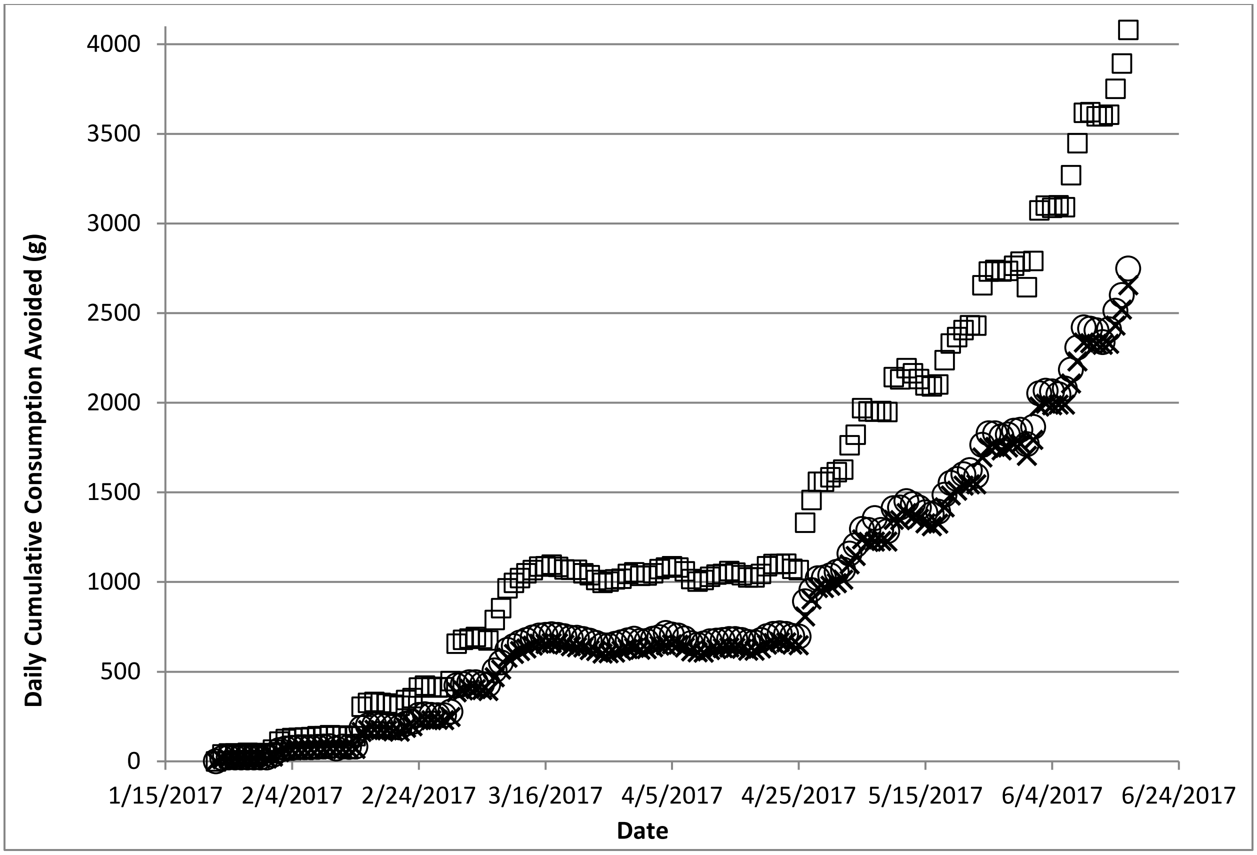


Figure 55. Cumulative Striped Bass Consumption of Chinook Salmon Avoided (O), with Lower (X) and Upper (□) Bookends, from the Variable-Parameter Bioenergetics Model.

3.8.2 *The Effect of Age Class on Consumption*

Although individual Striped Bass larger than the minimum harvest length have the potential to consume more juvenile Chinook Salmon, there were substantially more Striped Bass less than minimum harvest length removed in 2017, resulting in age classes 1-3 comprising the bulk of the estimated potential Chinook Salmon consumption (Figure 56). This finding is consistent for both the fixed-parameter and variable-parameter models.

The variable-parameter model produced calculations with modest variation in the total amount consumed by each age class, but generally the variability within age classes was smaller than that between age classes. In addition, these results were similar to Stroud and Simonis (2016): the fixed-parameter model produced a downward-biased estimate in the 2017 analysis (Figure 56).

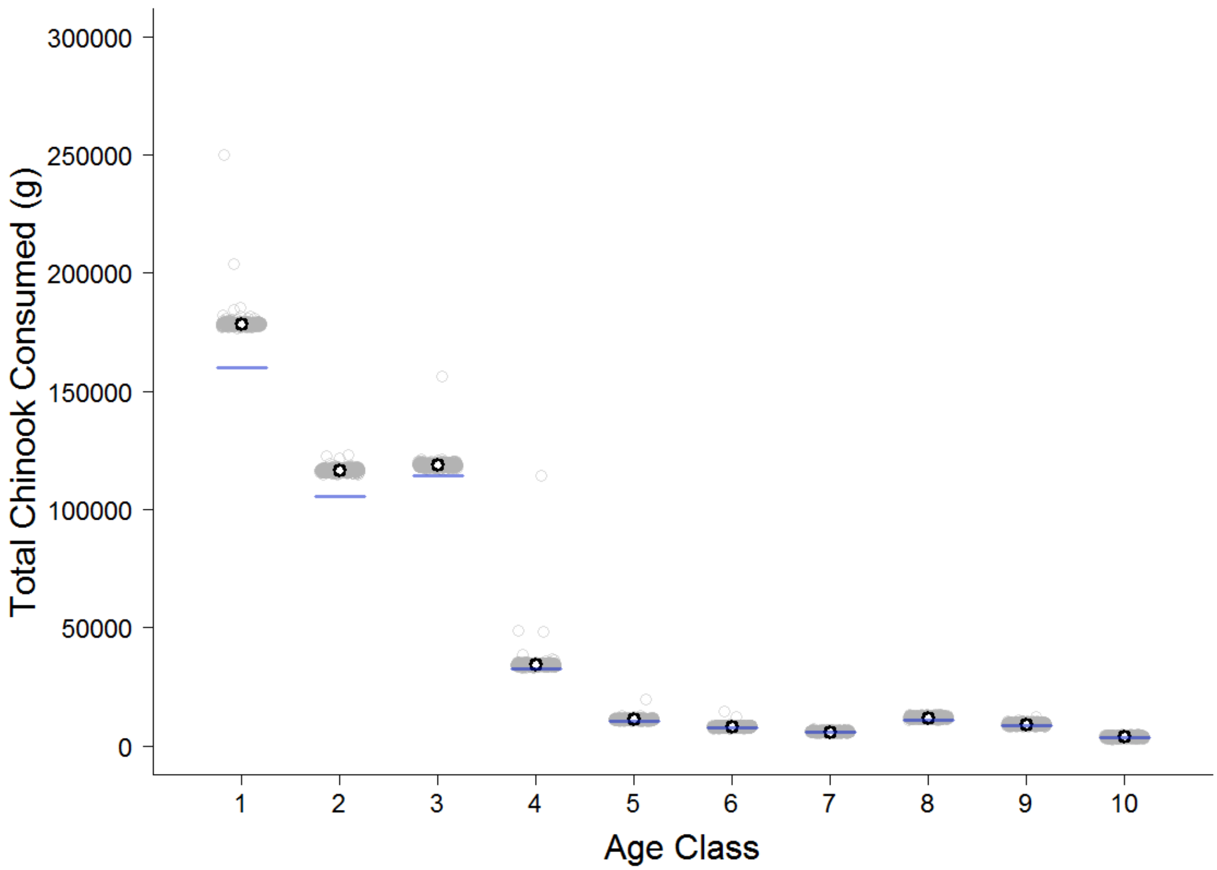


Figure 56. Total Consumption of Chinook Salmon by Striped Bass Age Classes Removed from CCF in 2017 (Figure elements described in text below)

Consumption values are for the 2017 field season, summed across all individuals within the age class, and assumed that Striped Bass do not grow in size after they were removed from the CCF. Grey circles are the individual iterations of the variable-parameter model, and are jittered in the x-axis direction and are transparent to show overlaps. The white circle shows the mean of the iterations and the vertical lines depicting the 95% confidence bounds of the iterations are smaller than the size of the point representing the mean and are therefore not visible. The blue lines show the companion values for the fixed-parameters model.

3.8.3 Predator Population Extrapolation

As described in Section 2.11.3 *Predator Population Extrapolation*, a simple, illustrative calculation was made for estimating proportion of maximum consumption avoided (C_P): C_P was reduced by an order of magnitude for each order of magnitude of population-size increase in the two simulations. For reference, the proportion of maximum consumption avoided for a population of 5,236 Striped Bass is shown (Figure 57a). The visualization in Figure 57b depicts the limited consumption reduction that takes place at a population size of 52,360 Striped Bass. As would be expected, removal of 5,236 Striped Bass from a population 100 times larger, 523,600, shows a negligible effect on the proportion of maximum consumption avoided (Figure 57c).

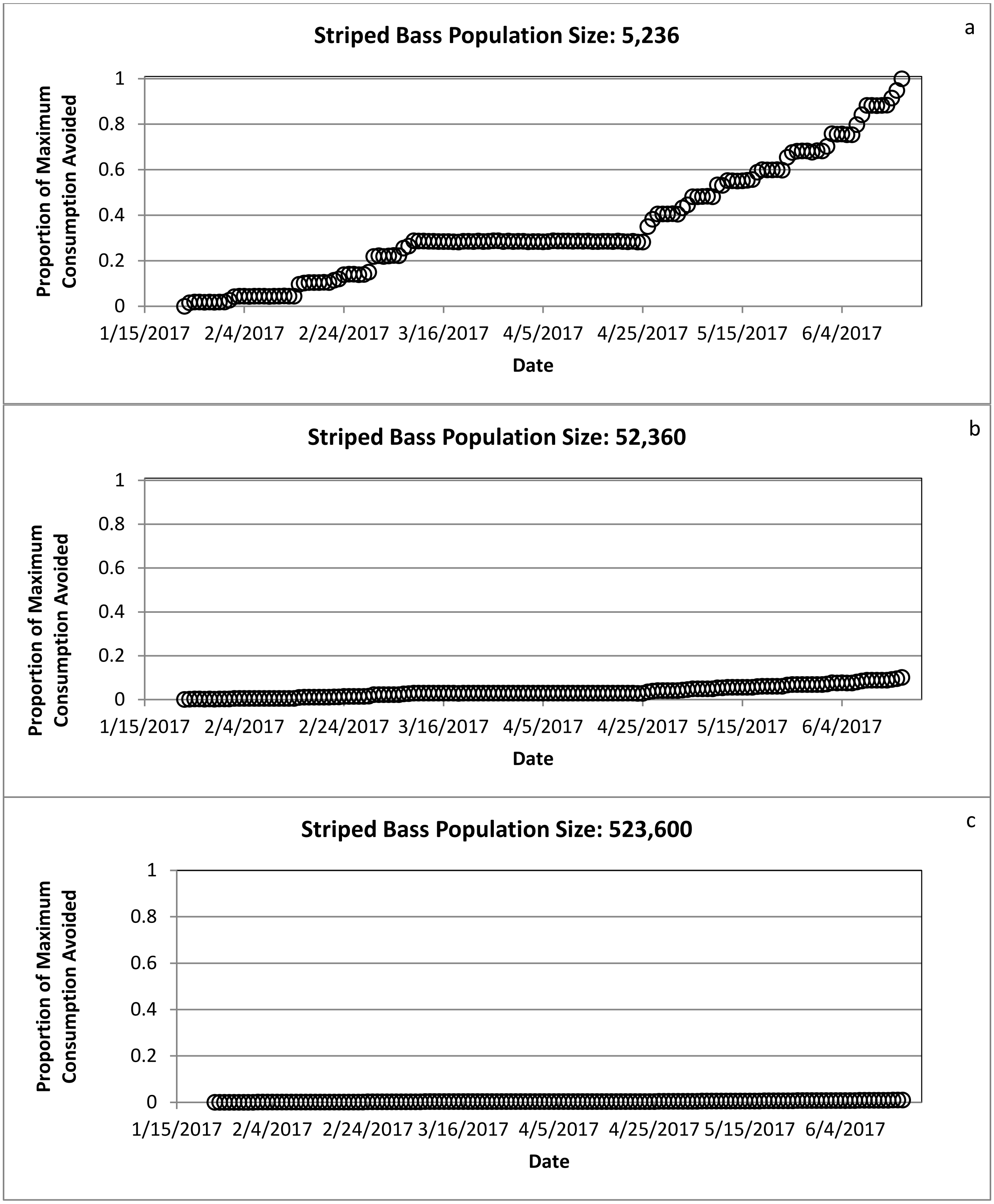


Figure 57. 95% Confidence Interval-Upper Bound of Proportion of Consumption Avoided Estimated for Three Striped Bass Population Sizes. The proportion of maximum consumption (p) was set to 1.0 to estimate the maximum possible consumption avoided through predator removals.

3.9 Listed Species

There was the potential for fish protected under FESA and CESA to be shocked during the PRES. The maximum allowable take for the 2017 field season of species listed under FESA and CESA is shown in Table 20.

During late May and June (5/17/17 to 6/13/17), several live Chinook Salmon juveniles and one steelhead juvenile were seen on multiple days. The fish were noticed swimming quickly away from the electrofishing boat, presumably after they detected the electrical field from the electrofishing boat. No individuals became unconscious and all appeared to be swimming upright. Field staff followed the established protocol of moving electrofishing away from the area and reporting the sightings to DWR project managers. In addition, the locations of these fish and approximate numbers were recorded in the GIS Collector app (Figure 58). DWR project managers reported these encounters to NMFS. No “take” of Chinook Salmon was recorded because the fish were not likely listed runs. DWR believes that all of these individuals were hatchery fish. The majority of these individuals were seen during June when most wild fish had already moved farther down the estuary. It is likely that these individuals were hatchery fish from three large releases from the Merced River hatchery made on 4/24/17 (330,363 Fall-Run Chinook Salmon), 5/3/17 (520,282 Fall-Run Chinook Salmon), and 5/18/17 (484,195 Fall-Run Chinook Salmon), as Chinook Salmon encounters occurred near these releases.

No other FESA or CESA listed species were encountered during the 2017 field season and, therefore, there was no take.

Table 20. Maximum allowable take of fish protected under FESA and CESA for the PRES.

Fish Species	Federal Listing Status	State Listing Status	Take Limit	
			Federal	State
Delta Smelt	Threatened	Endangered	1	20
Longfin Smelt	No Listing	Threatened	N/A	20
Green Sturgeon (Southern DPS)	Threatened	No Listing	20	N/A
Steelhead (Central Valley DPS)	Threatened	No Listing	50	N/A
Winter-run Chinook Salmon	Endangered	Endangered	50	20
Spring-run Chinook Salmon	Threatened	Threatened	50	20

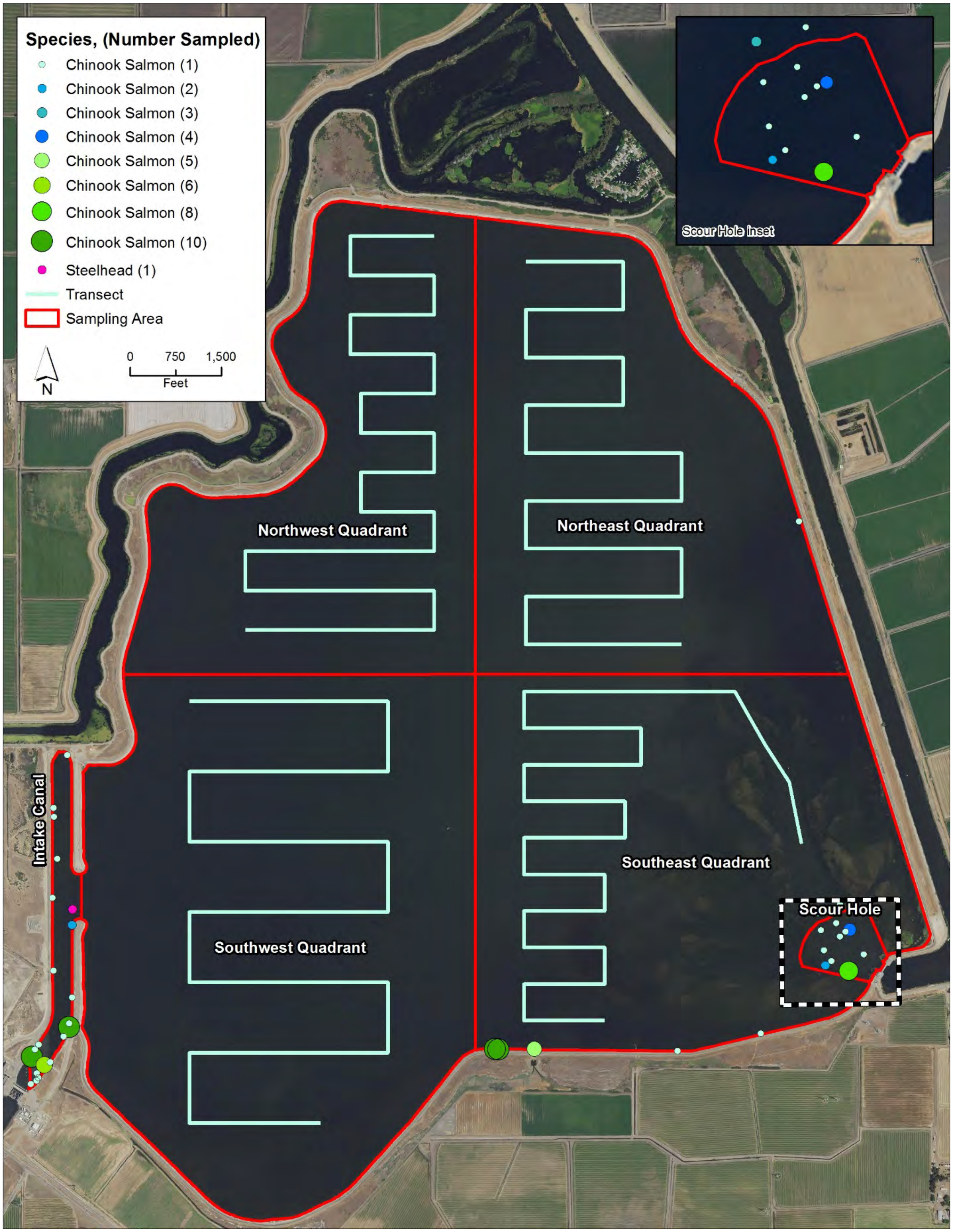


Figure 58. Map of Listed Species Encounters during the 2017 Field Season.

4. Discussion

4.1 Predator Catch Composition

In 2017 we caught and removed 6,151 predatory fish from CCF (Table 6), estimated at nearly 7,200 lb (3.26 metric tons) of predator biomass. The majority of individuals (5,236 fish) and biomass (just over 5,800 lb; 2.63 metric tons) was Striped Bass. The remainder consisted mostly of black bass (879 fish; just over 1,300 lb; 0.60 metric tons) and a small number of catfish (36 fish, ~70 lb). As a result of the predominance of Striped Bass in the overall catch, overall predator catch patterns largely reflect Striped Bass catch patterns.

The very high relative catch rates of Striped Bass suggest that the species is abundant in CCF, consistent with previous CCF predator studies (Kano 1990). However, it also may indicate that Striped Bass were effectively caught using the electrofishing protocol in the PRES. Black bass, mostly Largemouth Bass, were also collected in reasonable numbers, with relative proportions somewhat greater than observed in previous electrofishing of CCF (Kano 1990). This probably reflects the general increase in Delta black bass abundance over the past two decades (Mahardja et al. 2017).

Catfish were rarely caught during the PRES, which could indicate that they are either not abundant in CCF or that the methods used in the PRES were not effective in capturing them. Kano (1990) caught more White Catfish (74 percent of total catch) in CCF than any other species in his year-long predation study and employed several methods that were not used in the PRES: gill nets, angling, Merwyn traps, and hoop traps that allowed sampling over the entire 24 hour period. This supports the hypothesis that the electrofishing protocol used in the PRES was ineffective at catfish capture, but does not reject the hypothesis that catfish are not abundant in CCF. If catfish are more abundant in CCF, other methods, including nets and traps should be used. The upcoming Predator Fish Relocation Study (PFRS) will likely evaluate the effectiveness of several of these methods.

There was a brief attempt to increase catfish catch during 2017 field season at the Scour Hole. A dropper cable with an attached cathode was lowered into deep water in the Scour Hole. The attempt caught no fish after ~15 minutes and the method was abandoned. Given the typical high catch rates in the Scour Hole, the likely cause for the lack of catch with the dropper cable was an ineffective sampling method. The distance between the dropper cable cathode may have been too far from the anode attached to the electrofishing boat, causing a dispersed electric field that was ineffective at shocking fish. If this method is used again, it should be performed in shallower water. Capture of catfish may be of importance because they can have relatively high rates of predation on juvenile Chinook Salmon: in the San Joaquin River, genetics studies revealed that ~4% of White Catfish and ~21% of Channel Catfish had consumed juvenile Chinook Salmon within 2-3 days of capture, which compared to ~4% for Striped Bass and just over 2% for Largemouth Bass (Hayes et al. 2017).

Based on 2017 catch data, only 7 percent of the Striped Bass caught in electrofishing would be recreationally harvestable (above the legal size limit of 18 inches [457 mm]). This would severely limit the ability for increased recreational angling to reduce the population, assuming that the size distribution of Striped Bass captured by electrofishing was reasonably representative of the overall size distribution of Striped Bass in CCF. This is further evidence to 2016 data, in which only 1 percent of Striped Bass caught were recreationally harvestable, suggesting that increased fishing pressure would not reduce Striped Bass unless regulations were altered in CCF. DWR submitted letters to the California Fish and Game Commission (F&GC) requesting a reduction in size limits and increase in bag limits of Striped Bass in CCF (DWR 2015), but no response has been received from the F&GC.

4.2 Environmental Influences on Predator Catch and Predator Habitat Suitability

The statistical analysis found that sampling section, water temperature, boat, and turbidity were the most important drivers of catch rates both using electrofishing time and total time on the water as the measure of effort. Among sampling sections, the Scour Hole, Intake Canal, and all shoreline sections generally had the highest catch rates of all predators combined. There were small differences in spatial patterns between Striped Bass, black bass, and all predators combined, but overall, to maximize predator removal, the Scour Hole, Intake Canal, and shoreline locations should be the focus of targeted removal efforts for the 2018 field season. Discontinuing electrofishing in open water locations would greatly increase removal efficiency and yield more fish per unit effort.

Although there was a statistically significant difference in total catch rates between electrofishing boats, the differences were between the FISHBIO2 and DWR boats; catch rates between FISHBIO and DWR boats were statistically indistinguishable. The FISHBIO and DWR boats conducted the majority of sampling; the FISHBIO2 boat was used only as a backup for when another electrofishing boat was inoperable. As a result, this finding is less concerning than if the differences were between DWR and FISHBIO boats. Regardless, current plans for the 2018 field season are that a new electrtofishing boat similar to the FISHBIO boat will replace the DWR boat.

Warmer water temperature correlated with a significant increase in catch rate of Striped Bass, as others have found for other species (e.g., Bodine and Shoup 2010). This may be due to habitat shifts associated with water temperature, such as spawning movement, which affect the vulnerability of fish to electrofishing (Carline et al. 1984). Significant positive correlations between large fish (potential predators >30 cm) abundance and temperature were found with hydroacoustic surveys at the Head of Old River-San Joaquin River junction in 2011-2012 (DWR 2015). In contrast, there was no significant relationship between angling catch rate of Striped Bass and temperature at the Sacramento River-Georgiana Slough junction in 2014, and the catch rate of Largemouth Bass was only weakly positively related to temperature (DWR 2016). Although not included in the statistical analyses, conductivity in CCF generally decreased as temperature increased in 2017, from around 250-300 µS/cm in mid-January to 100-150 µS/cm in May/June. This decrease in conductivity would have brought the water in CCF closer to the conductivity of the fish (typically ~100 µS/cm), which would have increased the transfer of electric power from the water to the fish per the maximum power transfer theorem (Reynolds and Kolz 2012); this could have increased electrofishing catch efficiency.

Lower turbidity was significantly related to an increase in catch rate of Striped Bass, but not black bass. This may be because increased turbidity reduced netting efficiency (reduced visibility of fish to netters; Lyon et al. 2014) and was greater than any effect of turbidity on Striped Bass behavior and susceptibility to electroshocking (i.e., less tendency of fish to flee from the electrofishing boat if it is not visible to them; Reynolds and Kolz 2012). Black bass catch rates have been positively related with turbidity in some studies (e.g., McInerny and Cross 2000), whereas other studies have found no relationship (Edwards et al. 1997; Gibson-Reinemer et al. 2016) or negative relationships (Gibson-Reinemer et al. 2016).

Radial gate flow and pumping rate at the Banks Pumping Plant did not exhibit statistically significant relationships with predator catch rates. Further, there was no significant interaction between either variable and sampling location, indicating that the lack of correlation of each variable was consistent at all sampling sections. This is consistent with the telemetry study by Clark et al. (2009), who found that the proportion of time acoustically tagged Striped Bass spent near the radial gates or in the Intake Canal were not related to radial gate operations or pumping rate.

4.3 Small-Scale Spatial Patterns

Visual examination of catch patterns at a scale smaller than a quadrant or study section (e.g. Intake Canal or Scour Hole) revealed that there are smaller hotspots on which targeted electrofishing efforts could focus. These locations are: (1) just east of the opening of the Intake Canal to the rest of CCF; (2) the ring around deeper water within the Scour Hole; (3) the open water area to the Northeast of the Scour Hole delineation within the Southeast quadrant; (4) the linear southwest reach of shoreline in the Southwest quadrant; (5) the middle reach of the Northeast quadrant shoreline; and (6) the upper reach of the Northwest quadrant shoreline.

Spatial statistical results largely corroborate these results, such as showing that the Scour Hole is a hotspot for Striped Bass and reaches along the Northeast and Northwest quadrant shorelines are hotspots for black bass. The Getis-Ord Gi* statistical analysis was limited in that it does not include temporal patterns within the analysis, and other methods should be sought if temporal patterns are of management interest.

Interestingly, the portion of shoreline with the lowest number of predatory fish catches was along the south and east portions of the strip of land separating the Intake Canal and the Southwest Quadrant. This area was typically used by anglers during sampling and, therefore, was generally avoided by electrofishing boats, thus greatly reducing the electrofishing effort in the area. The sparse catch could be reflecting either low sampling effort or predator depletion from angling pressure. However, when correcting for effort, catch rates are still low in this reach, suggesting that CPUE is low, potentially due to removal by anglers.

4.4 Comparison to 2016 Results

In 2016, sampling occurred for 11 days between April 20, 2016 and May 18, 2016. A total of 2,686 predatory fish were caught, consisting of 2,059 Striped Bass (77% of total captures), 594 black bass (22% of total captures), and 33 catfish (1% of total captures; Table 21).

The proportions of fish caught by species group are broadly similar between 2016 and 2017, although a higher proportion of Striped Bass and lower proportion of black bass were caught during 2017 (Table 21). This likely reflects differences in the sampling locations chosen.

Mean fork lengths were similar between field seasons, although mean fork length in 2017 was consistently larger than that in 2016 across species groups and overall (Table 21).

Catch of all predatory fish per electrofishing hour for all sites pooled was over two times higher in 2016 (86.4 fish per hour) than in 2017 (38.6 fish per hour; Table 21). This likely reflects the difference in sampling strategies between field seasons. The purpose of the 2016 field season was to investigate different methods as a pilot study, whereas the 2017 field season methodically sampled the various sections of CCF in order to characterize spatial patterns in predatory fish populations. Therefore, the low counts in the cold spots in 2017 may have brought down overall catch rates.

Mortality of caught fish was substantially lower during the 2017 field season (4.5%) compared to 2016 (15.0%). This reduction in mortality is likely due to improvements made in the barge holding tank aeration systems, reductions in fish processing times and requirements, and general efficiency improvements with field staff experience.

Table 21. Comparison of 2016 and 2017 predatory fish sampling, catch composition, catch rate, and mortality.

Species Group	Days sampled		n		% of total		Mean Fork Length (mm)		Mean catch per electro-fishing hr		% Mortality	
	'16	'17	'16	'17	'16	'17	'16	'17	'16	'17	'16	'17
Black Bass			594	879	22.0	14.3	309.3	333.0	19.2	5.6	0.3	0.2
Catfish			33	36	1.2	0.6	363.8	382.7	1.2	0.2	0	0
Striped Bass			2,059	5,236	76.7	85.1	289.5	323.9	66.6	32.8	19.5	5.2
Total	11	39	2,686	6,151	100	100	294.8	325.5	86.4	38.6	15.0	4.5

4.5 Predator Removal in Relation to Chinook Salmon Survival Estimates (Skinner Evaluation and Improvement Study)

In WY 2017, the SEIS investigation implemented use of a second mark-recapture methodology (Predation Detection Acoustic Tags) during a short period of the study in addition to releases of PIT tagged Chinook Salmon throughout the season. Utilizing data from 16 releases of PIT tagged Chinook Salmon (8 late-fall and 8 fall run releases), Pre-Screen Loss (PSL) was estimated as 77.16% for all races combined using tag detections and modeled results from the 16 releases of PIT tagged Chinook Salmon. PSL was estimated as 56.07% (range=26.1% to 88.5%) and 92.1% (range=92.1% to 98.5%) for late-fall and fall run Chinook Salmon, respectively. However, survival across CCF was higher than expected for acoustically tagged fish, with point estimates indicating greater than 90% pre-screen survival of four late-fall Chinook Salmon releases in February and March.

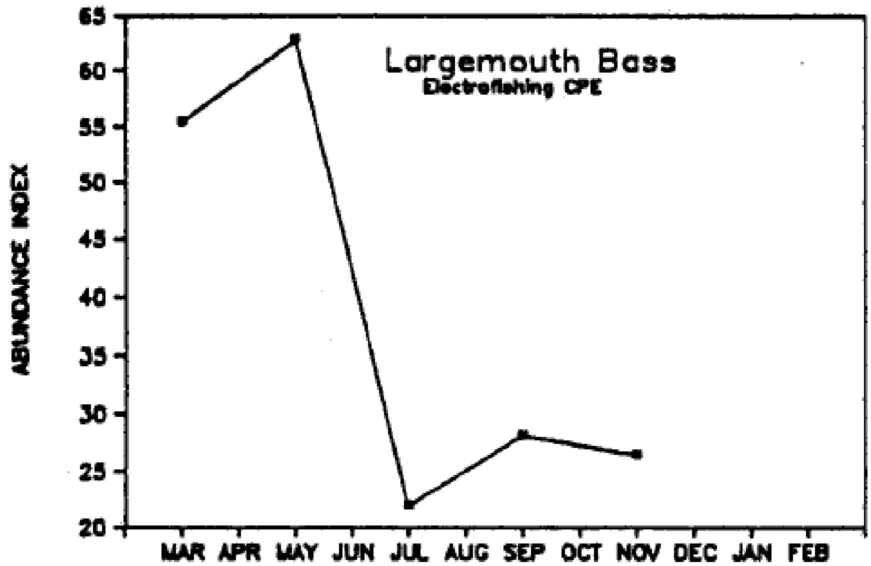
Based on release-specific survival model results with biomass removed and CPUE covariates added, it was determined that predator relocation efforts had no significant effect on salmon survival. The absence of detectable effects of the 2017 predator relocation effort may be due to a variety of reasons including the limited nature of the removal effort in 2017. Based on the SEIS effort, one possible explanation for continued low survival estimates is that there is substantial loss occurring in the area near the debris boom and trashrack as fish enter the salvage facility. Predators and predation at this location may not be effectively influenced by the PRES effort.

Additional information on Chinook Salmon survival in CCF during 2017 can be found in the "Skinner Evaluation and Improvement Study 2017 Annual Report."

4.6 Predator Depletion

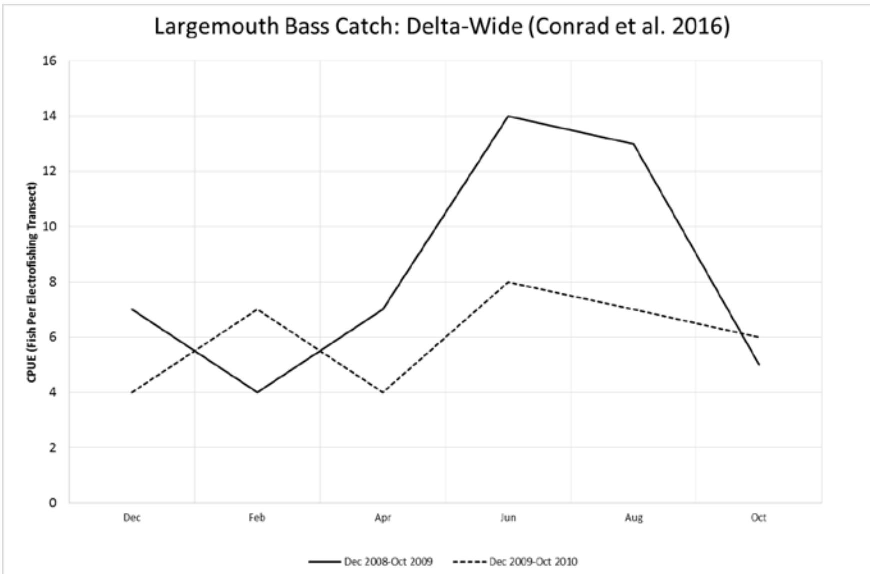
There was little statistical evidence that depletion of black bass occurred during the PRES, although it is again emphasized that the PRES did not aim to achieve depletion. It is noteworthy, however, that the black bass CPUE in the Intake Canal decreased from 20 fish per electrofishing hour in early June to 0 fish per hour in mid-June at the end of the PRES (Figure 44). Together with the Scour Hole, this was the only location where electrofishing occurred intensively (i.e., sessions every 1-5 days, or every 2 days on average), following cessation of sampling at the other sections. However, the observation that CPUE of tagged black bass released back to the water also significantly declined over the same period suggests that seasonal migration out of the Intake Canal could have driven the declining trend in abundance (Figure 54). To examine this further, other data sources were reviewed to assess seasonality of black bass.

Largemouth Bass are the main black bass species salvaged at the Skinner Fish Protective Facility but are primarily (~87%) juveniles (Grimaldo et al. 2009), which is essentially the opposite of the age composition seen in the PRES. Therefore, it was not felt that the salvage database was a useful source of seasonality information for larger black bass. Electrofishing in CCF in 1983/1984 suggested that abundance of larger Largemouth Bass (mean size ~300-mm FL, similar to black bass in the PRES) is greatest in spring, before declining later in the year (Kano 1990; Figure 59). However, relatively few (87) Largemouth Bass were caught in that study. A Delta-wide 2-year electrofishing survey found that CPUE of larger-than-juvenile Largemouth Bass peaked in spring but remained high during summer in the first year of the study, and was highest in spring but with less pronounced seasonality in the second year (Figure 60).



Source: Kano (1990: Figure 6).

Figure 59. Monthly Catch Per Effort Abundance Index of Largemouth Bass Collected by Electrofishing in CCF, March 1983-February 1984.



Source: Conrad at al. (2016: Adapted from values in Table 1).

Figure 60. Mean Catch Per Transect of Largemouth Bass Collected by Electrofishing in the Delta, December 2008-October 2010.

Overall, the studies by Kano (1990) and Conrad et al. (2016), together with the observations of declining tagged black bass CPUE from the PRES, suggest that seasonality partly or fully explains the pattern of declining abundance of black bass in the Intake Canal during June. However, given the intense electrofishing regime in the Intake Canal in June and some evidence for fewer days between electrofishing sessions giving a greater chance of reduction in black bass CPUE in the Southeast quadrant shoreline (Figure 51), it is suggested that future studies aiming to achieve depletion should conduct electrofishing at no more than 1-5 days apart throughout the season. Ideally, multiple (three or more) electrofishing sessions covering the same area could be undertaken on a daily basis, in order to estimate the proportion of fish that had been removed. This level of intensity is recommended to avoid violation of the main assumptions of statistical depletion assessment methods (Maceina et al. 1995; Cavallo et al. 2013). Cavallo et al. (2013) found that single-day, three-pass electrofishing was able to remove ~80-90% of predators in a 1.6-km reach of the tidal Mokelumne River, but that 5 days after the first removal effort, the numbers of predators (including black bass) captured in the second removal effort was several times greater than in the first effort. Although the black bass were smaller than those collected in the PRES (e.g., Largemouth Bass mean size of 175 mm), this emphasizes that depletion efforts probably need to be relatively frequent (< 5 days apart) and intensive (multiple passes per day) to be successful. One drawback of this approach is that many fish that are shocked but not captured may flee to deeper waters, potentially skewing depletion estimates.

4.7 Chinook Salmon Consumption

In 2017, the variable-parameters bioenergetics model estimated that 127.6 kg of Chinook Salmon avoided consumption (Table 19). This avoided consumption was accomplished through the removal of 5,236 Striped Bass between January 23 (00:00 hr) and June 16 (23:59 hr), 2017. Bookends were calculated on this estimate that went beyond a single confidence interval. The lower bookend was estimated at 126.4 kg and represents the lower bound of Chinook Salmon consumption that would be avoided in 95% of the years that had conditions similar to 2017. The upper bookend was estimated at 185.7 kg and this is a conservative estimate, due to the "No Growth" assumption (see Section 2.11.2, *Fixed Parameters: Basic Consumption*), and represents the upper bound of consumption that would be avoided in 95% of the years that had conditions similar to 2017. As discussed in Section 3.8.1, *Total Possible Consumption and Removed Consumption*, the lower bookend was much closer to the mean estimated cumulative consumption avoided than was the upper bookend. This was a result of consumption being bound by zero at the lower end but not at the upper end.

4.7.1 The Effect of Age Class on Consumption

The age analysis showed that the majority of juvenile Chinook Salmon mass was consumed by age classes 1, 2, and 3. Because Striped Bass in these age classes are all below the minimum recreational harvest length requirement (457 mm [18 in]), none of these fish are subject to recreational harvest.

4.7.2 Predator Population Extrapolation

The calculation of proportion of maximum consumption avoided (C_P) was a simplification of a complex problem. But, no data existed regarding the 2017 Striped Bass population size in CCF. Thus, this simplification was the only method possible to visualize the potential effect of Striped Bass population size on Chinook Salmon consumption avoided. In Figure 57b it was suggested that the removal of 5,236 Striped Bass would have limited effect on the Chinook Salmon juvenile consumption by a population of 52,360 Striped Bass. While there may not have been 52,360 Striped Bass in CCF at any one time, this is an open system where immigrating fish could easily replenish the population. If the population size of all the Striped Bass in the south Delta in the vicinity of CCF is taken into account, then the population could be greater than 52,360. Thus, the removal of 5,236 Striped Bass from CCF in 2017 may have had a limited effect on the consumption of Chinook Salmon.

4.8 Recommendations

Results from 2016 and 2017 field seasons have shown that electrofishing can work effectively for capturing and removing non-native predatory fish from CCF. While immigration and emigration of predatory fish occurs regularly in CCF (Gingras and McGee 1997), removals of large numbers of predatory fish could potentially improve the survival of listed species. This section provides recommendations for maximizing predator removals, which is the primary objective of the 2018 field season.

1. **Increase predator removal effort to maximize predator removals.** There was very little evidence of predator depletion during the 2017 field season, as estimated by CPUE curves through time (Section 4.5). In addition, there was little evidence that predator removal efforts had any effect on juvenile salmonid survival. This suggests that predator removal efforts should be increased to maximize the ability to determine whether predator removal would result in an increase to salmonid survival. Electrofishing effort could be increased by increasing the number of electrofishing days per week, increasing the duration of time on the water, and fishing with more than two electrofishing boats concurrently.

2. **Focus targeted removal efforts on Scour Hole, Intake Canal, and shorelines.** Catches of all predatory fish were statistically higher in the Scour Hole, Intake Canal, and along the shorelines than in open water locations (Section 3.3). Therefore, these locations should be the focus for targeted removal efforts and open water locations should be dropped. If there is a desire to emphasize removal of Striped Bass, efforts should focus most on the Scour Hole. For black bass, the Intake Canal and shoreline locations would be expected to yield the most fish, whereas the Scour Hole would be expected to have low catches.

3. **Focus targeted removal on other smaller scale locations.** The small-scale spatial analysis (Section 3.4) provides evidence that there are specific areas with consistently higher catch rates ("predator hotspots"). These locations include: (1) Just east of the opening of the Intake Canal to the rest of CCF for Striped Bass and black bass; (2) the ring around deeper water within the Scour Hole for Striped Bass; (3) the open water area to the Northeast of the Scour Hole delineation within the Southeast quadrant for Striped Bass; (4) the linear southwest reach of shoreline in the Southwest quadrant for Striped Bass and black bass; (5) the middle reach of the Northeast quadrant shoreline for black bass; and (6) the upper reach of the Northwest quadrant shoreline for black bass. These areas could be targeted to increase predator catch rates.

4. **Consider more effective options for catching catfish.** Electrofishing as undertaken for the PRES does not effectively catch catfish. The dropper cable did not work, likely due to the long distance between the anode and the electrofishing boat, which diffused the electrical field to the point of being ineffective on fish near or at the bottom like catfish. Although not a consideration for the PRES, the utilization of other gear types, such as traps and nets, for full diel (24-hour) periods should be strongly considered as part of the upcoming PFRS.

5. **Continue predator transport to Bethany Reservoir using current methods but with additional trailers.** There were no statistically significant predictors of predator mortality, and mortality rates were low. This suggests that the transport was generally effective. With the 2018 focus on predator removal, additional transport trailers may be needed to effectively process the anticipated increased predator catch.

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State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES
Bay-Delta Office

Clifton Court Forebay Predator Reduction Electrofishing Study Annual Report 2018

DECEMBER 2018

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Executive Summary

The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (PRES) was implemented in response to the National Marine Fisheries Service (NMFS) letter dated April 9, 2015, requiring that the California Department of Water Resources (DWR) immediately implement interim measure (a) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative (RPA) Action IV.4.2(2) of the 2009 Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and State Water Project (NMFS BiOp; NMFS 2009). The PRES length was three years, beginning with a pilot year effort in 2016, a 2017 effort to refine methods and determine the main factors affecting predator catch, and a 2018 effort focused on maximizing predator removal based on knowledge gained during the 2016 and 2017 campaigns. The PRES involves electroshocking and removing predators from CCF and transporting them to Bethany Reservoir with the goal of decreasing pre-screen loss of protected fish species with an emphasis on Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*). Concurrent with the PRES, releases of Passive Integrated Transponder (PIT) and acoustically tagged juvenile Chinook Salmon occurred to determine rates of pre-screen loss in the Skinner Evaluation and Improvement Study (SEIS).

During the 2018 field effort we focused on maximizing removal of predatory fish based on lessons learned and recommendations from the 2016 and 2017 efforts. Effort increased by fishing 4 days per week using 3 concurrent electrofishing boats (2017 field work used 2 boats on 3 days per week). Fishing removals focused primarily on the locations with highest catch rates identified in 2017: the Intake Canal, Scour Hole, and shore lines. In addition, sunfish species were added to the list of predatory fish removed.

Electrofishing occurred at CCF on 54 days between January 8 and May 3, 2018. During the 54 field days, there was a total of 329 hours of active electrofishing, when electricity was being applied to the water column, for a total of 431 hours on the water.

Overall, the goal of the 2018 field season of maximizing predator removal was met. There were 13,138 predatory fish weighing approximately 13,877 lb (6.3 metric tons) electroshocked and removed from CCF. The large majority (11,839 fish, or 90.1%) of fish removed during the 2018 field season were Striped Bass, weighing approximately 12,098 lb (5.5 metric tons). Black bass accounted for 7.5% of total removals (989 fish; 1,678 lb or 0.8 metric tons). There were also 287 sunfish (2.2% of total predators; 79 lb) and 23 catfish (0.2% of total predators; 22 lb) removed from CCF.

Predator catch rates (measured as catch per unit effort) were lower or similar in 2018 compared to 2016 and 2017. While the reduced catch rates observed in 2018 may be due to seasonal and annual variations of predator densities in CCF, they might also have been merely a consequence of high overall effectiveness of predator removal. Analyses of the 2018 catch data provided evidence of depletion (reduced catch rate through time) of black bass and Striped Bass during periods when fishing strategies were designed to specifically target removal of these predatory fish. These findings of depletion indicate that predator removal can be effective at reducing predatory fish numbers and biomass in CCF, however, it is uncertain whether changes to predator densities were enough to significantly reduce pre-screen loss.

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Acronyms and Abbreviations

ANOVA	Analysis of Variance
BiOp	Biological Opinion
BDCP	Bay Delta Conservation Plan
CESA	California Endangered Species Act
CDEC	California Data Exchange Center
cfs	Cubic Feet per Second
CIMIS	California Irrigation Management Information System
CCF	Clifton Court Forebay
C.I.	Confidence Interval
CPUE	Catch per Unit Effort
CVP	Central Valley Project (federal)
˚C	Degrees Celsius
Delta	Sacramento-San Joaquin River Delta
DFW	California Department of Fish and Wildlife
DO	Dissolved Oxygen
df	Degrees of Freedom
DPS	Distinct Population Segment
DWR	California Department of Water Resources
FESA	Federal Endangered Species Act
FSB	Fish Science Building
GPP	Generator Powered Pulsator
GPS	Global Positioning System
Hz	Hertz
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
L	Liter
lb(s)	Pound(s)
mm	Millimeter
MOTC	Motorboat Operator Training Course
µS/cm	Microsiemens per Centimeter
NMFS	National Marine Fisheries Service
NMFS BiOp	Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project
PIT	Passive Integrated Transponder
PRES	Clifton Court Forebay Predator Reduction Electrofishing Study
PSL	Pre-Screen Loss
radial gates	Clifton Court Forebay Intake Radial Gates
RPA	Reasonable and Prudent Alternative
SD	Standard Deviation
SDFPF	John E. Skinner Delta Fish Protective Facility
sp.	Species
SWP	State Water Project (California State)
USFWS	United States Fish and Wildlife Service
USFWS BiOp	2008 Biological Opinion on the Long-Term Operational Criteria and Plan
WY	Water Year

1. Introduction

The Clifton Court Forebay (CCF) Predator Reduction Electrofishing Study (PRES) was implemented in response to the National Marine Fisheries Service (NMFS) letter dated April 9, 2015, requiring that the California Department of Water Resources (DWR) immediately implement interim measure (a) (Initiate interim measures to improve predator control in Clifton Court Forebay (CCF) by electroshocking and relocating predators) of condition 3 as part of the larger effort to comply with Reasonable and Prudent Alternative (RPA) Action IV.4.2(2) of the 2009 Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS BiOp; NMFS 2009). The purpose of the PRES was to electroshock and remove predatory fish from CCF and transport them to Bethany Reservoir in an effort to decrease pre-screen loss of protected fish species, particularly juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and California Central Valley Steelhead (*O. mykiss*). The PRES began in 2016 with a pilot effort, followed by a full-scale effort of standardized sampling to document spatial and temporal variations of predator densities in 2017, and ended in 2018 with full-scale effort intended to maximize predator removals.

1.1 Background

Located near Byron in Contra Costa County, California, CCF was constructed in 1969 by inundating a 2,200-acre tract of land approximately 2.6 miles long and 2.1 miles across (Kano 1990). CCF is operated as a regulating reservoir within the tidally influenced region of the Sacramento-San Joaquin River Delta (Delta) to improve operations of the State Water Project (SWP), Harvey O. Banks Pumping Plant, and water diversions to the California Aqueduct (Figure 1). During high tide cycles, when the elevation of water in Old River exceeds that in CCF, up to five radial gates that are in the southeast corner of CCF are opened to allow water to be diverted from the Delta into CCF. Daily operation of the gates depends on scheduled water exports, tides, and storage availability within CCF (Le 2004). Diversion of water from Old River into CCF results in the entrainment of numerous fish species, some of which are listed under the California and/or Federal Endangered Species Acts (CESA and FESA, respectively), including California Central Valley Steelhead, Sacramento River Winter-run and Central Valley Spring-run Chinook Salmon, Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), and the Southern Distinct Population Segment [DPS] of North American Green Sturgeon (*Acipenser medirostris*)). As such, operation of the SWP is performed in compliance with the terms and conditions of the NMFS BiOp, U.S. Fish and Wildlife Service (USFWS) 2008 Biological Opinion on the Long-Term Operational Criteria and Plan (USFWS BiOp; USFWS 2008), and California Department of Fish and Wildlife (DFW) 2009 Longfin Smelt incidental take permit (ITP; DFW 2009) actions.

Fish entering CCF must travel approximately 2.1 miles across CCF to reach the John E. Skinner Delta Fish Protective Facility (SDFPF). The SDFPF was designed to protect fish from entrainment into the California Aqueduct by diverting them into holding tanks where they can be salvaged and safely returned to the Delta clear of the SWP and Central Valley Project (CVP) pumping facilities (Morinaka 2013). Water is drawn to the SDFPF from CCF via an intake canal past a floating trash boom. The trash boom is designed to intercept floating debris and guide it to an onshore trash conveyor. Water and fish then flow through a trash rack, equipped with a trash rake, to a series of louvers arranged in a V pattern. Fish are behaviorally guided by the louvers and directed to salvage holding tanks where they remain until transported and released back into the Delta.

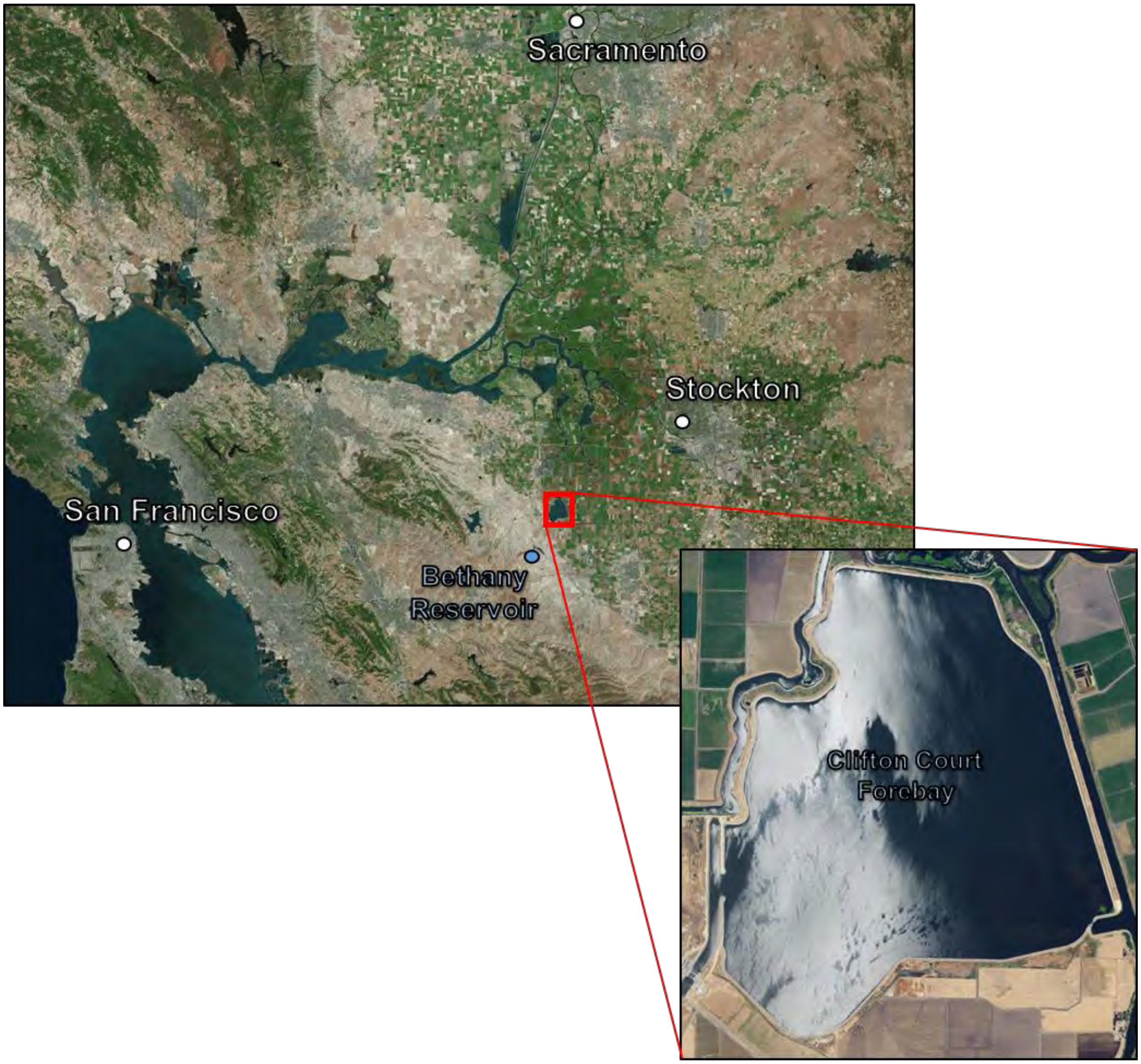


Figure 1. Clifton Court Forebay Location Map

The loss of fish between the CCF Radial Gates and the SDFPF is termed pre-screen loss (PSL). PSL includes, but is not limited to, predation by fish, birds, and other predatory species. Studies conducted by DWR and DFW indicate that PSL of juvenile Chinook Salmon varies from 63 to 99 percent (Gingras 1997) and PSL of juvenile steelhead was 82 ± 3 percent (Clark et al. 2009). Predation by Striped Bass is thought to be the primary cause of high PSL in CCF (Brown et al. 1996, Gingras 1997, Clark et al. 2009).

RPA Action IV.4.2(2) of the NMFS BiOp required DWR to "develop predator control methods for Clifton Court Forebay that will reduce Chinook Salmon and steelhead pre-screen loss in Clifton Court Forebay to no more than 40 percent." Further, "Full Compliance (of this RPA) shall be achieved by March 31, 2014" and "DWR may petition the Fish and Game Commission to increase bag limits on Striped Bass caught in Clifton Court Forebay."

To comply with this RPA action, DWR petitioned the Fish and Game Commission to remove size restrictions and increase or eliminate bag limits on Striped Bass recreational fishing in CCF on March 24, 2011, December 6, 2011, and March 23, 2015. Additionally, DWR proposed and planned to construct a public access fishing facility within CCF near the radial gates to increase recreational fishing pressure on legally sized predatory fishes in an effort to reduce predation of protected fish species.

Since 2011, NMFS has twice approved time extensions of RPA Action IV.4.2(2). First, in a letter dated May 1, 2011, DWR requested extending the timeline for improving predator reduction methods until December 2014, with full compliance by December 2017. NMFS agreed to the extension in a July 2, 2012 response letter, with the understanding that an additional number of actions would be implemented over the next three years. DWR implemented predation surveys and selected a fishing pier as the best alternative to meet the RPA Action IV.4.2(2) requirement. Then, in a letter dated February 7, 2014, DWR requested a one-year extension until December 2015 to complete environmental permitting and FESA Section 7 consultation associated with the construction of a new fishing pier. In a May 15, 2014 letter, NMFS agreed to the second request for a one-year time extension. However, during the consultation process it became apparent that implementation of the Bay Delta Conservation Plan/California WaterFix would conflict with the fishing pier. Specifically, changes in the design of CCF would limit public access to the proposed fishing pier, thereby reducing the fishing pressure at the proposed fishing pier.

DWR and NMFS staff met in December 2014 to evaluate alternatives to the fishing pier for reducing predation in CCF. On February 4, 2015, DWR requested another extension until November 2015 to deliver a final plan, schedule, and formal extension. In a response letter dated April 9, 2015, NMFS granted DWR this extension with conditions. Condition 3 states that, "DWR shall initiate interim measures to improve predator control before December 2015, to reduce predators in the CCF until an acceptable alternative can be implemented. Interim measures agreed to at the March 12, 2015 meeting that could be immediately implemented include: (a) electro-shocking and relocating predators; (b) controlling aquatic weeds; (c) developing a fishing incentives or a reward program for predators; and (d) operational changes when listed species are present (e.g., preferential pumping via the Central Valley Project [CVP] rather than the SWP)."

1.2 PRES Objective

The objective of PRES was to evaluate the feasibility of electro-shocking and relocation of predatory fish in CCF to comply with interim measure (a) from condition 3 of the April 9, 2015 NMFS response letter. The specific objective of the 2018 field season was to maximize predator removal from CCF by applying knowledge gained in prior years regarding spatial and temporal patterns in predator catch and techniques that maximize predator catch.

Each year of the three-year PRES had a specific focus. During 2016 we conducted a pilot effort, focusing on field logistics, equipment and personnel needs, developing effective sampling methods, and collecting initial data on predator density patterns. During 2017 we evaluated the effectiveness of refined methods based on the 2016 effort, determined spatial and temporal patterns in predator catch rates using a standardized sampling regime, and assessed environmental variables that may affect catch rates, and assessed factors contributing to mortality of predators transported to Bethany Reservoir. In addition, we evaluated evidence for depletion of predators and estimated Chinook Salmon biomass potentially saved from predator consumption through predator removal. During the 2018 field season we utilized the information gained regarding the factors that affect predator catch rates as well as additional lessons learned from 2016 and 2017 efforts to maximize predator removal rates.

1.3 Concurrent Predator Studies in Clifton Court Forebay

1.3.1 Skinner Evaluation and Improvement Study (SEIS)

In Water Year (WY) 2013, DWR initiated the Skinner Evaluation and Improvement Study (SEIS), a mark-recapture study to evaluate losses of tagged salmonids from the SWP intake at CCF radial gates to the termination of the fish salvage process (approximately 2.1 miles) at the SDFPF. Similar to the PRES, the SEIS was developed in response to RPA Action IV.4.2(2) from the NMFS BiOp, which directs the DWR to reduce PSL and improve screening efficiency of juvenile salmonids.

The SEIS has three main objectives:

- Estimate juvenile Chinook Salmon total survival from the CCF radial gates to the salvage release sites;
- Estimate survival in the various segments of the CCF entrainment and salvage process, including survival across CCF (pre-screen loss) and Whole-SWP survival and efficiency at the SDFPF;
- Assess the importance of operational and environmental covariates on survival including the effectiveness of predator reduction activities.

All predator removal effort involved with the PRES aimed to reduce PSL of juvenile salmonids in CCF to comply with RPA Action IV.4.2(2). As such, the PRES and SEIS have coordinated closely to time releases of tagged salmonids with predator removal efforts to determine the potential effects of predator removal efforts on juvenile salmonid PSL.

1.3.2 Clifton Court Forebay Predation Study (CFPS)

The Clifton Court Forebay Predation Study (CFPS) was initiated in 2013 in response to RPA Action IV.4.2 from the NMFS BiOp to gain a better understanding of predation as a factor in survival of listed salmonids in CCF. One element of CFPS is to tag predatory fish with Passive Integrated Transponder (PIT) and Floy tags and follow their recaptures through time to estimate movement, population size, and prey consumption. Field sampling during the PRES regularly captures predatory fish that were tagged for CFPS and reports all recaptured fish to the CFPS project manager. All recaptured fish were subsequently released back into CCF until 3/14/2018. Just prior to this date, DWR management directed PRES field staff to begin removing non-acoustically tagged recaptured fish and relocating them to Bethany Reservoir. These relocated fish were added to the fish and biomass totals removed from CCF. Acoustically tagged recaptured fish were released back into CCF as was done prior to the new direction provide by DWR management.

2. Methods

2.1 Overview

In 2018, field work for the PRES consisted of three main parts: electrofishing, fish processing, and fish transportation. Three electrofishing boats were used to collect target predatory fish species. The captured target species were regularly transferred from electrofishing boats to a 28-foot fish processing barge (barge). After all target captures were processed, they were transferred to a land-based transportation livewell secured to a large trailer pulled by a pick-up truck. Target captures were then transported to and released into Bethany Reservoir.

Target predator species selected for the PRES were based on previous studies conducted in the CCF (Kano 1990):

- Striped Bass (*Morone saxatilis*);
- Largemouth Bass (*Micropterus salmoides*);
- Spotted Bass (*Micropterus punctulatus*);
- Channel Catfish (*Ictalurus punctatus*);
- White Catfish (*Ameiurus catus*);
- Black Bullhead (*Ameiurus nebulosus*); and
- Brown Bullhead (*Ameiurus melas*).

During the 2017 field season, several large redear sunfish were captured during the electrofishing effort. After discussions with CDFW staff, all sunfish species were determined to be potential predators of juvenile salmonids. Therefore, the following sunfish species were added to the 2018 list of non-native predators slated to be relocated to Bethany Reservoir:

- Bluegill Sunfish (*Leponis macrochirus*);
- Green Sunfish (*Lepomis cyanellus*);
- Redear Sunfish (*Lepomis microlophus*);
- Warmouth (*Lepomis gulosis*);
- Black Crappie (*Pomoxis nigromaculatus*); and
- White Crappie (*Pomoxis annularis*)

Electrofishing during 2018 occurred between 1/8/2018 and 5/3/18. Fishing typically occurred on Monday through Thursday of every week. Electrofishing ended when the take limit set by NMFS of 50 steelhead individuals was reached. Water temperatures had not yet exceeded ~21°C, which is the temperature above which field work would have stopped because survival of juvenile salmonids being released into CCF as part of the SEIS would have been affected.

2.2 Study Site

2.2.1 Clifton Court Forebay

CCF is operated as a regulating reservoir within the tidally influenced region of the Delta to improve operations of the SWP Harvey O. Banks Pumping Plant and water diversions to the California Aqueduct (Figure 1). CCF was divided into four sections for the 2018 field season to maintain consistency with previous years of PRES and previous studies conducted at CCF (Figure 2):

- *Intake Canal*: This section, located along the southwest border of CCF, is a long, narrow channel that is connected to the main body of CCF by a narrow entrance along the eastern boundary. The entrance is bounded by long, narrow spits of land to the north (37.83325°N, 121.59307°W) and south (37.83168°N, 121.59308°W). The Skinner Delta Fish Protection Facility (SDFPF) is located at the southern end of the Intake Canal. The area just outside the entrance in the main forebay was included in this section for analysis purposes.
- *Scour Hole*: This section is in the southeast corner of CCF just to the west of the radial gates. The section is characterized by a deep scour hole created by water rapidly flowing into CCF through the

radial gates due to the head differential between the river and CCF. A small section of shoreline was included in this section (37.82944°N, 121.55765°W to 37.83039°N, 121.55679°W).

- *North Shoreline*: This section consists of the north shoreline of CCF between the entrance to the Intake Canal at the end of the northern spit of land (37.83325°N, 121.59307°W) and the north end of the Scour Hole near the radial gates (37.82944°N, 121.55765°W). A public fishing area is located in this section on the western end and receives a fair amount of recreational use.
- *South Shoreline*: This section consists of the south shoreline of CCF between the entrance to the Intake Canal (37.83168°N, 121.59308°W) and the south end of the Scour Hole near the radial gates (37.83039°N, 121.55679°W).

Figure 2. PRES Site Map Indicating the Sections of CCF used for Electrofishing during the 2018 Field Season

2.2.2 Bethany Reservoir

Bethany Reservoir is a small reservoir (6 miles of shoreline) in northeastern Alameda County (Figure 1). The reservoir is approximately 7 miles from CCF (~15-minute drive) and is the first reservoir along the California Aqueduct after leaving Harvey O. Banks Pumping Plant. It serves as the forebay for the South Bay Pumping Plant. Bethany Reservoir and surrounding area compose the Bethany Reservoir State Recreation Area and is open to the public for boating, fishing, and other forms of recreation.

2.3 Electrofishing Design

The 2018 field season was characterized by three distinct periods based on the original objective and observed catch patterns. From the first day of electrofishing on 1/8/2018 through 2/8/2018, fishing patterns consisted of regularly visiting all shorelines, the Scour Hole, and the Intake Canal such that each location was fished at least once per week. The goal was to visit all locations each day that electrofishing occurred to provide an initial "knock down" of the resident predatory fish population. While this was done on most days, weather conditions and fishing logistics limited the ability to do this on several days. Capture data indicated that this was successful along the shorelines and, as a result, the second period began on 2/12/2018 and lasted until 3/27/2018 during which the Scour Hole and Intake Canal were the focal fishing locations. The final period began on 4/2/2018 and was caused by dramatic increases in small Striped Bass (~250-320 mm TL) catches. In this period, boats would begin a fishing session in a different area that tended to have high capture rates (South Shore, North Shore or Scour Hole). If a boat that started along the shoreline came upon an area with high Striped Bass catch rates, then the boat operator would veer 90 degrees offshore up to ~1500 m in an attempt to target a school of Striped Bass. This offshore fishing would continue until it was clear that the boat was no longer in range of the school of Striped Bass. In addition, the other boats would be called in to fish the area unless they were catching high numbers of fish on their route. If a boat started a fishing session in the Scour Hole and experienced high Striped Bass catch rates, then the other boats would be called in to also fish the area unless they were catching high numbers of fish on their route. To maximize fish capture and to maintain flexibility and allow boats to remain adaptive to specific scenarios, no further rules were established governing intraday changes in strategy.

Prior to the start of the field season, four primary fishing sections were established for CCF: Scour Hole, Intake Canal, North shoreline, and South shoreline (Figure 2).

2.4 Electrofishing

For the 2018 PRES field season, we utilized four electrofishing boats, uniquely identified as DWR-1, DWR-2, FISHBIO-1, and FISHBIO-2 (Table 1). Three of these boats fished concurrently to capture target predatory fish species. Each electrofishing boat was specifically designed and outfitted with equipment necessary to temporarily stun fish and hold them in recirculating livewells. The DWR-1 electrofishing boat, which was used as a back-up to the other three, is a 20-foot North River jet boat outfitted with a Smith-Root Generator Powered Pulsator (GPP) 7.5 shore unit. The DWR-2 boat is a 23-foot Midwest Lakes welded aluminum boat outfitted with a Midwest Lakes Infinity Series Control Box coupled to a 60Hz, 240-volt AC generator. The FISHBIO-1 boat is an 18-foot V hull standard Smith-Root electrofishing boat with a GPP 5.0 electrofishing unit. The FISHBIO-2 boat is an 18-foot Alumaweld jet inboard with a Smith-Root GPP 5.0 electrofishing unit. Power for each electrofishing boat is produced by a gasoline powered generator securely attached to the floor (DWR-1: 7,500 watts; DWR-2: 7500 watts; FISHBIO-1: 5,000 watts; FISHBIO-2; 5000 watts). All electrofishing boats have adjustable front mounted insulated boat booms with umbrella type anodes and an integrated cathode array mounted to the front of the hull. To control the application of power through the front arrays, the DWR-1 and DWR-2 boats have a control box with a foot pedal, and the FISHBIO-1 and FISHBIO-2 boats contain standard integrated foot switches in the bow deck and operator consoles.

Table 1. Electrofishing Boats used during the 2018 PRES Field Season

Boat Name	Make/Model	Length (ft)	Engine	Power
DWR-1	North River	20	325 HP inboard jet	7.5 Generator Powered Pulsator
DWR-2	Mid West Lake	23	200 HP propeller	7.5 Generator Powered Midwest Lake Infinity Control Box
FISHBIO-1	Smith-Root SR-18EH	18	150 HP outboard jet	5.0 Generator Powered Pulsator
FISHBIO-2	Alumaweld	18	351 HP inboard jet	5.0 Generator Powered Pulsator

Each electrofishing boat was staffed by four crew members: two netters, a data collector, and a boat operator. Netters used variable length monorail electrofishing nets to capture stunned fish and transfer them to livewells. The data recorder recorded time, number of fish caught by species, and location via ArcGIS Collector software loaded onto a tablet. External GPS hardware was connected to the tablets to provide meter plus accuracy. Point files were collected at each capture location. The boat operator navigated CCF with a digital map on a separate tablet utilizing the same external GPS hardware as stated above. The map had 10-foot resolution bathymetry as background to safely navigate the shallow water and sandbars that characterize CCF. The map also had sampling area boundaries to delineate fishing sections. Boat operators use portable VHF radios and cell phones to communicate start times and electrofisher settings.

Electrofisher settings typically started at 60Hz, 50-500 volts, and at 20-40% range on the GPP 5.0 (FISHBIO-1 and FISHBIO-2 boats); 60Hz, 240-500 volts, and at 15-50% range on the 7.5 GPP (DWR-1 boat); and 60Hz, 0-300 volts, and at 25-27% range on the Infinity Control Box (DWR-2 boat). If necessary, the range was adjusted upward until fish were caught. Power output settings were recorded for each sampling period and included frequency, percent of range, voltage, and amperage. Settings were adjusted as needed based on environmental conditions and observed fish response to the electrical field to ensure high capture efficiency while maintaining minimal injury to fish. The amount of time electricity was applied to the water was recorded in seconds on the control box.

Safety equipment for electrofishing boat staff included Coast Guard approved Type I or Type III personal flotation devices and, for netters, Class I linesman gloves to protect from electrical current. Electrofishing boats were also equipped with an automated external defibrillator (AED). All vessels were equipped with Coast Guard approved safety equipment: flares, fire extinguisher, first aid kit, and throwable flotation device.

2.5 Electrofishing Techniques

Electrofishing techniques included near shore, and open water fishing.

Fishing along the shoreline was conducted primarily to target black bass. Fishing consisted of moving slowly parallel or at a slight angle to the shoreline to concentrate the electrical field around vegetation, rip-rap, and other likely fish holding features. While moving within the shoreline, one of two electricity application strategies was used. First, electricity was applied continuously unless there was a break in sampling. Second, electricity was applied to the water at rate of 12 to 15 seconds on and 5 seconds off as the electrofishing boat moved forward into unsampled water. This "on/off" strategy was meant to create breaks in the electrical field in front of the electrofishing boat that fish sense and avoid. This allowed the electrical field to get closer to fish when power was reapplied, facilitating capture. Boat operators used the two strategies unsystematically during electrofishing and no effort was made to record when and how often each strategy was applied.

Fishing in open water was conducted primarily to target Striped Bass. Fishing consisted of electrofishing in open water and circling in areas where fish were found. When schools of fish were located, the electrofishing boat operator would stop forward propulsion, allowing the electrofishing boat to drift over the affected fish so netters could maximize capture. As fish drifted past or away from the electrofishing boat, the boat operator would reposition the electrofishing boat to capture all shocked fish. Once the school dispersed, the electrofishing boat would move from the area in a broadening pattern in an attempt to relocate the school of fish. If the school was not relocated, the boat operator would return to where the school was originally located and continue sampling.

2.6 Fish Processing

Target captures were transported to the barge after the livewells in the electrofishing boats reached capacity or at the end of the sampling day. The barge was positioned in close proximity to the electrofishing boats to minimize travel time and maximize time spent electrofishing. The barge was outfitted with two or three rectangular recirculating livewells (~660 liter [L]) to hold fish during and after processing. Supplemental oxygen was used in the livewells when needed. Livewells were securely placed onto the deck of the barge and filled with water from CCF using submersible pumps.

The barge was staffed by four crew members: two fish handlers, a data collector, and a barge operator. Handlers processed fish by scanning for tags, weighing, and measuring.

Fish were first scanned for PIT tags with a Biomark® HPR PLUS PIT tag scanner. If a PIT tag was detected, the fish was further scanned visually for a Floy tag. Fish that contained a PIT tag and/or Floy tag were likely from other CCF studies conducted by DWR (see Section 1.3). The PIT tag number from each fish was queried in a database on site to determine whether it also had an acoustic transmitter (all acoustically tagged fish from other CCF studies by DWR were also PIT tagged). For each tagged fish, the barge crew recorded the species, tag number(s), length as fork length (FL) and total length (TL) to nearest millimeter (mm), weight to nearest tenth or hundredth of a pound (lb) using a Salter-Brecknell SA3N ElectroSamson portable hanging scale (55 lb. max), and whether the fish was alive. All tagged fish were then returned to CCF until 3/17/2018. After 3/17/2018, non-acoustically tagged recaptured individuals were relocated to Bethany, while acoustically tagged individuals were returned to CCF.

For each untagged fish, the species, FL (mm), and TL (mm), and whether the fish was alive were recorded. For approximately every tenth fish of each species, weight (lb) was recoded to the nearest tenth of a lb. Fish that died ("mortalities") were placed in secure plastic bags and disposed of at the Fish Science Building (FSB) waste container. Water quality data were recorded at the beginning and end of each sample day with a YSI® Pro2030 meter and included conductivity (microsiemens per centimeter, µS/cm), dissolved oxygen (DO) percent saturation, and water temperature (°C). In addition, turbidity (Nephelometric Turbidity Units; NTU) was measured using a handheld turbidity meter. Water temperature and DO levels were monitored throughout the day in livewells to ensure acceptable conditions. An oxygen diffuser bar was used in conjunction with an oxygen tank to increase DO levels in livewells when necessary. After processing, all live target captures were transported to a land-based transportation truck and livewell.

2.7 Fish Transportation

To transport fish to Bethany Reservoir, a ¾-ton pickup truck towed a flatbed trailer on which a 1,314 L insulated fish transport livewell with oxygen diffusers and an oxygen tank was securely fastened. Prior to receiving fish, the livewell was filled with water from CCF and, if warranted, DO level was increased to a range of 90 to 120 percent saturation. The transportation truck and livewell was strategically positioned on the levee of CCF to minimize barge travel time on the water for fish transfers. Two staff members were assigned to the transport truck. Fish were transferred from the barge to the transport livewell using short handled monorail nets. Fish were then transported to Bethany Reservoir, approximately seven miles from CCF, and released at the public boat ramp. DO percent saturation and water temperature in the livewell were measured using a YSI® Pro2030 multi-meter just prior to departure from CCF and just prior to releasing fish into Bethany Reservoir. In addition, just prior to fish release into Bethany Reservoir, DO percent saturation and water temperature in the reservoir, and the number of mortalities by species during transport, were recorded. Mortalities were removed prior to fish release, placed in secure plastic bags, and disposed of at the FSB. On one occasion it was noted that mortalities were occurring to Striped Bass after they were released into Bethany Reservoir. ESA staff collected and disposed of all the dead individuals found near the release site. After this incident, fish transport staff were informed to retain, dispatch and dispose of fish that were near death. No additional mortalities were observed in Bethany after this instance.

2.8 Environmental Data

In addition to environmental data collected by the barge staff for each sampling day and by the transport staff for each trip to Bethany Reservoir, environmental data from other sources were collected.

Water temperature and turbidity data were gathered from the California Data Exchange Center (CDEC) Water temperature (°C), turbidity (NTU), wind speed (miles per hour; mph), and wind direction (°) data were downloaded for the Clifton Court station (CLC; 37.8298°N, 121.5574°W; Figure 2) maintained by DWR.

Operational data were provided to BDO staff by the DWR Operations and Maintenance (O&M) office. This dataset included each radial gate position (feet), calculated flow through each gate (cfs), stage upstream and downstream of the radial gates (feet), and pumping rates at Banks Pumping Plant (cfs). As part of the QA/QC process, pumping rates at Banks Pumping Plant from O&M were compared to pumping rates reported as part of the salvage process (ftp://ftp.dfg.ca.gov/salvage/). If pumping rates differed by more than 5% between datasets, pumping rates from the salvage data were used. These data were deemed more reliable than O&M data because O&M data sometimes consisted of null values or characterized unrealistic conditions such as draining CCF due to high pumping rates and low or no radial gate flows. Radial gate flows were calculated with data provided by O&M using equations developed by Hills (1988) for each gate, *i*:

$$Q_1 = H_1 \times (0.44 + 215.244 \times (elev_{out} - elev_{in})^{0.5})$$

$$Q_2 = H_2 \times (4.46 + 181.804 \times (elev_{out} - elev_{in})^{0.5})$$

$$Q_3 = H_3 \times (4.76 + 173.378 \times (elev_{out} - elev_{in})^{0.5})$$

$$Q_4 = H_4 \times (3.38 + 173.378 \times (elev_{out} - elev_{in})^{0.5})$$

$$Q_5 = H_5 \times (2.38 + 168.79 \times (elev_{out} - elev_{in})^{0.5})$$

$Q_{total} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$

where,

Q_i = flow through gate *i* (cfs)

H_i = gate height / position of gate *I* (ft)

$elev_{out}$ = stage outside radial gates in Old River (ft)

$elev_{in}$ = stage inside radial gates in CCF (ft)

Q_{total} = Total CCF inflow through radial gates (cfs)

2.9 Staff Training

Smith-Root provided an on-site electrofishing course for permanent DWR staff and contractors working on this project. A classroom session took place in Sacramento and covered basic electrical theory, electrofishing equipment, operation and safety, and applied electrofishing methods. A field session took place at CCF where participants operated electrofishing equipment, including adjusting settings on the control panel, and applied information learned in the classroom. The training focused on the following:

- Minimizing/eliminating potential harm to fish;
- Proper electrofishing settings to maximize capture efficiency;
- Working safely as a team in a variety of environments;
- Techniques and settings for a variety of target species in different life stages;
- Operation and safety, including dangers to humans and fish; and
- Electrofishing techniques as they apply to bioassessments, fisheries characterizations, population estimates, and age and growth studies.

Contractor staff that had access to the Department of the Interior Learn completed the USFWS Electrofishing Safety Course (Course Number FWS-CSP2202A-OLT). This course emphasized electrofishing safety to minimize hazards and maximize performance.

All project boat operators were required to have taken either the USWFS Motorboat Operator Certification Course or Scientific Boating Safety Association Motorboat Operator Training Course certification, or have a U.S. Coast Guard captain's license. These multi-day training courses combined classroom sessions and field sessions. The courses emphasize safe motorboat operations and include review of legal requirements, preparations, navigation, operations, emergency procedures, rescue, self-rescue, trailering, fire suppression, and basic seamanship. In addition, all boat operators were required to have a California Boater Card issued by the California State Parks Division of Boating and Waterways, which indicates that they have successfully taken and passed a boater safety education examination approved by the National Association of State Boating Law Administrators and California.

All field staff were required to complete adult cardiopulmonary resuscitation with AED procedures and first aid. All DWR employees were required to complete the 8-hour OP-2 certification course and contractor field staff were required to take the 4-hour OP-2 Awareness certification course.

2.10 Analysis

Because electrofishing during 2018 focused on maximizing predator removal regardless of location and boats often electrofished in more than one location within a single sampling session, the ability to analyze results spatially was conducted with georeferenced catch data. As a result, all total and mean catch and effort values are reported using fishing day as the unit.

2.10.1 Calculation of Catch, Effort, and Catch per Unit Effort (CPUE)

2.10.1.1 Catch

Catch was calculated as the total number of individuals caught and removed from CCF.

2.10.1.2 Effort

Effort was calculated in two ways: (1) time on the water and (2) electrofishing duration. Time on the water was calculated as the difference between the clock start and stop time of an electrofishing session. It included time actively electrofishing and not electrofishing, such as offloading fish to the processing barge, travel time, time in between pulses of electrofishing when the "on/off" strategy was used (see Section 2.5 *Electrofishing Techniques*), and other breaks in electrofishing. Electrofishing duration was recorded as time that electricity was applied to the water. This value was obtained from an individual electrofishing unit's control box counter. The number of fish per hour spent on the water provides perspective on the overall yield of fish given the logistics associated with electrofishing.

For some electrofishing sessions, one or both of the effort measurements were not recorded in the field. If both values were missing, no attempt was made to approximate the values and the fishing session and all associated catch data (except listed species data) were removed from the analysis. In these cases, we generated approximate values using the following process. First, for electrofishing sessions for which both effort measurements were recorded, we generated a relationship between time on the water and electrofishing duration (Figure 3). Equations used were:

$$Time\ on\ Water = (1.1962 \times Electrofishing\ Duration) + 0.824$$

$$Electrofishing\ Duration = (0.6889 \times Time\ on\ Water) + 0.1199$$

These equations were applied to electrofishing sessions in which one effort measurement was missing. Approximated Time on Water values were used in 2 of 283 electrofishing sessions and approximated Electrofishing Duration values were used in 8 of 283 electrofishing sessions.

To assess the effect of this approximation method on overall effort values, effort is reported in the Section 3.1 both with and without the approximated data.

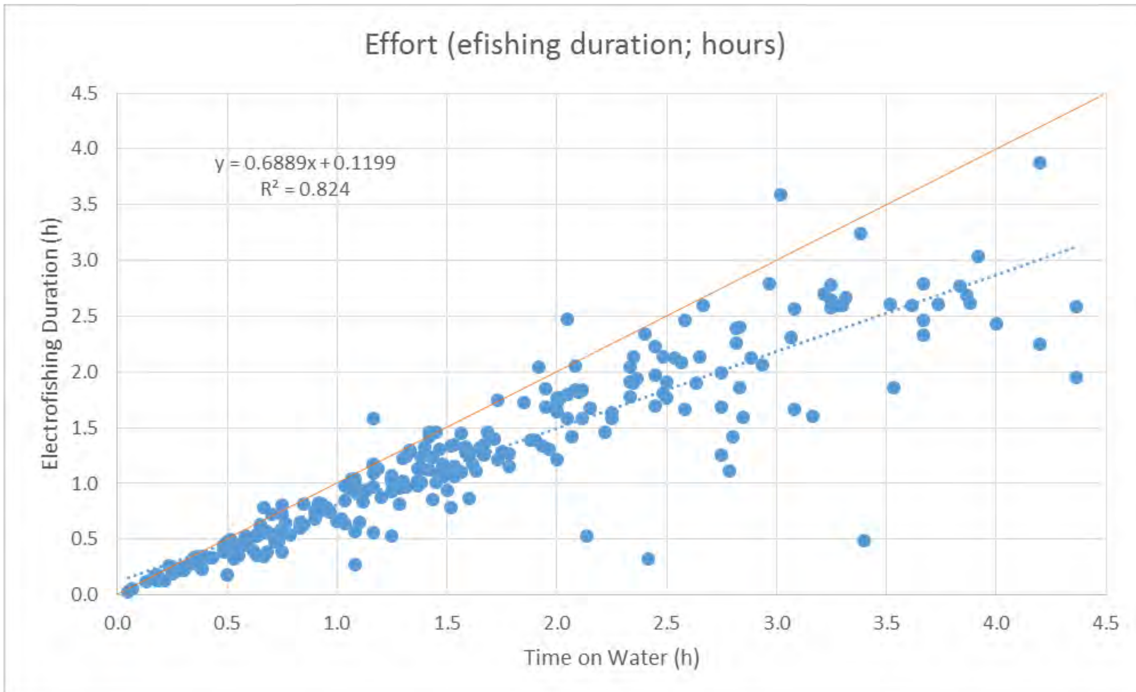


Figure 3. Scatterplot of Effort Calculated as Time on Water vs. Electrofishing Duration, 2018 Field Season. The blue dotted line shows the relationship. The orange line indicates y=x.

2.10.1.3 Catch per Unit Effort (CPUE)

Catch per unit effort (CPUE) was calculated for each fishing session for which effort was recorded or could be calculated (see Section 2.10.1.2, *Effort*). CPUE is calculated in terms of number of fish per hour of electrofishing (electrofishing duration) and as number of fish per hour spent on the water (total time on water), as described in Section 2.10.1.2, *Effort*. The number of fish per hour of electrofishing, whereas the number of fish per hour spent on the water provides perspective on the overall yield of fish given the logistics associated with electrofishing.

2.10.2 Spatial Patterns in Predator Catch and CPUE

Geospatial data for fish catches are presented in maps of CCF to reveal spatial patterns of each predatory fish species group. These patterns do not correct for unequal fishing effort throughout CCF.

To evaluate spatial differences in densities of predators removed, the Create Fishnet tool in ArcGIS (v 10.5.1) (ESRI 2017) was used to create 50-foot georeferenced grid cells ("neighborhoods"). The study area comprised two domains, one for the Intake Canal and another for the main Forebay. Getis-Ord Gi* hotspot analysis (Getis and Ord 1992) was used to identify statistically significant predator hotspots at a monthly time step from January- May 2018. Getis Ord Gi* is a spatial statistic used to determine whether hotspots within a neighborhood are significantly different across neighbors. The degree of local clustering relative to background density was determined using a 550-foot fixed distance band (i.e., search radius). Each grid cell containing catch data received a z -score as a measure of spatial clustering, with higher z-scores for more intense clustering. Positive z-scores with $p < 0.05$ were significantly hot and displayed as red in the figure with a confidence range of 95-99%. Negative z-scores with $p < 0.05$ were significantly cold and displayed as blue (Figure 18).

2.10.3 Striped Bass Depth Preference

An analysis was conducted to determine whether Striped Bass showed a depth preference in CCF based on 2018 catch data. The distribution of depths where Striped Bass were captured was compared to the distribution of depths found within CCF by binning all data into 1-foot increments and plotted.

2.10.4 Striped Bass Hotspots in Terms of River Length

Catch per unit effort data in 2018 suggested that around the beginning of April, large schools of Striped Bass began to migrate into CCF. The area that these schools of Striped Bass occupied was documented by marking individual captures with GPS and analyzing the data using a Hotspot Analysis. As these large schools could only have entered CCF from the South Delta through the radial gates, we decided to assess how they might occupy South Delta channels. To do this, we took a portion of Old River adjacent to and just east of CCF and calculated the linear distance of river channel that equaled the volume of water that these schools occupied in CCF. In a river setting, migratory prey species, such as Chinook salmon and steelhead, would need to travel through this reach of river on their way to the ocean and they may encounter these large migrating schools of Striped Bass.

2.10.5 Predator Biomass

Total biomass for all predators removed during 2018 was calculated based on weights collected in the field or through the use of length-weight relationships developed with 2017 or 2018 data (for sunfish only).

The weights of only 48 Striped Bass, 20 black bass, and 1 catfish were recorded during the 2018 field season because high catch rates limited processing time. As a result, to estimate biomass removed from CCF of the remaining individuals, the following length-weight relationships calculated in DWR (2017) for Striped Bass, black bass, and catfish, were used (all weights in lb; all lengths in mm):

- Striped Bass:

Preferred Relationship: $Weight = 3.615 \times 10\text{-}8 \times (FL^{2.94})$, $r^2 = 0.955$

Alternative Relationship: $Weight = 2.874 \times 10^{-8} \times (TL^{2.95})$, $r^2 = 0.953$

- Black bass:

Preferred Relationship: $Weight = 2.701 \times 10^{-8} \times (TL^{3.03})$, $r^2 = 0.944$

Alternative Relationship: $Weight = 3.011 \times 10^{-8} \times (FL^{3.03})$, $r^2 = 0.943$

- Catfish:

Preferred Relationship: $Weight = 1.860 \times 10^{-7} \times (FL^{2.70})$, $r^2 = 0.93$

Alternative Relationship: $Weight = 9.660 \times 10^{-7} \times (TL^{2.40})$, $r^2 = 0.90$

Because relationships with both TL and FL were available, the strongest relationship (highest r^2) was used preferentially (Striped Bass: FL; black bass: TL; catfish: FL). If the preferred length measurement was missing for a given species but the other length measurement was available, the alternative length and corresponding relationship was used. If neither was available, the fish was excluded.

A length-weight relationship for both FL and TL as the predictor value was calculated on the 11 sunfish for which lengths and weights were recorded during 2018. The same preference logic was employed to determine which predictor value (FL versus TL) to use to calculate weight. This information is included below in Section 3.3, *Predator Biomass*.

2.10.6 Environmental Influences on Predator Catch

We used generalized linear models (GLMs) with a negative binomial error distribution and logarithmic link function in the R package MASS (Venables and Ripley 2002) to model the relationship between environmental variable predictors and the number of predators captured while electrofishing. A negative binomial distribution eliminated overdispersion evident in initial GLMs with Poisson distribution. GLMs were conducted separately for total predatory fish, Striped Bass, and black bass. Catfish and sunfish were not evaluated independently because very few individuals were caught. Effort (hours) was included as an offset in each model. Effort was recorded in two ways as described above: Electrofishing duration and time on water. Analyses were repeated for both effort measures. The set of candidate predictors included water temperature, turbidity, wind speed, radial gate flow, and Banks pumping rate (Table 2). Mean values of predictor variables were calculated for each sampling day. There were no substantial correlations ($r \leq |0.57|$) between predictors, so all predictors were retained in the analysis based on a threshold of $r < |0.7|$ (Zeug and Cavallo 2013).

Table 2. Environmental Variables Included in Generalized Linear Modeling of Predator Catch from Electrofishing in CCF, January-May 2018

Variable	Unit (continuous; with source)	Rationale for Inclusion
Water Temperature	°C (CDEC CLC station)	Predator species may have seasonal migrations or increased bioenergetics demand with greater temperature (DWR 2015)
Turbidity	NTU (CDEC CLC station)	Greater turbidity may lower fish boat avoidance through reduced visibility but also may reduce visibility of fish to netters (Reynolds and Kolz 2012)
Wind Speed	Mph (CDEC CLC station)	Wind could affect distribution of fish by physical displacement or make fish difficult for netters to see (Reynolds and Kolz 2012)
Gate Flow	cfs (calculated by DWR Operations staff and supplemented by calculations by PRES consultant staff)	Gate flow could affect availability of prey fish to predators in CCF, particularly near the Scour Hole.
Banks Pumping Rate	cfs (DFW salvage reports, supplemented with calculated values by DWR Operations staff)	Pumping rate could affect the availability of prey fish to predators in CCF, particularly in the Intake Canal.

For each analysis, model averaging was undertaken from all possible model combinations using the R package MuMIn, with weights based on the support for each model (Barton 2018), as assessed from Akaike's Information Criterion (AIC; Mazerolle 2006). Variable importance was assessed by summing the weights of all models in which the variable appeared. A variable was considered "important" if the variable importance was greater than 0.8 and the 95% confidence intervals did not include zero, (after Calcagno and de Mazancourt 2010 and Zeug and Cavallo 2013). The pseudo-r^2 was calculated for each full model to indicate deviance explained. Plots of the model-averaged predicted values were created for variables considered important. GLMs including predictors were assessed to provide a better fit to the data than intercept-only models if the AIC of the full model (with all predictors included) was three or more units less than the AIC of the intercept-only model (after Zeug and Cavallo 2013).

All GLM analyses were conducted in R (Version 3.3.2; R Core Team 2017).

2.10.7 Predator Mortality

We used a beta regression (Zeilis et al. 2016) to model the relationship between environmental variables and the proportion of fish that died during each transport trip from CCF to Bethany Reservoir. Beta regression involves predicting the count of events (in this case mortality) while accounting for the total number of events (mortality + survival, i.e., total fish per transport trip), to give a mortality proportion or rate. The covariates included in the analyses were hypothesized to have potential effects on mortality, i.e., dissolved oxygen at the start and end of the transport and at Bethany Reservoir, water temperature at the start of transport, hour of the day, time spent in the transport trailer, and the amount of biomass removed (as a measure of potential crowding/stress in the transport trailer). The ending temperature and temperature at Bethany Reservoir were not included because of a high correlation with starting temperature ($R > 0.9$). Model averaging and assessment of predictor importance were undertaken using the same methods as the negative binomial models for predator capture during electrofishing, as described in Section 2.10.1. The pseudo r^2 for the full model was reported to indicate variance explained.

2.10.8 Predator Depletion

Evidence for predator depletion was assessed using linear regressions of CPUE (as catch per hour electrofishing and catch per hour per hour on the water) against date. The analyses were conducted for Striped Bass and black bass, the two most abundant species caught in CCF. Separate linear regressions were conducted for three time periods during which different predator capture strategies were used: a) 1/8/18-2/8/18, when there was a focus on shoreline locations; b) 2/12/18-3/27/18, when there was a focus on the intake canal and scour hole; and c) 4/2/18-5/3/18, when there was an adaptive strategy to maximize catch by focusing on hotspots and calling other boats in when a school of striped bass was found.

2.10.9 Predator Consumption of Tagged Chinook Salmon

As part of fish processing protocols for PRES, captured predatory fish were scanned for PIT tags using a HPR Plus PIT tag reader (Biomark, Boise, Idaho). Occasionally, predatory fish were identified as Chinook salmon from the SEIS study. This could only happen if the predatory fish consumed the Chinook salmon. Such information may provide information on the spatial-temporal dynamics of predation in CCF that could be useful for future predator management.

Positively identifying predation events through the detection of SEIS tagged fish within predators can provide information on the direct causes of prescreen loss of Chinook Salmon. Predator capture locations and fork lengths were recorded and compared with SEIS data which included fork length, weight, tagging date, release date and time, and release site. These data provide information that can be useful to determine whether predation upon Chinook Salmon is correlated to specific environmental or biological variables. Additionally, confirmed predators were compared to the same-species catch data on the day of their capture. Interpretation of these data may be used to provide information on which predators, both species and size classes, are mostly commonly consuming Chinook Salmon, and may help to provide direction for future predator management.

2.11 Chinook Salmon Consumption (Bioenergetics Modeling)

Bioenergetics modeling was conducted to: (a) estimate the total amount of Chinook Salmon that could be consumed by captured Striped Bass in CCF, and (b) estimate the amount of Chinook Salmon which may have avoided consumption due to removal of these fish.

2.11.1 Approach

The methodology used was that of Stroud and Simonis (2016) using data obtained from Wunderlich (2016 and 2017). Consumption was calculated as the product of the proportion of maximum daily ration (Loboschefsky, Personal Communication; Loboschefsky et al. 2012); the maximum feeding rate, which is an allometric function of fish mass at the optimal temperature; and an age-specific temperature dependence function (Hanson et al. 1997). Stroud and Simonis (2016: p.12-27) described in more detail the fixed-parameter point-estimate bioenergetics model that was based on the "Wisconsin" Bioenergetics Model developed by Kitchell et al. (1977). The Kitchell et al. (1977) methodology was generalized and documented in Hanson et al. (1997).

Stroud and Simonis (2016) conducted a sensitivity analysis of the fixed-parameter point-estimate bioenergetics model by comparing it to a variable-parameter version of the same bioenergetics model. A key finding of Stroud and Simonis (2016) was that the fixed-parameter point-estimate model produced a downward bias on estimates of consumption rate. Therefore, for the present study, fixed-parameter point-estimates were calculated in addition to the variable-parameter bioenergetics model being employed to avoid the downward bias; both sets of results are reported here. However, the variable-parameter model results are relied on for interpretation and discussion purposes in the present study.

The methodology of Stroud and Simonis (2016) was followed except for the inputs described in the following three sections. Temperature data were specific to 2018. Data on number and size of Striped Bass were from those fish removed by electrofishing and relocated to Bethany Reservoir in 2018. No predator diet information was collected in 2018 and therefore various data sets from previous studies were combined to estimate the fraction of the diet composed of Chinook Salmon. The bioenergetics model was run on a daily time step from 1/8/18 through 5/5/18. January 8 was selected because that was the first day of predator removals to Bethany Reservoir. May 5 was selected for the end date because that was the last full 24-hour period to occur after predator removals ended on May 4.

2.11.1.1 Temperature Data

Hourly temperature data were taken from observations from CDEC, station ID CLC. Because the bioenergetics functions and model operate on a daily time step, hourly temperature data were averaged to generate a single daily temperature.

2.11.1.2 Predator Sizes

For this model, fork lengths of captured Striped Bass were translated to mass using a standard allometric relationship ($W=a \times L \wedge b$). A refitted length-weight relationship based on Stroud and Simonis (2016) was used, which used measured length and weight of Striped Bass collected in CCF during 2017 and 2018 sampling seasons (Figure 4). The Striped Bass captured in the present Study ranged in length from 108 to 1125 mm, and the fit of the data from this study produced nearly identical point estimates as the Tucker et al. (1998) relationship. Using the methods from Stroud and Simonis (2016) also allowed for variances on the length-mass regression and thus for inclusion of uncertainty in predator mass for the variable-parameter model.

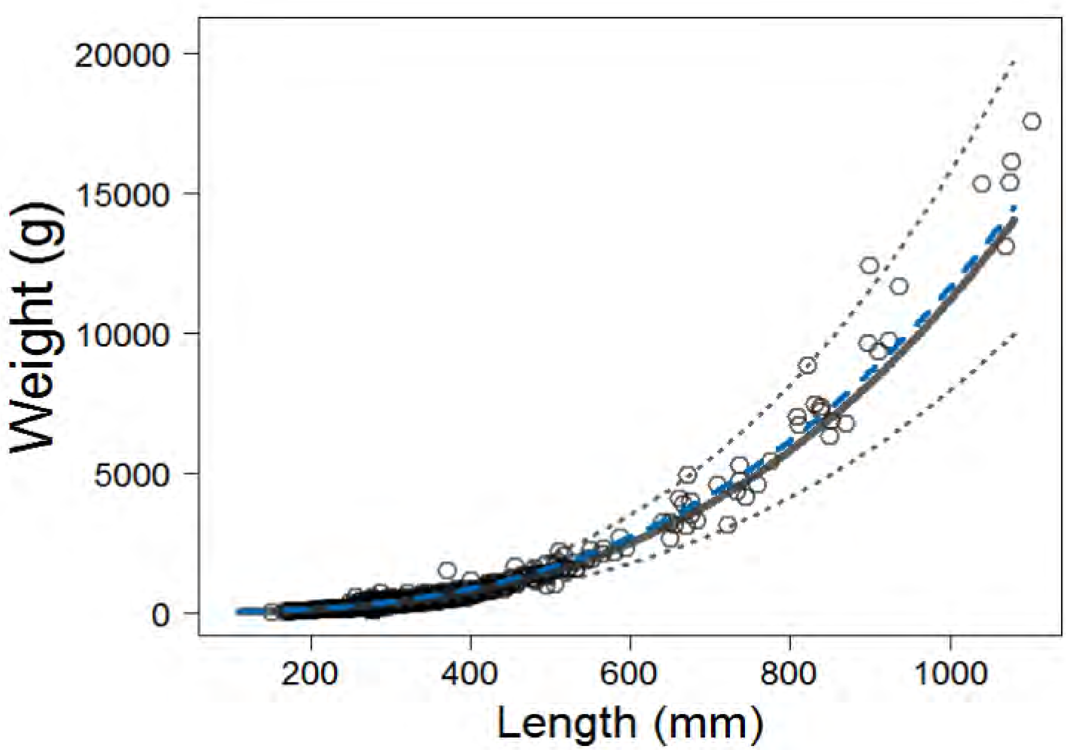


Figure 4. Length-Weight Regression Fit to Data from CCF Sampling Compared to the Regression from Tucker et al. (1998). Grey lines are associated with the newly fit model: the solid line is the predicted value and the dotted lines show the 95% prediction interval. The blue dashed line shows the predicted value for the Tucker et al. (1998) model.

There were 91 individual Striped Bass that did not have lengths recorded. These fish were removed from the analyses to provide a conservative estimate of consumption avoided because the lengths of the 91 individuals cannot be known.

The bioenergetics calculations are defined by age class (age-1, age-2, age-3, age-4, age-5 and up), so each predator collected during sampling was then placed into an age class (yearly) according to its length based on Simonis and Stroud (2016) (Table 3.)

Table 3. Striped Bass Ages at Length Used for Bioenergetics Calculations

Age Class	Minimum Length	Maximum Length	n
1	108	309	5407
2	310	374	4478
3	375	449	1310
4	450	524	378
5	525	599	102
6	600	674	31
7	675	749	18
8	750	899	14
9	900	1099	8
10	1100	1500	2

2.11.1.3 Predator Diets

Predator diet proportions were estimated following the methods outlined in Stroud and Simonis (2016), but with first condensing the frequency of occurrence data (measured by QPCR assays) across time. This produced a frequency of occurrence data set based on 1,401 Striped Bass (21 of which, 1.5%, had positive detection of Chinook DNA in their gut contents). Gut content data was obtained through the CCF Predation Study (Wunderlich, 2016 and 2017). The calculations of the predator diet proportions (ratio of the total mass of diet that belongs to a particular prey class) included the frequency of occurrence, percent by number, and percent by mass (see Stroud and Simonis 2016). These metrics were averaged to produce the overall diet proportions used for the fixed-parameter analysis, for which the proportion made up by Chinook Salmon was estimated to be 1.95% (Table 4).

Table 4. Striped Bass Diet Proportions Used for Bioenergetics Calculations

Species	Diet Fraction
Chinook Salmon	0.0195
Delta Smelt	0.0046
Largemouth Bass	0.0219
Longfin Smelt	0.0006
Mississippi Silverside	0.0061
Steelhead/Rainbow Trout	0.0036
Sacramento Pikeminnow	0.0026
Sacramento Splittail	0.0024
Threadfin Shad	0.2520
White Sturgeon	0.0069
Striped Bass	0.0639
Other Fish Species	0.2919
Non-Fish Items	0.3222

For the variable-parameter estimates, 100,000 iterations were drawn of the diet data from distributions based on the means and standard deviations of the percent by number and by mass metrics (Stroud and Simonis 2016) and the back-transformed fit of a logistic regression to the QPCR data (following the methods of Stroud and Simonis 2016). This generated a distribution of diet proportions made up by Chinook Salmon with a mean of 2.1%, a median of 1.9%, a standard deviation of 1.5%, and a range of 0.2% to 12.6%.

2.11.2 Fixed Parameters: Basic Consumption

Fixed-parameter estimates were conducted using all parameters following the methodology described in Hanson et al. (1997). For each Striped Bass, the total daily food consumption in CCF was calculated based on the daily average temperatures and assuming a fixed predator size through time (i.e., no growth). It was assumed that Striped Bass were eating the proportions of maximum consumption (p) estimated in the work described by Loboschefsky et al. (2012): p = 0.69 for Striped Bass aged 1-2 years, 0.73 for Striped Bass aged 3 years, 0.68 for Striped Bass aged 4 years, and 0.72 for Striped Bass aged 5 years and up (Loboschefsky personal communication). The bioenergetic consumption function generated a specific consumption rate (Cmax: g prey/g predator/day), and this was converted to the total consumption on that day by multiplying by the mass of the predator to produce the total consumption rate (g prey/day). This was then converted to a rate of Chinook eaten (g Chinook/day) by multiplying by the proportion of the diet made up by Chinook Salmon.

For all analyses including fixed and variable parameters (described in the next section), no growth was assumed in the Striped Bass, after they were captured and removed, through the course of the 2018 field season. The “no growth” option was selected because if an electrofished Striped Bass had been returned to CCF it could then have left CCF. Other Striped Bass could have entered CCF and no data were collected on the Striped Bass population size or changing size distribution during the 2018 field season. In the absence of these data, the “No Growth” option was selected because it was conservative: estimated consumption must be the estimated value or greater.

“Estimated” Consumption was calculated using the cumulative daily consumption if all 11,748 Striped Bass were present and feeding each day of the field season, and iteratively summed across all days of the field season that was modeled. “Removed” Consumption was estimated by iteratively summing the daily possible consumption of each Striped Bass after it was removed to estimate how much cumulative consumption potential was removed from the population.

2.11.3 Variable Parameters: Basic Consumption

Variable-parameter model calculations were conducted following the methods of Stroud and Simonis (2016) that allow for uncertainty to be incorporated into the consumption calculations. This included re-fitting the allometric scaling of maximum consumption (Figure 5) and the temperature-dependence of maximum consumption for the three age categories (age-1, age-2, and age-3+) (Figure 6). As a result, unlike the fixed-parameters model, variability in model parameters was included in the variable-parameters model.

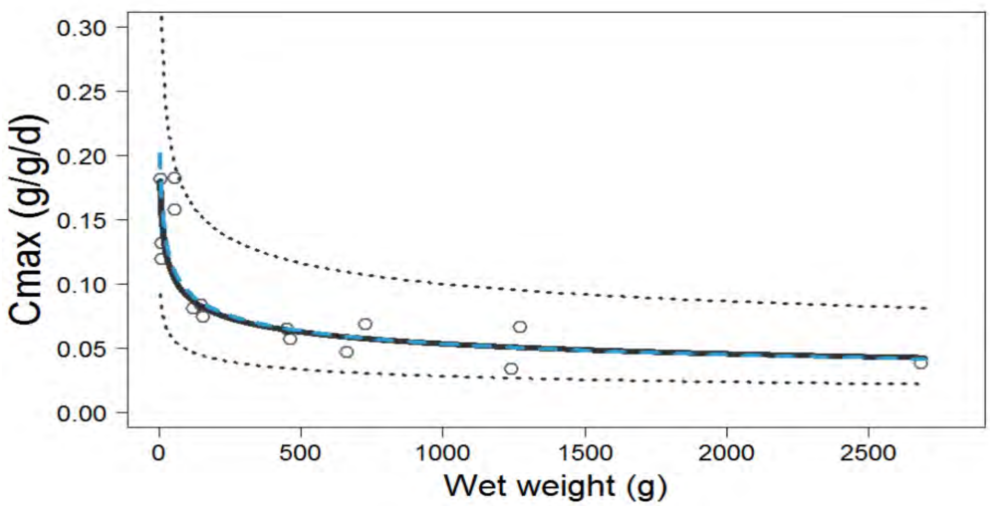


Figure 5. Cmax-Mass Regression Fit to Data from Hartman and Brandt (1995). The black line is the predicted value, the dotted lines show the 95% prediction interval, and the blue dashed line is the original fit (Hartman and Brandt 1995). Source: Stroud and Simonis (2016).

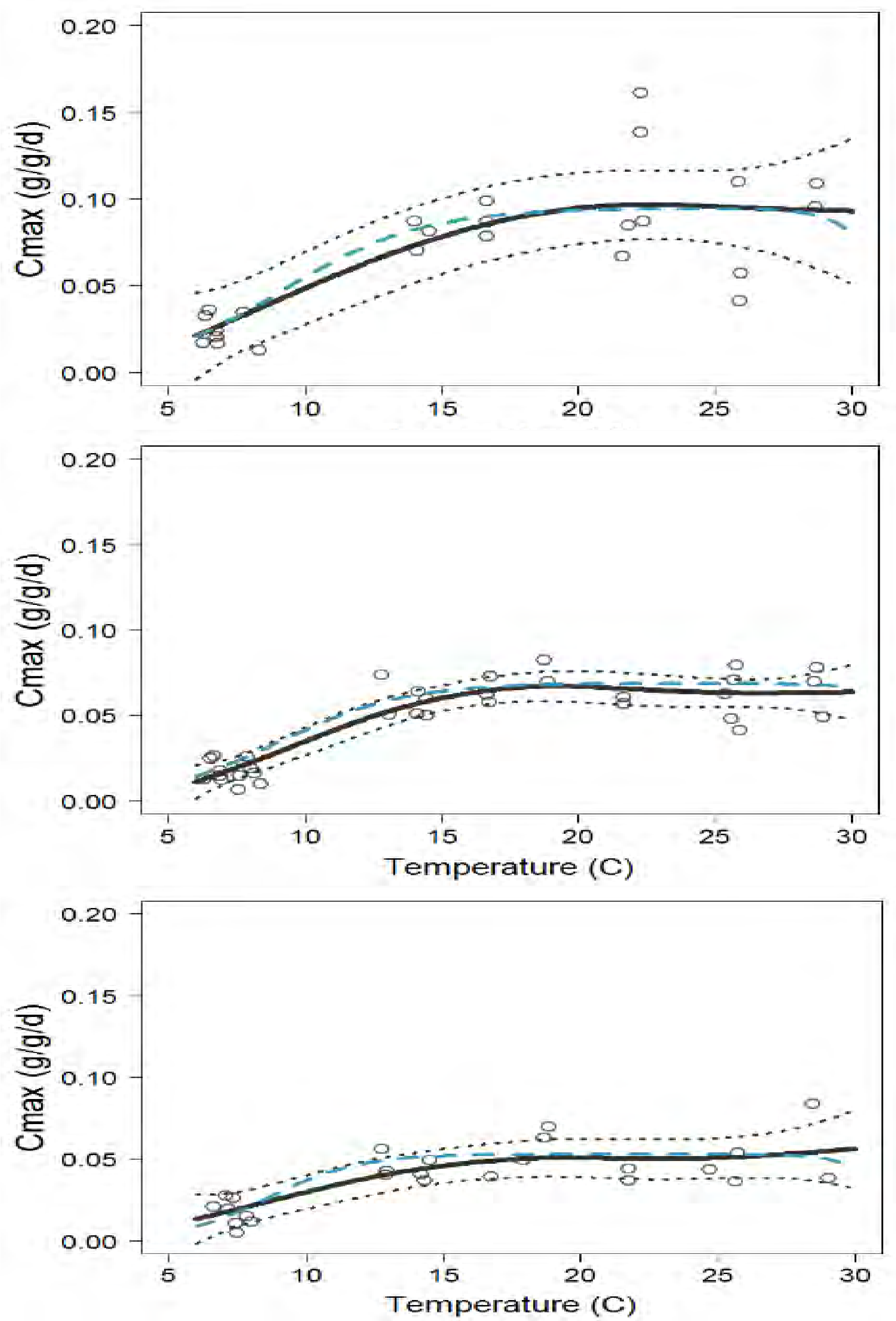


Figure 6. Temperature-Dependence of Cmax for Age-1, -2, and -3+ Striped Bass (top-to-bottom). The black line is the predicted value and the dotted lines the 95% prediction interval of the GAM. The blue dashed line is the “by eye” fit (Hartman and Brandt 1995). Source: Stroud and Simonis (2016).

Variability was provided in the mass of the predator, by drawing a mass value from the prediction of the length-mass regression based on the measured length. Then, on each day, the specific maximum consumption and temperature-dependence values were drawn from the statistical distributions generated by the re-fit functions. The total specific consumption rate was then calculated based on the predator size and temperature on that day from these random draws. The resulting estimated specific consumption rate was multiplied by the mass of that individual Striped Bass to generate the estimated consumption rate. The estimated consumption rate was then multiplied by a value of the Chinook diet fraction drawn at random from the 100,000 iterations. This method was repeated 500 times to generate distributions of Striped Bass-specific daily Chinook Salmon consumption values. The number of permutations (500) was selected due to computational time and resource limitations involved with such a large dataset.

Similar to the methods of the fixed-parameter analyses (Section 2.11.2 *Fixed Parameters: Basic Consumption*), for the variable-parameter analyses “Estimated” Consumption was calculated by summing the consumption if all 11,748 relocated Striped Bass were present and feeding each day of the field season. The amount that could have been consumed by each individual was summed for every day of the field season to calculate cumulative “Estimated” Consumption. Cumulative “Removed” consumption was estimated by iteratively summing the daily possible consumption of each Striped Bass after it was removed to estimate how much consumption potential was removed from the population. These calculations were done for each of the 500 iterations. All variable-parameter model results were summarized with means and 95% confidence intervals.

2.11.4 Potential Number of Chinook Salmon Consumed and Avoided

Salvage data from the State Water Project (SWP) was used to calculate the average size of Chinook Salmon in CCF during the sampling season (ftp://ftp.dfg.ca.gov/salvage/). The salvage data contains lengths and catch numbers for all fish species entrained into CCF and diverted into holding facilities. Length data was converted to mass using the allometric relationship described in McFarlane & Norton (2002). This produced an average mass for an individual Chinook Salmon during the sampling season. The calculated values for Chinook Salmon consumption from the bioenergetics model were divided by this average to produce an estimate for the potential number of individual Chinook Salmon that may have been consumed during the sampling season by Striped Bass that were removed during the 2018 PRES effort.

3. Results

3.1 Sampling Effort

Electrofishing occurred at CCF on 54 days between January 8 and May 3, 2018. Electrofishing ended after the take limit for Steelhead of 50 fish was reached and NMFS instructed DWR to stop the study (see Section 3.11, *Listed Species*. During the 54 field days, there was a total of 430.7 hours on the water, calculated with approximated data, or 427.6 hours on the water calculated without approximated data (Table 5). There was a total of 328.8 hours of electrofishing duration, calculated with approximated data, or 322.7 hours of electrofishing duration, calculated without approximated data.

Daily mean time on water was 8.0 ± 2.3 h (± SD) with approximated data and 7.9 ± 2.3 h without approximated data (Table 5). Daily mean electrofishing duration was 6.1 ± 1.8 h with approximated data and 6.1 ± 1.7 h without approximate data.

The highest effort occurred during January (14 days, 116.9 hours on the water and 85.6 hours of electrofishing with approximated data, 113.8 hours on the water and 81.3 hours of electrofishing without approximated data) and the lowest number of samples were taken during May (3 days, 25.5 hours on the water and 18.8 hours of electrofishing with approximated data, 25.5 hours on the water and 16.9 hours of electrofishing without approximated data; Table 5).

Scouring under the concrete apron and wing-walls adjacent to the radial gates caused a failure to the intake structure in CCF. This resulted in a complete shut-down of radial gate operation and to SWP exports. Emergency repairs of the damaged structure resulted in a reduced CCF-PRES sampling effort from March 20[th] to March 30[th].

Because the values reported here are very similar between when approximated data were or were not included and to maximize the amount of data reported, all effort values in the remainder of this report include approximated data.

Table 5. Electrofishing Effort during the 2018 Field Season. Note: “Time on Water” represents the total amount of time during an electrofishing session. “Electrofishing Duration” represents time when electricity was applied to the water column. “Approximated data” are described in Section 2.10.1

		Time on Water				Electrofishing Duration			
		With Approximated Data		Without Approximated Data		With Approximated Data		Without Approximated Data	
Month	Days	Total (h)	Daily Mean ± SD (h)	Total (h)	Daily Mean ± SD (h)	Total (h)	Daily Mean ± SD (h)	Total (h)	Daily Mean ± SD (h)
January	14	116.9	8.3 ± 3.0	113.8	8.1 ± 3.1	85.6	6.1 ± 2.0	81.3	6.3 ± 1.5
February	12	97.6	8.1 ± 1.8	97.6	8.1 ± 1.8	77.6	6.5 ± 1.6	77.6	6.5 ± 1.6
March	10	83.3	8.3 ± 2.0	83.3	8.3 ± 2.0	65.2	6.5 ± 1.9	65.2	6.5 ± 1.9
April	15	107.5	7.2 ± 2.4	107.5	7.2 ± 2.4	81.7	5.4 ± 1.6	81.7	5.4 ± 1.6
May	3	25.5	8.5 ± 1.5	25.5	8.5 ± 1.5	18.8	6.3 ± 1.3	16.9	5.6 ± 2.3
Total	**54**	**430.7**	**8.0 ± 2.3**	**427.6**	**7.9 ± 2.3**	**328.8**	**6.1 ± 1.8**	**322.7**	**6.1 ± 1.7**

3.2 Predator Catch

There were 13,249 predatory fish electrofished and collected during the 2018 field season (Figure 7). Of these, 13,138 fish were removed from CCF. The remaining 111 fish either escaped back into CCF after capture (n = 44 fish) or were deliberately released back into CCF because they were recaptured tagged fish from other CCF studies (n = 67 fish; see Section 3.6, *Predator Recapture*). A total of 750 fish, or 5.7% of all fish caught, died during either electrofishing, processing, or transport to Bethany Reservoir (see Section 3.7, Predator Mortality). Of these, 191 individuals (1.4%) died during electrofishing or processing and 559 individuals (4.2%) died during transport to Bethany Reservoir. The remaining 12,388 individuals were relocated to Bethany Reservoir.

For simplicity, we refer to "caught" or "captured" fish in this report as those that were both caught and removed from CCF (n = 13,138 fish), either through mortality or relocation to Bethany Reservoir. Other than here and when reporting tagged predator recaptures (Section 3.6, Predator Recapture), we do not include predatory fish that were captured but returned to CCF as "caught" or "captured".

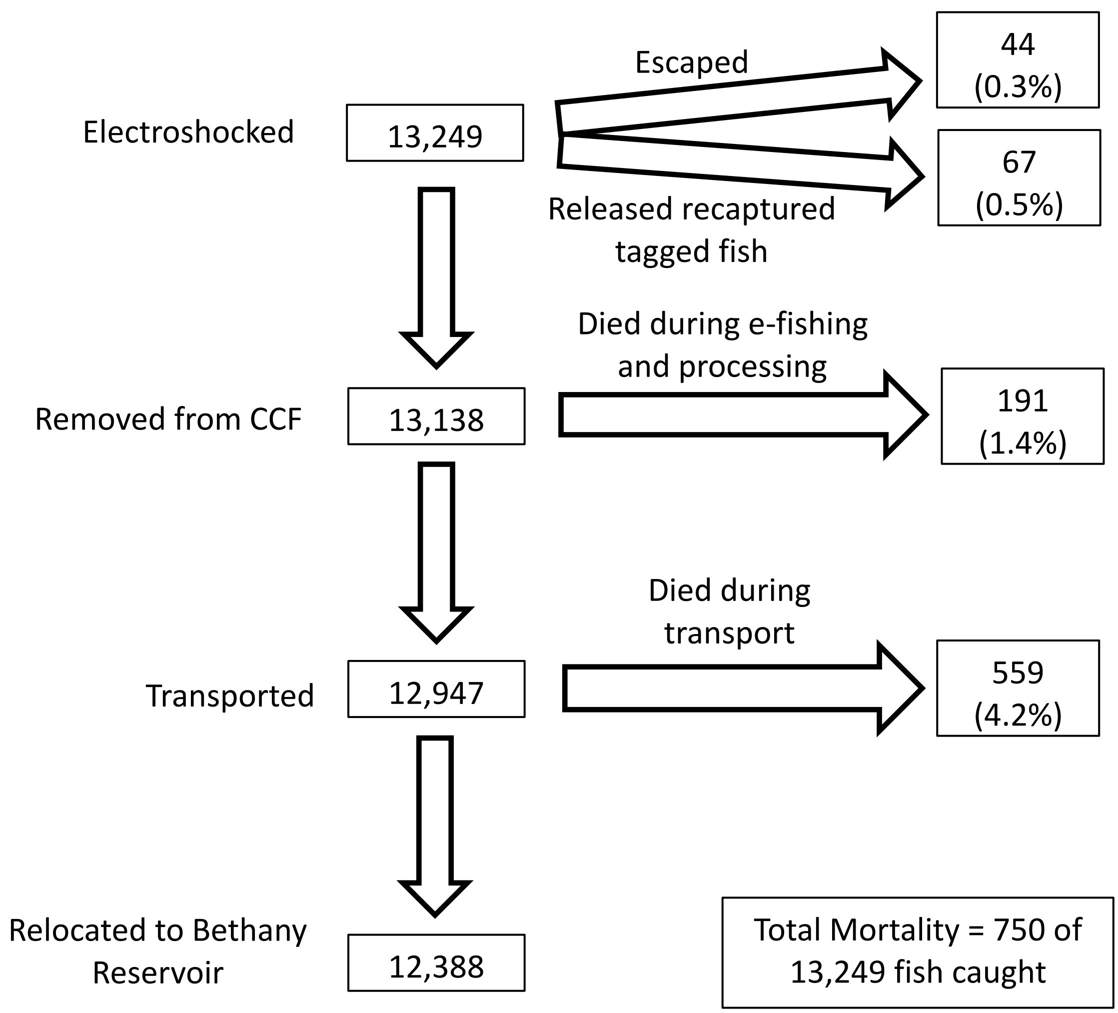


Figure 7. Fate of All Predatory Fish Electroshocked, 2018 Field Season. Percentages are in relation to total fish electroshocked (n = 13,249 fish).

The large majority (11,839 fish, or 90.1%) of fish captured during the 2018 field season were Striped Bass (Table 6). Black bass accounted for 7.5% of total removals (989 fish), sunfish accounted for 2.2% of total catch (287 fish), and only 23 catfish (0.2% of total predators) were removed. Early in the field season (January-February), ~20-30% of total catches were black bass and ~57-75% were Striped Bass. During this time, electrofishing was very successful in removing black bass from all locations. During March through May, black bass catch rates were lower (~3-7% of total catch) and Striped Bass catch increased (~90-97% of total catch) Sunfish accounted for 7-9% of total catch during January and February, but, like black bass, remained low for the remainder of the field season (~1-2%).

Mean total lengths (± SD) of black bass, catfish, Striped Bass, and sunfish for the entire 2018 field season were 346.0 ± 104.3 mm, 263.0 ± 147.8 mm, 345.6 ± 78.2 mm, and 148.4 ± 71.2 mm, respectively (Table 6; Figure 8, Figure 9, Figure 10, Figure 11). The largest individual captured was a 1,195 mm (TL), 1,125 mm (FL), 35.8 lb Striped Bass and the smallest individual captured was a 48 mm (TL), 44 mm Bluegill Sunfish.

Mean total length of Striped Bass decreased by ~50 mm during the field season (Table 6). Striped Bass total length distribution was highly skewed because of infrequent captures of very large individuals (Figure 8). Peaks in the length-frequency distribution occurred at ~270-310 mm and ~350-390 mm. This pattern probably indicates multiple year classes. The reduction in mean size of Striped Bass during the field season (Table 6) combined with this length frequency pattern indicates that larger individuals were present early in the season and a group of smaller (~270-310 mm) individuals gained prominence as the season progressed.

Mean total length of black bass was fairly consistent through time, although mean total length was greatest in January when over half of all black bass were caught (Table 6, Figure 9). The black bass size distribution is fairly normally shaped with the large majority of individuals between 330 mm and 450 mm, although there is a second peak between 150 mm and 180 mm.

Sizes of sunfish caught were fairly constant among months, except for April, when several larger individuals (~270 mm-346 mm) were captured. The size distribution was right-skewed with evidence of two size classes: one peaking near 60 mm – 80 mm and another peaking near 120 mm to 150 mm (Figure 10)

Too few catfish were captured to observe any clear patterns in length (Figure 11).

CCF is within the Delta, as defined in DFW's Freshwater Sport Fishing Regulations (section 1.71). As such, recreational harvest regulations in CCF are consistent with those listed for the Delta. Recreational harvest of Striped Bass is permitted year-round in the Delta with an 18-inch (457.2-mm) minimum size limit (TL) and a 2-fish daily bag limit. Recreational harvest of black bass is permitted year-round in the Delta with a 12-inch (304.8-mm) minimum size limit (TL) and a 5-fish daily bag limit. Recreational harvest of catfish is permitted year-round in the Delta with no size restrictions and no daily bag limit. Recreational harvest of sunfish is permitted year-round in the Delta with no size restrictions and a 25-fish daily bag limit for all species combined. Only 7% of Striped Bass caught were larger than the legal minimum size limit (Figure 8). However, the majority of black bass (79%) were larger than the legal minimum size limit (Figure 9).

Table 6. Number, Percent of Total, and Total Length of Predatory Fish Caught in and Removed from CCF by Species Group, 2018 Field Season

Species Group	n	% of Total	Mean Total Length (mm; ± SD)	Min Total Length (mm)	Max Total Length (mm)
January					
Black bass	501	33.6	363.1 ± 93.8	84	595
Catfish	3	0.2	194.7 ± 29.7	171	228
Striped Bass	856	57.3	389.9 ± 103.6	216	1,165
Sunfish	133	8.9	131.1 ± 61.3	48	345
Total	**1,493**	**100.0**	**357.3 ± 121.1**	**48**	**1,165**
February					
Black bass	210	18.9	315.7 ± 121.7	87	648
Catfish	2	0.2	119.0 ± 29.7	87	151
Striped Bass	826	74.2	368.4 ± 73.5	126	932
Sunfish	76	6.8	134.7 ± 57.5	52	336
Total	**1,114**	**100.0**	**342.3 ± 103.2**	**52**	**932**
March					
Black bass	48	2.7	350.6 ± 95.0	107	574
Catfish	3	0.2	350.3 ± 238.4	176	622
Striped Bass	1,685	95.9	339.7 ± 88.0	142	955
Sunfish	21	1.2	133.8 ± 45.5	65	278
Total	**1,757**	**100.0**	**337.6 ± 90.8**	**65**	**955**
April					
Black bass	161	2.1	331.6 ± 103.4	90	544
Catfish	11	0.1	254.6 ± 131.3	65	485
Striped Bass	7,562	97.1	340.5 ± 69.9	117	1,060
Sunfish	50	0.6	214.1 ± 79.7	71	346
Total	**7,784**	**100.0**	**339.4 ± 71.7**	**65**	**1,060**
May					
Black bass	69	7.0	343.2 ± 105.1	110	562
Catfish	4	0.4	343.8 ± 168.5	194	526
Striped Bass	910	91.9	337.0 ± 83.0	128	1,195
Sunfish	7	0.7	197.3 ± 99.6	67	310
Total	**990**	**100.0**	**336.5 ± 85.9**	**67**	**1,195**
2018 Total					
Black bass	989	7.5	346.0 ± 104.3	84	648
Catfish	23	0.2	263.0 ± 147.8	65	622
Striped Bass	11,839	90.1	345.6 ± 78.2	117	1,195
Sunfish	287	2.2	148.4 ± 71.2	48	346
Total	**13,138**	**100.0**	**341.2 ± 85.5**	**48**	**1,195**

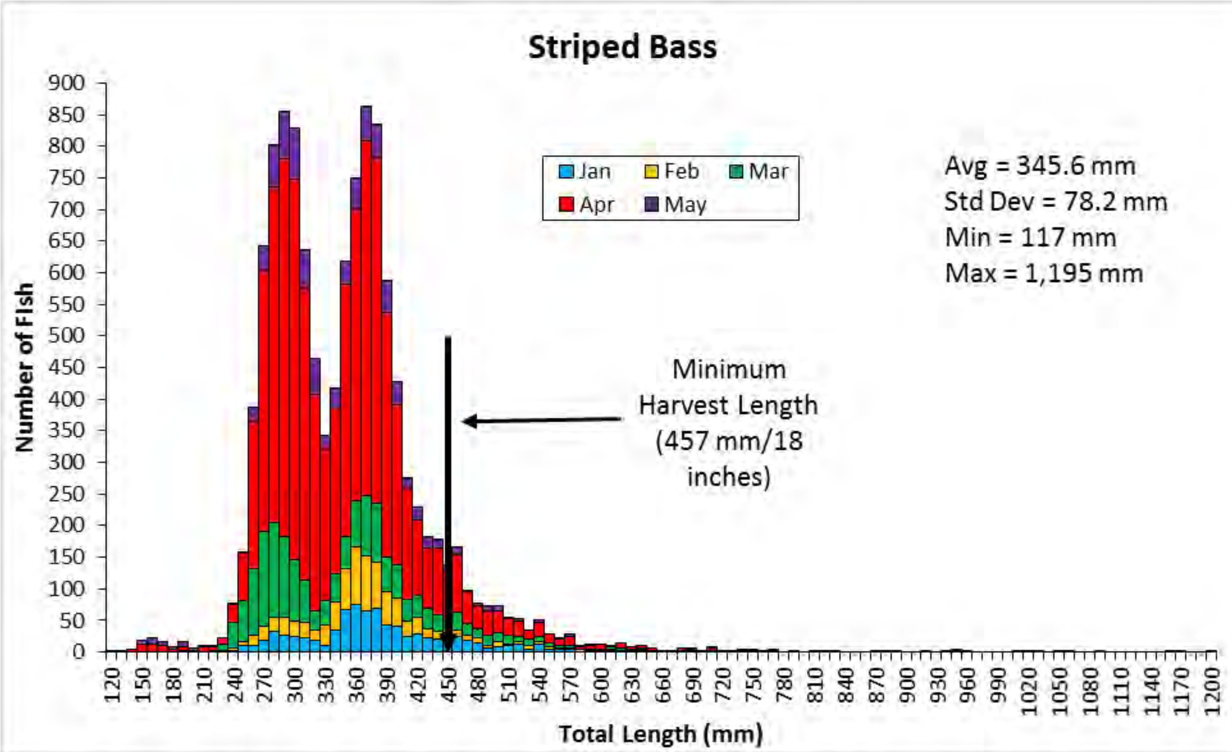


Figure 8. Histogram of Total Lengths of Striped Bass Caught in CCF and Relocated to Bethany Reservoir, 2018 Field Season. Minimum legal harvest length noted with an arrow.

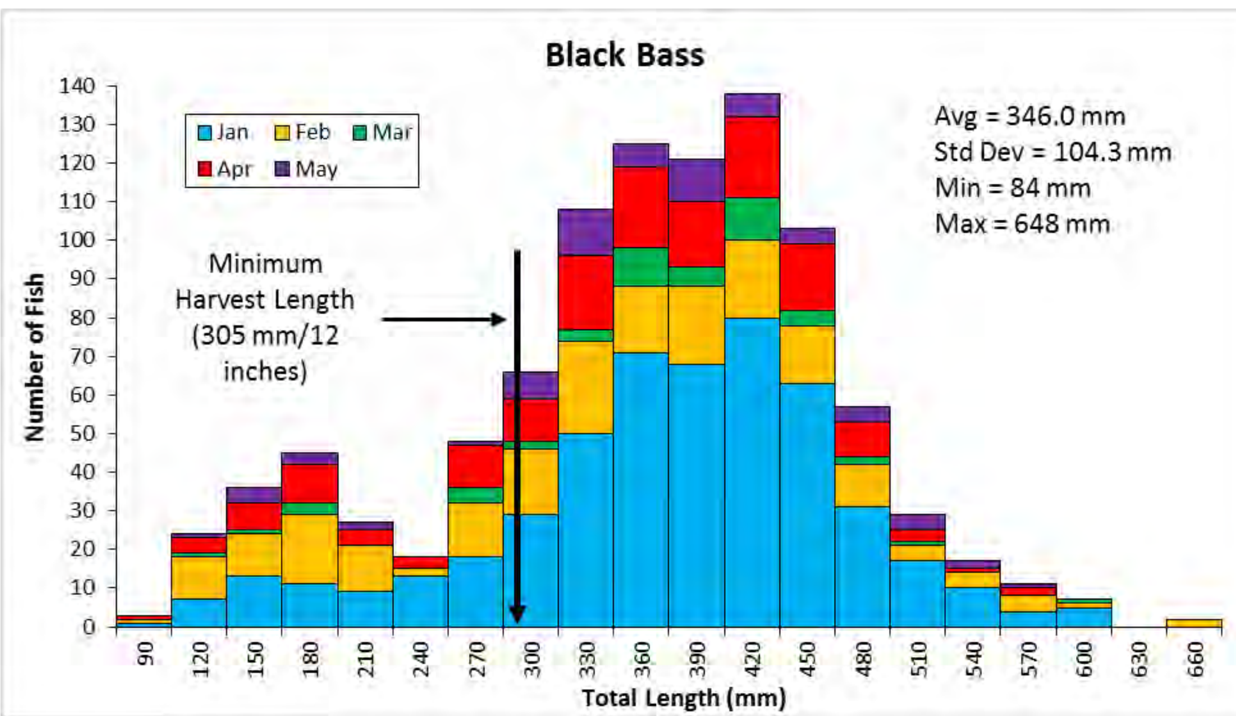


Figure 9. Histogram of Total Lengths of Black Bass Caught in CCF and Relocated to Bethany Reservoir, 2018 Field Season. Minimum legal harvest length noted with an arrow.

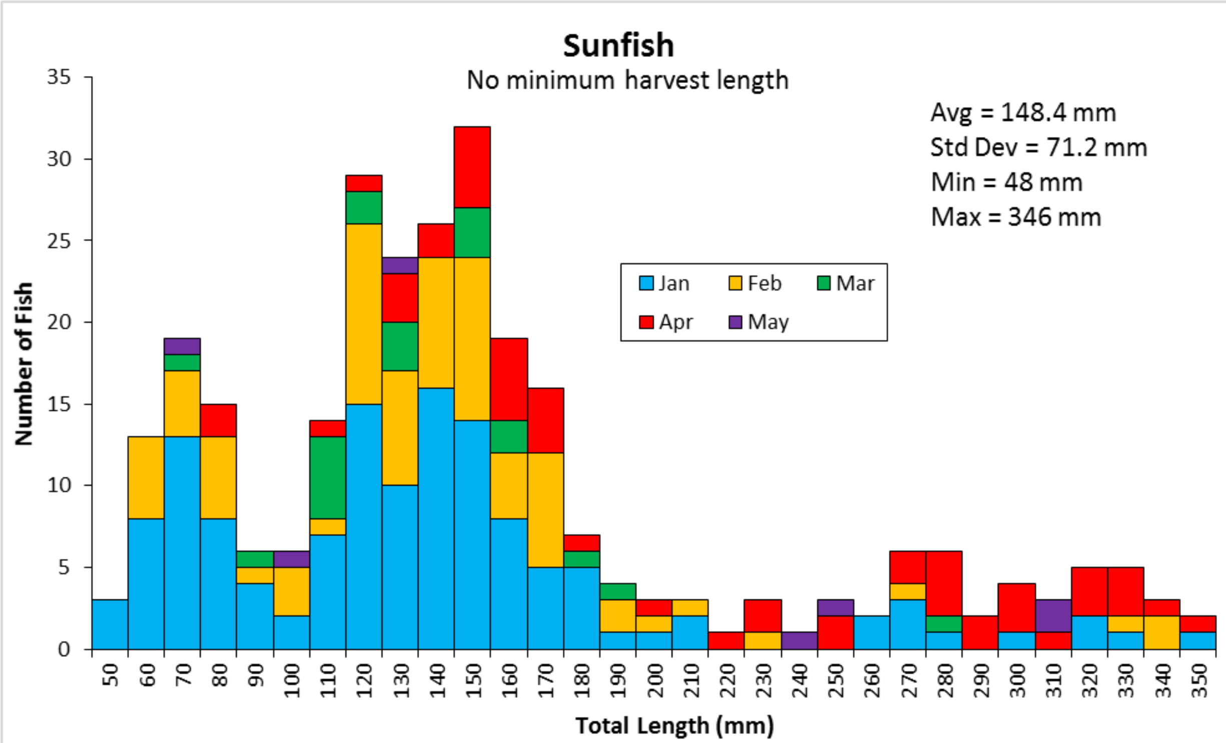


Figure 10. Histogram of Total Lengths of Sunfish Caught in CCF and Relocated to Bethany Reservoir, 2018 Field Season

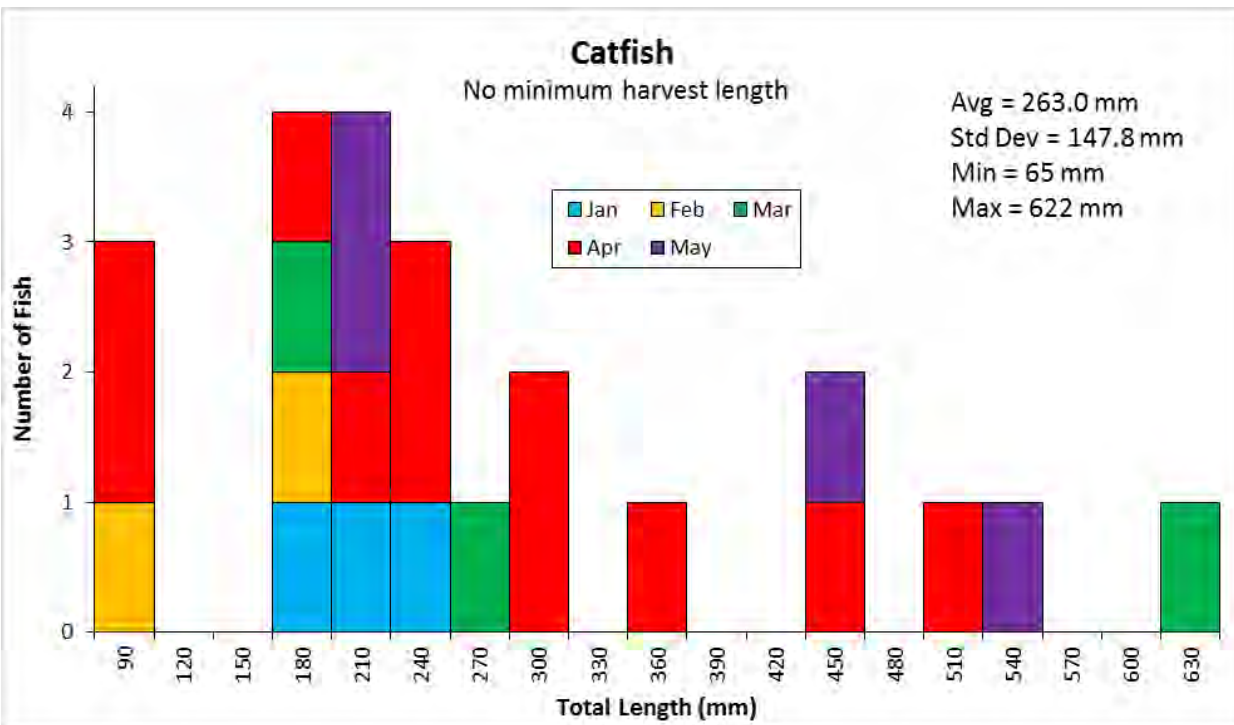


Figure 11. Histogram of Total Lengths of Catfish Caught in CCF and Relocated to Bethany Reservoir, 2018 Field Season

3.3 Spatial Patterns in Predator Catch and CPUE

Examination of spatial patterns in predator catches reveals several patterns (Figure 12, Figure 13, Figure 14, Figure 15, Figure 16, Figure 17). Predatory fish were captured throughout the entire range of CCF that was fished. The Scour Hole and Intake Canal yielded large numbers of predators, as found in 2017. In addition, the offshore portions of the northwest and southwest corners of CCF yielded large numbers of Striped Bass beginning in February and March, respectively.

The formal Gettis-Ord Gi* hot spot analysis confirmed these findings, as three hotspots emerged as statistically significant: (1) Scour Hole, (2) just east of the Intake Canal combined with the southwest end of CCF, and (4) the northwest section of CCF (Figure 18). These patterns were fairly consistent through time at each hot spot. Combining all months in the Intake Canal, the southernmost region was a hot spot, whereas the northern most tip was classified as a cold spot. These patterns in the Intake Canal were variable across months.

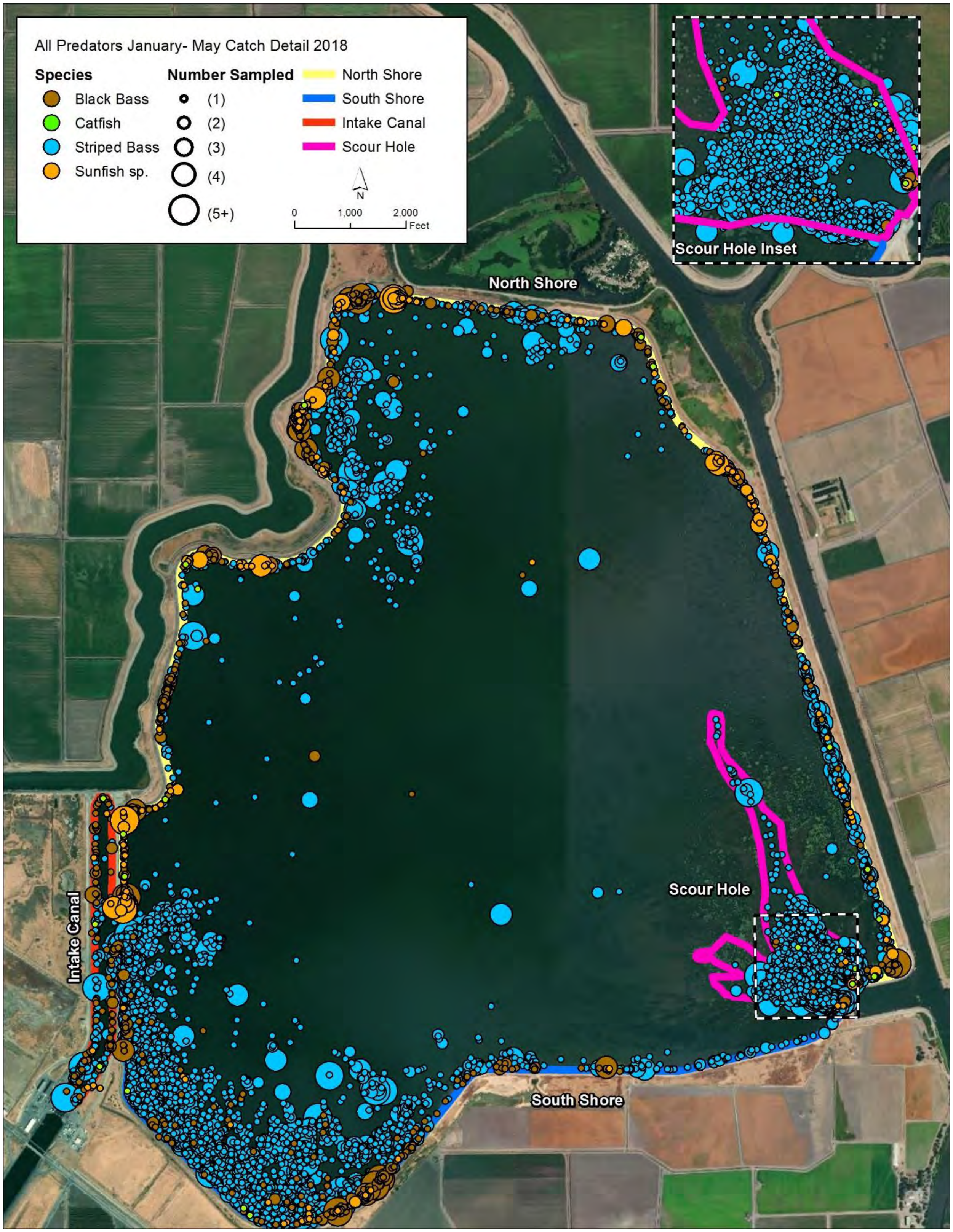


Figure 12. Spatial Patterns in all Predatory Fish Species Catch in Clifton Court Forebay, 2018 Field Season

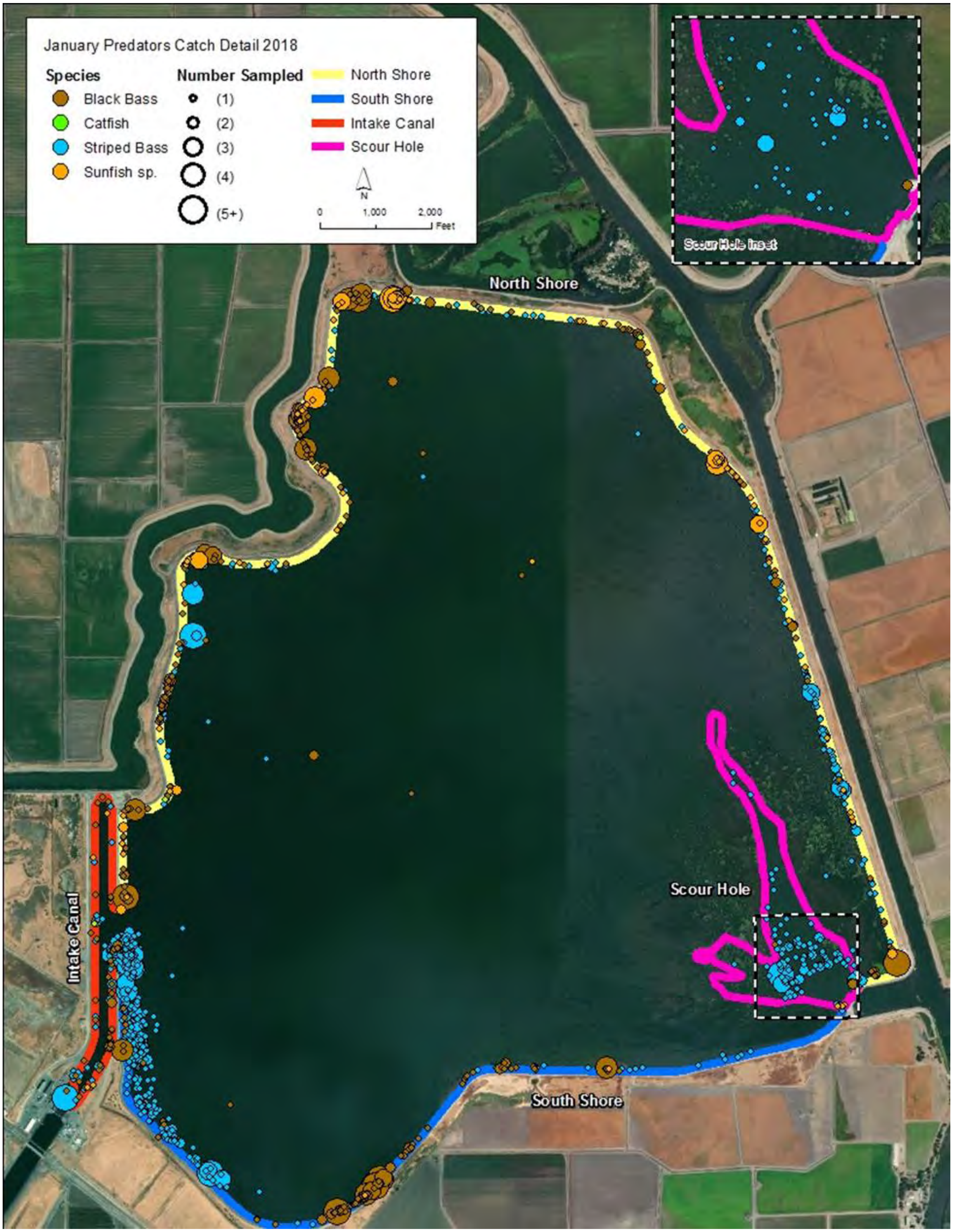


Figure 13. Spatial Patterns in all Predatory Fish Catch in Clifton Court Forebay, January 2018

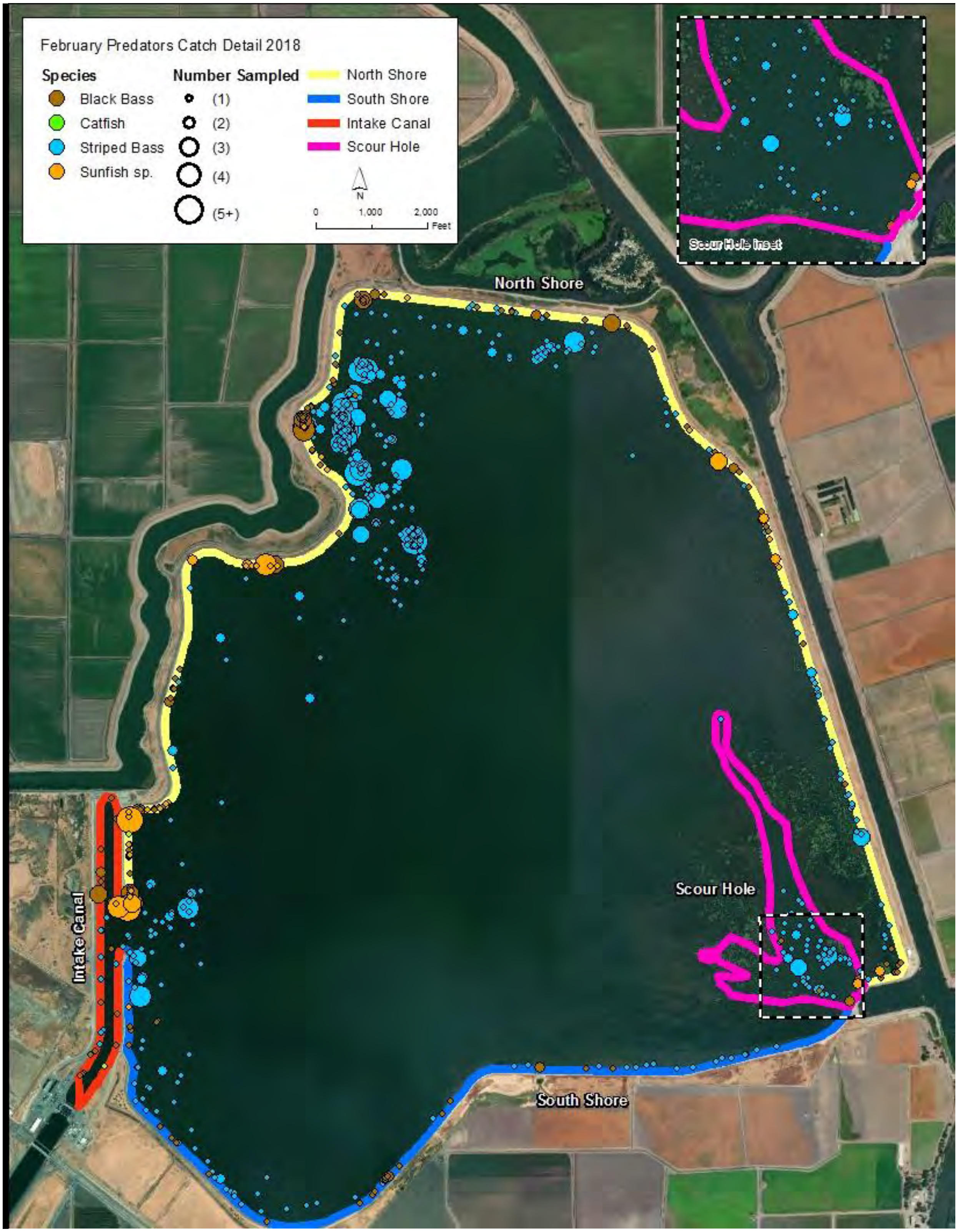


Figure 14. Spatial Patterns in all Predatory Fish Catch in Clifton Court Forebay, February 2018

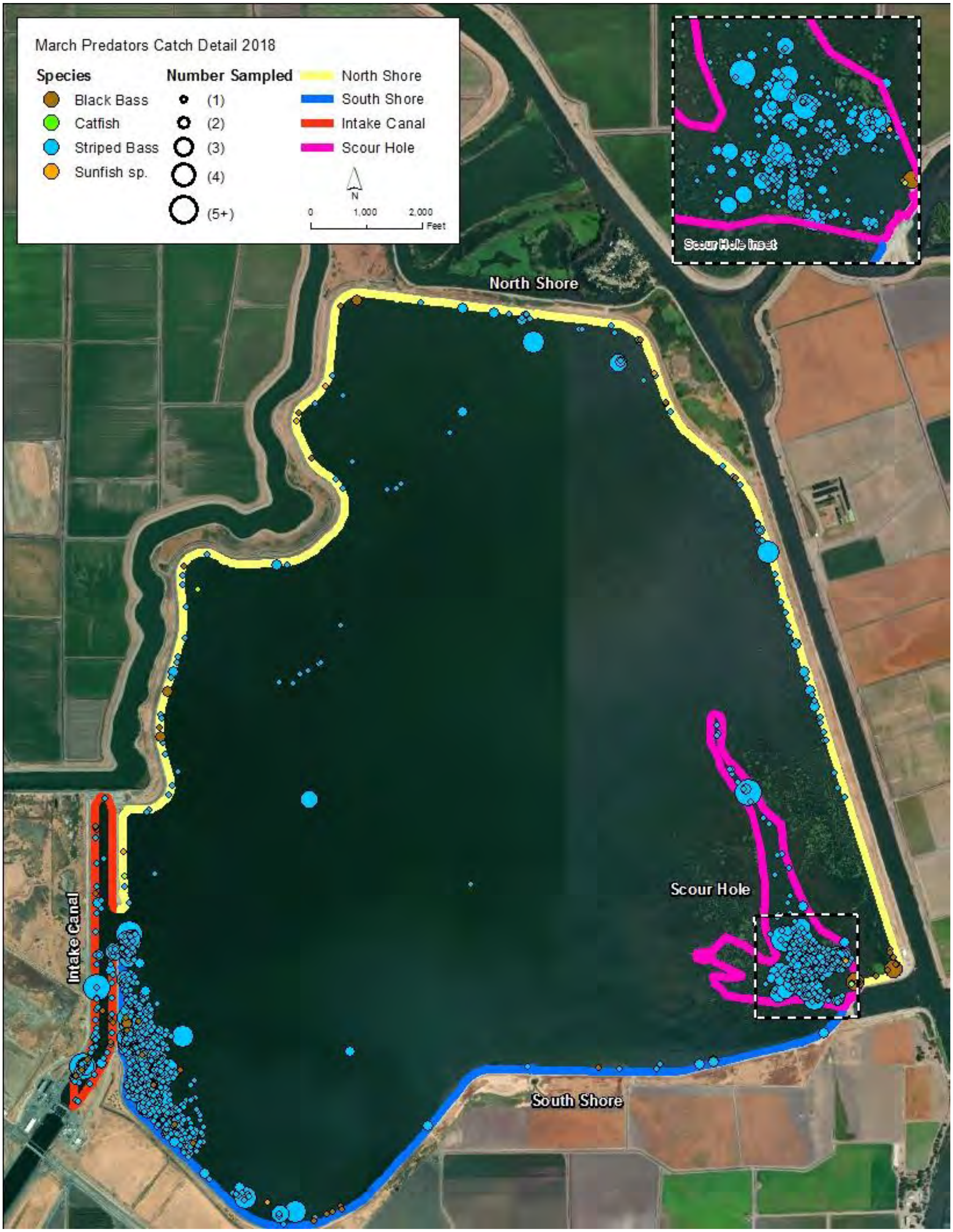


Figure 15. Spatial Patterns in all Predatory Fish Catch in Clifton Court Forebay, March 2018

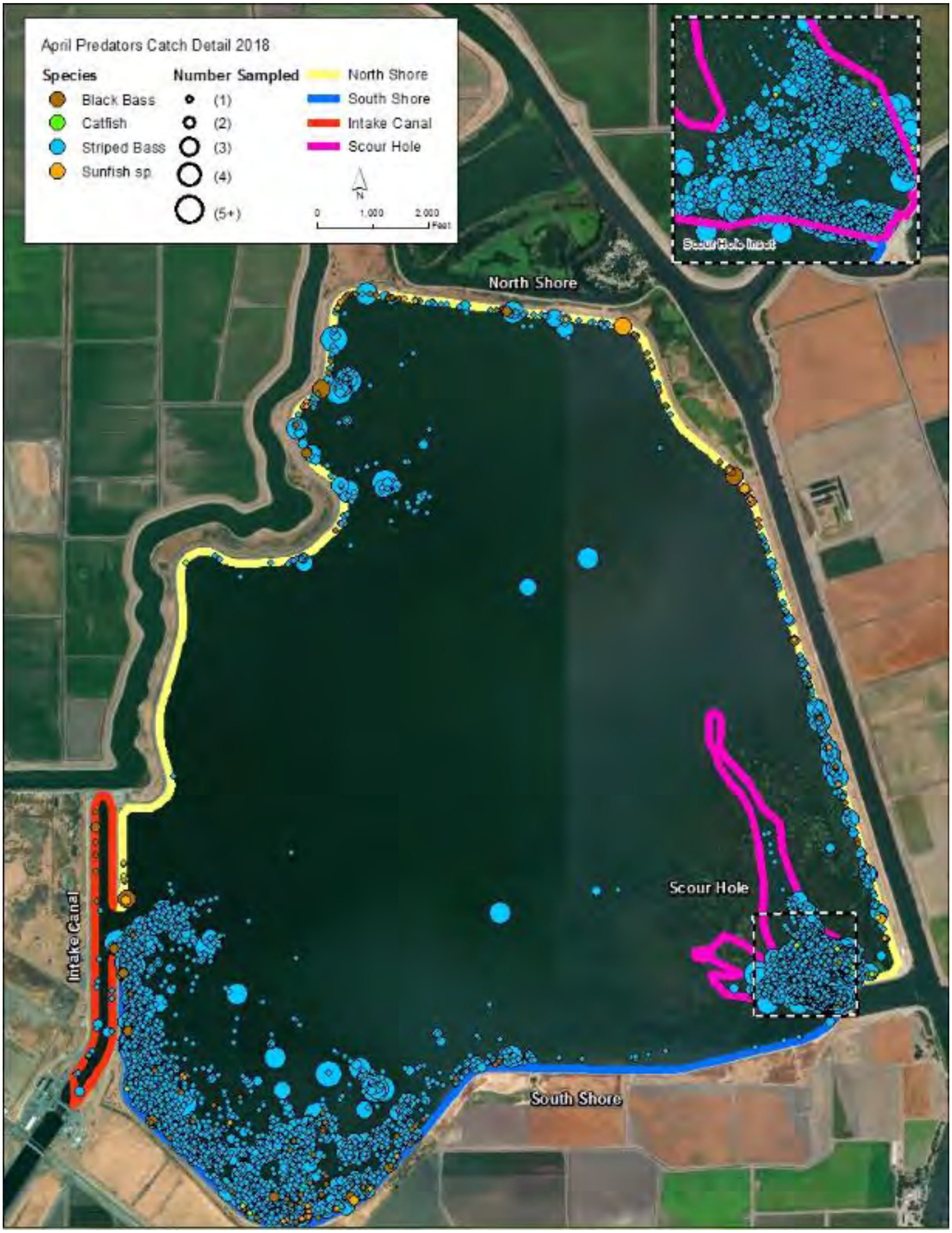


Figure 16. Spatial Patterns in all Predatory Fish Catch in Clifton Court Forebay, April 2018

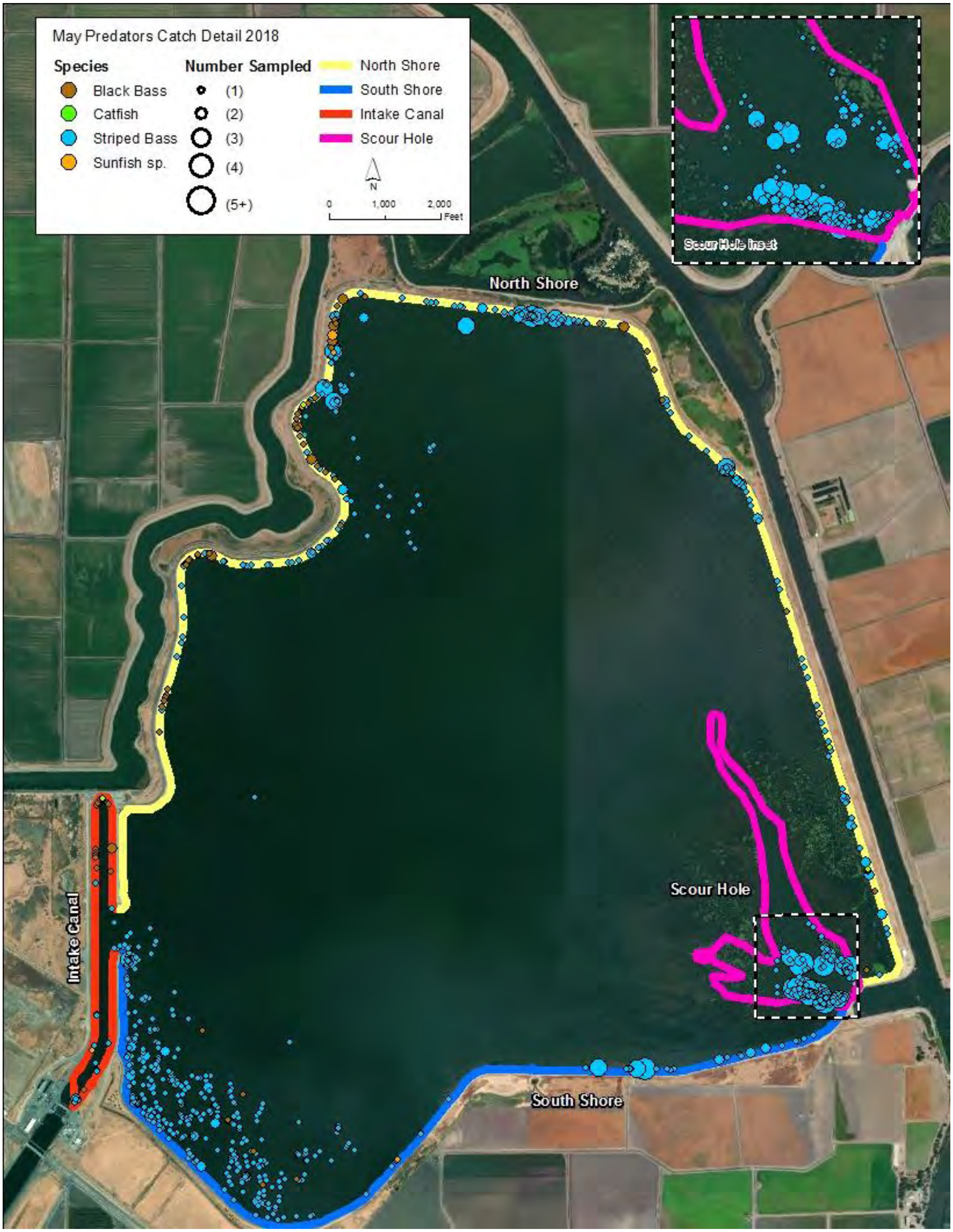


Figure 17. Spatial Patterns in all Predatory Fish Catch in Clifton Court Forebay, May 2018

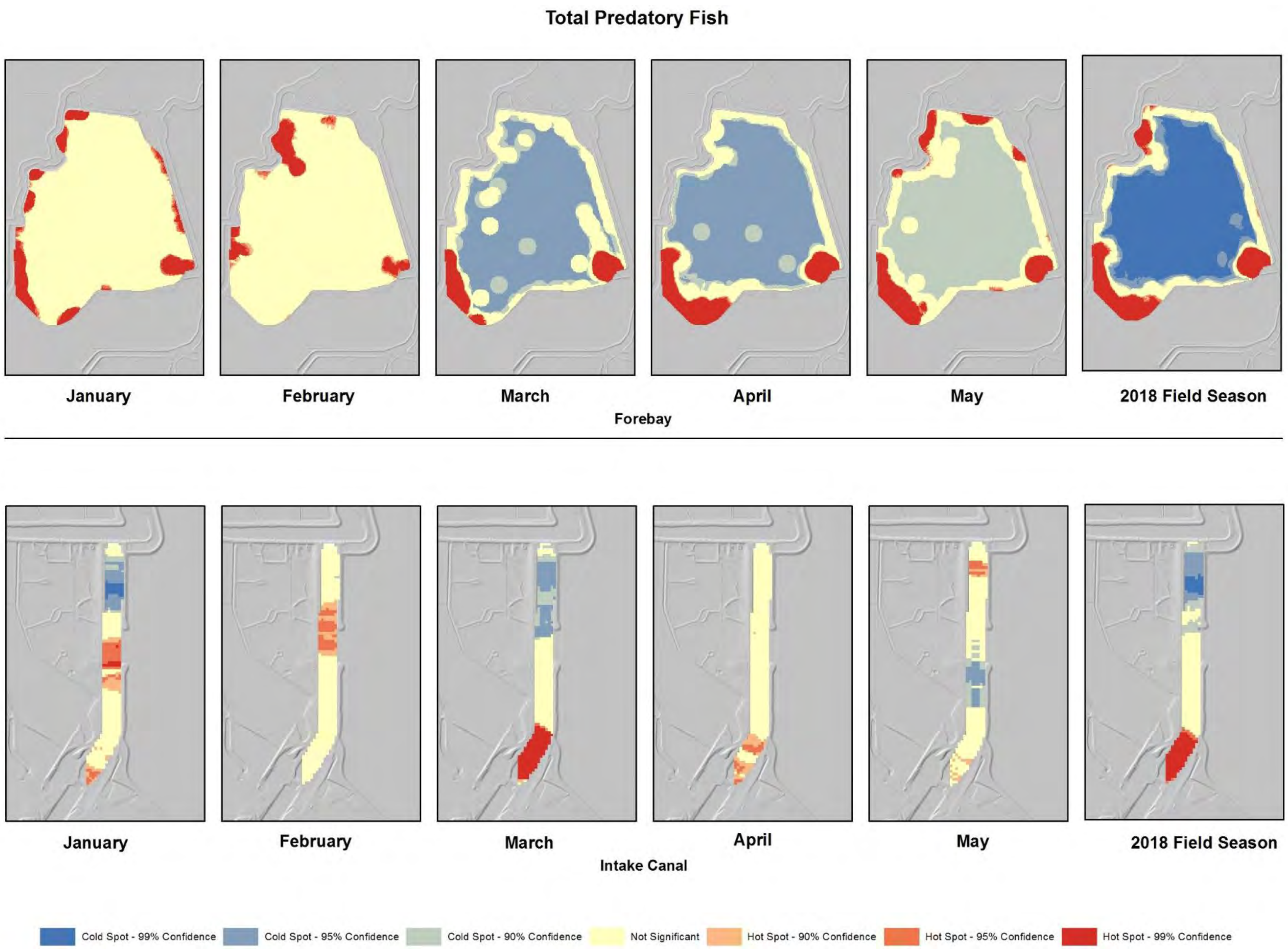


Figure 18. Result of the Hotspot Analysis of all Predatory Fish Catch in Clifton Court Forebay, 2018 Field Season

3.4 *Striped Bass Depth Preference*

The large majority (~95%) of Striped Bass individuals were caught in a depth range of 2 to 8 feet, with a mean depth of 4.6 feet (Figure 19). The large majority (~95%) of CCF ranges between 3 and 7 feet of depth, with a mean depth of 5.3 feet. Figure 19 illustrates the differences between catch rates at specific depths and the total available depths within CCF. One of the possibilities for this discrepancy between these distributions, is that Striped Bass may utilize some habitats at a higher rate than others in CCF, while another explaination could be that electrofishing could be less effective at sampling deeper habitat. Additional studies using alternative sampling techniques will allow us to improve our understanding of Striped Bass habitat utilization and of the effectiveness of electrofishing in deeper areas of CCF.

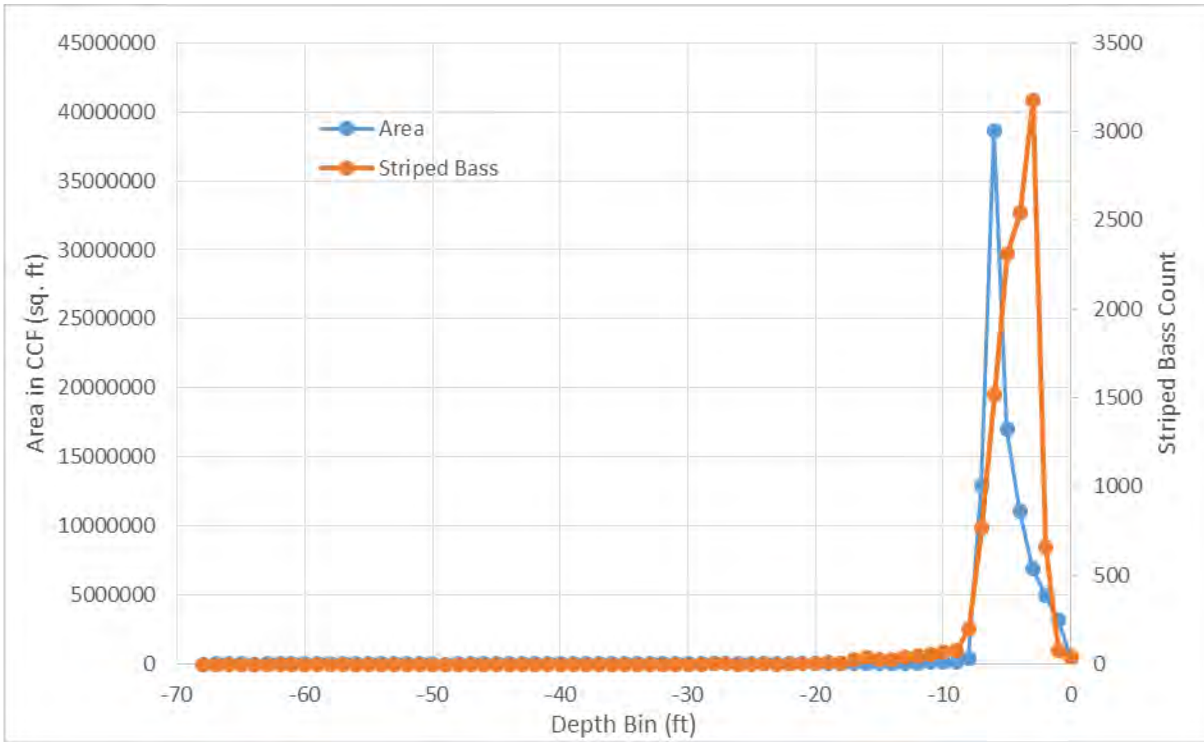


Figure 19. Distribution of Depths throughout CCF Measured as Area and Total Captures of Striped Bass

3.5 *Striped Bass Hotspots in Terms of River Length*

A total of 5,563 Striped Bass were captured within the two hotspots in northwest and southwest portions of CCF. The volume of water in these hotspots was calculated to be 31.2 million cubic feet. The length of Old River that would provide the same volume of water is 1.96 miles (Figure 20). The Striped Bass that were captured in these hotspots moved into CCF during the 2018 sampling effort in relatively short periods of time, suggesting that large roving schools of young Striped Bass in the South Delta could be occupying miles of channels at any given time. These large schools of Striped Bass could form formidable barriers to out-migrating Salmon and steelhead before they enter CCF and after they leave. This suggests that a focused predator removal effort limited to CCF is only addressing predation in a relatively small spacio-temporal scale.

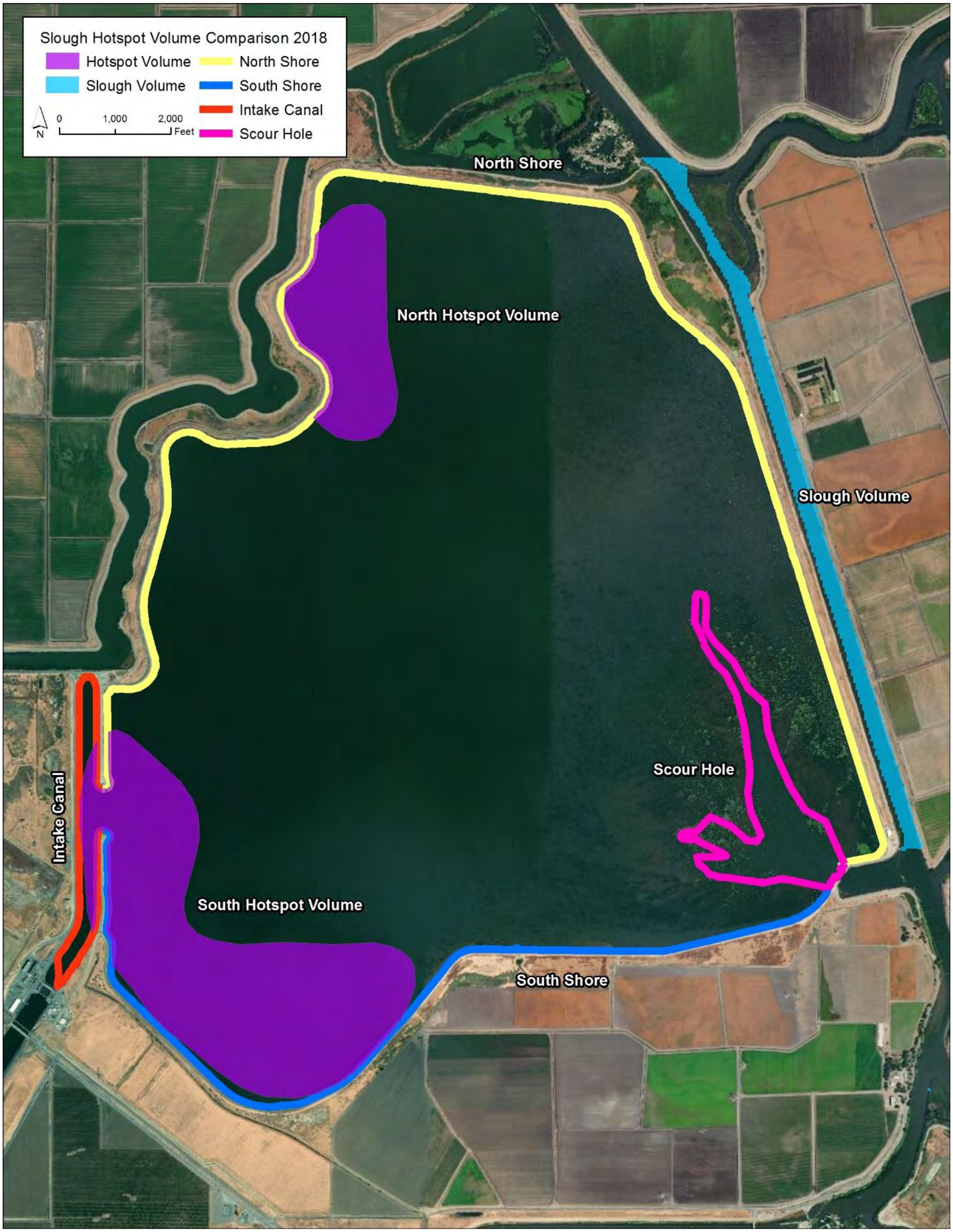
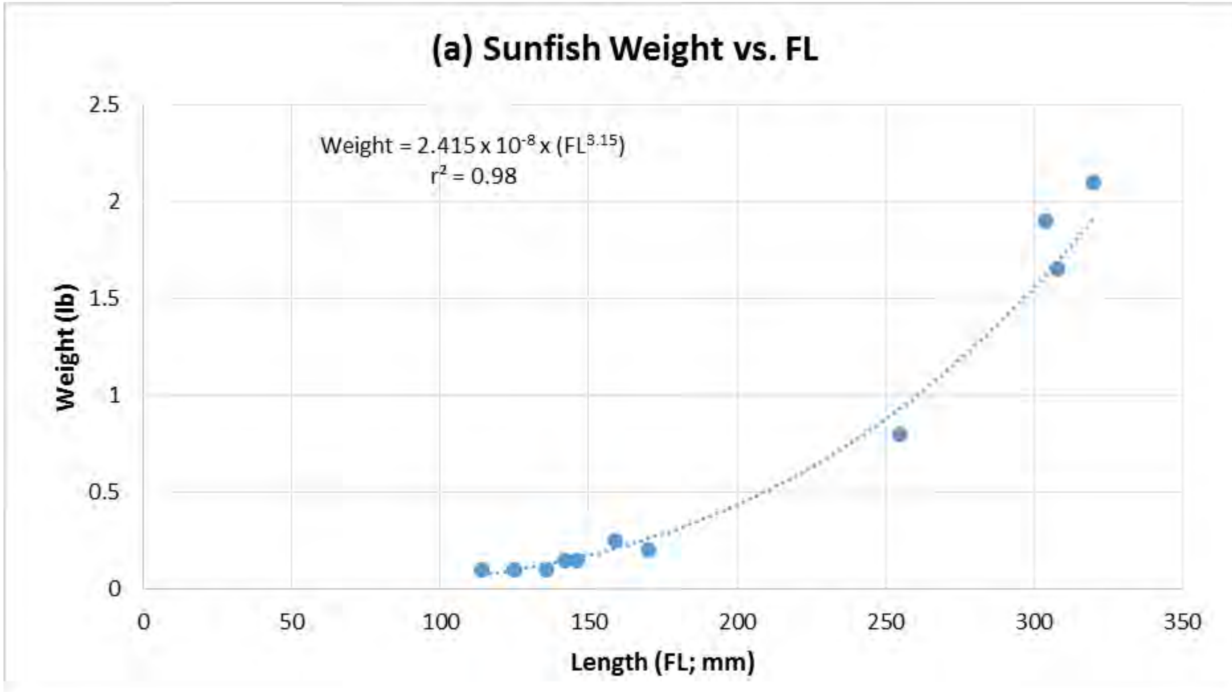


Figure 20. Locations of Hotspots in the Northwest and Southwest Portions of CCF and the Reach of Old River of Equal Volume to the Combined Hotspot Volume

3.6 Predator Biomass

Despite limited weight data (n = 11 fish), length-weight relationships for sunfish had strong predictive value (FL: $r^2 = 0.98$; TL: $r^2 = 0.98$; Figure 21).



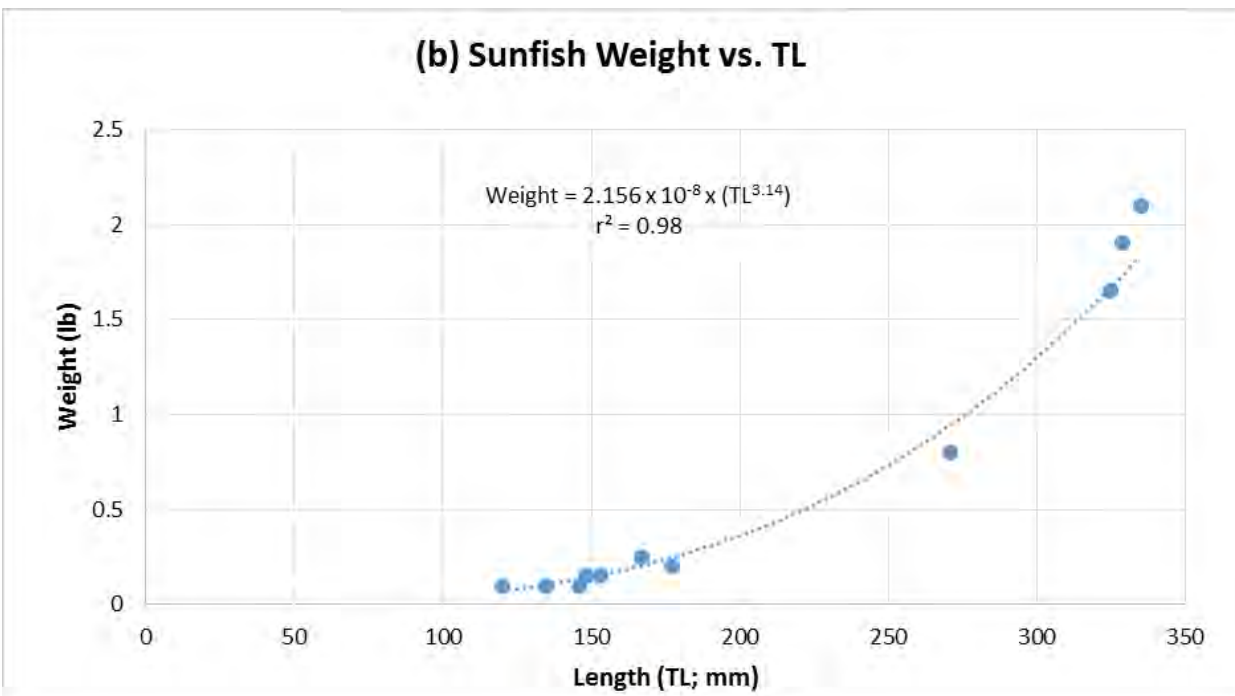


Figure 21. Weight versus (a) Fork Length and (b) Total Length of Sunfish Caught in CCF and Released into Bethany Reservoir during the 2018 Field Season

Only 94 total fish were excluded from biomass calculations due to a lack of length and weight data, which, based on total numbers of fish removed (13,138 fish), represents a negligible proportion (~0.7%) of total biomass removed.

A total of 13,877 lb (6.29 metric tons) of predatory fish biomass was removed from CCF during the 2018 field season (Table 7; Figure 22). Much of the biomass removal occurred in January and April, as noted by the increased slope during these two months in Figure 22. Overall biomass removal by species was roughly proportional to the number of individuals removed (Table 6), as were these patterns through time. A total of 12,098 lb (5.49 metric tons) of Striped Bass were removed, representing 87.2% of total biomass. Over half of the Striped Bass biomass was removed during April alone (7,117 lb). Black bass biomass removal was the second highest among species groups (1,678 lb, or 12.1% of total biomass). Over half of total black bass biomass was removed during January alone (923 lb). Consistent with patterns in total catches, catfish and sunfish contributed little to biomass removed (<1% of total biomass).

Table 7. Total Biomass (lb) of Predatory Fish Removed from CCF by Species and Month during the 2018 Field Season.

Month	Black Bass	Catfish	Striped Bass	Sunfish	All Fish
January	922.6	0.8	1,369.9	24.3	2,317.6
February	316.4	0.2	1,004.7	14.9	1,336.1
March	81.2	6.0	1,717.4	3.0	1,807.6
April	242.8	9.0	7,116.9	32.9	7,401.5
May	115.0	6.3	888.9	4.3	1,014.4
Total (Percent of Total)	**1,677.9 (12.1%)**	**22.2 (0.2%)**	**12,097.8 (87.2%)**	**79.3 (0.6%)**	**13,877.2**

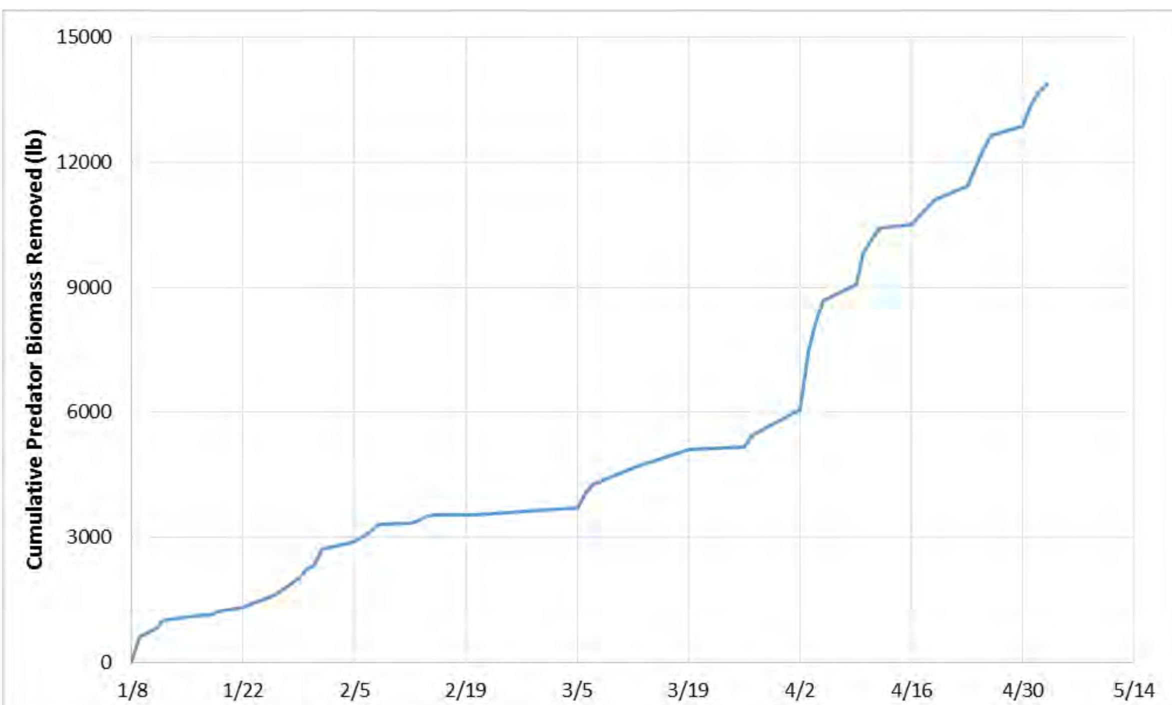


Figure 22. Cumulative Biomass of Predatory Fishes Removed from CCF during the 2018 Field Season

3.7 CPUE Summary

CPUE is summarized herein in terms of number of fish per hour of electrofishing (electrofishing duration) and as number of fish per hour spent on the water (total time on water), as described in Section 2.10.1.2, *Effort*.

Because time on water was generally greater than electrofishing duration, CPUE was smaller when using time on water as effort (Table 8). Regardless, overall patterns of CPUE using either effort metric were similar. Because of this similarity, the remainder of this section will describe results using time on water only, but the patterns apply to both CPUE calculations.

Mean monthly total predator CPUE increased from 11.8 ± 7.4 fish per hour on the water in January to 69.3 ± 20.5 fish per hour in April, with a decline to 38.3 ± 10.9 fish per hour in May (Table 8). Because the majority of fish caught were Striped Bass, Striped Bass patterns drove overall patterns in predator CPUE (Table 8). Striped Bass CPUE rose from 6.4 ± 6.3 fish per hour in January to 67.2 ± 21.1 fish per hour during April, then declined to 35.3 ± 10.5 fish per hour during May. Black bass CPUE was greatest during January, declined until March, and then increased again through May. Sunfish CPUE was greatest during January and declined in later months. Too few catfish were captured to meaningfully describe patterns in CPUE. There was high variation in mean CPUE within months for each species group and when combining all predators, as reflected in high standard deviations.

Table 8. Mean CPUE ± SD (Fish per hour) by Month and Species using Time on Water and Electrofishing Duration as Effort, 2018 Field Season. Replicates are Electrofishing Days. Shaded cells indicate the month where the highest CPUE was observed for each species.

Month	Electro-Fishing Days	Black Bass	Catfish	Striped Bass	Sunfish	Total
Effort Expressed as Time on Water						
Jan	14	4.1 ± 3.0	0.1 ± 0.2	6.4 ± 6.3	1.1 ± 1.0	11.8 ± 7.4
Feb	12	2.1 ± 1.4	0.03 ± 0.06	7.9 ± 11.0	0.9 ± 1.0	11.0 ± 10.8
Mar	10	0.5 ± 0.5	0.03 ± 0.05	21.9 ± 22.8	0.2 ± 0.5	22.7 ± 22.5
Apr	15	1.5 ± 1.5	0.1 ± 0.1	67.2 ± 21.1	0.5 ± 0.6	69.3 ± 20.5
May	3	2.5 ± 1.4	0.2 ± 0.2	35.3 ± 10.5	0.3 ± 0.2	38.3 ± 10.9
Total	**54**	**2.2 ± 2.2**	**0.1 ± 0.2**	**28.1 ± 30.1**	**0.7 ± 0.8**	**31.1 ± 29.3**
Effort Expressed as Electrofishing Duration						
Jan	14	5.9 ± 5.6	0.1 ± 0.3	9.0 ± 9.7	1.5 ± 1.4	16.6 ± 13.1
Feb	12	2.8 ± 1.9	0.03 ± 0.07	10.2 ± 14.1	1.1 ± 1.3	14.1 ± 14.0
Mar	10	0.7 ± 0.6	0.04 ± 0.07	30.1 ± 33.0	0.3 ± 0.6	31.1 ± 32.7
Apr	15	2.0 ± 2.0	0.2 ± 0.2	89.5 ± 35.2	0.6 ± 0.7	92.3 ± 34.6
May	3	3.5 ± 2.0	0.2 ± 0.2	48.7 ± 17.2	0.4 ± 0.2	52.7 ± 17.9
Total	**54**	**3.0 ± 3.6**	**0.1 ± 0.2**	**37.8 ± 41.9**	**0.9 ± 1.1**	**41.8 ± 41.0**

3.8 Environmental Parameters

Water temperature gradually increased over the course of the PRES period, from just over 10°C in January to 18-20°C during April and May (Figure 23).

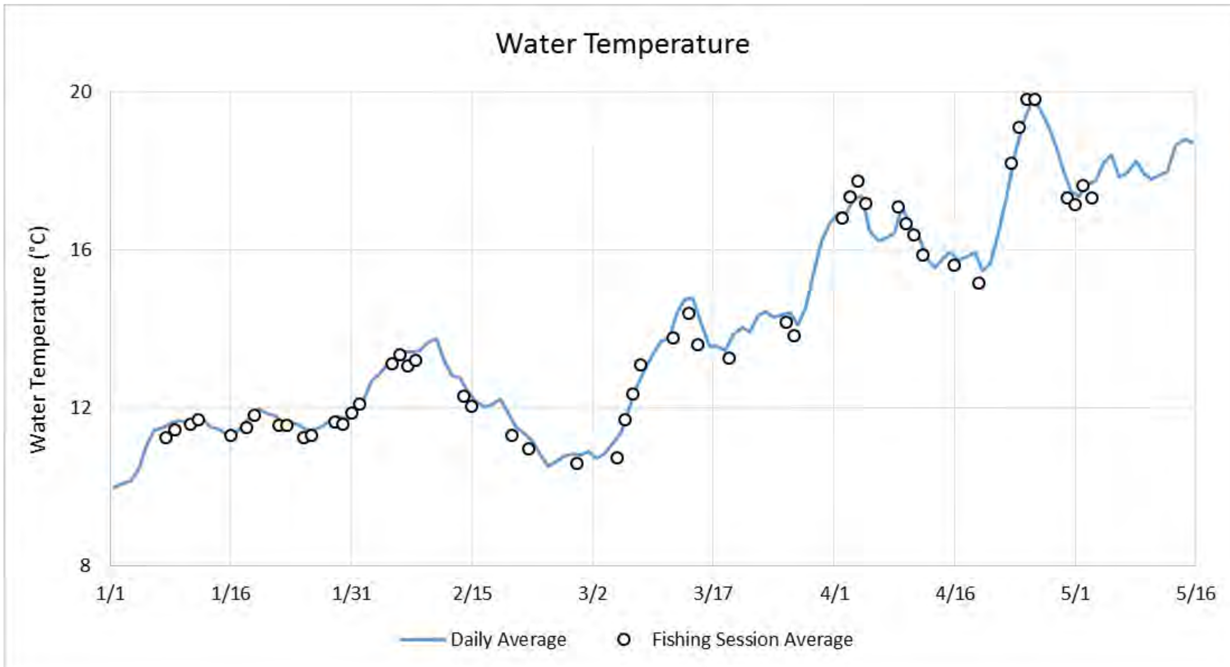


Figure 23. Water Temperature during the 2018 Field Season Measured at CDEC Station CLC. Symbols Represent Mean Water Temperatures Recorded during Daily Fishing Sessions

Mean daily turbidity was consistently low (~<10 NTU) during January through the end of March, when a turbidity plume entered the South Delta and drove mean daily turbidity to over 100 NTU on 3/28/2018 (Figure 24). Mean daily turbidity remained higher than before the spike (~20-40 NTU) through the end of the field season in the beginning of May.

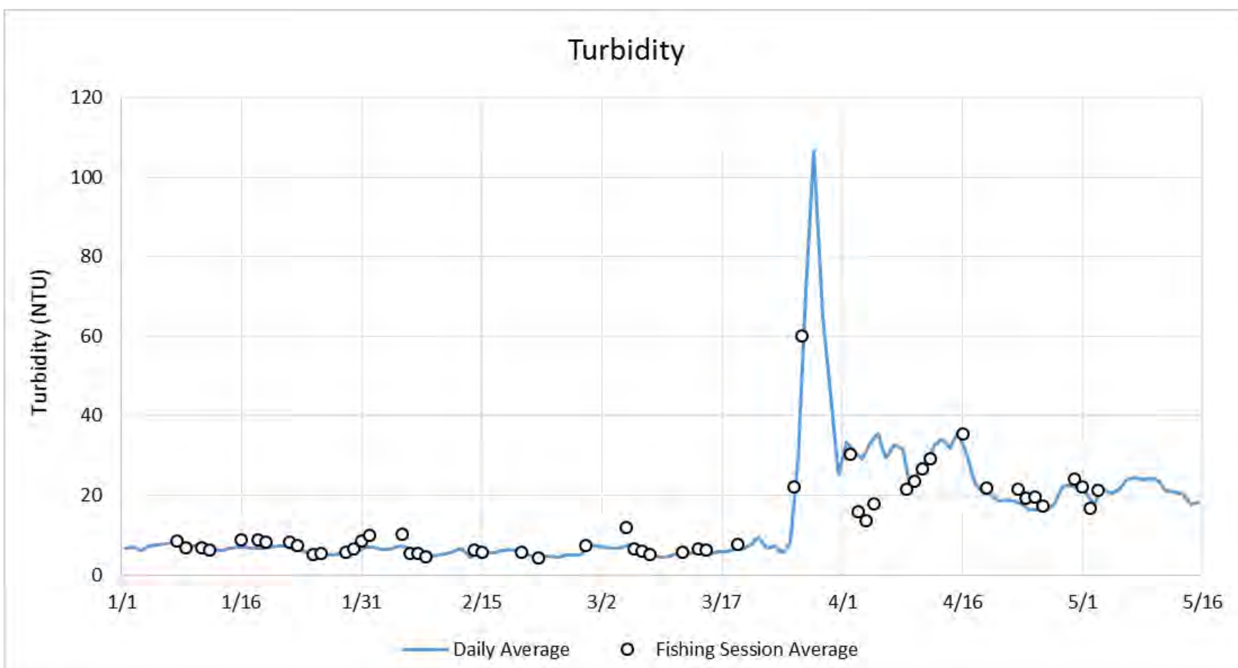


Figure 24. Turbidity During the 2018 Field Season Measured at CDEC Station CLC. Symbols Represent mean Turbidity Recorded during Daily Fishing Sessions.

Wind speed was variable during the 2018 field season with no discernible patterns until March. (Figure 25). Beginning in March, there is a slight increasing trend in wind speed.

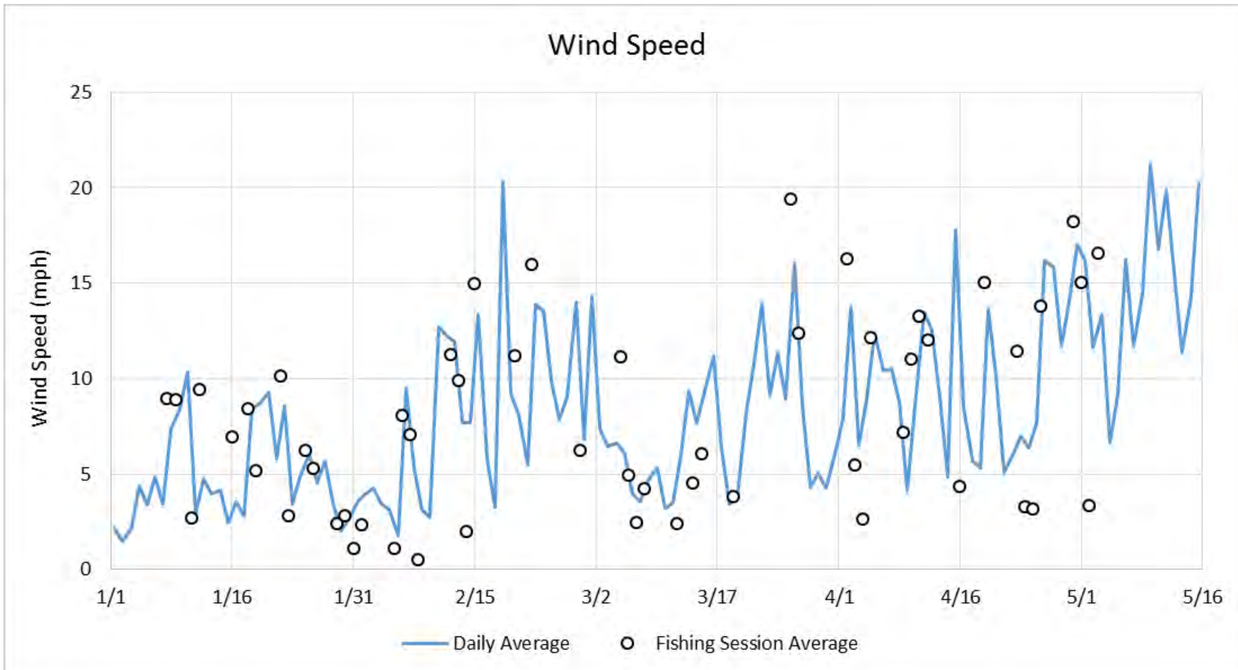


Figure 25. Wind Speed During the 2018 Field Season Measured at CDEC Station CLC. Symbols Represent Mean Wind Speed Recorded during Daily Fishing Sessions

Flow through the CCF radial gates varied considerably both daily and seasonally (Figure 26). The PRES field season began during a period of relatively moderate gate flows near 4000 cfs for most of January through the beginning of April. On 4/10/208, radial gate flows dropped to a range of 1,000-2,000 cfs. Mean radial gate flows during individual electrofishing sessions were as high as 11,000 cfs and approximately half of electrofishing sessions occurred during periods when radial gates were closed.

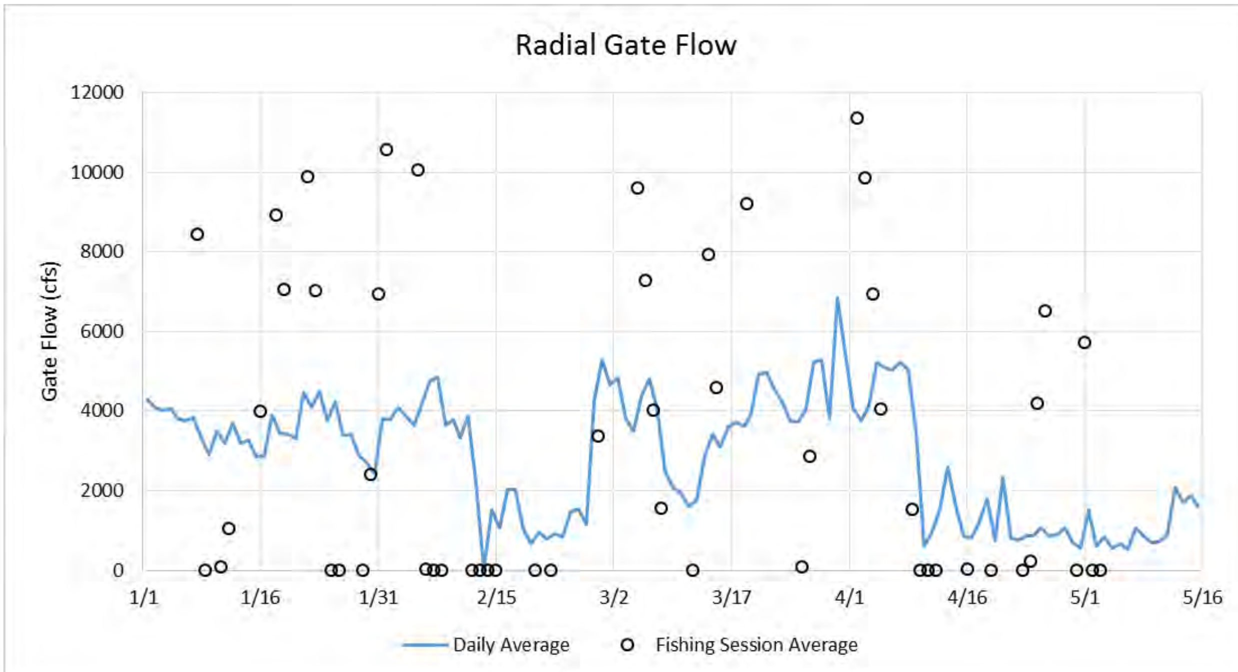


Figure 26. CCF Radial Gate Flow During the 2018 Field Season Measured with Data Obtained from DWR O&M. Symbols represent mean gate flow recorded during daily fishing sessions.

Mean daily pumping at Banks Pumping Plant was fairly steady at ~2,500-3,500 cfs until mid-February, when pumping dropped below 2,000 cfs (Figure 27). In the beginning of March, pumping increased to ~4,000 cfs until April, when it dropped to <~1,000 cfs for the remainder of the field season. Reduced pumping rates are thought to increase the residence time of fish in the Forebay, which increases their exposure to predators. However, if predator removal was successful in driving down the predator population in the Forebay in 2018, the Forebay may not have been as inhospitable as it would have been if predator abundance were not reduced, assuming no other factors, such as water temperature, affected salmon survival. Salmon survival assessments as part of SEIS from 2018 may provide information to improve our understanding of the relationships between predator reduction, pumping rate, and salmon survival.

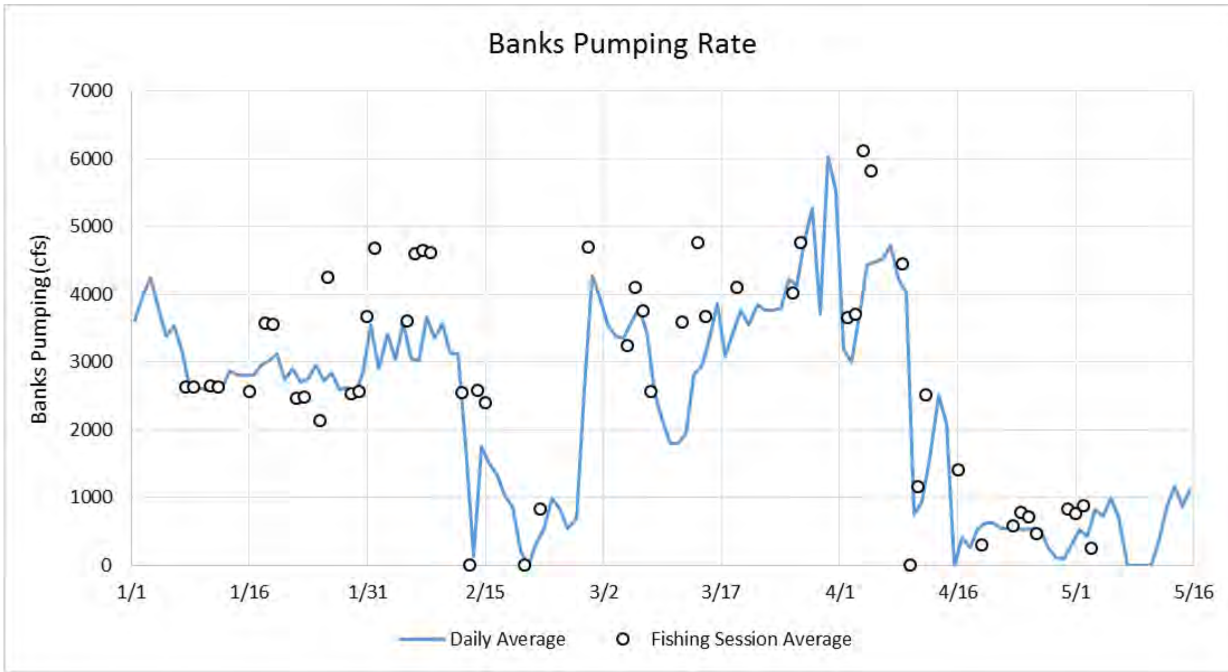


Figure 27. Banks Pumping During the 2018 Field Season Measured with Data Obtained from DWR O&M and DFW Salvage Reports. Symbols represent mean pumping recorded during individual samples.

3.9 Environmental Influences on Predator Catch

3.9.1 Statistical Analysis

3.9.1.1 Effort as Electrofishing Hours

The statistical analysis of environmental influences on predator catch per electrofishing hour found that water temperature was the only significant predictor in models for total predators and Striped Bass, whereas turbidity was the only significant predictor for black bass. In all three sets of analyses, addition of environmental predictors to the models improved the prediction of predator catch relative to an intercept-only model with no predictors (i.e., the full models had AIC more than 3 units below those of the intercept-only models). The remainder of this section describes results for total predators, Striped Bass, and black bass separately.

3.9.1.1.1 Total Predators

The only significant predictor of total predator count was water temperature (Table 9). Predicted catch of total predators increased with increasing water temperature (Figure 28).

Table 9. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Total Predator Catch Accounting for Electrofishing Duration in CCF, January-May 2018 (Full Model Pseudo r^2 = 0.61)

Variable	Estimate	95% CI Lower	95% CI Upper	Importance
Water Temperature	**0.306**	**0.233**	**0.379**	**1.00**
Wind Speed	-0.032	-0.070	0.006	0.49
Banks Pumping Rate	0.000	0.000	0.000	0.39
Turbidity	0.006	-0.017	0.029	0.26
Gate Flow	0.000	0.000	0.000	0.25

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

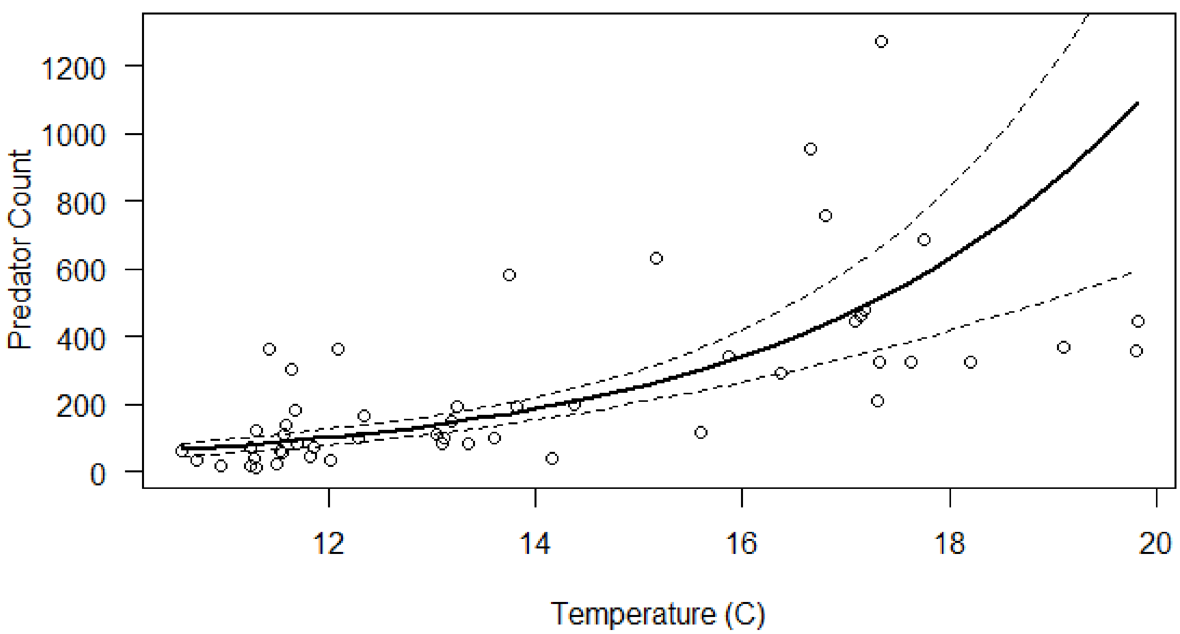


Figure 28. Predicted Total Predator Count (Line with 95% Confidence Interval) as a Function of Water Temperature from Generalized Linear Modeling Accounting for Electrofishing Duration Compared to Observed Counts (Points) of CCF Catch Data, January-May 2018

3.9.1.1.2 *Striped Bass*

The statistical relationships between environmental predictors and Striped Bass catch generally were similar to those for total predators: a positive relationship between catch and temperature, with no other variables having significant predictive ability (Table 10; Figure 29).

Table 10. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Striped Bass Catch Accounting for Electrofishing Duration in CCF, January-May 2018 (Full Model Pseudo r^2 = 0.60)

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Water Temperature	**0.386**	**0.293**	**0.480**	**1.00**
Wind Speed	-0.050	-0.099	-0.002	0.64
Banks Pumping Rate	0.016	-0.013	0.045	0.43
Turbidity	1.1×10^{-4}	-4.6×10^{-5}	2.6×10^{-4}	0.35
Gate Flow	1.4×10^{-5}	-4.5×10^{-5}	7.4×10^{-5}	0.26

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

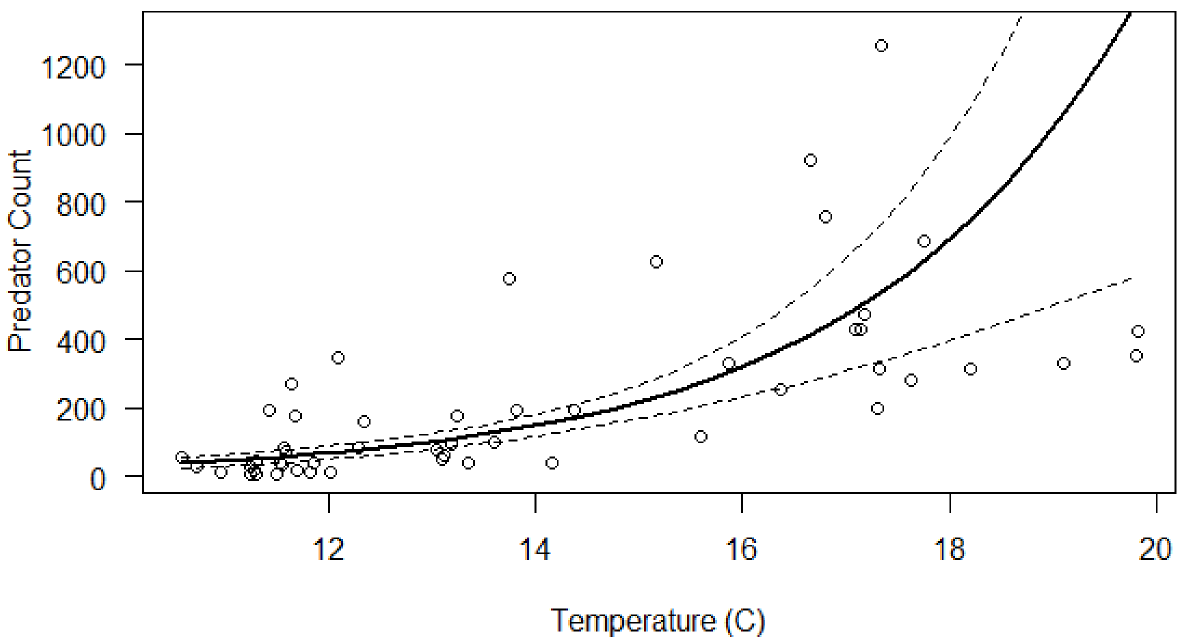


Figure 29. Predicted Striped Bass Count (Line with 95% Confidence Interval) as a Function of Water Temperature from Generalized Linear Modeling Accounting for Electrofishing Duration Compared to Observed Counts (Points) of CCF Catch Data, January-May 2018

3.9.1.1.3 *Black Bass*

The statistical analysis of black bass catch as a function of environmental variables found only turbidity to be a significant predictor (Table 11). The ability of the GLM to explain the variability in black bass catch (pseudo $r^2 = 0.19$) was considerably lower than for total predator and Striped Bass catch (pseudo $r^2 = 0.60$-0.61), and the negative relationship between turbidity and catch was not strong (Figure 30).

Table 11. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Black Bass Catch Accounting for Electrofishing Duration in CCF, January-May 2018 (Full Model Pseudo $r^2 = 0.19$)

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Turbidity	**-0.049**	**-0.083**	**-0.015**	**0.83**
Banks Pumping Rate	-2.2×10^{-4}	-4.2×10^{-4}	-2.9×10^{-5}	0.69
Gate Flow	-5.2×10^{-5}	-1.3×10^{-4}	2.4×10^{-5}	0.44
Water Temperature	-0.060	-0.216	0.097	0.32
Wind Speed	-0.012	-0.081	0.056	0.25

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

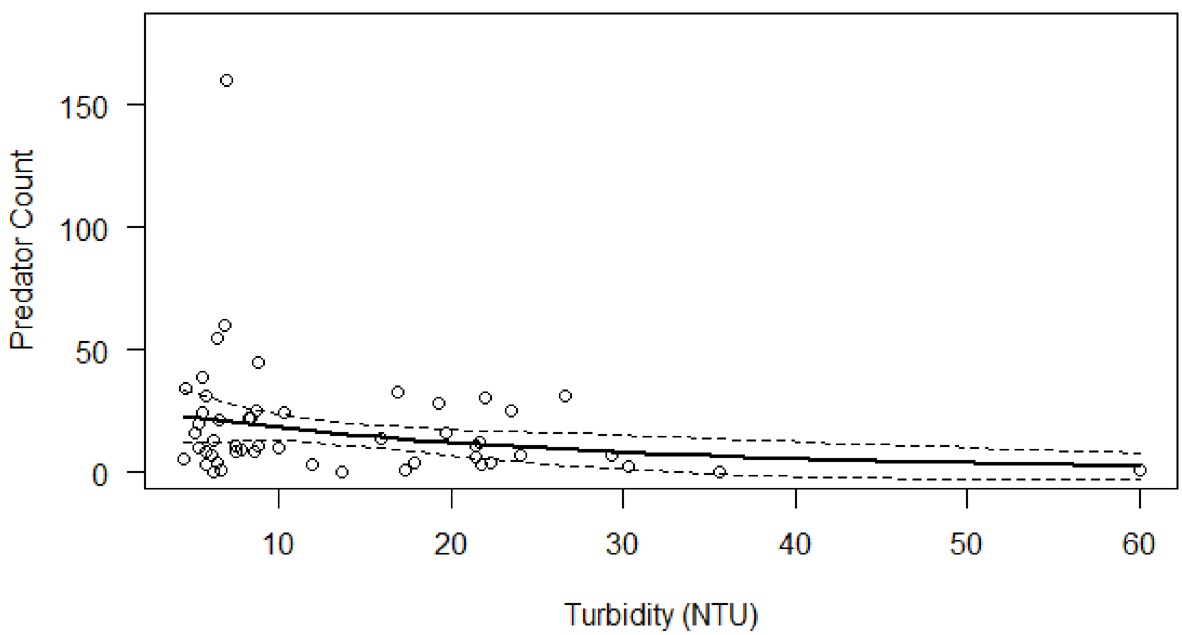


Figure 30. Predicted Black Bass Count (Line with 95% Confidence Interval) as a Function of Turbidity from Generalized Linear Modeling Accounting for Electrofishing Duration Compared to Observed Counts (Points) of CCF Catch Data, January-May 2018

3.9.1.2 *Effort as Hours on the Water*

The statistical analyses based on effort as hours on the water found essentially the same results as the analyses based on electrofishing hours, for total predators (Table 12, Figure 31), Striped Bass (Table 13, Figure 32), and black bass (Table 14, Figure 33).

Table 12. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Total Predator Catch Accounting for Time on the Water in CCF, January-May 2018 (Full Model Pseudo r^2 = 0.65)

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Water Temperature	**0.307**	**0.237**	**0.378**	**1.00**
Wind Speed	-0.034	-0.071	0.002	0.59
Banks Pumping Rate	7.9×10^{-5}	-3.7×10^{-5}	1.9×10^{-4}	0.42
Turbidity	0.011	-0.011	0.033	0.33
Gate Flow	1.0×10^{-5}	-3.5×10^{-5}	5.6×10^{-5}	0.25

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

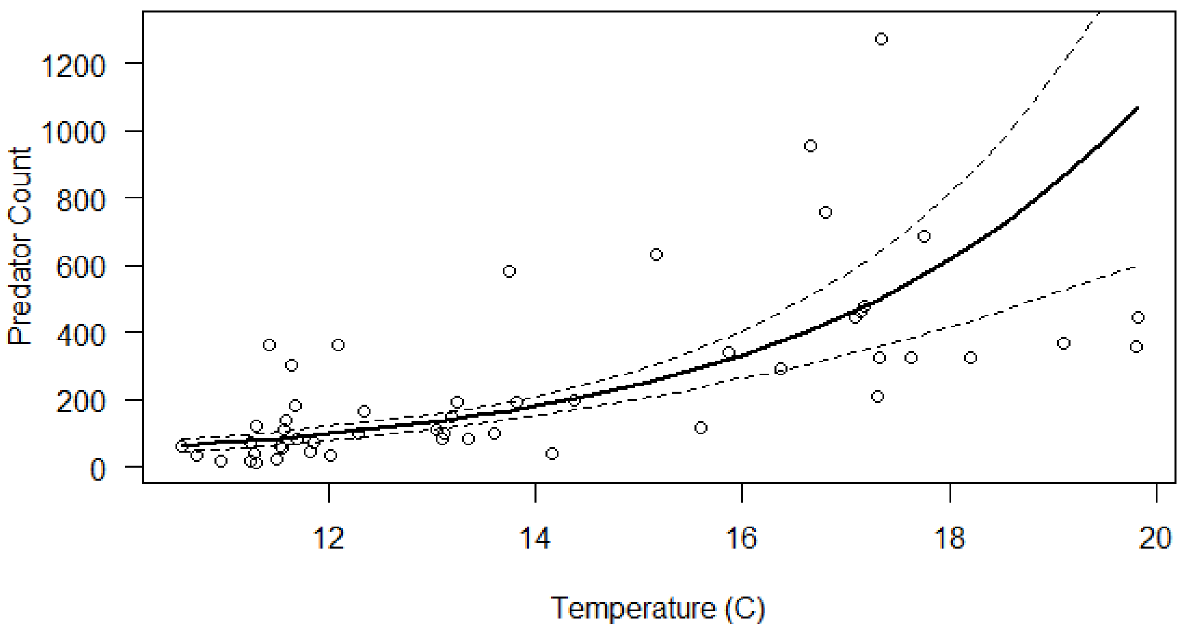


Figure 31. Predicted Total Predator Count (Line with 95% Confidence Interval) as a Function of Water Temperature from Generalized Linear Modeling Accounting for Time on Water Compared to Observed Counts (Points) of CCF Catch Data, January-May 2018

Table 13. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Striped Bass Catch Accounting for Time on the Water in CCF, January-May 2018 (Full Model Pseudo r^2 = 0.63)

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Water Temperature	**0.383**	**0.289**	**0.477**	**1.00**
Wind Speed	-0.054	-0.103	0.048	0.72
Turbidity	0.021	-0.007	-0.005	0.46
Banks Pumping Rate	1.1×10^{-4}	-4.4×10^{-5}	2.6×10^{-4}	0.43
Gate Flow	1.5×10^{-5}	-4.2×10^{-5}	7.3×10^{-5}	0.26

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

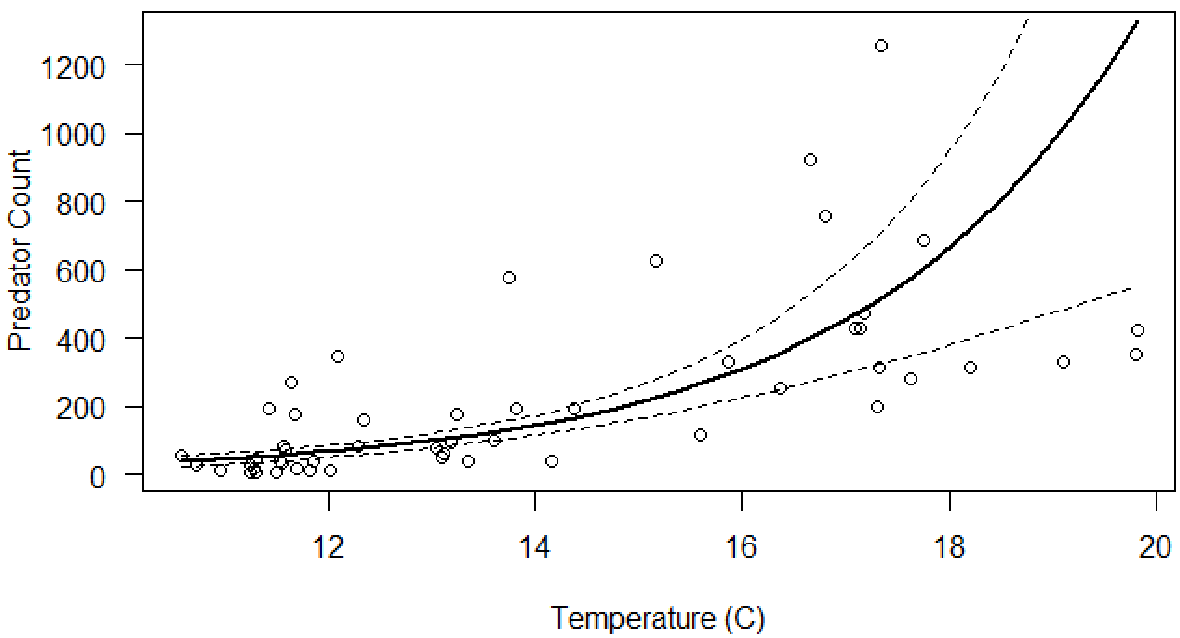


Figure 32. Predicted Striped Bass Count (Line with 95% Confidence Interval) as a Function of Water Temperature from Generalized Linear Modeling Accounting for Time on the Water Compared to Observed Counts (Points) of CCF Catch Data, January-May 2018.

Table 14. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Generalized Linear Modeling of Black Bass Catch Accounting for Time on the Water in CCF, January-May 2018 (Full Model Pseudo r^2 = 0.19)

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Turbidity	**-0.046**	**-0.078**	**-0.013**	**0.82**
Banks Pumping Rate	-2.1×10^{-4}	-3.9×10^{-4}	-2.3×10^{-5}	0.68
Gate Flow	-4.9×10^{-5}	-1.2×10^{-4}	-1.2×10^{-4}	0.43
Water Temperature	-0.048	-0.198	0.102	0.31
Wind Speed	-0.019	-0.084	0.045	0.27

Note: Variables in bold have importance ≥ 0.80 and 95% CI not overlapping zero.

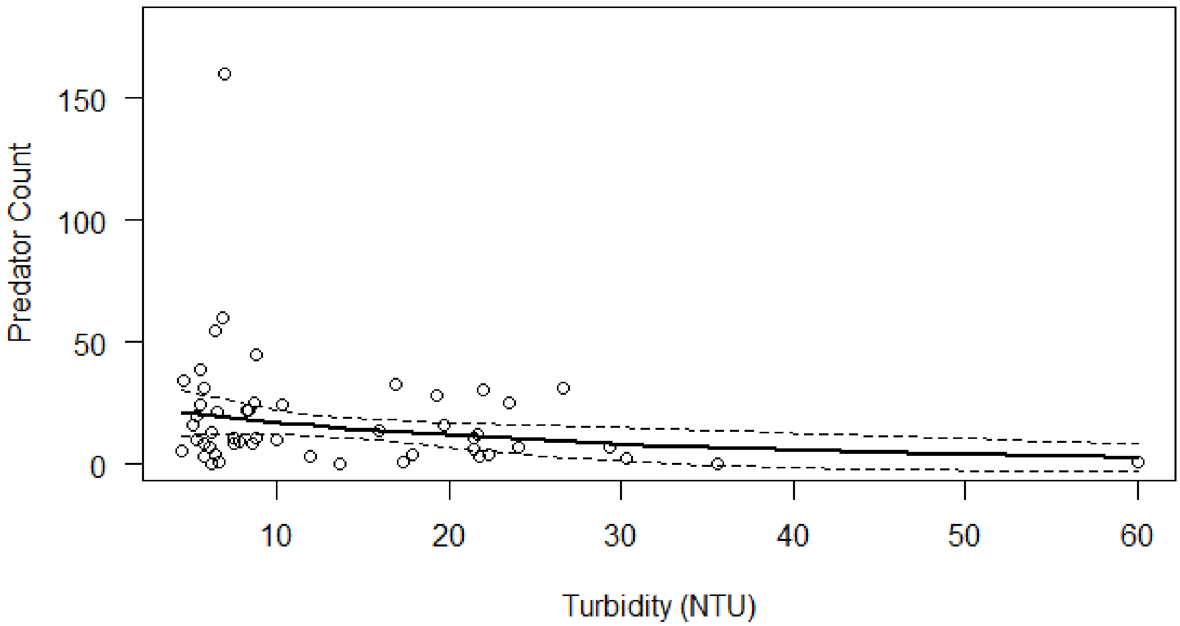
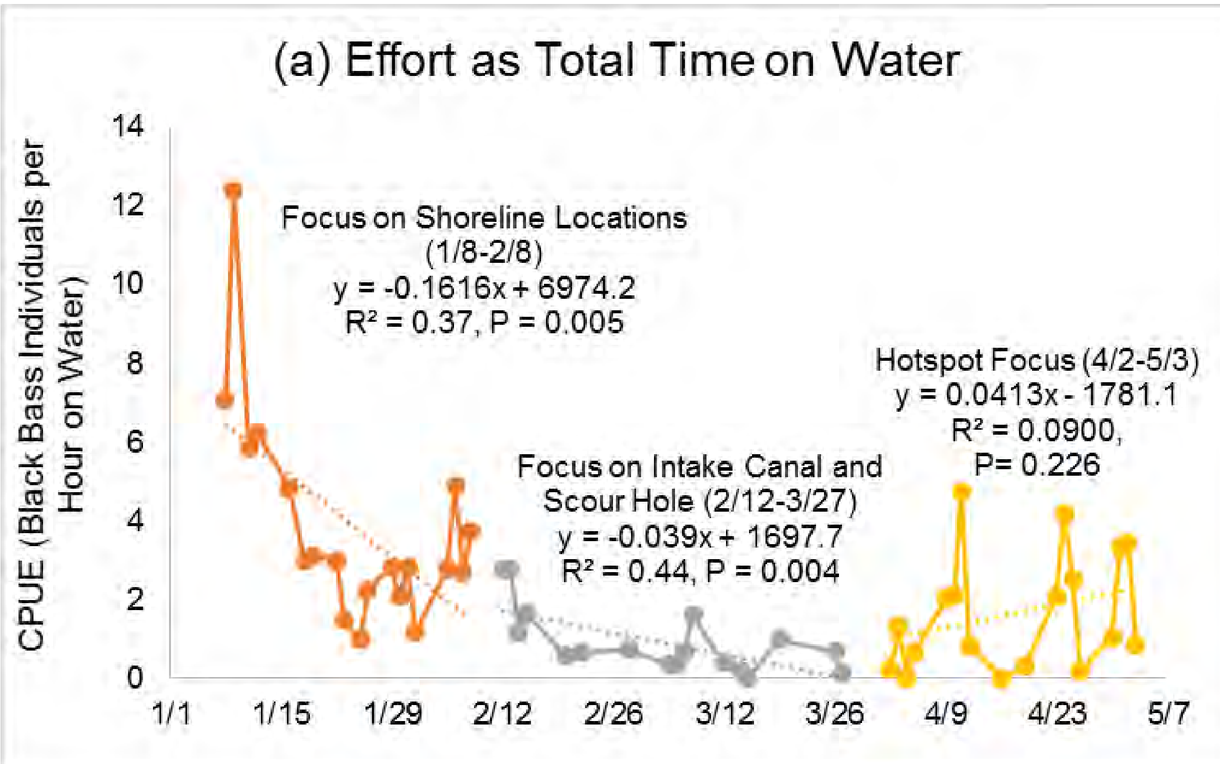


Figure 33. Predicted Black Bass Count (Line with 95% Confidence Interval) as a Function of Turbidity from Generalized Linear Modeling Accounting for Time on the Water Compared to Observed Counts (Points) of CCF Catch Data, January-May 2018

3.10 Predator Depletion

There was statistical evidence for depletion of black bass in CCF during the 2018 field season (Figure 34). Black bass CPUE in the beginning of the 2018 field season was high, but steadily declined after approximately 2 weeks and was generally maintained well below the initial rate through the rest of the field season. The fishing strategy change in mid-February was made as a result of the success of this initial depletion of black basses along the shorelines and desire to focus on more densely populated locations of CCF. Beginning on 2/12/18, fishing focus shifted away from the shorelines and towards the Intake Canal and Scour Hole initially. Beginning on 4/2/18, the focus shifted again on southwest and northwest Striped Bass hotspots. There was a statistically significant decrease in black bass CPUE between 1/8/18 and 2/8/18 (effort as total time on water: $r^2 = 0.37$, $p = 0.005$; effort as electrofishing duration: $r^2 = 0.29$, $p = 0.017$) and also between 2/12/18 and 3/27/18 effort as total time on water: $r^2 = 0.44$, $p = 0.004$; effort as electrofishing duration: $r^2 = 0.44$, $p = 0.004$), whereas there was no trend between 4/2/18 and 5/3/18, when the focus shifted more to hotspots of Striped Bass ($r^2 < 0.09$; $p > 0.22$).

Striped Bass CPUE showed the opposite pattern from black bass (Figure 35). Catch rates were very low in the beginning of the field season until mid-March and then became very high. There was an influx of small (250-320 mm) individuals that began showing up in CCF during March. Beginning in the third period of fishing (4/2/18 to 5/3/18) when the focus shifted to hot spots and used a strategy of maximizing fishing in highly productive areas, depletion was observed in Striped Bass. This depletion was statistically significant (effort as total time on water: $r^2 = 0.51$, $p = 0.001$; effort as electrofishing duration: $r^2 = 0.41$, $p = 0.004$), whereas there was no trend during the other two periods ($r^2 \leq 0.18$, $p > 0.08$).



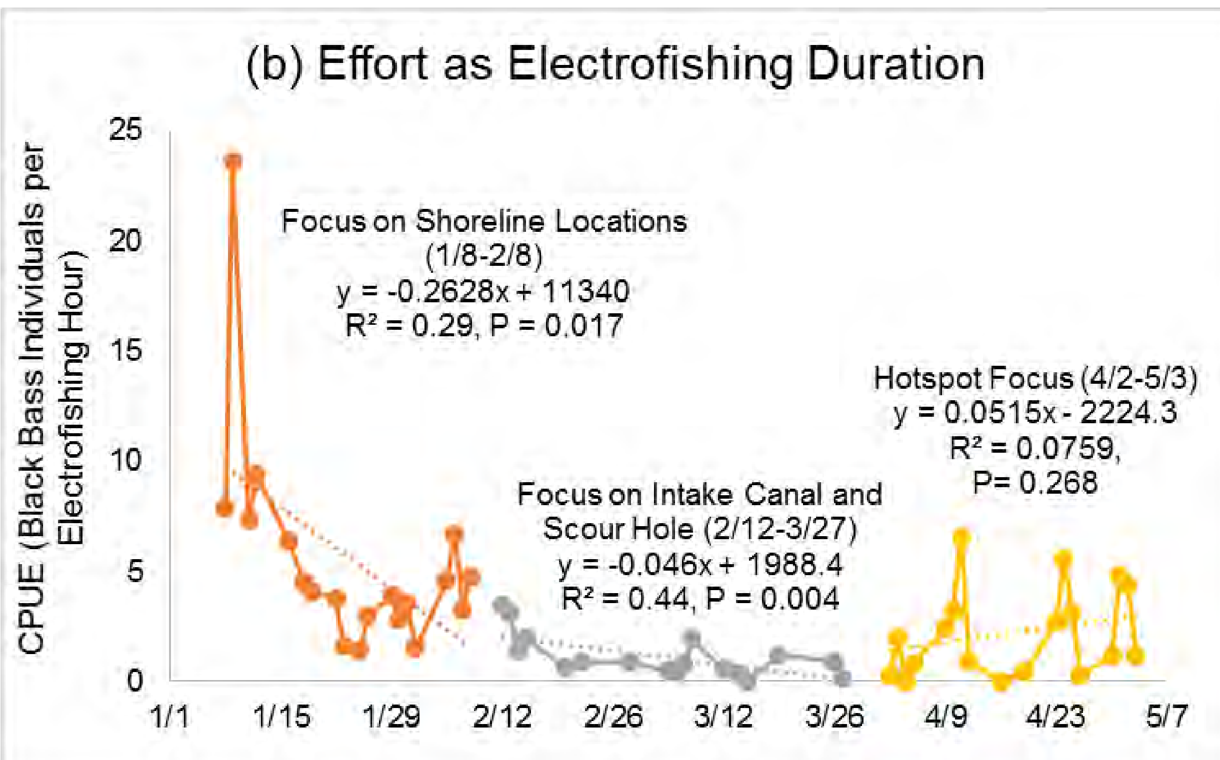
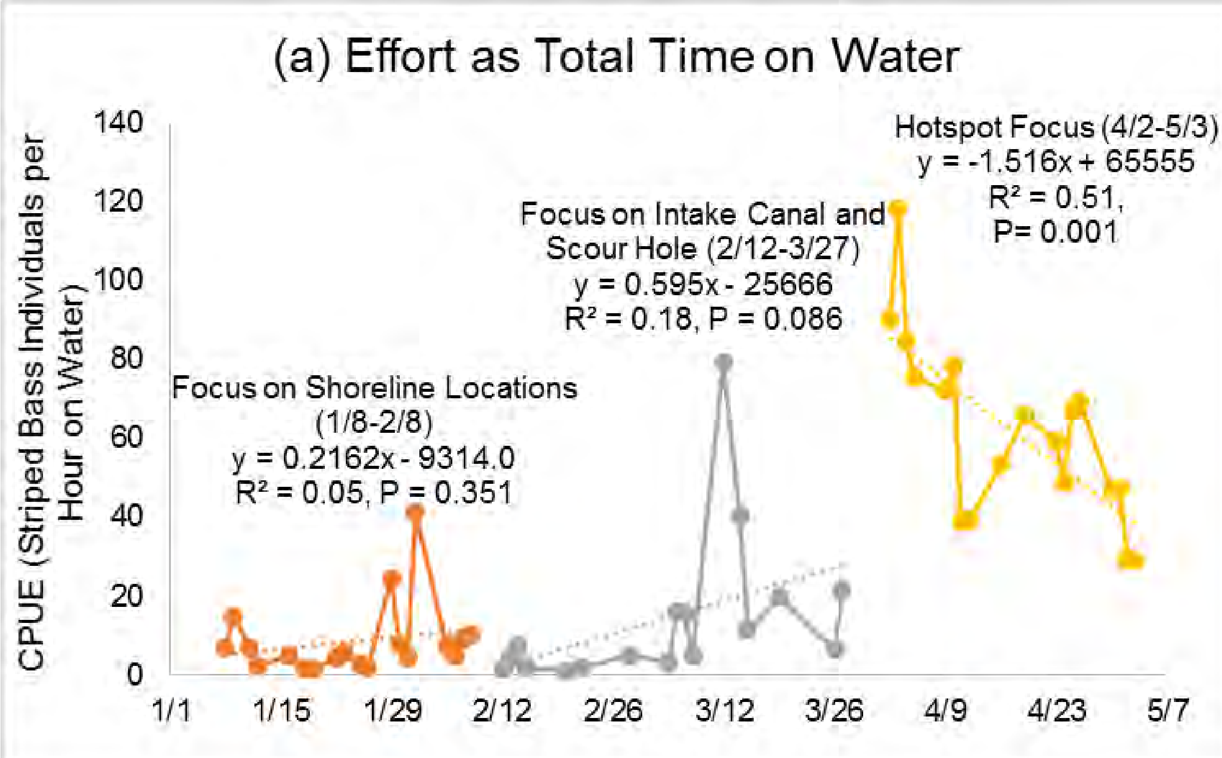


Figure 34.Summary of Linear Regressions of Black Bass Catch per Unit Effort in CCF during Three Time Periods in the 2018 Field Season where Effort Was Measured as (a) Total Time on Water and (b) Electrofishing Duration



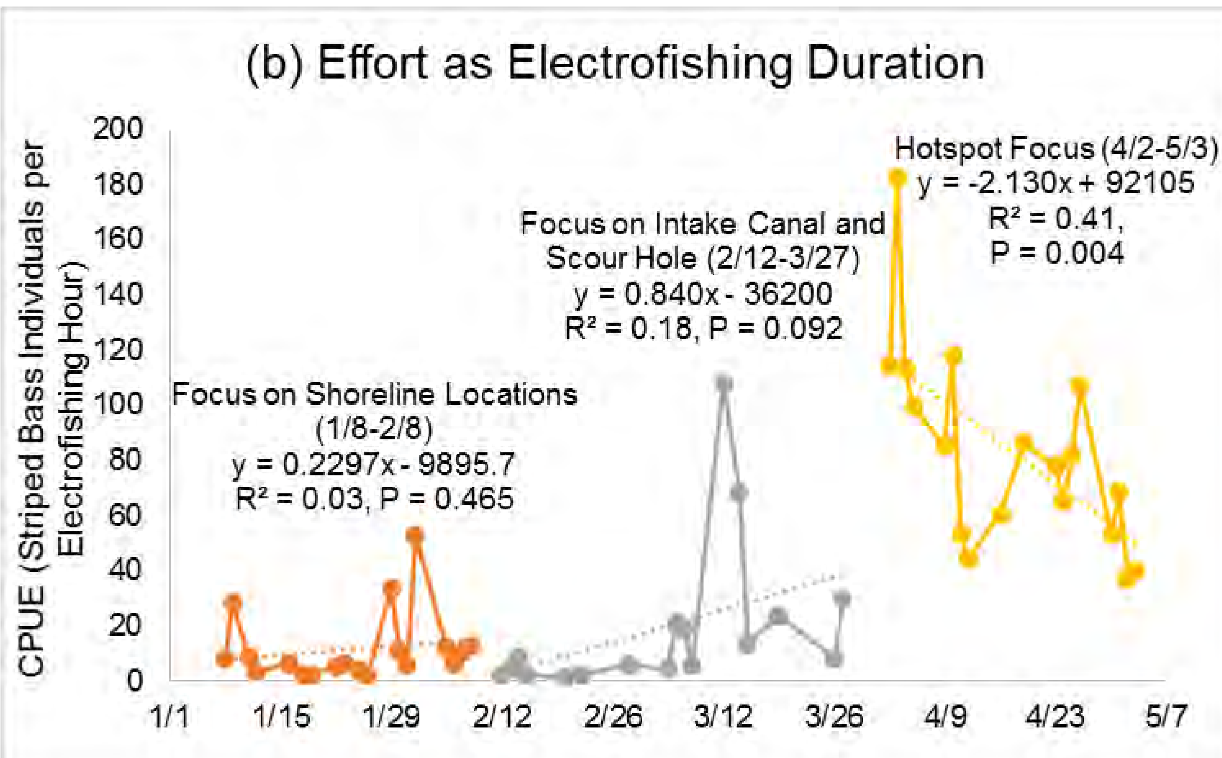


Figure 35. Summary of Linear Regressions of Striped Bass Catch per Unit Effort in CCF during Three Time Periods in the 2018 Field Season where Effort Was Measured as (a) Total Time on Water and (b) Electrofishing Duration

3.11 Predator Recapture

There were 34 predatory fish previously tagged for other CCF predator studies (see Section 1.3, *Concurrent Predator Studies in Clifton Court Forebay*) that were recaptured during the 2018 field season, accounting for 57 total recapture events (Table 15). There were 23 black basses, all of which were Largemouth Bass, and 11 Striped Bass recaptured, accounting for 46 and 11 recapture events, respectively. Geospatial data throughout the 2018 field season were not consistently accurate and reliable; therefore, fish capture locations will not be discussed in this section.

Twelve individuals, all Largemouth Bass, were recaptured more than once during 2018, including three individuals (PIT tag # 3D9239F883DE3, 3D9239F884E9A, and 3DD003BC7F48B) that were recaptured four times each (Table 15). These same individuals were each recaptured once during the 2017 field season (DWR 2017). There were 17 individuals recaptured during both 2017 and 2018 field seasons and two individuals that were recaptured during both 2016 and 2018 field seasons. One Largemouth Bass (PIT tag # 3D6.000B3AA22E), was recaptured twice in 2016, once in 2017, and three times in 2018. Another individual, also a Largemouth Bass, (PIT tag # 3DD.003BC7F305) was captured twice in 2016 and once in both 2017 and 2018.

There were 26 predatory fish captured during the 2018 field season with a PIT tag from a Chinook Salmon tagged as part of the SEIS study. These predatory fish apparently consumed the tagged Chinook Salmon. Further information about these fish can be found in Section 3.10, *Predator Consumption of Tagged Chinook Salmon.*

Table 15. Predatory Fish Tagged in the CFPS Study that Were Recaptured during the 2018 Field Season

Original Capture Data						Recapture Data			Captured in Previous Years	
Species	PIT Tag #	Floy Tag #	Date Tagged	Weight (lb)	Fork Length (mm)	Date	Weight (lb)	Fork Length (mm)	2016	2017
Largemouth Bass	3D9.239F888ED6	2996	3/23/2015	3.5	405	1/9/2018	6.4	490		X
Largemouth Bass	3D6.000B3AA22E		6/5/2014	0.95	325	1/9/2018	3.5	435	X	X
						1/19/2018	3.35	435		
						1/22/2018	3.45	432		
Largemouth Bass	3DD.003BC7F48B		11/14/2014	1.3	325	1/9/2018	2.8	413		X
						3/6/2018	3.5	418		
						3/15/2018	2.8	400		
						4/5/2018	2.6	406		
Largemouth Bass	3D9.239F8855C6	5450	12/23/2016	2.35	395	1/9/2018	4.1	440		X
						2/7/2018	4	434		
						2/22/2018	3.9	440		
Largemouth Bass	3D9.239F884DE3		4/8/2016	2.7	425	1/9/2018	4.1	460		X
						1/19/2018	4.05	444		
						1/22/2018	4	450		
						1/30/2018	3.95	462		
Largemouth Bass	3D9.239F884E9A	5366	12/20/2016	2.2	385	1/11/2018	2.95	410		X
						1/18/2018	3	400		
						1/23/2018	3.05	405		
						1/29/2018	2.9	400		
Largemouth Bass	3DD.003BC7F305		3/25/2016	1.15	325	1/11/2018	2.5	380	X	X
Largemouth Bass	3D9.1C2DB955EC		12/7/2016	1.85	370	1/12/2018	2.5	385		X
						2/1/2018	2.5	385		
Largemouth Bass	3D6.001569C095		7/21/2016	2	380	1/22/2018	3	420		X
Striped Bass	3DD.003BEAC55A		12/20/2016	0.85	340	1/22/2018	1.35	378		
Largemouth Bass	3DD.003BC7F416		11/13/2015	0.75	280	1/23/2018	1.65	343		X
Striped Bass	3D6.001569BF04		12/18/2015	6.3	620	1/23/2018	14.1	741		
	3DD.003BEAC584	3638	10/17/2016	1.3	345	1/26/2018	1.9	374		

Original Capture Data						Recapture Data			Captured in Previous Years	
Species	**PIT Tag #**	**Floy Tag #**	**Date Tagged**	**Weight (lb)**	**Fork Length (mm)**	**Date**	**Weight (lb)**	**Fork Length (mm)**	**2016**	**2017**
Largemouth Bass						3/14/2018	1.7	376		
						5/3/2018	1.55	376		
Largemouth Bass	3D9.239F888AD4	4036	10/27/2016	1.6	380	1/26/2018	1.85	386		X
						2/13/2018	1.8	375		
						3/19/2018	2	374		
Largemouth Bass	3D9.239F885258	4866	7/21/2016	2	415	1/30/2018	3.05	435		
Striped Bass	3DD.003BC7F2E7		3/1/2016	0.8	325	1/30/2018	2.4	435		
Largemouth Bass	3DD.003BC7F24B		11/23/2015	1.1	330	2/1/2018	2	389		X
						2/7/2018	2	390		
Largemouth Bass	3D9.239F88518C		11/13/2015	2.6	415	2/12/2018	3	434		X
Striped Bass	3D6.001569BF6E		2/12/2014	3.5	510	2/13/2018	12.8	805		
Largemouth Bass	3DD.003BC7F417		10/15/2015	1.15	310	3/5/2018	3.3	420		
						4/24/2018		433		
Striped Bass	3D9.239F88380F	4699	11/29/2016	1.8	410	3/7/2018	2.4	434		
Largemouth Bass	3D9.239F888527		1/7/2016	1.95	385	3/8/2018	4.1	465		X
Striped Bass	3DD.003BC7F4F1		5/6/2016	0.5	310	3/27/2018	2.9	462		
Largemouth Bass	3D9.239F8850D4	4756	12/29/2016	1.5	350	4/2/2018	2.6	364		
						4/9/2018	1.9	358		
						4/10/2018	1.8	367		
Striped Bass	3DD.003BEAC546		12/26/2016	0.6	305	4/3/2018	1.6	414		
Striped Bass	3DD.003BEAC548	4741	11/21/2016	37.5	1	4/4/2018	1.9	420		
Striped Bass	3DD.003BEAC4DE	4760	12/30/2016	0.7	315	4/5/2018	1.1	364		
Largemouth Bass	3D9.239F886FC8		9/14/2015	2.4	400	4/9/2018	3.8	443		X
Striped Bass	3DD.003BEAC4CB		12/30/2016	1.15	365	4/10/2018	1.4	390		
Striped Bass	3DD.003BEAC4C1		12/30/2016	0.6	315	4/10/2018	1.2	371		
Largemouth Bass	3DD.003BC7F443	2775	10/5/2015	1.25	320	4/11/2018	2.6	392		
						4/30/2018		400		
Largemouth Bass	3DD.003BC7F4F0		7/21/2016	0.8	285	4/30/2018		390		

Original Capture Data						Recapture Data			Captured in Previous Years	
Species	PIT Tag #	Floy Tag #	Date Tagged	Weight (lb)	Fork Length (mm)	Date	Weight (lb)	Fork Length (mm)	2016	2017
Largemouth Bass	3DD.003BC7F438		11/2/2015	0.8	280	5/3/2018	2	375		X
Largemouth Bass	3D9.239F884DD9		11/14/2016	1.8	385	5/3/2018	2.55	412		X

3.12 Predator Mortality

There were 750 predatory fish mortalities representing 5.7% of the 13,249 total captures during the 2018 field season (Table 16). The vast majority of mortalities were Striped Bass (746 of 750 mortalities). There were no black bass or catfish mortalities and four sunfish mortalities. The majority of mortality occurred in the transport process (75% of mortalities, which is 4.2% of total capture).

Table 16. Summary of Mortalities from the 2018 Field Season

Species Group	Efishing and Processing		Transport		Combined	
	Total	Percent of Total Electro-shocked[1]	Total	Percent of Total Electro-shocked[1]	Total	Percent of Total Electro-shocked[1]
Black Bass	0	0.0%	0	0.0%	0	0.0%
Catfish	0	0.0%	0	0.0%	0	0.0%
Striped Bas	188	1.6%	558	4.7%	746	6.3%
Sunfish	3	1.0%	1	0.3%	4	1.4%
Total	191	1.4%	559	4.2%	750	5.7%

[1] Percent of total capture by species group is based on total fish electroshocked by species group (1,048 black bass, 23 catfish, 11,890 Striped Bass, and 288 sunfish)

For each transport event, DO levels (% saturation) in the transport livewell at the time of CCF departure ranged from 73% to 176% and averaged 116% (Figure 36). DO in the transport livewell upon arrival at Bethany Reservoir ranged from 36% to 195% and averaged 107%. DO in Bethany Reservoir at the time of fish release (shortly after arriving at Bethany Reservoir) ranged from 81% to 122% and averaged 100%.

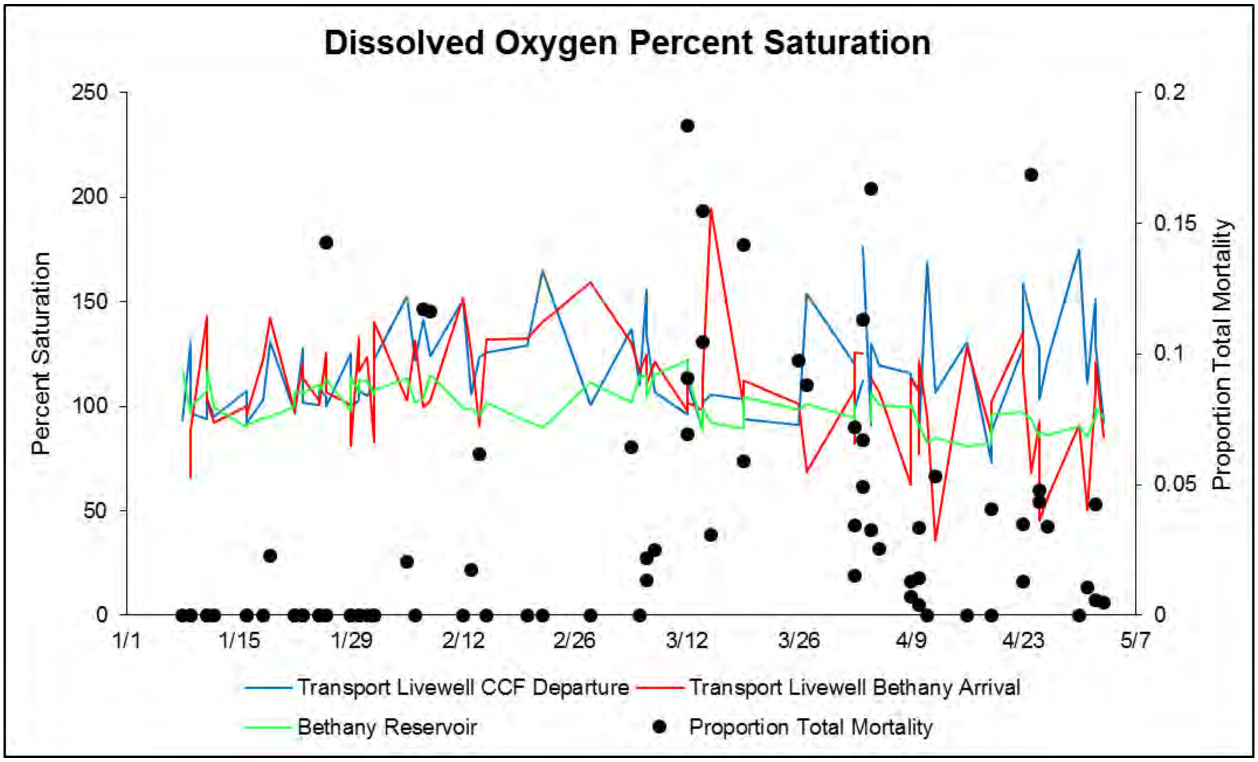
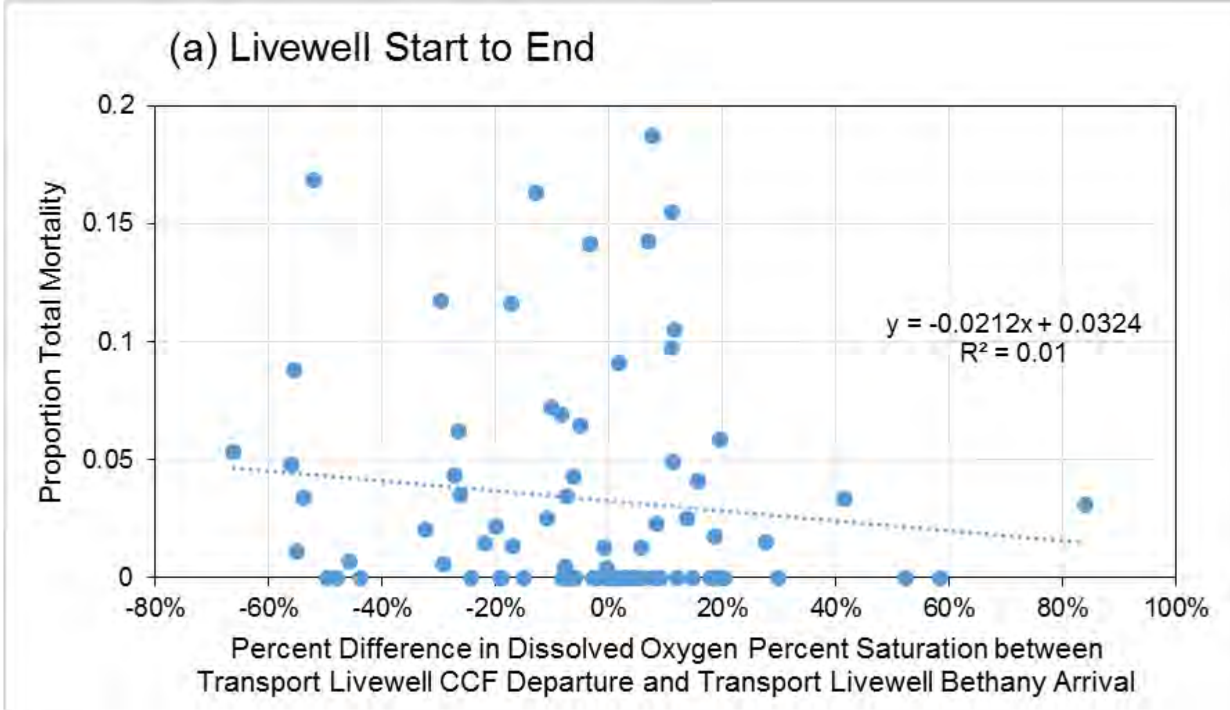


Figure 36. Dissolved Oxygen (Percent Saturation) and Proportion of Predators that Died during the 2018 Field Season

The effect of change in dissolved oxygen between: (1) transport livewell at the time of departure and upon arrival at Bethany Reservoir, and (2) transport livewell upon arrival at Bethany Reservoir and in Bethany Reservoir, was examined graphically (Figure 37). This figure indicates that there was no clear relationship between mortality and change in dissolved oxygen from either livewell at departure to arrival ($r^2 = 0.01$, Figure 37a), or livewell at departure to Bethany Reservoir ($r^2 = 0.001$; Figure 37b). In fact, the highest proportion of predator mortality occurred when change in percent dissolved oxygen was <5%.



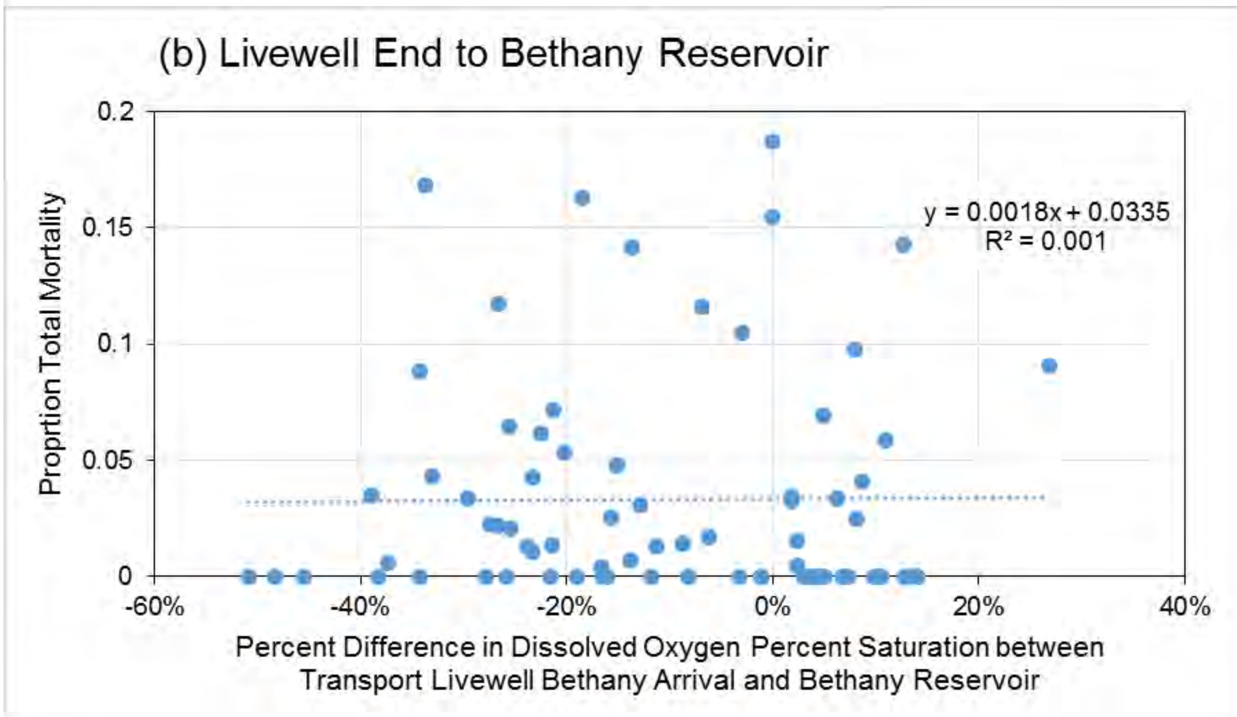


Figure 37. Proportion of Predators that Died during the 2018 Field Season as a Function of (a) Percent Difference in Dissolved Oxygen between Transport Livewell CCF Departure and Transport Livewell Bethany Arrival, and (b) Percent Difference in Dissolved Oxygen Percent Saturation between Transport Livewell Bethany Arrival and Bethany Reservoir

Water temperature in the transport livewell at the time of departure from CCF ranged among transport events from 10.2 °C to 21.8 °C and averaged 14.2 °C (Figure 38). Water temperature in the transport livewell upon arrival at Bethany Reservoir ranged from 10.5 °C to 22.1 °C and averaged 14.4 °C. Water temperature in Bethany Reservoir at the time of fish release (shortly after arriving at Bethany Reservoir) ranged from 10.5 °C to 19.5 °C and averaged 14.4 °C.

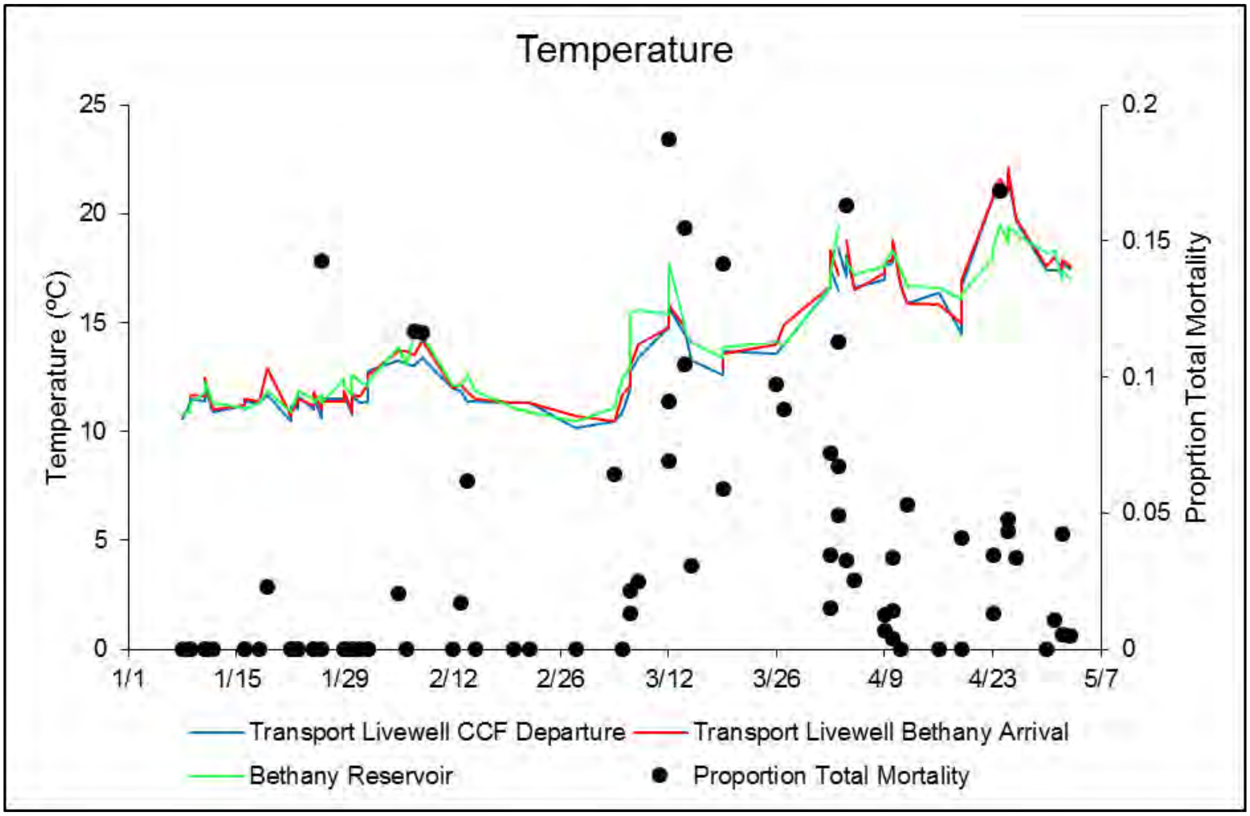


Figure 38. Water Temperature (°C) and Proportion of Predators that Died during the 2018 Field Season

Predator biomass removed per transport event ranged from 7.0 lb to 567.2 lb, and averaged 169.3 lb (Figure 39).

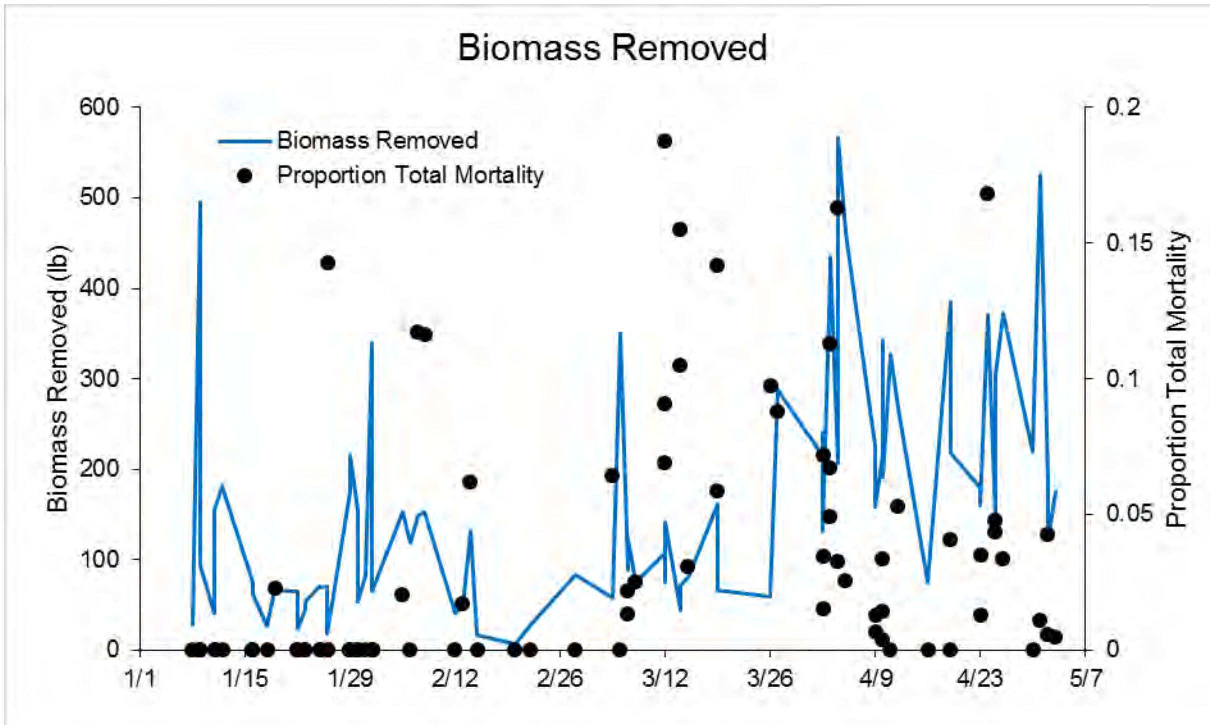


Figure 39. Biomass (lb) of Predatory Fish Removed from CCF and Proportion of Predators that Died for Each Transport Event during the 2018 Field Season

Only starting temperature was supported as a significant predictor of total predator mortality, as indicated by importance > 0.8 and 95% confidence interval for the coefficient not overlapping zero (Table 17). Predicted predator mortality increased with increasing starting temperature (Figure 40).

Table 17. Environmental Variable Importance and Model-Averaged Coefficient Estimates for Beta Regression of Total Predator Mortality during Transport from CCF to Bethany Reservoir, January-May 2018 (Full Model Pseudo r^2 = 0.31)

Variable	Estimate	95% CI		Importance
		Lower	Upper	
Starting temperature	**0.118**	**0.047**	**0.190**	**0.99**
Dissolved oxygen at Bethany	0.024	0.002	0.045	0.67
Hour of day	0.150	-0.071	0.370	0.41
Ending dissolved oxygen	-0.004	-0.013	0.005	0.33
Time in transport trailer	0.082	-0.127	0.292	0.30
Biomass removed	-0.001	-0.003	0.001	0.29
Starting dissolved oxygen	-0.002	-0.011	0.007	0.26

Note: Variables in bold have importance ≥ 0.80 and coefficients not overlapping zero.

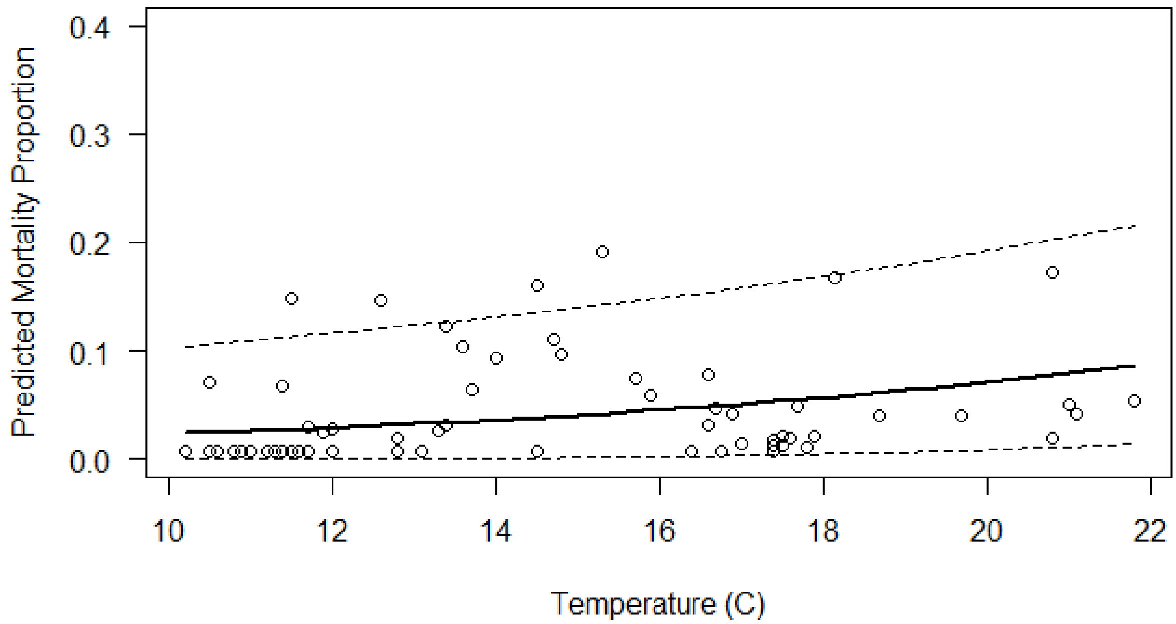


Figure 40. Predicted (Line, with 95% Confidence Interval as Broken Lines) and Observed (Points) Proportion of Predator Fish Dying during Transport from CCF to Bethany Reservoir as Function of Starting Water Temperature in the Transport Trailer

3.13 Predator Consumption of Tagged Chinook Salmon

During the 2018 field season 4,195 hatchery reared late fall-run (LFCS) and fall-run (FCS) Chinook Salmon were released axs surrogates for wild Chinook Salmon within CCF under the SEIS study (Table 18, Figure 41). Chinook Salmon were tagged with PIT tags and acoustic transmitters and released into CCF from 1/8/2018 to 4/24/2018. Fish were either released inside CCF from a ramp on the South Shore (Ramp), or outside of CCF directly in front of the radial gates (Gates) (Table 18). There were large differences in size and release time between the two species groups: LFCS were released earlier and were substantially larger (Table 18, Figure 41). When compared to the Length-at-Date Delta Model (Greene 1995), LFCS fish are closest in size to wild LFCS and winter-run Chinook Salmon, while FCS salmon were closest in size to Spring Run at release (Figure 41) Additionally, the releases of these fish occurred approximately within the timeframe of likely Chinook Salmon presence in the Delta as averaged over 10 years of Delta Juvenile Fish Monitoring Program (DJFMP) observations during Chipps Island trawls (Figure 41, https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm). For Chipps Island Trawl, the first day with <7 consecutive “0” presence surveys was selected as the first day of migration timing, while the last day with >7 consecutive “0” presence surveys was selected as the last day of migration timing. Due to environmental variability, run timing of Chinook Salmon varies from year to year, thus 10 years of data were averaged together to create a “likely” migration time period.

Table 18. Numbers and Average Length of Chinook Salmon Released into CCF. FCS = fall-run Chinook salmon; LFCS = late fall-run Chinook Salmon

Species	Release Site Numbers				Average FL (mm)	Average Weight (g)	Median Release Date	Release Duration (days)
	Gates	Ramp	Unknown	Total				
FCS	168	1,176	207	1,551	90	9.05	4/10/2018	102
LFCS	301	1,988	305	2,594	165	55.09	2/9/2018	81

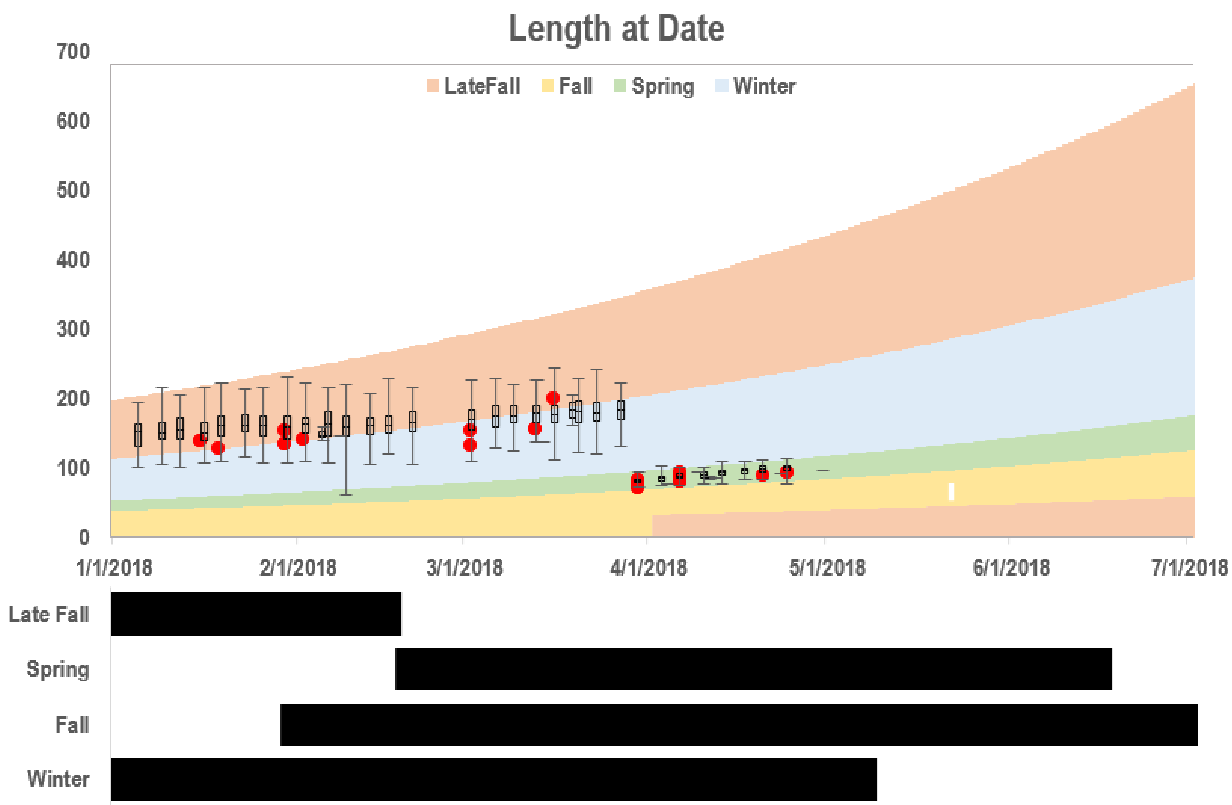


Figure 41. Upper Panel: SEIS Released Fish FL (boxes and whiskers) and Eaten Individual FL with Length at Date Delta Model (colored areas) Digitized using Data from Greene (1995). Each colored area represents the approximate FL range of fish from a given run (Late Fall = Orange, Fall = Yellow, Spring = Green, Winter = Blue) on a given date. Lower panel shows main periods of Chinook juvenile presence in Chipps Island trawl samples averaged over 10 years. Timing bookends were created by using the first and last observations with >7 consecutive “0” presence observations before or after, respectively.

Of the 4,195 SEIS individuals released, 26 tags were later scanned within predators (24 Striped Bass, 1 Largemouth Bass, and 1 Unidentified) captured during PRES electrofishing sampling. Predation occurred over the entire period of analyzed SEIS releases, with the first SEIS Chinook Salmon tag detected in a predator on 1/23/2018 and the last tag detected on 4/30/2018. Chinook Salmon assigned to tags found inside predators ranged in fork length from 75 mm to 206 mm, and on average were 31% of the fork length of associated predators.

Of the 24 confirmed Striped Bass predators of SEIS Chinook salmon, 23 were under the legal recreational fishing limit of 457 mm (California Freshwater Sport Fishing Regulations Article 4.5.75). Of these, 13 had fork lengths within 1 standard deviation of the mean fork length of Striped Bass caught that day, while 11 were outside of one standard deviation, nine averaged 100 mm larger than the mean, and two averaged 63 mm smaller than the mean (Table 19). The one Largemouth Bass that consumed a tagged 85-mm (FL) Chinook Salmon was 225 mm (FL).

Table 19. Lengths of Striped Bass Containing SEIS Chinook Salmon PIT Tags Compared to the Mean Fork Length ($\bar{x}_{FL}$), Standard Deviation of Fork Length (s_{FL}), and Total Catch of all Striped Bass Caught on Day of Capture

Date	Individual FL (mm)	Daily $\bar{x}_{FL}$ (mm)	Daily s_{FL} (mm)	Daily Catch
1/23/2018	473	389	80	41
	455			
2/5/2018	360	378	122	63
	405			
	386			
3/6/2018	357	387	110	176
3/14/2018	277	275	40	194
3/19/2018	463	343	74	178
	425			
4/3/2018	270	335	62	1257
	290			
	335			
4/4/2018	353	339	65	685
4/9/2018	453	307	66	425
4/10/2018	379	299	51	918
	370			
	465			
	279			
4/11/2018	370	316	77	253
	330			
	320			
4/12/2018	238	300	54	329
4/23/2018	404	321	79	313
4/30/2018	357	285	53	314

On average, Chinook tags were discovered within predators three days (53 h) after release and 95% of fish were consumed within four days (84 h). Three tags were found within predators within a day, two within four hours and one within five hours of release. These three individuals were of average FL at their release, released at the Ramp, and were preyed upon by predators of average FL. The longest time from release to predation was nine days (219 h) and this fish was of average size, 138 mm (FL), and eaten by a 227-mm (FL) Striped Bass.

3.14 Chinook Salmon Consumption (Bioenergetics Modeling)

3.14.1 Total Possible Consumption and Removed Consumption

Similar to the findings of Stroud and Simonis (2016), the classical fixed-parameter bioenergetics model produced a downward-biased estimate of consumption in 2018 (Table 20); thus, the variable-parameter bioenergetics model was relied on for results interpretation. The variable-parameter model estimated 3.2 to 5,149.0 g of Chinook Salmon avoided consumption daily (Figure 42). The sum of these daily values estimated that removal of 11,748 Striped Bass between January 8 (00:00 hr) and May 5 (23:59 hr) potentially avoided 179.6 kg of juvenile Chinook Salmon being consumed in 2018 (Table 20).

Bookends were calculated on these daily estimates of daily cumulative consumption avoided. The lower bookend of the estimated total consumption avoided was the lower bound of the 95% CI of variable-parameters model estimates for $p < 1.0$ (Figure 42). When $p < 1.0$, the model simulates the situation in which Striped Bass do not eat their maximum possible ration. Instead, the independent estimate of the proportion of maximum consumption likely realized by Striped Bass in the Delta, obtained by the modeling described by Loboschefsky et al. (2012) (Loboschefsky, Personal Communication), was used to estimate likely consumption by Striped Bass. The lower bound of the 95% confidence interval on the cumulative consumption avoided at $p < 1.0$ was 178.6 kg (Table 20).

The upper bookend was estimated first by setting $p = 1.0$. This simulates the situation in which every Striped Bass consumed its maximum daily ration. Then, the variable-parameter model was used to determine the cumulative daily consumption for each day of the 2018 field season and the 95% confidence interval about that mean. The upper bound of the 95% CI of variable-parameters model estimates for $p = 1.0$ was plotted against date (Figure 42). The upper bookend was the upper bound of the 95% confidence interval of the cumulative consumption avoided for the entire 2018 field season with $p = 1.0$, which was 262.1 kg (Table 20).

Table 20. Estimates of Cumulative Juvenile Chinook Salmon Consumption for the 2018 Field Season

P[1] (Proportion of Max. Consump.)	Type[2]	Fixed-Parameter Model (g)	Variable-Parameter Model		
			Lower Bound 95% CI (g)	Mean (g)	Upper Bound 95% CI (g)
1	Total	667,280.4	698,974.6	701,768.6	708,898.5
1	Removed	238,000.7	258,668.3	259,982.7	262,128.6
< 1	Total	461,579.2	483,182.4	485,224.8	488,589.3
< 1	Removed	164,395.5	178,576.2	179,559.7	180,884.3

Notes: [1]The value of P differed by age class: 0.69 for Striped Bass ages 1-2 years, 0.73 for age 3 years, 0.68 for age 4 years, and 0.72 for ages 5 years and up (Loboschefsky et al. (2012); Loboschefsky (Personal Communication)).
[2]Type is Total consumption that could have occurred if all 11,748 Striped Bass removed were present in the CCF every day of the field season and Removed is potential consumption avoided by those predators the day following their removal and every day following until the end of the field season.

The salvage data from the SWP contained records for 4422 Chinook Salmon captured during the 2018 sampling season, with an average mass of 6.29g. The total mass of estimated Chinook consumption was then divided by this average to provide estimated numbers of Chinook potentially consumed and avoided, presented in Table 21.

Table 21. Estimated Numbers of Cumulative Juvenile Chinook Salmon Consumed for the 2018 Field Season Based on an Average Mass of 6.29 g/Chinook Salmon Juvenile

P[1] (Proportion of Max. Consump.)	Type[2]	Fixed-Parameter Model	Variable-Parameter Model		
			Lower Bound 95% CI	Mean	Upper Bound 95% CI
1	Total	106,086	111,125	111,569	112,702
1	Removed	37,838	41,124	41,333	41,674
< 1	Total	73,383	76,818	77,142	77,677
< 1	Removed	26,136	28,390	28,547	28,757

Notes: [1]The value of P differed by age class: 0.69 for Striped Bass ages 1-2 years, 0.73 for age 3 years, 0.68 for age 4 years, and 0.72 for ages 5 years and up (Loboschefsky et al. (2012); Loboschefsky (Personal Communication)).
[2]Type is Total consumption that could have occurred if all 11,748 Striped Bass removed were present in the CCF every day of the field season and Removed is potential consumption avoided by those predators removed up to and including the previous day.

The estimated cumulative consumption avoided (Figure 42) climbed from the first day of predator removals (1/8/18) through the final day that was modeled (5/5/18). This increase was not linear because Striped Bass catch increased in a nonlinear way through time, and estimated consumption rises exponentially with temperature.

In Figure 42, the lower bookend was much closer to the estimated cumulative consumption avoided than was the upper bookend. This was because consumption cannot be less than zero for a given day. However, on some days in the variable-parameter model consumption could be considerably higher than the estimated cumulative consumption by random chance of the draw of multiple variable parameters. This reflected a situation where an individual Striped Bass consumed a large amount of food, a relatively large proportion of which was Chinook Salmon. Thus, the upper bound was further from the estimated cumulative consumption because its value was not bound on the positive side while there was such a constraint on the lower bound of consumption.

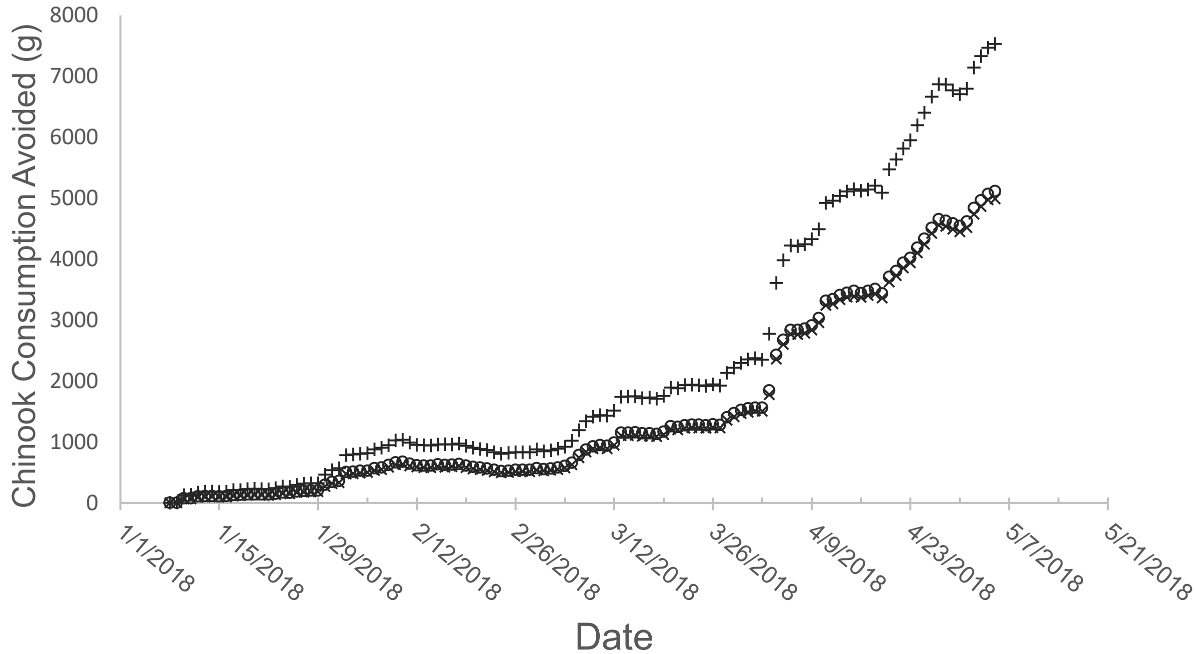


Figure 42. Cumulative Striped Bass Consumption of Chinook Salmon Avoided (○), with Lower (x) and Upper (+) Bookends, from the Variable-Parameter Bioenergetics Model

3.14.2 The Effect of Age Class on Consumption

Although Age Class 4-10 Striped Bass were estimated to have the potential to individually consume more juvenile Chinook Salmon (Table 22), there were substantially more Age Class 1-3 Striped Bass removed in 2018, resulting in Age Classes 1-3 comprising the bulk (>80%) of the estimated potential Chinook Salmon consumption (Figure 43, Figure 44). This finding is consistent for both the fixed-parameter and variable-parameter models.

The variable-parameter model produced estimates with modest variation in the total amount consumed by each age class, but generally the variability within age classes was smaller than that between age classes. As noted earlier, these results were similar to Stroud and Simonis (2016): the fixed-parameter model produced a downward-biased estimate in the 2018 analysis, especially for age classes 1 and 2 (Figure 44).

Table 22. Estimated Average Total Mass (g) of Juvenile Chinook Salmon Consumed per Individual Striped Bass for the 2018 Field Season

	Age Class									
	1	2	3	4	5	6	7	8	9	10
Total P=1	36.0	63.6	93.6	137.6	194.3	258.9	319.2	472.5	692.5	939.5
Total P<1	24.8	43.9	68.2	93.5	120.3	160.4	200.6	292.8	428.8	572.9
Removed P=1	10.9	23.7	37.5	60.2	87.7	133.7	160.3	201.1	390.6	387.9
Removed P<1	7.5	16.4	27.4	40.9	54.3	82.9	99.3	124.5	241.4	240.2

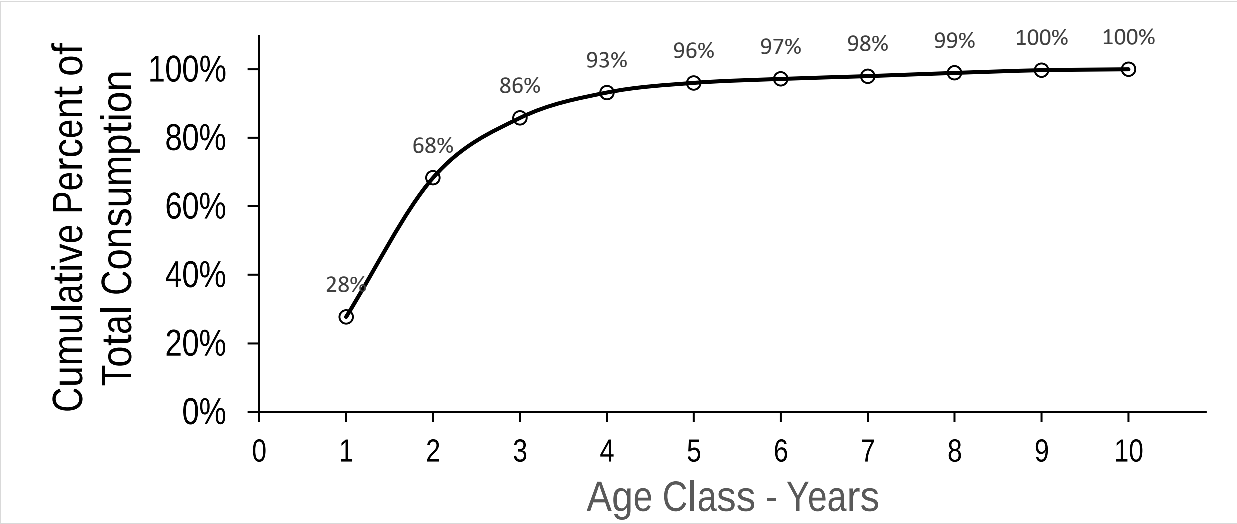


Figure 43. Cumulative Percent of Total Consumption of Chinook Salmon by Striped Bass based on 2018 Catch Data

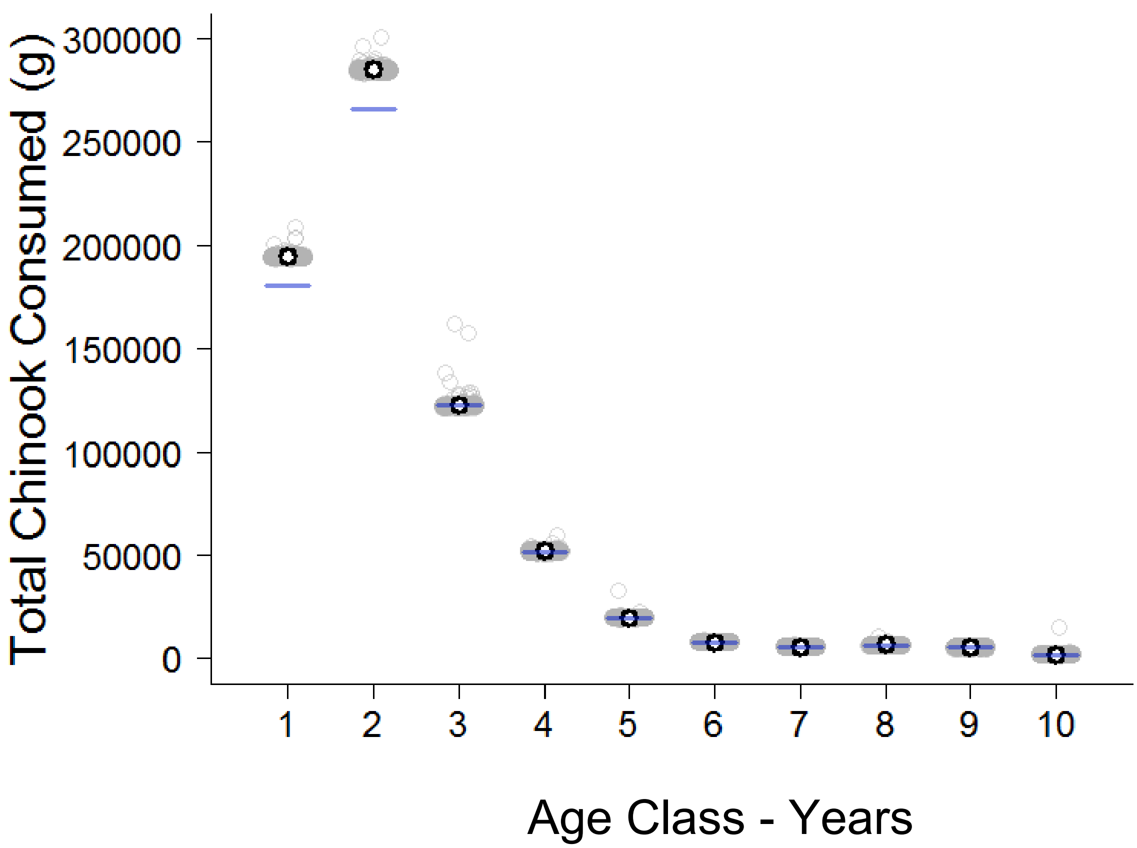


Figure 44. Total Estimated Consumption of Chinook Salmon by Striped Bass Removed from Clifton Court Forebay in 2018.

3.15 Listed Species

There was the potential for fish protected under FESA and CESA to be shocked during the PRES. The maximum allowable take for the CCF-PRES of species listed under FESA and CESA is shown in Table 23.

Table 23. Maximum Allowable Take of Fish Protected under FESA and CESA for the PRES.

Fish Species	Federal Listing Status	State Listing Status	Take Limit	
			Federal	State
Delta Smelt	Threatened	Endangered	1	20
Longfin Smelt	No Listing	Threatened	N/A	20
Green Sturgeon (Southern DPS)	Threatened	No Listing	20	N/A
Steelhead (Central Valley DPS)	Threatened	No Listing	50	N/A
Winter-run Chinook Salmon	Endangered	Endangered	50	20
Spring-run Chinook Salmon	Threatened	Threatened	50	20

There were a total of 55 Chinook Salmon and 49 steelhead encountered during the 2018 field season (Table 24). None of the Chinook Salmon encountered were handled, therefore, run designation was not able to be determined. Individuals from both species were encountered primarily in the Intake Canal, Scour Hole, and northwestern and southwestern predator hot spots, with the greatest encounters in the southwest hotspot and Intake Canal (Figure 45).

The take limit of 50 steelhead was reached on 5/2/2018. This was due to one steelhead being encountered in 2017 and 49 steelhead being encountered in 2018. DWR notified the NMFS and was instructed to stop sampling on 5/3/2018. No individuals became unconscious and all appeared to be swimming upright. Field staff followed the established protocol of moving electrofishing away from the area and reporting the sightings to DWR project managers. DWR project managers regularly reported these encounters to NMFS. Individuals ranged from approximately 3 inches to adult size, although most were juveniles. Both adipose fin-clipped and -unclipped individuals observed.

No other FESA or CESA listed species were encountered during the 2018 field season and, therefore, there was no take.

Table 24. Listed Species Encounters by Month during the 2018 PRES Field Season

Month	Chinook Salmon	Steelhead
January	6	1
February	13	7
March	7	17
April	22	23
May	7	1
Total	**55**	**49**

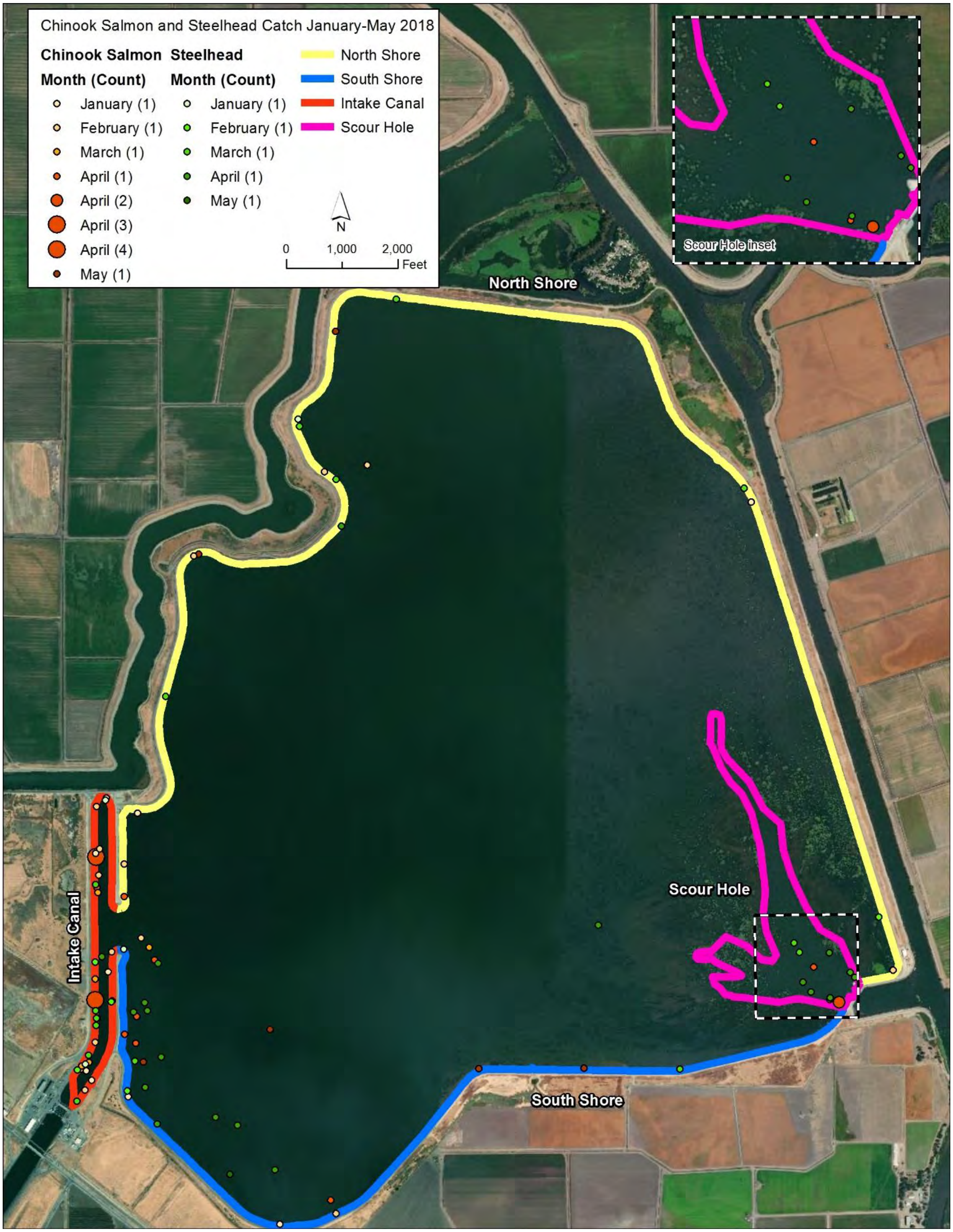


Figure 45. Map of Listed Species Encounters during the 2018 Field Season

4. Discussion

4.1 Predator Catch Composition

In 2018 a total of 13,138 predatory fish were caught in and removed from CCF (Table 6), estimated at nearly 13,877 lb (6.29 metric tons) of predator biomass (Table 7). The majority of individuals (11,839 fish) and biomass (12,098 lb; 5.49 metric tons) were Striped Bass. The remainder consisted mostly of black bass (989 fish; just over 1,678 lb; 0.76 metric tons) and a small number of catfish (23 fish, ~22 lb) and sunfish (287 fish, ~79 lb). As a result of the predominance of Striped Bass in the overall catch, overall predator catch patterns largely reflect Striped Bass catch patterns.

The very high relative catch rates of Striped Bass suggest that the species is abundant in CCF, consistent with previous CCF predator studies (Kano 1990). However, it also may indicate that Striped Bass were effectively caught using the electrofishing protocol in the PRES. Black bass, mostly Largemouth Bass, were also collected in reasonable numbers, with relative proportions somewhat greater than observed in previous electrofishing of CCF (Kano 1990). This probably reflects the general increase in Delta black bass abundance over the past two decades (Mahardja et al. 2017).

Catfish were rarely caught during the PRES, which could indicate that they are either not abundant in CCF or that the methods used in the PRES were not effective in capturing them. Kano (1990) caught more White Catfish (74 percent of total catch) in CCF than any other species in his year-long predation study and employed several methods that were not used in the PRES: gill nets, angling, Merwyn traps, and hoop traps that allowed sampling over the entire 24-hour period. This supports the hypothesis that the electrofishing protocol used in the PRES was ineffective at catfish capture, but does not reject the hypothesis that catfish are not abundant in CCF. If catfish are more abundant in CCF, other methods, including nets and traps should be used. The upcoming Predator Fish Relocation Study (PFRS) will evaluate catch efficiency of all predatory fish, including catfish, using hoop traps, fyke traps, trawls, purse seines, and beach seines. Capture of catfish may be of importance because research has suggested that they can have relatively high rates of predation on juvenile Chinook Salmon: in the San Joaquin River, genetics studies revealed that ~4% of White Catfish and ~21% of Channel Catfish had consumed juvenile Chinook Salmon within 2-3 days of capture, which compared to ~4% for Striped Bass and just over 2% for Largemouth Bass (Hayes et al. 2017).

Based on 2018 catch data, only 7 percent of the Striped Bass caught in electrofishing would be recreationally harvestable (above the legal size limit of 18 inches [457 mm]). In 2016 and 2017, 1 percent and 7 percent of total Striped Bass catch, respectively, would be recreationally harvestable. Under current DFW regulations, this would severely limit the ability for increased recreational angling to reduce the population, assuming that the size distribution of Striped Bass captured by electrofishing was reasonably representative of the overall size distribution of Striped Bass in CCF. DWR submitted letters to the California Fish and Game Commission (F&GC) requesting a reduction in size limits and increase in bag limits of Striped Bass in CCF (DWR 2015), but no response has been received from the F&GC.

4.2 Environmental Influences on Predator Catch and Predator Habitat Suitability

The statistical analysis found that water temperature and turbidity were the most important drivers of catch rates both using electrofishing time and total time on the water as the measure of effort.

Warmer water temperature correlated with a significant increase in catch rate of Striped Bass, as others have found for other species (e.g., Bodine and Shoup 2010) and as was found in CCF during 2017 (DWR

2017). As described by DWR (2017), this may be due to habitat shifts associated with water temperature (e.g., spawning migration) which affect the vulnerability to electrofishing (Carline et al. 1984).

In 2017, lower turbidity was significantly related to an increase in catch rate of Striped Bass, but not black bass. The opposite was the case in 2018: black bass catch rate increased with decreasing turbidity, whereas there was no significant relationship for Striped Bass. Positive relationships between catch rate and turbidity may be because increased turbidity reduces netting efficiency (reduced visibility of fish to netters; Lyon et al. 2014). Black bass catch rates have been negatively related with turbidity in some studies (Gibson-Reinemer et al. 2016), whereas other studies have found no relationship (Edwards et al. 1997; Gibson-Reinemer et al. 2016) or positive relationships (e.g., McInerny and Cross 2000).

Consistent with 2017 results, radial gate flow and pumping rate at the Banks Pumping Plant did not exhibit statistically significant relationships with predator catch rates. We were unable to evaluate whether this lack of relationship was constant among different sections of CCF, but 2017 data indicated this. In addition, this finding was supported by Clark et al. (2009), which found that the proportion of time that acoustically tagged Striped Bass spent near the radial gates or in the Intake Canal was not related to radial gate operations or pumping rate.

It should be noted that this was not a controlled study in a closed system. Due to daily and seasonal variations in predator densities within CCF, model findings may have limited utility.

4.3 Spatial Patterns

Visual examination of catch patterns indicates that fish were captured throughout CCF (Figure 12, Figure 13, Figure 14, Figure 15, Figure 16, Figure 17). Also, there were three hotspots seen in visual observation and confirmed with the Gettis-Ord Gi* analysis: (1) Scour Hole, (2) just east of the Intake Canal combined with the southwest end of CCF, and (4) the northwest section of CCF (Figure 18). The center of CCF was designated as a cold spot, which is likely due to a combination of very little effort in the area, the area being too deep for electrofishing to adequately sample and very few fish available there, as determined during 2017 field efforts. Within the Intake Canal, the south end was designated as a hotspot, whereas the north end was designated as a cold spot. The Intake Canal hot spot may be indicating a preference by predatory fish to congregate in the south where prey fish regularly pass on their way to the export facility. Indeed, some of the highest numbers of salmonids were caught in this area of the Intake Canal in both 2017 (DWR 2017, Figure 58) and 2018 (Figure 45).

4.4 Comparison to 2016 and 2017 Results

The main goal of the 2018 field season was to maximize catch and relocation of predatory fish using methods that were refined during 2016 and 2017 field seasons. The study was successful in meeting this goal. There was an increased effort in 2018 that yielded more predatory fish than in prior years (Table 25).

In 2016, sampling occurred on 11 days between April 20, 2016 and May 18, 2016. A total of 2,686 predatory fish were caught, consisting of 2,059 Striped Bass (77% of total captures), 594 black bass (22% of total captures), and 33 catfish (1% of total captures; Table 25). In 2017, sampling occurred on 39 days and yielded 6,151 predatory fish, consisting of 5,236 Striped Bass (85% of total captures), 879 black bass (14% of total captures), and 36 catfish (0.6% of total captures).

The proportions of fish caught by species group trended directionally (Table 25). Black Bass and catfish percentages declined while Striped Bass percentages increased from 2016 to 2018. Even without including sunfish in the 2018 totals, these patterns hold up (black bass: 7.7 percent; catfish: 0.2 percent;

Striped Bass: 92 percent). It is not known why these trends exist. They could reflect a broader trend in relative abundance among these species, or they could reflect differences in the methods, locations within CCF, and fishing strategies used among the three years.

Mean fork lengths of black bass and Striped Bass increased from 2016 to 2018, although catfish fork length was variable among years (Table 25). Again, the trends in black bass and Striped Bass could be due to differences in the methods, locations within CCF, and fishing strategies used among the three years.

Catch of all predatory fish per electrofishing hour was over two times higher in 2016 (86.4 fish per hour) than in 2017 (38.6 fish per hour) and 2018 (41.8 fish/hr; Table 25). This was somewhat surprising for 2018 given the different purposes among years. The purpose 2016 field season was to investigate different methods as a pilot study, the 2017 field season methodically sampled the various sections of CCF in order to characterize spatial patterns in predatory fish populations, and the 2018 field season was implemented to maximize predator catch and removal. The drop in 2017 CPUE relative to 2016 was expected given the regular low predator catch rates in open water areas during 2017, but CPUE was predicted to be higher in 2018. One potential reason is that depletion of fish was occurring such that efficiency in catch was reduced through time as fewer fish were available for capture. There was evidence of depletion of black bass in the first two phases of the 2018 field season (Figure 42) and of Striped Bass in the last phase (Figure 43). It is possible that not fishing during most of May and June, months with above average highest catch rates during 2017 (DWR 2017; Table 8), may account for the lower 2018 CPUE.

Mortality of caught fish was substantially lower during 2017 and 2018 field season (4.5 percent and 5.7 percent) compared to 2016 (15.0 percent). This reduction in mortality is likely due to improvements made in the barge holding tank aeration systems, reductions in fish processing times and requirements, and general efficiency improvements with field staff experience in 2017 and 2018.

Table 25. Comparison of 2016 and 2017 Predatory Fish Sampling, Catch Composition, Catch Rate, and Mortality

Species Group	Year	Black Bass	Catfish	Striped Bass	Sunfish	Total
Days sampled	2016					11
	2017					39
	2018					54
n	2016	594	33	2,059		2,686
	2017	879	36	5,236		6,151
	2018	989	23	11,839	287	13,138
% of total	2016	22	1.2	76.7		100
	2017	14.3	0.6	85.1		100
	2018	7.5	0.2	90.1	2.2	100
Mean Fork Length (mm)	2016	309	364	290		294.8
	2017	333	383	324		325.5
	2018	346	263	346	148	341
Mean catch per electro-fishing hr	2016	19.2	1.2	66.6		86.4
	2017	5.6	0.2	32.8		38.6
	2018	3	0.1	37.8	0.9	41.8
% Mortality	2016	0.3	0	19.5		15
	2017	0.2	0	5.2		4.5
	2018	0	0	6.3	0.3	5.7

4.5 Predator Removal in Relation to Chinook Salmon Survival Estimates (Skinner Evaluation and Improvement Study)

Information related to Chinook Salmon survival and how predator reductions associated with the 2018 CCF-PRES influenced this survival will be discussed in the 2018 Skinner Evaluation and Improvement Study Annual Report

4.6 Predator Depletion

There was some statistical evidence that depletion of black bass and Striped Bass occurred during the PRES in 2018 (Figure 42, Figure 43). For black bass, the focus on the shoreline locations early in the study (1/8/2018-2/8/2018) was associated with a significant decline in CPUE (effort as total time on water: $r^2 = 0.37$, $p = 0.005$; effort as electrofishing duration: $r^2 = 0.29$, $p = 0.017$), and the decline continued during the period focusing on the Intake Canal and Scour Hole (2/12-3/27; effort as total time on water: $r^2 = 0.44$, $p = 0.004$; effort as electrofishing duration: $r^2 = 0.44$, $p = 0.004$). During these two periods there was no trend in Striped Bass CPUE ($r^2 \leq 0.18$, $p > 0.08$), whereas a switch to adaptively targeting Striped Bass hotspots during 4/2/18-5/3/18 coincided with a statistically significant decrease in Striped Bass CPUE (effort as total time on water: $r^2 = 0.51$, $p = 0.001$; effort as electrofishing duration: $r^2 = 0.41$, $p = 0.004$), but no trend in black bass ($r^2 < 0.09$; $p > 0.22$). Overall, these results indicate species-specific capture strategies (shoreline for black bass; adaptive targeting of hotspots for Striped Bass) have potential for decreasing predator abundance in CCF.

4.7 Predator Mortality

Predator mortality during electrofishing and the transport of fish from CCF to Bethany Reservoir was low (5.7% of fish; Table 16). The large majority of fish that died were Striped Bass (746 of 750 fish). Most of the mortality occurred during the transport process. Only 1.4% of the fish that were electroshocked died during electrofishing and processing. This indicates that electrofishing is a relatively benign method for removing fish from CCF.

The single factor influencing predator mortality during transfer of fish from CCF to Bethany Reservoir was starting temperature in the transport tank (Table 17). As expected, predator mortality increased with increasing starting temperature. Interestingly, dissolved oxygen concentration and amount of biomass of fish in the transport tank did not influence mortality.

4.8 Predator Consumption of Tagged Fish

While data from predation events of tagged Chinook Salmon provide initial information on the spatial-temporal dynamics of Striped Bass predation of juvenile Chinook Salmon in CCF, any analysis of recaptured individuals must be confined to descriptive analyses due to the issues inherent with small sample numbers, mixing study designs and methods of observation, as well as an open, dynamic system such as CCF. Therefore, this discussion will be limited to describing general trends and patterns seen in the recapture data and other regional data on predators and Chinook Salmon, and the implications for predator management in CCF. Predation by Striped Bass is suspected to have an impact on the Chinook Salmon population within the Delta, and studies (e.g. Loboschefsky et al. 2012) have shown that even with very low rates of feeding on Chinook Salmon, the population of Striped Bass in the San Francisco Bay–Delta, because of its size, could consume all salmon production in the Central Valley. Furthermore, Pre-Screen Loss (PSL) in CCF has been largely attributed to predation, the extent of which is the focus of this and future studies. Dietary studies based on visualizing predation events (e.g. Demetras 2016), gut content analyses (e.g. Nobriga & Feyrer 2008) or genetics (e.g. Blankenship et al. 2014, 2015), have shown that Chinook Salmon are generally present in 1-3% of Striped Bass, except in cases where physical barriers, such as man-made structures like dam outflows or diversion intakes which physically concentrate prey and predators, or environmental variables, such as temperature, cover, and salinity zones which define habitat may overlap for both prey and predator, increases Chinook Salmon susceptibility allowing predation events to increase (e.g. Sabal et al. 2016).

Predation data of tagged Chinook Salmon in CCF indicate that predation is dominated by the sub-legal-size class of Striped Bass. The majority of confirmed predators were collected from either the southern half of CCF or from the scour hole and averaged 361 mm FL. Using the length-at-age data from Simonis and Stroud (2016), the average predator age was 2 years, and 80% of predators were age-3 or lower, while the max age was 4. Predators of age-3 or lower also appear to have the largest impact on juvenile Chinook Salmon from the bioenergetics analyses (Section 3.14). The combination of these two data sources suggest that management specific to sub-legal sized Striped Bass is likely to have the largest impact on PSL. Male Striped Bass are sexually mature at a much younger age (1-2 years) than females, who reach maturity in 4-5 years (Callahan 1989). Thus, it is likely, given the timing, that many of the individuals within CCF are newly mature males, rather than females, migrating to spawning grounds. Focusing on the removal of these plentiful males, rather than larger, less plentiful females may be beneficial in two ways. First, it is likely to be the most effective in reducing the impact on Chinook Salmon. Second, it allows larger fish, which include the most successful males and a larger proportion of females to remain in the area for spawning. The sub-legal Striped Bass are not being removed by recreational activities in the same way larger fish are, thus their impact on Chinook Salmon remains unchecked, whereas the population of legal-sized bass is kept lower due to recreational fishing.

However, that is not to say that larger fish were not consuming tagged salmon, which has not been documented during the study. Age 4+ Striped Bass represented only 175 of 11,838 total fish caught during PRES activities (See Bioenergetics Modeling Section 2.11.1.2). Confirmed predation events occurred in <1% of all fishes aged 1-3 and only 1.3% of age 4 fish, therefore the likelihood of confirming a single predation event in catches of <100 fish is severely diminished. Additionally, it is possible that larger fish contain more than one fish within their gut, creating the possibility of "tag collision," where two or more PIT tags cancel each other out when in the same scanning field. These issues do not allow us to say for certain whether a captured individual did not contain a Chinook Salmon, thus causing issues of potential false negatives.

In this study, Striped Bass catch rates increased within CCF during peak Chinook Salmon presence, potentially making CCF a unique hotspot for predation. The data from Chipps Island and Mossdale do not show a similar temporal-spatial matchup between the two species, suggesting that CCF is unique in this convergence. Numerous factors may be causing this meeting of predator and prey in CCF. First, the spring upstream migration of Striped Bass into freshwater, and higher catches of Striped Bass coincide with increased inflow to CCF as measured by radial gate flow (Figure 26). This suggests that Striped Bass may be entering into CCF during these higher CCF intake flows as they are migrating upstream, concentrating them in CCF just prior to the arrival of Chinook Salmon. Second, temperatures in CCF during this period are in the ideal range for Striped Bass spawning of 15-21°C (Moyle 2002). Furthermore, Striped Bass movement out of CCF during the Spring may be limited as they must travel against the large influx of water when the radial gates are opened, or travel into the Intake Channel and be removed during salvage.

CCF is a highly altered habitat within the Delta, a large man-made structure unlike any other surrounding areas: it lacks substantial cover or vegetation, it has relatively low velocities except during intake flows which are often extremely high, and it does not have an outlet, concentrating predators and prey inside. Sabal et al. (2016) showed that a man-made structure, the Woodbridge Irrigation District Dam (WIDD), had a significant influence on Striped Bass behavior and consumption of Chinook Salmon, creating a hotspot for predation at the base of the dam. Similarly, the area directly in front of the Radial Gates in CCF is assumed to be an area of high predatory abundance, based on 2018 field observations. DWR (2017) reported that during the 2017 field season the Scour Hole and areas directly adjacent to the Radial Gates tended to be predator "hotspots". Therefore, when Chinook Salmon do begin to appear in CCF in the late spring, these Striped Bass are in a prime location, and are ready to intercept and consume them.

4.9 Chinook Salmon Consumption (Bioenergetics Modeling)

In 2018, the variable-parameters bioenergetics model estimated that a mean of 179.6 kg, or approximately 28,547 Chinook Salmon avoided consumption. This estimated avoided consumption was accomplished through the removal of 11,748 Striped Bass from 1/8/2018 to 5/5/2018.

4.9.1 The Effect of Age Class on Consumption

The age analysis showed that the majority of Chinook Salmon mass (86%) is estimated to be consumed by age classes 1, 2, and 3. These age classes were also the most frequently captured classes, representing over 95% of all captured individuals. It is possible that the population of Striped Bass within CCF has a similarly skewed age class distribution. This skew in distribution likely leads to greater Chinook Salmon encounter rates for these age classes and represents the greatest risk for Chinook Salmon. As Striped Bass in these age classes are all below the minimum recreational harvest length requirement (457 mm [18 inches]), none of these fish are subject to recreational harvest, which may be a factor in their over-representation.

4.9.2 Comparison of 2017 and 2018 Studies

The study collected and removed 11,748 Striped Bass in 2018 and 5,235 Striped Bass in 2017. This led to an estimated 179.6 kg, or 28,547 Chinook Salmon avoiding consumption in 2018, while the 2017 sampling season is estimated to have removed 127.4 kg or 20,257 Chinook salmon.

Despite more than doubling the number of predators removed, the model of the 2018 predators only estimated that 41% more Chinook Salmon avoided consumption. This is likely because the 2017 field season extended 27 days longer than 2018 during the warmest period of the year and the majority of the Striped Bass were captured during the latter part of the sampling period. The 2018 field season extended from 1/8/18 to 5/4/18 (108 days) while the 2017 field season extended from 1/23/17 to 6/16/17 (145 days). In addition to the extended sampling season, the average daily water temperature during the 2017 sampling season was 15.1°C compared to 13.9°C in 2018. In 2017, the additional sampling period included daily average water temperatures exceeding 22°C. These higher temperatures led to higher metabolic demands and therefore would also have likely led to higher estimated consumption rates. In order to begin understanding the interactions between modeling length and modeling temperature, a brief set of modeling exercises was conducted. First, the length of the modeled field season was extended while holding the daily average temperature constant during the extension, which provided results much closer to those we expect to see given the larger number of predators removed. The second modeling exercise using observed temperatures did not produce substantially higher estimates than when temperature was held constant. These two modeling exercises suggest that length of the field season had a larger effect on model consumption estimates than does temperature in this application. A complete sensitivity analysis would be useful to determine the individual effects of field season length and temperature independently.

The 2017 age class comparison (DWR 2017; Figure 43) showed that Age Class 1 would have eaten the greatest mass of Chinook Salmon in 2017 if they had not been removed. The 2018 age class comparison showed that Age Class 2 would have eaten the greatest mass of Chinook Salmon if they had not been removed. It is important to note that these two groups represent the same cohort of Striped Bass. This suggests that age class strength may play a role in determining age-specific Striped Bass consumption of Chinook Salmon that may change from year to year and possibly with water year type.

4.9.3 Model Assumptions and Limitations

As with any modeling endeavor, there are a number and assumptions which must be taken into account during interpretation to provide context and ensure the best understanding of the model results and limitations. Please review Stroud and Simonis (2016) for detailed assumptions and limitations dealing directly with the model and modeling output, especially as it relates to the addition of variability to the model. The assumptions detailed by Simonis and Stroud (2016) highlight some of the issues inherent with using a model such as this on a highly dynamic and poorly summarized system such as CCF. Due to the open nature of CCF, it is impossible to estimate the abundance of all predatory fish. Thus, using the current bioenergetics model to understand the potential overall impact of PRES activities is limited to estimating the potential consumption avoided. It cannot compare this value to any estimate of the total potential consumption within CCF. This limits the usefulness of the model to management decision making, as there is no estimate of baseline level of consumption to which one can compare the estimated avoided consumption, and thus no management benchmark or goal can be developed except through the use of proxy variables such as decreases in PSL which have confounding variables.

Additionally, Stroud and Simonis (2016) suggest a number of important steps for generating better model output including: 1) collect weights of predators instead of lengths, removing the need for a potentially flawed (or at least highly uncertain) length weight relationship; 2) perform a more robust mark-recapture experiment to better estimate growth of individuals within season; 3) conduct additional diet sampling to refine composition estimates; 4) A more complete knowledge of predator and prey movement and presence in the delta; and 5) inclusion of other predators besides Striped Bass.

We believe that of these assumptions, within the model framework and input, the dietary composition inputs heavily limit the usefulness of this style of analysis. Striped Bass, like many of the other predators within CCF, are opportunistic and the use of static dietary proportions does not adequately represent the temporally varied dietary composition of these predators. Abundance of prey species within CCF varies temporally and, therefore, so would the dietary composition an opportunistic predator, such as Striped Bass. Additionally, timing of Striped Bass presence within CCF varies temporally, thus the “Total” Consumption potential which assumes that all 11,748 Striped Bass are consuming their entire Chinook ration on each day is likely an overestimation of daily consumption for captured predators.

Another major limitation with the dataset used was the size-at-age classifications. Simonis and Stroud (2016) use a non-overlapping range of sizes for each age-class which may incorrectly assign ages. Tucker et al. (1998) had overlapping ranges of size at each age which are not well reflected in the values used by Simonis and Stroud (2016). These size-at-age classifications were used to assign growth rates and consumption rates which are known to vary by age and are defined as such within the model. Unfortunately, as the current model does not account for uncertainty through the use of a size-at-age regression, it does not adequately reflect the potential variation in growth rate and consumption.

Future studies should aim to address the deficiencies outlined in Simonis and Stroud (2016) as well as those listed here. More robust studies of predator and prey abundance using novel population estimation techniques such as environment DNA (eDNA) could aid in developing more robust dietary compositions, as well as providing data useful to determining total predator consumption. In addition, age classification work using fish captured and measured in CCF could be more helpful than the limited set from Tucker et al. (1998), and inclusion of uncertainty within the age-classification system of the model could aid in more robust estimates. Finally, this modeling effort focuses on only one predator species within CCF, while modeling the consumption of other predators within CCF may be useful to evaluate their relative impacts on listed species.

4.10 Conclusion

Results from 2018 indicate that predator removal in Clifton Court Forebay can be effective at reducing predatory fish numbers. By increasing effort from 2 boats and 3 days per week during 2017 to 3 boats and 4 days per week and focusing efforts on the highest catch rate locations identified in 2017, predatory fish catch more than doubled in 2018. Predator catch rates (measured as catch per unit effort) were lower or similar in 2018 compared to 2016 and 2017. While the reduced catch rates observed in 2018 may be due to seasonal and annual variations of predator densities in CCF, they might also have been merely a consequence of high overall effectiveness of predator removal. Analyses of the 2018 catch data provided evidence of depletion (reduced catch rate through time) of black bass and Striped Bass during periods when fishing strategies were designed to specifically target removal of these predatory fish. These findings of depletion indicate that predator removal can be effective at reducing predatory fish numbers and biomass in CCF, however, it is uncertain whether changes to predator densities were enough to significantly reduce pre-screen loss.

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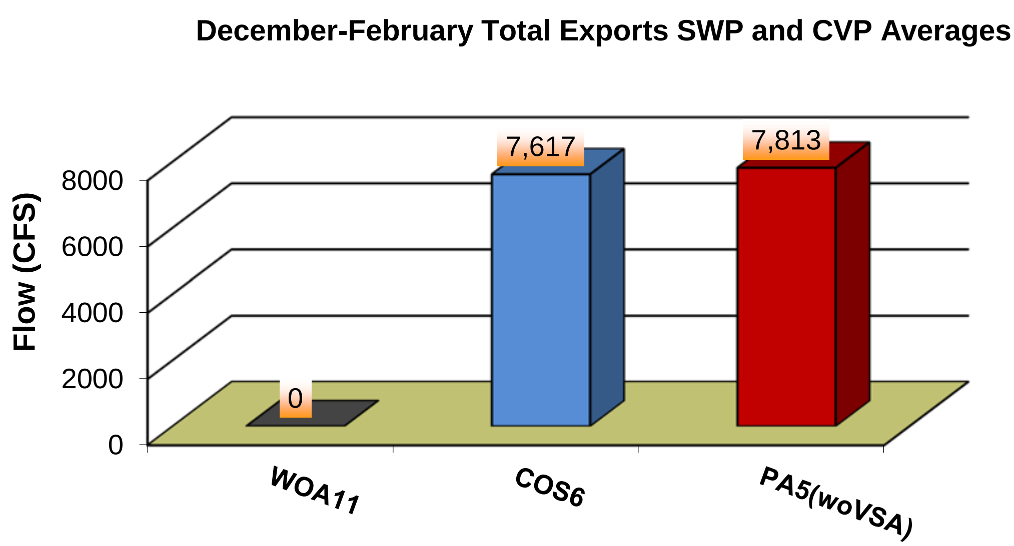
Appendix H Bay-Delta Aquatics Effects Figures



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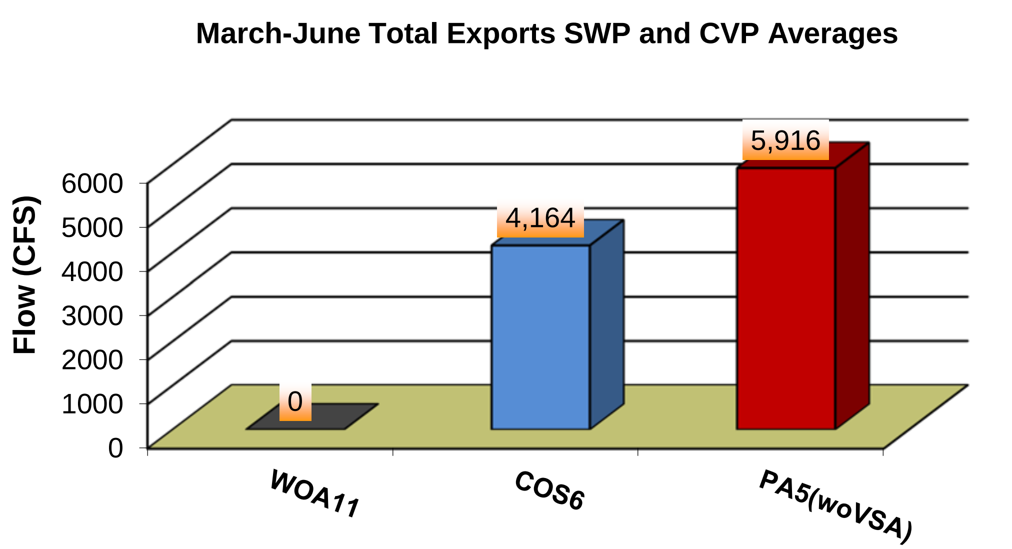

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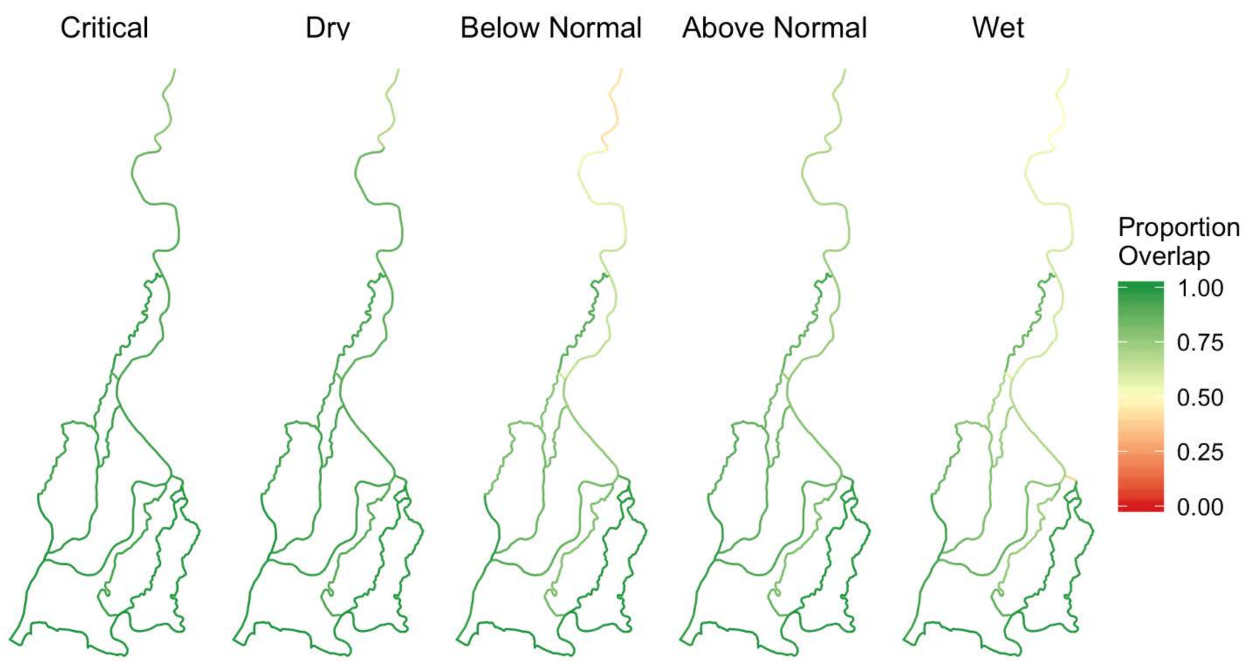

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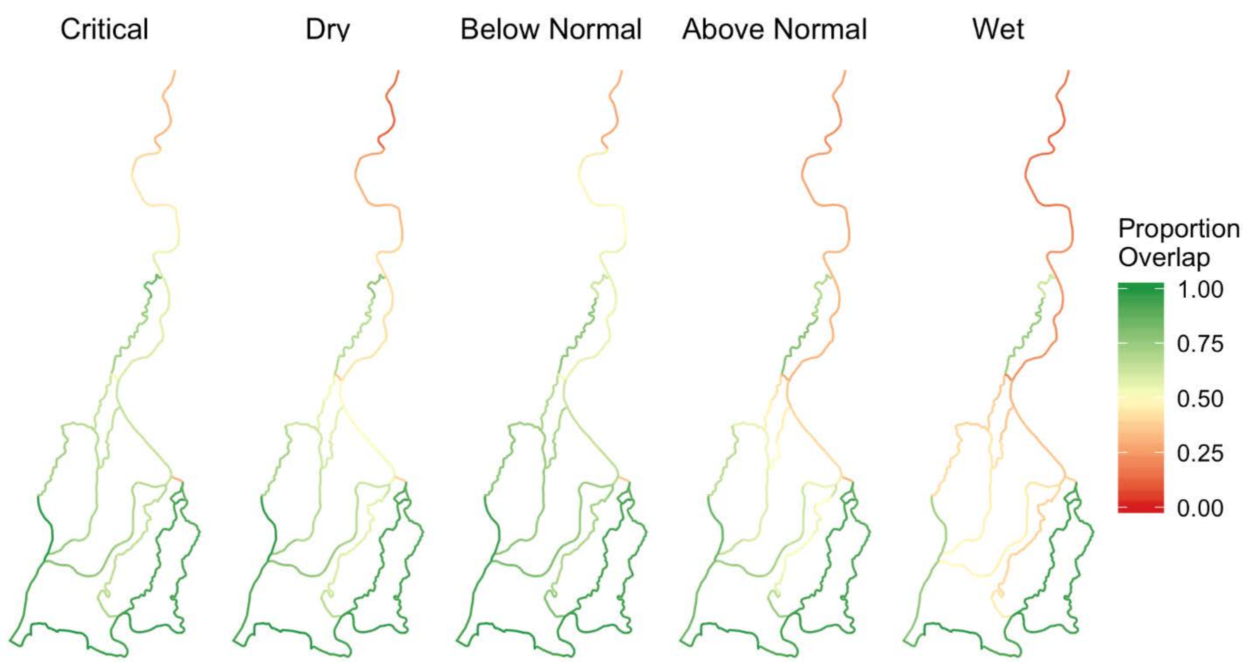

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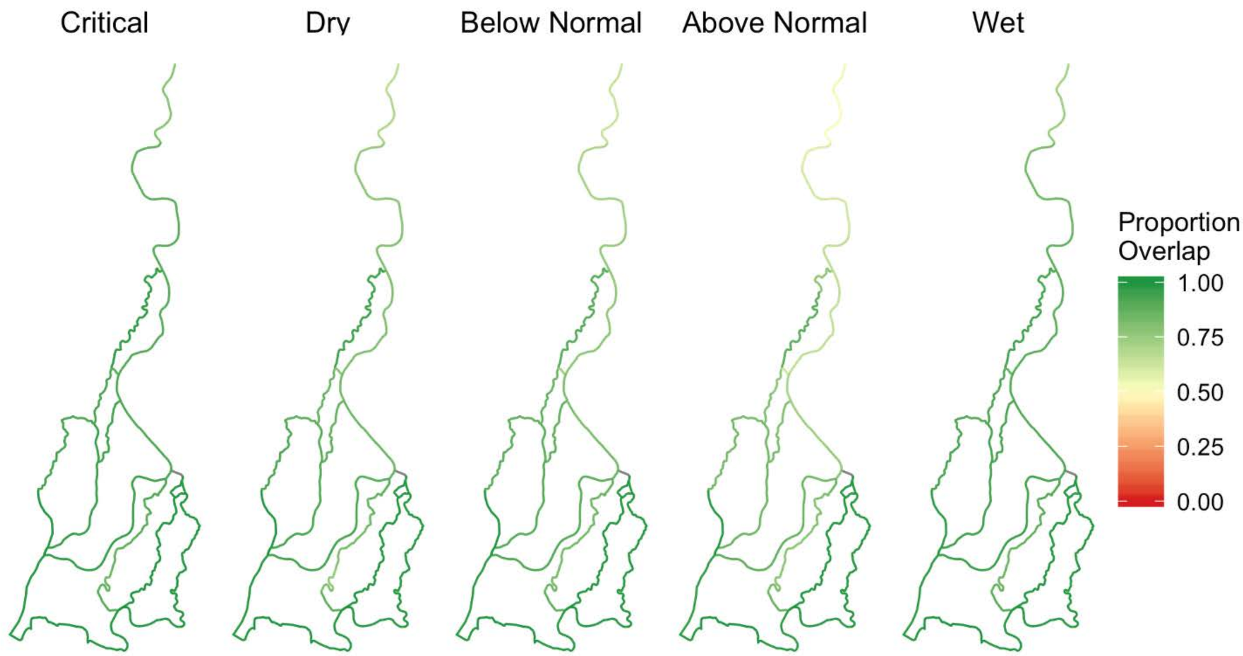

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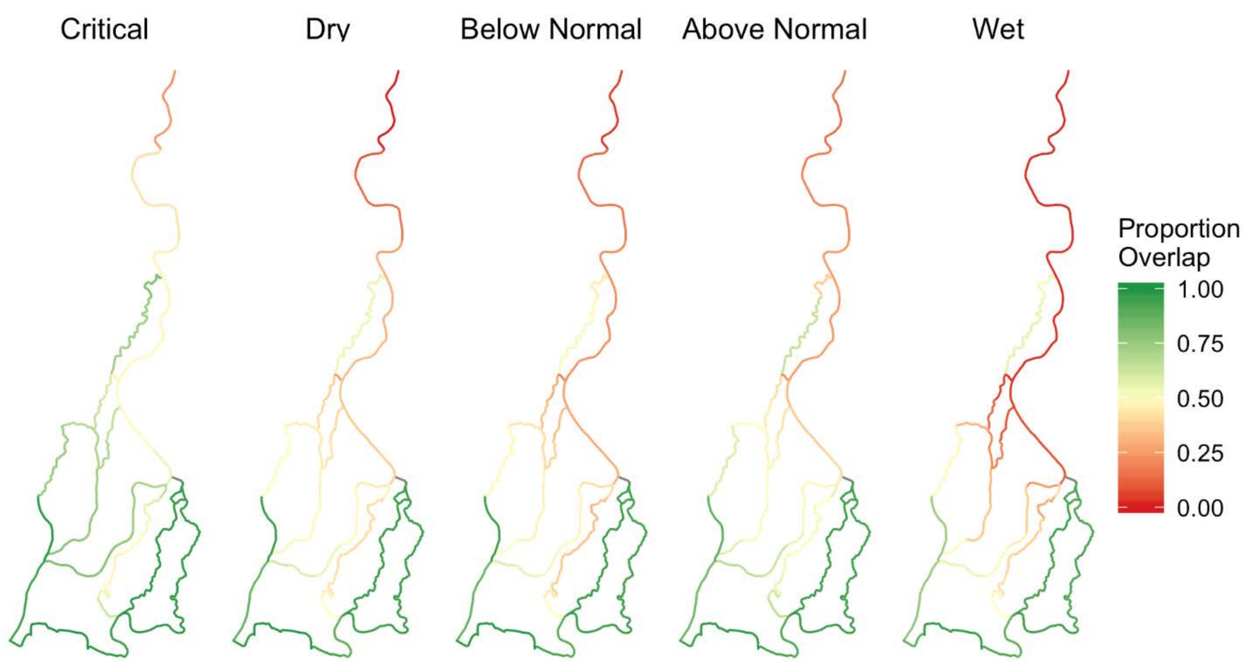

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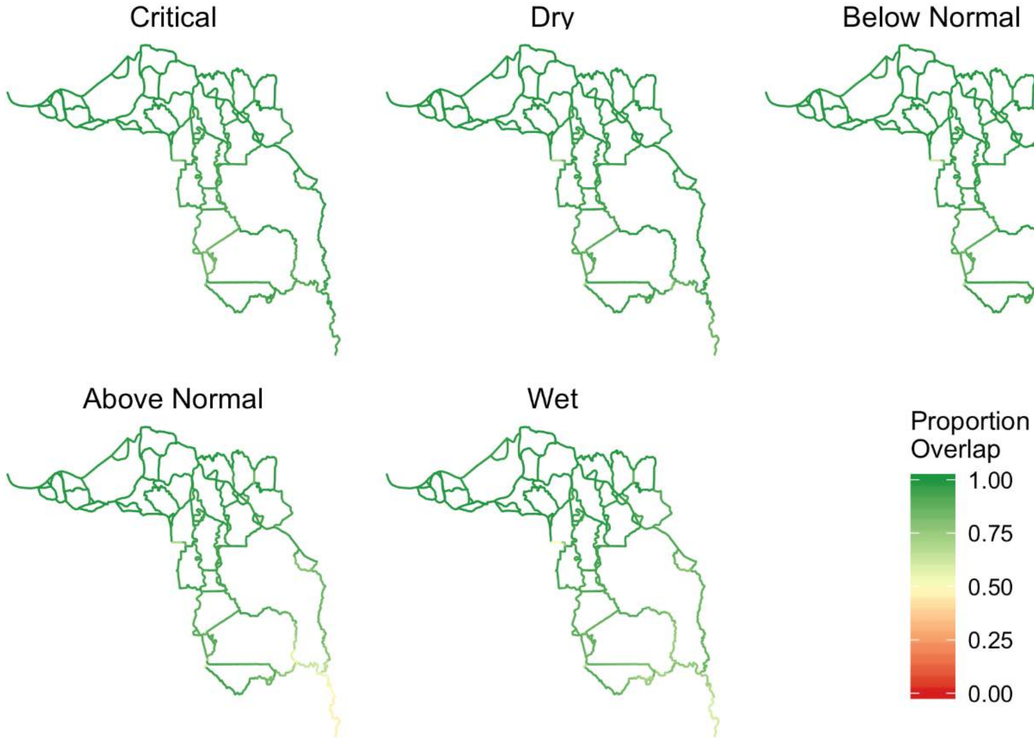

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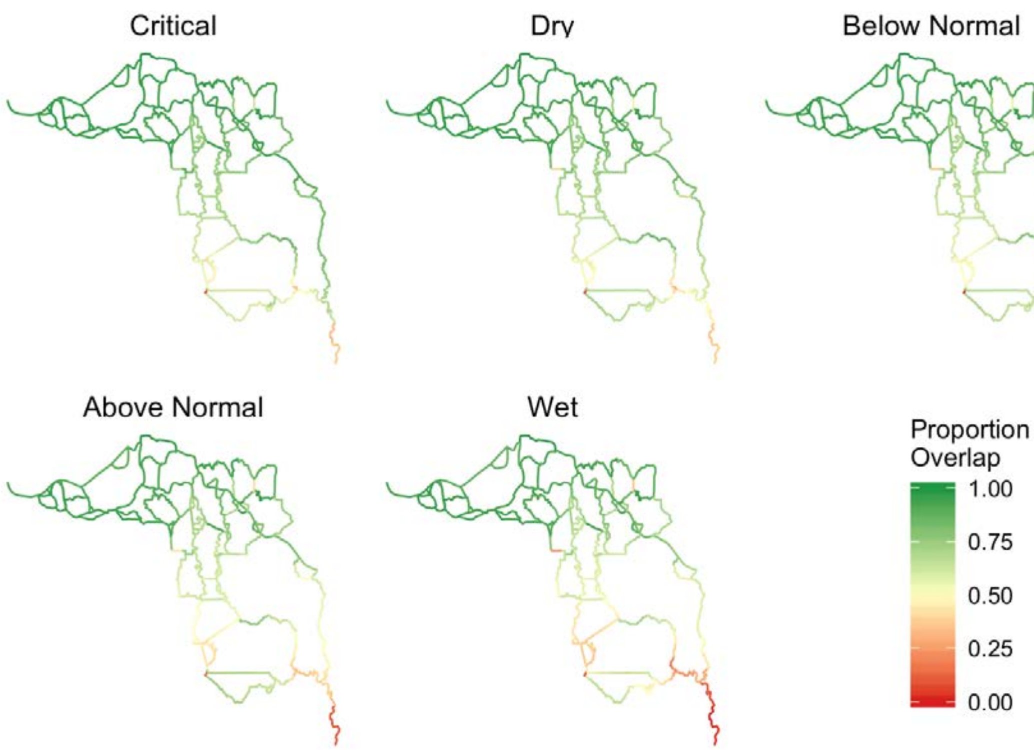

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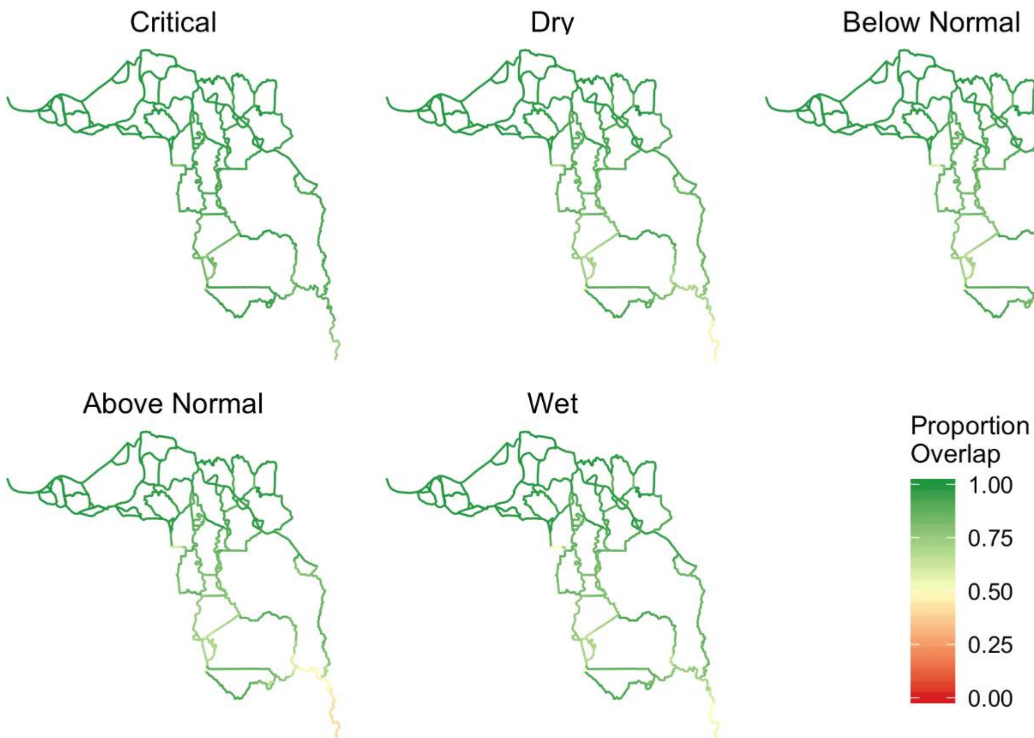

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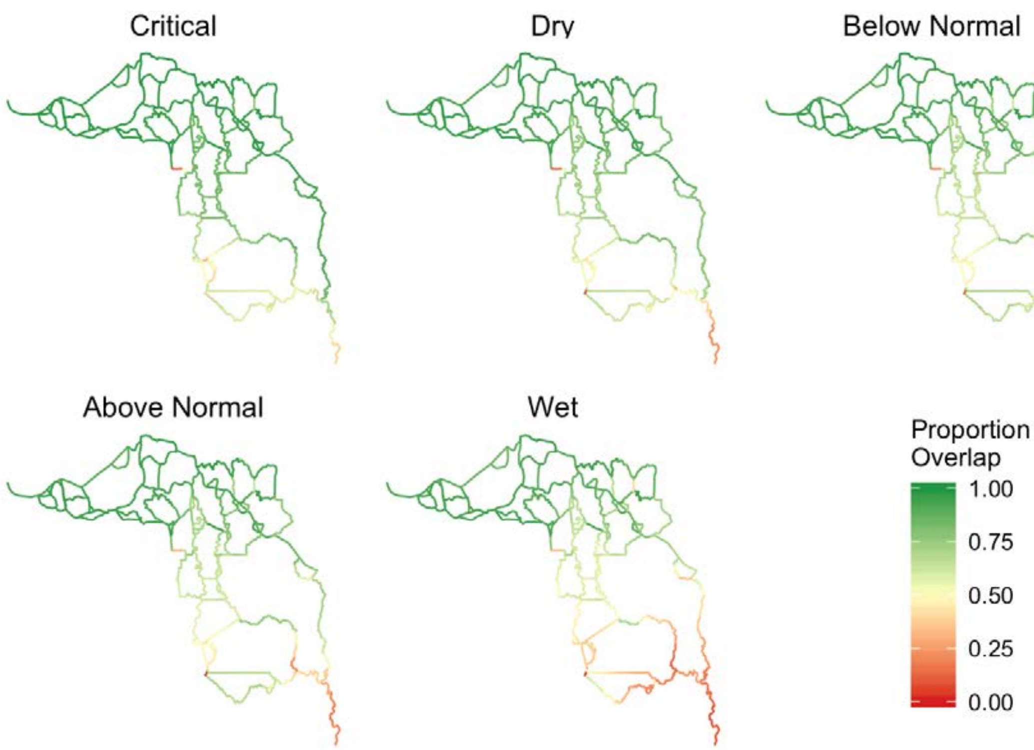

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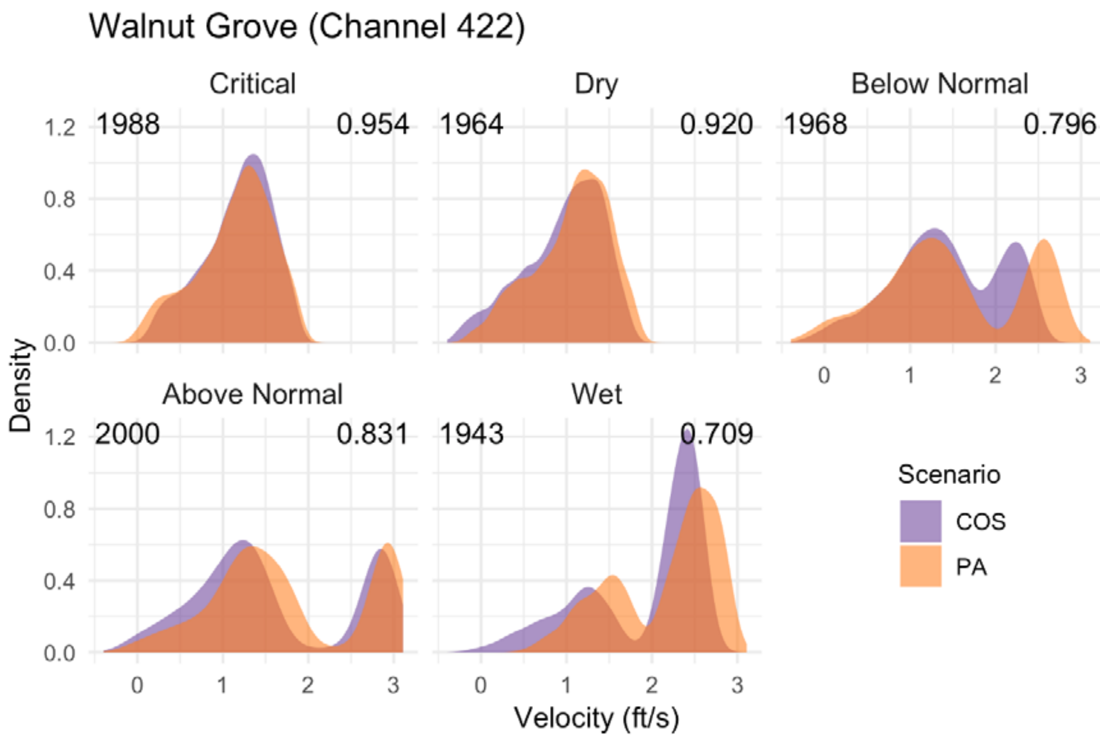

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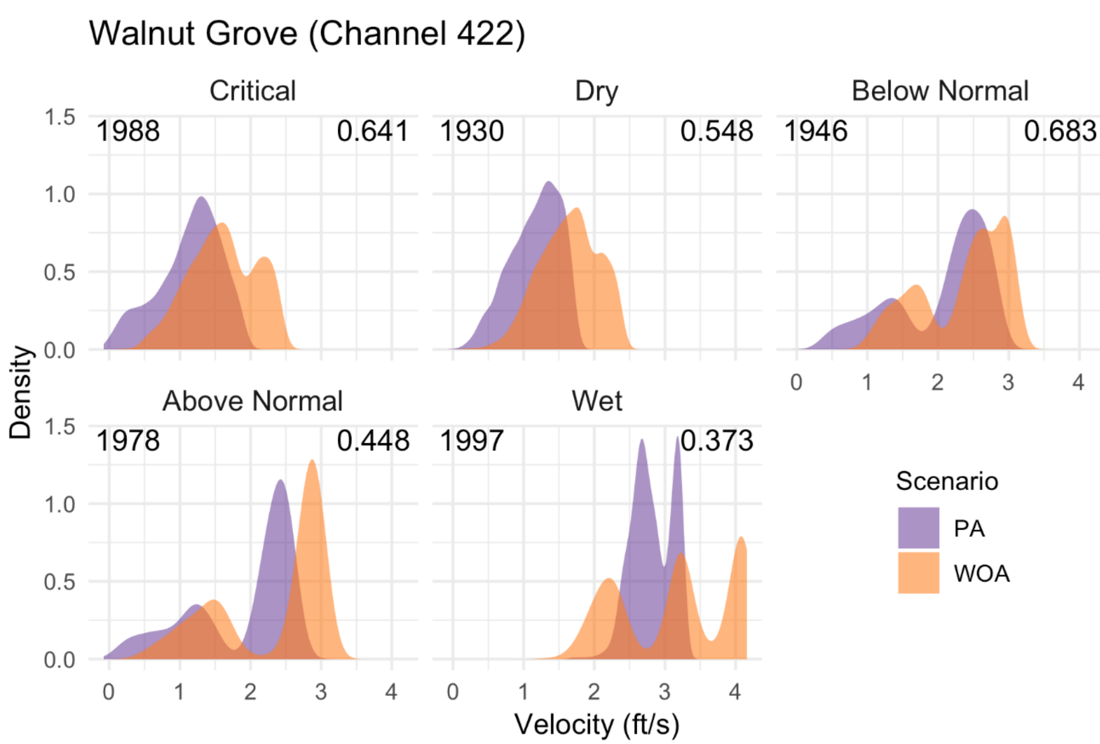

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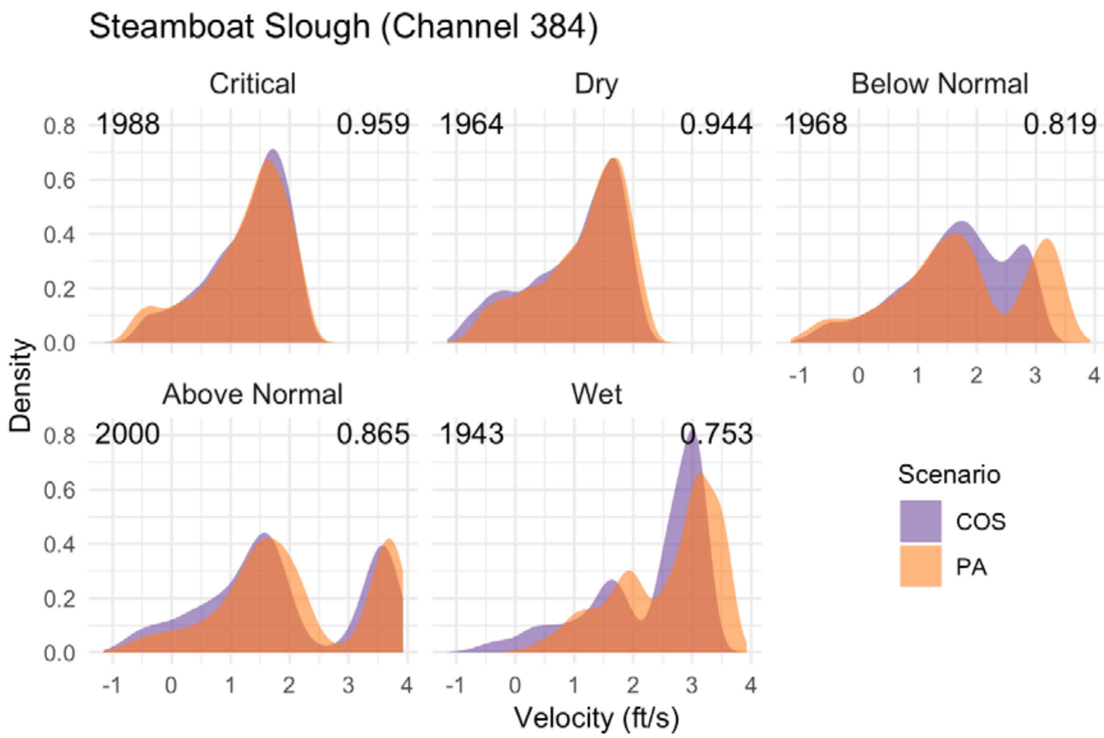

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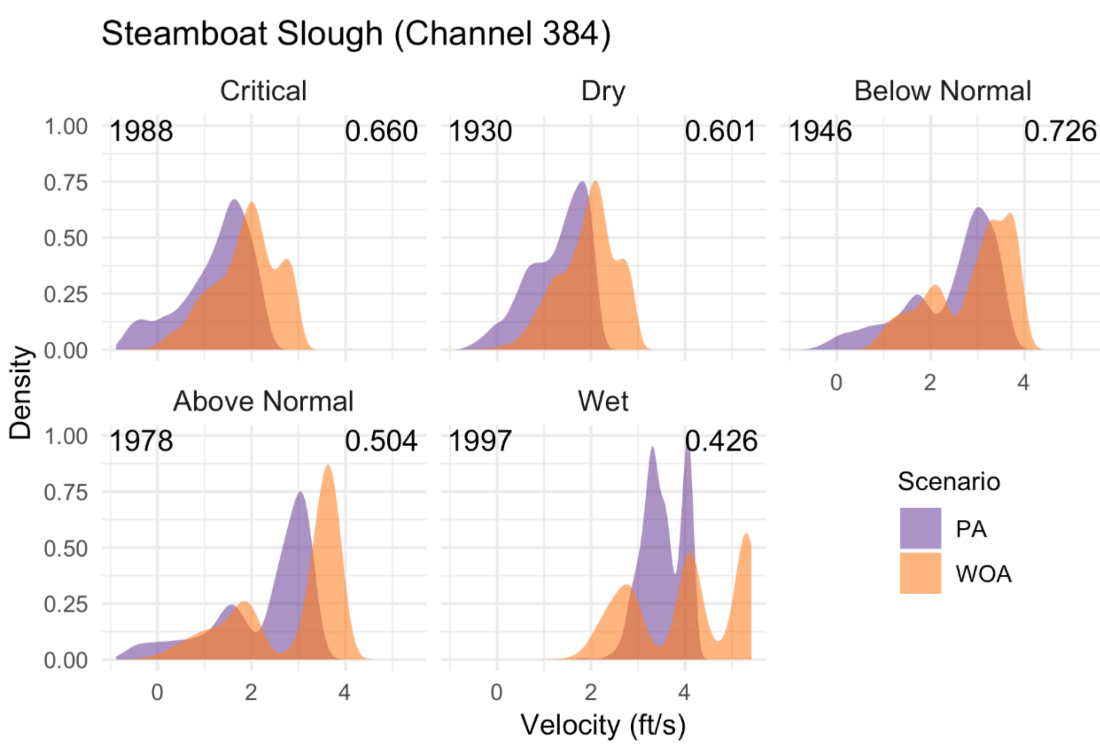

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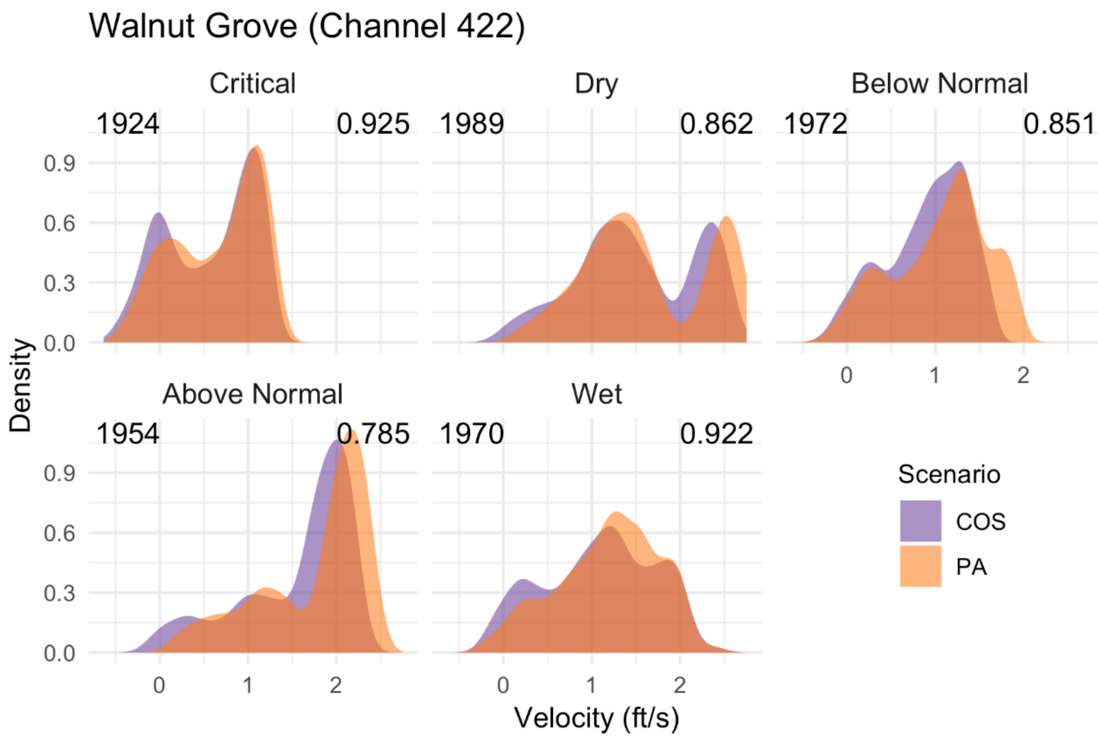

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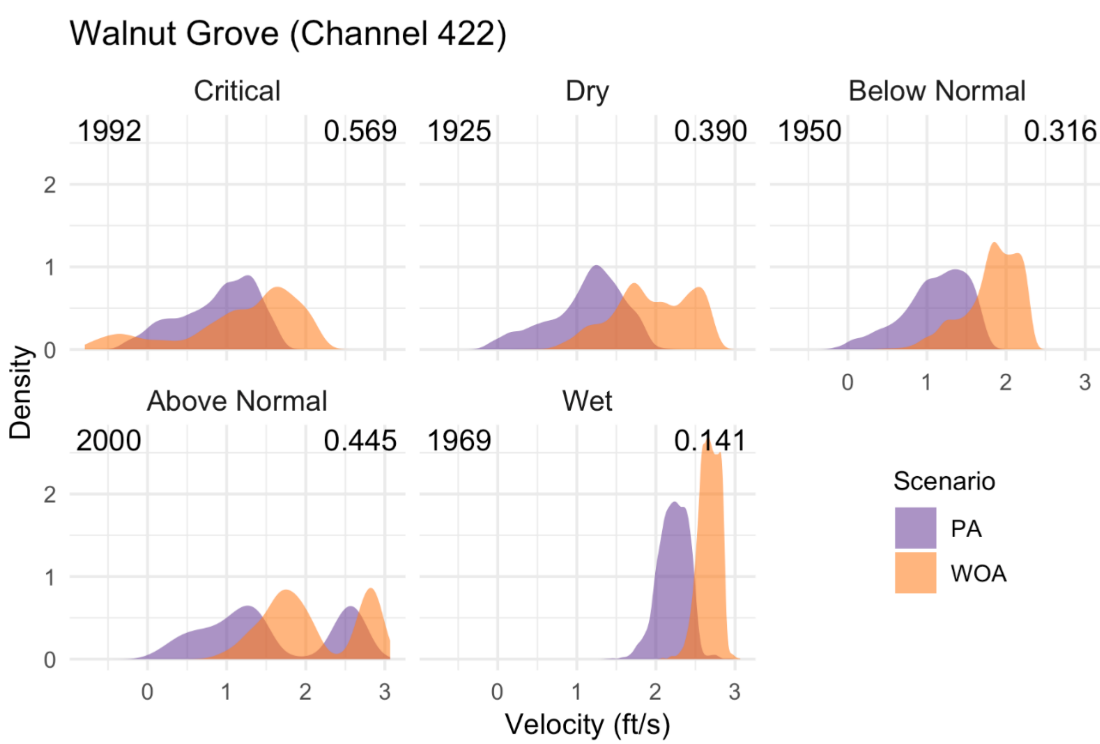

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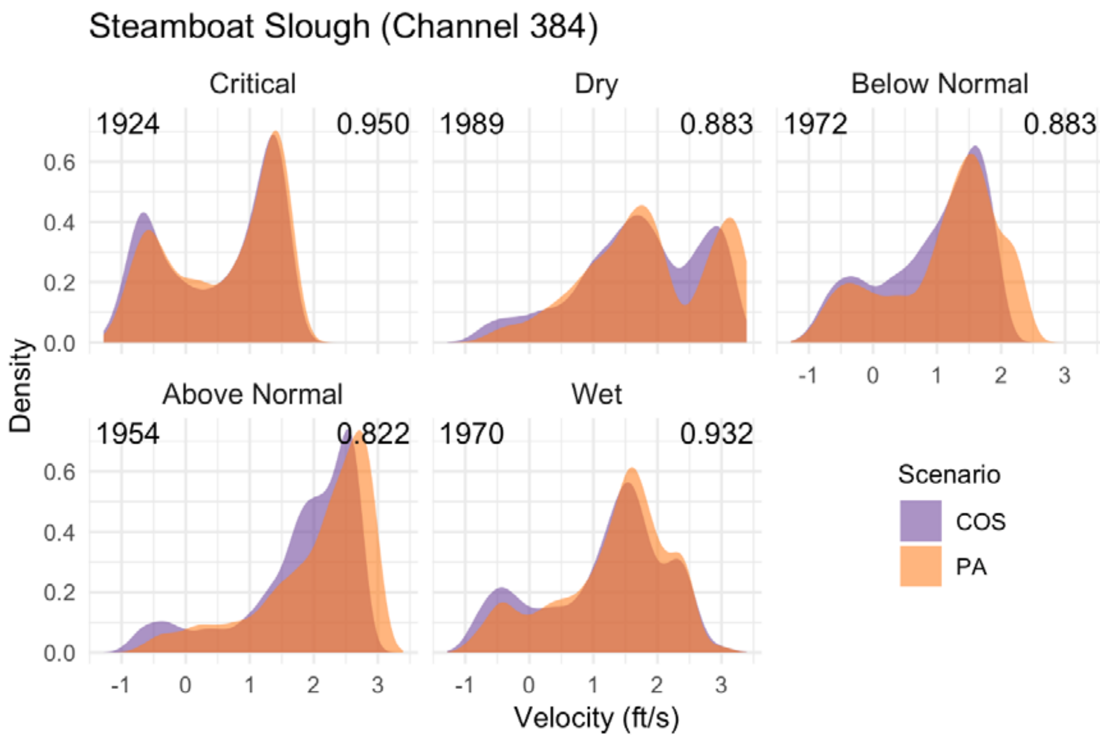

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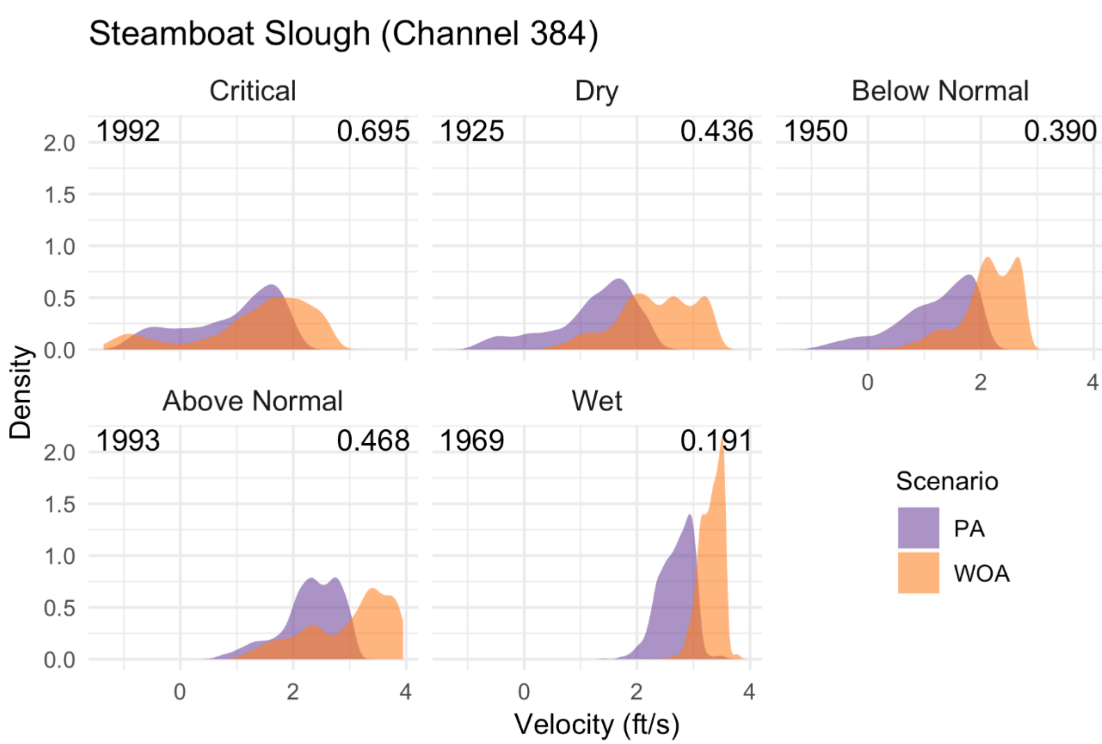

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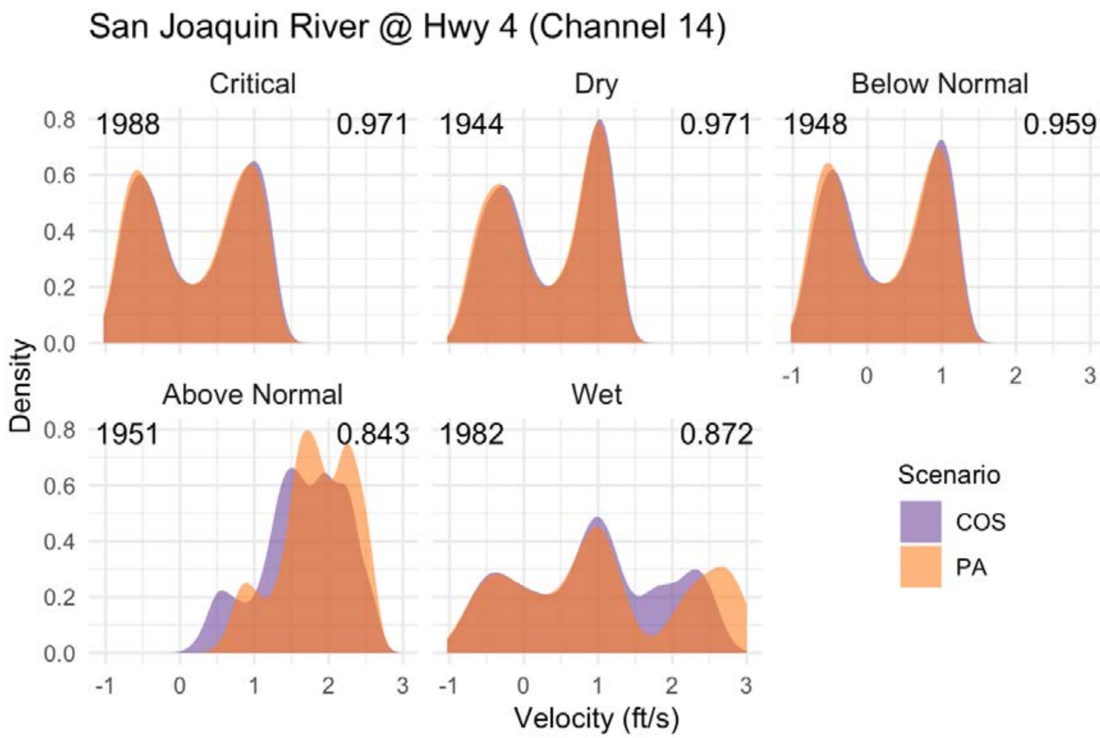

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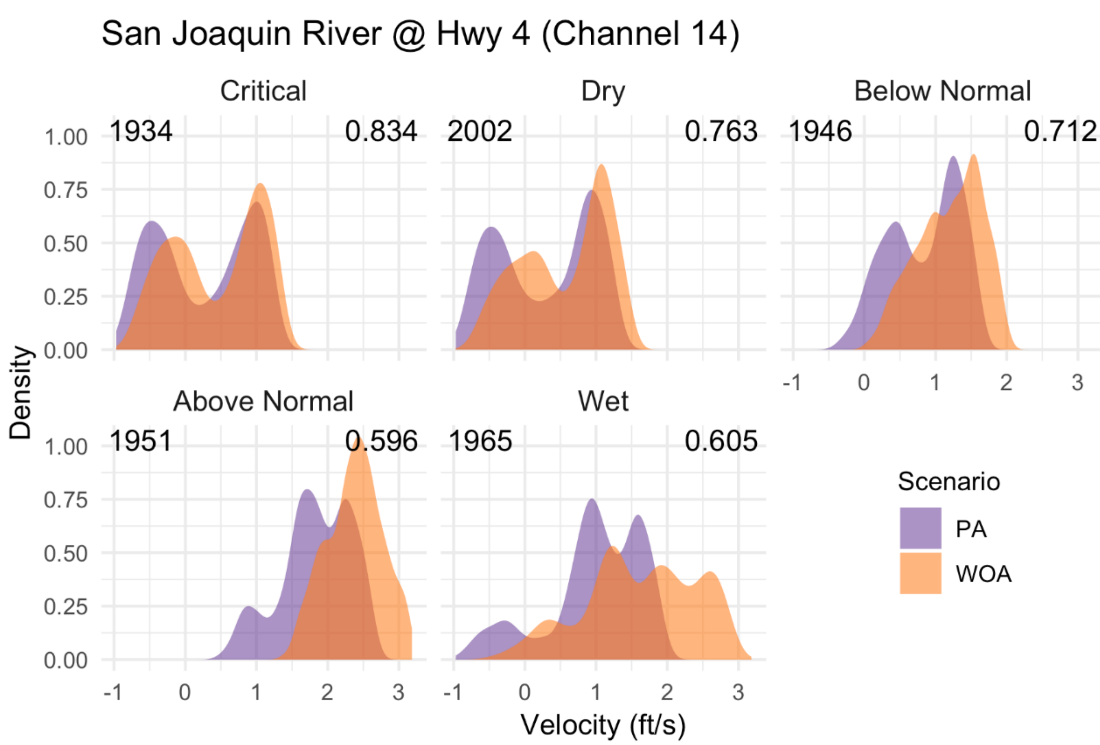

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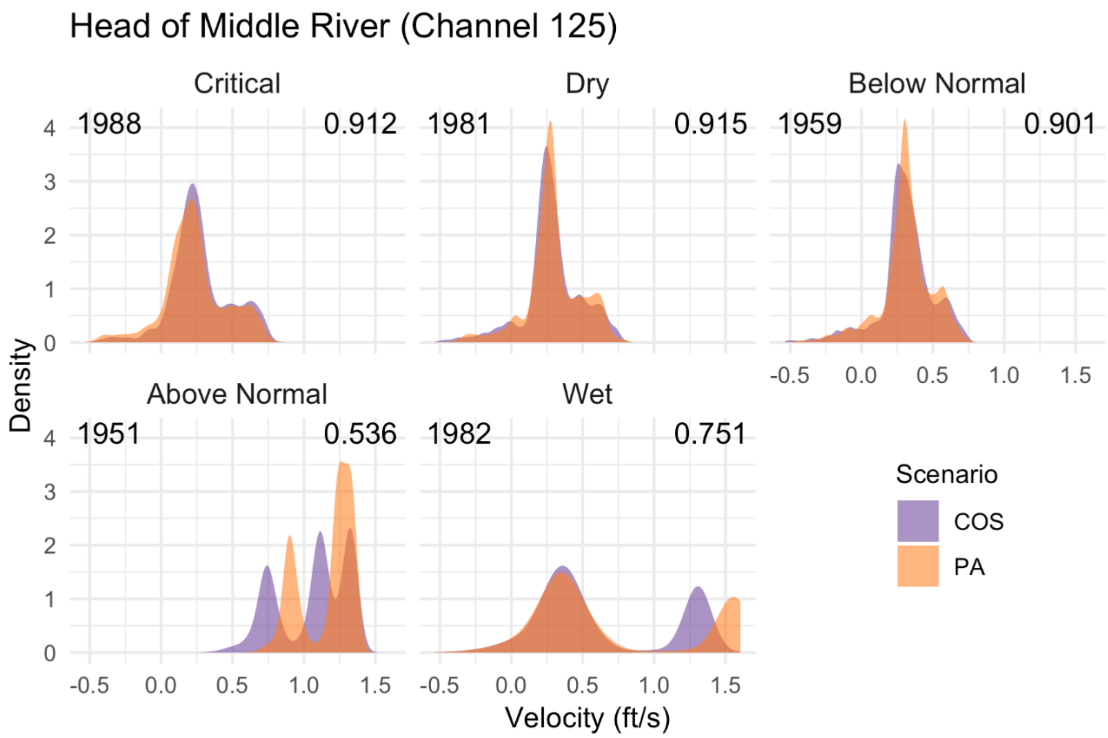

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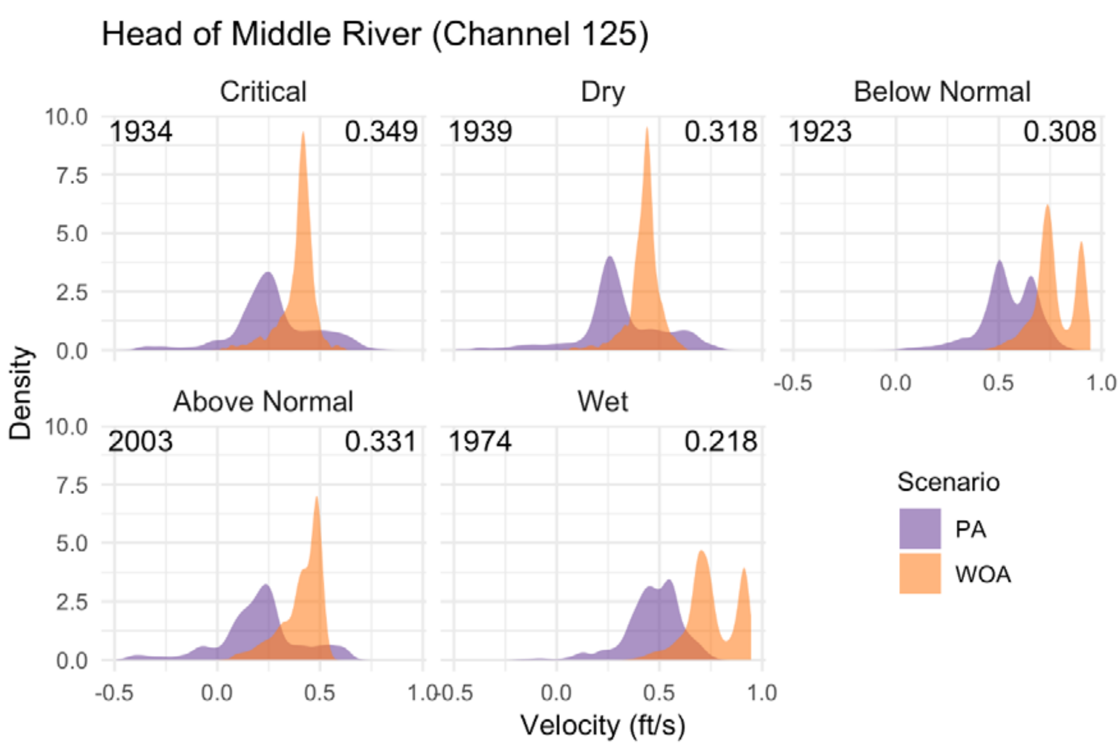


Figure H-22. PA vs. WOA Dec-Feb

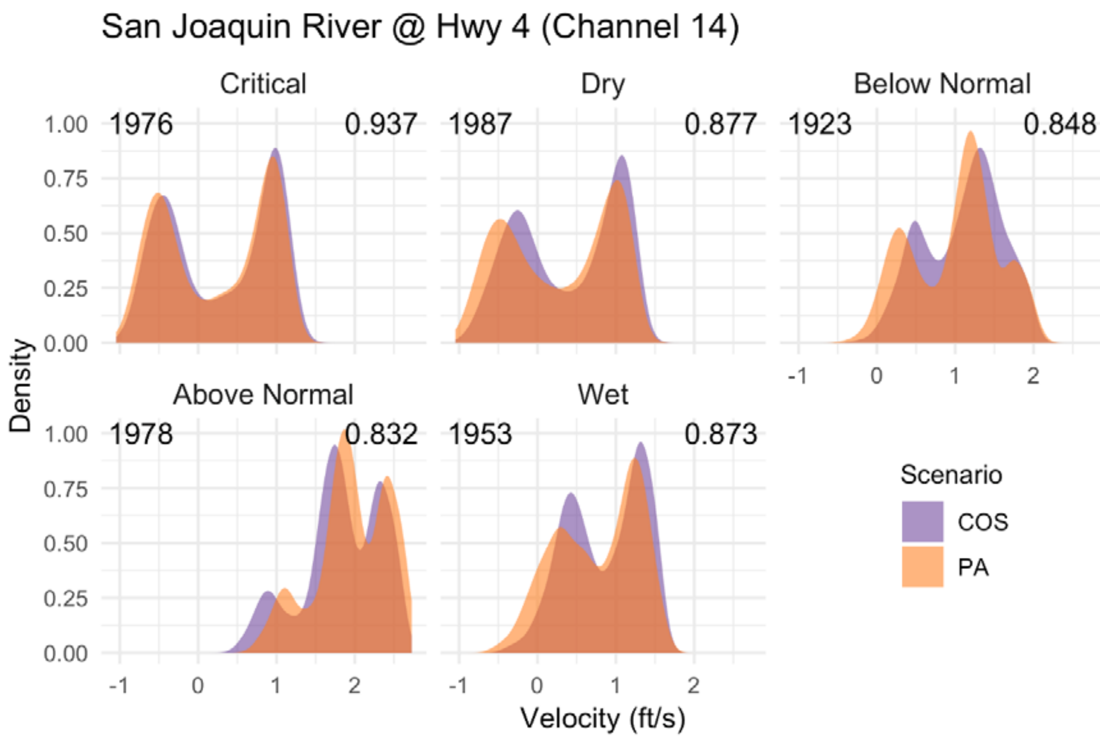


Figure H-23. PA vs. COS Mar-May

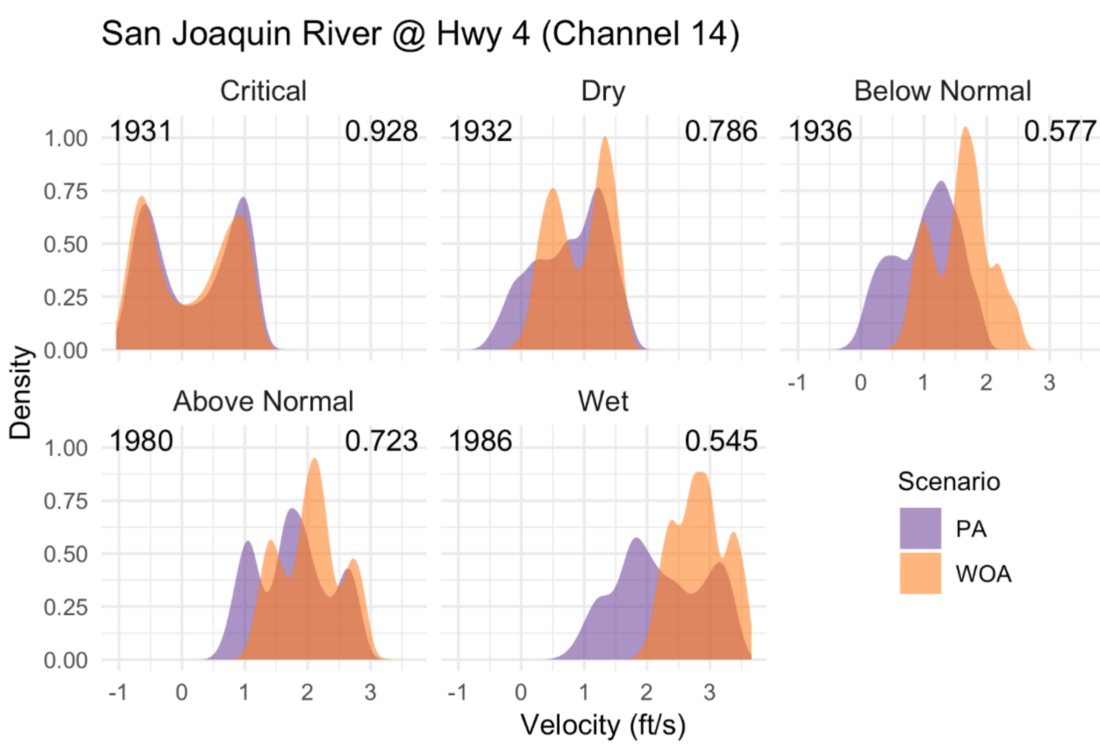


Figure H-24. PA vs. WOA Mar-May

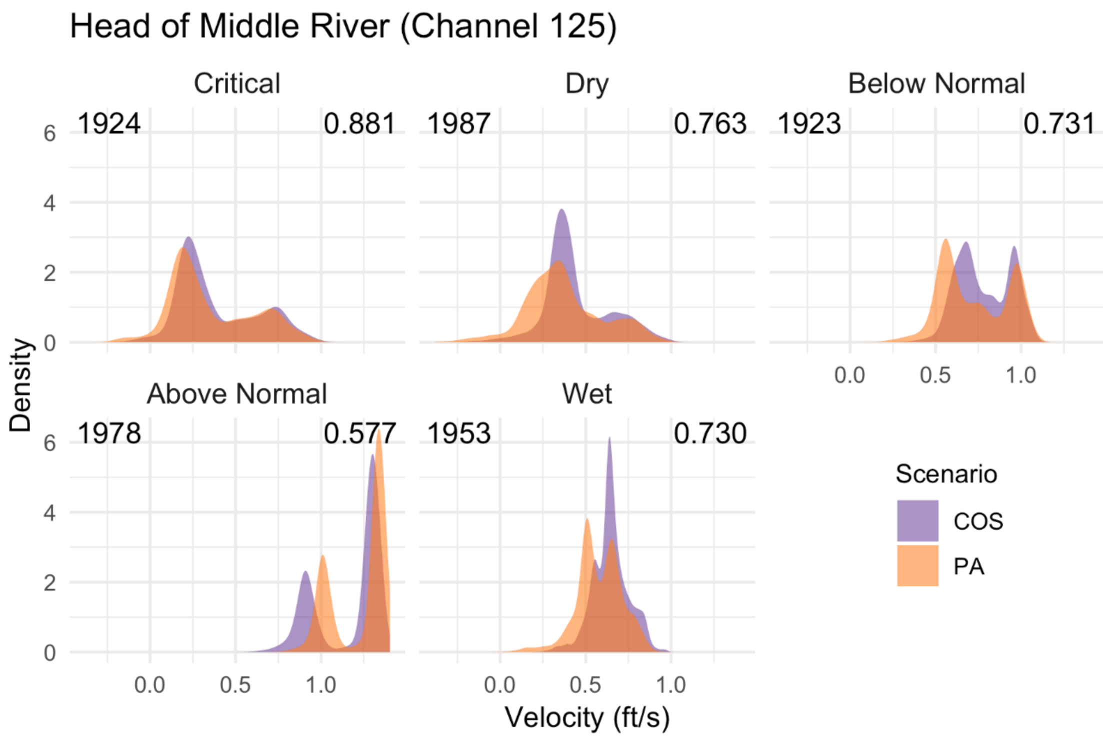


Figure H-25. PA vs. COS Mar-May

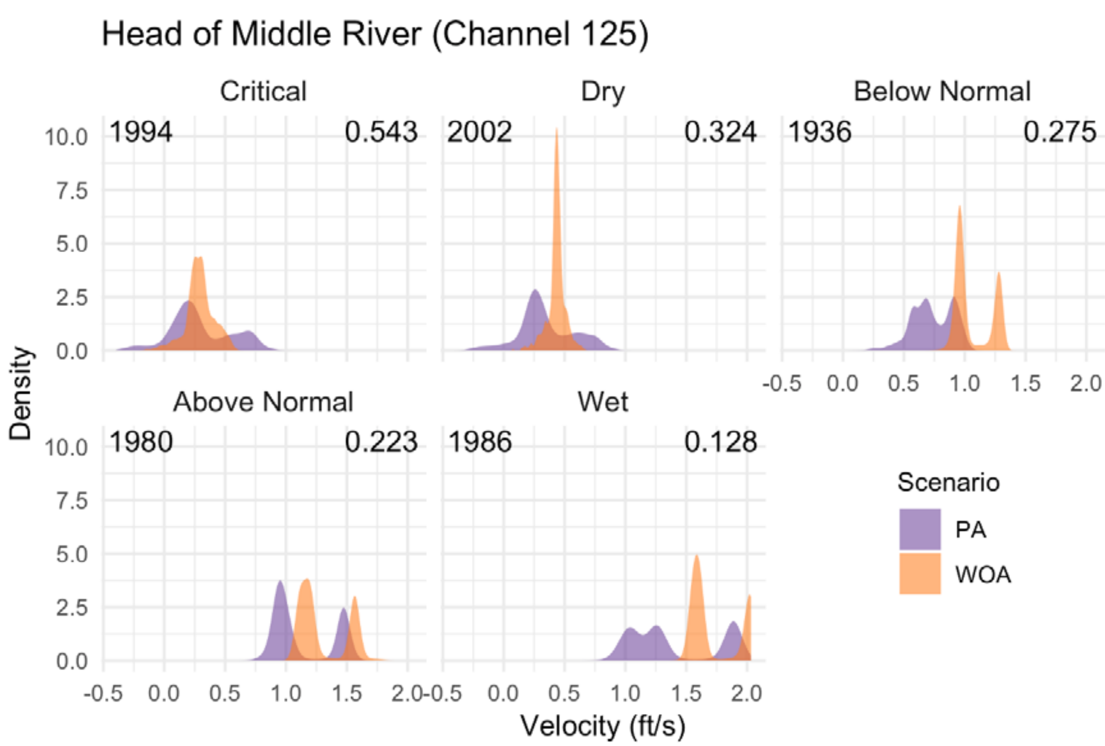


Figure H-26. PA vs. WOA Mar-May

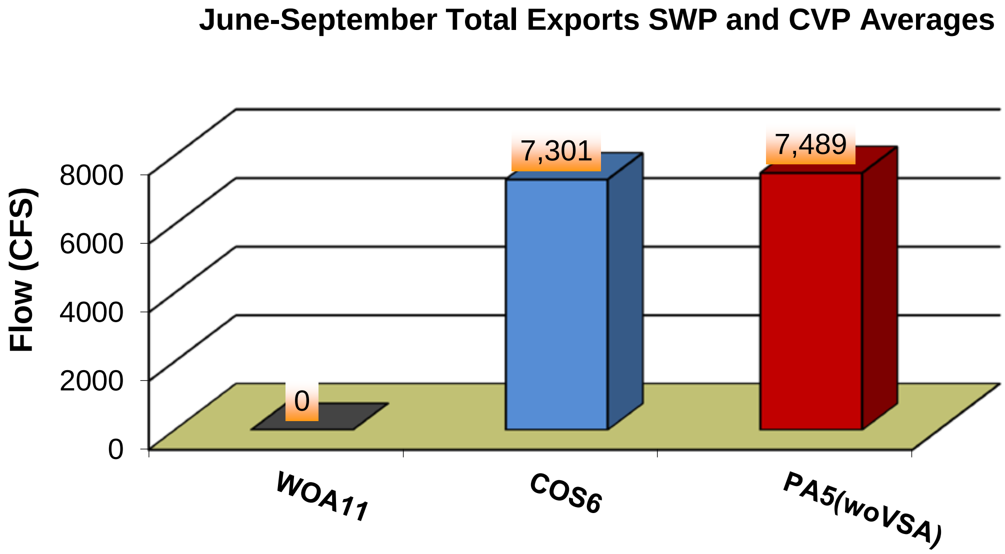


Figure H-27. Mean exports from June-September

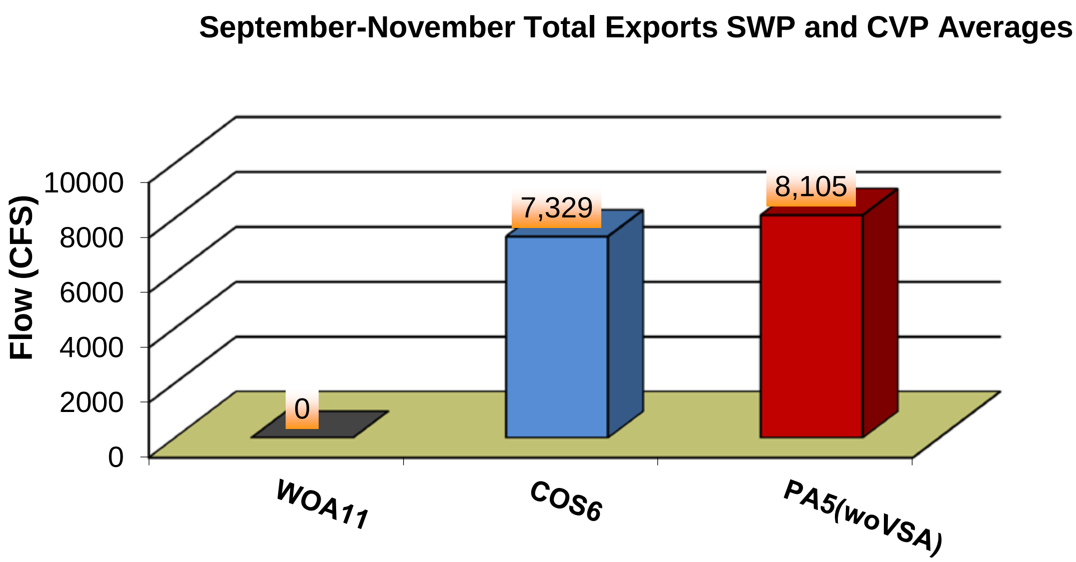


Figure H-28. Mean exports from September-November

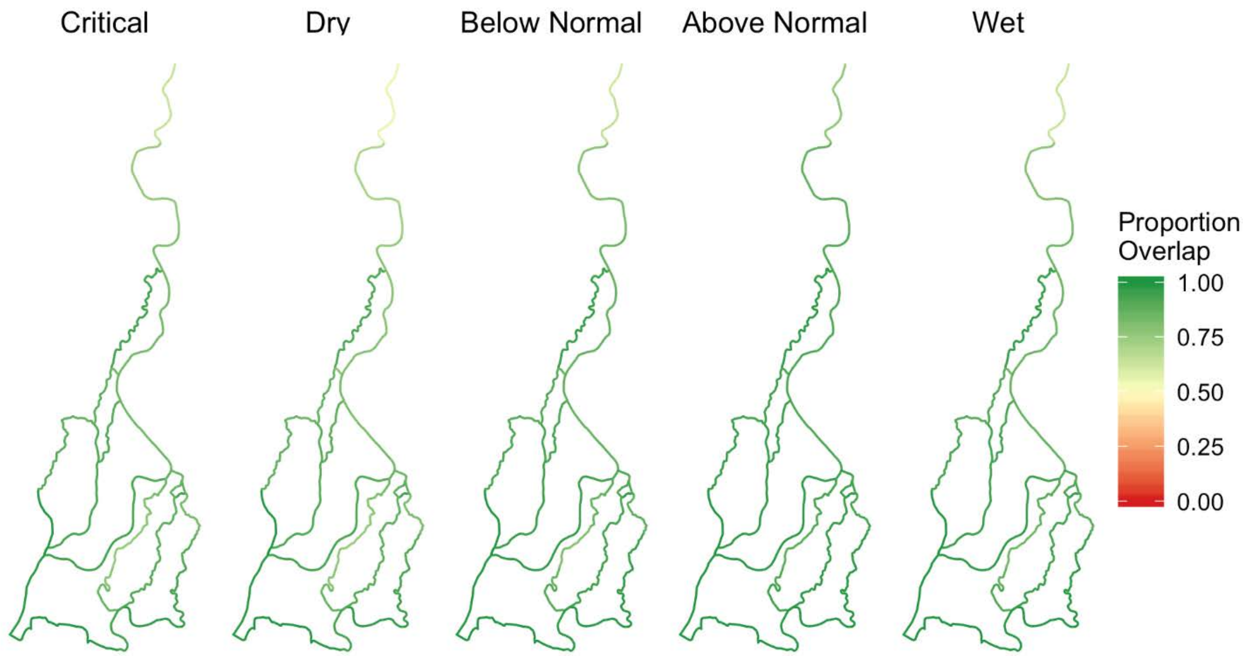


Figure H-29. PA vs. COS June-August

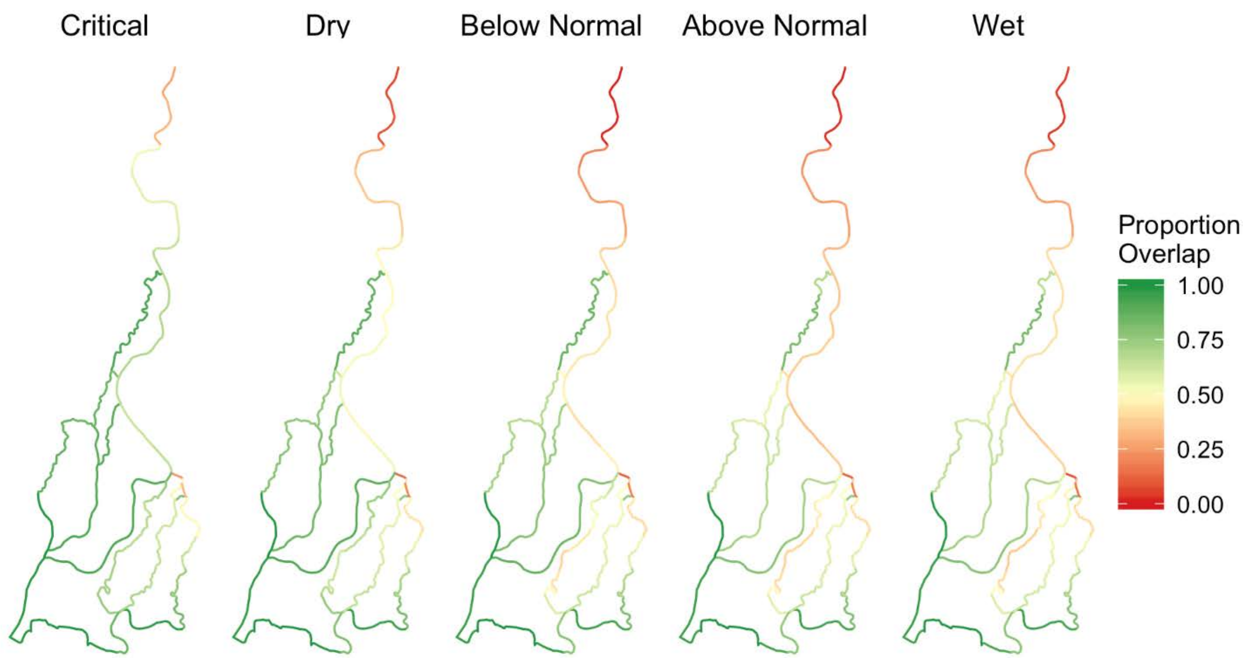


Figure H-30. PA vs. WOA June-August

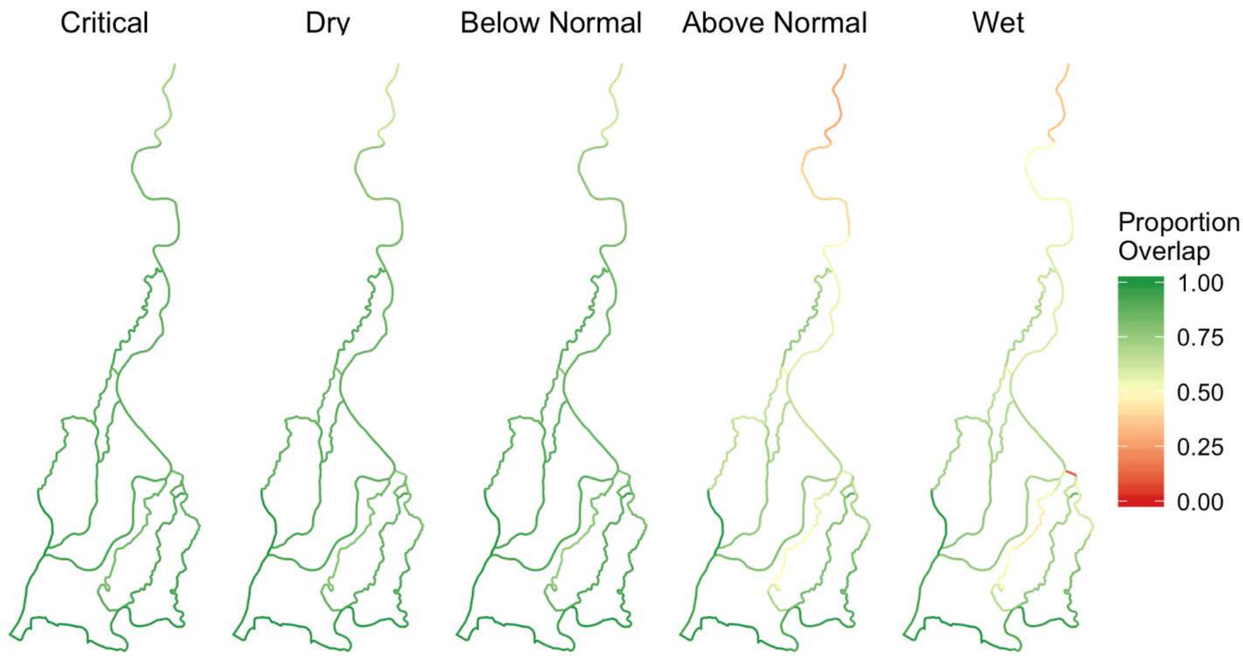


Figure H-31. PA vs. COS Sep-Nov

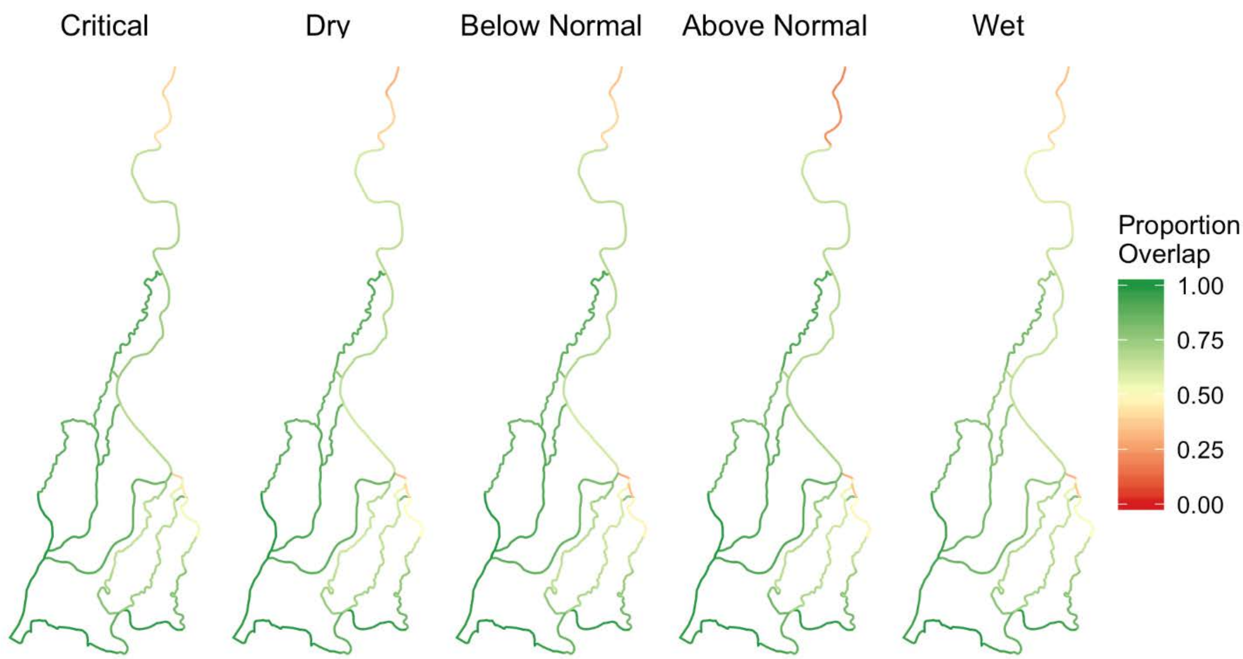


Figure H-32. PA vs. WOA Sep-Aug

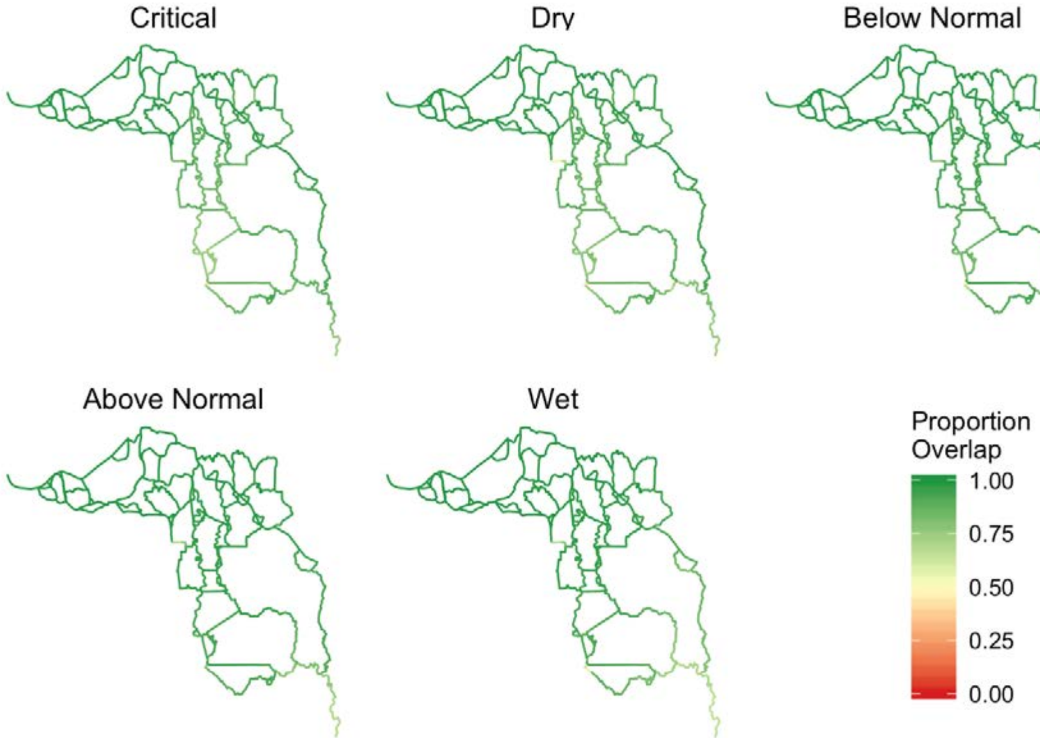


Figure H-33. PA vs. COS June-Aug.

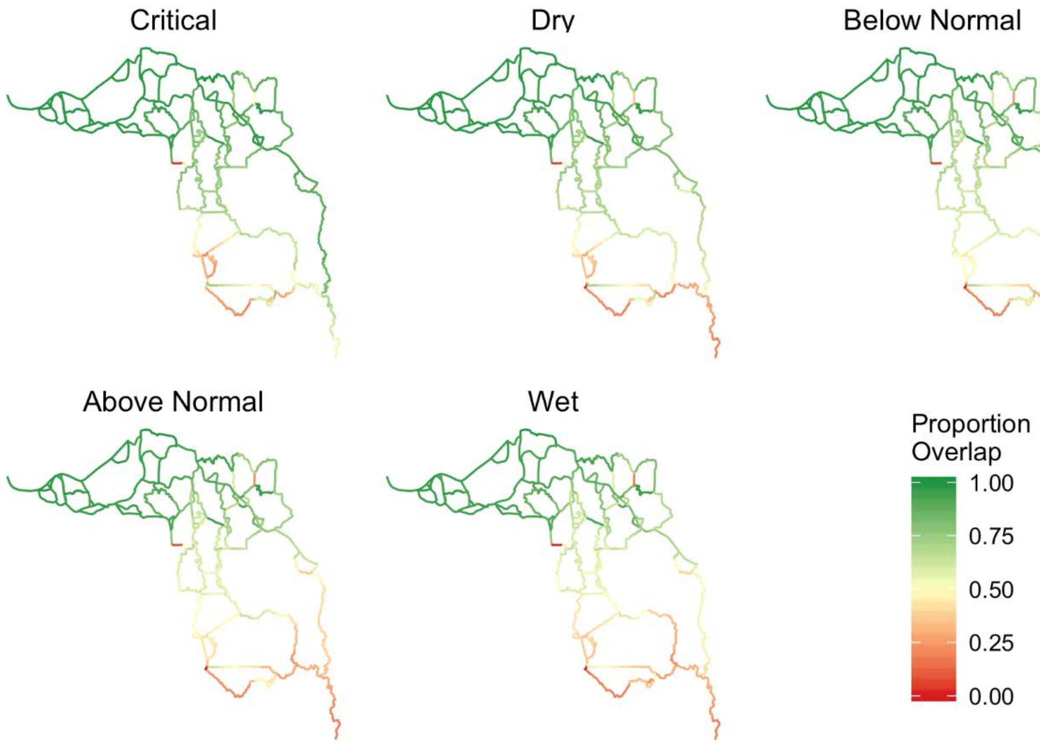


Figure H-34. PA vs. WOA June-Aug

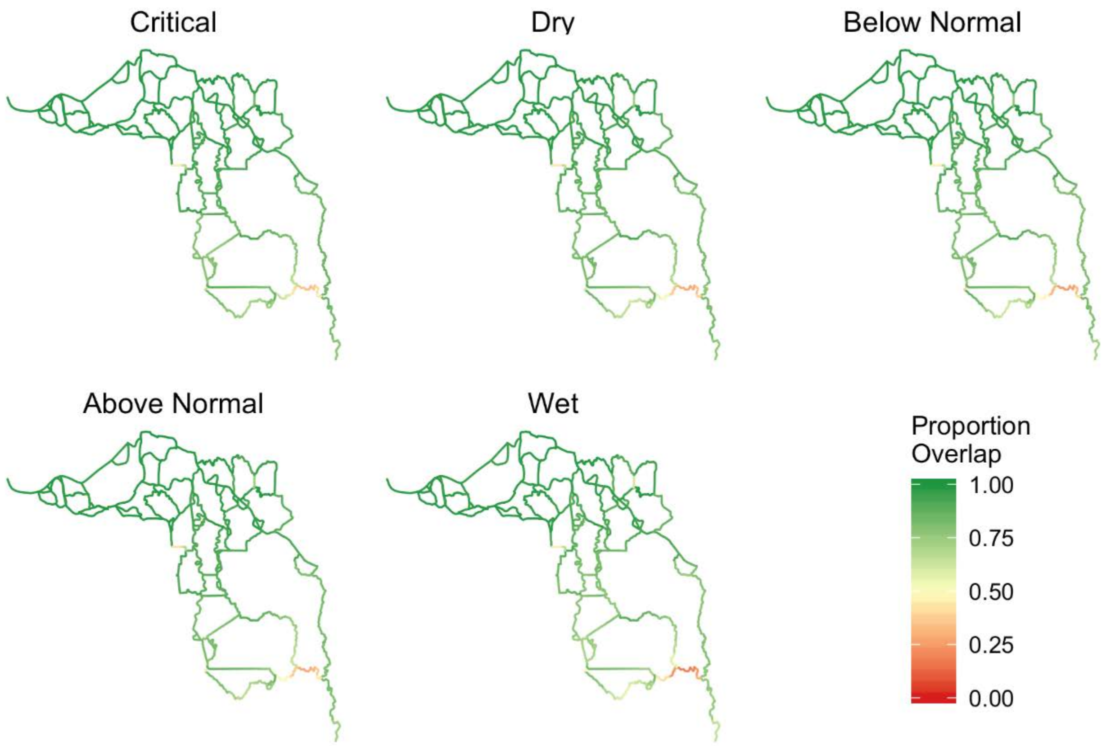


Figure H-35. PA vs. COS Sep-Nov

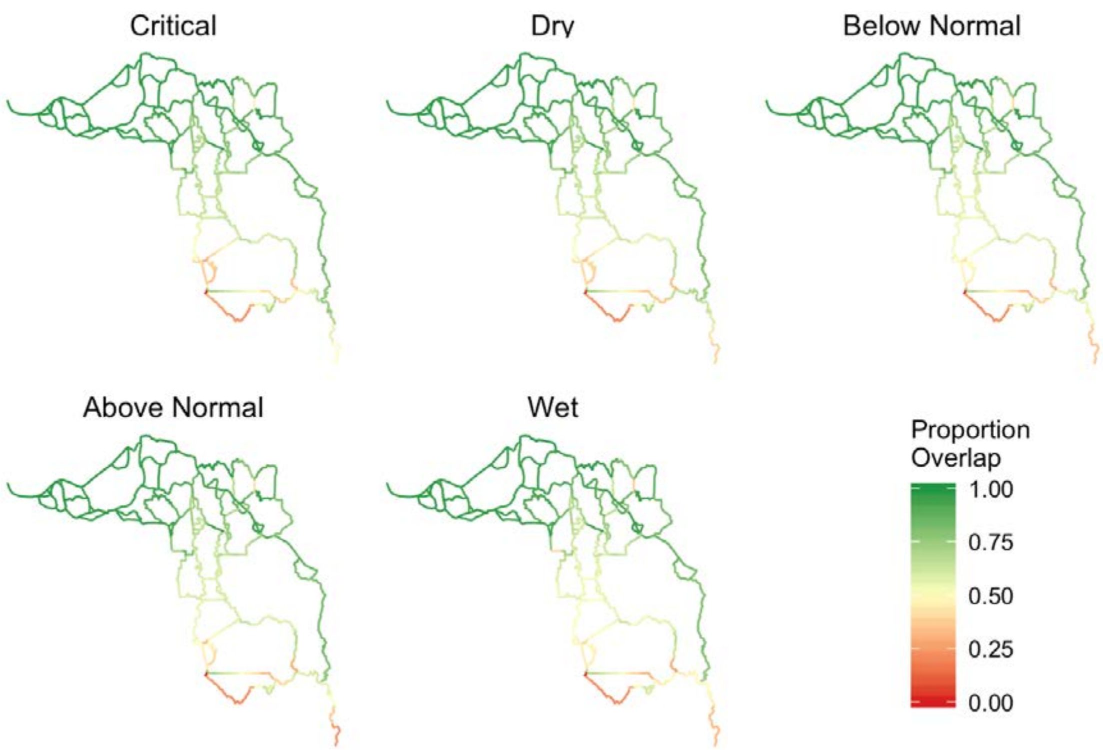


Figure H-36. PA vs. WOA Sep-Nov

Appendix I Biological Modeling and Analysis

The National Marine Fisheries Service (NMFS) requested the U.S. Bureau of Reclamation prepare specific biological models and analyses to support NMFS' preparation of their Biological Opinion for the ROC on LTO project. The following sections describe the methods and key assumptions for the seven biological models/analyses prepared: Delta Passage Model, Interactive Object-Oriented Simulation Model, Floodplain Inundation Habitat Analysis, Weighted Usable Area Analysis, Salvage-Density Method, Reclamation Salmon Mortality Model, and SALMOD.

I.1 Delta Passage Model (DPM) Documentation

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. Although the DPM is based primarily on studies of winter-run Chinook salmon smolt surrogates (late fall–run Chinook salmon), it is applied here for winter-run, spring-run, fall-run, and late fall–run Chinook salmon by adjusting emigration timing and assuming that all migrating Chinook salmon smolts will respond similarly to Delta conditions. The DPM results presented here reflect the current version of the model, which continues to be reviewed and refined, and for which a sensitivity analysis has been completed to examine various aspects of uncertainty related to the model's inputs and parameters.

Although studies have shown considerable variation in emigrant size, with Central Valley Chinook salmon migrating as fry, parr, or smolts (Brandes and McLain 2001; Williams 2001), the DPM relies predominantly on data from acoustic-tagging studies of large (>140 mm) smolts, and therefore should be applied very cautiously to pre-smolt migrants. Salmon juveniles less than 70 mm are more likely to exhibit rearing behavior in the Delta (Moyle 2002) and thus likely will be represented poorly by the DPM. It has been assumed that the downstream emigration of fry, when spawning grounds are well upstream, is probably a dispersal mechanism that helps distribute fry among suitable rearing habitats. However, even when rearing habitat does not appear to be a limiting factor, downstream movement of fry still may be observed, suggesting that fry emigration is a viable alternative life-history strategy (Healy 1980; Healey and Jordan 1982; Miller et al. 2010). Unfortunately, survival data are lacking for small (fry-sized) juvenile emigrants because of the difficulty of tagging such small individuals. Therefore, the DPM should be viewed as a smolt survival model only, with its survival relationships generally having been derived from larger smolts (>140 mm), with the fate of pre-smolt emigrants not incorporated into model results.

The DPM has undergone substantial revisions based on comments received through the BDCP preliminary proposal anadromous team meetings and in particular through feedback received during a workshop held on August 24, 2010, a 2-day workshop held June 23–24, 2011, and since then from various meetings of a workgroup consisting of agency biologists and consultants. This effects analysis uses the most recent version of the DPM as of September 2015. The DPM is viewed as a simulation framework that can be changed as more data or new hypotheses regarding smolt migration and survival become available. The results are based on these revisions.

Survival estimates generated by the DPM are not intended to predict future outcomes. Instead, the DPM provides a simulation tool that compares the effects of different water management options on smolt migration survival, with accompanying estimates of uncertainty. The DPM was used to evaluate overall through-Delta survival for the COS, PA and WOA scenarios. Note that the DPM is a tool to compare different scenarios and is not intended to predict actual through-Delta survival under current or future conditions. In keeping with other methods found in the effects analysis, it is possible that underlying relationships (e.g., flow-survival) that are used to inform the DPM will change in the future; there is an assumption of stationarity of these basic relationships to allow scenarios to be compared for the current analysis, recognizing that it may be necessary to re-examine the relationships as new information becomes available.

I.1.1 Model Overview

The DPM is based on a detailed accounting of migratory pathways and reach-specific mortality as Chinook salmon smolts travel through a simplified network of reaches and junctions (Figure I.1-1). The biological functionality of the DPM is based on the foundation provided by Perry et al. (2010) as well as other acoustic tagging–based studies (San Joaquin River Group Authority 2008, 2010; Holbrook et al. 2009) and coded wire tag (CWT)–based studies (Newman and Brandes 2010; Newman 2008). Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available.

The major model functions in the DPM are as follows.

1. Delta Entry Timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon.
2. Fish Behavior at Junctions, which models fish movement as they approach river junctions.
3. Migration Speed, which models reach-specific smolt migration speed and travel time.
4. Route-Specific Survival, which models route-specific survival response to non-flow factors.
5. Flow-Dependent Survival, which models reach-specific survival response to flow.
6. Export-Dependent Survival, which models survival response to water export levels in the Interior Delta reach (see Table I.1-1 for reach description).

Functional relationships are described in detail in the Section *Model Functions*.

I.1.2 Model Time Step

The DPM operates on a daily time step using simulated daily average flows and Delta exports as model inputs. The DPM does not attempt to represent sub-daily flows or diel salmon smolt behavior in response to the interaction of tides, flows, and specific channel features. The DPM is intended to represent the net outcome of migration and mortality occurring over days, not three-dimensional movements occurring over minutes or hours (e.g., Blake and Horn 2003). It is acknowledged that finer scale modeling with a shorter time step may match the biological processes governing fish movement better than a daily time step (e.g., because of diel activity patterns; Plumb et al. 2015) and that sub-daily differences in flow proportions into junctions make daily estimates somewhat coarse (Cavallo et al. 2015).

I.1.3 Spatial Framework

The DPM is composed of nine reaches and four junctions (Figure I.1-1; Table I.1-1) selected to represent primary salmonid migration corridors where high-quality data were available for fish and hydrodynamics. For simplification, Sutter Slough and Steamboat Slough are combined as the reach SS; and Georgiana Slough, the Delta Cross Channel (DCC), and the forks of the Mokelumne River to which the DCC leads are combined as Geo/DCC. The Geo/DCC reach can be entered by Mokelumne River fall-run Chinook salmon at the head of the South and North Forks of the Mokelumne River or by Sacramento runs through the combined junction of Georgiana Slough and DCC (Junction C). The Interior Delta reach can be entered from three different pathways: Geo/DCC, San Joaquin River via Old River Junction (Junction D), and Old River via Junction D. The entire Interior Delta region is treated as a single model reach3. The four distributary junctions (channel splits) depicted in the DPM are (A) Sacramento River at Fremont Weir (head of Yolo Bypass), (B) Sacramento River at head of Sutter and Steamboat Sloughs, (C) Sacramento River at the combined junction with Georgiana Slough and DCC, and (D) San Joaquin River at the head of Old River (Figure I.1-1, Table I.1-1).

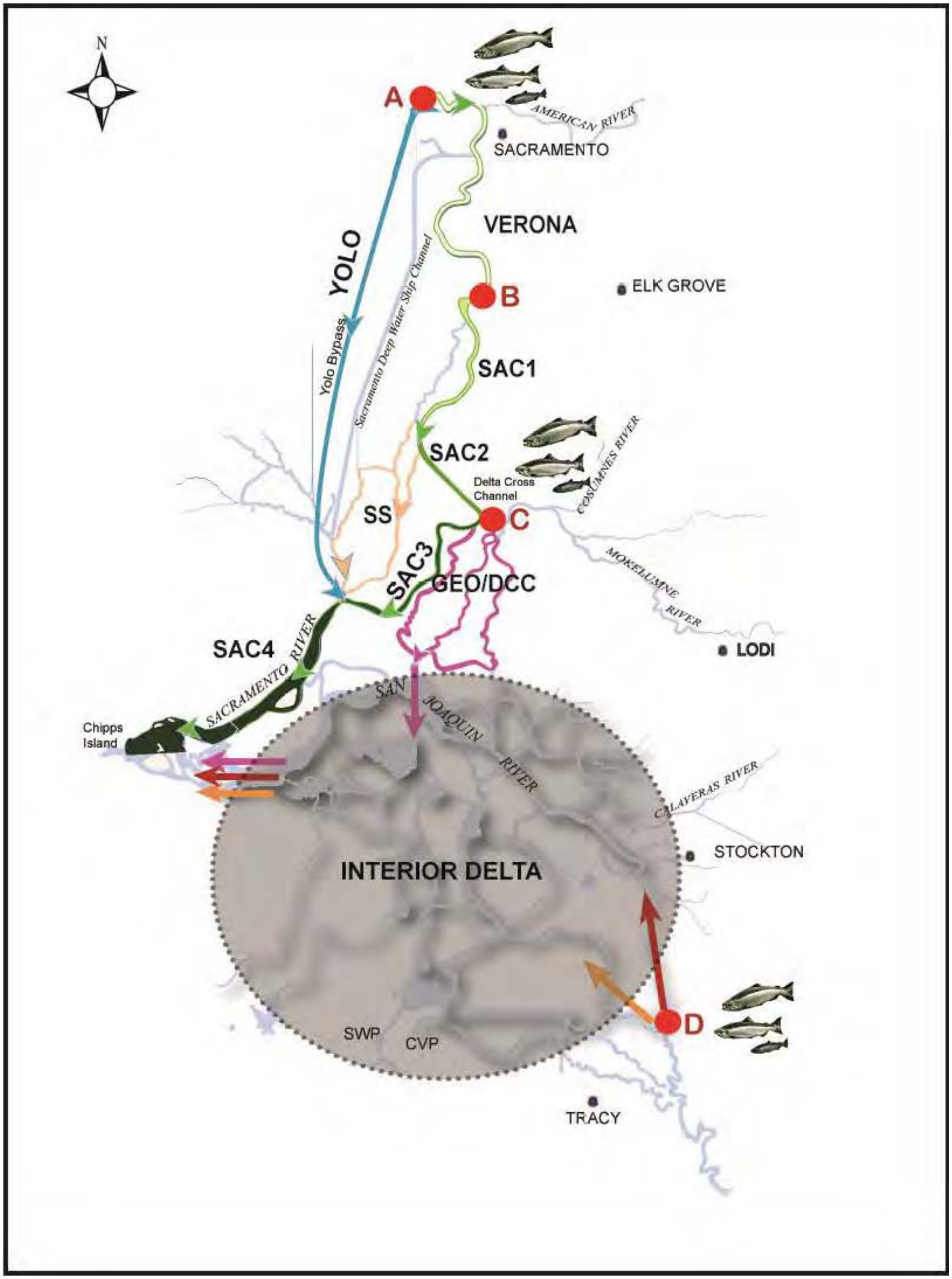
Table I.1-1. Description of Modeled Reaches and Junctions in the Delta Passage Model

Reach/Junction	Description Reach Length (km)	Reach Length (km)
Sac1	Sacramento River from Freeport to junction with Sutter/Steamboat Sloughs	19.33
Sac2	Sacramento River from Sutter/Steamboat Sloughs junction to junction with Delta Cross Channel/Georgiana Slough	10.78
Sac3	Sacramento River from Delta Cross Channel junction to Rio Vista, California	22.37
Sac4	Sacramento River from Rio Vista, California to Chipps Island	23.98
Yolo	Yolo Bypass from entrance at Fremont Weir to Rio Vista, California	NA[a]
Verona	Fremont Weir to Freeport	57
SS	Combined reach of Sutter Slough and Steamboat Slough ending at Rio Vista, California	26.72
Geo/DCC	Combined reach of Georgiana Slough, Delta Cross Channel, and South and North Forks of the Mokelumne River ending at confluence with the San Joaquin River in the Interior Delta	25.59
Interior Delta	Begins at end of reach Geo/DCC, San Joaquin River via Junction D, or Old River via Junction D, and ends at Chipps Island	NA[b]
A	Junction of the Yolo Bypass[c] and the Sacramento River	NA
B	Combined junction of Sutter Slough and Steamboat Slough with the Sacramento River	NA
C	Combined junction of the Delta Cross Channel and Georgiana Slough with the Sacramento River	NA
D	Junction of the Old River with the San Joaquin River	NA

[a] Reach length for Yolo Bypass is undefined because reach length currently is not used to calculate Yolo Bypass speed and ultimate travel time.

[b] Reach length for the Interior Delta is undefined because salmon can take multiple pathways. Also, timing through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

[c] Flow into the Yolo Bypass is primarily via the Fremont Weir but flow via Sacramento Weir is also included



Bold headings label modeled reaches, and red circles indicate model junctions. Salmonid icons indicate locations where smolts enter the Delta in the DPM. Smolts enter the Interior Delta from the Geo/DCC reach or from Junction D via Old River or from the San Joaquin River. Because of the lack of data informing specific routes through the Interior Delta, and tributary specific survival, the entire Interior Delta region is treated as a single model reach but survival varies within the Interior Delta depending upon whether fish enter from the Sacramento River, Mokelumne River, the San Joaquin River, or Old River.

Figure I.1-1. Map of the Sacramento–San Joaquin River Delta Showing the Modeled Reaches and Junctions of the Delta Applied in the Delta Passage Model.

I.1.4 Flow Input Data

Water movement through the Delta as input to the DPM is derived from daily (tidally averaged) flow output produced by the hydrology module of the Delta Simulation Model II (DSM2- HYDRO; <http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/>) or from CALSIM-II.

The nodes in the DSM2-HYDRO and CALSIM II models that were used to provide flow for specific reaches in the DPM are shown in Table I.1-2.

Table I.1-2 Delta Passage Model Reaches and Associated Output Locations from DSM2-HYDRO and CALSIM II Models

DPM Reach or Model Component	DSM2 Output Locations	CALSIM Node
Sac1	rsac155	
Sac2	rsac128	
Sac3	rsac123	
Sac4	rsac101	
Yolo		d160a+d166aa
Verona		C160a
SS	slsbt011	
Geo/DCC	dcc+georg_sl	
South Delta Export Flow	Clifton Court Forebay + Delta Mendota Canal	
Sacramento River flow at Fremont Weir		C129a

I.1.4.1 *Model Functions*

I.1.4.1.1 Delta Entry Timing

Recent sampling data on Delta entry timing of emigrating juvenile smolts for six Central Valley Chinook salmon runs were used to inform the daily proportion of juveniles entering the Delta for each run (Table I.1-3). Because the DPM models the survival of smolt-sized juvenile salmon, pre-smolts were removed from catch data before creating entry timing distributions. The lower 95th percentile of the range of salmon fork lengths visually identified as smolts by the USFWS in Sacramento trawls was used to determine the lower length cutoff for smolts. A lower fork length cutoff of 70 mm for smolts was applied, and all catch data of fish smaller than 70 mm were eliminated. To isolate wild production, all fish identified as having an adipose-fin clip (hatchery production) were eliminated, recognizing that most of the fall-run hatchery fish released upstream of Sacramento are not marked. Daily catch data for each brood year were divided by total annual catch to determine the daily proportion of smolts entering the DPM for each run (Figure I.1-2). Sampling was not conducted daily at most stations and catch was not expanded for fish caught but not measured. Finally, the daily proportions for all brood years were plotted for each race, and a normal distribution was visually approximated to obtain the daily proportion appeared evident for winter-run entry timing, a generic probability density function was fit to the winter-run daily proportion data using the package “sm” in R software (R Core Team 2012). The R fitting procedure estimated the best-fit probability distribution of the daily proportion of fish entering the DPM for winter-run. A sensitivity analysis of this assumption was undertaken and showed that patterns in results would be expected to be similar for a range of entry distribution assumptions.

Table I.1-3. Sampling Gear Used to Create Juvenile Delta Entry Timing Distributions for Each Central Valley Run of Chinook Salmon

Chinook Salmon Run	Gear	Agency	Brood Years
Sacramento River Winter Run	Trawls at Sacramento	USFWS	1995–2009
Sacramento River Spring Run	Trawls at Sacramento	USFWS	1995–2005
Sacramento River Fall Run	Trawls at Sacramento	USFWS	1995–2005
Sacramento River Late Fall Run	Trawls at Sacramento	USFWS	1995–2005
Mokelumne River Fall Run	Rotary Screw Trap at Woodbridge	EBMUD	2001–2007
San Joaquin River Fall Run	Kodiak Trawl at Mossdale	CDFW	1996–2009

Agencies that conducted sampling are listed: USFWS = U.S. Fish and Wildlife Service, EBMUD = East Bay Municipal District, and CDFW = California Department of Fish and Wildlife.

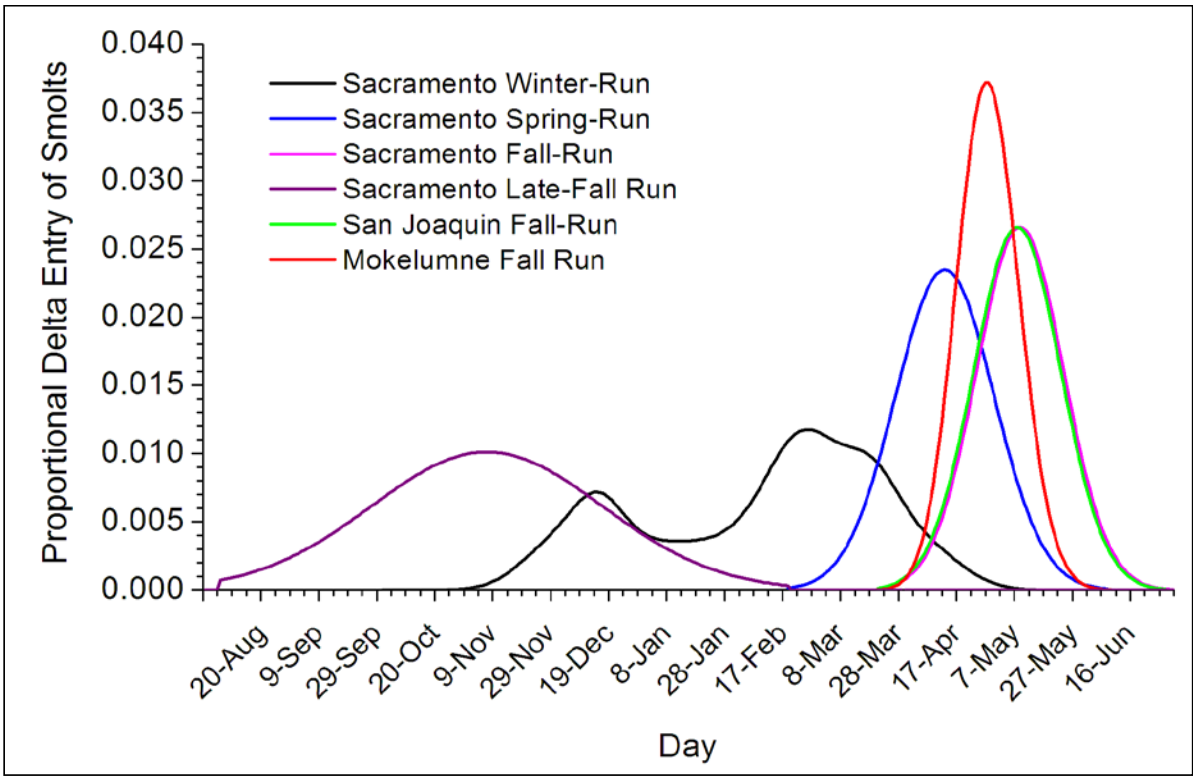


Figure I.1-2. Delta Entry Distributions for Chinook Salmon Smolts Applied in the Delta Passage Model for Sacramento River Winter-Run, Sacramento River Spring-Run, Sacramento River Fall-Run, Sacramento River Late Fall–Run, San Joaquin River Fall-Run, and Mokelumne River Fall-Run Chinook Salmon.

I.1.4.1.2 Migration Speed

The DPM assumes a net daily movement of smolts in the downstream direction. The rate of smolt movement in the DPM affects the timing of arrival at Delta junctions and reaches, which can affect route selection and survival as flow conditions or water project operations change.

Smolt movement in all reaches except Yolo Bypass and the Interior Delta is a function of reach-specific length and migration speed as observed from acoustic-tagging results. Reach-specific length (kilometers

[km]) (Table I.1-4) is divided by reach migration speed (km/day) the day smolts enter the reach to calculate the number of days smolts will take to travel through the reach.

For north Delta reaches Verona, Sac1, Sac2, SS, and Geo/DCC, mean migration speed through the reach is predicted as a function of flow. Many studies have found a positive relationship between juvenile Chinook salmon migration rate and flow in the Columbia River Basin (Raymond 1968; Berggren and Filardo 1993; Schreck et al. 1994), with Berggren and Filardo (1993) finding a logarithmic relationship for Snake River yearling Chinook salmon. Ordinary least squares regression was used to test for a logarithmic relationship between reach-specific migration speed (km/day) and average daily reach-specific flow (cubic meters per second [m^3/sec]) for the first day smolts entered a particular reach for reaches where acoustic-tagging data was available (Sac1, Sac2, Sac3, Sac4, Geo/DCC, and SS):

$$Speed = \beta_0 \ln(flow) + \beta_1;$$

Where $\beta 0$ is the slope parameter and $\beta 1$ is the intercept.

Individual smolt reach-specific travel times were calculated from detection histories of releases of acoustically-tagged smolts conducted in December and January for three consecutive winters (2006/2007, 2007/2008, and 2008/2009) (Perry 2010). Reach-specific migration speed (km/day) for each smolt was calculated by dividing reach length by travel days (Table I.1-4). Flow data was queried from the DWR's California Data Exchange website (<http://cdec.water.ca.gov/>).

Table I.1-4. Reach-Specific Migration Speed and Sample Size of Acoustically-Tagged Smolts Released during December and January for Three Consecutive Winters (2006/2007, 2007/2008, and 2008/2009)

Reach	Gauging Station ID	Release Dates	Sample Size	Speed (km/day)			
				Avg	Min	Max	SD
Sac1	FPT	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	452	13.32	0.54	41.04	9.29
Sac2	SDC	1/17/07–1/18/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	294	9.29	0.34	10.78	3.09
Sac3	GES	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	102	9.24	0.37	22.37	7.33
Sac4	GES[a]	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	62	8.60	0.36	23.98	6.79
Geo/DCC	GSS	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	86	14.20	0.34	25.59	8.66
SS	FPT-SDC[b]	12/05/06–12/06/06, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	30	9.41	0.56	26.72	7.42

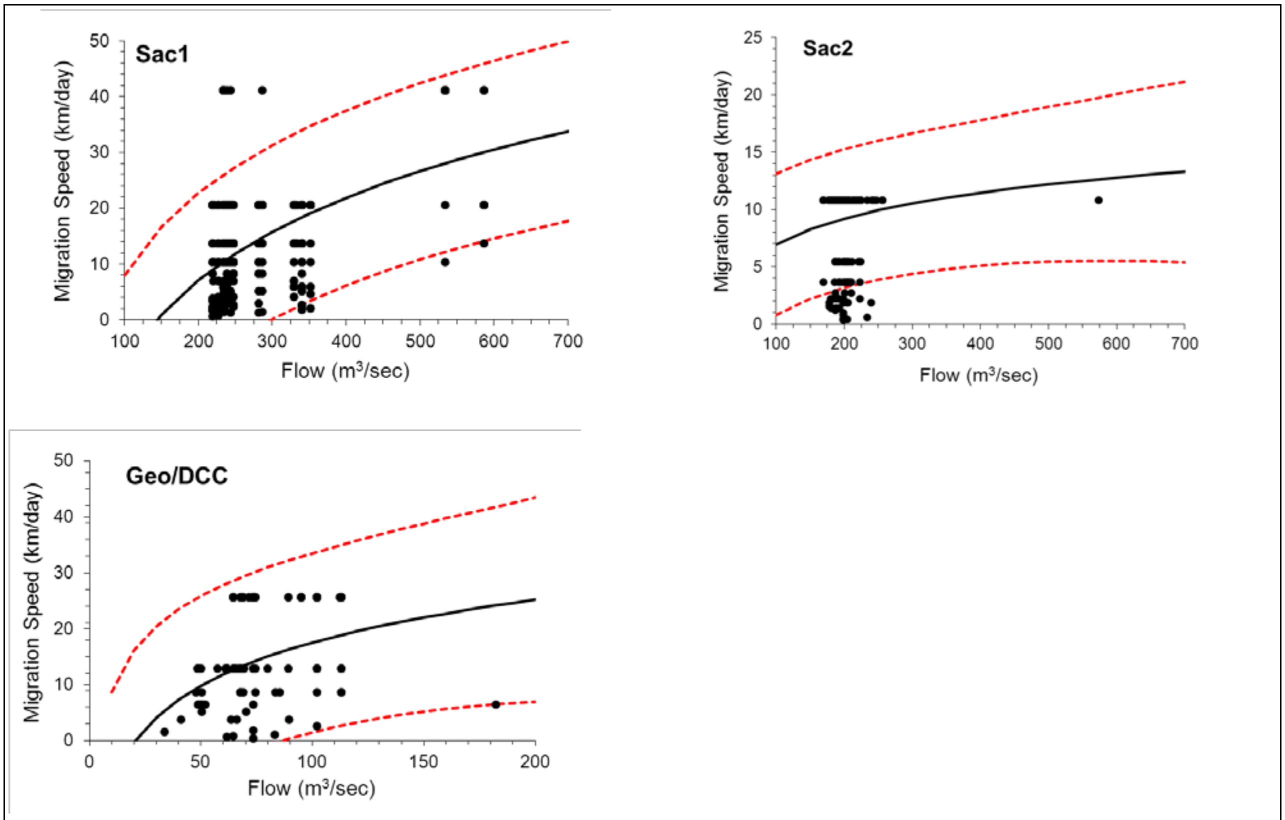
[a] Sac3 flow is used for Sac4 because no flow gauging station is available for Sac4.
[b] SS flow is calculated by subtracting Sac2 flow (SDC) from Sac1 flow (FPT).

Migration speed was significantly related to flow for reaches Sac1 (df = 450, F = 164.36, P < 0.001), Sac2 (df = 292, F = 4.17, P = 0.042), and Geo/DCC (df = 84, F = 13.74, P <0.001). Migration speed increased as flow increased for all three reaches (Table I.1-5, Figure I.1-3). Therefore, for reaches Sac1, Sac2, and

Geo/DCC, the regression coefficients shown in Table I.1-5 are used to calculate the expected average migration rate given the input flow for the reach and the associated standard error of the regressions is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their migration speed throughout the reach. The minimum migration speed for each reach is set at the minimum reach-specific migration speed observed from the acoustic-tagging data (Table I.1-4). The flow-migration rate relationship that was used for Sac1 also was applied for the Verona reach.

Table I.1-5. Sample Size and Slope (β_0) and Intercept (β_1) Parameter Estimates with Associated Standard Error (in Parenthesis) for the Relationship between Migration Speed and Flow for Reaches Sac1, Sac2, and Geo/DCC

Reach	N	β_0	β_1
Sac1	452	21.34 (1.66)	-105.98 (9.31)
Sac2	294	3.25 (1.59)	-8.00 (8.46)
Geo/DCC	86	11.08 (2.99)	-33.52 (12.90)



Circles are observed migration speeds of acoustically-tagged smolts from acoustic-tagging studies from Perry (2010), solid lines are predicted mean reach survival curves, and dotted lines are 95% prediction intervals used to inform uncertainty.

Figure I.1-3. Reach-Specific Migration Speed (km/day) as a Function of Flow (m^3/sec) Applied in Reaches Sac1, Sac2, and Geo/DCC.

No significant relationship between migration speed and flow was found for reaches Sac3 (df = 100, F = 1.13, P =0.29), Sac4 (df = 60, F = 0.33, P = 0.57), and SS (df = 28, F = 0.86, P = 0.36). Therefore, for these reaches the observed mean migration speed and associated standard deviation (Table I.1-4) is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their migration speed throughout the reach. As applied for reaches Sac1, Sac2, and Geo/DCC, the minimum migration speed for reaches Sac3, Sac4, and SS is set at the minimum reach-specific migration speed observed from the acoustic-tagging data (Table I.1-4).

Yolo Bypass travel time data from Sommer et al. (2005) for acoustic-tagged, fry-sized (mean size = 57 mm fork length [FL]) Chinook salmon were used to inform travel time through the Yolo Bypass in the DPM. Because the DPM models the migration and survival of smolt-sized juveniles, the range of the shortest travel times observed across all three years (1998–2000) by Sommer et al. (2005) was used to inform the bounds of a uniform distribution of travel times (range = 4–28 days), on the assumption that smolts would spend less time rearing, and would travel faster than fry. On the day smolts enter the Yolo Bypass, their travel time through the reach is calculated by sampling from this uniform distribution of travel times.

The travel time of smolts migrating through the Interior Delta in the DPM is informed by observed mean travel time (7.95 days) and associated standard deviation (6.74) from North Delta acoustic-tagging studies (Perry 2010). However, the timing of smolt passage through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

I.1.4.1.3 Fish Behavior at Junctions (Channel Splits)

Perry et al. (2010) found that acoustically-tagged smolts arriving at Delta junctions exhibited inconsistent movement patterns in relation to the flow being diverted. For Junction A (entry into the Yolo Bypass at Fremont Weir), the following relationships were used.

- Proportion of smolts entering Yolo Bypass = Fremont Weir spill/(Fremont Weir spill + Sacramento River at Verona flows).

As noted above in *Flow Input Data*, the flow data informing Yolo Bypass entry were obtained by disaggregating CALSIM estimates using historical daily patterns of variability because DSM2 does not provide daily flow data for these locations.

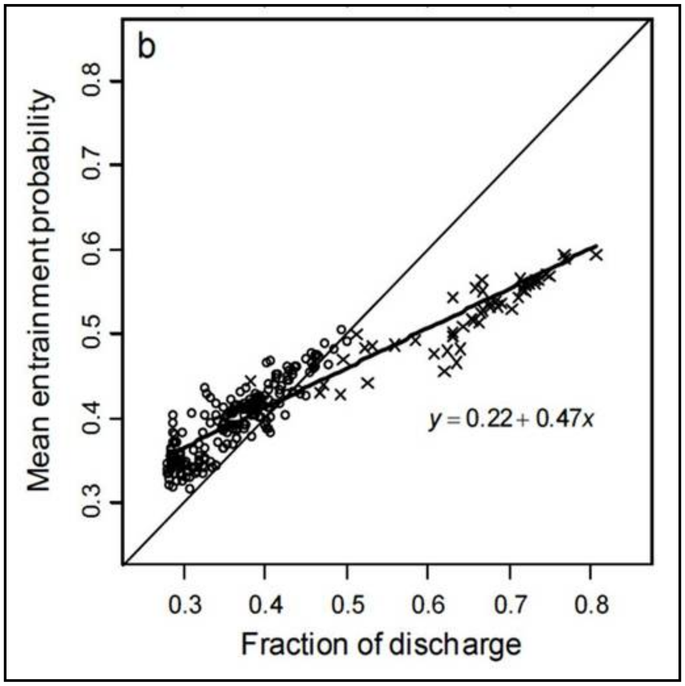
For Junction B (Sacramento River-Sutter/Steamboat Sloughs), Perry et al. (2010) found that smolts consistently entered downstream reaches in proportion to the flow being diverted. Therefore, smolts arriving at Junction B in the model move proportionally with flow. Similarly, with data lacking to inform the nature of the relationship, a proportional relationship between flow and fish movement for Junction D (San Joaquin River–Old River) also was applied. Note that the operation of the Head of Old River gate proposed under the PA is accounted for in the DSM2 flow input data (i.e., with a closed gate, relatively more flow [and therefore smolts] remains in the San Joaquin River).

For Junction C (Sacramento River–Georgiana Slough/DCC), Perry (2010) found a linear, nonproportional relationship between flow and fish movement. His relationship for Junction C was applied in the DPM:

$$y = 0.22 + 0.47x;$$

where y is the proportion of fish diverted into Geo/DCC and x is the proportion of flow diverted into Geo/DCC (Figure I.1-4).

In the DPM, this linear function is applied to predict the daily proportion of fish movement into Geo/DCC as a function of the proportion of flow into Geo/DCC.



Circles Depict DCC Gates Closed, Crosses Depict DCC Gates Open.

Figure I.1-4. Figure from Perry (2010) Depicting the Mean Entrainment Probability (Proportion of Fish Being Diverted into Reach Geo/DCC) as a Function of Fraction of Discharge (Proportion of Flow Entering Reach Geo/DCC).

I.1.4.1.4 Route-Specific Survival

Survival through a given route (individual reach or several reaches combined) is calculated and applied the first day smolts enter the reach. For reaches where literature showed support for reach-level responses to environmental variables, survival is influenced by flow (Sac1, Sac2, Sac3 and Sac4 combined, SS and Sac 4 combined, Interior Delta via San Joaquin River, and Interior Delta via Old River) or south Delta water exports (Interior Delta via Geo/DCC). For these reaches, daily flow or exports occurring the day of reach entry are used to predict reach survival during the entire migration period through the reach (Table I.1-6). For all other reaches (Geo/DCC and Yolo), reach survival is assumed to be unaffected by Delta conditions and is informed by means and standard deviations of survival from acoustic-tagging studies.

Table I.1-6. Route-Specific Survival and Parameters Defining Functional Relationships or Probability Distributions for Each Chinook Salmon Run and Methods Section Where Relationship is Described

Route	Chinook Salmon Run	Survival[a]	Methods Section Description
Verona	All Sacramento runs	0.931 (0.02)	This section
Sac1	All Sacramento runs	Function of flow	Flow-Dependent Survival
Sac2	All Sacramento runs	Function of flow	Flow-Dependent Survival
Sac3 and Sac4 combined	All Sacramento runs	Function of flow	Flow-Dependent Survival
Yolo	All Sacramento runs	Various	This section
Sac4 via Yolo[b]	All Sacramento runs	0.698 (0.153)	This section
SS and Sac4 combined	All Sacramento runs	Function of flow	Flow-Dependent Survival
Geo/DCC	Mokelumne fall-run	0.407 (0.209)	This section
	All Sacramento runs	0.65 (0.126)	This section
Interior Delta	All Sacramento runs	Function of exports	Export-Dependent Survival
	San Joaquin fall-run via Old River	Function of flow	Flow-Dependent Survival
	San Joaquin fall-run via San Joaquin River	Function of flow	Flow-Dependent Survival

[a] For routes where survival is uninfluenced by Delta conditions, mean survival and associated standard deviation (in parentheses) observed during acoustic-tagging studies (Michel 2010; Perry 2010) are used to define a normal probability distribution that is sampled from the day smolts enter a reach to calculate reach survival.

[b] Although flow influences survival of fish migrating through the combined routes of SS–Sac4 and Sac3–Sac4, flow does not influence Sac4 survival for fish arriving from Yolo.

For reaches Geo/DCC, Yolo, and Sac4 via Yolo, no empirical data were available to support a relationship between survival and Delta flow conditions (channel flow, exports). Therefore, for these reaches mean reach survival is used along with reach-specific standard deviation to define a normal probability distribution that is sampled from when smolts enter the reach to determine reach survival (Table I.1-7).

Mean reach survival and associated standard deviation for Geo/DCC are informed by survival data from smolt acoustic-tagging studies from Perry (2010). Separate acoustic-study survival data are applied for smolts migrating through Geo/DCC via the Sacramento River (Sacramento River runs) or Mokelumne River (Mokelumne River fall-run) (Table I.1-7). Smolts migrating down the Sacramento River during the acoustic-tagging studies could enter the DCC or Georgiana Slough when the DCC was open (December releases), therefore, group survivals for both routes are used to inform the mean survival and associated standard deviation for the Geo/DCC reach for Sacramento River runs. For Mokelumne River fall-run, only the DCC route group survivals are used to inform Geo/DCC survival because Mokelumne River fish are not exposed to Georgiana Slough.

Smolt survival data for the Yolo Bypass were obtained from the UC Davis Biotelemetry Laboratory (M. Johnston pers. comm.). These data included survival estimates for five reaches from release near the head of the bypass to the base of the bypass. The means (and standard errors) of these estimates defined normal probability distributions from which daily value for the DPM were drawn, and were as follows: reach 1 (release site): 1.00; reach 2 (release site to I-80): 0.96 (SE = 0.059); reach 3 (I-80 to screw trap): 0.96 (0.064); reach 4 (screw trap to base of Toe Drain): 0.94 (0.107); reach 5 (base of Toe Drain to base of Bypass): 0.88 (0.064). Fish leaving the Yolo reach in the model then entered Sac4 and were subject to survival at the rate shown in Table I.1-7.

Mean survival and associated standard deviation for the Verona reach between Fremont Weir and Yolo Bypass were derived from the 2007–2009 acoustic-tag study reported by Michel (2010), who did not find a flow-survival relationship for that reach.

Table I.1-7. Individual Release-Group Survival Estimates, Release Dates, Data Sources, and Associated Calculations Used to Inform Reach-Specific Mean Survivals and Standard Deviations Used in the Delta Passage Model for Reaches Where Survival Is Uninfluenced by Delta Conditions

DPM Reach	Survival	Release Dates	Survival Calculation	Mean	Standard Deviation
Geo/DCC via Mokelumne River	0.648	12/05/06	$S_{C1}*S_{C2}$	0.407	0.209
	0.286	12/04/07–12/06/07	S_{C1}		
	0.286	11/31/08–12/06/08	S_{C1}		
Geo/DCC via Sacramento River	0.648	12/05/06	S_{D1}	0.559	0.194
	0.600	12/04/07–12/06/07	$S_{D1,SAC}*S_{D2}$		
	0.762	1/15/08–1/17/08	$S_{D1,SAC}*S_{D2}$		
	0.774	11/31/08–12/06/08	$S_{D1,SAC}*S_{D2}$		
	0.467	1/13/08–1/19/09	$S_{D1,SAC}*S_{D2}$		
	0.648	12/05/06	$S_{C1}* S_{C2}$		
	0.286	12/04/07–12/06/07	S_{C1}		
	0.286	11/31/08–12/06/08	S_{C1}		
Sac4 via Yolo	0.714	12/5/2006	$S_{A6}*S_{A7}$	0.698	0.153
	0.858	1/17/2007	$S_{A6}*S_{A7}$		
	0.548	12/4/07-12/6/07	$S_{A7}*S_{A8}$		
	0.488	1/15/08-1/17/08	$S_{A7}*S_{A8}$		
	0.731	11/31/08-12/06/08	$S_{A7}*S_{A8}$		
	0.851	1/13/09-1/19/09	$S_{A7}*S_{A8}$		

Source: Perry 2010.

I.1.4.1.5 Flow-Dependent Survival

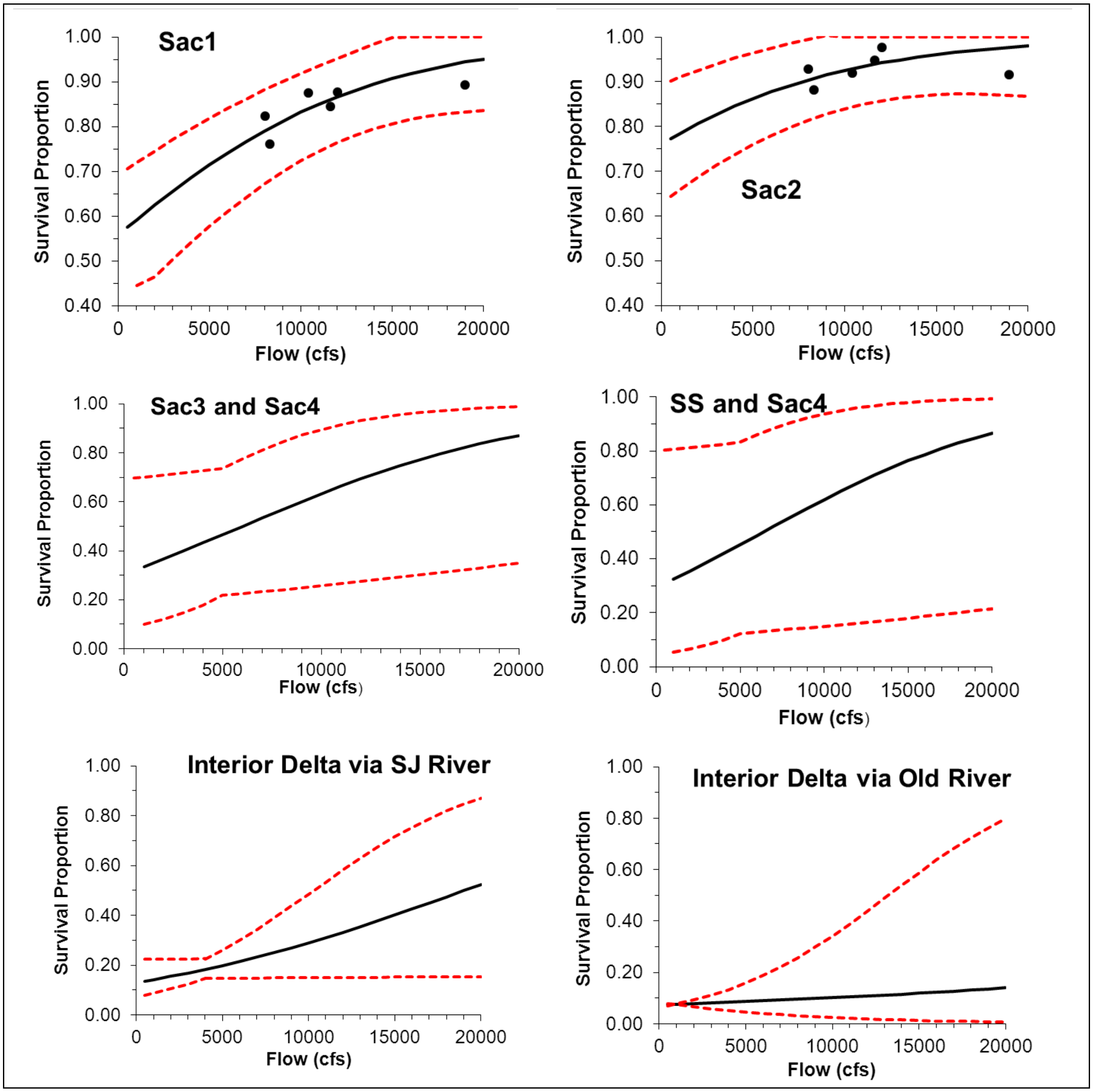
For reaches Sac1, Sac2, Sac3 and Sac4 combined, SS and Sac4 combined, Interior Delta via San Joaquin River, and Interior Delta via Old River, flow values on the day of route entry are used to predict route survival (Figure I.1-5). Perry (2010) evaluated the relationship between survival among acoustically-tagged Sacramento River smolts and Sacramento River flow measured below Georgiana Slough (DPM reach Sac3) and found a significant relationship between survival and flow during the migration period for smolts that migrated through Sutter and Steamboat Sloughs to Chipps Island (Sutter and Steamboat route; SS and Sac4 combined) and smolts that migrated from the junction with Georgiana Slough to Chipps Island (Sacramento River route; Sac3 and Sac4 combined). Therefore, for route Sac3 and Sac4 combined and route SS and Sac4 combined, the logit survival function from Perry (2010) was used to predict mean reach survival (*S*) from reach flow (*flow*):

$$S = \frac{e^{(\beta_0 + \beta_1 flow)}}{1 + e^{(\beta_0 + \beta_1 flow)}}$$

where $\beta 0$ (SS and Sac4 = -0.175, Sac3 and Sac4 = -0.121) is the reach coefficient and $\beta 1$ (0.26) is the flow coefficient, and *flow* is average Sacramento River flow in reach Sac3 during the experiment standardized to a mean of 0 and standard deviation of 1.

Perry (2010) estimated the global flow coefficient for the Sutter Steamboat route and Sacramento River route as 0.52. For the Sac3 and Sac4 combined route and the SS and Sac4 combined route, mean survival and associated standard error predicted from each flow-survival relationship is used to inform a normal probability distribution that is sampled from the day smolts enter the route to determine their route survival.

With a flow-survival relationship appearing evident for group survival data of acoustically-tagged smolts in reaches Sac1 and Sac2, Perry's (2010) relationship was applied to Sac1 and Sac2 while adjusting for the mean reach-specific survivals for Sac1 and Sac2 observed during the acoustic-tagging studies (Figure I.1-5; Table I.1-8). The flow coefficient was held constant at 0.52 and the residual sum of squares of the logit model was minimized about the observed Sac1 and Sac2 group survivals, respectively, while varying the reach coefficient. The resulting reach coefficients for Sac1 and Sac2 were 1.27 and 2.16, respectively. Mean survival and associated standard error predicted from the flow-survival relationship is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determining Sac1 and Sac2 reach survival.



For Sac1, Sac2, Sac3, and Sac4, circles are observed group survivals from acoustic-tagging studies from Perry (2010). Raw data are not available from Newman (2010) for Interior Delta via San Joaquin River and Interior Delta via Old River from Newman (2010). Solid lines are predicted mean route survival curves, and dotted lines are 95% confidence bands used to inform uncertainty.

Figure I.1-5. Route Survival as a Function of Flow Applied in Reaches Sac1, Sac2, Sac3 and Sac4 Combined, SS and Sac4 Combined, Interior Delta via the San Joaquin River, and Interior Delta via Old River.

Table I.1-8. Group Survival Estimates of Acoustically-Tagged Chinook Salmon Smolts from Perry (2010) and Associated Calculations Used to Inform Flow-Dependent Survival Relationships for Reaches Sac1 and Sac2

DPM Reach	Survival	Release Dates	Source	Survival Calculation
Sac1	0.844	12/5/06	Perry 2010	$S_{A1} * S_{A2}$
Sac1	0.876	1/17/07	Perry 2010	$S_{A1} * S_{A2}$
Sac1	0.874	12/4/07-12/6/07	Perry 2010	$S_{A1} * S_{A2}$
Sac1	0.892	1/15/08-1/17/08	Perry 2010	$S_{A1} * S_{A2}$
Sac1	0.822	11/31/08-12/06/08	Perry 2010	$S_{A1} * S_{A2}$
Sac1	0.760	1/13/09-1/19/09	Perry 2010	$S_{A1} * S_{A2}$
Sac2	0.947	12/5/06	Perry 2010	S_{A3}
Sac2	0.976	1/17/07	Perry 2010	S_{A3}
Sac2	0.919	12/4/07-12/6/07	Perry 2010	S_{A3}
Sac2	0.915	1/15/08-1/17/08	Perry 2010	S_{A3}
Sac2	0.928	11/31/08-12/06/08	Perry 2010	S_{A3}
Sac2	0.881	1/13/09-1/19/09	Perry 2010	S_{A3}

For smolts originating in the San Joaquin River that migrate through the Interior Delta via San Joaquin River or Old River, survival is modeled as a function of flow and exports as modeled by Newman (2010).

$$S_{SJ,OR} = \frac{e^{(\beta_0 + \beta_1 flow + \beta_2 \exp orts)}}{1 + e^{(\beta_0 + \beta_1 flow + \beta_2 \exp orts)}}$$

Where *SSJ*, *OR* is survival through the Interior Delta via the San Joaquin River or Old River, flow is average San Joaquin River flow downstream of the head of Old River or flow in Old River during the coded-wire tagging study standardized to a mean of 0 and standard deviation of 1, and exports is the combined export flow from the state and federal facilities in the south Delta during the study.

Exports are standardized as described for flow. Uncertainty in these parameters is accounted for by using model-averaged estimates for the intercept, flow coefficient and export coefficient (Table I.1-9; Figure I.1-5). The model-averaged estimates and their standard deviations are used to define a normal probability distribution that is resampled each day in the model. San Joaquin River flows downstream of the head of Old River that were modeled by Newman (2010) ranged from -49 cfs to 10,756 cfs, with a median of 3,180 cfs. Exports modeled by Newman (2010) ranged from 805 cfs to 10,295 cfs, with a median of 2,238 cfs.

Table I.1-9. Model Averaged Parameter Estimates and Standard Deviations Used to Describe Survival through the Interior Delta via the San Joaquin River and Old River Routes

Parameter	San Joaquin Route	Old River Route
Intercept	-1.577 (0.275)	-2.297 (0.537)
Flow	0.376 (0.289)	0.166 (0.524)
Exports	0.291 (0.290)	0.279 (0.363)

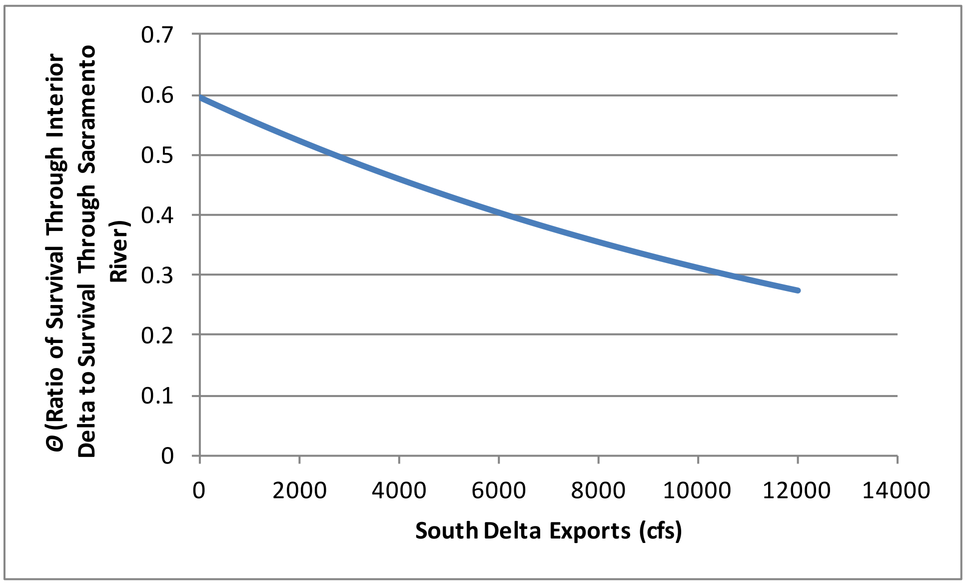
I.1.4.1.6 Export-Dependent Survival

As migratory juvenile salmon enter the Interior Delta from Geo/DCC for Sacramento races or Mokelumne River fall-run Chinook salmon, they transition to an area strongly influenced by tides and where south Delta water exports may influence survival. The export–survival relationship described by Newman and Brandes (2010) was applied as follows:

$$\theta = 0.5948 * e^{(-0.000065 * Total\_Exports)};$$

where θ is the ratio of survival between coded wire tagged smolts released into Georgiana Slough and smolts released into the Sacramento River and Total_Exports is the flow of water (cfs) pumped from the Delta from the State and Federal facilities.

θ is a ratio and ranges from just under 0.6 at zero south Delta exports to ~0.27 at 12,000-cfs south Delta exports (Figure I.1-6).



Source: Newman and Brandes 2010

Figure I.1-6. Relationship between θ (Ratio of Survival through the Interior Delta to Survival through Sacramento River) and South Delta Export Flows.

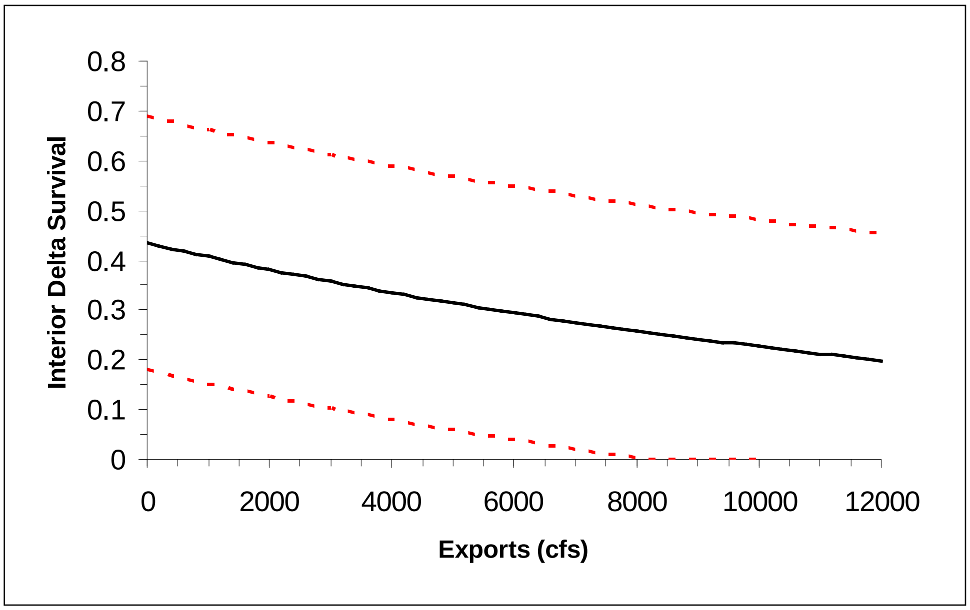
θ was converted from a ratio into a value of survival through the Interior Delta using the equation:

$$S_{ID} = \frac{\theta}{S_{Geo/DCC}} * (S_{Sac3} * S_{Sac4});$$

where S_{ID} is survival through the Interior Delta, θ is the ratio of survival between Georgiana Slough and Sacramento River smolt releases, $S_{Geo/DCC}$ is the survival of smolts in the Georgiana Slough/Delta Cross Channel reach, $S_{Sac3} * S_{Sac4}$ is the combined survival in reaches Sac 3 and Sac 4 (Figure I.1-7)[1].

Uncertainty is represented in this relationship by using the estimated value of θ and the standard error of the equation to define a normal distribution bounded by the 95% prediction interval of the model that is then re-sampled each day to determine the value of θ.

The export-dependent survival relationship for San Joaquin-origin fish was described above in the section on *Flow-Dependent Survival*.



Survival values in reaches Sac3, Sac4, and Geo/DCC were held at mean values observed during acoustic-tag studies (Perry 2010) to depict export effect on Interior Delta survival in this plot. Dashed lines are 95% prediction bands used to inform uncertainty in the relationship.

Figure I.1-7. Interior Delta Survival as a Function of Delta Exports (Newman and Brandes 2010) as Applied for Sacramento Races of Chinook Salmon Smolts Migrating through the Interior Delta via Reach Geo/DCC.

[1] Note that the Mokelumne River fall-run does not occur in the Sacramento River but daily survival values in Sac3/Sac4 are calculated in order to inform interior Delta survival for this run according to the equation above; the Sac3/Sac4 daily survival values for this run are used solely for this purpose. Although daily survivals in Sac3/Sac4 are used to calculate Sacramento River survival for Sacramento River runs (winter-run, spring-run, Sacramento fall-run, and late fall–run), the combined Sac3/Sac4 survival used to calculate Sacramento River survival would be slightly different than that used to calculate interior Delta survival because of the travel time required for smolts to reach the interior Delta via Geo/DCC.

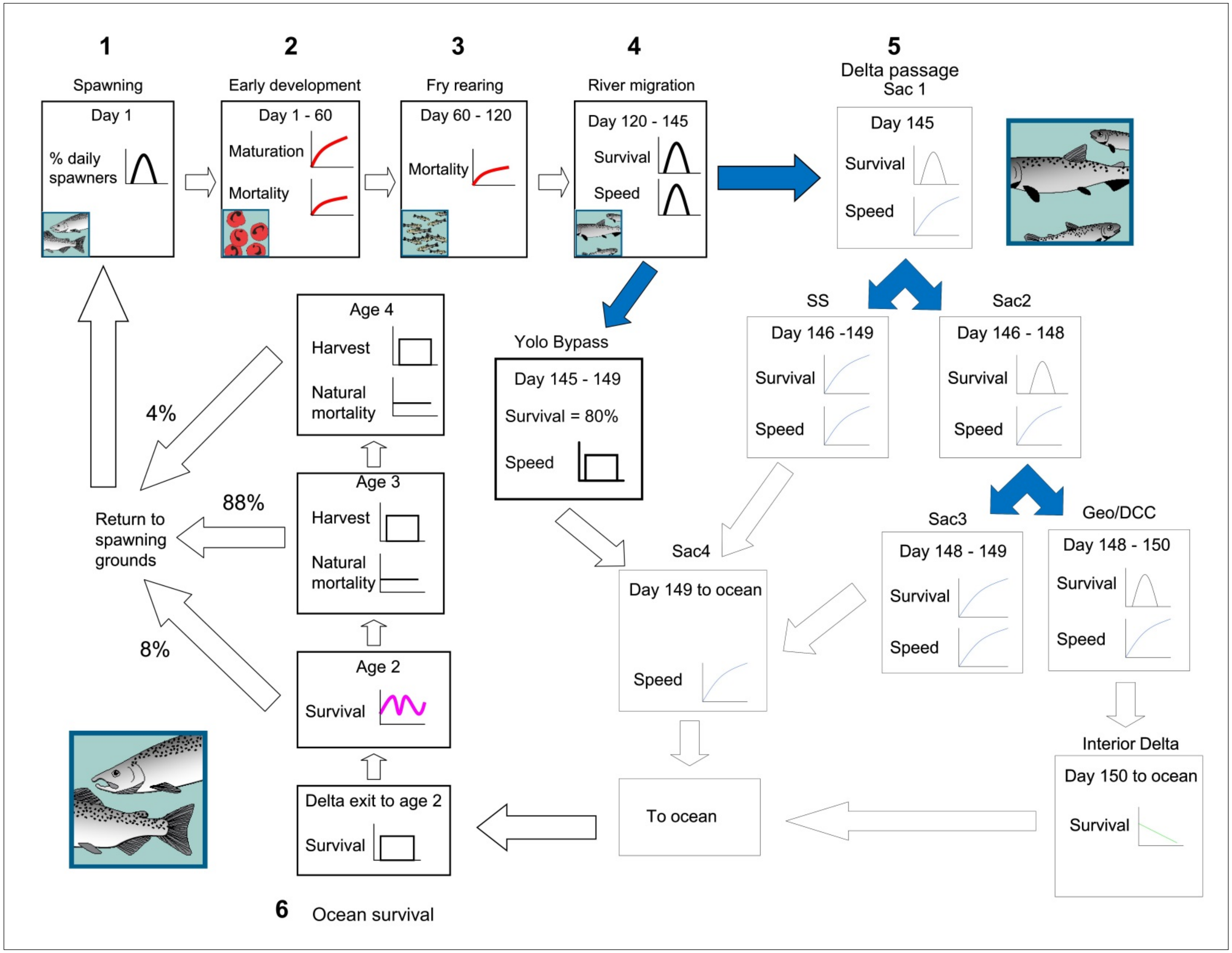
I.2 IOS Model Documentation

I.2.1 Model Structure

The Interactive Object-Oriented Simulation (IOS) Model is composed of six model stages defined by a specific spatiotemporal context and are arranged sequentially to account for the entire life cycle of winter-run Chinook salmon, from eggs to returning spawners (Figure I.2-1). In sequential order, the IOS Model stages are listed below.

1. *Spawning*, which models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds in the upper Sacramento River between Red Bluff Diversion Dam and Keswick Dam.
2. *Early Development*, which models the effect of temperature on maturation timing and mortality of eggs at the spawning grounds.
3. *Fry Rearing*, which models the relationship between temperature and mortality of fry during the river rearing period in the upper Sacramento River between Red Bluff Diversion Dam and Keswick Dam.
4. *River Migration*, which estimates mortality of migrating smolts in the Sacramento River between the spawning and rearing grounds and the Delta.
5. *Delta Passage*, which models the effect of flow, route selection, and water exports on the survival of smolts migrating through the Delta to San Francisco Bay.
6. *Ocean Survival*, which estimates the effect of natural mortality and ocean harvest to predict survival and spawning returns by age.

A detailed description of each model stage follows.



Note: Red = temperature, blue = flow, green = water exports, pink = ocean productivity.

Figure I.2-1. Conceptual Diagram of the IOS Model Stages and Environmental Influences on Survival and Development of Winter-Run Chinook Salmon at Each Stage.

I.2.1.1 *Spawning*

For the first four simulation years of the 82-year CALSIM simulation period, the model is seeded with 5,000 spawners, of which 3,087.5 are female based on the wild male to female ratio of spawners. In each subsequent simulation year, the number of female spawners is determined by the model's probabilistic simulation of survival to this life stage. To ensure that developing fish experience the correct environmental conditions during each year, spawn timing mimics the observed arrival of salmon on the spawning grounds as determined by 8 years of carcass surveys (2002–2009) conducted by the U.S. Fish and Wildlife Service (USFWS). Eggs deposited on a particular date are treated as cohorts that experience temperature and flow on a daily time step during the early development stage. The daily number of female spawners is calculated by multiplying the daily proportion of the total carcasses observed during the USFWS surveys by the total Jolly-Seber estimate of female spawners (Poytress and Carillo 2010).

(Equation 1) $Sd = CdSJS$

where, *Sd* is the daily number of female spawners, *Cd* is the daily proportion of total carcasses and *SJS* is the total Jolly-Seber estimate of female spawners.

To account for the time difference between egg deposition and carcass observations, the date of egg deposition is assumed to be 14 days prior to carcass observations (Niemela pers. comm.).

To obtain estimates of juvenile production, a Ricker stock-recruitment curve (Ricker 1975) was fit between the number of emergent fry produced each year (estimated by rotary screw–trap sampling at Red Bluff Diversion Dam) and the number of female spawners (from USFWS carcass surveys) for years 1996–1999 and 2002–2007:

(Equation 2) $R = \alpha Se\text{-}\beta S + \varepsilon$

where α is a parameter that describes recruitment rate, and β is a parameter that measures the level of density dependence.

The density-dependent parameter (β) did not differ significantly from 0 (95% CI = -6.3×10^{-6} – 5.5×10^{-6}), indicating that the relationships between emergent fry and female spawners was linear (density-independent). Therefore, β was removed from the equation and a linear version of the stock-recruitment relationship was estimated. The number of female spawners explained 86% of the variation in fry production ($F_{1,9} = 268$, $p<0.001$) in the data, so the value of α was taken from the regression:

(Equation 3) $R = 1043*S$

In the IOS Model, this linear relationship is used to predict values for mean fry production along with the confidence intervals for the predicted values. These values are then used to define a normal probability distribution, which is randomly sampled to determine the annual fry production. Although the Ricker model accounts for mortality during egg incubation, the data used to fit the Ricker model were from a limited time period (1996–1999, 2002–2007) when water temperatures during egg incubation were too cool (<14°C) to cause temperature-related egg mortality (U.S. Fish and Wildlife Service 1999). Thus, additional mortality was imposed at higher temperatures not experienced during the years used to construct the Ricker model.

I.2.1.2 *Early Development*

Data from three laboratory studies were used to estimate the relationship between temperature, egg mortality, and development time (Murray and McPhail 1988; Beacham and Murray 1989; U.S. Fish and Wildlife Service 1999). Using data from these experiments, a relationship was constructed between maturation time and water temperature. First *maturation time* (days) was converted to a *daily maturation rate* (1/day):

(Equation 4) *daily maturation rate = maturation time-1*

A significant linear relationship between maturation rate and water temperature was detected using linear regression. Daily water temperature explained 99% of the variation in *daily maturation rate* (F =2188; df =1,15; p<0.001):

(Equation 5) *daily maturation rate = 0.00058*Temp-0.018*

In the IOS Model, the daily mean maturation rate of the incubating eggs is predicted from daily water temperatures using a linear function; the predicted mean maturation rate, along with the confidence intervals of the predicted values, is used to define a normal probability distribution, which then is randomly sampled to determine the daily maturation rate. A cohort of eggs accumulates a percentage of total maturation each day from the above equation until 100% maturation is reached.

Data from experimental work (U.S. Fish and Wildlife Service 1999) was used to parameterize the relationship between temperature and mortality of developing winter-run Chinook salmon eggs. Predicted proportional mortality over the entire incubation period was converted to a daily mortality rate to apply these temperature effects in the IOS Model. This conversion was used to calculate daily mortality using the methods described by Bartholow and Heasley (2006):

(Equation 6) *mortality = 1-(1-total mortality)(1/development time)*

where *total mortality* is the predicted mortality over the entire incubation period observed for a particular water temperature and *development time* was the time to develop from fertilization to emergence.

Limited sample size (n = 3) in the USFWS study (1999) did not allow a statistically valid test for effects of temperature on mortality (e.g., a general additive model) to be performed. However, the following exponential relationship was fitted between observed *daily mortality* and observed water temperatures (U.S. Fish and Wildlife Service 1999) to provide the required values for the IOS Model:

(Equation 7) *daily mortality = 1.38*10-15e (0.503*Temp)*

Equation 7 yields the following graphic (Figure I.2-2), which indicates that proportional daily egg mortality increases rapidly with only small changes in water temperature. For example, within the predominant water temperature range found in model scenarios (55°F to 60°F), proportional daily mortality increases over ten-fold (~0.001 at 55°F to ~0.018 at 60°F).

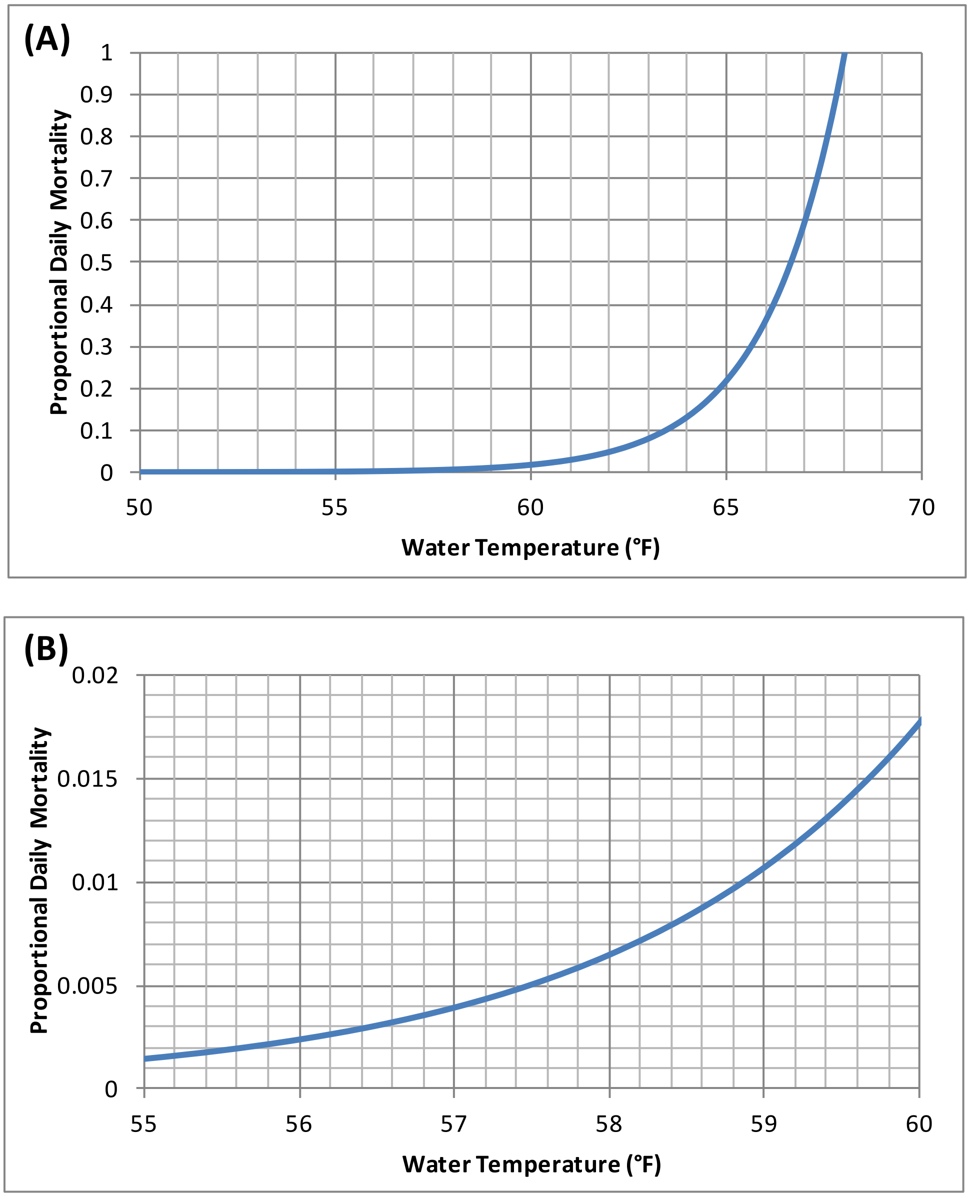


Figure I.2-2. Relationship between Proportional Daily Mortality of Winter-Run Chinook Salmon Eggs and Water Temperature (Equation 7) for (A) the Entire Temperature Range, and (B) the Predominant Range Found in Model Scenarios.

In the IOS Model, mean daily mortality rates of the incubating eggs are predicted from daily water temperatures measured at Bend Bridge on the Sacramento River using the exponential function above. The predicted mean mortality rate, along with the confidence intervals of the predicted values, is used to define a normal probability distribution, which then is randomly sampled to determine the daily egg mortality rate.

I.2.1.3 *Fry Rearing*

Data from USFWS (1999) was used to model fry mortality during rearing as a function of water temperature. Again, because of a limited sample size from the study by USFWS, statistical analyses to test for the effects of water temperature on rearing mortality could not be run. However, to acquire predicted values for the model, the following exponential relationship was fitted between observed daily mortality and observed water temperatures (U.S. Fish and Wildlife Service 1999):

(Equation 8) *daily mortality = 3.92*10-12e (0.349*Temp)*

Equation 8 yields the following graphic (Figure I.2-3), which indicates that proportional daily fry mortality increases rapidly with only small changes in water temperature. For example, within the predominant water temperature range found in model scenarios (55°F to 60°F), proportional daily mortality increases over five-fold (~0.001 at 55°F to ~0.005 at 60°F). This indicates that, although fry mortality is highly sensitive to changes in water temperature, this sensitivity is not as great as that of egg mortality within the predominant range observed in the model scenarios in focus.

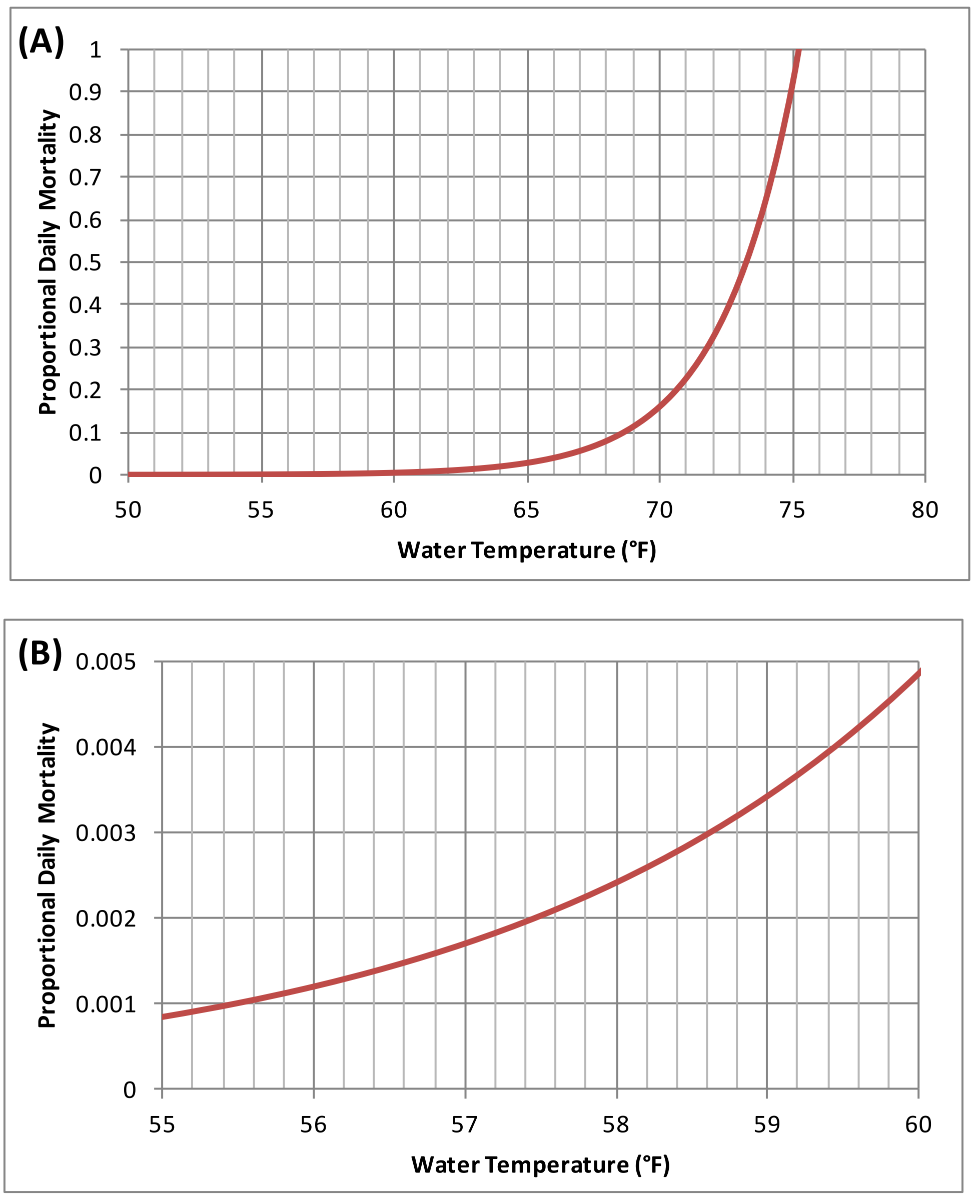


Figure I.2-3. Relationship between Proportional Daily Mortality of Winter-Run Chinook Salmon Fry and Water Temperature (Equation 8) for (A) the Entire Temperature Range, and (B) the Predominant Range Found in Model Scenarios.

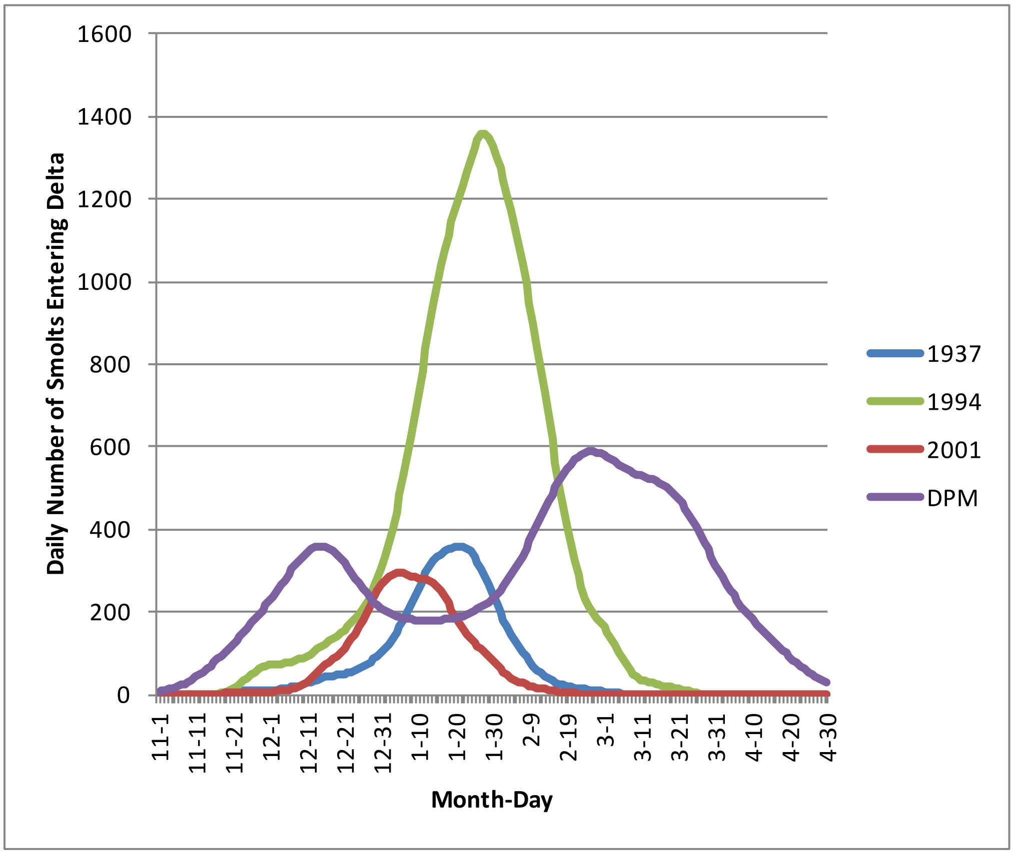
Each day the mean proportional mortality of the rearing fish is predicted from the daily water temperature using the above exponential relationship; the predicted mean mortality, along with the confidence intervals of the predicted values, is used to define a normal probability distribution, which then is randomly sampled to determine the daily mortality of the rearing fish. Temperature mortality is applied to rearing fry for 60 days, which is the approximate time required for fry to transition into smolts (U.S. Fish and Wildlife Service 1999) and enter the *River Migration* stage. All fish migrating through the Delta are assumed to be smolts.

I.2.1.4 *River Migration*

Survival of smolts from the spawning and rearing grounds to the Delta (city of Freeport on the Sacramento River) is a normally distributed random variable with a mean of 23.5% and a standard error of 1.7%. Mortality in this stage is applied only once in the model and occurs on the same day that a cohort of smolts enters the model stage because there were no data to support a relationship with flow or water temperature. Smolts are delayed from entering the next model stage to account for travel time. Mean travel time (20 days) is used along with the standard error (3.6 days) to define a normal probability distribution, which is randomly sampled to provide estimates of the total travel time of migrating smolts. Survival and travel time means and standard deviations were acquired from a study of late-fall run Chinook salmon smolt migration in the Sacramento River that employed acoustic tags and several monitoring stations (including Freeport) between Coleman National Fish Hatchery (Battle Creek) and the Golden Gate Bridge (Michel 2010).

I.2.1.5 *Delta Passage*

Winter-run Chinook salmon passage through the Delta within IOS is modeled with the DPM, which is described fully above. Note that there is one difference between the implementation of the DPM in IOS and the standalone DPM. The timing of winter-run entry into the Delta is a function of upstream fry/egg rearing and so timing changes annually, in contrast to the fixed nature of Delta entry for the standalone DPM. Also, the IOS entry distribution is a unimodal term that tends to peak between the bimodal peaks of the standalone DPM entry distribution (Figure I.2-4). As each cohort of smolts exits the final reaches of the Delta (Sac4 and the interior Delta), the cohorts accumulate until all cohorts from that year have exited the Delta. After all cohorts have arrived, they all enter the *Ocean Survival* model as a single cohort and the model begins applying mortality on an annual time step.



DPM: purple line, fixed bimodal distribution.
IOS in 1937: blue line, an average peak of January 21.
IOS in 1994: green line, a late peak of January 28.
IOS in 2001: red line, an early peak of January 4.

Figure I.2-4. Winter-Run Chinook Salmon Smolt Delta Entry Distributions Assumed under the Delta Passage Model Compared with Entry Distributions for IOS in 1937, 1994, and 2001.

I.2.1.6 *Ocean Survival*

As described by Zeug et al. (2012), this model stage uses a set of equations for smolt-to-age-2 mortality, winter mortality, ocean harvest, and spawning returns to predict yearly survival and escapement numbers (i.e., individuals exiting the ocean to spawn). Certain values during the ocean survival life stage were fixed constant among model scenarios. Ocean survival model-stage elements are listed in Table I.2-1and discussed below.

Table I.2-1. Functions and Environmental Variables Used in the Ocean Survival Stage of the IOS Model

Model Element	Environmental Variable	Value
Smolt-age 2 mortality	None	Uniform random variable between 94% and 98%
Age 2 ocean survival	Wells' Index of Ocean productivity	Equation 13
Age 3 ocean survival	None	Equation 14
Age 4 ocean survival	None	Equation 15
Age 3 harvest	None	Fixed at 17.5%
Age 4 harvest	None	Fixed at 45%

Relying on ocean harvest, mortality, and returning spawner data from Grover et al. (2004), a uniformly distributed random variable between 94% and 98% mortality was applied for winter-run Chinook salmon from ocean entry to age 2 and functional relationships were developed to predict ocean survival and returning spawners for age 2 (8%), age 3 (88%), and age 4 (4%), assuming that 100% of individuals that survive to age 4 return for spawning. In the IOS Model, ocean survival to age 2 is given by:

(Equation 13) $$A_2 = A_i(1-M_2)(1-M_w)(1-H_2)(1-S_{r2})*W$$

Survival to age 3 is given by:

(Equation 14) $$A_3 = A_2(1-M_w)(1-H_3)(1-S_{r3})$$

And survival to age 4 is given by:

(Equation 15) $$A_4 = A_3(1-M_w)(1-H_4)$$

where Ai is initial abundance at ocean entry (from the DPM stage), $A_{2,3,4}$ are abundances at ages 2–4, $H_{2,3,4}$ are harvest percentages at ages 3–4 represented by uniform distributions bounded by historical harvest levels, M_2 is smolt-to-age-2 mortality, M_w is winter mortality for ages 2–4, and $S_{r2,r3}$ are returning spawner percentages at age 2 and age 3.

Harvest mortality is represented by a uniform distribution that is bounded by historical levels of harvest. Age 2 survival is multiplied by a scalar W that corresponds to the value of Wells Index of ocean productivity. This metric was shown to significantly influence over-winter survival of age 2 fish (Wells et al. 2007). The value of Wells Index is a normally distributed random variable that is resampled each year of the simulation. In the analysis, the following values from Grover et al. (2004) were used: H_2 = 0%, H_3 = 0-39%, H_4 = 0-74%, M_2 = 94-98%, M_w = 20%, S_{r2} = 8%, and S_{r3} = 96%.

Adult fish designated for return to the spawning grounds are assumed to be 65% female and are assigned a pre-spawn mortality of 5% to determine the final number of female returning spawners (Snider et al. 2001).

I.2.1.6.1 Time Step

The IOS Model operates on a daily time step, advancing the age of each cohort/life stage and thus tracking their numerical fate throughout the different stages of the life cycle. Some variables (e.g., annual mortality estimates) are randomly sampled from a distribution of values and are applied once per year. Although a daily time step is implemented for the Delta Passage component of IOS, for the ocean phase of the life cycle, the model operates on an annual time step by applying annual survival estimates to each ocean cohort.

I.2.1.6.2 Model Inputs

Delta flows and export flow into SWP and CVP pumping plants were modeled using monthly flow output from DSM2 CALSIM II, as described above in the DPM description. Temperature data for the Sacramento River at Keswick and Balls Ferry was obtained from the SRWQM developed by the Bureau of Reclamation (Reclamation).

I.2.1.6.3 Model Outputs

Four model outputs are used to determine differences among model scenarios.

1. Egg survival: The Sacramento River between Keswick Dam and the Red Bluff Diversion Dam provides egg incubation habitat for winter-run Chinook salmon. Water temperature has a large effect on the survival of Chinook salmon during the egg incubation period by controlling mortality as well as development rate. Temperatures in this reach are partially controlled by releases of cold water from Shasta Reservoir and ambient weather conditions.
2. Fry survival: The Sacramento River between Keswick Dam and Red Bluff Diversion Dam provides rearing habitat for juvenile winter-run Chinook salmon. Water temperature can have a large effect on the survival of Chinook salmon during the fry rearing stage by controlling mortality and development rate. Temperatures in this reach are partially controlled by releases of cold water from Shasta Reservoir and ambient weather conditions.
3. Through-Delta survival: The Delta between the Fremont Weir on the Sacramento River and Chipps Island is a migration route for juvenile winter-run Chinook salmon. Flow magnitude in different reaches of the Delta influences survival and travel time through the Delta and entrainment into alternative migration routes. Fish entering the interior Delta via the Geo/DCC reach are potentially exposed to mortality from water exports in the interior Delta.
4. Escapement: Each year of the IOS Model simulation, escapement is calculated as the combined number of 2-, 3-, and 4-year-old fish that leave the ocean and migrate back into the Sacramento River to spawn between Keswick Dam and the Red Bluff Diversion Dam. These numbers are influenced by the combination of all previous life stages and the functional relationships between environmental variables and survival rates. Only the 1926–2002 water years were considered because the first four years of the CALSIM modeling (1922–1925) were used to seed the model and had fixed numbers of spawners assumed, as described above.

I.2.2 Model Limitations and Assumptions

The following model limitations and assumptions should be recognized when interpreting results.

- Other important ecological relationships likely exist but quantitative relationships are not available for integration into IOS (e.g., the interaction among flow, turbidity, and predation). To the extent that these unrepresented relationships are important and alter IOS outcomes, each alternative considered is assumed to be affected in the same way.
- For relationships that are represented in IOS, the operational alternatives considered are not assumed to alter those underlying functional relationships.
- There is a specific range of environmental conditions (temperature, flow, exports, and ocean productivity) under which functional relationships were derived. These functional relationships are assumed to hold true for the environmental conditions in the scenarios considered.
- Differential growth because of different environmental conditions (e.g., river temperature) and subsequent potential differences in survival and other factors are not directly included in the

model. Differences in survival related to growth are indirectly included to an unknown extent in flow-survival, temperature-survival, and ocean productivity-survival relationships.

- Survival and travel time during Stages 4 (River Migration) and 5 (Delta Passage) are based on studies of yearling late fall–run Chinook salmon (c. 150–170-mm fork length) (Stage 4: Michel 2010; Stage 5: Perry et al. 2010), which are appreciably larger than downstream-migrating winter-run Chinook salmon (c. 70–100-mm fork length during the peak downstream migration) (Williams 2006:101); however, differences between model scenarios do not occur during stage 4 because survival and travel time during River Migration are independent of flow.
- Juvenile winter-run Chinook salmon migrating through the Delta all are assumed to be smolts that are not rearing in the Delta.
- Between Stage 5 (Delta Passage) and Stage 1 (Spawning), the only differences in survival between model scenarios comes from random differences based on probability distributions, although some functions have been fixed at constant values to minimize these random differences. There are no modeled flow effects on adult upstream migration (e.g., attraction flows) because there are no data available for such effects to be modeled.

I.2.3 Model Sensitivity and Influence of Environmental Variables

Zeug et al. (2012) examined the sensitivity of the IOS model estimates of escapement to its input parameter values, input parameters being the functional relationships between environmental inputs and biological outputs. Although revisions have been undertaken to IOS since that time, the main points from their analysis are still likely to be valid.

Zeug et al. (2012) found that escapement of different age classes was sensitive to different input parameters (Table I.2-2). Escapement of age-2 fish (which compose 8% of the total returning fish in a given cohort) was most sensitive to smolt-to-age-2-survival and water year when considering either independent or interactive effects of these parameters, and there was also sensitivity to river migration survival when considering interactive effects of this parameter with other parameters. Escapement of age-3 fish (which compose 88% of the total returning fish in a given cohort) was sensitive to several input parameters when considering the independent effects of these parameters but was sensitive to through-Delta survival alone when considering first-order interactions between parameters. Escapement of age-4 fish (which compose 4% of the total returning fish in a given cohort) was sensitive to nearly all input parameters when considering the independent effects of these parameters, but was not sensitive to any of the parameters when considering first-order interactions between parameters (Zeug et al. 2012).

Zeug et al. (2012) also explored how uncertainty in model parameter estimates influences model output by increasing by 10–50% the variation around the mean of selected parameters that could be addressed by management actions (egg survival, fry-to-smolt survival, river migration survival, Delta survival, age-3 harvest, and age-4 harvest). They found that model output was robust to parameter uncertainty and that age-3 and age-4 harvest had the greatest coefficients of variation as a result of the uniform distribution of these parameters. Zeug et al. (2012) noted that there are limitations in the data used to inform certain parameters in the model that may be ecologically relevant but that are not sensitive in the current IOS configuration: river survival is a good example because it is based on a three-year field study of relatively low-flow conditions that does not cover the range of potential conditions that may be experienced by downstream-migrating juvenile Chinook salmon.

To understand the influence of environmental parameter inputs on escapement estimates from IOS, Zeug et al. (2012) performed three sets of simulations of a baseline condition and either a 10% increase or a 10% decrease in river flow, exports, water temperature (on the Sacramento River at Bend Bridge; see above), and ocean productivity (i.e., Wells Index; see above). They found that only 10% changes in temperature produced a statistically significant change in escapement; a 10% increase in temperature produced a far greater reduction in escapement (>95%) than a 10% decrease in temperature gave an increase in escapement (>10%). Zeug et al. (2012) suggested that the lack of significant changes in escapement with 10% changes of flow, exports, and ocean productivity may reflect the fact that these variables' relationships within the model were based on observational studies with large error estimates associated with the responses. In contrast, temperature functions were parameterized with data from controlled experiments with small error estimates. Also, Zeug et al. (2012) noted that water temperatures within the winter-run Chinook salmon spawning and rearing area are close to the upper tolerance limit for the species; therefore, even small changes have the potential to significantly affect the population.

Table I.2-2. Sobol' Sensitivity Indices (Standard Deviation in Parentheses) for Each Age Class of Returning Spawners Based on 1,000 Monte Carlo Iterations, Conducted to Test Sensitivity of IOS Input Parameters by Zeug et al. (2012)

Input Parameter	Age 2		Age 3		Age 4	
	Main Index (Effect Independent of Other Input Parameters)	Total Index (Effect Accounting for First-Order Interactions with Other Input Parameters)	Main Index (Effect Independent of Other Input Parameters)	Total Index (Effect Accounting for First-Order Interactions with Other Input Parameters)	Main Index (Effect Independent of Other Input Parameters)	Total Index (Effect Accounting for First-Order Interactions with Other Input Parameters)
Water year	0.300[a] (0.083)	0.306[a] (0.079)	0.181[a] (0.091)	0.150 (0.091)	0.073 (0.067)	0.012 (0.065)
Egg survival	0.030 (0.016)	-0.006 (0.016)	0.222[a] (0.081)	-0.021 (0.081)	0.102[a] (0.044)	-0.072 (0.044)
Fry-to-smolt survival	0.039 (0.020)	-0.009 (0.020)	0.166 (0.090)	0.091 (0.092)	0.079a (0.017)	-0.071 (0.017)
River migration survival	0.007 (0.034)	0.135a (0.034)	0.164 (0.084)	0.062 (0.085)	0.079 (0.018)	-0.07 (0.018)
Delta survival	0.010[a] (0.002)	-0.009 (0.002)	0.404[a] (0.180)	0.643[a] (0.177)	0.313[a] (0.134)	-0.009 (0.132)
Smolt to age 2 survival	0.734[a] (0.118)	0.454[a] (0.113)	0.015 (0.016)	-0.006 (0.016)	0.057a (0.017)	-0.052 (0.017)
Ocean productivity	0.003 (0.009)	0.009 (0.009)	0.034[a] (0.015)	-0.034 (0.015)	0.061[a] (0.030)	-0.048 (0.029)
Age 3 harvest	N/A	N/A	0.029[a] (0.001)	-0.028 (0.001)	1.48[a] (0.306)	0.188 (0.293)
Age 4 harvest	N/A	N/A	N/A	N/A	0.055a (0.003)	-0.054 (0.003)

Source: Zeug et al. 2012.

[a] Index value was statistically significant at α=0.05.

I.3 Methods for the Science Integration Team (SIT) Model Floodplain Inundation Habitat Analyses for the Rivers and Bypasses

I.3.1 Sacramento River

The entire area of potential juvenile Chinook salmon rearing habitat, including the 253.3 miles of Sacramento River channel and its floodplain, was modeled using the Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS hydraulic model, refined for use in the NOAA-NMFS Winter Run Chinook Salmon life cycle model. The surface area of the active river channel was subtracted from total inundated area to estimate the inundated floodplain area. Using CalSim II estimates of Sacramento River flow, the CVFED model maps the area inundated at each flow and provides fine-scale, spatially explicit estimates of flow velocity, depth and roughness for the entire inundated area. The model sums the surface areas of all locations (cells) possessing high quality velocity and depth conditions for rearing Chinook salmon juveniles, as defined in Table I.3-1.

Table I.3-1. Habitat Variables Influencing Capacity for Each Habitat Type

Habitat type	Variable	Habitat* quality*	Variable range
Mainstem	Velocity	High	<= 0.15 m/s
		Low	> 0.15 m/s
	Depth	High	> 0.2 m, <= 1 m
		Low	<= 0.2 m, > 1 m
	Roughness	High	> 0.04
		Low	<= 0.04

* Ranges of high and low habitat quality were based on published studies of habitat use by Chinook salmon fry across their range.

The rearing habitat surface areas were estimated for the four major CVPIA reaches of the Sacramento River, described as follows (the CalSim II node used to model flow for the reach is given in parentheses):

- Upper Sacramento River (CalSim Node = C104). Keswick Dam to Red Bluff, 59.3 miles.
- Upper-mid Sacramento River (CalSim Node = C115). Red Bluff to Wilkins Slough, 122.3 miles.
- Lower-mid Sacramento River (CalSim Node = C134 and Node C160). Wilkins Slough to the American River confluence, 58.0 miles.
- Lower Sacramento River (CalSim Node = C166). American River confluence to Freeport, 13.7 miles.

Note that these reaches are different than those that were used for the Sacramento River CVFED modeling, which are: Keswick Dam to Battle Creek (28.9 miles), Battle Creek to the Feather River confluence (186.5 miles), and the Feather River confluence to Freeport (33.9 miles). The rearing habitat surface area results from the modeling for these three reaches were scaled using the proportional overlap (in river miles) between them and the CVPIA reaches. For example, the results for the first CVPIA reach, Keswick Dam to Red Bluff (59.3 miles), were computed as the sum of the results from the first modeling reach, Keswick Dam to Battle Creek (28.9 miles), and 0.163 times the results from the second modeling reach, Battle Creek to the Feather River confluence (186.5 miles). The results for the Battle Creek to the Feather River confluence are multiplied by 0.163 because 0.163 is the channel distance from Keswick to Red Bluff minus the channel from Keswick to Battle Creek (59.3-28.9 = 30.4) divided by the distance from Battle Creek to the Feather River confluence, 186.5.

I.3.2 American River

The entire area of potential juvenile Chinook salmon rearing habitat, including the 22.81 miles of the lower American River channel and its floodplain, was modeled using the CVFED HEC-RAS hydraulic model. The active channel surface area of 670.2 acres, estimated through remote sensing analysis, was subtracted from total inundated area to estimate the inundated floodplain area. Juvenile Chinook salmon rearing habitat quality was not determined for the modeled area, so the surface area of high quality habitat was assumed to be 27 percent of the total inundated area, based on results from the San Joaquin River, reported in SJRRP (2012).

I.3.3 Stanislaus River

The entire area of potential juvenile Chinook salmon rearing habitat, including the 60.31 miles of lower Stanislaus River channel and its floodplain, was modeled using the SRH-2D hydraulic model. The active channel area of 409.1 acres, estimated through remote sensing analysis, was subtracted from total inundated area to estimate the inundated floodplain area. Juvenile Chinook salmon rearing habitat quality was not determined for the modeled area, so the surface area of high quality habitat was assumed to be 27 percent of the total inundated area, based on results from the San Joaquin River, reported in SJRRP (2012).

I.3.4 San Joaquin River

The entire area of potential juvenile Chinook salmon rearing habitat in the San Joaquin River, including the 45.68 miles of river channel and its floodplain, was modeled using Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS hydraulic model (for Combined Upper and Lower San Joaquin River). The active channel area of 534.2 acres, estimated through remote sensing analysis, was subtracted from total inundated area to estimate inundated floodplain area. Juvenile Chinook salmon rearing habitat quality was not determined for the modeled area, so the surface area of high quality habitat was assumed to be 27 percent of the total inundated area, based on results from a San Joaquin River Restoration Program study SJRRP (2012).

I.3.5 Yolo Bypass

The entire area of potential juvenile Chinook salmon rearing habitat within the Yolo Bypass; including stream channels, ponds, canals, and ditches, and the floodplain; was modeled using the Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS hydraulic model, refined for use in the NOAA-NMFS Winter Run Chinook Salmon life cycle model. The surface areas of the stream channels, ponds, canals and ditches was subtracted from total inundated area to estimate the inundated floodplain area. Using CalSim II estimates of Yolo Bypass flow, the CVFED model maps the area inundated at each flow and provides fine-scale, spatially explicit estimates of flow velocity, depth and roughness for the entire inundated area. The model sums the surface areas of all locations (cells) possessing high quality velocity and depth conditions for rearing Chinook salmon juveniles, as defined in Table I.3-1.

The rearing habitat surface areas were estimated for two major reaches of the Yolo Bypass: Fremont Weir to the Sacramento Weir, and the Yolo Bypass downstream of the Sacramento Weir. The CalSim II nodes used to represent flow in these two reaches are D160 and C157, respectively.

I.3.6 Sutter Bypass

The entire area of potential juvenile Chinook salmon rearing habitat within the Sutter Bypass; including stream channels, basins, ponds, canals, and ditches, and the floodplain; was modeled using the Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS hydraulic model, refined for use in the NOAA-NMFS Winter Run Chinook Salmon life cycle model. The surface areas of the stream channels, basins, ponds, canals and ditches was subtracted from total inundated area to estimate the inundated floodplain area. Using CalSim II estimates of Sutter Bypass flow, the CVFED model maps the area inundated at each flow and provides fine-scale, spatially explicit estimates of flow velocity, depth and roughness for the entire inundated area. The model sums the surface areas of all locations (cells) possessing high quality velocity and depth conditions for rearing Chinook salmon juveniles, as defined in Table I.3-1.

The rearing habitat surface areas were estimated for four major reaches of the Sutter Bypass: upstream of Moulton Weir, Moulton Weir to Colusa Weir, Colusa Weir to Tisdale Weir, and downstream of Tisdale Weir. The CalSim II nodes used to represent flow in these four reaches are D117, C135, C136A, and C137, respectively.

I.4 Weighted Usable Area Modeling

I.4.1 Spawning Habitat Weighted Usable Area

The weighted usable area (WUA) is an index of the surface area of physical habitat available, weighted by the suitability of that habitat. WUA curves are normally developed as part of instream flow incremental methodology (IFIM) studies. The WUA curves used for Chinook salmon and CCV steelhead spawning habitat in the Sacramento River were obtained from two U.S. Fish and Wildlife Service (USFWS) reports (U.S. Fish and Wildlife Service 2003a, 2006). As noted above, WUA is computed as the surface area of physical habitat available weighted by its suitability. Modeling assumptions used to derive WUA curves include that the suitability of physical habitat for salmon and steelhead spawning is largely a function of substrate particle size, water depth, and flow velocity. The race- or species-specific suitability of the habitat with respect to these variables is determined by observing the fish and is used to develop habitat suitability criteria (HSC) for each race or species of fish. Hydraulic modeling is then used to estimate the amount of habitat available for different HSC levels at different river flows, and the results are used to develop spawning habitat WUA curves (Bovee et al. 1998). The WUA curves and tables are used to look up the amount of spawning WUA available at different flows.

USFWS 2003a provides WUA curves and tables for spawning winter-run, fall-run, and late fall–run Chinook salmon and CCV steelhead for three segments of the Sacramento River encompassing the reach from Keswick Dam to Battle Creek (Figure I.4-1). The WUA tables were updated in USFWS 2006. No WUA curves were developed for spring-run Chinook salmon, but, as discussed later, the fall-run curves were used to quantify spring-run spawning habitat.

Figure I.4-2 through Figure I.4-5 show the flow versus spawning WUA results for winter-run, fall-run, and late fall-run Chinook salmon and CCV steelhead in the three river segments (Segment 6 = Keswick to Anderson-Cottonwood Irrigation District [ACID] Dam, Segment 5 = ACID Dam to Cow Creek, and Segment 4 = Cow Creek to Battle Creek) as provided in USFWS 2006 (Figure 5.D-86). Note that for Segment 6, separate WUA curves were developed for periods when the ACID Dam boards were installed (April through October) and for when the boards were out because installation of the boards affects water depths and velocities for some of the sampling transects used to develop the curves.

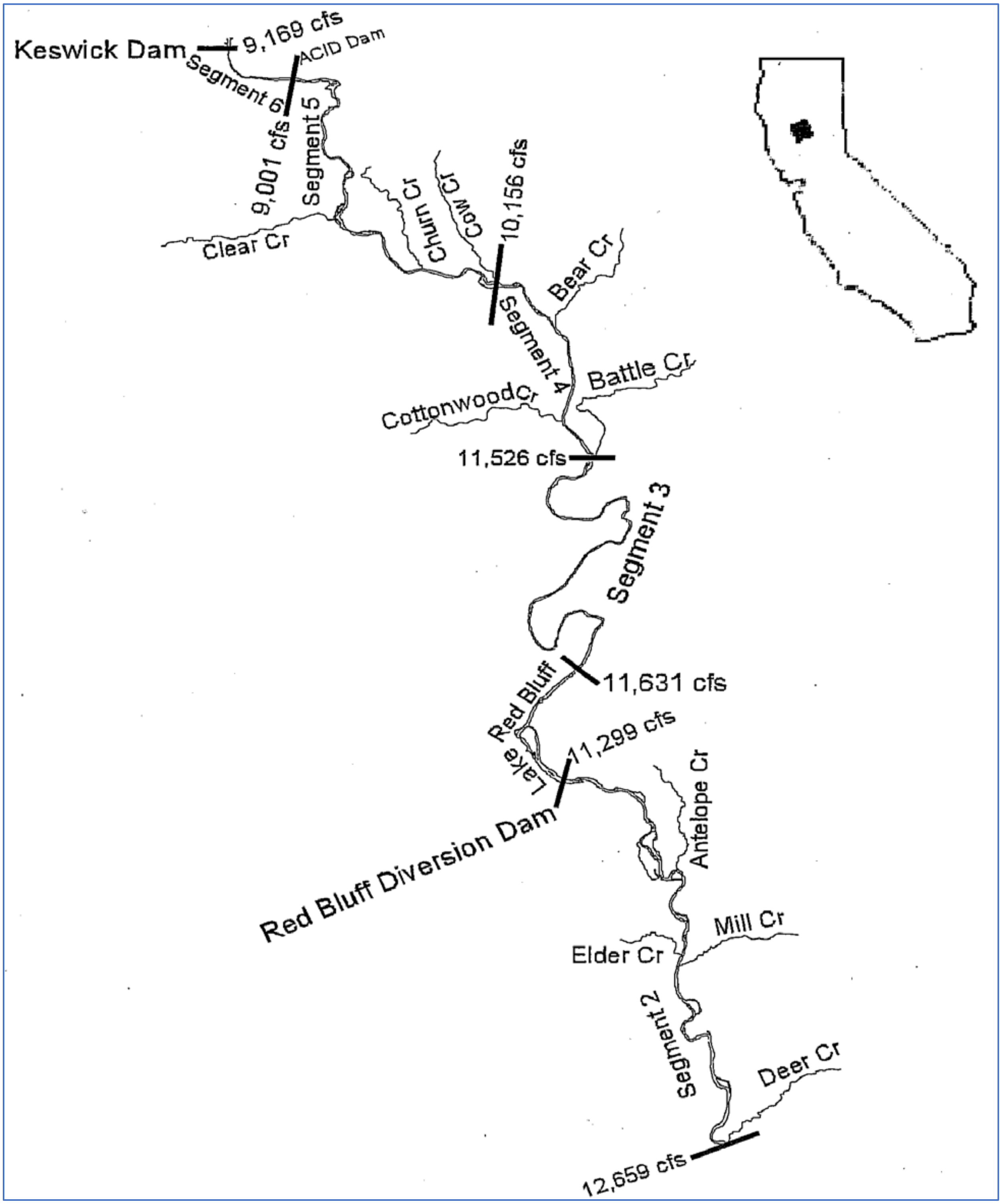


Figure I.4-1. Segments 2–6 of the Sacramento River Used in USFWS Studies to Determine Spawning Weighted Usable Area (WUA) (flows in the figure are the average flows at the upstream boundary of each segment for October 1974 to September 1993). Source: USFWS 2003a.

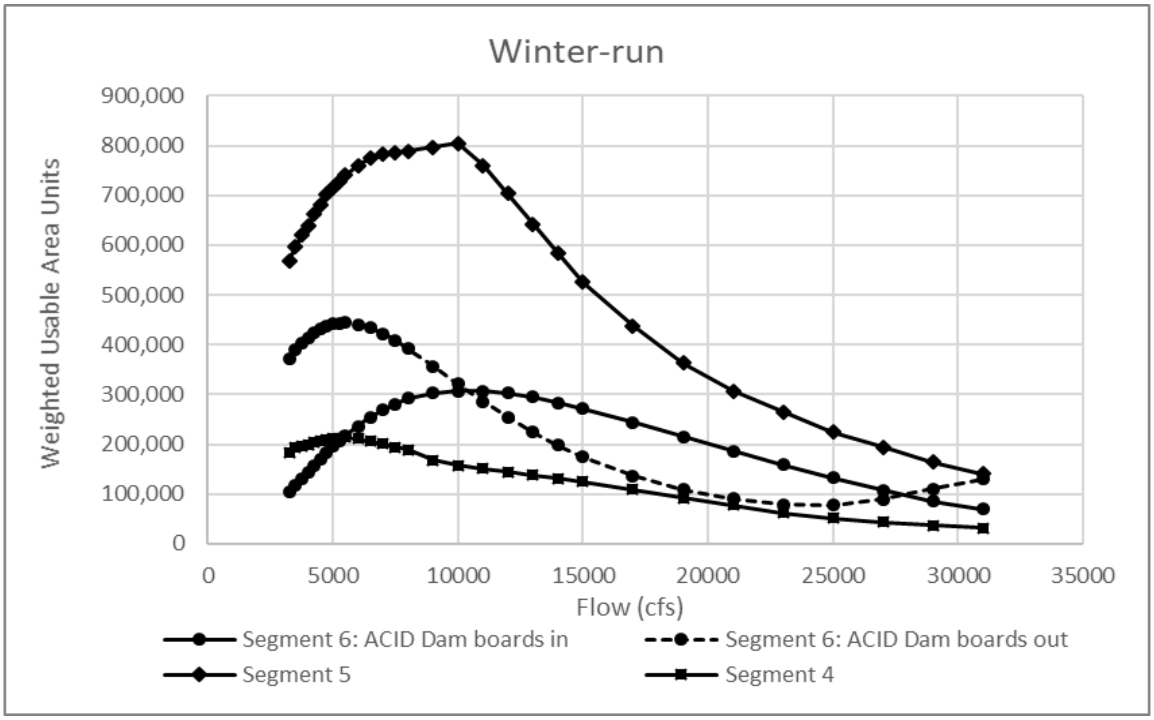


Figure I.4-2. Spawning WUA Curves for Winter-Run Chinook Salmon in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District Irrigation District.

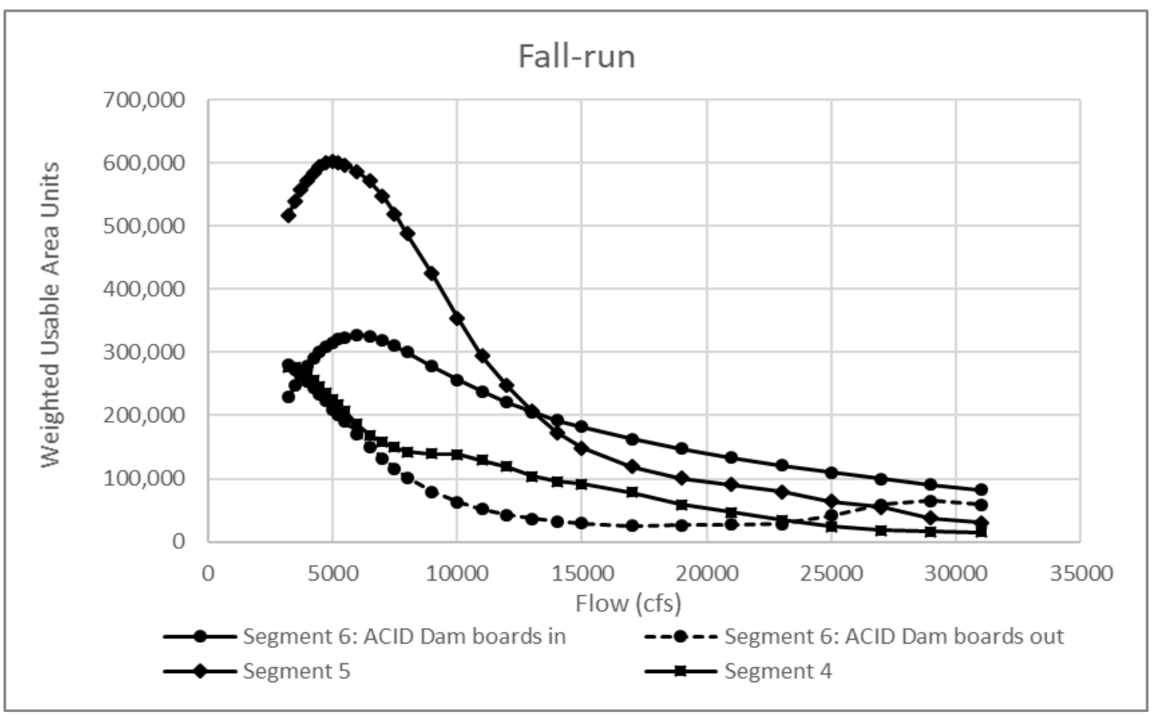


Figure I.4-3. Spawning WUA Curves for Fall-Run Chinook Salmon in the Sacramento River, Segments 4 to 6. The fall-run curves were also used to quantify spring-run Chinook salmon WUA, as discussed in the text. ACID = Anderson-Cottonwood Irrigation District.

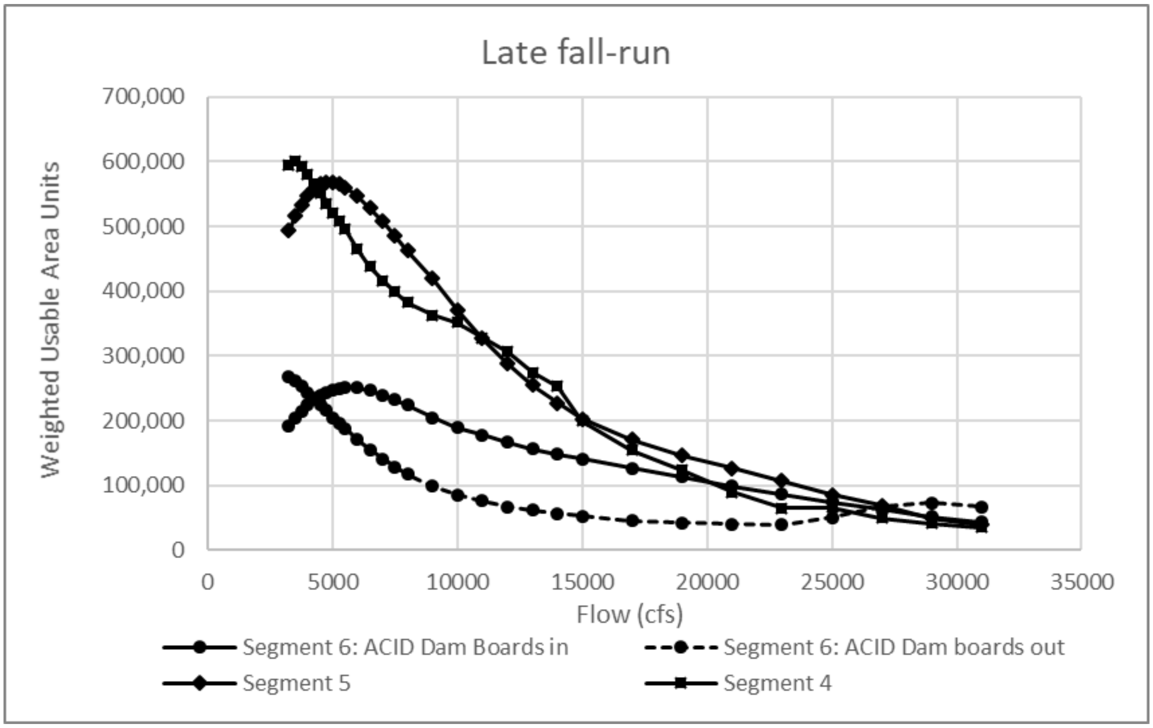


Figure I.4-4. Spawning WUA Curves for Late Fall-Run Chinook Salmon in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

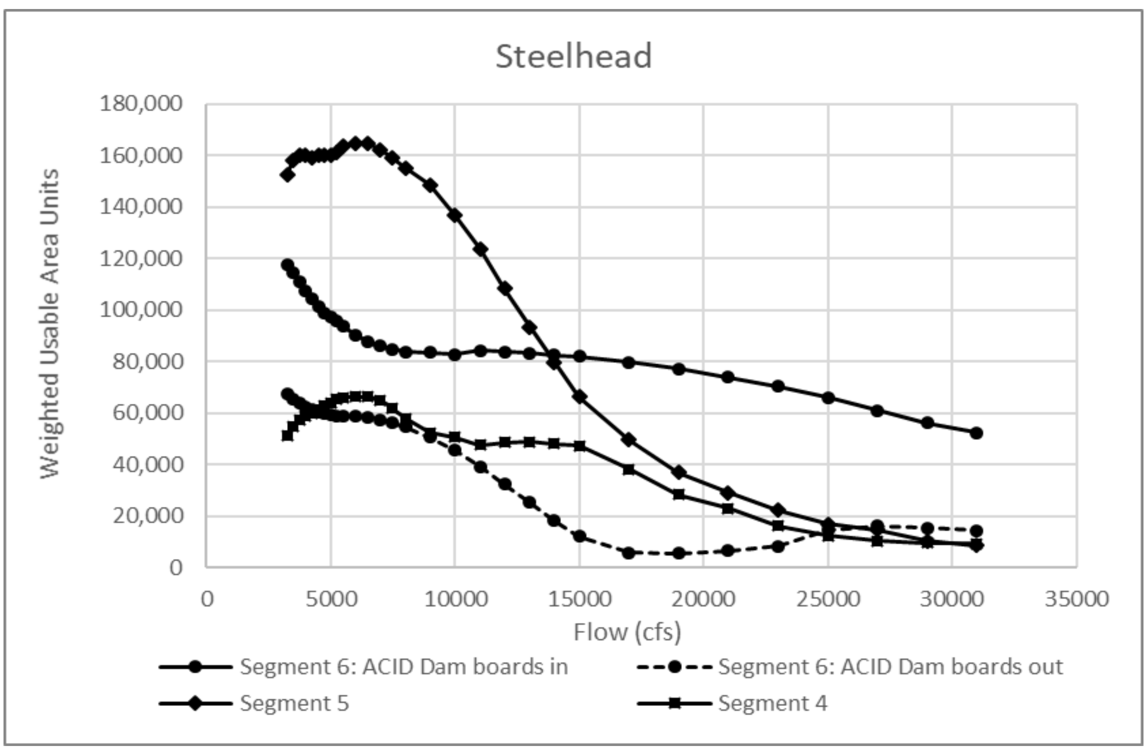


Figure I.4-5. Spawning WUA Curves for California Central Valley Steelhead in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

To estimate WUA, the segment flows were estimated using Sacramento River CALSIM II flows at Keswick Dam under the project scenarios. For Segment 6, the WUA curves for the months when the ACID Dam boards are installed (April through October) were used with CALSIM II flows for those months and the WUA curves for the months when the ACID Dam boards are out were used with the flows for the rest of the year.

Although fall-run spawning WUA curves were used as surrogates for spring-run spawning, CALSIM II flows for the months of spring-run spawning, not those of fall-run spawning, were used to compute the spring-run WUA results.

Because there are no spring-run Chinook salmon WUA curves in the USFWS documentation, previous practice, as described below, has been to use fall-run Chinook salmon WUA curves to model spring-run habitat. Two models that currently produce spawning WUA outputs for spring-run Chinook salmon, SALMOD and SacEFT, derive the spring-run WUA results using the fall-run Chinook salmon spawning WUA curves as surrogates (Bartholow 2004; ESSA 2011). Mark Gard, who led the USFWS studies that produced the Sacramento River WUA curves, has endorsed this practice (Gard pers. comm.). However, this practice introduces uncertainty to the spring-run Chinook salmon results.

A potential limitation of the WUA curves presented above, as of all IFIM studies, is that they assume the channel characteristics of the river during the time of field data collection by USFWS (1995–1999), such as proportions of mesohabitat types, have remained in dynamic equilibrium to the present time and will continue to do so through the end of the project in question. If the channel characteristics substantially change, the shape of the curve may no longer be applicable.

A further limitation of the WUA curves for CCV steelhead is that the HSC used in developing the curves was obtained from previous studies of steelhead in the American River (USFWS 2003b). HSC data were not collected by USFWS for steelhead in the Sacramento River because very few steelhead redds were observed and because the steelhead redds could not be distinguished from those of resident rainbow trout. The validity of this substitution could not be tested and is uncertain (USFWS 2003a).

I.4.2 Rearing Habitat Weighted Usable Area Analysis

The rearing habitat weighted usable area (WUA) curves used for Chinook salmon rearing habitat in the Sacramento River were obtained from a U.S. Fish and Wildlife Service (USFWS) report (U.S. Fish and Wildlife Service 2005b). As noted above for spawning habitat, WUA is computed as the surface area of physical habitat available weighted by its suitability. Modeling assumptions used to derive rearing WUA curves include that the suitability of physical habitat for salmon and steelhead rearing is largely a function of water depth, flow velocity, and the availability and type of cover. The race- or species-specific suitability of the habitat with respect to these variables is determined by observing the fish and is used to develop habitat suitability criteria (HSC) for each race or species. Hydraulic modeling is then used to estimate the amount of rearing habitat available for different HSC levels at different river flows, and the results are used to develop rearing habitat WUA curves and tables (Leclerc et al. 1995; Bovee et al. 1998). These curves and tables are used to look up the amount of WUA available at different flows.

USFWS (2005b) provides WUA curves and tables for rearing winter-run, fall-run, and late fall–run Chinook salmon for three segments of the Sacramento River described above that encompass the reach from Keswick Dam to Battle Creek (Figure I.4-1). Separate curves were developed for fry and juveniles, with fry defined as fish less than 60 millimeters and juveniles defined as greater than 60 millimeters. No WUA curves were developed for spring-run Chinook salmon or CCV steelhead, but, as discussed later, the fall-run curves were used to quantify spring-run rearing habitat and the late fall-run curves were used for steelhead. Figures I.4-6 through I.4-11 show the flow versus rearing WUA results for fry and juvenile winter-run, fall-run, and late fall-run Chinook salmon as provided in USFWS 2006. Note that for Segment 6, separate WUA curves were developed for periods when the ACID Dam boards are installed (April through October) and for when the boards are out because installation of the boards affects water depths and velocities for some of the sampling transects used to develop the curves. All rearing WUA analyses were limited to juveniles less than a year old.

To estimate WUA, the segment flows were estimated using Sacramento River CALSIM II flows at Keswick Dam under the project scenarios. For Segment 6, the WUA curves for the months when the ACID Dam boards are installed (April through October) were used with CALSIM II flows for those months and the WUA curves for the months when the ACID Dam boards are out were used with the flows for the rest of the year.

Although fall-run rearing WUA curves were used as surrogates for spring-run rearing, CALSIM flows for the months of spring-run rearing, not those of fall-run rearing, were used to compute the spring-run WUA results. This caveat applies as well to the use of the late fall-run rearing WUA curves to compute CCV steelhead WUA results.

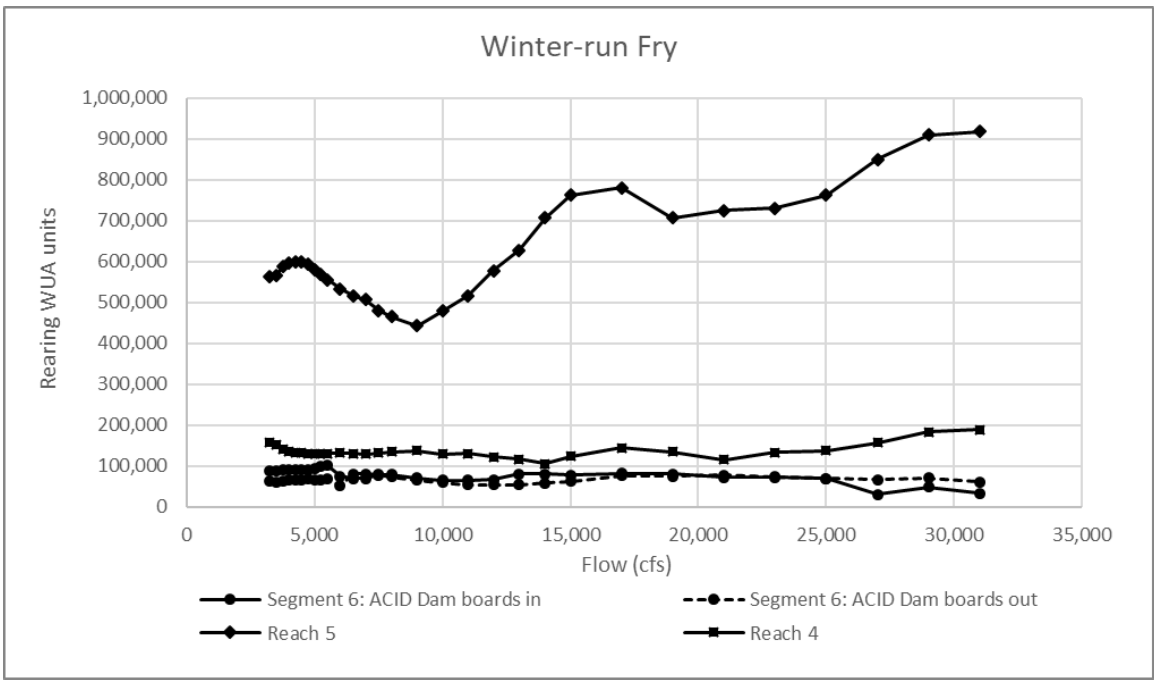


Figure I.4-6. Rearing WUA Curves for Winter-Run Chinook Salmon Fry in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

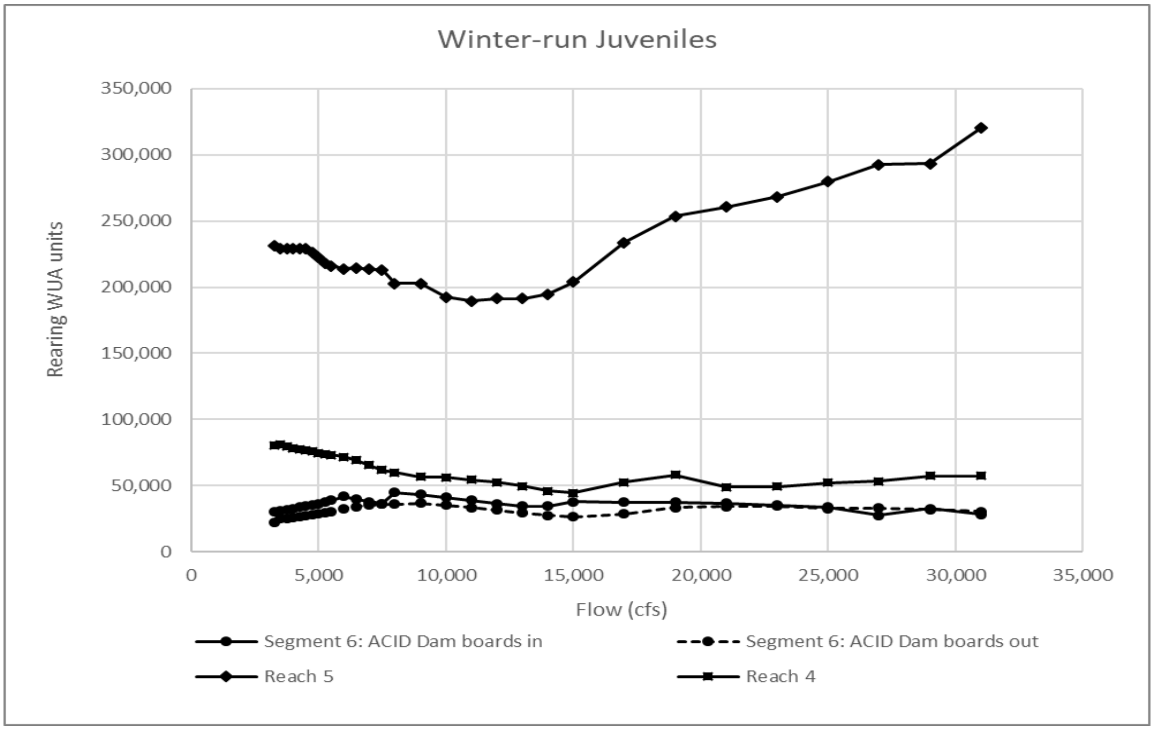


Figure I.4-7. Rearing WUA Curves for Winter-Run Chinook Salmon Juveniles in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

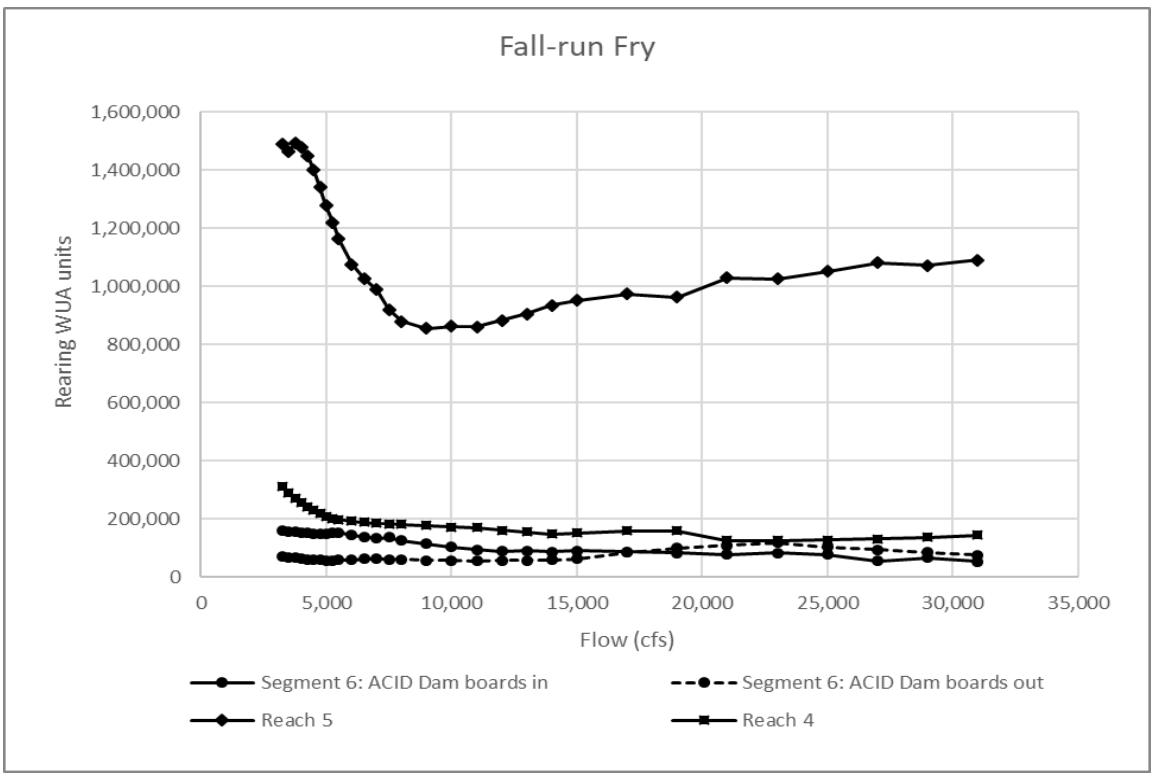


Figure I.4-8. Rearing WUA Curves for Fall-Run Chinook Salmon Fry in the Sacramento River, Segments 4 to 6. (The fall-run curves were used to quantify spring-run Chinook salmon WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

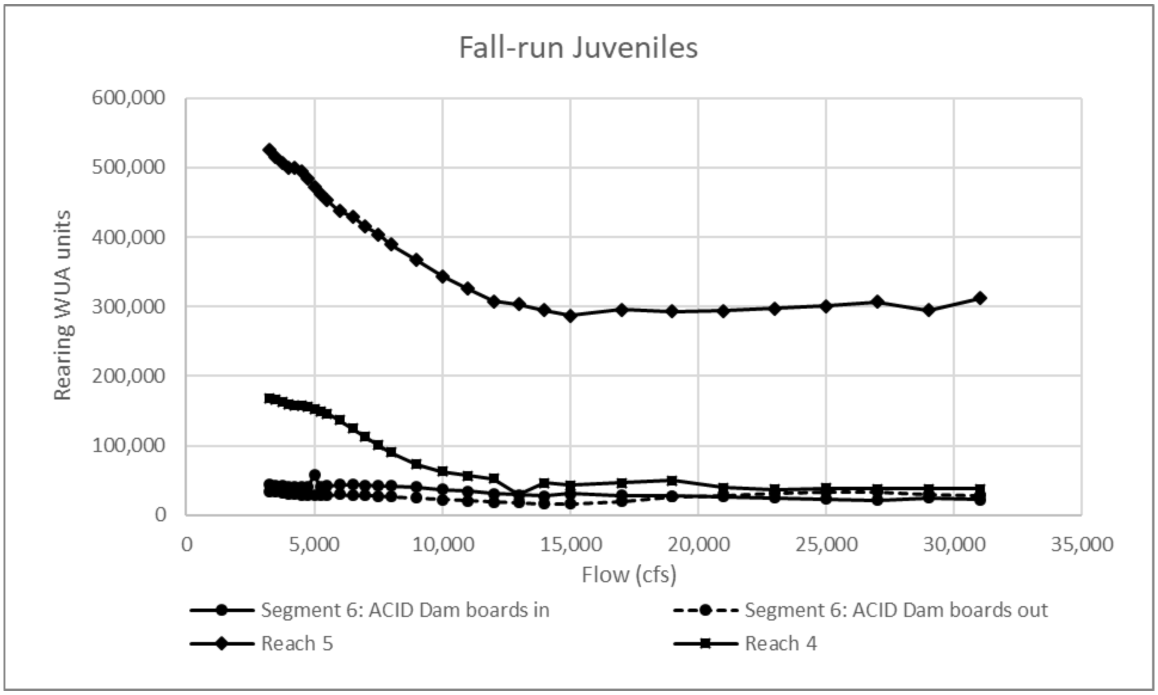


Figure I.4-9. Rearing WUA Curves for Fall-Run Chinook Salmon Juveniles in the Sacramento River, Segments 4 to 6. (The fall-run curves were used to quantify spring-run Chinook salmon WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

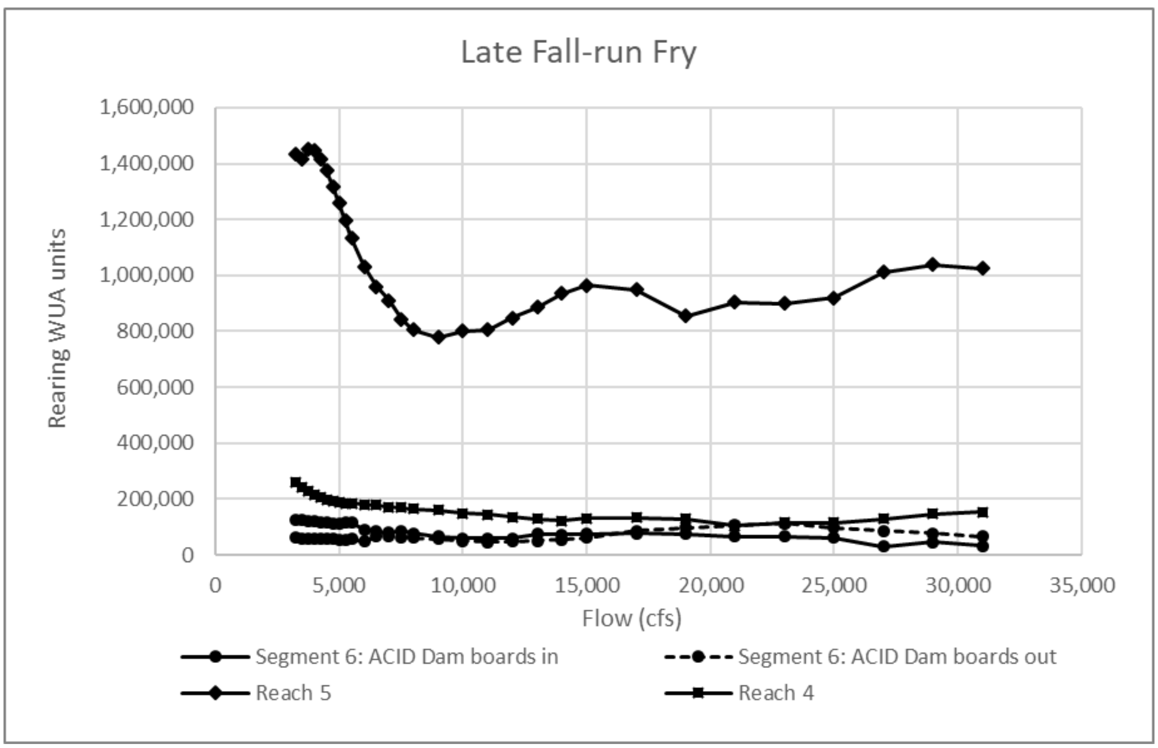


Figure I.4-10. Rearing WUA Curves for Late Fall-Run Chinook Salmon Fry in the Sacramento River, Segments 4 to 6. (The late fall-run curves were used to quantify CCV steelhead rearing WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

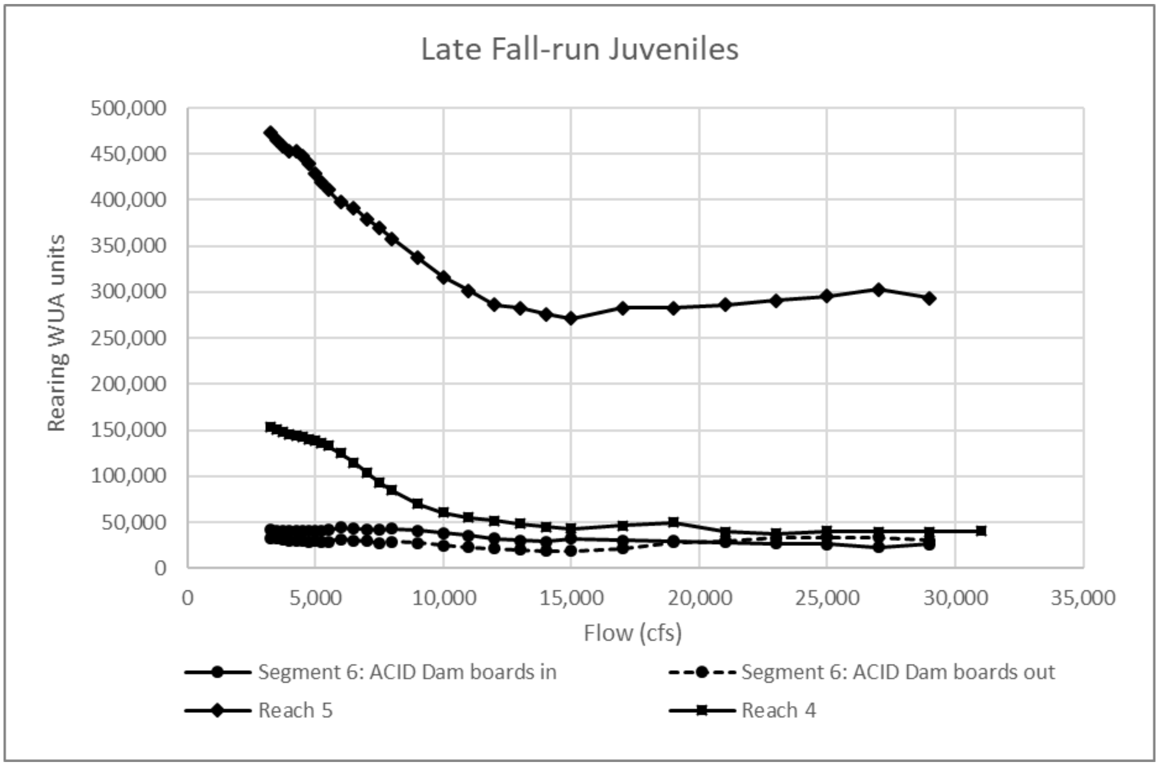


Figure I.4-11. Rearing WUA Curves for Late Fall-Run Chinook Salmon Juveniles in the Sacramento River, Segments 4 to 6. (The late fall-run curves were used to quantify CCV steelhead rearing WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

As noted above, there are no spring-run Chinook salmon or CCV steelhead rearing WUA curves in the USFWS documentation, so the fall-run and late fall-run Chinook salmon rearing WUA curves were used as surrogates to model rearing habitat for spring-run and steelhead, respectively. These substitutions follow previous practice. For instance, the SacEFT model, which produces spawning and rearing WUA outputs for spring-run Chinook salmon and CCV steelhead, derives the spring-run WUA results using the fall-run Chinook salmon WUA curves as surrogates and the CCV steelhead WUA results using the late fall-run Chinook salmon WUA curves as surrogates (ESSA 2011; Robinson pers. comm.). Mark Gard, who led the USFWS studies that produced the Sacramento River WUA curves, has endorsed this practice for both spring-run Chinook salmon and CCV steelhead (Gard pers. comm.). It should be noted that this practice introduces additional uncertainty to the spring-run Chinook salmon and CCV steelhead results.

A potential limitation of the WUA curves presented above, as of all IFIM studies, is that they assume the channel characteristics of the river during the time of field data collection by USFWS (1995–1999), such as proportions of mesohabitat types, have remained in dynamic equilibrium to the present time and will continue to do so through the end of the project in question. If the channel characteristics substantially change, the shape of the curves may no longer be applicable. A further limitation is that the curves were developed for the Sacramento River upstream of Battle Creek, but all races of Chinook salmon and CCV steelhead spend time rearing downstream of this part of the river.

I.5 Salvage-Density Method

The salvage-density method relies on salvage data and was used to estimate changes in entrainment at the SWP/CVP export facilities. The same basic method has been used in recent effects analyses (e.g., the DMC/California Aqueduct Intertie [Bureau of Reclamation 2009]), with refinements as necessary for the present analysis. ***Note that the method essentially functions as a description of changes in export flows weighted by seasonal changes in salvage density of covered species; although it generates estimates of numbers of fish lost, these estimates should only be used to compare one operational scenario to another (i.e., proposed action [PA] vs. no action alternative [NAA]) in order to get a sense of how south Delta exports differ during the period of Delta occurrence of NMFS-managed fishes***[2]**.**

I.5.1 Preprocessing of Input Data

Historical monthly export data (acre-feet) for water years 1995–2009 were obtained from Reclamation's Central Valley Operations Total Tracy Pumping web page (http://www.usbr.gov/mp/cvo/vungvari/tracy_pump.pdf) and California Department of Water Resources' (DWR's) State Water Project Annual Reports of Operations (http://www.water.ca.gov/swp/operationscontrol/annual.cfm). Historical monthly salvage data for the water years 1995–2009 were provided by Sheila Greene (DWR) for all species (S. Greene pers. comm.). (Water year 2009 was excluded for some species because the data were not complete.) These data are expanded salvage data, i.e., the extrapolated estimates of the total number of fish salvaged based on a subsample that was actually identified, counted, and measured. These data provided the basic estimates of fish density (number of fish salvaged per volume of water exported) that were subsequently multiplied by simulated export data for the CALSIM modeling period (1922–2003) to assess differences between NAA and scenarios, as described in Appendix 5.B, *DSM Methods and Results*. It is acknowledged that expanded salvage estimates have inherent statistical error associated with the expansion of subsamples (Jahn 2011) but, consistent with typical analyses employing these data (e.g., Grimaldo et al. 2009), this statistical error has not been accounted for in the current salvage-density method. The salvage-density method does not account for spatial distribution of the fish populations, which could differ between NAA and PA because of other operational factors (e.g., north Delta diversions), and assumes a linear relationship between entrainment and export flows. The assumption of a linear relationship is made because of the lack of information on how salvage would increase with increasing flows. One study that examined entrainment in relation to export rate was that of Kimmerer (2008), who showed for hatchery-released Chinook salmon that percentage salvage or percentage entrainment loss was roughly linear up to total south Delta export flows of around 250–275 cubic meters/sec (approximately 8,800–9,700 cfs), depending on assumptions regarding prescreen losses (Kimmerer 2008: his Figures 9 and 10). For perspective on the current effects analysis modeling, the percentage of CALSIM-simulated months during the main entrainment period for Chinook salmon and other covered species (December–June) in which average total south Delta exports were below 8,800 cfs and 9,700 cfs were as follows.

- NAA: 83% < 8,800 cfs, 86% < 9,700 cfs.
- PA: 95% < 8,800 cfs, 98% < 9,700 cfs.

The majority of months were below export flows at which Kimmerer's (2008) study of Chinook salmon suggested considerable nonlinear percentage salvage or entrainment loss would occur. Kimmerer's (2008)

[2] For this reason, various complex methodological refinements suggested by a scientific panel reviewing the method as part of the phase III review of the public draft Bay Delta Conservation Plan have not been implemented, as these would not be justified given the fairly coarse intent of the analysis.

study does not provide an indication of export flow rates at which nonlinearity may occur for the other species included in this analysis.

Juvenile Chinook salmon were divided into races based on fork length on the date of salvage, according to the Delta model of length at date (Brown et al. 1996). It should be noted that these divisions are not without considerable overlap between races, especially for juvenile spring-run and fall-run Chinook salmon; extrapolations of numbers of fish salvaged by race should be regarded cautiously, particularly given the relative abundance of the adult stocks from which the juveniles originate (e.g., fall-run are considerably more abundant than spring-run, and therefore the relative proportions salvaged should reflect such differences but may not when based on length criteria). Techniques such as such rapid, real-time DNA analysis are under development and may allow better classification of race in the future (Harvey et al. 2014). Data for juvenile Chinook salmon salvage were extrapolated into total entrainment losses to reflect prescreen losses (75% at SWP and 15% at CVP), louver efficiency (size-specific equations based on primary water velocity through the intake screens [California Department of Water Resources and California Department of Fish and Game 1986: Appendix A]), and losses during transport to the release site (2% for younger fish, 0% for larger fish [California Department of Water Resources and California Department of Fish and Game 1986: Appendix A]). In similar fashion, steelhead also had various entrainment losses applied: prescreen losses of 75% at SWP and 15% at CVP, and louver losses of 50%.

I.5.2 Normalization to Population Size

Winter-run Chinook salmon salvage and loss data for analysis were normalized, by measures of annual juvenile population abundance in the year of entrainment. This step aimed to adjust the salvage and loss to account for the abundance of the population (e.g., a relatively high number of fish would be expected to be entrained in a year of relatively high abundance). Normalization was undertaken by multiplying the raw monthly salvage or loss in a given month by a factor to account for the relative size of the population in that year compared to the average population size over the years from which salvage or loss data were available. The factor was the average population size in the years from which salvage data were available (1996–2009) divided by the juvenile population size appropriate to the year of salvage. Winter-run Chinook salmon estimates were normalized by the juvenile production estimate (National Marine Fisheries Service 2009). No normalization was undertaken for spring-run Chinook salmon, fall-/late fall-run Chinook salmon, steelhead, or green sturgeon because there are no suitable indices of juvenile annual abundance for these species.

I.5.3 Entrainment Index Calculation

For each species in each month at each facility, density (fish per thousand acre-foot [taf]) as entrainment loss or expanded salvage was simply calculated as the total loss or expanded salvage for the facility divided by the total volume of water exported in that month. It is acknowledged that the assumption of a linear relationship between entrainment and flow may be an oversimplification given the evidence for nonlinear relationships (e.g., Kimmerer 2008; see discussion above) and so, as previously described, ***the method essentially functions as a description of changes in export flows weighted by seasonal changes in salvage density of covered species***. The mean entrainment index in each month of each water-year type was calculated as follows: the salvage or loss density for a given month in a given water-year type was multiplied by the CALSIM-modeled export volume for the same month for all of the water years of that water-year type. For example, there were 5 wet years (1996–1999, 2006) in the data used to calculate salvage or loss densities and there were 26 wet years in the CALSIM modeling of 1922–2003. Using the month of January as an example, there were five unique wet January salvage or loss densities calculated.

Each of these was then multiplied by each of the 26 wet January export volumes from CALSIM, giving a sample size of 130 from which to calculate means.

Although the salvage-density method does give estimates of entrainment loss or salvage in numbers of fish and there are a number of factors included in the calculations such as multipliers applied for prescreen loss and normalization to population size, ***it is most appropriate to view the results comparatively, i.e., to compare relative differences between scenarios as opposed to examining the estimates of total number of fish lost to entrainment or salvaged***. In essence, and as noted previously, the salvage-density method provides an entrainment index that reflects export pumping weighted by each covered species' seasonal pattern of abundance in the Delta, as reflected by historical salvage data.

I.6 Reclamation Salmon Mortality Model

The Reclamation Salmon Mortality Model simulates the early life stage mortality of Chinook Salmon along reaches of the Sacramento (below Keswick Dam to Princeton), American (below Nimbus Dam to the Sacramento River confluence), and Stanislaus Rivers (below Goodwin Dam to Riverbank). The model sets an initial spawning distribution along the different river reaches (as a percentage) and uses water temperature data to simulate egg development and mortality based on temperature relationships specified in the model. Daily water temperature results come from the HEC5Q models. The final output from the Reclamation Salmon Mortality Model used in this analysis is the resulting annual percent mortality. Operations Criteria and Plan (OCAP) Biological Assessment (BA) Appendix L (Reclamation 2008a) provides detailed description of the Reclamation Salmon Mortality model structure, assumptions, and processes.

I.7 SALMOD

The SALMOD model simulates the life-stage dynamics of fall-run, late fall-run, spring-run, and winter-run Chinook Salmon populations within the Sacramento River, from below Keswick Dam to the Red Bluff Diversion Dam. The model uses daily flow and temperature data from the Sacramento River HEC5Q model to simulate the annual growth, movement, and mortality of the various riverine life stages of the four Chinook Salmon populations based on an initial annual adult population that resets each biological year. The dynamics simulated are based on assumptions and relations specified in the model. The final output from SALMOD used in this analysis is annual production (number of surviving members of each life-stage) and annual mortality based on a variety of factors, including temperature and habitat (flow) based mortality. The 2008 Operations Criteria and Plan (OCAP) Biological Assessment (BA), Appendix P provides detailed description of the SALMOD model structure, assumptions, and processes (Reclamation 2008b).

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I.8.1 Personal Communications

Gard, M. 2015. Personal communication by email. July 5, 2015—Email.

Robinson D. June 16, 2015—Email from Don Robinson, ESSA Technologies to Clint Alexander, ESSA Technologies about the use of surrogate species in the SacEFT model.

Appendix J Shasta Temperature Operations

J.1 Introduction

Temperature regulations downstream of Shasta Dam led to the construction of the Temperature Control Device (TCD), a selective withdrawal system which allows the extraction of water from four different depths. This grants access to colder water at lower depths and the opportunity to blend water extracted from different depths. Blending allows operators to meet temperature regulations while conserving cold water pool for future use.

The HEC-5Q temperature model features a Fortran implementation of the TCD in its simulations of Shasta Dam operations (Reclamation, 2008). The model requires a time series input of target Shasta Dam outlet temperatures, which it then meets as closely as possible using blending between different elevations. For comparative analysis purposes in the Reinitiation of Consultation on Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) Biological Assessment (ROC on LTO BA), Proposed Action (PA) temperature operations were developed at a monthly scale (Reclamation, 2019). Although monthly scale temperature targeting managed Shasta outflow temperature with perfect foresight, sub-monthly influences (e.g. heat waves) were not observed.

To better understand real-time operations under the PA, daily-scale temperature targeting was performed for specific years of interest, which are those designated under the PA as falling into the "Tier 3" temperature management operation. Because daily-scale temperature targeting adjusts to available cold water pool, Shasta inflows, and meteorology, it manages temperature in a manner similar to actual operations. It should be noted that daily-scale temperature targets were developed with perfect foresight. Temperature compliance of daily-scale temperature targeting was measured with modeled Sacramento River temperature. Impacts of Sacramento River temperature were then assessed with Winter run Chinook salmon egg mortality. Two proposed temperature-dependent egg mortality models were utilized, developed by Drs. Martin and Anderson.

In Tier 3 years with low cold water pool volume, daily-scale temperature targeting decreases simulated mortality. In Tier 3 years with low mortality, there is little change between daily-scale and monthly-scale temperature targeting in the simulations.

J.2 Sensitivity Analysis Details

Published PA results indicate significant temperature-based egg mortalities in Tier 3 years (End-of-April Shasta storage between 2,500 and 3,500 thousand acre-feet [TAF]). A simple spreadsheet tool was created to facilitate daily-scale temperature targeting for Tier 3 years: 1924, 1929, 1930, 1935, 1990, and 1992. For each year, a separate model run was created starting on January 1st, 1922, the beginning of the HEC-5Q simulation used for the ROC on LTO BA, to the end of the year of interest. All years before the year of interest were given the Shasta Dam temperature target time series from ROC on LTO BA modeling. Commencing simulations at the beginning of the planning time-period ensures that the daily-scale model experiences the exact same antecedent conditions as the monthly-scale analysis.

The spreadsheet calculates warming from Shasta Dam to Sacramento River below Clear Creek, as ROC on LTO BA temperature compliance is set to this location. To minimize the number of variables changing between iterations, the warming between the locations in the monthly-scale run was used for all iterations. Daily-scale Shasta Dam tailwater targets were back-calculated using daily warming values from Shasta release to Sacramento River below Clear Creek.

Late-season violations typically resulted from depleted cold water pool. Monthly-scale temperature targeting attempted to address this issue by setting warmer temperature targets (while still maintaining 56 or 53.5 degrees Fahrenheit) at the beginning of the season. Theoretically, warmer early-season temperature targets preserves cold water pool volume, reducing major violations later in the season. Daily-scale temperature targeting employed this same technique at a more refined scale.

For each year, daily-scale temperature targeting results were processed through the Martin and Anderson temperature-dependent egg mortality models. Results from these runs were compared with results from the original monthly-scale runs. Timeseries plots of Shasta storage, Shasta outflow (by extraction location), Shasta release temperature, and Sacramento River below Clear Creek temperature for each year and HEC-5Q simulation are presented in Attachment 1.

J.3 Conclusions

Mortality results for all six Tier 3 years can be subdivided into two halves, good and bad years. The bad years - 1924, 1990 and 1992 - have mortalities above 35%, while mortalities in good years - 1929, 1930 and 1935 - never exceed 13%. Daily-scale temperature targeting achieved reductions in bad year mortalities by as much as 16%, but reductions were not found for the good years, in which the monthly-scale method already achieved low mortality. Mortality results, summarized by year, are presented in Table 1.

Table 1. Annual Winter-Run Chinook Salmon Temperature-Based Egg Mortality by HEC 5Q Simulation, Mortality Model and Year

HEC 5Q Run	1924		1929		1930		1935		1990		1992	
	Anderson	Martin	Anderson	Martin	Anderson	Martin	Anderson	Martin	Anderson	Martin	Anderson	Martin
Monthly-scale	46%	66%	8%	13%	7%	6%	5%	6%	35%	36%	66%	77%
Daily-scale	30%	57%	11%	23%	8%	10%	7%	17%	30%	36%	57%	70%

Mortality reduction in bad years is roughly consistent between the Martin and Anderson mortality models, although the Anderson model typically predicts lower mortality than the Martin model. This is because the Anderson model uses only the temperatures of the five days before hatching to estimate mortality, while the Martin model uses all days between fertilization and emergence. Because the PA attempts to meet a lower target toward the middle of the temperature management period, when the largest number of redds are constructed and reach hatching stage, the Anderson model will tend to favor the PA. This does not affect comparisons between different implementations of the PA.

These results indicate that daily-scale temperature targeting reduces simulated temperature-dependent Winter run Chinook salmon egg mortality in Tier 3 years with low initial cold water pool volumes. As daily-scale temperature targeting better represents real-time operations, temperature-based egg mortalities are likely to be lower than what is suggested in the ROC on LTO BA in Tier 3 years.

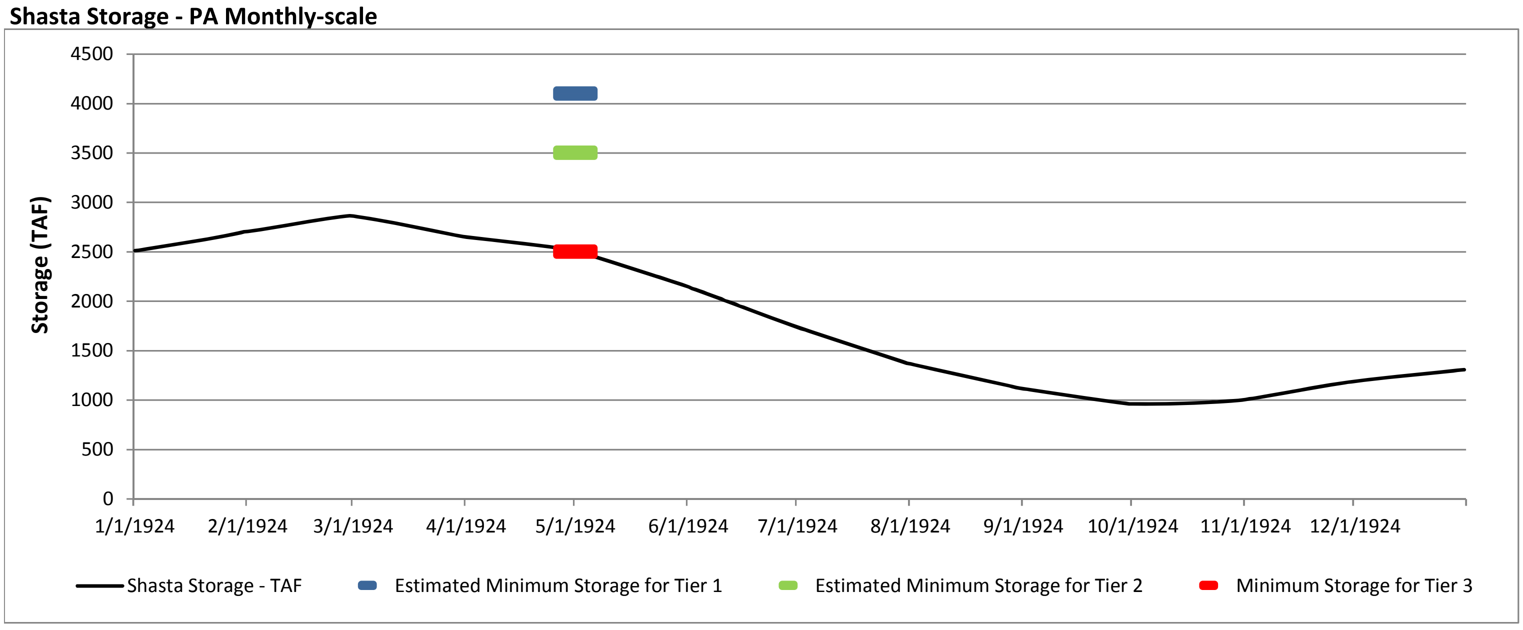
J.4 References

U.S. Bureau of Reclamation, 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix H Reclamation Temperature Model and SRWQM Temperature Model, August 2008.

U.S. Bureau of Reclamation, 2019. Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project: Final Biological Assessment, January 2019.

Reinitiation of Consultation on the Coordinated Long-term Operation of the Central Valley Project and State Water Project: Shasta Temperature Management Sensitivity Analysis - Attachment 1

Shasta Storage - PA Monthly-scale



Select Year:

1924

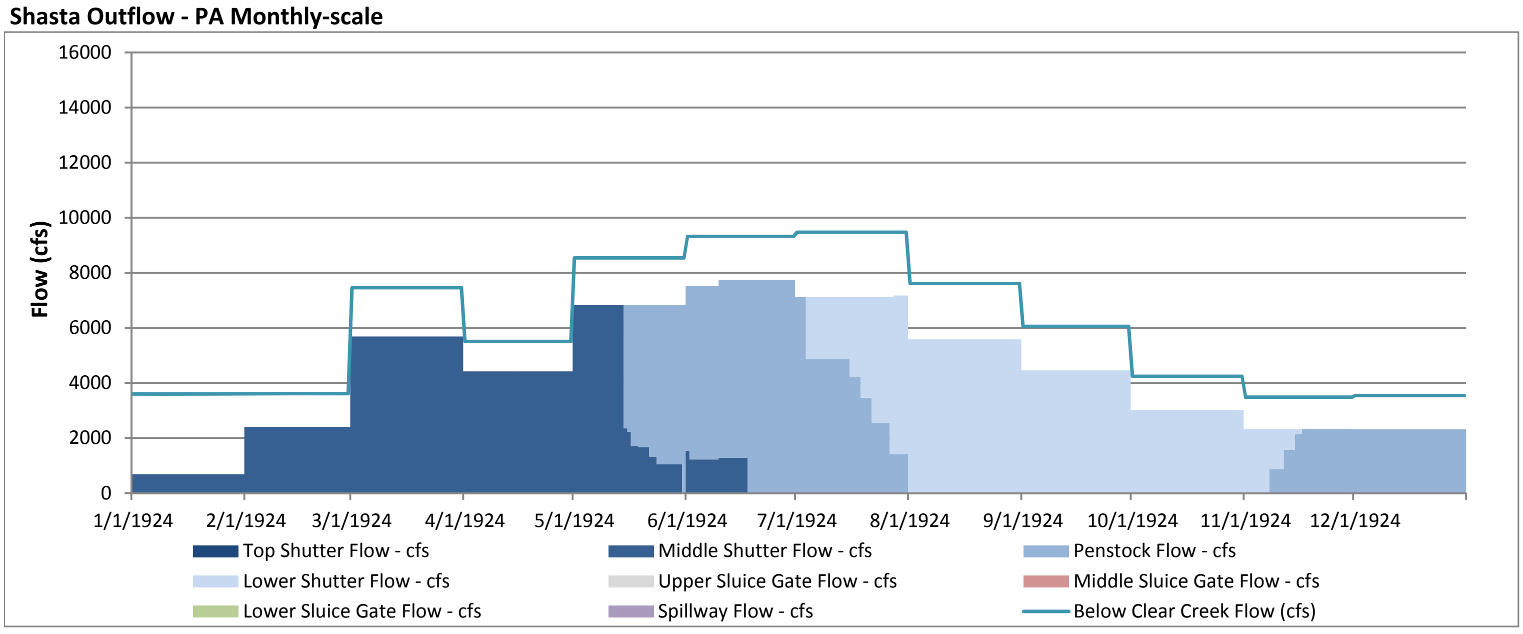
Temperature Tier:

Tier 3

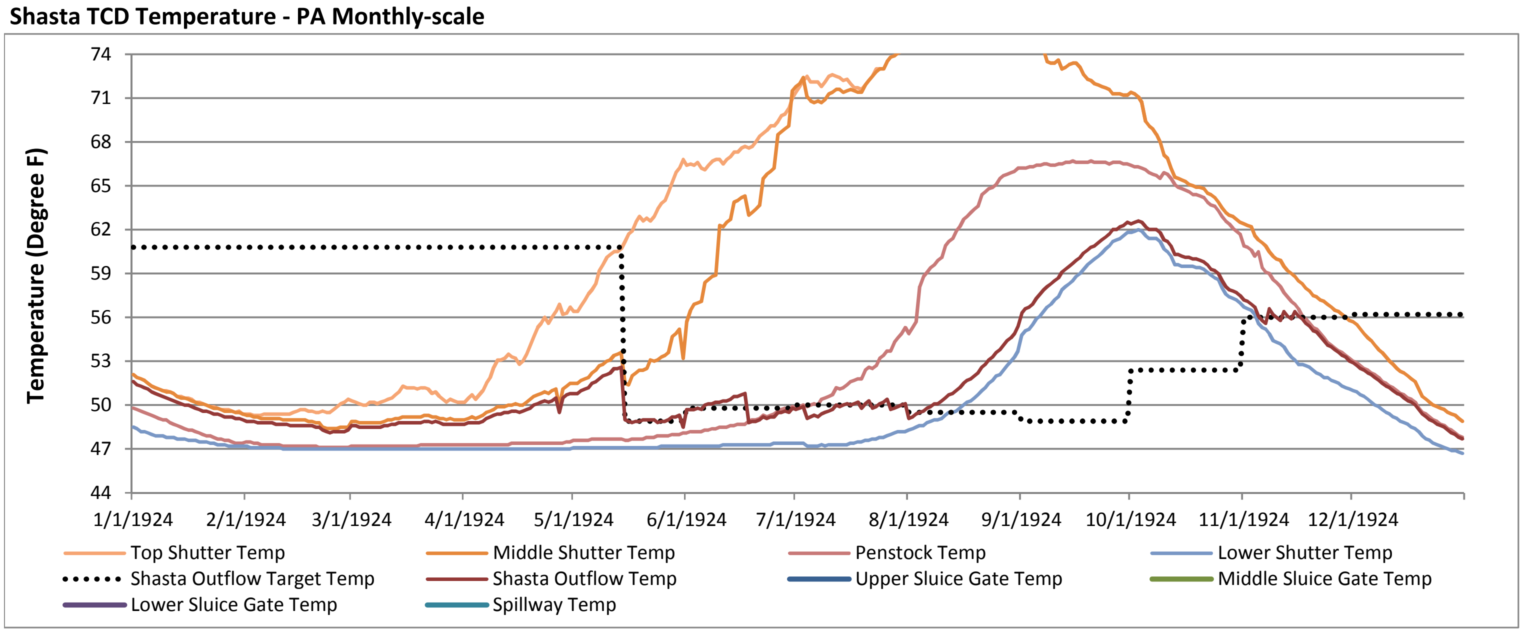
Annual Mortalities:

Anderson	46%
Martin	66%

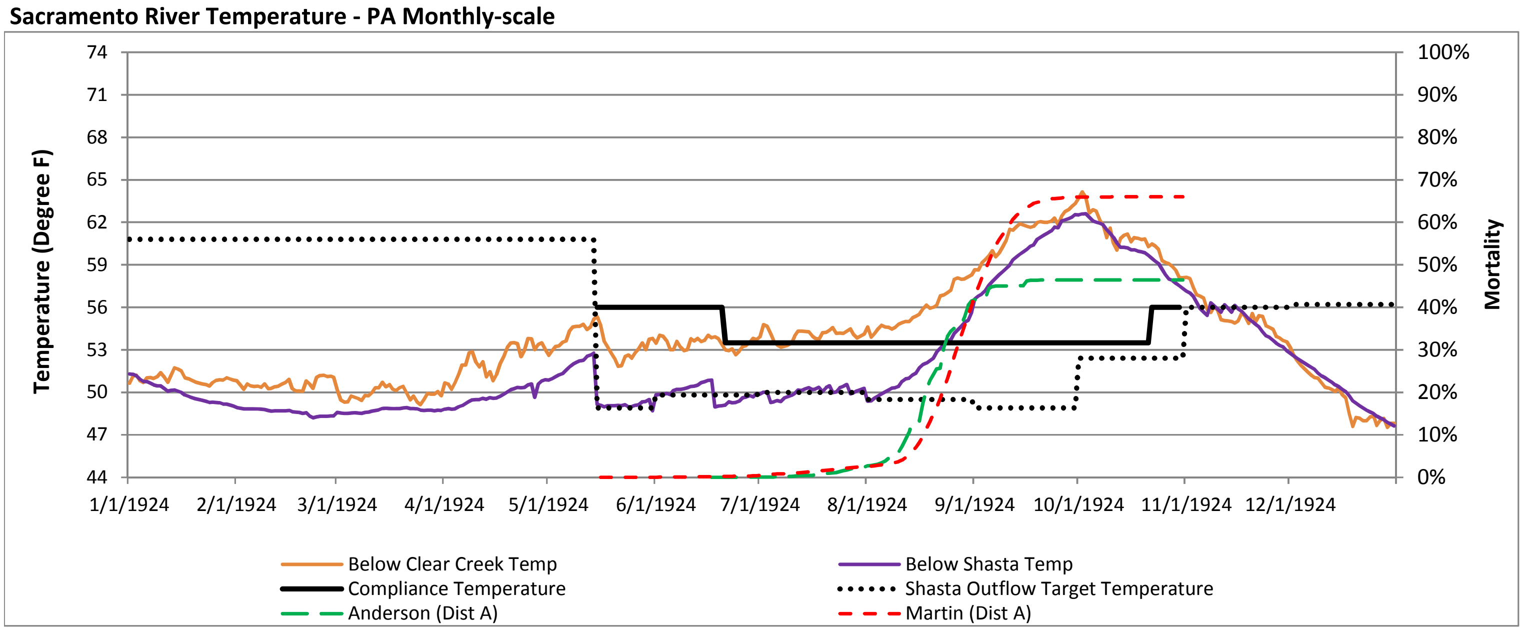
Shasta Outflow - PA Monthly-scale



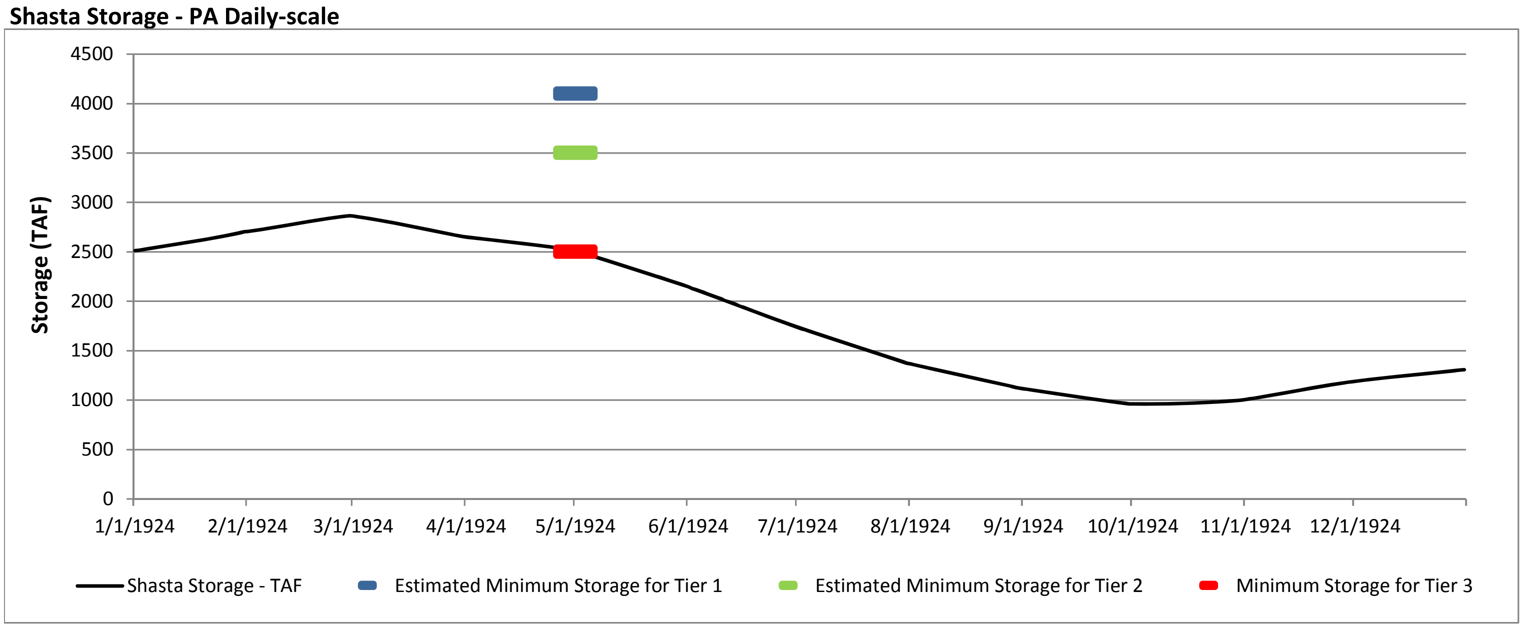
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1924

Temperature Tier:

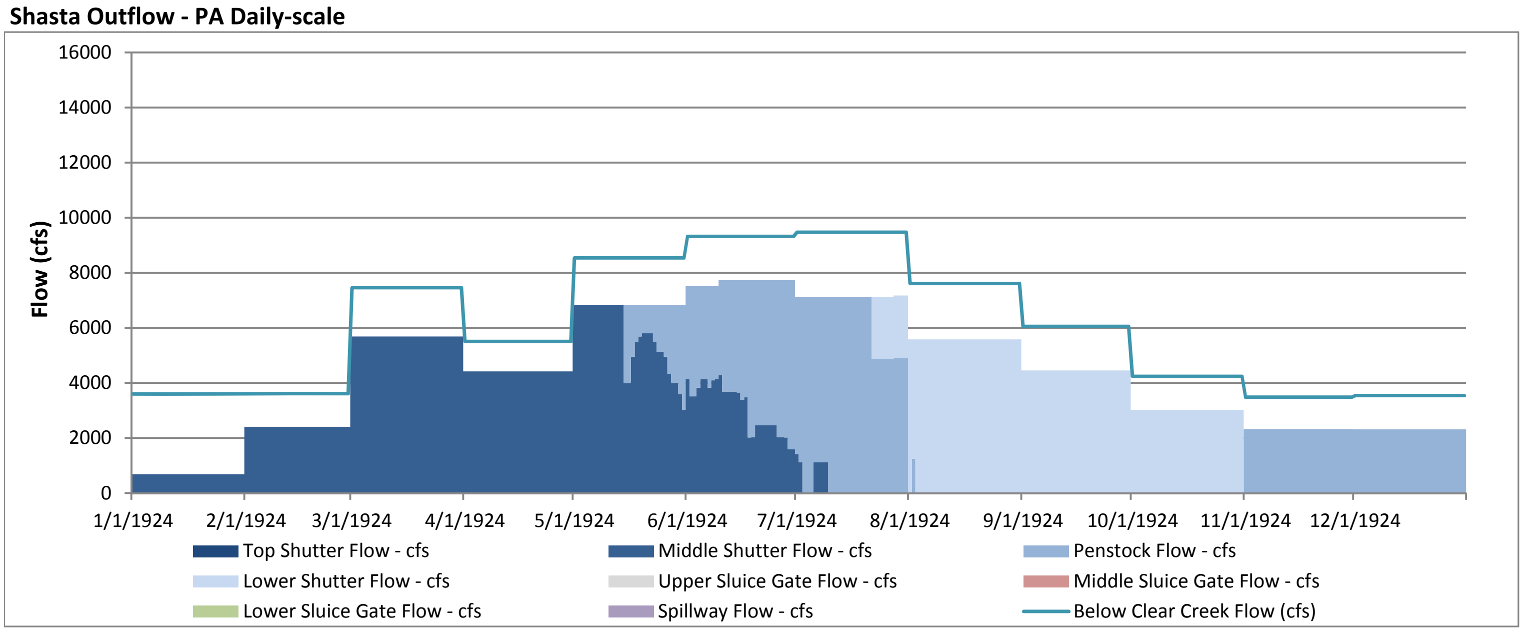
Tier 3

Annual Mortalities:

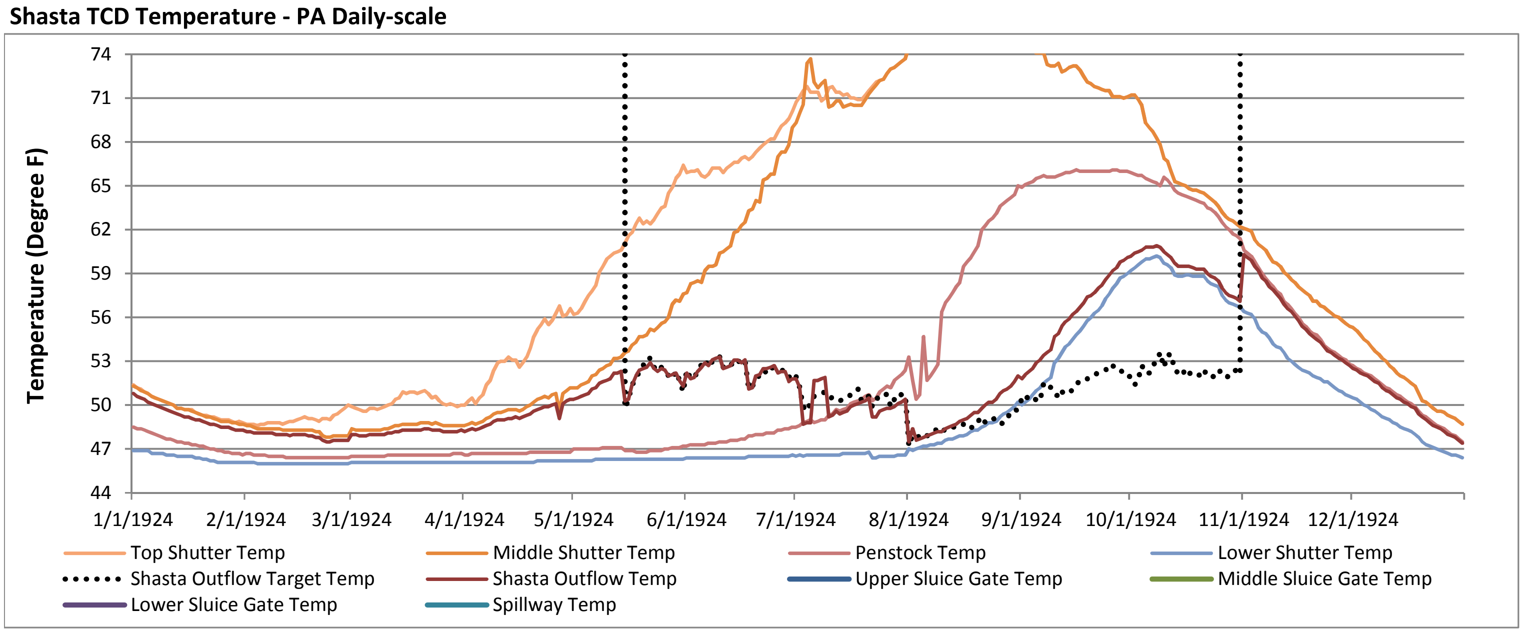
Anderson 30%

Martin 57%

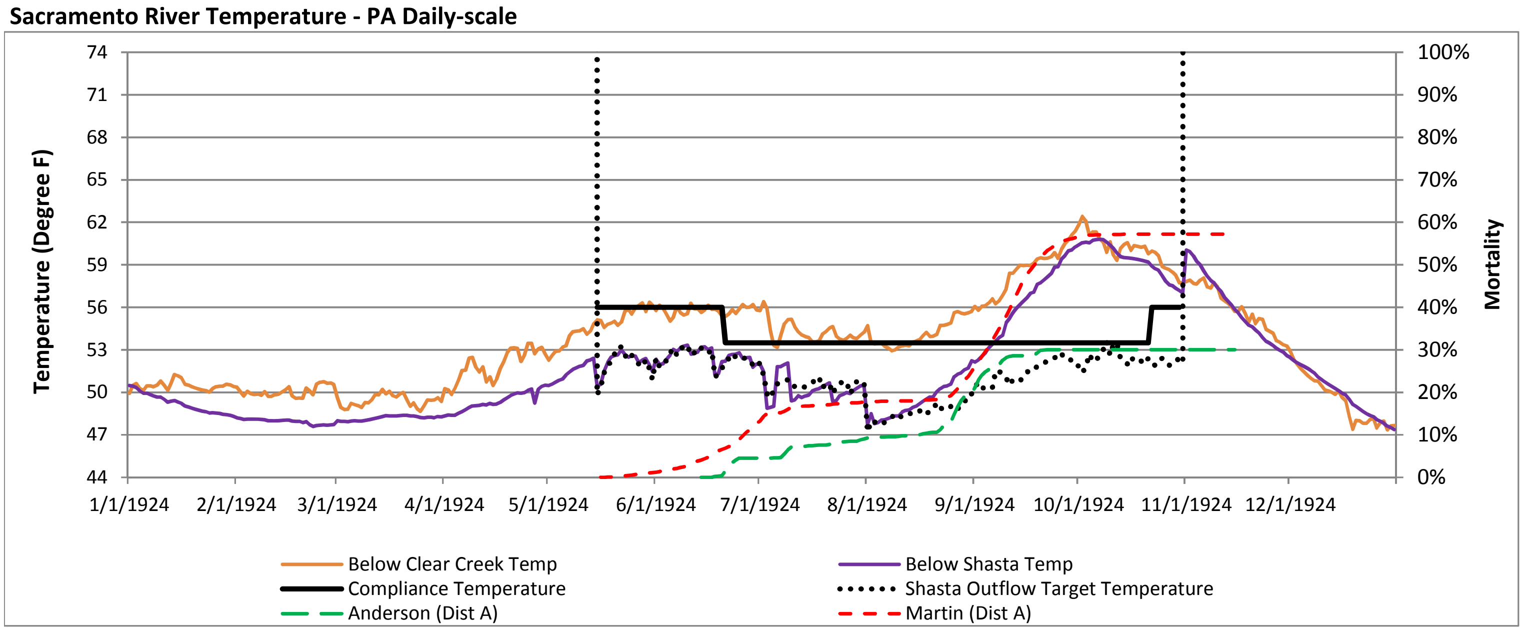
Shasta Outflow - PA Daily-scale



Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



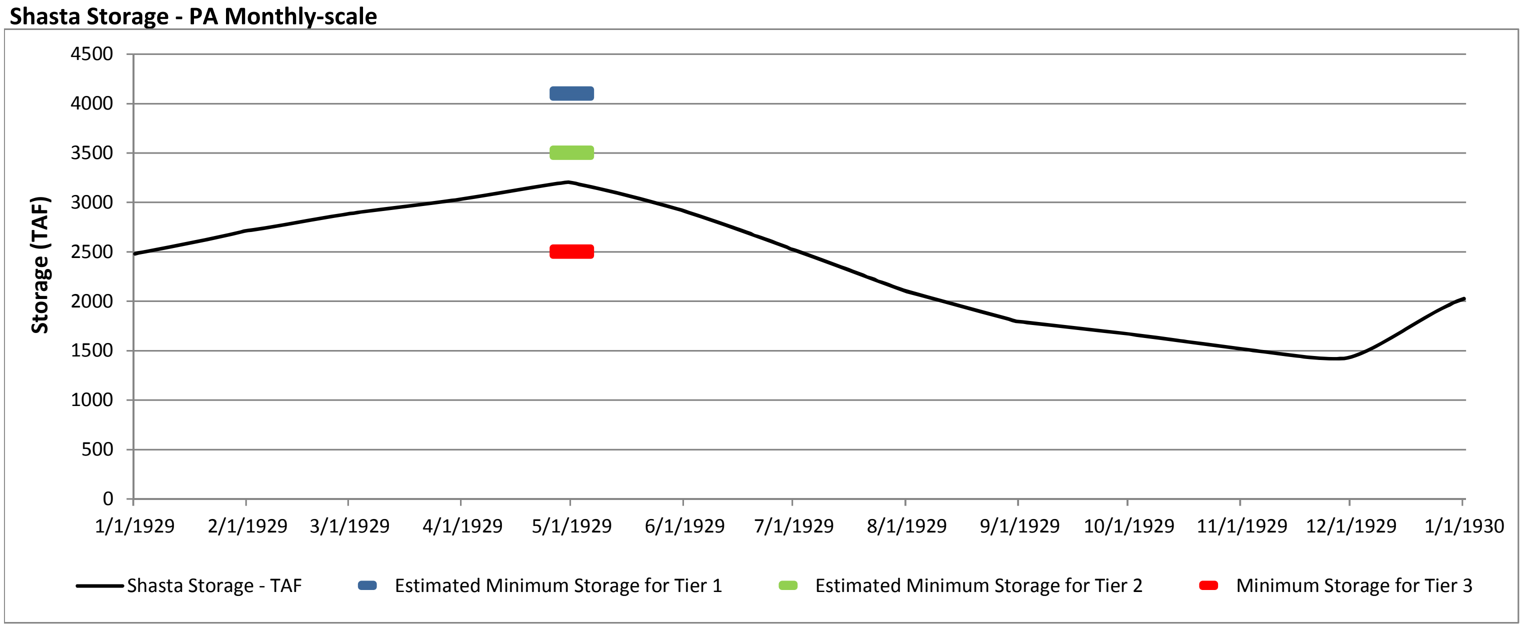
Select Year:
1929

Temperature Tier:
Tier 3

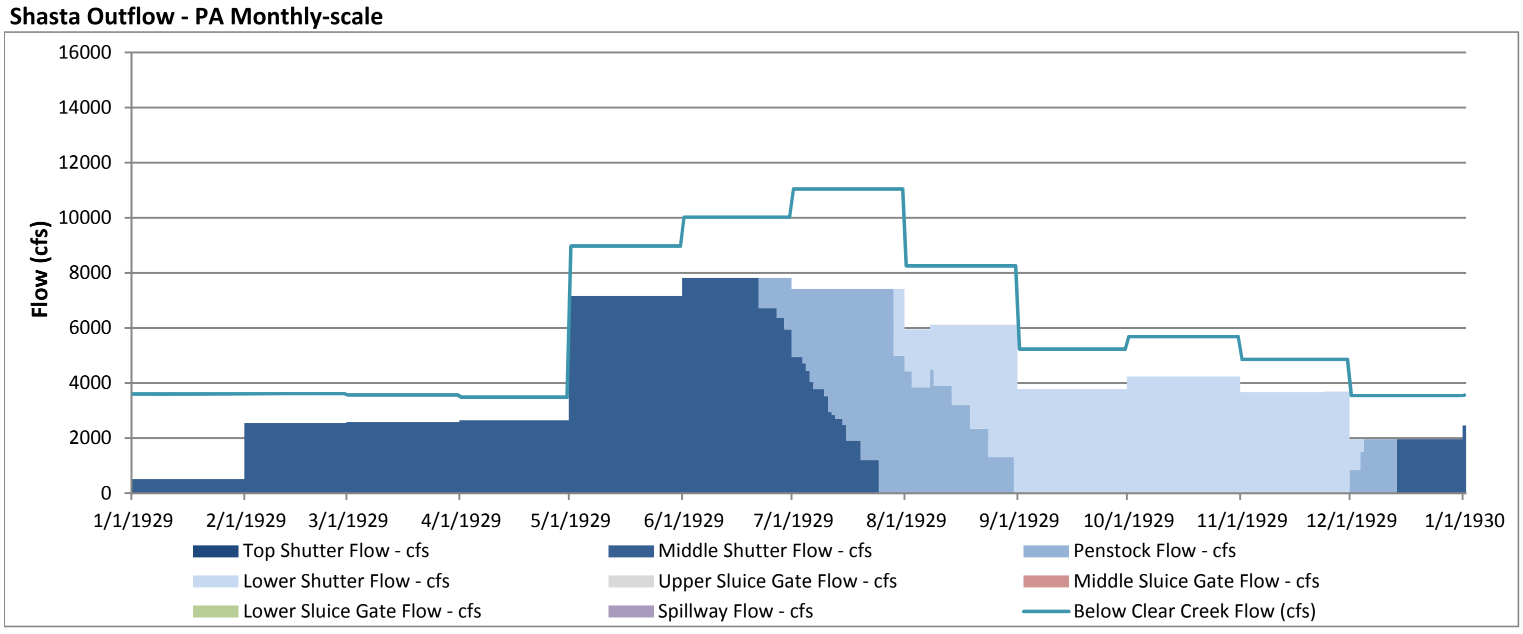
Annual Mortalities:

Anderson	8%
Martin	13%

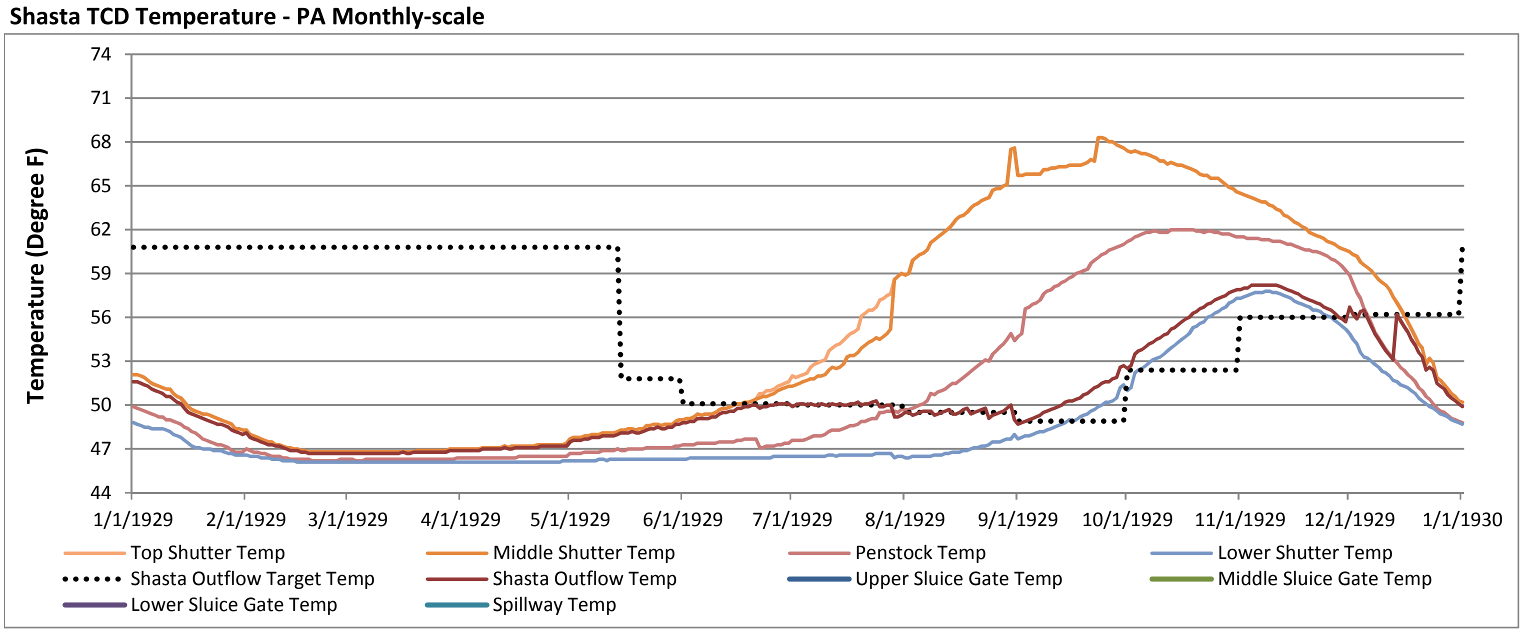
Shasta Storage - PA Monthly-scale



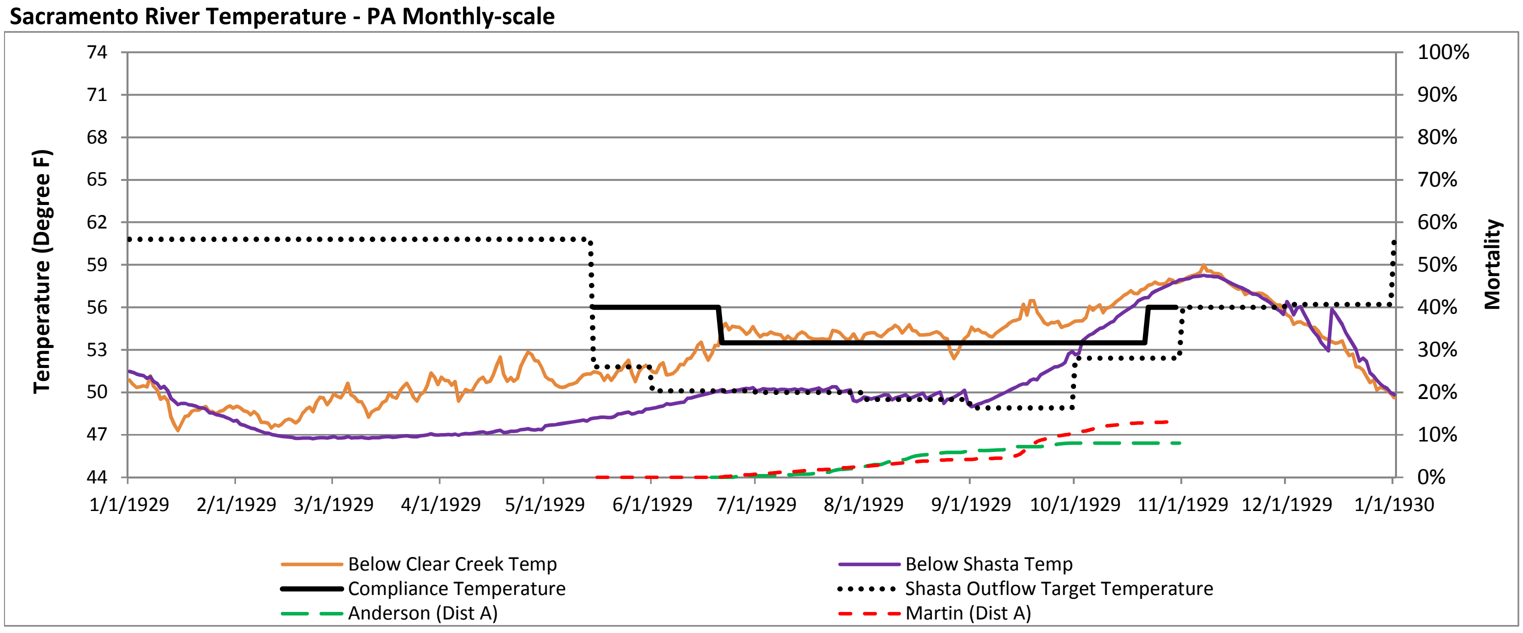
Shasta Outflow - PA Monthly-scale



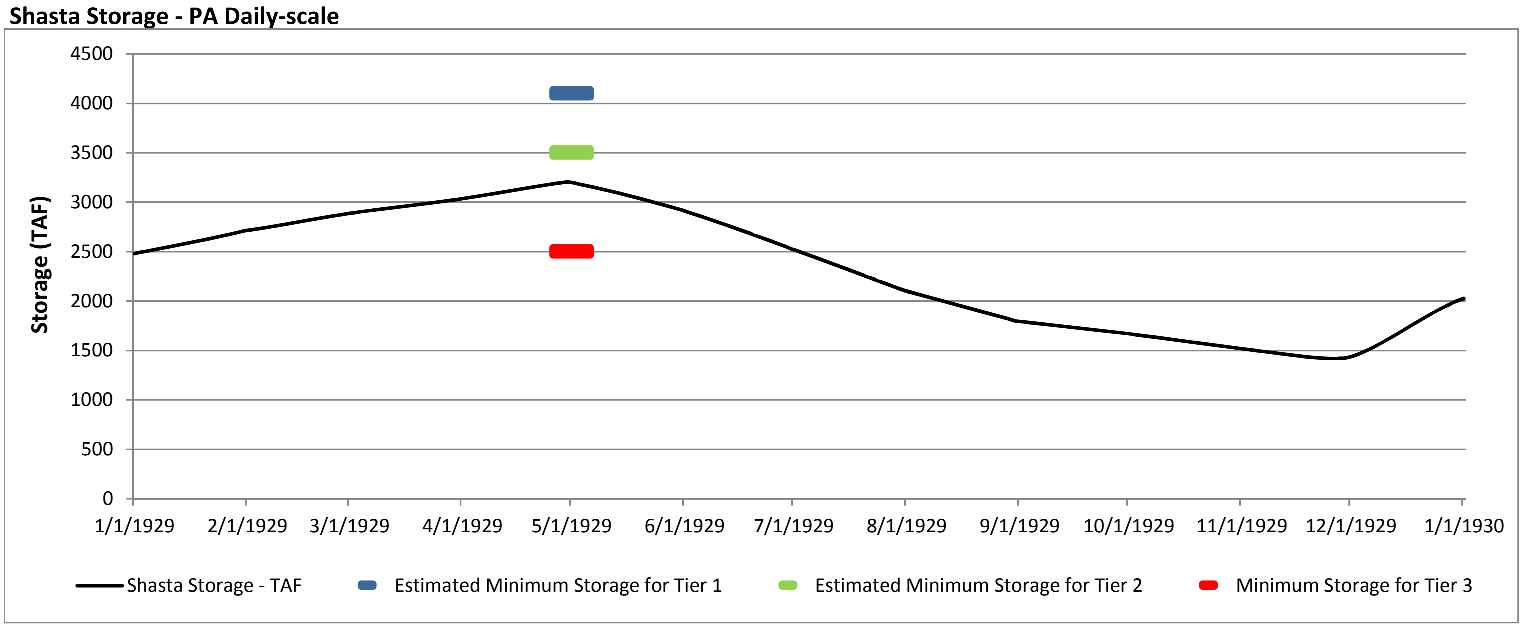
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1929

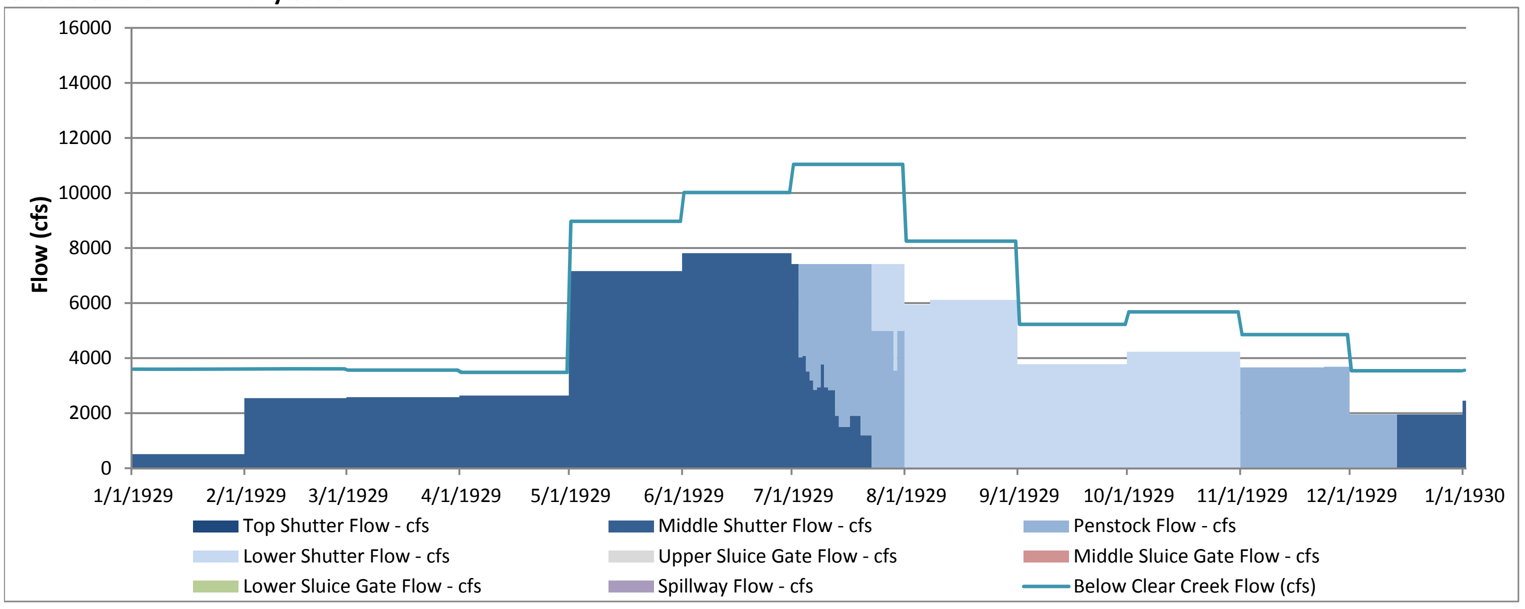
Temperature Tier:

Tier 3

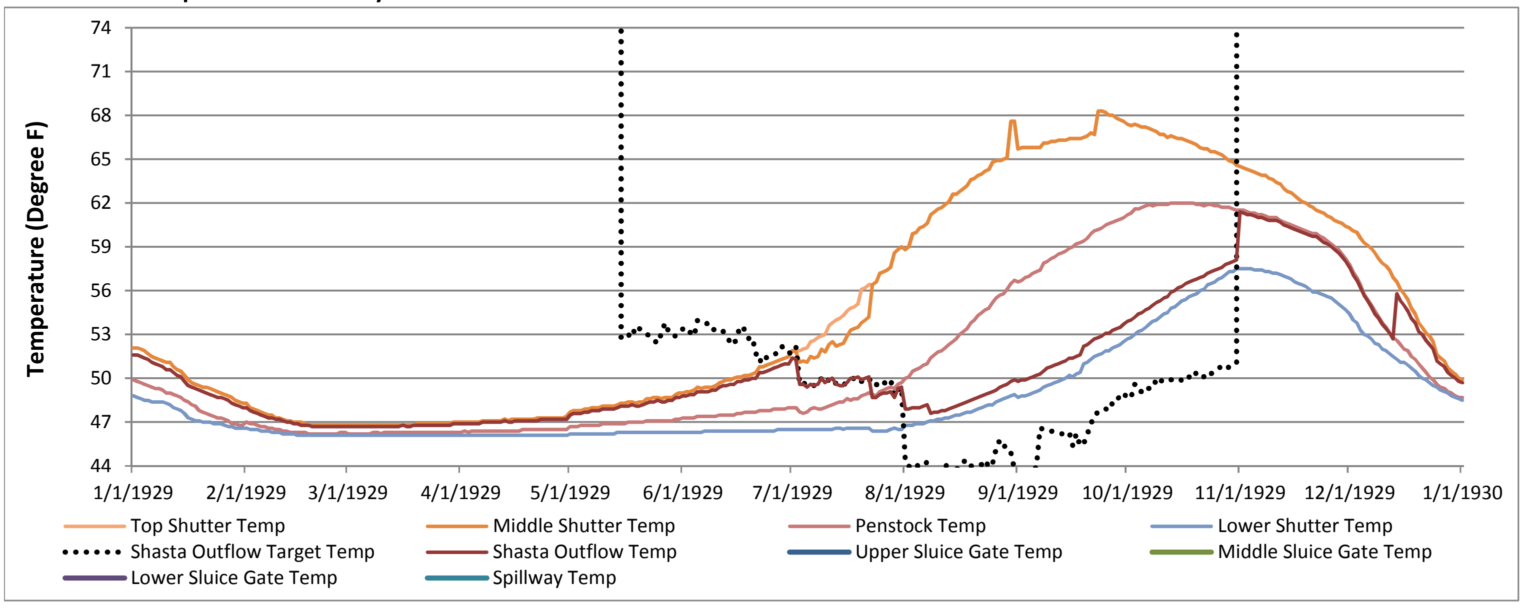
Annual Mortalities:

Anderson	11%
Martin	23%

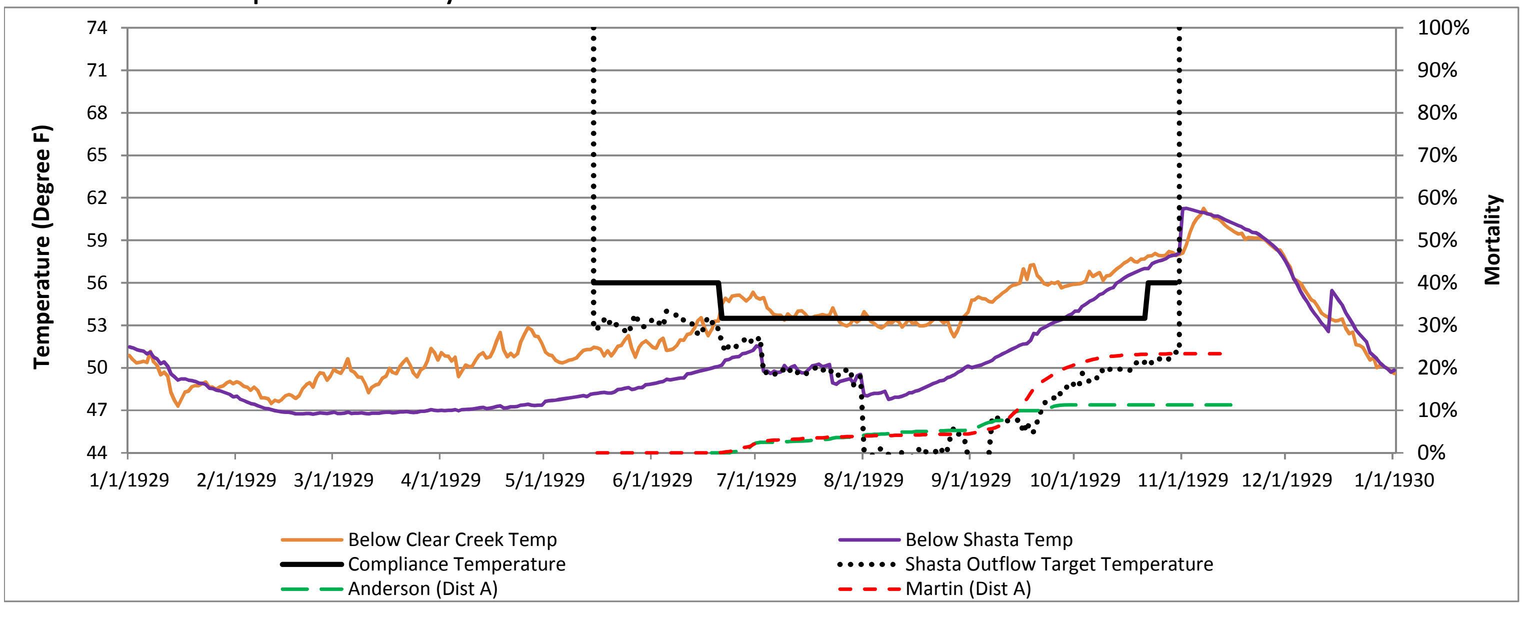
Shasta Outflow - PA Daily-scale



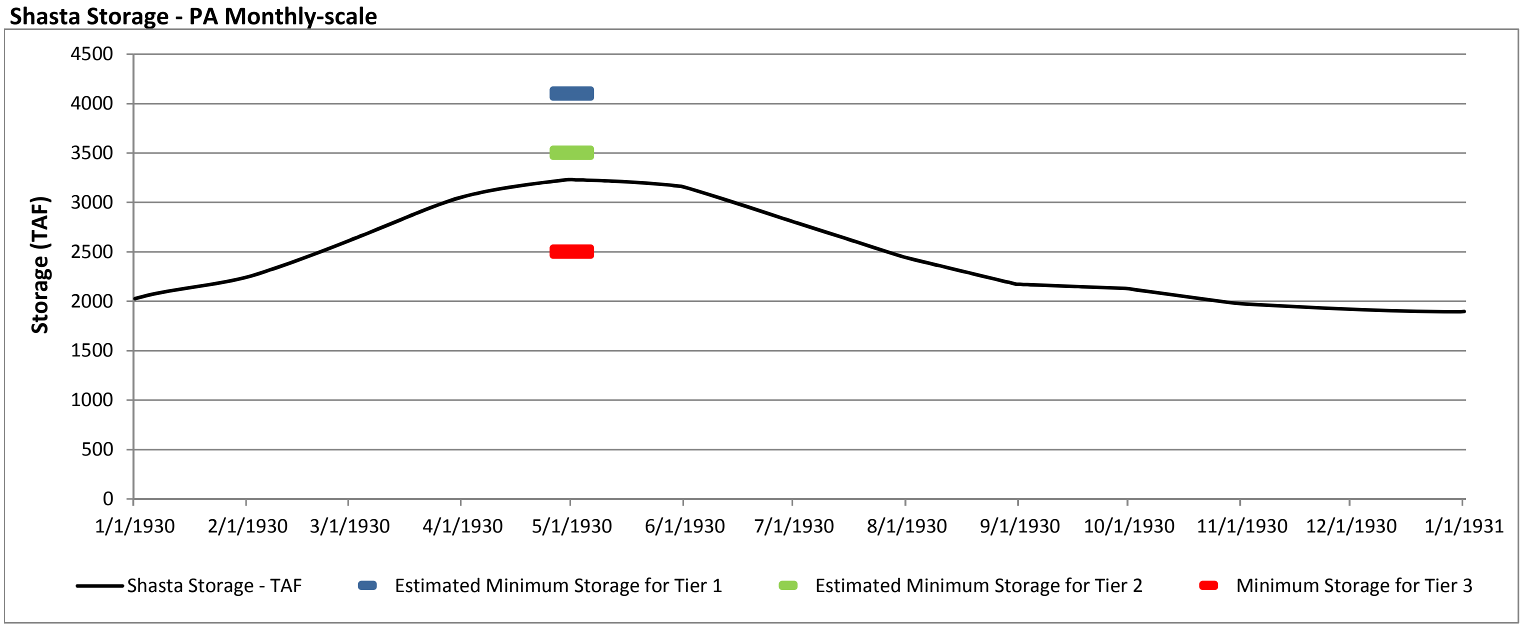
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1930

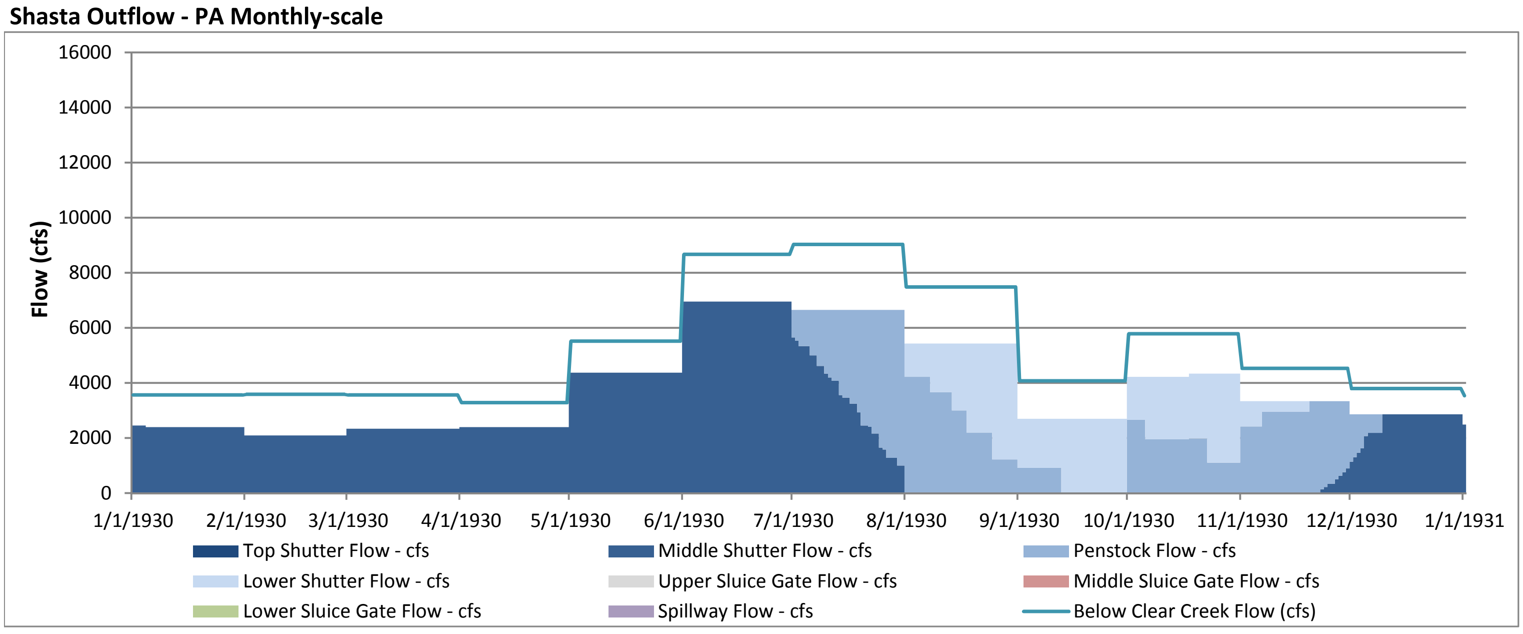
Temperature Tier:

Tier 3

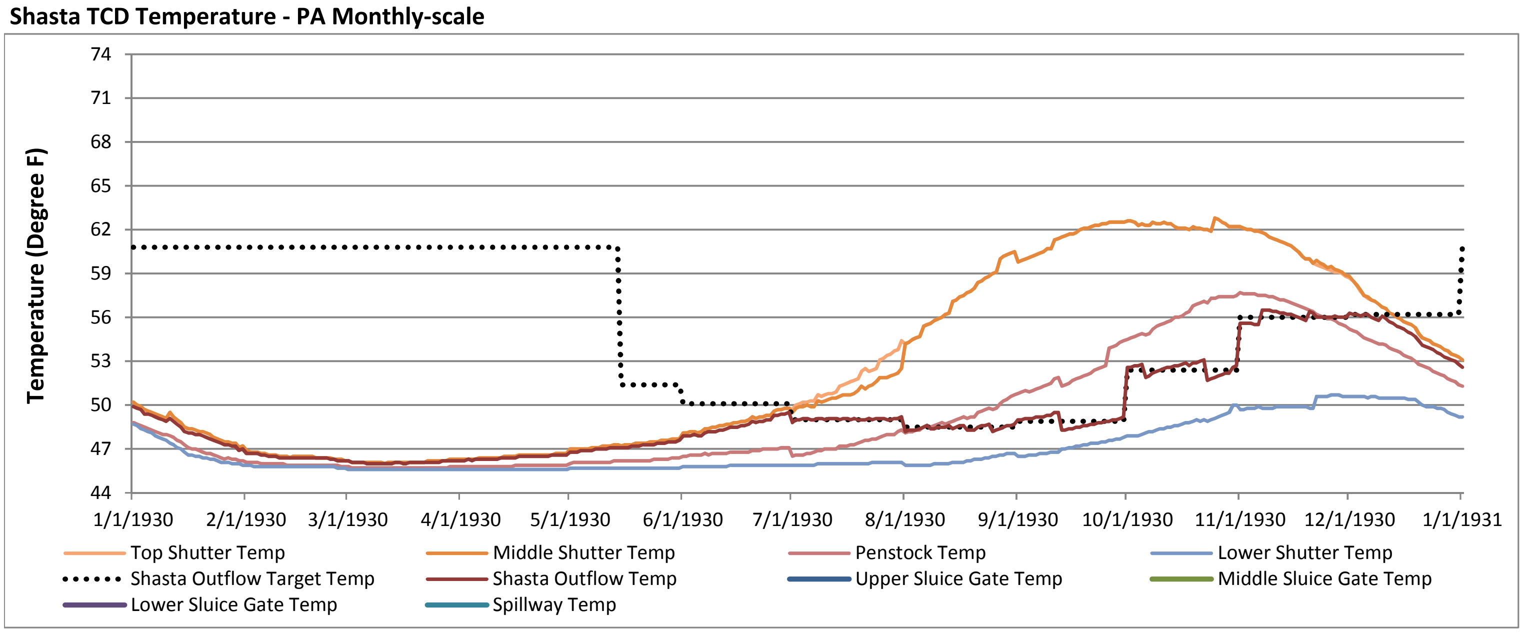
Annual Mortalities:

Anderson	7%
Martin	6%

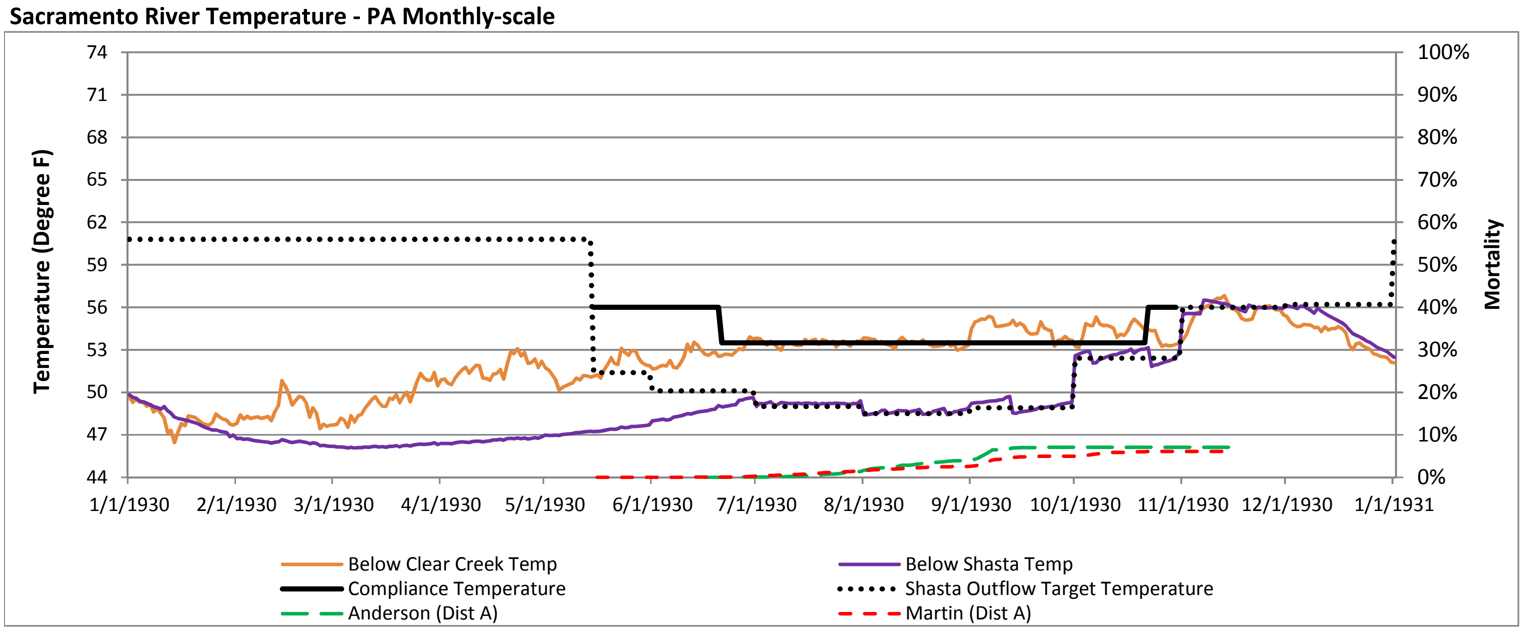
Shasta Outflow - PA Monthly-scale



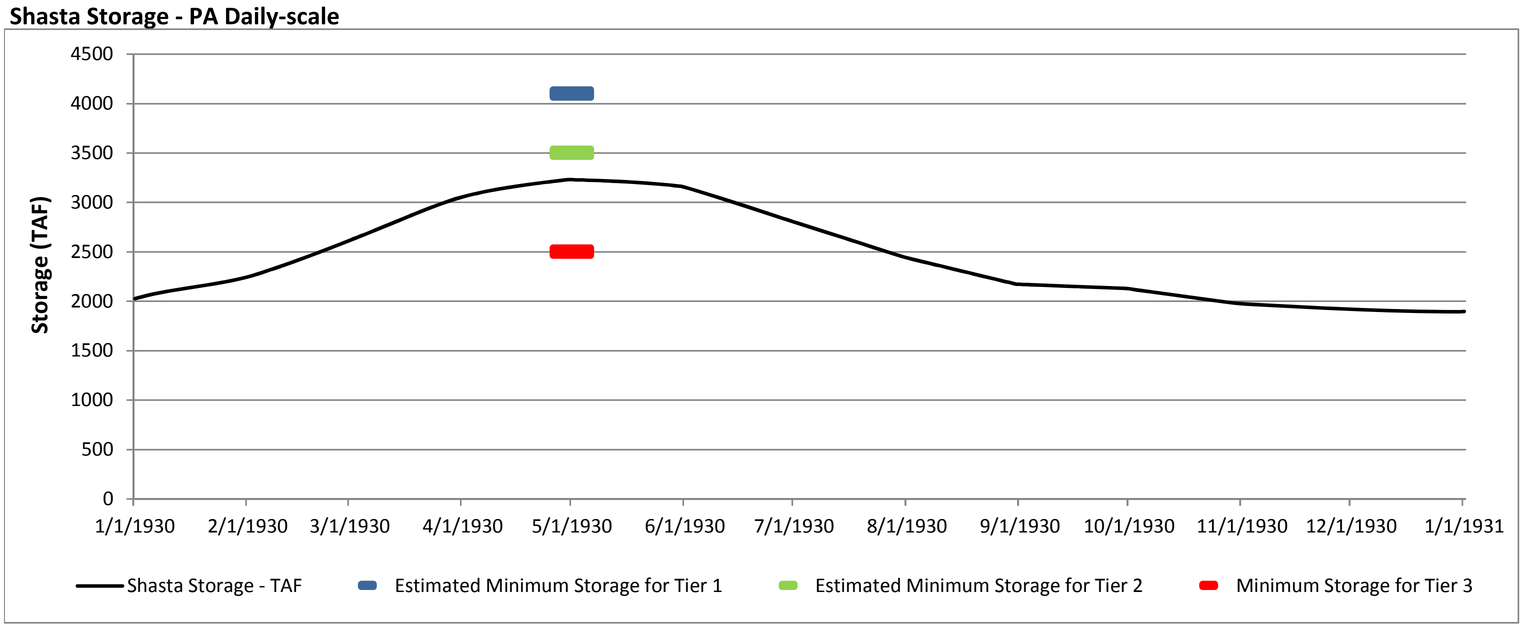
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1930

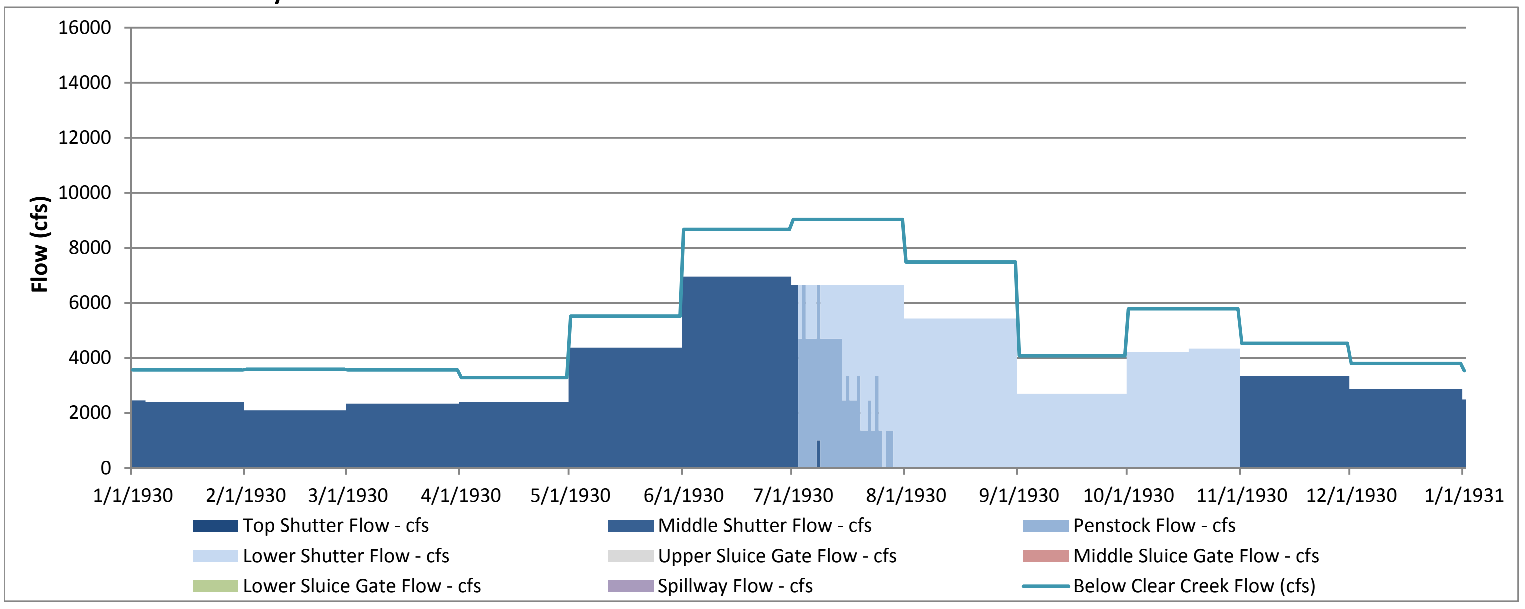
Temperature Tier:

Tier 3

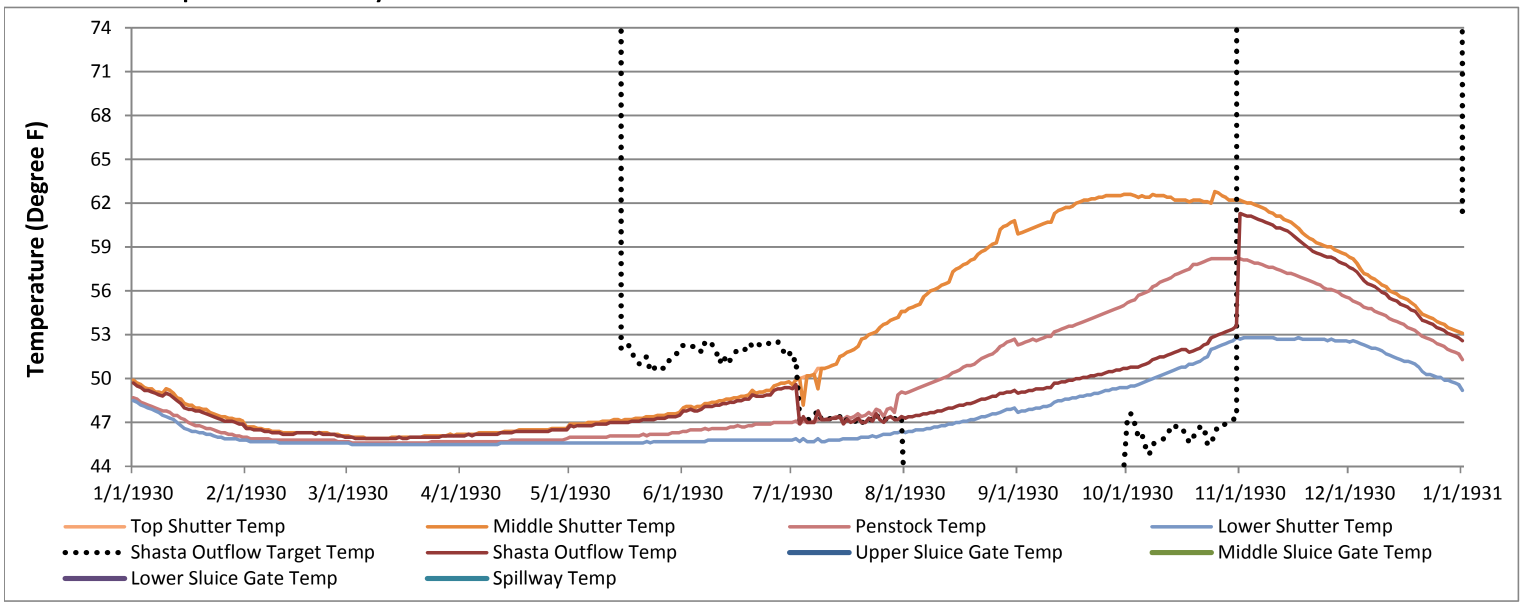
Annual Mortalities:

Anderson	8%
Martin	10%

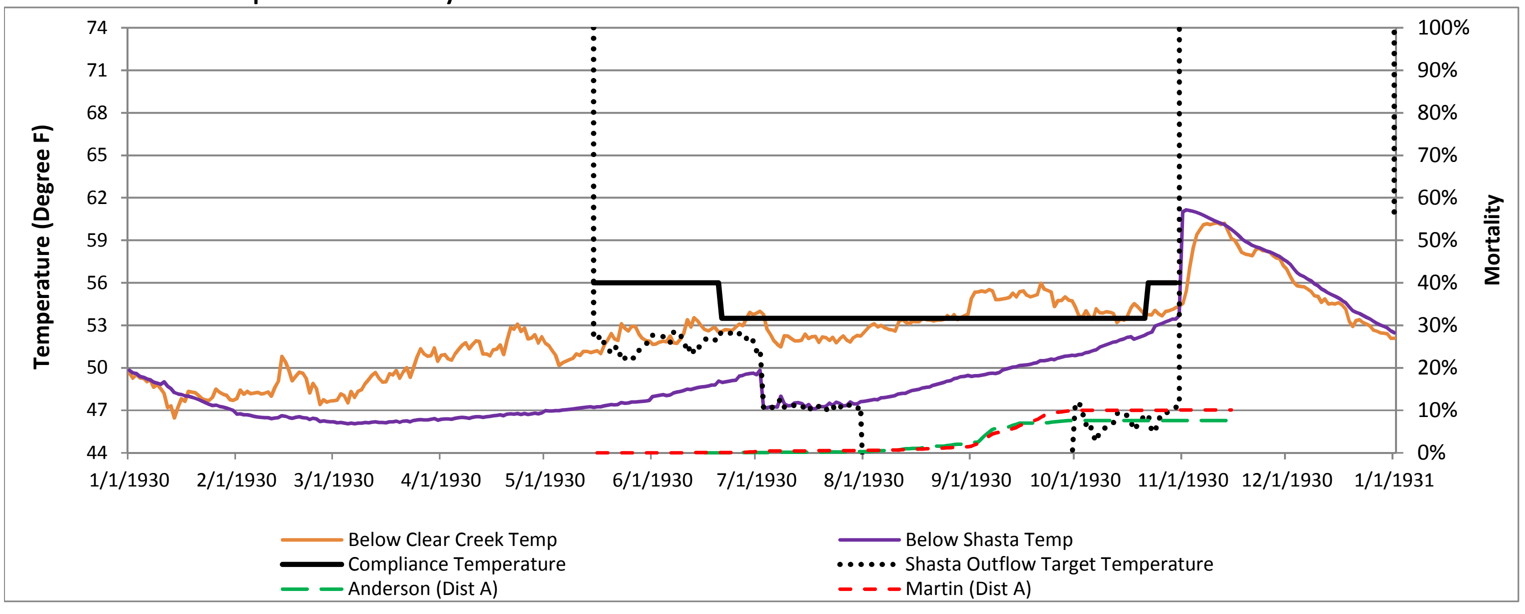
Shasta Outflow - PA Daily-scale



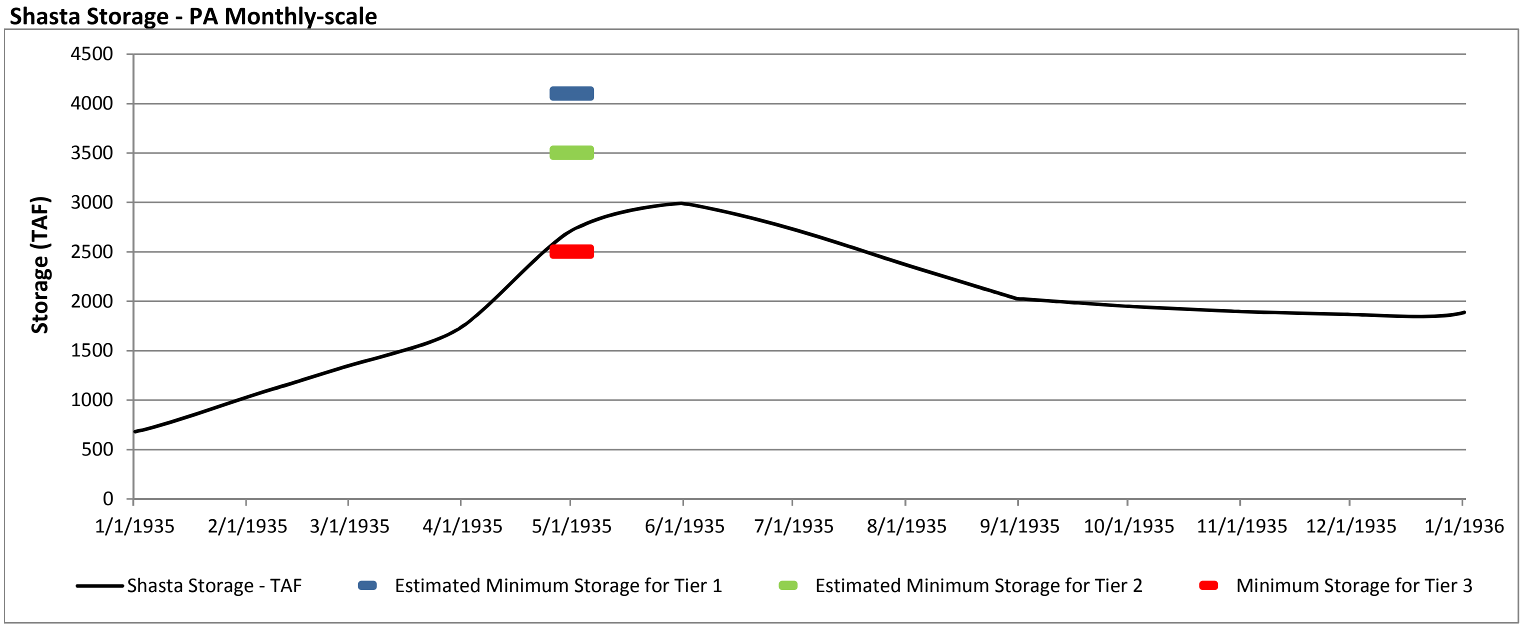
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1935

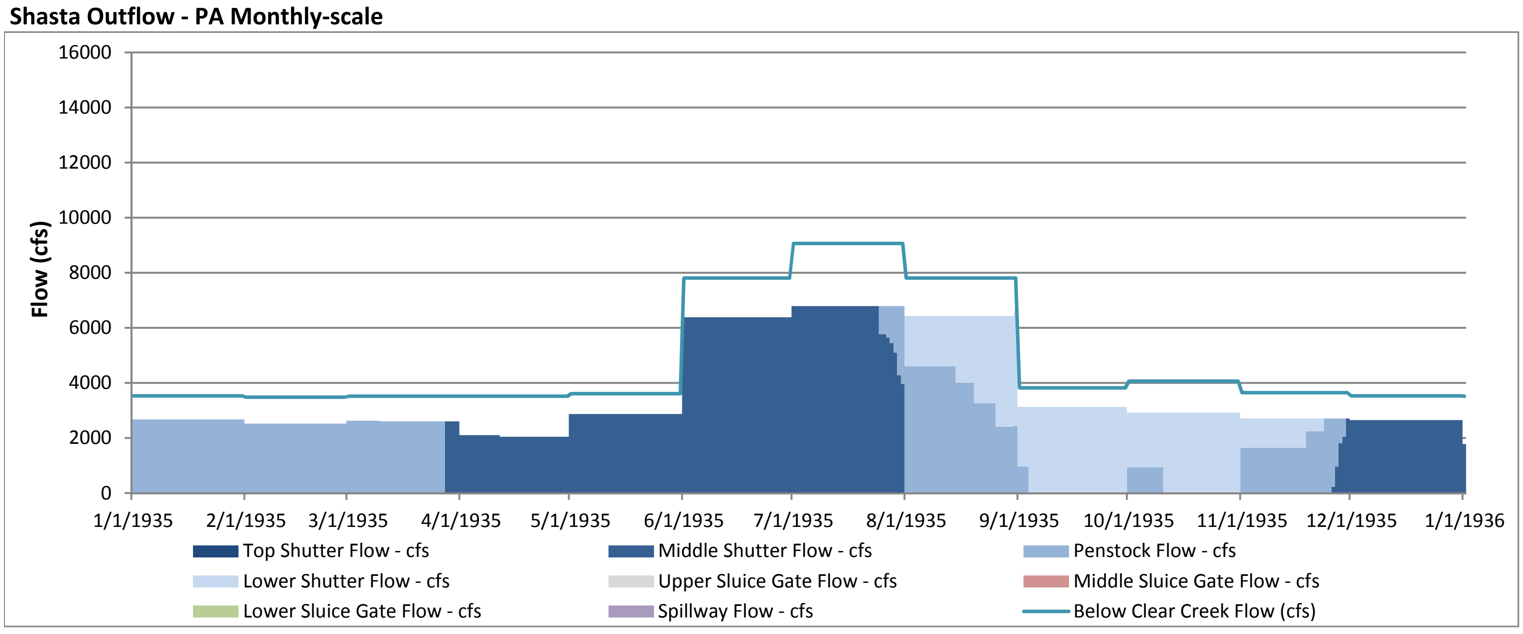
Temperature Tier:

Tier 3

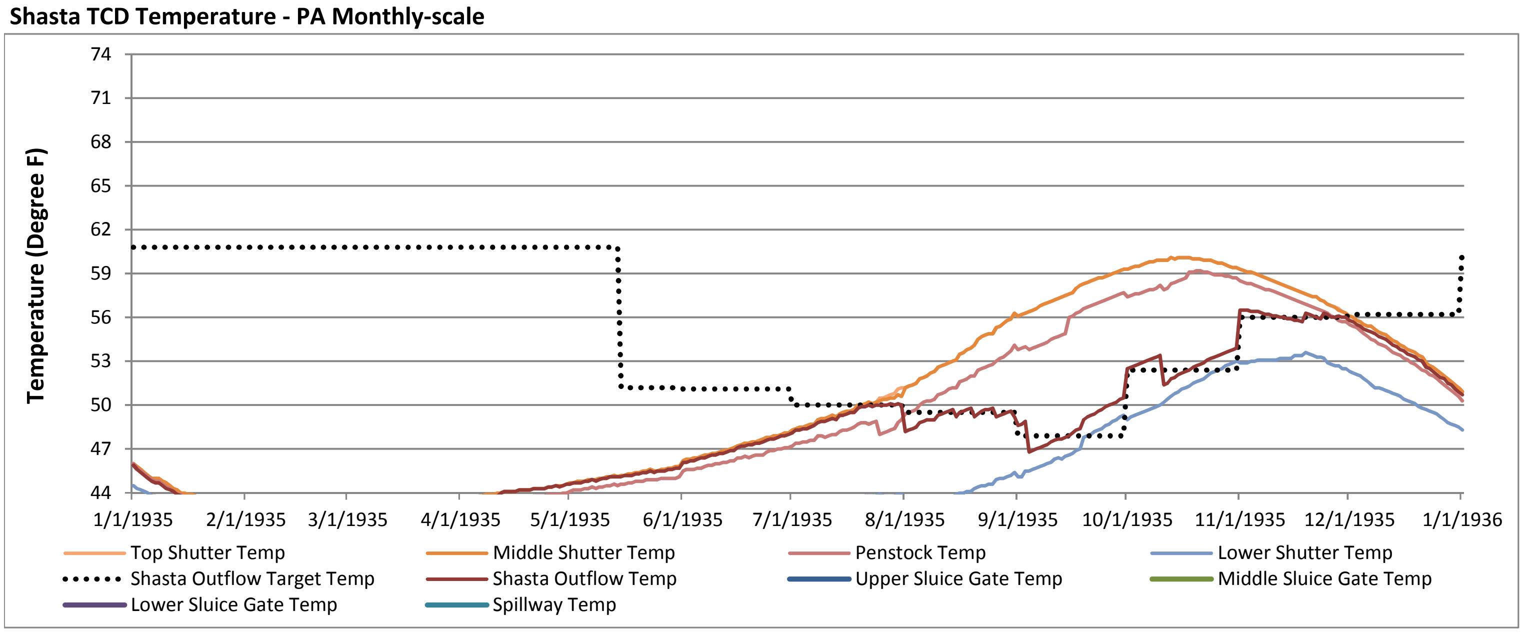
Annual Mortalities:

Anderson	5%
Martin	6%

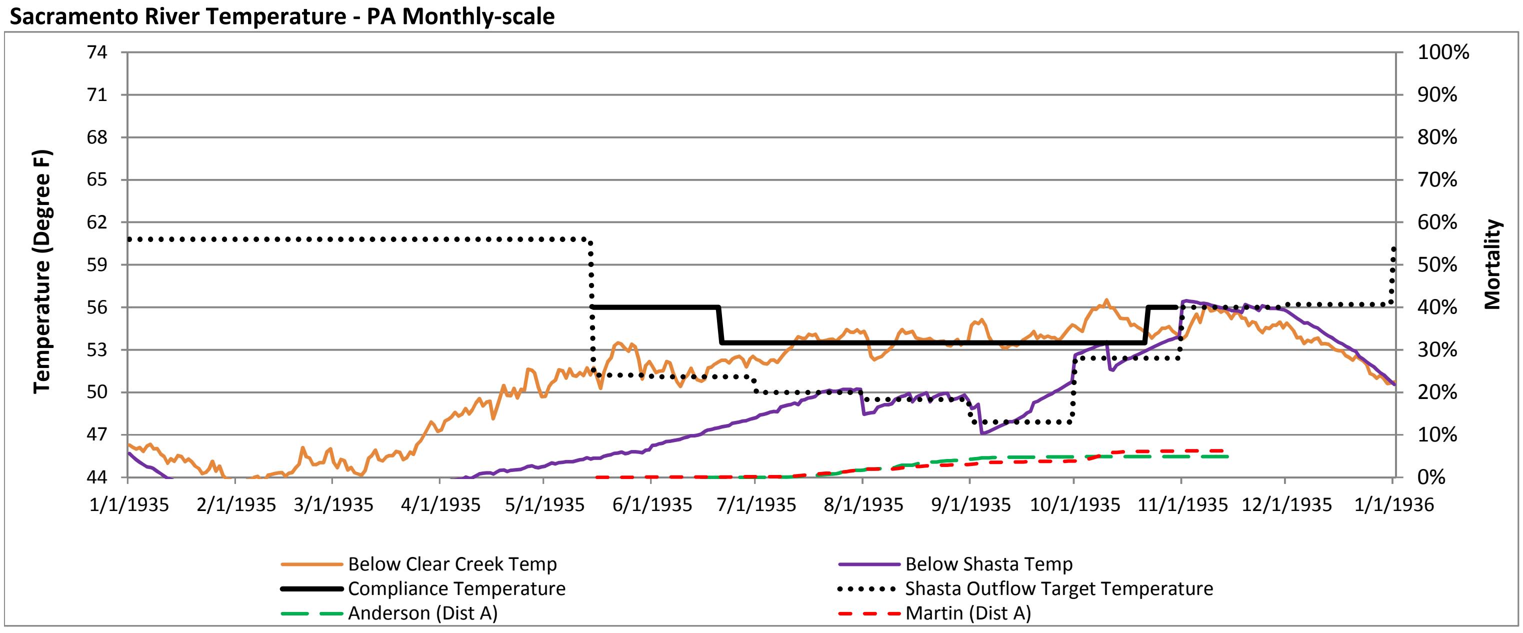
Shasta Outflow - PA Monthly-scale



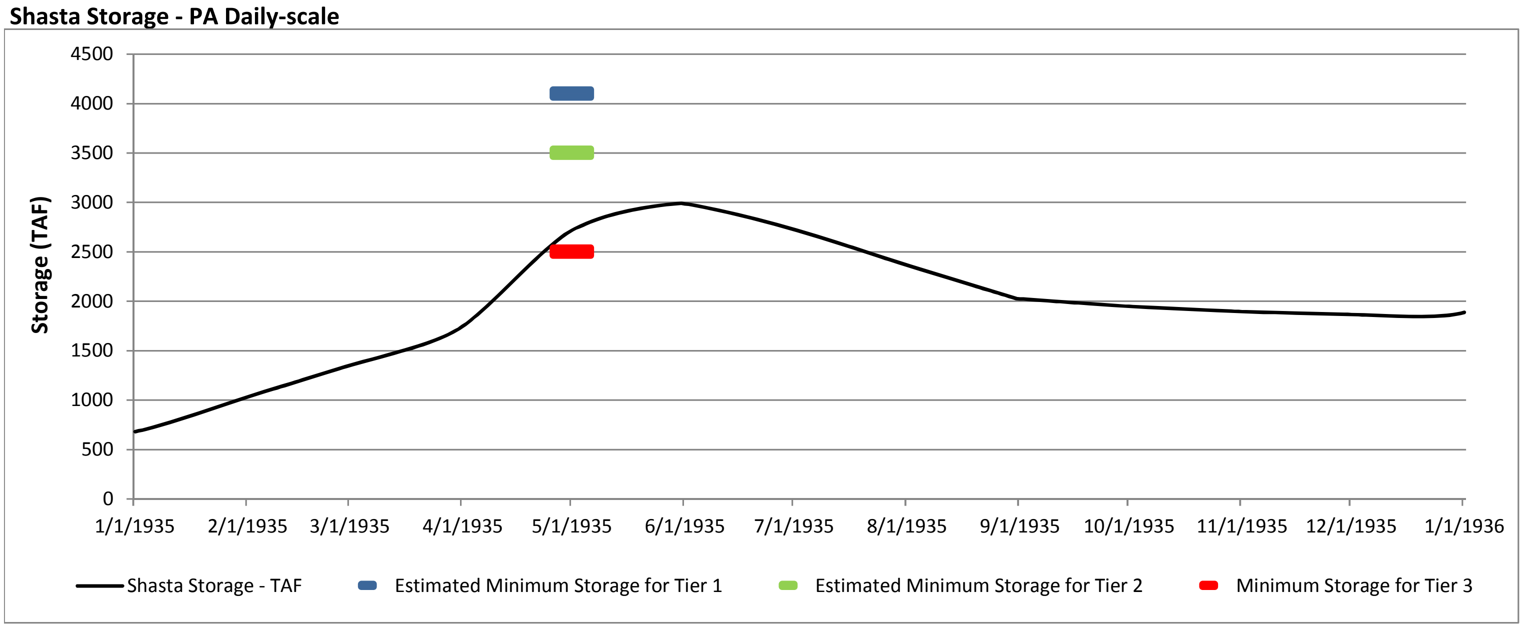
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1935

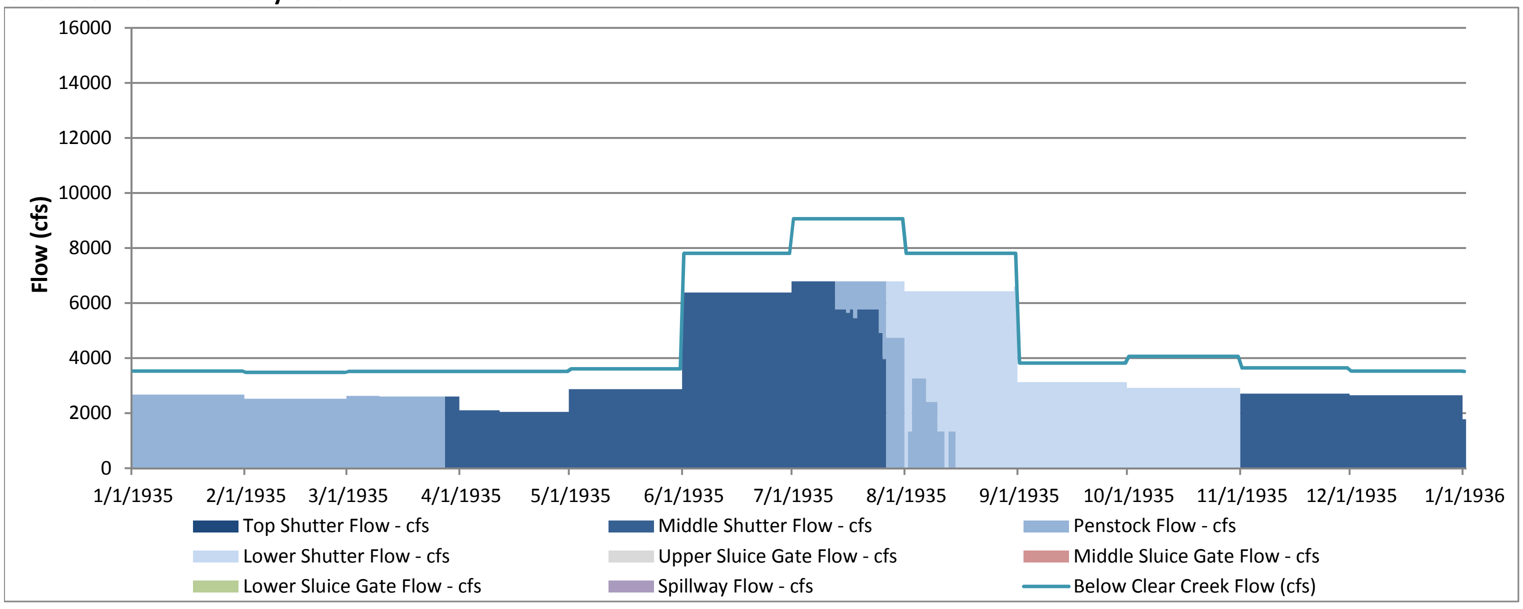
Temperature Tier:

Tier 3

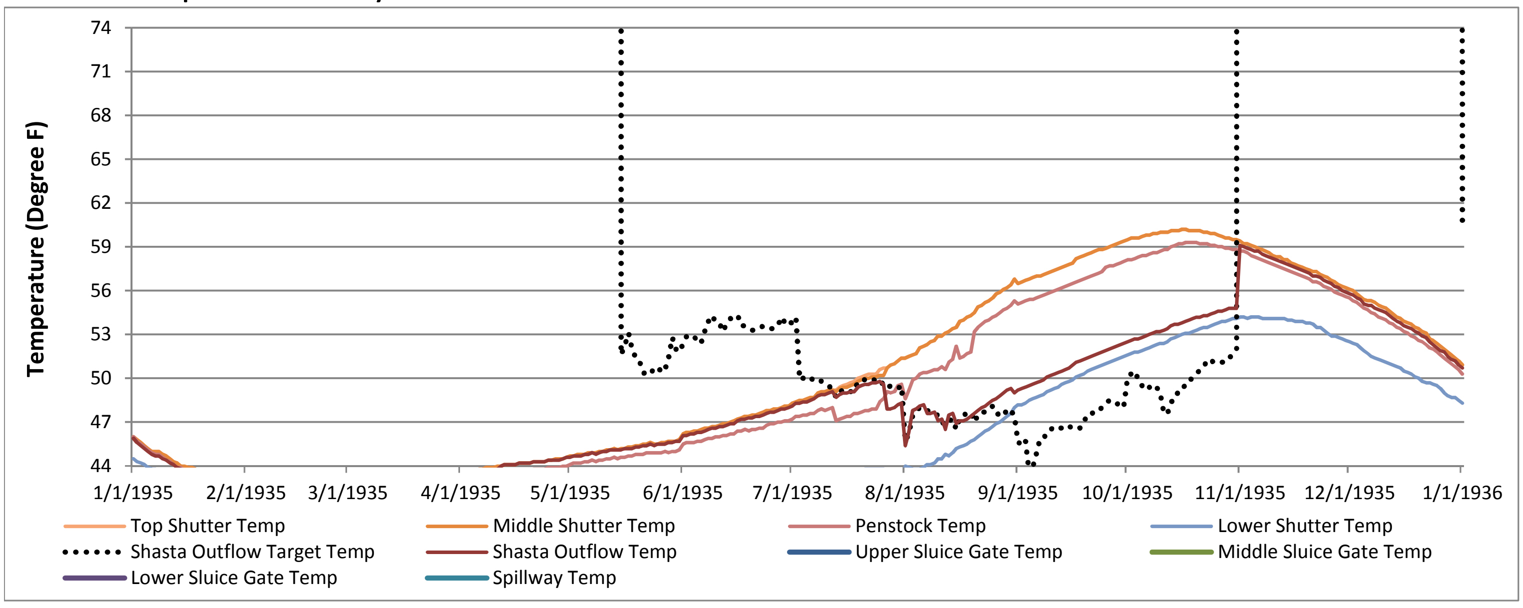
Annual Mortalities:

Anderson	7%
Martin	17%

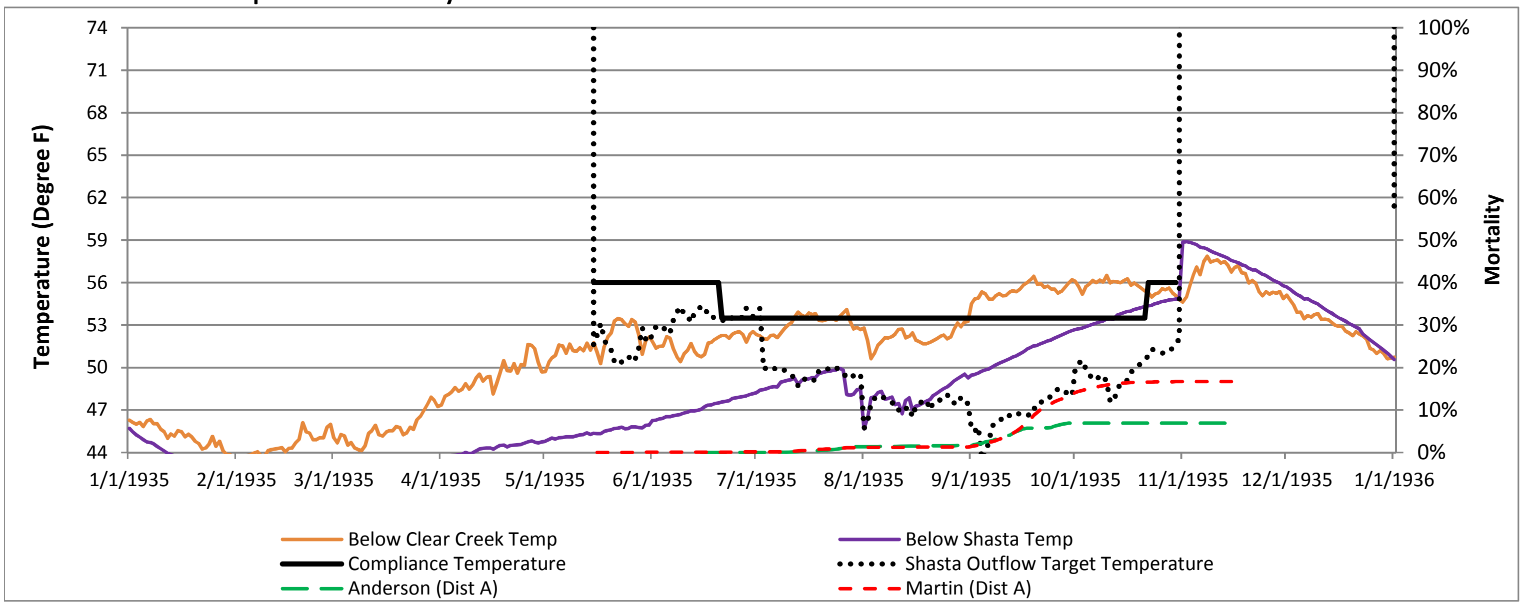
Shasta Outflow - PA Daily-scale



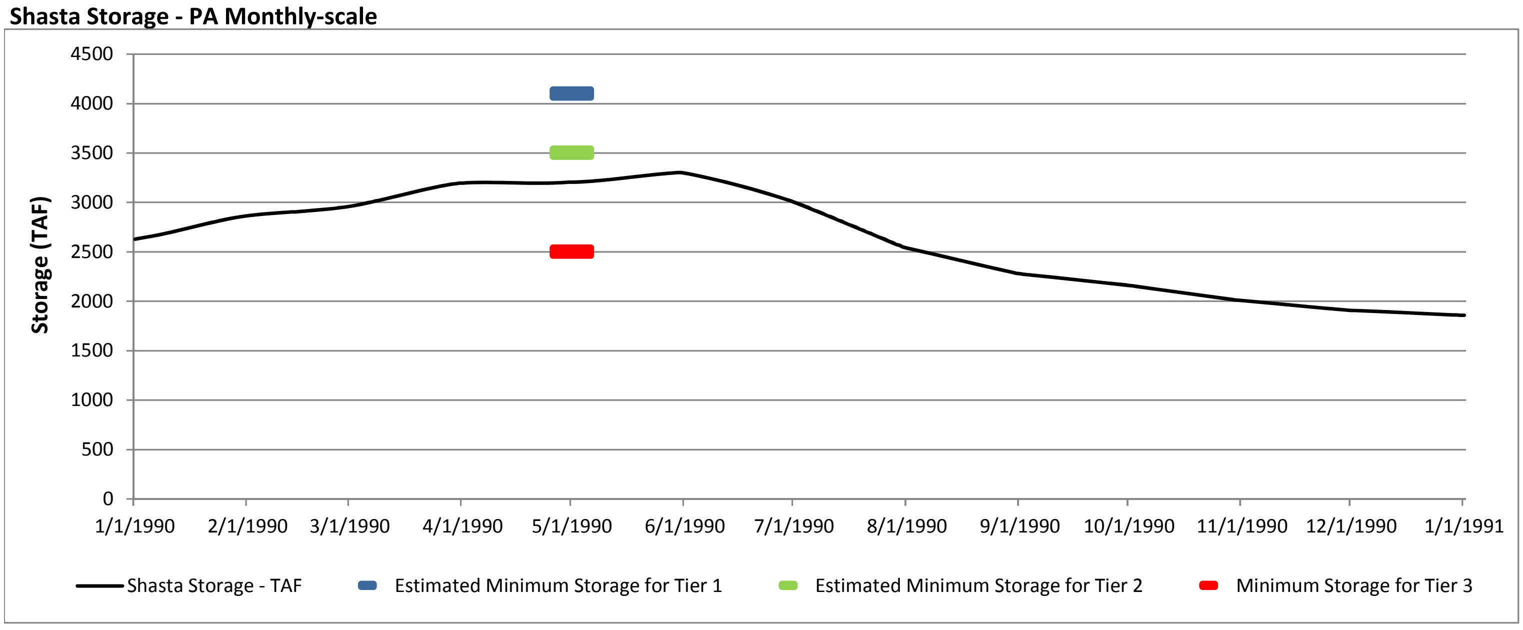
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1990

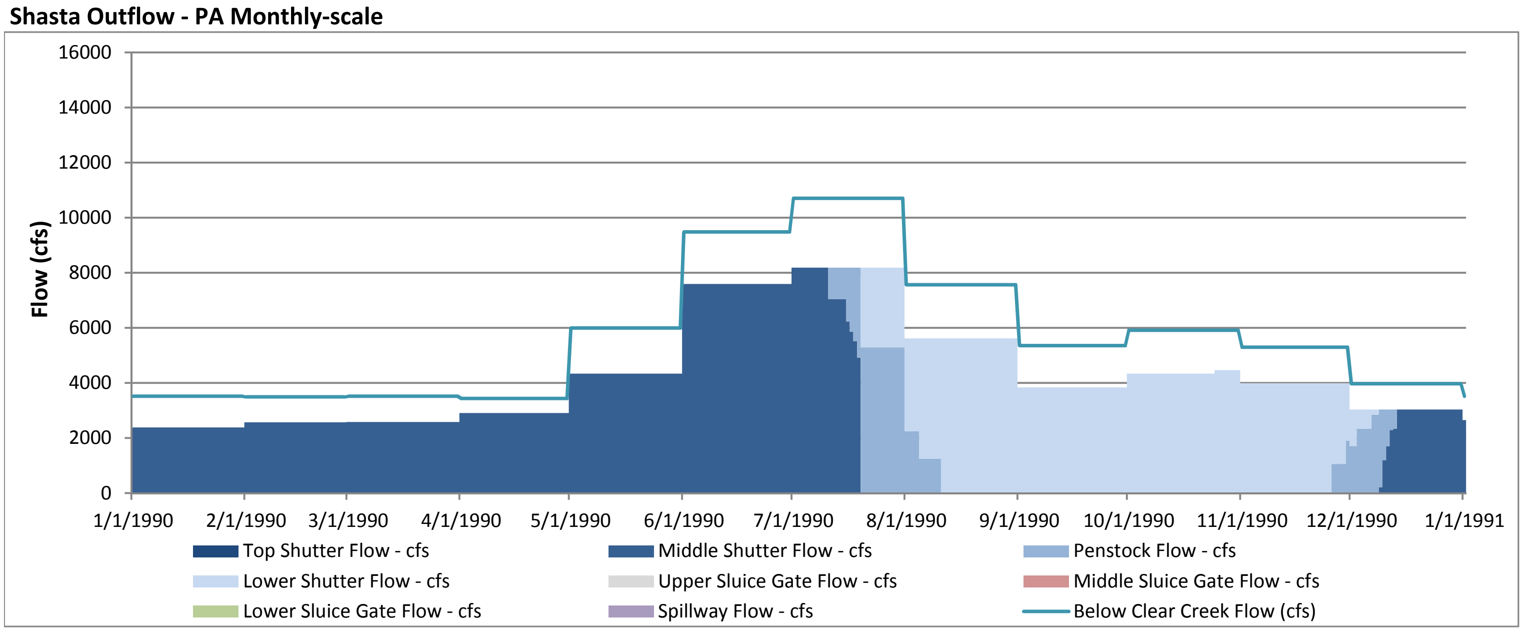
Temperature Tier:

Tier 3

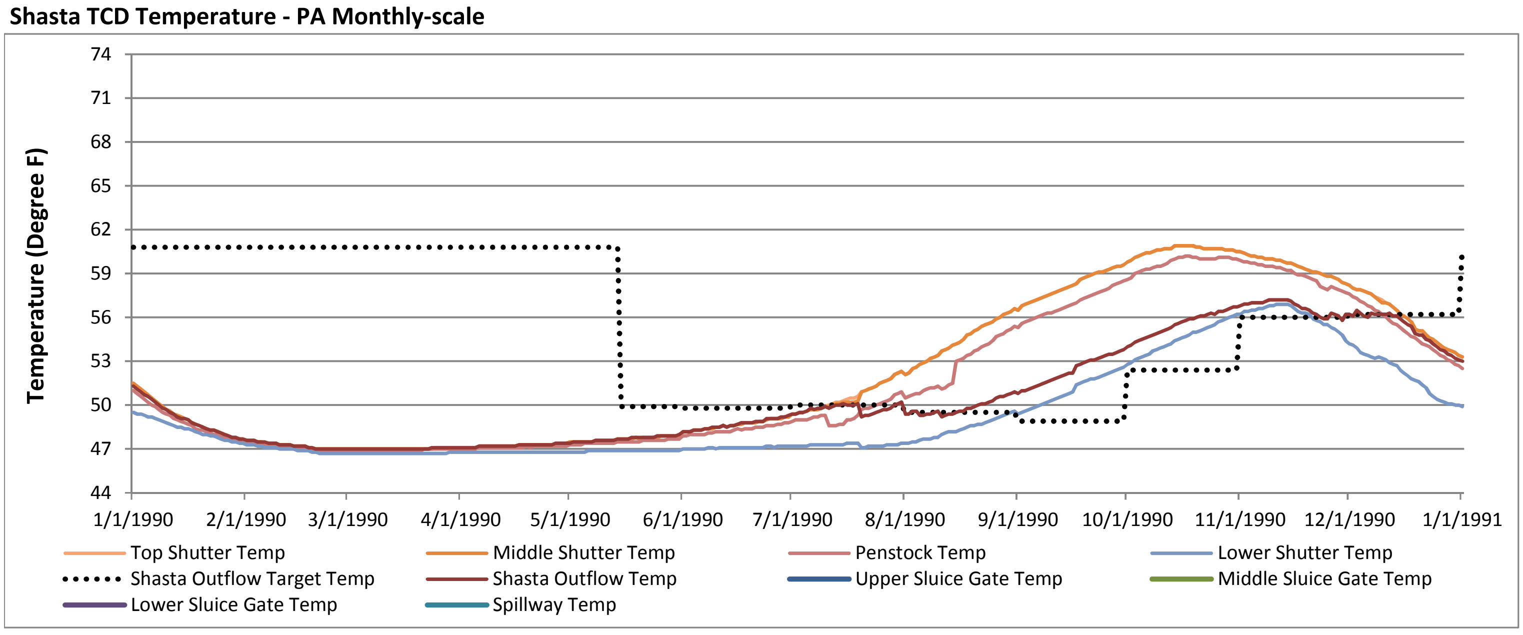
Annual Mortalities:

Anderson	35%
Martin	36%

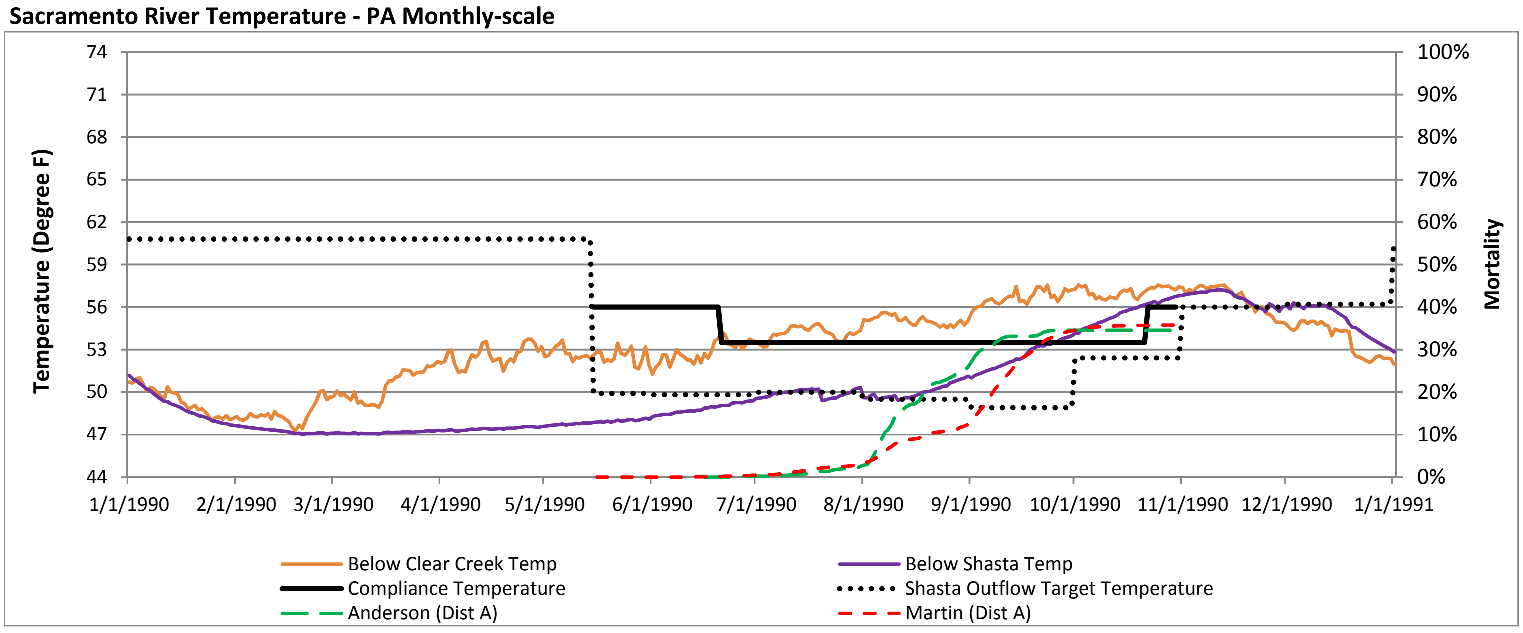
Shasta Outflow - PA Monthly-scale



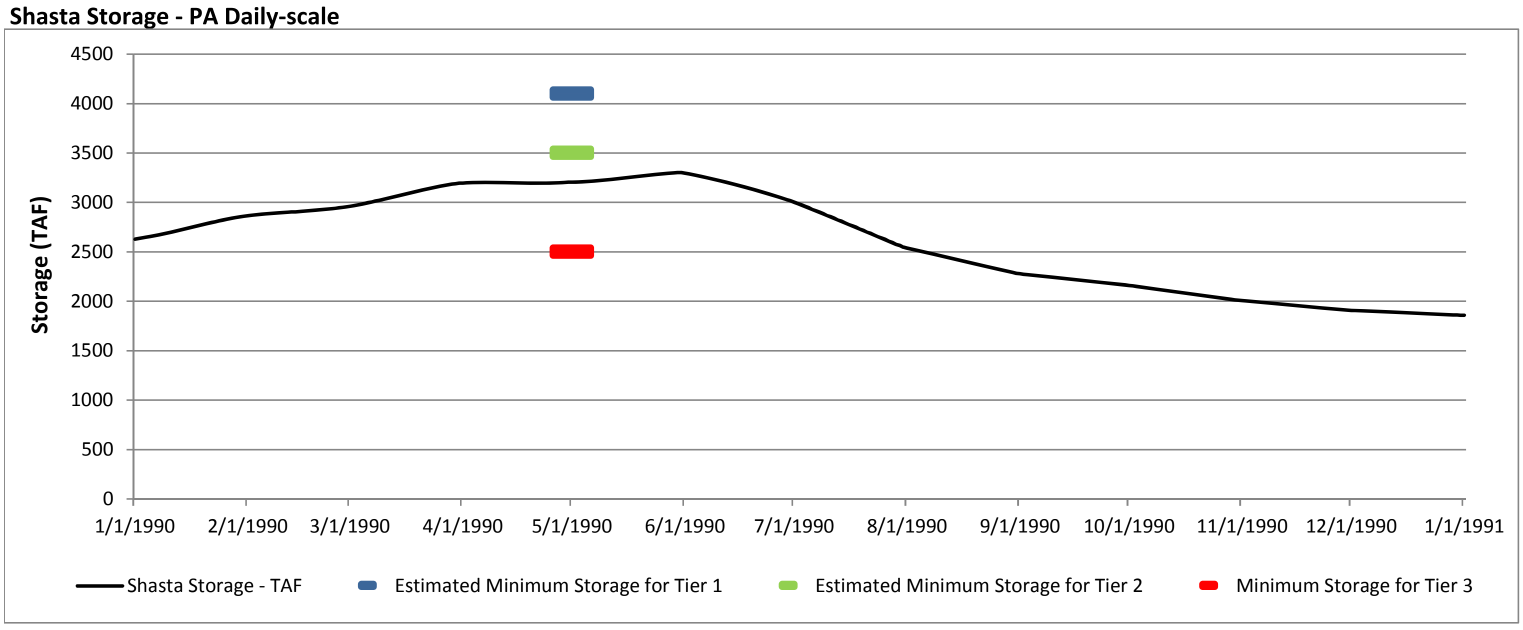
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1990

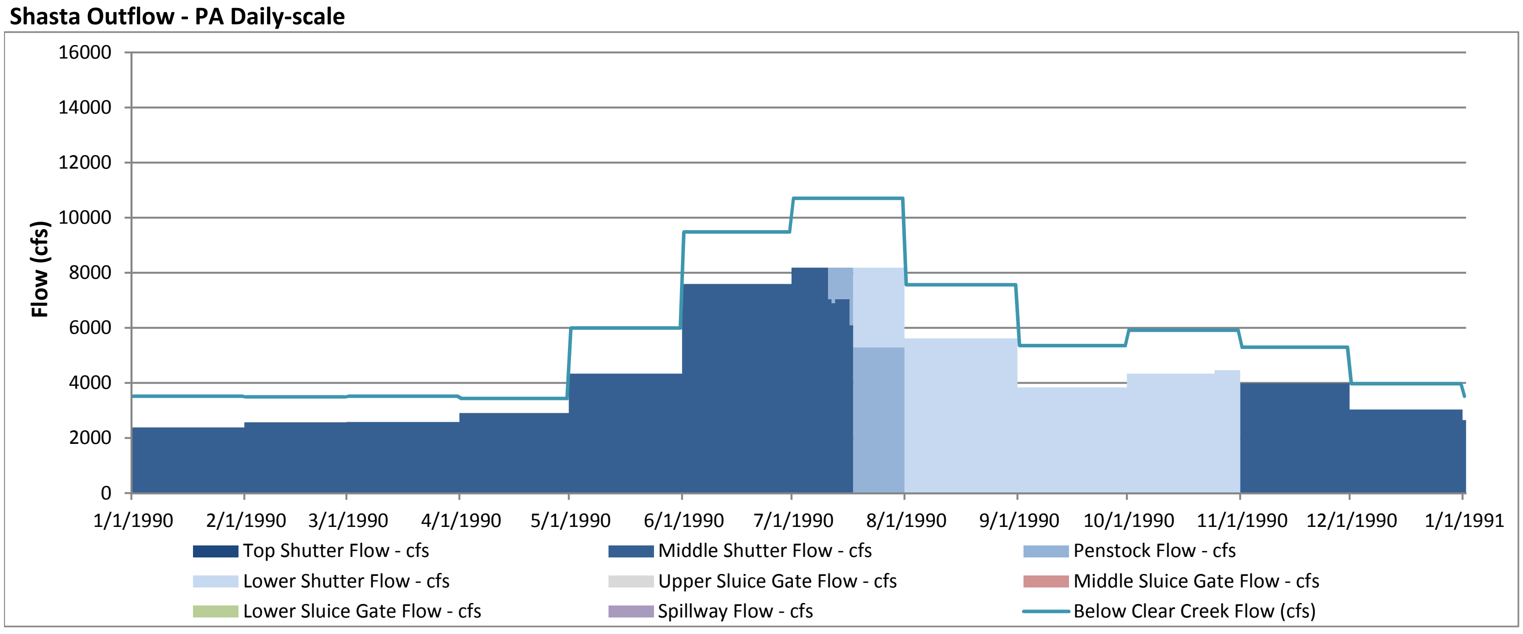
Temperature Tier:

Tier 3

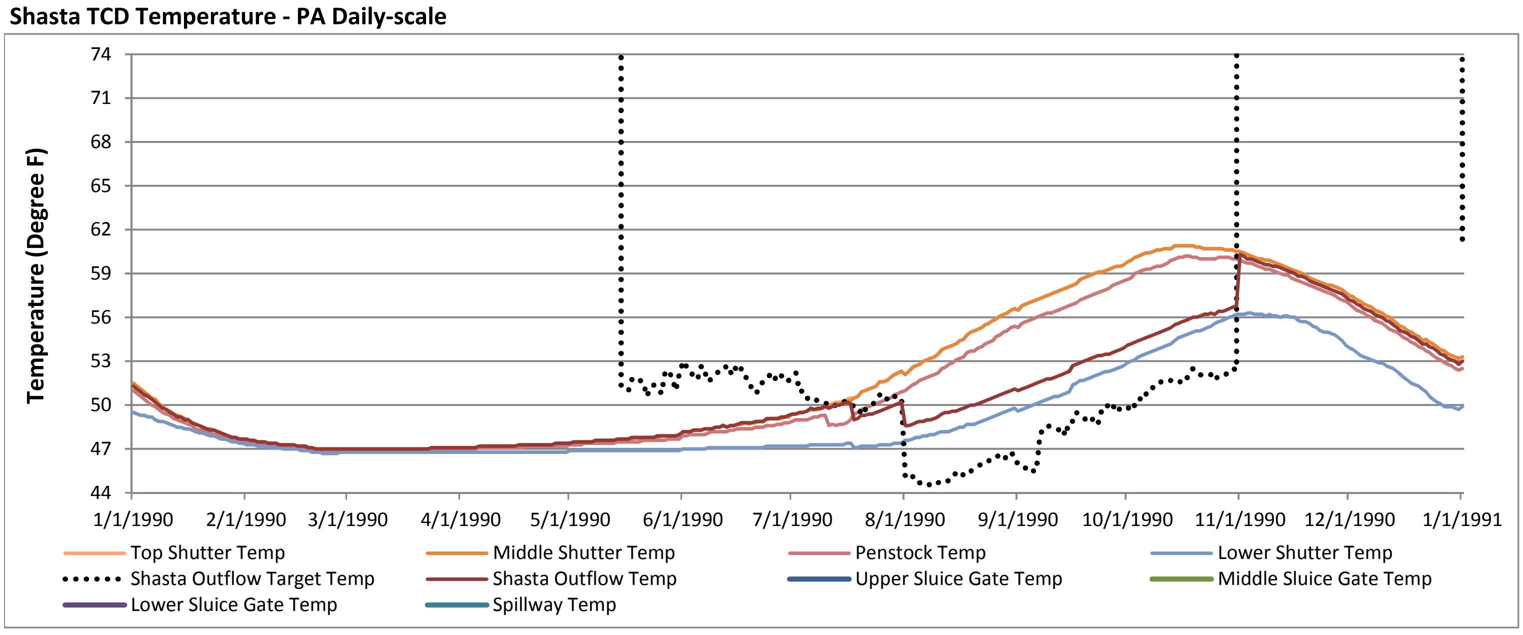
Annual Mortalities:

Anderson	30%
Martin	36%

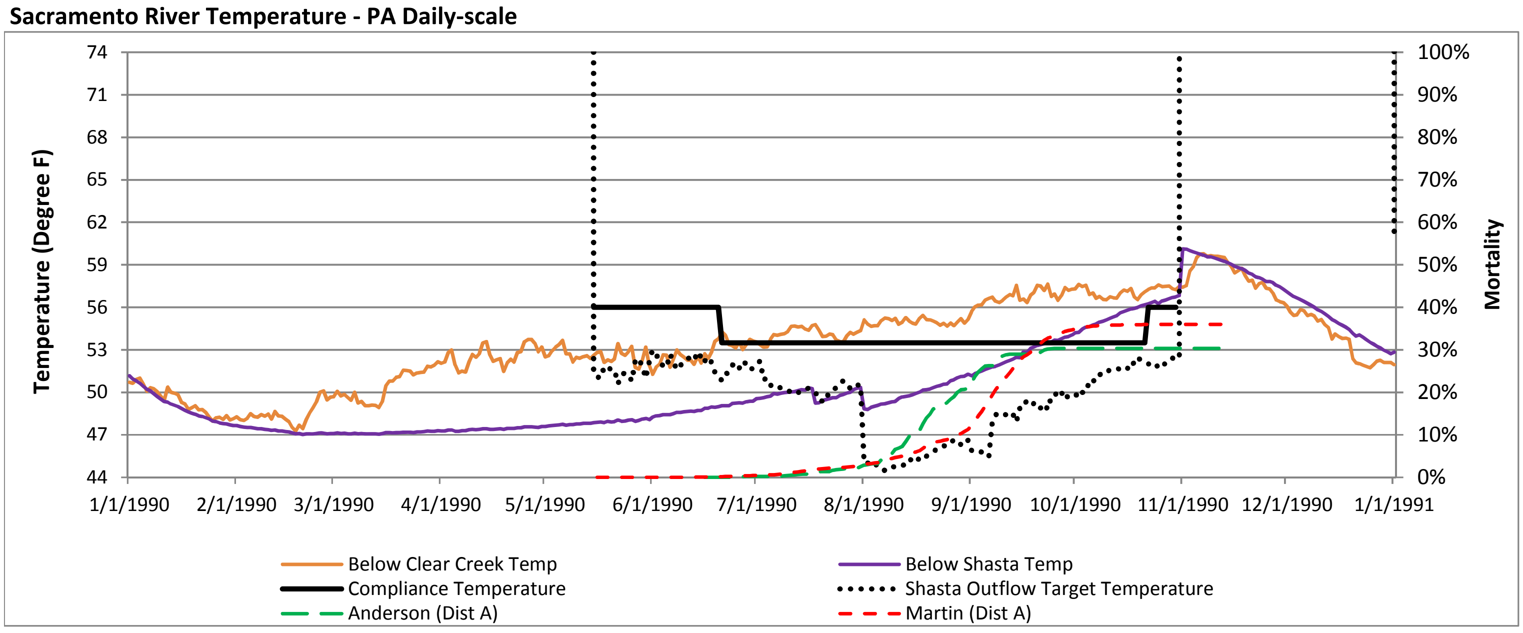
Shasta Outflow - PA Daily-scale



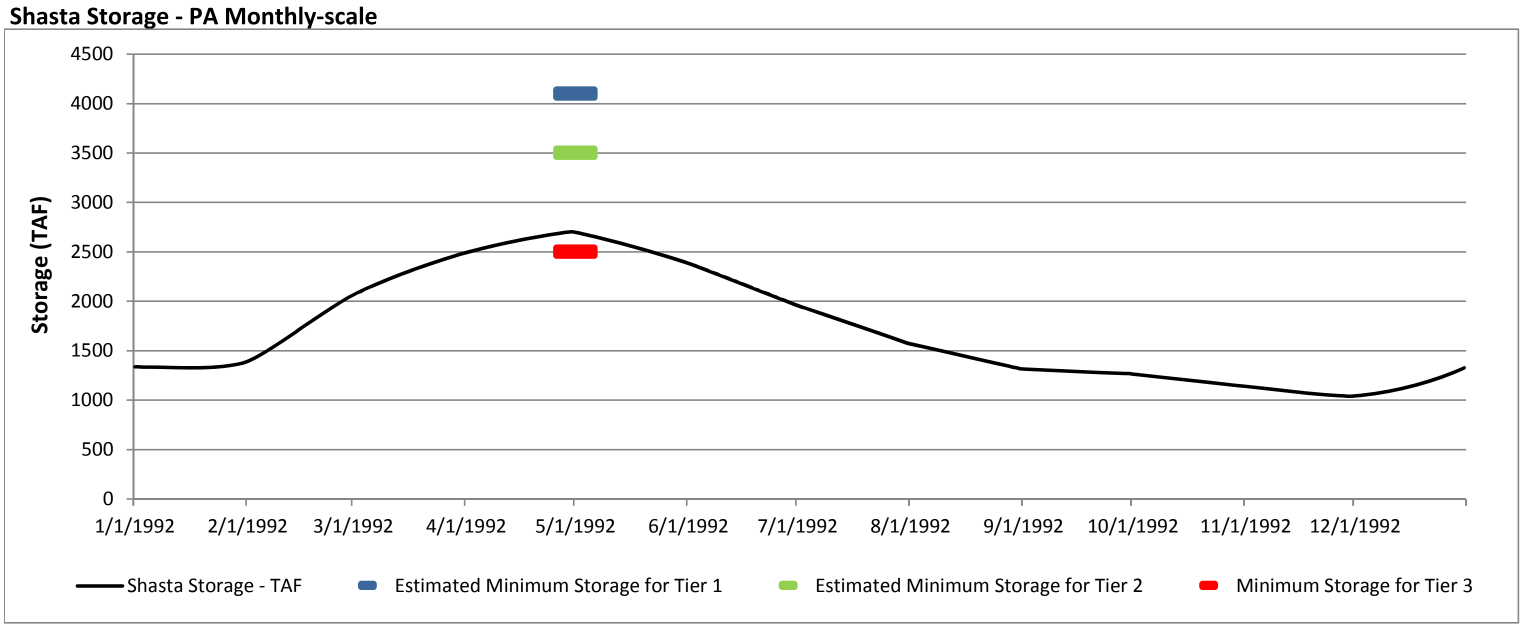
Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale



Shasta Storage - PA Monthly-scale



Select Year:

1992

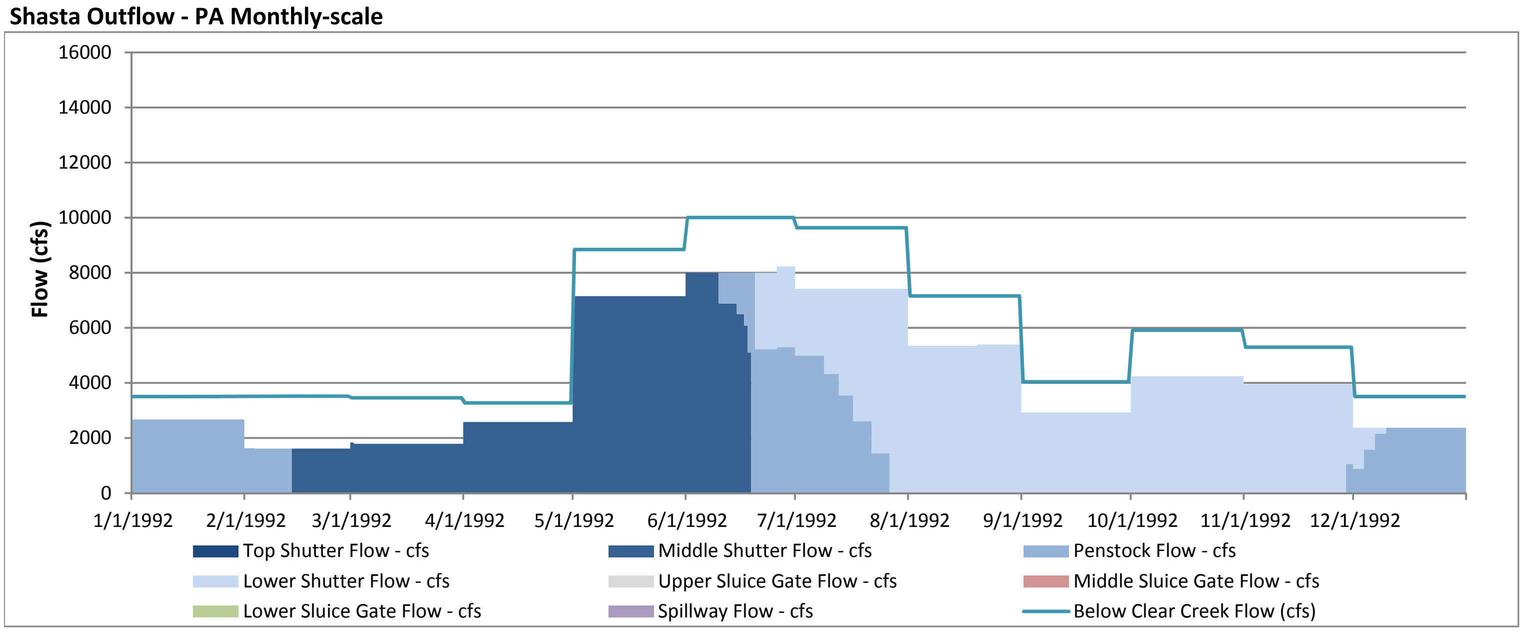
Temperature Tier:

Tier 3

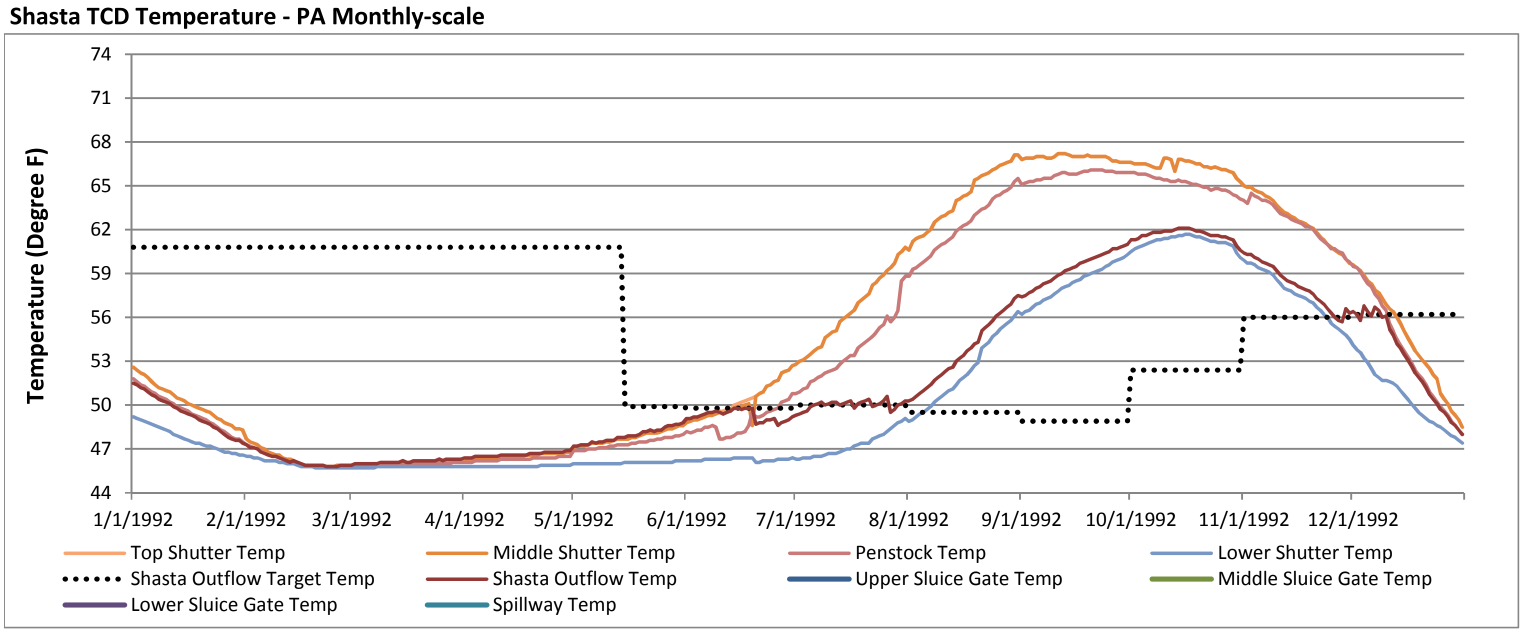
Annual Mortalities:

Anderson	66%
Martin	77%

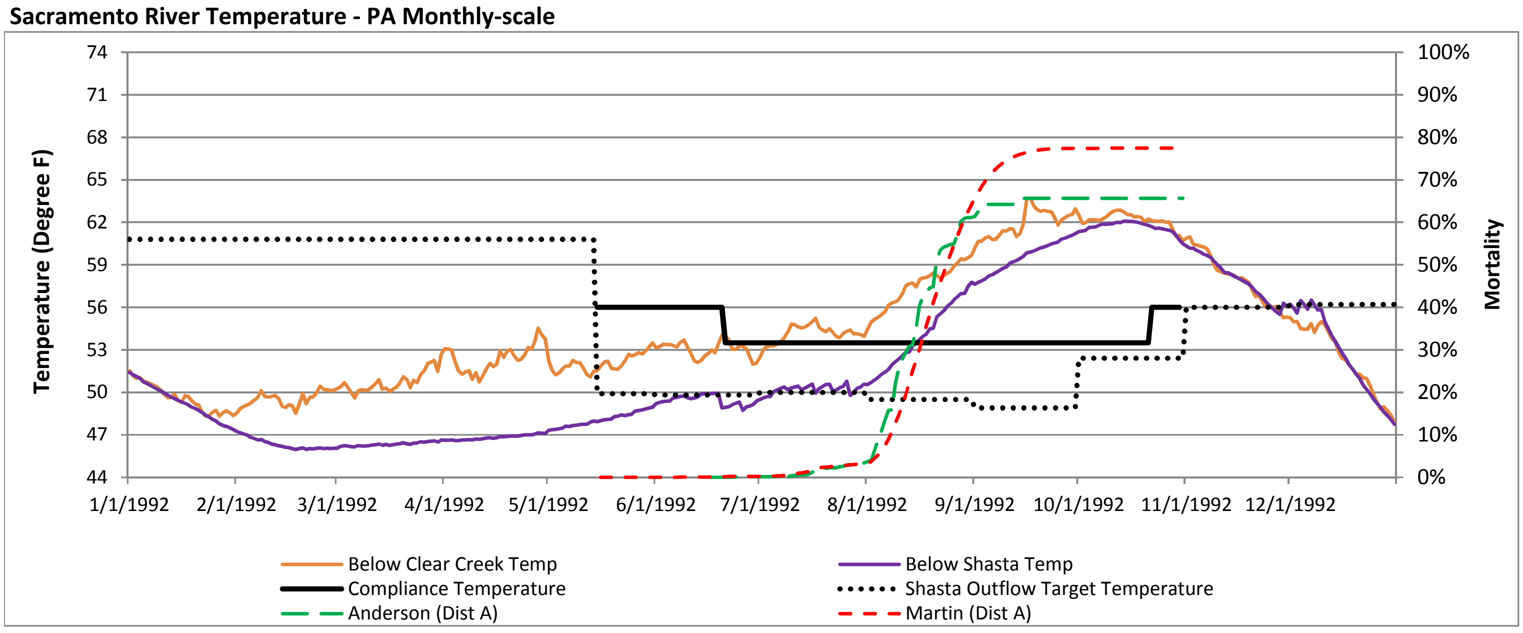
Shasta Outflow - PA Monthly-scale



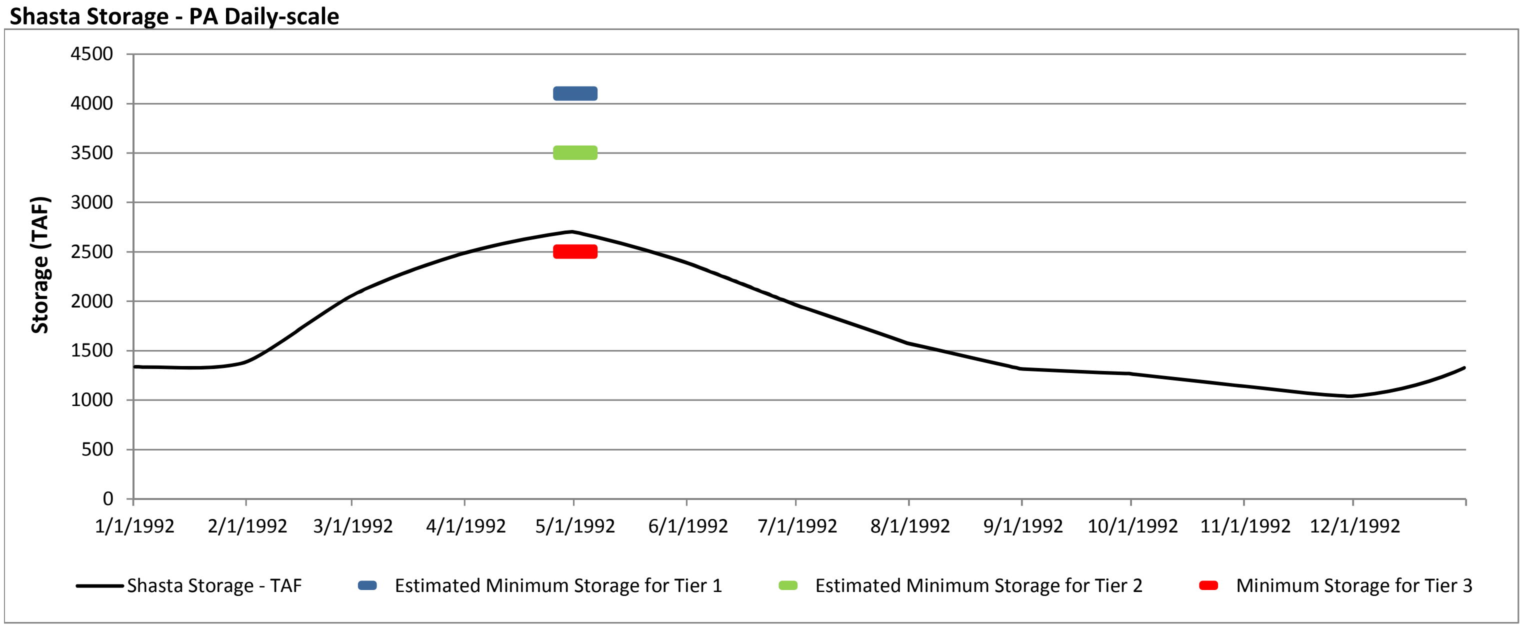
Shasta TCD Temperature - PA Monthly-scale



Sacramento River Temperature - PA Monthly-scale



Shasta Storage - PA Daily-scale



Select Year:

1992

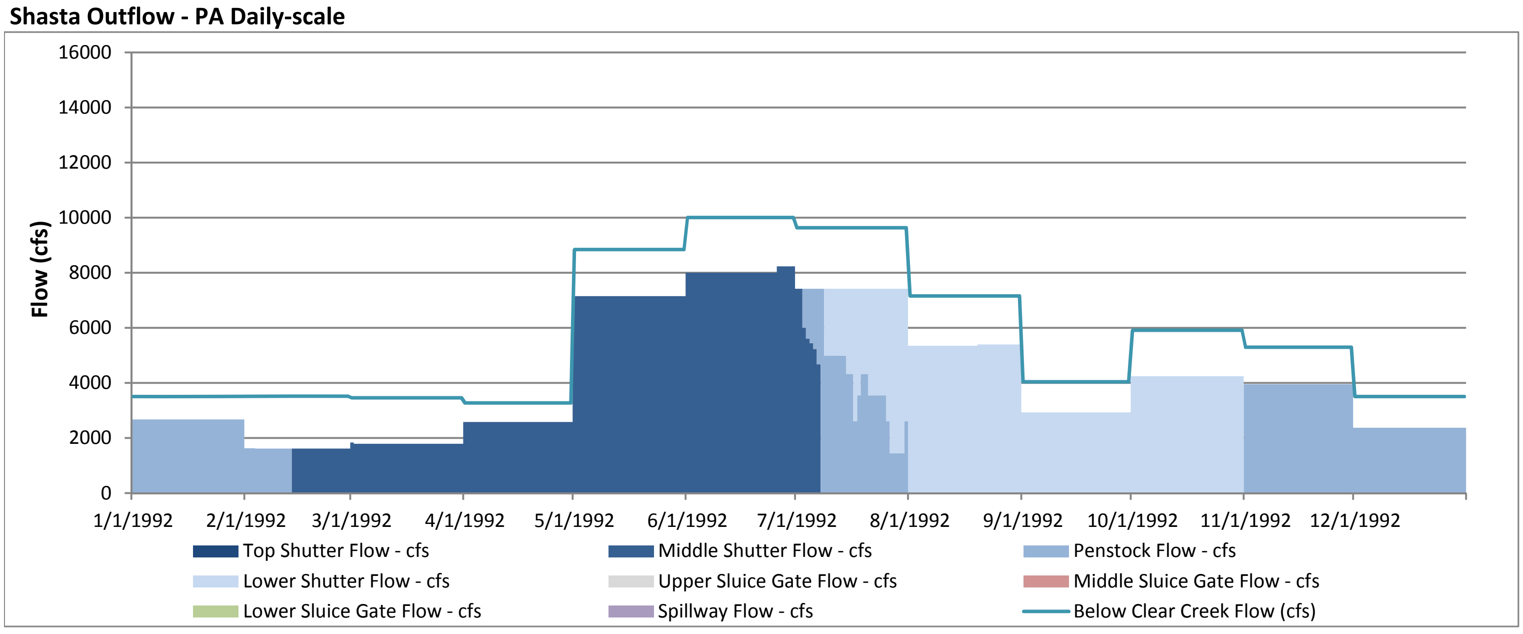
Temperature Tier:

Tier 3

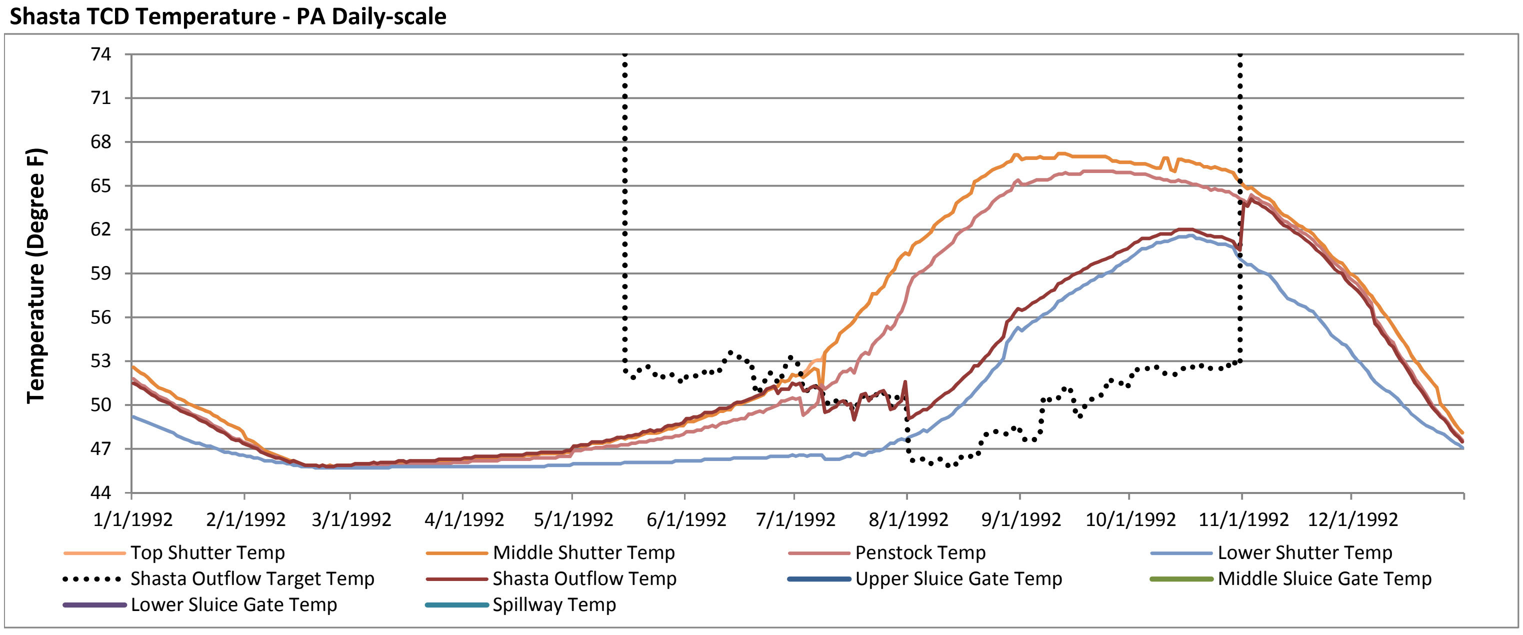
Annual Mortalities:

Anderson	57%
Martin	70%

Shasta Outflow - PA Daily-scale



Shasta TCD Temperature - PA Daily-scale



Sacramento River Temperature - PA Daily-scale