FIELD EVALUATION OF AN ELECTRICAL CROWDER IN THE SECONDARY CHANNEL AT THE TRACY FISH COLLECTION FACILITY

Investigators

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Summary

Federal and state fish screening facilities in the south Sacramento-San Joaquin Delta have been known to provide favorable habitat for predator fish, primarily striped bass *Morone saxatilis* (Gingras 1997, Bark *et al*. in draft). Predators tend to concentrate in and around fish screening facilities in zones where water velocities are lower (Bark *et al.* in draft). At the Tracy Fish Collection Facility (TFCF), striped bass are frequently found residing upstream, downstream, and within the facility (Bark *et al.* in draft). Striped bass are piscivorous fish that consume smaller fish and can reside within the TFCF year round feeding on seasonal influxes of entrained fish. Thus, striped bass can sustain a viable population within and near the facility as long as they have favorable environmental and feeding conditions (Bark *et al.* in draft). According to the Reasonable and Prudent Alternative in the 2009 National Marine Fisheries Service Biological Opinion, by December 31, 2011, Reclamation shall complete studies to determine methods for removal of predators in the primary channel, using physical and non-physical removal methods (*e.g*., electricity, sound, light, CO_2), with the goal of reducing predation loss to 10 percent or less (National Marine Fisheries Service, 2009).

A rolling electrical crowder was designed and tested in Reclamation's hydraulics laboratory for the purpose of deterring large predator fish (greater than 300 mm FL) from taking up residency in the TFCF. The crowder consisted of an electrical sequencer, electrofisher unit, and series of electrodes (Svoboda and Horn, 2013). The electrical crowder moved fish through avoidance rather than taxis, so injury to fish was minimized. Small laboratory flume tests showed that most striped

bass (285–590 mm FL) avoided the electrical crowder, swimming quickly out of the field. Juvenile Chinook salmon and rainbow trout (88–108 mm FL) displayed twitch or slight movement when exposed to the field. Lighting conditions affected behavioral response. Nineteen of 20 fish crowded through the bypass on the first pass of the electrical crowder when the bypass was light. All 20 fish moved through the bypass after 3 passes. Only 3 of 20 fish crowded on the first pass of the electrical crowder when the bypass was dark. Seventeen of 20 fish were driven through the bypass after 5 attempts at crowding.

In a larger laboratory flume similar to the TFCF secondary channel, a pulsed DC electrical field was produced with an average voltage gradient of 0.4 V/cm at 320 µS/cm water conductivity and 2.4 m (8 ft) electrode spacing. Although only 60 percent of adult striped bass were crowded, no fish experienced taxis. To minimize harm to fish, the crowder can be operated at the lowest possible settings on an intermittent basis with the goal of reducing predator populations over time.

From laboratory testing, it appears that a rolling electric crowder may be an effective way of reducing predator populations at the TFCF. The 2009 Biological specifies that Reclamation shall determine methods for removing predators in the primary channel. Full coverage of the primary channel with an electrical crowder has been investigated on a preliminary level. The budget associated with a field trial in the primary channel is significant due the large channel width, deep water depth, inability to dewater, and equipment needs. Therefore, it is proposed that an electrical crowder be installed in the secondary channel for field testing as proof-of-concept, since it is a smaller, more controlled environment.

In FY13, an initial proposal for field testing in the secondary channel was written. Permitting requirements for a field evaluation were investigated. A safety plan was drafted in the form of a Job Hazard Analysis. By the end of FY13, the safety plan for a field test in the secondary channel will be discussed with local and regional Reclamation safety officers.

Problem Statement

This proposal focuses on the use of an electrical crowder as a method for reducing predator populations at the TFCF. Laboratory tests have shown that a rolling electrical crowder may be an effective way of controlling predators. Due to the complexities of a field test in the primary channel, a field test is recommended in the TFCF secondary channel after removal of the existing louvers and installation of the traveling screens (scheduled for spring 2014). The electrode layout and electrical parameters will be set up to produce a near-uniform electrical field in the secondary channel.

The primary goal of the field test is to determine if predator populations can be reduced with an electric crowder. This field test will not determine if the reduction in predators correlates to an increase in survival of salmon smolts. A separate study would be needed to determine how many predators must be removed to improve smolt survival. For the current test plan, tag-and-release experiments will be conducted with striped bass to determine collection efficiencies and survival for various size classes. Salmon smolts will also be tested to determine if the electrical crowder affects collection rates or survival. Experiments will also be conducted with variable lighting conditions in the bypass opening.

Goals and Hypotheses

Goals:

1. Document the effectiveness of an electrical crowder at removing predator fish in the TFCF secondary channel.

2. Document the effect of an electrical crowder on smaller fish in the TFCF secondary channel.

3. Produce a safe environment for personnel working at the TFCF during electrical crowding and document safety procedures.

Hypotheses:

1. An electrical crowder can be used to increase the capture rate of larger bodied fish (e.g. striped bass) while minimally affecting the capture rate of smaller bodied fish (e.g. salmon smolts).

2. An electrical crowder will not increase morality of tagged striped bass or juvenile salmon over results of control tests.

3. An electrical crowder will not increase mortality of naturally occurring fish over results of control tests.

4. More striped bass will be collected during the first round of crowding when the bypass entrance is artificially lighted.

Materials and Methods

Experimental Set-up

An electrical crowder was installed in a laboratory flume similar in dimensions to the TFCF secondary channel. The initial field set-up will replicate the layout of electrodes in the laboratory. Pairs of 1.9-cm-diameter (¾-in-diameter) aluminum poles with PVC slotted covers will be attached every 2.4 m (8 ft) in the secondary channel with brackets or epoxy. Along the traveling screen, electrodes will be attached every 4.0 m (13.0 ft) on the traveling screen frame with electrode pairs on the concrete sidewall offset by 2.0 m (6.5 ft). This spacing should minimize harm to fish encountering the electric field in the narrower section of the channel. The electrode set-up will be modified as needed based on final construction of the traveling screen.

The electrical field will be measured in the secondary channel with a voltage gradient meter. If the field is not uniform, the electrode spacing will be modified. It may be possible to install electrodes behind the traveling screen on the concrete sidewall if voltage gradients are too high in the narrower channel section. Electrodes may also be placed at the end of the primary bypass to discourage predators from moving upstream into the pipes to avoid the electric field.

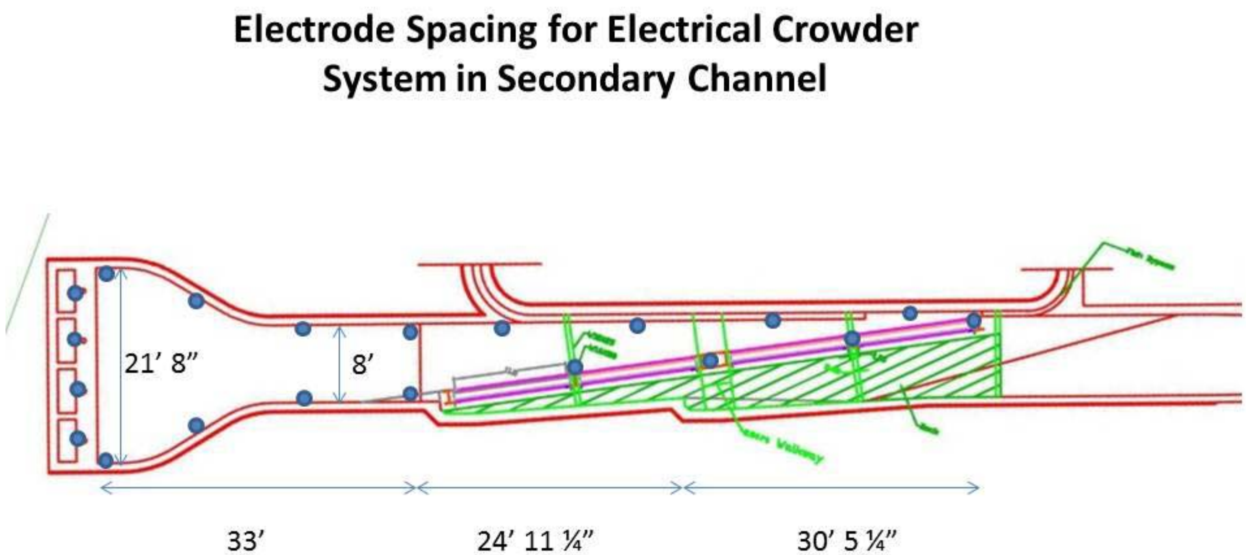

Figure 1.—Proposed spacing of electrodes in the secondary channel. Blue dots represent electrodes. Electrodes may be placed at the end of the bypass pipes entering the channel.

In the laboratory, an electrofisher unit was used to pulse DC with a peak voltage of 300 V, pulse width of 1.2 ms, and frequency of 7 Hz. With these electrical parameters, an average voltage gradient of 0.4 V/cm was produced at a water conductivity of 320 µS/cm. These laboratory settings will be used as the initial settings for the field evaluation. Temperature and water conductivity will be measured in the secondary channel at the start of each test day. A voltage gradient meter will be used to record the electrical field at mid-depth in the water column at various points in the secondary channel. Measurements will be collected at 5 locations across the width of the channel (0.5, 2.0, 4.0, 6.0, and 7.5 ft from the electrode) and at multiple transects depending on access to the water surface. Electrical settings will be modified as needed to produce appropriate voltage levels in the secondary channel.

Test Plan

Striped bass will be collected from the TFCF during routine secondary channel predator removals. Approximately 200-250 adult striped bass will be held in tanks for use during the experiments. The desired size class is greater than 200 mm. Depending on availability, striped bass in size classes of 200-350 mm, 350-500mm, and greater than 500 mm should be run to identify any size dependence on response. Salmon smolts will also be used during testing. Approximately 200 salmon smolts in the size range of 100-150 mm will be obtained from a local fish hatchery. Fish will be tagged before release. Striped bass will be floy tagged and salmon smolts will be fin clipped with distinct markings signifying the specific test run. Fish will be released at the upstream end of the secondary channel with a lowered bucket and collected in a holding tank after the experiment is complete.

The secondary channel will be run under standard operating conditions. Temperature and water conductivity will be measured in the secondary channel at the start of each test day. During testing, the secondary velocity will be held relatively constant as water level changes with the tidal cycle. Laboratory tests showed that water velocity was not a factor in fish response to the field. Water velocity is most important in determining how fast the electric field should roll through the channel. To allow any stunned fish to drift out of the electric field, the crowder should roll more slowly than the channel velocity.

Crowder Duration Tests

During laboratory tests, the electric field was rolled through the channel up to 5 times based on visual observations of fish response. The duration of electric crowder exposure for successful predator crowding in the secondary channel will need to be determined. The crowder will be run for 10 minutes every half hour with a total of three crowding sessions. Ten tagged striped bass will be placed in the secondary channel. The catch rate for the first 10 minute session will be compared to the second and third 10 minute sessions. The crowder duration tests will be repeated 3 times to assist researchers in deciding how long the crowder should be run for successful predator collection.

Bypass Lighting Tests

Model results showed that lighting conditions had a significant effect on fish crowding behavior. Recommendations from laboratory tests state that if the electric crowder is operated during the daytime, lights should be installed in the bypass to facilitate fish movement. If it is not feasible to install lights, crowding should be accomplished during the evening, when there is less difference between the ambient light condition and bypass light condition.

The effect of bypass lighting should be examined in the TFCF field test. The electrical crowder should be run during the daytime with a dark bypass (existing condition) and a light bypass (test condition) to determine if there is a statistically significant difference in collection rates. In order to add light to the bypass entrance, a string of low profile, waterproof LED lights can be attached to the sidewall of the 6-in-wide bypass entrance. If a vertical string of LED lights blocks too much of the entrance, a light could be installed above the water surface shining downward through the water column. Ten tagged striped bass will be added to the secondary channel for each replicate with a dark and light bypass. Initially, five replicates will be conducted and modified based on variance.

Control Tests without Electricity

Control tests will be conducted with the bypass lighting settings recommended from the Bypass Lighting Tests. With the electrical crowder off, 10 tagged striped bass and 20 tagged salmon smolts will be run through the secondary channel and collected in holding tanks after 2 hours. These tagged fish will be sorted, removed, and placed in a fish tank for observation of 72 hour survival. Initially, five replicates will be conducted and modified based on variance.

Electrical Crowder Collection Tests

The electrode set-up and electrical settings determined during the experimental set-up will be utilized for the crowder tests. Test will be conducted with the bypass lighting settings recommended from the Bypass Lighting Tests. Ten tagged striped bass and 20 tagged salmon smolts will be released in the secondary channel at the beginning of the experiment. The electrical crowder will be turned on for the amount of time specified during the Crowder Duration tests. Fish that move through the bypass will be collected in a holding tank. Seventy-two hour survival will be observed. Initially, five replicates will be conducted and modified based on variance. Success of the electric crowder will be defined as a statistically significant difference between collection rates with and without the electrical crowder operating.

Safety Plan

Electric barrier equipment uses voltages and currents that can produce electric shock in humans. Humans are three times more likely to be electrocuted by AC current than DC current; therefore DC current is used in electric barriers. Smith-Root barrier systems are designed to be non-lethal by using only low-frequency pulsed DC to create an electric field. The maximum pulse duration for electric barrier units is less than the electrocution threshold for a typical adult and less than the threshold for a typical ground fault interrupter (see Figure 1, from Smith Root, Inc. website). However, a number of factors affect electric shock including current path, exposure duration, age, size, and health. Personnel with a prior heart ailment are at greatest risk. Ventricular fibrillation, respiratory arrest, or asphyxia can result from electric shock.

Operators of electrical equipment must always keep in mind that the chance of receiving an electrical shock is multiplied in or near water. The total voltage applied to the system, however, is not the total voltage that a person encountering the field would experience. The voltage is dissipated over the length of the field, so the voltage gradient over any small length of the field is much less than the total voltage applied.

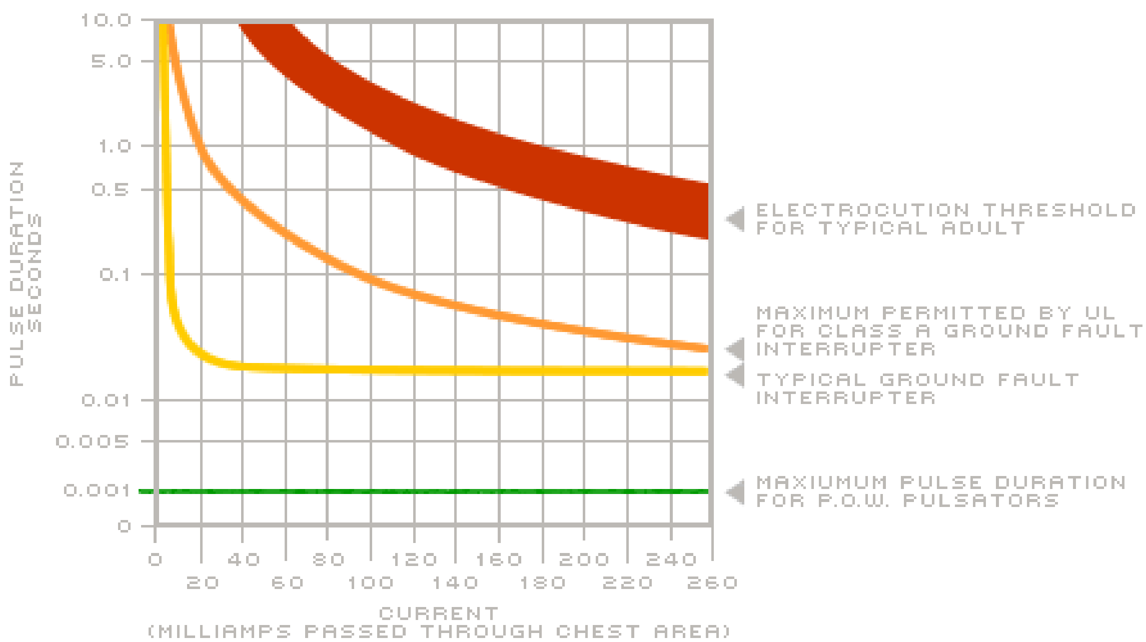

Figure 2.—Comparison of current produced by a Smith-Root pulsator units versus the electrocution threshold for a typical adult (Smith-Root, Inc., www.smith-root.com).

Although there are instances where humans have inadvertently floated through electric barriers without harm (Carl Burger, Smith-Root, Inc., personal communication), the electrical crowder will be treated as inherently dangerous. As such, mitigation of the hazard is required.

A Job Hazard Analysis (JHA) was developed by the principal researchers, Connie Svoboda and Mike Horn, in FY12 (draft available upon request). The JHA outlines hazards, mitigation of hazards, necessary safety equipment, procedures for working near electricity, and emergency information. The Technical Service Center (TSC) Safety Officer, Ken Somolinos, and South-Central California Area Office (SCCAO) Safety Officer, Tom Cooper, will be asked to participate in and approve the final JHA. Before work begins, the JHA will be signed by all workers involved in the experiments, TFCF management, and TSC and SCCAO safety officers. The Chief of the Tracy Office O&M Division will ensure that all workers at the TFCF (permanent and temporary) are aware of the test procedures and precautions prior to testing.

Since the secondary channel contains a significant amount of metal, consideration will be given to cathodic protection. Because the electric field will be generated for only a short time interval during field testing, it is likely that no mitigation is necessary. The cathode and anode alternate as the crowder moves downstream to successive electrode pairs. For example, the first set of electrodes is positive and the second set of electrodes is negative to create an electric field for a set period of time. Then, the electric field moves downstream such that the second set of electrodes is positive and the third set of electrodes is negative, and so forth. Grounding issues will also be addressed before a field study begins.

Coordination and Collaboration

This project will be coordinated between Reclamation's Technical Service Center, TFCF personnel, and Tracy Office personnel. Brent Bridges (209-836-6221), Joel Imai (209-836-6233), Carl Dealy (209-836-6236) and Ron Silva (209-836-6252) will be informed of dates when field tests will be conducted so that all affected staff can be notified. Brandon Wu and Andrew Schultz at the TFCF will be contacted prior to field testing to collect striped bass from predator removals and pick up juvenile salmon from a hatchery.

Researchers will work with local and regional Reclamation safety officers to discuss human safety concerns relating to a field test in the secondary channel. A JHA will be agreed upon by all project personnel. Researchers will file for a permit with the State of California for use of an electrical crowder during a field evaluation.

Endangered Species Concerns

This study will not involve the use of wild endangered or threatened species during the experiments. Striped bass will be obtained at the TFCF from predator removals. Juvenile salmon will be obtained from a hatchery. Incidental “take” of ESA listed species may occur during the tests. Any incidental capture of ESA listed species will result in that fish returned to Delta waters as quickly as possible. The total number of each ESA species incidentally caught or collected during the experiment will be recorded and sent to the reporting agencies. It is possible that mortality, as a result of electrical shock, may occur in ESA species. If this occurs, these fish will be recorded throughout testing. It is also possible that the addition of striped bass to the secondary channel for testing may increase predation loss of ESA species. All appropriate permitting will be obtained before field testing begins. The incidental “take” from this research will be covered under a permit from the State of California, USFWS, and NMFS.

Dissemination of Results (Deliverables and Outcomes)

Investigators will prepare a peer-reviewed Tracy Volume Series Report with results from the secondary channel field evaluation.

Literature Cited

Bark, R., B. Wu and W. Frizell. *In Draft. Sonic Tag Tracking Studies of Striped Bass Passage at the Tracy Fish Collection Facility.* Tracy Fish Collection Facility Studies, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

Gingras, M. 1997. Mark/Recapture Experiments at Clifton Court Forebay to Estimate Pre-Screening Loss to juvenile Fishes: 1976–1993. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 55.

National Marine Fisheries Service. 2009. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. National Marine Fisheries Service, Southwest Region. Long Beach, CA.

Smith-Root Inc., Barrier and Guidance Systems, www.smith-root.com