USFWS DELTA JUVENILE FISH MONITORING PROGRAM REVIEW

BACKGROUND REPORT PREPARED FOR REVIEW BY THE IEP SCIENCE ADVISORY GROUP, JUNE 2013

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LIST OF ACRONYMS

The following acronyms have been used in this report:

BDCP – Bay Delta Conservation Plan
CESA – California Endangered Species Act
CDEC – California Data Exchange Center
CDFW – California Department of Fish and Wildlife
CDWR – California Department of Water Resources
CNFH – Coleman National Fish Hatchery
CPUE – Catch per Unit Effort
CVP – Central Valley Project
CVPIA – Central Valley Project Improvement Act
CWT – Coded Wire Tag
DJFMP – Delta Juvenile Fish Monitoring Program
DJSSS – Delta Juvenile Salmon Survival Studies
ESA – Endangered Species Act (Federal)
Evolutionarily Significant Unit – ESU
FL – Fork Length
FRFH – Feather River Fish Hatchery
IEP – Interagency Ecological Program
KDT – Kodiak Trawl
LVT – Larval Trawl
MWT – Mid-water Trawl
NMFS – National Marine Fisheries Service
PWT – Project Work Team (Interagency Ecological Program)
SD – Standard Deviation
SE – Standard Error
SJRGA – San Joaquin River Group Authority
STFWO – Stockton Fish and Wildlife Office
SWP – State Water Project
USBR – United States Bureau of Reclamation
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey
VAMP – Vernalis Adaptive Management Plan

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INTRODUCTION

The purpose of this review of the DJFMP and Delta Juvenile Salmonid Survival Studies (DJSSS) is to determine if the programs are meeting present objectives, are robust enough to answer likely future questions, and are providing information to managers that can be integrated to facilitate the protection and recovery of salmonids and other native species in the Central Valley of California.

Based on recommendations from the Brandes et al. (2000) review of the DJFMP, and given that the survival studies are important for understanding juvenile salmonid abundance and distribution, the DJSSS are included within the scope of this current review. In terms of organization, the DJSSS is considered a sub-program within the DJFMP. We also believe that with considerable collaboration between programs, further integration in the future will assure efficient and effective use of shared resources. Finally, sampling at Liberty Island is reviewed in the context of pilot efforts and current methods that were adopted in the 2013 DJFMP workplan for the IEP.

As part of this review, a public workshop was convened in May of 2012 to notify and receive input from partners on the scope of this review. In addition, input was solicited at the workshop from population modelers in terms of data gaps for developing life-cycle models of salmonids and other fish species of management concern. Notes were taken at the workshop and they are provided in Appendix A. Input from the workshop was considered when the outline for this background report was finalized. Some recommendations were not followed (a survey) due to institutional constraints, however all recommendations were reviewed and incorporated where possible.

We are providing this background report to facilitate the technical review by the IEP Science Advisory Group (SAG). The background report represents an internal (DJFMP and DJSSS staff) review that summarizes the goals and objectives of the program, including recommendations and changes from previous reviews, and how the DJFMP fits into other salmonid and non-salmonid monitoring in the Central Valley. The purpose of the background document is to provide the necessary information to SAG for a comprehensive programmatic review of the DJFMP and DJSSS. Specifically, we present information on the following aspects of the programs:

1. goals and objectives;
2. sampling design, techniques and types of data gathered;
3. the appropriateness of spatial and temporal scale of the program;
4. data analysis and inference;
5. quality assurance and quality control;
6. data management;
7. data dissemination to users; and
8. recommendations for program modifications.

Recommendations from the SAG review will be summarized and addressed in a final report written by DJFMP and DJSSS staff. Although not all recommendations may be implemented, the final report will address each recommendation and provide justification and rationale for the decision process.

Finally, the review complements and promotes the vision of the USFWS Stockton Fish and Wildlife Office. In addition to the DJFMP, other current programs within the office include the Aquatic Invasive Species Program and the Anadromous Fish Restoration Program (AFRP). The AFRP also includes employees working on the San Joaquin River Restoration Program. The vision of the office is to be an organization that promotes native self-sustaining ecosystems through leadership in anadromous fish restoration, fisheries research and monitoring, and non-native invasive species prevention, management, and control. To achieve our objectives, we foster and value strong productive collaborations, internally and with other organizations, peers, stakeholders, and the public. Our work towards recovery and conservation of species and their habitats is governed by honesty and integrity and incorporates excellence in science, creativity, and flexibility.

PROGRAM HISTORY AND CURRENT OBJECTIVES

The DJFMP, as part of the Four Agency Ecological Study Program, the Interagency Ecological Study Program, and the Interagency Ecological Program for the Sacramento-San Joaquin Estuary (now San Francisco Estuary), has been monitoring populations of juvenile Chinook salmon *Oncorhynchus tshawytscha* in the lower Sacramento River and in the Sacramento-San Joaquin Delta (Delta) since the late 1970s (Brandes et al. 2000). The program and its goals have evolved based on water management needs and endangered species listings. The salmon studies began in the early 1970s with two primary objectives (Figure 1). The first objective was to monitor juvenile Chinook salmon abundance and determine the importance of the San Francisco Estuary (Estuary) as nursery habitat. The second objective was to determine how reduced river flows below the proposed Peripheral Canal intake would affect the survival of juvenile Chinook salmon migrating though the Estuary or using it as a nursery (Brandes et al. 2000). Following the defeat of the Peripheral Canal proposal in 1982, the focus of the program shifted to evaluating the impacts of through-Delta water conveyance and finding appropriate measures to mitigate those impacts on the relative abundance, distribution and survival of juvenile Chinook salmon in the Estuary.

The greatest change in the program occurred in response to the endangered species listing of Sacramento River winter-run Chinook salmon. The Sacramento River winter-run Evolutionarily Significant Unit (ESU) was listed by the State of California as “endangered” in May 1989, and federally listed as “threatened” by the National Marine Fisheries Service (NMFS) in November 1990 (55 FR 46515) and reclassified as “endangered” in January 1994 (59 FR 440). The listings prompted the United States Bureau of Reclamation (USBR) and California Department of Water Resources (CDWR) to fund expanded Chinook salmon monitoring in the lower Sacramento River and Delta to collect information on all the runs of juvenile Chinook salmon in the Estuary. Other listings of salmonids in the Central Valley followed. Central Valley steelhead *Oncorhynchus mykiss irideus* was federally listed as “threatened” in 1998 (63 FR 13347). The

Spring-run Chinook salmon ESU was listed as “threatened” by the State of California in February 1999 and federally listed as “threatened” in September 1999 (64 FR 50394).

In response to the endangered species legislation, the DJFMP expanded the historical sampling program to one that operated between October and June at the entry (Sherwood Harbor on the Sacramento River and Mossdale on the San Joaquin River) and exit points (Chipps Island) of the Delta. The temporal scope of beach seining was also expanded in the lower Sacramento River and Delta. The beach seine sampling in the San Francisco Bay was done by the DJFMP in 1981 and 1982 but was taken over by CDFW’s Bay Study program in 1983. The CDFW continued seining in the Bay year round until they stopped in 1986 due to funding limitations. The DJFMP restarted the Bay seining in 1997 to document the distribution of Chinook salmon in the Bay year round (Brandes et al. 2000). In response to recommendations from the Delta Salmon Project Work Team, the entire program was further expanded in ~1995 to sample year round at all locations, in part, to expand the temporal and geographic sampling for resident fish and steelhead. The goal for the year-round expansion was to provide broad geographic scope and full temporal coverage, so that the program was robust enough to answer future questions on the relative abundance and geographic distribution of a variety of species that the gears sampled. In recognition of the value of understanding assemblage-level responses and biotic interactions in the Delta, all species captured have been identified since the early 1970s, with a few minor exceptions, and reported in the DJFMP annual reports since 2006.

Juvenile salmon survival studies have been conducted in the Delta since the late 1960s. The studies have used mark-recapture techniques to estimate survival and to determine flow needs in the Estuary for Chinook salmon. As the studies evolved, focus shifted to evaluating the factors influencing survival in, and through the Delta. Marking techniques have evolved over time and have included fin-clipping (1969–1971), spray-dyeing (1976–1977), coded-wire tagging (1978–2006) and more recently, acoustic tagging (2006 to the present). Multiple life stages of juvenile Chinook salmon originating from hatcheries have been used for these studies, including fry, smolts and yearlings. Chinook salmon races used for these studies have included fall-run, late fall-run, and spring/fall-run hybrids. The sources of the experimental fish were from Feather River Hatchery, Merced River Hatchery and Coleman National Fish Hatchery. Ancillary information on the recovery and survival indices to Chipps Island of any natural or hatchery coded-wire-tagged group released upstream has been provided to our cooperators, as all Chinook salmon marked with a coded-wire tag (CWT) that are recovered in the DJFMP sampling are decoded. In 2011, the survival studies incorporated steelhead and are now referred to as salmonid survival studies.

Today, year-round monitoring continues with an emphasis on populations of all races of Chinook salmon in the Delta per the monitoring and reporting terms of the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project (CVP) and State Water Project (SWP, NMFS 2009a). Additionally, data are recorded for all fish species and selected invertebrates sampled in the Estuary. Presently, the DJSSS includes participation in the 6 year steelhead survival study, and a Chinook salmon survival study (which includes an assessment of the head of Old River junction). The monitoring and survival components of the

DJFMP organization are considered together in this review. Therefore, the six objectives of the DJFMP are to:

1. Document the long-term abundance and distribution of juvenile Chinook salmon in the Delta.
2. Comprehensively monitor throughout the year to document the presence of all races of juvenile Chinook salmon.
3. Intensively monitor juvenile Chinook salmon during the fall and winter months for use in managing water project operations (Delta Cross Channel gates and water export levels) on a real-time basis.
4. Document the abundance and distribution of steelhead.
5. Document the abundance and distribution of non-salmonid species.
6. Identify the factors influencing salmonid survival in the Delta such as route, flow, exports, and other covariates (DJSSS).

PREVIOUS REVIEWS

DJFMP

In 2000, the Delta Salmon PWT conducted a review of the DJFMP to evaluate if the program was meeting its objectives and to determine if sampling should be modified to better meet present and future needs (Brandes et al. 2000). Results suggested that the monitoring program was meeting its objectives of (1) indexing the abundance and distribution of primarily fall-run Chinook salmon in the Delta, (2) documenting the relative abundance and distribution of all races of juvenile Chinook salmon in the Delta, and (3) monitoring the abundance of juvenile Chinook salmon between October 1 and January 31 for real-time water operations management. The reviewers also made several recommendations to improve the program.

The review recommended that the mid-water trawling (MWT) frequency at Chipps Island and Sherwood Harbor be reduced from three to two days per week in May and June due to high salmonid catches. Similarly, reduced sampling effort was recommended for the Sacramento seine region from the middle of December through the end of January each year as it did not provide more information compared to other sampling for managing water operations. In addition, the review assessed the value of the information generated from the program for documenting the status and trends of steelhead and resident species in the Delta and recommended that the program be altered to explicitly include Delta resident fish monitoring as an objective (Brandes et al. 2000). Other recommendations from the review included improving non-salmonid fish identification, elimination of plus counts (only a subset of fish are measured) and instituting a voucher collection to verify identification. Further, the need was highlighted for conducting comparisons between the MWT and the Kodiak trawl (KDT) at Sacramento to verify the KDT was catching more of the larger juvenile Chinook salmon. It was also recommended that the KDT continue sampling into April and May for assessing steelhead trends, but this was not implemented to avoid increased take of Chinook salmon. In terms of future reviews, it was recommended that a review similar to that conducted in 2000 be implemented for the juvenile salmon survival component of the program. Finally, the conclusion was made that it was critical that the long-term monitoring program continue to provide baseline data for future recovery efforts (Central Valley Project Improvement Act, CVPIA, and CALFED). With few exceptions, recommendations from the review were largely adopted after 2000.

Studies on non-salmonids have been initiated since the Brandes et al. (2000) review. In collaboration with the Stone Lakes National Wildlife Refuge, the DJFMP was tasked with monitoring all life stages of fish inhabiting Liberty Island during the 2003-2005 field seasons. Liberty Island is a restoring wetland that likely provides important habitat for species of management concern, including delta smelt (*Hypomesus transpacificus*) and Chinook salmon. Larval fish trawls and beach seine sampling at Liberty Island were initiated again in 2010 and these sampling elements continue today as part of the baseline monitoring program. In addition, zooplankton sampling in conjunction with the larval trawls has been incorporated into the 2013 workplan.

On behalf of the IEP Management Team, a team of IEP scientists reviewed all IEP fish monitoring elements in 2004 to inform management regarding data utility and long-term IEP priorities and resource commitments (Honey et al. 2004). Results from a review questionnaire produced several recommendations regarding the DFJMP sampling elements. For all gear types, it was recommended that bias, or the degree that samples were representative of the population as a whole, be assessed. In addition, random sampling was advised for beach seining and new methods or protocols were suggested in general to sample different habitats. Evaluating the limitations of the Chipps Island Trawl by experimenting with different gears was also recommended along with more data analysis and publications. Finally, it was suggested that bias be evaluated at the Sacramento and Mossdale Trawl sites, particularly investigating diel effects on catch. Although the majority of the recommendations were not adopted, some additional work was done by the DJFMP to assess diel effects on Chinook salmon catch at Sacramento (Wilder and Ingram 2006).

DJSSS

The Chinook salmon studies conducted as part of the DJSSS were summarized by Kjelson et al. (1982), USFWS (1987), Kjelson and Brandes (1989), and Brandes and McLain (2001), but a specific review was not conducted until Newman (2008). With funding from CALFED, Newman (2008) reviewed and re-analyzed four long-term Chinook salmon CWT survival studies that evaluated the impact of (1) the open Delta Cross Channel gates on survival down the Sacramento River, (2) diversion into the interior Delta via Georgiana Slough on survival relative to juvenile salmon staying on the mainstem Sacramento River, (3) CVP and SWP exports on relative survival in the interior Delta (referred to as Delta Action 8 studies), and (4) the effect of river flow, water project exports, and a physical barrier at the head of Old River on survival of juvenile Chinook salmon through the San Joaquin Delta between Mossdale and Jersey Point from the Vernalis Adaptive Management Plan (VAMP) studies and pre-VAMP studies. Newman (2008) made eight recommendations in his report:

1. “Use embedded replicated tags to check for violations of the assumption of independence between fish.
2. Make releases below freshwater recovery locations (e.g. below Chipps Island), as to allow separate estimates of capture probabilities at the recovery location.
3. Carry out a more detailed analysis of the ocean catch recovery patterns by age-port-month of recovery to better determine how similar the recovery patterns are within paired releases.
4. Carry out a benefit-cost comparison of CWT’s and acoustic tags, including a comparison of the precision of estimates of survival probabilities per number of fish released.
5. Specify an underlying probability model for any analyses of release-recovery data, and in the case of multi-year survival studies, in particular, formulate hierarchical probability models.
6. Use such probability models prior to carrying out release-recovery experiments to evaluate design and sample size options.
7. Estimate the sampling errors for estimated ocean recoveries and incorporate the errors into the probability model for observed and estimated recoveries; hierarchical models can be extended to another level to include such variation.
8. Carry out a more rigorous model-selection procedure for the various VAMP models using Reversible Jump MCMC.”

The review resulted, in part, to the movement away from CWT to the use of acoustic tag technology, which does allow for the use of probability models for analyses and for evaluating design and sample size options (recommendation 6 above).

Not long after the Newman (2008) review, the CWT and early acoustic tag survival information generated in the San Joaquin River, prior to and during the VAMP, was the subject of a Delta Science review (Dauble et al. 2010). As part of this review, Newman (personal communication) completed a more rigorous model-selection procedure for the VAMP model (see Appendix B: Analyses of CWT Releases into the San Joaquin System). Dauble et al. (2010) made eight recommendations for future studies and management:

1. Conduct 3-D hydrodynamic modeling at the head of Old River junction with the San Joaquin River.
2. Measure fine-scale movements of juvenile salmon on the San Joaquin River downstream of Old River.
3. Consider using Passive Integrated Transponder (PIT) tags for selective studies on smolt behavior and survival.
4. Install a physical barrier at the head of Old River.
5. Conduct studies to more broadly characterize predator distribution, abundance and feeding habits to better determine the extent of predation.
6. Improve collection, handling, trucking and release (CHTR) procedures to reduce mortality and reduce pre-screen mortality and predation in Clifton Court Forebay to increase survival.
7. Review VAMP findings on a more regular basis (every 3 years).
8. Assure adequate funding for studies (the VAMP study in particular).

The VAMP studies were completed in 2011 and this funding source is no longer available for supporting survival studies in the south Delta. It has been difficult to secure annual funding for this effort, let alone stable, multi-year funding sources.

Lastly, the 6 year steelhead survival study has been conducted since 2011 as part of the Operations and Coordinated Operating Agreement (OCAP) Biological Opinion and will continue until 2016. As part of the 2012 OCAP Annual Review, the VAMP studies and the 6 year steelhead study plan were cursorily reviewed along with the 2012 CDWR/NMFS Stipulation study as part of the OCAP settlement agreement in 2012 (Anderson et al. 2012). One recommendation that pertained to the VAMP and 6 year steelhead study was to evaluate array-specific detection probabilities under different environmental conditions. As a first step, the review panel suggested first focusing range detection tests on arrays associated with high mortality. The uncertainty in survival associated with predators eating acoustically tagged fish was also identified as a concern, but no recommendations were made to further address this problem. In addition, it was suggested that more mechanistic studies be conducted (Anderson et al. 2012).

BACKGROUND

Salmon and steelhead in the Central Valley

Conceptual Life Cycle Model

For perspective and understanding of how the DJFMP and DJSSS fit into other Chinook salmon and steelhead monitoring in the Central Valley, and to partially address a recommendation from comments after the Brandes et al. (2000) review, we provide a generalized salmonid life-cycle model to link life stages with current monitoring and its purpose (Figure 2).

The Importance of the Delta to Salmonids

The Delta is potentially of critical importance for the life-cycle of Chinook salmon and steelhead in the Central Valley. Chinook salmon and steelhead migrate through the Delta as adults returning from the ocean to spawn and migrate again through the Delta when they move downstream from the spawning grounds to the ocean as juveniles. The degree of rearing and growth in the Delta varies by species and run but can be significant, particularly for fall-run Chinook salmon (Kjelson et al. 1982). However, the relative importance of different habitats within the Delta for Chinook salmon rearing, and the contribution of Delta-reared fish to adult production remains poorly understood (Brown 2003; McLain and Castillo 2009). Mortality sources are also variable within the Delta both annually and intra-annually depending on several factors. Generating needed information on these juveniles as they migrate downstream through the Delta, and trying to understand the impacts of past and future water development and exports on these species in the Delta has been the basis for funding of both the DJFMP and the DJSSS for the last 40 years. However, without incorporating a life-cycle perspective and linking ocean dynamics with the Delta and upstream tributaries, it is hard to understand the relative importance of the Delta to the recovery of these species in the Central Valley. Such information is relevant in determining how to spend increasingly scarce monitoring dollars.

In a simple simulation model, we determined that without significant improvements in Delta survival for juvenile Chinook salmon migrating from the San Joaquin tributaries and entering the Delta at Mossdale, adult recruitment would not improve substantially, given average conditions in other phases of the life-cycle (Figure 3). In similar simulation efforts we determined that 50% survival through the Delta was needed to reach the CVPIA doubling goal in the San Joaquin Basin of 78,000 in 9 generations (27 years). We started with the number of smolts estimated at Mossdale in 2010 and used average survival in other components of the life-cycle (USFWS 2011c) to produce this estimate. While these simulations are imprecise and dependent upon average survival rates in different components of the life-cycle, they suggest the Delta may play an important role in recovering and meeting target escapement levels in the Central Valley.

Salmonid Monitoring in the Central Valley

Significant effort is expended by the CDFW, USFWS, USBR, CDWR, East Bay Municipal Utility District and consultants (FISHBIO) using carcass surveys, aerial and river redd surveys, video and DIDSON monitoring, snorkel surveys, and barrier, weir, and Vaki monitoring to estimate salmonid escapement in the rivers and creeks of the Central Valley (Table 1). This information provides the basis for estimating annual adult escapement and production for a variety of purposes, such as assessing status and trends or managing the steelhead and Chinook salmon fisheries. Specifically, it provides information for assessing progress in meeting the CVPIA's Chinook salmon and steelhead doubling goals. The CDFW released a monitoring plan with the primary objective of improving estimates of the number of Chinook salmon that spawn in Central Valley streams, including statistically valid estimates of accuracy and precision (Bergman et al. 2013).

Recognizing that there are unique needs for a program focused on steelhead, the CDFW completed a comprehensive monitoring plan for Central Valley steelhead (Eilers et al. 2010) with the goal of providing the data necessary to assess the restoration and recovery of Central Valley steelhead. Objectives of the plan include:

1. "Estimating steelhead population abundance with estimated levels of precision in the Central Valley.
2. Examining the trends in steelhead abundance in the Central Valley.
3. Identifying the spatial distribution of steelhead in the Central Valley to assess their current range and observe changes in their range."

Recommended monitoring actions in CDFW's plan include estimating the abundance of adult steelhead in the mainstem Sacramento River using mark-recapture studies and examining the spatial distribution of steelhead across the Central Valley using spatially balanced sampling and a rotating panel design. It was noted in the comprehensive steelhead monitoring plan that "steelhead monitoring programs in the Central Valley lack statistical power, are not standardized and in many cases lack dedicated funding." They also noted that monitoring programs targeting Chinook salmon are inadequate for monitoring steelhead populations due to differences in "immigration timing, spawning timing, spawning requirements, rearing time, rearing requirements, emigration timing, reproductive strategy, etc."

As juvenile salmonids migrate downstream from the spawning grounds on their way to the ocean, they are monitored by various agencies in the Sacramento and San Joaquin River basins and in the Estuary. Monitoring is conducted using snorkel surveys, fyke traps, rotary screw traps, KDT, MWT, and beach seines (Table 2). Most monitoring is conducted to estimate juvenile Chinook salmon abundance and outmigration timing. Some rotary screw trap (RST) programs conduct trap efficiency tests and therefore are able to develop juvenile Chinook salmon production estimates where trap captures are expanded to account for trap efficiency. Other RST programs do not conduct trap efficiency tests and therefore are only able to report the number of Chinook salmon caught. The CVPIA's Comprehensive Assessment and Monitoring Program (CAMP) developed a data framework that calculates juvenile Chinook salmon production estimates using RST data from several locations in the Central Valley (http://www.fws.gov/sacramento/Fisheries/CAMP-Program/Documents-Reports/Documents/catalog_of_rotary_screw_traps_in_the_central_valley_of_California.pdf). These locations include the American River, Battle Creek, Clear Creek, Feather River, Mokelumne River, Sacramento River at Red Bluff Diversion Dam, and Stanislaus River at Caswell State Park. The CAMP also developed a catalog describing the RST operations in the Central Valley. The DJFMP monitors the abundance and distribution of juvenile Chinook salmon and steelhead as they migrate through the Delta with trawls and beach seines

The USBR and CDWR also sample juvenile salmonids and all other fish greater than 20 mm (FL) as part of the salvage process at the SWP and CVP. Sampling is usually conducted for 30 minutes every 2 hours. Salmonids and other fish of management concern are measured and reported. CWT fish are kept and decoded for tag code. Although fish are salvaged and returned to the western Delta via truck- there is loss prior to salvage, due to pre-screen loss and other losses associated with the salvage process itself. Genetic tissue samples have also been taken for several years from unmarked salmon encountered during the sampling process. A report on the results is forthcoming from IEP (B. Harvey, CDWR, personal communication). For most of the years, microsatellites were used to estimate race (Hedgecock 2002; B. Harvey, CDWR, personal communication).

In addition to the DJFMP, the IEP funded ocean recovery of CWTs for several years. It has also funded the tagging and marking of late-fall Chinook salmon from Coleman National Fish Hatchery, so they would not be mistaken for naturally spawned winter-run Chinook salmon in terms of take at the Central Valley Project and State Water Project fish salvage facilities. IEP also solicited proposals and funded or supported the following projects in 2013: (1) an analysis of historical Chinook salmon CWT data to determine factors affecting migration routes and apparent residence time in the Delta, (2) a synthesis of the 2010-2012 south Delta Chinook salmon survival studies, (3) a spatiotemporal reconstruction of Central Valley winter-run

Chinook salmon migratory histories and habitat use with otolith microchemistry, (4) a study to identify the genetic basis of migration and survival in Central Valley steelhead and Chinook salmon, and (5) the development and evaluation of salmonid abundance indices from repeated measurements using DJFMP beach seine data. Although a proposal was submitted to IEP in 2013 to provide funding for the DJSSS to estimate Chinook salmon survival in the south Delta, the proposal was not funded.

Although the DJSSS were funded originally by the IEP, they have not been funded by the IEP since the mid-1990s. However, some annual funds for the south Delta survival studies have been provided by the CDWR Planning Division (approximately $75,000 per year) through the IEP contract. These funds are for additional trawling needed to recover CWTs from Chinook salmon at Chipps Island from releases made in the south Delta, prior to, and during the early years of VAMP. In recent years the CDWR-IEP funding has been used to supplement the acoustic tag studies on salmon in the south Delta. Since the mid-1990s, funding for the survival studies has been from the CVPIA (B2) monitoring and signatories of VAMP. Both of these funding sources have been reduced or eliminated in recent years. Funding for the 6 year steelhead survival study is provided by USBR. Support for the Chinook salmon survival study in 2013 is provided by CDWR, USFWS-CVPIA, and USBR.

Delta Science (previously CALFED) has also funded specific research projects on Chinook salmon and steelhead monitoring, research, and modeling between 2003 and 2011 (Table 3). Since 2004, approximately 9 million of the 23 million dollars obligated for projects was spent on salmonid related studies or analyses. The DJSSS was awarded two of these grants (see Brandes, Table 3) and was significantly involved in others (see Perry and Klimley, Table 3) and these are discussed later in this document. These projects, in some cases, have been fundamental in the progress made relative to understanding Chinook salmon and steelhead in the Central Valley, especially those relating to salmonid survival through the Delta. In addition, we provided data to some of the modeling projects funded through this process (see Dodd and Hendrix, Table 3).

There are several reasons why salmonid monitoring continues to be important to the IEP members, especially the USFWS and NMFS. First of all, the USFWS (and USBR) have been tasked with implementing the CVPIA's Anadromous Fish Restoration Plan which requires making "*all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis.*" In addition, the final restoration plan for the AFRP identified the Delta as the highest priority area for restoration, since all the production of all anadromous fish must migrate through the Delta (USFWS 2001). Furthermore, spring-run and winter-run Chinook salmon and steelhead are listed as threatened or endangered and information is needed to inform Biological Opinions, regulate incidental and directed take and to mitigate present water project impacts. As climate change accelerates and large-scale restoration or new water conveyance systems are built (Bay-Delta Conservation Plan), monitoring of salmon and steelhead populations continues to be important for assessment and adaptive management of these Chinook salmon runs and steelhead as well as other anadromous species.

NMFS defines viable salmonid population (VSP) parameters using four attributes of a population: abundance, productivity, diversity, and spatial structure, recognizing that the freshwater, estuarine and marine habitat capacity and diversity are a critical foundation to VSP (Public Draft of Recovery Plan, NMFS 2009b). It is necessary to provide monitoring that evaluates these components, so accurate assessments may be made of recovery trajectory, status, and outcomes. NMFS also uses a juvenile production estimate (JPE) to set winter-run Chinook salmon take limits of 1 and 2% for the SWP and CVP. This production estimate is based on an estimate of the female escapement, fecundity and estimates of survival from egg to smolts at Sacramento. These estimates of survival in the various components of the life-cycle are based on best estimates of average levels of survival (NMFS 2009a). The take of 2% of the natural production of winter-run smolts was adopted in recognition that take would be over-estimated by about 100% using winter-run-sized fish to identify take at the CVP and SWP, as only about half of the winter-run sized fish (using the Delta length at date model) are truly winter run.

Salmonid Project Work Teams

The DJFMP is funded and coordinated through the IEP (Figure 4) to monitor the status and trends of fish populations to provide ecological information and scientific leadership for the management of natural resources in the Estuary (http://www.water.ca.gov/iep/). To accomplish this mission, the IEP is led by directors from participating agencies (Directors), work planning is guided and reviewed by an interagency coordinator team (Coordinators), and all activities are developed and supported by a technical research and monitoring group (Management Team). Currently, the DJFMP has two representatives on the Management Team and status reports are regularly provided to the USFWS Coordinator and Director to facilitate research and monitoring and to avoid redundancy within the annual IEP work plan. In addition, the IEP provides a comprehensive scientific framework, including peer review and data management, for the DJFMP to coordinate and collaborate with other agencies to improve the use and sharing of resources and data. Finally, staff from the DJFMP and DJSSS serve on several project work teams (PWT). Although PWTs for salmonids and non-salmonids (described in next section) are discussed separately in this report, many of the PWTs have broader focus making the categories somewhat artificial. All PWTs are open to the public and interest groups, including universities and stakeholders, and serve to highlight and recommend research priorities to IEP.

The DJFMP and DJSSS coordinate their activities through many venues, including many of the salmonid PWTs. The Central Valley Salmonid Project Work Team (CVSPWT) is the parent group with others being satellite teams (Figure 4). The CVSPWT coordinates Chinook salmon and steelhead research, monitoring and management activities in the Central Valley. The team facilitates communication and information exchange among the agencies and stakeholders through the organization of meetings, workshops, and seminars. The team meets quarterly and also provides technical advice and informal peer review. Team members currently include staff from the CDFW, CDWR, State Water Resources Control Board, East Bay Municipal Utility District, Westlands Water District, NMFS, Pacific States Marine Fisheries Commission, USBR, and the USFWS.

As needed, the CVSPWT establishes technical working groups to coordinate monitoring and management activities related to individual salmonid races or technical issues. These working groups currently include: Upper Sacramento River Monitoring, Genetics, Hatcheries, Winter-run Chinook salmon, Salmonid Escapement Monitoring, Juvenile Monitoring, Steelhead, and Biotelemetry PWTs. Project work teams are intended to fulfill a current need, but when needs change project work teams are disbanded or new PWTs are started. For example, the Biotelemetry team is a relatively new PWT. It was started in September of 2011 and meets twice a year. The VAMP PWT, the Delta Salmon and Delta Salmon Rearing PWT are three examples of salmon PWTs that have been disbanded. The VAMP PWT disbanded after the VAMP field study was completed at the end of 2011. The Delta Salmon and Delta Rearing PWTs were disbanded several years ago due to lack of interest and time constraints among organizers. Restarting the Delta salmon PWT has been discussed as a way to better coordinate life-cycle modeling and other salmon and steelhead analyses specific to the Delta but as of yet has not occurred.

Three other notable groups, while not explicitly IEP project work teams, have been coordinating biotelemetry activities and analyses from south Delta acoustic studies in 2012 and developing proposal for the south Delta in 2014: the 6 year salmonid studies, the CDWR/NOAA 2012 Stipulation Study, and the South Delta Collaborative Study Group. The program manager for the DJSSS has been participating in these groups and activities.

Non-Salmonid Fish in the Estuary

Conceptual Habitat and Drivers Model

For perspective and understanding of how the DJFMP fits into other non-salmonid fish monitoring in the Estuary, we provide a generalized habitat and driver model (Figure 5) adapted from the Pelagic Organism Decline (POD) model developed by Sommer et al. (2007a). POD refers to the sudden and overlapping decline of pelagic fishes within the Estuary beginning in 2000. Species of management concern include delta smelt, longfin smelt (*Spirinchus thaleichthys*), threadfin shad (*Dorosoma petenense*), and young-of-year striped bass (*Morone saxatilis*). Drivers of the decline are grouped into the following categories: (1) prior fish abundance, (2) habitat, (3) top-down effects, and (4) bottom-up effects (Sommer et al. 2007a). Although this model was further refined for the POD species, many of the drivers affecting population dynamics apply to the other fishes reported by the DJFMP.

Coordinating Non-Salmonid Monitoring in the Estuary

The IEP has funded over 15 fish monitoring program elements that directly or indirectly provide non-salmonid data to natural resource managers and researchers within the Central Valley (Honey et al. 2004). Sample designs have varied in temporal and spatial scale or extent and gear types have included beach seining, boat electrofishing, long-lines, gill-nets, fyke traps, creel surveys, and a variety of surface, oblique, and benthic trawls targeting multiple life stages of fish

(Honey et al. 2004). The information collected by these program elements allows for the assessment of fish assemblage structure and status and trends of non-salmonid fishes of management concern including delta smelt, longfin smelt, green sturgeon (*Acipenser medirostris*), and striped bass (Honey et al. 2004).

The DJFMP currently provides critical data on factors affecting fish assemblage structure in the Delta (Figure 5). Long-term trends can potentially demonstrate population dynamics including stock-recruit effects of declining spawner abundance. The reporting of fish assemblage structure also provides information on intra- and inter-specific competition and predation threat. The spatial scope of the DJFMP further allows comparisons of habitat variability and fish-habitat relationships within the Delta at coarse scales. We have emphasized quantitative habitat assessments in the last year associated with our beach seine and trawl surveys and improved fish-habitat models are in development. Bottom-up effects are largely not considered by the DJFMP with the exception of regular zooplankton sampling conducted in conjunction with the larval fish sampling at Liberty Island.

Non-Salmonid Project Work Teams

The DJFMP staff participates on several non-salmonid PWTs, including the Estuarine Ecology PWT. With quarterly meetings, the main objective of the Estuary Ecological PWT is to discuss ecological issues regarding the Estuary with scientists from agencies, academic institutions, and private organizations. Examples of relevant topics include improving population estimates of delta smelt and longfin smelt. Similarly, the objective of the Pelagic Organisms Decline Management Team (PODMT) is to plan and implement studies about the population status and drivers of pelagic organisms in the Delta and Suisun Bay and to synthesize study results. The synthesis aspect has been formalized as a pilot project in 2012 in the form of the Management Analysis and Synthesis Team (MAST), which includes participation from the DJFMP. In support, the POD-Contaminants PWT was formed to prioritize contaminant research and to inform the PODMT. More generally, the POD-Contaminants PWT serves as a forum among agencies, stakeholders, and other institutions to discuss the impacts of contaminants on the structure and function of the Estuary. Finally, staff from the DJFMP participates on the Yolo Bypass PWT which provides guidance and reviews research and monitoring efforts in the Yolo Bypass region. DJFMP efforts to monitor the movements and habitat occupancy of fish at Liberty Island are particularly relevant to the Yolo Bypass PWT.

SAMPLING ELEMENTS

This section of the report describes the DJFMP sampling methods, including long-term monitoring elements (seines and trawls) and current tagging studies for the DJSSS.

Long-term monitoring elements

The DJFMP samples at 3 trawl sites and 58 beach seine sites located throughout Estuary (Figure 6, Table 4). The sampling frame is presented in Table 4 and highlights the spatial and temporal coverage of the monitoring program. Future program modification must be assessed in the context of the value of continuing long-term monitoring components that provide a baseline for understanding salmonid and resident fish demographics in the Delta.

Trawl sites are located at the entry (Sherwood Harbor on the Sacramento River and Mossdale on the San Joaquin River) and exit (Chipps Island) points of the Delta (Figure 6). Trawling is generally attempted at each site three days per week throughout the year except when prohibited by take restrictions for endangered species of management concern. One exception is that the CDFW samples at Mossdale between April and June of each year, at a more intensive schedule (between 3 and 7 days per week), whereas the DJFMP samples at Mossdale the remaining months of the year 3 days per week. Although long-term trends from MWT salmonid data are typically reported for Sherwood Harbor and Chipps Island between April and June (Brandes et al. 2000), trawl sites have been generally sampled year-round since 1995 and at Mossdale starting in 2000.

The beach seine sites are stratified into seven geographic regions, including the (1) Lower Sacramento River Seine, (2) North Delta Seine, (3) Central Delta Seine, (4) South Delta Seine, (5) Lower San Joaquin River Seine, (6) San Francisco and San Pablo Bay Seine, and the (7) Sacramento Seine (Figure 6). Seine regions are delineated by proximity to canals or water bypasses where fish may be diverted from historical migration routes. Beach seining is generally attempted one day per week throughout the year within all seine regions excluding the Sacramento and Bay seine regions. Sites within the Sacramento seine region are sampled three days per week from October through January for use in real-time water operations. San Francisco and San Pablo Bay sites are sampled every two weeks throughout the year.

Beach Seine Methodology.–Sampling at beach seine sites is conducted between sunrise and sunset. We sample using a 15.2 x 1.3 m beach seine net with 3 mm delta square mesh, a 1.2 m bag in the center of the net, and a float line and lead line attached to 1.8 m tall wooden poles on each side. In general, beach seines are deployed along the shoreline by two crew members within unobstructed habitats including boat ramps, mud banks, and sandy beaches. When sampling mud dominated habitats (i.e., dominated by substrata with particles < 62.5 µm in diameter), we apply rollers to the lead line of the beach seine to limit the net from sinking into the substrate and impeding the completion of the seine.

The beach seines are generally deployed starting from the downstream portion of each site to limit disturbance (e.g., displacement of sediment into the site). Crew member 1 distributes the seine into the water, perpendicular from the shoreline, as crew member 2 secures the opposite end of the seine to the shoreline. After reaching a depth of up to 1.2 m, a distance (i.e., length) of up to15 m, or an obstacle, crew member 1 measures and records the distance to the shoreline and depth to the nearest 1 m and 0.1 m, respectively. Obstacles are defined as structure that could compromise safety or gear efficiency including steep banks or holes, fast water current, submerged aquatic vegetation, or large woody debris. Next, crew member 2 carries their end of the seine to crew member 1 and places their end of the seine in the same location as crew member 1. The seine is then distributed from that point upstream and as parallel to the shoreline as possible by crew member 1. When crew member 1 reaches a depth of up to 1.2 m, a distance (i.e., width) of up to15 m, or an obstacle that could compromise safety or gear efficiency, crew member 1 stops and the width and depth of the seine is measured to the nearest 1 m and 0.1 m, respectively. If the depths of the seine varies between measurements, the maximum seine depth is obtained by averaging the two depth measurements. Lastly, crew members 1 and 2 pull the ends of the seine simultaneously toward (i.e., perpendicular) the shoreline while attempting to maintain the starting distance (i.e., seine width) apart. After the seine haul is completed, all fish are collected from the bag and other parts of the seine and placed in a holding container filled with river water for processing. This method has been consistent since 1985, when we started estimating the volume of water sampled for calculating catch per cubic meter.

Despite the consistent methods, the spatial and temporal variability of seine efficiency among sites and regions is unknown. Therefore, we implemented a year-round beach seine efficiency study in 2013 in conjunction with regular DJFMP sampling (see proposal in Appendix C: Beach Seine Efficiency Evaluations). During each season, we randomly sample a minimum of five sites per region from the 58 fixed monitoring sites. We are conducting the study using a standard DJFMP beach seine net inside a block-net enclosure. Although DJFMP beach seining is not traditionally conducted within an enclosure, the enclosure is necessary to determine the true population within the sampling area for efficiency estimation. To validate that all fish occurring within each enclosure are retained, observed, and recorded, fish are temporarily marked by stain dye and released into the enclosures for recapture using seines and secondary gears (Bayley and Herendeen 2000). The fish used for mark-recapture are common benthic and pelagic species collected from nearby habitats.

Trawl Methodology.–Trawl sites are sampled with a MWT or KDT. The DJFMP exclusively uses a MWT at the Chipps Island trawl site and a KDT at the Mossdale trawl site. The Sacramento trawl site has exclusively used a MWT prior to 1994, and has used a KDT from October to March and a MWT for the remainder of each field season thereafter (Brandes et al. 2000). The KDT is used in place of the MWT at the Sacramento trawl site to maximize the capture of larger and less abundant runs of Chinook salmon (Brandes et al. 2000). The larger mouth opening of the KDT is hypothesized to increase the probability of capturing winter-run, yearling late fall-run, and yearling spring-run Chinook salmon as it approximately doubles the volume of water sampled relative to the MWT (Brandes et al. 2000; McLain 1998). Simultaneous and adjacent trawling at the Sacramento trawl site suggested that despite similar CPUE, the KDT captured significantly larger Chinook salmon compared to the MWT but the difference of 2.0 mm fork length (FL) was minimal (McLain 1998).

During each sampling day, we generally conduct a maximum of ten 20-minute tows between sunrise and sunset at all sites. All tows are conducted facing upstream in the middle of the channel at the Sacramento and Mossdale trawl sites, which constitute a reach length of approximately 6.5 km and 3 km, respectively. In contrast, tows are generally conducted facing both upstream and downstream, regardless of tidal stage, in the north, south, and middle portions of the channel at the Chipps Island trawl site, which constitutes a reach length of approximately 4 km. The MWT and KDT nets are towed by one and two boats, respectively, in the top few meters of the water column at a speed necessary and distance apart (for KDT) to ensure the net mouth remained fully extended and submerged. The measure of the distance traveled during each tow is recorded using a mechanical flow meter (General Oceanics, Model #2030). In general, the Sacramento MWT net is towed at speeds between 0.7-1.0 meters per second (m/s), the Chipps Island MWT net is towed at speeds between 0.9-1.12 m/s, and the KDT nets are towed at speeds between 0.45-0.67 m/s at both the Mossdale and Sacramento trawl sites. It was reported previously (Kjelson and Brandes 1989) that engine speed was held constant at Chipps Island and that tows were typically made against the current except at slack tide. The Chipps Island MWT fishes approximately the upper half of the water column where 90% of the smolts are found during the daylight hours (Kjelson and Brandes 1989; Wickwire and Stevens 1971).

The Sacramento MWT net is composed of six panels, each decreasing in mesh size towards the cod end. The mesh size for each panel ranged from 20.3 cm stretch at the mouth to 0.6 cm stretch just before the cod end. The cod end was composed of 0.3 cm weave mesh. The fully extended mouth size was 4.15 x 5 m. Two depressors and hydrofoils enabled the net to remain at the top few meters of the water column while sampling. Depressors were made of 0.7 cm thick stainless steel (one on each side of the net lead line) and were attached to the net with shackles to extend the bottom line of the mouth. Hydrofoils were made of 0.7 cm thick aluminum plates with split floats (one on each side of the net float line) and were attached to the net with shackles to extend the top of the net at the water’s surface. On each side of the net, the depressor and hydrofoil were connected to the boat using a 30.5 m Amsteel rope bridle (0.64 cm diameter). The net was fished approximately 30 m behind the boat.

The MWT net used at the Chipps Island trawl site is similar in construction to the MWT net used at Sacramento. There are five panels, each with decreasing mesh size towards the cod end. The mesh size for each panel ranged from 10.2 cm stretch at the mouth to 2.5 cm stretch just before the cod end. Prior to 1997, the cod end was composed of 0.64 cm knotless material. Although larger mesh (0.79 cm) was intermittently used after 1997, the switch was not fully implemented until 2001 (see documentation in Appendix D: DJFMP Metadata). The cod end mesh size for the Chipps Island MWT was increased from 0.64 cm to 0.79 cm to minimize the incidental take of larval delta smelt. The fully extended mouth size of the Chipps Island MWT net was 7.64 x 9.65 m (previously reported as 7.9 x 9.1 m, Kjelson and Brandes 1989). The depressors and hydrofoils of the Chipps Island MWT are larger and are connected to the boat identically to those on the Sacramento MWT. On each side of the net, the depressor and hydrofoil are connected to the boat using a 30.5 m Amsteel rope bridle (0.6 cm diameter) attached to a 15.2 m tow rope (0.95 cm diameter). Therefore, the Chipps MWT net fishes approximately 45 m behind the boat.

The KDT nets used at the Mossdale and Sacramento trawl sites are composed of five panels, each decreasing in mesh size towards a live box at the cod end. The mesh size for each panel ranges from 5.1 cm stretch at the mouth to 0.6 cm stretch just before the live box. The live box (36 cm wide x 36 cm tall x 49 cm long) is composed of 0.18 cm think aluminum that is perforated with numerous 0.46 cm diameter holes. The live box containes several internal baffles to minimize fish mortality and stress due to flow pressure. The fully extended mouth size of the KDT nets is 1.96 x 7.62 m. A float line and lead line enabled the nets to remain at the top few meters of the water column while sampling. In addition, at the front of each wing of the net is a 1.83 m bar with floats at the top and weights at the bottom to keep depth constant while sampling. The KDT nets are connected to two boats using a 2.3 m rope bridle (2.4 cm diameter) attached to a 30.5 m tow rope (0.95 cm diameter) on each side of the net. The net fishes approximately 31 m behind the boats.

At the end of each tow, the MWT nets are retrieved by the towing vessel using winches to collect all the fishes captured in the cod ends. Whereas at the end of each tow using the KDT nets, the two towing vessels (i.e., net and chase boats) come together and the chase boat transfers its tow rope to the net boat. The crew on the chase boat then retrieves the live box from the KDT net and collects all the captured fish. Prior to 2013, the KDT would be retrieved before checking the livebox at the end of the sampling day or when the boats reached the boundary of the trawl reach and all fishes found on the net (i.e., gilled) or within the livebox would be counted as catch. Unfortunately, these activities likely biased high the catch for those tow samples relative to other tow samples where just the livebox was checked. In 2013, the DJFMP defined catch as fish found within the livebox prior to retrieving the KDT to ensure comparability among all tows within a sample day to allow finer scale analysis in the future. All fishes collected from the cod ends or live boxes are placed in a holding container filled with river water for processing.

Environmental Measurements.–Although Secchi depth and water temperature have been recorded during the Chipps MWT since 1976, we improved the consistency and extent of the habitat measurements sampled during the seine and trawl surveys in 2012 (Table 5). In general, we record Secchi depth (trawl only), temperature, conductivity, dissolved oxygen, and turbidity during each trawl or seine haul. Substrate composition and flow velocities are also measured during the seine efficiency trials and we intend on recoding these variables during the regular beach seine monitoring in the next year. Finally, substrate composition is also collected at Liberty Island during the larval and zooplankton trawls using a ponar grab sampler and proximity to vegetation is estimated visually.

Invertebrate Monitoring.–In the early 2000s, the DJFMP also began documenting the number of two nonnative aquatic invertebrate species (Chinese mitten crabs and mysid shrimp *Exopalaemon modestus*) throughout the Estuary to better help elucidate possible inter-specific interactions between non-native aquatic invertebrates that may impact fishes of management concern. In 1999, the DJFMP partnered with the USFWS Aquatic Invasive Species program to document catches of the Chinese Mitten crab and provide basic information on the distribution of the Chinese Mitten crab within the Estuary until their collapse in 2003. In 2000, the DJFMP also began documenting the catch of several non-native jellyfish which could be used as indicators of environmental conditions. In addition, the catch of a nonnative freshwater shrimp started to be recorded in 2002 and are continuing today to provide occupancy information. These efforts of documenting shrimp catch expanded in 2012 per the expansion of a new aquatic shrimp species that was initially introduced into the Mokulemne River in 2006.

Fish processing.–In general, all fish ≥ 25 mm (FL) are identified and measured in the field. However, three-spined stickleback (*Gasterosteus aculeatus*), western mosquitofish (*Gambusia* *affinis*), rainwater killifish (*Lucania parva*), Sacramento sucker (*Catostomus occidentalis*), and Sacramento splittail (*Pogonichthys macrolepidotus*) are more easily distinguished and are measured down to 20 mm FL. Fish that cannot be identified with certainty in the field are returned to the laboratory for expert analysis and identification. All salmonids collected in the field, including steelhead, are examined thoroughly for adipose fin clips prior to being released. Unless specifically notified otherwise, all adipose-clipped juvenile Chinook salmon are collected, labeled, and returned to the office for CWT processing. After extraction, the CWT data are recorded and made available on the DJFMP website. Although the CWT tables are not currently formatted for the Regional Mark Information System, we anticipate making the necessary changes in 2013 and uploading all CWT data to this database.

If large samples are collected, only the first 30 individuals of a non-listed species and the first 50 individuals of a listed species are measured per haul (seine) or tow (trawl). In the case of Chinook salmon, 50 individuals are measured for each run. The remaining individuals are summed and recorded as plus counts. Although it was recommended that plus counting be terminated (Brandes et al. 2000), the DJFMP continues to employ this protocol due to time constraints and to ensure that fish are quickly returned to the water. However, the frequency of plus counting has declined in recent years. For example, plus counting was employed for Chinook salmon (fall- and spring-run only) on average during 58 tows (range = 16–102) at Chipps Island between 2000 and 2006. In contrast, plus counting occurred at Chipps Island during only two tows on average between 2007 and 2012 (range = 0–4). Similarly, plus counting for longfin smelt occurred on average during 32 tows (range = 13–54) at Chipps Island from 2000–2003 and declined to one tow on average from 2004–20012 (range = 0–5).

Relative and Absolute Abundance Calculations.–Samples from each gear type are standardized to catch-per-unit effort (CPUE) as fish per unit volume (fish / 10,000 m^3) sampled for each seine or tow following:

$$\text{Seine CPUE} = \frac{\text{Catch}}{\tfrac{1}{2}\,\text{Depth} \times \text{Width} \times \text{Length}} \times 10{,}000 \qquad (1)$$

$$\text{Trawl CPUE} = \frac{\text{Catch}}{\text{Distance Traveled} \times \text{Net Mouth Area}} \times 10{,}000 \qquad (2)$$

Because the MWT and KDT nets do not open completely while under tow and net mouth dimensions vary within and among tows (USFWS 1993a), we used previously quantified estimates of mean net mouth area for this report. The mean net mouth area for MWTR nets used for the Chipps Island and Sacramento Trawl Sites were obtained from 3-4 physical measurements taken while sampling and were reported as 18.58 m^2 and 5.08 m^2, respectively (USFWS 1993a). The mean net mouth area for KDT nets used for the Mossdale and Sacramento Trawl Sites were obtained by extrapolating from the mean net mouth area of the MWTRs and were reported as 12.54 m^2 (USFWS 1998). During February 2009, Desert Star Systems contracted by the CDFW estimated the mean mouth area of the MWT at Chipps while being towed by two DJFMP research vessels using acoustic technology (Andy Goldstein, personal communication). A total of 17 ten-minute tows for each research vessel during the study. Preliminary results indicated that the MWT mouth area varied within and among tows and averaged 12.78 m^2 and 13.45 m^2 between the two vessels, suggesting that the DJFMP has been underestimating fish densities at Chipps Island. It is apparent that further investigation is needed to determine if and how the net mouth areas of both MWTs and KDTs vary.

We examined the spatial and temporal trends of the relative abundance by averaging CPUE data at the desired scale. To minimize the overweighting of sample days and locations when the number of samples collected varied within and among weeks for sites within seine regions and trawl sites, data are summarized using daily, weekly, monthly, and yearly CPUE averages. The mean daily CPUE is calculated as the sum of the trawl or seine CPUE for a trawl or seine site during each sample day divided by the number of samples taken each day. The mean weekly CPUE is calculated for trawl sites and seine regions as the sum of the mean daily CPUE for a trawl or seine site during each sample week divided by the number of days sampled each sample week and averaging among seine sites within a seine region for each sample week. A sample week was defined as Sunday to Saturday. The mean monthly CPUE is calculated as the sum of the mean weekly CPUE for a trawl site or seine region during each calendar month divided by the number of sample weeks sampled each calendar month. If a sample week occurred in more than one calendar month, the sample week was assigned to the calendar month that contained the start of the sample week. The mean yearly CPUE was calculated as the sum of the mean monthly CPUE for a trawl site or seine region during each field season divided by the number of months sampled each field season.

To make sound temporal comparisons using beach seine data, the primary assumption of this averaging approach is that either at least one sample is collected at each site within a seine region during each sampling interval (e.g., weekly), that the underrepresentation of one or more sites within a region is identical among years, or there is no spatial dependency regarding fish catch densities among sites within regions. However, the proportion of incomplete samples among most seine sites has exceeded, on average, 15% of all sampling occasions from 2006 to 2012 and varied considerably among years for some seine locations (Figure 7). Further, there is obvious spatial dependency among seine sites regarding mean catch densities for a number of species, including juvenile Chinook salmon and Sacramento splittail (Figures 8–9). Therefore, there may be considerable bias in the relative abundance trends and distributional patterns obtained using seine data collected within particular regions such as the lower Sacramento River, lower San Joaquin River, and South Delta seine regions based on incomplete sampling (Figure 7). The lower Sacramento and San Joaquin River seine sites may not be sampled due to low and high flows that may desiccate, inundate, or modify (i.e., wash away or obstruct) the historical seine site. Sites within the South Delta seine region may not be sampled due to a growing presence of invasive submerged (e.g., *Egeria densa*; Brown and Michniuk 2007) and floating aquatic vegetation (e.g., *Eichhornia crassipes*; Toft 2000) coupled with tidal extremes. Unfortunately, the resulting bias has not been adequately quantified and no adjustments are made with the catch data despite the violated assumptions. Further investigation is needed to determine the extent of the spatial bias within and among seine regions and how it may interact temporally (e.g., among seasons) regarding catch indices. There are no sources for spatial bias for surface trawl sampling elements due to the single sampling location for each trawl throughout the field season.

The monthly absolute abundance of unmarked Chinook salmon (N) is estimated at Chipps Island using the methods modified from USFWS (1987) as:

$$N_i = \frac{n_i}{t_i \text{ x } \overline{TRR}}$$

where *i* indexes months, n_i represents the total number of unmarked juveniles collected in the Chipps Island trawl during a month, t_i represents the fraction of time Chipps Island was sampled during a month, and $\overline{TRR}$ represents the mean trawl recovery rate (TRR) in the Chipps Island trawl. The assumption of this approach is that juvenile salmon are equally distributed in time as they migrate past Chipps Island.

The TRR at Chipps Island is estimated using the capture of CWT juvenile Chinook salmon released approximately 10 km upstream of the Chipps Island Trawl Site at Sherman Island or Jersey Point as:

$$TRR_k = \frac{n_{recovered}}{n_{available}}$$

where *k* indexes release groups at Sherman Island or Jersey Point, $n_{recovered}$ represents the total number of juvenile CWT Chinook salmon within a release group collected at the Chipps Island Trawl Site, and $n_{available}$ represents the number of juvenile CWT Chinook salmon within a release group available for collection at the Chipps Island Trawl Site. Recognizing that the TRR can vary among release groups based on differences in sampling effort, $n_{available}$ was estimated for each release group as:

$$n_{available} = n_{released} \text{ x } t$$

where $n_{released}$ represents the total number of CWT juvenile Chinook salmon within a release group and t represents the fraction of time the Chipps Island Trawl Site was sampled from the first recovery to the last recovery of CWT juvenile Chinook salmon in the release group. The assumption of this approach is that juvenile Chinook salmon within a release group are equally distributed in time and have 100% survival. However, recent information from acoustic tag studies indicated that survival between Jersey Point and Chipps Island may be as low as 69%.

A release group is defined as a group of individuals that possessed identical CWT numbers, had the same hatchery origin, and were released at the same location and time. A total of 74 releases have occurred at Sherman Island or Jersey Point from field seasons 1989 to 2011. All release groups at Sherman Island and Jersey Point were included in the calculation of $\overline{TRR}$ to maximize sample size and obtain a more robust estimate. Mean FL from the release groups ranged from 76 mm to 183 mm (mean = 93mm), which includes the majority of unmarked juvenile Chinook salmon historically collected at Chipps Island. All release group data were obtained through the Regional Mark Processing Center maintained by the Pacific States Marine Fisheries Commission (PSMFC 2012).

The $\overline{\text{TRR}}$ is calculated as an average of all recovery rates weighted by the number of individuals within each release group. The monthly absolute abundance estimates are calculated using the $\overline{\text{TRR}}$ and its 95% confidence limits to incorporate uncertainty. Monthly absolute abundance estimates are tabulated for inter- and intra-annual comparisons.

Absolute abundance estimates for juvenile Chinook salmon are only presented for Chipps Island in this background report. However, net efficiency estimates are available for the Mossdale and Sacramento trawl sites. Net efficiency and absolute abundance estimates are calculated annually by CDFW at Mossdale since 1989 (SJRGA 2013), and net efficiency has been measured periodically at Sherwood Harbor by the DJFMP since 2002 (Wilder and Ingram 2006; USFWS 2007; P. Brandes, USFWS, personal communication). In general, the CDFW uses two methods to estimate the absolute abundance of unmarked juvenile Chinook salmon at Mossdale (SJRGA 2013). The first approach uses a catch per acre feet expansion method which does not require efficiency estimates and assumes that all unmarked juvenile Chinook salmon are evenly distributed throughout the channel and all individuals are captured that occupy the volume of water sampled. Using this approach, the absolute abundance is estimated by taking the number of unmarked individuals captured within a sample divided by the volume sampled and expanding in space by multiplying that index by the mean daily flow (SJRGA 2013). For days not sampled, the catch per acre feet index is averaged during the two days before and two days after the non-sampled period and expanded by flow for each day (SJRGA 2013). The second approach uses net efficiency estimates derived from the recoveries of marked hatchery reared individuals released in multiple groups each year approximately 2.25 km upstream of the Mossdale trawl site (SJRGA 2013). All marked fish released are assumed to have 100% survival and assumed to have moved through the sample area during sampling during the day of the release. Marked individuals within each group are released at the beginning of each sampling day and sampling persisted until at least ten tows were completed and few marked individuals were recovered in a tow (e.g., two or less). Annual efficiency estimates are calculated by dividing the total number of individuals recovered by the total number of individuals released during the year (SJRGA 2013). To estimate the absolute abundance of unmarked juvenile Chinook salmon passing the Mossdale trawl site each day, the catch per minute of sampling index for unmarked individuals is divided by either year-specific or predicted net efficiency estimates (derived from a model regressing all efficiency estimates based on river flow) and later extrapolated to a 24-hour period to account for the proportion of time not sampled each day (SJRGA 2013). For days not sampled, the catch per minute index for unmarked individuals is averaged during the two days before and two days after the non-sampled period, corrected for efficiency, and expanded by time (SJRGA 2013).

At the Sacramento trawl site, net efficiency was estimated by conducting 24-hour intensive sampling with hatchery releases made approximately 4.5 km or 8.5 km upstream of the sampling area (Wilder and Ingram 2006; USFWS 2007; Brandes, USFWS, personal communication). Six and three 24-hour efficiency tests were conducted between 2002 and 2005 and in 2009, respectively. In general, efficiency sampling for each efficiency test started when the marked fish were released upstream, continued for 24 hours, and it was assumed that all marked individuals moved through the sample area. Efficiency estimates derived from efficiency tests conducted from 2002 to 2005 assumed 100% survival and the efficiency of the trawls were calculated using the number of marked fish recovered divided by the number of fish available for capture (Wilder and Ingram 2006; USFWS 2007). In the USFWS (2007) report, it was assumed that all marked individuals were available for capture. Wilder and Ingram (2006) assumed that marked fish were evenly distributed in time and space and estimated the number of fish available for capture by multiplying the number release by both the proportion of time sampled during the 24-hour period and the proportion of the channel width that was sampled. Conversely, efficiency tests conducted in 2009 did not assume 100% survival (P. Brandes, USFWS, personal communication). In this case, the investigators estimated the number of fish available for capture by multiplying the total released by the survival probability and proportion of time sampled during the 24-hour period. The survival from the two upstream release locations relative to the Sacramento trawl site was estimated by dividing the Chipps Island recovery rates of the release groups upstream of the Sacramento trawl site by the recovery rates of fish released approximately 8 km downstream of Sacramento trawl site and assuming that the difference in recovery rates was due to mortality. However, the estimated survival may be biased low based on the distance between the upstream and downstream release locations far exceeds the distance from the upstream release locations and the Sacramento trawl site. Currently, the DJFMP is compiling all Sacramento trawl CWT recovery data associated with groups released ≤ 8 km upstream of the Sacramento trawl site to develop efficiency estimates that follow the same methods reported earlier for the Chipps Island trawl site. More studies are needed with standardized efficiency sampling and analysis methods prior to estimating and comparing the absolute abundance at each of the trawl sites sampled by the DJFMP.

Current tagging projects for DJSSS

The DJSSS tagged and released approximately 1500 acoustically tagged steelhead as part of the collaborative 6 year steelhead survival study in 2012 and 2013. This effort includes DJFMP staff and those hired temporarily between late-February and May. The 6 year steelhead study is led by USBR and is required as part of the NMFS's OCAP Biological Opinion. USGS participates as a collaborator responsible for the deployment and maintenance of the acoustic receiver array and data collected for the study. In 2012, approximately 1200 acoustically tagged Chinook salmon were also tagged and released to monitor survival of Chinook salmon through the Delta and to assess the mortality at the head of Old River, with a physical barrier installed. The 2012 Chinook studies were funded by USBR, USFWS, CVPIA, and CDWR. In 2013, 960 Chinook salmon will be acoustically tagged to estimate survival from Mossdale to Chipps Island without a physical or non-physical barrier installed at the head of Old River, using the acoustic receivers deployed as part of the 6 year steelhead study. Funding in 2013 was provided by CDWR, USFWS and USBR for the purchase of tags, the tagging and release of the Chinook salmon, and the analyses, respectively, of the 2013 Chinook salmon study in the south Delta.

PROGRAM OBJECTIVES

This section of the report summarizes the long-term and current objectives of the DJFMP, including the survival studies (objective 6) that encompass the DJSSS. Although sampling at Liberty Island complements the salmonid and non-salmonid objectives, this study is uniquely focused on monitoring restoring tidal wetlands. Therefore, Liberty Island is discussed separately at the end of the objectives section.

Objective 1: Document the long-term abundance and distribution of juvenile Chinook salmon in the Delta

Introduction

The first objective of the DJFMP is intended to continue the long-term monitoring that originated early in the life of the program for Chinook salmon in the lower Sacramento River, Delta and Bay. At the onset of the program and for several years thereafter, we did not attempt to identify juvenile Chinook salmon by run in the catch. Catches were reported as juvenile salmon catch per haul (seines) or catch per tow (trawl) (Kjeslon et al. 1981; Kjelson et al. 1982, USFWS 1987; Brandes and McLain 2001). The sampling was intended to document the relative abundance and distribution of juvenile Chinook salmon during the spring. We recognized that most of the salmon caught during sampling in the winter and spring were from the most abundant run, fall-run. In general, beach seining for Chinook salmon fry was conducted between January and March and trawling for Chinook salmon smolts was conducted between April and June at Chipps Island. Trawling at Sacramento between April and June began in 1988. The survival studies were integrated into the early program and some additional sampling at Chipps Island and Clarksburg (prior to 1988) was conducted to collect marked (fin-clipped, spray-dyed or CWT) juvenile hatchery Chinook salmon as part of experiments.

Assessing the relative abundance and distribution of juvenile Chinook salmon began in the mid-1970s but sampling stations and timing of sampling did not stabilize until the early to mid-1980s. Once stabilized, sampling consisted of beach seining at 30 sites on a weekly basis primarily between January and March or April to document relative fry abundance in the lower Sacramento River and the North and Central Delta. Starting in 1985, the volume of the water sampled by the seine was estimated, thus long-term comparisons start in 1985. Some seining occurred in San Francisco Bay in 1981 and 1982, but was taken over by CDFW as part of the IEP Bay Study until 1986, at which time it was stopped. The volume of the seine was estimated in these Bay sites starting in 1981. The sampling of a subset of these Bay stations (10) was re-initiated by the DJFMP starting in 1997 and has continued since. It is our understanding that the original beach seine sites were chosen based on their accessibility by car. There are not many accessible beaches in the Delta, thus boat ramps were included in the original beach seine sites. The beach seine sampling during the day catches smaller fry than seining at night, suggesting the smaller fish move away from the shoreline at night (Schaffter 1980).

Larger juvenile Chinook salmon were sampled in the main part of the river channel using a MWT at Chipps Island between the months of April and June starting in 1978. A smaller MWT was used for sampling near Sacramento (Sherwood Harbor) between April and June starting in 1988. In 1990, the sampling near Sacramento was done further downstream near Courtland/Hood. Although Chinook salmon caught in the sampling were not designated by race, most were presumably fall-run due to their timing and relative abundance compared to the other races and also in part due to the large fall-run hatchery component.

Trawling indicated that the size of juvenile salmon increased toward the middle of the channel (Schaffter 1980; Wickwire and Stevens 1971). Sampling near Chipps Island in the early years, indicated that Chinook salmon occurred primarily at the surface during the day and were more evenly distributed at night (Wickwire and Stevens 1971). The salmon were most numerous in the middle of the channel and the distribution was related to the size of the fish, with the greatest mean length at the surface in mid-channel (Wickwire and Stevens 1971). The vertical distribution of salmonids was verified in 1974 and determined that juvenile Chinook salmon outmigrants were most numerous in the top 2 meters of the water column during daylight and avoid the surface layer during darkness (IEP 1975).

Comparing catches at the same stations sampled over consistent seasonal time periods allows us to index the relative abundance and distribution of juvenile Chinook salmon since the late 1970s and mid-1980s to the present. However, this approach assumes that sampling efficiency does not vary in time or space, an assumption that is likely violated to an unknown extent.

One idiosyncrasy of comparing trends for catches of primarily smolts among years is the fact that unmarked juvenile Chinook salmon catches at Sacramento and Chipps Island after 2007 contain fewer hatchery fish because a larger proportion of fall-run hatchery production released upstream are tagged with CWT. Juvenile Chinook salmon that are marked and tagged with an adipose clip and CWT are not included in the catches for calculating CPUE. In earlier years, most of the tagged fish were the result of experimental studies (Kormos et al. 2012) and depending upon where the juvenile salmon were released, could artificially bias high the index of salmon caught, so they were historically excluded in comparisons of catch between years. However, a higher proportion of the fall-run Chinook salmon hatchery production (a minimum of 25%) have been adipose clipped and tagged with a CWT since 2007 (Kormos et al. 2012) and these individuals are excluded from seasonal indices. Therefore, indices may be lower than in the past due to this change. A 100% of the late fall-run, winter-run and spring-run produced at Central Valley hatcheries have been marked and tagged for several years. Thus relative comparisons between years, especially for periods prior to, and after 2007 should be viewed recognizing this potential limitation. The problem is likely less for fish caught in the beach seines, as the hatcheries did at one time release unmarked hatchery fry, but curtailed the practice in the 1990s.

Kjelson et al. (1981) summarized the preliminary results of early studies on the influence of freshwater inflow on Chinook salmon in the Estuary. These early studies indicated that additional inflow at the appropriate time would increase the abundance of fry and juvenile salmon using the Estuary and on the survival of juveniles, with survival increasing at higher flows. Results were based on the seine and trawl surveys, collections in fish salvage facilities of the CVP and SWP, and mark-recapture studies.

Kjelson et al. (1982) demonstrated that CWT fry (<70 mm FL) reared in the Estuary for about two months, primarily in the upper freshwater portion of the Delta. They also showed that the areas downstream, in the brackish water bays, were used primarily as a migration corridor for smolts (>70 mm). They concluded that fry abundance and distribution in the Estuary was influenced by the magnitude and timing of the river flows. Growth rates were measured (between 0.4 to 1.2 mm per day) and main diet items were identified, including dipterans, cladocerans, copepods, and amphipods (Kjelson et al. 1982).

Methods

The relative abundance of juvenile Chinook salmon is presented as mean monthly and seasonal CPUE values. We treated site and gear separately for all calculations. Because the number of samples varied within and among weeks for seine and trawl sites, data were summarized using daily, weekly, monthly, and seasonal CPUE averages to minimize the overweighting of sample days or locations. The mean seasonal CPUE was calculated as the sum of the mean monthly CPUE for a trawl site or seine region during each season divided by the number of months sampled each season. Sample volumes for beach seines were recorded starting in 1985 permitting the catch per cubic meter comparisons among seasons (January–March).

We compared the CPUE estimates among seine regions, using the historical sites (see site locations in Appendix D: DJFMP Metadata), between the months of January through March for the years 1985–2011 with the exception of the Bay seine that included years prior to 1985. For the trawl locations, we used the months of April through June between 1978 and 2011. We also compared seasonal abundance in the Bay (January–March), in the north Delta (January–March), and at Sacramento (April–June) to average daily river flow on the Sacramento River at Freeport in February using standard regression techniques. For Chipps Island, seasonal abundance (April–June) was compared to flow at Rio Vista during the same months. These regressions update those that were presented in Brandes and McLain (2001). We estimated the seasonal (April through June) absolute abundance of juvenile Chinook salmon using long-term data collected at Chipps Island from 1978 to 2011. See sampling elements (above) for detailed descriptions of relative and absolute abundance calculations.

Results and Discussion

Long-term abundance and distribution trends varied among regions and locations within the lower Sacramento River and Delta. In the beach seine, catches of juvenile Chinook salmon between January and March were usually greatest in the lower Sacramento River followed by the north Delta (Figure 10). Low catches are found in the central Delta, with the lowest catches observed in San Francisco Bay. Seasonal beach seine catches were lowest in 1985 and 2009 and highest in 1999 with above average catches in 1986, 1995, 1996, 2000, 2003, and 2004.

The abundance of Chinook salmon (mean catch per cubic meter) in the north Delta appears to be related to Sacramento River flow at Freeport during the month of February ($r^2 = 0.5296$, $p<0.01$, $n = 27$; Figure 11). The abundance of Chinook salmon (mean catch per cubic meter in San Francisco Bay also appears to be related to the log of the mean river flow at Freeport in February ($r^2 = 0.7447$, $n = 20$, $p<0.01$; Figure 12). Indices in the north Delta in 2008, 2009 were lower than for similar years at the same flow, with the exception of 2001.

Average CPUE at Sacramento between April and June has steadily declined since the late 1980s and early 1990s (Figure 13). While historically, catch per cubic meter between April and June at Sacramento was inversely related to Sacramento River flow at Freeport in February, this relationship seems to be lessening over time (Figure 14). Catch per cubic meter between April and June at Sacramento since 2007, has been extremely low, and although the exclusion of a greater proportion of marked hatchery fish since 2007 may provide lower estimates given all other things are equal, estimates seem lower than they would be from that factor alone, considering the other 75% of hatchery fish are unmarked and any juveniles from naturally spawned fish would be included. These estimates would indicate the abundance of juvenile salmon immigrating into the Delta between April and June is at historically low levels.

CPUE of Chinook salmon at Chipps Island appeared to be at a maximum in 1982 and 1983 and at a minimum in 2008 (Figure 15). Even with recognizing fewer hatchery fish are included in the catch index in 2008, indices were lower in 2008 than in any of the previous or post 2008 years. Indices in 2011 were higher than any of the post 2007 years.

Catch per cubic meter between April and June at Chipps Island also appears related to flow at Rio Vista between April through June, with higher catches in higher flow years (Figure 16). Even considering the lower abundance of hatchery fish in the indices since 2007, there still appears to be a relationship between abundance and flow, with higher abundance observed at higher Rio Vista flows between April and June (Figure 17). There may also be a reduction in CPUE per unit of flow for the 1995–2006 period relative to the previous period (1978–1994), but there is some overlap between data points within the two relationships (Figure 17).

Comparison of relative abundance versus flows appear to indicate the abundance and distribution of juvenile Chinook salmon is related river to flow, with higher abundance in the beach seines in the north Delta and Bay with higher flows in February, and higher abundance at Chipps Island with higher flows at Rio Vista between April and June. In contrast, the relative abundance at Sacramento appears lower between April and June when there are higher flows during February. This pattern supports our general hypothesis that a higher proportion of the salmon population enters the Delta as fry in wet years and thus are caught in the beach seines and then not available to migrate into the Delta as smolts later in the season and be caught in the trawl at Sacramento between April and June. However, this trend is no longer apparent in recent years since 2007.

The average absolute abundance of unmarked Chinook salmon at Chipps Island between April and June is approximately 15 million, with a long-term declining trend apparent even without including data since 2007 (Figure 18). The average since 2007 has been approximately 5 million

Chinook salmon (Figure 18). The trend for fall-run Chinook salmon is similar, supporting our claim that most of the production during April–June is fall-run (Figure 18).

In this report, we estimated absolute abundance differently than in previous annual reports. Previous reports estimated $n_{available}$ by multiplying the known number of released CWT smolts by an estimate of Delta survival (USFWS 1997). First, Delta survival is estimated by dividing the ratio of expanded ocean recoveries from CWT fish released upstream by the ratio of expanded ocean recoveries for CWT fish released at Benicia, Port Chicago, or Ryde (given that estimated survival must be >0, <1). This calculation assumed that the difference in expanded ocean recovery rates between the two groups was due to mortality between the upstream and downstream release locations. The downstream location is assumed to approximate the expanded ocean recovery rates of CWT fish if released at Chipps Island.

Our present methods uses recovery from groups released at Jersey Point and assumes 100% survival between Jersey Point and Chipps Island. However, recent and upcoming results from acoustic tagging studies suggests there is may be substantial mortality between Jersey Point and Chipps Island, suggesting our estimates of trawl efficiency using this approach may be biased low, which would in turn bias estimates of absolute abundance high. We have used the newer approach outlined above as it is more parsimonious and does not require extrapolations from the ocean fishery.

A special project, funded by the Delta Science Program, evaluated several different efficiency estimates to calculate abundance. Estimates at Jersey Point were in the mid-range of the efficiency estimates (Pyper et al. in draft). One aspect of the project was to determine if trawl efficiency could be modeled using flow, Secchi measurements (inversely related to turbidity), temperature, and fish size or fish race. Although some trends were apparent, it was determined that the data did not support using such a model to estimate trawl efficiency and an average estimate for all years was used to expand catches to abundance (Pyper et al. in draft).

The indices at Chipps Island have been used by other researchers to assess year class strength, when escapement two and a half years later did not meet Central Valley goals. This happened in 2007 when fall-run Chinook salmon collapsed (Lindley et al. 2009), and is ongoing for winter-run in discussion with the winter-run PWT.

Objective 2: Comprehensively monitor throughout the year to document the presence of all races of juvenile salmon

Introduction

Due in part to a rich diversity of life-history strategies, production of the four runs of Chinook salmon in the Central Valley of California was amongst the highest in the world (Yoshiyama et al. 1998). Today, three Chinook salmon runs along with Central Valley steelhead are listed for protection under state and federal endangered species legislation. Water diversions from the SWP and CVP are conditioned by endangered species take permits issued by the NMFS, USFWS and the State Water Resources Control Board (SWRCB). Therefore, vital biological information on the status of steelhead and Chinook salmon is needed. The NMFS 1993 and 2009 Biological opinions required the CDWR and the USBR to fund an expanded monitoring program to provide information on all juvenile Chinook salmon runs in the Delta.

Providing information on relative abundance and distribution for all the runs of juvenile Chinook salmon is challenging because juveniles among the four runs cannot be visually differentiated. Since the mid-1990s, catches have been reported by race using the river model, length-at-capture-date criteria (LDC), with the exception of those caught at Mossdale and the lower San Joaquin River seine region. The river LDC was developed by Fisher (1992) and modified to daily criteria by Greene (1992). Essentially, the LDC designates run by the length of the juvenile Chinook salmon caught on a particular date. The assumptions associated with the river LDC for the Sacramento-San Joaquin River basin include that the (1) spawning of fall-run Chinook salmon occurs between October 1st and December 31st, (2) spawning of late fall-run Chinook salmon occurs between January 1st and April 15th, (3) spawning of winter-run Chinook salmon occurs between April 16th and August 15th, (4) spawning of spring-run Chinook salmon occurs between April 16th and September 30th, and (5) juvenile growth rates are identical among all races of Chinook salmon (Fisher 1992). Although one or more of these assumptions are likely violated (Fisher 1994; Yoshiyama et al. 1998), the LDC is currently widely used by managers, and is the primary tool being used to differentiate between runs of juvenile Chinook salmon in the field. Furthermore, the LDC is currently used by the NFMS for tracking and assessing research take of winter-run Chinook salmon. CDWR and USBR use the Delta LDC model, which is slightly different than the river model, for enumerating incidental take and loss of winter-run Chinook salmon at the SWP and CVP, respectively.

Until 2000, the fall- and spring-run races, as determined using the LDC, were combined for reporting purposes, because there was recognition that fall- and spring-run were no longer spatially separated during spawning in the main-stem Sacramento River (Fisher 1994) and there was likely significant hybridization between the two races (Slater 1963). Overlaps in size between juveniles of the various runs in the Delta and lower Sacramento River is likely, especially for tributary spring run where conditions in the natal streams delay hatching and emergence making their size range similar to late-fall or winter-run juveniles (C. Harvey, personal communication). Considering all the uncertainties with the LDC (Williams 2006), the reported run designations are considered, at best, rough approximations.

Because fall-run Chinook salmon are reportedly the only race to still occur within the San Joaquin River and its main tributaries (Yoshiyama et al. 1998), all juvenile Chinook salmon collected at the Mossdale Trawl Site and within the Lower San Joaquin River Seine Region (Region 5) were classified as fall-run regardless of the LDC. Although the South and Central Delta Seine regions are located within the San Joaquin River basin, there is potential for spring-, winter-, and late fall-run juveniles of Sacramento River origin to migrate into the Central and South Delta through Georgiana Slough, the Delta Cross Channel, Three-mile Slough and the San Joaquin River. Therefore, the LDC is still used to determine the run of juvenile Chinook salmon within the South and Central Delta Seine regions and at Chipps Island.

The relative abundance of winter-run sized Chinook salmon in our catch at Chipps Island relative to that upstream at Knights Landing has been used to assess the residence time and the effect of flow on immigration of winter-run sized fish in the Delta (del Rosario et al. 2013). However, our estimates of the absolute abundance of winter-run sized fish at Chipps Island were evaluated for use in the refinement of the OBAN life-cycle model for winter-run Chinook salmon, but they were not informative due to the potential misclassification of winter-run using the river LDC (Noble Hendrix, personal communication). Hendrix also concluded that the data obtained at Chipps Island, although imprecise, can influence the results of the OBAN model (Hendrix, personal communication). The lack of definitive race designations has also been identified by others as a significant impairment to using the Chipps Island indices for assessing winter-run juvenile production at Chipps Island (Steve Cramer, personal communication). These limitations of using the LDC for winter-run Chinook salmon prompted us to submit a proposal to Delta Science for estimating the absolute abundance of winter- and spring-run Chinook salmon at Chipps Island as part of the PSP process in 2006. The project will be completed by June 30, 2013.

Methods

Sampling locations and timing (year-round) have been generally consistent beginning in 1995 facilitating more robust interannual comparisons (see site locations in Appendix D: DJFMP Metadata). However, site locations, sampling frequency, and gear changes are confounding factors for catch comparisons during the long-term monitoring period. Despite the ongoing changes, the focus of this objective is on the period after 1995 due to improved temporal coverage (year-round).

The relative abundance of juvenile Chinook salmon is presented as mean yearly CPUE values (by field season). We treated Chinook salmon run, site, and gear separately for all CPUE calculations. Lastly, the absolute abundance was calculated for each Chinook salmon run at Chipps Island from 1995 through 2011. See sampling elements (above) for detailed descriptions of relative and absolute abundance calculations.

Genetic Race Designation.–Tissue was collected from MWT samples at Chipps Island between October of 2007 and June of 2011 as part of the Delta Science project. On February 5th of 2008, sampling at Chipps Island was suspended due to high catches of delta smelt. Without knowing when the sampling would be reinstated at Chipps Island, permission was granted from Delta Science and NMFS to collect tissue samples at Sacramento. Thus, tissue samples were collected between March of 2008 and June 2011 at Sacramento. Sampling was reinstated at Chipps Island on March 10, 2008 and has continued at 2 to 3 days per week since then. We continued to take tissue samples at Sacramento, not knowing if a similar disruption to sampling would occur at Chipps Island during the remaining years of the study. Tissues were sent to the CDFW tissue archive lab, where they were split prior to being sent to Oregon State University (OSU). At OSU samples were analyzed to designate race using 21 microsatellites (Banks et al. in draft; Pyper et al. in draft). The race determination using genetics and the race designation using river LDC model have been compared assuming the genetics is 100% accurate, which we know is not true, depending on what run is being identified (Banks et al. in draft), but it is much more reliable and provides some assessment of the accuracy of the LDC. Pyper et al. (in draft) also considered the uncertainty associated with the genetic information based on the origin of known race tissues contained in the genetic baseline.

Results and Discussion

Absolute abundance estimates between 1995 and 2011 indicate annual fall-run Chinook salmon production ranges between about 5 to 20 million, with the highest production in 1995, 1996, and 1998 (Figure 19). It is likely that the annual abundance estimates contain juvenile Chinook salmon from multiple brood years. Absolute abundance estimates for the other Chinook salmon runs are also variable, but consistently low (Figure 19). Similarly, relative abundance for winter-run, spring-run, and late fall-run Chinook salmon among trawl sites and seine regions were consistently low (Figures 20–24).

Spring-run Chinook salmon have been identified genetically as either originating from Butte Creek or Mill and Deer Creeks (Banks et al. in draft). More genetic Butte Creek spring-run were observed in the sampling at Sacramento and Chipps Island than spring-run from Mill and Deer Creeks (Tables 6–7). As expected, most genetic spring-run Chinook salmon were identified as fall-run using the LDC, and some genetic fall-run were identified as spring-run using the LDC (Tables 6–7). The LDC for spring-run Chinook salmon over-estimated the number of genetic spring-run with 84% and 81% misclassified at Sacramento and Chipps Island, respectively. Most genetic spring-run Chinook salmon caught at Sacramento and Chipps Island were classified as spring-run or fall-run, but a few individuals were classified as winter-run using the LDC. Genetic spring-run Chinook salmon were observed at Sacramento between late February and early June (Figure 25a), and at Chipps Island between late March and late June (Figure 25b).

The LDC for winter-run Chinook salmon over-estimated the number of genetic winter-run with 16% at Sacramento and 56% at Chipps Island misclassified based on length (Tables 6–7). Most genetic winter-run Chinook salmon were classified as winter-run using the LDC both at Sacramento and Chipps Island. Only a small percentage of genetic winter-run Chinook salmon (10% at Sacramento and 6% at Chipps Island) fell into other LDC categories (spring-run or late fall-run). Genetic winter-run Chinook salmon were observed at Sacramento between late October and April (Figure 25a) and at Chipps Island between December and April (Figure 25b). Overall, the LDC significantly over-estimates the abundance of genetic winter- and spring-run, and under-estimates the abundance of genetic fall-run and late fall-run Chinook salmon. However, the LDC for winter-run is more accurate than for spring-run, but using the LDC over-estimates the abundance of both races. Thus without better resolution on the different runs within the catch, abundance estimates by run are not very robust.

The OBAN model consistently under-estimated winter-run Chinook salmon abundance relative to the abundance indices generated from catches of winter-run determined by LDC at Chipps Island (Hendrix, personal communication). Hendrix noted that the high false positive rate for winter-run Chinook salmon using the LDC for catches at Chipps Island could explain the under-estimates of winter-run abundance predicted in the OBAN. Preliminary results from our Delta Science Project, using corrected genetic assignments (to incorporate both the genetic assignments and the uncertainty associated with them) and the Jersey Point based efficiency estimates, demonstrated considerable variation among annual abundance estimates for the four Chinook salmon runs across the four years sampled (Pyper et al. in draft). The ranges in annual abundances by Chinook salmon run were: 1.4 million (in 2007–2008) to 7.5 million (2010–2011) for fall-run; 71,000 (2007–2008) to 186,000 (2010–2011) for late fall-run; 67,000 (2007–2008) to 331,000 (2009–2010) for Butte Creek spring-run; 36,000 (2007–2008) to 92,000 (2009–2010) for Mill-Deer creek spring-run; and 45,000 (2007–2008) to 63,000 (2009–2010) for winter-run (Pyper et al. in draft). These estimates for winter- and spring-run are substantially lower than those derived without the genetic identification.

As a check and independent estimate of abundance of winter-run Chinook salmon at Chipps Island, Hendrix re-ran the OBAN model to determine the expected abundance of winter-run at Chipps Island. Hendrix noted that the derived abundance estimates are confounded by the inability to differentiate survival in the Delta from survival in the ocean to age 2 (Hendrix, personal communication). It is noteworthy that this new estimate of winter-run ranged between 33,506 and 37,398 for the years between 2007-2008 and 2010-2011 (Hendrix, personal communication), similar to the estimates obtained by Pyper et al. (in draft) of 45,000 to 63,000 using the corrected genetics information but much lower than winter-run estimates we obtained using the LDC (~200,000 for all four years, Figure 19). As a result, taking tissues samples to better identify genetic winter-run in our sampling, especially at Chipps Island, is warranted and critical to understanding freshwater survival and relative take of winter-run Chinook salmon at the CVP and SWP. In addition, estimating absolute abundance of genetic winter-run Chinook salmon at Sacramento would help in validating the JPE calculations to determine CVP and SWP incidental take, thus we recommend determining absolute abundance in the years genetic samples have been taken to evaluate the need for future tissue sampling at that location.

Lastly, in addition to genetic samples, scales were taken from each individual sampled between 2007 and 2011. We collected the scales to determine if we could assess race using scales instead of DNA (Brandes et al. 2007), but we were not funded to answer that question. However, there is still value in analyzing the small number of scales from winter- and spring-run for age and annuli patterns to determine if patterns exist and for information on life-history characteristics.

Objective 3: Intensively monitor juvenile Chinook salmon during the fall and winter months for use in managing water project operations (DCC gates and water export levels) on a real-time basis

Introduction

The Delta Cross Channel (DCC) was constructed by the USBR in 1951 at Walnut Grove, California. The DCC was designed to assist in the transfer of fresh water from the Sacramento River southwards through the channels of the Mokelumne River system towards the south Delta. Ultimately, water is diverted to the CVP pumps at Tracy which, in conjunction with the pumps at the SWP, provide water for agricultural, municipal, and industrial users within the Central Valley and beyond to the Metropolitan Water District of Southern California. The DCC gates enable USBR operators to prevent mixing of Sacramento River water with the more saline water in the western Delta prior to export. Before 1978, the DCC gates remained open, except during periods of high Sacramento River flow (> 20,000 to 25,000 cfs) when risks of channel scouring or downstream flooding warranted their closure. The USBR currently operates the DCC gates in the open position to (1) improve the transfer of water from the Sacramento River to the CVP and SWP pumping facilities, (2) improve water quality in the southern Delta, and (3) reduce saltwater intrusion rates in the western Delta.

The operation of the DCC gates alters tidal and river flows throughout the Estuary and thereby influences the migration pathways and survival of emigrating juvenile Chinook salmon (Kjelson and Brandes 1989; Kimmerer 2008; Perry et al. 2010; Newman and Brandes 2010). Both the ESA listed spring-run and winter-run juvenile Chinook salmon can be diverted into the central Delta when the DCC gates are open and water is being conveyed. In the central Delta, juvenile Chinook salmon can experience lower survival rates due to water export, high temperatures, predation, and pollution (Moyle 1994; Kimmerer 2008; Newman and Brandes 2010). Because ESA-listed species including the spring-run and winter-run Chinook salmon are affected by DCC operations, attempts have been made by state and federal agencies to prevent their entry into the central Delta.

In 1978, the SWRCB instituted a decision (D-1485) to amend the water right permits of the CDWR and USBR for the SWP and the CVP facilities, respectively (SWRCB 1978). This decision mandated that in addition to reducing direct water diversion at the project pumps and releasing stored or natural water flows, DCC gate operations could be used to ensure adequate river water flow for salinity control and to improve water quality for fish and wildlife in the estuarine ecosystem. The 1995 Water Quality Control Plan (WQCP) for the San Francisco Estuary (95-1) and later the 2006 WQCP for the San Francisco Estuary included specific guidelines for the operation of the DCC gates for the protection of threatened or endangered fish (SWRCB 1995, 2006) and these criteria were reaffirmed by the SWRCB in 1999 (D-1641). Recovery and protection plans for juvenile winter-run and spring-run Chinook salmon were the basis for salmon decision processes in controlling DCC gate operations for the protection of ESA-listed species (NMFS 1997; Healey et al. 1998; NMFS 2009b).

Further modifications of DCC gate operations were instituted through the 2009 NMFS RPA, with 2011 amendments (NMFS 2011) as a result of a 2010 independent review panel report (Anderson et al. 2010). The current DCC operation plan (NMFS 2011, Action IV.1.2) mandates that the DCC gates be closed from October through November if fish are present and, depending on water quality conditions, remain closed from December through January except during experiments approved by NMFS investigating fish migration patterns occurring from December 1 through December 14 (Table 8). The NMFS RPA also mandates DCC closures from February 1 to May 20 and also from May 21 to June 15 if needed (NMFS 2011).

To facilitate coordination among the fishery resource agencies and project operators, a salmon decision process (refer to NMFS 2011 for the current process, Action IV.1.2) was drafted to minimize the impact of the DCC on emigrating salmonids and green sturgeon. Once the salmon decision process is triggered, depending on the magnitude of the catch and the water quality, recommendations are made to USBR through the Delta Operations for Salmon and Sturgeon group (DOSS) to close the DCC gates (Table 8). The DOSS group is a technical advisory group made up of NMFS, USFWS, CDWR, CDFW and USBR (NMFS 2011, Action IV.5). The Knights Landing Catch Index (KLCI) and the Sacramento Catch Index (SCI) are the criteria upon which the first action is based for closing the DCC gates. The KLCI catch data are provided by CDFW rotary screw traps located at Knights Landing. The DJFMP collects the juvenile Chinook salmon catch data used to generate the SCI. The SCI is made up of data collected by either the Sacramento trawl (Sherwood Harbor) or the Sacramento beach seine.

The catch data are provided to the DOSS group through the Data Assessment Team (DAT) report. The catch indices are catch standardized to one day of effort, but do not include catch efficiency. The SCI, used alone or in conjunction with the KLCI, and increases in the average daily flow rates, may trigger various actions of the modified Chinook salmon decision process (Table 8). In addition to the salmon decision process for the DCC gate closures, the SCI is used as an early warning alert for the export facilities to limit entrainment of ESA-listed species (NMFS 2011, Action IV.3).

Methods

The Sacramento trawl and eight beach seine sites located within the Sacramento region are sampled three days per week from October through January to target the arrival of older juvenile Chinook salmon entering the Delta. Six of the eight beach seine sites are sampled as part of the long term beach seine sampling element once per week during the rest of the year and two sites are sampled only from October through January. Although the Sacramento trawl does not increase the frequency of sampling during this period, the Sacramento trawl does change gear types from a MWT to a larger KDT to sample larger juvenile Chinook salmon.

Results and Discussion

According to the USBR, the DCC gates were closed for fish protection and for experimental purposes 394 times during October through December from 2000 to 2011 (Table 9).
Between October 2000 and December 2011, the salmon decision process would have been triggered 29 times by Sacramento trawl SCI and 89 times by Sacramento beach seine SCI assuming the water quality criteria were also met (Table 10).

Closing the DCC gates requires the coordination of various governing agencies and the process may require 24-48 hours of advanced notice prior to closing. Boaters also require notice of DCC closures to account for navigating alternate routes and longer distances. Therefore, monitoring data is critical to limit ESA-listed juvenile Chinook salmon from being diverted into the central Delta. However, seine and trawl efficiency studies are needed to quantify detection probability and to further prevent the entrainment of ESA-listed species within the export facilities.

Objective 4: Document the abundance and distribution of steelhead

Introduction

The California Central Valley steelhead ESU was federally listed as “threatened” in 1998 (63 FR 13347) and reaffirmed as “threatened” in 2006 (71 FR 834). Four Central Valley hatcheries produce steelhead, including the Coleman National Fish Hatchery, Feather River Hatchery, Nimbus Hatchery, and the Mokelumne River Fish Hatchery. Estimates from trawl data at Chipps Island (DJFMP) indicated the ratio of wild to hatchery steelhead smolts ranged from 0.062 to 0.30 in 1998–2000 (NMFS 2003; Good et al. 2005). In conjunction with known hatchery releases, the ratios indicated that between 100,000 and 300,000 wild smolts are produced annually in the Central Valley (NMFS 2003; Good et al. 2005). However, the assumption that wild and hatchery fish are equally vulnerable to the sampling gear has not been adequately assessed.

Brandes et al. (2000) acknowledged the utility of implementing year-round sampling by the DJFMP for assessing the status and trends of steelhead in the Delta. In addition, it was recommended that the program continue to apply the steelhead life-stage assessment protocol developed by the IEP Steelhead PWT and first implemented in 1999. However, program recommendations such as expanding the use of Kodiak trawling at Sherwood Harbor through May were not implemented due to concerns with increasing catch of fall-run Chinook salmon.

Although historical catch data have been reported by the DJFMP, spatial and temporal analyses were not conducted until the 2006 annual report (USFWS 2001a). Objectives of the DJFMP in regards to steelhead are intended to provide basic biological and demographic information that can be used by natural resource managers to evaluate the effectiveness of water operations and fish management practices within the Estuary. Steelhead data from the DJFMP are used by NMFS for Biological Opinions, including the Biological Opinion and Conference Opinion on the Long-Term Operations of the CVP and SWP (NMFS 2009a), ESA status updates (e.g., NMFS 2003; Good et al. 2005), and recovery plans (e.g., NMFS 2009b).

Methods

Central Valley steelhead are sampled sporadically in the DJFMP seine and trawl surveys. Sampling efficiency is unknown but likely very low. In addition, inferences from catch data are confounded with inconsistent sampling effort and variable gear types. Despite these limitations, steelhead catch data are reported during the periods reflecting greater sampling consistency and year-round monitoring. Steelhead data for Chipps Island are reported during the 1995–2011 field seasons, data from the Sacramento trawl and seine regions are reported from 2000–2011, and data from Mossdale is restricted to the 2004–2011 field seasons.

The relative abundance of juvenile steelhead is presented as mean monthly (2010 and 2011) and yearly (field season) CPUE values. We treated site, and gear separately for all calculations. Starting in 1997, all hatchery-reared fish have been marked with clipped adipose fins. Although marking error occurs and some unmarked fish are the progeny of hatchery fish, all unmarked steelhead are considered wild in this report.

Results and Discussion

Relative abundance and distribution trends for wild and hatchery steelhead varied among regions within the Delta (Figures 26–30, from Speegle et al. 2013). Detections at Chipps Island occurred primarily from January through May and detections at Sherwood Harbor occurred in January through June (Figures 26–27). The ratio of wild to hatchery steelhead captured at Chipps Island was 0.053 and 0.087 in 2010 and 2011, respectively. Regardless of origin, steelhead catches at Mossdale from 2004–2011 are relatively small (Figure 28). Catches within the seine regions are also minimal and limited primarily to the Lower Sacramento River, North Delta, and Central Delta Seine regions (Figures 29–30).

Hatchery fish dominated DJFMP catches and stocking timing and location were likely the driving factors influencing temporal and spatial patterns, respectively. Nobriga and Cadrett (2001) noted that catches of hatchery steelhead at Chipps Island between 1997 and 2001 were positively related to discharge, with peak catches occurring after increased Delta outflow post stocking. In contrast, wild steelhead catches were not related to discharge but rather appeared to be responding to temperature (Nobriga and Cadrett 2001). Cumulative percent catch (CPUE) data indicated that wild fish emigrated at warmer temperatures relative to hatchery fish with approximately 50% of catch occurring at or before surface water temperatures reached 15°C and 10°C, respectively (Nobriga and Cadrett 2001).

Low catches of wild and hatchery steelhead are a product of both population size and gear efficiency. Length-frequency distributions from the 2010 and 2011 field seasons (data not shown) indicated that steelhead ranged from 200–300 mm (FL) among trawl sites and from 160–300 mm (FL) among seine regions (Speegle et al. 2013). Therefore, gear efficiency is likely very low for this large and highly mobile species. In addition, factors influencing the age and growth rates of steelhead are dynamic thus gear efficiency may not be constant. Relative to late fall-run Chinook salmon, hatchery steelhead smolts marked with ultrasonic transmitters demonstrated greater outmigration movements during the day in the Delta (Chapman et al. 2013). Therefore, nocturnal migration patterns may not be a major source of bias for making inferences regarding steelhead from daylight surveys. Unfortunately, seine and trawl efficiency is unknown at this time and relative abundance and distribution trends should be considered with caution. New sampling methods, including electrofishing, are needed to increase sampling efficiency for steelhead in a variety of habitats within the Estuary.

Inferences regarding the proportion of hatchery and wild steelhead emigrating from the Delta may also be biased. Collis et al. (2001) investigated bird predation on steelhead and suggested that hatchery-reared steelhead may be more surface oriented and potentially more vulnerable to avian predators compared to wild steelhead. However, many factors contribute to predation threat and the degree that hatchery steelhead are more surface oriented and potentially more susceptible to surface trawls is an important source of uncertainty. Therefore, hatchery fish may not be an appropriate surrogate for estimating population parameters for wild steelhead. Gear efficiency evaluations and studies investigating bias associated with behavioral differences among stocks are needed for more robust inferences regarding the status and trends of steelhead in the Central Valley.

Objective 5: Document the abundance and distribution of non-salmonid species

Introduction

The DJFMP has recorded the catch of all non-salmonid fishes since monitoring was first initiated in 1976. However, these data were originally intended to only provide anecdotal information to the IEP. The utility of the data collected prior to 1994 are often questioned based on possible fish misidentification and sampling design limitations (e.g., seasonal sampling; Honey et al. 2004). The resolution of fish identification by the DJFMP was often variable for non-salmonid fishes in the late 1970s and early 1980s. For example, some non-salmonid fishes were only identified to family (e.g., Cyprinids or Osmerids). Furthermore, the number of individuals of each species measured in each sample varied considerably from 1976 to 1994 (ranging 0 to 50 individuals). The DJFMP also estimated large catches (>75) of non-salmonid fishes (particularly Osmerids) prior to 1992 using both visual and volumetric techniques. These intricacies of early monitoring may have hindered the ability of the program to produce species- and age-specific population indices for non-salmonid fishes (Honey et al. 2004; Feyrer et al. 2005).

In the early 1990s, the DJFMP began implementing several design and protocol changes in an attempt to minimize the bias or uncertainty associated with non-salmonid catch data. By 1995, sampling was conducted year-round for most long-term monitoring elements to maximize temporal coverage and to better monitor the recruitment success of non-salmonids spawning during the spring (see Appendix D: DJFMP Metadata; Brandes et al. 2000). It was not until a program review conducted in 2000 when the objectives of the program expanded to include documenting the abundance and distribution of non-salmonids (Brandes et al. 2000). Following the recommendations of the review, the DJFMP hired a fish identification biologist to strengthen the future dataset by ensuring the accurate identification of non-salmonids to strengthen the future dataset (see QA/QC Procedures section below for more information). Although concerns still exist among researchers regarding the bias associated with the original sites and gear selection of the DJFMP (Honey et al. 2004), the monitoring program provides researchers and managers with non-salmonid fish data that are complementary to other IEP monitoring programs within the Estuary (Brandes et al. 2000). All gear types and thus monitoring programs possess bias within their catch data (Bayley and Peterson 2001). However, these biases can be minimized when making inferences from multiple data sources (e.g., Sommer et al. 1997; Moyle et al. 2004).

Relative to other IEP monitoring programs, the DJFMP beach seine sampling provides broad geographical coverage within the upper Estuary and it provides catch data within unobstructed littoral habitats (i.e., beaches and boat ramps). In addition, approximately 24 beach seine sites have been sampled at least seasonally in the lower Sacramento River and northern Delta since

1981. As a result, Moyle and Bennett (2008) noted that the long-term seine sampling element was likely the best long-term record of documenting the expansion of non-native fishes in the Delta. Beach seining also provides important information regarding the assemblage structure of juvenile and small adult fishes in near-shore habitats (Brown and May 2006; Moyle and Bennett 2008). Furthermore, these data compliment most IEP surveys that use trawls to sample mid-channel habitats (Brandes et al. 2000). The Chipps Island, Mossdale, and Sacramento trawl surveys offer year-round data collection at fixed mid-channel sites and can provide information on migratory small or juvenile fishes occupying the upper and lower boundaries of the Delta. However, the change to a larger cod-end mesh at the Chipps Island from 1997 to 2001 may have weakened the comparability of the pre-1997 and post-2001 data.

The DJFMP first reported non-salmonid monitoring data in the IEP Newsletter (grey literature) in 2004. In addition to reporting juvenile Chinook salmon data, Marshall (2004) reported the raw catch numbers of dominant non-salmonid species by trawl and seine region during the 2004 field season. Similar reports were later published again in 2005 and 2008 (Marshall 2005; Webb and Wichman 2008). The majority of these reports identified the dominance of several non-native species in our catch including the inland silverside (*Menidia beryllina*), threadfin shad, American shad (*Alosa sapidissima*), striped bass, and red shiners (*Cyprinella lutrensis*) within one or several regions of the upper Estuary. Sacramento suckers, Sacramento splittail, and ammocoete lamprey (*Lampetra sp.*) often dominated the native non-salmonid catch in the upper Estuary with top smelt (*Atherinops affinis*) dominating the catch within San Francisco and San Pablo Bay seine region. Unfortunately, abundance indices were not established and inter-annual comparisons were not attempted.

In a series of IEP Newsletter publications (Wichman and Hanni 2005; Hanni 2005; Wichman 2006), the DJFMP conducted a preliminary assessment of fish assemblage structure between seine regions and trawl locations using a relatively broad ecological approach. The Kendall’s coefficient of concordance with tied ranks approach (Zar 1999) was used to rank CPUE consistency over time to assess assemblage stability (Wichman and Hanni 2005; Wichman 2006). The Simpson’s Index of Diversity (Grundmann et al. 2001) was used to assess assemblage diversity among years (Hanni 2005; Wichman 2006). In general, the fish assemblage structure was determined to be fairly stable during the fall (September-December from 1995-2005; Wichman 2006), winter (January-April from 2000-2005; Wichman and Hanni 2005), and summer (May-August from 1995-2005) during their respective study periods in most seine regions and trawl locations. However, assemblage diversity demonstrated significant declines in the North and Central Delta seine regions, within the San Francisco and San Pablo Bay seine region, and the Chipps Island trawl during the fall from 1995 to 2005. Although these trends may suggest some increasing level of assemblage homogeneity within parts of the Estuary, further analysis was recommended to understand if this is a response of increasing proportions of nonnative fishes or simply shifts in dominance of native fishes.

The DJFMP has reported the CPUE (standardized by volume sampled) of pelagic fish species of management concern (i.e. delta smelt, longfin smelt, striped bass, and threadfin shad) and Sacramento splittail within annual reports starting in 2006 to present intra-annual temporal and spatial distribution information (USFWS 2010a; USFWS 2011a; USFWS 2012). These data were intended to supplement other IEP investigations such as the Pelagic Organisms of Decline (POD; Feyrer et al. 2005; Sommer et al. 2007a; MacNally et al. 2010). However, no inter-annual comparisons or syntheses were made in the reports which limited the utility of the data to IEP partners (R. Baxter, CDFW, personal communication). As a result, the DJFMP expanded on its reporting of pelagic fish species of management concern and Sacramento splittail in the 2010 and 2011 annual report (Speegle et al. 2013). In the report, the DJFMP presented intra- and inter-annual distributional information among monitoring locations within the Estuary to better disseminate programmatic trends in non-salmonid catch data (Speegle et al. 2013).

In addition to DJFMP publications, the non-salmonid data collected by the DJFMP has contributed to multiple peer reviewed and grey literature articles authored by IEP partners investigating various trends in fish assemblage structure (Table 11). The DJFMP monitoring data was most notably used by IEP partners, in conjunction with other IEP survey data, for understanding the ecology, viability, and life history of the Sacramento splittail. The DJFMP beach seine data were used to understand juvenile Sacramento splittail distribution, migratory behavior, and floodplain inundation dependency (Meng and Moyle 1995; Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2005; Sommer et al. 2007b). Many of these results were used in several USFWS ESA findings (e.g., USFWS 1994; USFWS 1999; USFWS 2003; USFWS 2010b). Since 2000, the DJFMP has provided the CDFW age-0 splittail data derived from beach seining to report inter-annual recruitment success trends within the IEP Newsletter (e.g., Baxter 2001; Baxter 2003; Greiner et al. 2006; Fish et al. 2008; Messineo et al. 2010; Contreras et al. 2011; Contreras et al. 2012).

Currently, the DJFMP is supplying monitoring data to numerous researchers conducting a wide variety of non-salmonid investigations within the Estuary. Delta smelt catch data from the Chipps Island trawl is being incorporated into a life-cycle model being developed by the USFWS (K. Newman, USFWS, personal communication). The data will be used in conjunction with five other IEP survey data sets to gain a better understanding of how environmental factors might influence the population dynamics of delta smelt. The Chipps Island trawl catches of delta smelt are of unique interest to researchers because, in contrast to other IEP surveys, multiple samples are taken during a single day at a fixed location over a variety of tidal cycles, which allows assessment of the effect of tides on the probability of capture (K. Newman, USFWS, personal communication). In addition, the DJFMP will be providing the CDWR inland silverside data collected during beach seine monitoring within the Estuary to begin assessing possible inter-specific interactions (i.e., predation and competition) with delta smelt (L. Conrad, CDWR, personal communication; Moyle 2002; USFWS 2010c). Lastly, data and specimens collected by the DJFMP are regularly used by many entities within or outside of the IEP in addressing a wide range of topics (Honey et al. 2004).

Methods

We calculated the relative abundance of primarily non-benthic non-salmonid fishes of management concern including delta smelt, longfin smelt, Sacramento splittail, threadfin shad, and striped bass (USFWS 2010a; USFWS 2011a; USFWS 2012; Speegle et al. 2013). Relative abundance is presented as mean weekly or monthly (intra-annual) and yearly (inter-annual) CPUE values. For inter-annual comparisons of relative abundance for each species, we calculated mean yearly (field season) CPUE values starting in the 2000 field season (Speegle et al. 2013). Sampling methods have generally remained consistent from 2000 to the present, including year round sampling, presumed higher fish identification accuracy, and standardized gears (e.g., mesh sizes). However, we calculated mean yearly CPUE values for the Mossdale Trawl Site only during the 2004 through 2011 field seasons for fishes of management concern because the start of year-round collaborative sampling with the CDFW did not occur until January 2003 (see Appendix D: DJFMP Metadata). For intra-annual comparisons of relative abundance, we presented mean weekly or monthly CPUE values (USFWS 2010a; USFWS 2011a; USFWS 2012; Speegle et al. 2013). We treated site, seine regions, species, and gear separately for all CPUE calculations.

Results and Discussion

The DJFMP identified both spatial and temporal patterns in the catch and relative abundance of delta smelt, longfin smelt, Sacramento splittail, threadfin shad, and striped bass among beach seine and surface trawl sites since the 2000 field season (Figures 31–48; following Speegle et al. 2013). However, the life history strategies of these non-salmonid species vary considerably and thus the utility of each long-term sampling element varies among the species.

The delta smelt and longfin smelt are short lived native pelagic species that generally reside in the low salinity zone (1-6 ppt; Jassby et al. 1995) and the San Francisco Bay where the salinity ranges from 15-30ppt, respectively, until they migrate into the freshwater Delta and spawn during the spring (Stevens et al. 1990, Moyle et al. 1992; Moyle 2002; Dege and Brown 2004). Because the Chipps Island Trawl Site is often within or near the low salinity zone, the majority of delta smelt and nearly all longfin smelt observed by the DJFMP have been captured by the Chipps Island trawl during the summer or autumn (USFWS 2010a; USFWS 2011a; USFWS 2012; Speegle et al. 2013). Speegle et al. (2013) suggested that the relatively high CPUE of delta smelt during the summer was a result of juveniles and sub-adults residing within or migrating through Suisun Bay to rear in the low salinity zone and that the relatively high CPUE of delta smelt during autumn is a result of adults migrating upstream into the Delta to spawn. Similarly, the occurrence of adult longfin smelt at the Chipps Island Trawl Site from November to March were likely a result of adults migrating pre or post spawn (Speegle et al. 2013). In addition to the Chipps Island trawl, a relatively low number of adult delta smelt (n<100) and longfin smelt (n<15) have been captured by beach seines or surface trawls within the Delta each year during their spawning period (USFWS 2010a; USFWS 2011a; USFWS 2012; Speegle et al. 2013). However, the low number of detections distributed over a large geographic extent (i.e., the interior delta) makes inter-annual patterns difficult to discern for delta and longfin smelt (e.g., Speegle et al. 2013). Although the Chipps Island catch data does appear to broadly illustrate shifts in smelt distribution (i.e., migration timing) within field seasons, the catch data are likely greatly influenced by proximity of the location to the low salinity zone and thus by Delta outflow conditions. Bias can be introduced without taking into account the position of the low salinity zone when making intra- and inter-annual relative abundance comparisons as attempted by Speegle et al. (2013).

The Sacramento splittail is a relatively long lived (7-9 years) native benthic iteroparous species that resides within the lower Estuary (e.g., Suisun Bay). Adult splittail migrate upstream as early as November through February to reproduce within inundated floodplain habitats in the Sacramento River, San Joaquin River, and tributaries (Young and Cech 1996; Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2005). The DJFMP primarily captures juvenile Sacramento splittail in most surface trawls and nearly all beach seine regions from May to July on an annual basis (Speegle et al. 2013). These data provided useful indices for determining recruitment success in recent annual reports (e.g., Speegle et al. 2013), IEP Newsletter articles (e.g., Contreras et al. 2012), and peer reviewed publications (e.g., Feyrer et al. 2005). During the 2011 field season, Sacramento splittail recruitment reached its highest index value on record based presumably on sufficient floodplain inundation within the San Joaquin River (Contreras et al. 2012; Speegle et al. 2013). Although the DJFMP does not adequately sample adult Sacramento splittail, adults are captured by the Chipps Island trawl primarily during their upstream spawning migration in the winter (Speegle et al. 2013). Overall, the DJFMP provides useful information on the recruitment and migration of juvenile Sacramento splittail within the Estuary and lower Sacramento and San Joaquin rivers (Speegle et al. 2013).

Introduced threadfin shad is a short lived (~2 years) pelagic species that is dependent on fresh water and distributed throughout the Central Valley within reservoirs, the Sacramento-San Joaquin River system, and the upper Estuary. Adult threadfin shad spawn in the spring when water temperatures exceed 20°C and experience low survival when water temperatures approach 8°C (Turner 1966; Moyle 2002). Threadfin shad have been captured by the DJFMP in nearly all freshwater dominated seine regions and trawl sites from July to January (USFWS 2010a; USFWS 2011a; USFWS 2012; Speegle et al. 2013). The low densities of threadfin shad observed from February to June at most monitoring locations may be, in part, the result of cool water temperatures, particularly during the winter (Speegle et al. 2013). Mean yearly CPUE estimates suggest that threadfin shad have generally been observed in higher densities within the Lower Sacramento River, Lower San Joaquin River and South Delta Seine regions relative to other seine regions since the 2000 field season. In general, the densities within most seine regions and trawl sites have declined considerably over the last decade. The relatively low densities and declines of threadfin shad observed by the DJFMP in most trawl sites and seine regions is consistent with the findings from other fish surveys and investigations within the Estuary (e.g., Sommer et al. 2007; Contreras et al. 2012).

The striped bass is a long-lived, introduced, anadromous, and iteroparous species (Moyle 2002). Adults generally occur within the lower Estuary (e.g., San Francisco and San Pablo bays) and the Pacific Ocean throughout much of the year and migrate upstream to spawn within or upstream of the lower Sacramento and San Joaquin rivers during the spring (Turner and Chadwick 1972; Moyle 2002). After spawning, embryos and larval striped bass are translocated to the Estuary where juveniles normally rear in and near the low salinity zone (Turner and Chadwick 1972; Moyle 2002; Sommer et al. 2011). The majority of striped bass observed by the DJFMP are juveniles or sub-adults captured during the summer and early fall at most monitoring locations while perhaps migrating to the low salinity zone to rear (Speegle et al. 2013). However, few individuals have been detected at the Sacramento Trawl Site or within the lower Sacramento seine region since the 2000 field season (Speegle et al. 2013). Therefore the utility of the surface trawl and beach seine sampling elements in monitoring juvenile striped bass are not fully understood.

In general, there are several limitations associated with the surface trawl sampling elements that constrain the utility of the DJFMP data when assessing non-salmonid populations. Because the DJFMP does not sample the entire Estuary using surface trawls, the inter-annual abundance trends of most non-salmonid species of interest do not account for distribution shifts and the resulting bias is unknown (Kimmerer et al. 2001; Sommer et al. 2011; Speegle et al. 2013). The DJFMP deploys surface trawls in mid-channel open water habitat at only three fixed sites generally three days per week in the lower Sacramento River (Sacramento Trawl Site), the lower San Joaquin River (Mossdale Trawl Site), and Suisun Bay (Chipps Island Trawl Site). As a result, the majority of individuals of a population may not pass one or more of these trawl sites (e.g., Osmerids), making it difficult to convert catch to a representative abundance index. Another limitation may be that the data collected at the trawl sites may not be comparable among locations based on the use of different gear types (i.e., Chipps Island = MWT, Mossdale = KDT, and Sacramento = KDT & MWT), cod-end designs (i.e., Mossdale = live box, Chipps Island = mesh, and Sacramento = mesh and live box), and cod-end mesh sizes (i.e., Chipps Island MWT = 0.8 mm, Mossdale and Sacramento KDT = 0.46 mm, and Sacramento MWT = 0.3 mm), which can greatly affect the gear efficiency for different size classes of non-salmonid fish. Lastly, efficiency estimates are lacking for non-salmonids while using the surface trawls currently deployed by the DJFMP. As a result, the true abundance of non-salmonid fishes within catch data are likely underestimated to varying degrees across time and space (Bayley and Peterson 2001), which may bias abundance estimates. Therefore the surface trawl sampling elements of the DJFMP may be more useful for detecting the movement of migratory fishes at the entry and exit points of the Delta relative to assessing the abundance and distribution of populations.

The DJFMP beach seining sampling element provides good spatial and temporal coverage surveying non-salmonid fishes using standardized methods in near-shore habitats in the lower Sacramento and San Joaquin rivers, Delta, and San Francisco and San Pablo bays. However, there is inherent bias in catch data based on the current sample design. For example, the beach seines do not sample representative habitats throughout the Estuary. Beach seine sites were originally selected by the DJFMP based on access and to maximize efficiency when sampling juvenile Chinook salmon. As a result, beach seines are only deployed within sites containing unobstructed littoral habitats including boat ramps, mud banks, and sandy beaches. Because the majority of the shoreline in the Delta and lower Sacramento and San Joaquin rivers is dominated by alternative habitats (e.g., rip-rap, aquatic vegetation), beach seine catch data may not accurately reflect the abundance or distribution of all non-salmonid populations.

Regions that are not well represented by the DJFMP include sites that are dominated by submerged aquatic vegetation. Therefore, it is difficult to make inferences regarding the relative abundance and distribution of vegetation-associated fishes including centrarchids, western mosquitofish (*Gambusia affinis*), rainwater killifish (*Lucania parva*), and tule perch

(*Hysterocarpus traski*; Brandes et al. 2000). In addition, there is evidence of seine site dependency of non-salmonid catch within most seine regions (Figure 9). Unfortunately, the inability to consistently sample some historical sites in these seine regions in recent years (Figure 7), due to extreme water heights (both tide and flow driven) coupled with vegetation expansion, may be introducing bias into beach seine CPUE trends for some non-salmonids (e.g., Sacramento splittail). New analytical approaches are needed to provide alternative methods for calculating the relative abundance of fishes when effort is not consistent. Mixed effects general additive models may correct for spatial dependency in catch and potentially better illustrate CPUE trends over time using a spatial random effect and temporal smoothers or splines, respectively (Zuur et al. 2009).

Seine efficiency estimates also are lacking, which prohibits robust inferences for non-salmonids. The DJFMP has assumed that beach seining is effective at sampling mostly juvenile or small adult pelagic fish species including atherinids, clupeids, juvenile Sacramento splittail, juvenile striped bass, and juvenile Sacramento sucker (*Catostomus occidentalis*; Brandes et al. 2000). However, Brandes et al. (2000) made this assumption based on the proportional abundance of catch among species, which is a product of both absolute abundance and gear efficiency. Therefore, the presumed efficiency of beach seines for some species may be perceived as low as a result of minimal catch based solely on low abundance or limited distribution and not poor gear efficiency. In addition, the efficiency of beach seining has been observed to vary among fish species, sizes, and environmental gradients (Pierce et al. 1990; Allen et al. 1992; Bayley and Herendeen 2000). By not understanding if and how beach seine efficiency varies, the non-salmonid metrics developed by the DJFMP including both distribution and abundance, are likely underestimated and biased to an unknown extent (Bayley and Peterson 2001). Currently, the DJFMP is implementing a pilot study to investigate the absolute efficiency of its beach seining methods (see Appendix C: Beach Seine Efficiency Evaluations).

Although the DJFMP regularly provides catch data of all non-salmonids to its partners, the DJFMP has only recently began reporting the total catch of all non-salmonid fishes observed at trawl sites and within seine regions during each field season to gain a coarse understanding of assemblage structure (e.g., USFWS 2010a; USFWS 2011a; USFWS 2012; Speegle et al. 2013). However, it may be advantageous to begin calculating and presenting species richness or CPUE estimates for different guilds or groups (e.g., native or non-native, pollution tolerance, feeding strategy, reproduction strategy, or general life history strategy) to better represent trends in assemblage structure using the beach seine data (Elliott et al. 2007; Moyle and Bennett 2008; McClelland et al. 2012). Taking an assemblage based approach to monitoring and reporting can detect early signs of ecological shifts or environmental perturbation such as declines in juvenile Chinook salmon abundance or homogenization of the ecological community over time (Link 2002). Fish have an effect on and are affected by the assemblage in which they live. Therefore, the interactions among fish species and the supporting assemblage should be considered to effectively monitor and manage fishes of management concern including juvenile Chinook salmon within the Estuary (Link 2002; Elliott et al. 2007; Moyle and Bennett 2008).

It is evident that the DJFMP, particularly the beach seine sampling element, is providing useful information for evaluating the ecology and status of various non-salmonids within the Estuary

(Moyle and Bennett 2008). However, beach seine data should continue to be paired with other survey data to compensate for design limitations such as the under sampling of dominant habitat types within the Estuary (e.g., mid-channel open water, rip-rap, and vegetated near shore habitats; Brandes et al. 2000). Unfortunately, the DJFMP beach seine sampling element is the only IEP monitoring program that is currently sampling fish within littoral habitats in the Delta. Therefore, there is currently no means to compensate for the under sampling of rip-rap or vegetated near-shore habitats. The IEP Resident Fish Monitoring Program once sampled near shore habitats throughout the Delta using boat electrofishing methods and a stratified random sampling design in the early 1980s and 1995 to 2003 during odd years (Honey et al. 2004; Brown and Michniuk 2007). However, the Resident Fish Monitoring Program was suspended in 2004 due to staffing or logistical constraints (R. Baxter, CDFW, personal communication). Therefore, it may be advantageous for the DJFMP to reinitiate boat electrofishing within the Delta to supplement beach seine monitoring to better assess the status and trends of fishes occupying littoral habitats within the Delta. In addition, because the expansion of aquatic vegetation is beginning to affect the frequency and geographical distribution of beach seine sampling, it is important to begin considering alternative sampling gears and designs to compliment and even sustain near-shore fish monitoring in the Estuary.

A consistent and robust near-shore boat electrofishing survey funded by the IEP and implemented by the DJFMP would provide useful and needed information within the Delta and lower Sacramento and San Joaquin rivers on the status and trends of fishes of management concern (Honey et al. 2004). A near-shore electrofishing survey would provide information on the small scale (i.e., intraregional) habitat use of fishes of all life stages including juvenile Chinook salmon (McLain and Castillo 2010), and fish assemblage structure (Brown and Michniuk 2007). In addition, this survey also would provide valuable information on the relative abundance and distribution of piscivorous fishes (e.g., striped bass) that may be influencing the habitat use or abundance of native fishes of management concern (e.g., delta smelt and juvenile Chinook salmon). Such information can greatly improve our understanding of near shore littoral fish assemblages and better inform the current and future conservation efforts (e.g., restoration) within the Estuary. Currently, the CDFW possesses two electrofishing boats previously used by the Resident Fish Monitoring Program (R. Baxter, CDFW, personal communication). Assuming that the DJFMP can initially obtain one of the two electrofishing boats under an interagency maintenance agreement, the initial cost to the DJFMP is thought to be minimal. Therefore, it is our recommendation that the DJFMP begin pursing the necessary permitting and interagency agreements to implement at least a two year pilot study to determine the utility of such sampling.

Objective 6: Identify the factors influencing salmonid survival in the Delta such as route, flow, exports, and other covariates (DJSSS)

Introduction

The Delta Juvenile Salmon Survival Studies have been used to study the flow needs of Chinook salmon and a variety of hypotheses about juvenile salmon survival in the Delta over the last 40 years. Most of the historical studies using coded-wire tag methodology are summarized in

Kjelson et al. (1981, 1982), USFWS (1987), Kjelson and Brandes (1989), Brandes (1996), Brandes and Pierce (1998), Pierce and Brandes (1999), Newman and Rice (1997, 2002), CDWR (1994, 1995, 1996, 1997, 1998, 1999) Brandes and McLain (2001), Newman (2003), San Joaquin River Group Authority (2001, 2002, 2003, 2004, 2005, 2006, 2007), Newman (2008) and Newman and Brandes (2010). Studies using acoustic tags are summarized in Holbrook et al. (2009), Perry et al. (2010), Perry (2010), Perry and Skalski (2008, 2009, 2010), Perry et al. (2012), Holbrook et al. (2012), Perry et al. (2013), Buchanan et al. (2013) and SJRGA (2008, 2009, 2010, 2011, 2013).

Initial survival studies focused on quantifying the flow needs of juvenile salmon in the Estuary, given the proposed future peripheral canal in the Delta. Kjelson et al. (1981) found correlations that suggested river flow influenced survival during the juvenile salmon downstream migration. They also noted that survival was higher through the Sacramento River and Steamboat Slough, relative to those released in the south and north forks of the Mokelumne River and Georgiana Slough (Kjelson et al. 1981). In addition, they also noted recoveries were greatest for the larger fish within a release group and concluded that survival increased with migrant size (Kjelson et al. 1981). Kjelson et al. (1982) also reported that survival was lower for smolts migrating through the Delta than for those released in the lower estuary and that survival was influenced by water temperatures and, or river flow rate (Kjelson et al. 1982).

Once the peripheral canal was defeated by voters of the State of California in 1982, a through-Delta conveyance alternative was selected. Studies of juvenile salmon survival then shifted to evaluating through-Delta water conveyance on juvenile salmon survival. In 1987 “The Needs of Chinook Salmon, *Oncorhynchus Tshawytscha* in the Sacramento-San Joaquin Estuary” was entered as Exhibit 31 in the State Water Resources Control Board’s 1987 Water Quality/Water Rights Proceeding on the San Francisco Bay/Sacramento-San Joaquin Delta. Results from Delta salmon survival studies were summarized and indicated that survival through the Delta from Sacramento to Chipps Island (Suisun Bay) using two separate methodologies (differential ocean recovery rates and trawl recovery rates of upstream groups), was related to mean daily flow at Rio Vista (USFWS 1987) with smolt survival at about 100% at flows over 21,000 -30,000 cfs (USFWS 1987). Estimates of over 100% were generated but were attributed to sampling imprecision or some unknown bias (USFWS 1987). The caveat of viewing all values as indices and not absolute estimates was noted (USFWS 1987). Although potential biases were evaluated (differences in fish size, dates of release and temperature conditions between the two release sites) none were identified (Appendices 18 and 19 in USFWS 1987). Replication using multiple tag codes within the same release group, indicated variability was small relative to the variation in survival estimates (USFWS 1987). While it was acknowledged that recently planted hatchery fish would not survive as well as wild fish, it was thought that information gained from hatchery fish could provide valuable information on the factors influencing survival of wild fish. The relationship of unmarked salmon abundance to flow, temperature and diversion appeared to provide collaborating information (USFWS 1987).

Two primarily mechanisms were evaluated to help explain the relationship between survival through the Delta (Sacramento to Chipps Island) and flow; water temperature and diversion off the mainstem Sacramento River. Water temperature was found to decrease smolt survival and it was noted that average late May and June water temperatures in the lower Sacramento River, between the Feather and American Rivers, were found to have increased by 2-3 degree C in the previous 10 years (USFWS 1987).

Diversion of salmon smolts off the Sacramento River into the interior Delta through the open Delta Cross Channel and Georgiana Slough was also tested as a mechanism for lowering survival through the Delta. CWT smolts were released at Courtland (3.5 miles upstream) and Ryde (3.0 mile downstream) of the DCC and Georgiana Slough between 1983 and 1987 (USFWS 1987) to determine if relative survival was less for the Courtland group when compared to the Ryde group due to diversion into the interior Delta via Georgiana Slough or the open DCC. Results indicated that in three of the four years, with the Delta Cross Channel gates open, survival was less by about 50% for smolts released above the diversion (USFWS 1987), In contrast, when the gates were closed with high flows in the fourth year, there was no difference in survival for the two groups (USFWS 1987). With the gates closed in a low flow year (1987), survival was about 25% lower for the upstream group (USFWS 1987). CWT fish released in the same years in the north and south forks or the mouth of the Mokelumne River had slightly lower survival than those released upstream of the diversion, appearing to confirm the hypotheses that once fish were diverted into the central (interior) Delta their survival was worse than for those remaining in the Sacramento River. Releases made into lower Old River south of the San Joaquin River indicated they had the lowest survival (USFWS 1987). These types of experiments, explicitly with DCC gate manipulation, continued in 1988 and 1989 to determine how closing the DCC in low flow years could benefit juvenile salmon survival (Brandes and McLain 2001).

Results from the smolt studies were published in “The Use of Smolt survival Estimates to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California (Kjelson and Brandes 1989) and continued to suggest water temperature, inflow and diversion off the mainstem Sacramento River were the main factors influencing smolt survival through the Delta. Furthermore, simulations were presented to estimate how survival through the Delta may have changed under different levels of water development scenarios. Results indicated reduced inflow caused by water development reduced survival through the Delta by a substantial amount. Mean survival declined from 0.76 with unimpaired flows to 0.46 under 1990 level of development. In critical years, survival under unimpaired flows was 0.33 while at the 1990 level of development it was estimated at 0.12.

Kjelson et al. (1989) developed a model to estimate survival in the Delta breaking the Sacramento Delta into three reaches. Factors used in the model to estimate survival were water temperature, the fraction of water diverted from the Sacramento River, and combined exports from the Central Valley Project and State Water Project. Simulations were done to predict survival under various combinations of these environmental conditions. The Kjelson et al. (1989) model was closely scrutinized as part of the SWRCB water rights/ water quality hearings (~1995) and the decision was made to build a more robust model using statisticians unaffiliated with the work (Newman and Rice 2002). Although Newman and Rice approached the modeling differently some of the conclusions were consistent with previous efforts (Newman and Rice 2002). The initial modeling by Newman and Rice (1997, 2002) was done using unpaired survival estimates fitting an extended quasi-likelihood model. These models concluded that increasing flow and salinity was associated with higher survival and higher water temperatures were associated with lower survival (Newman and Rice 2002). Consistent with previous analyses, releases in Mokelumne River or Georgiana Slough showed lower survival relative to those released on the main stem Sacramento River (Newman and Rice 2002). The effect of the DCC being open was negative for fish released upstream on the Sacramento River, whereas it was positive for fish released in the interior Delta (Newman and Rice 2002). There was evidence the export/inflow ratios reduced survival but the effect was slight and not statistically significant (Newman and Rice 2002). Later, a tri/binomial product model, a pseudo-likelihood model and a Bayesian nonlinear hierarchical model were fit to “paired release data” where results from among the three models were compared (Newman 2003). Covariates, significant under all models included water temperature, water flow and the amount of water exported (Newman 2003). The paired models did not show that the DCC gate position was significant (Newman and Rice 2002). The paired analyses were considered more powerful if the assumptions held (K. Newman, USFWS, personal communication).

Several juvenile survival studies have also been conducted annually in the South Delta starting in the late 1980s. Relationships had been identified between spring flows and adult escapement two and a half years later on the San Joaquin tributaries (IEP 1972; Kjelson and Brandes 1989; Baker and Morhard 2001; SJRGA 2007). Between 1985 and 1991, paired spray-dyed (1985) or CWT (1986-1991) groups were released on the mainstem San Joaquin River (near Dos Reis) and into Old River, just downstream of the head of Old River (Brandes and McLain 2001). Results indicated survival was low in most years for both routes, but that the survival appeared higher for the smolts released on the main stem San Joaquin River (Brandes and McLain 2001; Baker and Morhardt 2001). These studies were the foundation for recommending a full rock barrier at the head of Old River – which was installed and tested in 1992 and 1994 (Brandes and McLain 2001). In 1997, the rock barrier was installed with two culverts (Brandes and McLain 2001), and in 2000-2004 it was installed with six culverts (SJRGA 2001, 2002, 2003, 2004, 2005). In 2012, it was installed with eight culverts. Required studies as part of the San Joaquin River Group Agreement’s VAMP began in 2000 to assess the relative roles of river flow at Vernalis and project exports with the physical head of Old River in place. Previous studies had been conducted in the south Delta to measure survival from Mossdale to Jersey Point using groups of CWT fish released at Mossdale and Jersey Point recovered at Chipps Island and in the ocean fishery. When the VAMP started (2000), trawling at Chipps Island was increased to two shifts per day (20, 20 minute tows per day), and trawling at Antioch was initiated to increase the number of marked fish recovered to increase the precision of survival estimates. Recoveries were also made in the ocean fishery of both the upstream and downstream groups to estimate survival between Mossdale or Durham Ferry and Jersey Point. Initially recoveries from each trawl and in the ocean fishery were analyzed separately, but in later years (SJRGA 2007) the analyses combined recoveries based on statistical advice (Newman, personal communications).

Fall-run Chinook salmon fry have also historically been marked with CWTs and released in the Delta to answer the questions; how does fry survival compare between the upper Sacramento River (below RBDD) and in the north Delta (Brandes and McLain 2001; Brandes et al. 2006); how does fry survival differ between the north and central Delta (Brandes and McLain 2001; Brandes et al. 2006); and how does fry survival differ between the Delta and Bay (Brandes and

McLain 2001)? Some general trends have been observed (upstream fry have higher survival than those released in the Delta in higher flow years, Brandes and McLain 2001; Brandes et al. 2006) but recoveries are made in the ocean fishery with data forthcoming 2 to 3 years after release.

In 2006, a CALFED grant was awarded to the USFWS Stockton Fish and Wildlife Office, through the 2004 PSP to review and reanalyze four CWT salmon survival studies: 1) the effect of the DCC, 2) the effect of the being diverted into the interior Delta, 3) the effect of SWP and CVP exports on the relative survival of smolts released into Georgiana Slough, relative to those released in the main stem Sacramento River at Ryde, and 4) the influence of river flow, CVP and SWP exports and a barrier at the head of Old River on survival through the San Joaquin Delta. The results and conclusions of this analysis were generally consistent with previous work (Newman 2008). There was modest evidence (64-70% probability) that the survival of CWT releases made just upstream of the DCC (Courtland) relative to the survival of releases made just downstream of the DCC and Georgiana Slough (Ryde) were higher when the DCC gates were closed (Newman 2008). In addition, survival for fish released into the interior Delta were lower than those released on the main stem Sacramento River – with those released in the interior Delta having only 44% of the survival of those for the Sacramento releases. There also was a negative association between project (CVP and SWP) exports and relative interior Delta survival (a 98% chance that as exports increased, survival would decrease for the fish released in the interior Delta relative to those released on the mainstem Sacramento River) (Newman 2008; Newman and Brandes 2010). Lastly, the analyses of the VAMP and pre-VAMP data in the south Delta, indicated that 1) survival was consistently higher for smolts staying on the San Joaquin River, relative to those migrating through Old River, 2) there was a positive association between flow on the San Joaquin River, downstream of Old River, and survival between Dos Reis and Jersey Point 3) and associations between survival and exports were weak to negligible. Newman (2008) recommended a more thorough model selection for the VAMP and pre-VAMP data. Bayesian hierarchical models were fit for the VAMP peer review in 2010 (Newman, personal communication) which indicated survival was usually higher if fish stayed on the San Joaquin river than if they went down Old River but there was a lot of environmental variation (see Appendix B: Analyses of CWT Releases into the San Joaquin System).

The results of the CWT study that assessed the impact of exports on the relative survival of fish released in the interior Delta (Delta Action 8), suggested that relative survival was negatively associated with exports, but the various models gave more (or nearly equal) weight to simpler models without exports, however there was a large signal to noise ratio. It was suggested that at least 100 data points would be needed to precisely evaluate the export effect (Newman and Brandes 2010). However even if the lower relative survival in the interior Delta was related to exports, it was unclear how many fish actually entered the interior Delta to be exposed to the higher mortality rate. It appeared obvious that closing the DCC would decrease the proportion of water and presumably salmon entering the interior Delta and thus would increase overall survival through the Delta. However, acoustic tag studies conducted between 2006 and 2011 have shown the relationship between the proportion of fish diverted into the interior Delta and the DCC gate status to be more complicated than previously understood.

Starting in 2006, acoustic tags were used to estimate survival in the Delta. A CALFED grant to UC Davis and NOAA provided the funding to install and maintain an acoustic telemetry array between Battle Creek and the Golden Gate Bridge. The DJSSS partnered with UC Davis and NOAA to tag and release yearling, late-fall juvenile Chinook salmon in the Delta from Coleman National Fish Hatchery. In addition, the DJSSS partnered with Russ Perry, a CALFED fellow, to model survival through the Delta using a branching mark-recapture model to explicitly estimate survival and migration route probabilities through the Delta (Perry et al. 2010). The DJSSS program also worked with the University of California at Davis, NOAA, Russ Perry, and USGS to recommend placement of receivers in critical locations for assessing survival through the Delta. The study design was to estimate survival through the Delta with the DCC gates open and with them closed (Perry et al. 2010). Releases were made at Sacramento in the first year (2006-2007)(Perry and Skalski 2008; Perry et al. 2010), and at both Sacramento and Georgiana Slough in the following years (Perry and Skalski 2009, 2010, 2012; Perry 2010). Results indicated the survival through the Delta was a function of both route entrainment and reach specific survival (Perry 2010). Survival in the interior Delta was consistently less than for fish that stayed on the Sacramento River downstream of the DCC and Georgiana Slough (Figure 49, Perry 2010; Perry et al. 2013), but as with the Newman and Brandes (2010) analyses suggested sample sizes were too small to sufficiently address the relative survival in the interior Delta versus exports question. Survival was also a function of flow in the Sacramento River and in Sutter and Steamboat Sloughs (Perry 2010). And although survival increased with discharge it was also inversely related to tidal fluctuations (Perry 2010). Tidal excursions are large when river flow is low, increasing the distance juvenile salmon would move upstream on the flood tide. Such movement likely increases travel time and mortality. Route entrainment was a function of flow (river discharge), velocity and the proportion of total outflow entering each channel (Perry 2010). Perry suggests survival through the Delta will increase most by management actions that alter both migration routing and reach specific survival (Perry et al. 2013).

Acoustic studies also began in the San Joaquin Delta in 2006. Pilot studies were conducted in 2006, but in 2007, it was determined that not enough fish were available at Merced River Hatchery to conduct a CWT study for VAMP. In addition, there was the possibility that the trawling at Antioch and Chipps Island could be interrupted due to high incidental catches of delta smelt and reduce the effort for recovering CWT fish. These two circumstances prompted the transition away from CWT studies to acoustic telemetry. Pilot efforts were continued in 2007, but survival through the Delta from Mossdale to Chipps Island was not achieved until 2008 (SJRGA 2009; Holbrook et al. 2009; Holbrook et al 2013). Unfortunately, premature tag failure in 2008 prevented unbiased estimates to be generated (Holbrook et al. 2009, 2013). In 2009, USGS was unable to provide the staffing necessary to install the large-water receivers at Jersey Point and Chipps Island. In 2010, receivers were installed at Chipps Island but not Jersey Point due to budgetary constraints. Finally in 2011, a full array was deployed and survival from Mossdale to Jersey Point and Chipps Island was estimated. A complete array was also deployed in 2012 and is planned in 2013. The array as part of the 6 year study is planned until 2016.

Acoustic telemetry provides greater temporal and spatial coverage of the outmigration process than CWT studies. They also facilitate estimation of distribution probabilities at junctions and reach-specific survival and are analyzed using robust and well developed statistical approaches that allow quantification of the uncertainty associated with estimates of survival, detection, and distribution probabilities. While acoustic telemetry provides more precise information on reach specific survival and route entrainment probabilities, they incorporate some additional level of uncertainty associated with tagged fish being detected after they have been consumed by a predator. If a predator consumes an acoustically tagged fish and then moves past monitors downstream, the resulting detections need to be removed from the dataset prior to estimating survival or estimates will be biased high. Also, the battery life of each acoustic tag needs to be estimated using a tag life test. The battery life of the tags need to be long enough to cover the entire migration period or survival estimates will be biased low (Holbrook et al. 2009, 2013). Premature failure of tags prevented obtaining unbiased estimates of survival through the San Joaquin Delta in 2008, and this could be determined because a tag life study was conducted (Holbrook et al. 2013).

The benefit of using acoustic tags in the south Delta is that survival can be measured in the two main reaches through the Delta for fish originating from the San Joaquin basin; the San Joaquin River and Old River. In addition, route entrainment (the proportion of fish entering each route) at the head of Old River can be estimated. Route entrainment at the head of Old River, without a barrier, appears to be related to velocity (SJRGA 2013). Survival in the Old River route now appears to similar (2010) or somewhat better than that on the San Joaquin River (2011) (SJRGA 2013), but more data are needed to assess the relative differences in survival between routes and survival through the Delta (SJRGA 2013).

The juvenile salmonid studies now being conducted (2013) are those focused on the south Delta. Steelhead are being released as part of the 6 year steelhead study identified in the OCAP. Salmon are being released as part of a CVPIA, CDWR and USBR study to measure salmon survival through the Delta in 2013 and the survival in the two main routes, without a head of Old River barrier installed. Such information is needed for assessing annual smolt survival and for modeling the factors influencing reach specific survival through the Delta.

Lastly, the south Delta collaborative research group is convening to assess conceptual models and hypothesis to develop study plans to study salmonid survival in the south Delta for 2014 and beyond. The DJSSS program is participating in that activity on behalf of NMFS.

Methods

In 2007, the juvenile salmon survival studies transitioned away from CWT studies to acoustic studies using HTI tags, primarily due to the lack of study fish at Merced and the potential instability of the sampling at Chipps Islaned and Antioch due to delta smelt take. In 2012, the salmonid studies transitioned away from the foundational VAMP study using HTI acoustic tags to the 6 year steelhead study (using 180 khz VEMCO tags). The DJSSS program is now responsible for providing the staff to tag and release steelhead as part of the 6 year study, and to tag and release salmon as part of a “post –VAMP” Chinook salmon study. The steelhead study is different than the Chinook study in the timing, but is similar in that it attempts to determine the factors influencing salmonid survival in the San Joaquin River and south Delta. In 2011 and 2012, both salmon and steelhead were released in such a fashion that survival between the two species could be compared and address the question of whether salmon were suitable surrogates for steelhead. In 2011, the south Delta Temporary barriers study also released both salmon and steelhead so additional comparisons associated with surrogacy between the two species could be evaluated. In 2012, the Chinook salmon releases were made to assess the effect of flow augmentation from a Merced Irrigation District water purchase by making releases during and after the flow release.

For the survival studies associated with VAMP and since VAMP, study proposals were developed for each study with specific objectives. A conceptual model was also developed for both the salmon and steelhead studies in the south Delta (Figure 50). The statistician responsible for developing and running the branching release-recapture model used in 2011-2013, was involved in assuring receivers were deployed at the necessary locations in the appropriate configuration (single, multiple, redundant or dual) to meet assumptions in the model (SJRGA 2013).

For the steelhead releases in 2013, there will be three separate release groups of 480 fish per group. Releases will be made over a 3 day tagging and 5 day release period for each of the three release groups. Releases are to be made in March, April and May. The steelhead are tagged in three separate groups per day, with three transports to the release site each day. There are two tag life studies planned with 50 tags in each.

In 2013 the Chinook salmon study will make two releases of 480 Chinook at Durham Ferry during the first and third weeks of May. Sample sizes were based on a power analyses done for the VAMP in 2011 (SJRGA 2013), to determine the number of fish needed if survival ranged between 0.05 and 0.10 through the Delta and all fish were released at Durham Ferry. Since survival in 2011 was only 0.02, the statistician analyzing the data suggested a minimum release of 960 fish in 2013. She will pool results from both weeks if survival is low and at the levels comparable for Chinook in 2011. One tag life study of 50 is planned, with 25 tags randomly coming from the group of tags used in each of the two weeks.

Since mortality through the Delta is estimated starting at Mossdale, tagged fish released at Durham Ferry have the distance between Durham Ferry and Mossdale to express any potential handling mortality that occurs, reducing its effect on survival through the Delta. Releasing all groups at Durham Ferry in 2011 reduced any impact of handling mortality on survival through the Delta and standardized the reach where it was expressed. We increased the numbers of fish released at Durham Ferry in 2011 to accommodate the study design change from that used in 2010, where supplemental release groups were made at Stockton and in Old River to augment releases at Durham Ferry in 2010 (SJRGA 2013).

As part of the studies, personnel responsible for the tagging in 2013 were trained by USGS – Cook, Washington, as was done in 2007, 2008, and 2012. In 2009, 2010 and 2011 training was conducted by FISHBIO using the same methodologies as USGS. New personnel have a full regiment (week) of training, while returning personnel have an abbreviated training schedule. At the end of the training, practice fish are tagged, held overnight and necropsied to evaluate incision depth and if incisions have hit any vital organs. A tagging SOP is developed annually and QA/QC evaluations are done during actual tagging to assess the process. Due to a limited budget USFWS will conduct an abbreviated training for the Chinook study in 2013, using a similar methodology as USGS. All personnel tagging Chinook in 2013, will have also tagged steelhead in 2013 and have gone through both training processes. In addition, 75 fish tagged on the second day of Chinook salmon training (25, from each person tagging) will be held for one week, to assess any mortality from the tagging alone.

We used fall-run Chinook salmon from the Merced River Hatchery for the 2013 acoustic study. This has been the case for all San Joaquin study fish since 2007, but in 2009, they were fall/spring hybrids from Feather River Hatchery because production was low at Merced and our request for fish from Merced hatchery was denied. The HTI Model 795 Lm micro acoustic tag used in 2009-2011 and weighed 0.65 g in air (range: 0.58 g to 0.73 g), was 16.4 mm long, with a diameter of 6.7 mm. A minimum fish weight criteria of 12.1 g was used to ensure a maximum tag weight to body weight ratio of 5.4%, in 2008, 2010 and 2011, although in 2010 some fish at 12.1 grams had a tag weight to body weight ratio of up 5.8%. In 2012, a 13.1 gram size cut off was used to be below the 5% tag weight to body weight ratio. In 2009, the tag weight to body weight ratio of 5.4% was not achieved (SJRGA 2010).

Tags for Chinook salmon in 2008, 2009, 2010 and 2011 were 0.65 gram tags from HTI. Tags used in 2012 were VEMCO V5 tags which also weighed 0.65 grams. The steelhead for the 6 year study are from Mokelumne River Hatchery and used 1.0 gram HTI (2011) or V6 -VEMCO tags (2012). Tags used in the Chinook salmon studies were weighed to calculate a tag weight to body weight ratio for each individual. Only a sub-sample of steelhead tags were weighed as the steelhead are much larger and do not approach the recommended 5% tag weight to body weight ratio.

Acoustic tagging for Chinook salmon occurred at Merced River Hatchery in 2007 and 2008 and the same is planned for 2013. Acoustic tagging in other years occurred at the Tracy Fish Collection Facility (TFCF) of the CVP in 2009, 2010, 2011 and 2012. It was a logistical advantage to tag locally and there was an opportunity to acclimate the fish to Delta temperatures over a week period prior to tagging. Fish were not held at ambient temperatures for the duration of holding at TCFC because Proliferative Kidney Disease (PKD) is progressive at temperatures greater than 15°C, and ambient Delta temperatures often exceed 15°C. PKD has been a concern for study fish used in the VAMP studies (SJRGA 2013). These issues are not present with steelhead at Mokelumne River hatchery where tagging was done in 2012 and 2013. In 2011, steelhead tagging was done at the State Water Project’s fish culture lab.

Temperature and dissolved oxygen in the transport tanks is recorded after loading buckets into the transport tanks but before leaving the tagging location, and at the release site prior to unloading. Water temperatures were sometimes higher at the TFCF than at the release site and ice was needed to keep water temperatures in the transport truck from increasing. If the water temperature difference between the transport truck and the river were less than 5 degrees C, no tempering was done per recommendations from CA/NV Fish Health Pathologist (Scott Foott, personal communication). If differences were greater than 5 degrees, river water was mixed with transport tank water in the totes or buckets holding the fish, such that water temperatures were raised, or lowered until they were within the 5 degree difference. Water temperatures at the hatcheries are generally much lower than those in the Delta.

Study fish were withheld food for 24 hours prior to transmitter implantation. Prior to transmitter implantation, fish were anesthetized in 70 mg/L tricane methanesulfonate buffered with an equal concentration of sodium bicarbonate until they lost equilibrium. Fish were removed from anesthesia, and were measured (FL to nearest mm) and weighed (to nearest 0.1 g). Surgical procedures were based on Adams et al. (1998) and Martinelli et al. (1998). Typical surgery times are less than 3 min. After tagging fish are placed into perforated buckets or totes with high dissolved oxygen concentrations (110 – 130%) to recover from anesthesia effects. Tags were verified after tagging to assure they were working before being loaded for transport. Tags were also verified using two receivers (dual array) deployed just downstream of the release site. After tagging and during transport and holding at the release site, fish are allowed access to the surface to fill their air bladder and compensate for weight of the tag as recommended in Peven et al. (2005).

Fish are tagged in batches (approximately 120 to 160 fish per day) and then transported shortly thereafter (within the day) to the release site in specially designed transport tanks to keep a series of perforated plastic “totes” or buckets secure during transport. Three individuals by tag code are tracked by tote or bucket number once they are tagged until they are combined into perforated garbage cans at the release site. Five buckets (15 Chinook salmon) or four totes (12 steelhead) are held in perforated garbage cans (32 gallon or 44 gallon, respectively) for a minimum of 24 hours after transport until release. Releases are made every 4 to 6 hours. The methodology for how the releases are made and release locations has changed over time and have ranged from one release after an hour of acclimation (2007, after being held at the hatchery for 48 hours), to a day and night release (2008) to present procedures (2011, 2012 and 2013) . Releases were made every 4 hours for the Chinook salmon and steelhead in 2012, but Chinook salmon will be released every 6 hours in 2013, due to budgetary constraints.

Fish were ferried out into the middle of the channel, downstream of the holding location, for releases in 2010 and 2012 and planned for 2013, but flows were too high in 2011 to safely allow field personnel to use the boat. Fish were to be released in the middle of the channel, downstream of the holding site, to potentially reduce initial predation of tagged fish immediately after release (SJRGA 2013). The high flows in 2011 may have reduced this concern as it may have been more difficult for predators to congregate near the holding location with the high flows (SJRGA 2013).

At the release time the holding container are rotated to detect and remove any dead or impaired fish. In 2009 and 2010, a small number of tagged fish (i.e., 3 at each location in 2010) were intentionally killed to determine if the live tag was observed at any downstream receiver. Given the change in study design in 2011, 2012 and 2013 with all releases being made at Durham Ferry, no tagged fish were intentionally killed in 2011 – 2013 as it was not likely they would move far enough downstream to be detected near Banta Carbona (the first receiver location downstream of Durham Ferry). In 2010, one of the intentionally killed dead fish was detected approximately 5 km downstream from where it was released, but it was not clear if it had been eaten by a predator upstream and defecated downstream or had drifted that far downstream.

In order to evaluate the effects of tagging and transport on survival, several groups of Chinook salmon and steelhead were implanted with inactive or dummy transmitters each year. Dummy-tagged fish are evaluated for condition and mortality after being held at the release site for approximately 48 hours. After dummy-tagged fish are held for approximately 48 hours, they are examined for mortality, then euthanized with MS-222, measured (FL to nearest mm) and qualitatively examined for condition: percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration. Additional dummy tagged fish that have been held for 48 hours at the release site are evaluated for fish health by the USFWS's CA/NV Fish Health Center. Additional Chinook salmon are sampled for fish health at the hatchery to control for tagging, transport and holding. Starting in 2013, we are documenting the water temperature and dissolved oxygen after fish have been held for 48 hours.

The analyses of the 2009, 2010 and 2011 VAMP, the 2011 6 year study and south Delta Barrier evaluation, and the 2012 and 2013 Chinook salmon and 6 year study data analyses and modeling has been or will be conducted by Rebecca Buchanan at the University of Washington. She has used a predator filter to distinguish "predator-type" detections from those that are "smolt-type" and has run the survival model using both the full and reduced data set. The predator filter she used was based on input from fish biologists in the system (SJRGA 2011, 2013) relative to assumed behavioral differences between salmon smolts and predators. The criterion in 2013 included residence times, fish speed, unexpected transitions between receiver sites, travel time since release and movements against flow (SJRGA 2013). A separate predator filter was developed for steelhead (R. Buchanan, personal communication). The model developed to estimate Chinook salmon smolt survival and migration route entrainment probabilities in the San Joaquin Delta was similar to the model developed for the Sacramento River Delta by Perry et al. (2010). The analyses also tests for tagger effects (SJRGA 2011, 2013).

Although, not part of the JSSS responsibilities, mobile monitoring and tagging predators have been part of the VAMP studies in the past, but are not explicitly contained within the studies conducted in 2013, although some predator tagging is planned in 2013 by others in a complementary fashion.

Results and Discussion

Specific results of the various south Delta studies are either available in stand-alone reports (SJRGA 2013) or not yet available.

Survival estimates from Mossdale to Chipps Island from acoustic studies in 2010 and 2011 were low (0.05 (SE= 0.01) and 0.02 (SE = 0.00), respectively) and similar to biased estimates in 2008 (average = 0.06, SE = 0.01) (C. Holbrook, USGS, personal communication). The 2010 and 2011 results included removing detections from those potentially from a predator, whereas the 2008 estimates did not. Survival including all detections resulted in a change in survival estimates in 2010 (0.11, SE = 0.01) but not in 2011.

Starting in 2008, the use of acoustic tags facilitated estimating the proportion of fish taking each route (route entrainment) and estimating survival in each route. In 2008, tag failure prevented unbiased survival estimates, but survival appeared to be higher on the San Joaquin route than for the Old River route (Holbrook et al. 2009). In contrast, the results in 2010 were mixed about which route through the Delta had higher survival (SJRGA 2011). Although, survival for each of the separate release groups was not significantly different between the Old River and San Joaquin routes, with the exception of the first release group, where survival in the San Joaquin River was higher, pooling all the release groups together suggested survival was higher in the Old River route in 2010 (SJRGA 2011). In 2011, survival appeared to be higher in Old River than in the San Joaquin River (SJRGA 2013). It is not clear if survival in the San Joaquin route decreased in 2010 and 2011 or whether survival in Old River has increased, for the relative survival to be higher in Old River.

One mechanism for the low survival in the San Joaquin River route may be diversion into the interior and south Delta as the tagged fish move downstream. Although an average of 21% of the fish on the San Joaquin River approaching the Turner Cut junction entered Turner Cut, none of those tagged fish entering the interior Delta via Turner Cut survived to Chipps Island (SJRGA 2013). Movement towards the interior and south Delta from the main-stem San Joaquin River may also account for the high mortality inferred by the low estimated transition probabilities between Medford Island (A10) and Jersey Point (G1). The average estimate of this transition probability was 0.08, suggesting many of the fish that arrive at Medford are not successfully making it downstream to Jersey Point. Movement into the interior Delta via Old or Middle rivers or through Frank’s Tract may contribute to this perceived mortality. The joint probability of moving and surviving from the CVP holding tanks to Chipps Island was relatively high with an average estimate of 0.62 (SE = 0.08). This is in contrast to the survival through Clifton Court Forebay and the SWP, where the average estimated transition probability from RGD to Chipps Island was 0.02 (SE = 0.01). This result seems consistent with previous studies (Clark et al. 2009; Gingras 1997; SJRGA 2011) that have identified high mortality for juvenile steelhead or salmon moving through Clifton Court Forebay and through the SWP. We were first able to measure survival between Jersey Point and Chipps Island in 2011. The average estimate of survival between Jersey Point and Chipps Island was 0.69 (SE = 0.13). The value of 0.69 is the estimate of the probability of getting from Jersey Point to Chipps Island (alive) and not going back upriver (alive) after reaching Chipps Island. If this estimate of mortality between Jersey Point and Chipps Island is correct, then we may be losing an additional 30% of our fish between Jersey Point and Chipps Island. Although the tidal action in this area may result in a longer travel time between these two locations, this seems like a large loss for this relatively short distance. However, it is important to note that there is large uncertainty on this estimate (SE = 0.13, CV = 0.19) because few tagged fish were actually detected at Jersey Point.

The probability of remaining in the San Joaquin River at the head of Old River at the head of Old River was positively correlated with flow and water velocity at Lathrop in 2011, with higher flows and water velocities corresponding to more salmon migrating in the San Joaquin River route (SJRGA 2013). Flow and water velocity were also a function of route entrainment in 2009 and 2010, but also included whether the non-physical barrier was on or not. The proportion of fish remaining in the San Joaquin River increased with the non-physical barrier was on (SJRGA 2013).

The interagency and integrated nature of the south Delta acoustic studies since 2009 has benefited all of the interested parties. Without such integration, acoustic studies were too expensive to run independently with the VAMP funding, as CWT studies originally planned and agreed to were much less costly to implement. However, we are just starting to get the type of route specific and reach specific survival data to better understand where and why the mortality is occurring. Survival studies in the Delta suffer from the challenge of detecting the signal from the environmental noise in the system. Additional studies to document survival through the Delta are needed to determine where the mortality is occurring and what relative survival is between years. With the VEMCO acoustic array in place for the 6 year study, until 2016, it provides an opportunity to get additional information on Chinook salmon at a lower cost as no additional receivers are needed. However, the tags for Chinook, even at 0.65 grams are large for young-of-the-year migrants such that absolute survival information is not likely accurate. It would be beneficial to use smaller tags (JSAT) but to do so would require purchasing and deploying a separate set of receivers.

The challenge of the survival studies is to integrate and analyze the multiple years of Chinook salmon data in a consistent and comprehensive framework. We plan to analyze the four years (2010-2013) of acoustic results (Buchanan's IEP funded proposal), but we would like to also integrate the results of the previous CWT studies into this framework. While it is possible (K. Newman, USFWS, personal communication), our USFWS office statistician is committed to delta smelt projects at this time and no funding has been identified to further support this integration of analyses. Testing the various models developed for the South Delta would be another application of this data to modeling (i.e. Delta Fish Passage Model) for Bay-Delta Conservation Plan (BDCP) evaluation. Integrating the south Delta with the north Delta is also a future goal. Migrating through the Delta is a complicated task for salmonids, with multiple factors affecting survival, including multiple routes, tides, the influence of net reverse flows, and entrainment and predation associated with the CVP and SWP pumping plants.

Developing a framework for future studies into an adaptive management program is also needed, but foundational information on survival through the Delta, as well as specific routes and reaches is needed for both the south and north Delta to develop survival models for both basins and provide baseline information needed to assess changes in Delta survival anticipated from the BDCP. In addition, specifically linking results to an overarching model to inform management actions and adaptive management is also needed, once these models are developed. Survival monitoring can and should be a component of adaptive management monitoring to help understand juvenile salmon survival in the Delta and the great uncertainties associated with the BDCP. A modeler or statistician could help with these activities if funding is made available.

Liberty Island

Introduction

The DJFMP samples fish within Liberty Island, a reclaimed tidally influenced wetland in the Cache Slough complex, to determine the effects of passive restoration on fish occupancy in the North Delta. Liberty Island is hypothesized to provide important habitat for species of management concern, including delta smelt, Sacramento splittail, and juvenile Chinook salmon (USFWS 1995; USFWS 2008). In 2000, the CALFED Bay-Delta Program provided funding to the USFWS to conduct a two-year pilot study within Liberty Island to (1) summarize the passive restoration that had occurred since the island was flooded in 1998, (2) develop aquatic monitoring protocols, and (3) document baseline conditions for fish and wildlife occupancy, vegetation, bathymetry, water quality, phytoplankton, zooplankton, benthic conditions and organic carbon prior to any restoration activities. The DJFMP participated in the Interagency Monitoring Group composed of CDFW and CDWR to complete the pilot project during the 2003 through 2005 field seasons (Hansen et al. 2005). The DJFMP was specifically tasked with fish sampling to determine habitat use of Sacramento splittail, delta smelt, and Chinook salmon within the island (Hansen et al. 2005). Results from the pilot study demonstrated the occupancy of Sacramento splittail, delta smelt, and juvenile Chinook salmon and provided broad scale temporal and spatial distributional patterns of native and nonnative fishes (e.g., among seasons and quadrats). The study also evaluated the feasibility of six gear types for monitoring fish within Liberty Island (e.g., beach seine, larval light trap, larval trawl, gill-net, purse seine, KDT, minnow trap; Hansen et al. 2005; USFWS 2007). Beach seines and larval trawls were highlighted as cost-effective gears for sampling multiple life stages.

In 2009, the DJFMP submitted a proposal to the IEP Management Team to reinitiate fish monitoring at Liberty Island. The additional effort was proposed to complement on-going studies in the region including BREACH III. The BREACH III study is a multidisciplinary investigation that was implemented in 2008 to provide information regarding how abiotic and biotic factors control vegetation colonization and expansion and to determine the resulting impact on higher trophic levels. Although no additional funding was provided, the IEP approved the request to continue monitoring at Liberty Island. As a result, larval fish trawls and beach seine sampling at Liberty Island were reinitiated in 2010 and these sampling elements continue today as part of the baseline monitoring program. In addition, zooplankton sampling in conjunction with the larval trawls has been incorporated into the 2013 DJFMP workplan.

The current objectives of the Liberty Island monitoring program are to (1) document the temporal and spatial distribution of native fishes, (2) evaluate the habitat associations of delta smelt, longfin smelt, Sacramento splittail, and Chinook salmon, and (3) determine the composition of native and nonnative fishes. Furthermore, data from the monitoring may provide basic information about the relative importance of the habitats within the reclaimed wetland to inform future restoration efforts within the Estuary (e.g., BDCP). Although not a long-term objective, the monitoring within Liberty Island builds on DJFMP salmonid and non-salmonid objectives in terms of understanding the importance of tidally influenced wetlands for all fishes at various life stages.

Methods

We used beach seines (15 m x 1.2 m with 3 mm delta square mesh) to monitor juvenile and small adult fishes within shallow and unobstructed near-shore habitats. Beach seining methods followed those already established by the DJFMP in order to allow comparisons between other monitoring locations in the Estuary. Beach seines were used at 21 fixed sites distributed throughout Liberty Island (Figure 51). Ten sites were selected from locations originally sampled during the pilot study in the southern portion of Liberty Island and 11 new sites were selected in the northern portion of Liberty Island to maximize spatial coverage. In general, beach seine sites were sampled once per month (10 - 11 sites per trip, two trips per month) on a year-round basis. We also recorded environmental variables hypothesized to affect juvenile and adult fish abundance at the beginning of each seine haul (Table 5).

Between February and June, larval fishes were monitored using two 152.4 cm long x 50 cm mouth diameter larval trawl nets (500 µm nylon mesh) within open water habitats greater than 0.8 m in depth. One net was deployed on each side of the vessel. Approximately ten surface trawls (10 minutes each) were conducted during daylight hours in both the northern and southern portions of Liberty Island. Trawl site locations were haphazardly selected each sample day near and between beach seine sites. As a result, most trawls were conducted near and parallel to the shoreline. Few samples were taken while traveling in the middle of Liberty Island. The linear distance traveled was recorded using a mechanical flow meter (General Oceanics, Model #2030). In general, trawl vessels were operated at 1,000 to 1,200 RPMs while sampling. We recorded several environmental variables hypothesized to affect larval occupancy at the beginning of each trawl (Table 5). The start and stop longitude and latitude for each trawl were recorded for possible future GIS analysis to assess the impacts of emergent aquatic vegetation and bathymetry on fish occupancy. At the end of each trawl, the samples from the two trawl nets were combined into one vial, preserved with 10% formalin and Rose Bengal mixture. Samples were brought back to the lab for processing and fish identification.

In 2013, the DJFMP made several modifications to the larval fish sampling methods to minimize bias associated with inferences made using the larval fish monitoring data. We implemented a stratified random sampling design to improve our coverage of different habitats within Liberty Island, particularly deeper open water habitats. Each month, five larval trawl sites were randomly selected in each quadrant (Northeast, Northwest, Southeast, and Southwest). In addition, larval trawl samples collected from the two nets were preserved and processed separately, allowing the estimation of capture probability and to investigate fine scale spatial patterns of larval fish occupancy. We also collected water quality and dominant substrate at the beginning and end of each trawl to obtain more representative habitat information. Based on the fact that tidal stage will greatly influence the accuracy of available bathymetry data during our sampling, we recorded trawl lanes and depth using side-scan sonar during each trawl.

In addition, zooplankton sampling was initiated in 2013 to better understand the relative importance of prey availability or composition on larval fish occupancy within Liberty Island.

Zooplankton sampling occurred in tandem with larval fish trawls. One 1m long x 0.127m mouth diameter zooplankton net (153µm mesh) was trawled at the surface of the water between the side of the boat and each larval net. A mechanical flow meter was mounted across the opening of each zooplankton net to determine volume of water sampled per tow and will be used to quantify zooplankton densities per tow. After the completion of each zooplankton trawl, samples are placed in a sample jar and preserved in 37% buffered formalin solution and Rose Bengal mixture. In the laboratory, the number of zooplankton will be counted and at least 10% of the zooplankton will be identified to the lowest taxonomic level possible for each sample. To date, no zooplankton samples have been processed and results are not included in this report.

Liberty Island Statistical Analyses.–Our primary objective for the Liberty Island monitoring was to assess the relative importance and quantify the influence of environmental variables on the occupancy of fish species of management concern within Liberty Island. Therefore, we examined the relative importance of water quality, physical habitat, and terrestrial vegetation characteristics on species-specific and life stage-specific occupancy using logistic multivariate regression models (Williams et al. 2002). We modeled the occupancy of species of management concern present in more than 5% of the samples for each gear type to minimize the distortion of trends (Gauch 1982). Therefore, we were limited to assessing the occupancy of juvenile or adult Sacramento splittail, Chinook salmon, delta smelt, threadfin shad, and striped bass within beach seine samples and the occupancy of larval Sacramento splittail, delta smelt, longfin smelt, threadfin shad, and striped bass within larval trawl samples. However, the preliminary results presented in this review are limited to Sacramento splittail to demonstrate the analytical approach.

All of the parameters in the regression models were modeled as logit linear functions of predictor variables, which allowed us to identify the factors related to the probability of capturing at least one individual within a sample. Because the probability of capturing at least one individual is a product of the probability of occupancy and the probability of detection (Bayley and Peterson 2001), the primary assumption of the approach is that the gear efficiency of seines and larval trawls were constant throughout the study for each species analyzed. As a result, volume sampled was included as a redundant variable in all models because of its known influence on detection and could complicate the occupancy analysis if not included.

We developed a global seine and larval trawl model for each species of concern that contained all of the predictor variables that corresponded to our *a priori* hypotheses (Table 12). To avoid multicollinearity, we included only uncorrelated variables ($r^2 < 0.40$) within the global models. Prior to constructing candidate models, all continuous data were standardized with a mean of zero and standard deviation of one to facilitate model fitting and ensure variables are being assessed on identical scales. In addition, discrete variables including quadrants and substrate type were coded as binary indicator variables (i.e., 0 or 1). The southeast quadrant and sand served as the baseline conditions for the quadrant and substrate indicator variables, respectively.

We evaluated the relative importance of environmental variables on fish occupancy by developing 256 and 128 candidate models as subsets of the global seine and larval trawl models for each species of concern, respectively. The goodness-of-fit of each global model was evaluated by graphing the residuals against predicted values for each of the global models.

When spatial or temporal dependence was detected among seine and trawl samples, we used hierarchical models (Royle and Dorazio 2008) to estimate occupancy (ψ) as:

$$\text{Logit}(\psi_{ik}) = \alpha_0 + \alpha_{1i} + \alpha_{2j} + \alpha_3 W_3 + \ldots + \alpha_r W_r$$

where *i* indexes sample sites, *k* indexes sample days, weeks, months, or years, W_r represents a predictor variable (e.g., physical habitat characteristic), α_0 represents a fixed intercept, α_{0i} represents a randomly varying intercept that varied among sample sites, α_{0k} represents a randomly varying intercept that varied among time, and α_r represents the effect of W_r on occupancy.

We quantified the relative importance of predictor variables by comparing the relative fit of candidate models for each species of concern and gear type using an information theoretic approach (Burnham and Anderson 2002). To assess the fit of each candidate model, we used the Akaike Information Criteria with the small sample bias adjustment (AIC_c; Akaike 1973; Hurvich and Tsai 1989). The small sample bias adjustment was used based on the relatively large number of model parameters in comparison to the seine and larval trawl sample sizes (Hurvich and Tsai 1989). The number of parameters (K) used to calculate AIC_c included both fixed effect and random effect parameters within each model. The best fitting candidate models were determined by calculating Akaike weights (w_i; Burnham and Anderson 2002) using the AIC_c value for each model. Akaike weights range from zero to one, with the highest weight being the best fitting model. To assess the amount of evidence one candidate model had over another, the ratios of Akaike weights were used (Burnham and Anderson 2002). Any candidate model with Akaike weights that were within 12% of the best-approximating candidate model's Akaike weight was included within the confidence set of models (Royall 1997). We determined the relative importance of predictor variables by summing the Akaike weights for candidate models in which each predictor variable was present within the confidence set of models (Burnham and Anderson 2002). All inferences regarding the effect of predictor variables on fish occupancy were based on a composite model derived from model-averaged estimates from the confidence set of candidate models (Burnham and Anderson 2002).

We developed composite models by calculating model-averaged estimates for each parameter within the confidence set of models using the AIC_c values from each of the models that contained the parameter of interest and calculating new associated Akaike weights. The associated candidate model estimates were then weighted by their new Akaike weights and summed to give a model-averaged estimate for a particular parameter. The precision of model-averaged parameters was assessed by calculating modeled averaged estimates for each parameter's upper and lower 95% confidence limits. Confidence intervals that contained zero were deemed inconclusive because of the variability of the relationship. All inferences were based on the composite models.

To allow for ease of interpretation, an odds ratio (OR) was estimated for each fixed effect parameter in the composite models (Hosmer and Lemeshow 2000). An OR adjusts for the logistic element and is calculated by taking the exponent of the parameter estimate. Because the data were standardized, an OR corresponded to a one standard deviation change for each predictor variable. An OR can range between zero and infinity. An OR that is less than one demonstrates that the response variable is less likely to occur and an OR that is greater than one demonstrates that the response variable is more likely to occur. Credible intervals for an OR that contained one were considered imprecise.

Results and Discussion

From January 2010 through July 2012, a total of 42,436 fish representing 27 species were captured using beach seines in Liberty Island. Catch included 12 native species (n = 4,288) and 15 non-native species (n = 3,8147; Table 13). The non-native inland silverside (n = 33,432) was the most abundant species captured in beach seines at Liberty Island, making up 88% of the non-native catch. The native Sacramento splittail (n = 3,286) was the second most abundant species captured in beach seines at Liberty Island, making up 77% of the native catch.

The DJFMP captured 58,377 fish representing 18 different species during the larval trawls in 2010 (April – June), 2011 (March – September) and 2012 (February – March). There were 6 native species (n = 5,382) and 12 non-native species (n=5,296; Table 14) captured. The most abundant species captured in the larval trawls at Liberty Island was the native prickly sculpin (n = 4,770), making up 89% of the native catch. The non-native inland silverside was the second most abundant species captured in the larval trawls at Liberty Island, comprising 61% of the total non-native catch.

There were 28 models in the confidence set of beach seine models for splittail. The best approximating candidate model included volume, quadrant, turbidity and conductivity (Table 15). Quadrant was the most important variable relative to other variable assessed in terms of splittail occupancy; however it was only 1.02 times more important in influencing splittail occupancy than turbidity (Table 16). The southeast quadrant (baseline) appeared to have the highest probability of splittail occupancy (Figure 52) and as turbidity increased the occupancy probability of splittail decreased (Figure 53).

The confidence set of larval trawl models for splittail included 28 models. The best approximating candidate model included volume, discharge, and depth (Table 15). Discharge was the most important variable influencing larval fish occupancy (Table 16). Depth was the second most important variable and was 2 times more influencing larval occupancy relative to discharge. As discharge (Figure 54) and depth (Figure 55) increased, the occupancy probability of splittail decreased.

Liberty Island beach seine catch data shares some of the same biases associated with the DJFMP long-term beach seine sampling element (e.g. methodology limitations and efficiency). Based on the current sample design, the fixed monitoring locations within the southern portion of the island are more representative of the dominant habitat types (mud banks and sandy beaches). However, the majority of the habitat in the northern portions of Liberty Island is dominated by emergent and submerged aquatic vegetation (SAV). Therefore, the DJFMP is under sampling the dominant littoral habitat in the northern portion of Liberty Island and thus underestimating the relative abundance and distribution of fishes that occupy these habitats. In three restored marshes in the Delta, Grimaldo et al. (2012) demonstrated differences in fish assemblages between habitats with and without SAV and that introduced fishes, including centrarchids, were more abundant in SAV. Therefore, it may be necessary for the DJFMP to explore new avenues for sampling littoral habitats dominated by emergent and submerged aquatic vegetation to more accurately determine the species composition in the northern portions of Liberty Island.

Beach seines do not address larger fish and other pelagic species occupying the deeper open water habitat of Liberty Island. Therefore, the DJFMP may need to consider other sampling methods to determine the composition of non-natives and natives associated with these habitats. During the pilot study (2002–2005), the DJFMP successfully used gill nets and a stratified random sampling design to collect larger native and non-native species occupying the deeper open water habitat of Liberty Island. However, gill nets have their biases and efficiency is generally related to the construction of the net (i.e. mesh size and color) and sampling regime (e.g. set time and sampling regime, Hubert 1996). In addition, gill nets stress fish more than any other passive gear due to injury or death upon removal or entanglement (Hopkins and Cech 1992, Hubert 1996).

The DJFMP sampling frequency at Liberty Island is also likely not accurately assessing the patterns in fish distribution within Liberty Island. Increasing the frequency of larval trawls and beach seines might allow for more robust investigations regarding inter- and intra-annual variability of fish rearing and species composition within open water and littoral habitats. However, the increase in sampling frequency of larval trawls could further increase the take of delta smelt after wet years as we learned in 2012 when the DJFMP had to cease larval trawls after 5 sample days due to reaching take limits. The USFWS is currently reviewing our request for an increase in take under our sub permit for Liberty Island to help alleviate this problem.

In addition to the design and frequency of sampling, the analytical approach used by the DJFMP must also be evaluated. While the logistic multivariate regression models currently used by the DJFMP are assessing the relative importance and quantifying the influence of environmental characteristics on the occupancy of certain fish species, these models do not address abundance or density within the various habitats in Liberty Island. Understanding fish-habitat relationships will be critical for informing managers during restoration efforts with the goal of recovering native fish assemblages in the Delta.

Freshwater tidally influenced wetlands are rare but important habitat in the Estuary. It is hypothesized that wetlands can be a source of organic and inorganic materials needed to support adjacent riverine production (Junk et al. 1989) and can provide essential habitat for aquatic species. Lehman et al. (2009) demonstrated that Liberty Island is a potential source of inorganic and organic material but the export of material is spatially and temporally variable and closely related to tidal flow rather than river discharge. The baseline monitoring at Liberty Island includes habitat that is not readily found in the Estuary and is more reminiscent of the Estuary prior to human alterations such as levees. Since beach seine monitoring in Liberty Island follows the protocols established by the DJFMP for the long-term beach seine sampling element, we are able to make comparisons of the abundance and composition of native and non-native species in Liberty Island to other DJFMP monitoring sites. Results from these comparisons may help demonstrate the importance of wetland habitat to native fish assemblages and guide restoration managers in efforts to restore critical habitat for native fishes.

INCIDENTAL TAKE

Introduction

The incidental take of fishes listed under the federal and state Endangered Species Acts is a growing concern to the DJFMP. Take of ESA-listed species by the DJFMP is summarized in Tables 17–18. Despite ongoing adaptive management efforts by the IEP, considerable uncertainty existed regarding the relative roles of habitat, population size, seasonality, and sampling methodologies on the incidental capture of delta smelt while monitoring juvenile salmonids at Chipps Island.

Based on relatively high incidental catches of delta smelt during water years 2007, 2011, and 2012, the DJFMP temporarily reduced the monitoring efforts at Chipps Island. Without understanding the factors that influence both delta smelt and juvenile Chinook salmon catch at Chipps Island, the implications and effectiveness of previous and possibly future modifications to the sampling methodology at Chipps Island, intended to reduce the incidental capture of delta smelt while monitoring juvenile Chinook salmon, are not understood. Thus, we evaluated the relative importance of environmental characteristics and surface trawl methods on catches of both delta smelt and juvenile Chinook salmon near Chipps Island to determine if and how the Chinook salmon monitoring can be modified at Chipps Island to reduce delta smelt take.

Methods

Data used for the analyses included a total of 20,131 fish samples collected at Chipps Island using the MWT from July 2001 to December 2011. This time period was selected based on standardized gear (i.e., 0.8 cm cod end mesh). A total of five categories of variables hypothesized to affect either the occupancy or capture efficiency of delta smelt and/or juvenile Chinook salmon were measured, estimated, or obtained for each sample: (1) water quality characteristics (temperature, Secchi depth, position of low salinity zone, X2), (2) tide (tidal stage, tidal current), (3) weather (rain, not clear, wind), (4) methods (trawl direction, trawl channel position, volume of water sampled), and (5) delta smelt annual population index (CDWF Fall Mid-Water Trawl Survey). The position of X2 was obtained from Dayflow (CDWR 2012a).

We evaluated the relative support for the influence of factors on delta smelt and juvenile Chinook salmon catch using hierarchical regression models in Program R. To avoid multicollinearity, we excluded correlated variables ($r^2<0.40$) from the analysis. All models included randomly varying intercepts that varied among year and month combinations and individual samples to account for dependency and overdispersion, respectively. Prior to constructing candidate models, all continuous data were standardized with a mean of zero and standard deviation of one to facilitate model fitting and ensure variables are being assessed on identical scales. In addition, discrete variables including trawl channel position, trawl direction, tidal stage, and weather were coded as binary indicator variables (i.e., 0 or 1). Trawling in the middle channel position on a clear day during low tide served as baseline conditions for the discrete variables.

Candidate models were developed relating delta smelt and juvenile Chinook salmon catch to all possible combinations of variable categories including and excluding delta smelt annual population index, respectively. All water quality variables were fitted using a quadratic term to maximize model fit. The best approximating candidate models were identified using Akaike Information Criteria with the small sample bias adjustment (AIC_c; Akaike 1973; Hurvich and Tsai 1989) and an information-theoretic approach (Burnham and Anderson 2002).

Results and Discussion

The most plausible model for predicting delta smelt catch was the water quality, tide, weather, methods, and population index candidate model (i.e., the global model). The global candidate model was 6.14 times more likely than the next best candidate model for predicting delta smelt catch at Chipps Island. Whereas, the most plausible model for predicting juvenile Chinook salmon catch was the candidate model using water quality, tide, and method variable as predictors. The water quality, tide, and methods candidate model was 12.67 times more likely than the next best candidate model for predicting juvenile Chinook salmon catch.

Peak juvenile Chinook salmon catch followed an inverse relationship with peak delta smelt catch among months (Figure 56). On average, as the delta smelt annual population index increased by 400, the catch of delta smelt per trawl doubled under average conditions at Chipps Island. As expected, the catch of both delta smelt and juvenile Chinook salmon increased with water volume sampled.

The effect of environmental and other methodological variables on catch differed among delta smelt and juvenile Chinook salmon (Figure 57). In general, modeling results indicated that the catch of delta smelt and juvenile Chinook salmon at Chipps Island are both influenced by water quality characteristics, tide, and surface trawl methodology. Although the results suggested that the catch of delta smelt can be reduced while monitoring juvenile Chinook salmon at Chipps Island by modifying when, where, and how samples are collected, there are no obvious ways to modify sampling based on targeting or avoiding environmental conditions or sample methodologies without also affecting the catch and therefore the long-term monitoring of juvenile Chinook salmon.

However, because the peak delta smelt catch followed an inverse relationship with peak juvenile Chinook salmon catch among months and was positively associated with the relative population estimates of delta smelt, the total annual take of delta smelt at Chipps Island can be reduced by simply collecting fewer or smaller samples when juvenile Chinook salmon are typically not captured or are captured in low numbers (July–January), particularly during the years when the annual population index of delta smelt is high. Given the results of this investigation, the DJFMP adopted a reduced sampling approach during the summer and fall seasons (July–November) to reduce the incidental capture of sub-adult and adult delta smelt when needed.

DATA TYPES AND NEEDS

Summary of Data Types and Collection Frequency

Table 5 summarizes the type and frequency of data collected by the DJFMP. Data types are broadly categorized as catch data, including measures to reduce bias, and habitat and water quality variables. Catch data are used primarily for monitoring the relative abundance, distribution, and survival or fish species that occupy littoral and pelagic habitats within the Delta. Habitat variables are used to explain and predict patterns in the catch data. Although habitat variables have typically not been included in DJFMP reports, we recommend expanding the collection and analysis of abiotic variables in the Delta.

Data Gaps

The accurate identification of Chinook salmon runs is a major data gap within the DJFMP. The LDC is imprecise and does not permit accurate production estimates by race. Although sampling all individuals for tissue collection would likely not be feasible, it may be cost effective to sample all Chinook salmon in the winter-run LDC category with the intent to remove false positives from the group. Given that most genetic winter-run fall into the winter-run LDC category, and that the main bias is from false positives, it may be cost effective to include some genetic sampling at Chipps Island, Sacramento and in the beach seines to better understand the movement of winter-run Chinook salmon in the Delta.

We also hope to use the genetic information obtained to estimate absolute abundance of winter- and spring-run Chinook salmon at Sacramento. Although we have taken the samples and summarized the data, we have not yet had time to expand the catch data to abundance estimates at Sacramento. NOAA (Sacramento) is willing to help with such a project. In addition, CDWR has recently written up the processed genetic samples (up to 2010) sampled in salvage at the CVP and SWP (B. Harvey, personal communication). We hope to compare our estimates of production of winter-run Chinook salmon to those at the fish facilities to evaluate the proportion of take in the future.

Another limitation of the absolute abundance calculations are robust trawl efficiency estimates. Brian Pyper, a statistician with Cramer Fish Sciences, has been working with us to develop the best approach for estimating trawl efficiency as part of the Delta Science project to estimate absolute abundance of winter- and spring-run Chinook salmon at Chipps Island. These analyses will be useful in determining the best approach for estimating trawl efficiency. A report on both aspects of these data gaps, trawl efficiency and abundance using genetic analyses, will be forthcoming.

We currently lack an understanding of the diel patterns of juvenile Chinook salmon at various life-stages (e.g., fry or smolt) within the San Francisco Estuary (Williams 2006). By not accounting for possible diel patterns that could vary among seasons, we may be biasing our Chinook population indices high or low given our consistent morning and afternoon sampling (Wilder and Ingram 2006). We should begin 24-hour sampling multiple times each year (trawls and seines) to target wild salmon to appropriately assess diel patterns in occupancy and movement.

A requirement for estimating fish densities using KDT and MWT is the need to accurately measure the area sampled by the trawls. Currently, the DJFMP is appropriately measuring the length of water sampled, but is still dependent on measures (MWT) and expansions of measures (KDT) made to approximate the mouth area of the trawls while sampling. Although previous studies indicate that the mouth area varies within and among tows, the DJFMP has continually applied estimates derived from very small datasets as constants to all sample data, which likely biases CPUE indices to an unknown degree. Therefore, to ensure accurate fish densities are reported, we should conduct a robust investigation to measure and subsequently model mean net mouth areas as a product of vessels used for towing, speed of vessels while in tow, and appropriate hydrodynamic characteristics (e.g., tidal direct and velocity).

Lastly, we also believe that the possible spatial bias associated with our beach seine data throughout the majority of the seine regions needs further investigation. We recognized earlier that the regional CPUE estimated for seine regions may be biased low or high due to not being able to sample one or more historical seine sites at least once during a particular sampling interval (e.g., weekly). Because the environmental conditions preventing seine samples from being collected (e.g., aquatic vegetation expansion) are also affecting the fish assemblage structure (Brown and Michniuk 2007), we are likely unable to appropriately monitor and assess the influence of current and future anthropogenic stressors on fish densities or distributions. Therefore it is imperative that we begin either investigating the utility and feasibility of implementing more robust alternative sampling methods to supplement our seine data or begin developing criteria for historical seine site replacement.

QA/QC PROCEDURES

Database

Data from seines and trawls are entered manually into the DJFMP database (Figure 58). After the datasheets have been entered, the data are previewed and transferred to the permanent tables in the database. The DJFMP collects large volumes of data and data-entry errors are inherent in the process. Line by line is a process whereby each line in the database is checked against the original data sheets. Errors are noted and corrected in the database. Unfortunately, the number of errors that are not found and corrected by this process is unknown. We recommend that more rigorous QA/QC procedures are developed such as double entry and random testing of the line by line process for errors. Further, we recommend that the database manager consider error checking and trapping further in a more formalized process of best management practices (described further in data management section).

Fish identification

Introduction

The DJFMP relies on the collection, identification, and counting of individuals to determine changes in fish distribution and abundance over time within the San Francisco Estuary. Therefore, the accuracy of the data collected by the DJFMP can be greatly affected by misidentification (Elphick 2008). For example, monitoring data containing identification errors may confound true fish distributional patterns and suggest false ecological patterns (Shea et al. 2011). Historically, the DJFMP has assumed perfect identification when making inferences using its monitoring data. Understanding that proper fish identification in the field can be influenced by the level of distinction of visible morphological traits between species (e.g., shape, color, etc.; Moyle 2002) coupled with observer bias (e.g., experience level), the assumption of perfect identification of small juvenile fishes within the San Francisco Estuary is likely unwarranted (Elphick 2008; Fitzpatrick et al. 2009; Shea et al. 2011).

The DJFMP has conducted sampling within the San Francisco Estuary since 1976 to help inform water operation decisions and assess the status of juvenile fish populations. Recognizing that misidentification could reduce the integrity of the DJFMP and its inferences, numerous control measures have been implemented throughout the program's history to minimize bias induced by identification errors. For example, all unidentifiable fish were brought back to the lab for identification, a reference collection was established, informal training was given to inexperienced field observers, and a minimum size criterion was established for proper fish identification (e.g., FL ≥ 25 mm) for most species after recognizing the difficulty of accurately identifying larval fish within the field. Furthermore, an extensive fish identification training program was created in response to a program review in 2000 that expressed concern regarding the identification accuracy of small non-salmonid resident fishes (Brandes et al. 2000). The fish identification training program was composed of one full-time fish identification biologist who was tasked with creating a formal training curriculum within the field and lab, developing accurate and effective fish identification keys, establishing a voucher collection, expanding the reference collection, and establishing minimum size criteria for proper identification of all fish species (P. Cadrett and P. Brandes, USFWS, personal communication).

Although the control measures implemented by the DJFMP have undoubtedly improved the identification accuracy of juvenile fishes, no robust study design was made prior to 2012 to quantify the fish identification accuracy among observers. As a result, the effectiveness of the fish identification training program remains largely unknown and the assumption of perfect identification among observers remains unsupported. However, the DJFMP designed a pilot study during the summer of 2012 to (1) estimate the species- and size-specific identification accuracy rates among DJFMP observers and (2) assess the effectiveness of the formal fish identification training program in order to optimally allocate limited management resources. To date, the pilot study has collected few data, but will likely be carried out extensively beginning the summer of 2013. The DJFMP is intending to publish the results of the pilot study sometime during 2014.

Methods

Sample Design.–Because an evaluation of fish identification error in the field would be logistically difficult, the fish identification study will occur under controlled conditions modified from Shea et al. (2011). Three fish identification exams will be conducted at the Stockton Fish and Wildlife Office each calendar year. One exam will occur during fall (September to November), winter (December to February), spring (March to May) and summer (June to August). One month prior to each exam, the DJFMP fish identification biologist will collect approximately 100 potential test specimens at DJFMP monitoring sites distributed throughout the Estuary (Figure 6) to obtain a representative sample of fish species and sizes throughout the year. Each potential test specimen collected in the field will be initially identified by the DJFMP fish identification biologist and immediately preserved by freezing in an attempt to preserve natural appearance (e.g., color). No fishes listed under the California or federal Endangered Species Act will be included within the potential test collections unless the individual(s) was an indirect mortality from regular DJFMP sampling.

The DJFMP fish identification biologist will select 20 to 40 fish specimens from the potential test collection for each exam. Potential test specimens will be selected after being defrosted during the morning of each exam. Recognizing that the test specimens may become damaged during the fish identification exams by extensive handling, a test specimen may be replaced by another individual of the same species, size (FL +/- 5 mm), and condition if one is available. To ensure the identification of the test specimens is accurate, three fish identification experts from the CDFW will verify the identification for each test specimen and their possible replacements (if available). If all the experts and our fish identification biologist cannot come to a consensus regarding the identification of a test specimen, the specimen will not be included in test collection.

Test specimens will be randomly assigned to test stations numbered in sequential order. During the exams, observers will be given three minutes to identify each test specimen before moving, in sequential order, to another station. To simulate conditions within the field, observers will be allowed to identify test specimens using their field keys. To prevent nomenclature errors during the exams, observers will be asked to identify test specimens by common names and will be provided sheets or keys that contain common and scientific names for all fishes occurring within the San Francisco Estuary. Observers also will be asked to record their experience (e.g., months and % of professional time each week) identifying juvenile or adult fishes within the San Francisco Estuary during each exam and note how much formal fish identification training they have had within the last two years by the DJFMP and other entities (e.g., academic institutions, etc.).

Statistical Analysis.–We will examine fish misidentification using a logit multivariate regression models (Williams et al. 2002; Shea et al. 2011). Individual test specimen identifications will serve as the response variable and will be coded as 1 when the specimen was misidentified and as 0 when the specimen was identified correctly. To estimate the probability of misidentification (m) using observers, species, morphological characteristics (e.g., shape, color, size, etc.) and identification experience, we will use hierarchical models (Royle and Dorazio 2008) as:

$$\text{Logit}(m_{ij}|\theta) = \beta_0 + \beta_{0i} + \beta_{0j} + \beta_1 X_1 + \ldots + \beta_r X_r \qquad (1)$$

where *i* indexes species, *j* indexes observers, β_0 represents a fixed intercept, β_{0i} and β_{0j} represents the effect of species and observer, respectively, on misidentification, and β_r represents the effect of morphological characteristics or identification experience (X_r) on misidentification. We will quantify the relative importance of predictor variables by comparing the relative fit of candidate models that represent different a priori hypotheses using an information theoretic approach (Burnham and Anderson 2002). The best fitting candidate models for fish misidentification will be determined by calculating Akaike weights (w_i; Burnham and Anderson 2002) using each model's Akaike Information Criteria with the small sample bias adjustment (AICc; Akaike 1973; Hurvich and Tsai 1989). To account for model selection uncertainty, we will construct a confidence set of candidate models that will include models with Akaike weights that are within 12% of the best approximating candidate model's Akaike weight (Royall 1997). All inferences will be based on a composite model derived from model-averaged estimates from the confidence set of candidate models (Burnham and Anderson 2002).

DATA REPORTING AND MANAGEMENT

Intensive sampling during the fall months provides near real-time data for managing water project operations (described previously in program objectives). In addition to providing Chinook salmon data for the Sacramento Catch Index, the DJFMP provides weekly catch reports for other species of management concern, including salmonids, smelts, and the Sacramento splittail. These reports are provided to the DAT group and also to the Delta Operations for Salmonids and Sturgeon working group (a technical advisory group for the WOMT and NMFS). Finally, the DJFMP has a dedicated database manager that responds to data requests from stakeholders, including IEP agencies, universities, consultants, and the public.

The database manager also provides quarterly data summaries, including CWT reports, and metadata updates on the DJFMP website. Annual reports summarizing the DJFMP catch data and objectives are also provided on the DJFMP website. Many of the figures and table provided in this review were obtained or adapted from the annual reports. Therefore, recommendations from this review regarding data collection and analysis will be directly applicable to future annual reports. Unfortunately, annual reports are generally not revised and formatted for peer-reviewed publications due to time constraints. Although technical staff are available to conduct the needed data synthesis for publication, other essential tasks are often prioritized and publishing is infrequent. Understanding that financial resources are limited, we recommend the development of a best management plan for the DJFMP database (described below) for making data reporting and publishing more efficient.

The DJFMP database is currently hosted by a CDFW server. However, our Virtual Private Network (VPN) access to the CDFW network is difficult to manage for both agencies. Account management is especially difficult and USFWS personnel are not permitted to make changes to users and passwords. In addition, it is a slow process to make changes to the structure of the database that is regularly needed to keep pace with the dynamic nature of the program (new studies, new protocols etc.). In response to the request by CDFW to terminate our server access, we are soliciting feedback regarding data management and reporting needs to inform and facilitate the pending database migration.

We recognize that proper data management is critical for providing accessible and reliable data per the terms of our contracts and agreements. Best management practices include dedicating personnel to data curation, including coordinating with collaborators and setting data standards, updating and documenting a relational database, and error checking and trapping (Kolb et al. 2013). For example, the data curator could work with other IEP agencies to develop standard species codes to facilitate data sharing. Importantly, improved data management not only reduces redundancy and maximizes limited resources, but it can also serve as formal documentation of scientific methods (Kolb et al. 2013). Although the process for the database migration has not been formalized, a more comprehensive data management plan needs to be implemented at the same time.

Broadly speaking, we need to seek another server to host our database or purchase our own server. Moving forward, we must consider IEP and USFWS constraints. First, we must ensure that our database conforms to the present and future needs of IEP. If we select an outside host, we must consider how the USFWS network will interact with VPNs from other agencies. A server within the USFWS may bypass many of these problems but we will still need to consider how data are accessed from outside the network. Due to USFWS restrictions, it seems likely that we will need to extract and post DJFMP data (outside users will not be able to access the database) further necessitating the need for a dedicated curator.

SUMMARY AND PROGRAM RECOMENDATIONS

One of the greatest challenges for estimating the relative abundance of Chinook salmon is our lack of precision regarding race identification. Given the need to index the population status of Chinook salmon prior to the Bay and ocean entry, we recommend adding regular tissue sampling to the program to identify genetic winter-run Chinook salmon, particularly at Chipps Island, to better understanding freshwater survival and relative take at the CVP and SWP. In addition, estimating absolute abundance of winter-run Chinook salmon at Sacramento would help validate the JPE calculations to determine CVP and SWP incidental take, thus we recommend determining absolute abundance in years with available genetic data to evaluate the need for future tissue sampling at that location. Depending on the results of these analyses, tissue sampling at Sacramento may be warranted.

We have instituted studies in 2013 to better estimate gear efficiency in our beach seines, but further analyses of trawl efficiency at Sacramento is also needed. However, efficiency studies must be designed to reflect the effort and methods of the long-term DJFMP sampling. In addition, standardized approaches (experimental design and analysis) are critical for comparing absolute abundance trends among trawl sites. In general, seine and trawl efficiency studies will greatly improve inferences regarding fish assemblage structure in the Estuary.

Despite previous recommendations to improve steelhead monitoring (Brandes et al. 2000), steelhead are captured infrequently by the DJFMP. Although limited, steelhead data from the DJFMP are used by the NMFS for Biological Opinions, status updates, and recovery plans. However, many of the inferences regarding population trends are made from catches of hatchery fish that may not be an appropriate surrogate for estimating population parameters for wild steelhead. Gear efficiency evaluations and studies investigating bias associated with behavioral differences among wild and hatchery stocks are needed for more robust inferences regarding the status and trends of steelhead in the Central Valley.

Additional south and north Delta Chinook salmon survival studies are needed to document inter-annual trends in survival and to determine where mortality in the Delta is occurring. With the VEMCO acoustic array in place for the 6 year study, until 2016, it provides an opportunity to get additional information on south Delta survival for Chinook salmon at a lower cost as no additional receivers are needed. However, it would be beneficial to use smaller tags (JSAT) but to do so would require purchasing and deploying a separate set of receivers. Funding to support a similar program for estimating survival in the north Delta is also needed. Foundational information on survival through the Delta, including route selection, is critical to develop survival models for both basins and to provide baseline information needed to assess changes in Delta survival anticipated from BDCP and climate change.

We also recommend funding a statistician to integrate multiple years of Chinook salmon survival data, including CWT and acoustic tag data, in a consistent and comprehensive framework. Using new data to test the various models developed for the south Delta and north Delta would be another way to integrate this data into an adaptive management framework. Linking results to an overarching model to inform management actions is also warranted. Survival monitoring in an important component of adaptive management needed to reduce uncertainty regarding future management actions in the Estuary.

The DJFMP is providing useful and complimentary information on the relative abundance and distribution of some juvenile and small adult non-salmonid fishes within the Estuary and lower Sacramento and San Joaquin rivers. The beach seine sampling element is considered one of the best long-term monitoring elements used for documenting the assemblage structure of non-salmonid fishes occupying near-shore littoral habitats within the lower Sacramento and San Joaquin rivers and Delta. However, there are several points of uncertainty or bias that need to be considered before making inferences using beach seine data including unknown and possibly variable efficiency, spatial dependency among non-salmonid catches at monitoring locations, and the under sampling of dominant littoral habitats. We recommend that data from the DJFMP be integrated into other IEP monitoring programs for assessing the status and trends of non-salmonid fishes. Regular estimation of absolute efficiency for beach seines and employing alternative gears to supplement beach seine sampling is also needed. We also recommend that the DJFMP begin reporting trends in assemblage structure (i.e., guilds) in addition to relative abundance and distribution of species of management concern.

Liberty Island is hypothesized to provide important habitat for species of management concern, including delta smelt, Sacramento splittail, and juvenile Chinook salmon. Freshwater tidally influenced wetlands are a major focus of restoration in the Delta and the DJFMP provides critical information regarding the occupancy of fish at multiple life stages to better inform management actions (e.g., restoration). To improve monitoring at Liberty Island, we recommend estimating seine and larval trawl efficiency and evaluating other gears to sample larger pelagic fish and fishes associated with emergent and submerged aquatic vegetation. In addition, the DJFMP should evaluate the analytical approaches used for Liberty Island data to address abundance or density within the various habitats in Liberty Island. Lastly, increasing the sampling frequency at Liberty Island may be needed for more robust analyses.

We recognize that proper data management is critical for providing accessible and reliable data per the terms of our contracts and agreements. Best management practices that include data curation and documentation are also needed, particularly considering the pending database migration. Although the process for the database migration has not been formalized, a more comprehensive data management plan needs to be implemented at the same time. Regardless of the server and hosting options, we need to contract a database programmer to assist with the transition and to maintain the function of the database. We recommend that the current DJFMP data manager work closely with a programmer to facilitate the database migration and to complete all pending and requested database updates. Ideally, technical staff, including the database manager and programmer, would begin drafting a best management plan for the DJFMP database prior to migration. However, we anticipate that this will be an iterative process as new data are collected in response to changing data and reporting needs. During the process, we anticipate minimal interruption in terms of responding to data requests and providing quarterly data summaries and metadata updates on the DJFMP website.

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Table 1. Adult Chinook salmon and steelhead monitoring in the California Central Valley.

Region / stream	Target species / run	Monitoring method	Variable measured	Agency
Central Valley-wide	Chinook (fall-run, late-fall run), steelhead	Angler survey	Angler effort and harvest	CDFW
Upper Sacramento River Basin				
Mainstem Sacramento River	Chinook (fall-run, late fall-run, winter-run, spring-run)	Aerial redd survey	Spawning dist.	CDFW
	Chinook (fall-run, late fall-run)	Carcass surveys	Annual escapement	CDFW
	Chinook (winter-run)	Carcass survey	Annual escapement	CDFW/USFWS
Clear Creek	Chinook (fall-run, late fall-run, spring-run), steelhead	Video monitoring	Annual escapement	CDFW/USFWS
	Chinook (fall-run)	Carcass survey	CWT recovery, biological data	CDFW
	Chinook (spring-run)	Snorkel survey	Annual escapement	USFWS
	Chinook (late-fall), steelhead	Redd counts	Annual escapement	USFWS
	Chinook (fall-run)	Redd mapping	Digitized spawning areas	USFWS
Cow Creek	Chinook (fall-run)	Video monitoring	Annual escapement	CDFW
Battle Creek	Chinook (fall-run)	Video monitoring	Annual escapement	CDFW/USFWS
	Chinook (spring-run), steelhead	Barrier weir monitoring	Annual escapement	USFWS
	Chinook (spring-run), steelhead	Snorkel survey	Annual escapement	USFWS
	Steelhead	Redd survey	Annual escapement	USFWS

Table 1. Continued.

Region / stream	Target species / run	Monitoring method	Variable measured	Agency
Battle Creek (continued)	Steelhead	Redd survey	Annual escapement	USFWS
Antelope Creek	Chinook (spring-run)	Snorkel survey	Annual escapement	CDFW
Beegum Creek	Chinook (spring-run)	Snorkel survey	Annual escapement	CDFW
Cottonwood Creek	Chinook (fall-run)	Video monitoring	Annual escapement	CDFW
	Chinook (fall-run)	carcass survey	CWT recovery, biological data	USFWS
Deer Creek	Chinook (spring-run)	Snorkel survey	Annual escapement	CDFW
	Chinook (fall-run)	Carcass survey or redd survey	Annual escapement	CDFW
Mill Creek	Chinook (spring-run)	Redd survey	Annual escapement	CDFW
	Chinook (fall-run, spring-run), steelhead	Video/DIDSON monitoring	Annual escapement	CDFW
	Chinook (fall-run)	Carcass survey	CWT recovery, biological data	CDFW
Butte Creek	Chinook (fall-run)	Carcass survey	Annual escapement	CDFW
	Chinook (spring-run)	Carcass survey	Annual escapement	CDFW
	Chinook (spring-run)	Snorkel survey	Annual escapement	CDFW
	Chinook (spring-run), steelhead	Vaki monitoring at Durham Mutual Ladder	Annual escapement	CDFW
Big Chico Creek	Chinook (spring-run), steelhead	Snorkel survey	Annual escapement	CDFW

Table 1. Continued.

Region / stream	Target species / run	Monitoring method	Variable measured	Agency
Lower Sacramento River Basin				CDFW
Yuba River	Chinook (fall-run)	Carcass survey below Daguerre Point Dam	Annual escapement	CDFW
	Chinook (fall-run, late fall-run, spring-run), steelhead	Vaki monitoring at Daguerre Point Dam	Annual escapement	CDFW
Feather River	Chinook (fall/spring-run)	Carcass survey	Annual escapement	DWR
American River	Chinook (fall-run)	Carcass survey	Annual escapement	CDFW
	Steelhead	Redd survey	Annual escapement/ spawning dist.	USBR
Delta tributaries				
Mokelumne River	Chinook (fall-run), steelhead	Video monitoring/live trapping	Annual escapement	EBMUD
	Chinook (fall-run)	Carcass survey	CWT recovery, biological data	EBMUD
San Joaquin River Basin				
Stanislaus River	Chinook (fall-run), steelhead	Weir counts	Annual escapement	FISHBIO
	Chinook (fall-run)	Carcass survey	Annual escapement	CDFW
Tuolumne River	Chinook (fall-run)	Carcass survey	Annual escapement	CDFW
	Chinook (fall-run)	Weir counts	Annual escapement	FISHBIO
Merced River	Chinook (fall-run)	Carcass survey	Annual escapement	CDFW

Table 2. Juvenile Chinook salmon and steelhead monitoring in the California Central Valley.

Region / stream	Target species / run	Monitoring method	Variable measured	Agency
Upper Sacramento River Basin				
Mainstem Sacramento River	Chinook (all runs), steelhead	Rotary screw trap at Red Bluff Diversion Dam	Abundance/ outmigration timing	USFWS
	Chinook (all runs), steelhead	Rotary screw trap at Tisdale Weir	Abundance/ outmigration timing	CDFW
Clear Creek	Chinook (all runs), steelhead	Rotary screw trap	Abundance/ outmigration timing	USFWS
Battle Creek	Chinook (all runs), steelhead	Rotary screw trap	Abundance/ outmigration timing	USFWS
Lower Sacramento River Basin				
Lower Sacramento River	Chinook (all runs), steelhead	Rotary screw trap at Knights Landing	Abundance/ outmigration timing	CDFW
	Chinook (all runs), steelhead	Kodiak/mid-water trawl at Sacramento	Spatial/temporal distribution, outmigration timing	USFWS
Feather River	Chinook (fall-run, spring-run), steelhead	Rotary screw trap	Abundance/ outmigration timing	DWR
American River	Chinook (fall-run), steelhead	Rotary screw trap	Abundance/ outmigration timing	USFWS

Table 2. Continued.

Region / stream	Target species / run	Monitoring method	Variable measured	Agency
Delta Tributaries				
Mokelumne River	Chinook (fall-run), steelhead	Rotary screw trap	Abundance/ outmigration timing	EBMUD
Calaveras River	Chinook (fall-run), steelhead	Rotary screw trap	Abundance/ outmigration timing	FISHBIO
San Joaquin River Basin				
San Joaquin River	Chinook (fall-run), steelhead	Kodiak trawl at Mossdale	Abundance/ outmigration timing	CDFW/USFWS
Stanislaus River	Chinook (fall-run), steelhead	Rotary Screw Trap (Oakdale)	Abundance/ outmigration timing	FISHBIO
	Chinook (fall-run), steelhead	Rotary screw trap (Caswell)	Abundance/ outmigration timing	Cramer Fish Sciences
Tuolumne River	Chinook (fall-run), steelhead	Beach seine, snorkel	Abundance/outmigration timing, distribution	Turlock Irrigation District
	Chinook (fall-run), steelhead	Rotary screw trap	Abundance/ outmigration timing	FISHBIO
Merced River	Chinook (fall-run)	Rotary screw trap (Hatfield St. Park)	Abundance/ outmigration timing	Cramer Fish Sciences

Table 2. Continued.

Region / stream	Target species / run	Monitoring method	Variable measured	Agency
Sacramento-San Joaquin Delta				
Lower Sacramento River, Lower San Joaquin River, North Delta, Central Delta, South Delta, SF/San Pablo Bays	Chinook (all runs), steelhead	Beach seine	Abundance/outmigration timing, recovery of marked smolts	USFWS
Suisun Bay	Chinook (all runs), steelhead	Mid-water trawl at Chipps Island	Abundance/outmigration timing, recovery of marked smolts	USFWS

Table 3. Salmonid research funded by CALFED and Delta Science between 2003 and 2011.

Project Title	Recipient organization	P.I. first name	P.I. last name	Start / end date (original)	Project type	Original amount
Restoration and Monitoring Chinook Salmon	Oregon State University	Michael	Banks	4/1/2003 - 3/31/2006	Other Research	$293,448
Development of a Simulation Model of Juvenile Salmon Movement in the Sacramento-San Joaquin Delta	HSU	Annjanette	Dodd	9/1/2005 - 8/31/2008	2005 Fellows	$166,376
Effects of Water Temperature, Streamflow and Food Availability on the Growth, Survival and Movement of Central Valley Juvenile Steelhead with Implications for Water Management	UCSC	Walter	Heady	9/1/2005 - 8/31/2008	2006 Fellows	$129,375
Are 'Apparent' Sex Reversed Chinook Salmon A Symptom of Genotoxicity?	UCD	Bernie	May	9/25/2005 - 12/31/2008	2004 PSP	$143,735
Chinook Salmon Rearing in the SF Bay-Delta System: Identification of Geochemical Markers to Determine Delta Use	UCB	Lynn	Ingram	1/1/2006 - 1/1/2008	2004 PSP	$197,689
Identifying the Causes of Feminization of Chinook Salmon in the Sacramento and San Joaquin River System	UCB	David	Sedlak	1/1/2006 - 12/31/2009	2004 PSP	$1,167,141

Table 3. Continued.

Project Title	Recipient organization	P.I. first name	P.I. last name	Start / end date (original)	Project type	Original amount
Life History Variation in Steelhead Trout and the Implications for Water Management	UCSC	Marc	Mangel	2/1/2006 - 1/1/2009	2004 PSP	$1,014,596
Life History Variation in Steelhead Trout and the Implications for Water Management	UCSC	Marc	Mangel	2/1/2006 - 10/31/2009	2007 Suppl. PSP	$194,620
Survival And Migratory Pattern Of Central Valley Juvenile Salmonids	UCD	Peter	Klimley	3/1/2006 - 1/31/2009	2004 PSP	$1,499,859
Review of Four Juvenile Salmon Coded Wire Tag Experiments Conducted in the Delta.	USFWS	Patricia	Brandes	9/1/2006 - 12/1/2007	2004 PSP	$83,100
Species Model Developer Chinook Salmon and Steelhead	Contractor	Jonathan A.	Rosenfield	9/5/2006 - 9/30/2007	Technical Expert	$15,000
Estimating Route-Specific Survival and Distribution of Juvenile Salmonids Migrating Through the Sacramento-San Joaquin River Delta	University of Washington	Russell	Perry	11/1/2006 - 10/31/2009	2006 Fellows	$129,365

Table 3. Continued.

Project Title	Recipient organization	P.I. first name	P.I. last name	Start / end date (original)	Project type	Original amount
Regional Salmon Outmigration Study Proposal Review Panel Member (Richard A. Denton) Interagency agreement with 4600007630	Contractor	Richard A.	Denton	8/13/2007 - 11/31/2007	Technical Expert	$11,000
Estimating Juvenile Chinook Salmon Spring and Winter Run Abundance at Chipps Island	USFWS	Patricia	Brandes	9/1/2007 - 6/30/2010	2006 PSP	$483,903
A Statistical Model of Central Valley Chinook Incorporating Uncertainty	R2 Resource Consultants Inc.	Noble	Hendrix	9/21/2007 - 1/31/2009	2004 PSP	$679,631
A Statistical Model of Central Valley Chinook Incorporating Uncertainty	R2 Resource Consultants Inc.	Noble	Hendrix	9/1/2008 - 12/31/2010	2007 Suppl. PSP	$296,442
Sacramento River Steelhead Trout: An Assessment of Behavioral Differences and Contributions of Hatchery and Wild Stocks	UCD	Phillip	Sandstorm	9/1/2008 - 8/31/2010	2008 Fellows	$98,750
Survival And Migratory Pattern Of Central Valley Juvenile Salmonids	UCD	Peter	Klimley	9/1/2008 - 12/31/2009	2007 Suppl. PSP	$256,676

Table 3. Continued.

Project Title	Recipient organization	P.I. first name	P.I. last name	Start / end date (original)	Project type	Original amount
Linking Freshwater Sources of California Chinook Salmon to Their Ocean Distribution Using Physical and Natural Tags of Origin	UCSC	Rachel Barnett	Johnson	1/21/2009 - 5/31/2010	2008 Fellows	$164,765
Co-Authorship of DRERIP Central Valley Salmonid Conceptual Model, to Address Peer-and Collegical-Review Comments, and Finalization of the Longfin Smelt Conceptual Model, to Address Peer-and Collegial-Review Comments	Contractor	Jonathan	Rosenfield	6/1/2009 - 12/31/2009	Technical Expert	$12,600
The Role of the San Francisco Bay Delta in juvenile Rearing for Winter and Spring Run Chinook Salmon, to be Determined by Otolith Microchemistry	UCB	Lynn	Ingram	6/1/2009 - 6/30/2012	2007 Suppl. PSP	$228,092
A Multi-Stock Population Dynamics Framework For The Recovery Of Sacramento River Chinook Salmon.	University of Washington	Ray	Hilborn	6/2/2009 - 6/30/2014	2011 PSP	$700,000

Table 3. Continued.

Project Title	Recipient organization	P.I. first name	P.I. last name	Start / end date (original)	Project type	Original amount
Quantifying Factors Affecting Migration Routing And Survival Of Juvenile Late-Fall Chinook Salmon In The Sacramento-San Joaquin River Delta	USGS	Russell	Perry	5/1/2010 - 6/30/2014	2011 PSP	$215,103
Impact Of Urbanization On Chinook Salmon, Steelhead Trout, And Their Prey: A Case Study Of The American River	UCB	Donald	Weston	7/1/2011 - 6/30/2014	2011 PSP	$600,000
Linking Freshwater Sources of California Chinook Salmon to Their Ocean Distribution Using Physical and Natural Tags of Origin	UCSC	Rachel Barnett	Johnson	6/1/2009 - 5/31/2010	Bridge Funding	$176,029
Sacramento River Steelhead Trout: An Assessment of Behavioral Differences and Contributions of Hatchery and Wild Stocks	UCD	Phillip	Sandstorm	9/1/2008 - 8/31/2010	Bridge Funding	$98,750

Table 4. Monthly sampling matrix indicating number of sampling days per week (0.25 and 0.5 indicate one and two samples per month, respectively). Sampling methods include mid-water trawl (MWT), Kodiak trawl (KDT), seine, and larval trawl (LVT). Sherwood (Harbor) and Mossdale are located on the Sacramento and San Joaquin rivers, respectively.

	Monthly sampling matrix (sample days / week)											
Sampling element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sherwood MWT	0	0	0	3	2	2	3	3	3	0	0	0
Sherwood KDT	3	3	3	0	0	0	0	0	0	3	3	3
Chipps Island MWT	3	3	3	3	2	2	3	3	3	3	3	3
Mossdale KDT[1]	3	3	3	3	3	3	3	3	3	3	3	3
Sacramento Seine	3	0	0	0	0	0	0	0	0	3	3	3
Lower Sacramento Seine	1	1	1	1	1	1	1	1	1	1	1	1
North Delta Seine	1	1	1	1	1	1	1	1	1	1	1	1
Central Delta Seine	1	1	1	1	1	1	1	1	1	1	1	1
South Delta Seine	1	1	1	1	1	1	1	1	1	1	1	1
San Joaquin Seine	1	1	1	1	1	1	1	1	1	1	1	1
Bay Seine	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Liberty Island Seine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Liberty Island LVT	0	0.25	0.25	0.25	0.25	0.25	0.25	0	0	0	0	0

[1] CDFW samples April through June.

Table 5. Data types and location by year first collected (LI = Liberty Island, Int. = intermittent).

Type	Data	Sampling element					
		Beach seine	Chipps trawl	Sacramento trawl	Mossdale trawl	Larval trawl (LI)	Zooplankton trawl (LI)
Catch	Date	1976	1976	1988	1994	2010	2013
	Time	1976	1976	1988	1994	2010	2013
	Location	1976	1976	1988	1994	2010	2013
	Species or genus	1976	1976	1988	1994	2010	2013
	Count	1976	1976	1988	1994	2010	2013
	Fork length	1976	1976	1988	1994	2010	–
	Mass	Int.	Int.	Int.	–	–	–
	Mark (fin clip, CWT)	1976	1976	1988	1994	2010	–
	Life stage (salmonids)	2000	2000	2000	2000	2010	–
	Reproductive status (smelts)	2008	2008	2008	2008	2010	–
	DNA (salmonids)	Int.	Int.	Int.	–	–	–
	Gear condition	1976	1976	1988	1994	2010	2013
	Gear efficiency (absolute)	2013	1987	2002	1994	2013	2013
	Gear efficiency (relative)	–	2013	1996	–	–	–
Habitat	DO (mg/L)	2010	2010	2012	2012	2010	2013
	Turbidity (NTU)	2012	2012	2012	2012	2010	2013
	Secchi (m)	–	1976	1988	1994	–	–
	Temperature (°C)	1976	1976	1988	1994	2010	2013

Table 5. Continued.

		Sampling element					
Type	Data	Beach seine	Chipps trawl	Sacramento trawl	Mossdale trawl	Larval trawl (LI)	Zooplankton trawl (LI)
Habitat	Conductivity (µs/cm)	1999	1999	2012	2012	2010	2013
	Speed Traveled (m/s)	–	1976	1988	1994	2010	2013
	Volume (m^3/s)	1985	1976	1988	1994	2010	2013
	Dominant substrate type	1992	–	–	–	2013	2013
	Weather	1993	1993	1993	1994	2010	2013
	Depth	1985	–	–	–	2010	2013

Table 6. Number of juvenile Chinook salmon caught at Sacramento by length-at-date criteria (LDC, row totals) and genetics (HMSC16+CRY, column totals).

		Genetics			
Year	LDC	Fall	Winter	Spring (Butte / Mill & Deer)	Late fall
2007–2008	Fall	214	0	8 / 4	10
	Winter	0	0	0 / 0	0
	Spring	33	0	4 / 1	2
	Late fall	0	0	0 / 0	0
2008–2009	Fall	476	0	27 / 7	37
	Winter	1	13	0 / 0	0
	Spring	106	0	22 / 4	3
	Late fall	0	2	0 / 0	0
2009–2010	Fall	206	0	8 / 3	15
	Winter	0	12	0 / 0	1
	Spring	68	0	9 / 3	2
	Late fall	1	0	0 / 0	1
2010–2011	Fall	899	0	11 / 16	34
	Winter	1	13	4 / 0	0
	Spring	229	1	35 / 8	2
	Late fall	0	1	0 / 0	8

Table 7. Number of juvenile Chinook salmon caught at Chipps Island by length-at-date criteria (LDC, row totals) and genetics (HMSC16+CRY, column totals).

		Genetics			
Year	LDC	Fall	Winter	Spring (Butte / Mill & Deer)	Late fall
2007–2008	Fall	229	0	5 / 1	11
	Winter	11	11	1 / 8	5
	Spring	123	0	13 / 1	2
	Late fall	14	0	0 / 0	8
2008–2009	Fall	401	0	24 / 6	32
	Winter	15	20	2 / 11	12
	Spring	152	1	55 / 6	4
	Late fall	3	2	0 / 0	4
2009–2010	Fall	810	0	31 / 15	49
	Winter	13	37	3 / 7	7
	Spring	293	0	48 / 15	2
	Late fall	7	0	0 / 0	11
2010–2011	Fall	1823	0	11 / 20	102
	Winter	14	30	14 / 1	3
	Spring	417	3	94 / 9	2
	Late fall	5	1	0 / 0	12

Table 8. Chinook Salmon Decision Process (revised in 2007). Note: Delta Action 8 (DA8) experiments occur first two weeks of December and January.

Time	Trigger	Action
First alert	Yearling Chinook salmon detected at mouths of tributaries and/or average daily tributary flow increased by 50%	None
Second alert	Sacramento River at Wilkins Slough water temperature < 13.5°C and flow > 7,500cfs	None
Oct 1 – Nov 30	Water quality criteria met, KLCI and/or SCI > 3 and ≤ 5	Close DCC gates for 4 days within 24 hours
	Water quality criteria met, KLCI and/or SCI > 5	Close DCC gates until index < 3
	Water quality criteria not met, KLCI and/or SCI > 3	Elevate decision to WOMT
Dec 1 – Jan 31	Water quality criteria are met	DCC gates closed, may be opened for DA8
	Water quality criteria not met, and KLCI and/or SCI < 3	Open DCC gates until water quality criteria met
	Water quality criteria not met, and KLCI and/or SCI > 3, or insufficient Environmental Water Account and/or b(2) assets.	Elevate decision to WOMT
Feb 1 – May 20	DCC gates closed per 2006 WQCP criteria	None
May 21 – Jun 15	DCC gates operated based on the 2006 WQCP criteria	DCC gates closed for 14 days during this period

Table 9. Number of days when the DCC has been closed from October to December.

Year	October	November	December
2000	31	8	4
2001	21	8	27
2002	3	1	22
2003	0	0	31
2004	0	0	25
2005	0	4	28
2006	1	0	16
2007	0	0	17
2008	0	17	18
2009	4	11	18
2010	3	4	31
2011	10	0	31
Average	6	4	22

Table 10. Number of times SCI may have triggered DCC closures.

Year	Trawl	Seine
2000	4	7
2001	7	18
2002	2	6
2003	3	8
2004	4	11
2005	4	14
2006	2	10
2007	0	1
2008	3	2
2009	0	2
2010	0	8
2011	0	2
Total	29	89
Average	2.42	7.42

Table 11. List of publications by type using non-salmonid data from the DJFMP.

Type	Data source	Species	Study objectives	Citation
Grey literature	Beach seine, Chipps Island trawl	Delta smelt	Distribution and population trends	Stevens et al. 1990
	Beach seine	All	Develop a list of fishes occurring in nearshore littoral habitats	Chotkowski 1999
	Beach seine	Tule perch, Centrarchids	Determine the impact of nonnative aquatic vegetation expansion on tule perch and Centrarchids	Nobriga and Chotkowski 2000
	Beach seine	Sacramento splittail	Track inter-annual trends in splittail recruitment	Baxter 2001; Baxter 2003; Greiner et al. 2006; Fish et al. 2008; Messineo et al. 2010; Contreras et al. 2011; Contreras et al. 2012
	Beach seine	All	Assemblage trends	Moyle and Bennett 2008
Peer reviewed	Beach seine	All excluding anadromous fishes	Compare resident fish assemblages in the lower Sacramento and San Joaquin rivers	Brown and May 2006
	Beach seine	Inland silverside; largemouth bass	Assess the relative importance of competition or predation on the POD	MacNally et al. 2010
	Beach seine	Delta smelt	Document the temporal and spatial distribution of delta smelt	Merz et al. 2011

Table 11. Continued.

Type	Data source	Species	Study objectives	Citation
Peer reviewed	Beach seine, Chipps Island trawl	Sacramento splittail	Determine the relative importance of factors affecting Sacramento splittail abundance and distribution	Meng and Moyle 1995
	Beach seine, Chipps Island trawl	Sacramento splittail	Determine the relative importance of factors affecting juvenile Sacramento splittail	Sommer et al. 1997
	Beach seine, Chipps Island trawl	Sacramento splittail	Review of the biology and population dynamics of Sacramento splittail	Moyle et al. 2004
	Beach seine	Sacramento splittail	Assess the distribution and habitat requirements of age-0 splittail	Feyrer et al. 2005
	Beach seine	Sacramento splittail	Review recent population trend and restoration activities of Sacramento splittail	Sommer et al. 2007b
ESA reviews	Beach seine, Chipps Island trawl	Delta smelt	Distribution and population trends	USFWS 1993b
	Beach seine, Chipps Island trawl	Sacramento splittail	Distribution, life history, and recruitment success of Sacramento splittail	USFWS 1994; USFWS 1999; USFWS 2003; USFWS 2010b
	Beach seine	Longfin smelt	Distribution of juvenile and adult longfin smelt	CDFW 2009

Table 12. Predictor variables and *a priori* hypotheses for occupancy models at Liberty Island.

Variables	Beach seine hypotheses	Larval trawl hypotheses
Turbidity	refuge from predators, food availability	refuge from predators, food availability
Temperature	affects fish physiology and behavior, spawning success , growth rates	affects fish physiology and behavior, spawning success, growth rates
Conductivity	osmoregulation	osmoregulation
Discharge	food and habitat availability, spawning	larval swimming capabilities, food supply
Quadrant	protected, not protected, levee erosion,	protected, not protected, levee erosion,
Season	migration, life stage, growth rates	life stage, growth rates
Vegetation	refuge from predators, food availability	refuge from predators, food availability
Depth	Food availability, oxygen concentration, carrying capacity	Food availability, oxygen concentration, carrying capacity
Dominate substrate	species composition	n/a

Table 13. Beach seine catch data for Liberty Island (January 2010 – August 2012).

Native / non-native	Species	N	% of total sample
Native	Splittail	3286	76.61
	Tule perch	488	11.38
	Sacramento sucker	170	3.96
	Chinook salmon	117	2.73
	Sacramento pikeminnow	97	2.26
	Prickley sculpin	66	1.54
	Delta smelt	49	1.14
	Pacific staghorn sculpin	2	0.05
	Starry flounder	1	0.02
	Hitch	9	0.21
	Sacramento blackfish	1	0.02
	Threespine stickleback	2	0.05
	Total	4288	
Non-native	Inland silverside	33432	87.64
	American shad	2113	5.54
	Threadfin shad	875	2.29
	Striped bass	664	1.74
	Mosquitofish	255	0.67
	Yellowfin goby	202	0.53
	Logperch	192	0.50
	Shimofuri goby	186	0.49
	Centrarchids	161	0.42
	Fathead minnow	27	0.07
	Wakasagi	18	0.05
	Carp	16	0.04
	Channel catfish	4	0.01
	Red shiner	1	0.00
	Spotted bass	1	0.00
	Total	38147	

Table 14. Larval trawl catch data for Liberty Island (April – June 2010, March – September 2011, February – March 2012).

Native / non-native	Species	N	% of total sample
Native	Prickely sculpin	4770	88.63
	Delta smelt	253	4.70
	Splittail	215	3.99
	Longfin smelt	137	2.55
	Sacramento sucker	4	0.07
	Hitch	3	0.06
	Total	5382	
Non-native	Inland silverside	3223	60.87
	Threadfin shad	1010	19.07
	Striped bass	833	15.73
	American shad	138	2.61
	Centrarchids	67	1.27
	Shimofuri goby	9	0.17
	Logperch	6	0.11
	Carp	3	0.06
	Fathead minnow	2	0.04
	White catfish	2	0.04
	Mosquitofish	1	0.02
	Red shiner	1	0.02
	Total	5295	

Table 15. Candidate Models and Akaike weights for Splittail (NE = North East Quadrant, SE=South East Quadrant, SW= South West Quadrant, NC=North Center and SC=South Center).

Gear	Candidate models	K	AICc	Δ_i	W_i	% Max W_i
Trawl	Volume, Discharge, Depth	5	87.12	0.00	0.10	1.00
	Volume, NE, NW, SW, NC, SC, Discharge	9	87.45	0.33	0.09	0.85
	Volume, Conductivity, Discharge, Depth	6	87.85	0.73	0.07	0.69
	Volume, Discharge	4	88.06	0.94	0.06	0.63
	Volume, NE, NW, SW, NC, SC, Conductivity, Discharge	10	88.37	1.25	0.05	0.54
	Volume, NE, NW, SW, NC, SC, Conductivity, Discharge, Depth	11	88.65	1.53	0.05	0.47
	Volume, NE, NW, SW, NC, SC, Turbidity, Conductivity, Discharge	11	88.71	1.59	0.05	0.45
	Volume, Temp, Discharge, Depth	6	88.80	1.68	0.04	0.43
	Volume, NE, NW, SW, NC, SC, Discharge, Depth	10	89.06	1.94	0.04	0.38
	Volume, Turbidity, Discharge, Depth	6	89.13	2.01	0.04	0.37
	Volume, Turbidity, Discharge	5	89.18	2.06	0.04	0.36
	Volume, NE, NW, SW, NC, SC, Turbidity, Discharge	10	89.18	2.06	0.04	0.36
	Volume, Turbidity, Conductivity, Discharge, Depth	7	89.35	2.23	0.03	0.33
	Volume, Temp, Discharge	5	89.54	2.42	0.03	0.30
	Volume, NE, NW, SW, NC, SC, Temp, Discharge	10	89.54	2.42	0.03	0.30
	Volume, Temp, Conductivity, Discharge, Depth	7	89.80	2.68	0.03	0.26
	Volume, NE, NW, SW, NC, SC, Turbidity, Conductivity, Discharge, Depth	12	90.01	2.89	0.02	0.24
	Volume, Conductivity, Discharge	5	90.09	2.97	0.02	0.23
	Volume, NE, NW, SW, NC, SC, Temp, Conductivity, Discharge	11	90.30	3.18	0.02	0.20
	Volume, Turbidity, Conductivity, Discharge	6	90.50	3.38	0.02	0.18

Table 15. Continued.

Gear	Candidate models	K	AICc	Δ_i	W_i	% Max W_i
Trawl	Volume, Temp, Turbidity, Discharge	6	90.55	3.43	0.02	0.18
	Volume, NE, NW, SW, NC, SC, Temp, Turbidity, Conductivity, Discharge	12	90.56	3.44	0.02	0.18
	Volume, NE, NW, SW, NC, SC, Temp, Conductivity, Discharge, Depth	12	90.58	3.46	0.02	0.18
	Volume, Temp, Turbidity, Discharge, Depth	7	90.79	3.67	0.02	0.16
	Volume, NE, NW, SW, NC, SC, Turbidity, Discharge, Depth	11	91.06	3.94	0.01	0.14
	Volume, NE, NW, SW, NC, SC, Tem , Discharge, Depth	11	91.16	4.04	0.01	0.13
	Volume, NE, NW, SW, NC, SC, Temp, Turbidity, Discharge	11	91.28	4.16	0.01	0.12
	Volume, Temp, Turbidity, Conductivity, Discharge, Depth	8	91.31	4.19	0.01	0.12
Seine	Volume, NE, NW, SW, Turbidity, Conductivity	9	282.02	0.00	0.10	1.00
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity	10	282.16	0.14	0.10	0.93
	Volume, NE, NW, SW, Turbidity	8	282.75	0.73	0.07	0.69
	Volume, NE, NW, SW, Turbidity, Conductivity, Gradient	10	282.98	0.96	0.06	0.62
	Volume, NE, NW, SW, Temp, Turbidity	9	283.04	1.02	0.06	0.60
	Volume, NE, NW, SW, Turbidity, Conductivity, Discharge	10	283.46	1.44	0.05	0.49
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Gradient	11	283.52	1.50	0.05	0.47
	Volume, NE, NW, SW, Turbidity, Conductivity, Vegetation	10	283.99	1.97	0.04	0.37
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Discharge	11	284.06	2.04	0.04	0.36
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Vegetation	11	284.11	2.09	0.04	0.35
	Volume, NE, NW, SW, Turbidity, Gradient	9	284.18	2.16	0.04	0.34
	Volume, NE, NW, SW, Turbidity, Discharge	9	284.18	2.16	0.04	0.34
	Volume, NE, NW, SW, Turbidity, Conductivity, Gradient, Discharge	11	284.60	2.58	0.03	0.28

Table 15. Continued.

Gear	Candidate models	K	AICc	Δ_i	W_i	% Max W_i
Seine	Volume, NE, NW, SW, Turbidity, Vegetation	9	284.75	2.73	0.03	0.26
	Volume, NE, NW, SW, Temp, Turbidity, Gradient	10	284.75	2.73	0.03	0.26
	Volume, NE, NW, SW, Temp, Turbidity, Discharge	10	284.77	2.75	0.03	0.25
	Volume, NE, NW, SW, Turbidity, Conductivity, Vegetation, Gradient	11	284.90	2.88	0.02	0.24
	Volume, NE, NW, SW, Temp, Turbidity, Vegetation	10	285.04	3.02	0.02	0.22
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Vegetation, Gradient	12	285.43	3.41	0.02	0.18
	Volume, NE, NW, SW, Turbidity, Conductivity, Vegetation, Discharge	11	285.46	3.44	0.02	0.18
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Gradient, Discharge	12	285.47	3.45	0.02	0.18
	Volume, NE, NW, SW, Turbidity, Conductivity, Gravel, Fine	11	285.72	3.70	0.02	0.16
	Volume, NE, NW, SW, Turbidity, Gradient, Discharge	10	285.72	3.70	0.02	0.16
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Gravel, Fine	12	285.74	3.72	0.02	0.16
	Volume, NE, NW, SW, Temp, Conductivity	9	285.89	3.87	0.02	0.14
	Volume, NE, NW, SW, Temp, Turbidity, Conductivity, Vegetation, Discharge	12	286.03	4.01	0.01	0.13
	Volume, NE, NW, SW, Turbidity, Vegetation, Gradient	10	286.16	4.14	0.01	0.13
	Volume, NE, NW, SW, Turbidity, Vegetation, Discharge	10	286.20	4.18	0.01	0.12

Table 16. Relative importance of environmental variables on fish occupancy (W_i = weighted average, N/A = variable not assessed).

Variable	W_i seine	W_i trawl
Quadrant	1.00	0.46
Turbidity (NTU)	0.98	0.33
Conductivity (µS)	0.65	0.42
Temperature °C	0.44	0.26
Gradient	0.31	N/A
Discharge (m^3/ sec)	0.26	1.00
% vegetation cover	0.23	N/A
Gravel	0.03	N/A
Fine	0.03	N/A
Depth	N/A	0.50

Table 17. Total catch of unmarked ESA-listed Chinook salmon by sampling element and calendar year during long-term monitoring within the San Francisco Estuary excluding Mossdale (fall-run assumed).

	Spring-run (unmarked)			Winter-run (unmarked)		
Year	Chipps Trawl	Sac. Trawl	Seine	Chipps Trawl	Sac. Trawl	Seine
1976	73	–	15	2	–	1
1977	459	–	18	7	–	2
1978	1036	–	19	59	–	11
1979	648	–	71	28	–	38
1980	619	–	83	98	–	11
1981	312	–	140	10	–	638
1982	798	–	216	23	–	112
1983	2696	–	262	59	–	84
1984	330	–	117	57	–	29
1985	1114	–	33	43	–	18
1986	2214	–	76	28	–	25
1987	803	–	51	12	–	17
1988	1466	2122	63	19	26	27
1989	851	191	23	19	8	16
1990	1354	–	49	26	–	5
1991	486	474	23	17	6	1
1992	1843	121	87	35	78	62
1993	2133	1587	197	225	268	104
1994	1004	1130	585	47	16	30
1995	3707	1114	1299	316	211	272
1996	3227	3066	1651	353	197	188
1997	1321	1776	632	168	54	200
1998	6618	636	395	115	122	421
1999	1657	367	201	144	23	89
2000	3891	470	352	177	53	112
2001	527	119	278	115	137	821
2002	1229	197	429	136	57	123
2003	3948	1008	1294	225	130	501
2004	889	289	841	112	74	300
2005	1880	558	579	125	118	650

Table 17. Continued.

	Spring-run (unmarked)			Winter-run (unmarked)		
Year	Chipps Trawl	Sac. Trawl	Seine	Chipps Trawl	Sac. Trawl	Seine
2006	2085	532	766	319	105	373
2007	788	168	127	115	55	125
2008	163	67	72	42	33	51
2009	429	224	60	73	20	56
2010	758	203	446	69	17	182
2011	593	316	938	64	11	50

Table 18. Total catch of ESA-listed species by sampling element and calendar year during long-term monitoring within the San Francisco Estuary (Moss., Chipps, and Sac. refer to trawl sites).

Year	Green sturgeon	Steelhead				Delta smelt				Longfin smelt			
	Moss.	Chipps	Moss.	Sac.	Seine	Chipps	Moss.	Sac.	Seine	Chipps	Moss.	Sac.	Seine
1976	–	9	–	–	4	16167	–	–	343	284	–	–	–
1977	–	24	–	–	12	2	–	–	169	82	–	–	–
1978	–	178	–	–	76	3083	–	–	597	488	–	–	–
1979	–	68	–	–	27	3234	–	–	506	45439	–	–	16
1980	–	103	–	–	12	17478	–	–	77	69074	–	–	62
1981	–	83	–	–	121	3060	–	–	802	41705	–	–	8
1982	–	23	–	–	11	796	–	–	128	22	–	–	–
1983	–	48	–	–	17	1510	–	–	82	15	–	–	–
1984	9	54	–	–	1	1460	–	–	45	986	–	–	7
1985	–	47	–	–	10	99	–	–	29	5151	–	–	–
1986	–	43	–	–	12	120	–	–	21	60	–	–	4
1987	–	12	–	–	7	101	–	–	19	241	–	–	1
1988	–	38	–	39	–	71	–	22	3	4934	–	1	–
1989	–	59	–	16	1183	84	–	1	5	1618	–	–	–
1990	–	35	–	–	1	96	–	–	–	802	–	–	–
1991	–	37	–	10	3	43	–	38	9	172	–	–	–
1992	–	54	–	314	20	97	–	9	21	208	–	–	–
1993	–	109	–	644	106	2423	–	53	32	1002	–	11	13
1994	–	182	1	115	78	9907	3	2	101	11621	–	1	5

Table 18. Continued.

	Green sturgeon	Steelhead				Delta smelt				Longfin smelt			
Year	Moss.	Chipps	Moss.	Sac.	Seine	Chipps	Moss.	Sac.	Seine	Chipps	Moss.	Sac.	Seine
1995	1	457	−	391	264	9253	−	1	78	3187	−	1	7
1996	−	277	1	294	162	16423	1	5	71	15933	−	−	8
1997	2	185	3	299	32	2396	8	23	46	9184	−	1	1
1998	1	70	4	23	−	3467	−	−	83	3516	−	−	3
1999	1	53	6	8	1	8252	9	8	112	11335	−	−	2
2000	−	57	3	6	7	4764	8	1	85	8428	−	−	2
2001	−	44	9	8	5	2254	−	17	61	9937	−	−	1
2002	−	40	6	2	−	576	3	5	49	5271	−	8	5
2003	1	29	17	3	6	630	−	21	127	5069	−	−	4
2004	−	41	12	3	6	492	8	3	85	2503	−	1	2
2005	−	43	7	4	1	742	2	6	29	1586	−	−	3
2006	2	22	11	3	4	874	−	1	81	488	−	−	1
2007	−	10	41	3	4	232	1	−	12	524	−	−	1
2008	−	7	4	1	−	89	−	2	26	602	−	−	−
2009	−	18	1	2	1	272	−	−	27	351	−	−	1
2010	−	5	3	7	1	333	1	1	122	565	−	−	4
2011	−	8	3	2	3	868	−	−	88	133	−	−	−

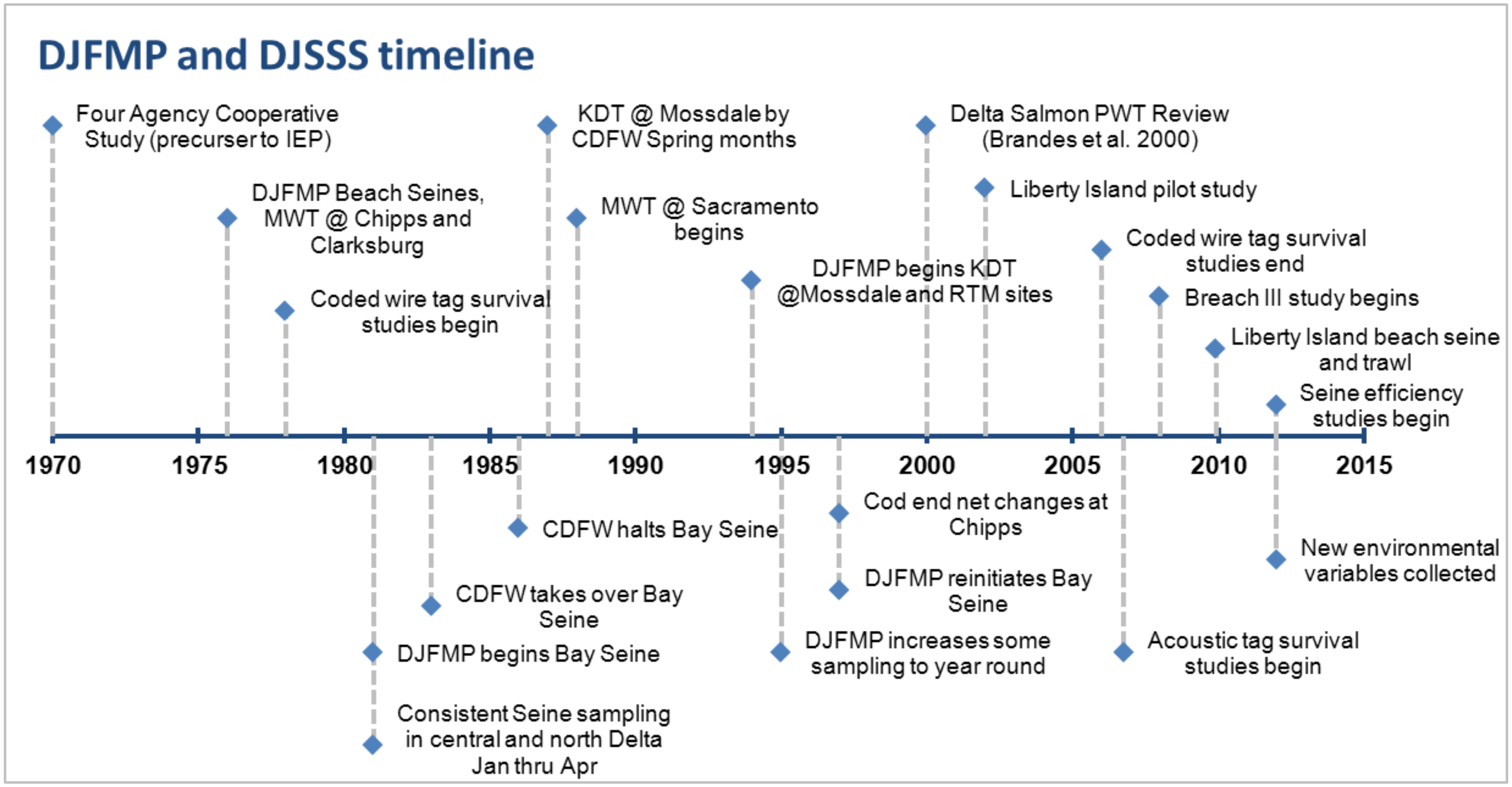


Figure 1. Program history and timeline of major events.

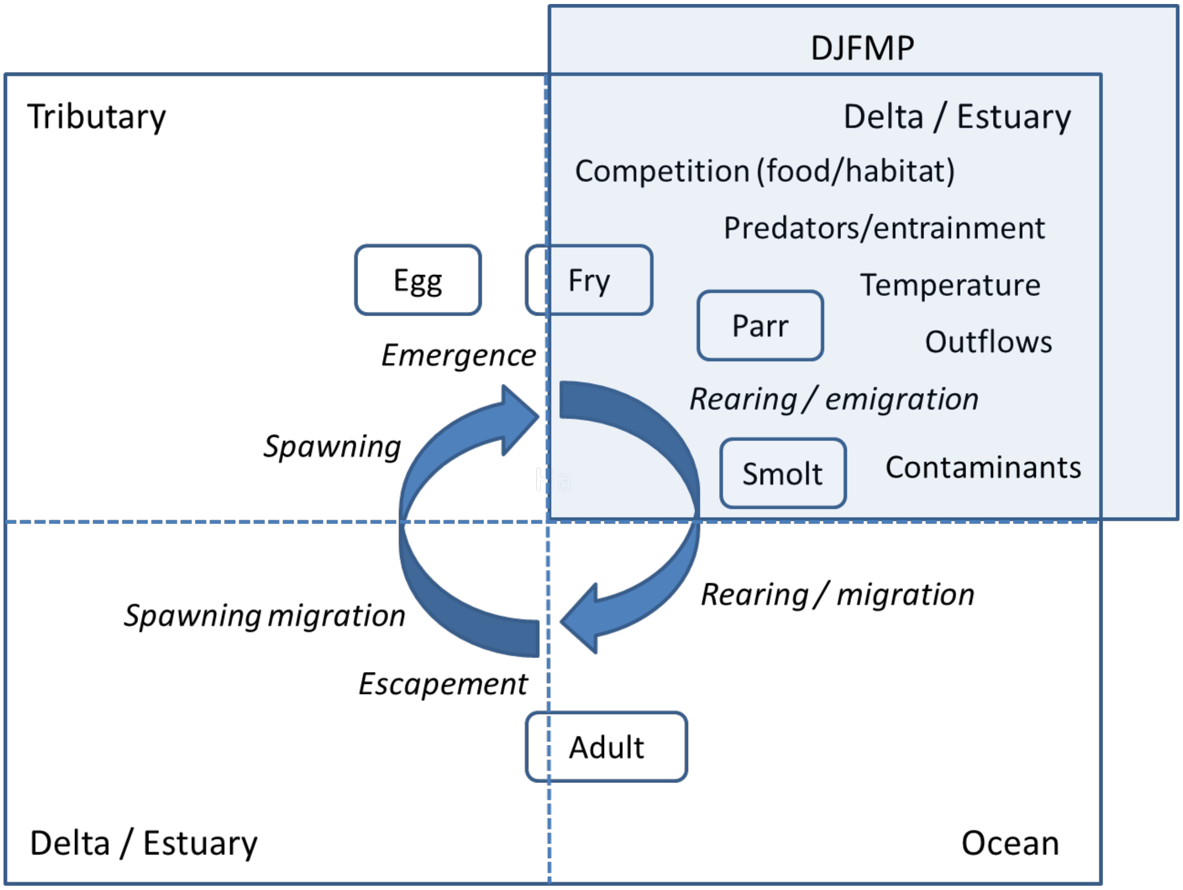


Figure 2. Conceptual life-cycle model for salmonids. Life stages are in boxes and transitions are indicated in italics. Habitat-specific drivers (for the Delta only) are indicated for the life stages sampled by the DJFMP.

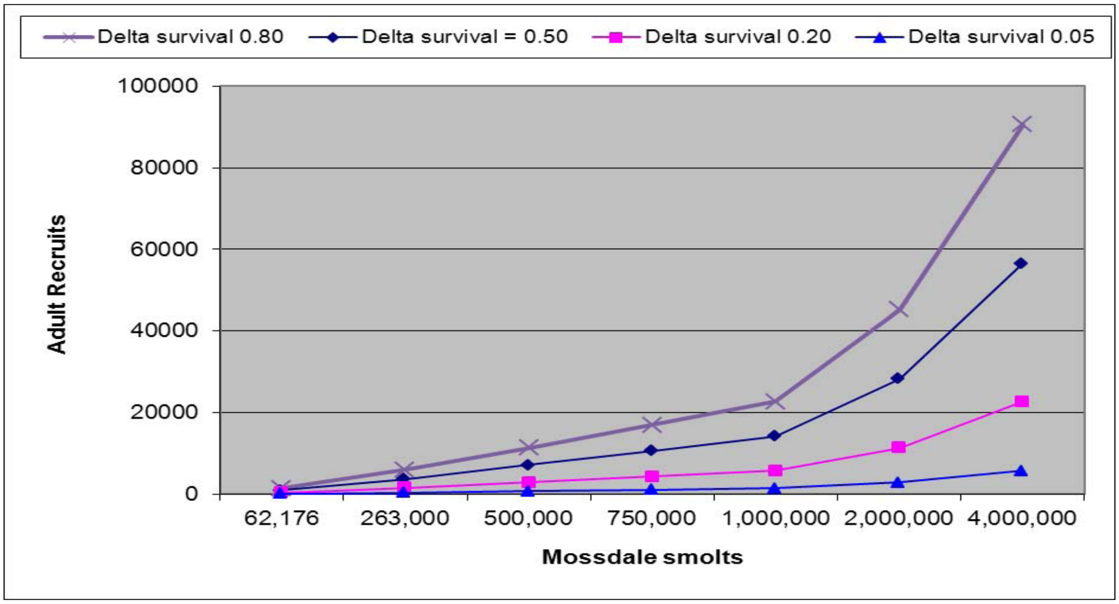


Figure 3. Simulation model of adult recruitment.

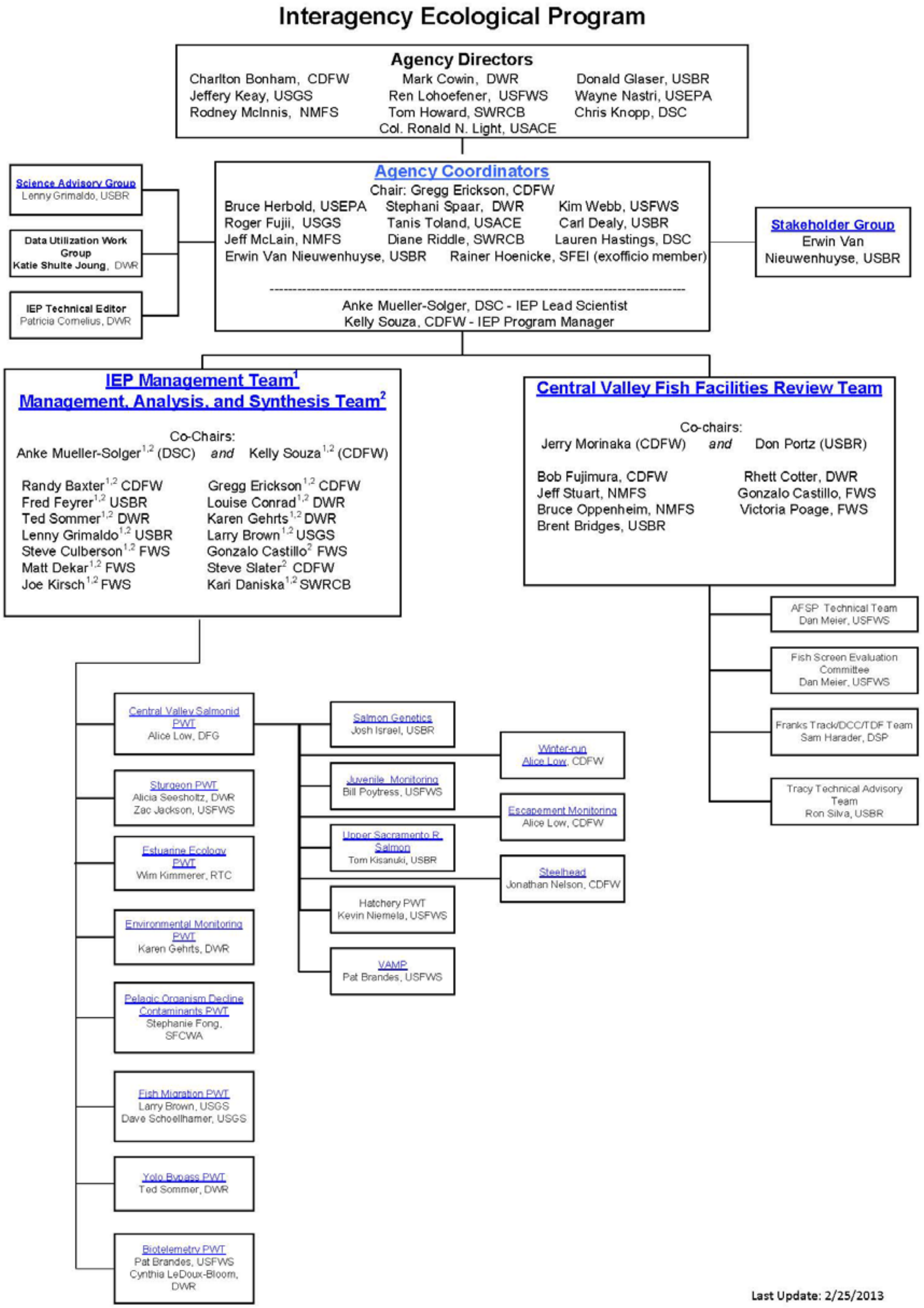


Figure 4. The Interagency Ecological Program Organizational Chart with Project Work Teams (source: http://www.water.ca.gov/iep/docs/IEP-ORG_2-25-2013.pdf).

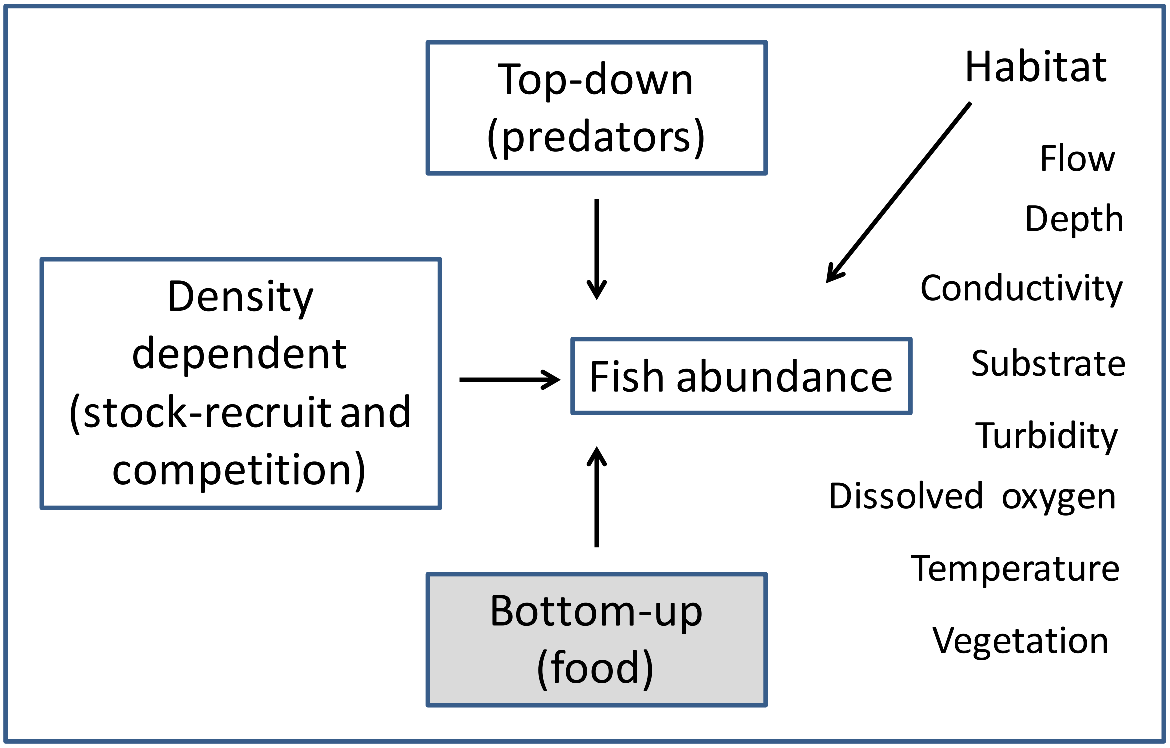


Figure 5. Conceptual model of abiotic and biotic factors affecting resident fish populations in the San Francisco Estuary (adapted from Sommer et al. 2007a). Bottom-up effects are largely not monitored by the DJFMP with the exception of zooplankton sampling at Liberty Island.

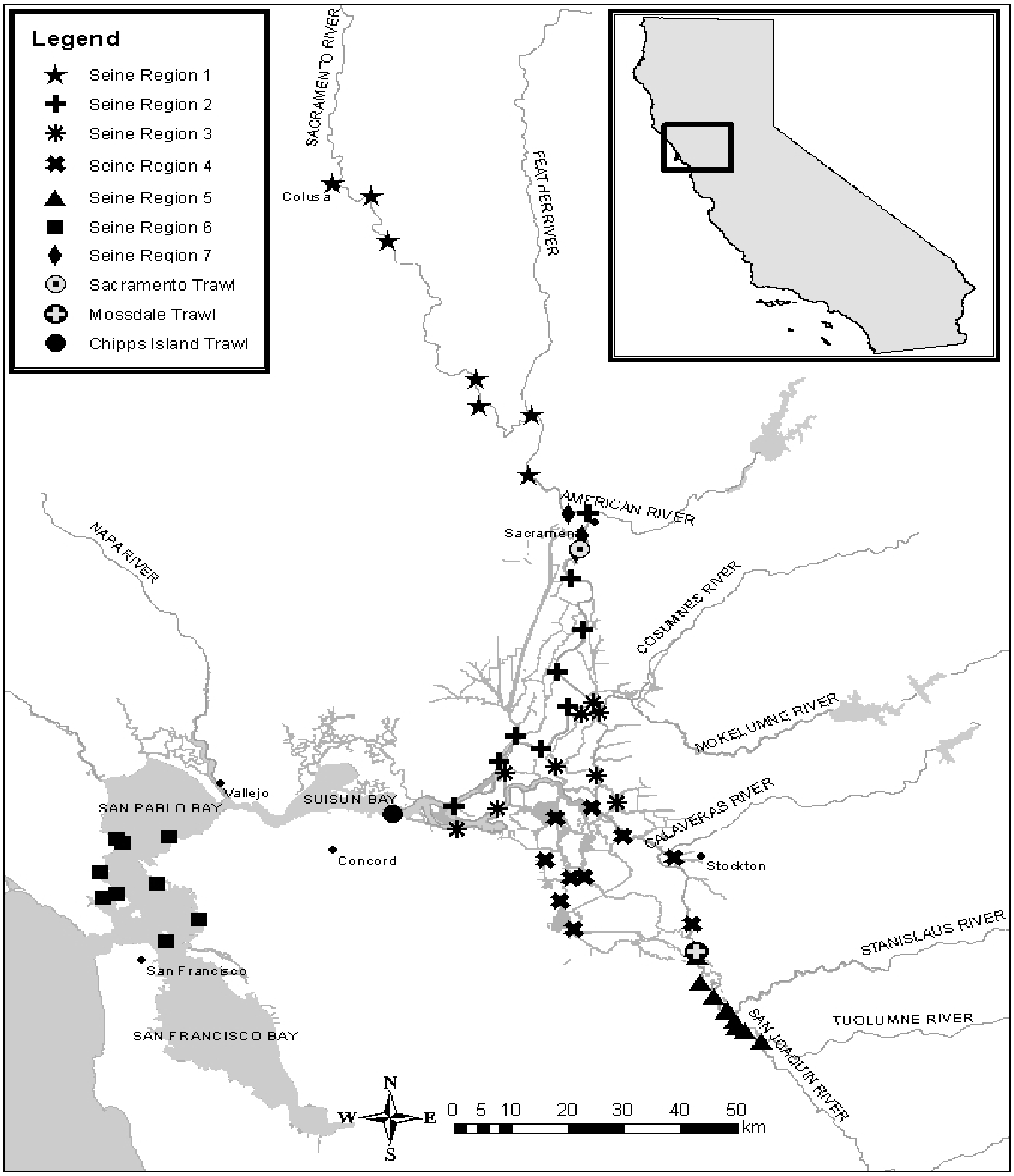


Figure 6. DJFMP sample sites within the Sacramento and San Joaquin rivers and San Francisco Estuary. The majority of these sites have been sampled annually since the mid-1990s (from: Speegle et al. 2013).

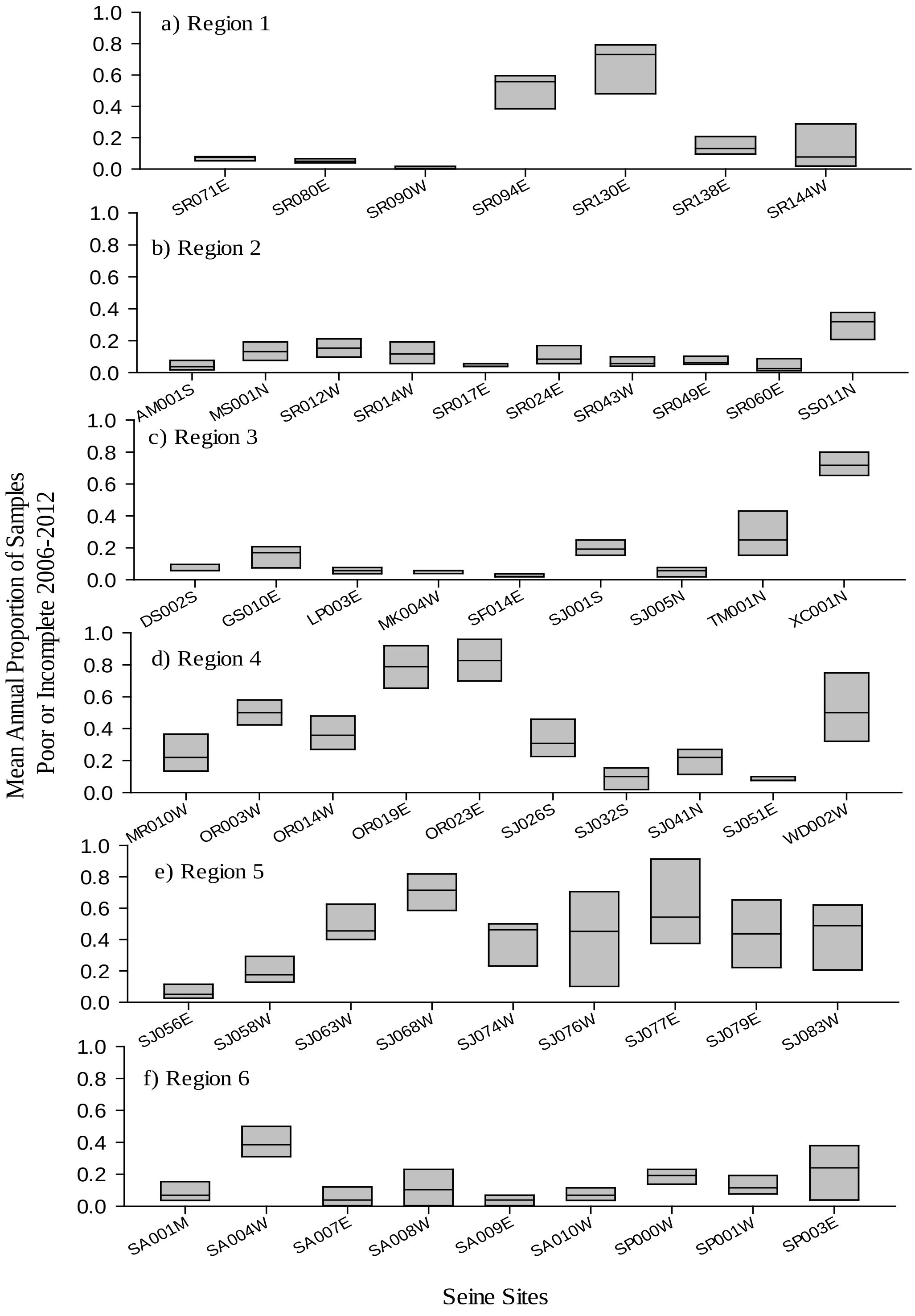


Figure 7. Box plot of annual proportion of beach seine samples not fully sampled by seine region and site from 2006 to 2012. Bar height represents the variability in the proportion sampled among years.

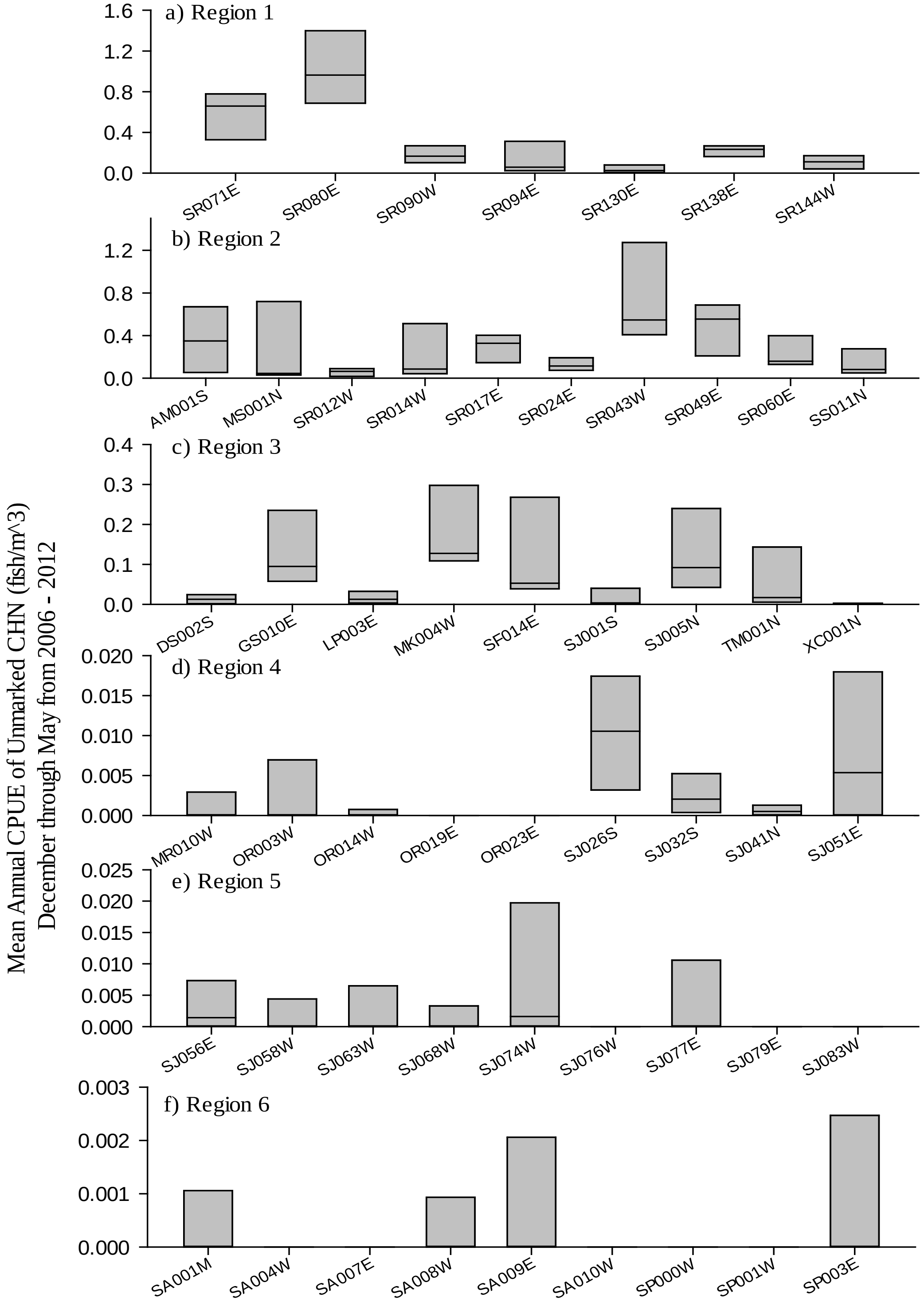


Figure 8. Box plots of annual mean catch per cubic meter of unmarked juvenile Chinook salmon from December through May by seine region and site during 2006 to 2012. Bar height represents the variability in the mean annual CPUE of unmarked Chinook salmon among years.

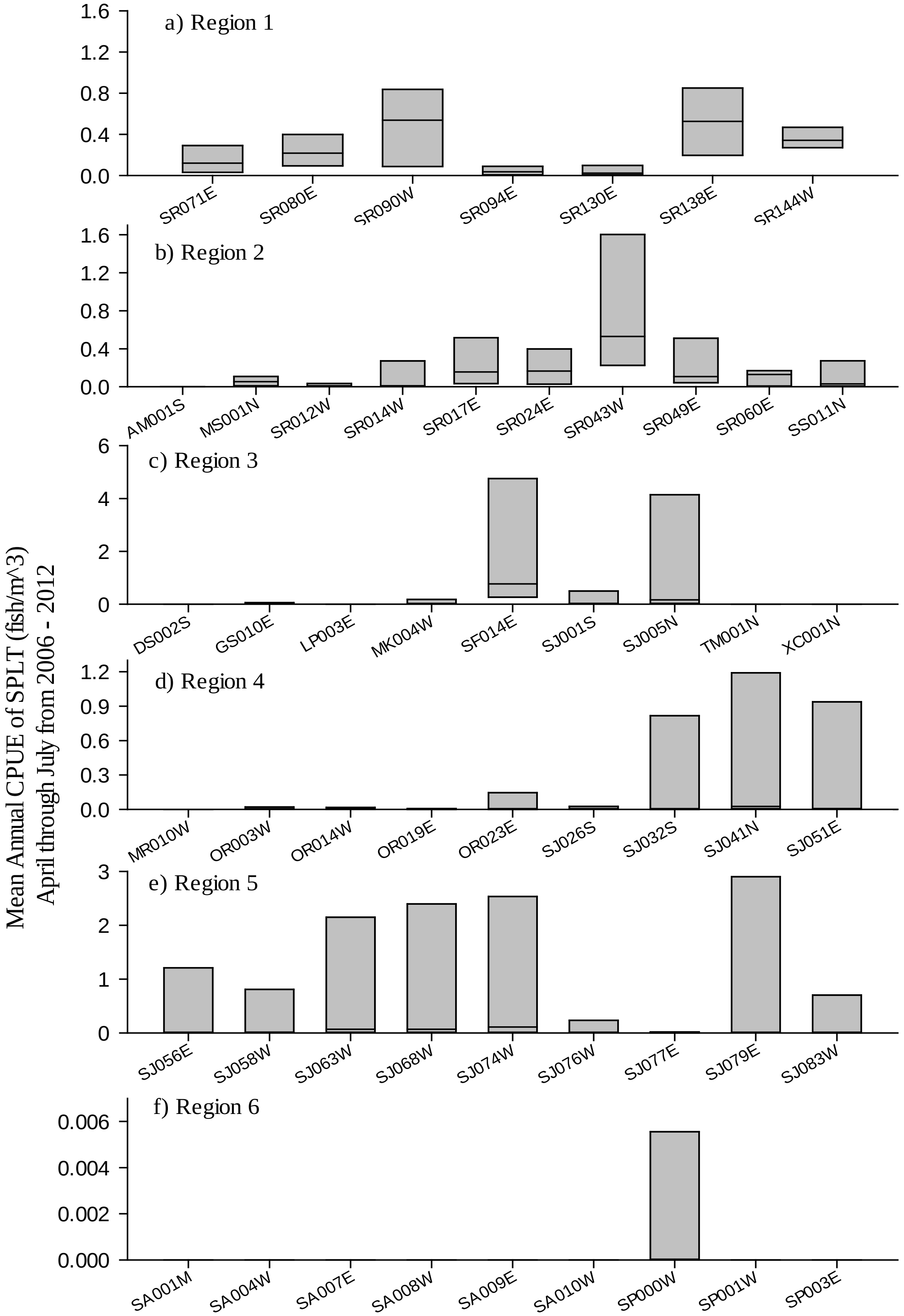


Figure 9. Annual mean catch per cubic meter of Sacramento splittail from April through July by seine region and site during 2006 to 2012. Bar height represents the variability in the mean annual CPUE of Sacramento splittail among years.

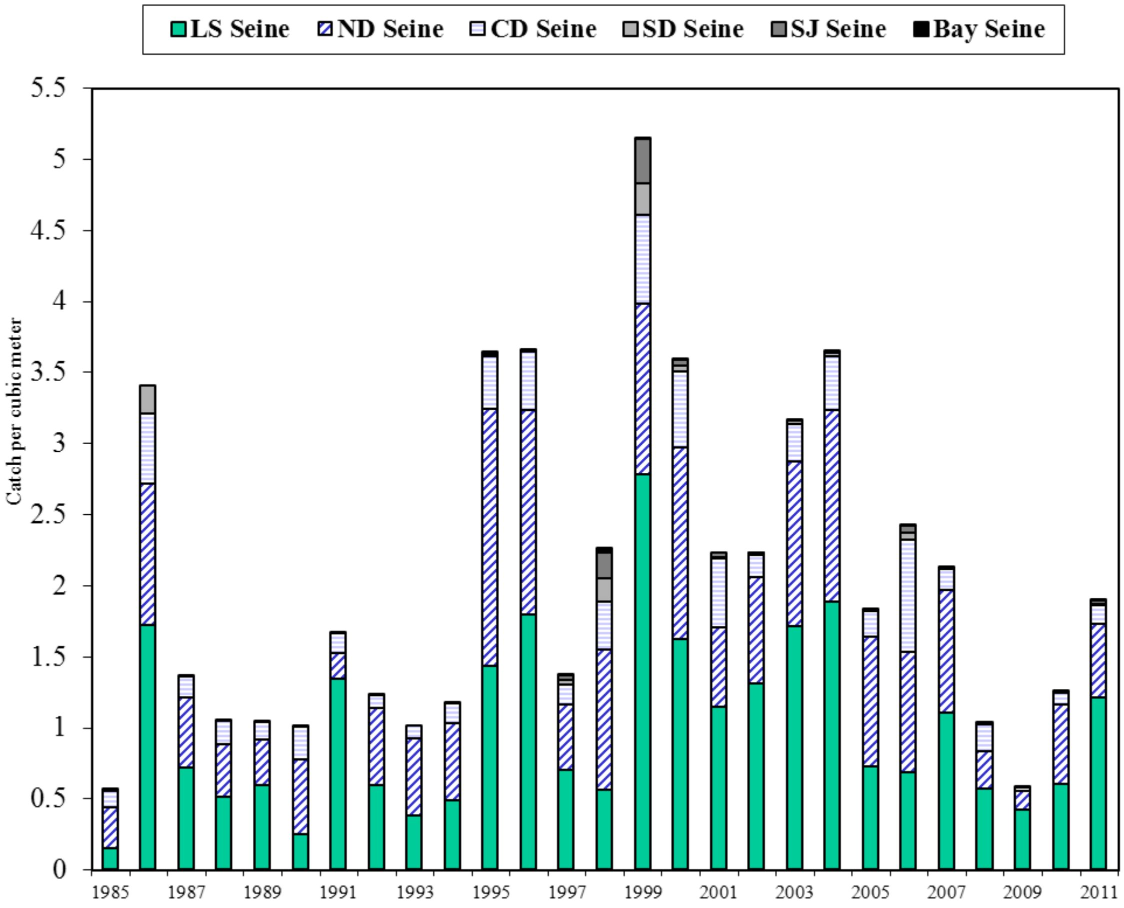


Figure 10. Summed mean catch per cubic meter for January through March of unmarked juvenile Chinook in the lower Sacramento, North Delta, Central Delta, South Delta, San Joaquin, and Bay area beach seines between 1985 and 2011. Bay area beach seining was not conducted between 1987 and 1996 and the San Joaquin beach seine started 1994.

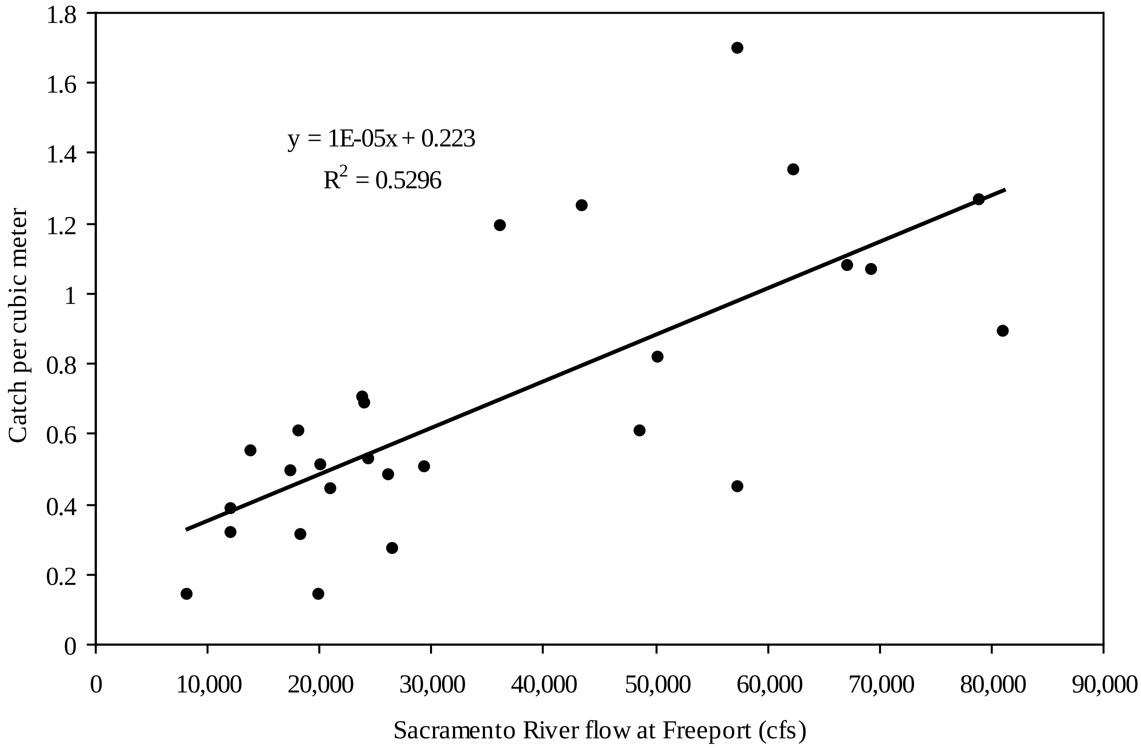


Figure 11. Mean catch per cubic meter of juvenile Chinook salmon between January and March, 1985 through 2011, in the North Delta beach seine regressed with mean February flow at Freeport.

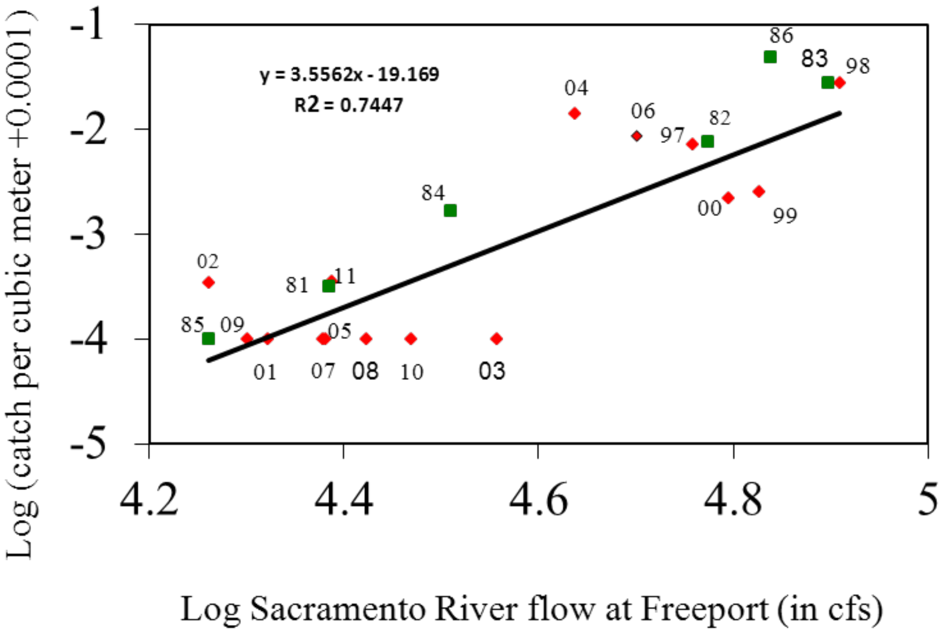


Figure 12. Mean Log of catch per cubic meter +0.0001 of juvenile Chinook salmon between January and March at beach seine sites within San Francisco Bay versus log of mean flow at Freeport during February between 1981 and 1986 (CDFW, green) and between 1997 and 2011 (USFWS, red).

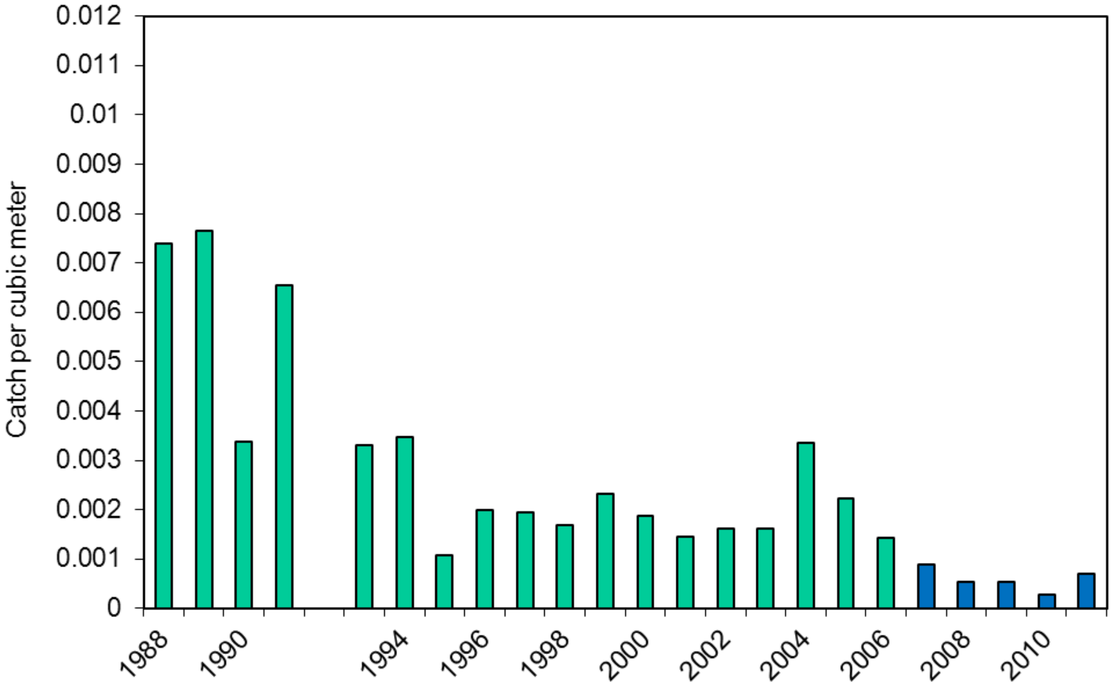


Figure 13. Mean catch per cubic meter of unmarked juvenile Chinook salmon between April and June 1985 through 2011, in the midwater trawl at Sacramento. There was no sampling during April 1992, so that year was not included. Indices between 2007 and 2011 contain less hatchery fish than historically, as 25% of the fall run hatchery production was marked in those years and not included in the indices.

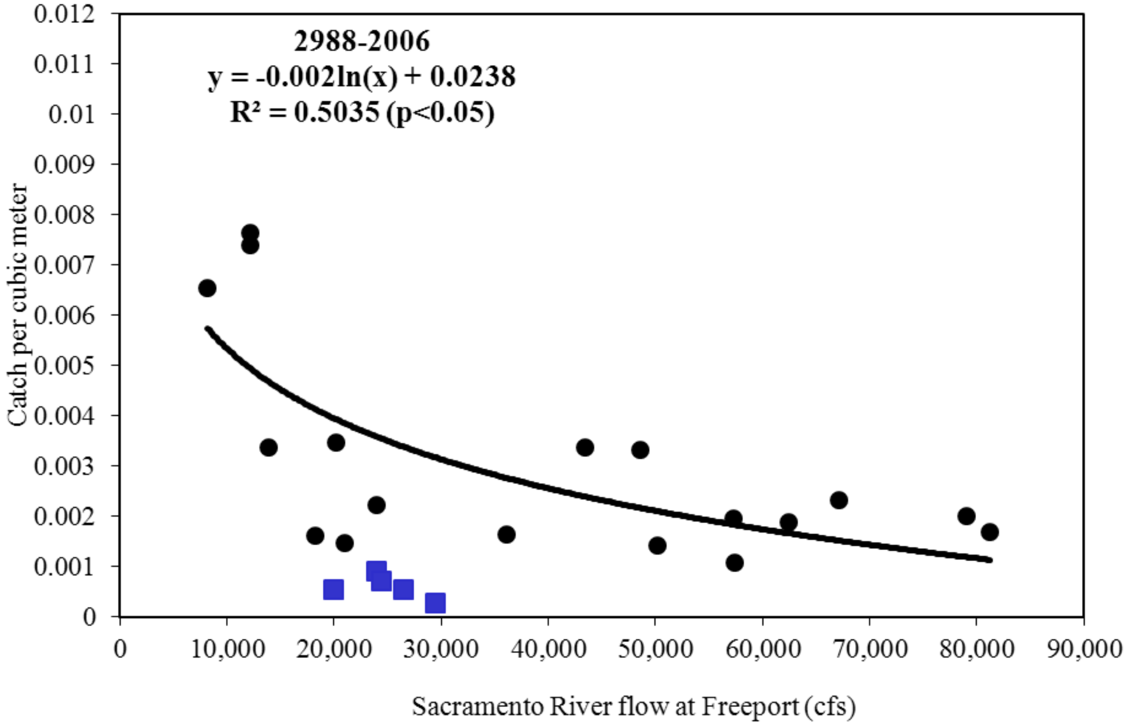


Figure 14. Mean catch per cubic meter of juvenile Chinook salmon between April and June, 1988 through 2011, in the midwater trawl at Sacramento regressed with mean February flow at Freeport. There was no sampling during April 1992, so that year was not included. Square (blue) data points are data from 2007–2011.

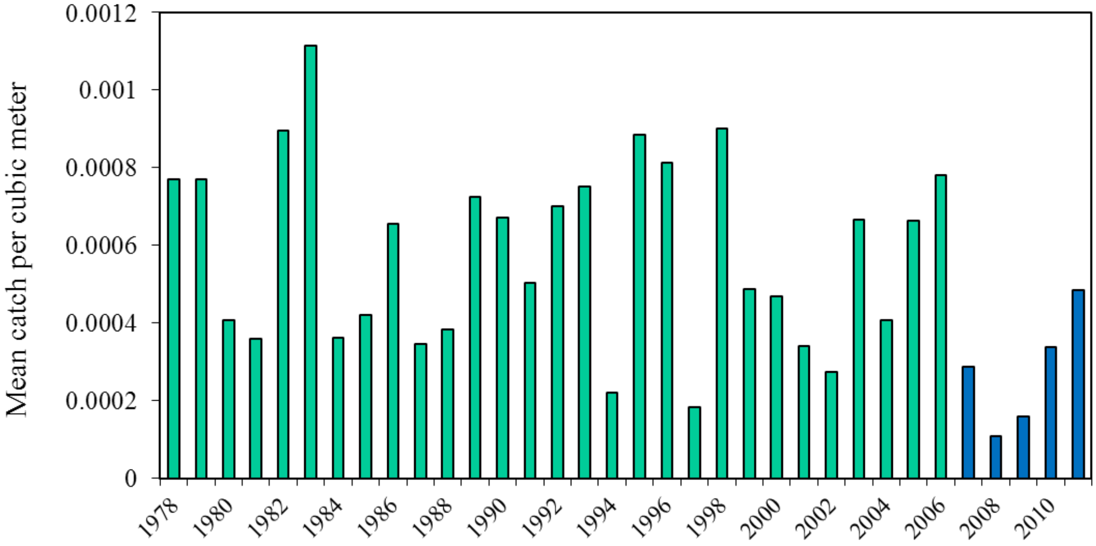


Figure 15. Mean catch per cubic meter of unmarked juvenile Chinook salmon in the midwater trawl at Chipps Island between April and June of 1978 to 2011. Catch in 2007 – 2011 does not include as many hatchery fish as a higher proportion of fall hatchery fish were marked in those years (25%).

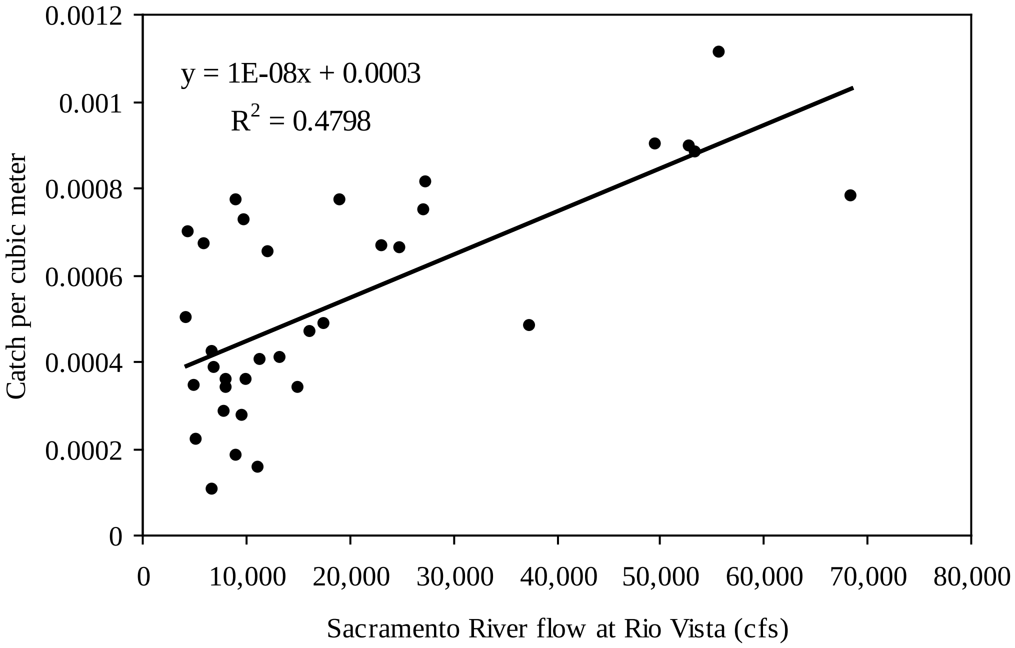


Figure 16. Mean catch per cubic meter of unmarked juvenile Chinook salmon in the midwater trawl at Chipps Island between April and June of 1978 to 2011 versus mean daily Sacramento River flow at Rio Vista between April and June in cfs.

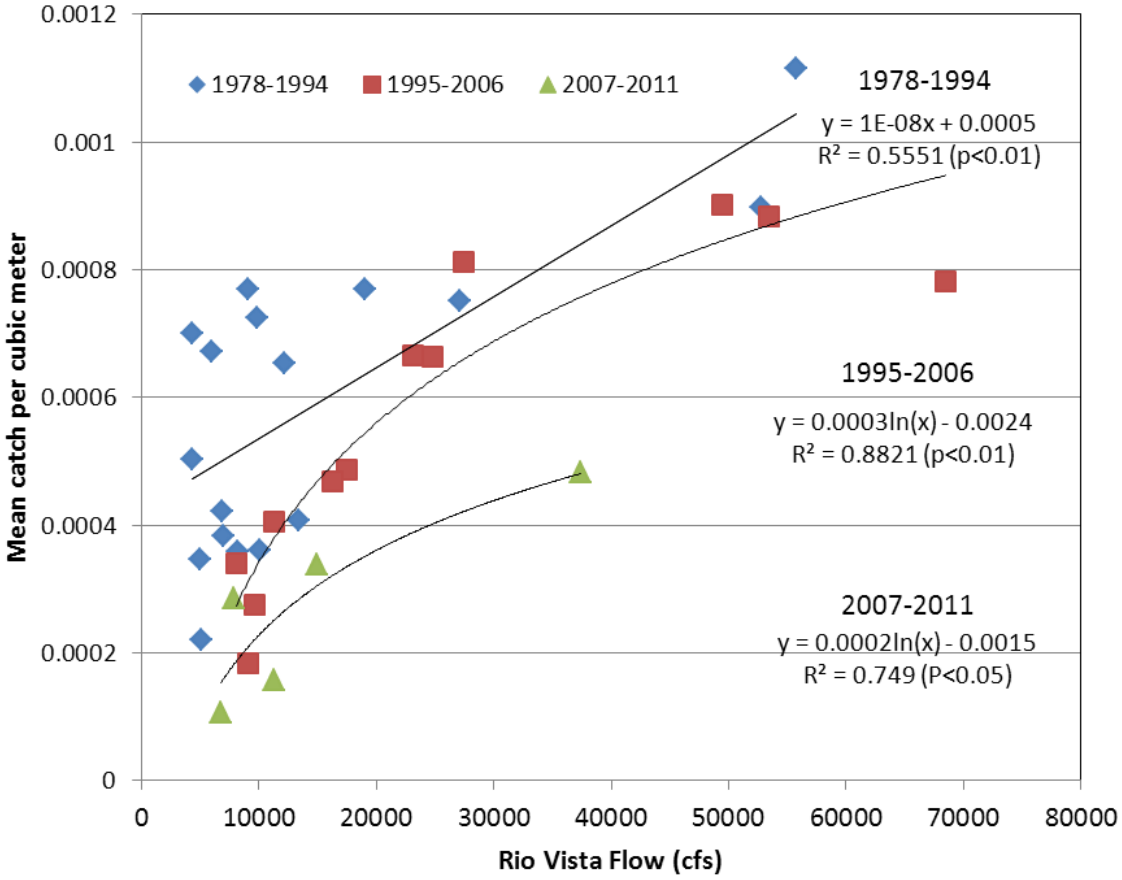


Figure 17. Mean catch per cubic meter of unmarked juvenile Chinook salmon in the midwater trawl at Chipps Island between April and June of three time periods, 1978 -1994, 1995-2006 and 2007-2011versus mean daily Sacramento River flow at Rio Vista between April and June in cfs.

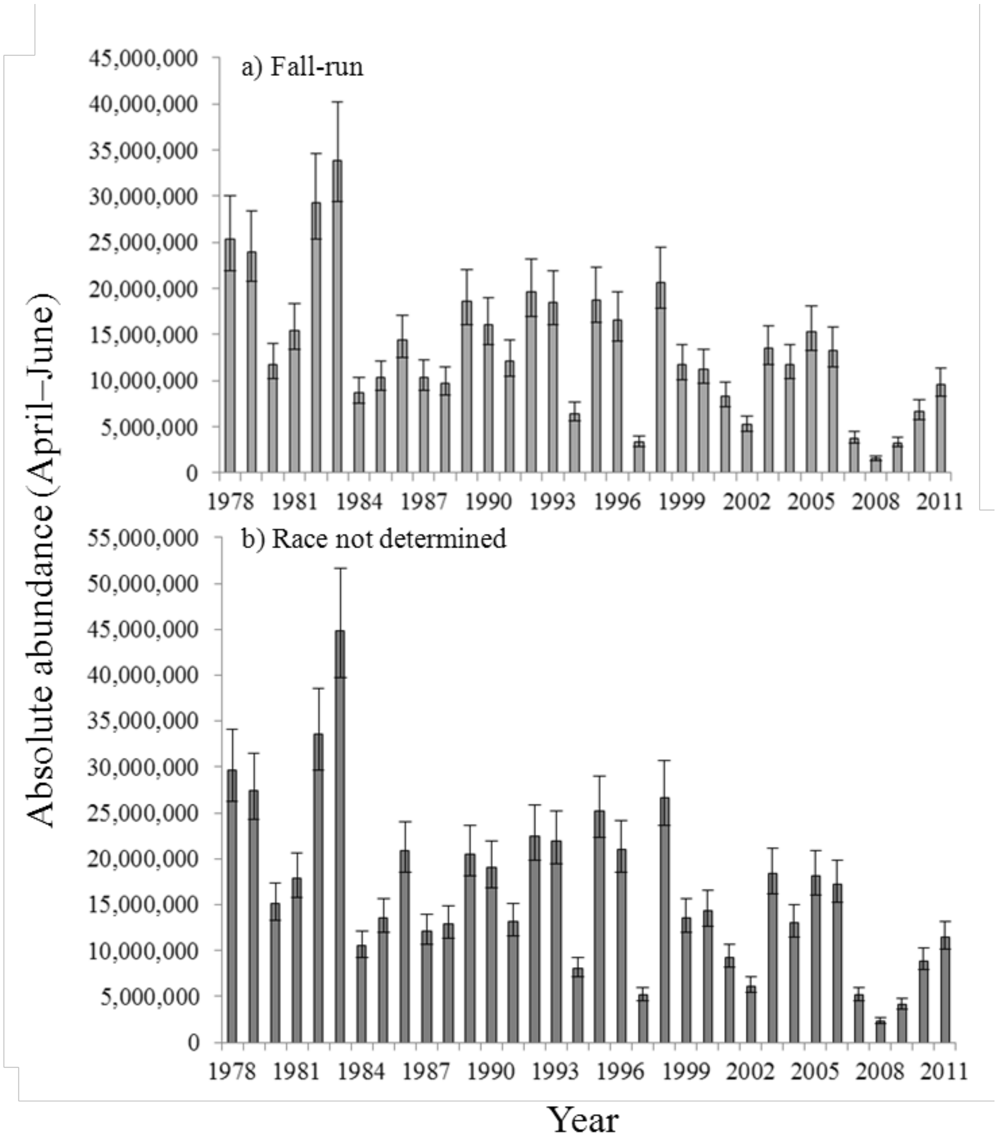


Figure 18. Seasonal absolute abundance estimates (April through June total) and 95% confidence intervals for all unmarked (race not determined) and fall-run juvenile Chinook salmon at Chipps Island from 1978 to 2011 (from: Speegle et al. 2013). Constant fractional marking (25%) of fall-run Chinook salmon was implemented by hatcheries in 2007 (tagging rates varied prior to 2007). Plus counts (fish counted but not measured) were proportioned based on the length-frequency distribution of measured individuals.

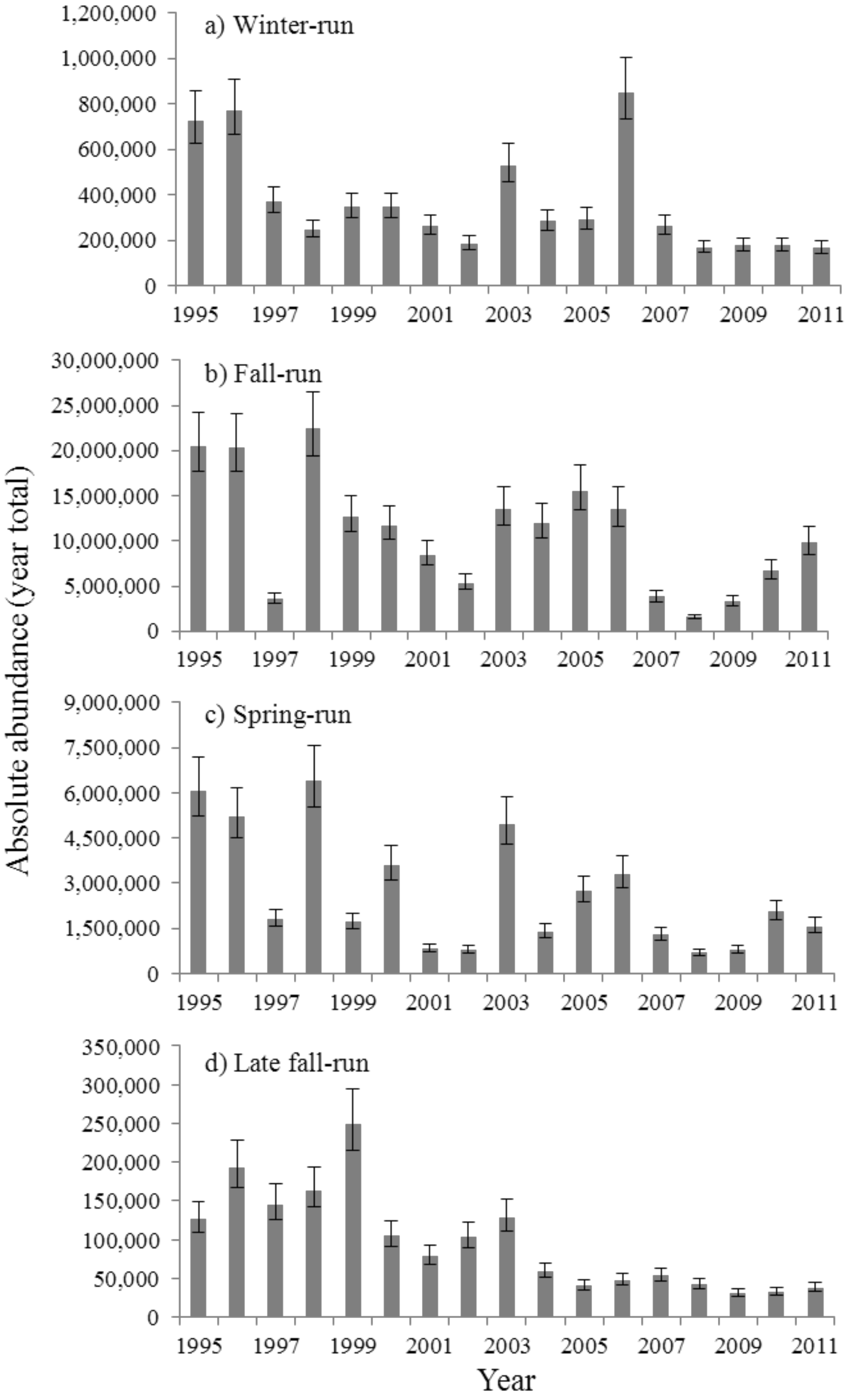


Figure 19. Annual absolute abundance estimates (year total) and 95% confidence intervals for unmarked juvenile Chinook salmon runs at Chipps Island from the 1995 to 2011 field seasons (from Speegle et al. 2013). Constant fractional marking (25%) of fall-run Chinook salmon was implemented by hatcheries in 2007 (tagging rates varied prior to 2007). Note, field seasons are defined as August 1 to July 31 (e.g. 1995 = August 1, 1994 to July 31, 1995).

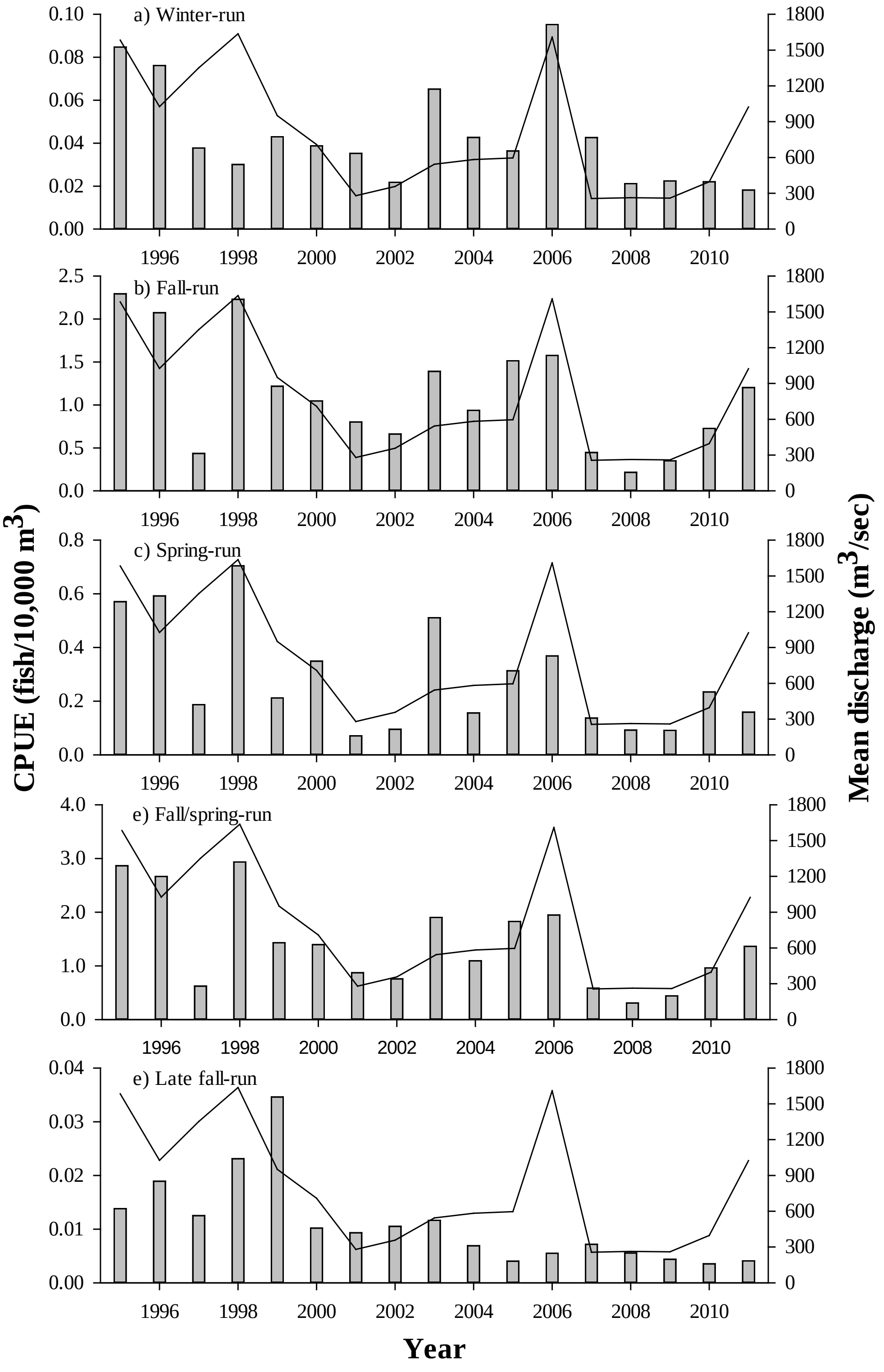


Figure 20. Mean yearly (field season) CPUE of unmarked juvenile Chinook salmon runs in mid-water trawls at Chipps Island and concurrent yearly Delta discharge from 1995 to 2011 (from Speegle et al. 2013). Note, field seasons are defined as August 1 to July 31 (e.g. 1995 = August 1, 1994 to July 31, 1995).

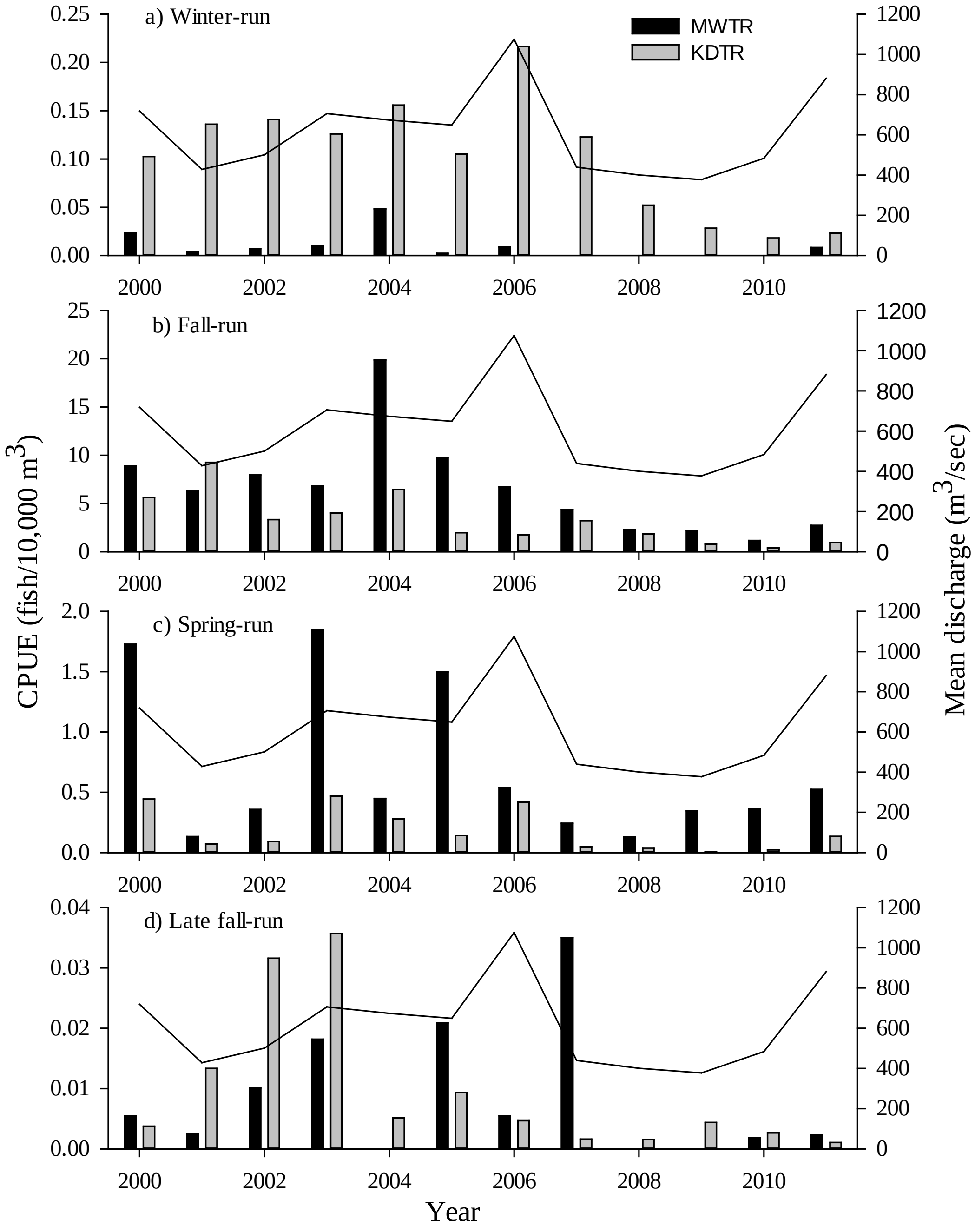


Figure 21. Mean yearly (field season) CPUE of unmarked juvenile Chinook salmon runs in mid-water (MWTR) and Kodiak (KDTR) trawls at Sherwood Harbor and concurrent yearly discharge on the Sacramento River at Freeport from 2000 to 2011 (from Speegle et al. 2013). Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

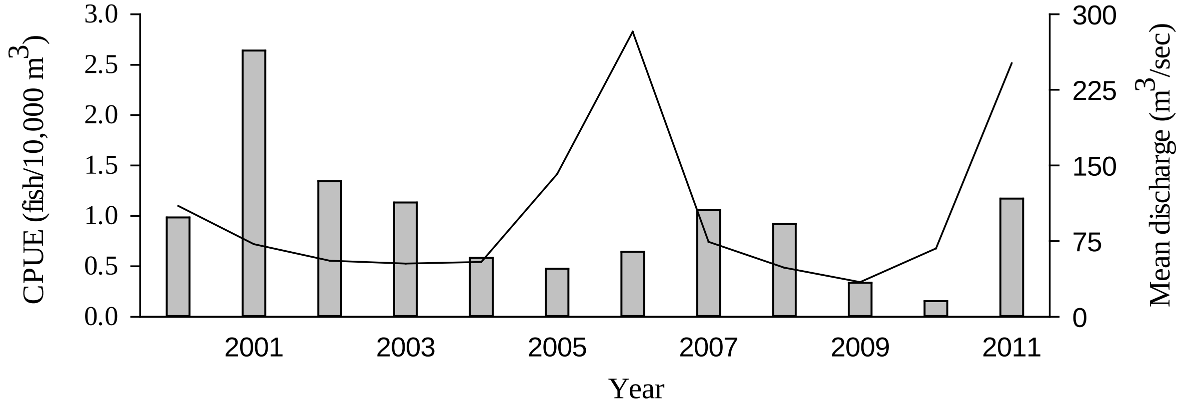


Figure 22. Mean yearly (field season) CPUE of unmarked juvenile Chinook salmon (fall-run) in Kodiak trawls at Mossdale and concurrent yearly discharge on the San Joaquin River at Vernalis from 2000 to 2011 (from Speegle et al. 2013). Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

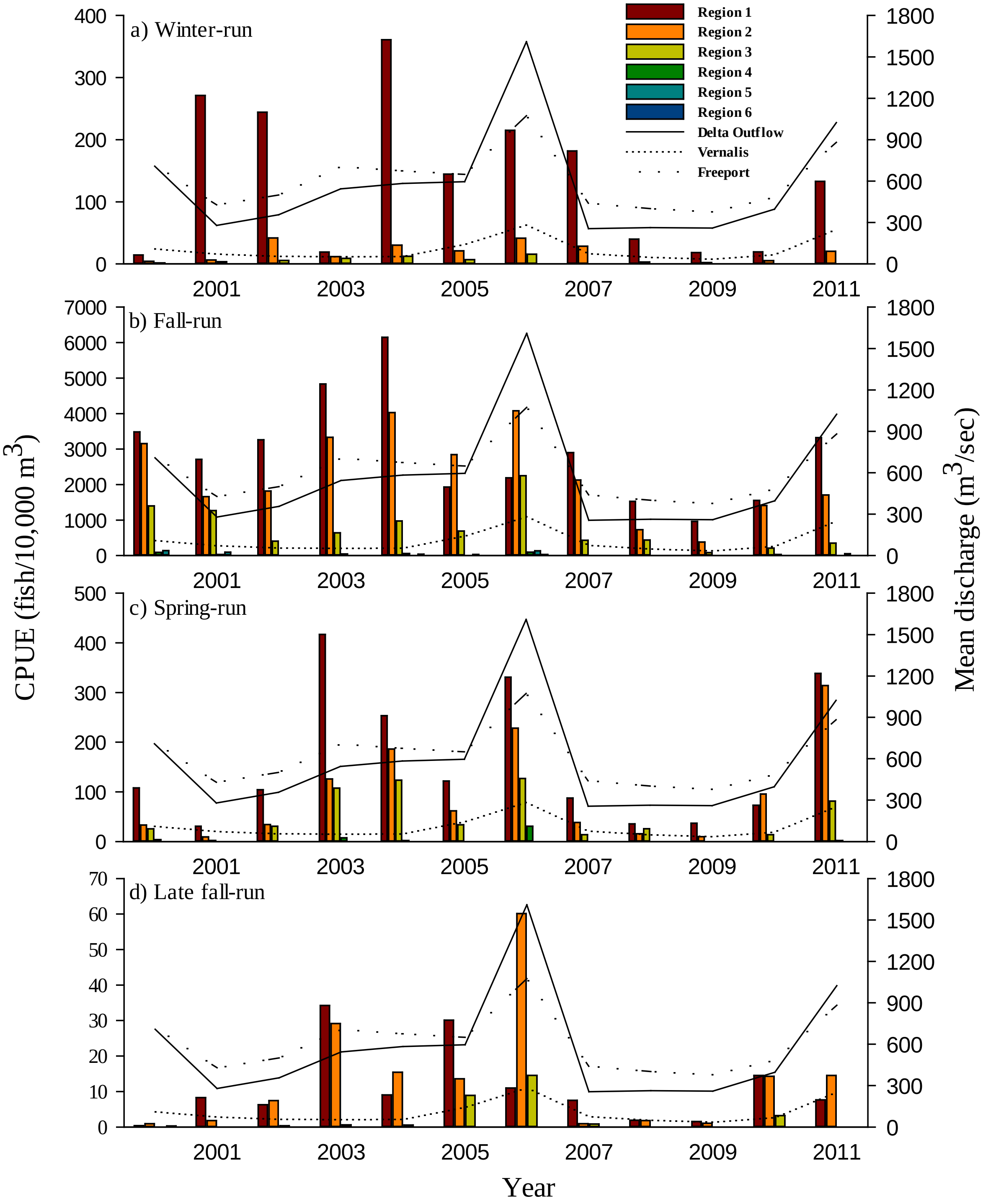


Figure 23. Mean yearly (field season) CPUE of unmarked juvenile Chinook salmon runs captured in beach seines (regions 1–6), and mean yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge from 2000 to 2011 (from Speegle et al. 2013). Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

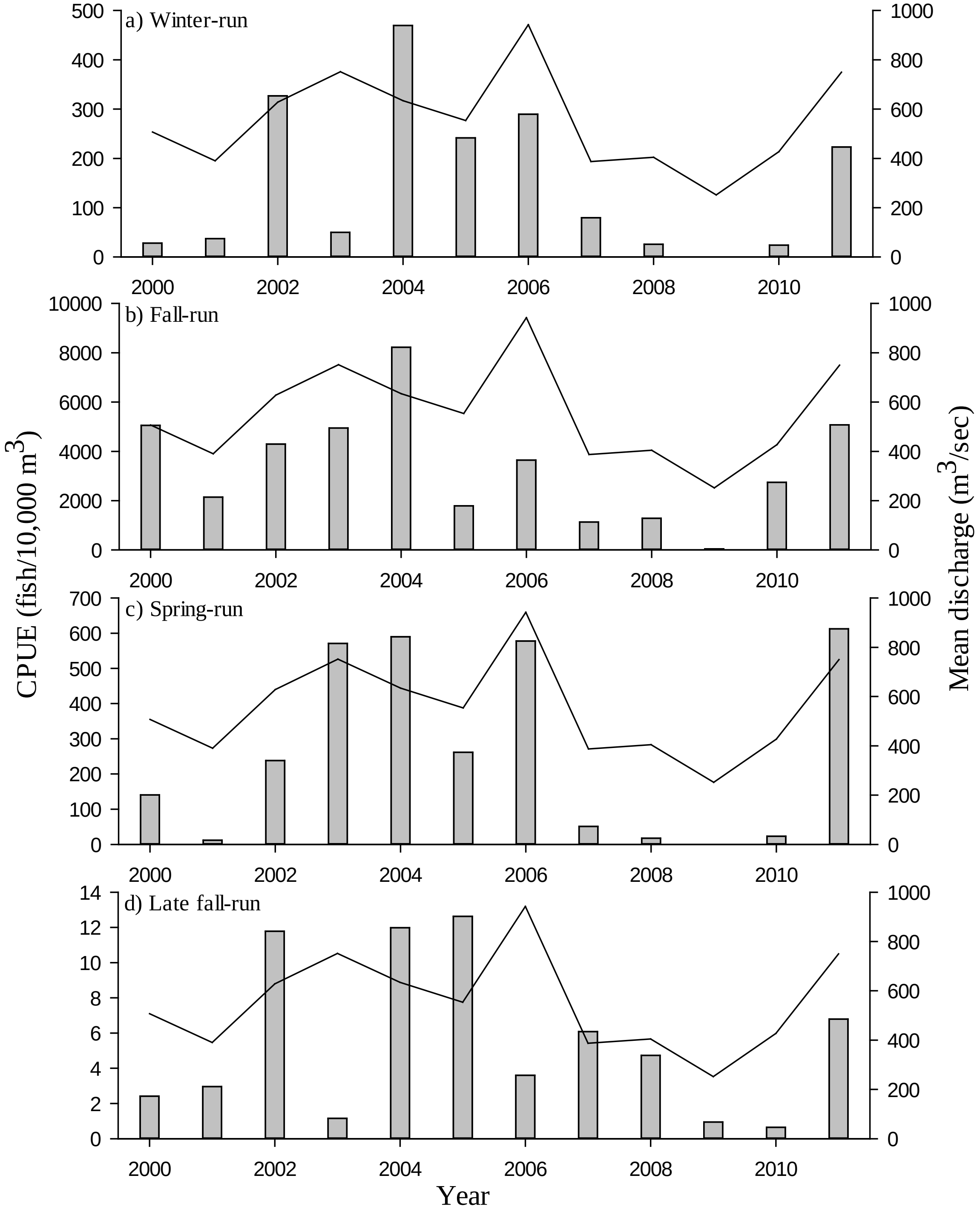


Figure 24. Mean yearly (field season) CPUE of unmarked juvenile Chinook salmon runs captured in the Sacramento Region beach seine (Region 7) and mean yearly Sacramento River discharge at Freeport from 2000 to 2011 (from Speegle et al. 2013). Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

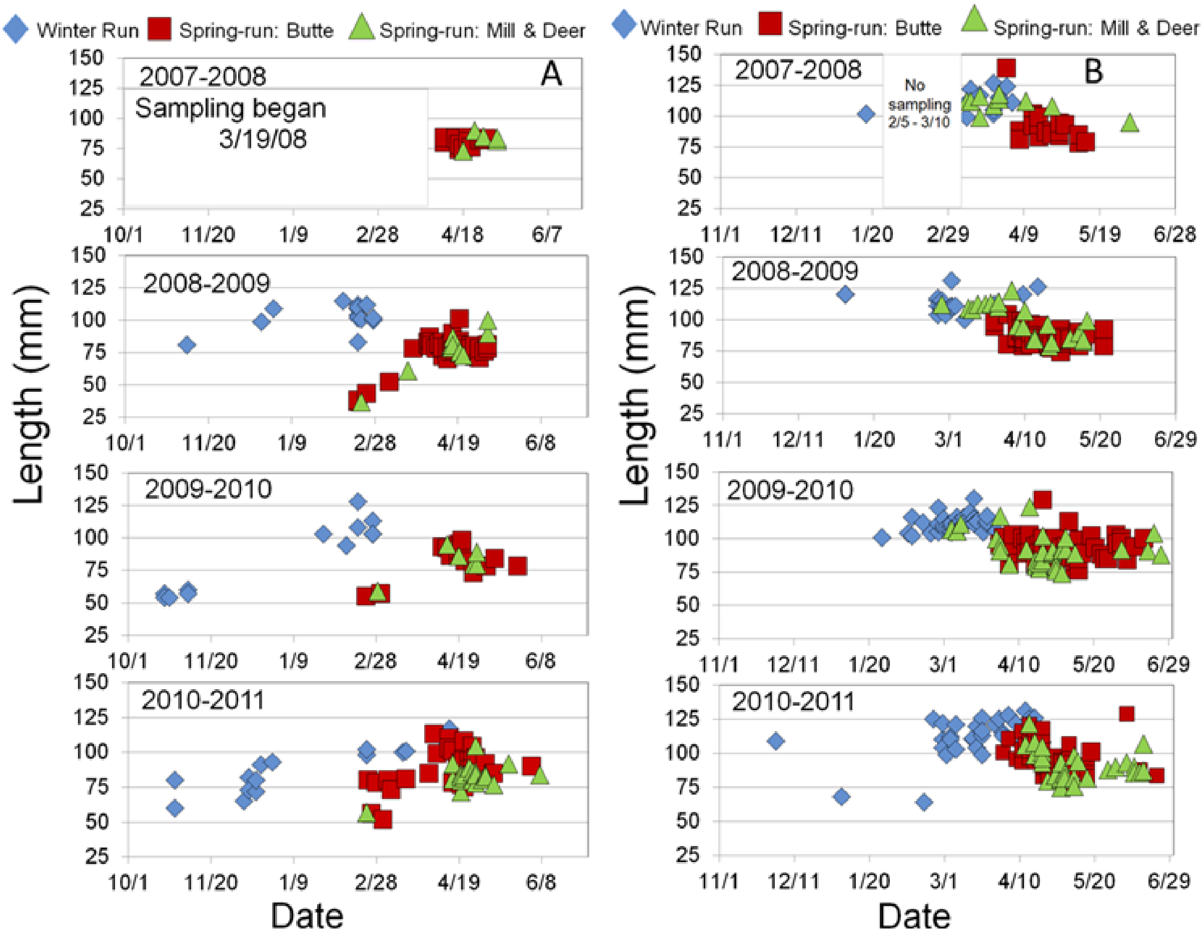


Figure 25. Timing of genetically designated winter- and spring-run Chinook salmon captured at Sacramento (A) and Chipps Island (B) in 2007–2011.

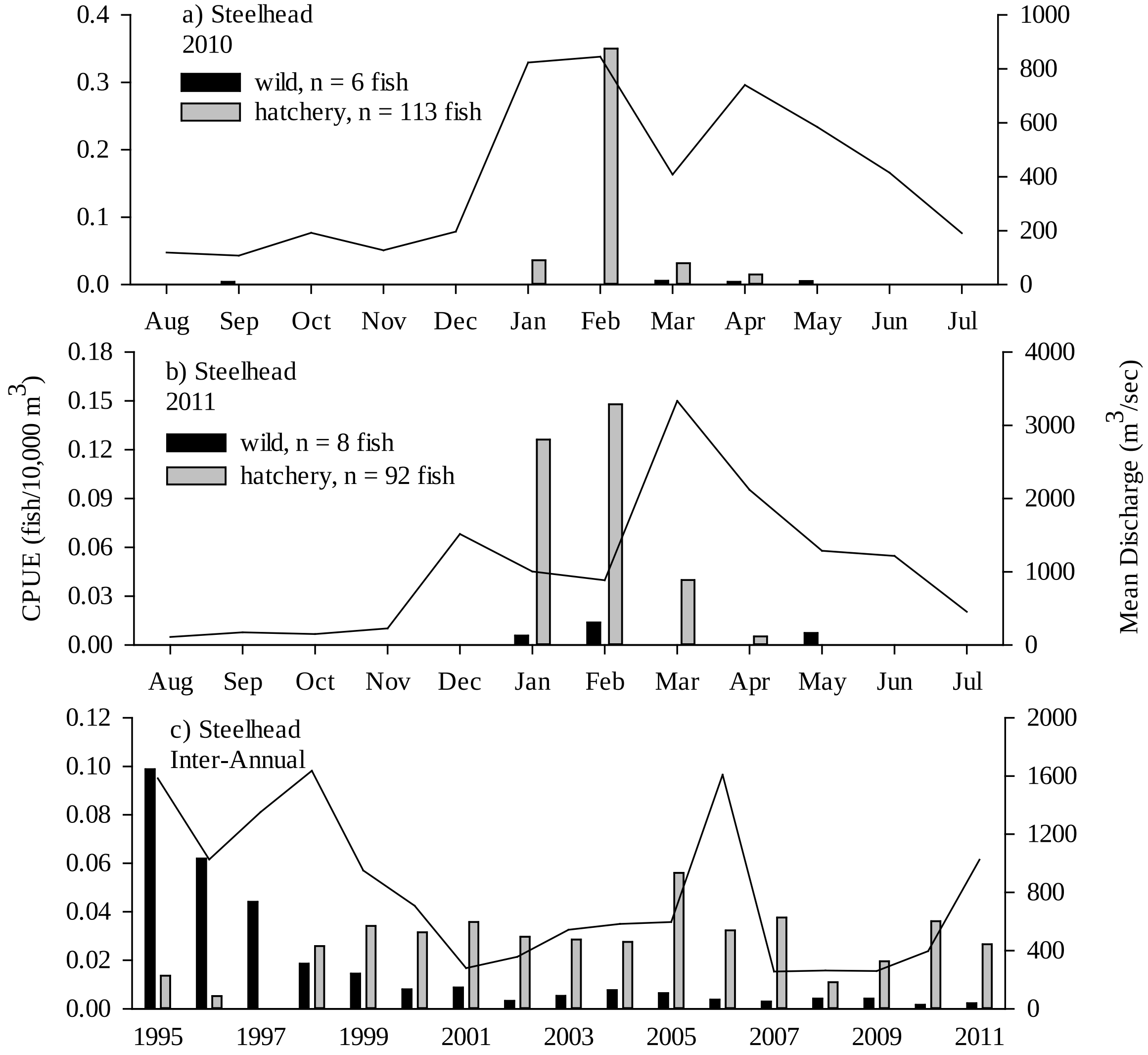


Figure 26. Mean monthly and yearly (field season) CPUE of hatchery and wild steelhead captured in mid-water trawls at Chipps Island and concurrent mean monthly and yearly Delta discharge during the a) 2010, b) 2011, and c) 1995 through 2011 field seasons. Sample size (n) corresponds to the total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 1995 = August 1, 1994 to July 31, 1995).

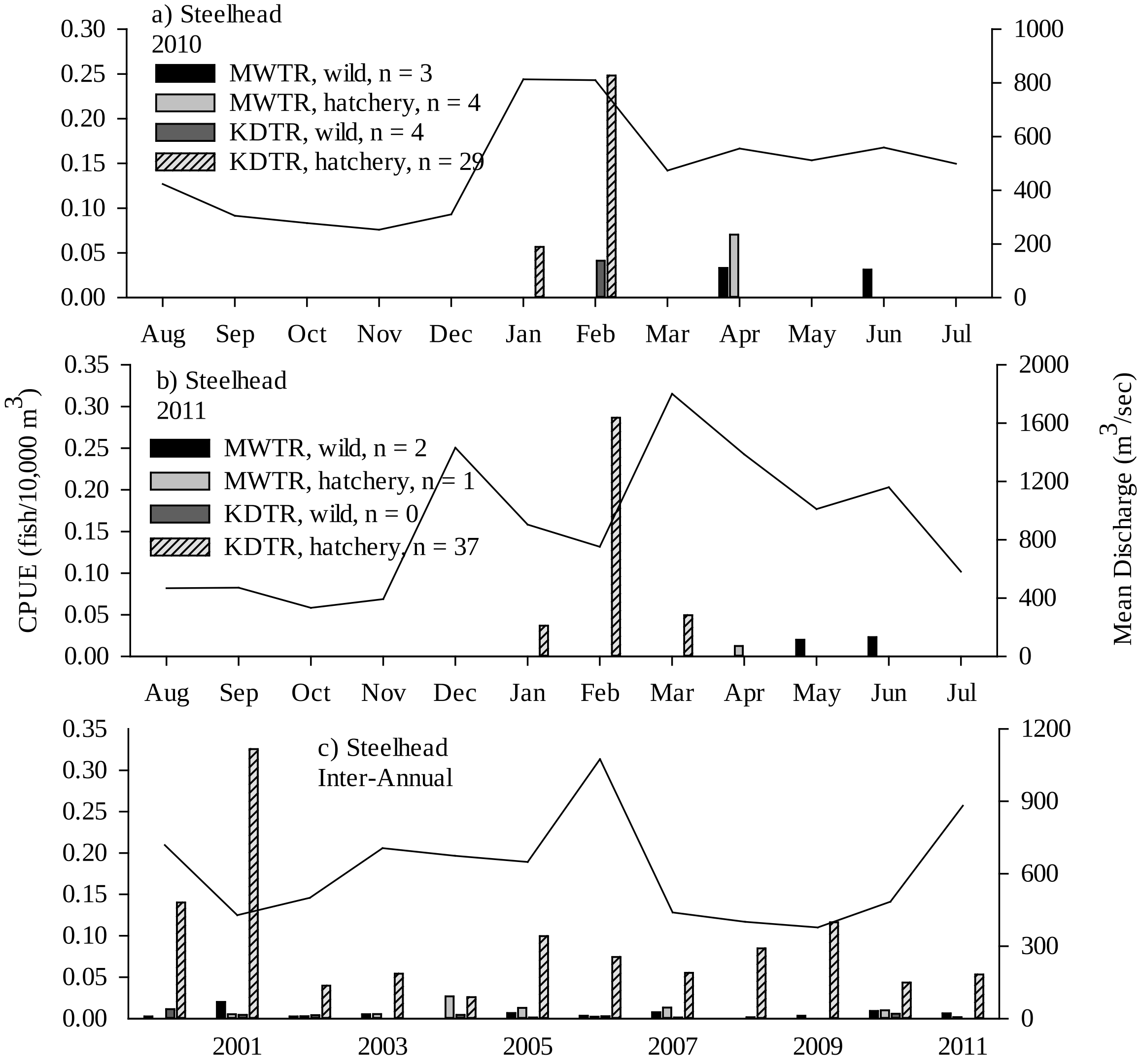


Figure 27. Mean monthly and yearly (field season) CPUE of hatchery and wild steelhead captured in mid-water (MWTR) and Kodiak (KDTR) trawls at Sherwood Harbor and concurrent mean monthly and yearly Sacramento River discharge at Freeport during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to the total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

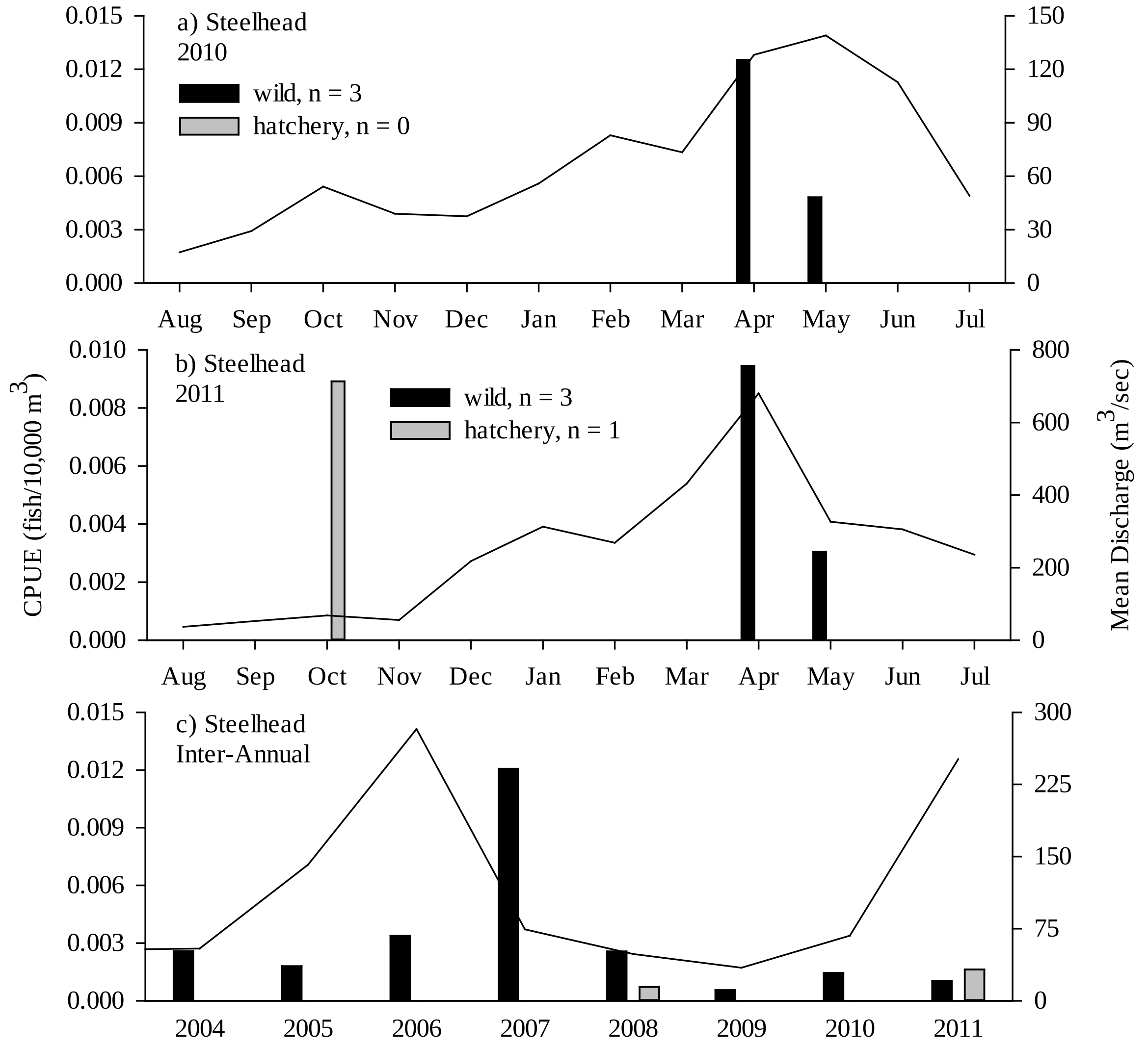


Figure 28. Mean monthly and yearly (field season) CPUE of hatchery and wild steelhead captured in Kodiak trawls at Mossdale and concurrent mean monthly and yearly San Joaquin River discharge at Vernalis during the a) 2010, b) 2011, and c) 2004 through 2011 field seasons. Sample size (n) corresponds to the total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2004 = August 1, 2003 to July 31, 2004).

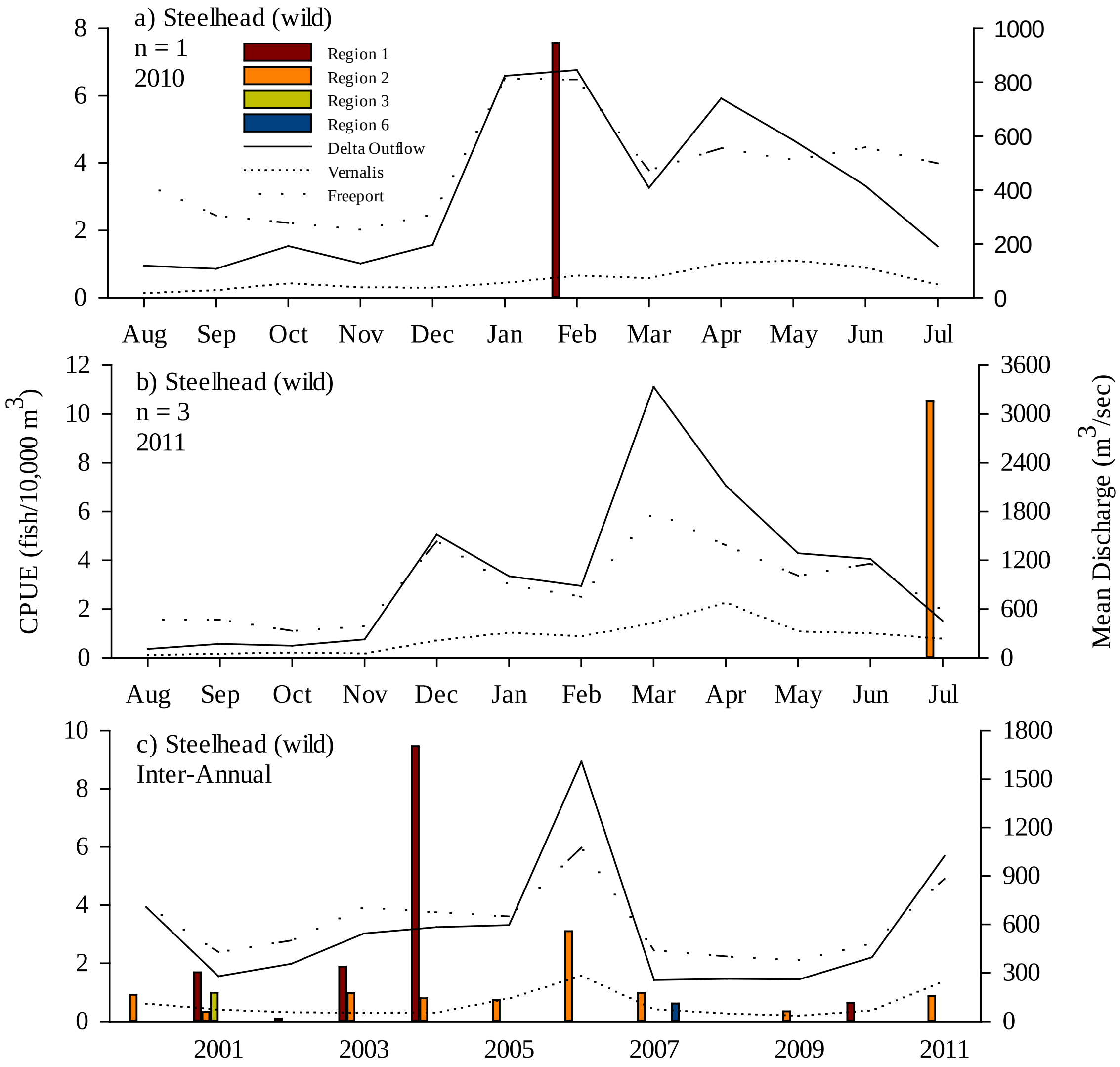


Figure 29. Mean monthly and yearly (field season) CPUE of wild steelhead captured in beach seines (Regions 1-6) and concurrent mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to the total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

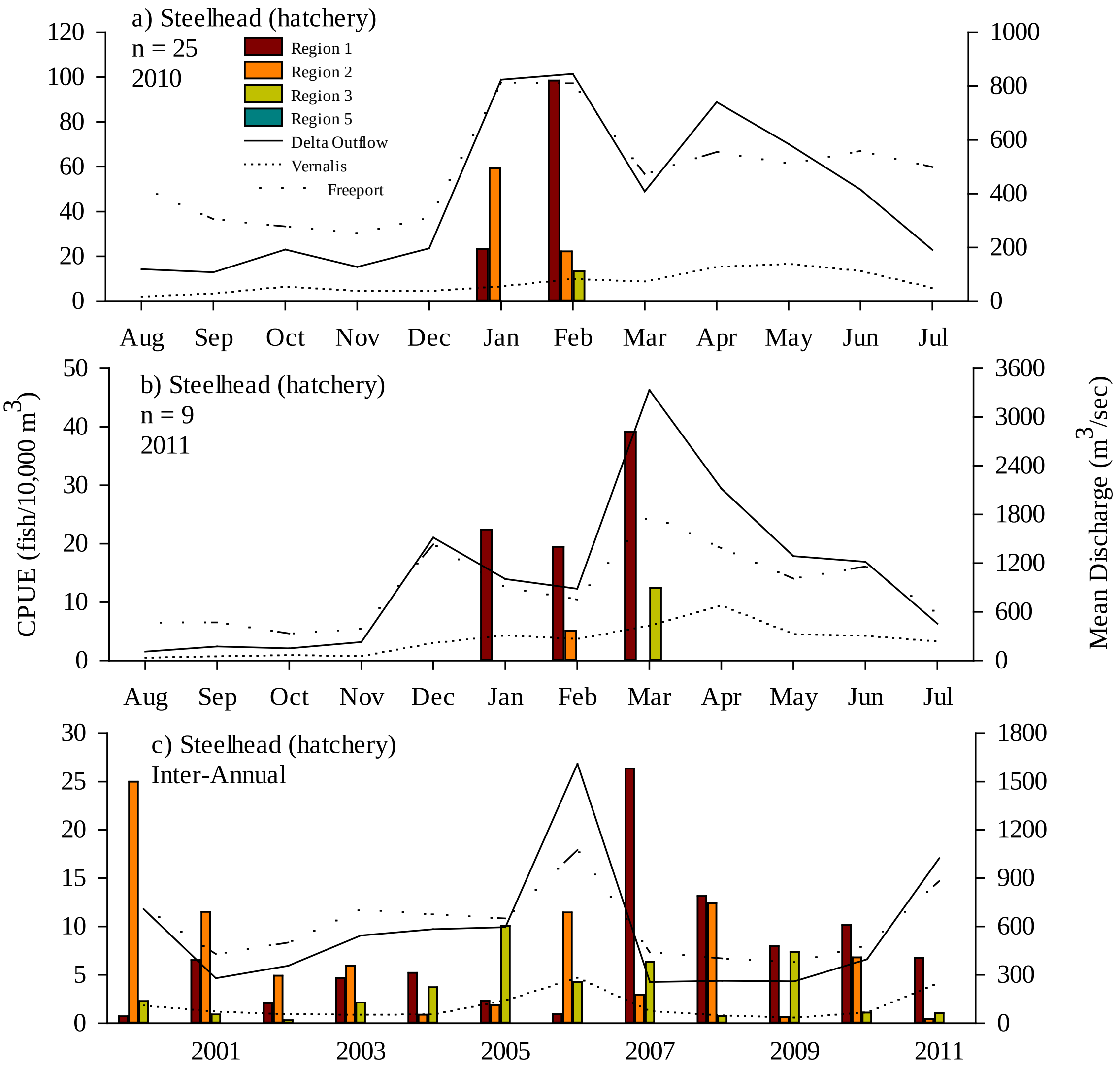


Figure 30. Mean monthly and yearly (field season) CPUE of hatchery steelhead captured in beach seines (Regions 1-6) and concurrent mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to the total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

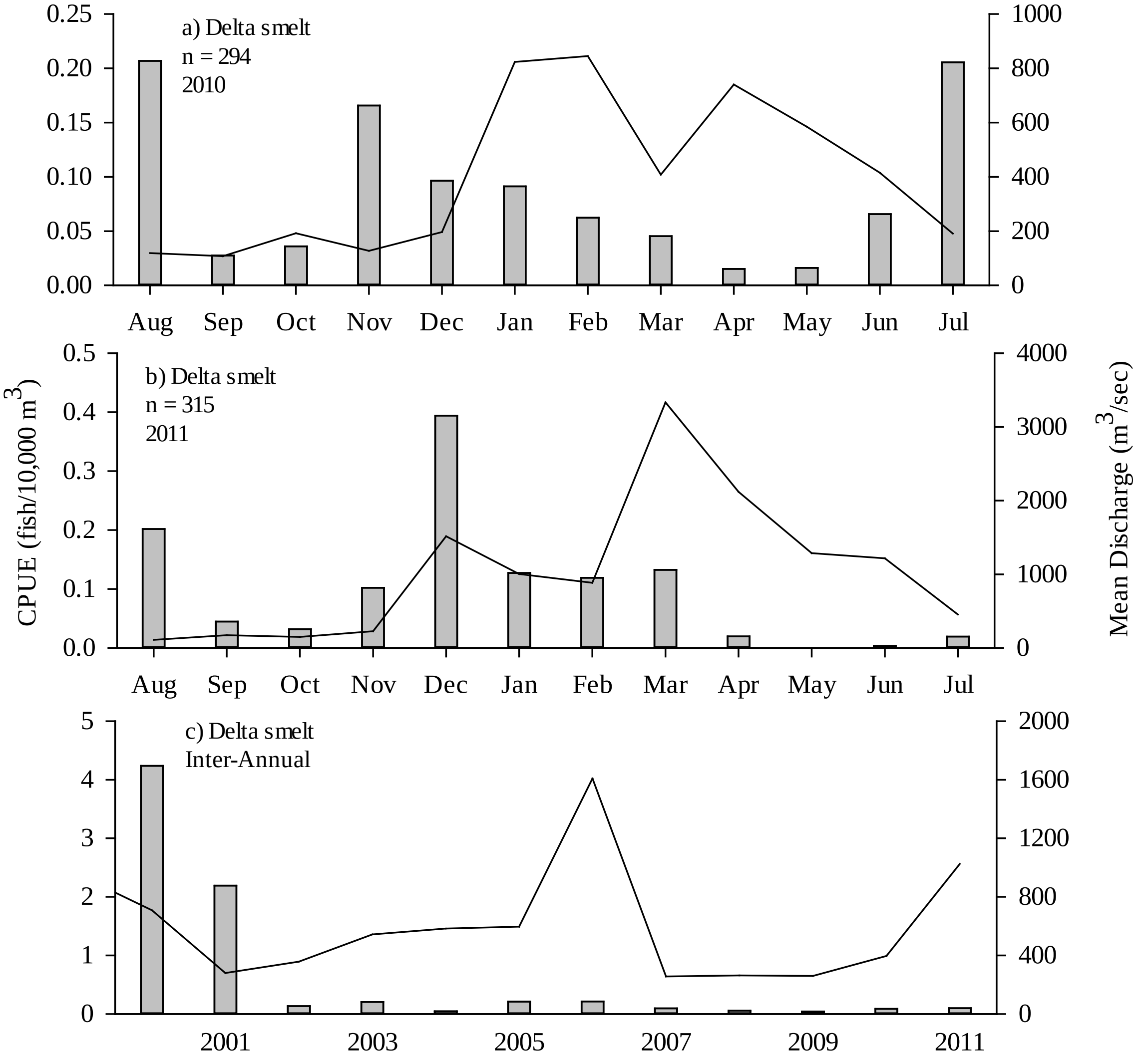


Figure 31. Mean monthly and yearly (field season) CPUE of delta smelt captured in mid-water trawls (MWTRs) at the Chipps Island Trawl Site, and mean monthly and yearly Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

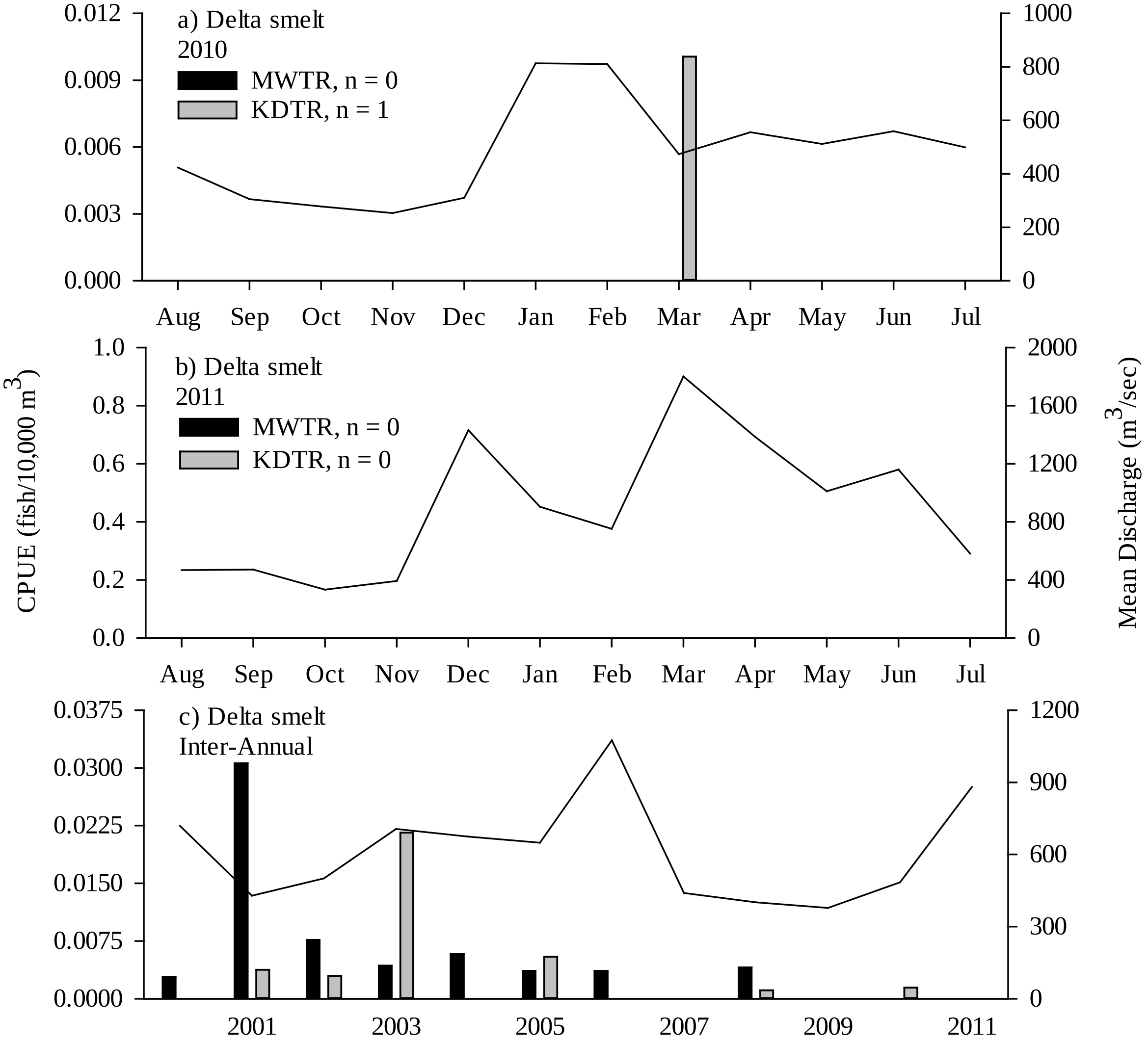


Figure 32. Mean monthly and yearly (field season) CPUE of delta smelt captured in mid-water (MWTRs) and Kodiak trawls (KDTRs) at the Sacramento Trawl Site, and mean monthly and yearly Sacramento River discharge at Freeport during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

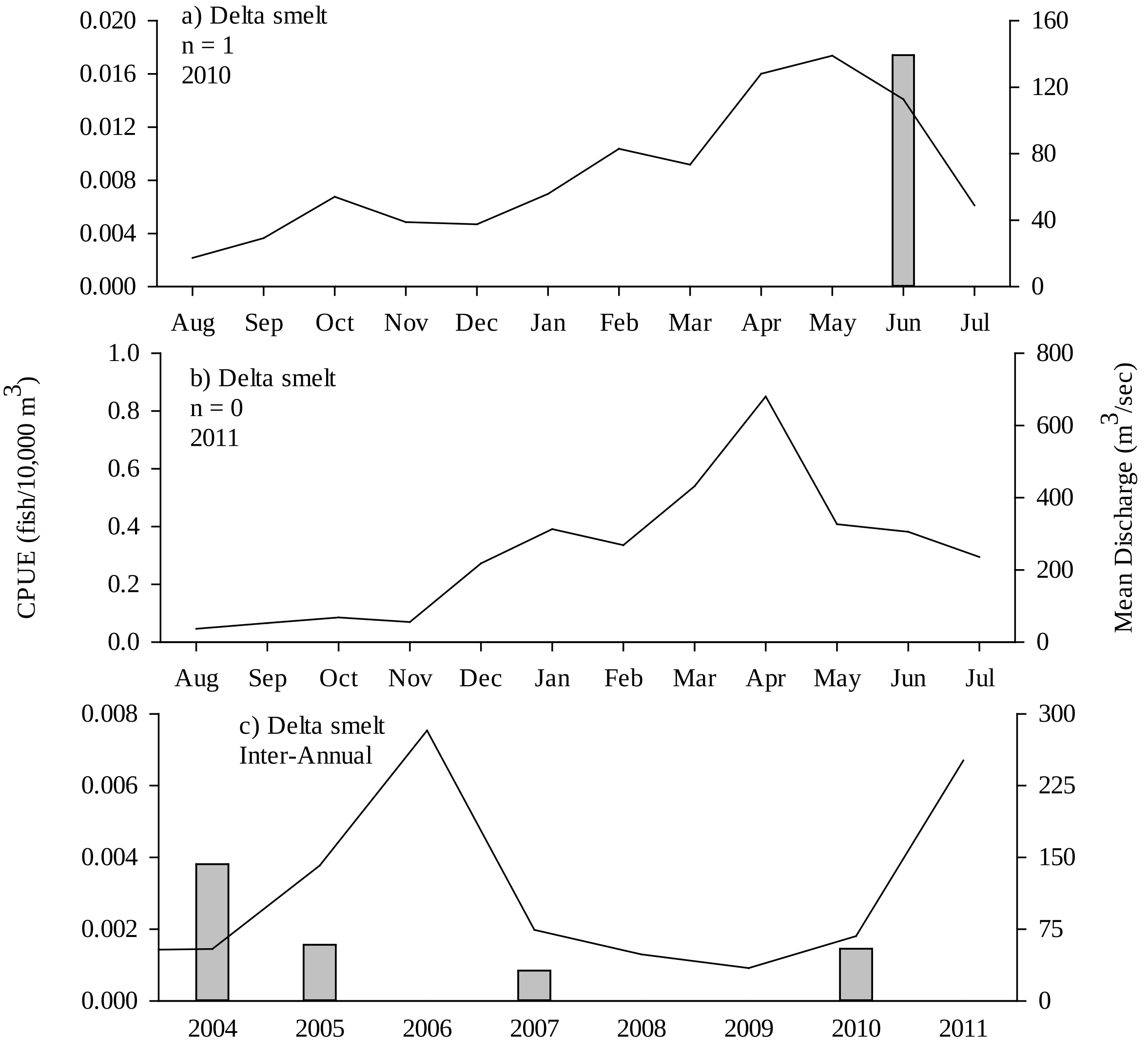


Figure 33. Mean monthly and yearly (field season) CPUE of delta smelt captured in Kodiak trawls (KDTRs) at the Mossdale Trawl Site, and mean monthly and yearly San Joaquin River discharge at Vernalis during the a) 2010, b) 2011, and c) 2004 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2004 = August 1, 2003 to July 31, 2004).

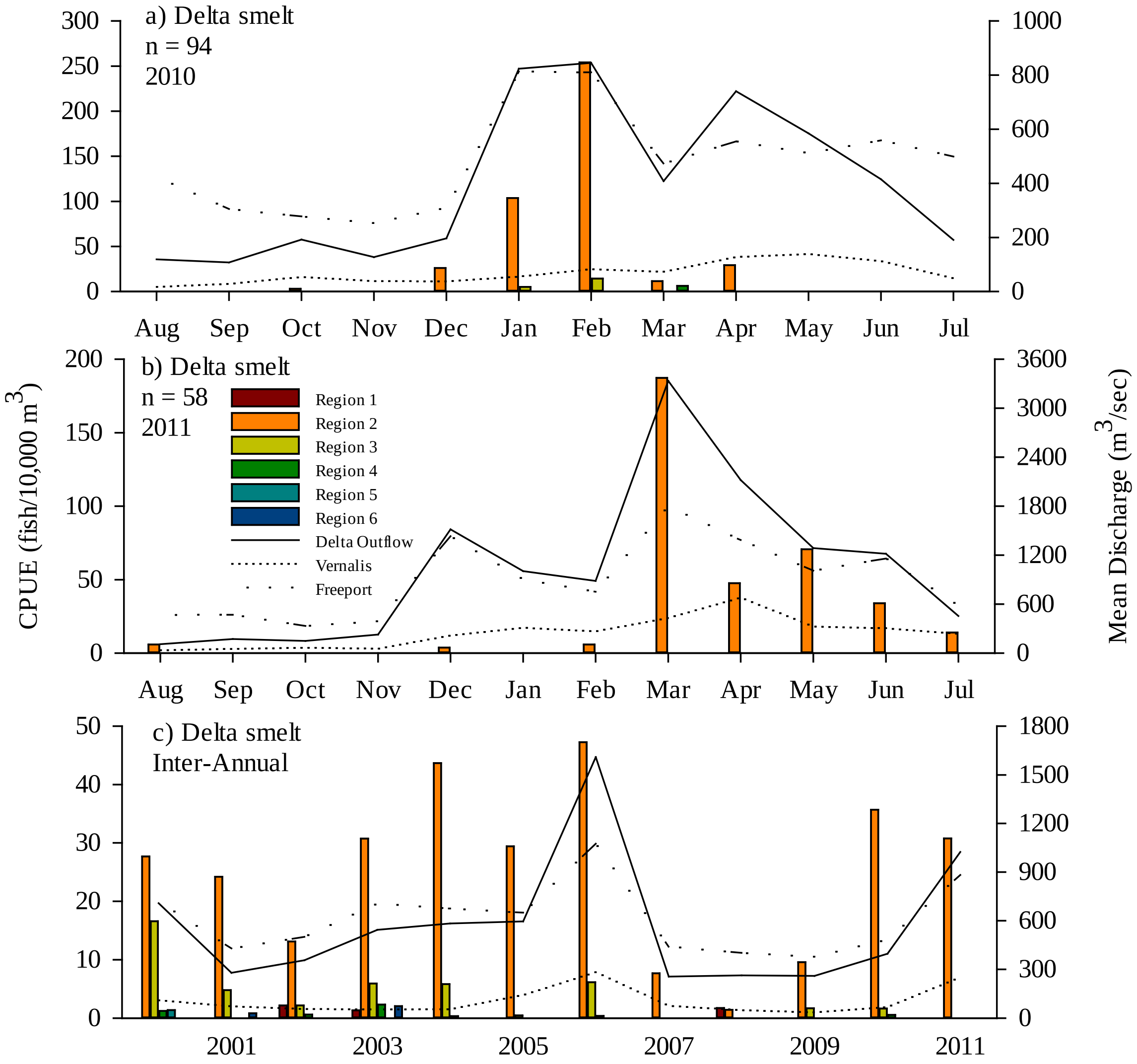


Figure 34. Mean monthly and yearly (field season) CPUE of delta smelt captured in beach seines at Regions 1-6, and mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

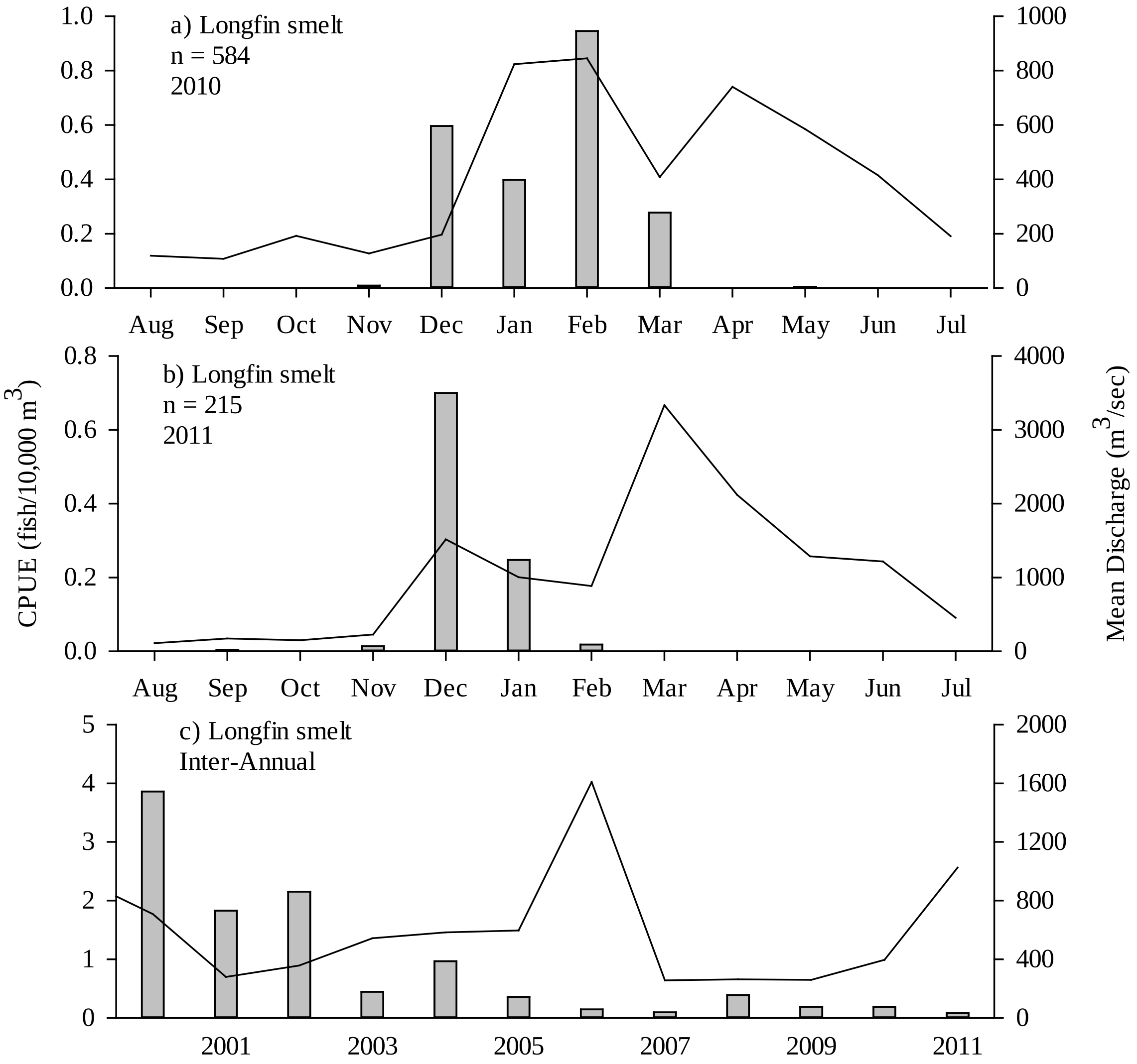


Figure 35. Mean monthly and yearly (field season) CPUE of longfin smelt captured in mid-water trawls (MWTRs) at the Chipps Island Trawl Site, and mean monthly and yearly Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

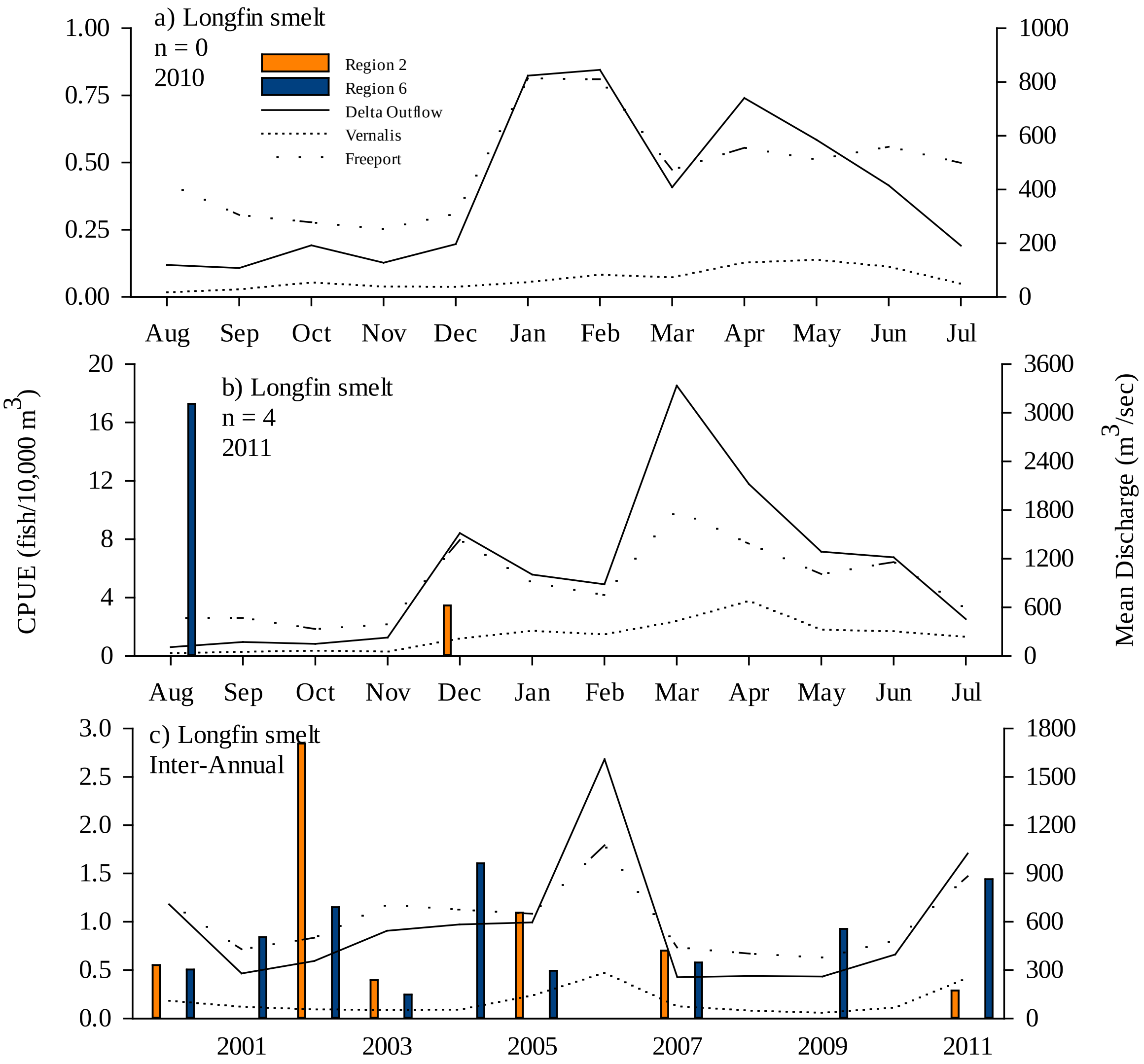


Figure 36. Mean monthly and yearly (field season) CPUE of longfin smelt captured in beach seines at Regions 1-6, and mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

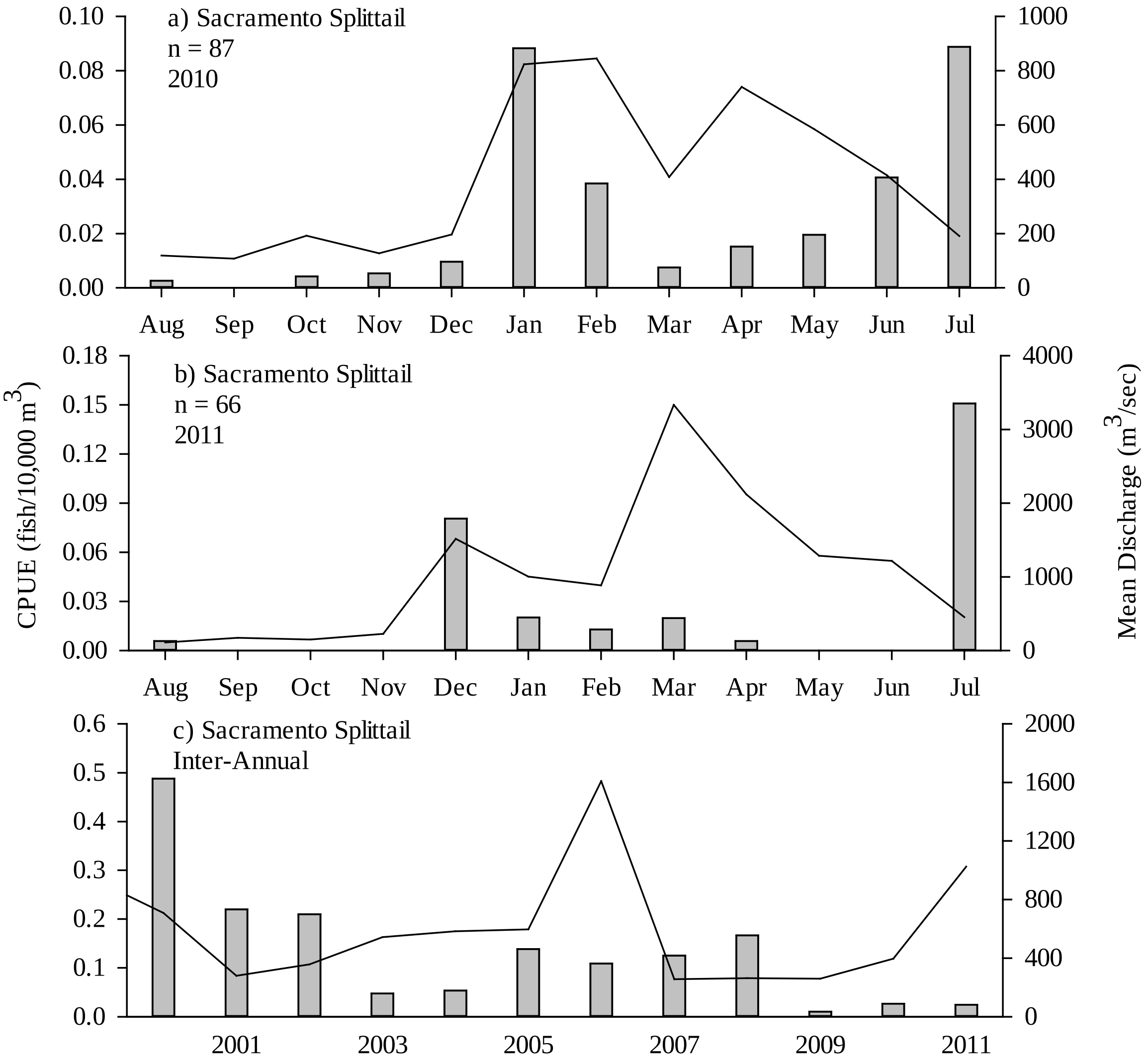


Figure 37. Mean monthly and yearly (field season) CPUE of Sacramento splittail captured in mid-water trawls (MWTRs) at the Chipps Island Trawl Site, and mean monthly and yearly Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

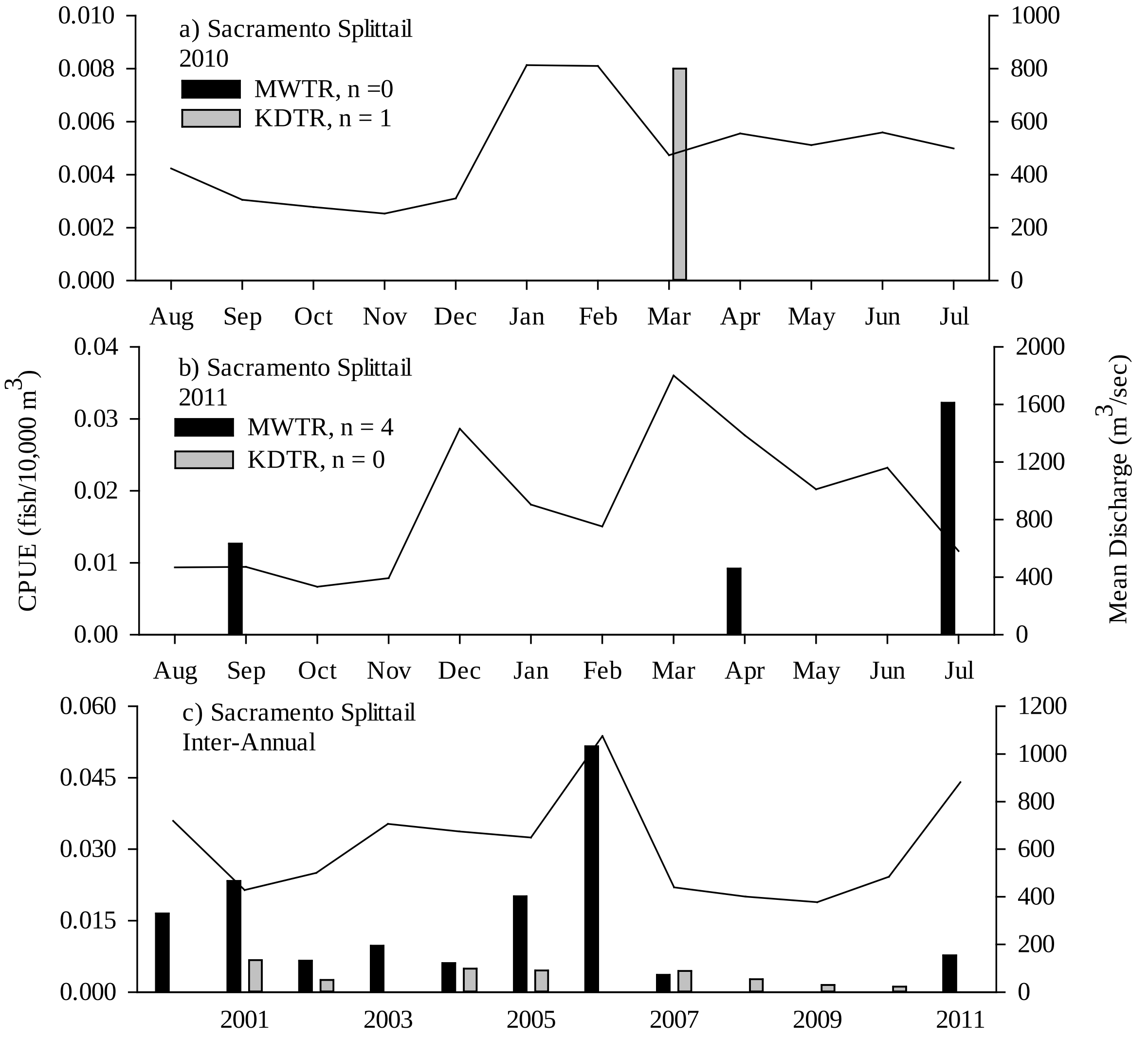


Figure 38. Mean monthly and yearly (field season) CPUE of Sacramento splittail captured in mid-water (MWTRs) and Kodiak trawls (KDTRs) at the Sacramento Trawl Site, and mean monthly and yearly Sacramento River discharge at Freeport during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

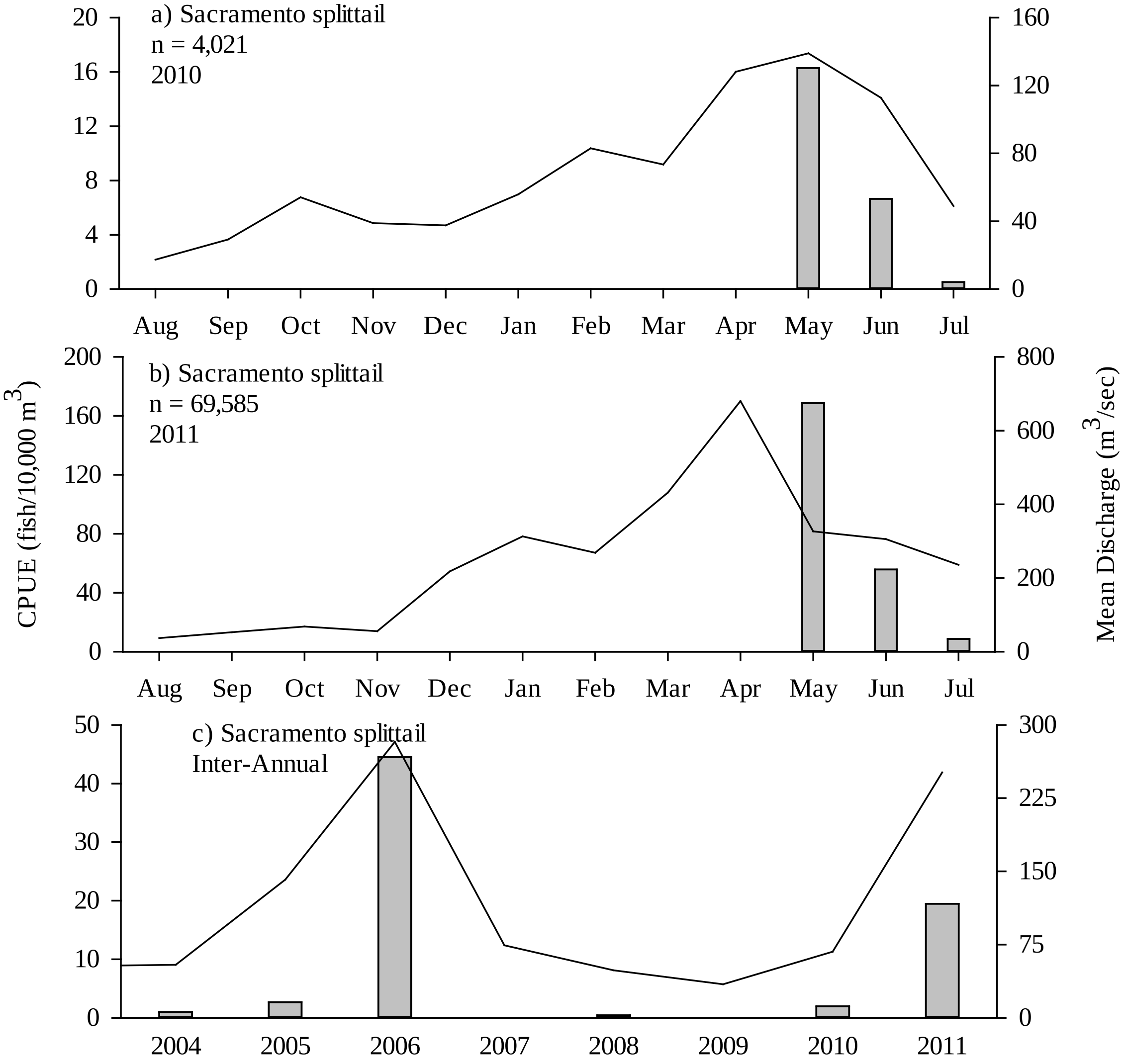


Figure 39. Mean monthly and yearly (field season) CPUE of Sacramento splittail captured in Kodiak trawls (KDTRs) at the Mossdale Trawl Site, and mean monthly and yearly San Joaquin River discharge at Vernalis during the a) 2010, b) 2011, and c) 2004 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2004 = August 1, 2003 to July 31, 2004).

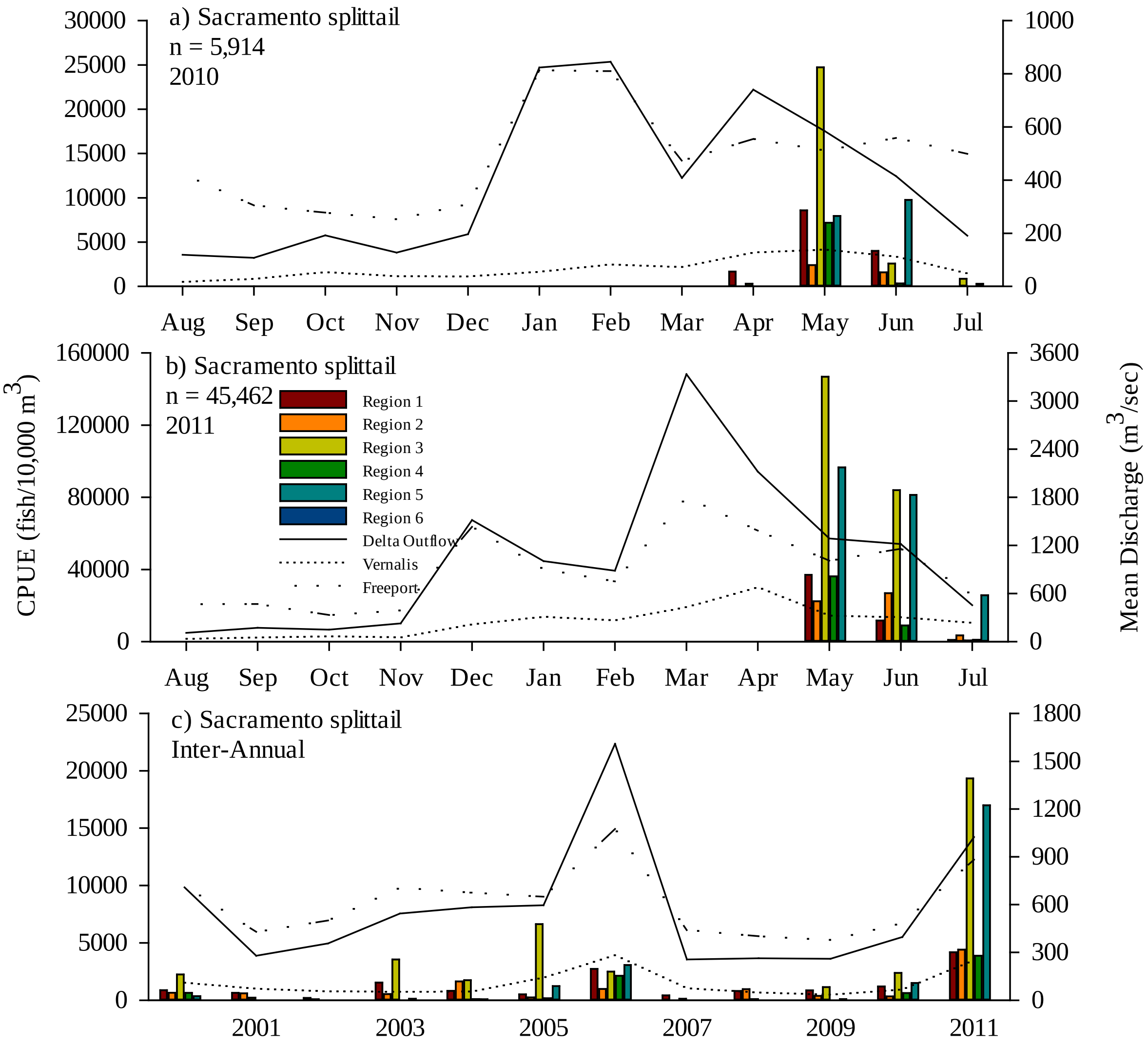


Figure 40. Mean monthly and yearly (field season) CPUE of Sacramento splittail captured in beach seines at Regions 1-6, and mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

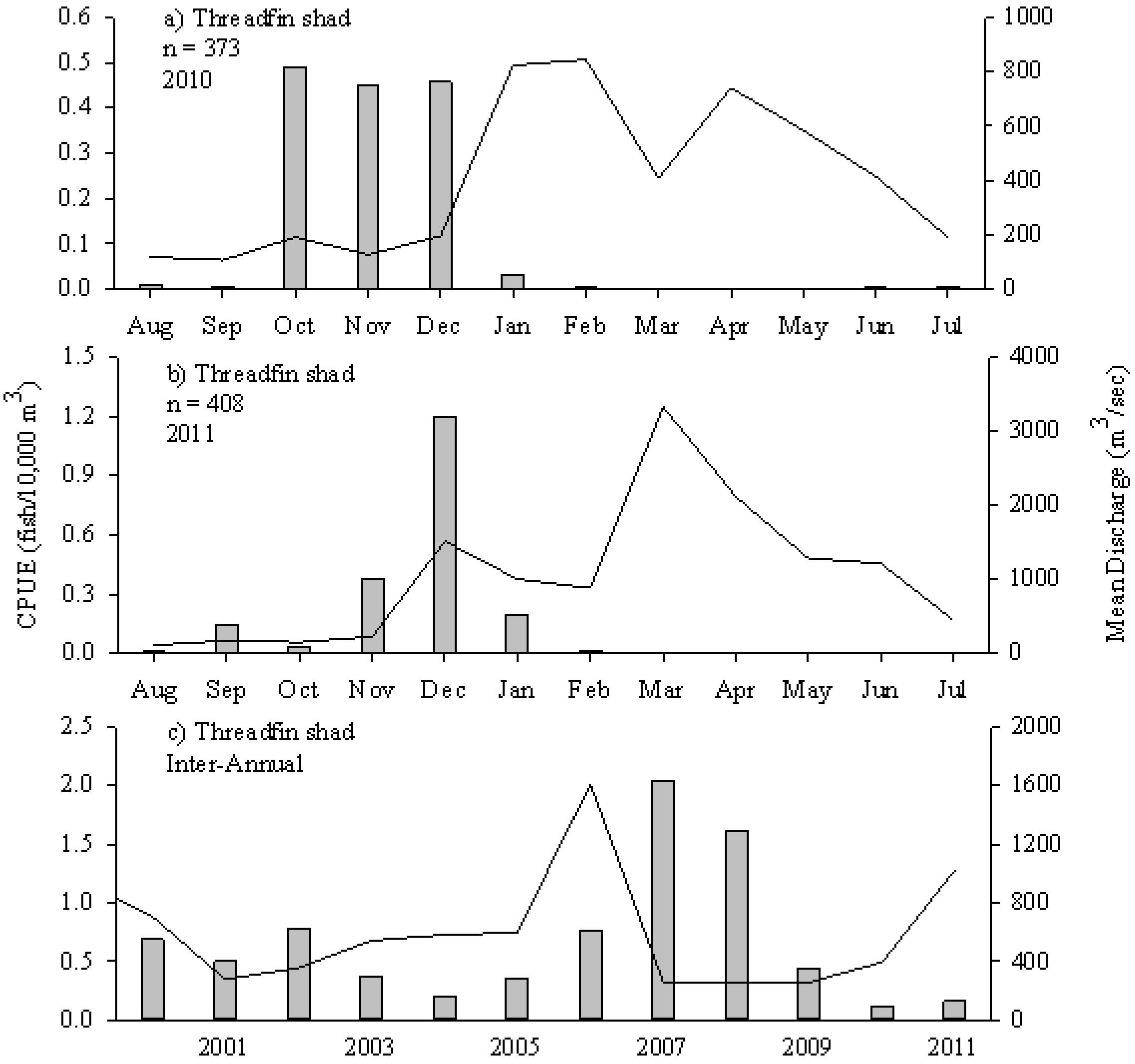


Figure 41. Mean monthly and yearly (field season) CPUE of threadfin shad captured in mid-water trawls (MWTRs) at the Chipps Island Trawl Site, and mean monthly and yearly Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

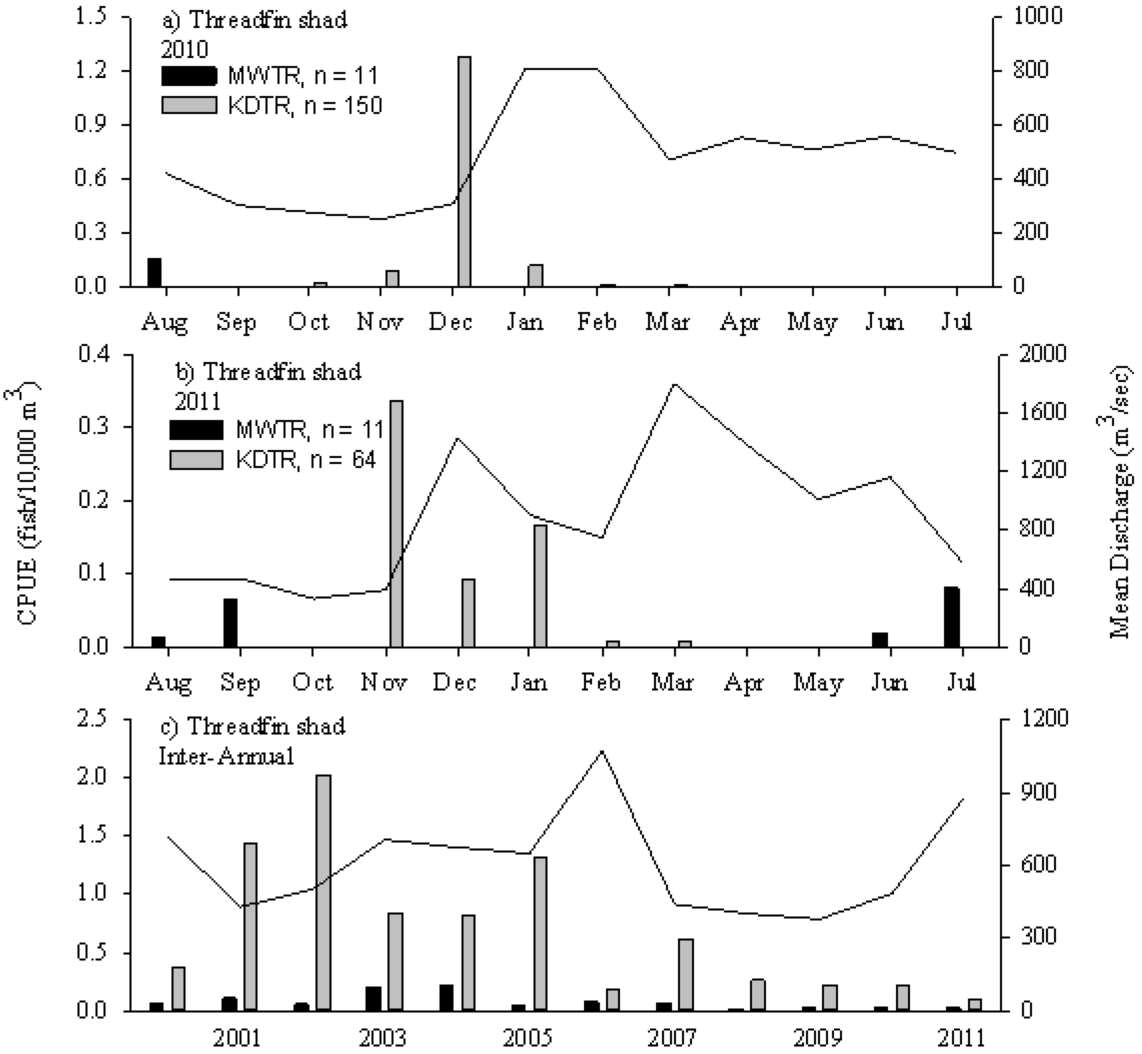


Figure 42. Mean monthly and yearly (field season) CPUE of threadfin shad captured in mid-water (MWTRs) and Kodiak trawls (KDTRs) at the Sacramento Trawl Site, and mean monthly and yearly Sacramento River discharge at Freeport during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

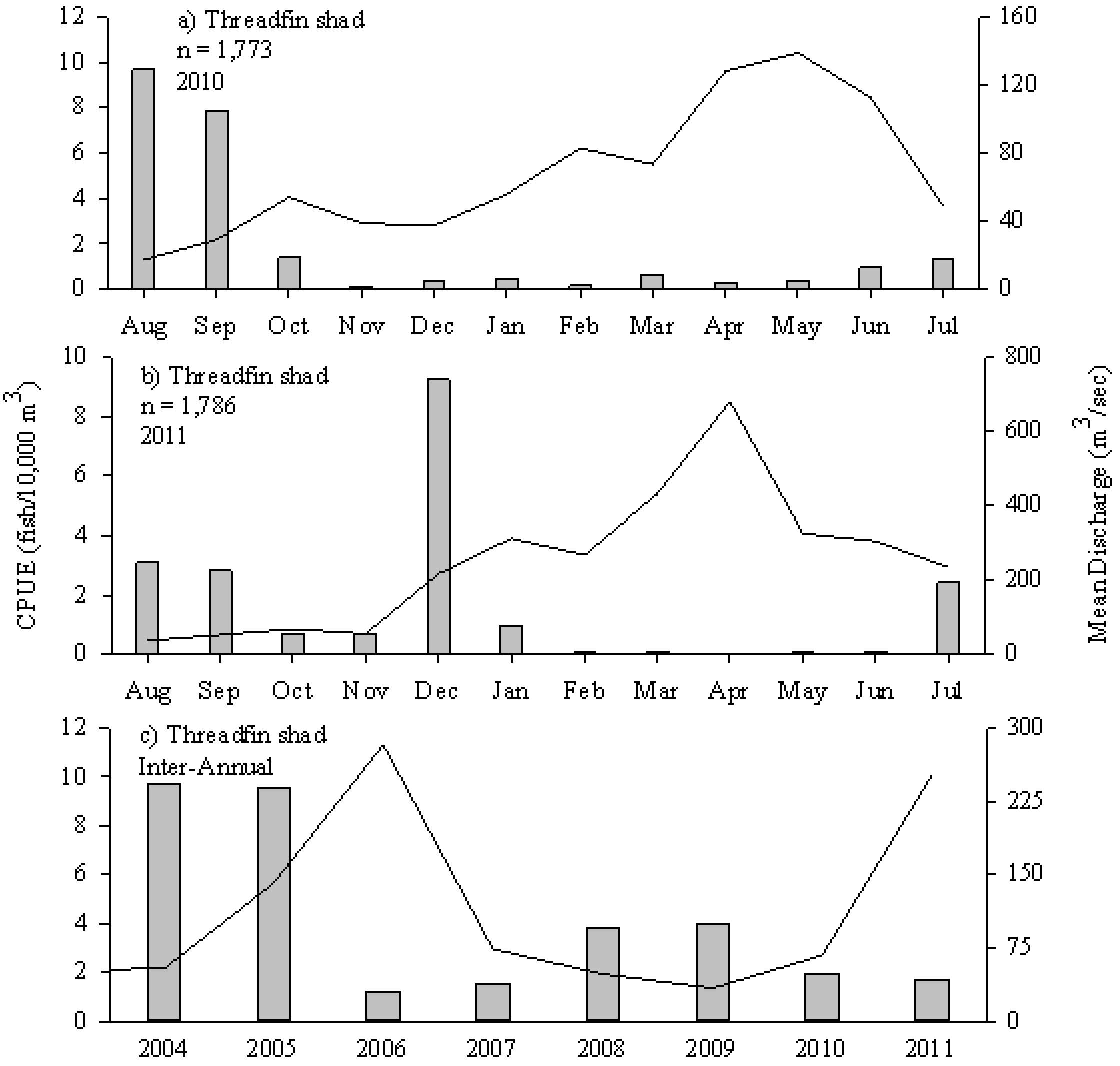


Figure 43. Mean monthly and yearly (field season) CPUE of threadfin shad captured in Kodiak trawls (KDTRs) at the Mossdale Trawl Site, and mean monthly and yearly San Joaquin River discharge at Vernalis during the a) 2010, b) 2011, and c) 2004 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2004 = August 1, 2003 to July 31, 2004).

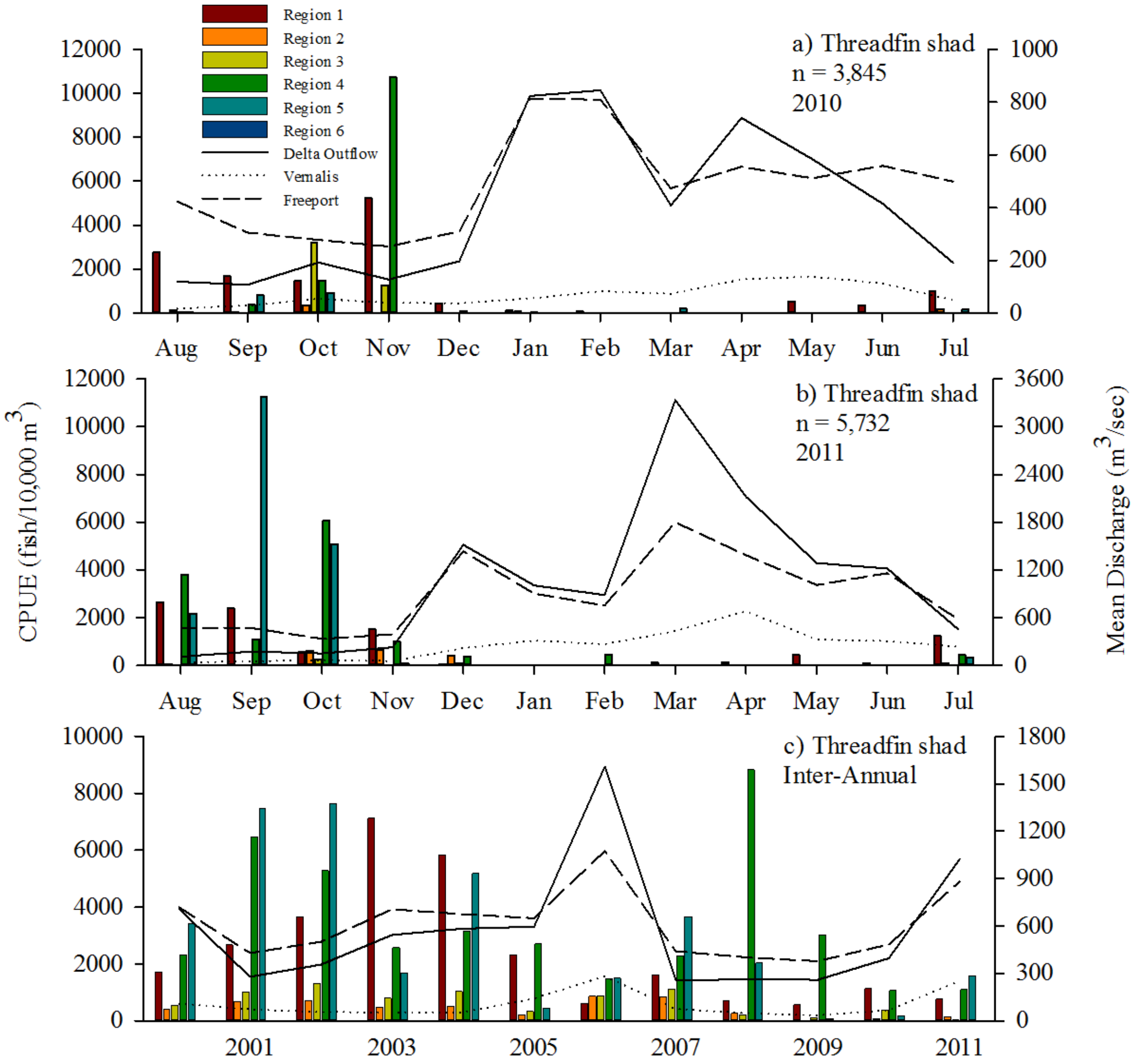


Figure 44. Mean monthly and yearly (field season) CPUE of threadfin shad captured in beach seines at Regions 1-6, and mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

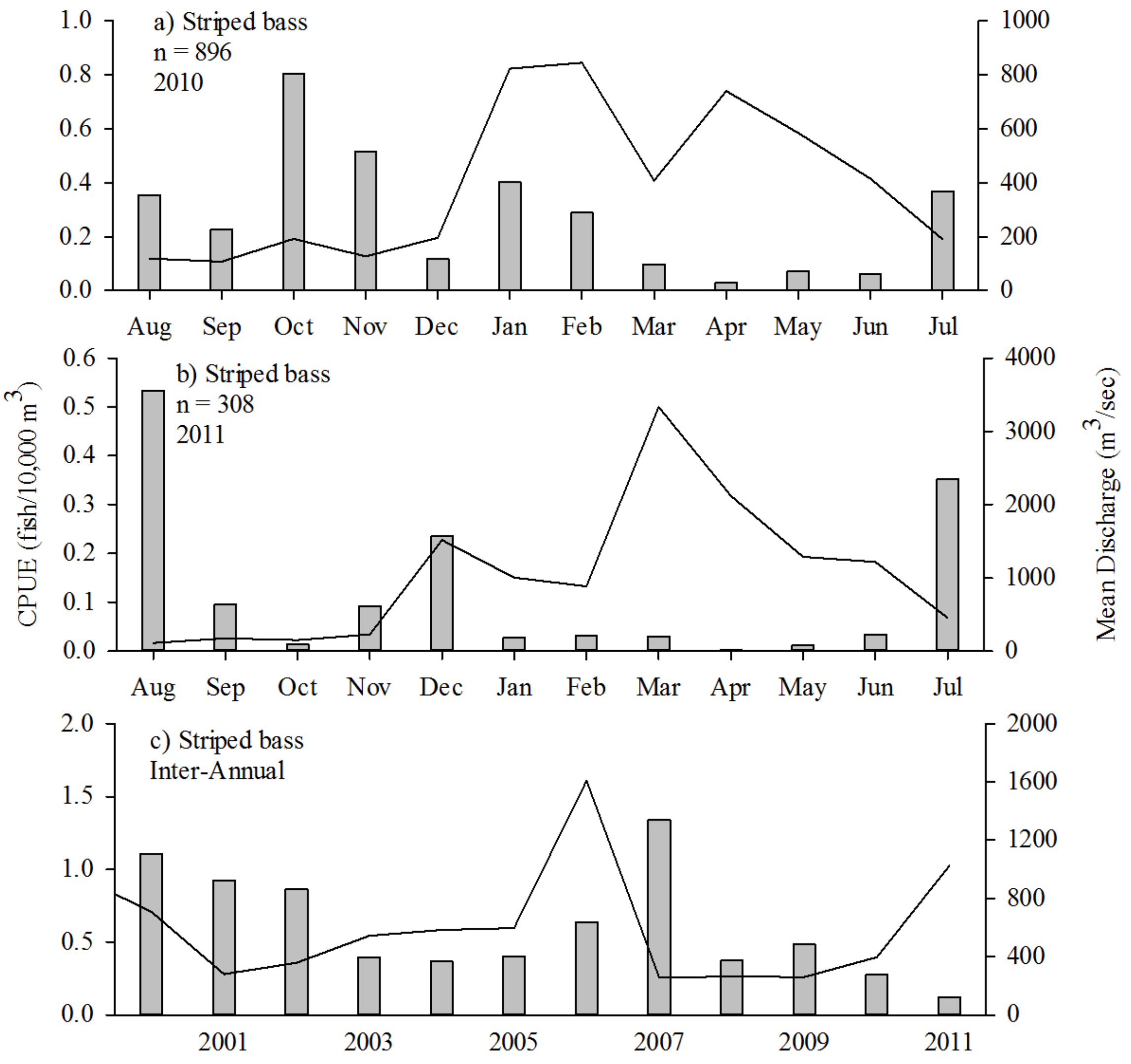


Figure 45. Mean monthly and yearly (field season) CPUE of striped bass captured in mid-water trawls (MWTRs) at the Chipps Island Trawl Site, and mean monthly and yearly Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

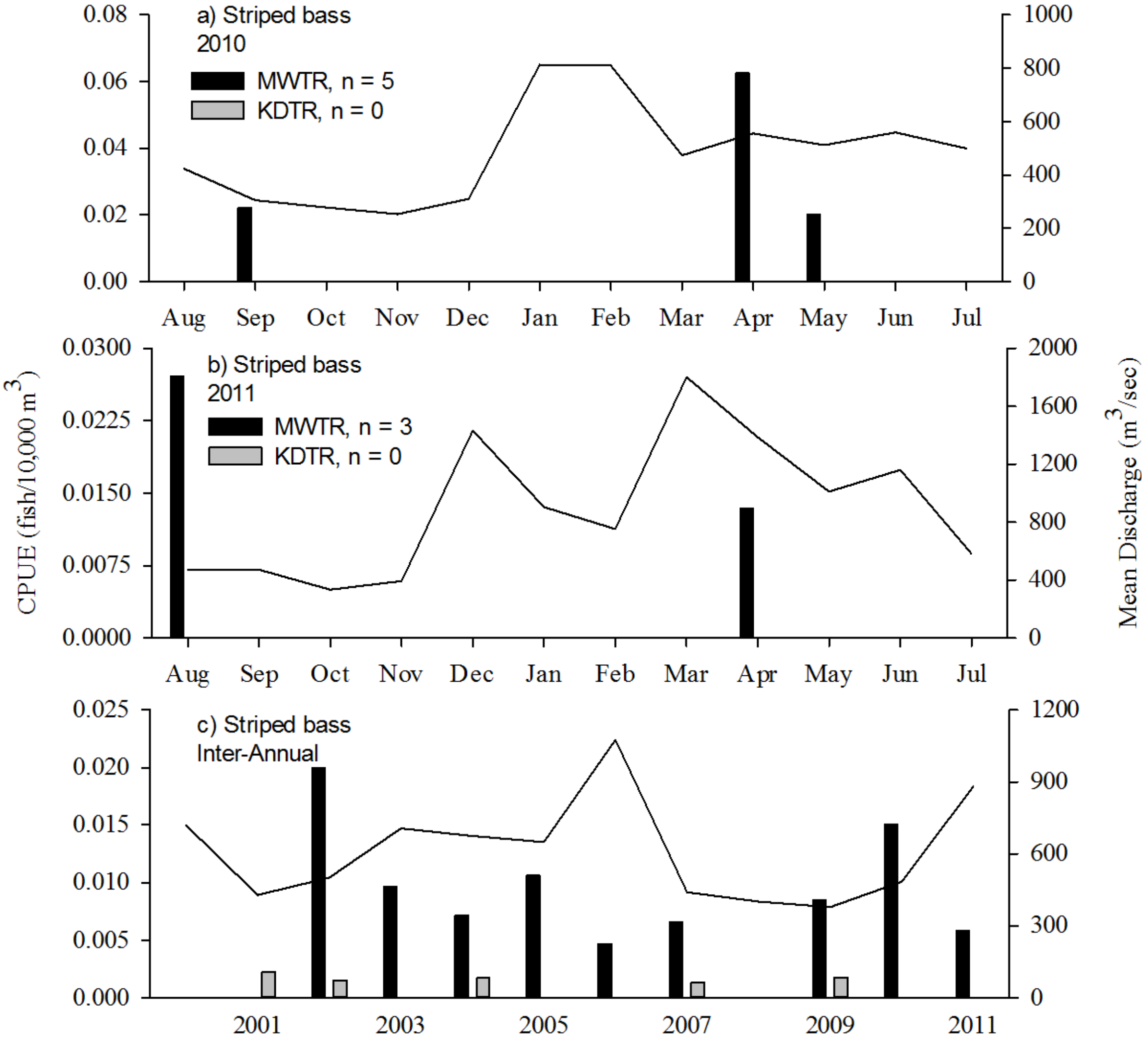


Figure 46. Mean monthly and yearly (field season) CPUE of striped bass captured in mid-water (MWTRs) and Kodiak trawls (KDTRs) at the Sacramento Trawl Site, and mean monthly and yearly Sacramento River discharge at Freeport during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

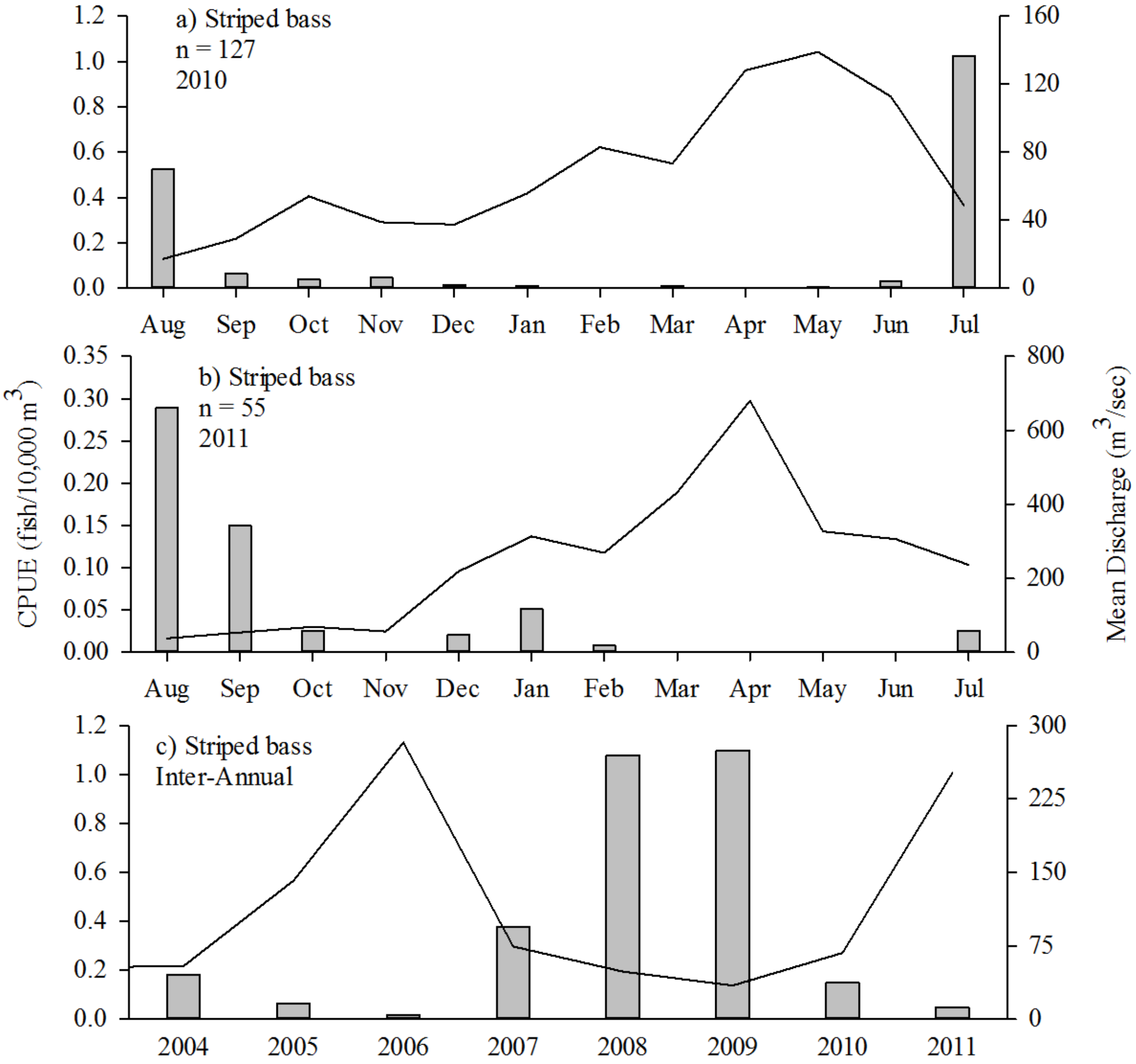


Figure 47. Mean monthly and yearly (field season) CPUE of striped bass captured in Kodiak trawls (KDTRs) at the Mossdale Trawl Site, and mean monthly and yearly San Joaquin River discharge at Vernalis during the a) 2010, b) 2011, and c) 2004 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2004 = August 1, 2003 to July 31, 2004).

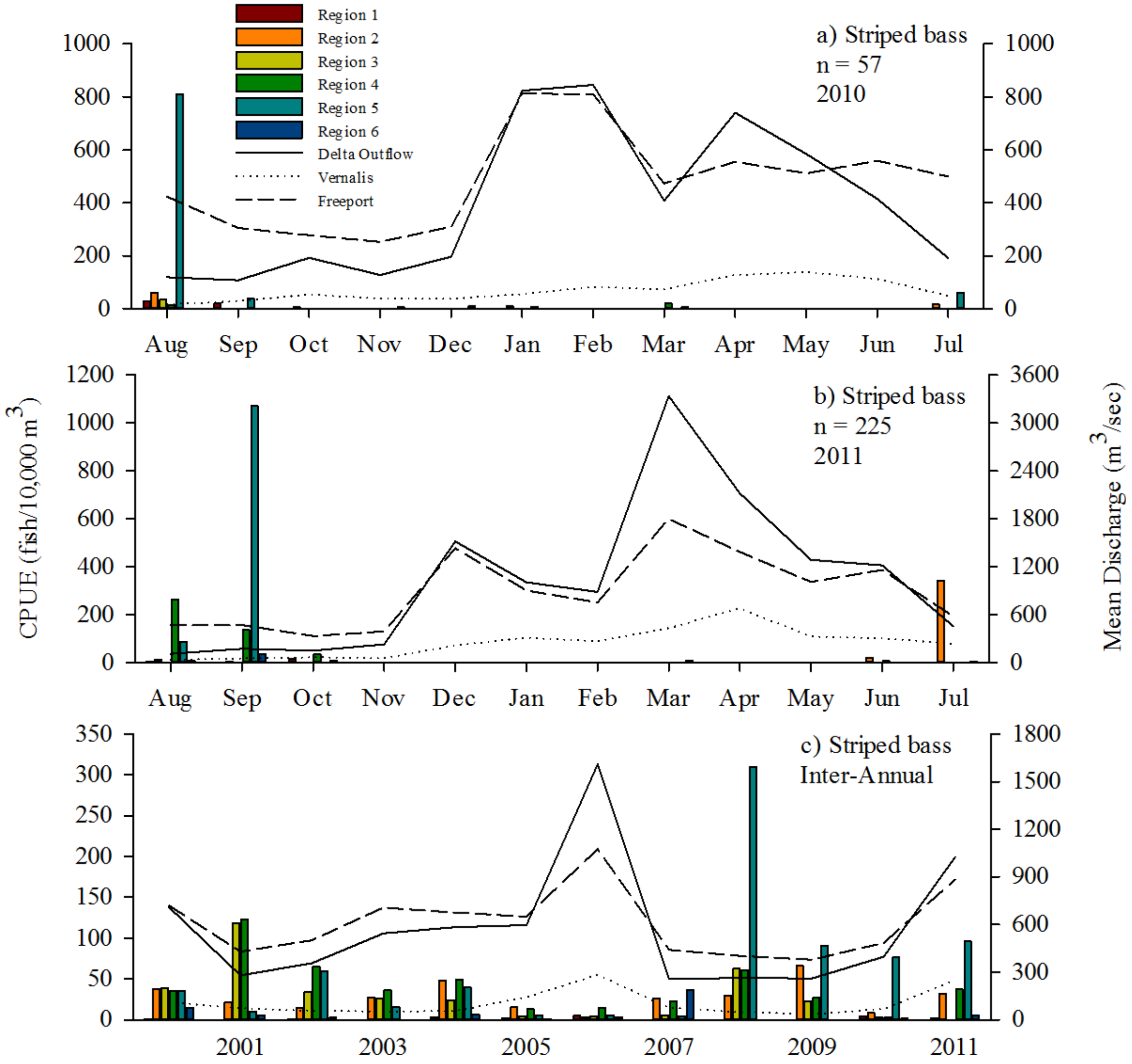


Figure 48. Mean monthly and yearly (field season) CPUE of striped bass captured in beach seines at Regions 1-6, and mean monthly and yearly Sacramento River discharge at Freeport, San Joaquin River discharge at Vernalis, and Delta discharge during the a) 2010, b) 2011, and c) 2000 through 2011 field seasons. Sample size (n) corresponds to total number of fish caught. Note, field seasons are defined as August 1 to July 31 (e.g. 2000 = August 1, 1999 to July 31, 2000).

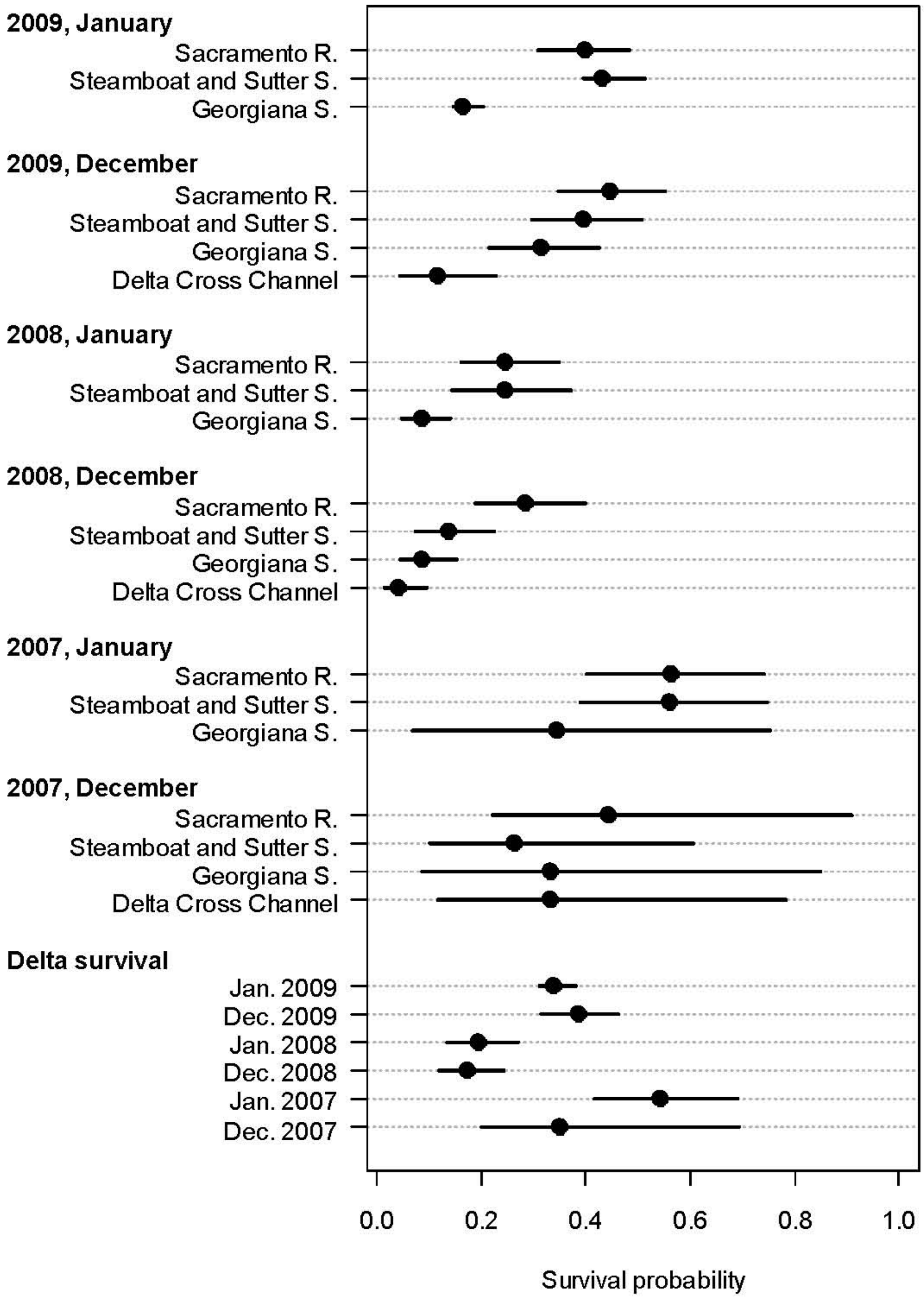


Figure 49. Survival through the north Delta and for different routes between Freeport and Chipps Island for tagged juvenile Chinook salmon (source: Perry 2010).

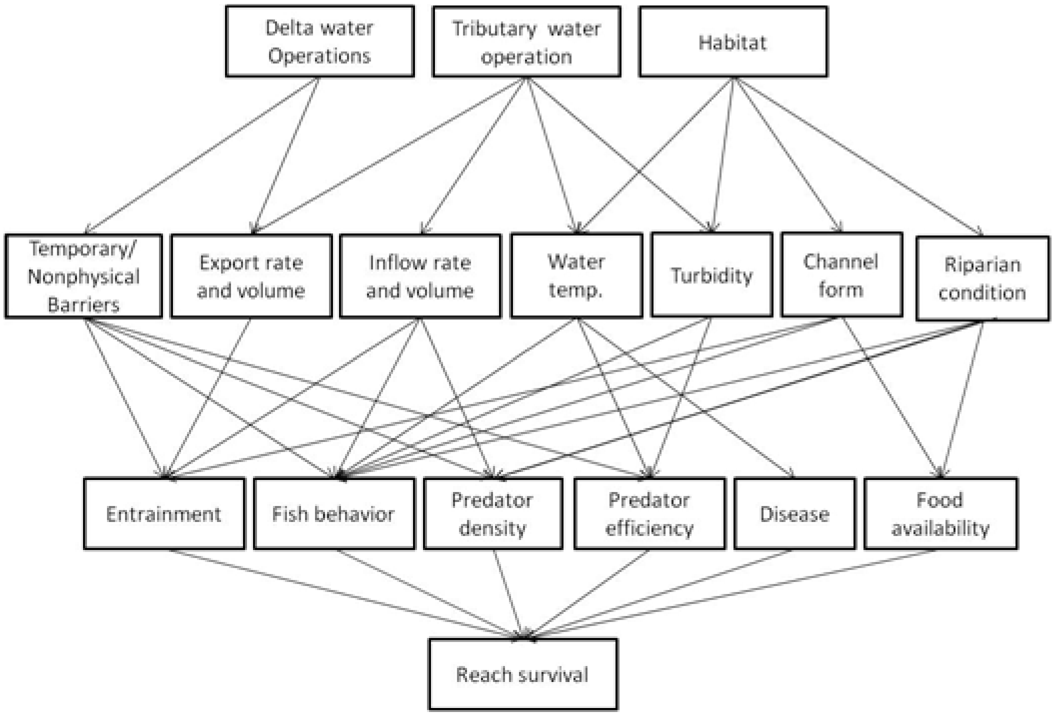


Figure 50. Conceptual model of how Delta water operations, tributary water operations, and habitat control biotic and biotic ecosystem variable influencing survival of steelhead and Chinook salmon smolts in a reach along the San Joaquin River and south Delta. The goal is to identify the factors influencing survival such that survival can be increased.

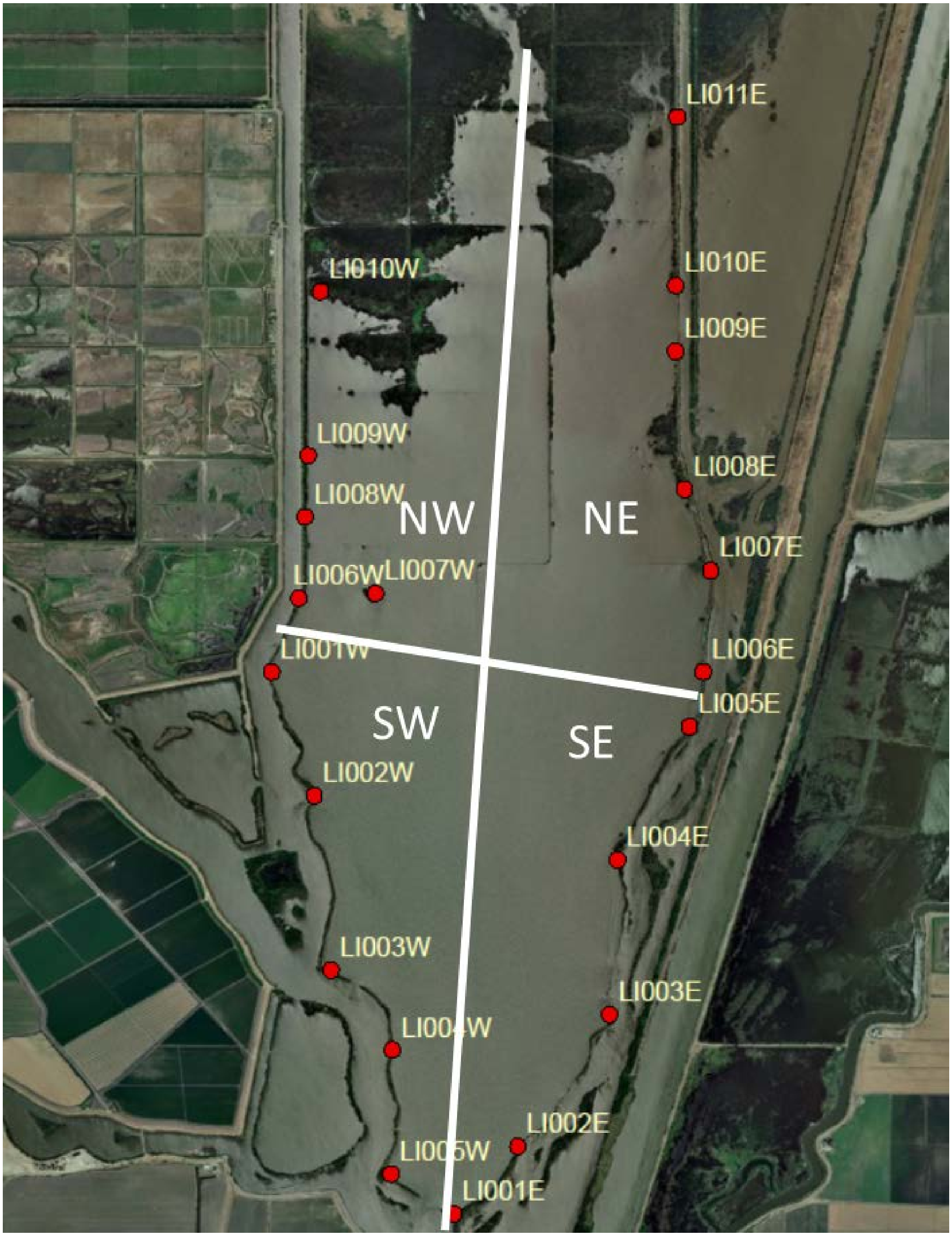


Figure 51. Beach seine sites within sampling quadrants at Liberty Island.

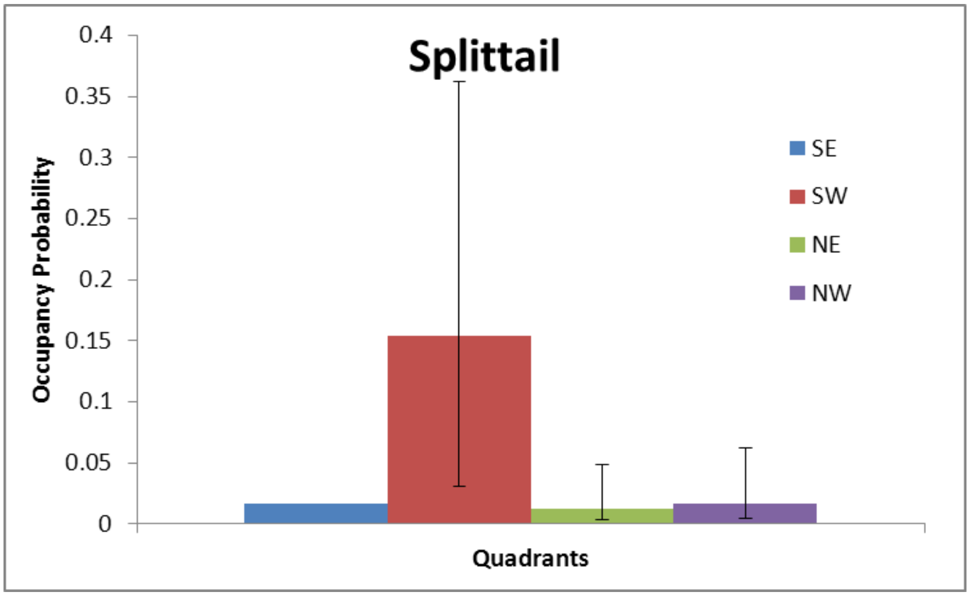


Figure 52. Splittail occupancy probability relative to quadrants for Liberty Island beach seine monitoring under baseline and average environmental conditions (January 2010 – July 2012). The southeast quadrant functions as the baseline condition, thus no error is reported while comparing among quadrants.

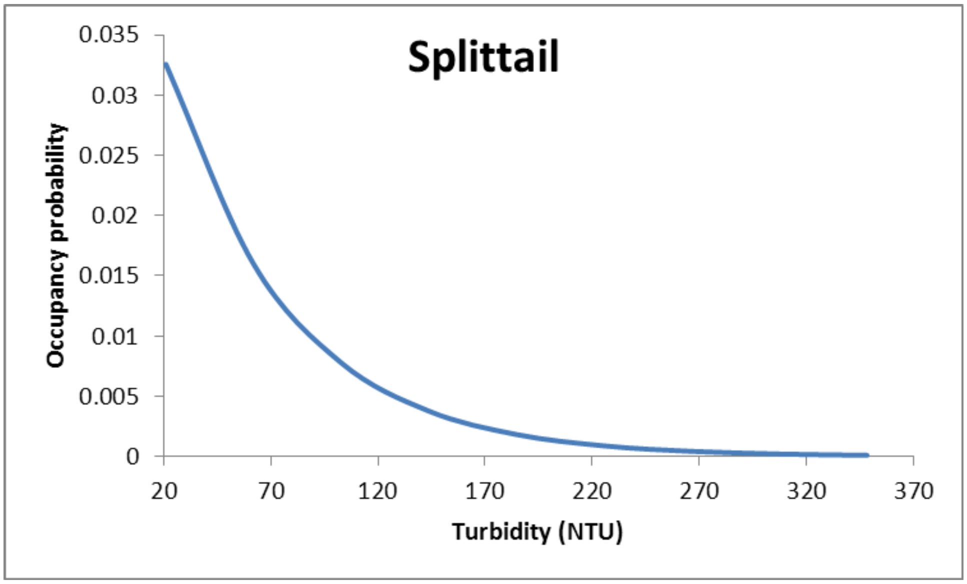


Figure 53. Splittail occupancy probability relative to turbidity for Liberty Island beach seine monitoring under baseline and average environmental conditions (January 2010 – July 2012).

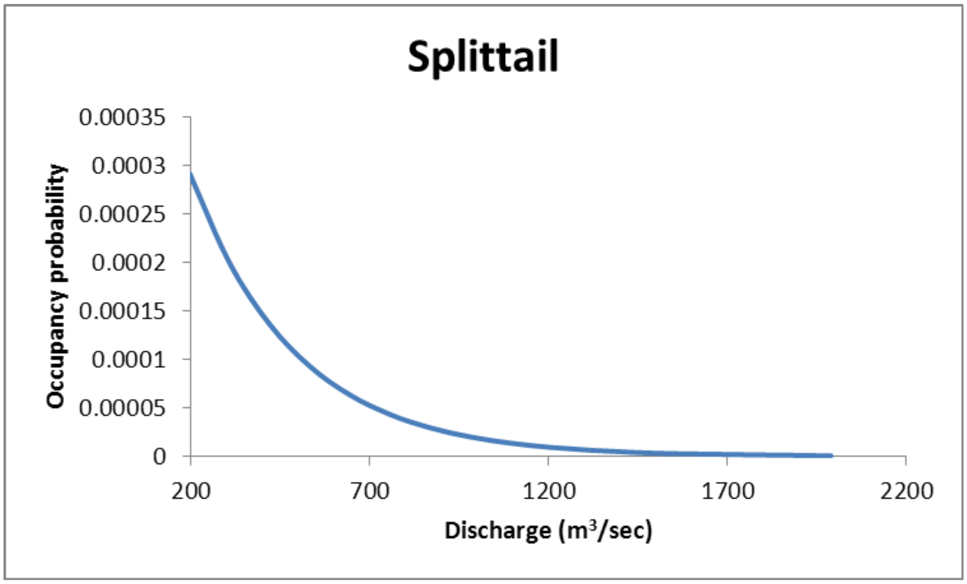


Figure 54. Splittail occupancy probability relative to discharge for Liberty Island larval trawls under baseline and average environmental conditions (April – June 2010, March – September 2011, February – March 2012).

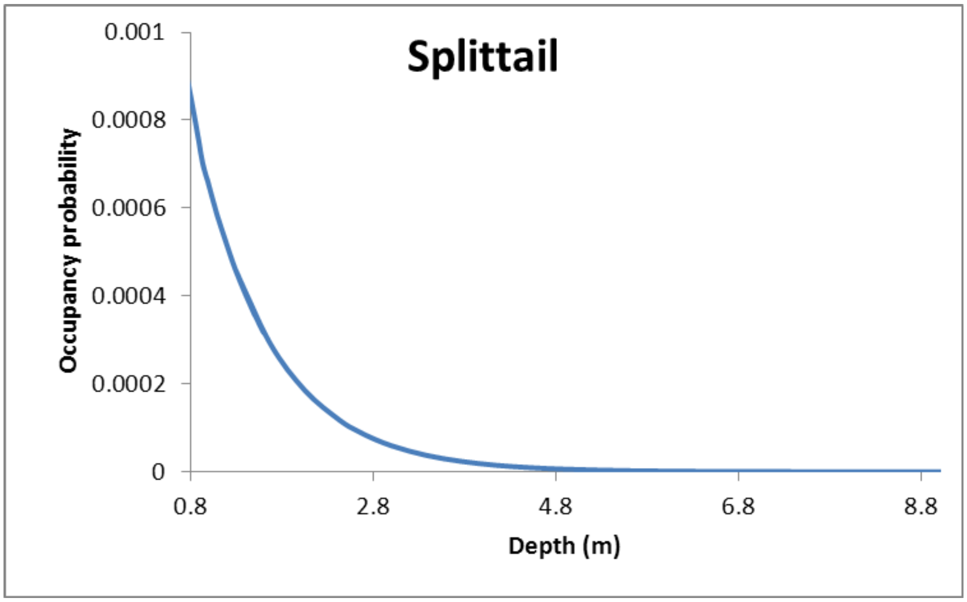


Figure 55. Splittail occupancy probability relative to depth for Liberty Island larval trawls under baseline and average environmental conditions (April – June 2010, March – September 2011, February – March 2012).

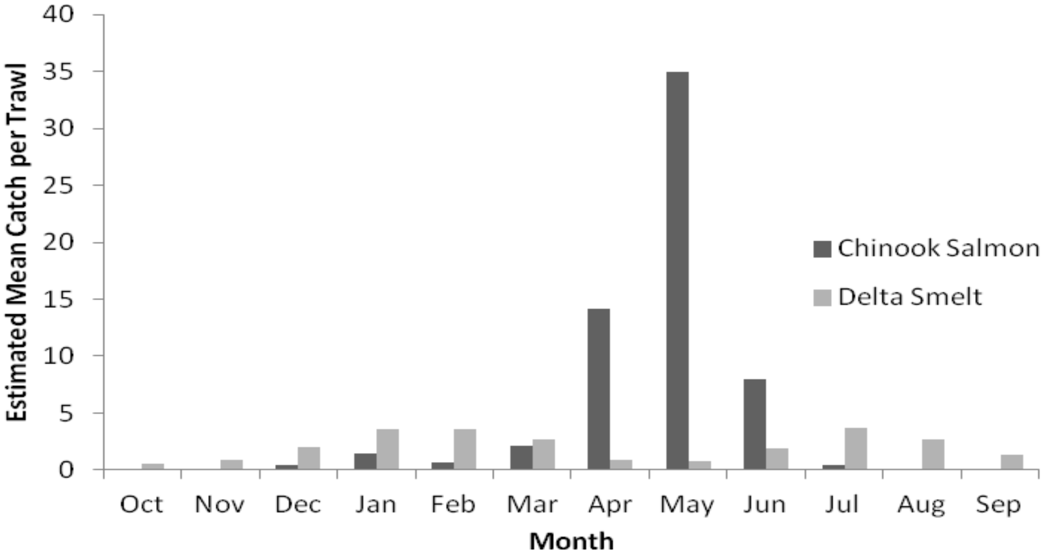


Figure 56. Estimated mean monthly catch of juvenile Chinook salmon and delta smelt per surface trawl at Chipps Island under average environmental conditions (samples were collected from July 2001 to December 2011). Estimates assumed the trawl occurred in the middle of the channel during a clear day, low tide, and sampled 20,000 m^3 of water.

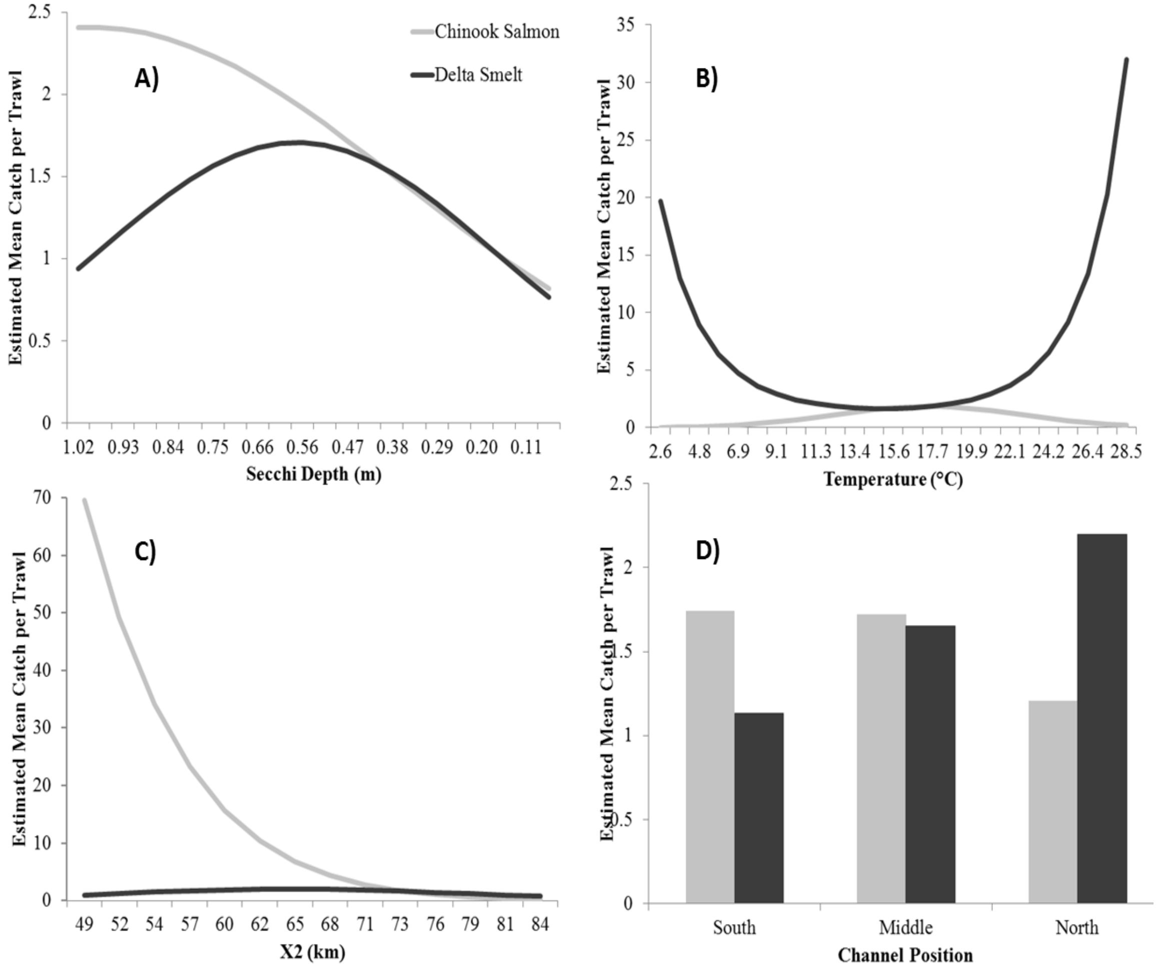


Figure 57. Estimated mean catch of juvenile Chinook salmon (grey) and delta smelt (black) per surface trawl at Chipps Island for varying (A) Secchi depths, (B) temperatures, (C) X2 positions, and (D) channel positions under average environmental conditions (samples were collected from July 2001 to December 2011). Estimates assumed the trawl occurred during a clear day, low tide, and sampled ~20,000 m^3 of water.

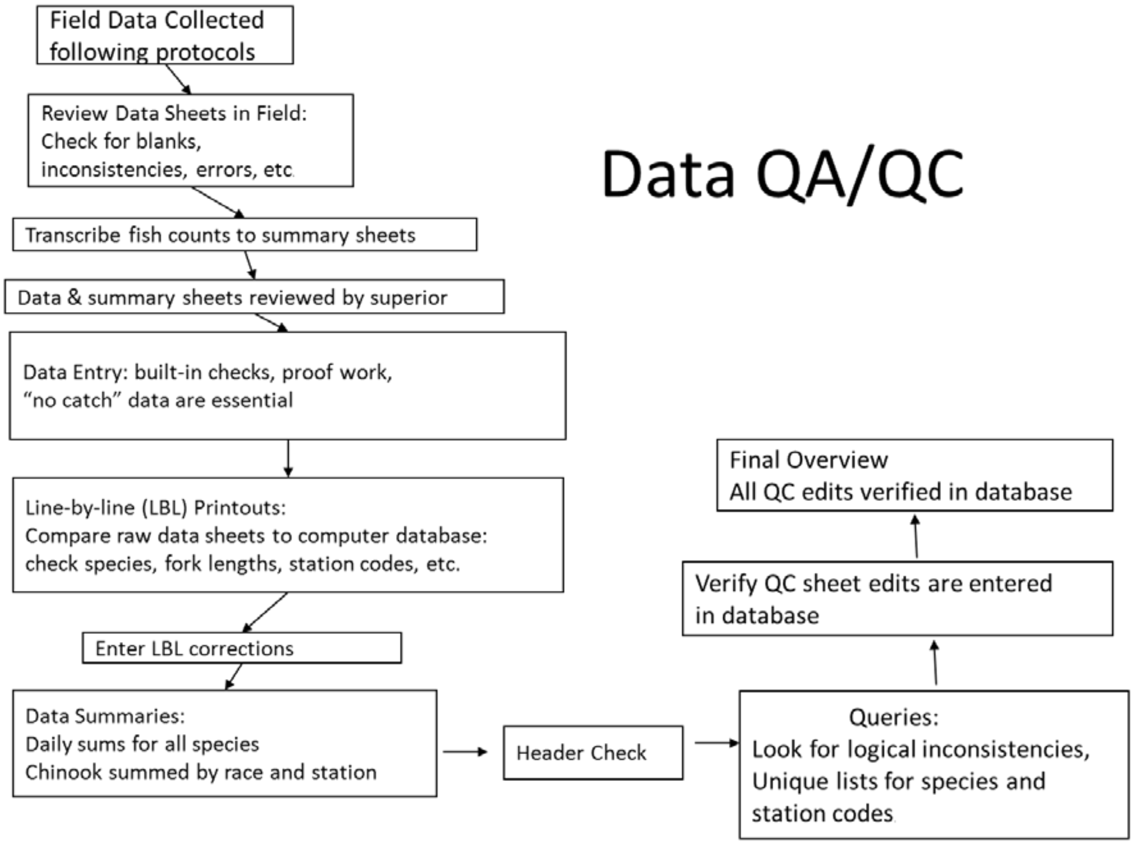


Figure 58. Data collection, entry and QA/QC procedures.

APPENDIX A: NOTES FROM DJFMP SCOPING WORKSHOP

Date: 5/11/12

A. Big Picture points about what should go into the review

1. FWS should identify key management and general life history needs and unknowns. For example, there are currently three ESA-listed salmonids (winter-run, spring-run, and steelhead) but it is not clear how the DJFMP can help inform the status and trends of the species/races. The review panel should be aware of the key management problems, so they can evaluate if the DJFMP monitoring program is providing sufficient data to address these unknowns.

2. FWS should develop conceptual models for the different salmonids, attempting to integrate how the Delta fits within the continuum of upstream to ocean dynamics. Developing a conceptual model could help reveal the components being satisfied by the DJFMP and JSSS programs and reveal components that need to be added.

3. FWS should state the benchmarks and performance metrics that data users want from the different components of the monitoring programs. This can help identify if the monitoring programs are providing information needed to satisfy management needs or if the programs need to be expanded to get additional critical information.

4. Perhaps there is a danger in the program attempting to be too comprehensive. The programs should be clear about the data being collected and what it is used for. In addition, FWS should be clear about the limitations of the data.

5. FWS needs to identify the data users. This could be done using a data survey form to IEP list serves. FWS should conduct a cost-benefit analysis to determine if the data collection is worth the bang for the buck.

6. FWS should describe how all the IEP monitoring programs fit together to answer questions about salmon abundance and trends. Going through this process may help inform the IEP, not just about DJFMP and JSSS limitations, but limitations of the IEP program as a whole as it relates to salmon.

7. FWS should state that ongoing life cycle model efforts by NMFS and describe their role in feeding this model work. Further, it would be helpful if FWS and NFMS identified management actions that feed the life cycle models, not only for understanding the past, but also, for predicting the future under different management scenarios (e.g., BDCP).

8. FWS should state the importance of the San Joaquin River and south Delta survival

9. FWS should describe what they believe are the mechanisms that underlie survival so they have better understanding of management decisions and monitoring information. It was noted that some of the JSSS manuscripts have done this and these should be highlighted to the review

panel. FWS could better clarify how the JSSS relate to population benefits for the different salmon runs.

10. The FWS should put hatchery effects in context of population-level dynamics.

11. FWS and NMFS should be distinguishing between management and research goals.

12. FWS should ask if they should be doing more special studies than voyeur monitoring and ask whether these studies would improve monitoring information and design.

13. FWS should make clear how juvenile production estimates relate to Chipps Island Trawl data

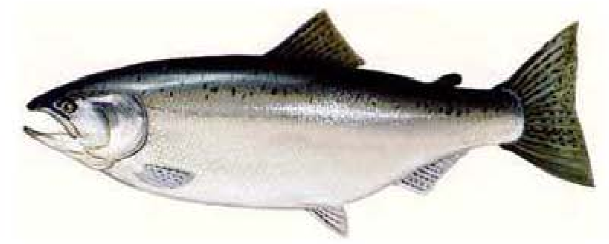
14. IEP and FWS need a better understanding of resource allocation of the DJFMP and JSSS monitoring programs.

15. The FWS should make a database that is readily available to all and be easy to use (e.g., have good metadata).

APPENDIX B: ANALYSES OF CWT RELEASES INTO THE SAN JOAQUIN SYSTEM

Analyses of Salmon CWT Releases into the San Joaquin System

Ken B. Newman, USFWS
2 March 2010



1. Overview
   - Objectives: to understand how different factors (flows, exports, barrier at head of Old River, HORB) affect survival of juvenile salmon outmigrating from San Joaquin system
   - Data Generation: CWT Release-Recovery "sets", 4-5 release locations and 2-3 recovery locations
   - Data Analysis: (Bayesian) Hierarchical Models
   - Key Results: Usually higher survival if stay in San Joaquin River than if go down Old River BUT lots of Environmental Variation, i.e., low Signal:Noise Ratio!
2. Data Generation
   (a) Between 1985 and 2006, 35 Release-Recovery sets.
   (b) Within a set, at most 3 release locations (e.g., Mossdale, Dos Reis, and Jersey Point).
   (c) At most 3 recovery locations: Chipps Island, Ocean fisheries, and since 2000, Antioch
   (d) $\Rightarrow$ 212 observations
3. Data Analysis
   (a) BHMs (Bayesian Hierarchical Models)
   (b) Key idea: 2 or more levels of modeling
   (c) Separate modeling of Observation (Sampling) noise from Survival (and capture) variation
   (d) Level 1: Observation Models y's $\sim$ Probability Distribution(R, S_t and p_t)
   (e) Level 2, Random effects: S_t, p_t $\sim$ Probability Distribution(η, Covariates)
   (f) Level 3, Hyperparameters: $\eta \sim$ Prior Probability Distribution
   (g)
   (h) Focus on Models for Survival down San Joaquin and Survival down Old River

$$\begin{aligned} E[logit(S_{DR\rightarrow JP})] &= \xi_0 + \xi_1 \text{Flow}_{Dos.Reis} + \xi_2 \text{Exports}_{Dos.Reis} \\ E[logit(S_{OR\rightarrow JP})] &= \zeta_0 + \zeta_1 \text{Flow}_{OldRiver} + \zeta_2 \text{Exports}_{Mossdale} \end{aligned}$$

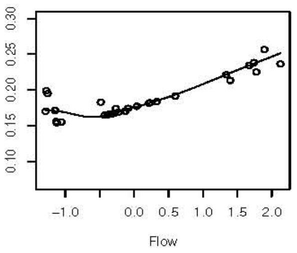
   (i) Fitting Details: WinBUGS with Reversible Jump model selection

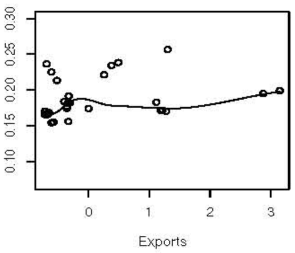
4. Results
   (a) Posterior Probabilities

Models	$S_{MD\rightarrow JP}$	$S_{OR\rightarrow JP}$
Constant	0.38	0.45
Flow	0.29	0.23
Exports	0.17	0.21
Both	0.16	0.11

   (b) Coefficients

Covariate	Average	SD	2.5%	median	97.5%
SJ-flow	0.16	0.25	-0.09	0.0	0.77
SJ-exports	0.07	0.19	-0.17	0.0	0.61
OR-flow	0.04	0.22	-0.42	0.0	0.62
OR-exports	0.04	0.20	-0.32	0.0	0.60


E[Survival DR->JP] vs Flow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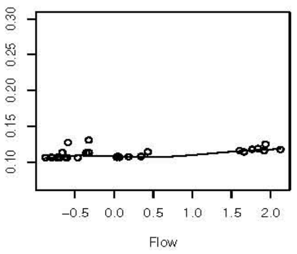
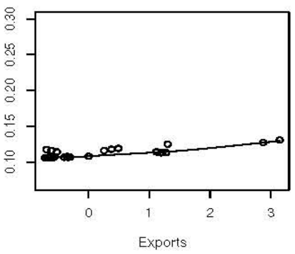

E[Survival OR->JP] vs Flow


E[Survival OR->JP] vs Exports

5. Caveats and Comments
   (a) Priors *do* matter, especially with Hierarchical Models
   (b) More to wring out of CWTs? Using time of capture? Add arrival time/travel time model?
   (c) Acoustic tags far preferable?
   (d) Value in probing extreme values for flows and exports

Some references:

- Clark, J.S. 2005. “Why environmental scientists are becoming Bayesians.” *Ecology Letters*, **8**: 2–14.
- Clark, J.S., and Gelfand, A.E. 2006. “A future for models and data in environmental science.” *Trends in Ecology and Evolution*, **21**: 375–380.
- Newman, K.B., and Brandes, P.L. 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports. *North American Journal of Fisheries Management*, **30**: 157–169.

APPENDIX C: BEACH SEINE EFFICIENCY EVALUATIONS

Introduction

Fishery managers rely on abundance and distribution metrics derived from long term monitoring data to make decisions that affect fish population dynamics and assemblage structure. The accuracy of population metrics and effectiveness of management decisions will depend on the accuracy of sample data (Price and Peterson 2010). Therefore, accurate sample data are essential in determining fish population trends and identifying the factors that influence them. Unfortunately, fish sample data are generally plagued by incomplete detection (i.e., false absences) of individual fish and fish species (Bayley and Peterson 2001). Many studies have demonstrated that the detection of fishes can vary considerably among sampling gears and methodologies, environmental conditions, and fish sizes and species (e.g., Bayley and Dowling 1990; Pierce et al. 1990; Peterson et al. 2004; Lapointe et al. 2006; Price and Peterson 2010). As a result, the true abundance and distribution of fishes from sample data are often underestimated to varying degrees across time and space (Bayley and Peterson 2001) and difficult to compare across studies (e.g., Feyrer and Healey 2003). Further, unknown and variable sample bias may produce misleading inferences regarding the spatial and temporal patterns of fish populations and assemblage structure within a study. Therefore, fishery managers must account for variable sampling efficiency when quantifying population metrics to minimize the effects of sampling biases (Bayley and Peterson 2001; Rosenberger and Dunham 2005; Peterson and Paukert 2009).

Beach seining has been used for more than 100 years to quantify and monitor fish abundance and distribution throughout the world's freshwater, estuarine, and marine environments (Pierce et al. 1990; Murphy and Willis 1996; Bayley and Herendeen 2000). Seine nets are often considered simple, cost effective, to cause minimal harm to fish, and effective for sampling unobstructed aquatic habitats (Pierce et al. 1990; Bayley and Herendeen 2000). However, numerous studies have identified limitations and biases of sample data collected using seines (e.g., Pierce et al. 1990; Allen et al. 1992; Bayley and Herendeen 2000). For example, Pierce et al. (1990) demonstrated that beach seine efficiency within littoral habitats located in Quebec's lentic systems is influenced by the size and life history strategies of fishes, physical obstructions (e.g., macrophytes, woody debris, etc.), and substrate. Although these limitations are recognized by most fishery managers today, there is considerable uncertainty of the absolute efficiency of beach seining. As a result, the relative measures of abundance and distribution may be biased if sampling efficiency varies across spatial and temporal scales.

Within the San Francisco Estuary, beach seining has been used since the 1970s by the DJFMP to monitor the relative abundance and distribution of juvenile Chinook salmon and other fishes of management concern occurring in near shore habitats. Over 2,000 seine samples are currently being collected throughout the San Francisco Estuary annually. Data from these surveys are used to inform managers on the relative abundance and distribution of fish populations within the San Francisco Estuary. By not accounting for the variability of species- and size-specific efficiency of beach seines across environmental gradients, the metrics developed by the DJFMP are likely underestimated and biased to an unknown extent. Consequently, the ability of the DJFMP to document the true occupancy of fishes may be limited. Therefore, the first objective of this study is to estimate the species- and size-specific capture efficiency of DJFMP beach seines for fishes occurring in near shore habitats within the San Francisco Estuary. The second objective is to model the observed efficiency estimates using habitat variables. Such information will allow managers to account for incomplete detection when estimating fish abundance and occupancy from DJFMP beach seine data.

Sampling design

The beach seine efficiency study is being conducted in conjunction with regular DJFMP beach seine sampling. The study will occur during three seasons each calendar year: fall (September to November), spring (March to May), and summer (June to August). During each season, we will conduct stratified random sampling of the 57 fixed monitoring sites distributed among six regions within the San Francisco Estuary (Figure 5). Five sites will be randomly selected from each of the six regions during each of the sampling seasons. No efficiency sampling will occur during the winter (December to February) season and during periods of peak juvenile Chinook salmon migration to minimize the take of salmonids listed under the State and Federal Endangered Species Acts (ESAs). Approximately one to two sites will be sampled within a day and all samples will be collected between sunrise and sunset.

Beach seine efficiency sampling will be conducted using a standard DJFMP beach seine net inside a block-net and gill-net enclosure. Although DJFMP beach seining is not traditionally conducted within an enclosure, the enclosure is necessary to determine the true population within the sampling area for efficiency estimation. We will use a standard DJFMP 15.2 x 1.3 m beach seine (3 mm delta square mesh) with a continuous lead bottom line, styrofoam floats along the top line, and a 1.2 m^3 bag in the center of the net. Unlike previous seine efficiency studies that used only a block-net enclosure (e.g., Pierce et al. 1990; Bayley and Herendeen 2000), the gill-nets will minimize the effects of fishes coming in contact with and reacting to the block-net. The gill-nets are intended to temporarily entrain fishes attempting to exit the sample area and therefore minimize fish reentering the sample area which can cause the overestimation of seine efficiency of fishes that would have been able to outrun and escape the gear and sample area. The block-net and gill-net enclosure will be composed of one 50 x 2m block-net (3 mm delta square mesh) and two 50 x 2 m monofilament gill-nets (~3 mm and ~10 mm square meshes; side by side) with a lead line bottom and the top line attached to numerous two-meter tall stakes installed one meter from the perimeter of the shoreline area to be sampled by the beach seine (Figure 2). The larger meshed gill-net will be placed on the inside portion of the enclosure to temporarily entrain larger fishes. The finer meshed gill-net will be placed on the outside portion of the larger meshed gill-net to temporarily entrain smaller fishes. The block-net will be placed on the outside portion of the enclosure (i.e., both gill-nets) to prevent fish recruitment from outside of the enclosure. We will install the stakes for the block-net and gill-net enclosure at least one hour prior to conducting the beach seine to minimize disturbance prior to sampling. During the installation of the stakes, the ends of the block-net and gill-nets will be secured to the shoreline (≤15 m apart) and the middle of the gill-nets will be attached to the top of each stake in the water and will be held just above the water surface. Just prior to sampling, the block-net and gill-nets will be released remotely, allowing the bottom of the nets to sink to the substrate to fully enclose the fishes inside the sample area. To minimize the stress to fishes listed under the ESAs, gill-nets will be monitored throughout the efficiency sampling. If any fishes listed under the

ESAs are observed in the gill-nets during sampling, they will be immediately removed, processed, and released unharmed outside of the enclosure to prevent injury and future capture. In addition, gill-nets will be deployed for less than 90 minutes to prevent mortality.

After the block-net and gill-nets are deployed, fish will be sampled within the enclosure using the DJFMP beach seine (henceforth referred to as primary seine) following the DJFMP standard operating procedures (see objective 1 for details regarding beach seine methods). All fish collected by the primary beach seine will be handled with wet hands, identified to species, measured for fork length, and recorded as the primary seine catch. We will immediately release all processed fish outside of the enclosure to prevent further capture. After the primary seine catch is processed, all fish remaining within the enclosure will be collected using a combination of other active sampling methodologies and gears (henceforth secondary gears; e.g., additional beach seines and backpack electro-fishers, etc.). When backpack electro-fishers are used as a secondary gear within the enclosures, all staff will follow the National Marine Fisheries Service June 2000 Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act to further reduce fish injury. In addition, no electrofishing will be conducted within San Pablo Bay based on expected low gear efficiency due to high salinity. Once no additional fish are collected within the enclosure by secondary gears, all fish will be immediately removed from the gill-nets around the sample area. The orientation of the fish entrained within the gill-nets will be recorded to differentiate the individuals that occurred within the study area from individuals that attempted to enter the enclosed area after the gill-nets were deployed. All fish collected within the secondary gears and gill-nets will be handled with wet hands, identified to species, measured for fork length, recorded as fish not detected by the primary beach seine, and be immediately released.

Stream habitat measurements

Water quality and physical in-stream habitat characteristics hypothesized to influence either fish occupancy or the ability to detect fish will be measured within each enclosure at each fixed beach seine site for each sampling occasion. After beach seine efficiency sampling, water quality characteristics will be measured one meter upstream from the gill-net enclosure using calibrated meters at each site to prevent any sample contamination. We will measure water temperature to the nearest 0.1 ºC, dissolved oxygen (DO) to the nearest 0.01 milligram per liter (mg/L), and specific conductance to the nearest 0.01 microsiemens per centimeter (µs/cm) using an YSI Pro 2030 meter. Turbidity will be measured using an HACH 2100P turbidimeter meter to the nearest 0.01 Nephelometric Turbidity Unit (NTU).

Immediately after the enclosure stakes are installed, prior to beach seine efficiency sampling, physical in-stream habitat characteristics will be quantified within the enclosure. Enclosure width, length, mean maximum depth, and mean water velocity will be recorded. Mean maximum depth will be estimated by averaging measurements taken at three to five randomly selected locations along the edge of the enclosure on the opposite end of the shoreline. We will measure water depth to the nearest centimeter using a two meter top-set rod. Mean water velocity will be estimated by averaging measurements taken at three to five randomly selected locations within the enclosure (Peterson and Rabeni 2001b). Water velocity measurements will be taken at 0.6 x depth using a Marsh McBirney model 2000 Flo-mate meter in conjunction with a two meter top-set rod. The length and width of each enclosure will be measured to the nearest centimeter using a standard measuring tape. We will also estimate the mean volume of the enclosure by multiplying the enclosure length by the width and by the maximum depth divided by two, assuming a constant gradient. The area of each enclosure will be estimated by multiplying the enclosure width by length. The mean shoreline gradient will be estimated by taking the inverse tangent of the enclosure's length divided by the mean maximum depth.

Substrate composition within an enclosure will be quantified visually, as percentages, by two or more crewmembers and averaged (Peterson and Rabeni 2001b). If water visibility is too poor for visual estimation, substrate composition will be estimated from ten random substrate samples taken by a small ponar or a shovel. Substrate composition will be categorized based on particle diameter as fine sediment (<5 mm), gravel (5-50 mm), cobble (50-300 mm), boulder (>300 mm), and concrete (modified from Dunne and Leopold 1978). Woody debris density will be quantified by counting the pieces of large wood within the enclosure that were >50 cm in length and >10 cm in diameter or aggregates of smaller pieces of wood with comparable volume and dividing by the enclosure's surface area. Submerged, emergent, and floating aquatic vegetation within an enclosure also will be quantified visually, as percentage of surface area present, by two or more crewmembers and averaged.

Beach seine efficiency analysis

We will calculate the DJFMP's beach seine efficiency (q) for fish species, guilds, and/or size classes as:

$$q = c/v \qquad (1)$$

where c represents fish captured by the primary beach seine and v represents the fish vulnerable to the primary beach seine. Assuming that all fish are retained in the enclosures and observed, the fish vulnerable to the primary beach seine will be calculated as:

$$v = c + nc \qquad (2)$$

where nc represents fish not captured by the primary beach seine. To quantify if and how the beach seine efficiency varies among environmental gradients, we will use logit multivariate regression models to estimate q given occupancy (θ) as:

$$\text{Logit}(q|\theta) = \beta 0 + \beta\ 1Y1 + \ldots + \beta\ rYr \qquad (3)$$

where Yr represents a habitat predictor variable (e.g., water quality or physical habitat characteristic), $\beta 0$ represents a fixed intercept, and $\beta\ r$ represents the effect of Yr on seine efficiency. We will quantify the relative importance of different environmental variables by comparing the relative fit of candidate models that represent different hypotheses using an information theoretic approach (Burnham and Anderson 2002). The best fitting candidate model will be tested for accuracy by ten-fold cross-validation (Williams et al. 2002). If the accuracy of the best fitting candidate model is adequate, the model can be used to adjust current and future DJFMP monitoring data to appropriately compare seine catches across time and space within the San Francisco Estuary to make more robust inferences about the distribution and abundance of fish. During subsequent years of seine efficiency sampling, the predictive beach seine efficiency model will further be validated or adapted using new data.

Fish Retention Validation

To validate that all fish occurring within each enclosure are retained, observed, and recorded, fish may be temporarily marked by stain dye and released into the enclosures for recapture using the secondary gears and gill-nets (Bayley and Herendeen 2000). The fish used for mark-recapture will be common representative benthic and pelagic fish collected in similar nearby habitats by beach seining downstream of the enclosure approximately one hour prior to efficiency sampling. Marked fishes will be identified to species, measured for fork length, marked by dye, and released into the enclosure after the completion of the primary beach seine haul. When fish that were not collected by the primary beach seine are processed, we will record all marked fish as recaptures, identify them to species, and measure for fork length. No fish listed under the ESAs will be used for mark-recapture.

We will determine the percent of fishes retained and observed within the enclosure using the secondary gears and gill-nets (r) as:

$$r = c_r / m \tag{4}$$

where c_r represents the number of recaptured fish and m represents the number of marked fish released in the enclosure. We will be able to validate the retention and observation of fish species, guilds, and/or size classes within the enclosures. In the event that fish retention and subsequent observation using secondary gears and gill-nets is low (e.g., <90%), the number of fishes vulnerable to the primary beach seine can be adjusted for the calculation of seine efficiency (Bayley and Herendeen 2000) or the methodologies for efficiency sampling may be modified.

APPENDIX D: DJFMP METADATA

April, 2013

Name of study: IEP Delta Juvenile Fish Monitoring Program

Program manager
Name: Matthew Dekar

Agency: U.S. Fish and Wildlife Service – Stockton Fish and Wildlife Office

Address: 850 S. Guild Ave, Suite 105
Lodi, CA 95240

Phone: (209) 334-2968

Purpose/Objective: The original objective of the Delta Juvenile Fish Monitoring Program in the 1970's and 1980's was to monitor effects of water projects in the Delta on abundance, distribution and survival of juvenile fall run Chinook salmon in the lower Sacramento and San Joaquin Rivers and the San Francisco Estuary. This objective was broadened in the 1990's to include relative abundance and distribution of all races of juvenile Chinook salmon. In 2001, the program objectives were broadened further to reflect the value of gathering information on non-salmonid species. Species information at times has also been recorded for jellyfish and crustaceans spp. that are encountered as well.

General category of data collected: Native and non-native species of fish found within the San Francisco Estuary and lower Sacramento and San Joaquin Rivers.

Geographic range of current field work: There are currently fifty-eight (58) beach seine sites located on the Lower Sacramento and San Joaquin Rivers, North, Central and South Delta and San Francisco Bay (Table 2; Figure 1). Three (3) boat trawling stations are also regularly sampled (Table 3; Figure 1). These are located at Sherwood Harbor on the Sacramento River, Chipps Island in Suisun Bay and Mossdale Crossing County Park on the San Joaquin River. In addition, special studies have been conducted throughout the years (i.e., Liberty Island, Delta Cross Channel, VAMP, Six Year Study, etc).

Each sampling site is designated by a Station Code which displays the abbreviations of the body of water sampled (Table 1), the number of miles from the mouth of the river or bay, and the orientation within the sample site (e.g., site AM001S is 1 mile from the mouth of the American River on the south bank).

Figure 1. Current Sampling Sites

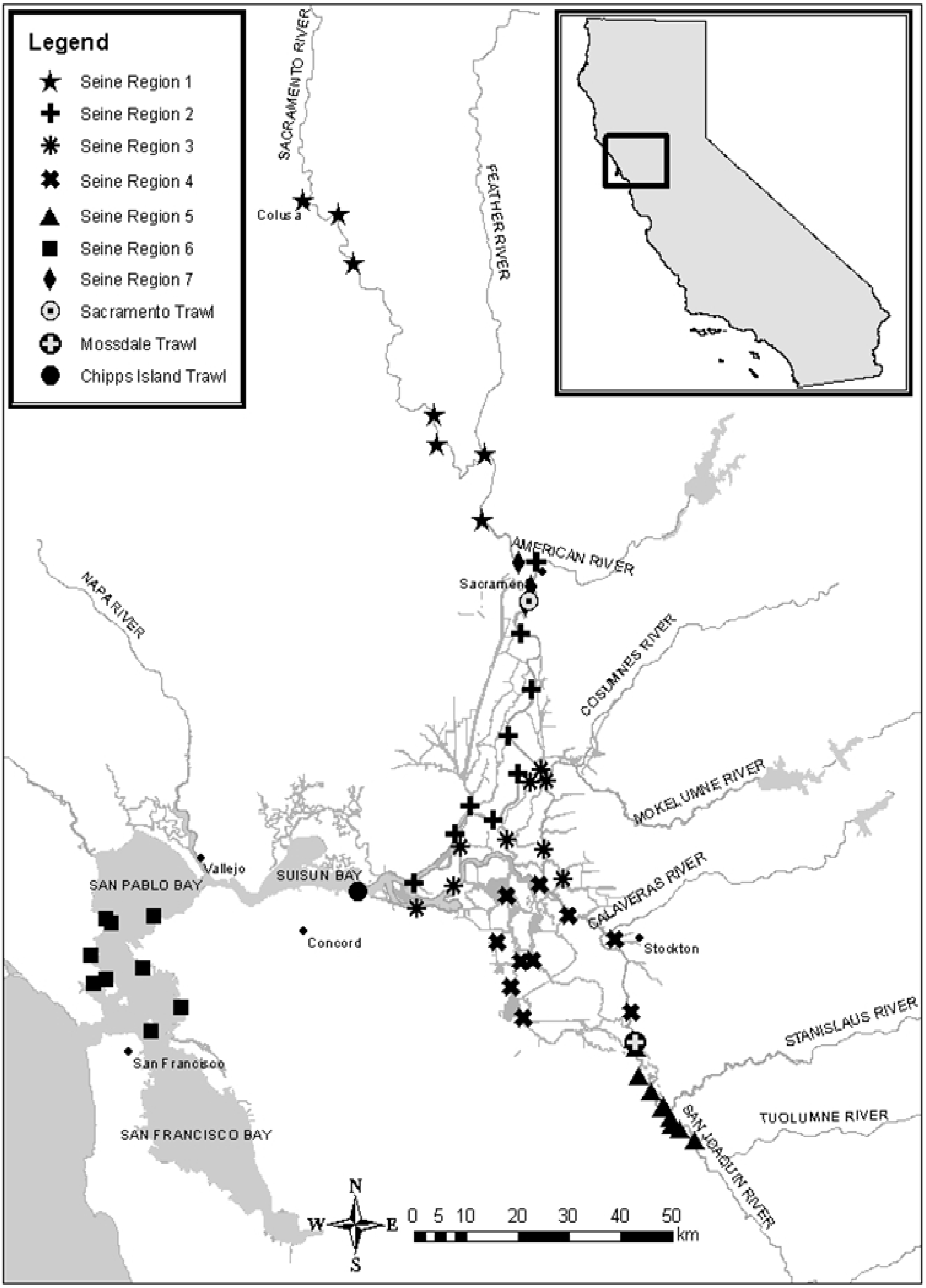


Table 1. Abbreviations of sampling sites.

Name of the body of water	**Abbreviations**
American River	AM
Big Break	BB
Clifton Court Forebay	CC
Columbia Cut	CL
Calaveras River	CR
Carquinez Straight	CS
Disappointment Slough	DS
Fabian Bell Canal	FC
False River	FR
Georgiana Slough	GS
Holland Cut	HC
Little Potato Slough	LP
North Fork Mokelumne River	MK
Middle River	MR
3 Mile Slough	MS
Montezuma Slough	MZ
Old River	OR
Petaluma River	PR
Richardson Bay	RB
Roaring River	RR
Rock Slough	RS
San Francisco Bay	SA
Suisun Bay	SB
South Fork Mokelumne River	SF
San Joaquin River	SJ
San Pablo Bay	SP
Sacramento River	SR
Steamboat Slough	SS
Turner Cut	TC
Tuolumne River	TM
Victoria Canal	VC
Werner Dredger Cut	WD
Whiskey Slough	WS
Delta Cross Channel	XC

Table 2. Current beach seining locations (2012). Location data are from UTM Zone 10 S.

Station Code	**Site Name**	**Seine Routes**	**Region**	**Northing**	**Easting**
SR144W	Colusa St. Park	Lower Sacramento	1	4341652	585032
SR138E	Wards Landing	Lower Sacramento	1	4338873	591787
SR130E	South Meridian	Lower Sacramento	1	4329625	594819
SR094E	Reels Beach	Lower Sacramento	1	4301235	610500
SR090W	Knights Landing	Lower Sacramento	1	4295506	610842
SR080E	Verona	Lower Sac. & Sac.	1	4293731	620049
SR071E	Elkhorn	Lower Sac. & Sac.	1	4281359	619626
SR062E	Sand Cove	Sacramento	7	4273283	626860
SR057E	Miller Park	Sacramento	7	4269001	629279
SR055E	Sherwood Harbor	Sacramento	7	4265358	628190
SR060E	Discovery Park	N. Delta & Sac.	2	4273503	629820
AM001S	American River	N. Delta & Sac.	2	4273377	630121
SR049E	Garcia Bend	N. Delta & Sac.	2	4259863	627056

Table 2. Continued

SR043W	Clarksburg	North Delta	2	4249352	629186
SS011N	Steamboat Slough	North Delta	2	4240586	624600
SR024E	Koket	North Delta	2	4233475	626473
SR017E	Isleton	North Delta	2	4224781	621633
SR015E	Vieira’s Resort	North Delta	2	4225797	618951
SR014W	Rio Vista	North Delta	2	4227355	617119
SR012W	Sandy Beach	North Delta	2	4222029	614333
MS001N	Sherman Island	North Delta	2	4212733	606513
XC001N	Delta Cross Channel	Central Delta	3	4234115	630930
GS010E	Georgiana Slough	Central Delta	3	4231900	628914
SF014E	Wimpy’s	Central Delta	3	4232068	632064
DS002S	King Island	Central Delta	3	4213457	635248
LP003E	Terminous	Central Delta	3	4219075	631488
MK004W	B&W Marina	Central Delta	3	4220909	624418
TM001N	Brannan Island	Central Delta	3	4219577	615378
SJ005N	Eddo’s	Central Delta	3	4212249	614110
SJ001S	Antioch Dunes	Central Delta	3	4208157	606855
SJ032S	Lost Isle	South Delta	4	4206624	636393
SJ026S	Medford Island	South Delta	4	4212589	630739
OR003W	Franks Tract	South Delta	4	4210312	624458
WD002W	Veale Tract	South Delta	4	4201793	622619
OR014W	Cruiser Haven	South Delta	4	4198087	626927
OR023E	Union Island	South Delta	4	4187462	627498
MR010W	Woodward Island	South Delta	4	4198130	629336
OR019E	Old River	South Delta	4	4193094	625167
SJ041N	Dad’s Point	South Delta	4	4202181	645287
SJ051E	Dos Reis	South Delta	4	4188374	648601
SJ056E	Mossdale	San Joaquin	5	4183536	649043
SJ058W	Weatherbee	San Joaquin	5	4181923	649451
SJ058E	Weatherbee E (Alt.)	San Joaquin	5	4181796	649579
SJ063W	Big Beach	San Joaquin	5	4176666	650093
SJ065W	Critchett Rd.	San Joaquin	5	4175464	651896
SJ068W	Durham Site	San Joaquin	5	4173594	652327
SJ070N	Durham Ferry	San Joaquin	5	4172602	653315
SJ074W	Sturgeon Bend	San Joaquin	5	4170903	654784
SJ074A	Sturgeon Bend Alt.	San Joaquin	5	4170228	654634
SJ076W	North of Route 132	San Joaquin	5	4168198	656679
SJ077E	Route 132	San Joaquin	5	4167222	656395
SJ079E	San Luis Refuge	San Joaquin	5	4166449	657914
SJ083W	North of Tuol. River	San Joaquin	5	4164462	660960
SA010W	San Quentin	Bay West	6	4199450	545475
SA004W	Tiburon	Bay West	6	4194324	544827
SA008W	Paradise Beach	Bay West	6	4194207	547678
SP001W	China Camp	Bay West	6	4205986	547332
SP000W	McNear’s Beach	Bay West	6	4205115	548092
SA001M	Treasure Island	Bay East	6	4185320	555450
SA007E	Berkeley Frontage	Bay East	6	4189618	561558
SA009E	Keller Beach	Bay East	6	4197177	553896
SP003E	Point Pinole E.	Bay East	6	4206949	556120

Table 3. Current boat trawling stations (2012), Location data are from UTM Zone 10 S.

Station Code	Site Name	Northing	Easting
SB018X	Chipps Island	4211218	595531
SR055M	Sherwood Harbor	4265965	628707
SJ054M	Mossdale Crossing	4185588	648278

If Latitude and Longitude are provided how were they determined? Latitude and Longitude are determined by either a hand held (Garmin, GPSmap76) or a mounted (Furuno, GPS185OD) GPS receivers are used to determine northing or easting coordinates. The coordinates are recorded as Zone 10 S UTM (Universal Transverse Mercator) beginning in 1995.

Period of record (start year): The Stockton Fish and Wildlife Office (STFWO) started sampling in 1976. In the 1990's, the range and scope of the study were broadened and are similar to those presently conducted. The number and location of the sites sampled and the methods have changed slightly over the years (see Tables 4, 5, & 6).

Sample frequency per time unit (week, month, etc): The number of days that a given trawl location or seine site is sampled has varied by location and by season (see Table 4 for the current year (2012), Table 5 for historical trawls and Table 6 for historical seines).

Currently, the Sherwood Harbor Trawl samples the Sacramento River three days per week between October 1st and March 31st using a Kodiak trawl (see methods). During the months of April, July, August and September Sherwood Harbor is sampled three days per week with a mid-water trawl. During the months of May and June the site is sampled twice per week with a mid-water trawl. The Mossdale Crossing Trawl site on the San Joaquin River is sampled three days per week year round with a Kodiak trawl. However, during the months of April, May and June the sampling is typically conducted by CDFW Region 4 and data are reported by STFWO. The Chipps Island Trawl site in Suisun Bay is sampled three days per week year round, except during May and June, and sometimes April, when it is sampled daily and at times two shifts per day for a total of 20 tows per day. During December and January, Chipps Island is sampled 7 days per week with ten 20 minute trawls conducted daily. This additional sampling is conducted to recover marked juvenile salmon released in the Delta and upstream. Sample times are recorded as military time and observe daylight savings time.

A daily take limit was established for delta smelt, primarily for the Chipps Island Trawls, since the majority of the delta smelt caught by the monitoring program are captured at Chipps Island. The Interagency Ecological Program has allotted an annual take for delta smelt of 1000 individuals per calendar year. Beginning October 21, 2011 sampling efforts (seine and trawls) were curtailed to limit the number of delta smelt caught. From October 26 to November 30, 2011 one day sampling per week were conducted and from January 09 to October 19, 2012 two day sampling per week were conducted for Chipps Island trawls. The field crew conducting Chipps Island trawls are required to get supervisory approval before continuing sampling after 8 delta smelt per day have been caught. The delta smelt daily catch limit can be adjusted in response to actual catch numbers.

Boat trawls are usually conducted in the upstream direction in the center of the river, with the exception of Chipps Island, which is conducted traveling either upstream or downstream depending on the tidal flux and in the north, center or south sides of the channel. Since the 2011 field season Mossdale trawl sampling is conducted upstream of a dividing bridge from August 08 to November 02 and downstream of the bridge after November 02 if flows increase.

Table 4. Current sampling methods (2012) and frequency of samples per week.

Sampling Method	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sherwood Harbor MWTR				2	2	2	3	3	3			
Sherwood Harbor MWTR				1								
Sherwood Harbor KDTR	3	3	3							3	3	3
Chipps Island MWTR	3	3	3	2	2	2	3	3	3	3	3	3
Chipps Island MWTR	4			1	1	1						4
Mossdale KDTR	3	3	3	3	3	3	3	3	3	3	3	3
Sacramento Seine	1									3	3	3
Lower Sacramento Seine	1	1	1	1	1	1	1	1	1	1	1	1
North Delta Seine	0.5	0.5	0.5	1	1	1	1	1	1	1	1	1
North Delta Seine	0.5	0.5	0.5									
Central Delta Seine	1	1	1	1	1	1	1	1	1	1	1	1
South Delta Seine	1	1	1	1	1	1	1	1	1	1	1	1
San Joaquin Seine	1	1	1	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5
West and East Bay Seines	1	1	1	1	1	1	1	1	1	1	1	1
Item 1 Juvenile salmon long-term fall-run abundance trends												
Item 2 Year-round abundance of juvenile Chinook salmon (less abundance races)												
Item 3 Monitoring for water project operations assistance and DAT												
Item 4 Monitoring the long-term abundance trends of Delta and Bay resident fishes												
Item 5 B(2) Late-fall												
Item 6 Sampled by DFG Region IV												

Table 5. Trawl locations (Historical) and dates sampled, mid-water and Kodiak trawls.

Year	Location/Station	Method	Tows/ Day	Min./ Tow	Days/ Wk	Dates
1976	Clarksburg/SR043*	MWTR	2-18	8-15	0-5	05/13/76- 07/09/76
1976	Chipps Is./SB018*	MWTR	5-13	17-20	0-6	05/18/76- 07/09/76, 10/18/76- 11/16/76
1977	Clarksburg/SR043*	MWTR	7-28	7-19	0-7	05/09/77- 07/08/77
1977	Chipps Is./SB018*	MWTR	6-12	19-20	1-7	05/09/77- 06/28/77
1978	Clarksburg/SR043*	MWTR	7-12	8-10	0-6	06/05/78- 06/15/78
1978	Chipps Is./SB018*	MWTR	7-12	19-20	0-7	04/03/78- 06/26/78
1979	Clarksburg/SR043*	MWTR	10	10	0-5	06/04/79- 06/14/79
1979	Chipps Is./SB018*	MWTR	3-10	19-20	0-7	04/02/79- 07/12/79
1980	Clarksburg/SR043*	MWTR	10	10	0-7	06/02/80- 06/25/80
1980	Chipps Is./SB018*	MWTR	1-10	15-20	0-7	01/14/80- 06/30/80, 10/01/80- 12/30/80
1981	Clarksburg/SR043*	MWTR	9-10	10	0-6	06/01/81- 06/17/81
1981	Chipps Is./SB018*	MWTR	3-10	18-20	0-7	04/06/81- 07/02/81
1982	Chipps Is./SB018*	MWTR	2-10	20	0-6	04/06/82- 06/24/82
1983	Chipps Is./SB018*	MWTR	1-10	13-20	1-7	04/08/83- 07/01/83
1984	Chipps Is./SB018*	MWTR	2-10	18-20	0-7	04/02/84- 07/03/84
1985	Chipps Is./SB018*	MWTR	2-10	15-20	0-7	04/01/85- 06/20/85
1986	Chipps Is./SB018*	MWTR	8-10	20	2-7	04/07/86- 06/18/86

Table 5. Continued

1987	Chipps Is./SB018*	MWTR	8-10	19-25	0-7	04/06/87- 06/22/87
1988	Chipps Is./SB018*	MWTR	3-21	18-20	2-7	04/05/88- 07/08/88
1988	Sherwood Hbr./SR055*	MWTR	5-10	6-20	2-5	04/05/88- 06/28/88
1989	Chipps Is./SB018*	MWTR	6-10	19-20	1-7	04/05/89- 06/30/89
1989	Sherwood Hbr./SR055*	MWTR	5-10	14-20	0-5	04/14/89- 06/28/89
1990	Chipps Is./SB018*	MWTR	3-10	17-20	1-7	04/05/90- 06/22/90
1990	Courtland/SR035*	MWTR	3-12	10	0-5	02/02/90- 03/22/90, 04/11/90- 06/20/90
1990	Hood/SR036*	MWTR	5-12	10	0-2	02/02/90- 03/22/90
1990	Hood/SR037*	MWTR	6-9	10	0-2	02/02/90- 03/22/90
1990	Hood/SR038*	MWTR	3-12	10	0-2	02/02/90- 03/22/90
1991	Chipps Is./SB018*	MWTR	8-10	19-20	1-7	04/02/90- 06/28/90
1991	Sherwood Hbr./SR055*	MWTR	2-12	10-20	0-3	04/15/91- 06/12/91, 12/05/91- 12/30/91
1992	Chipps Is./SB018*	MWTR	3-10	18-20	0-7	04/03/92- 06/26/92
1992	Sherwood Hbr./SR055*	MWTR	4-12	10-20	0-7	01/02- 03/25, 05/06- 06/12, 09/08-12/31
1992	Mayberry Slough/MS020*	MWTR	10	20	0-5	04/20/92- 05/01/92
1992	Sac. River/SR027*	PUSH	4-9	10-15	0-1	12/04/92- 12/10/92
1992	Walnut Grove/SR026*	PUSH	6-8	10-13	0-1	12/04/92- 12/15/92
1992	Verona/SR080*	PUSH	3	10	0-1	11/10/92
1992	Sac. River/SR059*	PUSH	3	10	0-1	11/17/92
1992	Sac. River/SR034*	PUSH	2-9	10-20	0-1	11/20/92, 12/04/92
1992	Georgiana Sl./GS009*	PUSH	5	10	0-1	12/15/92
1992	Georgiana Sl./GS004*	PUSH	4	10	0-1	12/15/92
1992	Sac. River 1/SR131*	PUSH	1	10	0-1	11/03/92
1992	Sac. River 2/SR132*	PUSH	2	10	0-1	11/03/92
1992	Sac. River 3/SR134*	PUSH	3	10	0-1	11/03/92
1992	Sac. River 4/SR137*	PUSH	4	10	0-1	11/03/92
1992	Wards Landing/SR138*	PUSH	5	10	0-1	11/03/92
1992	Sac. River/SR028*	PUSH	9-10	20	0-1	12/01/92
1992	Sac. River/SR090*	PUSH	1	10	0-1	11/20/92
1992	San Joaquin River/SJ019*	PUSH	1	10	0-1	12/18/92
1992	Mokelumne River/MK001*	PUSH	1-5	10	0-1	12/18/92- 12/29/92
1992	Mokelumne River/MK002*	PUSH	1-10	10	0-2	12/18/92- 12/31/92
1992	Mokelumne River/MK003*	PUSH	4-10	10	0-1	12/18/92- 12/29/92
1992	Delta X-Channel/XC001*	PUSH	3-4	10	0-1	12/01/92- 12/10/92
1992	Georgiana Sl./GS001*	PUSH	5-7	8-10	0-1	12/10/92- 12/29/92
1993	Chipps Is./SB018*	MWTR	7-10	10-20	1-7	04/05/93- 07/08/93, 11/01/93- 12/30/93
1993	Sherwood Hbr./SR055*	MWTR	4-11	10-20	0-5	01/04/93- 06/23/93, 09/27/93- 12/30/93
1993	Georgiana Sl./GS004*	PUSH	8	10	0-1	01/19/93
1993	Old River 5/OR015*	PUSH	2-10	20	1-3	02/09/93- 03/29/93
1993	Old River 4/OR018*	PUSH	10	21	0-1	03/30/93
1993	Montezuma Sl./MZ020*	MWTR	5-11	20	0-5	05/12/93- 05/25/93
1993	Montezuma Sl./MZ021*	MWTR	5-10	20	0-5	05/12/93- 05/25/93
1993	Sac. River/SR047*	MWTR	6	20	0-1	06/09/93
1993	Sac. River/SR048*	MWTR	7	20	0-1	06/09/93
1993	Sac. River/SR050*	MWTR	3	20	0-1	06/09/93
1993	Sac. River/SR053*	MWTR	2	20	0-1	06/09/93
1993	Mokelumne River/MK001*	PUSH	1-4	10	0-2	01/12/93- 01/19/93
1993	Mokelumne River/MK002*	PUSH	1-10	10	0-2	01/05/93- 01/19/93
1993	Mokelumne River/MK003*	PUSH	1-10	10	0-2	01/05/93- 01/19/93
1993	Mokelumne River/MK003*	MWTR	1-10	10-20	0-1	01/07/93- 01/11/93
1993	Georgiana Sl./GS001*	PUSH	4-10	20	0-3	01/21/93- 02/04/93, 04/02/93- 04/12/93
1993	Georgiana Sl./GS001*	MWTR	5-10	18-20	0-4	01/13/93- 04/01/93

Table 5. Continued

1994	Chipps Is./SB018*	MWTR	5-10	19-20	1-7	01/03/94- 06/20/94, 10/03/94- 12/31/94
1994	Sherwood Hbr./SR055*	MWTR	1-10	10-20	0-5	01/03/94- 06/17/94, 09/26/94- 12/28/94
1994	Sherwood Hbr./SR055*	KDTR	7-10	20	0-2	12/22/94- 12/30/94
1994	Mossdale/SJ054*	KDTR	1-10	10	0-5	04/22/94- 06/08/94
1994	Mayberry Slough/MS020*	MWTR	1-13	20	0-5	04/25/94- 05/06/94
1994	Mokelumne River/MK001*	MWTR	1-10	10-20	0-3	01/07/94- 02/16/94
1994	Mayberry Slough/MS021*	MWTR	5-15	20	0-5	04/26/94- 05/06/94
1994	Rock Slough/RS001*	PUSH	1-10	20	0-3	02/18/94- 06/03/94
1995	Chipps Is./SB018*	MWTR	1-10	16-20	0-7	01/03/95- 12/28/95
1995	Sherwood Hbr./SR055*	MWTR	4-26	18-20	0-7	03/16/95- 10/23/95
1995	Sherwood Hbr./SR055*	KDTR	1-10	10-20	0-7	01/03- 03/07, 04/06- 04/27, 10/20- 12/31
1995	Bacon Island/MR009*	KDTR	5-10	19-20	0-7	05/01/95- 06/29/95
1995	Fay Island/OR009*	KDTR	5-10	19-20	0-7	05/01/95- 06/29/95
1995	Jersey Point/SJ011*	MWTR	6-10	20	0-7	05/01/95- 05/21/95
1995	Head Old River/OR046*	KDTR	1-8	20	0-7	05/12/95- 05/20/95
1995	Dos Reis/SJ051*	KDTR	6-10	16-20	0-6	05/12/95- 05/20/95
1995	Webb Tract/OR001*	KDTR	1-10	20	0-7	05/02/95- 06/30/95
1996	Chipps Is./SB018*	MWTR	1-10	18-20	0-7	01/03/96- 08/19/96, 10/09/96- 12/30/96
1996	Sherwood Hbr./SR055*	MWTR	2-10	17-20	0-7	04/01/96- 10/03/96
1996	Sherwood Hbr./SR055*	KDTR	4-10	20	0-7	01/02/96- 04/04/96, 10/04/96- 12/31/96
1996	Mossdale/SJ054*	KDTR	1-13	10-20	0-7	04/01/96- 06/28/96, 09/04/96- 12/27/96
1996	Bacon Island/MR009*	KDTR	1-10	17-20	0-4	05/07/96- 06/29/96
1996	Fay Island/OR009*	KDTR	5-11	20	0-4	05/07/96- 06/29/96
1996	Jersey Point/SJ011*	MWTR	5-11	18-20	0-7	04/01/96- 06/30/96
1996	Head Old River/OR046*	KDTR	5-12	14-20	0-7	04/01/96- 05/06/96
1996	False River/FR002*	KDTR	5-11	20	0-7	04/04/96- 06/30/96
1996	Turner Cut/TC002*	KDTR	4-19	16-20	0-7	04/01/96- 06/30/96
1996	Walnut Grove/SR026*	KDTR	9-27	10	0-4	04/01/96- 06/27/96
1996	Dos Reis/SJ051*	KDTR	1-10	20	0-7	04/01/96- 05/06/96
1996	Webb Tract/OR001*	KDTR	1-10	5-25	0-7	04/05/96- 06/30/96
1996	Columbia Cut/CL000*	KDTR	5-11	13-20	0-7	04/01/96- 06/30/96
1996	Georgiana Sl./GS001*	KDTR	6-27	10	0-4	04/01/96- 06/27/96
1997	Chipps Is./SB018*	MWTR	2-10	18-20	0-7	01/03/97- 12/31/97
1997	Sherwood Hbr./SR055*	MWTR	5-10	18-20	0-5	01/24/97- 02/14/97, 03/31/97- 10/16/97
1997	Sherwood Hbr./SR055*	KDTR	2-10	17-20	0-5	01/21, 02/18- 03/25, 10/17- 12/23
1997	Mossdale/SJ054*	KDTR	9-21	10	1-7	03/21/97- 06/27/97
1997	Jersey Point/SJ011*	KDTR	1-10	20	0-5	04/03/97- 06/26/97
1997	Head Old River/OR046*	KDTR	2-5	19-20	0-4	04/03/97- 04/12/97
1997	False River/FR002*	KDTR	4-11	17-20	0-5	04/17/97- 06/26/97
1997	Turner Cut/TC002*	KDTR	2-10	18-20	0-5	04/03/97- 06/28/97
1997	Webb Tract/OR001*	KDTR	1-10	5-20	0-5	03/31/97- 06/28/97
1997	Columbia Cut/CL000*	KDTR	5-11	18-20	0-5	04/03/97- 06/28/97
1998	Chipps Is./SB018*	MWTR	1-20	10-20	0-7	01/03/98- 06/29/98, 09/02/98- 12/31/98
1998	Sherwood Hbr./SR055*	MWTR	5-11	18-20	0-3	03/30/98- 06/29/98, 12/01/98- 12/04/98
1998	Sherwood Hbr./SR055*	KDTR	1-10	18-20	0-5	01/02/98- 03/27/98, 09/03/98- 12/28/98
1998	Mossdale/SJ054*	KDTR	3-10	10-21	0-5	04/02/98- 06/30/98, 11/04/98- 12/28/98
1998	Bacon Island/MR009*	KDTR	10	20	0-2	04/20/98- 04/21/98
1998	Fay Island/OR009*	KDTR	10	20	0-5	05/11/98- 05/18/98
1998	Jersey Point/SJ011*	KDTR	2-10	18-20	0-5	04/03/98- 06/30/98
1998	Head Old River/OR046*	KDTR	5	20	0-2	04/17/98- 04/18/98
1998	False River/FR002*	KDTR	5-11	15-20	0-5	04/04/98- 06/30/98
1998	Turner Cut/TC002*	KDTR	5	18-20	0-6	04/02/98- 06/30/98

Table 5. Continued

1998	Webb Tract/OR001*	KDTR	1-10	20	0-5	04/02/98- 06/30/98
1998	Columbia Cut/CL000*	KDTR	6-10	19-20	0-5	04/02/98- 06/30/98
1999	Chipps Is./SB018*	MWTR	1-21	13-20	0-7	01/01/99- 12/31/99
1999	Sherwood Hbr./SR055*	MWTR	2-13	14-20	0-5	03/26/99- 10/01/99
1999	Sherwood Hbr./SR055*	KDTR	4-10	20	0-5	01/04/99- 03/26/99, 10/05/99-12/30/99
1999	Mossdale/SJ054*	KDTR	2-11	19-20	0-5	01/06/99- 06/29/99, 10/18/99- 12/29/99
1999	Bacon Island/MR009*	KDTR	2-10	10-20	0-5	04/02/99- 07/02/99
1999	Turner Cut/TC002*	KDTR	1-4	20	0-5	04/01/99- 07/02/99
1999	Webb Tract/OR001*	KDTR	1-10	14-20	0-5	04/01/99- 06/24/99
1999	Quimby East/OR004*	KDTR	3-9	12-22	0-5	04/01/99- 06/24/99
1999	Palm Tract/OR008*	KDTR	1-8	20-30	0-5	04/01/99- 06/29/99
1999	Prisoners Point/SJ024*	KDTR	1-10	19-20	0-5	04/01/99- 06/24/99
1999	Little Mandeville/HC002*	KDTR	1-8	20-30	0-5	04/01/99- 06/29/99
1999	San Joaquin River/SJ031*	KDTR	3-5	10-20	0-5	04/01/99- 07/02/99
1999	Connection Slough/CS001*	KDTR	7-8	13-20	0-5	04/01/99- 07/02/99
1999	Columbia Cut/CL000*	KDTR	5-7	10-20	0-5	04/01/99- 07/02/99
2000	Chipps Is./SB018*	MWTR	3-20	18-20	0-7	01/02/00- 12/27/00
2000	Sherwood Hbr./SR055*	MWTR	7-20	20	0-3	03/29/00- 09/28/00
2000	Sherwood Hbr./SR055*	KDTR	3-10	14-20	0-5	01/03/00- 03/27/00, 10/04/00-12/30/00
2000	Mossdale/SJ054*	KDTR	1-20	10-20	0-5	01/03/00- 06/30/00
2000	Sac. River/SR027*	MWTR	15-166	14-17	0-3	11/13/00- 11/22/00
2000	Delta X-Channel/XC001*	MWTR	16-90	14-19	0-3	11/13/00- 11/22/00
2001	Chipps Is./SB018*	MWTR	1-20	17-20	0-7	01/03/01- 12/31/01
2001	Sherwood Hbr./SR055*	MWTR	5-10	19-20	0-3	03/28/01- 07/16/01, 08/06/01- 09/28/01
2001	Sherwood Hbr./SR055*	KDTR	5-10	18-20	0-4	01/02/01- 03/26/01, 10/01/01-12/28/01
2001	Mossdale/SJ054*	KDTR	3-20	18-20	0-7	02/13/01- 09/10/01
2001	Sac. River/SR027*	MWTR	40-69	14	0-2	10/29/01- 11/02/01
2001	Benicia/SB001*	MWTR	5-10	17-20	0-6	01/20/01- 01/29/01
2001	Benicia/CS008*	MWTR	6-10	18-20	0-6	01/21/01- 02/16/01
2001	Antioch Dunes/SJ001*	KDTRX	5	19-20	0-1	05/01/01- 05/08/01
2001	Delta X-Channel/XC001*	MWTR	39-68	15	0-2	10/29/01- 11/02/01
2002	Chipps Is./SB018*	MWTR	10	20	0-7	01/02/02- 12/31/02
2002	Sherwood Hbr./SR055*	MWTR	2-10	19-20	0-3	03/28/02- 09/26/02
2002	Sherwood Hbr./SR055*	KDTR	4-51	17-20	1-4	01/02/02- 03/26/02, 09/30/02- 12/30/02
2002	Mossdale/SJ054*	KDTR	6-15	18-20	0-7	01/07- 01/18, 02/27- 07/17, 12/11- 12/30
2003	Chipps Is./SB018*	MWTR	1-61	18-20	0-7	01/02/03- 12/31/03
2003	Sherwood Hbr./SR055*	MWTR	3-48	18-20	0-3	04/02/03- 09/29/03
2003	Sherwood Hbr./SR055*	KDTR	2-51	20-21	0-4	01/03/03- 03/31/03, 10/01/03- 12/31/03
2003	Mossdale/SJ054*	KDTR	3-15	19-20	0-7	01/15/03- 12/31/03
2004	Chipps Is./SB018*	MWTR	2-20	18-20	0-7	01/02/04- 12/31/04
2004	Sherwood Hbr./SR055*	MWTR	6-10	12-20	0-3	02/18/04- 03/12/04, 04/05/04- 09/29/04
2004	Sherwood Hbr./SR055*	KDTR	6-42	18-20	0-4	01/02- 02/17, 03/15- 03/31, 10/01- 12/30
2004	Mossdale/SJ054*	KDTR	2-15	18-20	0-7	01/02/04- 12/30/04
2005	Chipps Is./SB018*	MWTR	8-20	19-20	0-7	01/02/05- 12/30/05
2005	Sherwood Hbr./SR055*	MWTR	9-55	19-20	0-4	04/01/05- 09/30/05
2005	Sherwood Hbr./SR055*	KDTR	9-10	19-20	0-3	01/03/05- 03/30/05, 10/03/05- 12/30/05
2005	Mossdale/SJ054*	KDTR	10-15	19-21	0-7	01/03/05- 12/30/05
2006	Chipps Is./SB018*	MWTR	10-20	20	3	01/02/06- 12/31/06
2006	Sherwood Hbr./SR055*	MWTR	10	20	2-3	04/03/06- 09/29/06
2006	Sherwood Hbr./SR055*	KDTR	10	20	3	01/06/06- 03/31/06, 10/02/06- 12/29/06
2006	Mossdale/SJ054*	KDTR	10	20	3	01/04/06- 12/29/06
2007	Chipps Is./SB018*	MWTR	10-13	5-20	3	01/02/07- 12/31/07

Table 5. Continued

2007	Sherwood Hbr./SR055*	MWTR	10	20	2-3	04/02/07- 09/29/07
2007	Sherwood Hbr./SR055*	KDTR	10	20	3	01/02/07- 03/30/07, 10/01/07- 12/31/07
2007	Mossdale/SJ054*	KDTR	10	20	3	01/03/07- 12/31/07
2008	Chipps Is./SB018*	MWTR	13	5-20	3	01/02/08- 02/04/08, 03/10/08- 12/17/08
2008	Benicia/SB001*	MWTR	10	20	3	02/08/08- 03/08/08
2008	Sherwood Hbr./SR055*	MWTR	10	20	2-3	04/02/08- 09/29/08
2008	Sherwood Hbr./SR055*	KDTR	10	20	3	01/02/08- 03/31/08, 10/01/08- 12/17/08
2008	Mossdale/SJ054*	KDTR	10	20	3	01/02/08- 12/17/08
2009	Chipps Is./SB018*	MWTR	10-20	20	3	01/02/09- 12/30/09
2009	Sherwood Hbr./SR055*	MWTR	10	20	2-3	04/01/09- 09/30/09
2009	Sherwood Hbr./SR055*	KDTR	10	20	3	01/02/09- 03/30/09, 10/02/09- 12/30/09
2009	Mossdale/SJ054*	KDTR	10	20	3	01/02/09- 12/30/09
2010	Chipps Is./SB018*	MWTR	10-20	20	3	01/01/10- 12/31/10
2010	Sherwood Hbr./SR055*	MWTR	10	20	2-3	04/02/10- 09/29/10
2010	Sherwood Hbr./SR055*	KDTR	10	20	3	01/01/10- 03/31/10, 10/01/10- 12/31/10
2010	Mossdale/SJ054*	KDTR	10	20	3	01/01/10- 12/31/10
2011	Chipps Is./SB018*	MWTR	10-20	20	2-3	01/03/11- 12/30/11
2011	Sherwood Hbr./SR055*	MWTR	10	20	3	04/01/11- 09/30/11
2011	Sherwood Hbr./SR055*	KDTR	10	20	3	01/03/11- 03/30/11, 10/03/11- 12/30/11
2011	Mossdale/SJ054*	KDTR	10	20	3	01/03/11- 12/30/11
2012	Chipps Is./SB018*	MWTR	10	20	2-3	01/02/12- Present
2012	Sherwood Hbr./SR055*	MWTR	10	20	3	04/02/12- 09/28/12
2012	Sherwood Hbr./SR055*	KDTR	10	20	3	01/02/12- 03/30/12, 10/01/12- Present
2012	Mossdale/SJ054*	KDTR	10	20	3	01/02/12- Present

* Indicates that channel location or compass bearings are not specified.

Table 6. Seine sites (Historical) and dates sampled

Station Code	Site Name	Region	First Sampled	Last Sampled
SR144W	Colusa St. Park	1	03/24/81	Current
SR138E	Wards Landing	1	02/18/81	Current
SR130E	South Meridian	1	05/19/81	Current
SR094E	Reels Beach	1	02/18/81	Current
SR090W	Knights Landing	1	02/18/81	Current
SR080E	Verona	1	02/18/81	Current
SR071E	Elkhorn	1	02/18/81	Current
SR062E	Sand Cove	1	09/30/94	Current
SR130X	Ox Bow	1	04/22/81	04/22/81
SR184E	Ord Bend	1	02/18/81, 09/01/92	06/23/82, 11/12/97
SR258E	Bend Bridge	1	02/19/81	06/23/82
SR298W	Posse Grounds	1	02/19/81, 03/24/84	06/23/82, 03/24/84
SR284W	Anderson	1	02/19/81	06/23/82
SR119E	Tisdale Weir	1	02/18/81	03/24/81
SR185W	Glen Gravel Bar	1	02/18/81	03/24/81
SR163W	Princeton	1	02/18/81, 09/01/92	06/23/82, 12/09/97
SR276E	Balls Ferry	1	02/19/81	06/23/82
SR244E	Lake Red Bluff	1	02/19/81	04/23/82
SR243E	RBDD	1	02/19/81, 05/24/03	06/23/82, 05/24/03
SR218E	Woodson Bridge	1	02/19/81	05/24/82
SR252W	Iron Canyon	1	12/09/92	12/09/92
SR193E	Bidwell	1	09/01/92	09/09/92
SR057E	Miller Park	2	09/21/94	Current

Table 6. Continued

SR055E	Sherwood Harbor	2	09/28/94	Current
SR060E	Discovery Park	2	12/07/76	Current
AM001S	American River	2	05/28/76	Current
SR049E	Garcia Bend	2	03/08/76	Current
SR043W	Clarksburg	2	03/08/76	Current
SS011N	Steamboat Slough	2	03/08/76, 11/18/92	06/21/78, Current
SR024E	Koket	2	03/09/76	Current
SR017E	Isleton	2	03/09/76	Current
SR014W	Rio Vista	2	03/09/76	Current
SR012E	Stump Beach	2	03/09/76	Current
MS001N	Sherman Island	2	03/24/76	Current
SS005W	Steamboat Slough	2	03/09/76	03/29/78
SR014E	Cliff House	2	06/15/76	06/15/76
XC001N	Delta Cross Channel	3	03/09/76	Current
GS010E	Georgiana Slough	3	03/09/76	Current
SF014E	Wimpy’s	3	10/26/76	Current
DS002S	King Island	3	02/07/79	Current
LP003E	Terminous	3	10/26/76, 02/07/79	11/03/76, Current
MK004W	B&W Marina	3	02/07/79	Current
TM001N	Brannan Island	3	03/09/76	Current
SJ005N	Eddo’s	3	03/16/76	Current
SJ001S	Antioch Dunes	3	02/06/79	Current
SB019S	Pittsburg Bridge	3	03/26/76	02/06/79
BB001S	Big Break	3	05/04/77	05/04/77
RR001N	Roaring River	3	01/30/80	05/20/81
CR005S	Calaveras River	3	12/02/93	01/14/99
MZ023E	Montezuma Slough 1	3	01/30/80	06/24/80
MZ022W	Montezuma Slough 2	3	01/30/80	06/24/80
MZ021W	Montezuma Slough 4	3	01/30/80	06/24/80
SJ032S	Lost Isle	4	11/23/93	Current
SJ026S	Medford Island	4	01/24/02	Current
OR003W	Franks Tract	4	11/23/93	Current
WD002W	Veale Tract	4	11/23/93	Current
OR014W	Cruiser Haven	4	11/23/93	Current
OR023E	Union Island	4	06/06/97	Current
OR001M	Webb Tract	4	03/16/76, 04/21/97	06/11/76, 04/21/97
MR010W	Woodward Island	4	02/07/79	Current
SJ041N	Dad’s Point	4	02/07/79	Current
SJ051E	Dos Reis	4	03/30/94	Current
OR019E	Old River 1	4	12/05/93	Current
FC006X	Fabian Bell Canal	4	03/12/76	05/15/78
OR001X	Old River (mouth)	4	03/16/76, 04/21/97	06/11/76, 04/21/97
OR022W	Federal Fish Facility	4	03/26/76	06/09/76
OR018W	Old River 4	4	03/26/76, 11/16/92	04/11/86, 01/27/94
SJ026N	Venice Island	4	02/07/79	09/02/03
TC002E	Turner Cut	4	01/28/93	08/31/95
WS001E	Whiskey Slough	4	03/17/93	11/12/93
VC002N	Victoria Canal	4	11/12/93	11/05/96
OR017E	Old River 3	4	11/23/93	01/06/94
OR018E	Old River 4	4	01/17/87	05/15/92
SJ056E	Mossdale	5	03/30/94	Current
SJ058W	Weatherbee	5	03/30/94	Current

Table 6. Continued

SJ058E	Weatherbee E (Alt.)	5	02/22/95	Current
SJ063W	Big Beach	5	03/30/94	Current
SJ065W	Critchett Rd.	5	06/19/08	Current
SJ068W	Durham Site	5	03/30/94	Current
SJ070N	Durham Ferry	5	08/12/08	Current
SJ074A	Sturgeon Bend Alt	5	06/19/08	Current
SJ074W	Sturgeon Bend	5	03/30/94	Current
SJ076W	North of Route 132	5	06/19/08	Current
SJ077E	Route 132	5	03/30/94	Current
SJ079E	San Luis Refuge	5	08/12/08	Current
SJ083W	North of Tuol. River	5	03/30/94	Current
SJ087W	Grayson	5	12/21/00	05/03/04
SJ063E	Big Beach E	5	06/24/97, 05/12/04	06/24/97, 05/12/04
SA010W	San Quentin	6	02/04/80, 01/29/97	02/04/80, Current
SA004W	Tiburon	6	02/04/97	Current
SA008W	Paradise Beach	6	03/11/76, 02/04/80, 01/29/97	05/20/76, 04/16/82, Current
SP001W	China Camp	6	01/29/97	Current
SP000W	McNear’s Beach	6	03/11/76, 02/04/80, 01/29/97	05/20/76, 03/18/82, Current
SA001M	Treasure Island	6	03/10/76, 01/30/80	05/20/76, 04/16/82, Current
SA007E	Berkeley Frontage	6	03/10/76, 02/04/80, 01/28/97	5/20/76, 03/18/82, Current
SP000E	Point Molate	6	02/04/80, 02/18/98	02/18/82, 07/11/03
SA009E	Keller Beach	6	02/04/80, 02/05/98	02/04/80, Current
SP003E	Point Pinole E.	6	01/30/80, 02/05/98	04/16/82, Current
SP003W	Point Pinole W.	6	02/03/81	05/12/81
SB000X	Martinez Bridge	6	01/30/80	01/30/80
SP008E	Rodeo	6	03/10/76, 01/30/80	06/09/76, 01/30/80
SP004E	Wilson Point	6	03/10/76	05/20/76
SB010X	Middleground Island	6	03/16/76	06/11/76
CS006S	Brickyard Beach	6	03/25/76, 05/15/78, 01/30/80	06/09/76, 05/15/78, 04/16/82
SB009S	Port Chicago	6	02/06/79	03/14/79
CS003S	Port Costa	6	02/06/79	02/06/79
CS001S	Crockett	6	01/30/80	04/16/82
PR001W	Petaluma River Br.	6	02/04/80, 02/25/98	04/16/82, 02/25/98
SA008E	Point Richmond Jetty	6	02/04/80	02/04/80
SP001E	Pt. San Pablo Harbor	6	02/04/80	02/04/80
RB003X	Richardson Bay	6	02/04/80	02/04/80
SA003S	S.F. Municipal Pier	6	02/04/80	02/04/80
SA010W	San Quentin Beach	6	02/04/80, 01/29/97	02/04/80, Current
SA003W	Sausalito Harbor	6	02/04/80	02/04/80

San Pablo and San Francisco Bay seine sites are presently sampled once every two weeks year round. The San Joaquin River seine sites are sampled weekly from January to June, then every two weeks from July to December. However, the San Joaquin River has often been too low to sample these sites effectively from July to December, so alternate truck accessible sites have been designated as sample sites during these times. Currently, the South, Central and North Delta seine sites are sampled weekly year round. South and Central Delta were only sampled every other week during the summer months in some years due to funding limitations. The Lower Sacramento seine sites are sampled once per week from January 1st to December 31st. The Sacramento seine sites are sampled three days per week from October 1st to January 31st. The Sacramento seine route combines some of the sites from the Lower Sacramento seine route and some of the sites from the North Delta seine route, plus three seine sites that are only sampled from October through January (Sand Cove, Sherwood Harbor and Miller Park).

Comments about study (e.g. idiosyncrasies, changes over time, special events, etc.): Modifications are made regularly to accommodate safety conditions and/or special studies. Of the 58 beach seine sites sampled, three of the sites on the Sacramento seine routes are only sampled between October and January (see comments above). The beach seine sites on the San Joaquin River are only sampled by boat when there is sufficient water depth for these sites to be accessible; otherwise, alternate sites that are accessible by truck are sampled (see comments above). All other sites are sampled year round if weather and physical site condition permits. Beach seine sites are evaluated regularly for access and suitability, and, since 1993, if the original seine site was compromised or was not suitable, an alternative site adjacent (within 50 m) to the original may have been selected.

Before August 1, 1977 all Chinook salmon captured were measured and fork lengths recorded. Between August 1, 1977 and July 31, 1992 only 50 Chinook salmon from each sample taken were measured and those not measure were recorded as a total sum, minus those measured. After August 1, 1992 fifty individuals from each race of Chinook salmon were measured and those not measured were summed and assigned a count reference number to associate with measured Chinook salmon. After August 1, 2007 the need for count reference numbers was eliminated as unmarked Chinook salmon and their associated summed counts were automatically raced in the database.

Our database program uses a length at date captured criteria to calculate the salmon race (see “Race Table” under the data tab, http://www.fws.gov/stockton/jfmp/index.asp). Fish that are not measured are designated with a fork length of “0” and a summed count of “1” or greater. Chinook salmon that were not measured between August 1, 1977 and July 31, 1992 are not able to be raced nor are they able to be associated with any measured fish.

Since July1995, fish species collected shorter than 25 mm FL are considered to be too small to be accurately identified in the field and as such are not recorded. Exceptions to this are: rainwater killifish, Sacramento sucker, mosquito fish, Sacramento splittail and three-spine sticklebacks which are considered identifiable down to 20 mm FL in the field.

Flow meters are checked every six months for accuracy using flow tanks at the UC Davis campus and if a meter’s discrepancy is greater than 5% outside of the factory stated calibration (K factor = 0.026873) then it is taken out of service and replaced with a meter that is within 5% of specifications. Previously, before 2007, re-calculated K factors were applied to each meter tested. K factors are used to calculate catch per unit effort (CPUE) and different K factors could be used depending on which meter was used at what time. Currently, we use one K factor for all flow meters, past or present, and assume an error rate up to 5%. CPUE = (Total flow meter value) x (mouth area of net) x (K factor).

Table 7. Idiosyncrasies, changes over time and special events

Changes in Procedure	**Date**	**Reason**
Juvenile salmon monitoring program started	1976	To monitor impact of water projects on juvenile salmon
Mid-water trawls conducted at Clarksburg	1976-1981	Recovery of marked fish released upstream
Gear Condition Codes 5, 6 and 7 used for some samples	1976-1992	To indicate: non-target species caught, or numbers were estimated, or 100-150 ft. seine nets were used.
No start or end values recorded for flow meters, only total meter entered into database	1976-1986	Transcription efficiency
Beach seining moved from beaches to boat ramps on Lower Sacramento River	1978	Many of the beaches previously sampled were rip-rapped
Reassigned beach seining sites upstream of Colusa to Red Bluff office	1982	Travel times to and from sample sites were unreasonable.
Numbers of a salmon race in excess of 50 are plus counted	1983	Sampling efficiency
Net dimensions and flow meter values started being recorded for catch per cubic meter calculations	1985	To determine volume of water sampled
Mid-water trawls conducted at Courtland and Hood	1990	* See notes below
Program's objective broadened to include all races of juvenile salmon	1992	Obtain information on all races of juvenile salmon
Tow net used at Sherwood Harbor	1991-1992	Index abundance of fry entering the delta
Push-net used on Sacramento & Mokelumne Rivers, Georgiana & Rock Sloughs	1992-1994	Alternative sampling methods evaluated
Salmon identified by race, determined by size criteria	1993	Estimate abundance of each race
Beach seining conducted on a year round basis	1993	To obtain information on all races of juvenile salmon
Kodiak trawls routinely conducted at Sherwood Harbor	1994	Greater chance of capturing larger, less abundant races of salmon
Beach seining was expanded to include San Joaquin River and South Delta	1994	Greater coverage of spatial area for juvenile salmon
Size restriction on measuring fish <25 mm FL	07/09/1995	Difficult to identify larval fish in field accurately
Flow meter gear ID recorded	1996	Document changing K factors
15 minute rule formalized on all disturbed areas prior to sampling	1996	To negate influences of recreational users and boat traffic on sampling results
Temperatures recorded in °C instead of °F	1996	To be consistent with scientific literature
Beach seines reinitiated in San Francisco and San Pablo Bays	1997	Greater spatial coverage for juvenile salmon
New net with a bigger mesh (1/4" changed to 5/16") used on Chipps trawl, not used consistently.	10/06/1997	To reduce capture of juvenile and larval Delta smelt
Adult salmon and steelhead counted, but not measured. Documented as >500 mm & >300 mm, respectively.	1998	Reduces handling stress
Fish not identified by species recorded as unidentified species	2000	Makes the database more consistent and less ambiguous
Program name changed to the Delta Juvenile Fish Monitoring Program	2001	To reflect broadened objectives and catch of multiple species
Larger mesh trawl nets (5/16") used consistently at Chipps Island for midwater trawls	11/01/2001	Previously, we used several trawl nets with smaller mesh sizes (1/4") intermittently at Chipps Island.
New seine nets ordered and 15 m measuring tape attached to nets	2004	To ensure accurate measurement of sampling area. Previous nets were found to be short 1-2 meters.
Gear Condition Code 4's are entered into database	08/01/2006	To provide electronic documentation of when sites are not sampled
Small gauge wires used to secure flow meters	10/06/2006	To reduce turbulence and improve flow meter accuracy

Table 7. Continued

Chinook salmon automatically raced in database	08/01/2007	Count referencing not required
Turbidity, D.O., & Conductivity measurements taken	08/01/2011	To provide environmental data for all sites
Mossdale trawl sampling area shift	08/01/2011	Bridge avoidance
Sampling efforts curtailed at Chipps Island	10/21/2011	To limit delta smelt catches
All sampling nets re-measured, new nets ordered	05/01/2012	Standardization & documentation

* Sampling conducted at Hood in February, March for winter run salmon to compare results with earlier study conducted at same location by Ray Shaffter (CDFW) in 1973.

* Sampling conducted near "Courtland" to determine how juvenile salmon were horizontally distributed across the channel just upstream of the Delta Cross Channel.

Field Sampling

Gear type or field instrument used:

Beach Seines

- A 50 ft. x 4 ft. (15.2 m x 1.3 m) seine net with 35 lb. Delta 1/8 inch (0.3 cm) square mesh and a 4 ft. x 4 ft. (1.3 m x 1.3 m) bag. Each net has a float line and lead line attached to 6 ft. (1.8 m) wooden poles at each end.
- An YSI Model 30 electro-conductivity meter for recording conductivity and temperature became part of the program's standard operating procedure in 1999, and an YSI Model 85 salinity, conductivity, dissolved oxygen and temperature meter became part of the program' standard operating procedure in 2010.
- A darkened bottle containing MS-222 in solution and two shallow 2 gal. (7.6 l) tubs for the anesthetizing and recovery of fish. Became part of the program's standard operating procedure in 2005.
- A sub-sampling kit composed of graduated containers of different sizes (4 liter, 700 ml and 600 ml) with 2 mm holes in the bottoms to allow drainage. Became part of the program's standard operating procedure in 2005.
- A Celsius thermometer (analog) is also available if a YSI meter is not.

Nets and gear used while seining are numbered and are uniquely identified and specifically used for individual routes to help prevent the spread of invasive species as part of our Hazard Analysis Critical Control Point Program (HACCP). This became part of the program's standard operating procedure in 2005.

Trawling

- Secchi disc
- Calibrated Flow meter, General Oceanics Inc., Model # 2030R.
- An YSI Model 85 became part of the program's standard operating procedure in 2010.
- The mid-water trawl net used at Sacramento is composed of six panels, each decreasing in mesh size towards the cod end. Fully extended mouth size is 13.6 ft. x 16.4 ft. (4.15 m

x 5.0 m) dry measurement and mesh size range from 8 inch (20.3 cm) stretch at the mouth to ½ inch (1.3 cm) stretch just before the cod end. The cod end is composed of 1/8 inch (0.3 cm) weave mesh. Doors made of ¼ inch (0.6 cm) stainless steel (one on each side of the bottom of the net) are attached to the net with shackles and connected to bridles with chain and then Miller Swivels. Hydrofoils with floats spread the top of the net at water level and are attached using the same equipment as the depressors. One hundred foot long ¼ inch (0.6 cm) diameter Amsteel rope bridles are attached to Miller Swivels and attached to the cables from the boat. The net is fished 100 ft. (30.5 m) from the boat (swivels are located just aft of the A-frame). Actual fishing dimensions of the net vary due to currents and weather conditions and have been described in past reports (1992 Annual Report, Sacramento/San Joaquin Estuary Fishery Resource Office, U. S. Fish and Wildlife Service, Stockton, California, 1993, pp. 23-27).

- The larger mid-water trawl net used at Chipps Island is similar in construction to the mid-water trawl net used at Sacramento and has a mouth dimension of 25.1 ft. x 31.7 ft. (7.64 m x 9.65 m) dry measurement. Six panels, each decreasing in mesh size towards the cod end. Mesh sizes ranged from 4 inch to ½ inch (10 cm to 1.3 cm) stretch just before the cod end. Cod end is composed of 5/16 inch (0.8 cm) knotless material. Depressors and hydrofoils were connected in the same manner as with the smaller Sacramento mid-water trawl. The net is fished 150 ft. (45.7 m) aft of the vessel.
- Kodiak trawl nets are used at Sacramento and Mossdale. They have variable mesh with fully expandable mouth openings of 6.4 ft. x 25 ft. (1.96 m x 7.62 m) dry measurement.
- Although called mid-water trawling, the trawls for all sampling are towed at the surface.

The estimated fishing net mouth area, extrapolated from mid-water trawl studies (United States Fish and Wildlife Service, 1993), is 12.5 m^2 for the Kodiak trawl, 18.6 m^2 for Chipps Island mid-water trawl and 5.08 m^2 for the smaller Sacramento mid-water trawl.

The Kodiak trawl nets have a float line and lead line attached to spreader bars that enables the net to fish the top 1.8 m of the water column. It is also fished with an aluminum live box as a cod end to avoid excessive fish mortality. Two boats tow the Kodiak net through the water, one pulling each wing. At the end of each tow, field crew on one of the boats retrieve the live box from the end of the net and remove the fish. To help prevent the spread of invasive species as part of our Hazard Analysis Critical Control Point Program (HACCP) trawl net and sampling gear are dedicated to specific sampling areas and sampling sites are visited in order from upstream to downstream.

Beach Seining

For on-shore sampling, a 50' (15.2 m) beach seining net is used. One person holds one end of the net on shore while the other person wades out to either the length of the net, a maximum 1.2 m depth or to where a break or obstruction occurs on the slope. The depth and distance out from shore is recorded in meters, which are pre-marked on each net. The person on shore brings the other end of the net out and the first person then stretches the net across parallel to the shore until either the full 15 m are deployed or an obstruction is reached. If the distance is less than 15 m the net is pulled taut and the measurement (in m) is recorded. The net is then pulled in towards the shore using the attached 6 ft (1.8 m) wooden poles, keeping the lead line on the bottom.

Average depth (calculated from the two ends of the net), width, and length of the net are also recorded.

Trawling

On mid-water boat trawls, the cod end of the net is tied with a quick release knot and thrown overboard when the boat operator has given the signal to toss. The Amsteel lines on the hydraulic spools are let out until the net has reached the proper distance from the boat (Chipps Island 45.7 m; Sherwood Harbor 30.5 m). The hydraulic spools are locked in place and the boat maintains a steady trawl speed for 20 minutes. Once time has been reached, the hydraulic spools are engaged to bring the net back in. Crew members haul the net back into the boat and pile it loosely in the stern of the boat. The cod end is picked up over the transom, untied and the contents are released into one of the water filled tubs. The fish are then counted in the same way as for beach seining as described below in the fish handling section. The measured and counted fish are then placed into another tub that has flowing water for recovery prior to release.

For Kodiak trawls, a live box is attached to the cod end and the cod end is left untied. At the end of each tow, one boat maintains headway with both wings of the net attached while the other boat motors back to retrieve the live box and process the catch.

Fish Handling and Identification

The bag of the net is collected and placed into a 10 gallon (38 l) tub with water from the river or bay. The net is thoroughly checked to ensure no fish are unaccounted for. Every organism found is placed in the tub. Fish are retrieved from the tub with a small hand net and are placed on a measuring board for identification to species and to obtain fork length measurements (in mm). The fish are then transferred to a 5 gallon (19 l) recovery bucket prior to being released.

Thirty individuals from each species are measured. The sum of all individuals in excess of these 30 is also recorded. The endangered, threatened, or species of management concern-- Chinook salmon, delta smelt, green sturgeon, hardhead, longfin smelt, river lamprey, Sacramento perch, Coho salmon and steelhead-- 50 of each species or race of salmon are measured with the remaining enumerated. Chinook salmon with a clipped adipose fin are brought back to the office to extract the embedded coded wire tags. A coded wire tag detector wand (Northwest Technologies) is used for adipose clipped Steelhead trout to determine the presence of coded wire tags. Those with embedded coded wire tags are brought back to the office.

If there are too many fish recovered (>2000), a sub-sample may be taken from the recovery tub and placed into six sub-samples, after first ensuring that a homogenous mix has been achieved. A graduated container, with holes in the bottom to allow for water drainage, is used to collect sub-samples. Sub-samples are then placed into flow through containers which are transferred to another tub to await identification, measurement and enumeration. Once a volume has been determined, remaining fish are then released to minimize handling stress and overcrowding. Measurements, numbers of individuals and the species composition of sub-samples are then extrapolated to the population previously in the tub. This new sub-sampling protocol was implemented in 2005. In the early 1980’s sub-sampling was conducted at Chipps Island using a graduated cylinder and discarding the excess water. In addition, reducing sampling times or areas have also been employed to reduce catch if too many fish are caught or the catch rate is anticipated to be high.

Physical Data Documentation

For each site sampled, a separate data sheet is used to record data. Much of the same physical data is recorded for both seines and trawls; this includes location, station code, sample date, sample time, gear code, conductivity, dissolved oxygen, turbidity, water temperature, weather code, gear serial numbers, and names of the crew involved. For beach seines, the measurement of the area seined and the substrate code are recorded. The volume of water sampled is determined by the product of the net length, width and depth multiplied by 0.5. For boat trawls, tow number, tow duration, tow direction, vessel used, and start and end values of the flow meter are recorded. For boat trawls, volume of water sampled is determined by subtracting the start from the end values of the flow meter and multiplied by the net size (face area) and then multiplied by a flow meter correction factor supplied by the manufacturer (Standard Factory K Value = 0.026873). Flow meters are checked annually at the University of California Davis to ensure accuracy. The flow meters are not calibrated, but the K values for the flow meters are re-estimated. If the K values are greater or less than 10% of the standard factory K value then the flow meter is taken out of service and replaced with one that is within tolerance.

The field "condition" is used to qualify data. A condition of "1" indicates no variation from the standard procedure. Condition of "2" indicates a less than perfect set of the net or an improperly tied net. A condition of "3" indicates that a sample was taken, but the catch was impeded by a blockage in the net or the net came untied completely. A condition of "4" indicates that a sample was not taken. A "code 4" has not been entered into the database prior to the 2006 field season. In 1976, 1977, 1981 and 1984 codes 5, 6 and 7 were recorded for Chipps Island and Clarksburg trawls and some seines. A condition code of "5" indicates that other species (other than Chinook) were caught, but were not recorded. A condition code of "6" indicates that the count of individual organisms was estimated. A condition code of "7" indicates that a 100-150 ft. (30.5 - 45.7 m) seine net was used.

References to any written protocols and how to obtain a copy: The Standard Operating Procedures manual (SOP) is updated on an annual basis and is available for review at the Stockton Fish and Wildlife Office.

Changes in gear or procedures that affected the data over time: Boat trawls conducted at Sherwood Harbor change from a Kodiak trawl, which uses two boats and a larger net (12.5 m^2 face area) to a mid-water trawl, which uses one boat and a smaller net (5.1 m^2 face area) usually from April 1st to September 30th to keep in accordance with historical sampling methods and to reduce operating costs. The Kodiak trawl is more efficient in capturing the larger and less abundant salmon races and is used from October 1st through March 31st. During high water or high debris events, the mid-water trawl is used during these months instead of the Kodiak trawl for fish health and safety reasons.

Quality assurance/control (QA/QC) procedures: Since 2001, a fishery biologist has been responsible for training field personnel in the identification of fish species and implementing a QA/QC program for fish identification in the field. The QA/QC program includes testing field fish identification skills twice a year at various life history stages, reviewing preserved fish samples and accompanying field personnel in the field to assure the correct identification of the fish species collected. All personnel are trained following standard operating procedures (SOP) for field sampling during their first week of employment and then work with experienced employees for the first 3 months of their employment. The field personnel are often tested using preserved and wild specimens to insure the correct identification of fish species in various stages of their life cycles. All unknown fish species are brought back to the office for identification.

Table 8. QA/QC activity

Activity	**Primary**	**Secondary**
Fish Identification	Printed photos, preserved fish collection, QC biologist, experienced field partner	Lab work and routine testing of identification skills
Data Entry	Data sheets proofed before entry, line by line proofing after entry	Spot checks, random queries, end of year proofing
Employee Training	Standard Operating Procedures, Training checklist	Experienced field partner first 3 months, formal training

Standard operating procedures and various reference sources on fish and invertebrate identification are used, including:

Cairns, Stephen D., et al. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Cnidaria and Ctenophora. Am. Fish. Soc. Sp. Pub. 28, 2nd ed., 2002.

McLaughlin, Patsy A., et al. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Crustaceans. Am. Fish. Soc. Sp. Pub. 31, 2005.
Miller, Daniel and Lea, Robert. Guide to the Costal Marine Fishes of California: California Fish Bulletin Number 157. Berkeley: The University of California Press, 1975.

Moyle, Peter. Inland Fishes of California. Berkeley: The University of California Press, 2002.

Nelson, Joseph, et al. Common and Scientific Names of Fishes from the United States, Canada and Mexico, Sixth Edition. Bethesda: American Fisheries Society Special Publication 29, 2004.

Turgeon, Donna, D., et al. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks. Am. Fish. Soc. Sp. Pub. 26, 2nd ed., 1998

U.S. Fish & Wildlife Service Standard Operating Procedures, U.S. Fish & Wildlife Service, Stockton, California, 2005.

Laboratory analysis – Chemical – n/a
Laboratory analysis – Biological

Current procedure since (1984)

Historical procedures (if known) or reference to other documentation: Chinook salmon and Steelhead/Rainbow trout that have been tagged with a coded wire tag are brought back to the office to have the tags removed and read. All adipose fin clipped (ad-clipped) salmon are returned to the office for tag processing, while ad-clipped Rainbow trout are checked with a Northwest Marine Technologies wand CWT detector to determine if there is the presence of a coded wire tag. The coded wire tags are read twice and any discrepancies are resolved with a third reading.

Reference used for identification of organisms: Moyle, Peter. Inland Fishes of California. Berkeley: The University of California Press, 2002.

Location of reference collection: STFWO Field Office

Appendix

Table 9. Species list

OrganismCode	Common Name	Family	Genus	Species
AAURIT	moon jelly	Ulmaridae	Aurelia	aurita
ACL	Asian clam	Sphaeriidae	Potamocorbula	amurensis
ALABIA	Aurelia labiata	Ulmaridae	Aurelia	labiata
AME	American eel	Anguillidae	Anguilla	rostrata
AMS	American shad	Clupeidae	Alosa	sapidissima
ARG	arrow goby	Gobiidae	Clevelandia	ios
BAS	bass unknown	Centrarchidae	Micropterus	n/a
BG	bay goby	Gobiidae	Lepidogobius	lepidus
BGS	bluegill	Centrarchidae	Lepomis	macrochirus
BKB	black bullhead	Ictaluridae	Ameiurus	melas
BKS	black crappie	Centrarchidae	Pomoxis	nigromaculatus
BLC	blue catfish	Ictaluridae	Ictalurus	furcatus
BMS	bigmouth sole	Paralichthyidae	Hippoglossina	stomata
BPF	bay pipefish	Syngnathidae	Syngnathus	leptorhynchus
BRB	brown bullhead	Ictaluridae	Ameiurus	nebulosus
BRF	Brown Rockfish	Scorpaenidae	Sebastes	auriculatus
BRY	bat ray	Mobulidae	Myliobatis	californica
BSFP	black perch	Embiotocidae	Embiotoca	jacksoni
BSK	big skate	Rajidae	Raja	binoculata
BSM	brown smoothhound	Carcharhinidae	Mustelus	henlei
BSP	barred surfperch	Embiotocidae	Amphistichus	argenteus
BT	brown trout	Salmonidae	Salmo	trutta
BUT	butter sole	Pleuronectidae	Isopsetta	isolepis
BVIRGI	Blackfordia virginica	Blackfordiidae	Blackfordia	virginica
C	common carp	Cyprinidae	Cyprinus	carpio
CAH	California halibut	Bothidae	Paralichthys	californicus
CAR	California roach	Cyprinidae	Hesperoleucus	symmetricus
CAT	catfish unknown	Ictaluridae	n/a	n/a
CBZ	cabezon	Cottidae	Scorpaenichthys	marmoratus
CCAPIL	lions mane	Cyaneidae	Cyanea	capillata
CFUSCE	Chrysaora fuscescens	Pelagiidae	Chrysaora	fuscescens
CHC	channel catfish	Ictaluridae	Ictalurus	punctatus
CHG	chameleon goby	Gobiidae	Tridentiger	trigonocephalus
CHN	Chinook salmon	Salmonidae	Oncorhynchus	tshawytscha
CHO	coho salmon	Salmonidae	Oncorhynchus	kisutch
CMC	Chinese mitten crab	Varunidae	Eriocheir	sinensis
Cnidaria	Cnidarian unknown	n/a	n/a	n/a
CPY	crappie unknown	Centrarchidae	Pomoxis	n/a
CRKF	crevice kelpfish	Clinidae	Gibbonsia	montereyensis
CSG	cheekspot goby	Gobiidae	Llypnus	gilberti
CSN	sunfish unknown	Centrarchidae	n/a	n/a
CSP	calico surfperch	Embiotocidae	Amphistichus	koelzi
Cspp	Crangon Spp.	Crangonidae	Crangon	n/a
DACE	speckled dace	Cyprinidae	Rhinichthys	osculus
DMT	diamond turbot	Pleuronectidae	Pleuronichthys	guttulatus

Table 9. Continued

OrganismCode	Common Name	Family	Genus	Species
DSH	Dock Shrimp	Pandalidae	Pandalus	danae
DSM	Delta smelt	Osmeridae	Hypomesus	transpacificus
DSP	dwarf surfperch	Embiotocidae	Micrometrus	minimus
EEL	eel unknown	n/a	n/a	n/a
ELS	English sole	Pleuronectidae	Parophrys	vetulus
EXP	Siberian prawn	Palaemonidae	Exopalaemon	modestus
FHM	fathead minnow	Cyprinidae	Pimephales	promelas
FLF	flatfish unknown	n/a	n/a	n/a
FWH	freshwater hydroid	Clavidae	Cordylophora	caspia
GBY	goby unknown	Gobiidae	n/a	n/a
GF	goldfish	Cyprinidae	Carassius	auratus
GKF	giant kelpfish	Clinidae	Heterostichus	rostratus
GSF	green sunfish	Centrarchidae	Lepomis	cyanellus
GSM	grey smoothhound	Carcharhinidae	Mustelus	californicus
GSN	golden shiner	Cyprinidae	Notemigonus	crysoleucas
GST	green sturgeon	Acipenseridae	Acipenser	medirostris
HCH	hitch	Cyprinidae	Lavinia	exilicauda
HER	herring unknown	Clupeidae	n/a	n/a
HH	hardhead	Cyprinidae	Mylopharodon	conocephalus
Hspp	Heptacarpus Spp.	Hippolytidae	Heptacarpus	n/a
JSM	jacksmelt	Atherinidae	Atherinopsis	californiensis
KOS	kokanee salmon	Salmonidae	Oncorhynchus	nerka
KSP	kelp perch	Embiotocidae	Brachyistius	frenatus
LAM	lamprey unknown	Petromyzontidae	Lampetra	n/a
LFS	longfin smelt	Osmeridae	Spirinchus	thaleichthys
LIC	lingcod	Hexagrammidae	Ophiodon	elongatus
LMB	largemouth bass	Centrarchidae	Micropterus	salmoides
LMS	longjaw mudsucker	Gobiidae	Gillichthys	mirabilis
LP	bigscale logperch	Percidae	Percina	macrolepida
LPS	leopard shark	Triakidae	Triakis	semifasciata
MIN	minnow unknown	Cyprinidae	n/a	n/a
MMARGI	Black Sea jellyfish	Olindiidae	Maeotias	marginata
MOERIS	Moerisia sp.	Moerisiidae	Moerisia	sp.
MQF	western mosquitofish	Poeciliidae	Gambusia	affinis
MSS	inland silverside	Atherinopsidae	Menidia	beryllina
NAN	northern anchovy	Engraulidae	Engraulis	mordax
NPK	northern pike	Esocidae	Esox	lucius
NSM	night smelt	Osmeridae	Spirinchus	starksi
ORSH	oriental shrimp	Palaemonidae	Palaemon	macrodactylus
OSH	opossum shrimp	Mysidae	Antromysis	cenotensis
PAH	Pacific herring	Clupeidae	Clupea	pallasii
PBACHE	comb jelly	Pleurobrachiidae	Pleurobrachia	bachei
PBL	western brook lamprey	Petromyzontidae	Lampetra	richardsoni
PBU	Pacific pompano	Stromateidae	Peprilus	simillimus
PCAMTS	egg yolk jelly	Ulmaridae	Phacellophora	camtschatica
PCH	perch unknown	Percidae	n/a	n/a
PCOLOR	purple-striped jelly	Pelagiidae	Pelagia	colorata

Table 9. Continued

OrganismCode	Common Name	Family	Genus	Species
PELR	Pacific electric ray	Torpedinidae	Torpedo	californica
PHA	Pacific halibut	Pleuronectidae	Hippoglossus	stenolepis
PHAP	penicillate jellyfish #2	Polyorchidae	Polyorchis	haplus
PKS	pink salmon	Salmonidae	Oncorhynchus	gorbuscha
PL	Pacific lamprey	Petromyzontidae	Lampetra	tridentata
PMP	plainfin midshipman	Batrachoididae	Porichthys	notatus
PPE	pile perch	Embiotocidae	Rhacochilus	vacca
PPENIC	penicillate jellyfish #1	Polyorchidae	Polyorchis	penicillatus
PRS	prickly sculpin	Cottidae	Cottus	asper
PS	Pacific sanddab	Paralichthyidae	Citharichthys	sordidus
PSA	Pacific sardine	Clupeidae	Sardinops	sagax
PSF	pumpkinseed	Centrarchidae	Lepomis	gibbosus
Pspp	Palaemonetes Spp.	Palaemonidae	Palaemonetes	n/a
PSS	Pacific staghorn sculpin	Cottidae	Leptocottus	armatus
PTG	penpoint gunnel	Pholidae	Apodichthys	flavidus
PTO	Pacific tomcod	Gadidae	Microgadus	proximus
RBT	rainbow / steelhead trout	Salmonidae	Oncorhynchus	mykiss
RDG	red gunnel	Pholidae	Pholis	schultzi
REB	redeye bass	Centrarchidae	Micropterus	coosae
RES	redear sunfish	Centrarchidae	Lepomis	microlophus
RFF	righteye flounder unknown	Pleuronectidae	n/a	n/a
RFK	rainwater killifish	Fundulidae	Lucania	parva
RFS	rosyface shiner	Cyprinidae	Notropis	rubellus
RL	river lamprey	Petromyzontidae	Lampetra	ayresii
ROC	rockfish unknown	Scorpaenidae	n/a	n/a
ROS	rock sole	Pleuronectidae	Lepidopsetta	bilineata
RSC	riffle sculpin	Cottidae	Cottus	gulosus
RSN	red shiner	Cyprinidae	Cyprinella	lutrensis
RSP	redtail surfperch	Embiotocidae	Amphistichus	rhodoterus
RSU	rubberlip seaperch	Embiotocidae	Rhacochilus	toxotes
SAPM	Sacramento pikeminnow	Cyprinidae	Ptychocheilus	grandis
SAS	sand sole	Pleuronectidae	Psettichthys	melanostictus
SASU	Sacramento sucker	Catostomidae	Catostomus	occidentalis
SBG	saddleback gunnel	Pholidae	Pholis	ornata
SBS	saddleback sculpin	Cottidae	Oligocottus	rimensis
SCB	Sacramento blackfish	Cyprinidae	Orthodon	microlepidotus
SCU	sculpin unknown	Cottidae	n/a	n/a
SDO	spiny dogfish	Squalidae	Squalus	acanthias
SHG	Shokihaze goby	Gobiidae	Tridentiger	barbatus
SHI	shiner unknown	Cyprinidae	n/a	n/a
SHM	shimofuri goby	Gobiidae	Tridentiger	bifasciatus
SHRIMP	shrimp unknown	n/a	n/a	n/a
SIL	silversides unknown	n/a	n/a	n/a
SKP	striped kelpfish	Clinidae	Gibbonsia	metzi
SMB	smallmouth bass	Centrarchidae	Micropterus	dolomieu
SMT	smelt unknown	Osmeridae	n/a	n/a
SMU	striped mullet	Mugilidae	Mugil	cephalus

Table 9. Continued

OrganismCode	Common Name	Family	Genus	Species
SPACIF	Scrippsia pacifica	Polyorchidae	Scrippsia	pacifica
SPB	spotted bass	Centrarchidae	Micropterus	punctulatus
SPCH	spotfin surfperch	Embiotocidae	Hyperprosopon	anale
SPK	speckled sanddab	Paralichthyidae	Citharichthys	stigmaeus
SPLT	splittail	Cyprinidae	Pogonichthys	macrolepidotus
SPR	Sacramento perch	Centrarchidae	Archoplites	interruptus
SRF	shiner perch	Embiotocidae	Cymatogaster	aggregata
SSM	surf smelt	Osmeridae	Hypomesus	pretiosus
STB	striped bass	Moronidae	Morone	saxatilis
STF	starry flounder	Pleuronectidae	Platichthys	stellatus
STSP	Striped Seaperch	Embiotocidae	Embiotoca	lateralis
STU	sturgeon unknown	Acipenseridae	Acipenser	n/a
SUC	sucker unknown	Catostomidae	n/a	n/a
SVR	silver surfperch	Embiotocidae	Hyperprosopon	ellipticum
TC	tui chub	Cyprinidae	Gila	bicolor
TFS	threadfin shad	Clupeidae	Dorosoma	petenense
TGO	tidewater goby	Gobiidae	Eucyclogobius	newberryi
THORNB	Thornback Ray	Platyrhinidae	Platyrhinoidis	triseriata
TP	tule perch	Embiotocidae	Hysterocarpus	traskii
TPS	tidepool sculpin	Cottidae	Oligocottus	maculosus
TSM	topsmelt	Atherinopsidae	Atherinops	affinis
TSS	threespine stickleback	Gasterosteidae	Gasterosteus	aculeatus
UNID	unidentified fish	n/a	n/a	n/a
W	warmouth	Centrarchidae	Lepomis	gulosus
WAG	wakasagi	Osmeridae	Hypomesus	nipponensis
WBS	whitebait smelt	Osmeridae	Allosmerus	elongatus
WCK	white croaker	Sciaenidae	Genyonemus	lineatus
WEE	wolf-eel	Anarhichadidae	Anarrhichthys	ocellatus
WHB	white bass	Moronidae	Morone	chrysops
WHC	white catfish	Ictaluridae	Ameiurus	catus
WHS	white crappie	Centrarchidae	Pomoxis	annularis
WSP	walleye surfperch	Embiotocidae	Hyperprosopon	argenteum
WST	white sturgeon	Acipenseridae	Acipenser	transmontanus
WTSP	white seaperch	Embiotocidae	Phanerodon	furcatus
YEB	yellow bullhead	Ictaluridae	Ameiurus	natalis
YEP	yellow perch	Percidae	Perca	flavescens
YFG	yellowfin goby	Gobiidae	Acanthogobius	flavimanus

APPENDIX E: PUBLICATIONS USING DJFMP AND DJSSS SALMON DATA

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