Public Water Agency 2017 Fall X2 Adaptive Management Plan Proposal

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California Department of Water Resources

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Introduction

The Fall X2[1] component of the Reasonable and Prudent Alternative (RPA) Action 4 of the US Fish and Wildlife Service's (USFWS) 2008 Biological Opinion (BiOp) on the coordinated operations of the State Water Project (SWP) and Central Valley Project (CVP) was developed as an adaptive management action, to be tested and refined over the first 10 years of BiOp implementation, based on studies to be conducted during that same period and in consideration of the results of those studies, other new data, other species needs, and other obligations.

At page 369, the BiOp describes the Fall X2 action as follows:

- **Objective:** Improve fall habitat for Delta Smelt by managing of X2 through increasing Delta outflow during fall when the preceding water year was wetter than normal. This will help return ecological conditions of the estuary to that which occurred in the late 1990s when smelt populations were much larger. Flows provided by this action are expected to provide direct and indirect benefits to Delta Smelt. Both the direct and indirect benefits to Delta Smelt are considered equally important to minimize adverse effects.

- **Action:** Subject to adaptive management as described below, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two-month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall target. The action will be evaluated and may be modified or terminated as determined by the Service.

The BiOp further states at p. 370 that, "…there is a high degree of uncertainty about the quantitative relationship between the size of the Action described above and the expected increment in Delta Smelt recruitment or production." For this reason, the BiOp requires an Adaptive Management Plan that requires the testing of the conceptual model to elucidate the operative mechanisms and the development of performance measures. The BiOp states at p. 283 that:

> In accordance with the adaptive management plan, the Service will review new scientific information when provided and may make changes to the action when the best available

[1] The distance upstream of the Golden Gate Bridge where the near-bottom, 2-parts-per-thousand isohaline is located.

> scientific information warrants…This action may be modified by the Service consistent with the intention of this action based on information provided by the adaptive management program in consideration of the needs of other listed species. Other CVP/SWP obligations may also be considered."

This 2017 proposal is part of Reclamation and DWR's implementation of the Fall X2 adaptive management program consistent with the BiOp and ongoing discussions in the Collaborative Science and Adaptive Management Program (CSAMP). The 2017 action builds upon the 2011 Fall Low Salinity Habitat Studies and Adaptive Management investigations ("FLaSH"). The proposed implementation of the Fall X2 action for 2017 considers the hypotheses, analysis, and framework presented in the 2008 BiOp; hydrology occurring in 2017; the Oroville spillway emergency and associated uncertainties; the need to monitor abiotic and biotic habitat conditions for Delta Smelt; and the needs of other species, including Winter-Run Chinook Salmon on the Sacramento River and Fall-Run Chinook Salmon on the Feather River.

In 2011, the Fall X2 RPA action was implemented[2] at approximately the wet year X2 target of 74 km for September and October. In conjunction with the RPA implementation, a large-scale investigation known as the FLaSH study was implemented by the U.S. Bureau of Reclamation (Reclamation) in cooperation with the Interagency Ecological Program (IEP) to examine hypotheses about the ecological role of low-salinity habitat to support Delta Smelt. Hypotheses about how Delta Smelt and their habitat would respond to increased outflows in the fall were initially presented in the USFWS (2008) BiOp but were developed in more detail through Reclamation's Fall X2 Adaptive Management Program (AMP). The purpose of the AMP was to provide a focused, science-based evaluation of the Fall X2 RPA for USFWS to consider in their assessment of the effectiveness Fall X2 RPA to support Delta Smelt abundance and habitat. Using a new conceptual model[3] about how fall X2 may affect Delta Smelt habitat, growth, abundance, and survival, the AMP developed predictions for expected biotic and abiotic habitat responses to X2.

Along with directed FLaSH studies in 2011, the IEP FLaSH synthesis team conducted a comparative analysis of data collected with another wet year (2006) and 2 dry years (2005, 2010) to determine how abiotic and biotic predictions responded in low salinity zone as function of X2 (Brown et al. 2014). Ultimately, directed 2011 FLaSH studies were considered largely inconclusive because many of the key predictions either could not be evaluated with the available data (e.g., primary production), or the necessary data were not collected (e.g., fecundity estimates). Abiotic habitat did increase in 2011 as predicted from the AMP, but other variables such as zooplankton abundance were too variable to draw a conclusion and Delta Smelt growth rate comparisons remain incomplete as of 2017. The effects analysis presented herein follows analyses from the completed FLaSH report (Brown et al. 2014) but with consideration of additional relevant information for the proposed 2017 Fall X2 action. For example, instead of limiting the analysis to the four years examined in the FLaSH report, the analysis was expanded to include all years within available time series, as well as

[2] The Fall X2 RPA was achieved via scheduled water releases to meet storage capacity requirements for 2012 water operations.

[3] Conceptual models were developed by the Habitat Study Group (HSG) and FLaSH Synthesis team

considering month-specific relationships (in particular for October, which has the greatest potential for differences in X2 between the proposed 2017 Fall X2 action and the Fall X2 as prescribed by the USFWS [2008]). Conclusions drawn here about how the proposed 2017 Fall X2 action may affect abiotic and biotic responses follow the basic framework from the FLaSH report and are consistent with the 2008 BiOp. Where the support for predicted responses is considered, the magnitude of effect is then estimated where possible.

The Fall X2 action is one of the primary topics discussed in the Collaborative Science and Adaptive Management Program (CSAMP), a process by which stakeholders and resource agencies can engage on critical scientific-based management questions for the CVP and SWP operations. The CSAMP has spent considerable time discussing the merits of the Fall X2 action and how it relates to new information.These conversations will inform future studies . Part of the proposed action described below includes enhanced monitoring to inform these ongoing discussions. The proposed action is meant to address the specific conditions and opportunities in 2017, but does not negate the ongoing discussions in CSAMP regarding the longer-term implementation of the Fall X2 action. This proposal and its associated effects analysis benefitted from review by the CSAMP's Collaborative Adaptive Management Team's Delta Smelt Scoping Team.

Project Description

The proposed implementation of the adaptive management action for 2017/2018 has the following elements:

Fall Outflow in 2017

- Maintain monthly average X2 of 74 km in September, consistent with the USFWS (2008) BiOp's Fall X2 action.

- Maintain monthly average X2 in October no greater (more eastward) than 81 km.

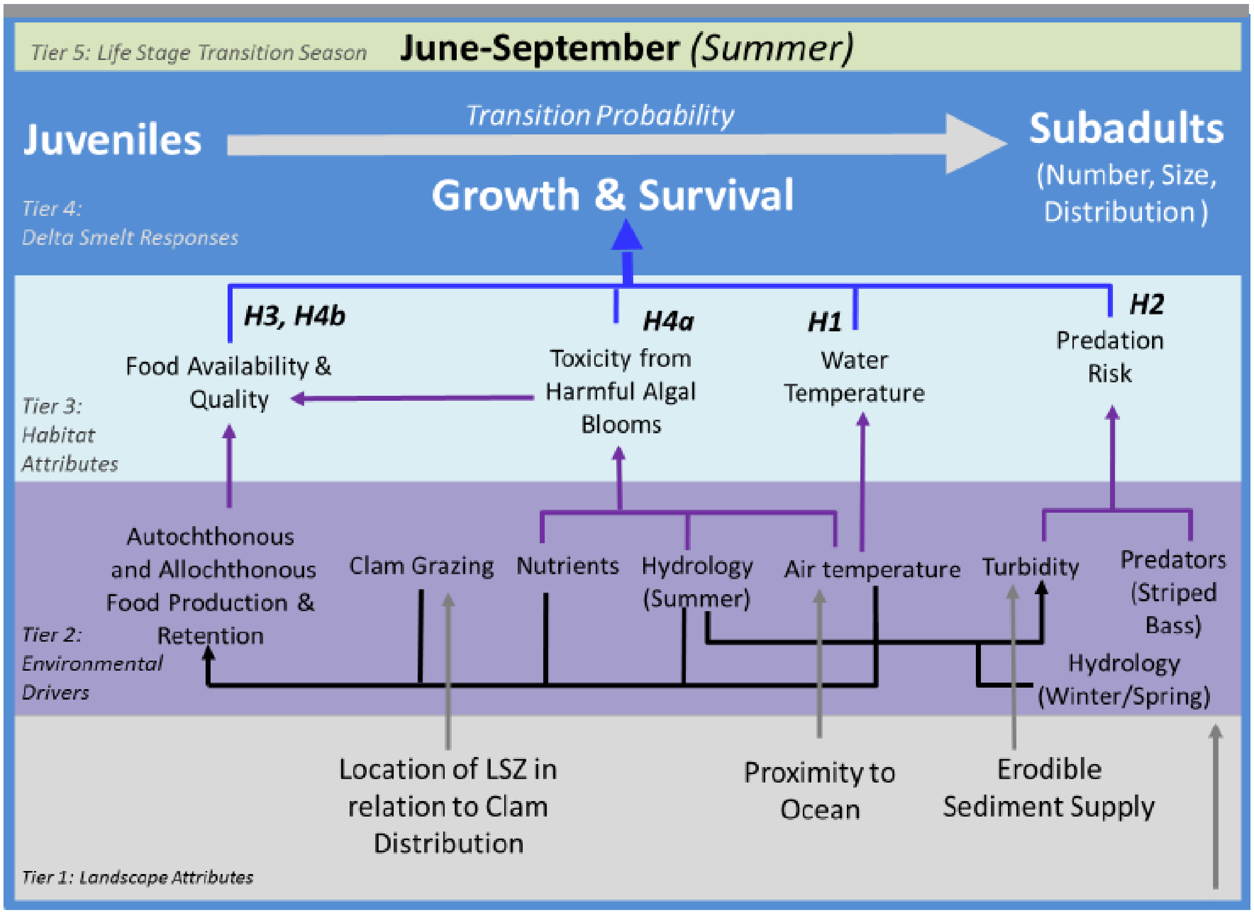
    - Hydrologic conditions and planned CVP and SWP reservoir releases are likely to result in a monthly average X2 in October between 81 km and 74 km without reduced exports. If hydrologic conditions and reservoir releases are not sufficient to meet a monthly average X2 of 81 km, SWP and CVP will coordinate to reduce exports to meet a monthly average X2 of 81 km. CVP and SWP will not actively reduce exports to meet a monthly average X2 in October more westward than 81 km.

- November conditions consistent with USFWS (2008) BiOp's Fall X2 action, i.e., the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall target.

The damage to Oroville Dam has necessitated different operations than would normally occur in a wet year. To maintain public safety as its greatest priority, DWR committed to lowering reservoir levels so that the emergency spillway or main flood control spillway would not have to be used after May 2017. At the request of the Federal Energy Regulatory Commission (FERC), DWR lowered reservoir levels at Oroville between March and May to ensure water would not go over the emergency spillway. Additionally, FERC requested lake levels to be at 700 feet by November 1, 2017. Upstream reservoir releases are expected to be dictated by needs for flood control operations and other downstream needs. Upstream reservoir releases, and therefore upstream reservoir storages, are not expected to differ between implementation of the Fall X2 action as written in the USFWS (2008) BiOp (i.e., X2 = 74 km in September and October) and the proposed 2017 action (X2 = 74 km in September, and X2 up to 81 km in October) because upstream reservoir releases are expected to be dictated by needs for flood control operations and other downstream needs. The only operational changes that are expected to occur are differences in south Delta exports. Therefore there would be no upstream effects of the proposed 2017 Fall X2 action beyond those that would have occurred with implementation of the Fall X2 action as written in the USFWS (2008) BiOp.

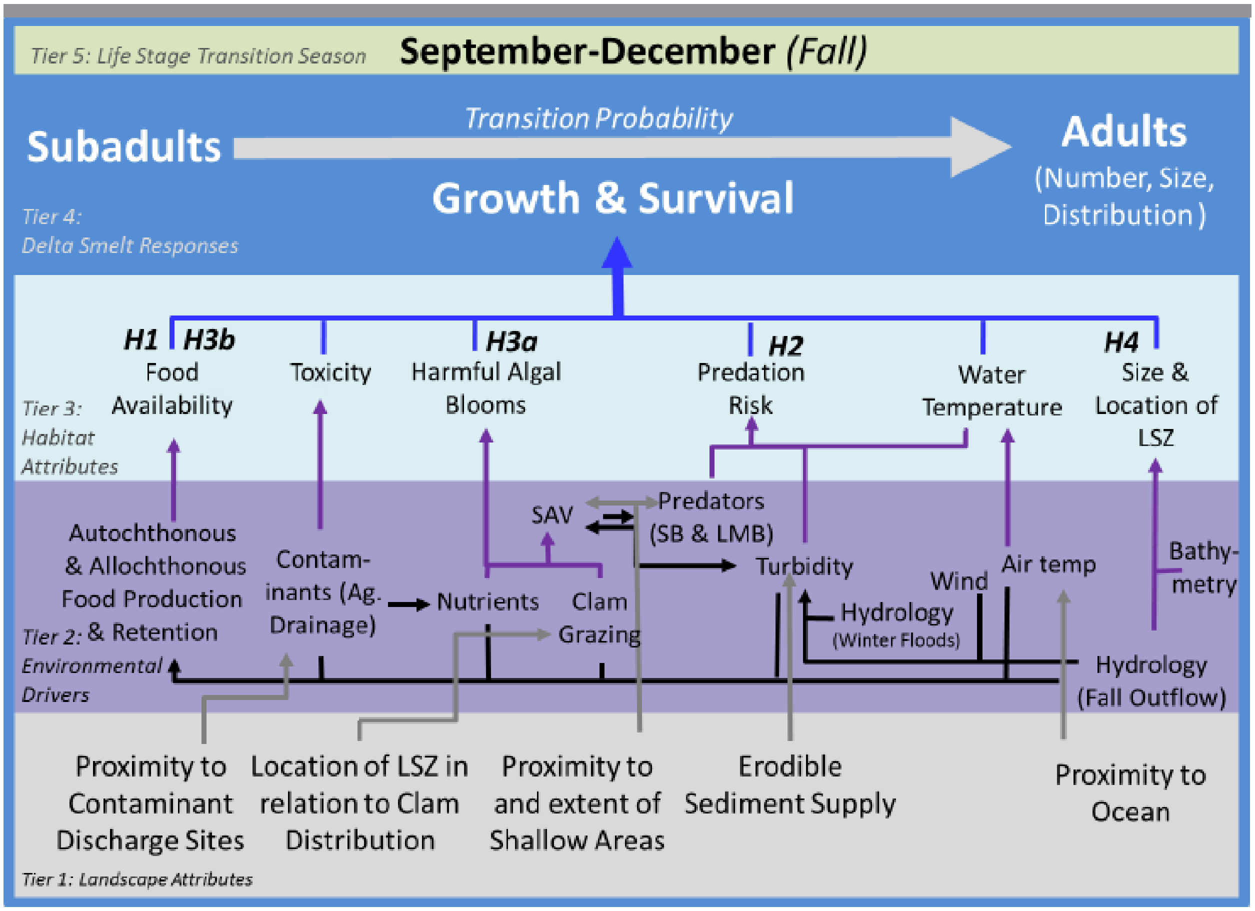
Habitat Studies and Actions

In addition to the fall outflow action in 2017, a number of habitat actions will be either implemented in 2017, or studied for their potential to be implemented in 2018 or 2019. The overarching drivers for these other proposed actions are first, the need to provide greater food availability to Delta Smelt, and second, the need for a greater extent of low salinity zone habitat in areas outside of the main range. Food availability and quality figure prominently in the IEP MAST (2015) conceptual models for the probability of survival from juveniles to subadults in summer (Figure 1) and subadults to adults in the fall (Figure 2).The subadult to adult model also considers the size and location of the low salinity zone to be of importance (Figure 1).



Source: IEP MAST (2015: Figure 48).

Figure 1. Conceptual Model of Drivers Affecting the Transition from Delta Smelt Juveniles to Subadults.



Source: IEP MAST (2015: Figure 49).

Figure 2. Conceptual Model of Drivers Affecting the Transition from Delta Smelt Subadults to Adults.

There have been several food augmentation actions in recent years that appear to have provided species benefits. For example, in 2016, flood-up and drain practices on rice fields were modified to test the potential for food production by draining rice fields earlier and more frequently to export food from fields to the mainstem Sacramento River. Participating landowners drained their fields to the Sacramento River and refilled these fields every 3-4 weeks, thus "exporting" floodplain fish food to the river ecosystem. Food monitoring results are expected in fall 2017, but preliminary analysis from UC Davis indicates that the program was successful. As such, this supplementation of the available food supply in the Sacramento River is proposed to occur again in fall 2017, and could also be implemented in 2018.

In 2016, DWR successfully implemented a food augmentation project called the North Delta foodweb project, an action included in the Delta Smelt Resiliency Strategy, which gave export of elevated levels of primary production to north Delta areas occupied by Delta Smelt. Unfortunately construction activity on the Wallace Weir salmon passage improvement project in the Yolo Bypass this summer has precluded implementation of the North Delta foodweb project in 2017, but DWR intends to implement the North Delta foodweb project in summer/fall of 2018.

Building upon these promising results, additional actions to benefit the food supply and other components of Delta Smelt habitat are being proposed for further study and potential implementation in 2018 or 2019.

- Suisun Marsh Salinity Control Gate reoperation: Opening and closing the Suisun Marsh Salinity Control gates so that a greater portion of Suisun Marsh is low salinity habitat with high probability of Delta Smelt occupancy.
- Napa River flow augmentation: Provide increased flows on the Napa River in the fall to increase low salinity Delta Smelt habitat.
- Sacramento River Deepwater Ship Channel lock reoperation: Opening the locks at West Sacramento to move the relatively high primary production in the Ship Channel downstream into a greater portion of areas where Delta Smelt occur[4].

Monitoring will be undertaken in fall 2017 to test the support for the conceptual models linking Delta Smelt growth and survival to food availability and the low salinity zone. In addition to the long-term monitoring program that has been in place for decades, USFWS/US Bureau of Reclamation is conducting Enhanced Delta Smelt Monitoring (EDSM) combined with additional paired habitat monitoring to assess the density and type of zooplankton, stomach content of Delta Smelt, and other habitat features. Outside of the EDSM study area, additional habitat monitoring is proposed for the Napa River. This fall 2017 monitoring effort will be synthesized in early 2018 to inform the ongoing CSAMP discussions described above, as well as discussions about modified operations of the Suisun Marsh Salinity Control Gates, another action included in the Delta Smelt Resiliency Strategy, and potential operational changes in Napa River.

The 2017 monitoring program includes the following:

- Enhanced Delta Smelt Monitoring (EDSM) by USFWS/Reclamation;
- Habitat monitoring, contracted through the State Water Contractors (SWC);
- Suisun Marsh/Montezuma Slough monitoring funded by DWR that will be used to inform the potential for Suisun Marsh Salinity Control Gate operations in 2018, per the Delta Smelt Resiliency Strategy;
- Napa River monitoring funded by the State and Federal Contractors Water Agency (SFCWA) to better understand habitat conditions of that low salinity zone;

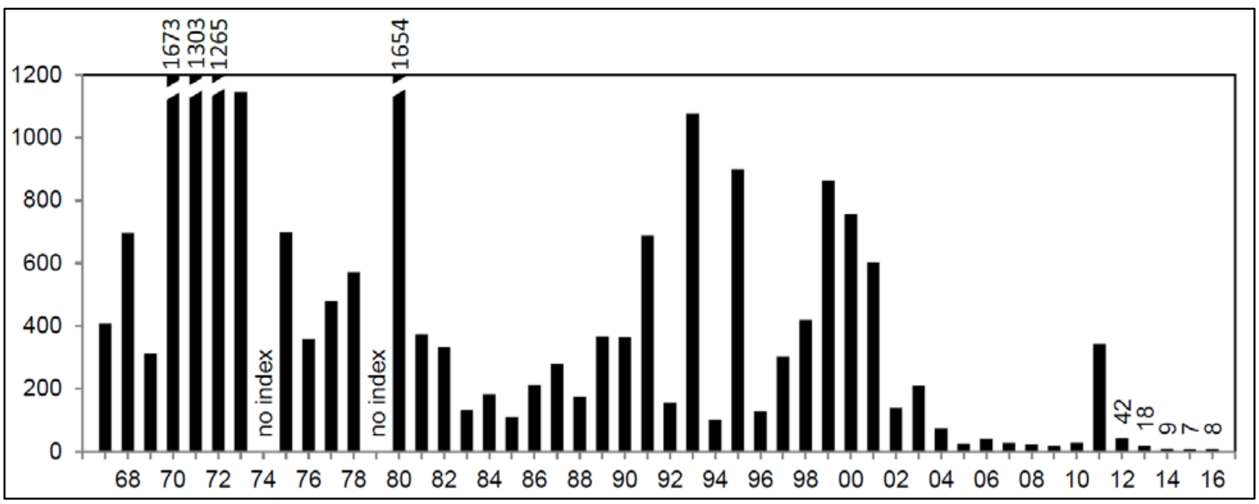
[4] The earliest that this action could occur is 2019.

- Synthesis of information by the IEP to be included in 10-year review and in reporting on 2017 research.

Status of Delta Smelt

Long-Term Delta Smelt Abundance Trends

Available survey indices of abundance suggested the current status of Delta Smelt to be poor compared to historic status. The 2016 fall midwater trawl abundance (FMWT) index (8) is the second lowest in the survey's history (Figure 3). The 2017 Spring Kodiak Trawl (SKT) index is 3.8 and a slight increase from the record-low 2016 SKT index (Figure 4). The 2017 20-mm Survey Delta Smelt index is 1.5. This is an increase from 2016 and is the highest index since 2013 (Figure 5). The annual Summer Townet (STN) Delta Smelt abundance index for 2017 is 0.2. It is the third lowest index on record and follows two years in which the index was zero (Figure 6). Although the long-term survey indices may to some extent reflect changes over time in catchability because of changes in gear avoidance (because of increased visibility; Latour 2016), the small increase in the the STN and 20-mm indices in 2017 could indicate slightly improved population status following the drought of 2012-2016. This slight improvement in the population status is also suggested by absolute adult Delta Smelt abundance estimates from extrapolations based on the SKT, with the estimated 2017 population of nearly 48,000 fish being almost four times greater than the estimate of ~16,200 from 2016; these numbers are still an order of magnitude lower than estimates from prior to 2016, however (Figure 7).



Source: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=136164

Figure 3. Fall Midwater Trawl Survey Delta Smelt Annual Abundance Indices (All Ages), 1967-2016.

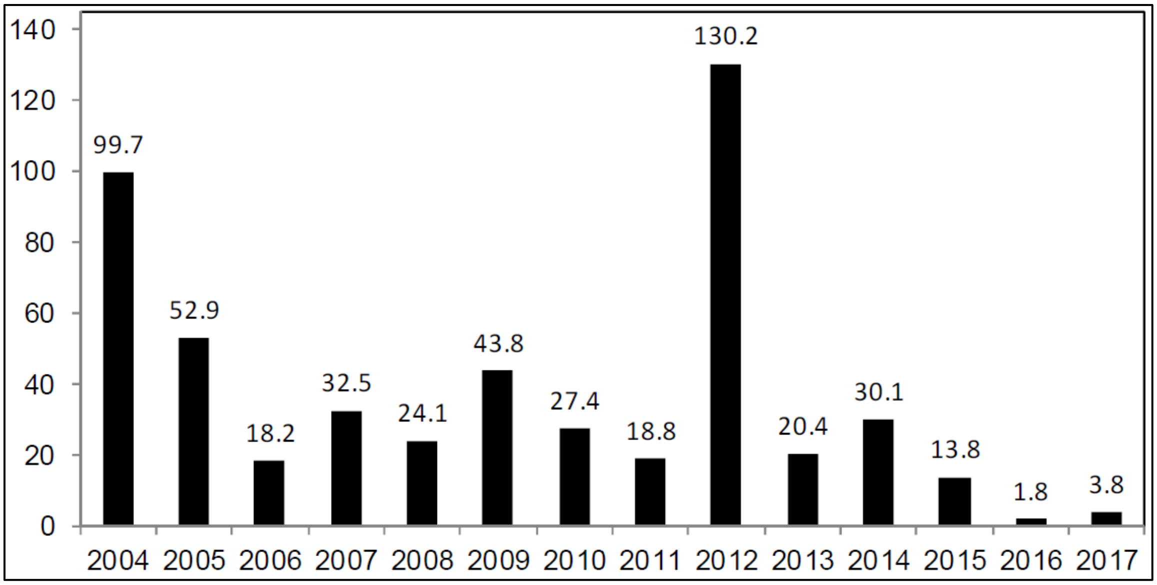


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Figure 4. Spring Kodiak Trawl Survey Delta Smelt Annual Abundance Indices, 2004-2017.

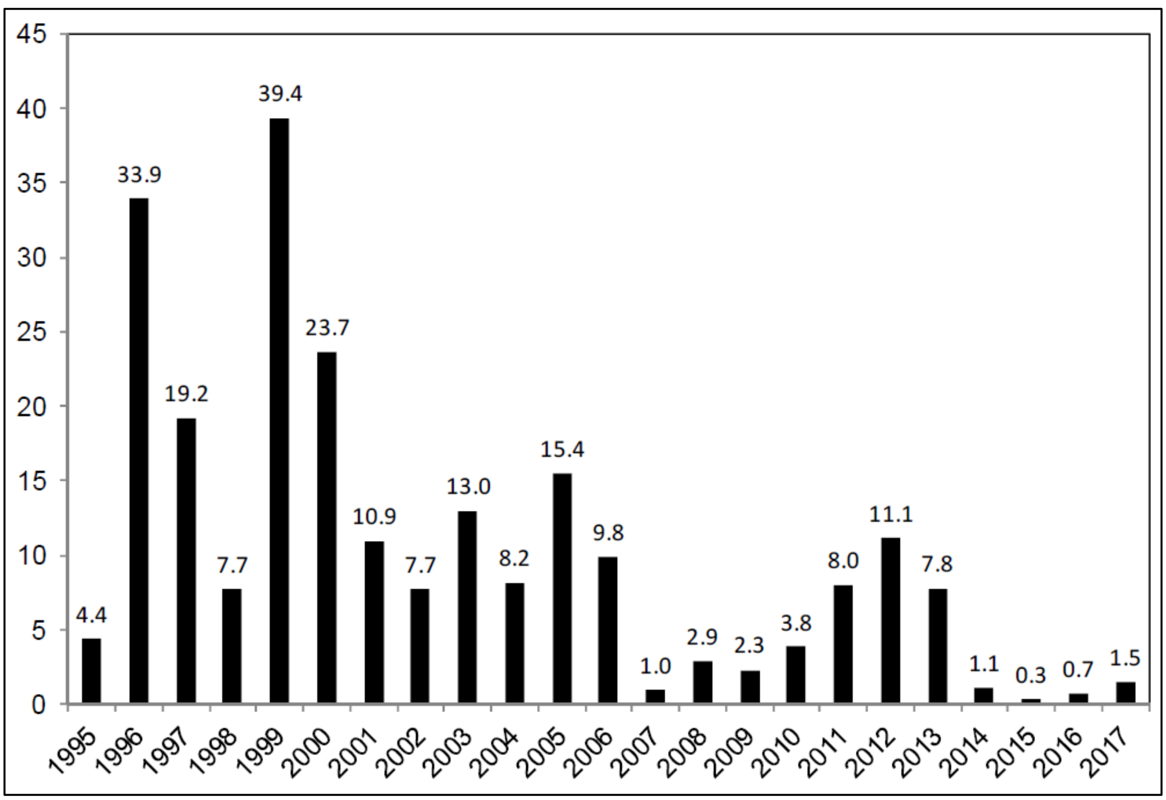

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Figure 5. 20-mm Survey Delta Smelt Annual Abundance Indices, 1995-2017.

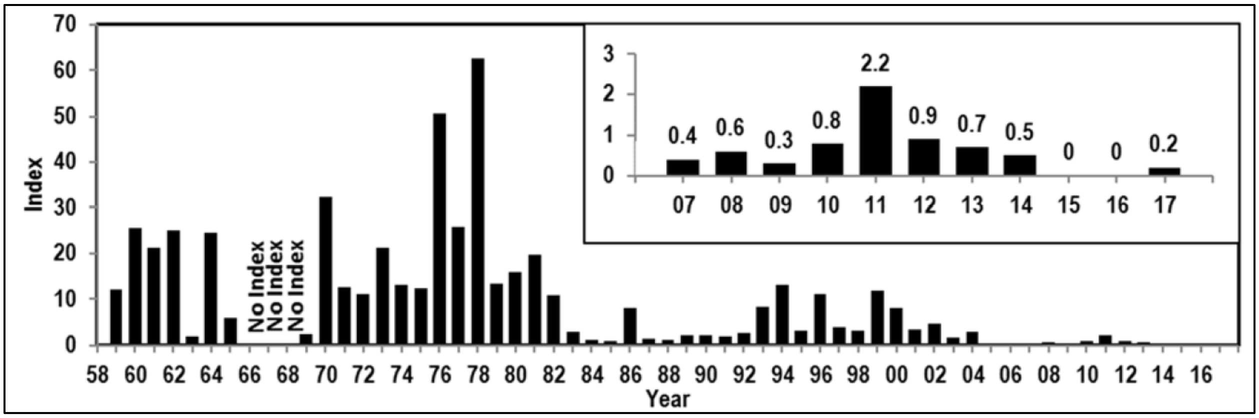

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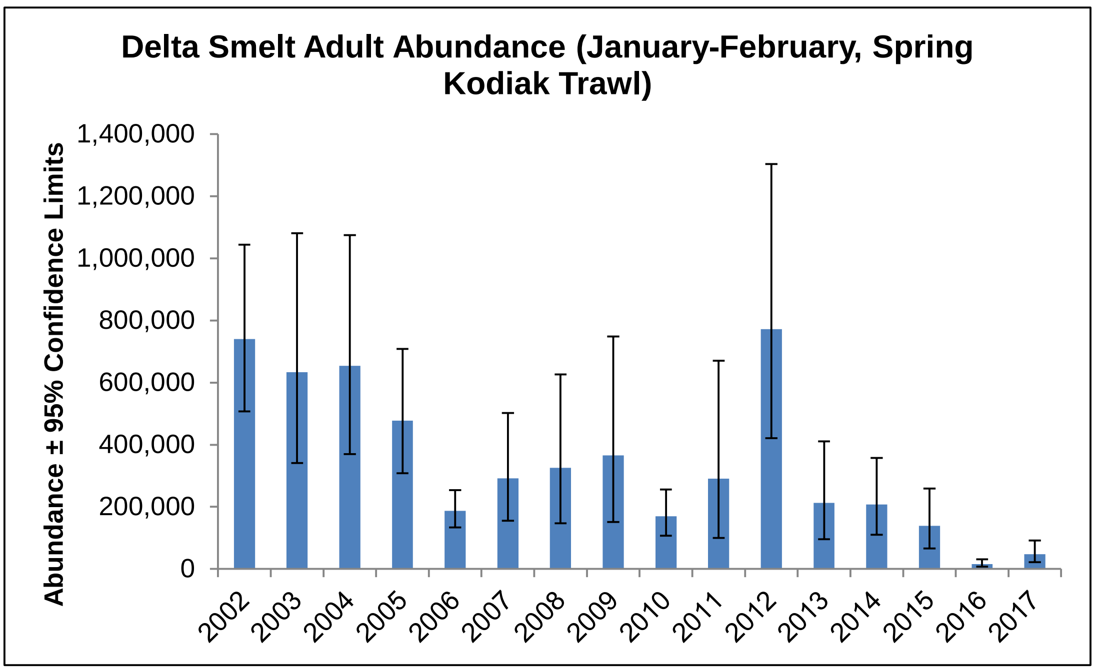
Figure 6. Summer Townet Survey Delta Smelt Annual Abundance Indices 1959-2017 with Inset Showing Indices From 2007 to 2017.

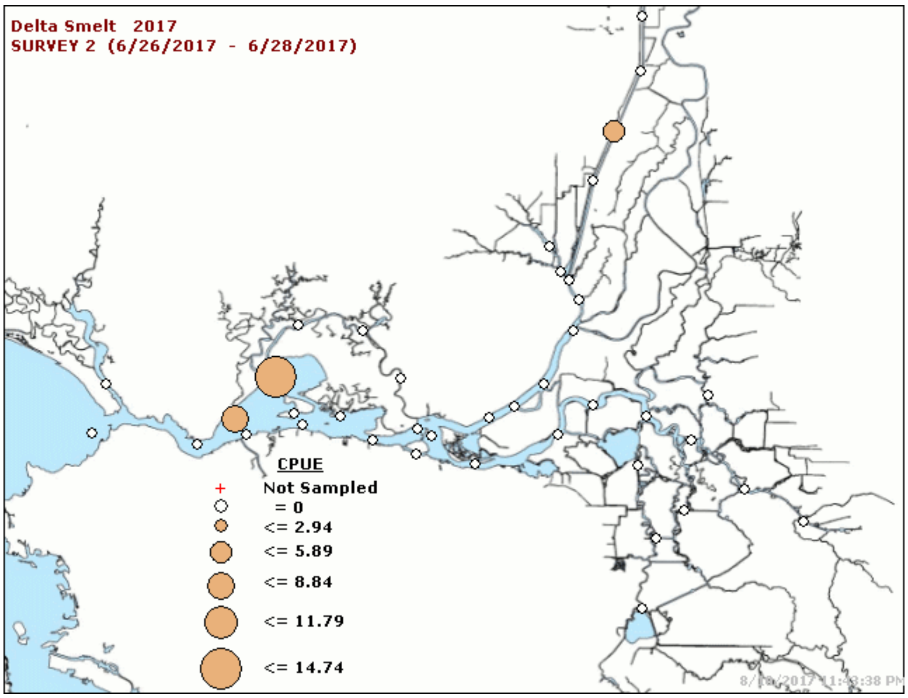


Source: Mitchell (pers. comm.)

Figure 7. Estimates of January-February Delta Smelt Adult Abundance from the Spring Kodiak Trawl Survey, 2002-2017.

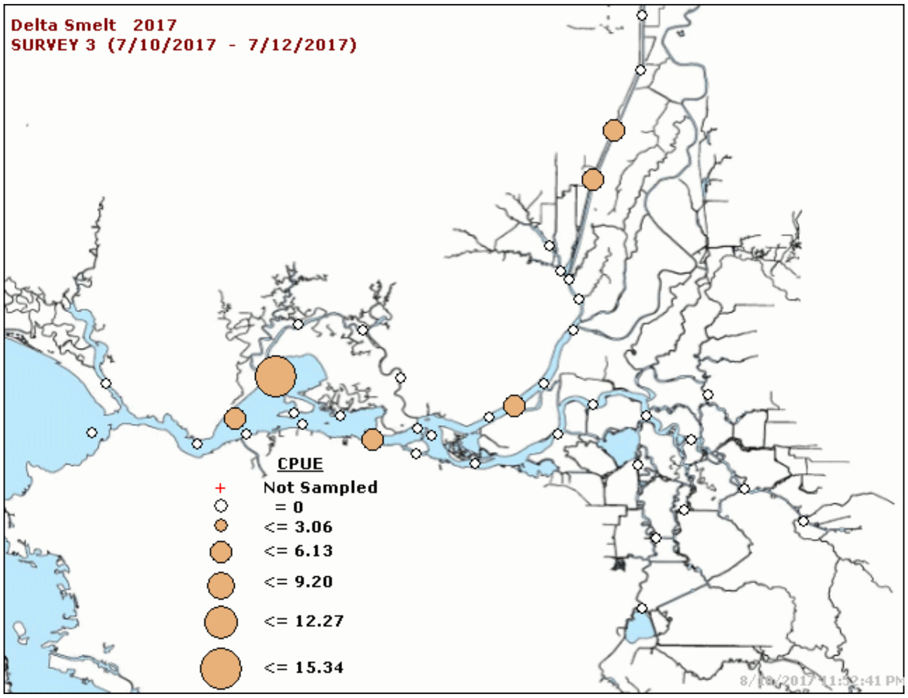
Current Delta Smelt Spatial Distribution

Townet survey monitoring data for 2017 suggest that a substantial portion of the population is within the low salinity zone (Figures 8-10). This conclusion is also supported by the Enhanced Delta Smelt Monitoring results from late August, which show around 93% of Delta Smelt in the low salinity zone (i.e., Suisun Bay Marsh, Lower Sacramento, and Lower San Joaquin strata), and the remainder in the Western Delta or the Sacramento Deep Water Ship Channel (Figures 11-12).



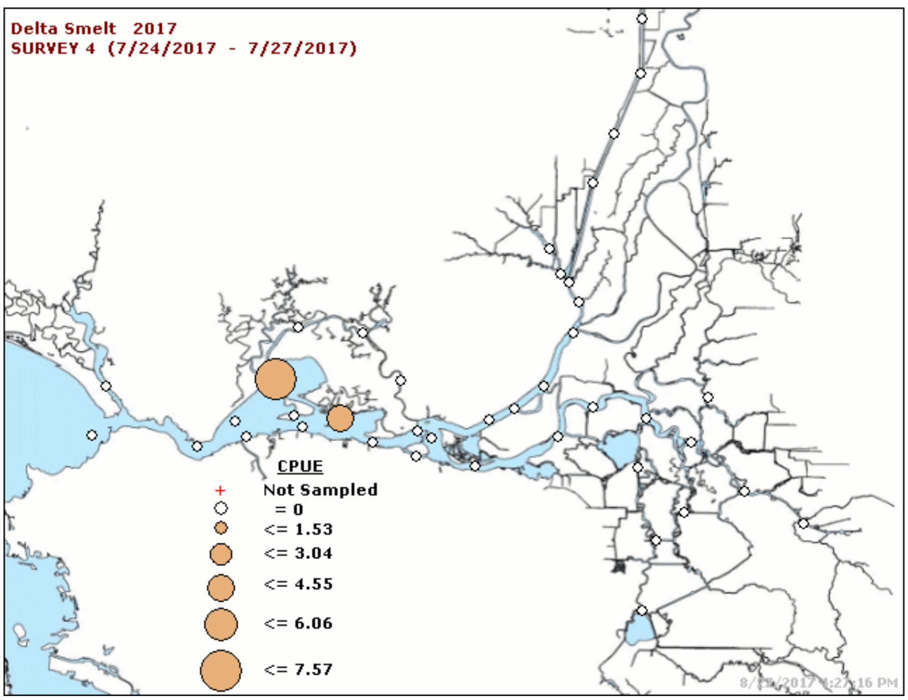
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp

Figure 8. Density (Fish per 10,000 m^3) of Delta Smelt from Summer Townet Survey 2, 2017.



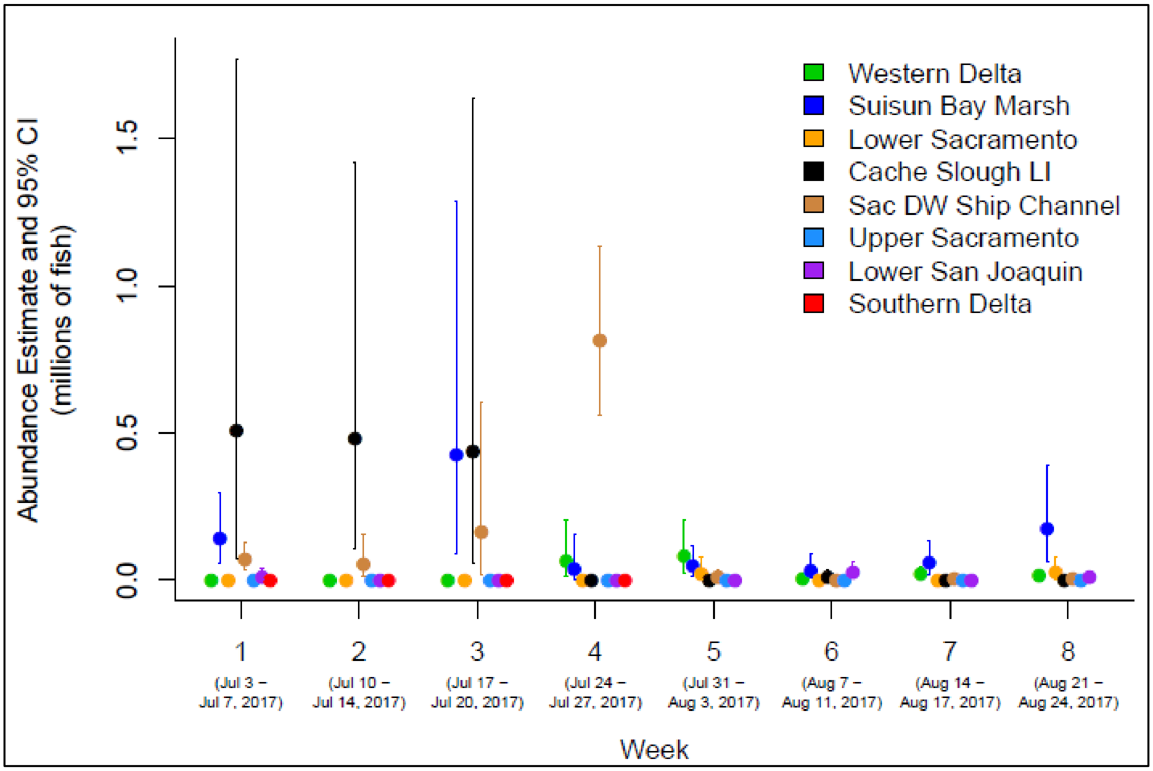
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp

Figure 9. Density (Fish per 10,000 m^3) of Delta Smelt from Summer Townet Survey 3, 2017.



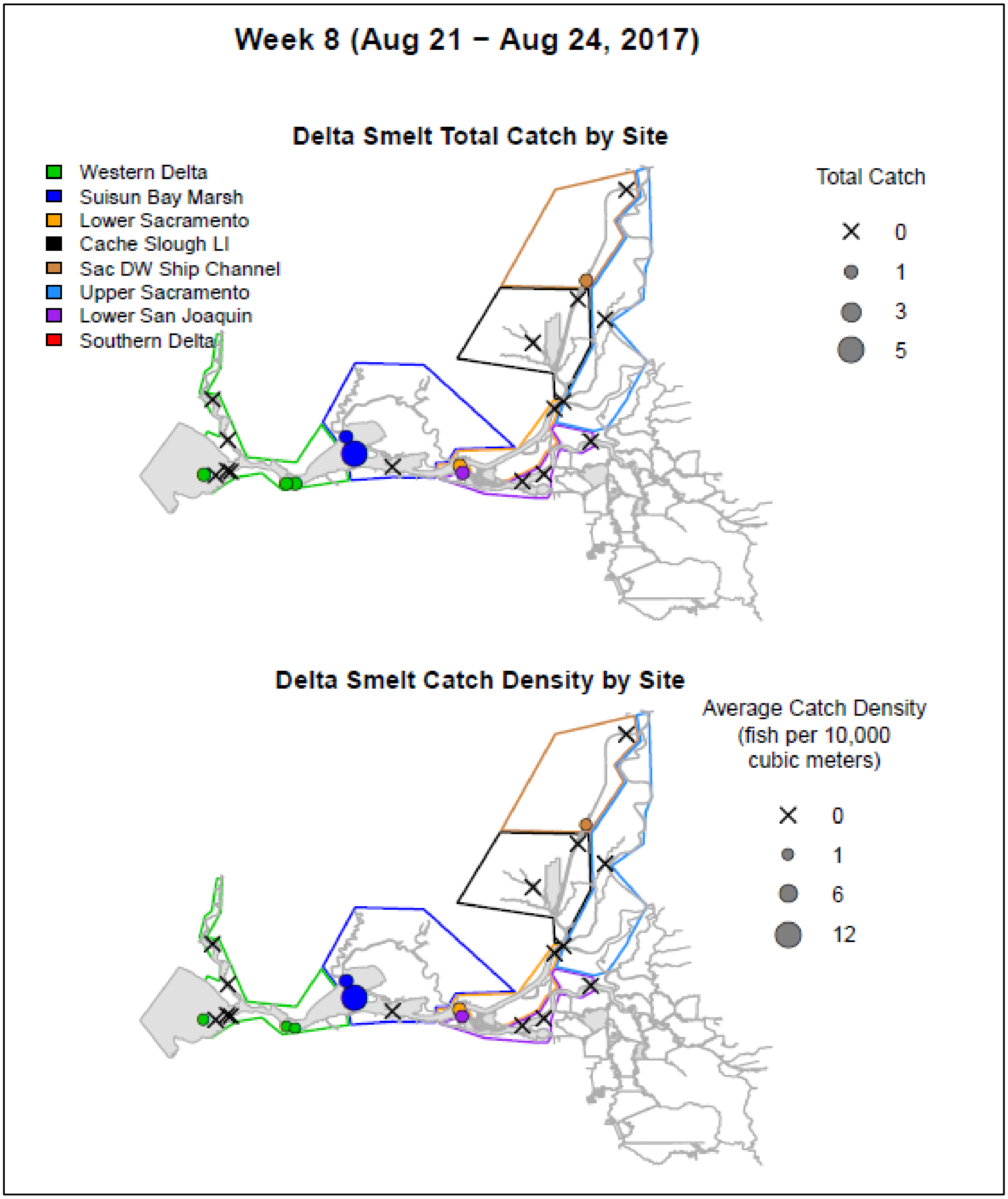
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp

Figure 10. Density (Fish per 10,000 m^3) of Delta Smelt from Summer Townet Survey 4, 2017.



Source: https://www.fws.gov/lodi/juvenile_fish_monitoring_program/data_management/EDSM_report_2017_08_25.pdf

Figure 11. Delta Smelt Abundance Estimates from Enhanced Delta Smelt Monitoring, Summer 2017.



Source: https://www.fws.gov/lodi/juvenile_fish_monitoring_program/data_management/EDSM_report_2017_08_25.pdf

Figure 12. Delta Smelt Total Catch and Catch Density by Site from Enhanced Delta Smelt Monitoring, Week 8 of Summer 2017.

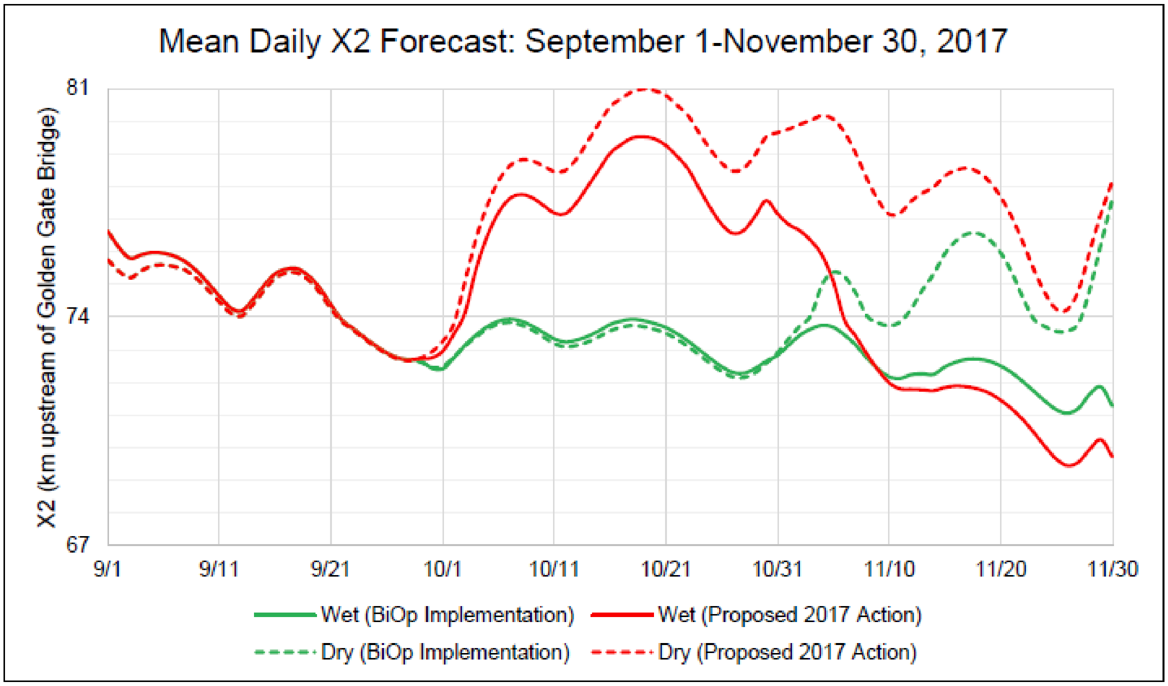
Effects Analysis

Introduction to the Effects Analysis

This effects analysis includes two main sections pertaining to Delta Smelt: *Effects on Delta Smelt* and *Effects on Delta Smelt Critical Habitat* consider potential effects from implementation of X2 of no greater than 81 km in October, as opposed to 74 km. Whereas the analyses primarily focus on the potential effects from the proposed 2017 Fall X2 action, the *Effects from Habitat Actions* subsection discusses the basis for the other actions considered as part of the overall implementation of the adaptive management program for 2017-2019.

In addition to the analyses focusing on Delta Smelt, the section entitled *Entrainment Effects* discusses potential differences in entrainment of other listed fishes caused by differences in south Delta exports between the proposed 2017 Fall X2 action and the Fall X2 action as prescribed in the USFWS (2008) BiOp. The discussion of *Upstream Effects (Reservoir Storage)* emphasizes that upstream operations will be similar regardless of how X2 is implemented in fall 2017.

An operational forecast for X2 during September-November 2017 was made by DWR (Yamanaka pers. comm.). This forecast included projections for X2 with full implementation of the USFWS (2008) BiOp (i.e., X2 = 74 km in September and October) and the proposed action (i.e., X2 = 74 km in September and no farther east than 81 km in October), for DWR's estimate of an 80% confidence interval of the range in fall hydrology, bracketed within 'wet' and 'dry' bounds in Figure 13. For October, X2 under the proposed 2017 action was modeled to range between 72 km and 81 km, depending on exceedance used (Figure 13). Whereas the mean X2 in September generally was close to 74 km for all four scenarios examined, mean X2 in October was just over 73 km for full implementation of the USFWS (2008) BiOp, compared to around 78 km for the proposed Fall X2 action (Table 1). Therefore, there is a very good chance that X2 in October could be farther downstream than 81 km, but the effects analysis includes the 81-km upper bound to conservatively describe the largest possible difference in X2.



Source: Yamanaka (pers. comm.)

Figure 13. Mean Daily X2 Forecast, September 1-November 30, 2017.

Table 1. Monthly Mean X2 (km) from Mean Daily Forecast, September-November, 2017.

Month	BiOp Implementation (Wet)	Proposed 2017 Action (Wet)	BiOp Implementation (Dry)	Proposed 2017 Action (Dry)
September	74.6	74.7	74.4	74.5
October	73.3	77.4	73.2	78.8
November	72.4	72.1	74.9	77.7

Source: Yamanaka (pers. comm.)

Effects on Delta Smelt are examined by essentially revisiting and updating the stock-recruitment-X2 analysis conducted by USFWS (2008) that formed an important basis for the Fall X2 RPA action. The analysis of effects on Delta Smelt critical habitat examines how abiotic and biotic characteristics of the low salinity zone vary in relation to X2. For all quantitative analyses, the time periods chosen reflected logical subsets of all possible data to account for known shifts over time, as explained further in the text for each analysis. In addition, analysis was conducted specifically to represent the current ecological regime in the Delta, the Pelagic Organism Decline (POD), for which data were limited to 2003 onwards[5]. Analyses for September included up to 2016, whereas for October and November, the analyses included up to 2015 (reflecting the most recently available data from DAYFLOW; see *Retrospective Analysis of X2*).

Note that the analyses presented herein do not quantitatively consider intraannual antecedent conditions, e.g., abiotic or biotic parameters at X2 of 81 km in October of a given year may be dependent on X2 (or other variables) in September or earlier portions of the year (such as spring or summer). As noted below in *Retrospective Analysis of X2*, the proposed mean X2 of 74 km in September 2017 followed by mean X2 of no greater than 81 km in October 2017 could be unique relative to observed conditions in the past several decades. It is uncertain what implications this could have for ecosystem conditions and Delta Smelt.

In addition to the analyses focused on Delta Smelt and its critical habitat, discussion is provided of *Upstream Effects (Reservoir Storage)* to demonstrate that there would be no upstream effects of having X2 at a particular location between 74 and 81 km because operational adjustments would be through south Delta water export changes.

Note that the modeling included herein assumes that the Delta Cross Channel (DCC) gates are open because DWR and Reclamation have not received a formal request for a change in DCC gate operations. Should such a request ultimately be made, it is expected that the results presented herein—generally pertaining to the low salinity zone at the confluence of the Sacramento and San Joaquin rivers, and points downstream (i.e., Suisun Bay and Suisun Marsh)—would not be greatly affected because even with X2 = 81 km, the low salinity zone is very close to the confluence of the Sacramento and San Joaquin rivers (Figure 14), and the likely difference in area of the low salinity zone habitat with the DCC gates closed instead of open is probably small.

Unless otherwise noted, the analyses presented herein were conducted by ICF.

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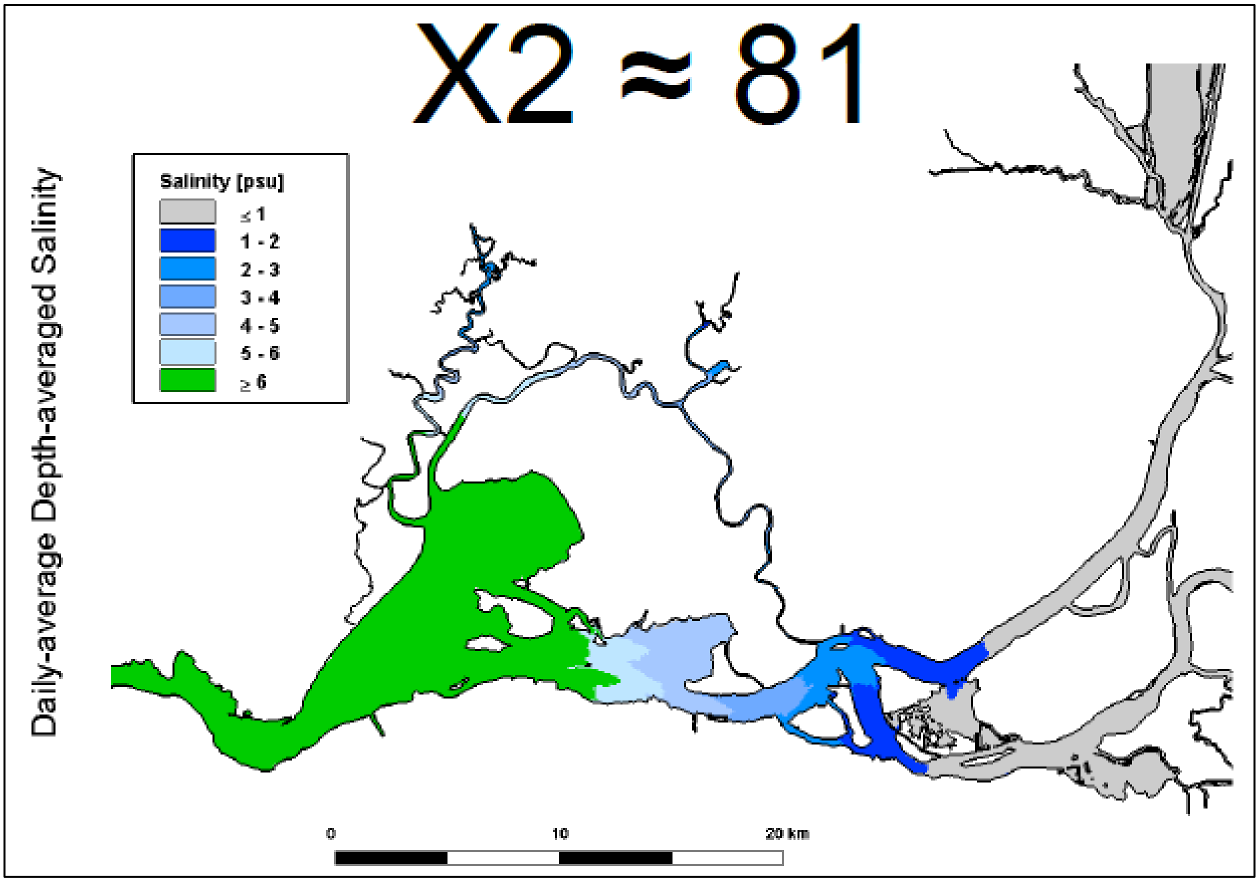
[5] 2003 was chosen to represent the start of the POD because it represented an intermediate year between a common regime change point for multiple species (2002) and a Delta Smelt-specific regime change point (2004) (Thomson et al. 2010).



Source: DMA (2014)

Figure 14. Daily-Average Depth-Averaged Salinity with X2 = 81 km, from the UnTRIM Bay-Delta Model.

Effects on Delta Smelt

One of the key elements of the IEP MAST (2015) conceptual model for Delta Smelt is that survival and growth are positively related to the size and location of the fall low salinity zone (Figure 68). For example, IEP MAST (2015: p. 141) summarized this aspect of the conceptual model as follows:

> According to the FLaSH [Fall Low-Salinity Habitat] conceptual model, conditions are supposed to be favorable for Delta Smelt when fall X2 is approximately 74 km or less, unfavorable when X2 is approximately 85 km or greater, and intermediate in between... Surface area for the LSZ [low salinity zone] at X2s of 74km and 85km were predicted to be 4000 and 9000 hectacres, respectively... The data generally supported the idea that lower X2 and greater area of the LSZ would support more subadult Delta Smelt... The greatest LSZ area and lowest X2 occurred in September and October 2011 and were associated with a high FMWT [fall midwater trawl

index] which was followed by the highest SKT [spring Kodiak trawl] index on record, although survival from subadults was actually lower in 2011 than in 2010 and 2006. There was little separation between the other years on the basis of X2, LSZ, or FMWT index.

Given the hypothesis for the effect of fall X2 on Delta Smelt survival as expressed in the IEP MAST (2015) and FLaSH (Brown et al. 2014) reports, the analysis below focuses on estimating the potential Delta Smelt abundance response using a similar framework to that used for the USFWS (2008) BiOp.

Delta Smelt Stock-Recruitment-X2 Relationship[6]

Introduction

The USFWS (2008) BiOp used an analysis analogous to that by Feyrer et al. (2007), which fit models of an index of juvenile Delta Smelt abundance in the summer (the summer tow net survey; STN) to an index of adults in the previous fall (the fall mid water trawl survey; FMWT) with various environmental covariates, including measures of salinity (specific conductance) and turbidity (Secchi depth). The best supported model included a covariate with a negative effect for salinity. Feyrer et al.'s (2007) results suggested that juvenile Delta Smelt recruitment is negatively correlated with increased salinity in the fall, a finding consistent with the hypothesis presented by Bennett (2005) that shrinking physical habitat is contributing to the decline of Delta Smelt. The USFWS (2008: p. 236 and p. 268) BiOp included fall X2 as a predictor, as opposed to salinity and turbidity. This relationship was subsequently used as part of the basis for the USFWS (2008) BiOp Fall X2 action intended to avoid the adverse modification of Delta Smelt critical habitat by SWP/CVP operations.

Herein, the USFWS (2008) stock-recruitment-X2 relationship is revisited, adopting a slightly different stock-recruit relationship, and extending the time series with several additional years of data. This procedure is described in *Model Fitting Methods* and *Model Fitting Results and Discussion*. The model is then applied to the proposed 2017 Fall X2 action, in order to illustrate potential effects to Delta Smelt, as described in *Application to Proposed 2017 Fall X2 Action*.

Model Fitting Methods

Consistent with the original analysis by Feyrer et al. (2007) and the subsequent analysis by USFWS (2008), Delta Smelt data from the California Department of Fish and Wildlife fall midwater trawl (FMWT[7]) and STN[8] surveys were used. The FMWT index and STN index are measures of adult spawning stock (S) and juvenile recruitment (R), respectively. For the index of fall X2, estimates

[6] This analysis is adapted from a working draft manuscript provided by Corey Phillis, MWD. The sections entitled *Application to Proposed 2017 Action* and *Response to Comments* were prepared by ICF, with the former including modeling outputs from Corey Phillis for predicted recruitment at potential X2 values that could occur in fall 2017.

[7] http://www.dfg.ca.gov/delta/data/fmwt/indices.asp

[8] http://www.dfg.ca.gov/delta/data/townet/indices.asp?species=3

from DAYFLOW were used[9], with calculations as subsequently described in *Retrospective Analysis of X2* in the discussion of *Effects on Delta Smelt Critical Habitat*.

The Ricker stock-recruit model was used to retest the fall X2-Delta Smelt recruitment correlation. The Ricker model assumes a multiplicative relationship between stock S and recruitment R (Ricker 1954):

$$R = \alpha S e^{-\beta S} \quad \text{(Equation 1)}$$

The productivity parameter α is the slope at the origin, or biologically, the recruitment rate in the absence of density dependence ($S \rightarrow 0$). Recruitment R is limited as spawning stock S increases by the strength of density dependence, β. The effect of environmental variation on survival of early life-stages can be incorporated as well (Quinn and Deriso 1999). For example, the effect of fall X2, γ, can be modeled as:

$$R = \alpha S e^{-\beta S + \gamma X2} \quad \text{(Equation 2)}$$

The multiplicative model above is a departure from the methods of Feyrer et al. (2007) and USFWS (2008), which modeled the relationship using multiple linear regression in the form of:

$$R = \alpha + \beta S + \gamma X2 \quad \text{(Equation 3)}$$

However, this formulation implies a linear additive relationship that can yield the biologically implausible case of positive recruitment R even when the spawning stock S is zero.

Both the original and updated data were analyzed assuming a Ricker stock-recruit function, by linearizing Equation 2 (Quinn and Deriso 1999):

$$\log(R/S) = a - \beta S + \gamma X2 \quad \text{(Equation 4)}$$

In order to examine whether relationship between stock, recruitment and X2 has changed over time, the stock-recruitment-X2 relationship was calculated for the 1987-2004 time period used by Feyrer et al. (2007) and compared to the same relationship calculated for 1987-2014. To facilitate use in the present effects analysis, for which only potential values of X2 in September (74 km) and October (assumed to be 81 km, as the maximum that could occur) could be provided, fall X2 was represented by the mean September-October X2. Akaike's Information Criterion corrected for small sample sizes (AICc) was used to evaluate a set of model alternatives, including the model (Equation 4) that is analogous to Feyrer et al.'s (2007) and USFWS's (2008) models, three reduced models (constant-only, density-dependent-only, and fall-X2-only), and the full model (Equation 4 with an added interaction term between S and fall X2). AICc ranks the model set on their fit to the data by evaluating the trade-off between bias and variance in the model parameters (Burnham and Anderson 2002; Burnham et al. 2011). In addition to ranking the models, evidence ratios were used

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[9] The original analysis conducted by Corey Phillis used the Sacramento River X2 branch estimates by Hutton et al. (2015); the DAYFLOW estimates were subsequently used at the request of ICF, for consistency with critical habitat analyses conducted by ICF.

to evaluate support for the Equation 4 relative to other models in the set (Burnham et al. 2011). Finally, AICc can rank competing models, but does not evaluate model fit. Therefore, adjusted R^2 was reported and leave-one out cross validation was used to generate estimates of model root-mean-square error as a proportion of mean response (CV_{RMSE}). Adjusted R^2 and CV_{RMSE} are measures of a model's fit to in-sample (observed variance explained) and out-of-sample data (prediction error), respectively.

The practical utility of the stock-recruitment-X2 relationship was explored by simulating how Delta Smelt recruitment from the FMWT index to the STN index responds to changes in fall X2. Simulated predictions of recruitment were generated for Equation 4 by taking 10,000 draws from a normal distribution:

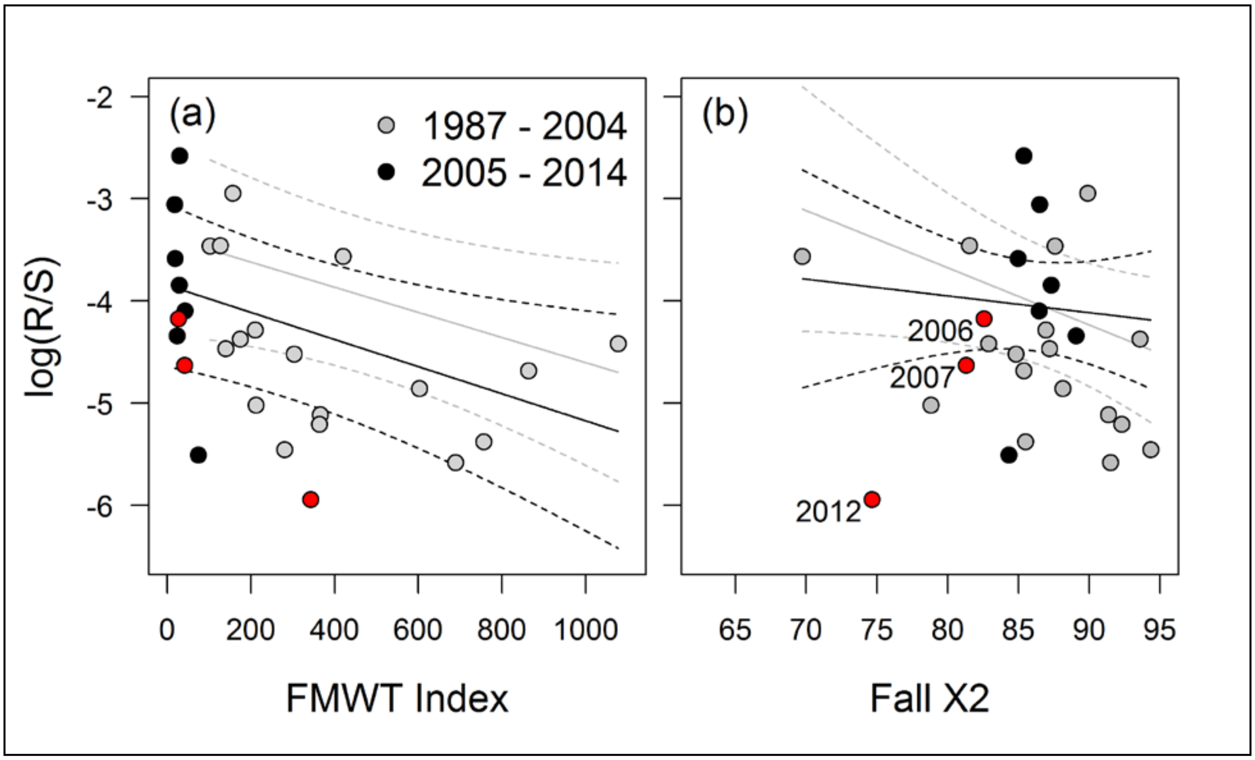
$$\log(R/S) \sim N(\mu,\sigma)$$

where the mean μ is equal to the model point estimate of recruitment for X2 locations between 60 and 95 kilometers when S is held constant at 17, the minimum observed FMWT index between 1987 and 2014, and standard deviation σ is equal to the model residual standard deviation. Taking the exponent puts the predictions of recruitment on the natural scale, yielding an index of survival from the FMWT to STN. The ratio of simulated survivals at upstream and downstream fall X2 locations were used to get a distribution of predicted changes in survival due to changes in fall X2. The distributions are plotted on a log scale so that increases and decreases in survival of equivalent magnitude (e.g., doubling, 2/1, and halving, 1/2) are represented symmetrically around 1 (no change).

All analyses were performed in R version 3.2.2 (R Core Team 2015). All data and code needed to reproduce the analyses can be obtained from Corey Phillis (MWD).

Model Fitting Results and Discussion

Between 2005 and 2014, the FMWT index in all but one year (2011) was lower than any year in the original 1987-2004 data used by Feyrer et al. (2007) (Figure 15a). During 2005-2014 recruitment to the summer STN index was within the 1987-2004 range, with the exception of 2012 (corresponding to the 2011 fall X2 and FMWT index) which was the lowest on record going back to 1969 and 2011, which was the third highest. The years 2005-2014 spanned an historically dry hydrologic period, yet fall X2 was within the range observed during 1987-2004 (Figure 15b). Only 2005, 2006, and 2011 met the criteria to trigger fall X2 compliance, and only 2011 occurred after the BiOp was implemented (Figure 15, red points).



Notes: (a) Fall X2 was fixed at 75 km; (b) FMWT Index was fixed at 17 to illustrate the X2 effect in the absence of density dependence. Points in red indicate falls following Above Normal and Wet water years during 2005-2014 that met the criteria to trigger action 4 in the USFWS (2008) BiOp. Note that year labels reflect the summer recruitment year, i.e., the summer following the fall used to predict survival.

Figure 15. The Selected Delta Smelt Juvenile Survival Model Fit to (a) the Fall Midwater Trawl Index and (b) Mean September-October X2.

The basic stock-recruitment-X2 relationship derived using the same time period but slightly different covariates and model structure as the USFWS (2008) analysis was not altered when the subsequent years of new data were added: consistent with USFWS (2008), there is still a negative effect of both FMWT index and mean September-October X2 on recruitment[10], at least for Equation 4 (Figure 16). However, model selection identified the full model as the best model for 1987-2004 and the stock-only model as best for 1987-2014 data. For 1987-2004, the model based on Equation 4 (analogous to Feyrer et al. 2007 and USFWS 2008) was ranked second out of the five models considered (Table 2), although with substantial support ($\Delta_{AICc} = 0.5$[11]). The evidence ratio ($\exp^{(-1/2)\cdot\Delta AICc)}$) for the Equation 4 model analogous to Feyrer et al. (2007) is 1.3; that is, evidence is 1.3 stronger for the full model relative to the Equation 4 model (Burnham et al. 2011). Including the additional years of data saw the Equation 4 model analogous to Feyrer et al. (2007) and USFWS (2008) move to the third-ranked model (Table 3), but support weakened ($\Delta_{AICc} = 2.4$) and evidence

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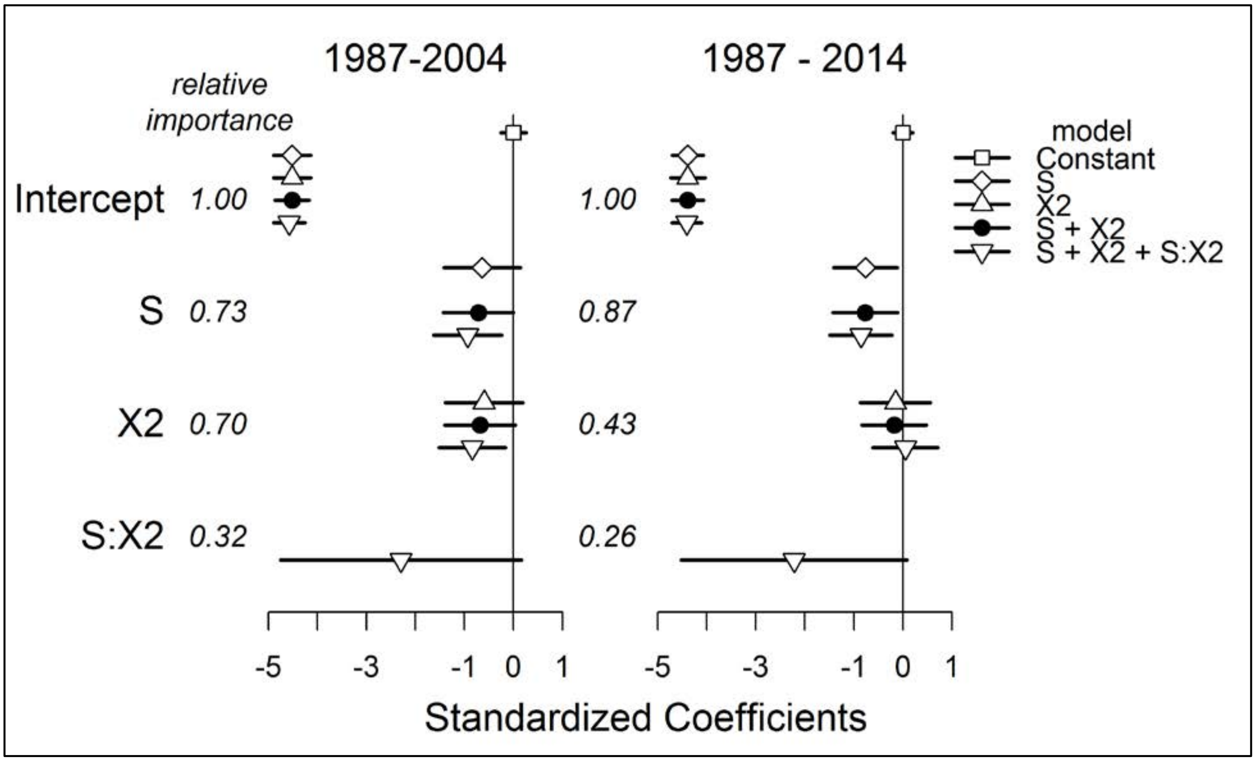
[10] A negative effect of X2 means an increase in recruitment.

[11] $\Delta_{AICc} < 2$ indicates a similar level of support to the best supported model.

for the spawning stock-only model became 3.4 stronger relative to Equation 4. Further, when considering the additional years of data, the effect size of fall X2 is smaller and more uncertain (95% C.I. has greater overlap with zero; Figure 16), while uncertainty in the effect size of the spawning stock (FMWT index) has decreased and the 95% C.I. no longer includes zero.



Notes: To aid interpretation of the regression coefficients the scale of the input variables are standardized by subtracting their mean and dividing by two standard deviations (Gelman 2008). The filled circle represents the model (Equation 4) analogous to that of the model forming part of the basis for the USFWS (2008) BiOp's Fall X2 action. Lines represent the 95% confidence intervals on the coefficient estimates. Relative importance—the support for individual parameters—is the summed AICc weights of models that include the parameter.

Figure 16. Regression Coefficients for the Five Models Fit to 1987-2004 (Time Span of Feyrer et al. 2007) and 1987-2014.

Table 2. Model Selection Results for the Effect of Delta Smelt Fall Stock (FMWT Index) and Mean September-October X2 Fit to Juvenile Recruitment (log(R/S)) Using 1987-2004 Data (n = 17).

Model	Degrees of freedom	Δ_{AICc}	Weight	Adj. R^2	CV_{RMSE}
S + X2 + S:X2	13	0.0	0.32	0.40	0.15
S + X2	14	0.5	0.25	0.27	0.16
S	15	1.4	0.16	0.11	0.18
Constant	16	1.6	0.14	NA	0.18
X2	15	1.9	0.13	0.09	0.17

Table 3. Model Selection Results for the Effect of Delta Smelt Fall Stock (FMWT Index) and Mean September-October X2 Fit to Juvenile Recruitment (log(R/S)) Using 1987-2014 Data (n = 27).

Model	Degrees of freedom	Δ_{AICc}	Weight	Adj. R^2	CV_{RMSE}
S	25	0.0	0.47	0.16	0.19
S + X2 + S:X2	23	1.2	0.26	0.23	0.19
S + X2	24	2.4	0.14	0.13	0.20
Constant	26	3.2	0.10	NA	0.20
X2	25	5.5	0.03	-0.03	0.21

The models explained different portions of variation in the 1987-2004 and 1987-2014 data. For 1987-2004, the best model (the full model) explained 40% of the observed variance in the 1987-2004 data compared to 27% when excluding the interaction to give the Equation 4 model analogous to that of Feyrer et al. (2007) and USFWS (2008) (Table 2). In contrast, for 1987-2014 the best model (stock only) explained 16% of the variation in the data, which is greater than the model analogous to Feyrer et al. (2007) and USFWS (2008) including X2 in addition to stock (13%; Table 3). In all cases the adjusted R2 is considerably lower than the model reported by USFWS (2008) (adjusted R2 = 56%), likely due to using an arguably more biologically appropriate multiplicative model rather than the additive model used by USFWS (2008). Any differences in variance explained by the models here were not reflected in differences in the expected prediction error. The prediction error for all five models is expected to be 15-18% of the mean for the original data. Prediction error is marginally worse for the five models (19-21%) including the 10 additional years of data. These results suggest that the stock-recruitment-salinity relationship from the USFWS (2008) analysis was overstated relative to results that would have been obtained with an arguably more appropriate multiplicative model, and that the effect of fall salinity (represented herein by X2) has become weaker with the addition of new data.

As illustrated by simulated management of fall X2, there is a great deal of uncertainty in how recruitment will respond across a wide range of changes in fall X2, including a non-trivial probability of observing a decline in recruitment under even the most aggressive management actions (Figure 17). For example, moving mean September-October X2 from 95 km to the required RPA- location following an above normal water year (81 km) is predicted to increase recruitment to the STN by a factor of 1.24, and a factor of 1.39 if fall X2 is moved to the RPA-required location following a wet year (74 km). However, the objective of increasing recruitment to the STN is met in only 58% and 61% of simulations when the statistical uncertainty of the model is accounted for.

The models presented herein are analogous to those used by Feyrer et al. (2007) and USFWS (2008), and are somewhat simplistic in that they violate certain assumptions, including independence of response and predictor variable (e.g., recruits in one time step become the stock in the following time step), ignore uncertainty in the stock and recruit indices, and do not address whether juvenile recruitment is the life-stage transition limiting Delta Smelt population productivity. Recently, more sophisticated methods have been employed to evaluate what effect fall X2 has on the Delta Smelt population trends. For example, studies using Bayesian change point analysis (Thomson et al. 2010) and multivariate autoregressive modeling (Mac Nally et al. 2010) both failed to identify fall X2 as an environmental covariate contributing to the declining abundance trends in Delta Smelt. State-space multistage life-cycle models (e.g., Maunder and Deriso 2011) consider multiple factors acting on different life-stages, including environmental covariates and density dependence. Development of such life-cycle models for Delta Smelt is ongoing (K. Newman, R. Deriso, personal communication to C. Phillis), but ultimately should be capable of assessing the influence of fall X2 on Delta Smelt population dynamics relative to factors affecting other life stages.

In summary, the fall X2 environment-recruitment correlation does not reliably predict recruitment from the adult index (FMWT) to the juvenile index (STN). This finding does not invalidate work by others hypothesizing fall X2 predicts the quality and quantity of Delta Smelt habitat (Feyrer et al. 2007; Feyrer et al. 2011); however, the analysis herein and work by others (Mac Nally et al. 2010; Thomson et al. 2010; Miller et al. 2012) have failed to detect a significant population-level response to changes in habitat associated with fall X2.

Figure 17. Posterior Density Distributions from 10,000 Simulations of the Change in Delta Smelt Fall to Summer Survival when Fall X2 is Moved from an Upstream Location to a Downstream Location.

Application to Proposed 2017 Fall X2 Action

The preceding model fitting of Delta Smelt juvenile recruitment in relation to adult stock size and fall X2 suggests that large changes in fall X2 would be necessary to provide a greater probability of an increase in survival. The proposed 2017 Fall X2 action would give X2 of ~74 km in September and up to 81 km in October, although available forecasts suggest that X2 could be as low as ~78 km in October (Figure 13; Table 1). With mean X2 in October of 81 km, the mean September-October X2 would be 77.557 km, as opposed to 74 km if X2 was kept at 74 km in both months. The simulation framework for the coefficients and associated confidence intervals developed for Equation 4 (i.e., the model analogous to Feyrer et al. 2007) using the 1987-2014 data were applied to mean September-October X2 of 77.557 km and 74 km to illustrate potential effects of the proposed 2017 Fall X2 action. This suggested that moving mean September-October X2 from 77.557 km to 74 km would be unlikely to have a measurable effect on Delta Smelt recruitment in 2018: the factor increase was predicted to be 1.06 with increases in survival in around half of simulations, decreases in the other half, and similar percentages of simulations with halving or doubling of survival (Figure 18). With X2 more similar to recent forecasts (Figure 13; Table 1), the factor increase would be even less.

Figure 18. Posterior Density Distributions from 10,000 Simulations of the Change in Delta Smelt Fall to Summer Survival when Mean September-October X2 is Moved from 77.557 km to 74 km.

Response to Comments

Comments received on drafts of the stock-recruitment-X2 relationship analysis presented above suggested a number of worthwhile avenues for further exploration. It should be borne in mind that the stock-recruitment-X2 relationship presented in this effects analysis aimed to revisit and advance the basic analysis presented in the USFWS (2008) BiOp. Some comments suggested that the underlying data for stock and recruitment are based on relatively inefficient gears; however, many studies have used the same data, including the USFWS (2008) BiOp, but this is certainly an issue to be revisited, possibly with gear collection adjustments.

Other comments suggested to limit the period of analysis to the POD-era regime (here taken to be 2003-2015/2016), and to consider using the ratio of the SKT index to the STN index as the stock-recruitment relationship to avoid potential confounding effects of winter-spring conditions, for example. Survival from STN (summer) to SKT (winter/spring) is actually a stage-survival relationship similar to that examined by Nobriga et al. (2013). Preliminary examination of the relationship between mean September-October X2 and the standardized residuals of a log(SKT-STN ratio) vs. STN index regression for 2003-2015—representing a Ricker survival relationship—show a weak negative relationship that is not statistically significant (P = 0.24; Figure 19).

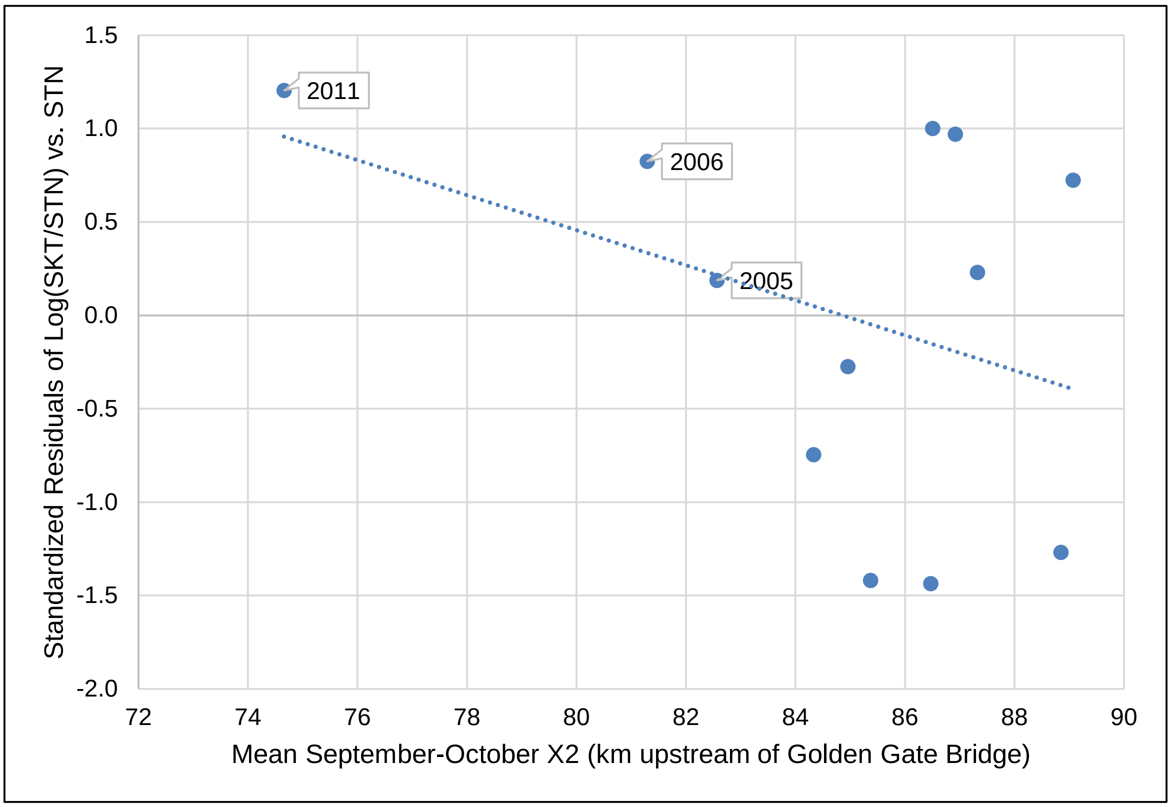


Figure 19. Delta Smelt: Relationship Between Mean September-October X2 and Residuals of Log(Spring Kodiak Trawl Index/Summer Townet Index) vs. Summer Townet Index, 2003-2014.

Another comment received was to consider using a Beverton-Holt stock-recruitment relationship, as opposed to the Ricker stock-recruitment relationship. While worthy of future consideration, the current low abundance of Delta Smelt suggests that survival is likely to be in the density-independent portion of stock-recruitment relationships, so that the choice of Ricker vs. Beverton-Holt relationships may not give greatly different predictions. Repeating the above analysis for a Beverton-Holt survival relationship—represented by the residuals of STN index/SKT index vs. STN index—gives a similar non-significant result ($P = 0.16$; Figure 20). Both of these preliminary analyses indicate, similar to the stock-recruitment-X2 relationship used in the present effects analysis, that X2 is only weakly statistically related to survival from summer to winter/spring.

Efforts to improve existing tools would be an appropriate topic for CAMT or IEP's Flow Alteration (FLoAT) Project Work Team.

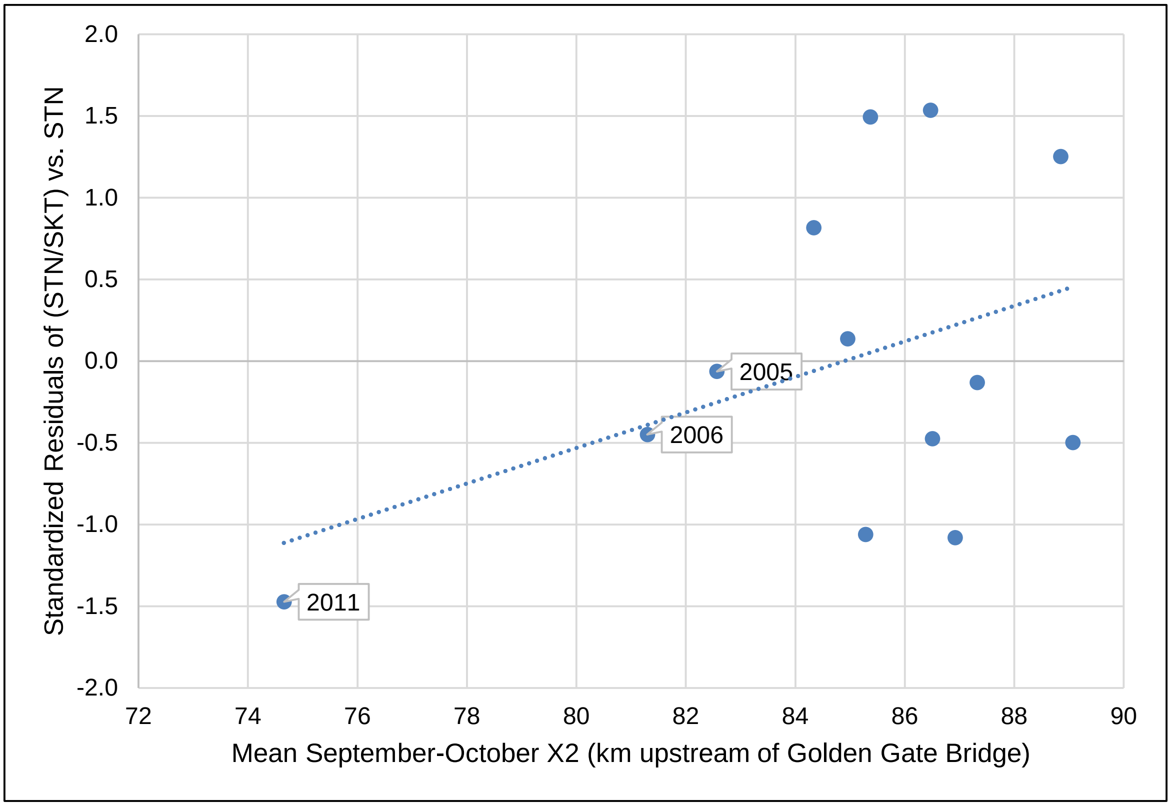


Figure 20. Delta Smelt: Relationship Between Mean September-October X2 and Residuals of (Summer Townet Index/Spring Kodiak Trawl Index) vs. Summer Townet Index, 2003-2015.

Effects on Delta Smelt Critical Habitat

As described by USFWS (2008: 190-191), the primary constituent elements (PCE) of designated critical habitat for Delta Smelt include physical habitat (PCE1: the structural component of habitat, namely spawning substrate, and potentially depth variation in pelagic habitat within the low salinity zone), water quality (PCE2: water of suitable quality to support Delta Smelt with abiotic elements allowing for survival and reproduction, and certain conditions of temperature, turbidity, and food availability), river flow (PCE3: transport flow to facilitate spawning migrations and transport of offspring to low salinity zone rearing habitats, as well as to influence the extent and location the highly productive low salinity zone where Delta Smelt rear), and salinity (PCE4: the low salinity zone nursery habitat, defined as salinity 0.5-6[12], which is generally of highest quality and extent when X2 is in Suisun Bay). The effects analysis focuses on the potential of the proposed 2017 Fall X2 action to affect PCE2, PCE3, and PCE4, although these terms are not used explicitly; instead, the focus is on the extent of the low salinity zone, food availability, and abiotic parameters. Although Delta Smelt fall occurrence is generally greatest in the low salinity zone and the centroid of distribution generally moves upstream as the salinity field moves upstream (Sommer et al. 2011), the overall distribution occurs over a broader range of salinity than solely the low salinity zone (Sommer and Mejia 2013; Moyle et al. 2016).

The FLaSH investigations (Brown et al. 2014) were undertaken to assess the effects of fall X2 on Delta Smelt and its habitat through testing of a number of predictions (Table 4). The effects analysis provided herein for the proposed 2017 Fall X2 action includes consideration of important biotic (food) and abiotic (salinity, water clarity, and water temperature) parameters that were identified as potentially important to Delta Smelt and its critical habitat by the FLaSH investigations, as well as in the subsequent updated conceptual model for Delta Smelt (IEP MAST 2015). The FLaSH investigations accounted for interannual antecedent conditions, i.e., comparison of a wet year preceded by a drier year for two comparative years (2005/2006 and 2010/2011), and so to provide some context related to the FLaSH studies, these years are highlighted in some of the analyses presented in the effects analysis for the proposed 2017 Fall X2 action. However, this effects analysis considers a wider range of years, while recognizing that some time series should not be examined in their entirety because of fundamental long-term changes that have occurred over time (e.g., changes in zooplankton assemblage composition and increase in water clarity). Although it was originally envisioned to conduct more formal statistical analyses, it became apparent during inspection of the data that in many cases the necessary subsetting—e.g., stations within the low salinity zone, only fall months—reduced sample sizes such that a more fundamental approach is appropriate. Thus, the main analyses plot trends in monthly-averaged variables of interest in relation to mean X2, with linear trend lines included to aid interpretation. Where the linear trend lines suggest potential for effects of concern and where appropriate based on sample characteristics, linear regressions are

[12] Subsequent investigations have used a low salinity zone definition of salinity = 1-6, which is adopted in the present effects analysis. As noted by Brown et al. (2014: p. 3), salinity of 1-6 is generally considered to be the optimal salinity range for Delta Smelt (Bennett 2005), although the fish are also found outside of this core range (Feyrer et al. 2007; Kimmerer et al. 2009; Sommer et al. 2011).

undertaken to indicate the magnitude of potential effect on Delta Smelt or its habitat; it is acknowledged, however, that correlation does not necessarily indicate causation.

Table 4. Assessment of Predicted Qualitative and Quantitative Outcomes for September to October of the Fall Low-Salinity Habitat of the USFWS (2008) Biological Opinion (Brown et al. 2014: p. 67).

[X2 is the horizontal distance in kilometers from the Golden Gate up the axis of the estuary to where tidally averaged near-bottom salinity is 2. Green shading means that data supported the prediction; orange shading means the prediction was not supported; gray shading means that data were not yet available to support a conclusion; no shading means there were no data to assess **Abbreviations**: CVP, Central Valley Project; DS, delta smelt; ha, hectares; km, kilometer; LSZ, low-salinity zone with salinity 1–6; SWP, State Water Project; ~, approximately]

Variable (September–October)	Predictions for X2 scenarios		
	85 km	81 km	74 km
	Year used to test prediction		
	2010 (X2 at 85 km)	2005, 2006 (X2 at 83 and 82 km, respectively)	2011 (X2 at 75 km)
Dynamic abiotic habitat components			
Average daily net delta outflow	~5,000 cfs	~8,000 cfs	11,400
Surface area of the fall LSZ	~4,000 ha	~5,000 ha	~9,000 ha
Delta smelt abiotic habitat index	3,523	4,835	7,261
San Joaquin River contribution to fall outflow	0	Very low	Low
Hydrodynamic complexity in LSZ	Lower	Moderate	Higher
Average wind speed in the LSZ	Lower	Moderate	Higher
Average turbidity in the LSZ	Lower	Moderate	Higher
Average Secchi depth in the LSZ	Higher	Moderate	Lower
Average ammonium concentration in the LSZ	Higher	Moderate	Lower
Average nitrate concentration in the LSZ	Moderate	Moderate	Higher
Dynamic biotic habitat components			
Average phytoplankton biomass in the LSZ (excluding *Microcystis*)	Lower	Moderate	Higher
Contribution of diatoms to LSZ phytoplankton biomass	Lower	Moderate	Higher
Contribution of other algae to LSZ phytoplankton biomass at X2	Higher	Moderate	Lower
Average floating *Microcystis* density in the LSZ	Higher	Moderate	Lower
Phytoplankton biomass variability across LSZ	Lower	Moderate	Higher
Calanoid copepod biomass in the LSZ	Lower	Moderate	Higher
Cyclopoid copepod biomass in the LSZ	Lower	Moderate	Moderate
Copepod biomass variability across LSZ	Lower	Moderate	Higher
Potamocorbula biomass in the LSZ	Higher	Moderate	Lower
Predator abundance in the LSZ	Lower	Moderate	Higher
Predation rates in the LSZ	Lower	Moderate	Higher
Delta smelt (DS) responses			
DS caught at Suisun power plants	0	0	Some
DS in fall SWP and CVP salvage	Some	0	0
DS center of distribution (km)	85 (77–93)	82 (75–90)	78 (70–85)
DS growth, survival, and fecundity in fall	Lower	Moderate	Higher
DS health and condition in fall	Lower	Moderate	Higher
DS recruitment the next year	Lower	Moderate	Higher
DS population life history variability	Lower	Moderate	Higher

Salinity, Abiotic Habitat Index, and Hydrodynamics-Based Station Index

Low Salinity Zone Extent

Based on the published lookup table between X2 and Delta Smelt fall abiotic habitat index (Table 2-1 of Brown et al. 2014), X2 of 74 km in September would give an approximate low salinity zone (salinity range of 1 to 6) area of 8,408 hectares (20,777 acres); whereas X2 of 81 km in October would give a low salinity zone area of 5,313 hectares (13,129 acres). X2 of 81 km would represent ~37% less low salinity zone area than if X2 were at 74 km in October. As previously described, forecasts exist for potential X2 in September-November 2017 (Figure 13; Table 1). For October, a mean X2 of ~78 km under the proposed 2017 Fall X2 action would give a low salinity zone extent of 7,959 hectares (19,667 acres), which would be 626 hectares (~7%) less than if X2 was at the forecasted location (73 km) based on implementation of the USFWS (2008) BiOp Fall X2 action as prescribed, for example. This method only takes into account the area of salinity and the corresponding tidal area, without consideration for other factors important to Delta Smelt habitat (e.g., biotic factors; see *Food Availability in the Low Salinity Zone*), and as described above in *Delta Smelt Stock-Recruitment-X2 Relationship*, there is no statistical relationship between the extent of the low salinity zone (as indexed by X2) and Delta Smelt recruitment.

Abiotic Habitat Index (Feyrer et al. 2011)

Based on the published lookup table between X2 and Delta Smelt fall abiotic habitat index[13] (Table 3-1 of Brown et al. 2014), X2 of 74 km in September would give an approximate abiotic habitat index of 7,261; whereas X2 of 81 km in October would give an approximate abiotic habitat index of 4,835[14]. Note that these are dimensionless units, being the area of habitat weighted by probability of Delta Smelt occurrence. Similar to the extent of low salinity zone difference discussed previously, X2 of 81 km in October would give an approximately 33% lower abiotic habitat index than if X2 was 74 km. Based on the available X2 forecast information for October 2017 (Table 1), the October abiotic habitat index for the proposed action with X2 ~78 km would be 6,099, which is ~19% less than if X2 was at the forecasted location (73 km: abiotic habitat index = 7,491) based on implementation of the USFWS (2008) BiOp Fall X2 action as prescribed, for example. Note that abiotic habitat is an important component of habitat but does not fully describe habitat, which also includes biotic factors such as food, for which potential effects related to X2 are evaluated in *Food Availability in the Low Salinity Zone*.

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[13] An index of the area of Delta Smelt abiotic habitat, weighted by the probability of Delta Smelt occurrence based primarily on Secchi depth and conductivity (Feyrer et al. 2011).

[14] Technically the abiotic habitat index refers to mean abiotic habitat index from September to December, but its calculation requires knowledge of X2 in November and December, which is unavailable for 2017.

Hydrodynamics-Based Station Index (Bever et al. 2016)[15]

Introduction

Bever et al. (2016) developed an approach to calculate a station index for Delta Smelt based on hydrodynamics (SI_H) which was predictive of a similar station index developed using historical Delta Smelt catch data from the Fall Midwater Trawl (SI_C). SI_H is derived from three primary variables: the percent of the time the salinity is less than 6; Secchi depth; and maximum depth-averaged current speed during the fall (Bever et al. 2016). Bever et al. (2016) calculated SI_H as shown in Equation 1.

Equation 1

$$SI_H = C_1S + C_2V \qquad \text{if T} < \text{cutoff}$$

$$SI_H = (C_1S + C_2V) \times C_3 \qquad \text{if T} > \text{cutoff}$$

where:

S	=	the Station Index computed based on percent time salinity is less than 6 psu
V	=	the Station Index computed from maximum depth-averaged current speed
T	=	is the Secchi depth in meters, with a cutoff value of 0.5 meter (m)
C_1	=	0.67 (from Table 3 in Bever et al. 2016)
C_2	=	0.33 (from Table 3 in Bever et al. 2016)
C_3	=	0.42 (from Table 3 in Bever et al. 2016)

SI_H was developed based on average fall conditions, but was also applied to individual years in order to evaluate average fall conditions during the period from September through December of 2010 and 2011. For the present effects analysis, rather than evaluating conditions for Delta Smelt during the fall period as a whole, the approach developed by Bever et al. (2016) was modified to generate maps of SI_H, and each underlying variable, corresponding to specific values of X2. This required some assumptions about the range of possible conditions likely to occur during the fall X2 period, particularly for Secchi depth, and required adapting some aspects of the approach developed by Bever et al. (2016) in order to develop each metric over shorter time-scales. For example, Bever et al. (2016) calculated the percent of the time salinity was less than 6 over the entire 4-month fall period (September-December), whereas the present analysis computes the percent of the time during which salinity is less than 6 over an individual day with a specific X2 value. In the calculation of SI_H, Secchi depth is used as a proxy for turbidity because of the much longer data record of Secchi depth. High Secchi depth indicates low turbidity conditions, while low Secchi depth indicates high turbidity conditions. The approach for calculating each underlying variable used to calculate SI_H is described next in *Calculation of Hydrodynamics-Based Station Index*. The general results obtained from applying the method are then presented in the *Results* section, followed by a discussion of *Application of Hydrodynamics-Based Station Index to Proposed 2017 Fall X2 Action.*

[15] This analysis was adapted by ICF from a draft report prepared by Anchor QEA, LLC.

Calculation of Hydrodynamics-Based Station Index

Bever et al. (2016) calculated SI_H over a region spanning from Carquinez Strait through Suisun Bay and the junction of the Sacramento and San Joaquin Rivers in the western Delta (Figure 21). This same geographic extent is used for the present effects analysis. This geographic extent includes 45 stations sampled as part of the FMWT survey. The observed Secchi depth from the sampling of these 45 stations between 2000 and 2015 during the months of September, October, November, and December was used to determine representative turbidity distributions in the vicinity of Suisun Bay for this analysis.

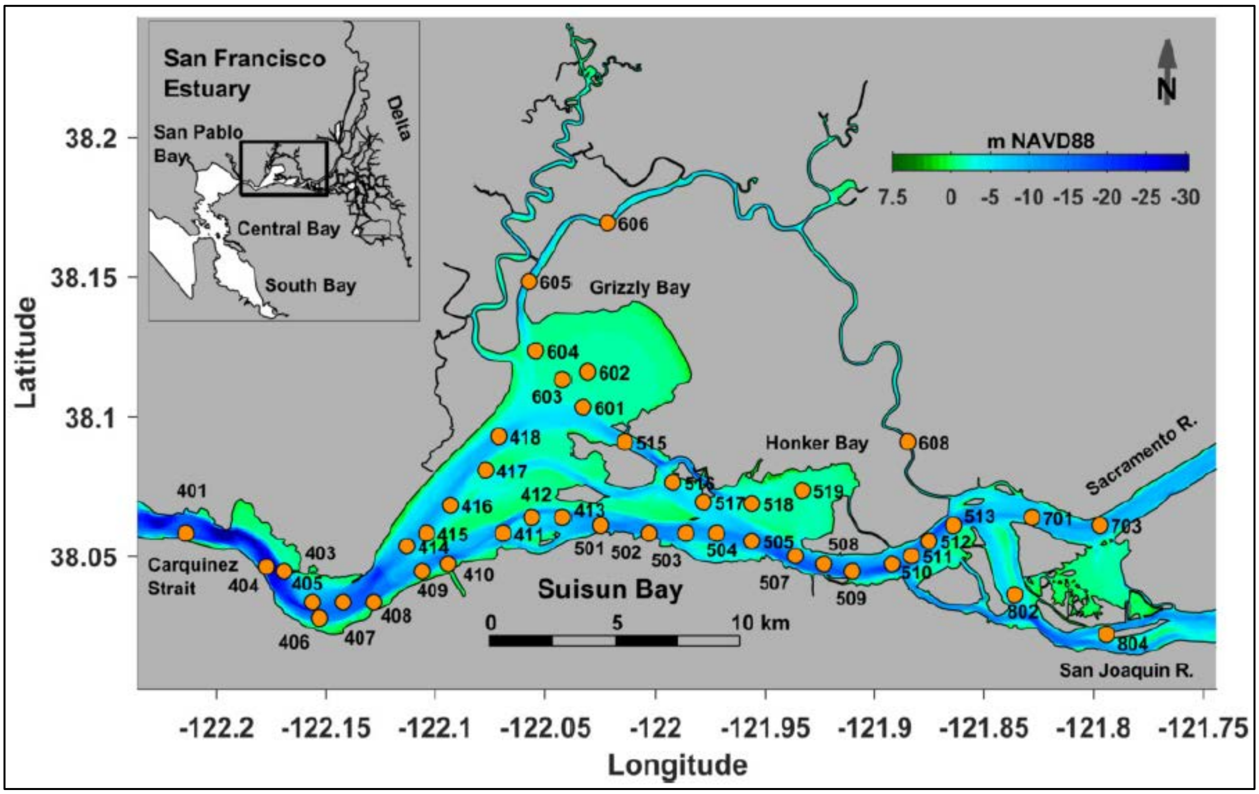

Figure 21. Locations of the Fall Midwater Trawl Sampling Stations included in the Hydrodynamics-Based Station Index Analysis.

Salinity

Maps of the percentage of time with salinity < 6, based on UnTRIM Bay-Delta modeling, were developed for the days shown in the Low Salinity Zone Flip Book (DMA 2014) for X2 values of 74 through 81 km. This is a modification of the approach used in Bever et al. (2016), because in the original approach the percentage of time with salinity < 6 was calculated over a 4-month period. The use of a single day should produce an equivalent result that is representative of the percentage of time with salinity < 6 for a single X2 value at a specific location. As discussed in the Low Salinity

Zone Flip Book (DMA 2014), there can be some variation in the overall salinity distribution for a given X2, particularly if flows are rapidly increasing or decreasing. However, the days selected for inclusion in the Low Salinity Zone Flip Book for each X2 value were identified as being representative of typical salinity conditions for each X2 value. Thus, while the salinity distribution for a given X2 value could vary depending on antecedent conditions or the timing of the spring-neap cycle, the salinity distributions shown in Figures 22-29 are likely to be representative of typical salinity distributions over the range of X2 from 74 km to 81 km.

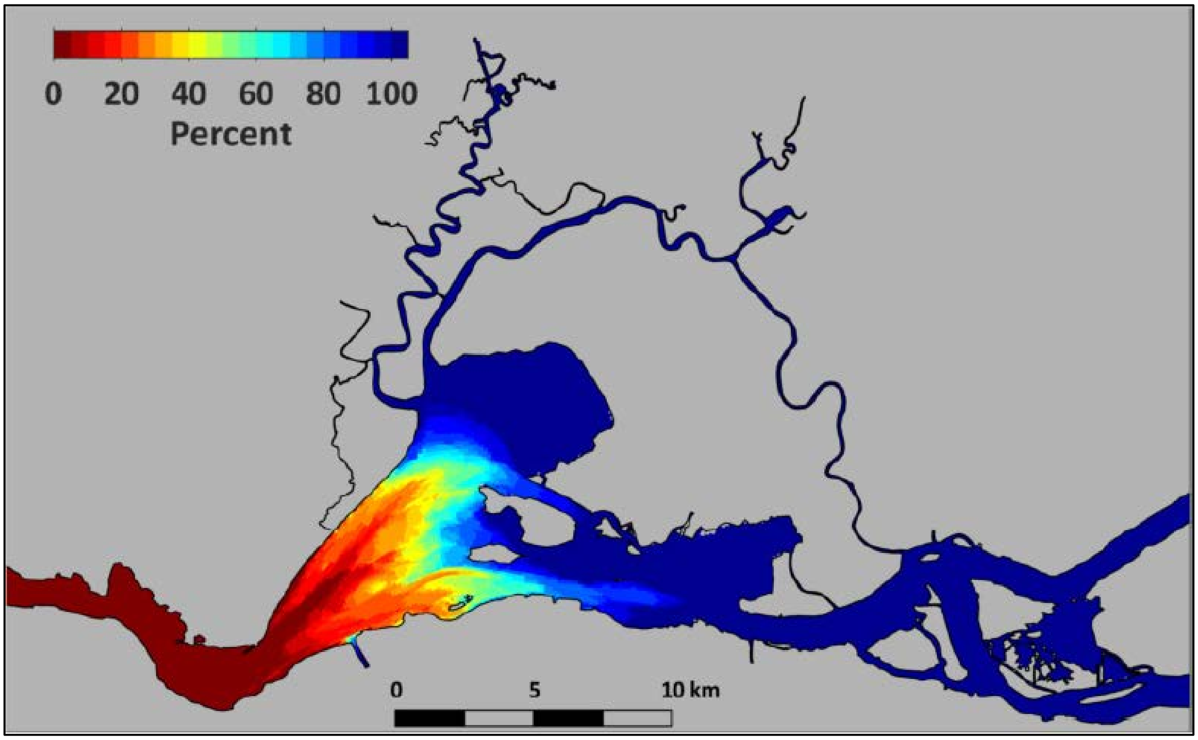

Figure 22. The Percentage of Time With Salinity < 6 for X2 = 74 km, As Used in the Hydrodynamics-Based Station Index Analysis.

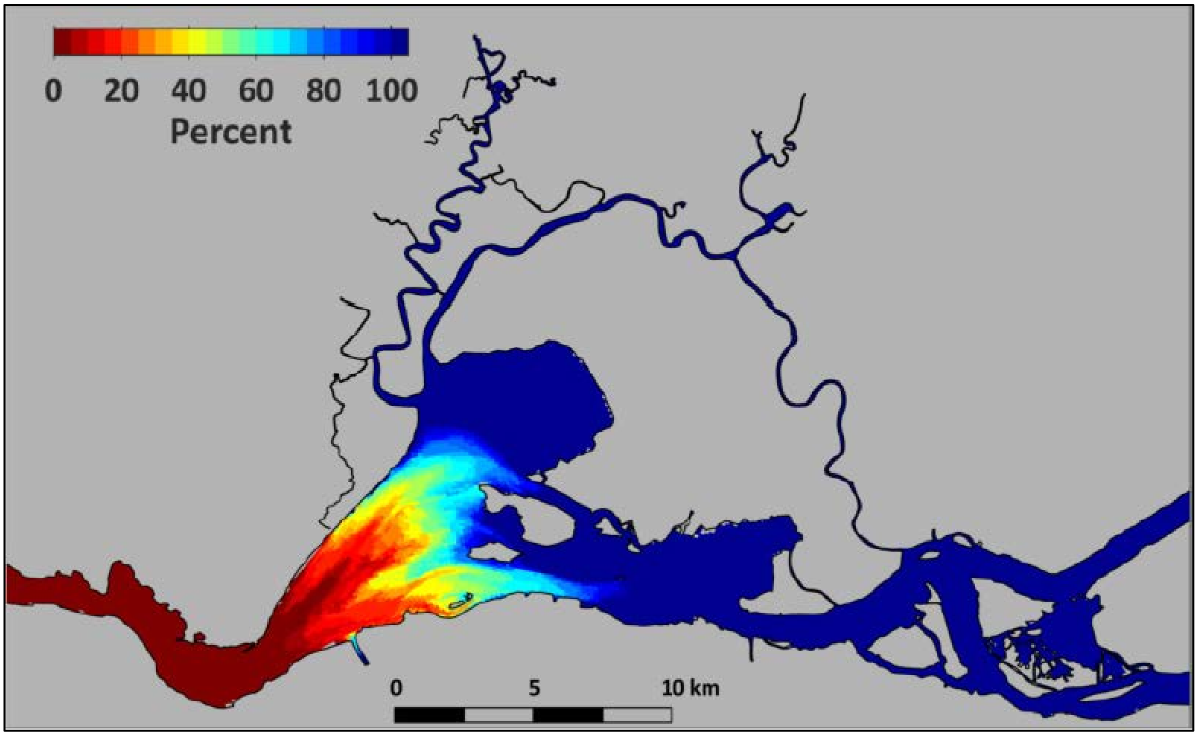

Figure 23. The Percentage of Time With Salinity < 6 for X2 = 75 km, As Used in the Hydrodynamics-Based Station Index Analysis.

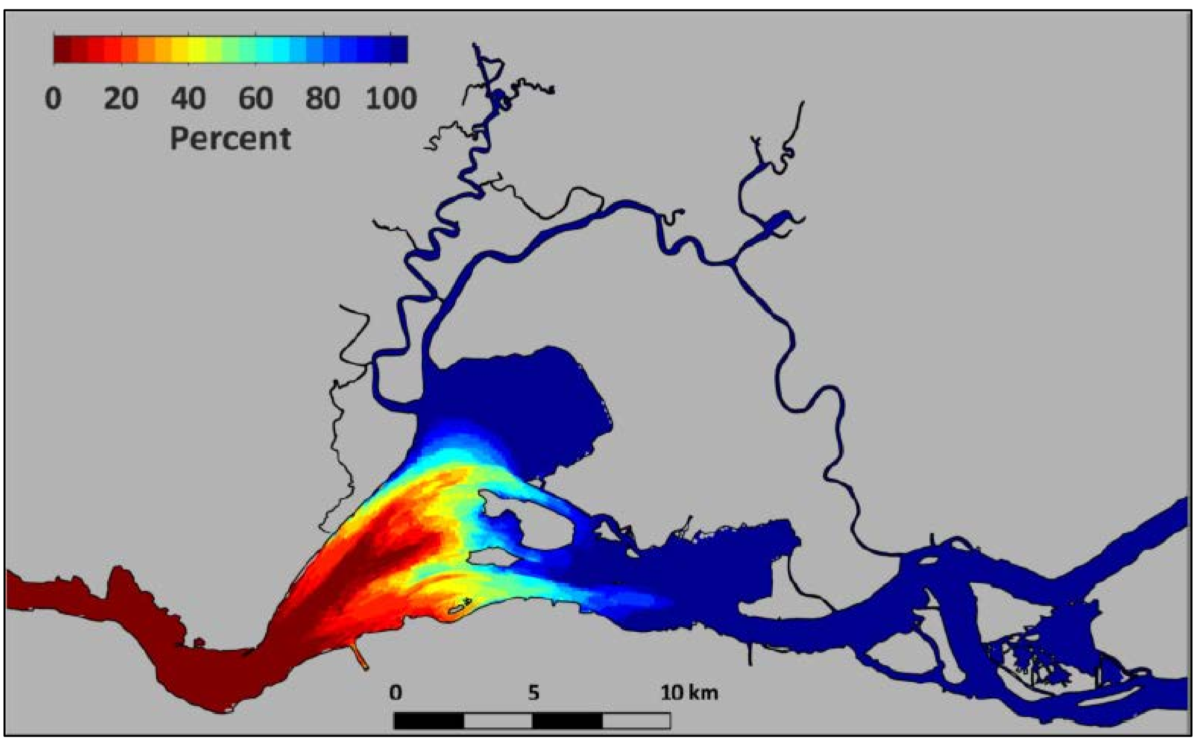

Figure 24. The Percentage of Time With Salinity < 6 for X2 = 76 km, As Used in the Hydrodynamics-Based Station Index Analysis.

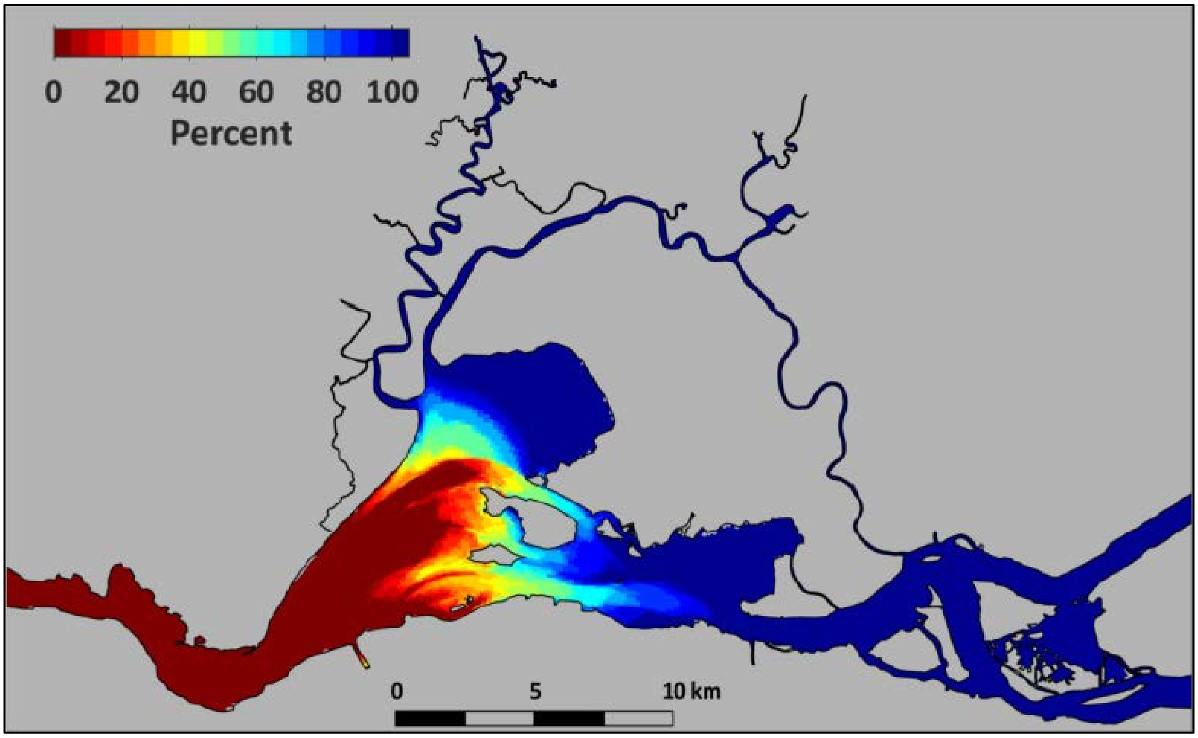

Figure 25. The Percentage of Time With Salinity < 6 for X2 = 77 km, As Used in the Hydrodynamics-Based Station Index Analysis.

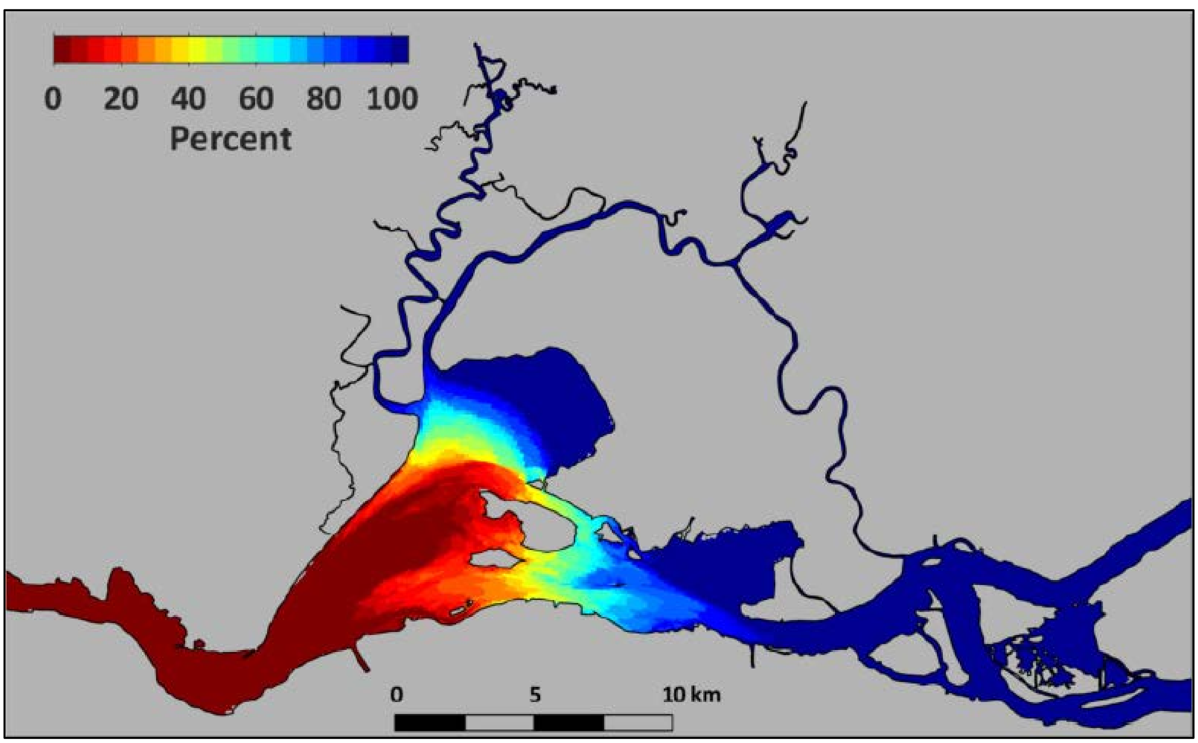

Figure 26. The Percentage of Time With Salinity < 6 for X2 = 78 km, As Used in the Hydrodynamics-Based Station Index Analysis.

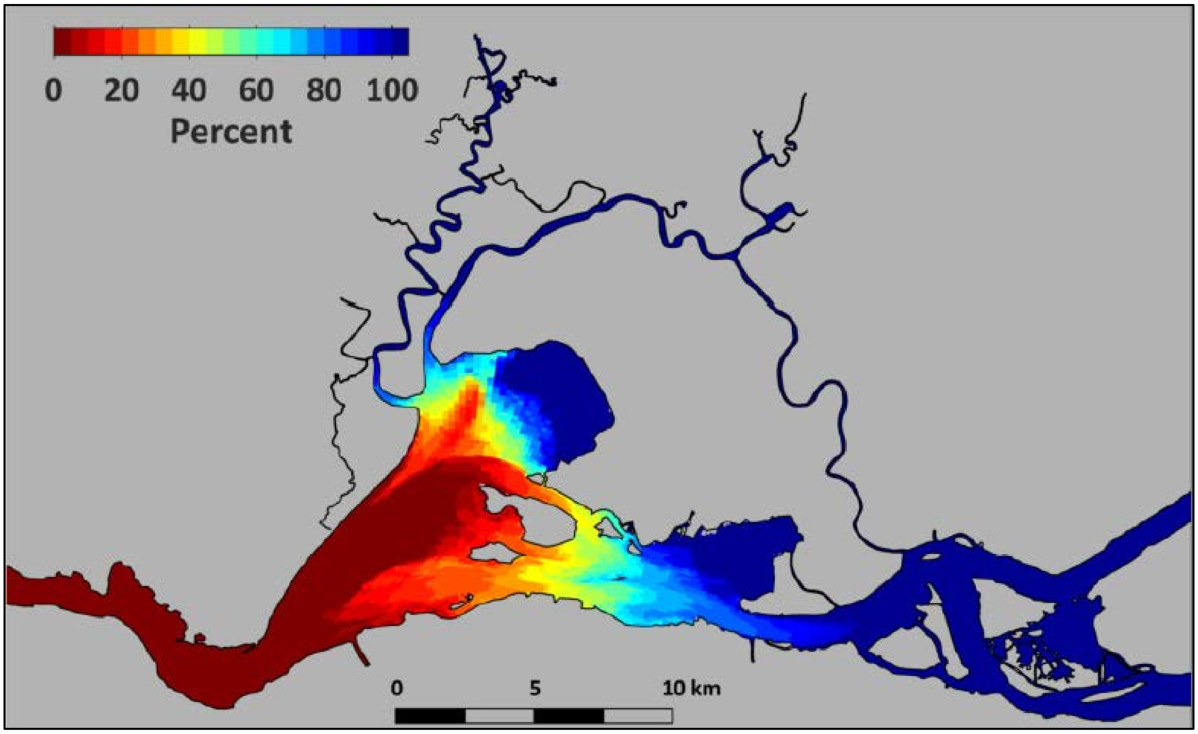

Figure 27. The Percentage of Time With Salinity < 6 for X2 = 79 km, As Used in the Hydrodynamics-Based Station Index Analysis.

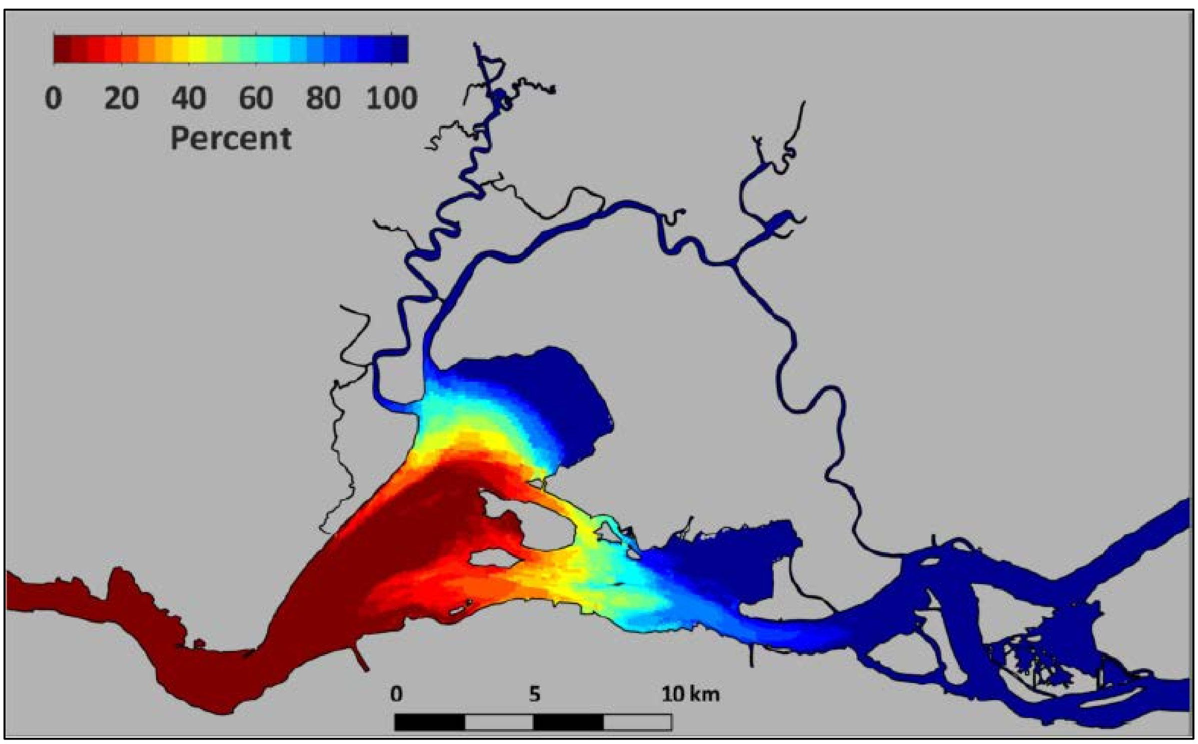

Figure 28. The Percentage of Time With Salinity < 6 for X2 = 80 km, As Used in the Hydrodynamics-Based Station Index Analysis.

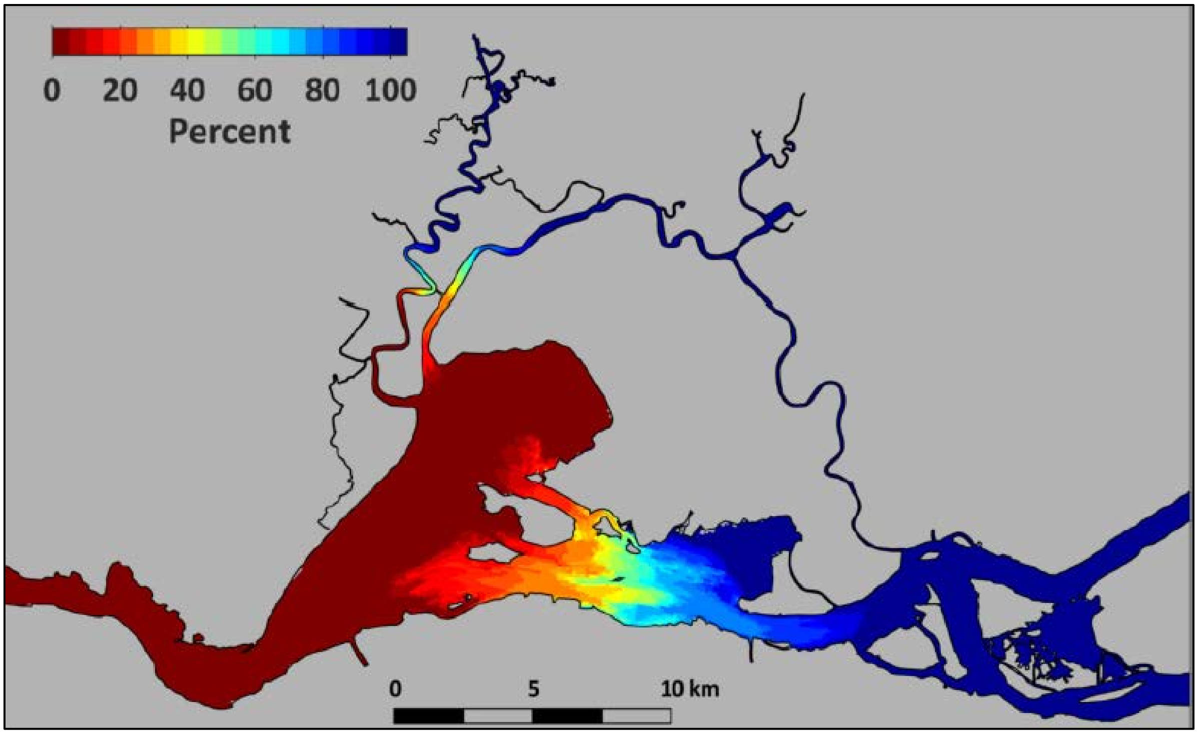

Figure 29. The Percentage of Time With Salinity < 6 for X2 = 81 km, As Used in the Hydrodynamics-Based Station Index Analysis.

Current Speed

Bever et al. (2016) developed maps of the maximum depth-averaged current speed for the fall of 2010 and 2011, using the UnTRIM Bay-Delta model. That analysis indicated that the distribution of the maximum depth-averaged current speed during the fall did not vary significantly between 2010 and 2011, despite differences in fall outflow (see Figures 12E and 12F in Bever et al. 2016). This is because the main driver of water velocity in Suisun Bay is tidal forcing (Cheng and Gartner 1984), which, when considered over a 4-month period, resulted in velocity metrics that were nearly identical year to year. Because the velocity metrics are largely invariable on an interannual time scale, potentially favorable regions for Delta Smelt catch can be narrowed to consider the interannual variability in the salinity and turbidity outside of the high-velocity regions. To determine a representative distribution of maximum depth-averaged current speed for this analysis, the maximum depth-averaged current speeds from 2010 and 2011 were averaged (Figure 30). The resulting distribution of maximum depth-averaged current speed provides a representative distribution of the maximum depth-averaged current speed expected to occur in the fall. This distribution of maximum depth-averaged current speed was used uniformly for all calculations of SI_H and did not vary either for different X2 values or for different turbidity distributions.

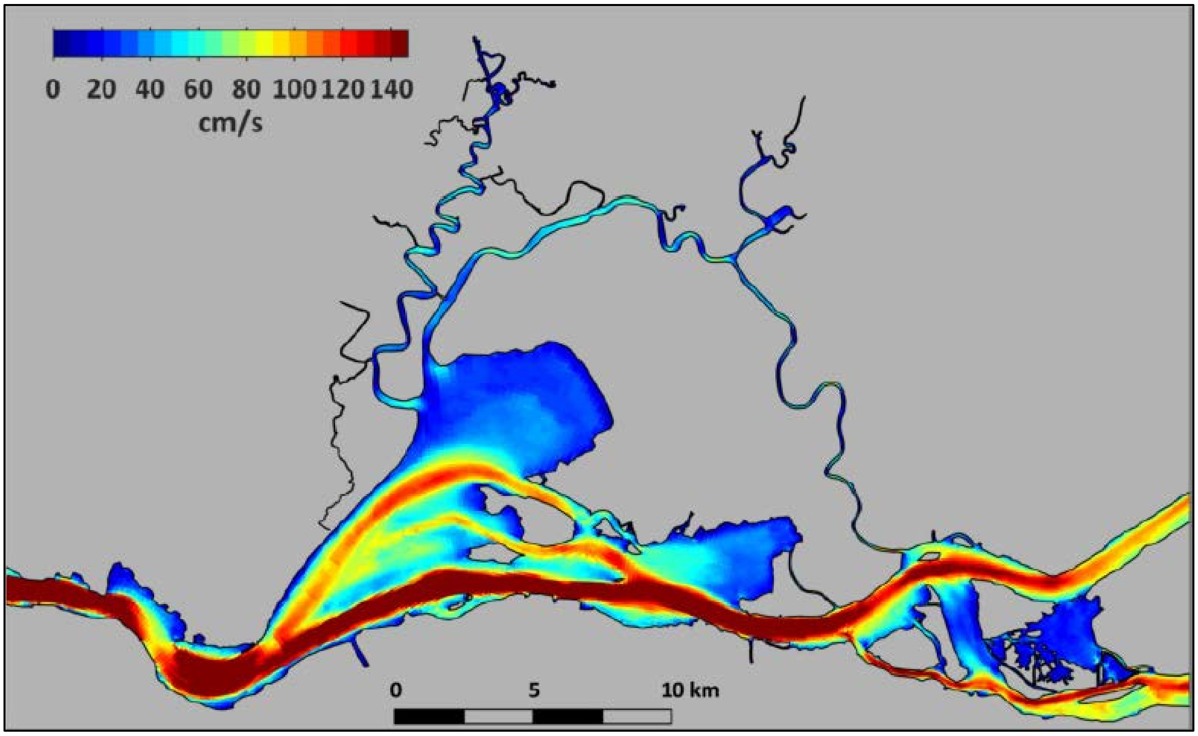

Figure 30. The Maximum Depth-Averaged Current Speed, As Used in the Hydrodynamics-Based Station Index Analysis.

Secchi Depth

Bever et al. (2016) developed maps of Secchi depth spanning the vicinity of Suisun Bay based on the monthly Secchi depth data recorded as part of the FMWT survey. Because the turbidity during the fall of 2017 will depend on a wide range of factors such as wind, sediment supply, and outflow, it is not possible to predict the turbidity conditions in advance with certainty. As a result, the present effects analysis examined historical Secchi depth in the vicinity of Suisun Bay over the period between 2000 and 2015 to estimate representative low and high turbidity conditions that could occur in Suisun Bay during the Fall X2 period. The low and high turbidity conditions provide bookends to the range of likely turbidity conditions and allow for the evaluation of SI_H over a range of X2 for two possible turbidity distributions. Observed Secchi depth was used as a metric for turbidity because the data record of Secchi depth is much longer than turbidity. While Bever et al. (2016) developed 4-month average maps of Secchi depth for September-December, the present effects analysis evaluated maps for individual months to select representative historic conditions with high Secchi depth (low turbidity) and low Secchi depth (high turbidity) which have occurred within the range of X2 between 74 km and 81 km in recent years.

As with other analyses conducted herein, estimates from DAYFLOW were used for X2, as subsequently described below in *Retrospective Analysis of X2*. For the period between 2000 and 2015, there does not appear to be a correlation ($r^2 = 0.05$) between the monthly-average X2 and average Secchi depth between September and December (Figure 31). This indicates that, over the range in X2 that has occurred in the fall since 2000, it is unlikely that X2 is strongly correlated with average Secchi depths in the area bounded by Figure 21. This agrees with other analyses presented in this effects analysis, illustrating that various measures of water clarity at fixed locations are not related to X2 (see the *CDEC Data* and *USGS Data* subsections of the *Water Clarity in the Low Salinity Zone* analysis).

Between 2000 and 2015, the average monthly September-December Secchi depth in the area bounded by Figure 21 varied between 0.37 and 0.63 with X2 of 74-81 km (Figure 31). These ranges of Secchi depth were used to determine representative months with low and high average Secchi depths that occurred when X2 was between 74 km and 81 km. The representative low and high average Secchi depths were selected to bookend conditions that could occur in the fall. The representative conditions were chosen based on the criteria of having a monthly-average X2 of between 74 km and 81 km and having relatively low and high average Secchi depths. Using these criteria, September 2011 was selected as representative of low Secchi depth conditions (high turbidity), and November 2004 was selected as representative of high Secchi depth conditions (low turbidity). September 2011 had an average Secchi depth of 0.37 m and an average X2 of 75.3 km. November 2004 had an average Secchi depth of 0.63 m and a monthly-average X2 of 80.5 km.

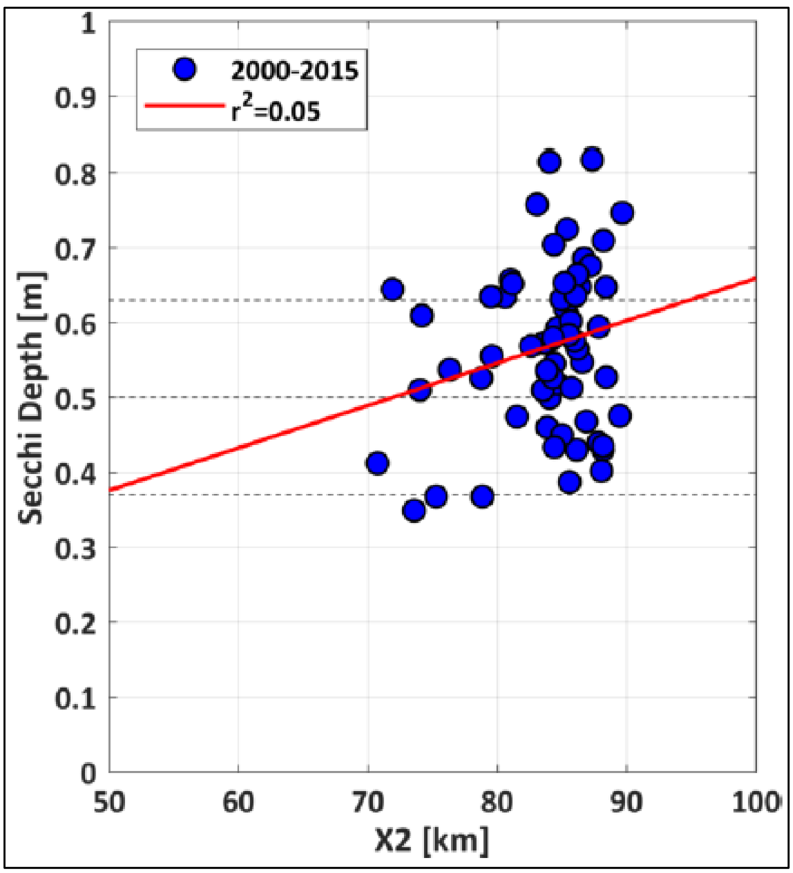

Figure 31. Average Secchi Depth Versus Monthly-Average X2 for September-December, 2000-2015 (Dashed Lines Show 0.37 m and 0.63 m).

Bever et al.'s (2016) method was used to extrapolate the individual FMWT Secchi depth measurements throughout Suisun Bay and the confluence region. During September 2011, with low Secchi depth conditions (Figure 32), most of Suisun Bay had a Secchi depth less than 0.5 m (favorable conditions for Delta Smelt), while Carquinez Strait, the Sacramento River, and the San Joaquin River had a Secchi depth greater than 0.5 m (poor conditions for Delta Smelt). During November 2004, with high Secchi depth conditions, the region where the Secchi depth was less than 0.5 m was confined to Grizzly Bay and Honker Bay (Figure 33). These two maps of Secchi depth were used for the representative low Secchi depth (high turbidity; Figure 32) and high Secchi depth (low turbidity; Figure 33) bookends for calculating SI_H in this analysis.

As with the Secchi depth maps used by Bever et al. (2016), the extrapolated maps of the Secchi depth for the low and high Secchi depth conditions (Figure 32 and Figure 33) can show large discontinuities and patchiness. This is partially a product of the simple extrapolation scheme used to develop these maps, which does not take into account differences in depth between channels and shoals. However, most of the patchiness likely results from the non-synoptic sampling of the FMWT. Because Secchi depth varies on tidal and daily time-scales, differences in the timing of individual measurements relative to the tidal cycle and periodic wind-wave resuspension events which can also lead to patchiness. The FMWT sampling in the region shown in Figure 21 generally spanned about 5 days in each monthly survey during 2011. This highlights the importance of near-synoptic sampling for the generation of maps from field-collected data, especially when the data vary on relatively short time-scales.

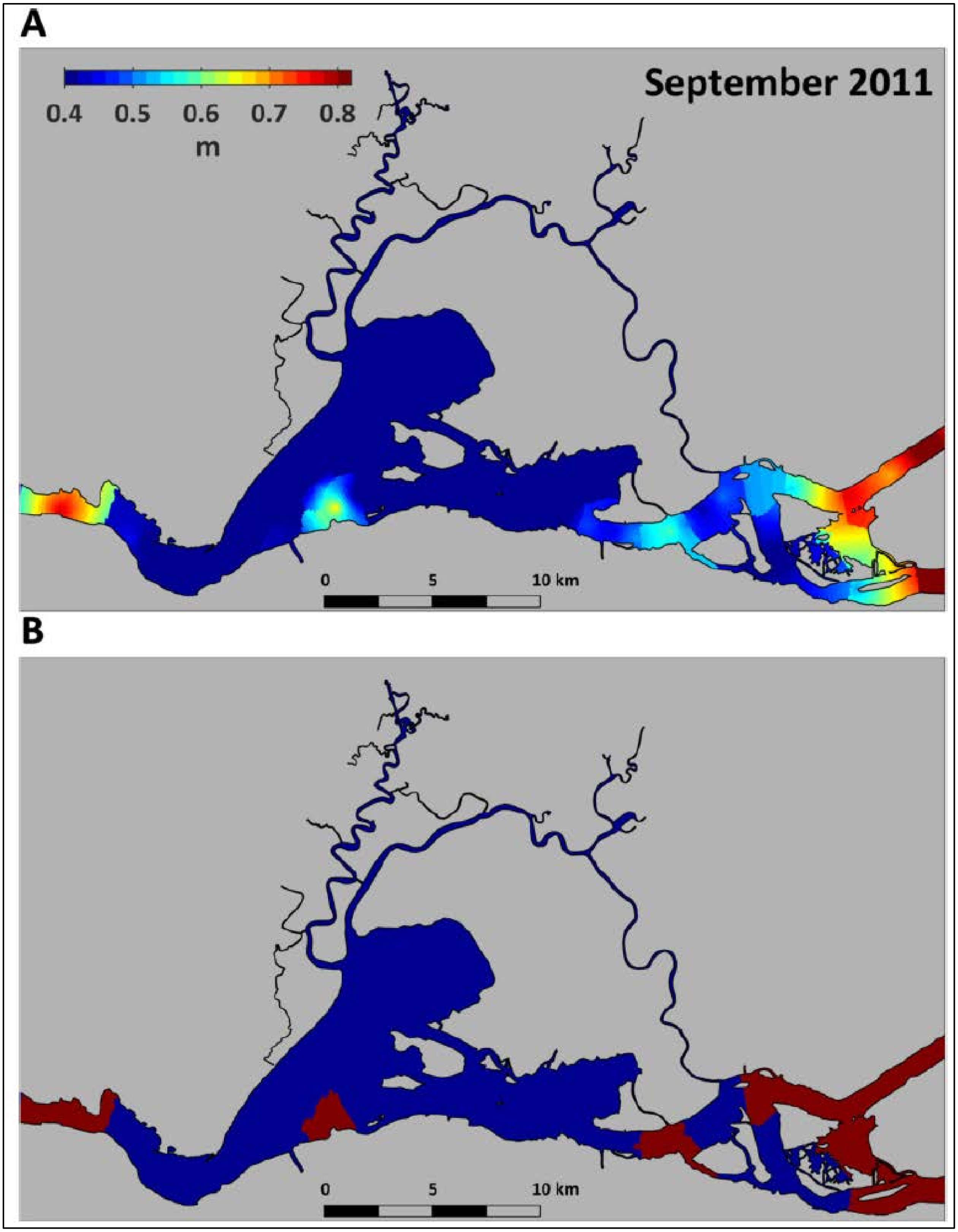

Figure 32. A) Distribution of Secchi Depth for September 2011; and B) Distribution of Secchi depth Above (Red) and Below (Blue) 0.5 m for September 2011.

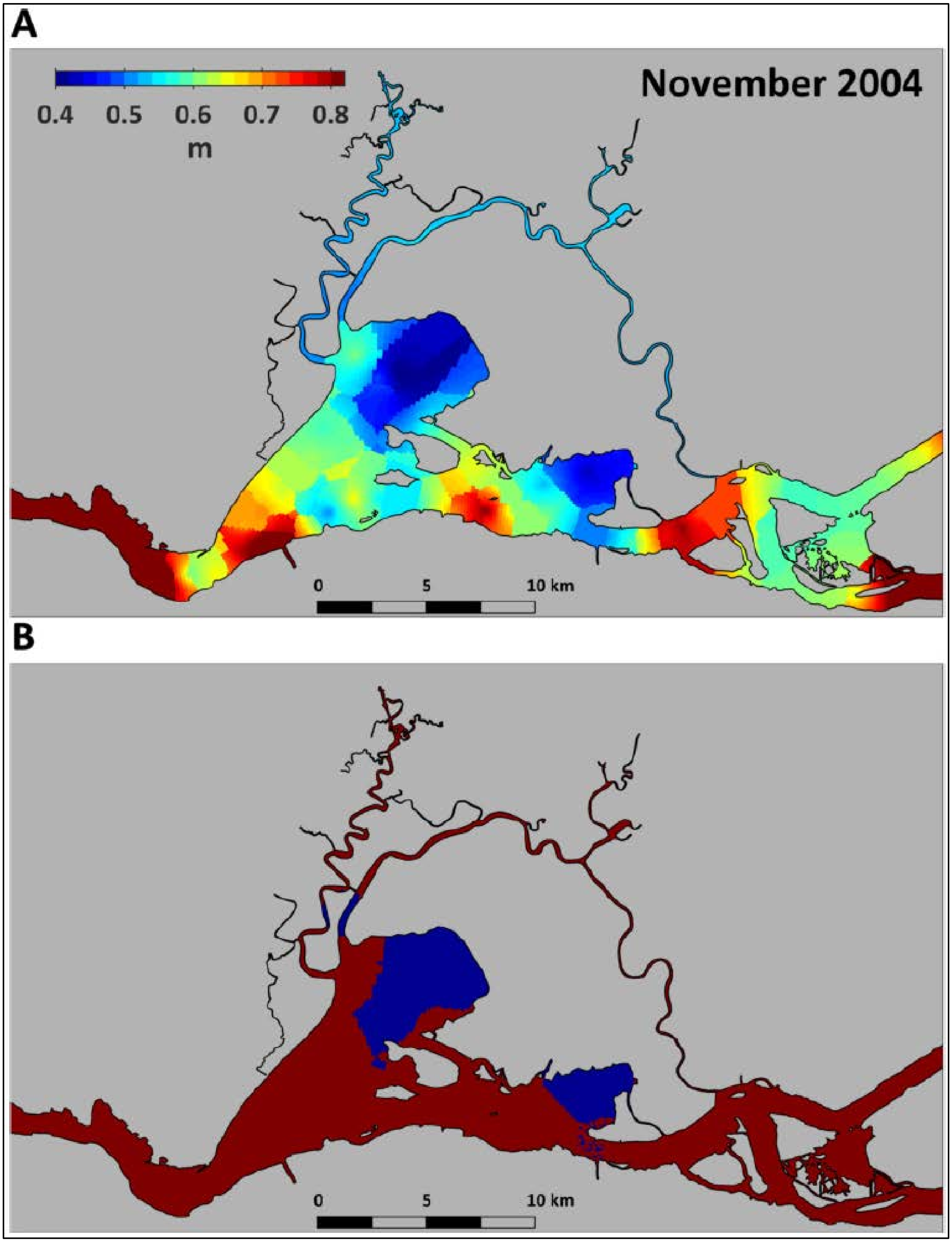

Figure 33. A) Distribution of Secchi Depth for November 2004; and B) Distribution of Secchi depth Above (Red) and Below (Blue) 0.5 m for November 2004.

Index Calculation

The data for each grid cell underlying the maps of the percentage of time with salinity < 6 (Figures 22-29), the Secchi depth for low turbidity (Figure 33) and high turbidity (Figure 32), and the maximum depth-averaged current speed during the fall (Figure 30) were combined using Equation 1 to calculate SI_H for X2 between 74 and 81 km.

Results

The results of the SI_H calculations are presented separately for *Low Turbidity* and *High Turbidity*, reflecting the need to provide reasonable bookends for possible conditions that could occur.

Low Turbidity

Using the high Secchi depth distribution (Figure 33) representative of conditions of low turbidity, it is evident that SI_H can be quite patchy (Figures 34-41). The patchiness is largely attributable to the patchiness of the extrapolated Secchi depth distribution, as discussed in the *Secchi Depth* subsection of the *Calculation of Hydrodynamics-Based Station Index*. During fall conditions with low turbidity, the regions with the highest values of SI_H are located primarily in Grizzly Bay and Honker Bay, where the most favorable turbidity, salinity, and current speed conditions overlap. It is notable that with a shift in X2 from 80 km to 81 km, the SI_H in a large portion of Grizzly Bay drops from 0.9-1 to 0.3-0.4 (Figure 40 and Figure 41). This reflects that this high turbidity, low current speed habitat area no longer is modeled to have salinity < 6 for a large percentage of the time at X2 = 81 km (see Figures 28-30, and 33).

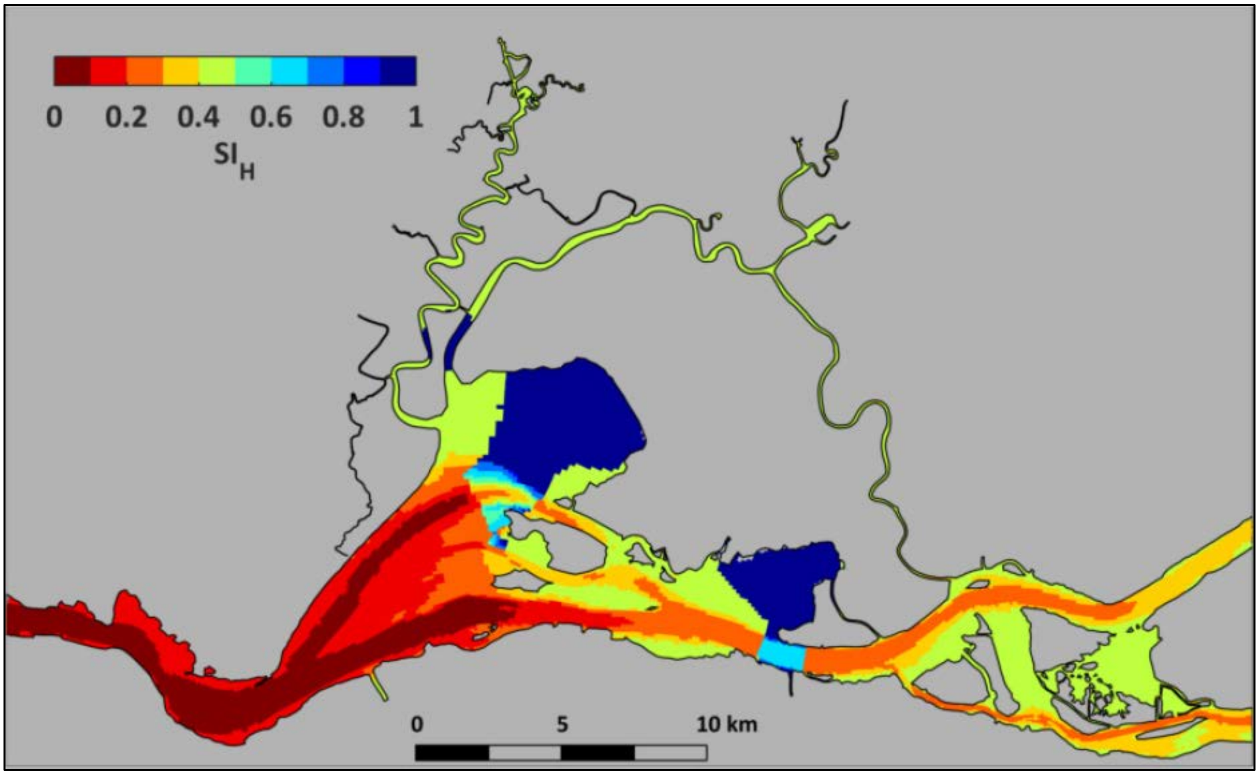

Figure 34. Hydrodynamics-Based Station Index (SI_H) for X2 = 74 km and Low Turbidity.

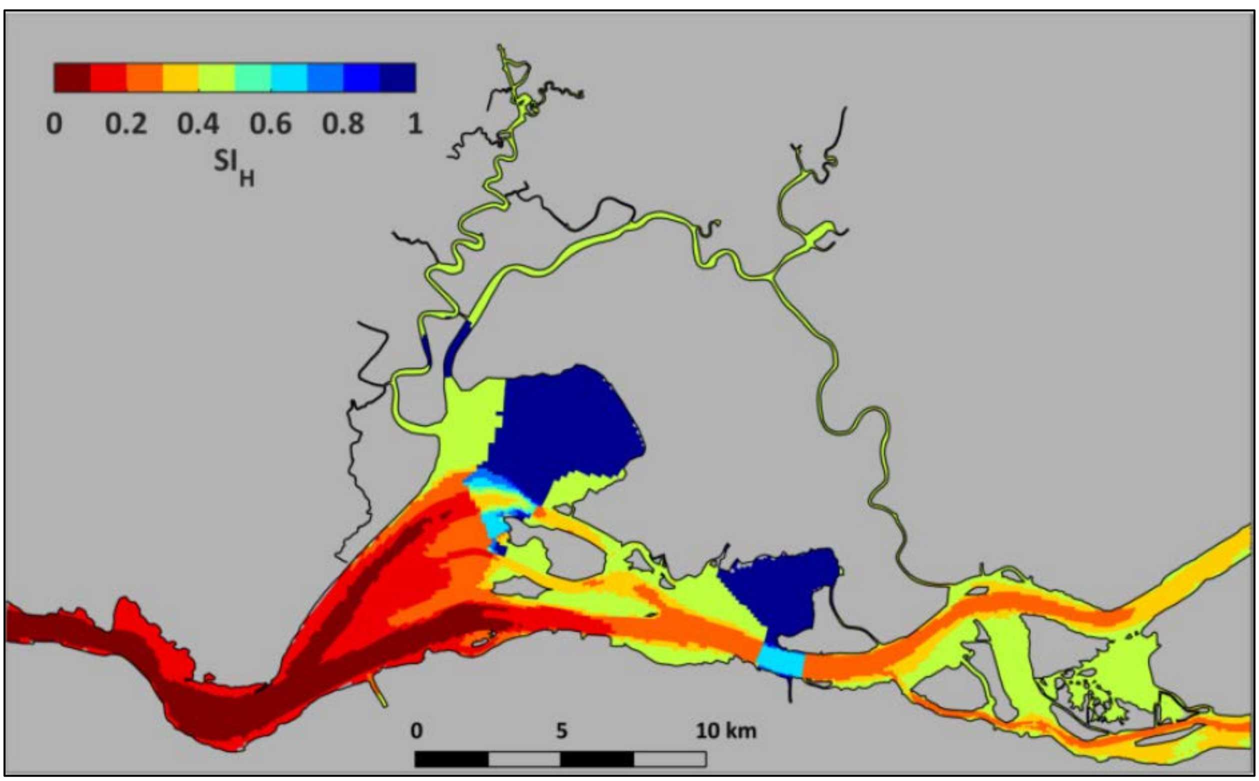

Figure 35. Hydrodynamics-Based Station Index (SI_H) for X2 = 75 km and Low Turbidity.

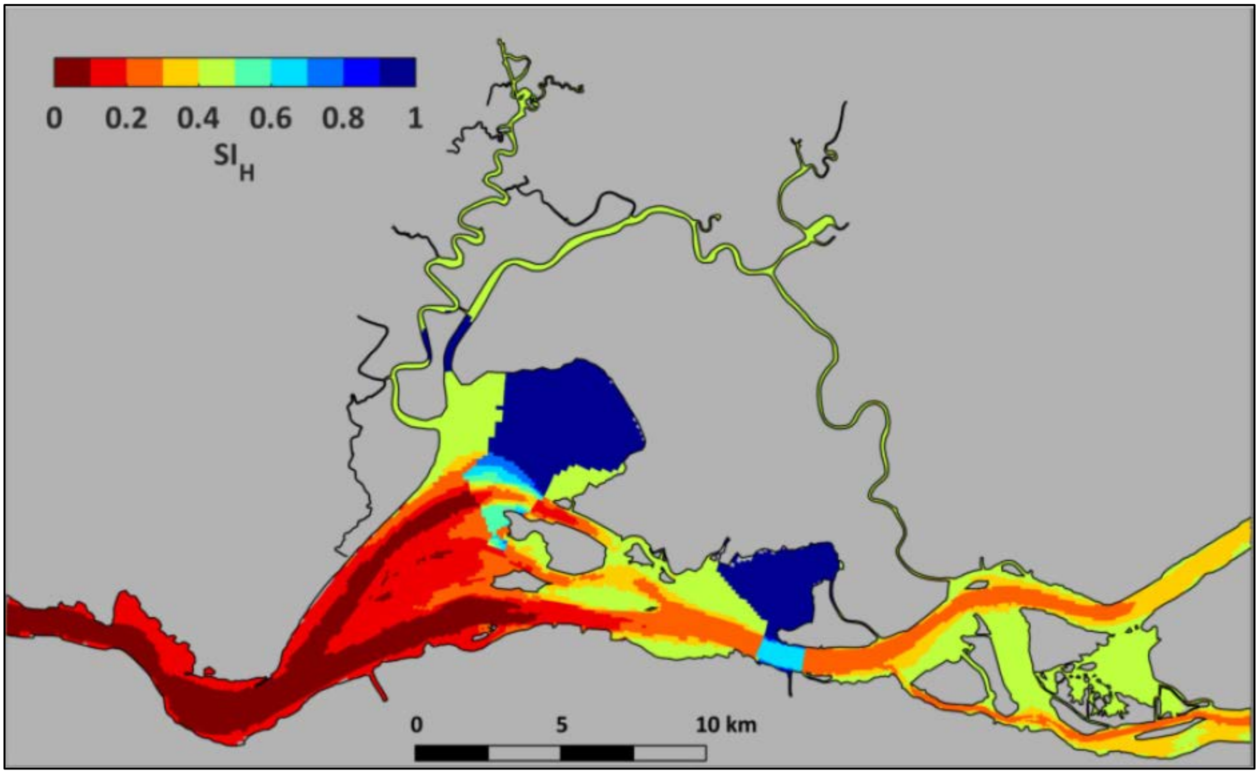

Figure 36. Hydrodynamics-Based Station Index (SI_H) for X2 = 76 km and Low Turbidity.

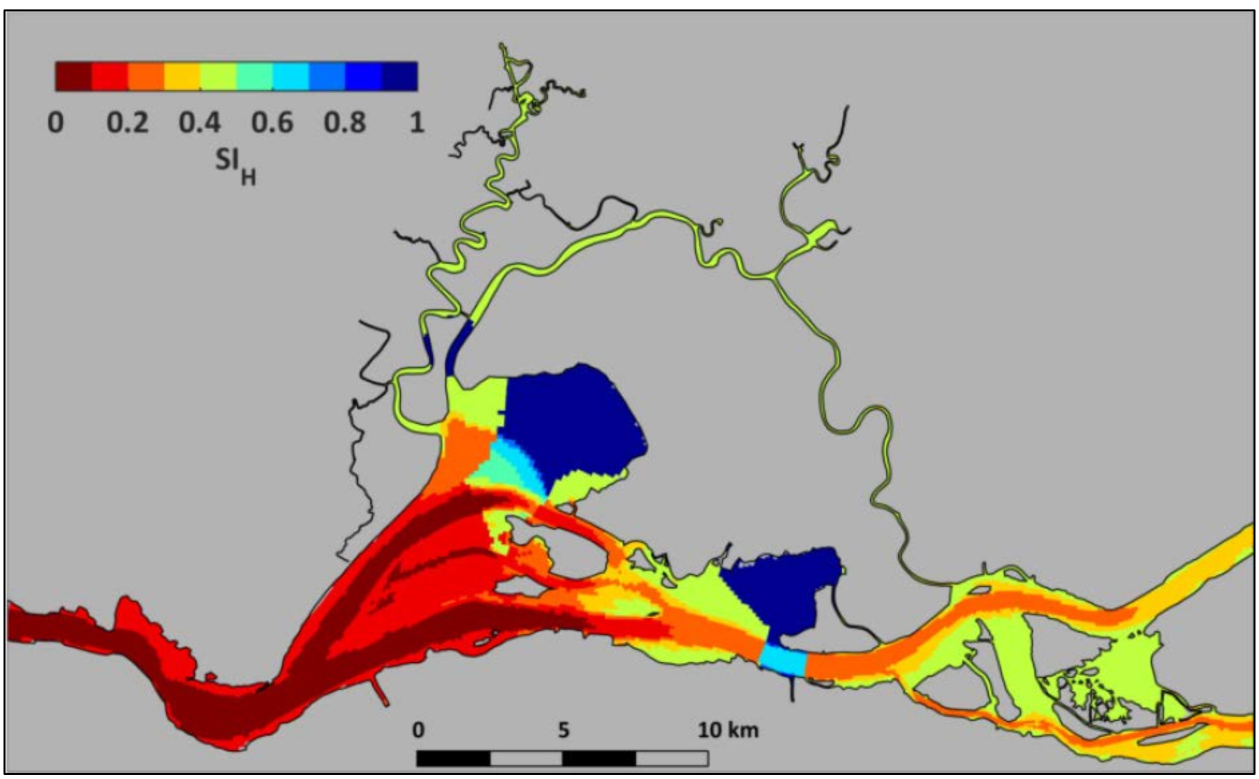

Figure 37. Hydrodynamics-Based Station Index (SI_H) for X2 = 77 km and Low Turbidity.

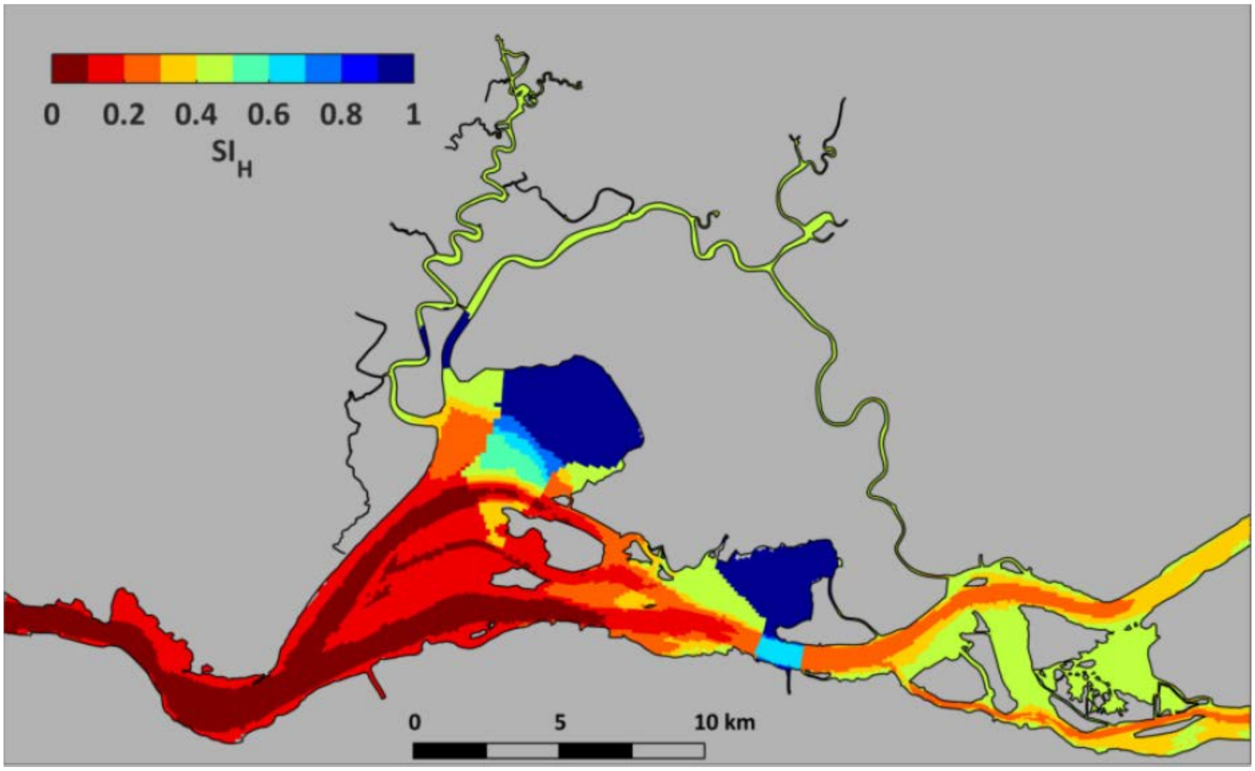

Figure 38. Hydrodynamics-Based Station Index (SI_H) for X2 = 78 km and Low Turbidity.

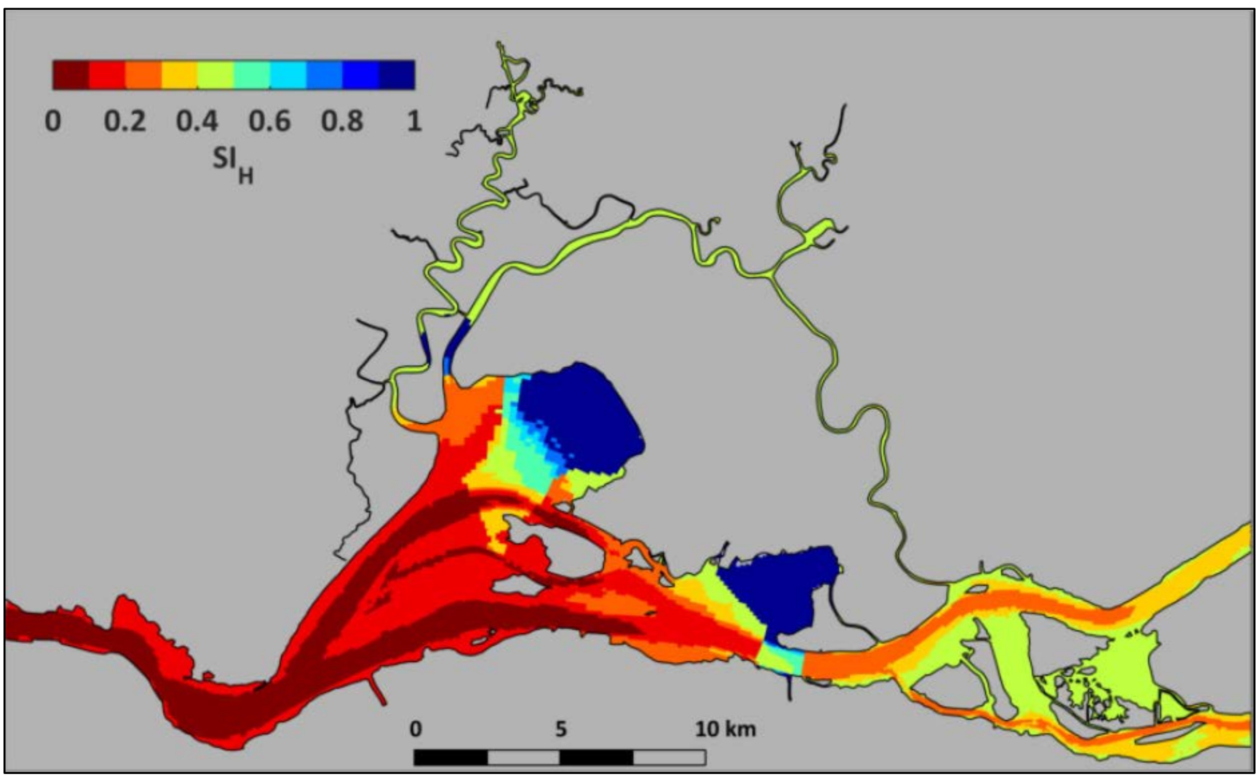

Figure 39. Hydrodynamics-Based Station Index (SI_H) for X2 = 79 km and Low Turbidity.

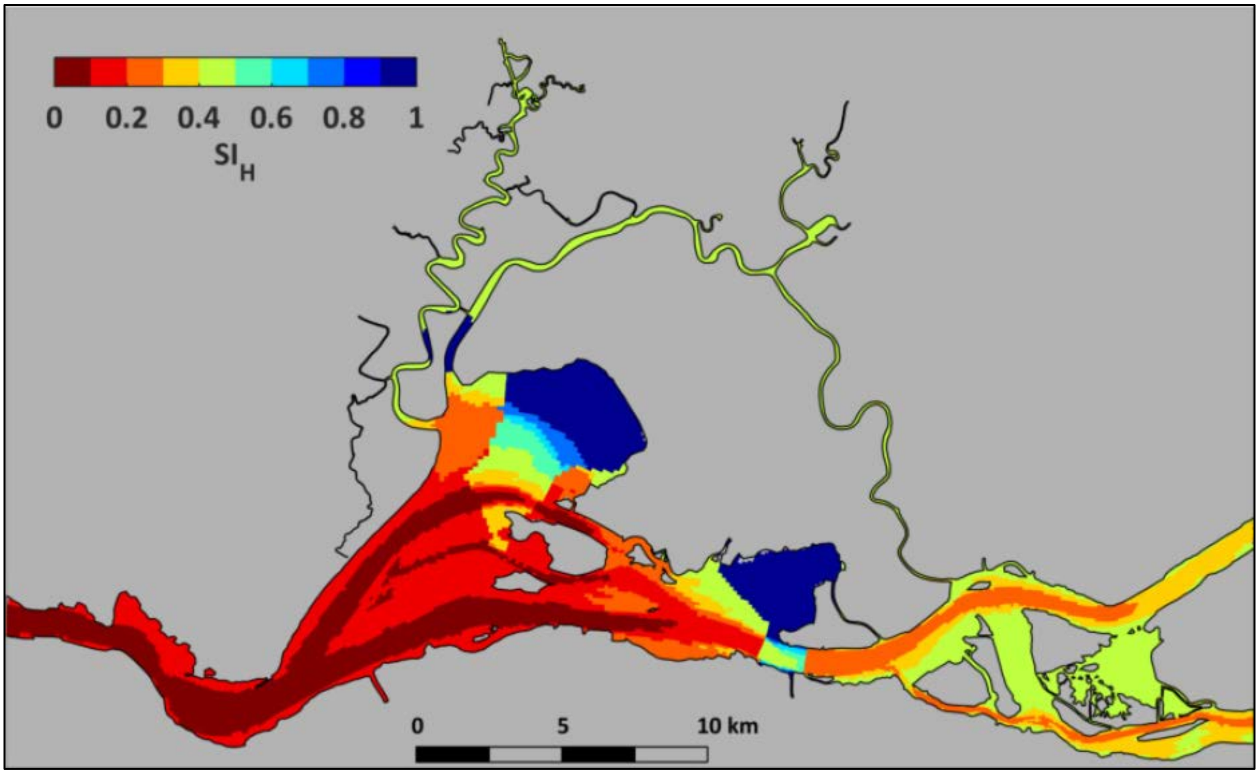

Figure 40. Hydrodynamics-Based Station Index (SI_H) for X2 = 80 km and Low Turbidity.

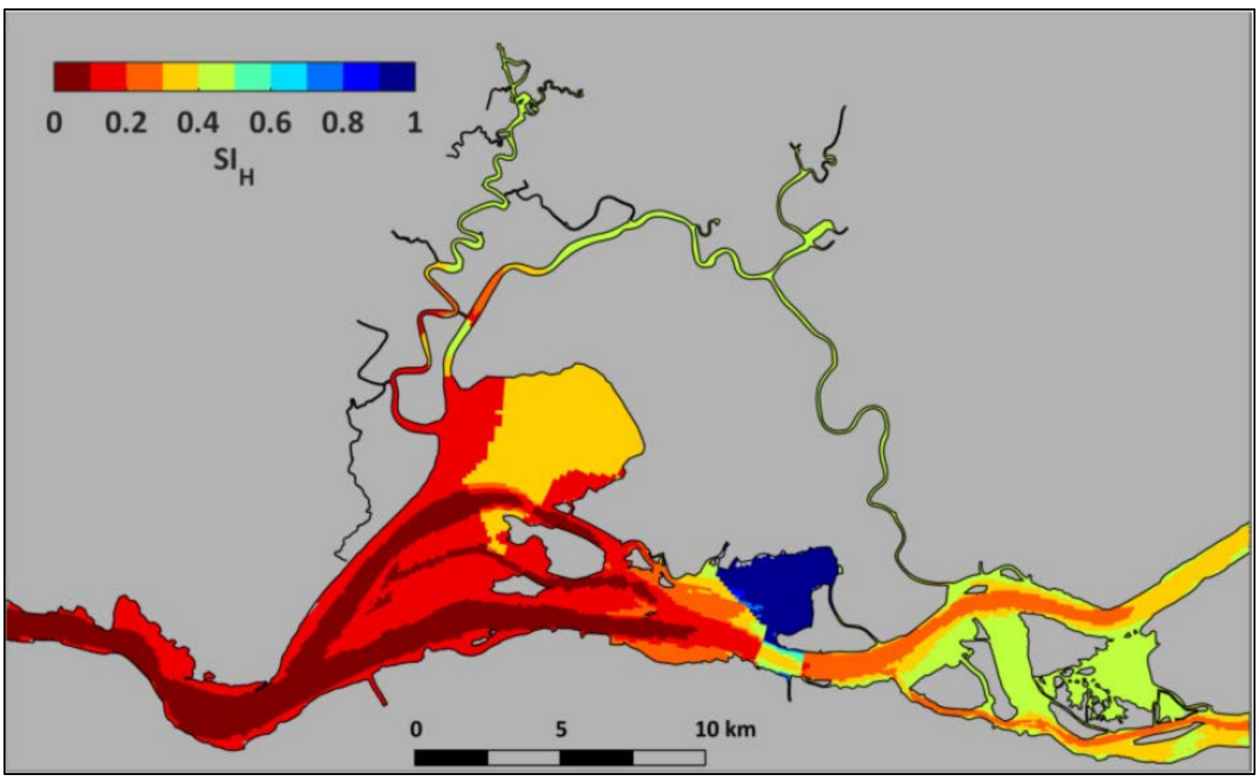

Figure 41. Hydrodynamics-Based Station Index (SI_H) for X2 = 81 km and Low Turbidity.

High Turbidity

As shown for low turbidity conditions, using the low Secchi depth distribution (Figure 32) representative of conditions of high turbidity, SI_H is generally patchy (Figures 42-49). During high turbidity conditions, the regions with the highest values of SI_H span from Grizzly Bay through Honker Bay and into the confluence region, where the most favorable turbidity, salinity, and current speed conditions overlap. Due to a larger overlap of favorable salinity and turbidity distributions resulting from higher turbidity in Suisun Bay, a much larger portion of Suisun Bay was predicted to have high values of SI_H for the maps developed with the high turbidity distribution (Figures 42-49) than the corresponding maps developed for the low turbidity distribution (Figures 34-41). However, the large SI_H decrease in much of Grizzly Bay between X2 = 80 km and X2 = 81 km was common to both low turbidity (Figure 41) and high turbidity (Figure 49).

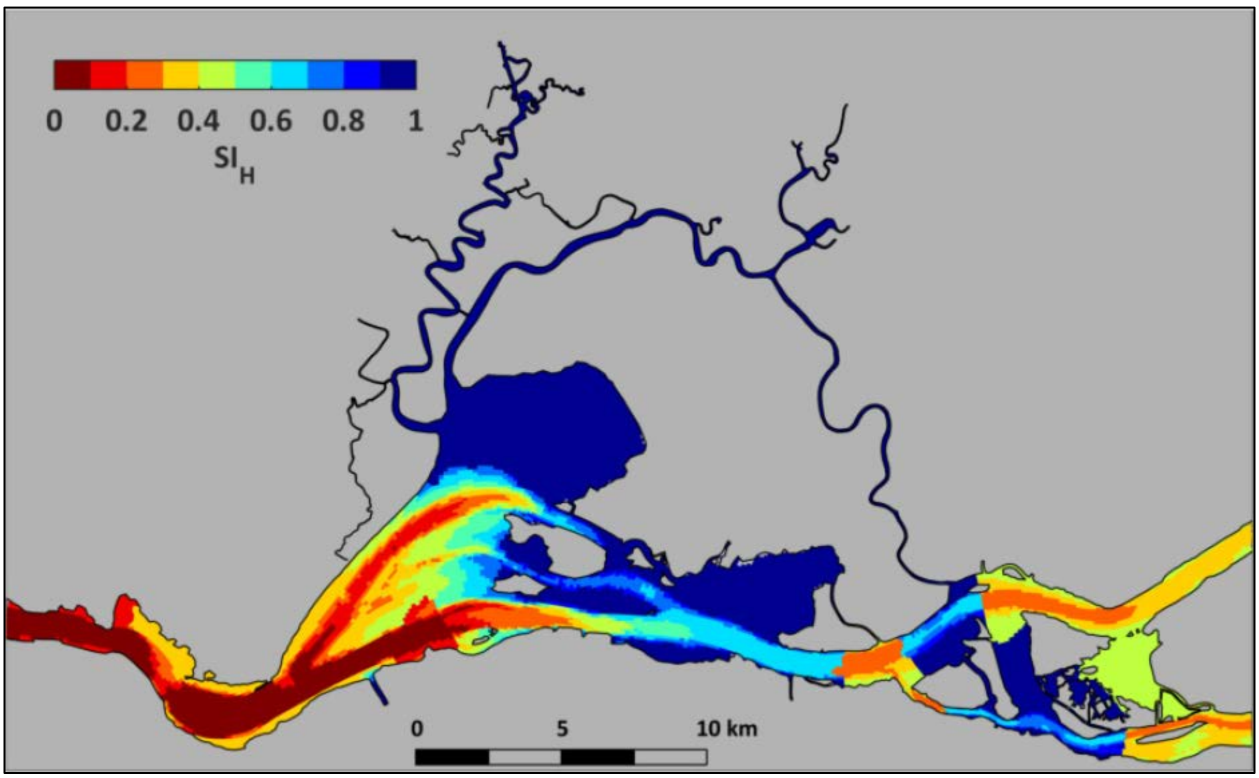

Figure 42. Hydrodynamics-Based Station Index (SI_H) for X2 = 74 km and High Turbidity.

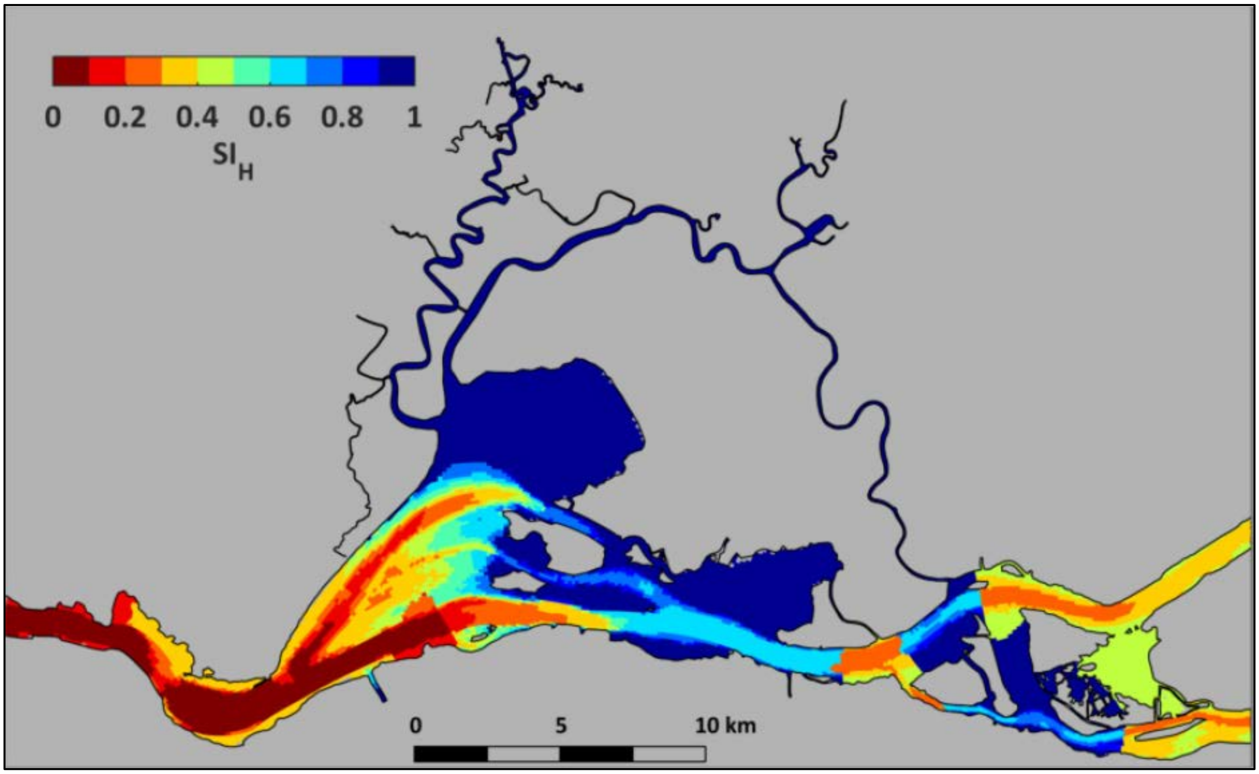

Figure 43. Hydrodynamics-Based Station Index (SI_H) for X2 = 75 km and High Turbidity.

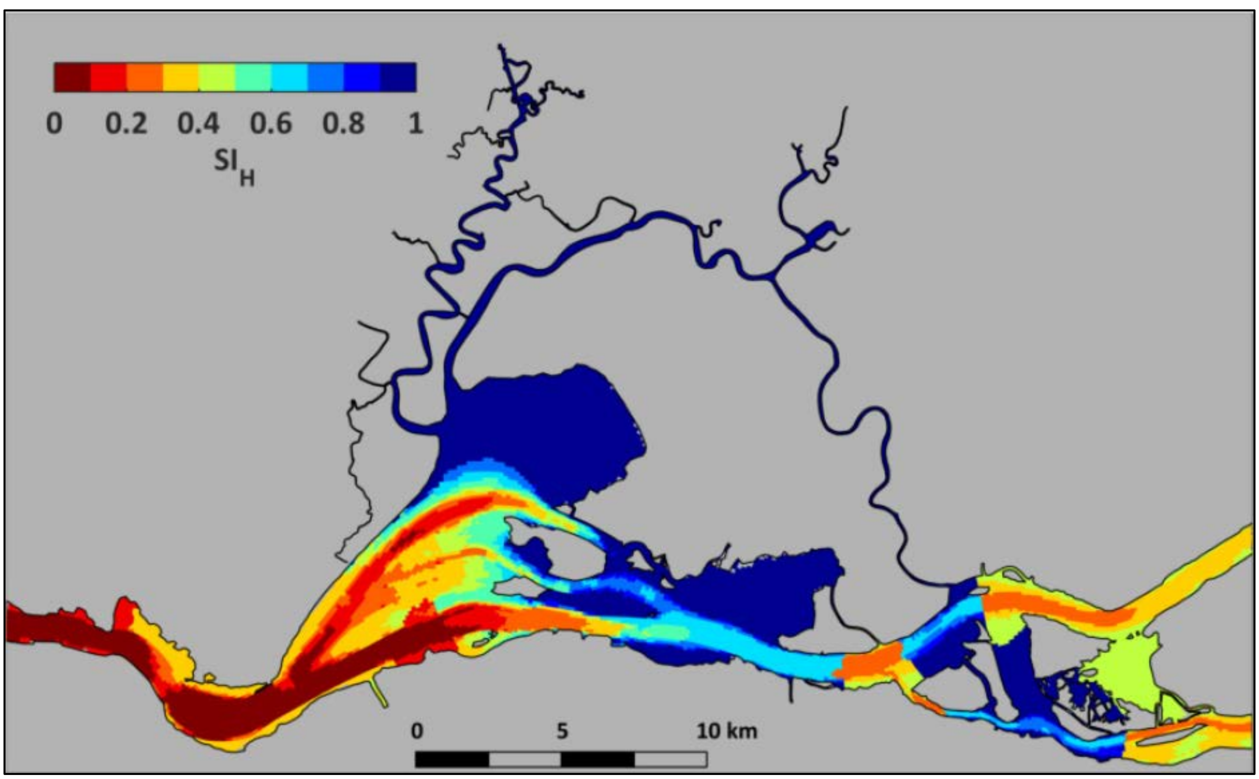

Figure 44. Hydrodynamics-Based Station Index (SI_H) for X2 = 76 km and High Turbidity.

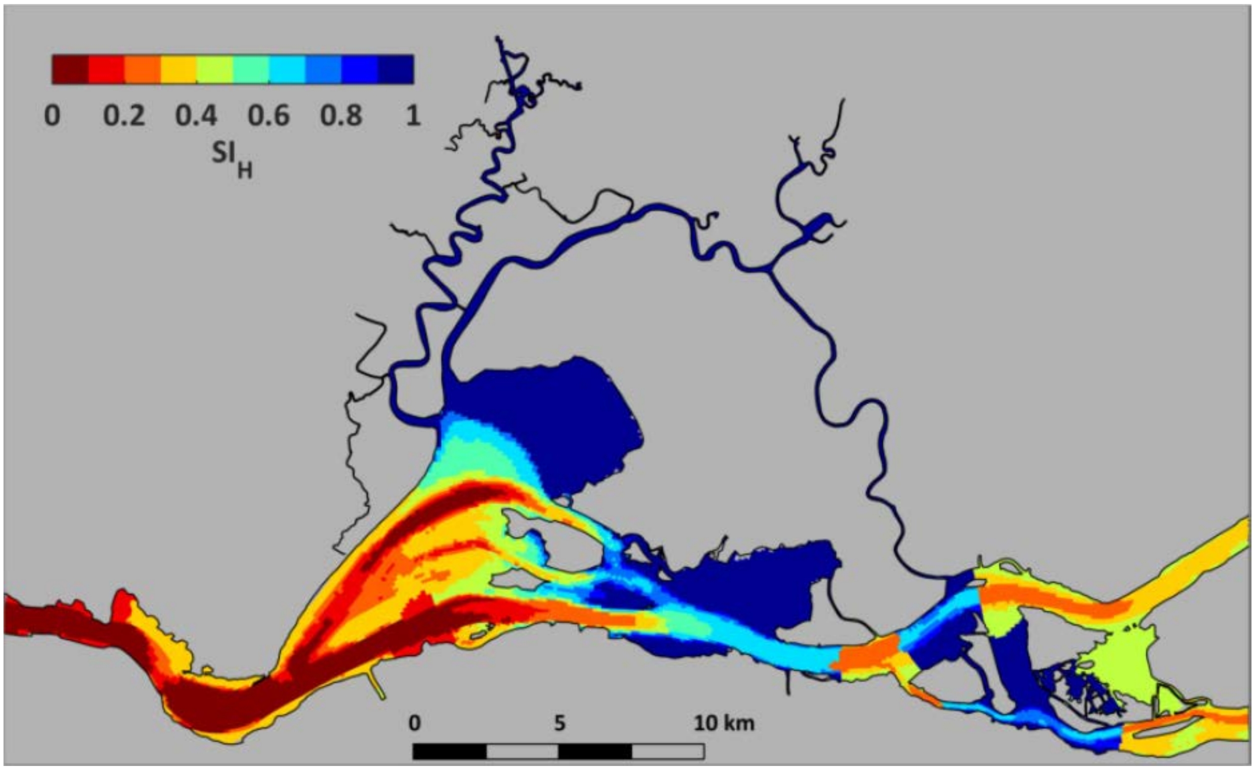

Figure 45. Hydrodynamics-Based Station Index (SI_H) for X2 = 77 km and High Turbidity.

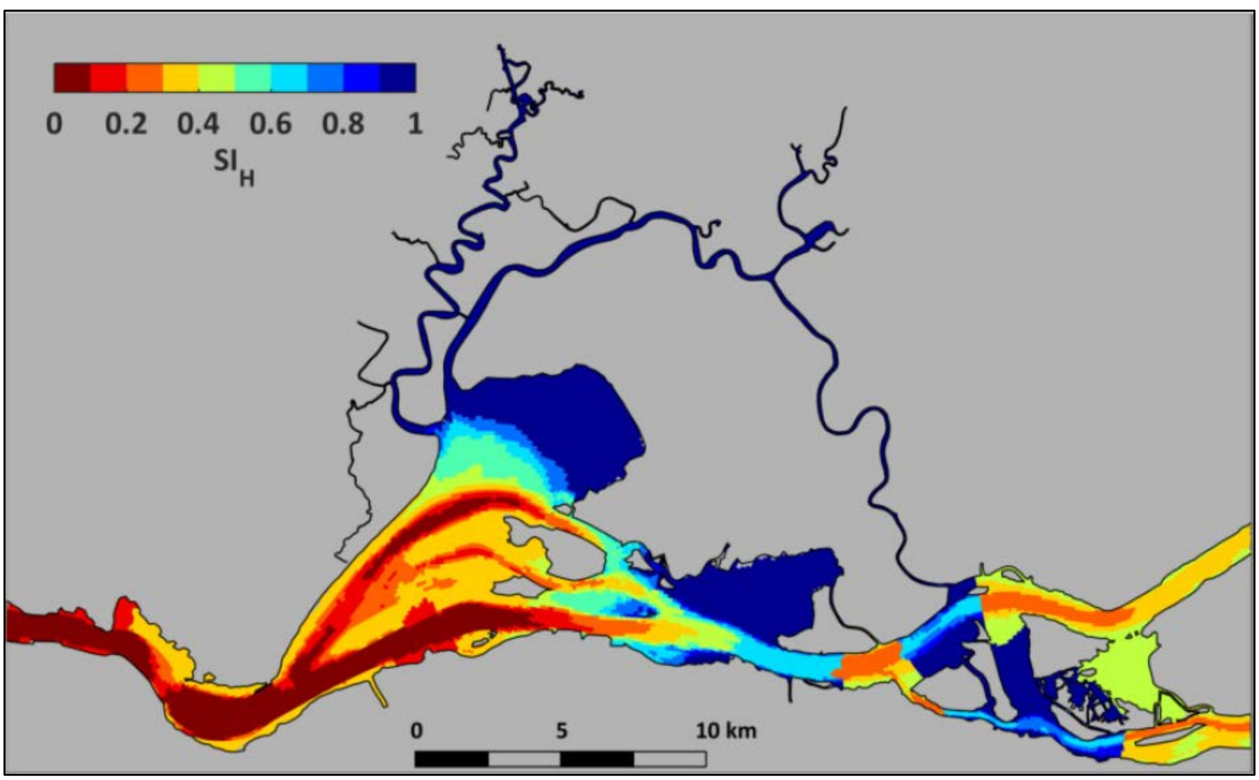

Figure 46. Hydrodynamics-Based Station Index (SI_H) for X2 = 78 km and High Turbidity.

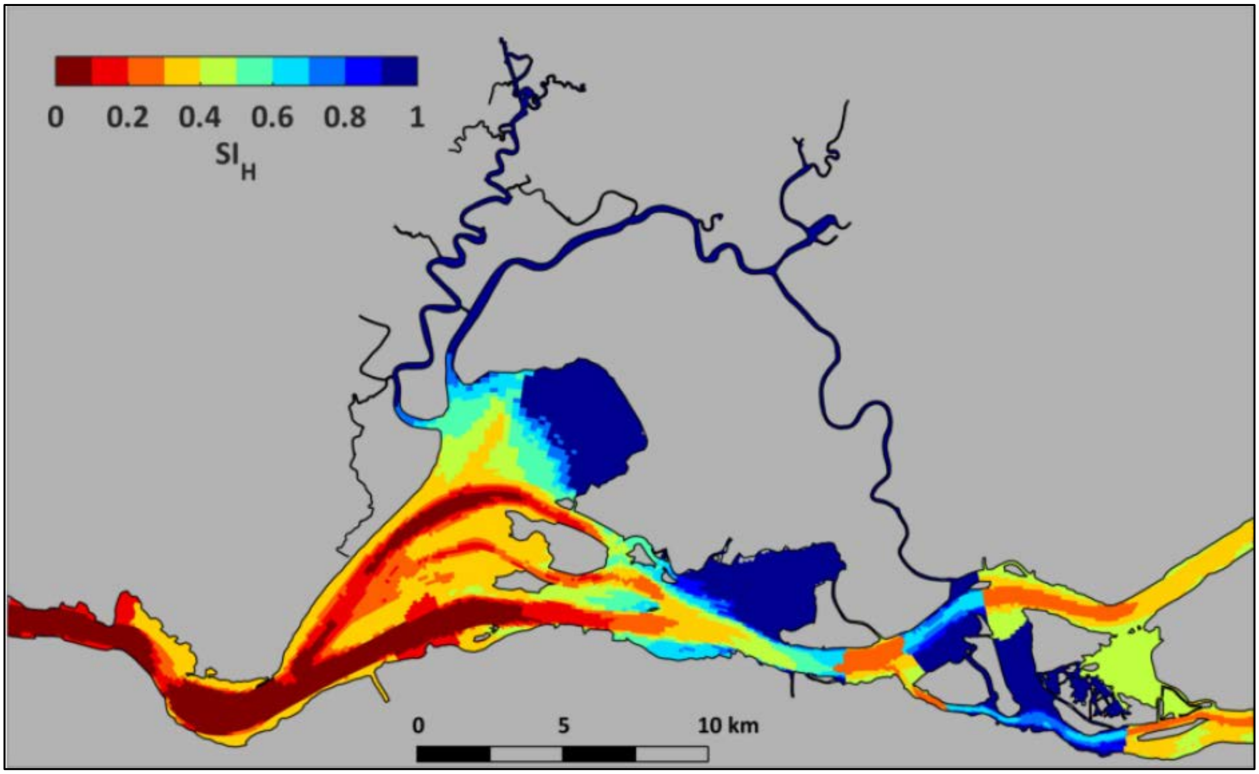

Figure 47. Hydrodynamics-Based Station Index (SI_H) for X2 = 79 km and High Turbidity.

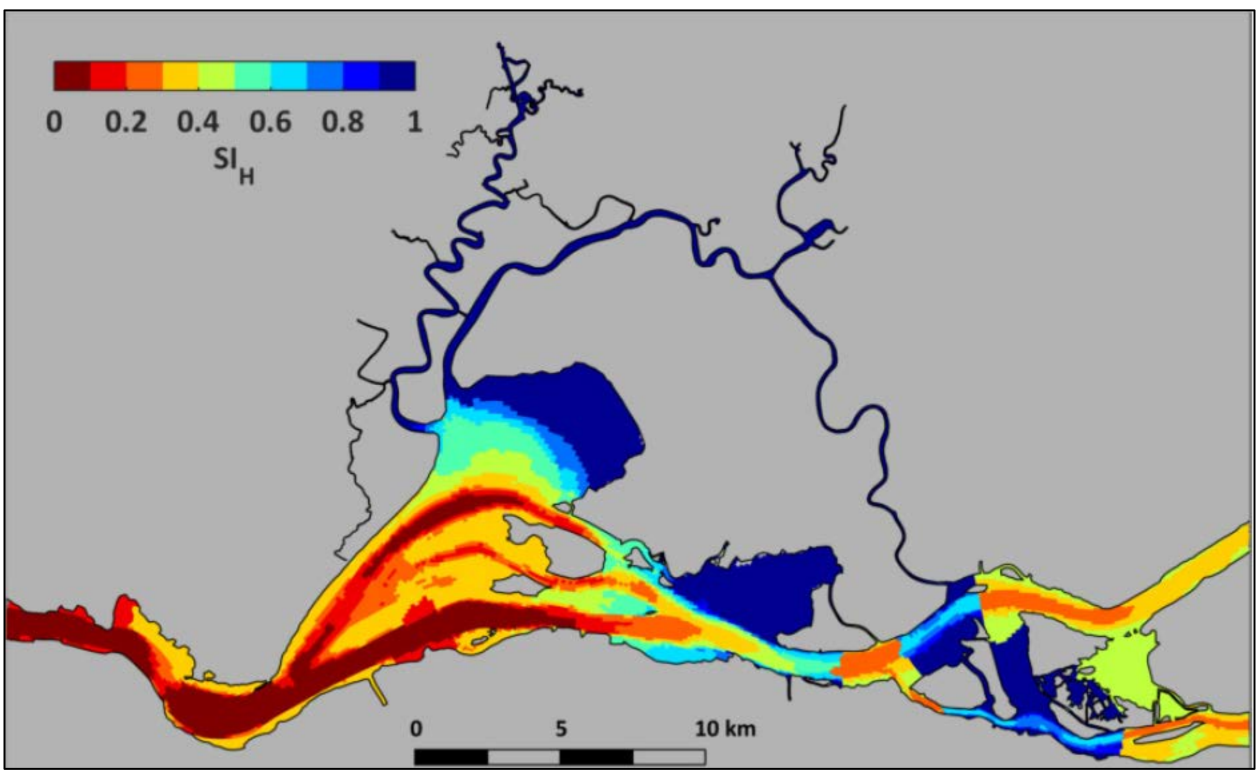

Figure 48. Hydrodynamics-Based Station Index (SI_H) for X2 = 80 km and High Turbidity.

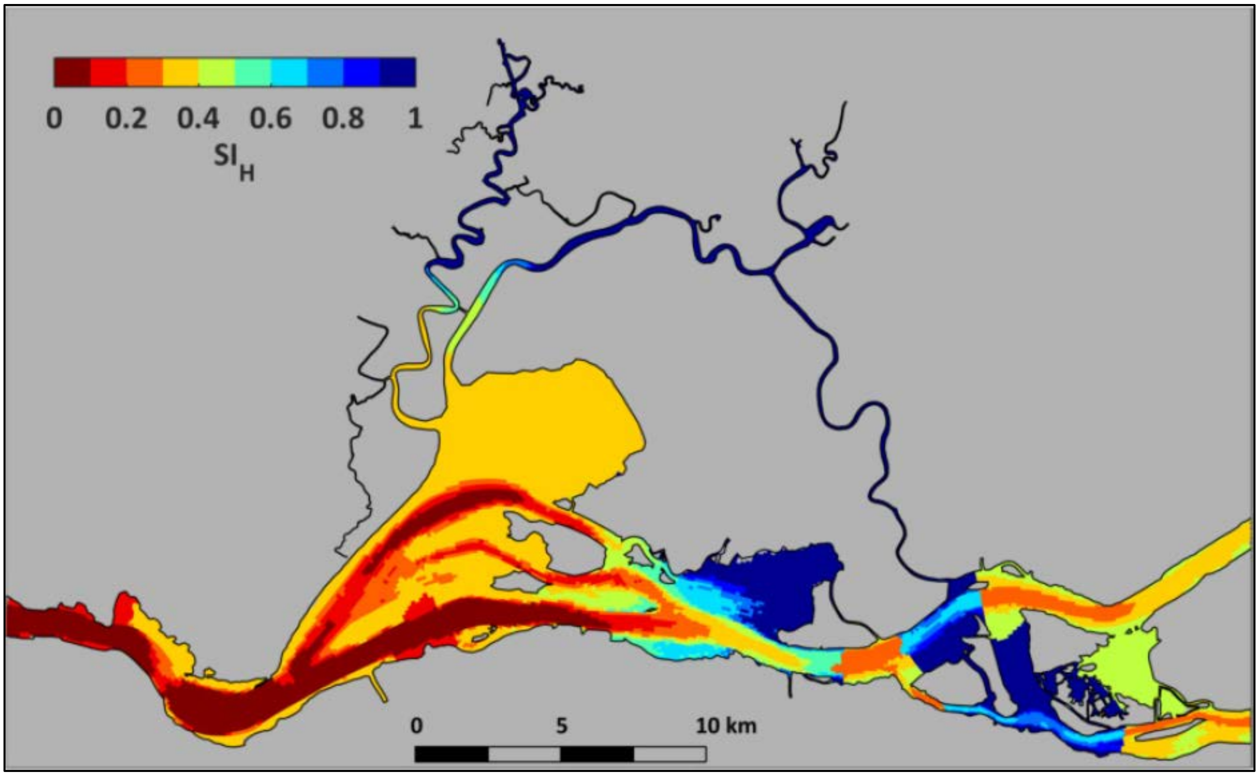

Figure 49. Hydrodynamics-Based Station Index (SI_H) for X2 = 81 km and High Turbidity.

Average Station Index in Relation to X2

The data underlying the maps of SI_H were used to calculate the average SI_H within the analysis region (Figure 21) for X2 at 1-km increments between 74 km and 81 km, for both high and low turbidity distributions (Table 5). Under conditions with low turbidity, average SI_H ranged between 0.40 for X2 = 75 km and 0.26 for X2 = 81 km. Under conditions with high turbidity, average SI_H ranged between 0.63 for X2 = 75 km and 0.42 for X2 = 81 km. For both low and high turbidity, average SI_H decreased markedly for X2 between 80 km and 81 km (Table 5).

Table 5. Average Hydrodynamics-Based Station Index (SI_H) In Relation to X2.

	X2 (kilometers)							
Turbidity	74	75	76	77	78	79	80	81
Low	0.39	0.40	0.38	0.36	0.35	0.33	0.33	0.26
High	0.62	0.63	0.61	0.57	0.54	0.50	0.51	0.42

Note that the salinity distributions used in this analysis were selected based on the daily X2 value, which is largely controlled by the eastern extent of the salinity intrusion near salinity = 2 isohaline. However, the tidal excursion of the salinity field across Suisun Bay varies with the spring-neap cycle, with larger tidal excursions in Suisun Bay during spring tides. For the day selected with X2 of 75 km (Figure 23), the percentage of time with salinity < 6 was slightly more favorable in western Suisun

Bay than the day selected with X2 of 74 km (Figure 22). As a result, the highest average value of SI_H occurred for X2 of 75 km for both the high and low turbidity distributions (Table 5). For X2 values of 74 km through 76 km, the distributions of the percentage of time with salinity < 6 are very similar. As a result, the value of SI_H is relatively similar for X2 values between 74 and 76 km for both the high and low turbidity distributions.

Application of Hydrodynamics-Based Station Index to Proposed 2017 Fall X2 Action

Based on the relationship between SI_H and X2 (Table 5) , X2 of 74 km in September would give SI_H of 0.39 if turbidity is low and 0.62 if turbidity is high; whereas X2 of 81 km in October would give SI_H of 0.26 if turbidity is low and 0.42 if turbidity is high. At low and high turbidity, X2 of 81 km would represent ~32-33% lower SI_H than if X2 were at 74 km in October. As previously described, forecasts exist for potential X2 in September-November 2017 (Figure 13; Table 1). For October, a mean X2 of ~78 km under the proposed 2017 Fall X2 action would give SI_H = 0.35 at low turbidity and SI_H = 0.54, which would be 0.04-0.08 (10-13%) less than if X2 was at 74 km[16] based on implementation of the USFWS (2008) BiOp Fall X2 action as prescribed, for example. As noted for the other abiotic habitat methods, this method does not consider other factors important to Delta Smelt habitat (e.g., biotic factors; see *Food Availability in the Low Salinity Zone*).

Retrospective Analysis of X2

Of relevance to the proposed 2017 Fall X2 action is a retrospective analysis of patterns in X2. Hutton et al. (2015) examined long-term monthly trends in X2 and found that September X2 in the lower Sacramento River had significantly decreased from 1922 to 2012 by 0.12 km/year, with a downward trend of 0.43 km/year from 1922 to 1967, and, following commencement of combined year-round SWP/CVP operations, an upward trend of 0.20 km/year in 1968 to 2012. October X2 had no significant trend over 1922 to 2012, but a significant downward trend (0.31 km/year) from 1922 to 1967 and a significant upward trend from 1968 to 2012 (0.28 km/year). November X2 had a significant overall trend of 0.11 km/year from 1922 to 2012, comprising a significant downward trend of 0.20 km/year from 1922 to 1967 and a significant upward trend of 0.37 km/year from 1968 to 2012 (Hutton et al. 2015).

In order to provide additional perspective on historic trends in X2 for context relative to the proposed 2017 action, in particular the distribution of X2 in wet water years, X2 estimates were taken from, or calculated from, the DAYFLOW database[17]. DAYLOW provides daily X2 estimates

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[16] An SI_H value for 73 km is not available for the forecasted value of X2 if the USFWS (2008) BiOp Fall X2 action were implemented as prescribed, because the analysis was initiated before the forecasted X2 data were available. As an example of a 5-km difference in X2, comparing SI_H for X2 = 79 km and X2 = 74 km gives an SI_H difference of 15-18% less with X2 = 79 km.

[17] http://www.water.ca.gov/dayflow/. DAYFLOW is used here because its method for calculating X2 is the one that has the most widespread recent use.

from Water Year 1997 onwards; calculations for earlier years (Water Years 1956 onwards) were made using the daily X2 formula from DAYFLOW:

$$X2(t) = 10.16 + 0.945*X2(t-1) - 1.487\log(QOUT(t))$$

Where t = a given day, t-1 = the previous day, and QOUT(t) is Delta outflow on the given day t, as provided in DAYFLOW. This calculation requires a starting value for X2 (on October 1, 1955), for which the estimate by Anke Mueller-Solger[18] was used, i.e., 84.3434152523116 km. Given the method of calculation, a certain duration of time is required for the calculations to stabilize at values consistent with DAYFLOW estimates, so the data period included in the analysis was from Water Years 1960 to 2016 (2015 for October and November, as data were not available for 2016).

The period from 1960 to 2016 included 19 wet water years. X2 in September of wet years ranged from ~64 km to 84.5 km, with a median of ~75 km (Table 6). X2 in October of wet years ranged from ~63 km to ~86 km, with a median of 72.5 km. Therefore the proposed 2017 Fall X2 action mean X2 values for September (74 km) and October (up to 81 km, and probably lower based on available forecasts; Figure 13, Table 1) are well within the range of wet-year variability observed in recent decades (see also Figure 50).

Table 6. Percentiles of Mean X2 in Wet Years, 1960-2015/2016

Percentile	September	October	November
100 (Max.)	84.5	86.2	86.1
95	83.5	86.2	84.0
75 (Med.)	78.4	75.1	79.5
50	75.3	72.9	72.5
25	70.5	71.1	69.4
5	67.4	66.5	64.4
0 (Min.)	63.9	62.9	60.3

The proposed mean daily X2 of 74 km in September 2017 followed by mean daily X2 of up to 81 km in October could be a unique situation relative to observed patterns from the past several decades. Within the period from 1960 to 2015, there were no years when mean daily X2 in September was close to 74 km, followed by mean daily X2 close to 81 km in October (Figure 50). The closest match appears to be 2006, with mean daily X2 of 78.9 km in September and 83.6 km in October. If X2 in October ends up being relatively near 74 km, then this is more similar to conditions that have been observed before (in 1984 and 2011).

[18] Mueller-Solger, A. 2012. Unpublished estimates of X2 presented in Excel workbook <FullDayflowAndX2WithNotes1930-2011_3-6-2012.xlsx>

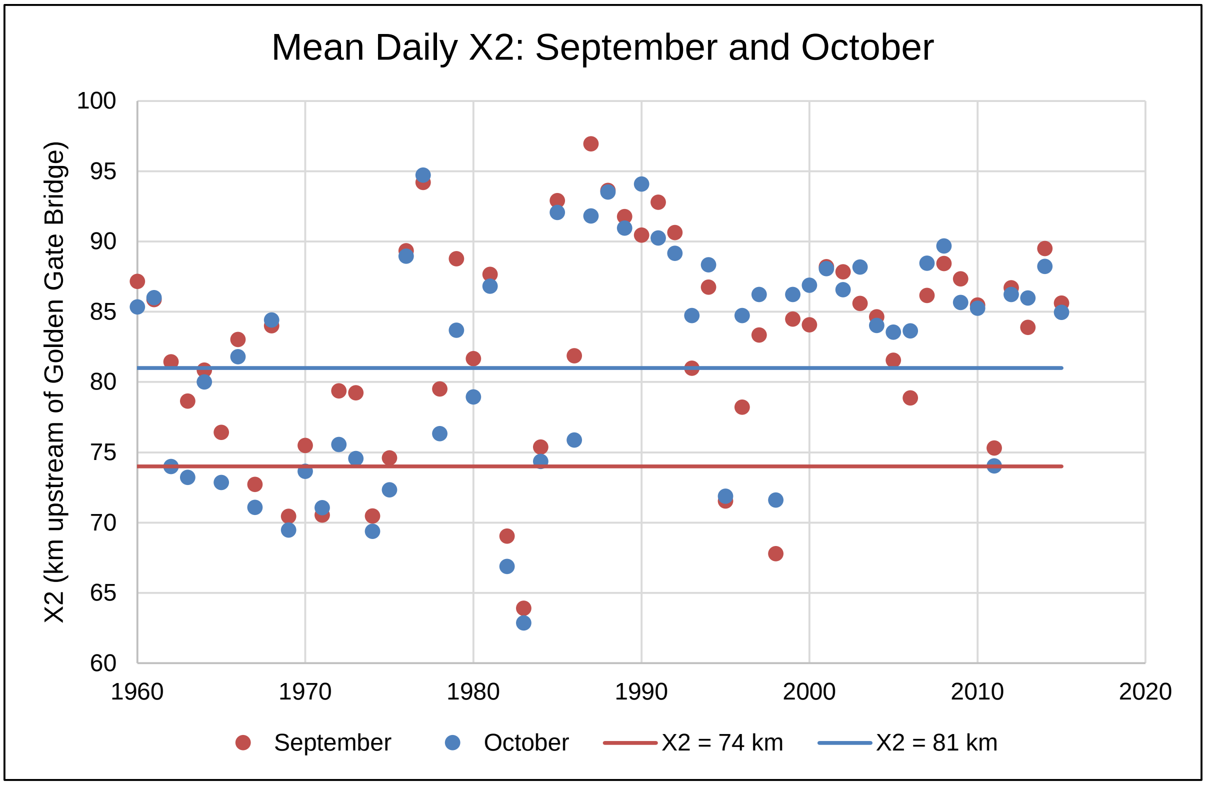


Figure 50. September and October: Mean Daily X2, 1960-2015.

Food Availability in the Low Salinity Zone

As previously illustrated, the FLaSH investigations predicted that important elements of Delta Smelt food availability (e.g., calanoid copepod biomass) in the low salinity zone would be greater with lower X2 (Table 4). The potential for food availability in the low salinity zone to be influenced by X2 was assessed based on both direct measures of principal prey abundance (density[19] of calanoid and cyclopoid copepods, mysids, and amphipods; Slater and Baxter 2014; Brown et al. 2014) and factors that could affect prey abundance (*Potamocorbula* and *Microcystis* density; Lehman et al. 2010; Crauder et al. 2016). Note that the 2017 adaptive management action includes enhanced habitat monitoring to better understand the location and type of food sources in relation to Delta Smelt occurrence, which will inform future assessments of potential X2 effects on Delta Smelt food availability.

[19] Use of the term 'density' here and elsewhere in this effects analysis does not imply that these are the true densities in the environment, only that this a relative measure of numbers for a given sampling volume; catch per unit effort is a more appropriate term.

Invertebrate Prey Density

Calanoid Copepods

Calanoid copepods such as *Eurytemora affinis* and *Pseudodiaptomus forbesi* are important prey items for Delta Smelt (Bennett 2005; Slater and Baxter 2014; IEP MAST 2015; Moyle et al. 2016). Per the hypotheses of the FLaSH study, moving fall X2 westward may increase the abundance of calanoids or improve Delta Smelt accessibility to higher densities of prey (Table 4). An assessment of the relationship between Delta Smelt calanoid copepods (adult, copepodite, and nauplii[20]) prey abundance in the low salinity zone and X2 was made using data from the Environmental Monitoring Program (EMP) zooplankton surveys. Analyses were limited only to core stations sampled since 1974 (Figure 51), and two analyses periods were considered: a) 1988 to 2015/2016 to account for long-term changes in zooplankton and other foodweb components community structure (Kimmerer 2002b, Winder and Jassby 2011), and b) 2003 to 2015/2016 to account for the onset of the Pelagic Organism Decline in the early 2000s (POD; Baxter et al. 2010; Thomson et al. 2010). Available data[21] were reduced to mean monthly values (September, October, and November) with these basic steps:

1. Subset to core stations (variable 'Core' = 1)

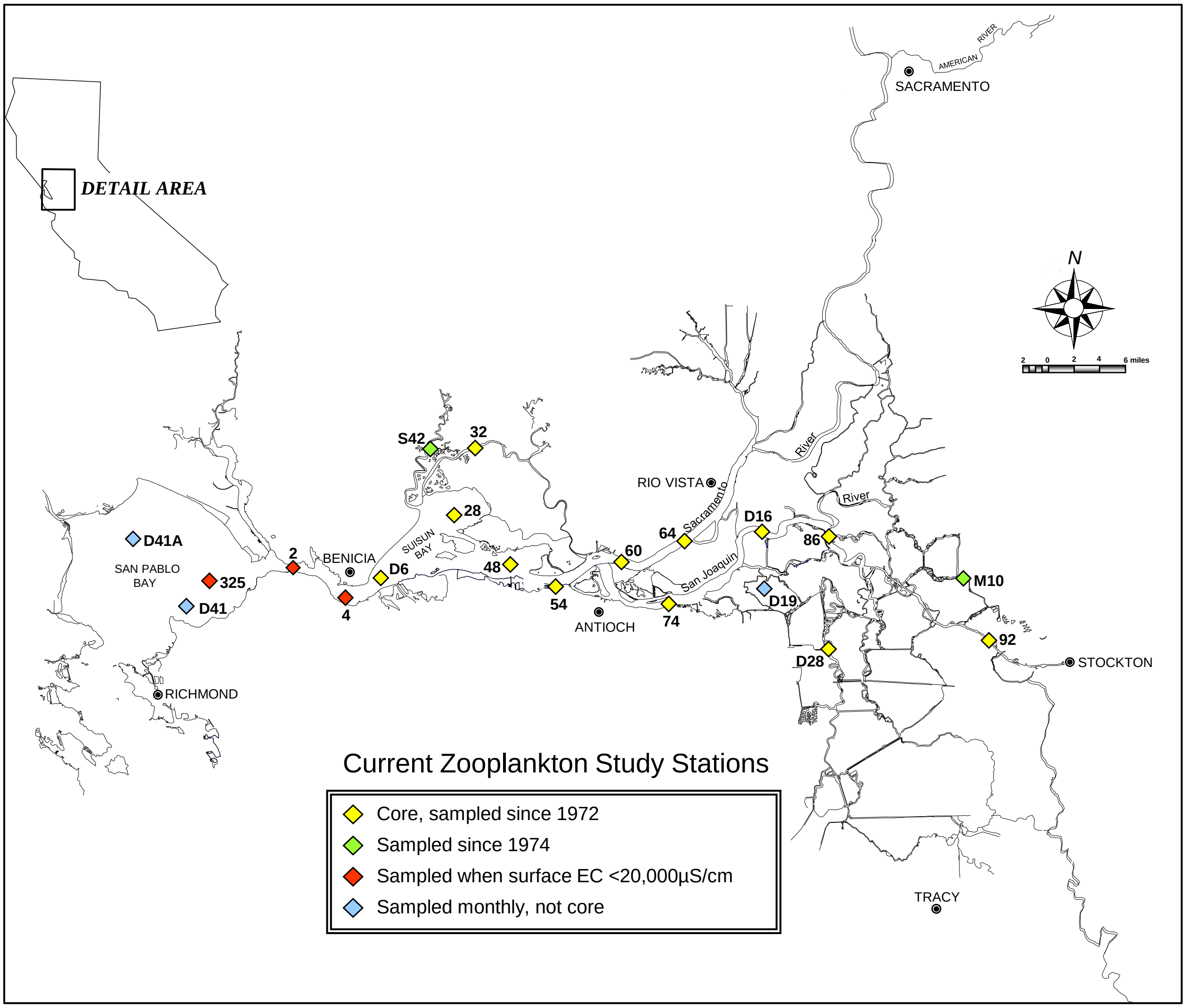
2. Convert specific conductance to salinity by applying Schemel's (2001) method, then select only samples within low salinity zone (salinity = 1-6);

3. Limit analyses for adults (variable 'ALLCALADULTS') and copepodites (variable 'ALL CALAJUV') to the 154-µm-mesh Clarke-Bumpus net, and for all copepod nauplii (variable 'ALLCOPNAUP') to the 64-µm-mesh pump sampler.

The mean monthly copepod density for calanoid adults, calanoid copepodites, and all copepod nauplii was then related to mean monthly X2, developed as described previously in *Retrospective Analysis of X2*.

[20] This includes all copepods, not just calanoids.

[21] ftp://ftp.dfg.ca.gov/IEP_Zooplankton/1972-2016CBMatrix.xlsx and ftp://ftp.dfg.ca.gov/IEP_Zooplankton/1972-2016PumpMatrix.xlsx



Source: ftp://ftp.dfg.ca.gov/IEP_Zooplankton/ZP%20Core%20and%20Current%20Stations.ppt

Figure 51. Current Zooplankton Study Stations.

There was no apparent relationship between X2 and calanoid copepod density in the low salinity zone from 1988 to 2015/2016, and therefore no basis that would suggest X2 of 81 km in November as opposed to 74 km would result in different calanoid copepod density.

Trends for adults were relatively flat across X2 (Figures 52-54), whereas for copepodites a high mean density coincident with the low X2 in September 2011 (Figure 55) was not evident in October (Figure 56) or November (Figure 57). Trends across X2 were also quite flat for all copepod nauplii (Figures 58-60). These patterns were quite similar for 2003-2015/2016 (Figures 61-69). Overall, the data provided little to no support for the predictions from the FLaSH investigations (Table 4: higher calanoid copepod biomass with lower X2), and did not suggest the potential for differences in food densities between X2 at 74km and 81km, or between 74 km and potential intermediate values of October X2 that have been forecast for the proposed 2017 action (e.g., ~78 km; Figure 13, Table 1).

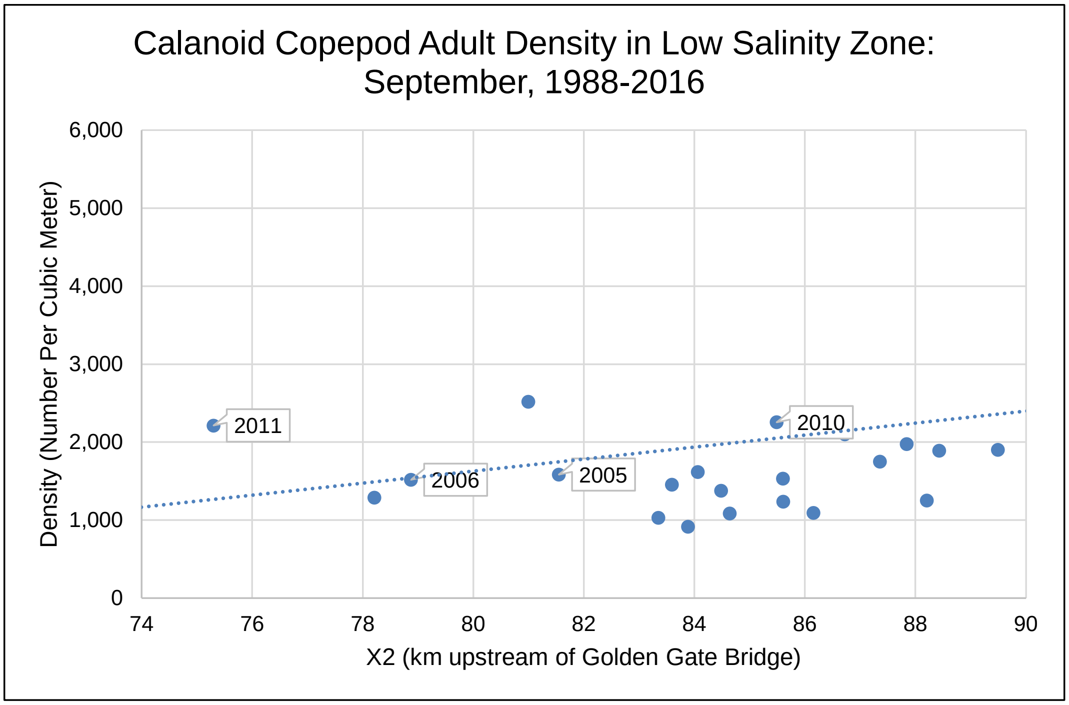


Figure 52. Mean September Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.

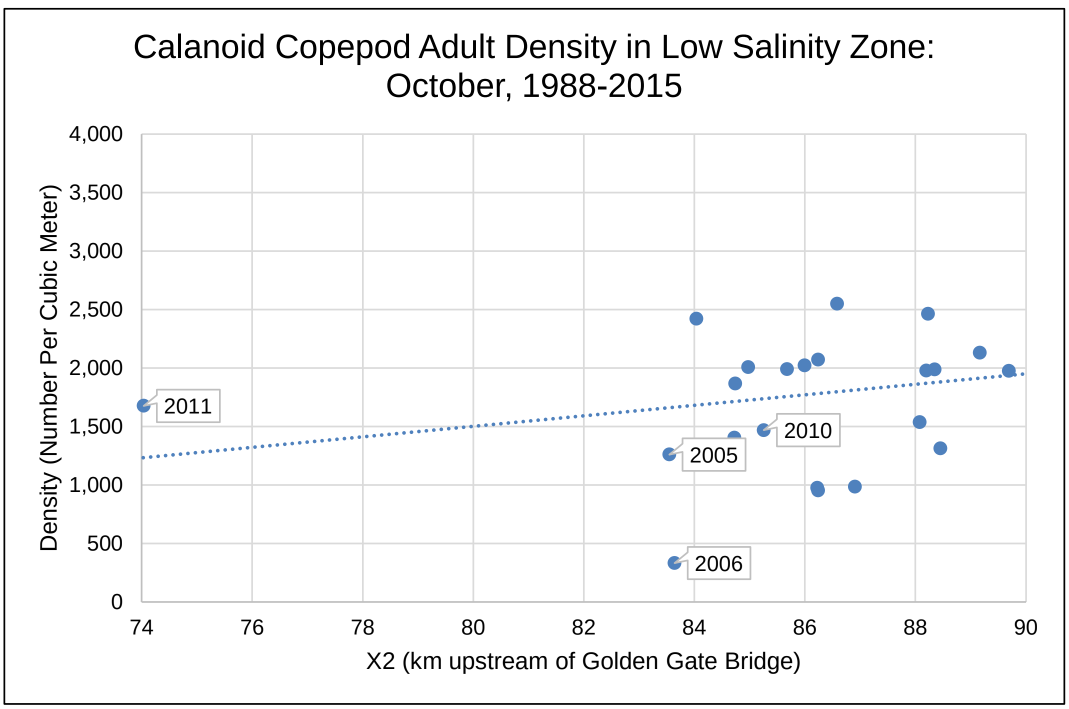


Figure 53. Mean October Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2015.

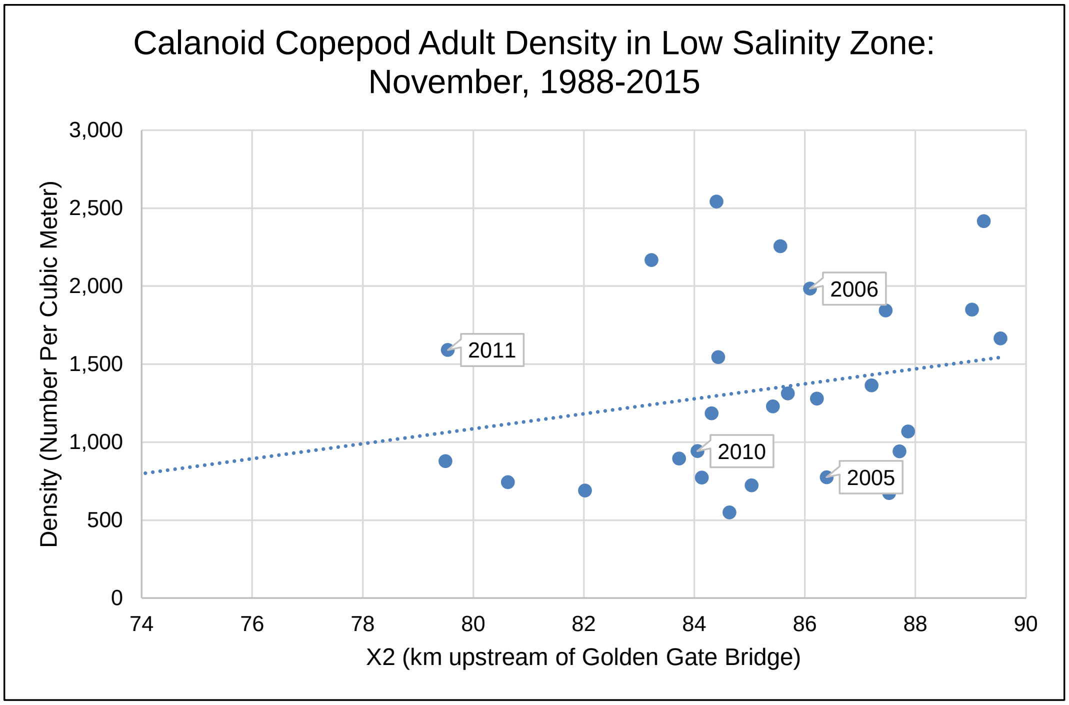


Figure 54. Mean November Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2015.

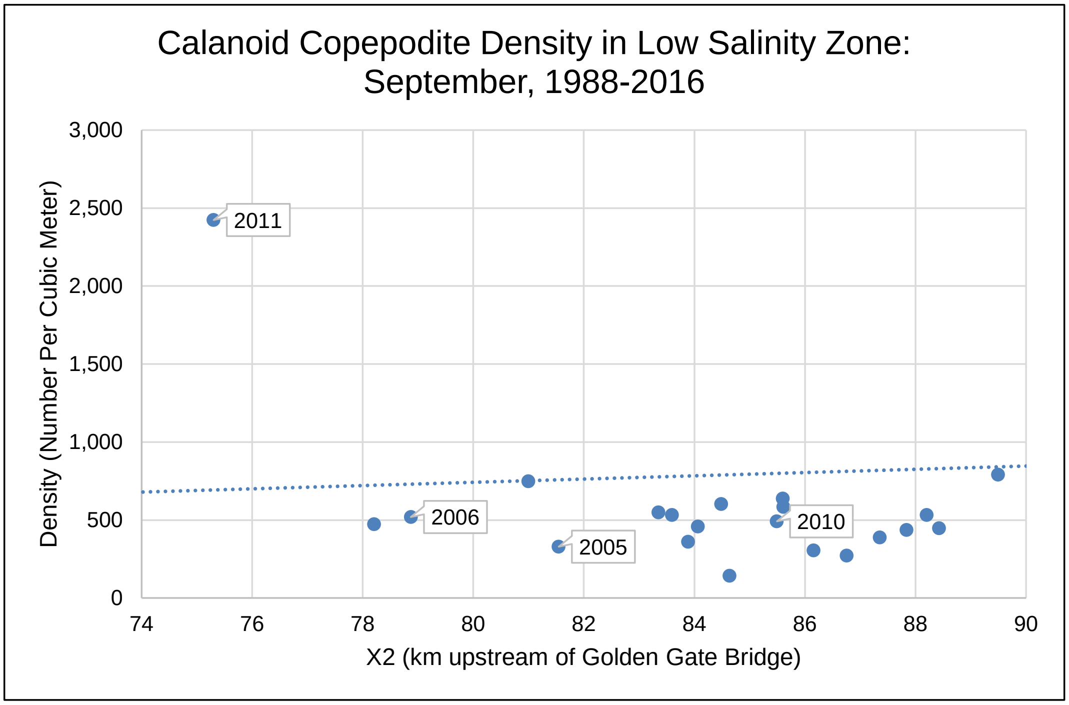


Figure 55. Mean September Calanoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.

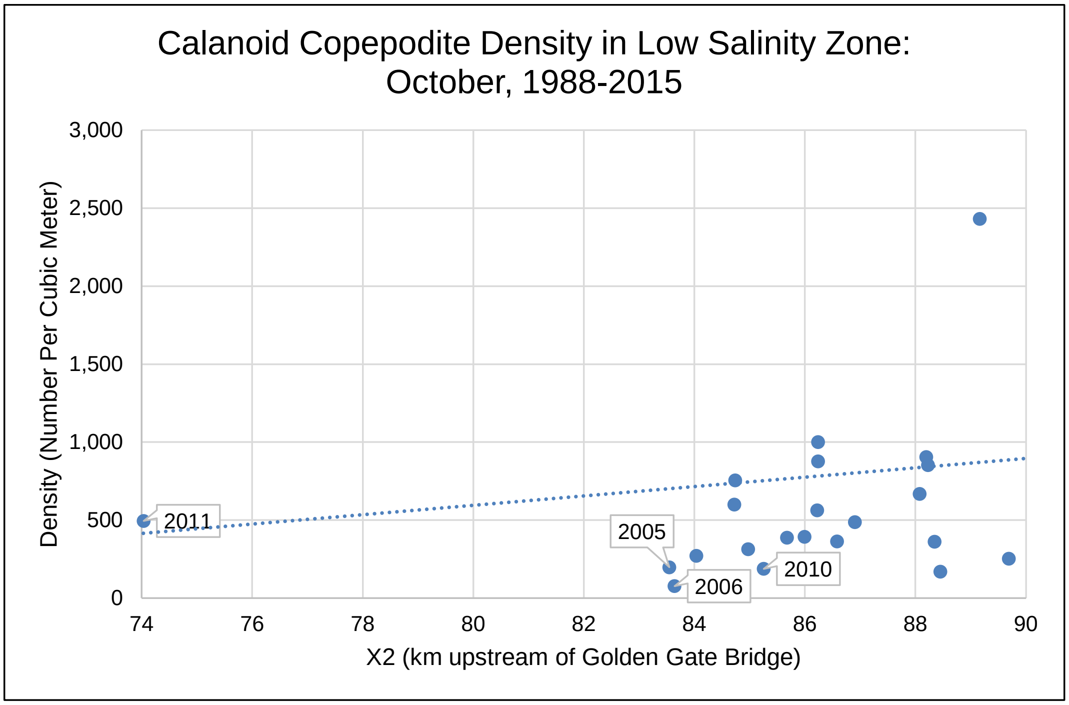


Figure 56. Mean October Calanoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2015.

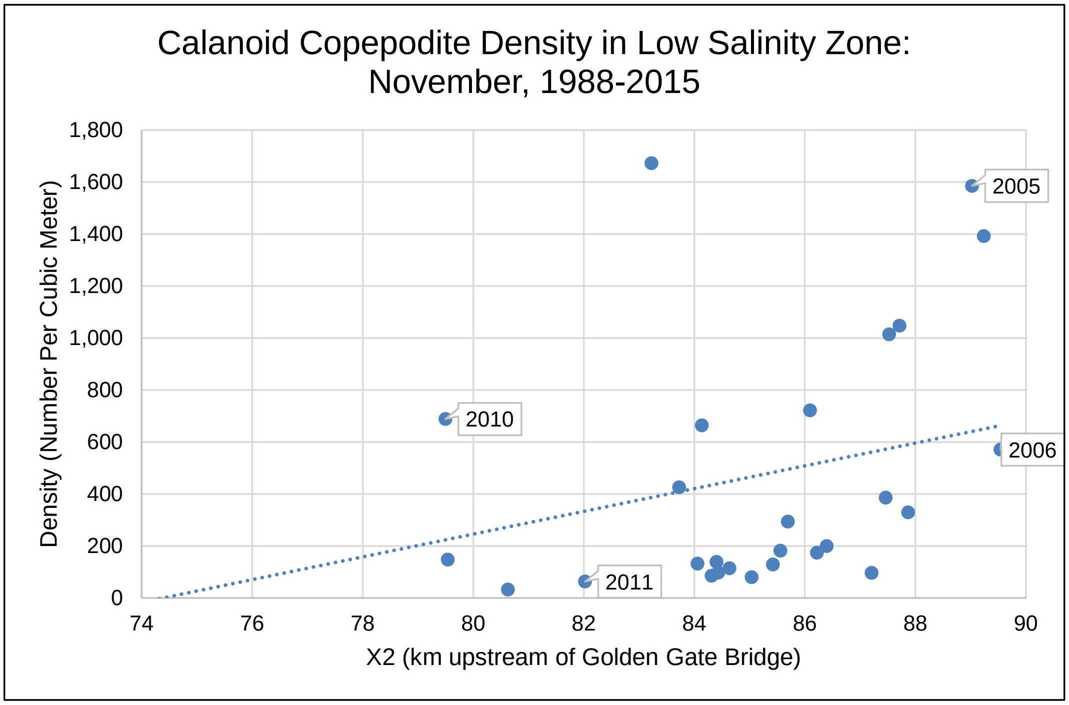


Figure 57. Mean November Calanoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2015.

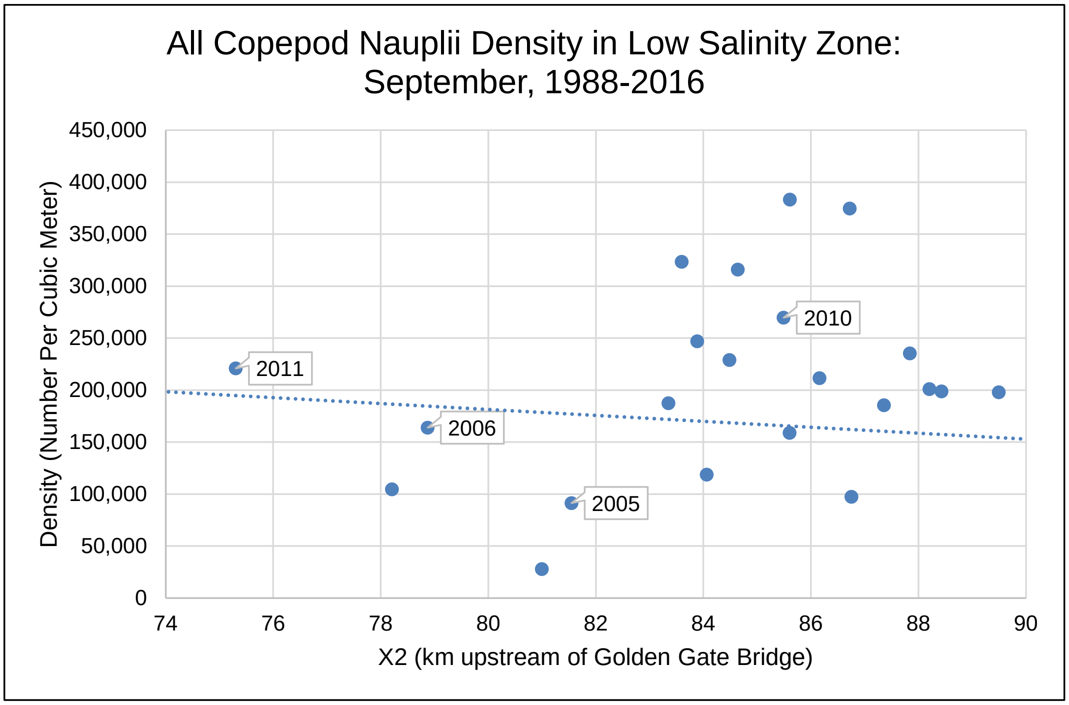


Figure 58. Mean September All Copepod Nauplii Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2016.

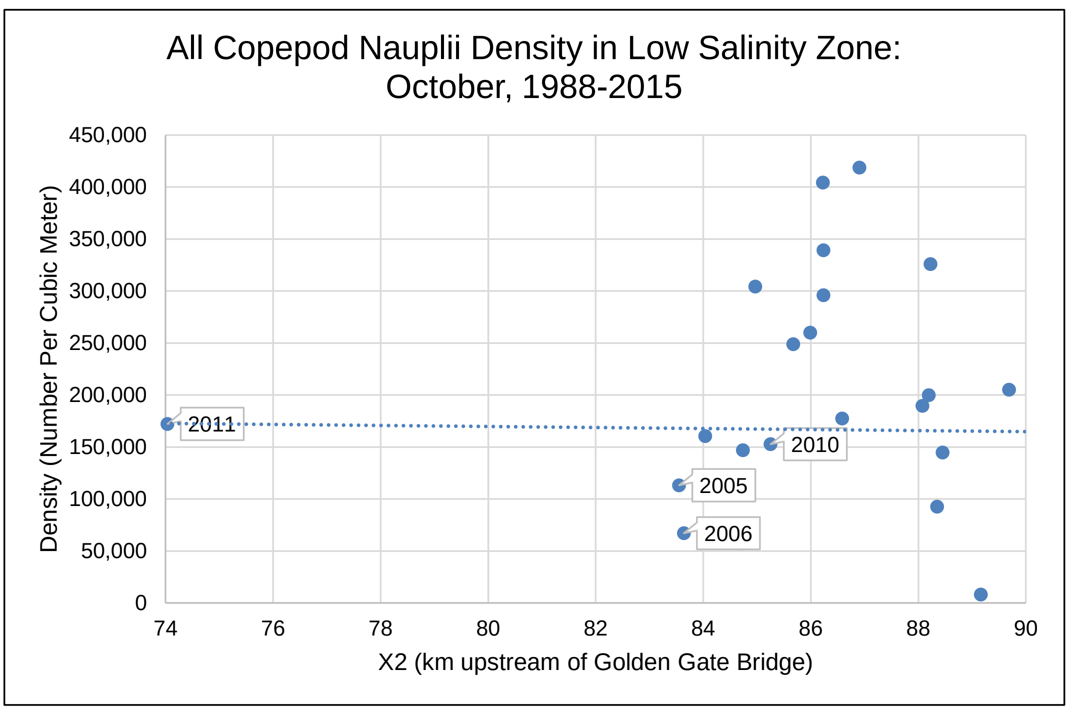


Figure 59. Mean October All Copepod Nauplii Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2015.

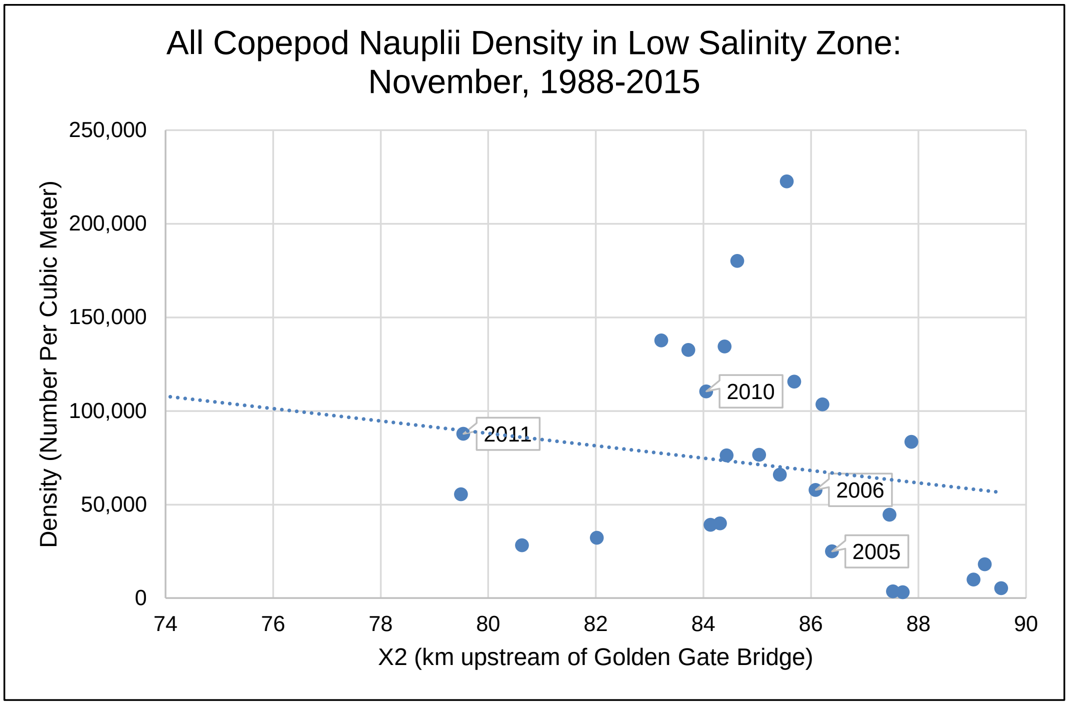


Figure 60. Mean November All Copepod Nauplii Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2015.

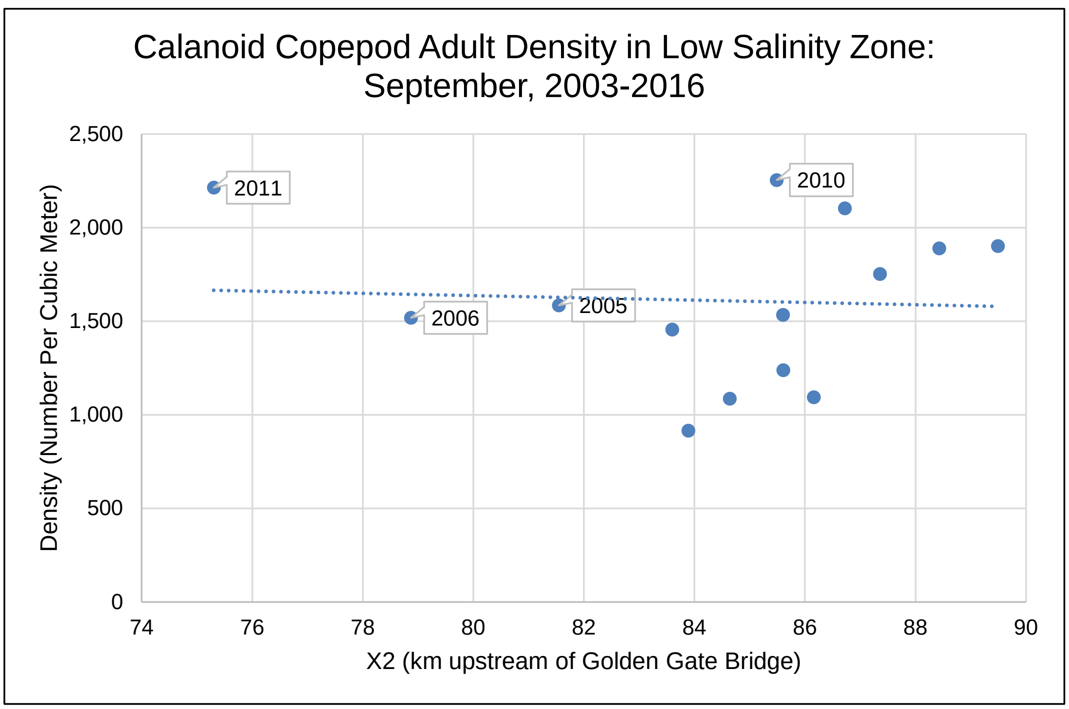


Figure 61. Mean September Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 2003-2016.

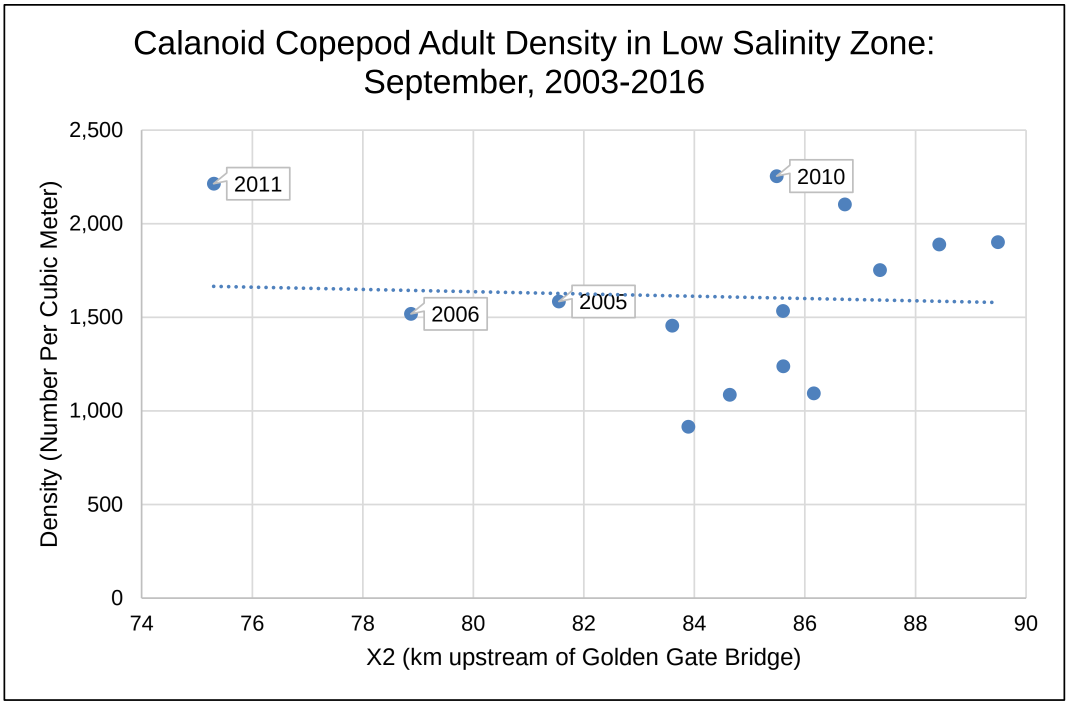


Figure 62. Mean October Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 2003-2015.

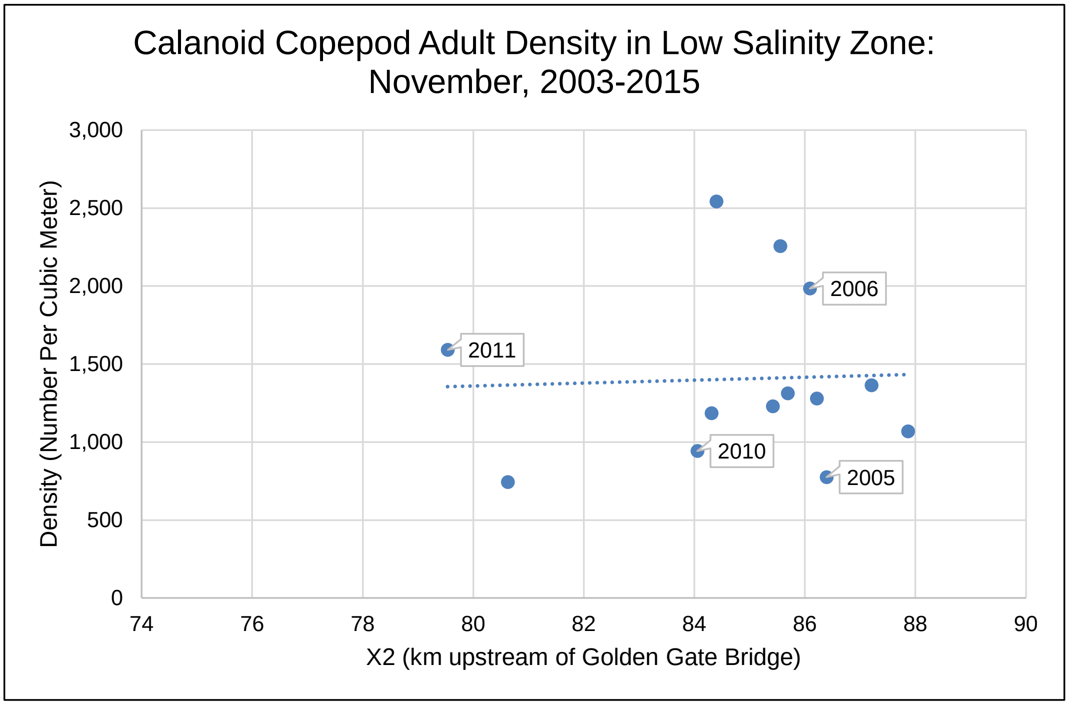


Figure 63. Mean November Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 2003-2015.

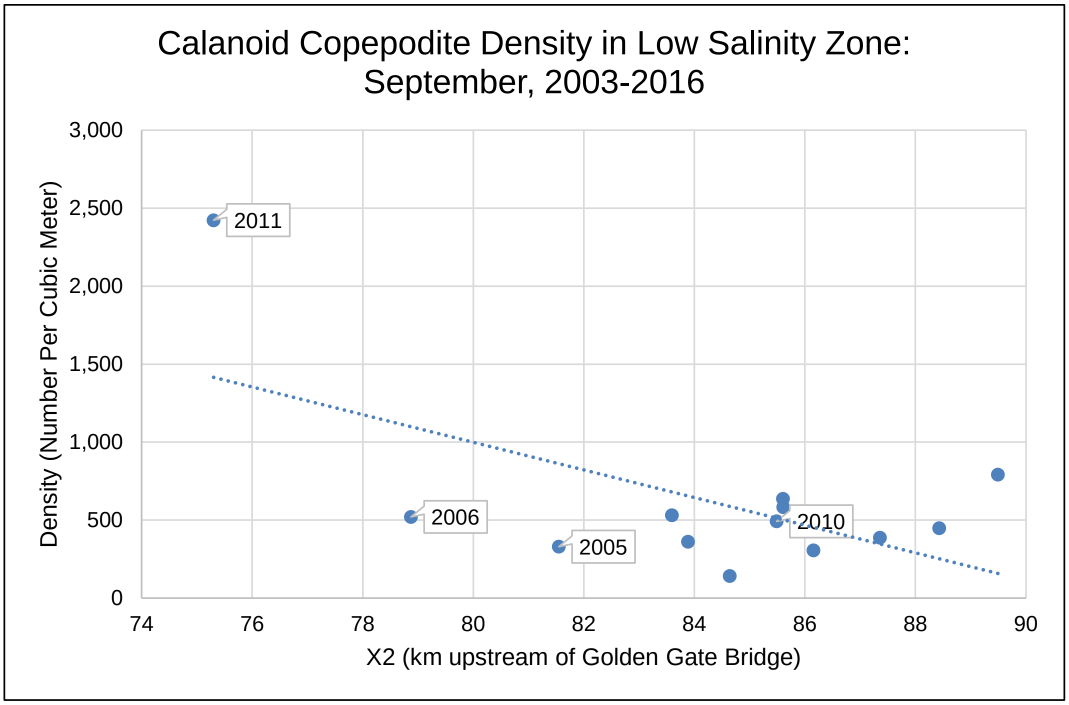


Figure 64. Mean September Calanoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 2003-2016.

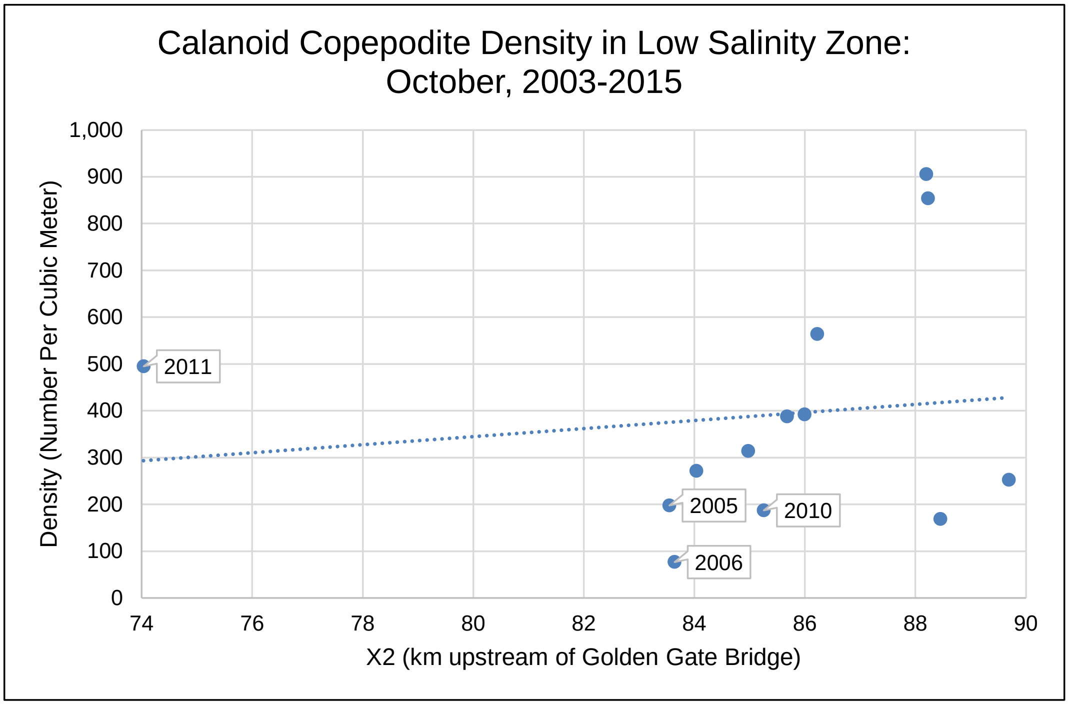


Figure 65. Mean October Calanoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 2003-2015.

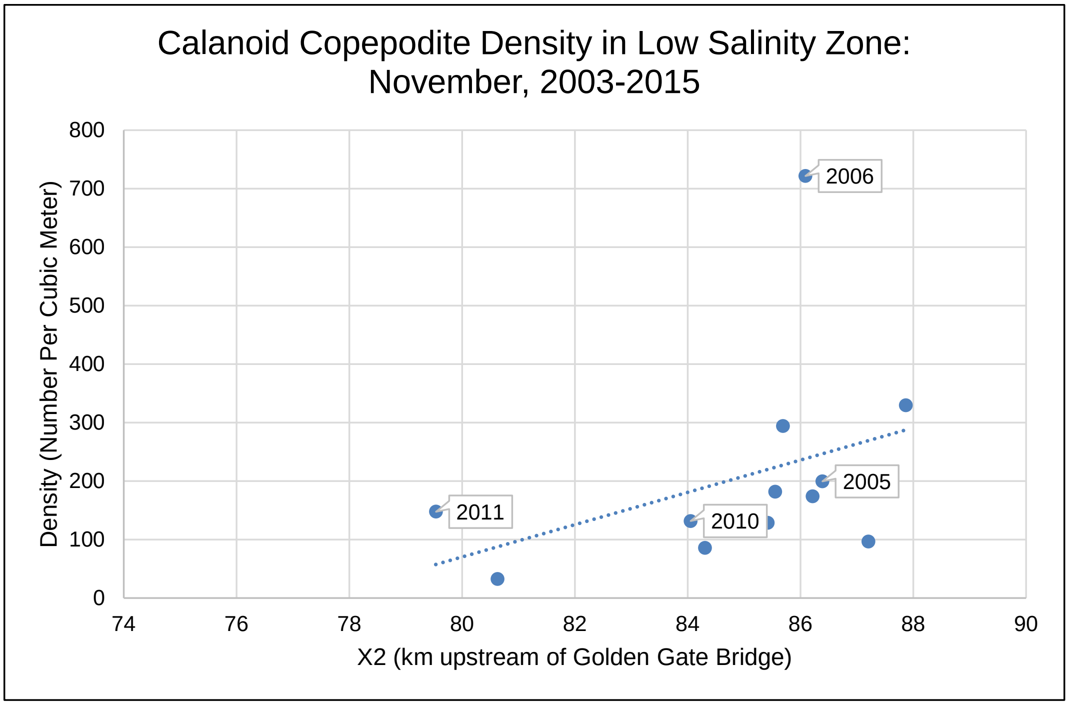


Figure 66. Mean November Calanoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 2003-2015.

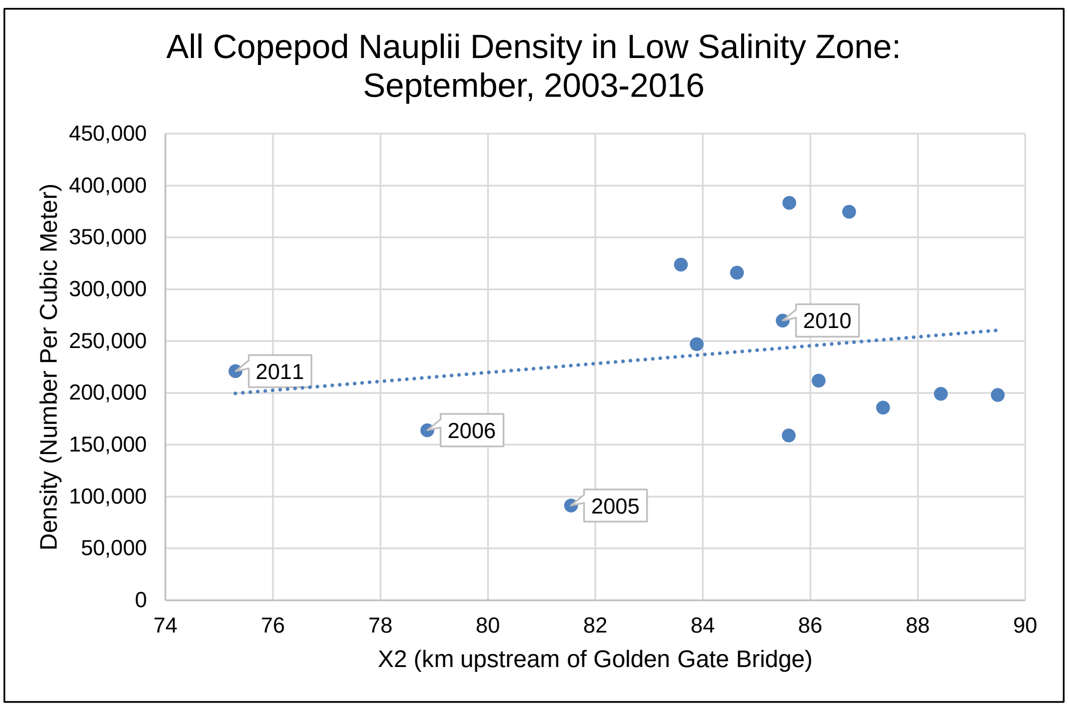


Figure 67. Mean September All Copepod Nauplii Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2016.

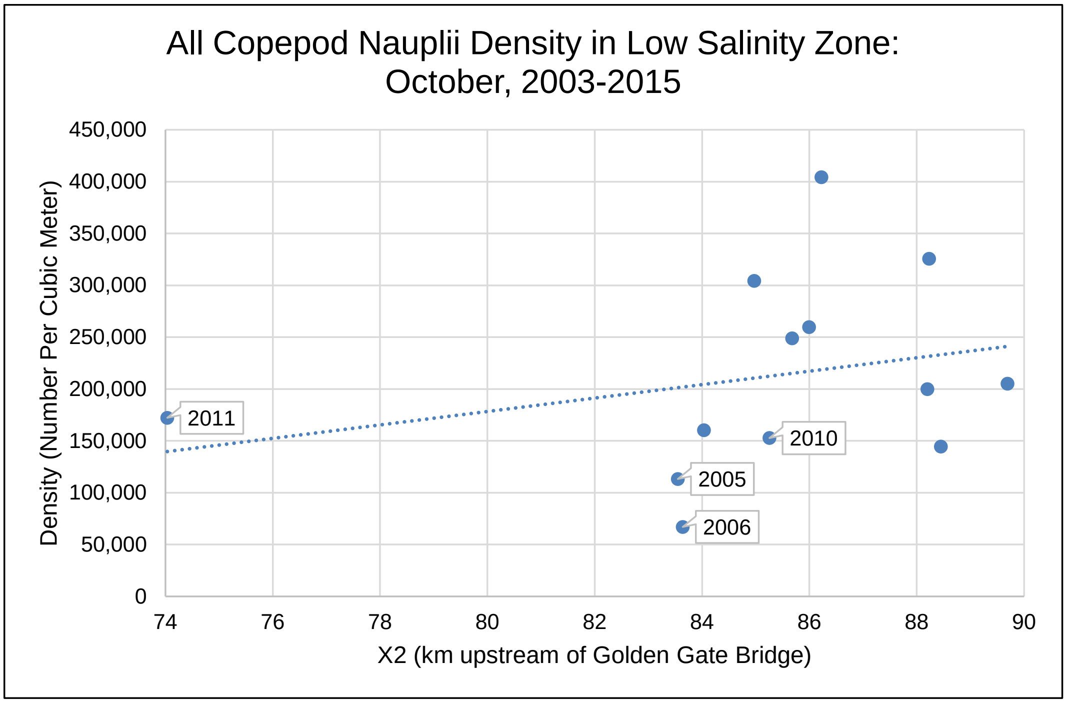


Figure 68. Mean October All Copepod Nauplii Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2015.

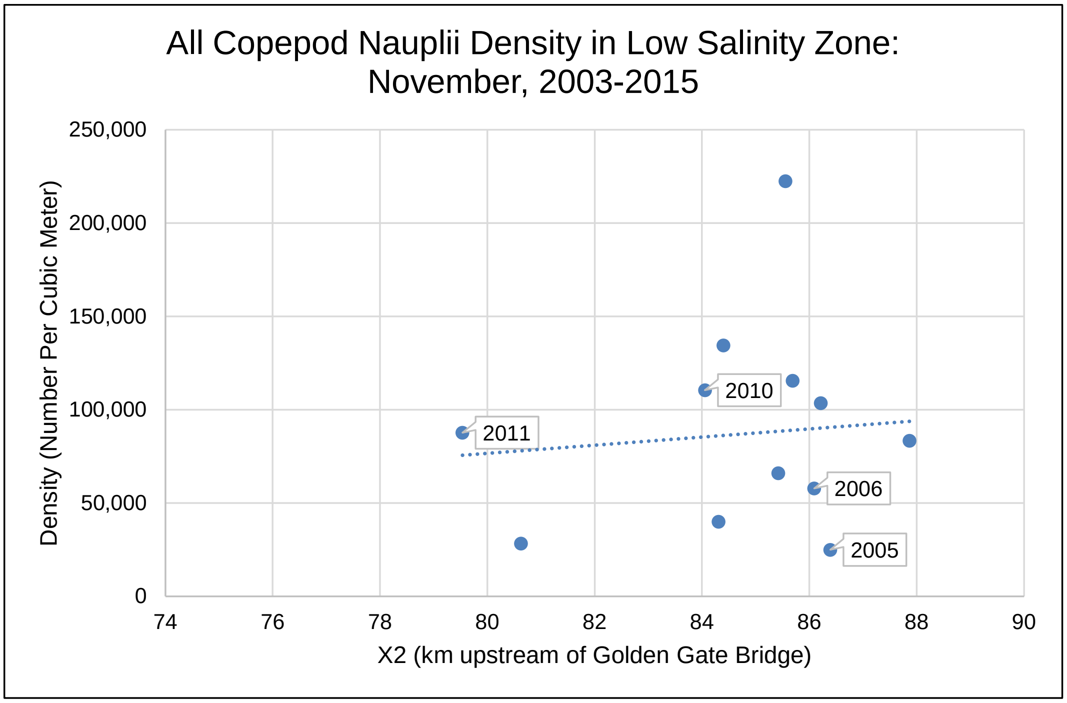


Figure 69. Mean November All Copepod Nauplii Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2015.

Cyclopoid Copepods

Although thought to be less desirable prey for Delta Smelt because of small size, sedentary behavior, and ability to detect predators, cyclopoid copepods contribute considerably to Delta Smelt diet, particularly *Limnoithona tetraspina* (IEP MAST 2015 and references therein). Data for cyclopoid copepod adults and juveniles were processed in the same manner as described previously in *Calanoid Copepods*, and focused on density estimates from the pump sampler. There was little evidence to suggest the potential for a change in cyclopoid copepod density within the low salinity zone with X2 of 81 km instead of 74 km in October 2017, whether considering 1988-2015/2016 (Figures 70-75) or 2003-2015/2016 (Figures 76-81). Density of copepodites was greatest in September 2011 with X2 of ~75 km (Figures 73, 79); the proposed 2017 action includes X2 of 74 km in September. Overall, the data provided little support for the predictions from the FLaSH investigations (Table 4: moderate cyclopoid copepod biomass with X2 = 74-81 km, lower biomass with X2 = 85), and did not suggest the potential for differences in food densities between X2 at 74km and 81km, or between 74 km and potential intermediate values of October X2 that have been forecast for the proposed 2017 action (e.g., ~78 km; Figure 13, Table 1).

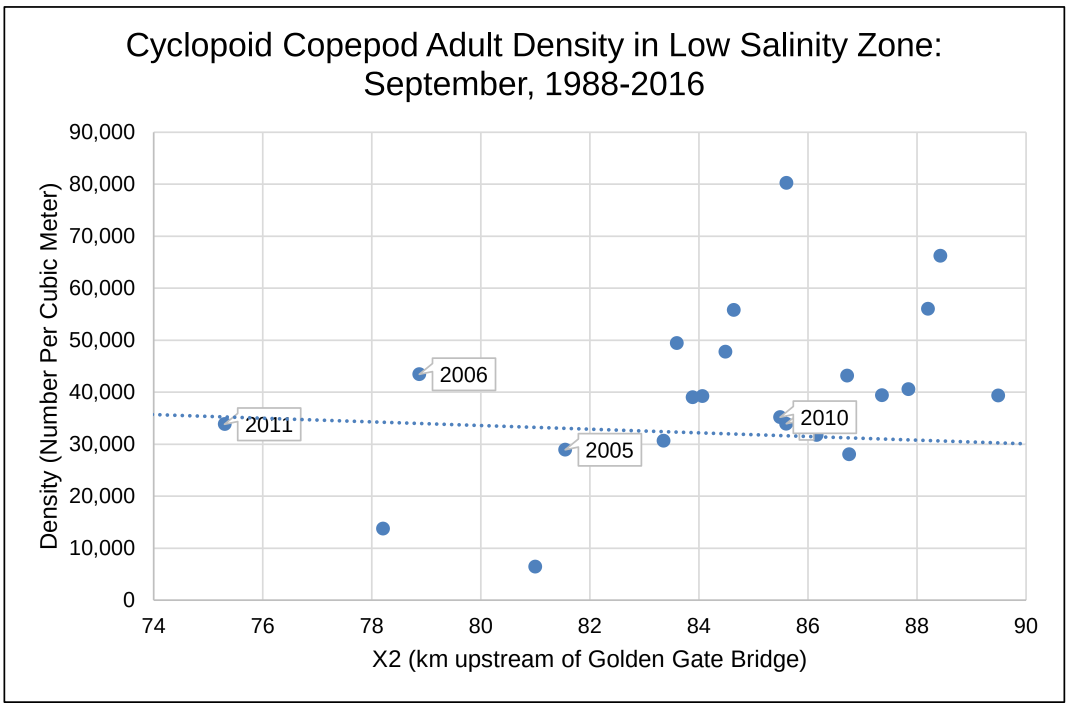


Figure 70. Mean September Cyclopoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2016.

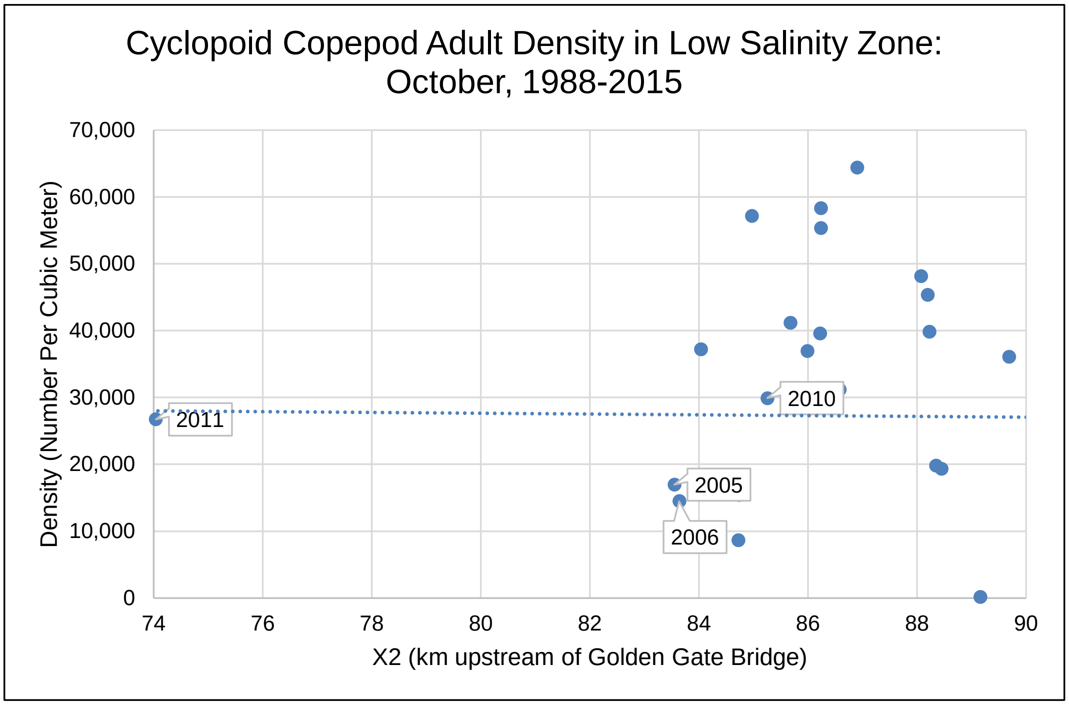


Figure 71. Mean October Cyclopoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2015.

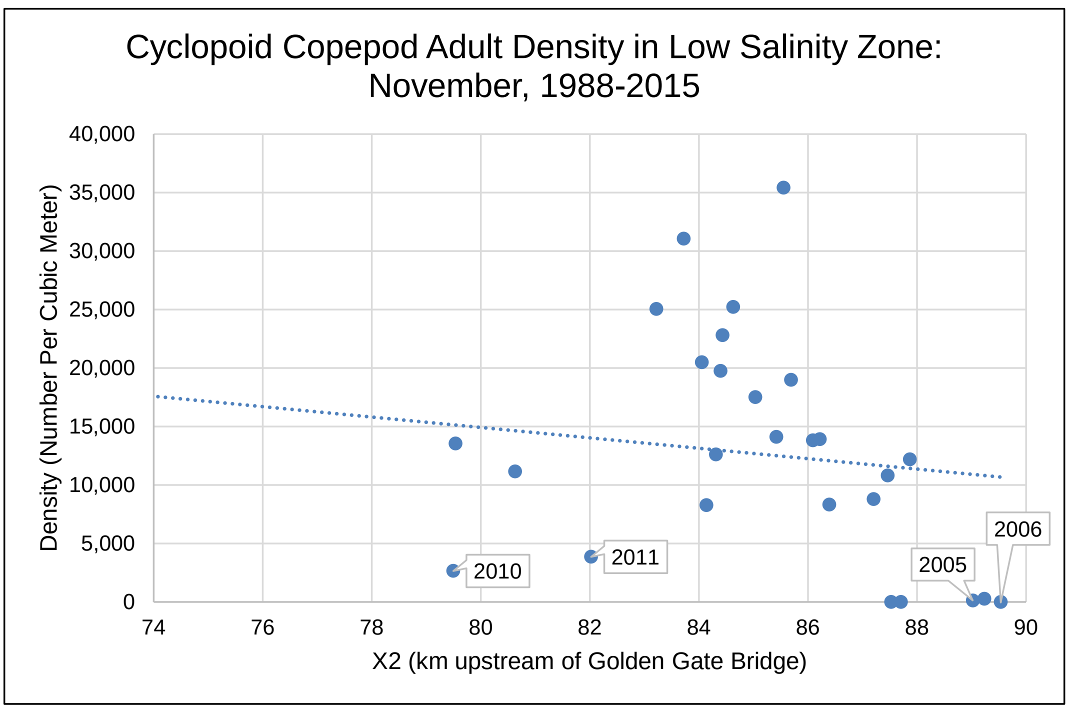


Figure 72. Mean November Cyclopoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump) versus Mean X2 from 1988-2015.

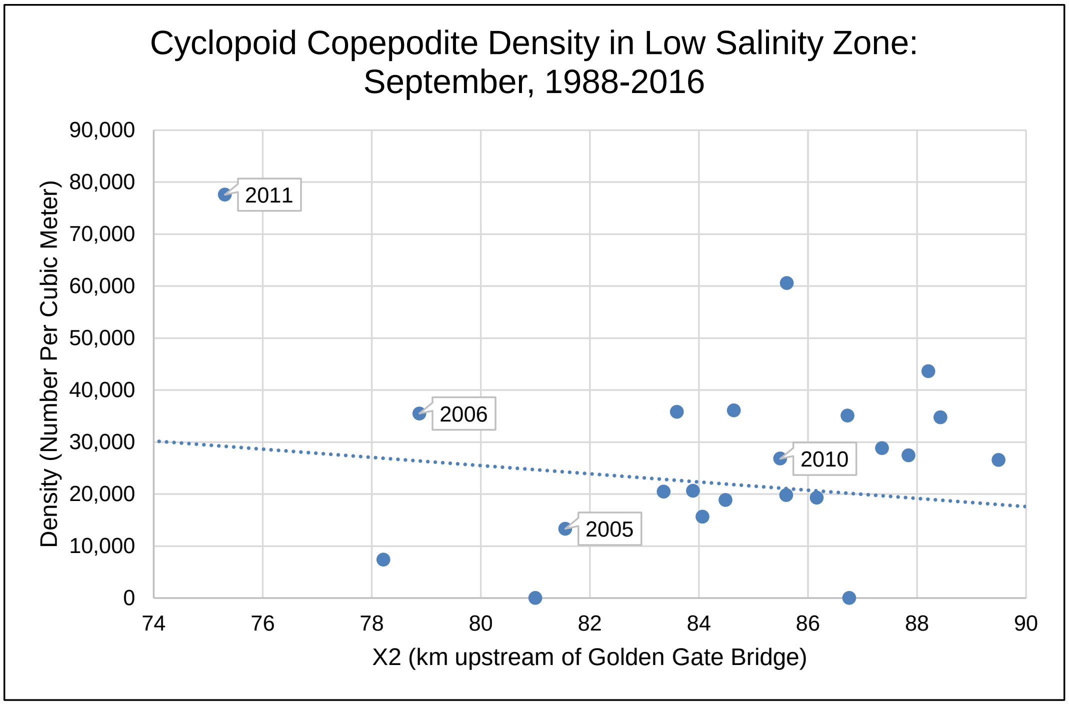


Figure 73. Mean September Cyclopoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2016.

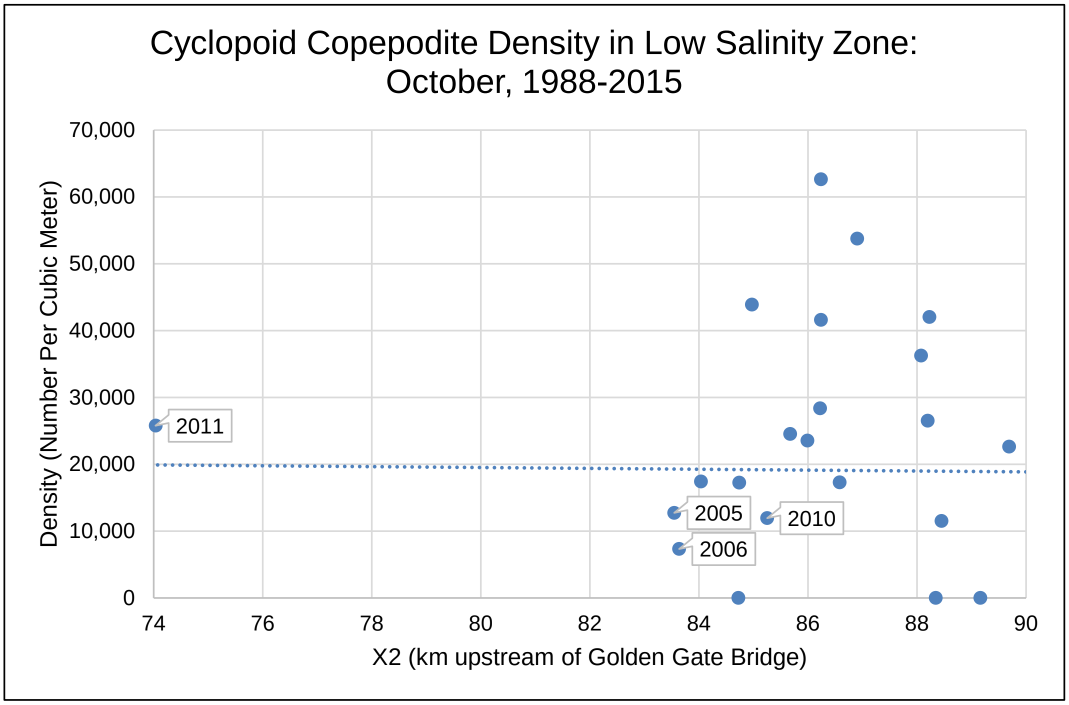


Figure 74. Mean October Cyclopoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2015.

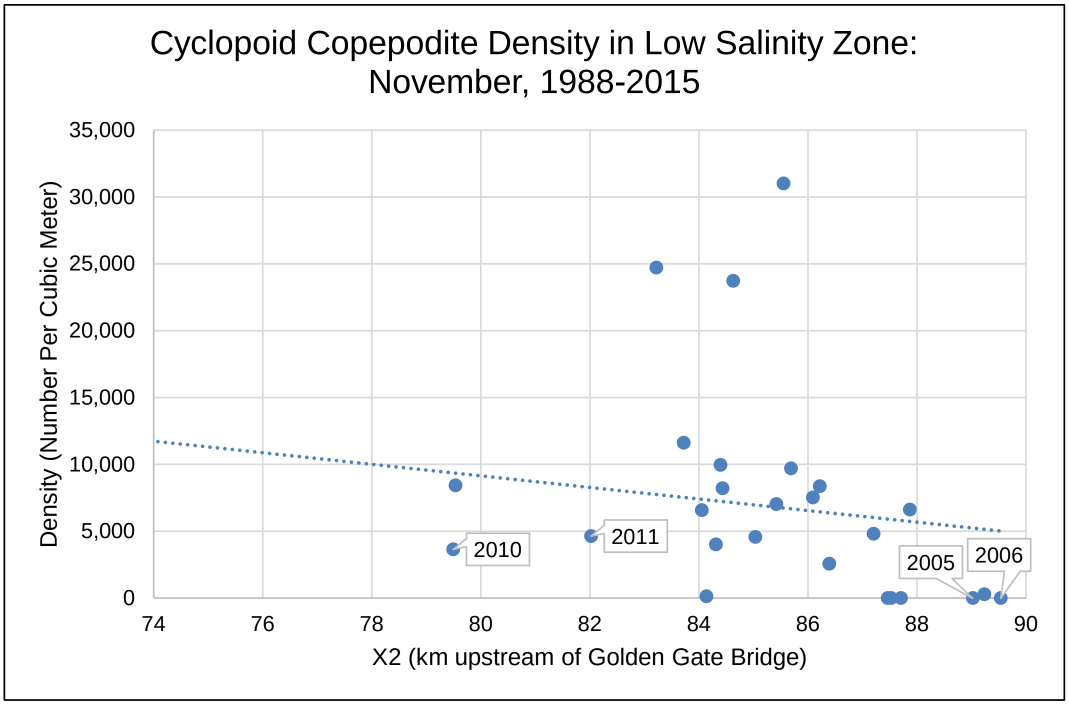


Figure 75. Mean November Cyclopoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 1988-2015.

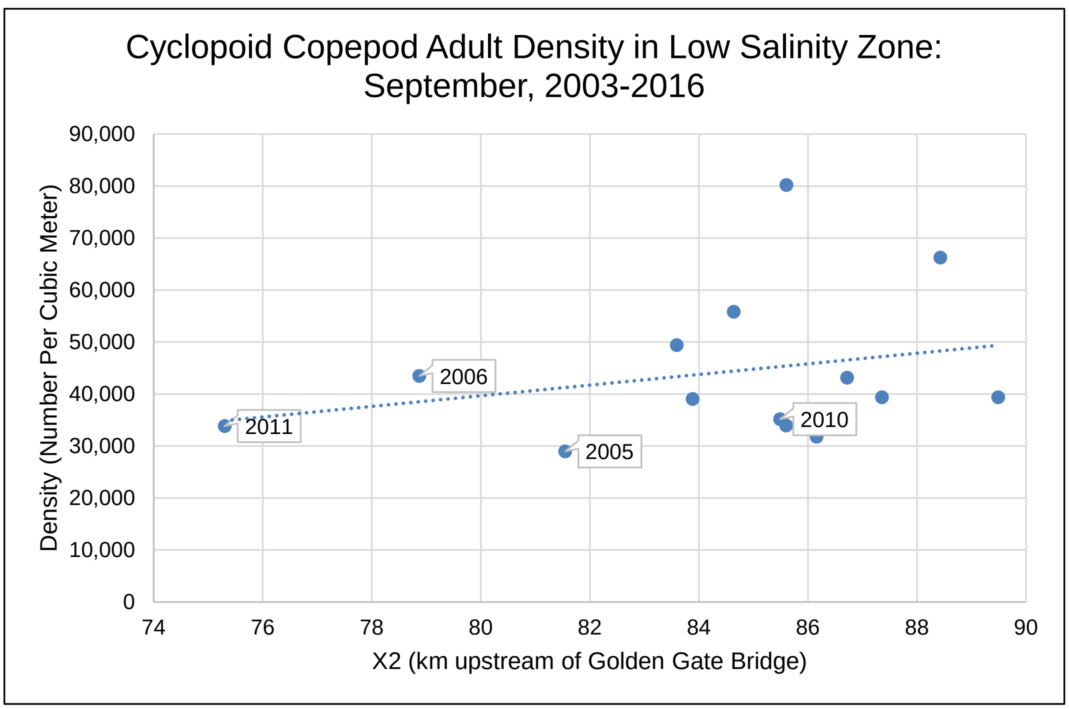


Figure 76. Mean September Cyclopoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2016.

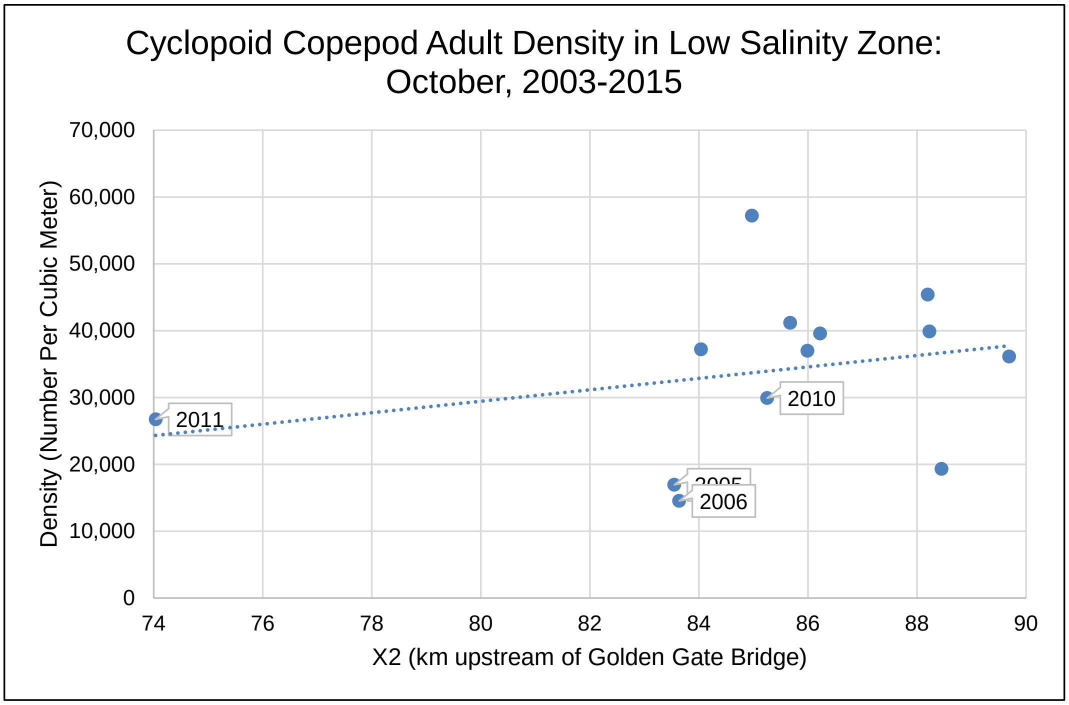


Figure 77. Mean October Cyclopoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2015.

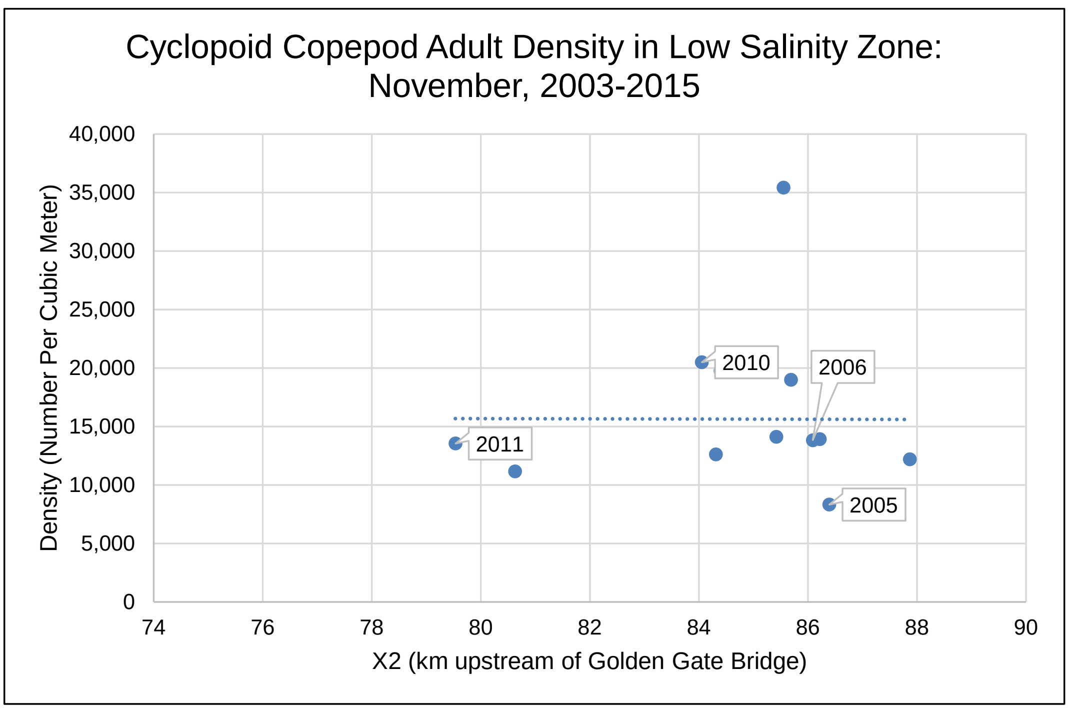


Figure 78. Mean November Cyclopoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump) versus Mean X2 from 2003-2015.

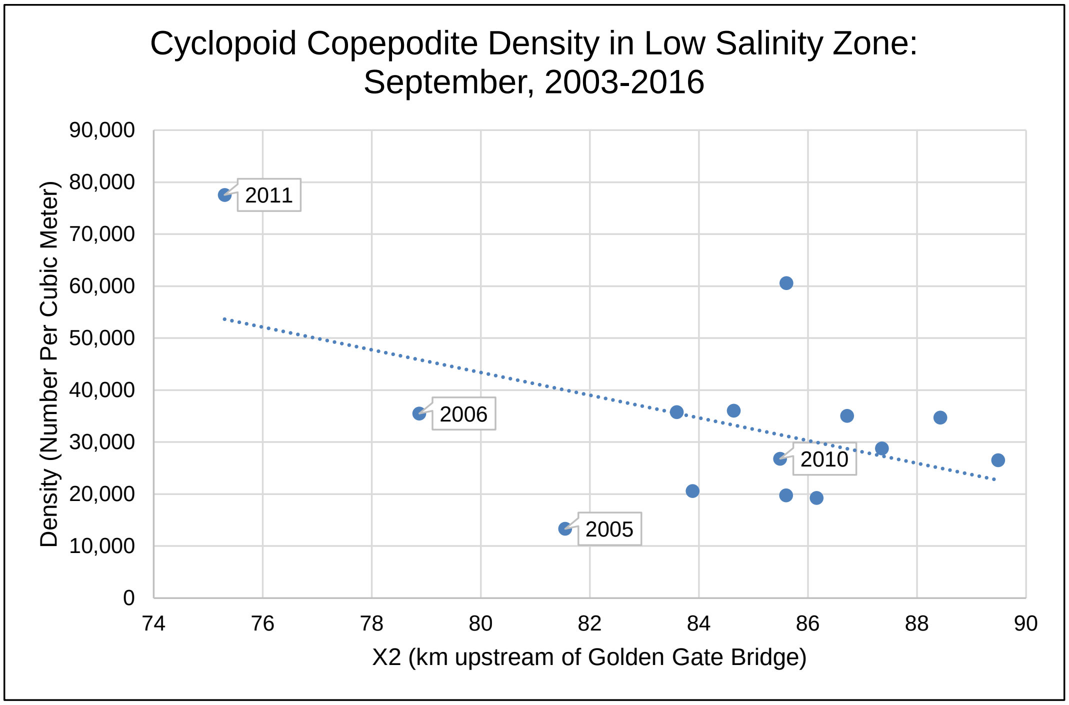


Figure 79. Mean September Cyclopoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2016.

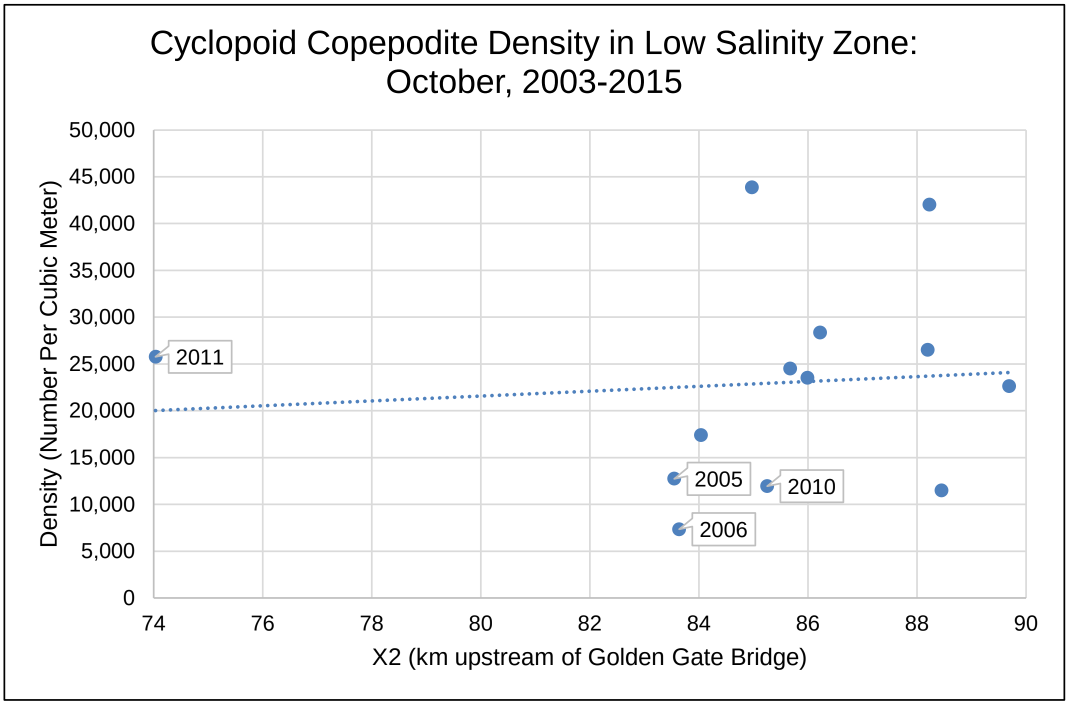


Figure 80. Mean October Cyclopoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2015.

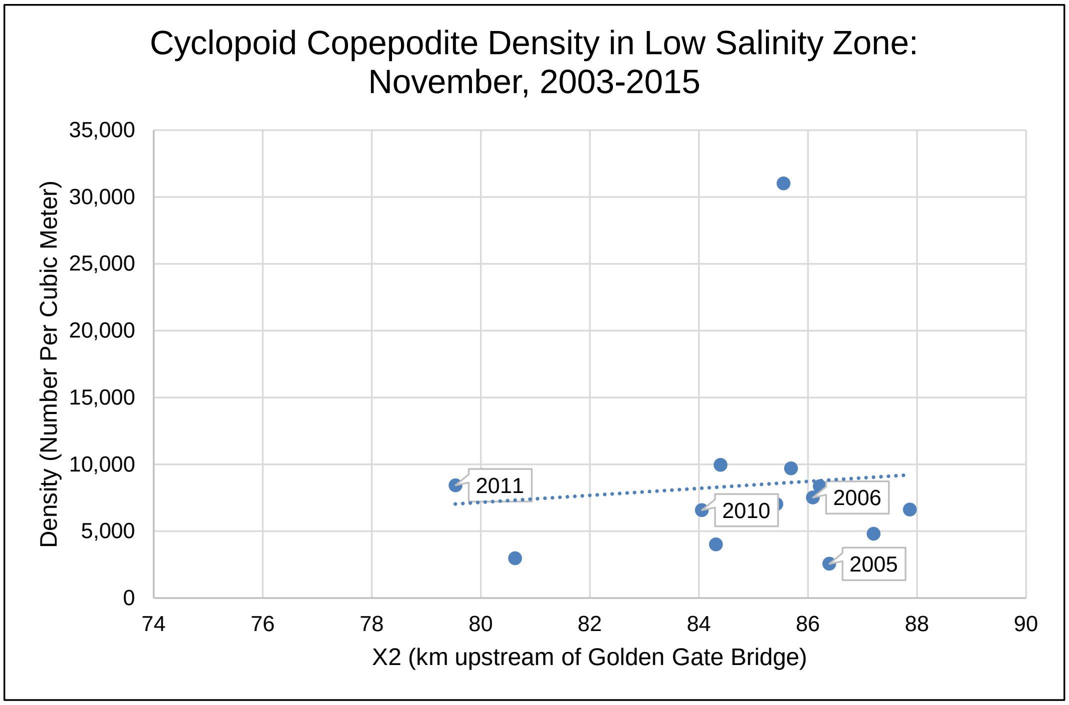


Figure 81. Mean November Cyclopoid Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Pump Sampler) versus Mean X2 from 2003-2015.

Mysids

Although mysids are not a significant portion of the average diet for Delta smelt (Slater and Baxter 2014), they were once considered to be significant prey (Bennett 2005; IEP MAST 2015; Moyle et al. 2016) and therefore are considered herein. Data for mysids were processed in the same manner as described previously in *Calanoid Copepods*, and focused on density estimates from the 505-µm-mesh conical net.

Mysid density in September, October, and November 1988-2016 did not show clear relationships to mean X2 (Figures 82, 83, 84), whereas for September 2003-2016 mysid density generally was lowest at the highest mean X2, although there was little difference over the range from ~75 km to ~81 km and a nonlinear curve probably would be a more appropriate fit to the data (Figure 85). There were no clear relationships for October and November, 2003-2015 (Figures 86, 87).

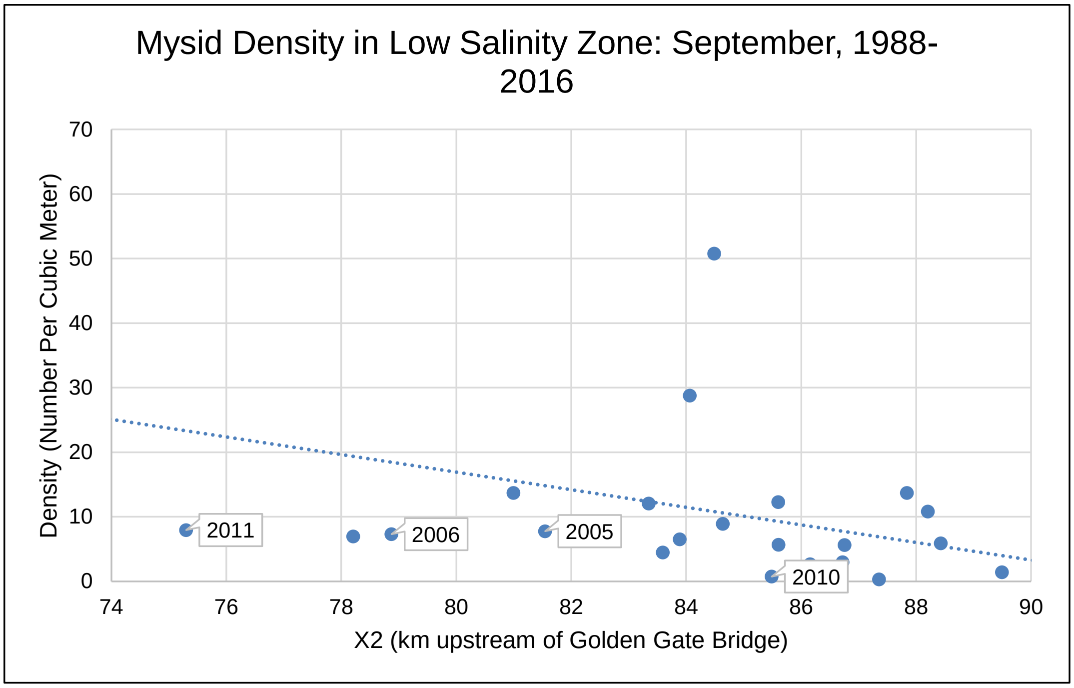


Figure 82. **September Mysid Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Conical Net) versus Mean X2 from 1988-2016.**

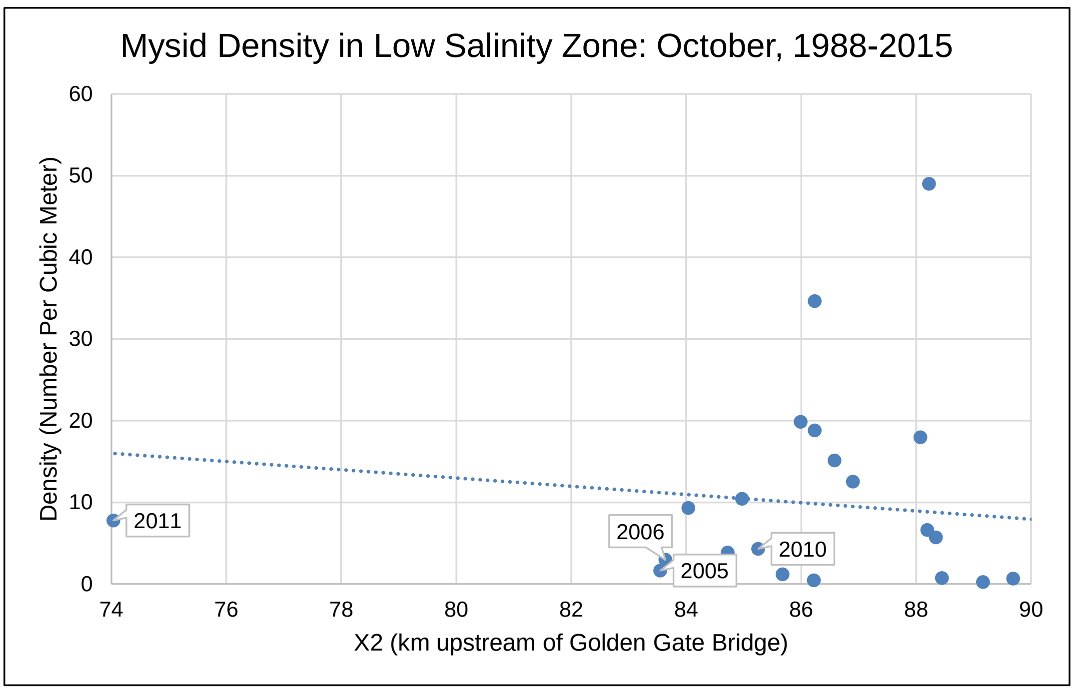


Figure 83. **Mean October Mysid Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Conical Net) versus Mean X2 from 1988-2015.**

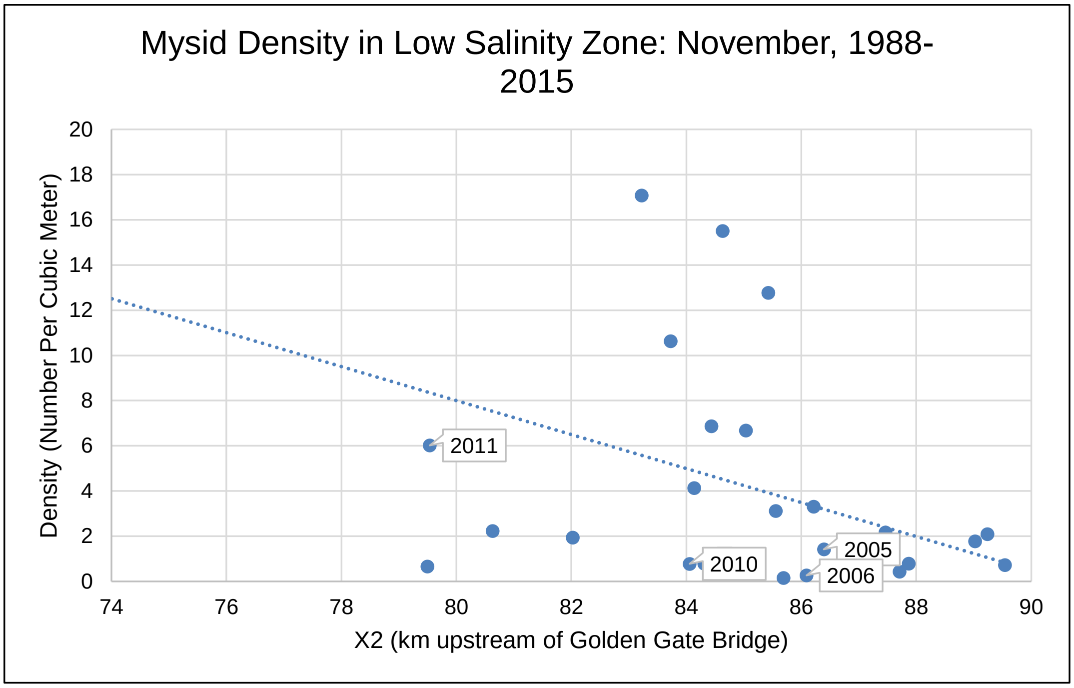


Figure 84. Mean November Mysid Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Conical Net) versus Mean X2 from 1988-2015.

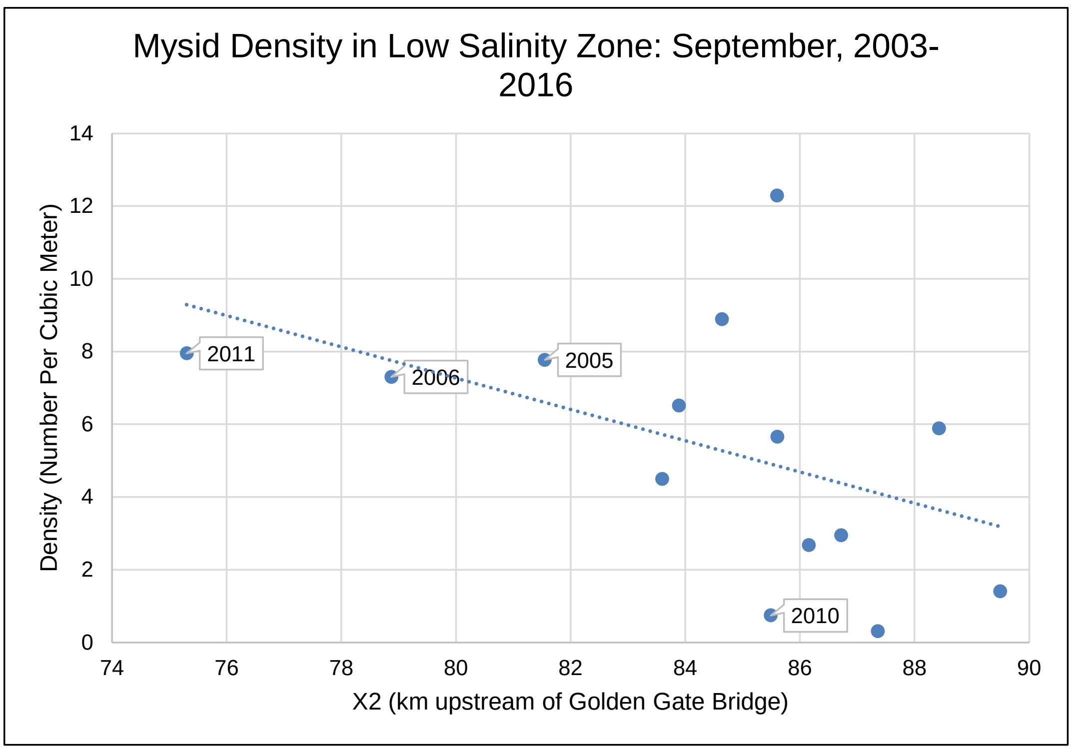


Figure 85. Mean September Mysid Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Conical Net) versus Mean X2 from 2003-2016.

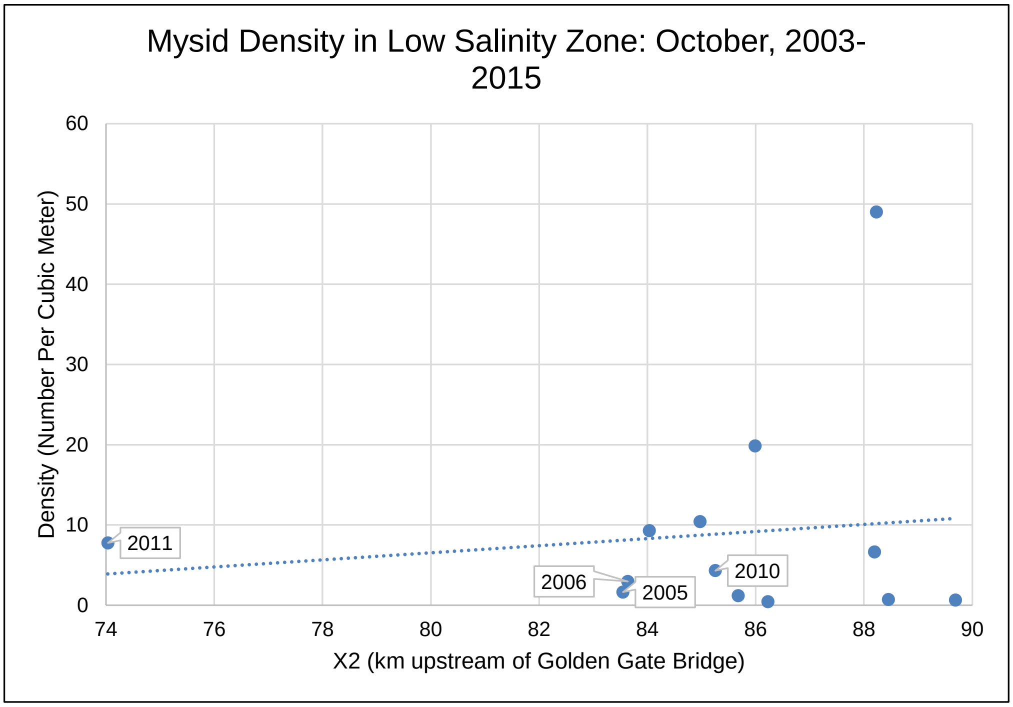


Figure 86. Mean October Mysid Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Conical Net) versus Mean X2 from 2003-2015.

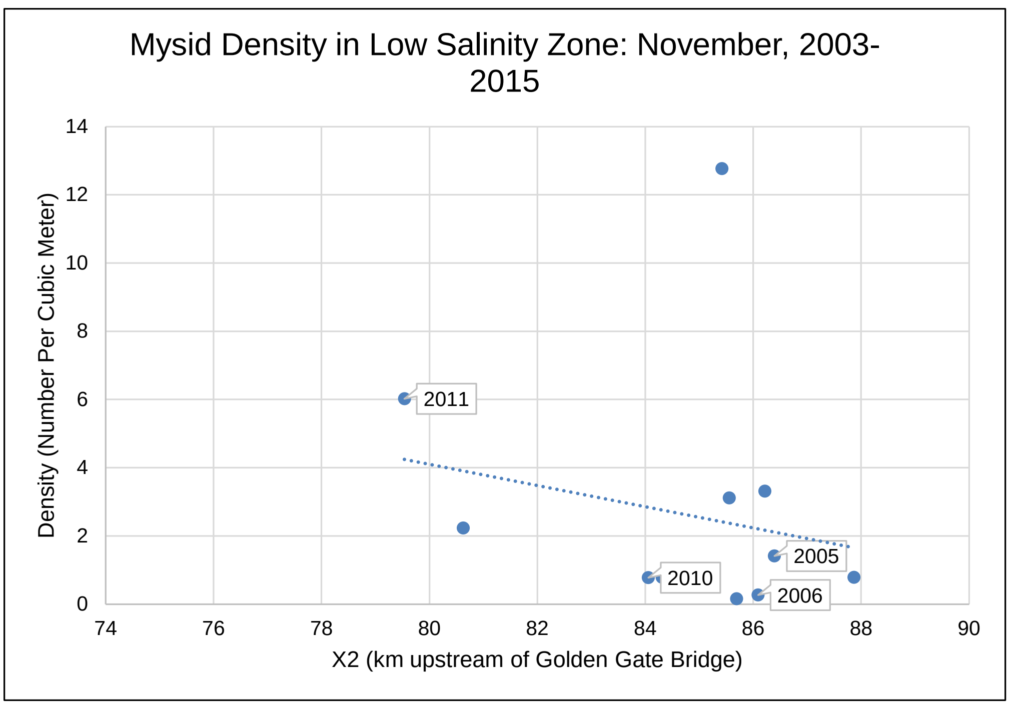
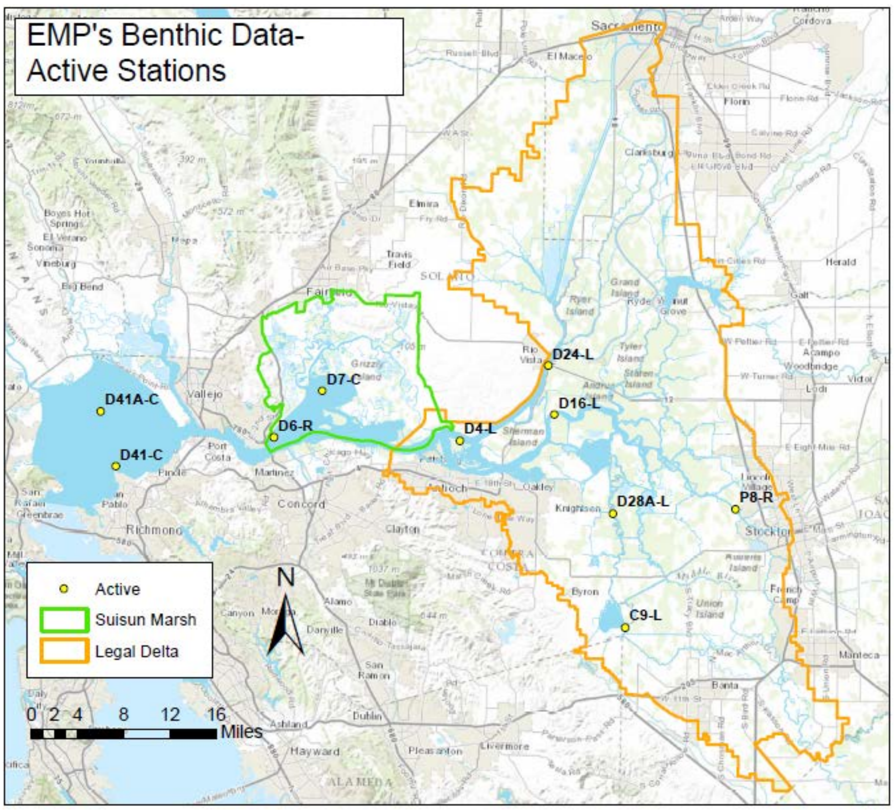


Figure 87. Mean November Mysid Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Conical Net) versus Mean X2 from 2003-2015.

Amphipods

Although amphipods make up a small percentage of Delta Smelt prey by number, they are much larger than other prey types and may potentially be significant contributors to the diet; this has been observed mostly for adult Delta Smelt (IEP MAST 2015), but also to some extent for juvenile Delta Smelt (Slater and Baxter 2014). Mean monthly amphipod density estimates in the low salinity zone were compiled from available EMP benthic monitoring data[22] in a similar manner to zooplankton data, although the number of samples and stations was appreciably less. Analyses were limited to stations D7-C and D4-L (Figure 88), reflecting their position generally within the low salinity zone and availability of data over time. The available time series was constrained to 1988 onwards to reflect the step change in benthic assemblages following the invasion by *Potamocorbula* (e.g., Kimmerer 2002a). Data included the summed density of all taxa within the order Amphipoda. Environmental parameters are not provided with the benthic monitoring data, so assessment of the monthly occurrence of each station within the low salinity zone was based on the closest available stations from the zooplankton survey (i.e., stations 28 and 60 in Figure 51).



Source: http://www.water.ca.gov/bdma/docs/benthic_active.pdf

Figure 88. Active Benthic Monitoring Stations.

[22] http://www.water.ca.gov/bdma/meta/benthic/data.cfm, Catch Per Unit Effort files.

There was little evidence to suggest that there would be any differences between X2 at 74km and 81km on amphipod density in the low salinity zone, or between 74 km and potential intermediate values of October X2 that have been forecast for the proposed 2017 action (e.g., ~78 km; Figure 13, Table 1). However, the data for October were limited and did not include mean X2 much below ~84 km. There was no clear relationship between amphipod density in September (Figure 89) or October (Figure 90), and although November amphipod density was greatest in 2011 (X2 just under 80 km), a very low density was also evident at a similar X2 (Figure 91). As noted by IEP MAST (2015: p. 120), amphipods might not be effectively sampled with current methods (substrate grabs using a Ponar dredge), which are more suited to sampling organisms in or attached to the substrate. This, as well as the fact that there were only two stations included in the present effects analysis, leads to some uncertainty in the conclusions. Subsetting the data to include only the POD period (2003-2015/2016) led to fewer data points within the range of interest for the analysis (X2 = 74-81 km) and did not change the basic conclusions from the 1988-2015/2016 period (Figures 92, 93, 94).

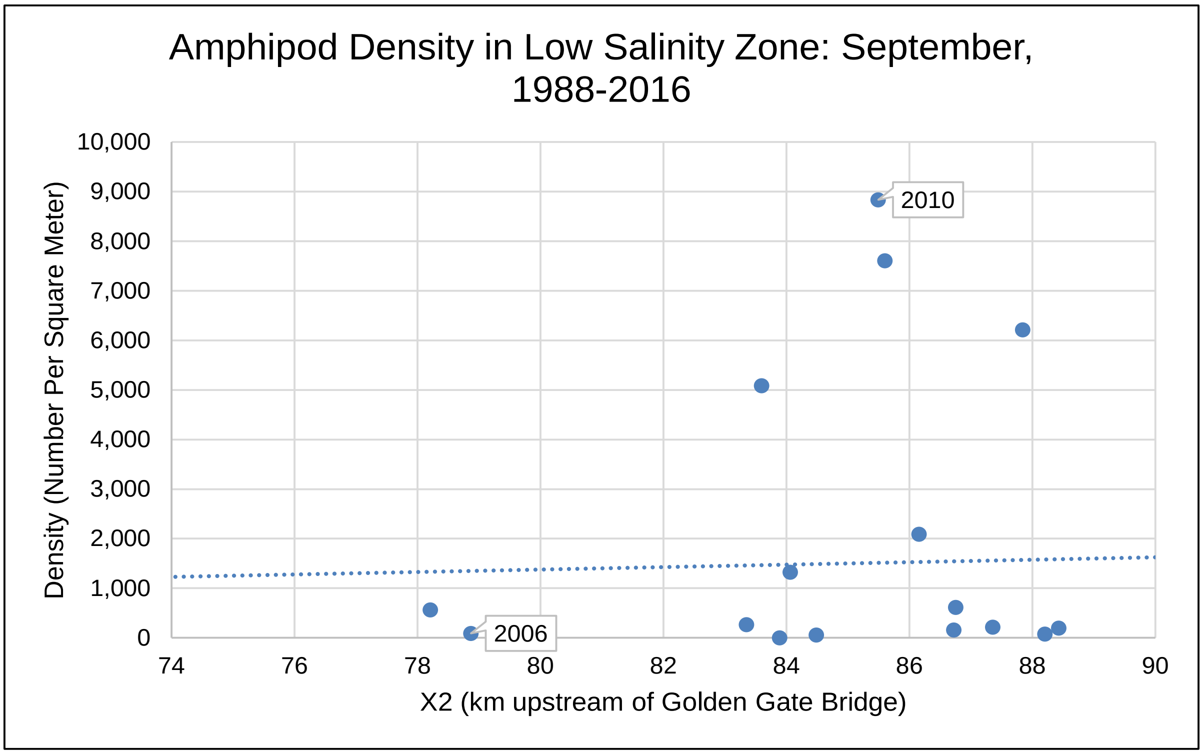


Figure 89. Mean September Amphipod Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 1988-2016.

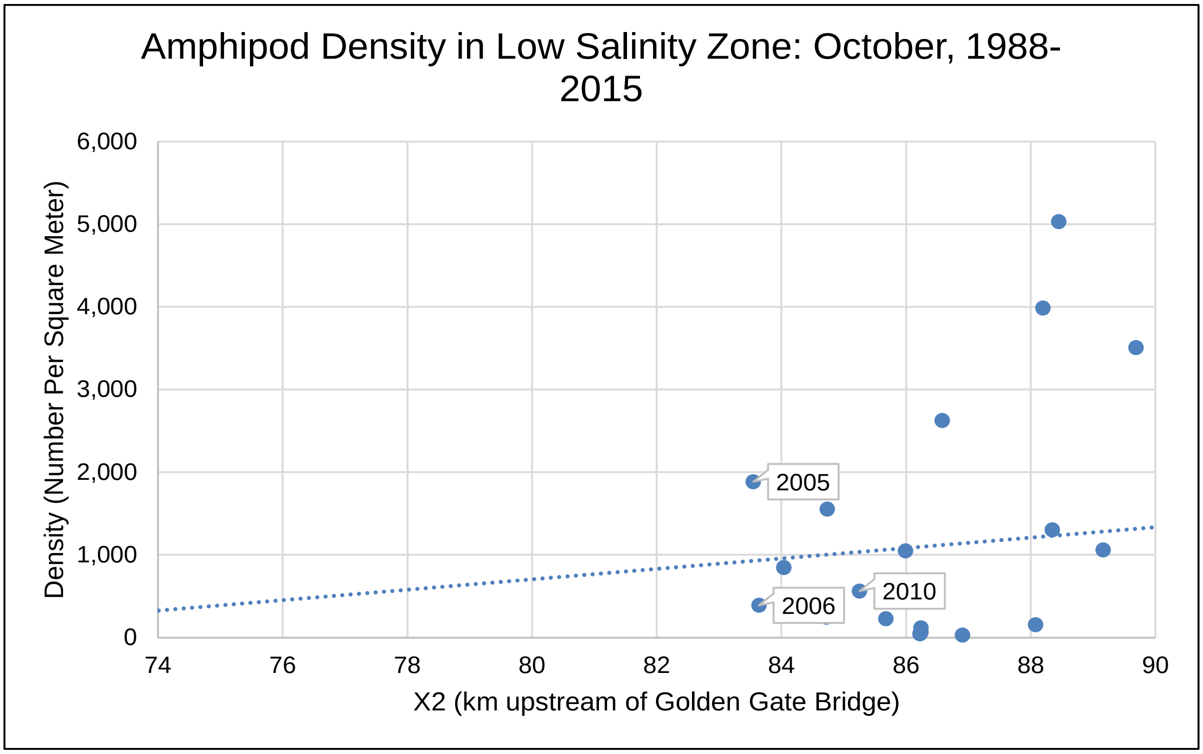


Figure 90. Mean October Amphipod Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 1988-2016.

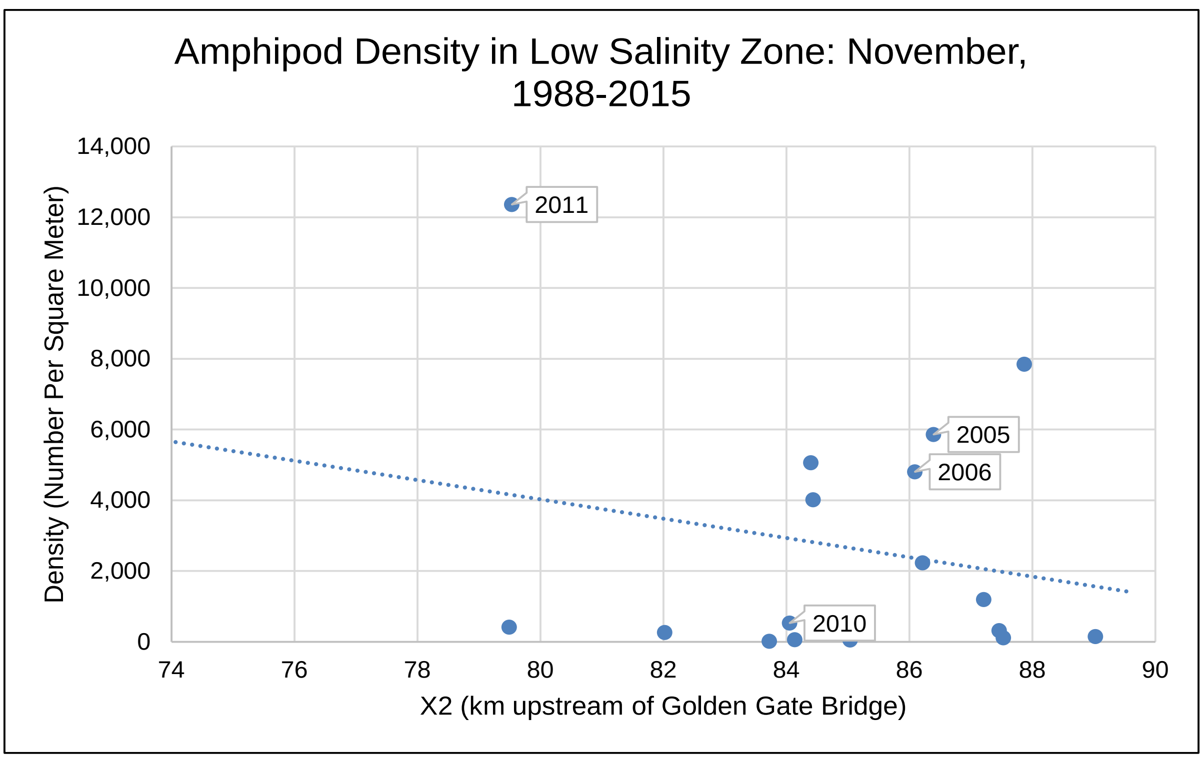


Figure 91. Mean November Amphipod Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 1988-2016.

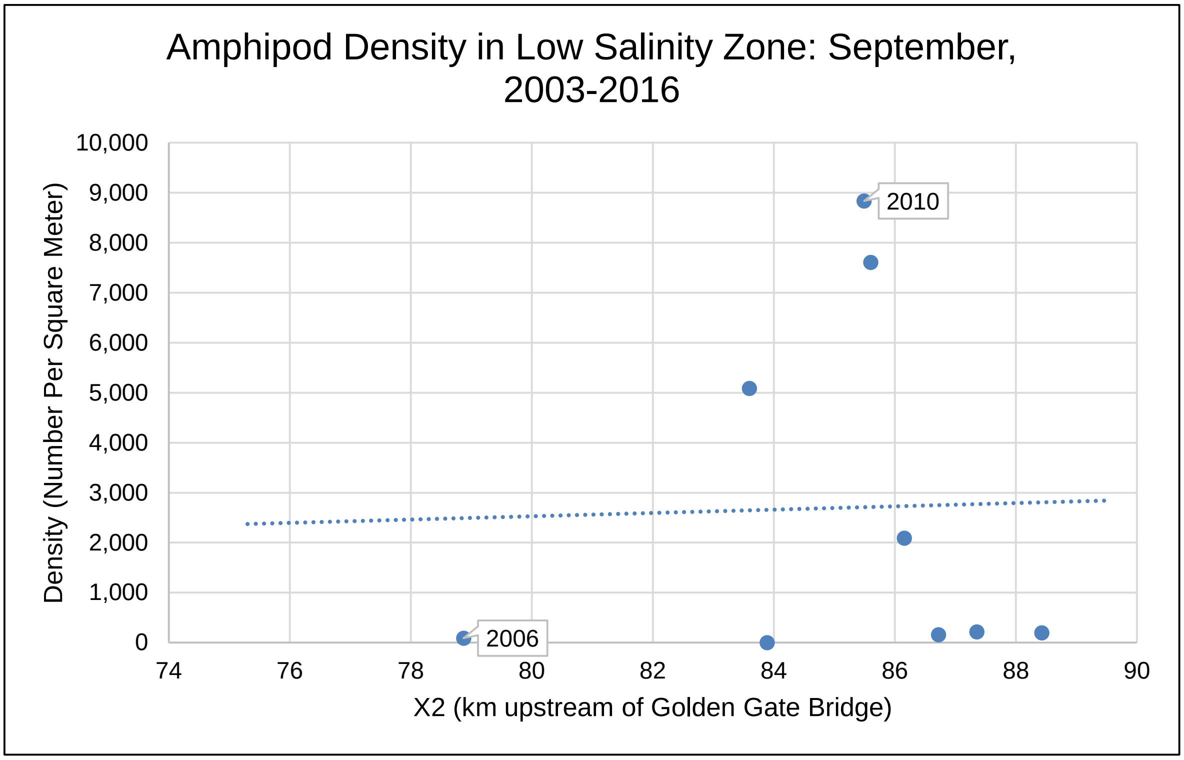


Figure 92. Mean September Amphipod Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 2003-2016.

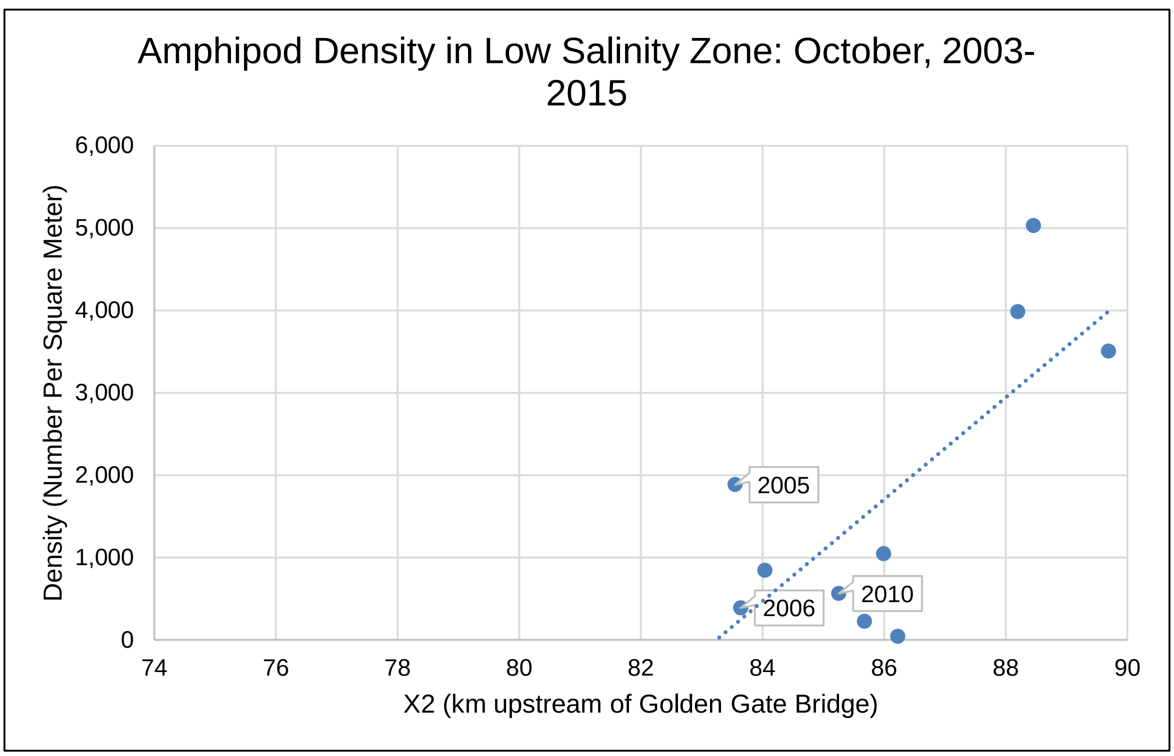


Figure 93. Mean October Amphipod Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 2003-2015.

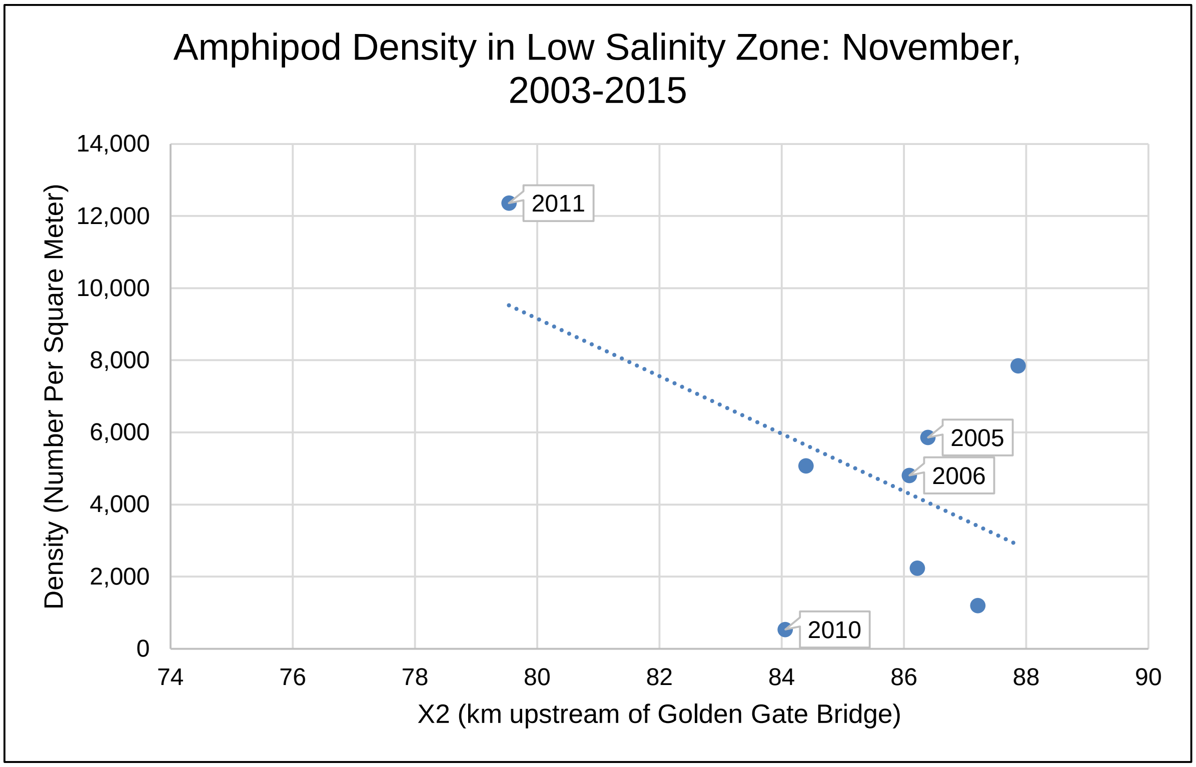
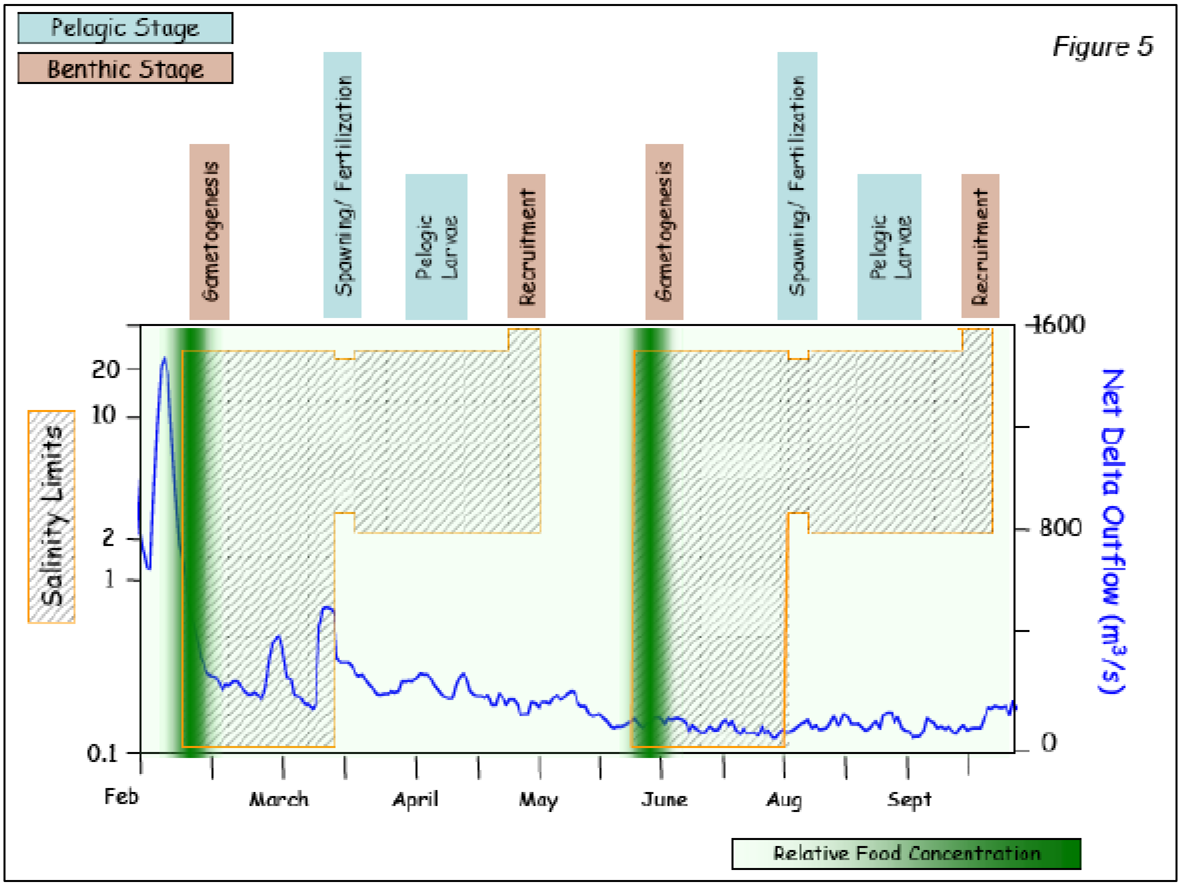


Figure 94. Mean November Amphipod Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 2003-2015.

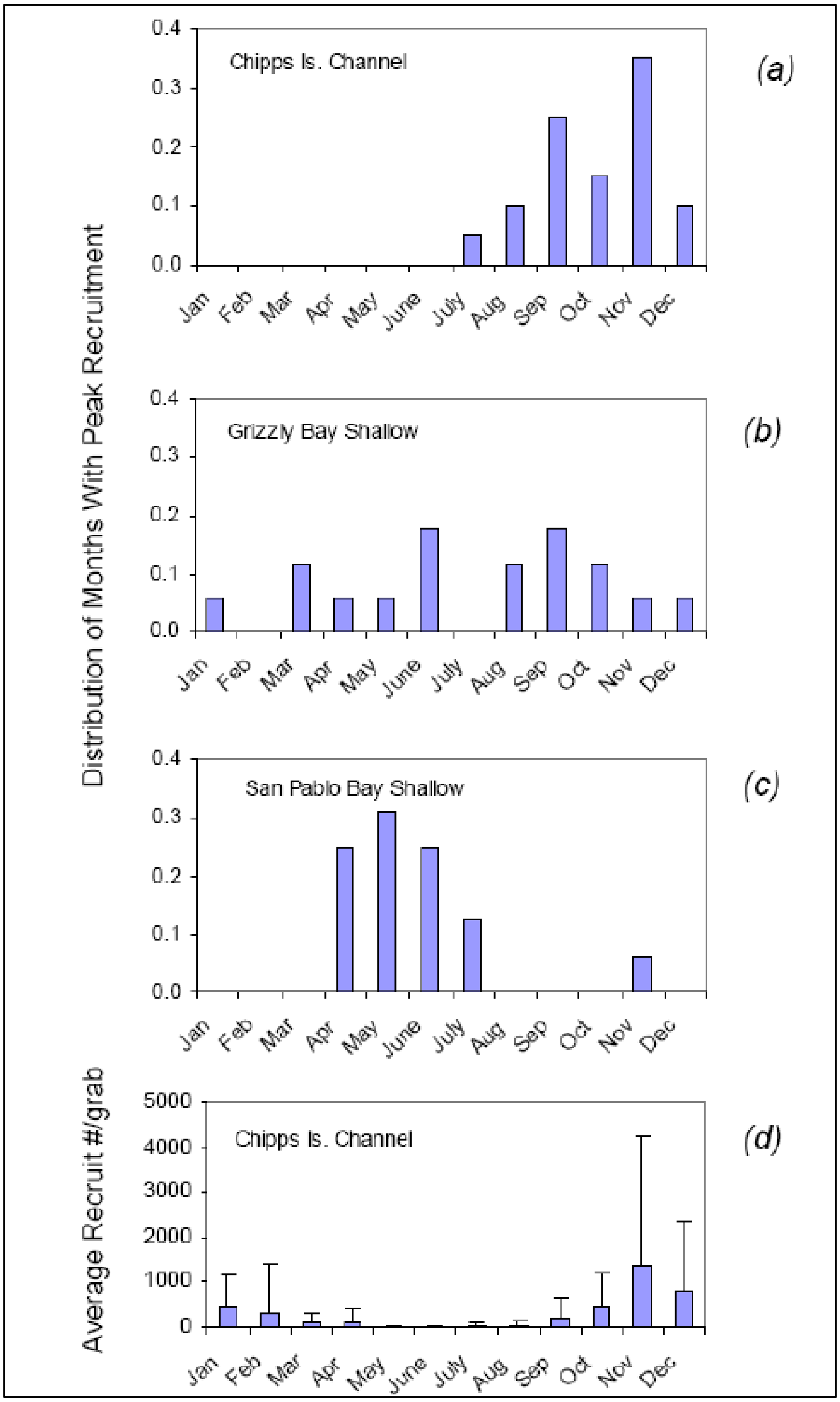
Potamocorbula Density

The life history of *Potamocorbula* is such that recruitment is limited by salinity of 2-25 and one of two annual events occurs in the fall (Figure 95), with upstream distribution being related to the extent of Delta outflow (Thompson and Parchaso 2012). Recruitment can be protracted, and at the upstream end of the geographic range tends to peak in fall (Figure 96). The same benthic monitoring data processed for amphipods were used to assess the relationship of *Potamocorbula* density within the low salinity zone to fall X2, following the basic prediction of the FLaSH investigations that biomass would be greater with higher X2 (Table 4).



Source: Figure 5 by Thompson and Parchaso (2012). Note: This conceptual diagram does not account for the variability in recruitment (Figure 48).

Figure 95. Life Cycle and Conceptual Model for *Potamocorbula*.



Source: Figure 2 by Thompson and Parchaso (2012).

Figure 96. Distribution of Months with Peak *Potamocorbula* Recruitment.

As noted for amphipods, the limited number of stations for analysis meant that there were some constraints on the inferences for the potential effects of the proposed 2017 Fall X2 action. A general upward trend in *Potamocorbula* density with increasing X2 was evident for September, although data were absent for X2 of 74 km and ~79-83 km (Figure 97). Absence of observations below X2~84 km in October precludes firm conclusions for this month (Figure 98), whereas November had sufficient data to include X2 below 80 km (including 2011) and there was a generally increasing trend in density with greater X2, with highest density beginning at X2~84 km (Figure 99). The available information tends to support the basic predictions of the FLaSH investigations (lower *Potamocorbula* biomass in the low salinity zone with lower X2), although the FLaSH investigations did not find support when considering biomass (Table 4). As noted in the FLaSH report (Brown et al. 2014: p. 56), various factors such as hydrodynamics and water depth in different areas can complicate the potential effect of *Potamocorbula* beyond simply considering biomass (or density, as herein). Nevertheless, across a broader suite of years, density of *Potamocorbula* in the low salinity zone was higher with greater X2, although the implications for 2017 are somewhat uncertain given that increases in density occurred at higher mean X2 (i.e., X2 > 84 km; Figures 97 and 98) than is proposed in October 2017 (i.e., no greater than 81 km; possibly ~78 km based on available forecasts; Figure 13, Table 1). Limiting the analysis to the POD regime (2003-2015/2016) resulted in somewhat less support for the FLaSH hypothesis (Figures 100, 101, 102), and reduced further the number of datapoints within the X2 range of interest (74-81 km). Ultimately, the density of copepods did not vary in relation to X2 (see *Invertebrate Prey Density* analysis), so that the effects of X2 on *Potamocorbula* in the low salinity zone do not appear to have translated into effects on Delta Smelt prey, particularly at the range of X2 that could occur in October 2017 (up to 81 km, although probably lower based on available forecasts; Figure 13, Table 1). The planned monitoring for 2017 includes evaluation of clam density and location, which will allow more informed assessment of these potential effects.

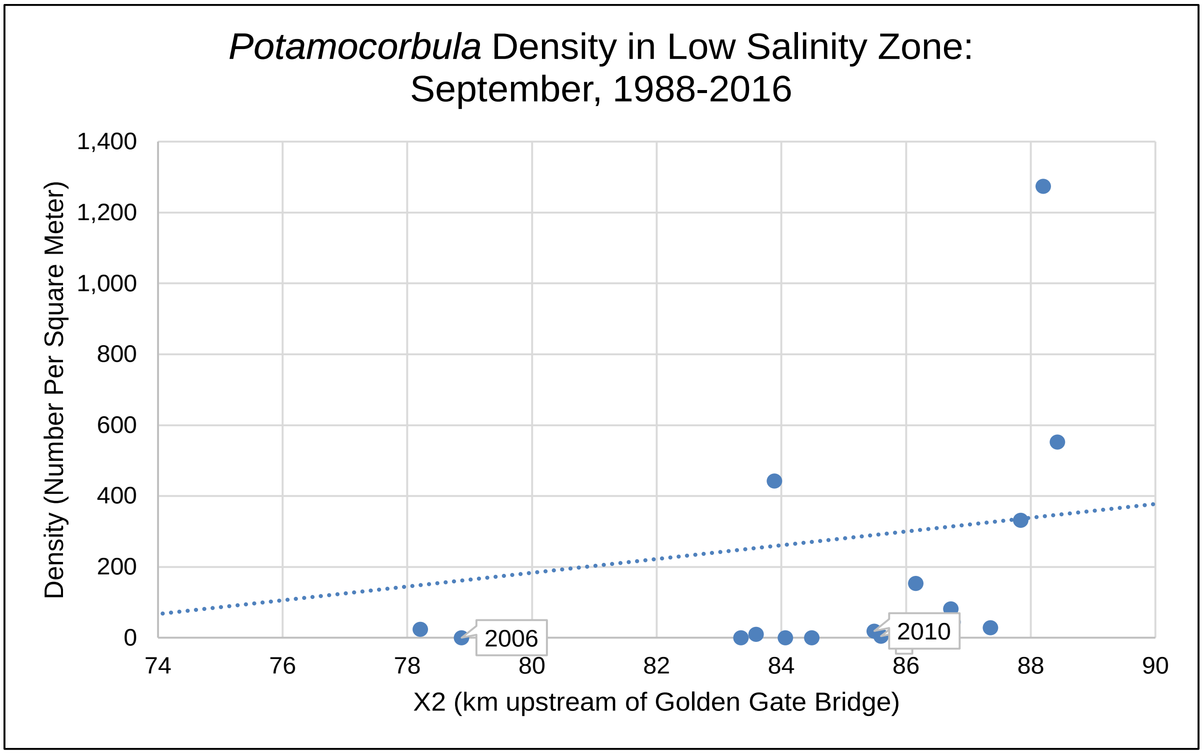


Figure 97. Mean September *Potamocorbula* Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 1988-2016.

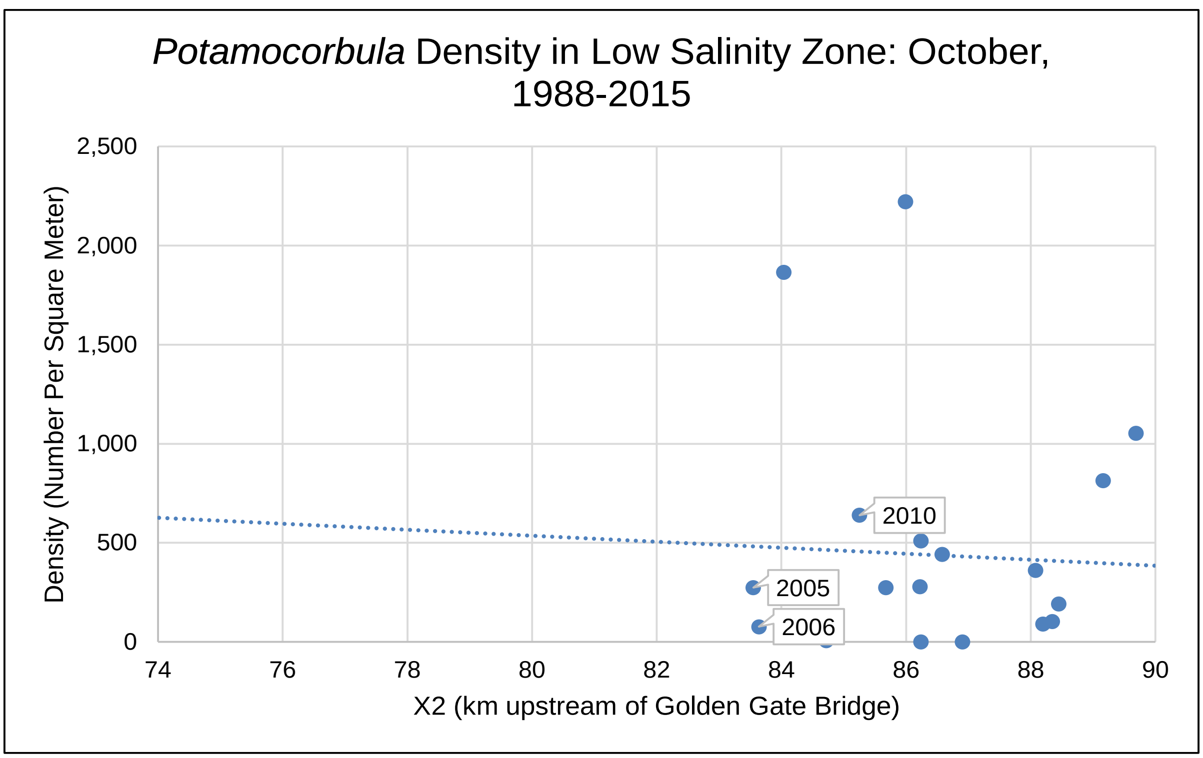


Figure 98. Mean October *Potamocorbula* Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 1988-2015.

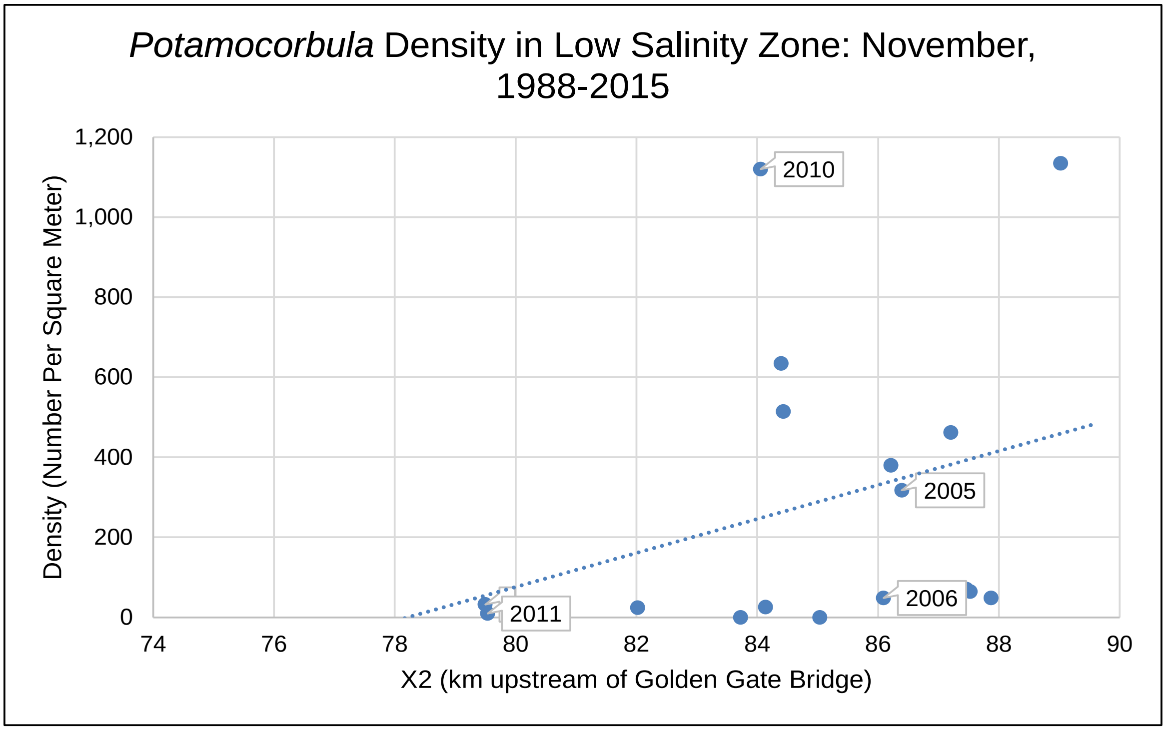


Figure 99. Mean November *Potamocorbula* Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 1988-2015.

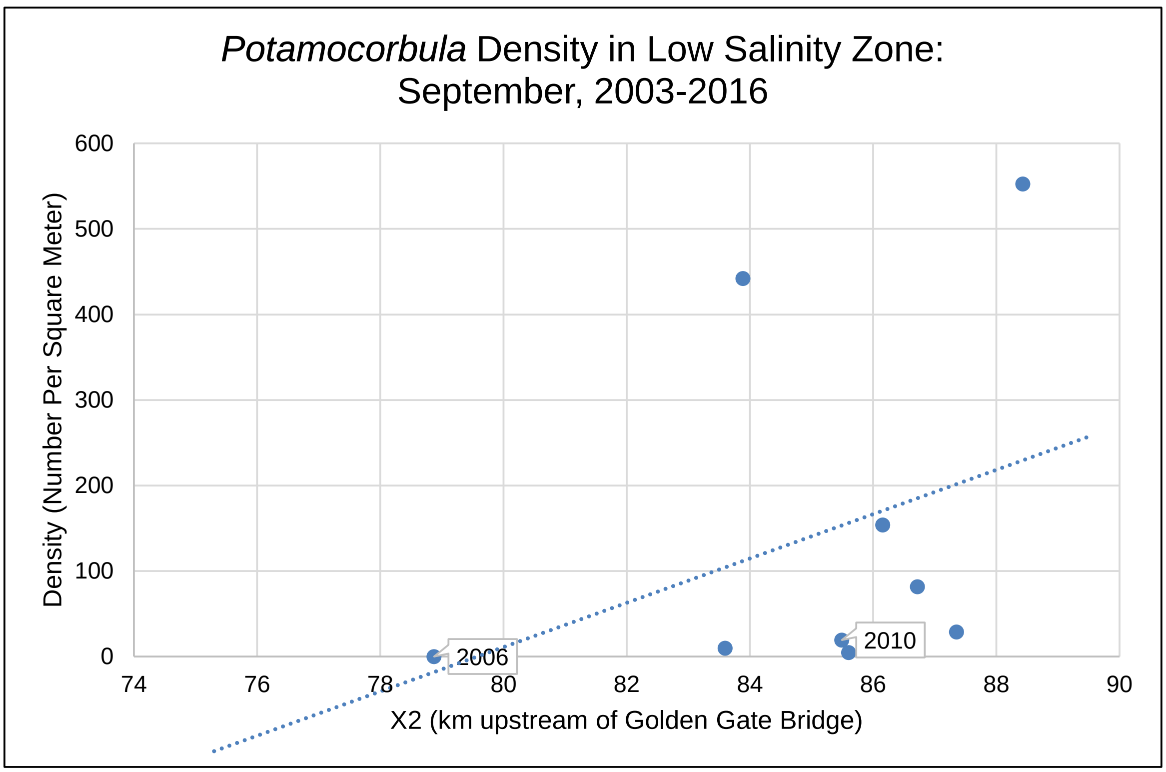


Figure 100. Mean September *Potamocorbula* Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 2003-2016.

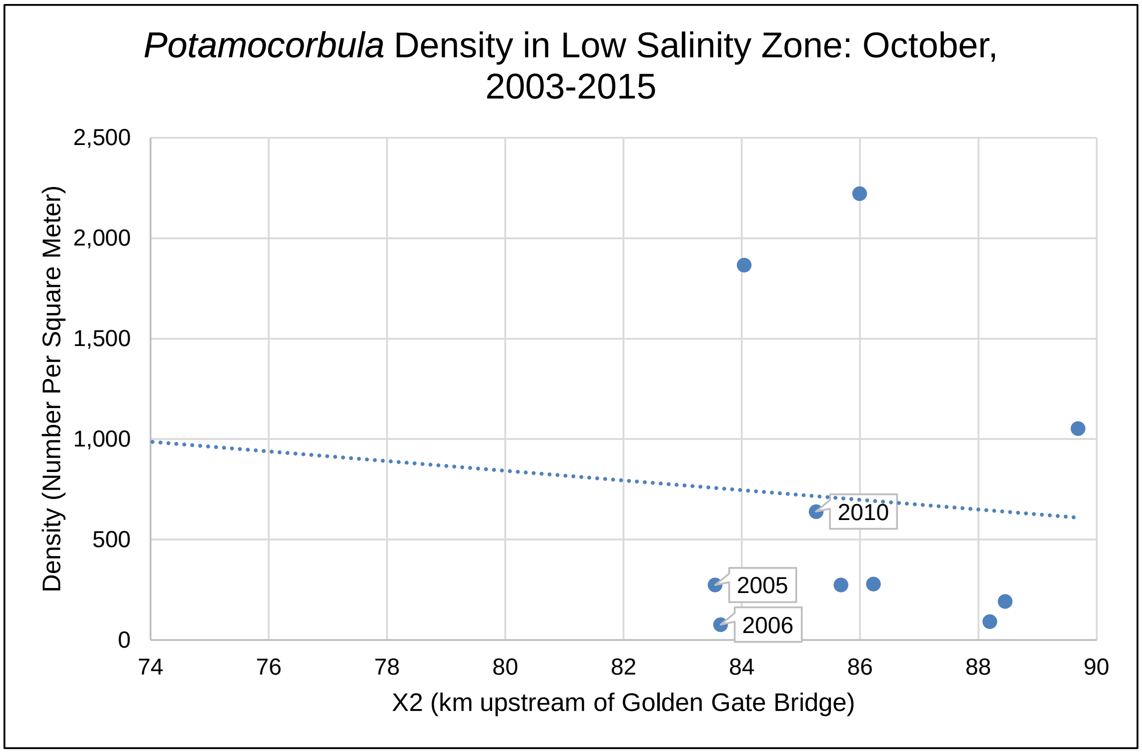


Figure 101. Mean October *Potamocorbula* Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 2003-2015.

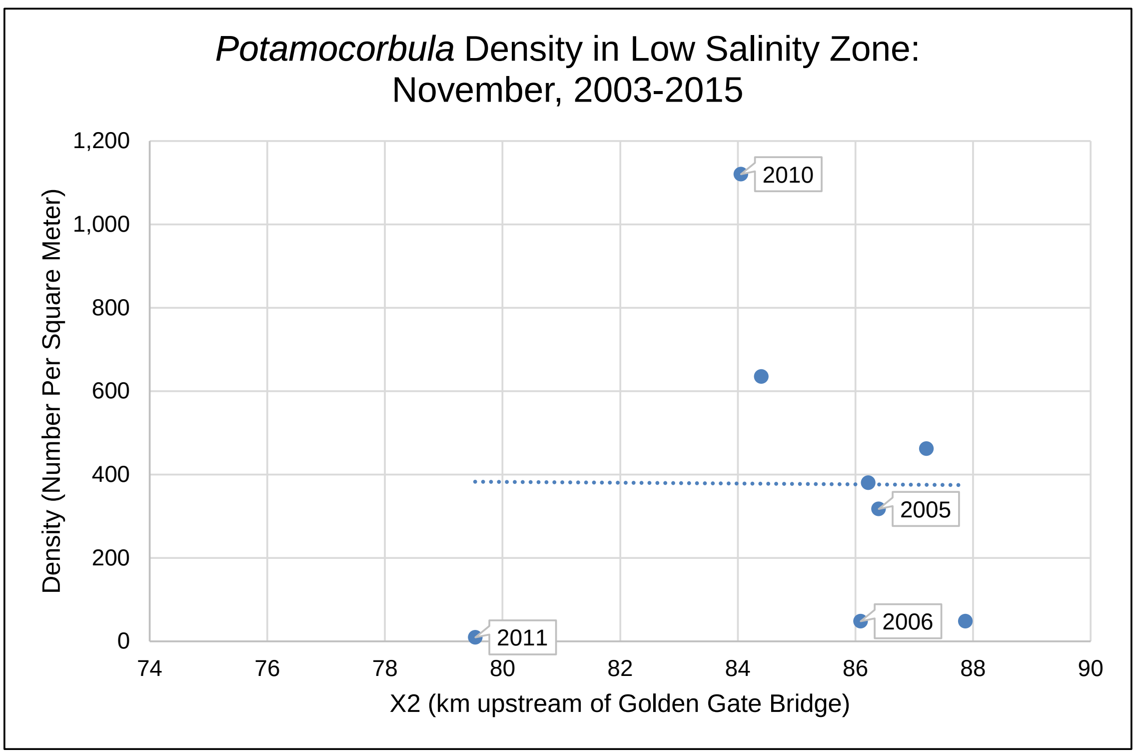
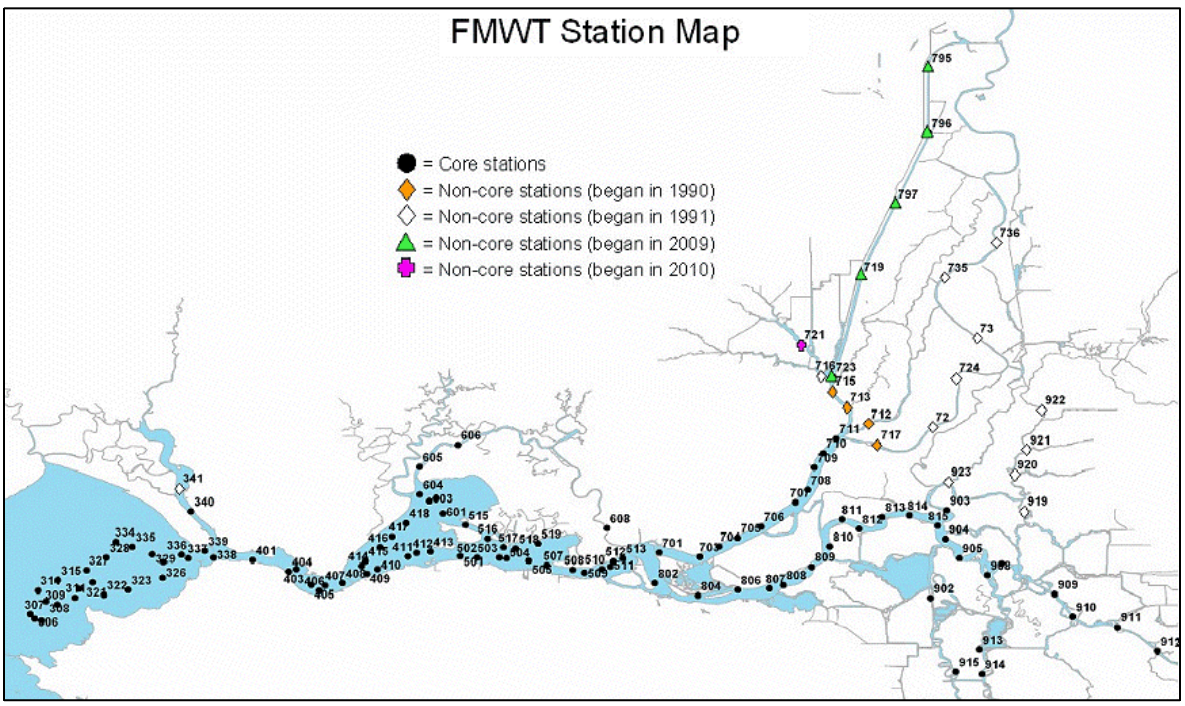


Figure 102. Mean November *Potamocorbula* Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Benthic Survey Data versus Mean X2 from 2003-2015.

Microcystis Density

The FLaSH investigations predicted that *Microcystis* density in the low salinity zone would be lower with lower X2, presumably because the low salinity would be farther away from the Delta areas where *Microcystis* occurs, and greater outflow would lead to lower residence time, allowing bloom accumulation (Lehman et al. 2013). The potential for *Microcystis* density to be influenced by fall X2 was investigated using fall midwater trawl survey data[23] and the qualitative ranking scale that was adopted in 2007. The survey covers a broad portion of the estuary (Figure 103), data were subsetted to only include index stations, and specific conductance data were converted to salinity (Schemel 2001); only stations occurring in the low salinity zone (salinity 1-6) for a given survey were included. Although the data are recorded on a qualitative 5-point ranking scale ranging from 1 (absent) to 5 (very high), the data were simplified to presence and absence given that 85% of observations with *Microcystis* present were categorized as 'low'; this data treatment is consistent with the FLaSH investigations (Brown et al. 2014: their Figure 37). Percentage presence of *Microcystis* by month was then examined in relation to mean X2.



Source: http://www.dfg.ca.gov/delta/data/fmwt/stations.asp

Figure 103. Fall Midwater Trawl Survey Stations.

Microcystis presence in the low salinity zone was variable during 2007-2015/2016 (Figure 104). Data in the range 74-81 km were relatively sparse for assessing the potential effects of the proposed

[23] ftp://ftp.dfg.ca.gov/TownetFallMidwaterTrawl/FMWT%20Data/FMWT%201967-2016%20Catch%20Matrix_updated.zip

2017 Fall X2 action, with a higher percentage (>40%) of *Microcystis* occurring at considerably higher X2 (≥85 km) than could occur in October 2017. The positive trend in the October data was not supported by a significant linear regression ($P = 0.15$) because of high variability at higher X2. Overall, the data are limited for assessing the potential for effects on Delta Smelt food availability in the low salinity zone from *Microcystis*, although given that most *Microcystis* presence observations were categorized as 'low' density, and presence was highly variable at high X2, there is no evidence to support that X2 of 81 km (or intermediate values from available forecasts, such as ~78 km; Figure 13, Table 1) compared to 74 km in October would result in appreciable increases in *Microcystis*. Lehman et al. (2013) found that *Microcystis* occurs across a broad range of environmental conditions, which are not linearly correlated with abundance. The high variability and generally low density also gave only weak support for the FLaSH investigation prediction of greater *Microcystis* with greater X2 (Table 4).

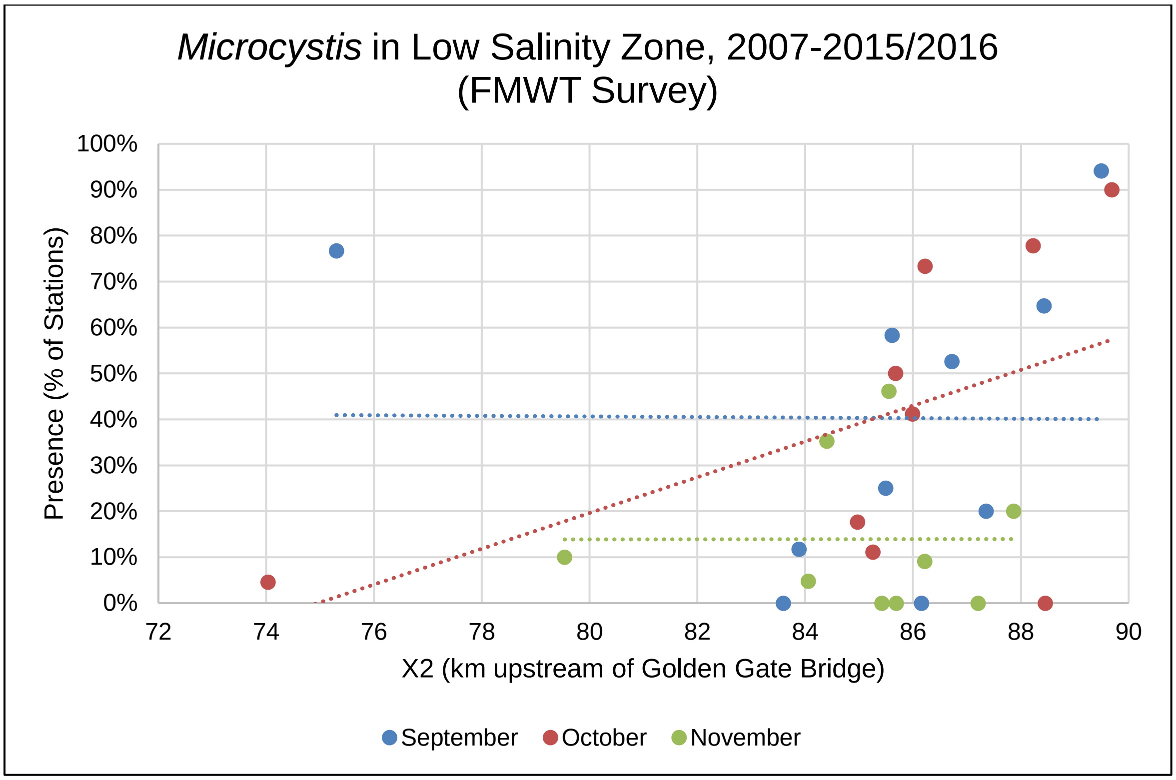


Figure 104. ***Microcystis*** **Presence in the Low Salinity Zone (Salinity = 1 to 6) from Fall Midwater Trawl Survey Data versus Mean X2 from 2007-2015/2016.**

Water Clarity in the Low Salinity Zone

The FLaSH investigations hypothesized that water clarity in the low salinity zone would be greater with lower X2 (Table 4). Several data sources were used to assess the potential for the proposed 2017 Fall X2 action to influence water clarity in the low salinity zone, which is a critical habitat attribute for Delta Smelt (Sommer and Mejia 2013). The previously discussed IEP EMP zooplankton survey and fall midwater trawl survey data provided data for a number of stations that were subsetted based on monthly presence within the low salinity zone. Data were also analyzed for turbidity/suspended sediment monitoring stations from the California Data Exchange Center (CDEC) and US Geological Survey (USGS), to assess the extent to which X2 (representing Delta outflow) affects water clarity. Monitoring data were limited to the period from 1984 onwards, reflecting the large downward step change in water clarity (total suspended solids) in Suisun Bay after the 1983 El Niño floods, albeit with a subsequent weakly declining trend (Hestir et al. 2013).

IEP EMP Zooplankton Survey Secchi Disk Data

Secchi disk data from the IEP EMP zooplankton survey (processed as previously described in *Calanoid Copepods*) were assessed to examine the relationship between water clarity and mean X2 in the low salinity zone. Mean Secchi disk depth in fall was quite variable, but was positively related to mean X2 (Figure 105). The statistically significant linear regression for the month of October predicts a Secchi disk depth of 36.0 cm with X2 = 74 km, and 45.5 cm with X2 = 81 km. Based on the relationships between Delta Smelt probability of occurrence and Secchi Disk depth from Feyrer et al. (2007: their Figure 4b), this would give habitat quality (represented by probability of occurrence[24]) in the low salinity zone of ~0.32 at 74 km and ~0.25 at 81 km. This represents a reduction of ~22% at X2 = 81 km. Predicted Secchi disk depth for an intermediate value of October X2 based on available forecasts (~78 km; Table 1) would be 41 cm, compared to 35 cm for the forecasted X2 (~73 km) with implementation of the Fall X2 action as prescribed in the USFWS (2008) BiOp; this would result in habitat quality of ~0.27 at 78 km and ~0.33 at 73 km, or a relative difference of ~18%.

Repeating the analysis to include only POD-regime years (2003-2015/2016) also gave a statistically significant linear regression for October (Figure 106). This regression predicts a greater difference in Secchi depth between X2 of 74 km (39 cm) and 81 km (52 cm), which translates into habitat quality of ~0.29 at X2 = 74 km and ~0.21 at X2 = 81 km; this is a difference of ~28%. Using the forecasted values of X2 (Table 1), predicted Secchi depth would be 37 cm at X2 = 73 km and 47 cm at X2 = 78 km; this would result in habitat quality of 0.31 (at 73 km) and 0.23 (at 78 km), a difference of ~26%.

Greater Secchi disk depth in the low salinity zone at higher X2 was a supported prediction of the FLaSH investigations (Table 4). Note, however that the results observed herein could reflect the effect of antecedent conditions: generally high outflow in wetter years would lead to greater amounts of sediment for resuspension in the low-flow, fall months of such years, which would tend to give lower fall Secchi disk depth measurements at times when fall X2 would be relatively low (because of antecedent conditions). Monitoring planned for 2017 can further test this assumption given the high flow nature of the first half of 2017 followed by lower flows in late summer.

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[24] It is also possible that the probability of occurrence reflects catchability, with decreased catchability occurring at higher Secchi depth if Delta Smelt evade the net more readily (Latour 2016).

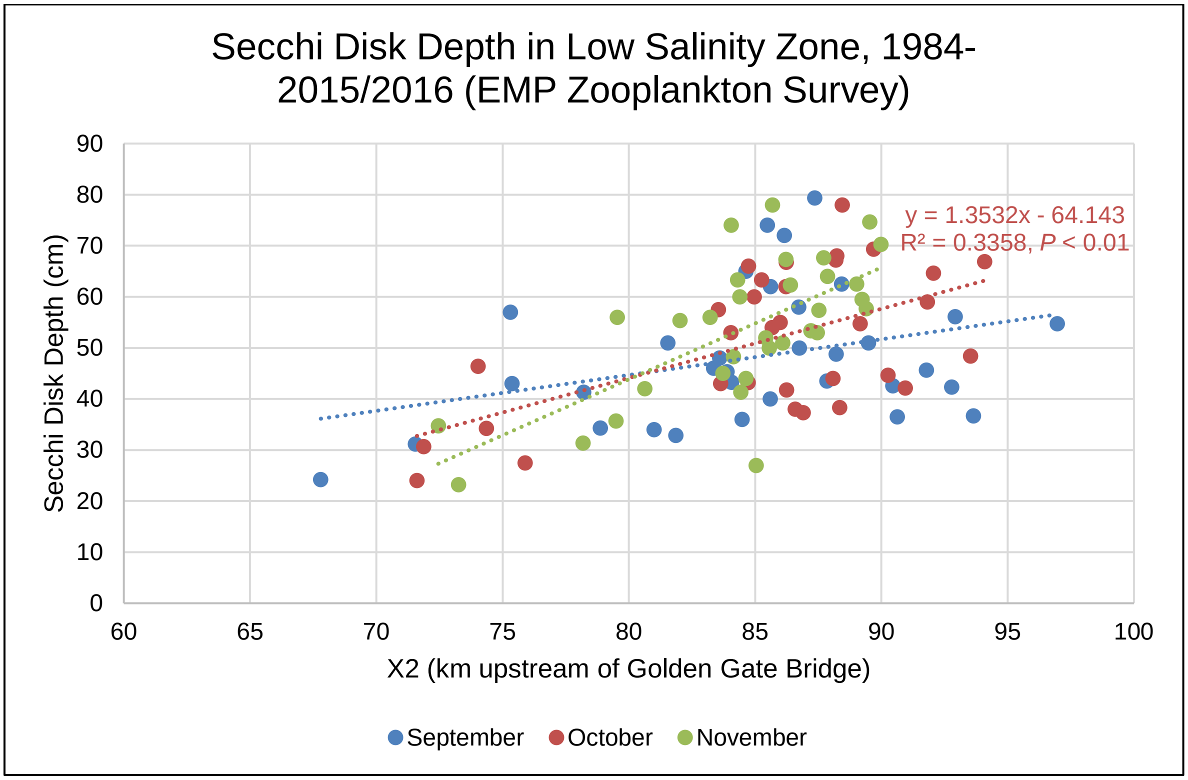


Figure 105. Mean Secchi Disk Depth in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data versus Mean X2 from 1984-2015/2016.

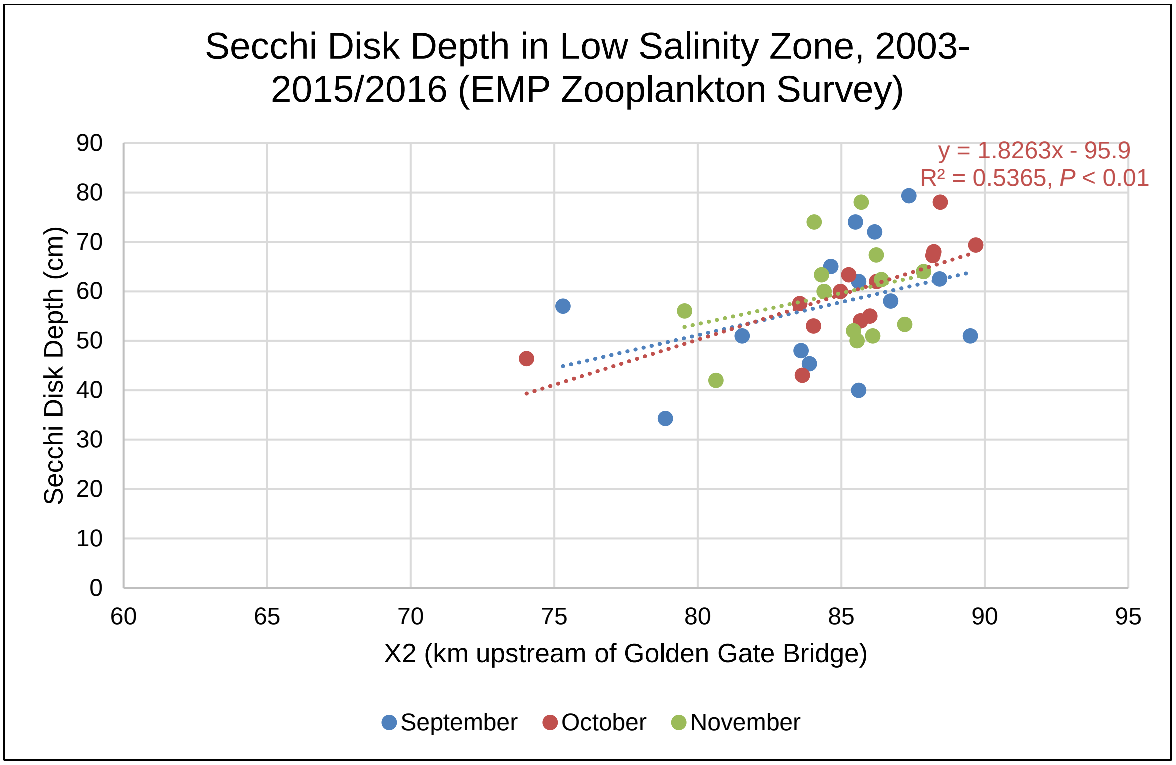


Figure 106. Mean Secchi Disk Depth in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data versus Mean X2 from 2003-2015/2016.

FMWT Secchi Disk Data

The fall midwater trawl data processed for the Microcystis *Density* analysis described previously were used in a similar manner to the zooplankton survey data to analyze the relationship between Secchi disk depth in the low salinity zone and fall X2. As with the zooplankton analysis, there was a positive relationship between X2 and Secchi disk depth (Figure 107). The significant regression relationship for October predicts a Secchi disk depth of 0.40 m with X2 = 74 km, and 0.48 m with X2 = 81 km, which are very similar estimates to those from the zooplankton survey. This would equate to Delta Smelt probability of presence of ~0.28 at 74 km and ~0.23 at 81 km (Feyrer et al. 2007), or an ~18% reduction at 81 km relative to 74 km. Using the forecasted estimates of mean X2 in October (Table 1), Secchi disk depth would be predicted to be 0.39 m with X2 = 73 km and 0.45 m with X2 = 78 km, giving probability of presence of Delta Smelt of ~0.29 at X2 = 73 km and ~0.25 at X2 = 78 km; this is a difference of ~14%.

Repeating the analysis to include only POD-regime years (2003-2015/2016) gave a marginally statistically significant linear regression for October (Figure 108). This regression predicts Secchi depth of 0.42 m at X2 = 74 km and Secchi depth of 0.53 m at X2 = 81 km, which translates into habitat quality of ~0.26 at X2 = 74 km and ~0.19 at X2 = 81 km; this is a difference of ~27%. Using the forecasted values of X2 (Table 1), predicted Secchi depth would be 41 cm at X2 = 73 km and 48 cm at X2 = 78 km; this would result in habitat quality of 0.27 (at 73 km) and 0.23 (at 78 km), a difference of ~19%.

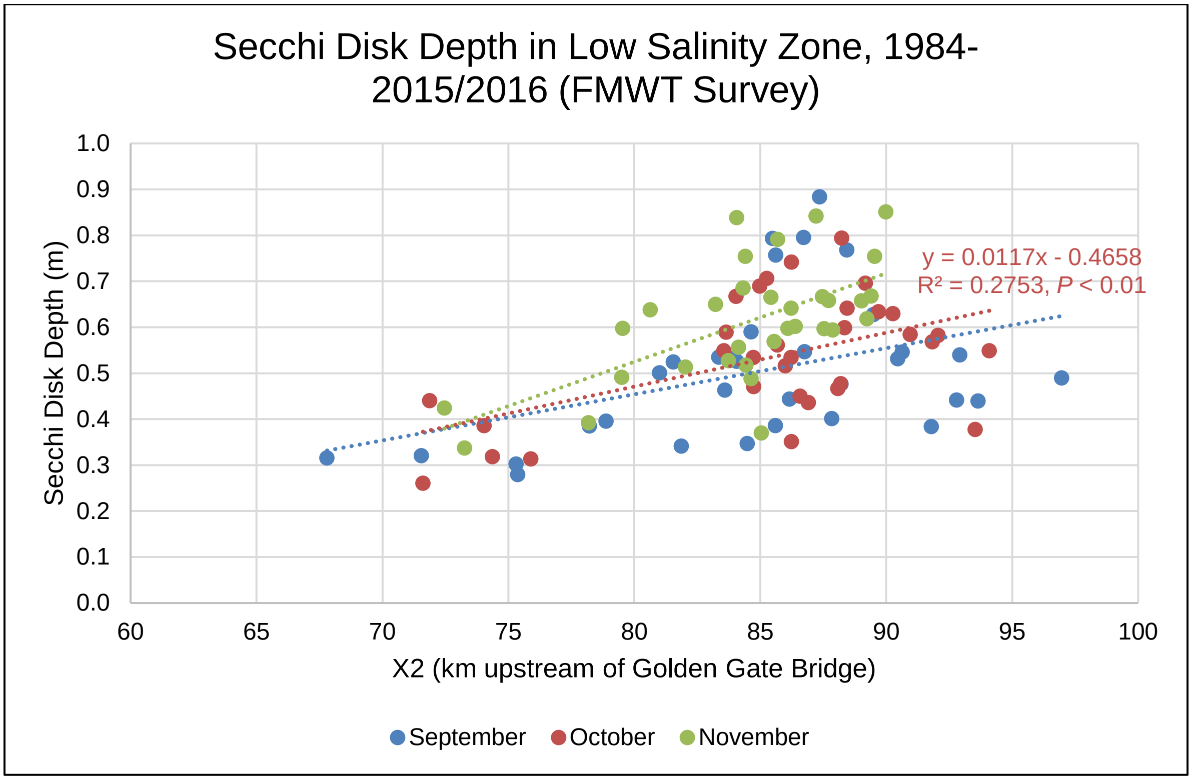


Figure 107. Mean Secchi Disk Depth in the Low Salinity Zone (Salinity = 1 to 6) from Fall Midwater Trawl Survey Data versus Mean X2 from 1984-2015/2016.

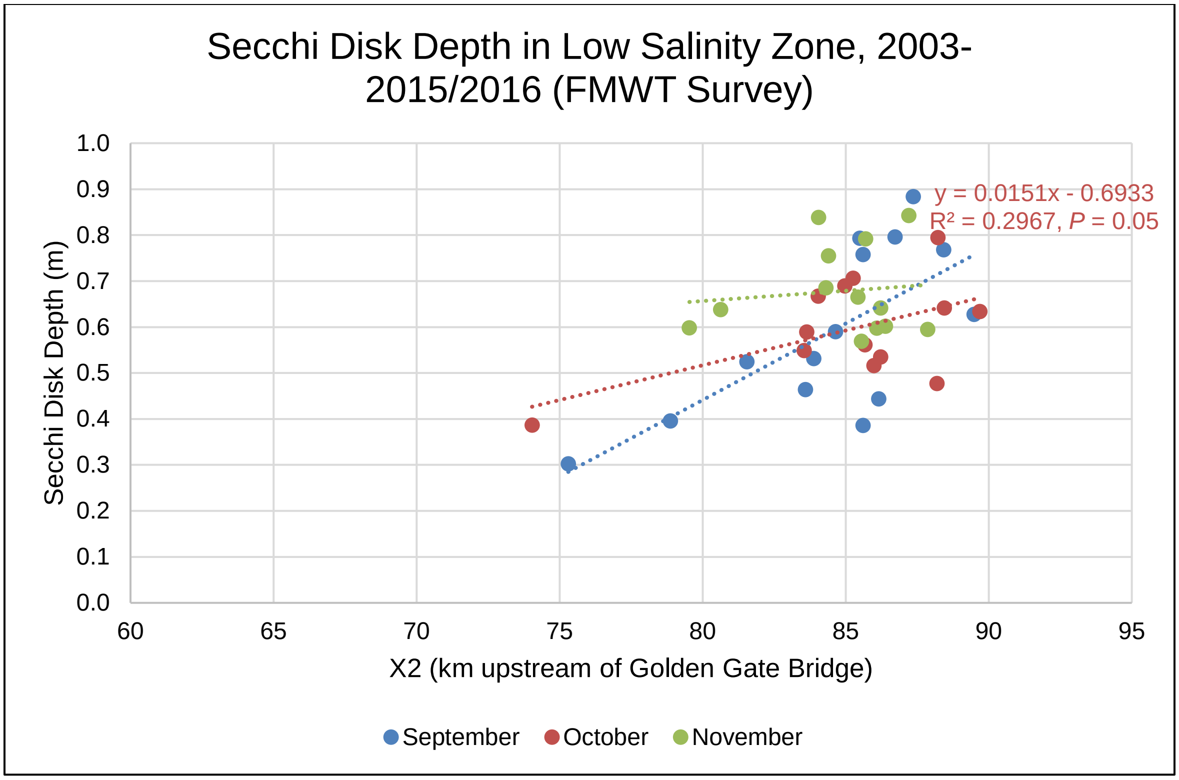


Figure 108. Mean Secchi Disk Depth in the Low Salinity Zone (Salinity = 1 to 6) from Fall Midwater Trawl Survey Data versus Mean X2 from 2003-2015/2016.

CDEC Data

As previously noted, CDEC data[25] were used to assess changes in turbidity in relation to fall X2 for a number of fixed monitoring locations: Rio Vista Bridge (RVB), Antioch (ANH), Mallard Island (MAL), and Martinez (MRZ). These locations are within, just upstream, or just downstream of the low salinity zone. Available data included the period from 2008 onwards. There was little to suggest that X2 was related to turbidity at RVB (Figure 109) or Antioch (Figure 110), at least not with the inverse relationship that would be of concern from the perspective of Delta Smelt habitat. Inverse linear trends were apparent at MAL (Figure 111), although the October linear regression was not statistically significant ($P = 0.29$), which could be a function of few observations (n = 8) and relatively high variability at higher X2. At MRZ, inverse linear trends were also apparent (at least in September and October; Figure 112), but there was considerable variability at higher X2 and the October linear regression was not statistically significant ($P = 0.69$).

[25] https://cdec.water.ca.gov/cgi-progs/queryCSV

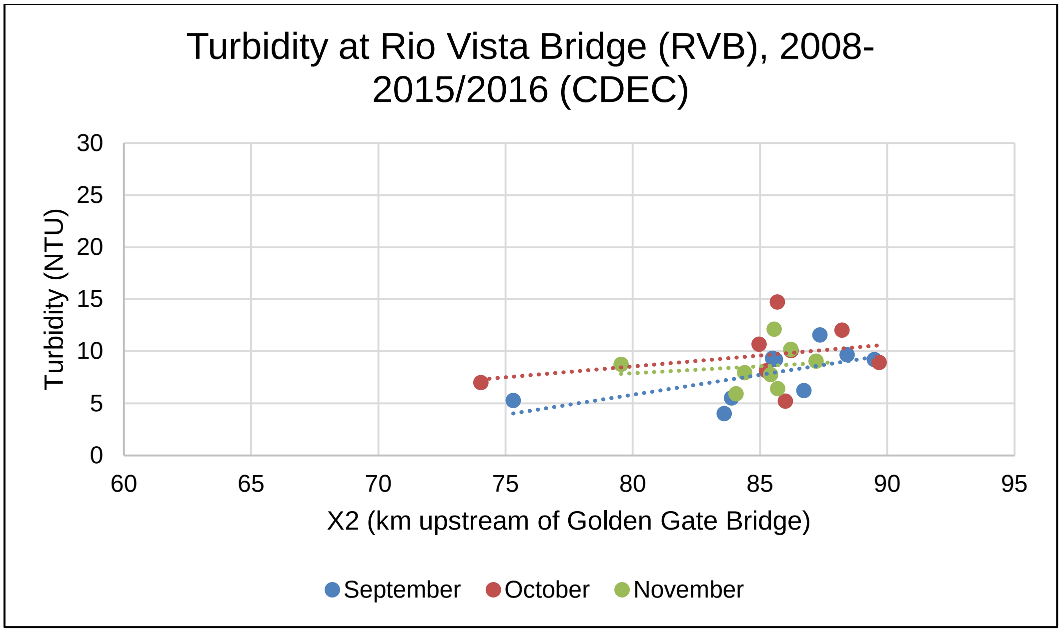


Figure 109. Mean Turbidity at Rio Vista Bridge (CDEC Station RVB) versus Mean X2 from 2008-2015/2016.

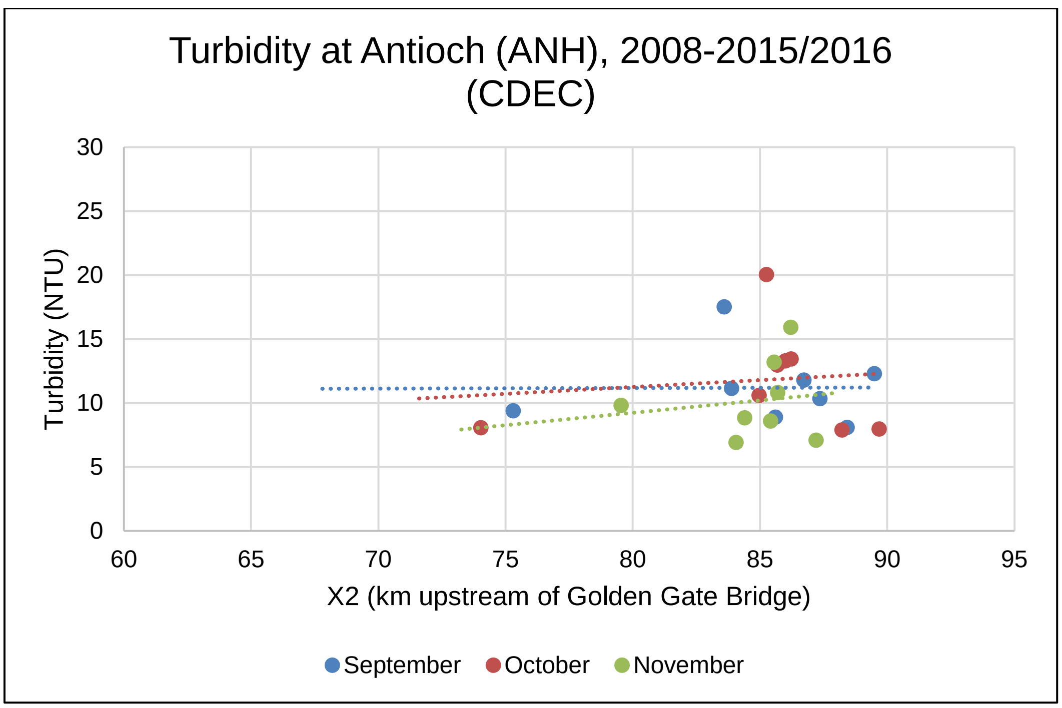


Figure 110. Mean Turbidity at Antioch (CDEC Station ANH) versus Mean X2 from 2008-2015/2016.

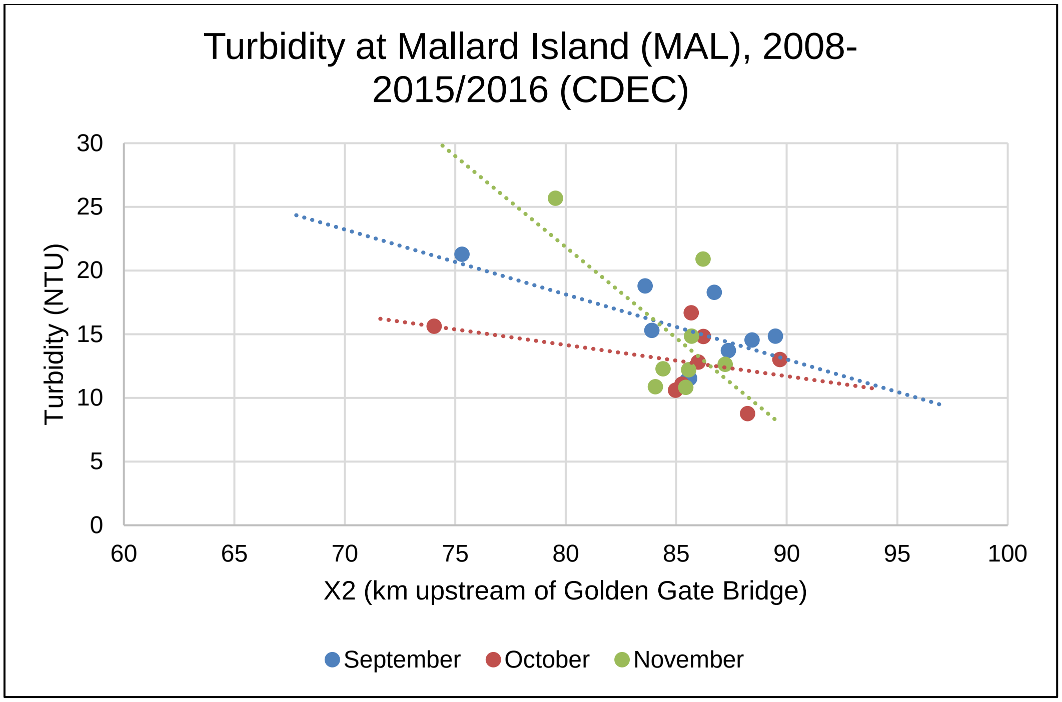


Figure 111. Mean Turbidity at Mallard Island (CDEC Station MAL) versus Mean X2 from 2008-2015/2016.

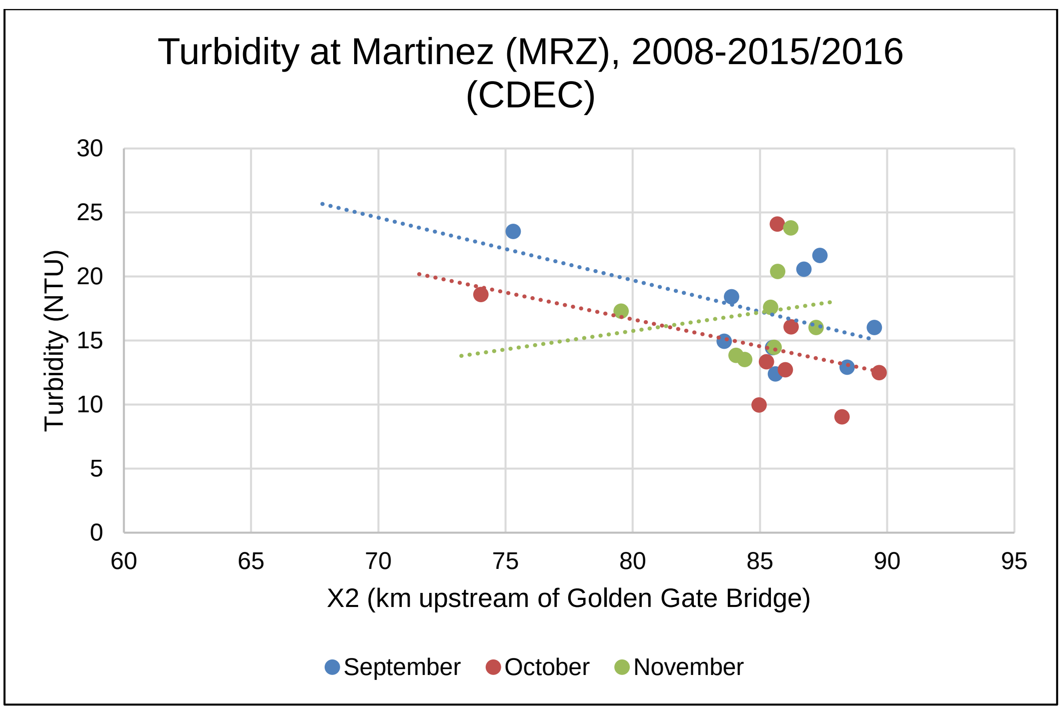


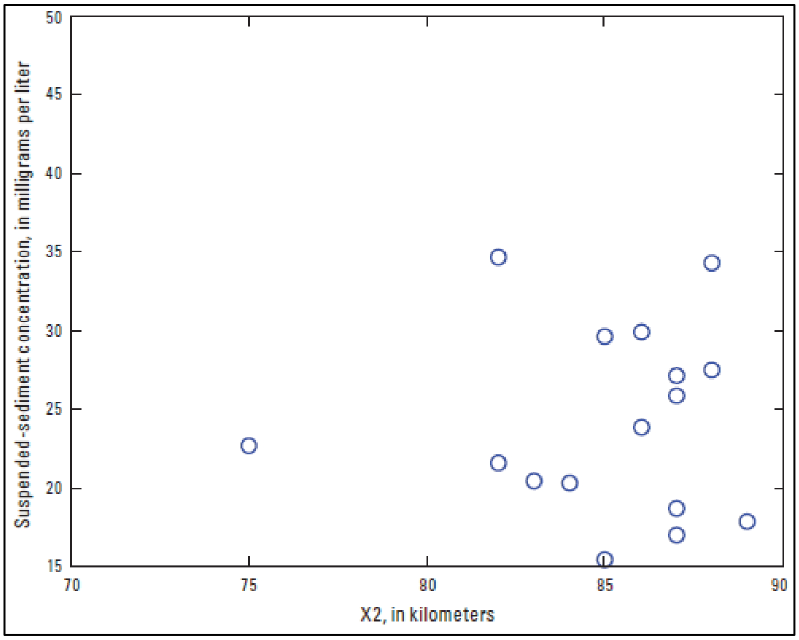
Figure 112. Mean Turbidity at Martinez (CDEC Station MRZ) versus Mean X2 from 2008-2015/2016.

USGS Data

Near-surface suspended sediment data for the USGS monitoring station 11185185 at Mallard Island were also examined for a relationship with X2. These were obtained from the same sources[26] as the analysis found in Appendix 5 of the FLaSH report (Brown et al. 2014). However, whereas the analysis presented in the FLaSH report did not find evidence for a relationship between X2 and suspended sediment concentration, SSC (Figure 113), the present effects analysis suggested an inverse relationship (Figure 114) in all months; linear regression for October gave a statistically significant result (P = 0.04). Although the FLaSH analysis calculated its values for September and October combined, this is unlikely to have driven the differences between the two analyses, as the time periods were similar. There appears to have been a different method used for estimating X2, as the present study included several values below 75 km, whereas the FLaSH report only had a single value (Figure 113). Based on the results from the present effects analysis, October X2 of 81 km would be predicted to give SSC of 28.0 mg/l vs. SSC of 33.0 mg/l if X2 was at 74 km. Applying a conversion between SSC and turbidity (Ganju et al. 2007) suggests that the approximate difference would be an average turbidity of ~21 NTU at X2 = 81 km and ~25 NTU at X2 = 74 km. These values are both well above the 12-NTU threshold of suitability for Delta Smelt (Sommer and Mejia 2013), suggesting little potential difference between X2 of 81 km vs. X2 of 74 km in October 2017 at this location; the same would be true for intermediate values of X2 that available forecasts suggest could occur (Table 1).

Limiting the analysis to the POD-era regime (2003-2015/2016) gave no significant linear regression between SSC and X2 in October (Figure 115), which provides further evidence that fall X2 (Delta outflow) would not be expected to affect suspended sediment at this location.

[26] https://ca.water.usgs.gov/cgi-bin/grapher/baydelta/table_setup.pl, http://waterdata.usgs.gov/ca/nwis/uv/?site_no=11185185&agency_cd=USGS&amp



Source: Brown et al. (2014: their Figure 5-1).

Figure 113. Near-Surface Suspended Sediment Concentration at Mallard Island as a Function of X2, September-October Mean Values, 1994-2011.

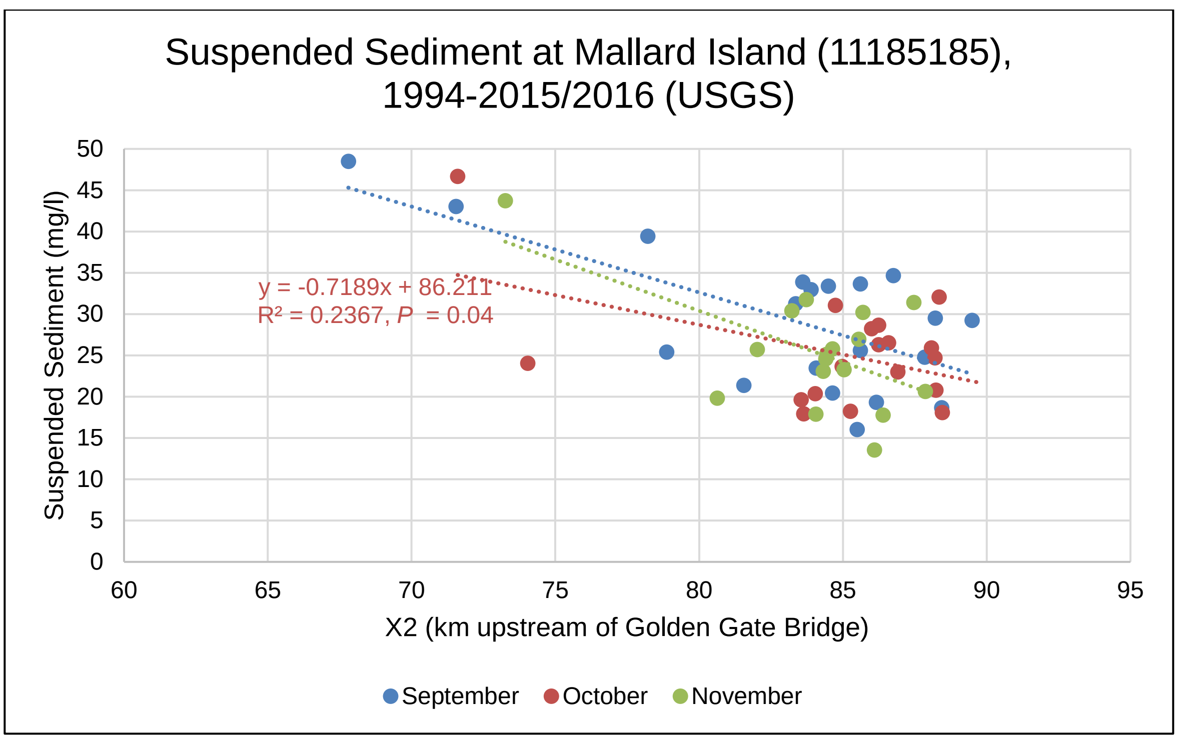


Figure 114. Mean Near-Surface Suspended Sediment Concentration at Mallard Island (USGS Station 11185185) versus Mean X2 from 1994-2015/2016.

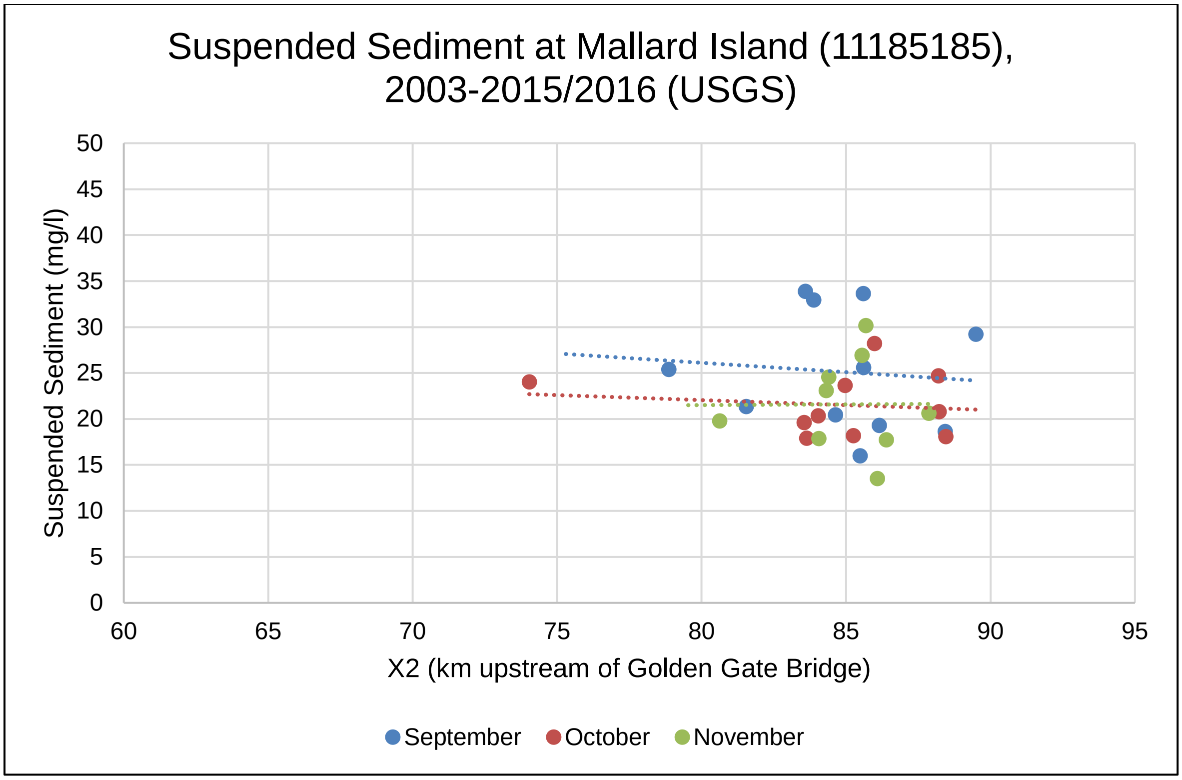


Figure 115. Mean Near-Surface Suspended Sediment Concentration at Mallard Island (USGS Station 11185185) versus Mean X2 from 2003-2015/2016.

Water Temperature in the Low Salinity Zone

Delta Smelt habitat generally occurs within the 7-25°C range (Sommer and Mejia 2013), and although temperature is an important predictor of occurrence in summer (Nobriga et al. 2008), it appears less so in fall (Feyrer et al. 2007). Analysis of potential water temperature effects in the low salinity zone was undertaken using the same basic framework as the analysis of water clarity: IEP EMP zooplankton survey and fall midwater trawl survey data to assess potential effects within the low salinity zone itself (as defined by salinity), together with CDEC data at several fixed monitoring locations to provide context for potential change at locations in or near the typical low salinity zone. These analyses were able to use relatively long duration time series because of the general lack of long-term trends in water temperature in the low salinity zone (IEP MAST 2015), although for consistency with the other analyses presented herein, data were also subsetted to consider the POD-era data (2003-2015/2016).

IEP EMP Zooplankton Survey Data

There were positive associations between water temperature in the low salinity zone and X2 for October and November (Figure 116). A statistically significant (P = 0.02) linear regression for October predicts mean temperature of 17.7°C with X2 of 74 km and 18.1°C with X2 of 81 km, although there is appreciable variability around the mean trend. Regardless of this variability, this small difference in water temperature would be expected to have little influence on habitat quality for Delta Smelt, based on the observed relationship between water temperature and probability of occurrence of Delta Smelt in the fall midwater trawl survey (Feyrer et al. 2007: their Figure 4a). Should X2 be closer to the forecasted X2 values, i.e., ~78 km for the proposed 2017 Fall X2 action compared to ~73 km as would occur if fall X2 were implemented as prescribed in the USFWS (2008) BiOp (Table 1), the differences in low salinity zone temperature would be even smaller. Repeating the analysis to consider only POD-era data (2003-2015/2016) gave no significant linear regression (P = 0.58; Figure 117), emphasizing the likely minimal effect of X2 on temperature in the low salinity zone.

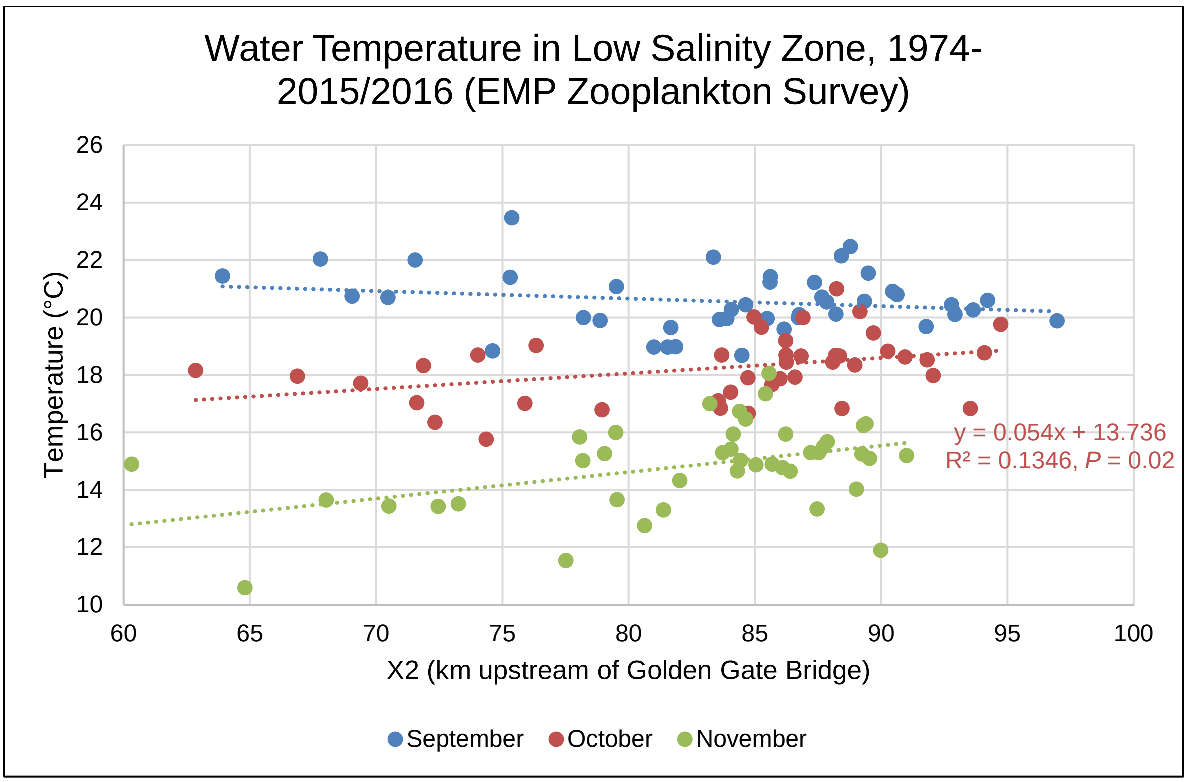


Figure 116. Mean Water Temperature in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data versus Mean X2 from 1974-2015/2016.

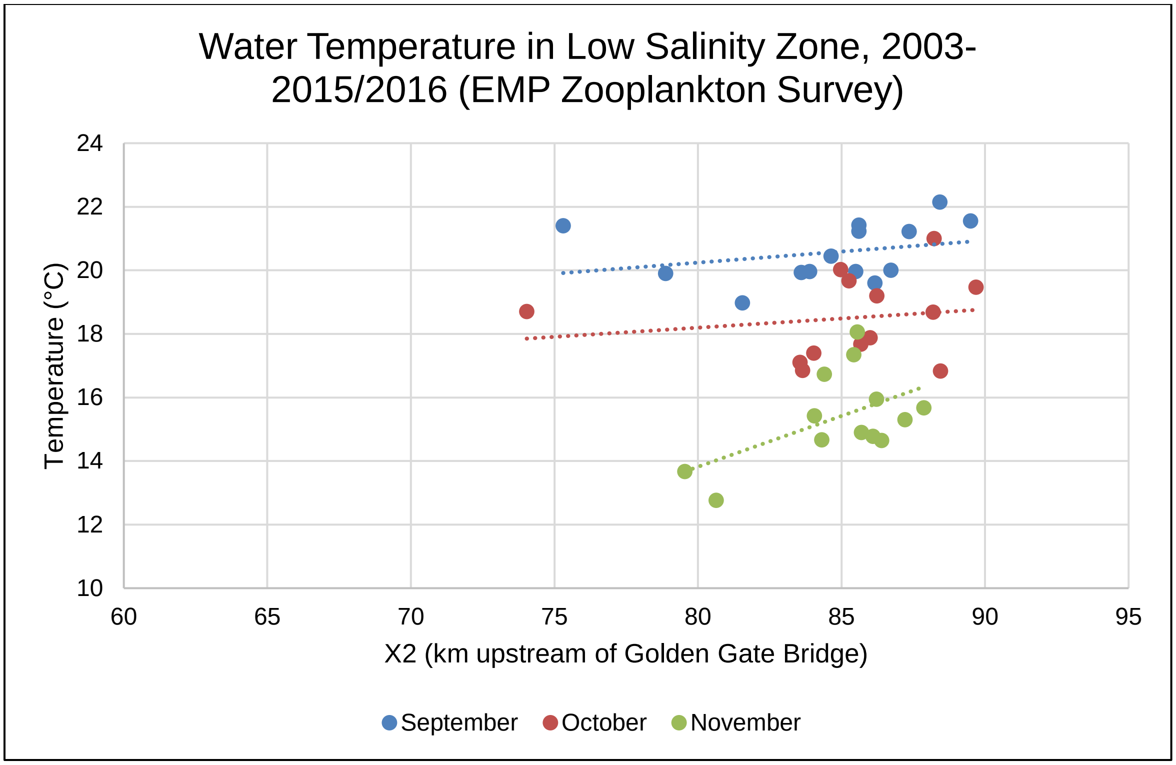


Figure 117. Mean Water Temperature in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data versus Mean X2 from 2003-2015/2016.

FMWT Data

As with the zooplankton survey data, the fall midwater trawl survey data showed evidence of a positive association between water temperature in the low salinity zone and X2, principally in October (Figure 118). A statistically significant ($P < 0.01$) linear regression for October predicts water temperature of ~17.9°C with X2 of 74 km and ~18.4°C with X2 of 81 km, although with relatively high variability. As noted for the zooplankton survey data, such differences would be expected to have little effect on Delta Smelt habitat quality based on observed relationships, as water temperature within the typical fall range does not greatly influence Delta Smelt probability of occurrence (Feyrer et al. 2007). This conclusion also holds for the forecasted values of October X2, i.e., ~78 km (predicted temperature = 18.2°C) for the proposed 2017 Fall X2 action and ~73 km (17.9°C) as would occur based on the prescription from the USFWS (2008) BiOp (Table 1).

Limiting the analysis to the POD-regime period (2003-2015/2016) did not give a significant regression for October (Figure 119), again suggesting limited effect on Delta Smelt habitat value as represented by probability of occurrence.

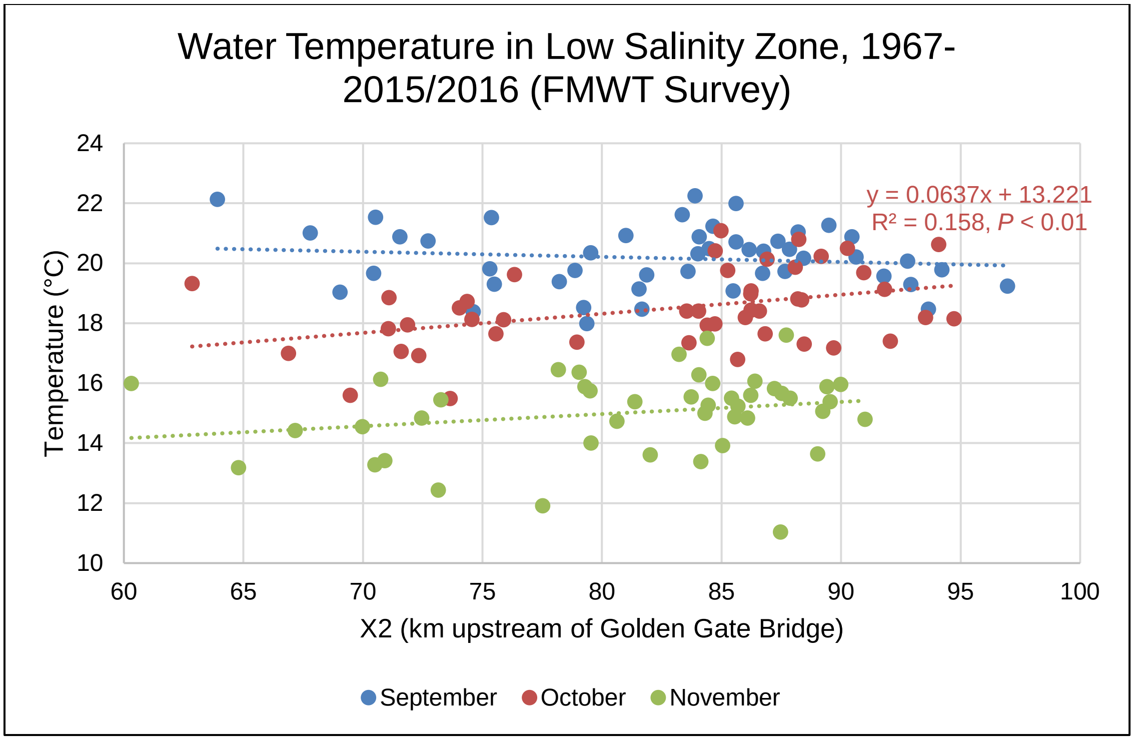


Figure 118. Mean Water Temperature in the Low Salinity Zone (Salinity = 1 to 6) from Fall Midwater Trawl Survey Data versus Mean X2 from 1967-2015/2016.

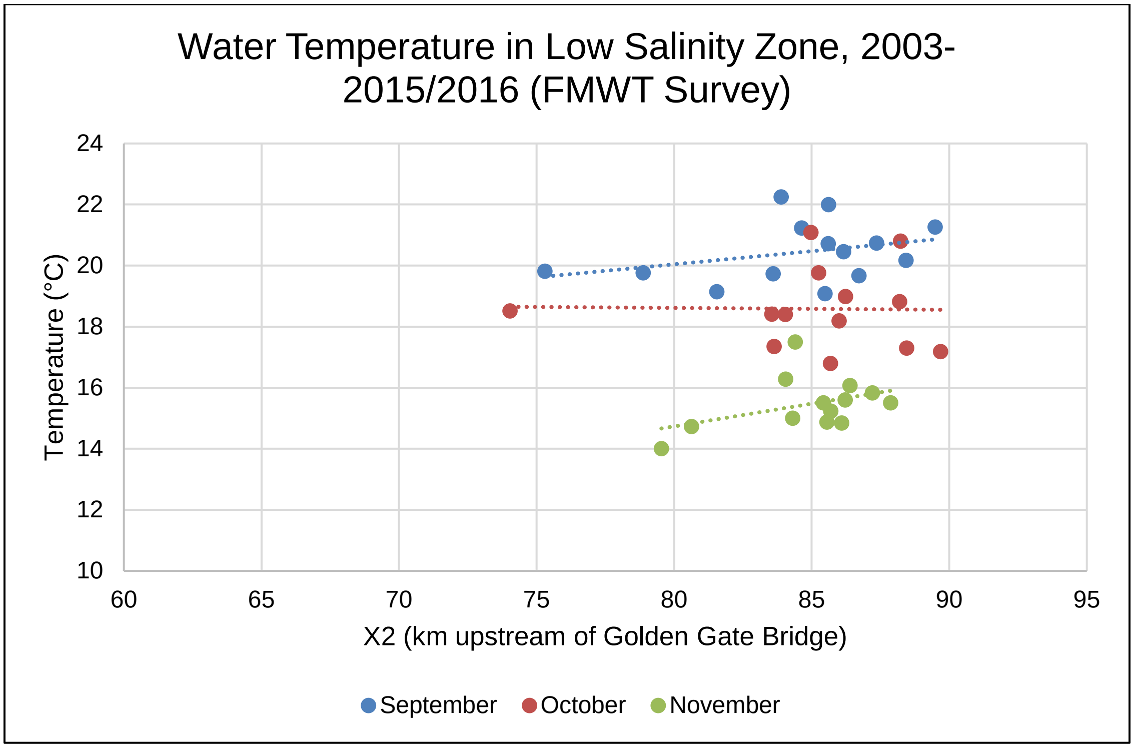


Figure 119. Mean Water Temperature in the Low Salinity Zone (Salinity = 1 to 6) from Fall Midwater Trawl Survey Data versus Mean X2 from 2003-2015/2016.

CDEC Data

The available CDEC data suggested little potential influence of fall X2 (representing magnitude of Delta outflow) on mean water temperature in September, October, or November at RVB (Figure 120), ANH (Figure 121), MAL (Figure 122), or MRZ (Figure 123). This is in keeping with general observations from the Delta that flow does not greatly affect temperature (Kimmerer 2004; Wagner et al. 2011).

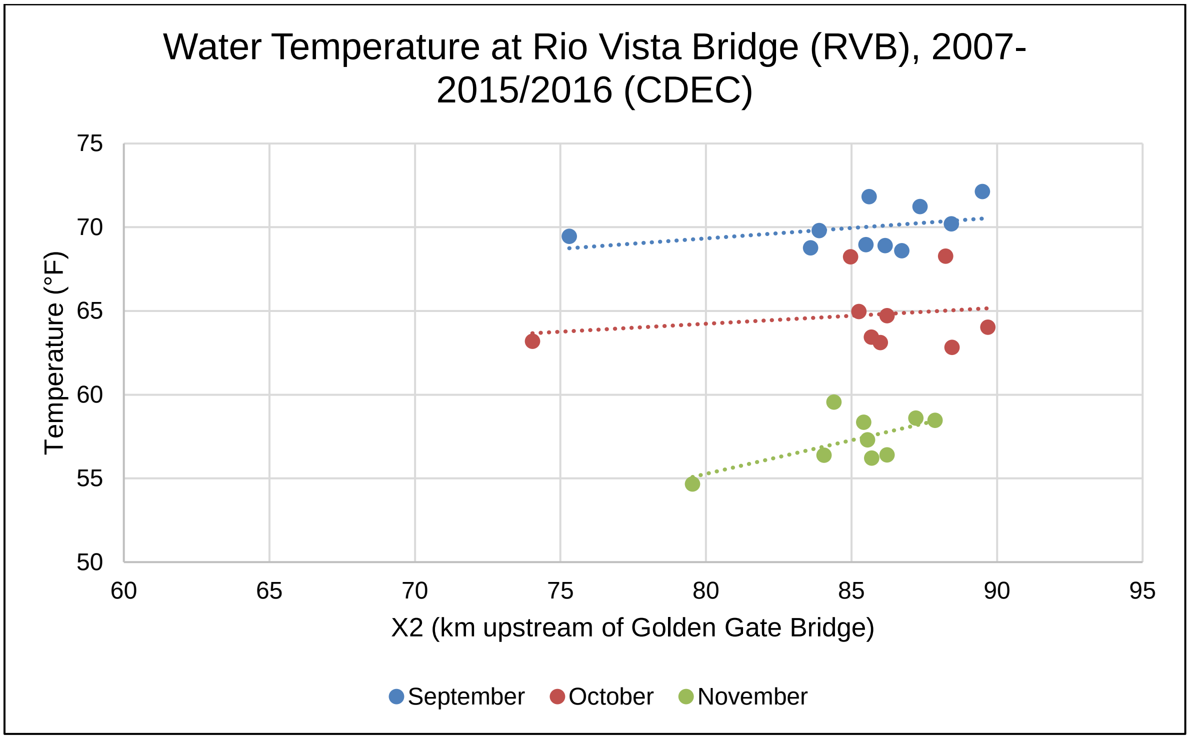


Figure 120. Mean Water Temperature at Rio Vista Bridge (CDEC Station RVB) versus Mean X2 from 2007-2015/2016.

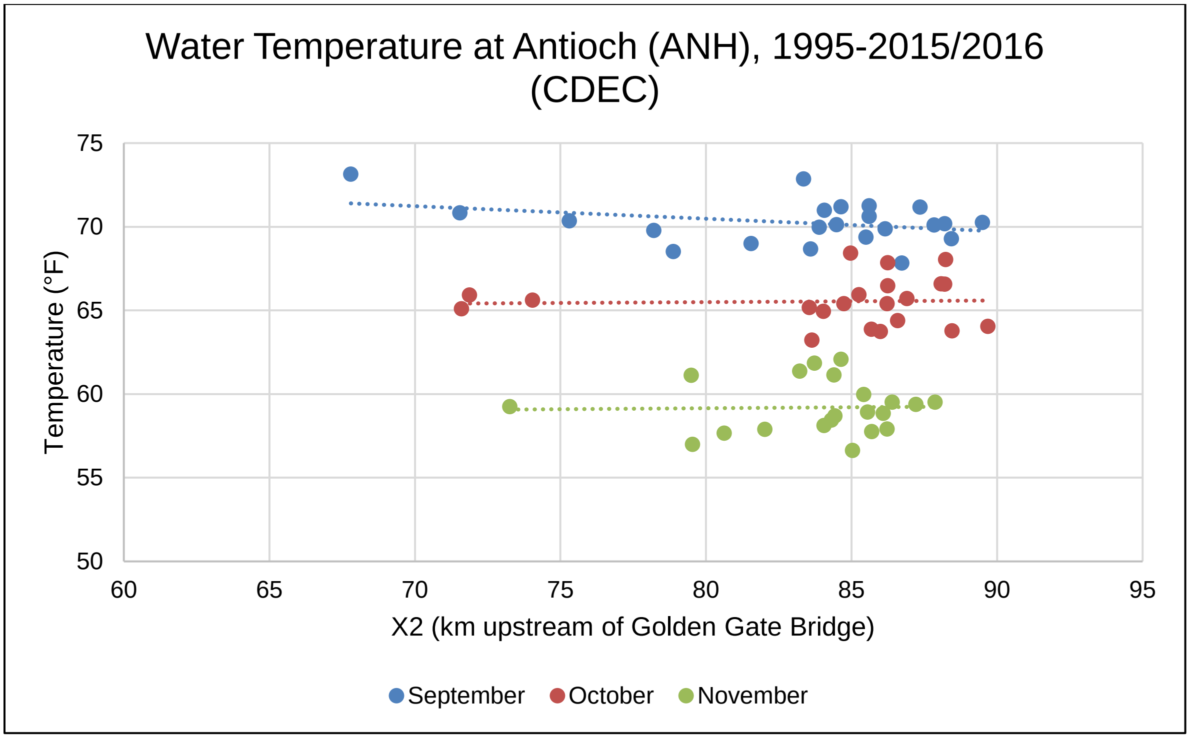


Figure 121. Mean Water Temperature at Antioch (CDEC Station ANH) versus Mean X2 from 1995-2015/2016.

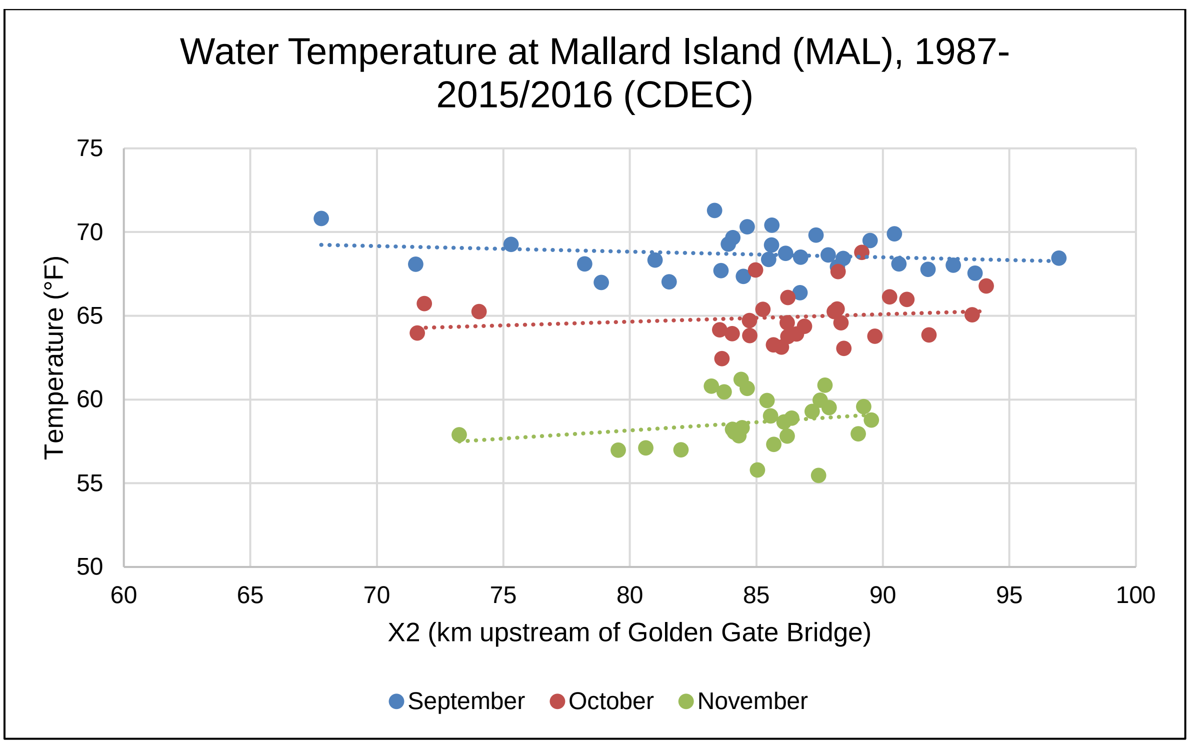


Figure 122. Mean Water Temperature at Mallard Island (CDEC Station MAL) versus Mean X2 from 1987-2015/2016.

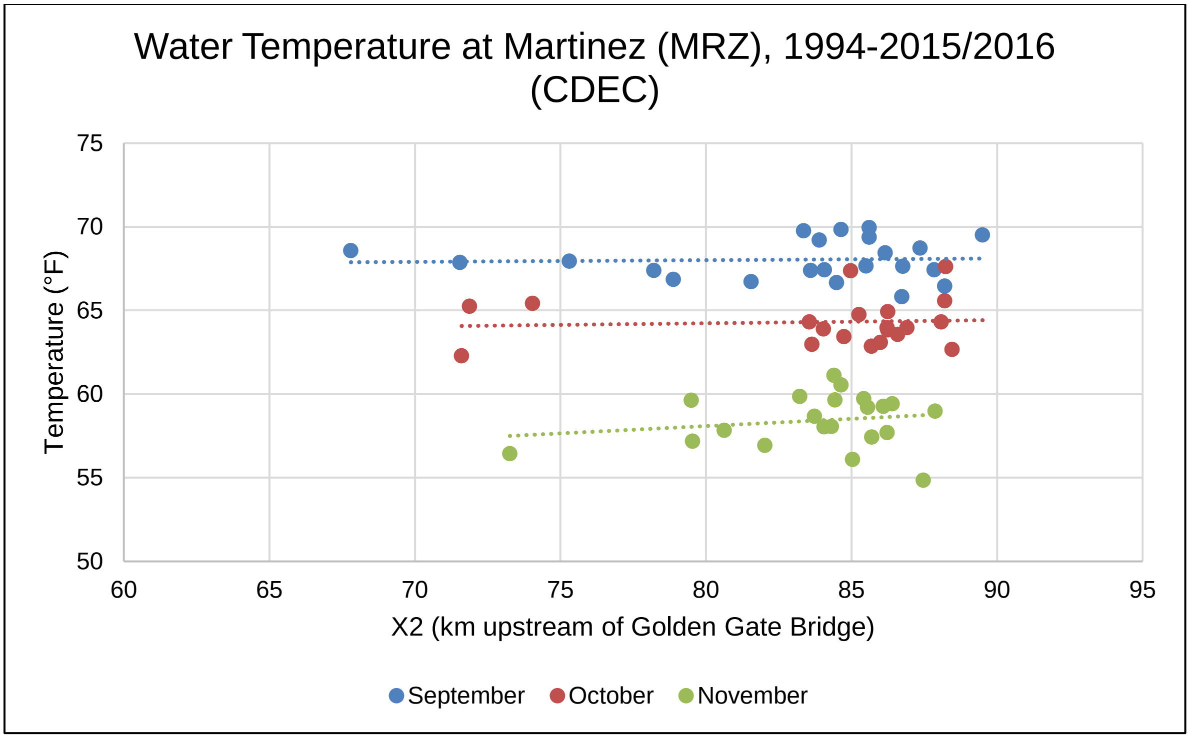


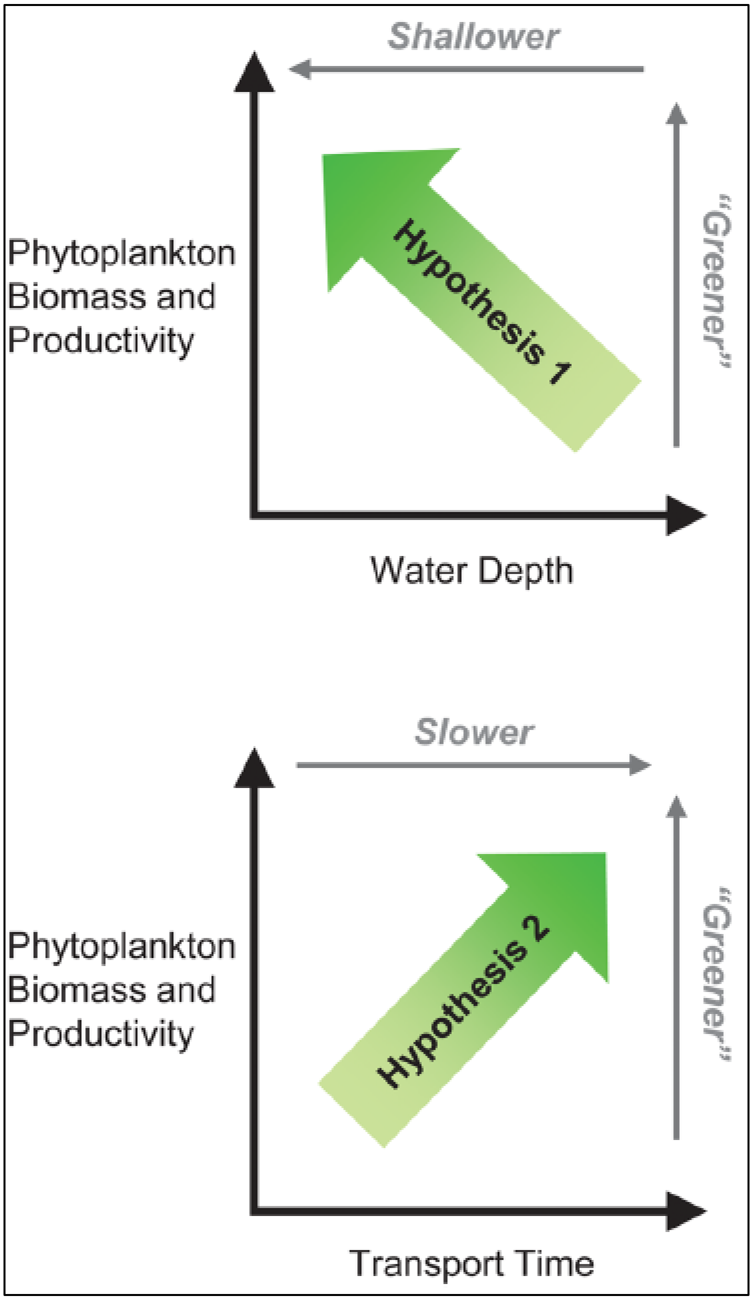
Figure 123. Mean Water Temperature at Martinez (CDEC Station MRZ) versus Mean X2 from 1994-2015/2016.

Effects from Habitat Actions

As described in the *Habitat Studies and Actions* section of the *Project Description*, a number of actions may occur as part of the overall implementation of the proposed adaptive management action in 2017-2019: the North Delta foodweb project, Suisun Marsh Salinity Control Gate reoperation, Sacramento Deep Water Ship Channel lock reoperation, Napa River flow augmentation, and supplementation of the available food supply in the Sacramento River through adjustmetns in rice field drainage practices to the Sacramento River.

Food Augmentation Actions

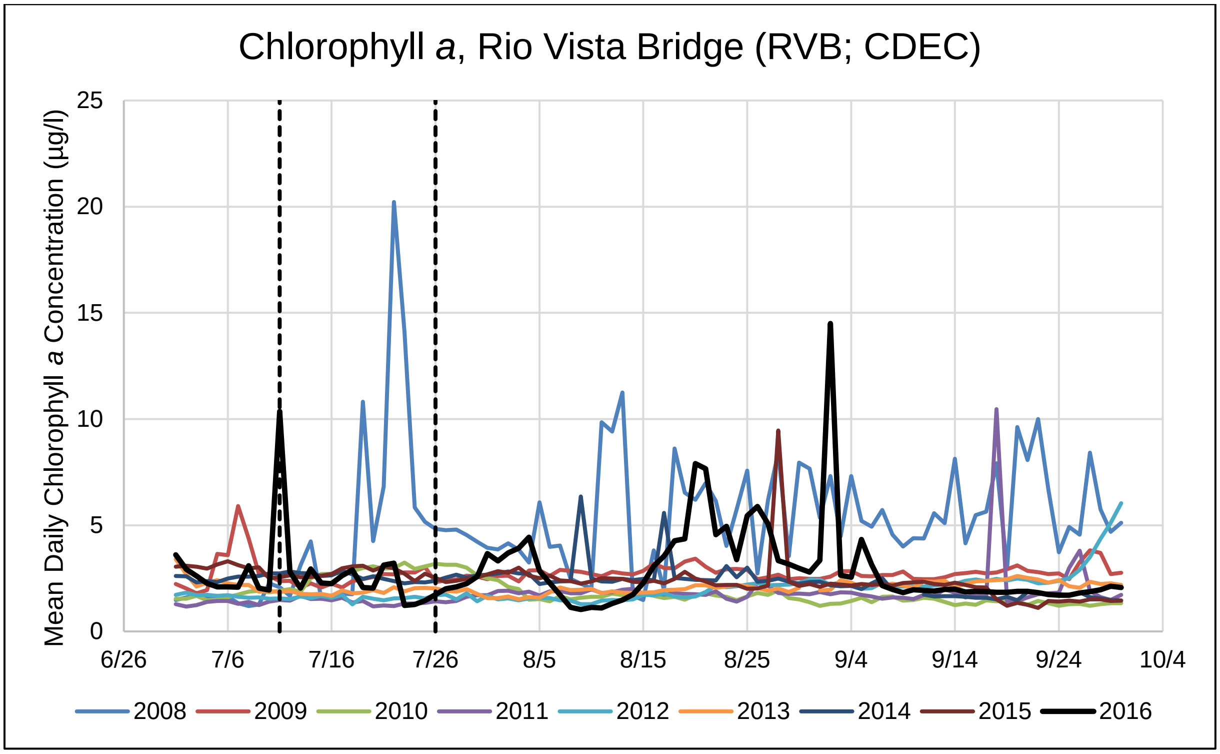
Although the locations and specific implementation details of the North Delta foodweb project, enhancement of high productivity rice field draining to the Sacramento River, and Sacramento Deep Water Ship Channel lock reoperation are quite different, the basic conceptual model behind them is quite similar: high primary production is driven by long residence time and in some cases shallow water depth (Figure 124). This primary production can then be directed to areas where it will benefit the invertebrate prey that Delta Smelt consume, i.e., by opening the Knights Landing Outfall Gates, directing more water onto and off flooded rice fields, or by reoperating the Deep Water Ship Channel locks in West Sacramento.



Source: Lucas and Thompson (2012).

Figure 124. Conceptual Model for Increased Primary Productivity ("Greener") as a Function of Shallower Habitat (Hypothesis 1) and Slower Habitat (Hypothesis 2).

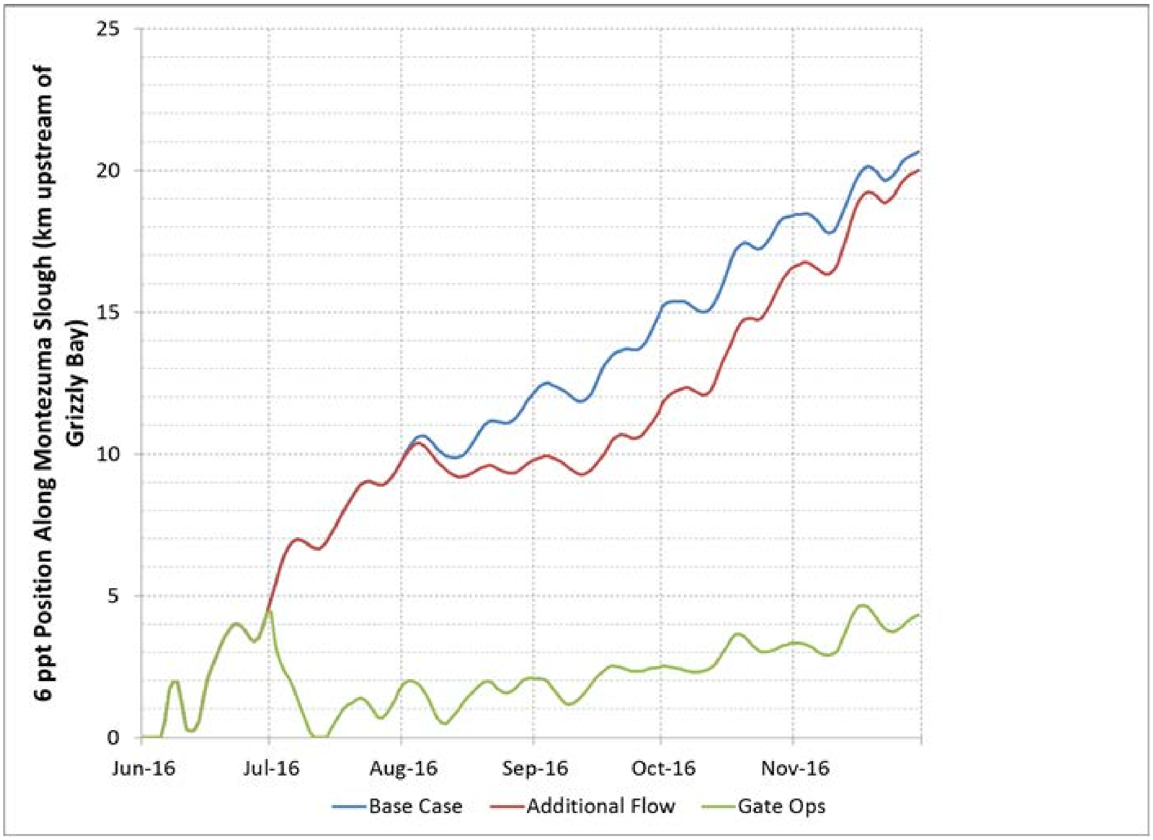
Preliminary evidence in support of this conceptual model was provided by a pilot implementation of the North Delta foodweb project in 2016, wherein 10,000 acre feet of water was pulsed into the Yolo Bypass from the Colusa Basin Drain from July 11 to July 26. An increase in chlorophyll *a* was apparent in the Sacramento River at Rio Vista several weeks later, with levels higher than most years in the available time series from 2008 onwards (Figure 125). The magnitude of benefit to Delta Smelt from these various potential actions would depend on the extent of the redirection of productivity to areas that the species occupies.



Note: Broken lines bracket the period in which 10,000 acre feet of water from the Colusa Basin Drain were released into the Yolo Bypass.

Figure 125. Mean Chlorophyll *a* Concentration at Rio Vista Bridge (CDEC Station RVB), July-September 2008-2016.

In contrast to the actions intended to route increased primary production to areas occupied by Delta Smelt, the conceptual model for Suisun Marsh Salinity Control Gate reoperation involves attraction of Delta Smelt to an area with high food availability, Suisun Marsh (Hammock et al. 2015), where *Potamocorbula* is spatially limited (Baumsteiger et al. 2017). Attraction of Delta Smelt would be facilitated by gate reoperation, which would decrease salinity within a greater portion of Suisun Marsh to within the low salinity zone range that has high probability of occupation by Delta Smelt (Figure 126).

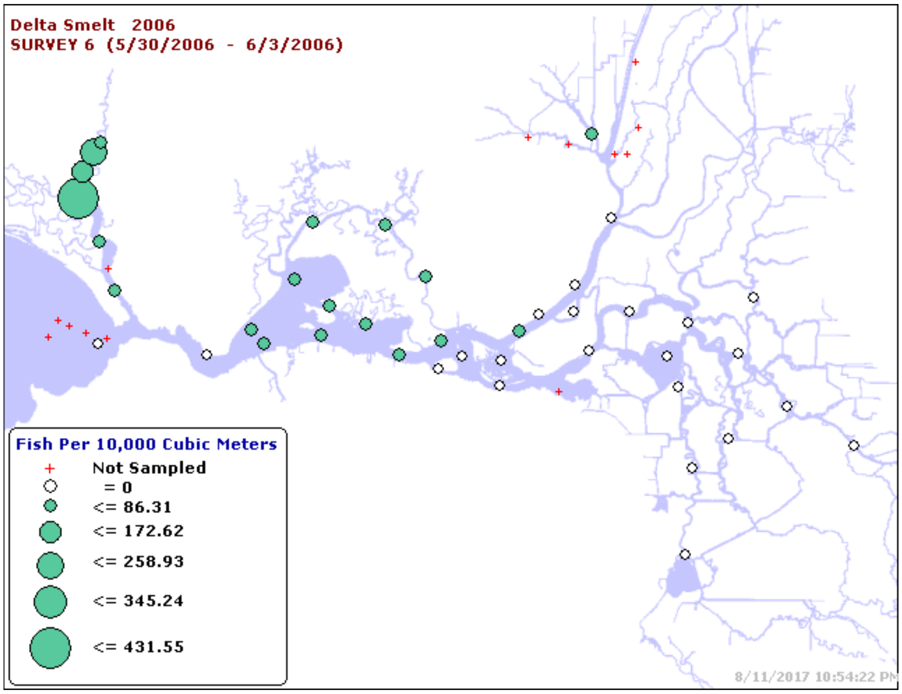


Source: MWD Technical review of Proposed Summer Flow Action for Delta Smelt (Final, August 2016). Note: A forecasted isohaline position is shown for the base condition (blue), the summer flow action (in red) and a scenario where the Suisun Marsh gates are operated (green).

Figure 126. The Forecasted Position of the Low Salinity Zone Upper Range (i.e. Salinity = 6) Along Montezuma Slough, in km Upstream from Grizzly Bay, for 2016.

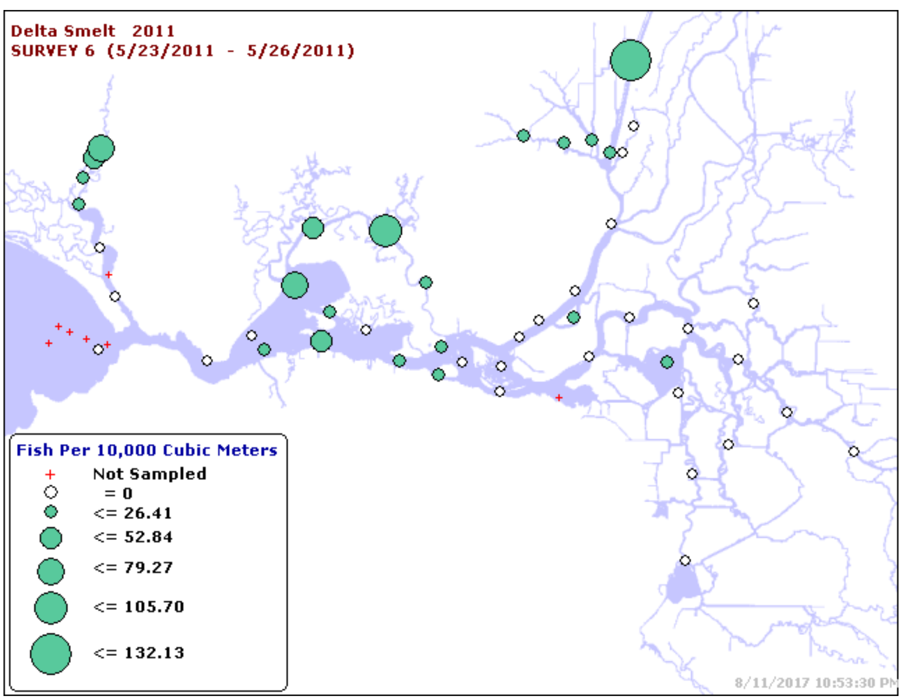
Napa River Flow Augmentation

The potential flow augmentation action in the Napa River would increase the extent of low salinity zone habitat in that small estuary, in order to increase habitat for Delta Smelt. In years with high Delta outflow, such as 2006, 2011, and 2017, the abundance of Delta Smelt can be high in the Napa River (Figures 127, 128, 129), resulting in a small but significant proportion of the population in that area (Hobbs et al. 2007). However, as flow decreases as the year progresses, the amount of low salinity habitat decreases. Augmenting fall flow would therefore benefit the portion of the Delta Smelt population occurring in Napa River, increasing the spatial diversity of the overall population and potentially increasing resiliency.



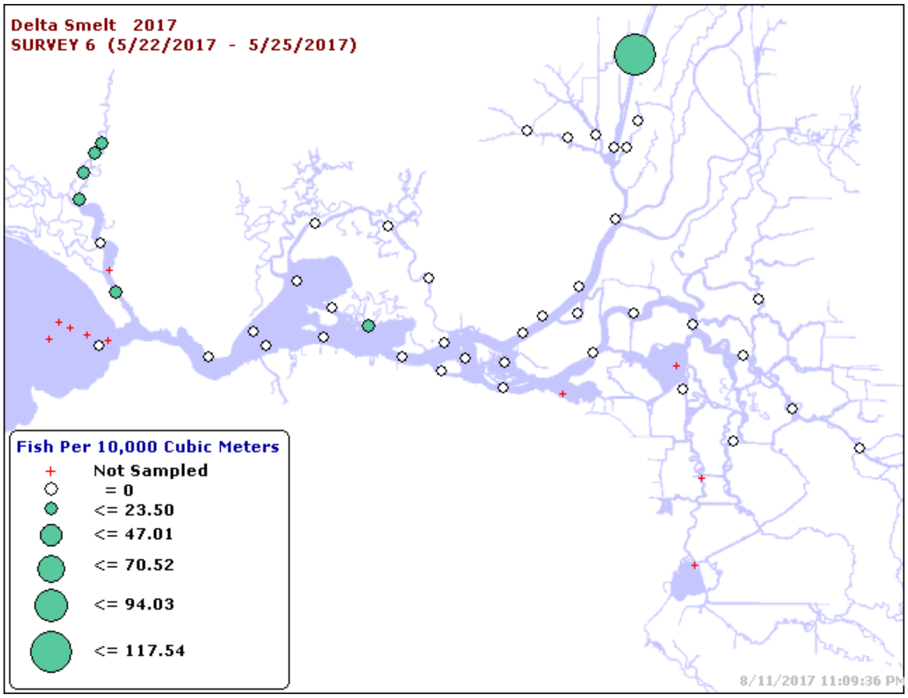
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp

Figure 127. Density of Delta Smelt in 20-mm Survey 6, 2006, Illustrating Relatively High Density in the Napa River.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp

Figure 128. Density of Delta Smelt in 20-mm Survey 6, 2011, Illustrating Relatively High Density in the Napa River.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp

Figure 129. Density of Delta Smelt in 20-mm Survey 6, 2017, Illustrating Relatively High Density in the Napa River.

Entrainment Effects

Delta Smelt are not likely to be entrained at the south Delta exports during the fall, as shown by historic data (e.g., Brown et al. 2014). Among other listed fishes, the seasonality of juvenile salmonids is such that entrainment is also unlikely during October, the period when export pumping could be greater under the proposed 2017 Fall X2 action than otherwise would occur if the Fall X2 action was implemented as prescribed in the USFWS (2008) BiOp. The most likely listed fish to be present and susceptible to entrainment is juvenile Green Sturgeon, which may spend several years in the Delta before migrating to the ocean (NMFS 2015). However, historic salvage data for October generally indicate low numbers of Green Sturgeon being entrained (Table 7). Therefore, while the proposed 2017 Fall X2 action could result in greater October exports than would occur if the Fall X2 action was implemented as prescribed in the USFWS (2008) BiOp, it is not certain that this would lead to additional entrainment; given the trends of recent years, it seems most likely that there would be no entrainment of Green Sturgeon in October 2017.

Table 7. Total Number of Green Sturgeon Salvaged and Total Volume of Water Exported from the Central Valley Project and State Water Project South Delta Export Facilities, October, 2003-2016.

Year	Salvage (Central Valley Project)	Exports (Acre-Feet) (Central Valley Project)	Salvage (State Water Project)	Exports (Acre-Feet) (State Water Project)
2003	0	264,138	0	180,067
2004	0	267,829	0	170,191
2005	12	266,552	0	388,338
2006	60	264,891	0	373,027
2007	0	261,605	0	192,080
2008	0	231,656	0	32,145
2009	0	233,372	0	114,805
2010	0	252,992	0	314,260
2011	0	245,364	0	403,779
2012	0	241,156	0	227,043
2013	0	139,786	0	70,736
2014	0	44,126	0	21,536
2015	0	64,241	0	15,134
2016	0	234,387	0	175,643

Upstream Effects (Reservoir Storage)

As described in the *Fall Outflow in 2017* section of the *Project Description*, there would be no difference in upstream operations between implementation of the Fall X2 action as written in the USFWS (2008) BiOp (i.e., X2 = 74 km in September and October) and the proposed 2017 action (X2 = 74 km in September, and X2 up to 81 km in October). The only operational changes are expected to occur through reduced exports. Therefore there would be no upstream effects of the proposed 2017 Fall X2 action beyond those that would have occurred with implementation of the Fall X2 action as written in the USFWS (2008) BiOp.

Conclusions

Implementation of the proposed 2017 Fall X2 action would result in X2 of 74 km in September and X2 up to 81 km in October, with values intermediate to these possible based on available forecasts. Relative to the situation that would otherwise occur in the Fall X2 action were implemented as prescribed in the USFWS (2008) BiOp, the present effects analysis suggested:

1. Based on predictions from available population modeling, there is unlikely to be a measurable effect on 2018 recruitment of Delta Smelt from the proposed 2017 Fall X2 action (mean October X2 of 74 km compared to 81 km is predicted to give a ~1.06 factor effect on 2018 recruitment, with only ~50% chance of an increase in recruitment based on simulations; see *Delta Smelt Stock-Recruitment-X2 Relationship*)—effects for the intermediate forecasted values of X2 would be even less;

2. For October X2 of 81 km instead of 74 km, there would be a ~7,600-acre (~37%) reduction in the area of the low salinity zone, whereas for forecasted October X2 of ~78 km relative to X2 of 73 km that would occur based on forecasts for the USFWS (2008) prescription, the difference would be ~630 acres (~7%) (see *Low Salinity Zone Extent*); similarly, the difference in abiotic habitat index between X2 = 74 km and 81 km (2,426; ~33%) is greater than the difference between forecasted X2 = 73 km and X2 = 78 km (~1,400; 19%) (see *Abiotic Habitat Index (Feyrer et al. 2011)*); in addition, the hydrodynamics-based station index (SI_H) was ~33% less with X2 = 81 km compared to X2 = 74 km, whereas the difference was around 10-18% less for the proposed 2017 Fall X2 action when comparing within the range of forecasted X2 values (see *Hydrodynamics-Based Station Index (Bever et al. 2016)*);

3. There is no evidence to suggest that Delta Smelt invertebrate prey density in the low salinity zone would be reduced based on the proposed 2017 Fall X2 action relative to implementation of the Fall X2 action as prescribed in the USFWS (2008) BiOp (see *Invertebrate Prey Density*), with little to no evidence for substantial increases in *Potamocorbula* (see Potamocorbula *Density*) or *Microcystis* (see Microcystis *Density*) being

likely over the 74 km to 81 km range, although for amphipods and *Potamocorbula* data were limited to make a full assessment and there is some uncertainty in the conclusion;

4. The low salinity zone would overlap areas with higher mean Secchi depth, equating to ~14-28% reduction in habitat quality for Delta Smelt based on the probability of occurrence and over the range of potential X2 values suggested by the proposed action and available forecasts, although Delta outflow (as indexed by X2) appears to have relatively little influence on turbidity or suspended sediment concentration at individual locations (see *Water Clarity in the Low Salinity Zone*);

5. With X2 occurring further upstream than if the USFWS (2008) BiOp was implemented as prescribed, the low salinity zone would overlap areas with marginally greater mean water temperature, although well within the range of Delta Smelt tolerance and therefore likely to have little influence on habitat quality (see *Water Temperature in the Low Salinity Zone*).

As described in the *Current Spatial Distribution* discussion within the *Status of Delta Smelt* section of this document, both the summer townet survey and EDSM indicate a large proportion of the juvenile Delta Smelt population is occurring within, or close to, the low salinity zone. Therefore the proposed 2017 Fall X2 action could affect the critical habitat currently being occupied by a large proportion of the population, unless there is movement upstream to the northern Delta, by reducing the area of the low salinity zone and its overlap with areas of relatively high turbidity and low current speed; however, as noted previously, modeling predicts population-level effects on Delta Smelt to be unlikely.

Actions to bolster food web and low salinity habitat in 2017-2019 have the potential to provide some beneficial effects to Delta Smelt, with the magnitude being dependent on the extent of the actions, and in particular their delivery of increased primary production to the areas inhabited by Delta Smelt, especially the north Delta.

Overall, considering the foregoing effects analysis, it is concluded that relative to the Fall X2 action prescribed in the USFWS (2008) BiOp:

- The proposed 2017 Fall X2 action would not adversely affect Delta Smelt;

- The proposed 2017 Fall X2 action would adversely affect Delta Smelt critical habitat, specifically PCE3 (river flow affecting the extent of the low salinity zone) and PCE4 (salinity influencing the location and extent of the low salinity zone).

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