Stockton and Sacramento Deepwater Ship Channel Maintenance Dredging Project

2009 Fish Community and Entrainment Monitoring Report

Prepared for

U.S. Army Corps of Engineers, Sacramento District
1325 J Street
Sacramento, California 95814

Prepared by

Mari-Gold Environmental Consulting Inc.
25385 South Hughes Lane
Canby, Oregon 97013

and

Novo Aquatic Sciences, Inc.
716 SE Malden Street
Portland, Oregon 97202

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Acknowledgements

This monitoring program has involved cooperative efforts by many individuals and organizations. Mari-Gold Environmental Consulting Inc. (MEC) biologist Jordan Gold, and Novo Aquatic Sciences, Inc. (NAS) biologist Steve Novotny were responsible for field operations, data collection, and reporting. Leuth Novotny (NAS) provided GIS/database services including database maintenance, technical editing and additional QA/QC. Derek and Colin Loree of Loree Consulting also provided GIS technical assistance. Jonas Moiel of Green Banks, LLC provided needed assistance with the fieldwork for a portion of 2009 dredging season. The authors extend their gratitude to Ross Island Sand and Gravel Company for their expertise and logistical support. This program could not be conducted without a close working relationship between the biologists and the dredgers. Each has their areas of expertise with little overlap. The ability to conduct the required sampling is due in large part to merge highly disparate disciplines with very different goals. It is only through careful analysis of activities, sampling needs, and operational parameters and constraints that the investigators are able to conduct the sampling with little to no interruption of the dredging activities. This could not be done without the full cooperation and enthusiasm of the Ross Island dredging crew. The authors also extend their gratitude to Robin Rosenau, Gary Kamei, and others at USACE - Sacramento District for monitoring oversight and regulatory compliance; CDFG - Stockton Office personnel Kelly Souza, Chuck Armor, and Marty Gingras for native fish regulatory guidance and Julio Adib-Samii for assistance with wakasagi identification; Damon Goodman, USFWS - Arcata for lamprey identification assistance; Dr. Jeanette Howard of The Nature Conservancy for native mussel identification assistance; and CDFG License and Revenue Branch, for their assistance with scientific collecting permits and renewals.

Dedication

This report is dedicated to my dog Cal. I had to euthanize Cal on February 11, 2010, while this report was being finalized. He had to go because his hips finally gave out, but he was as good a dog as a person can have right to the end. He came into my life in 1998 when I was living on a floating home in the Delta. He was a black lab and really loved living on the water. I miss that dog.

Abbreviations

Abbreviation	Full Term or Name
BO	biological opinion
CDFG	California Department of Fish and Game
CESA	California Endangered Species Act
CNDDB	California Natural Diversity Database
Corps or USACE	U.S. Army Corps of Engineers
CPUE	catch per unit effort
Delta	Sacramento River and San Joaquin River Delta
DMP	dredged material placement (site)
DO	dissolved oxygen
DPS	distinct population segment
DWSC	deepwater ship channel
EFH	essential fish habitat
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FMP	fish entrainment and fish community monitoring plan
FMWT	Fall Midwater Trawl [survey]
GPS	global positioning system
H^x	hypothesis
IEP	Interagency Ecological Program
IUCN	The World Conservation Union
MEC	Mari-Gold Environmental Consulting, Inc.
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NAS	Novo Aquatic Sciences, Inc.
NMFS	National Marine Fisheries Service
ntu	nepholometric turbidity unit
ppm	parts per million
ppt	parts per thousand
POD	Pelagic Organism Decline (study)
RISG	Ross Island Sand and Gravel
RM	river mile
SCP	scientific collecting permit
SD	standard deviation
SE	standard error
SF	San Francisco
SRSC	Sacramento River Deep Water Ship Channel
SSC	Stockton Deep Water Ship Channel
SWCA	SWCA Environmental Consultants, Inc.
USCG	U.S. Coast Guard
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service

1 Executive Summary

This document presents the results of the 2009 fish community and fish entrainment monitoring for maintenance dredging in two deepwater ship channels (DWSC): the Stockton Deepwater Ship Channel (SSC) and the Sacramento River Deepwater Ship Channel (SRSC). Monitoring was instituted to ensure compliance with applicable environmental laws and regulations including Section 7 of the Endangered Species Act (ESA), to quantify the level of incidental take of special-status fish species, and to provide feedback to the U.S. Army Corps of Engineers (Corps) regarding long-term dredging and dredged material placement activities. The Corps will use the feedback to assess and implement adaptive strategies that may decrease potential environmental impacts of the activities.

Fish entrainment was monitored during the 2009 dredging season exclusively using the prototype, mobile entrainment screen constructed in early 2008. Bottom trawling was used to monitor the fish community in the active dredge area of the shipping channels.

Dredging commenced on August 16, 2009, and ended on October 16, 2009. In general, each type of sampling (entrainment and fish community) was conducted on alternating days while the dredge was operating, although occasional night sampling was conducted for comparative purposes. Sampling did not occur on days when the dredge was being moved to a new location or was not in operation. Water quality sampling was conducted in conjunction with the fish community sampling efforts. Dredging operations in 2009 concluded prior to the close of the project in-water work window (November 30). Consequently, observational fish monitoring 24 hours a day aboard the active dredge was not required in 2009 as in 2006 and 2007.

The key findings of the 2009 entrainment monitoring at the dredged material placement (DMP) sites were:

- The prototype mobile entrainment screen was used at all DMP sites during the 2009 dredging season. This was the first dredging season that the sampling cell method was not used at any DMP sites. The goal was to sample 5% or more of the dredge output and 5.64% was sampled. This represents a significant improvement over previous years compared to 4.4% of overall dredged material sampled in 2008, 0.35% in 2007, and 0.37% in 2006.
- A total of 403 individual fish from 14 different taxa were encountered during 26 entrainment surveys.
- The introduced shimofuri goby (*Tridentiger bifasciatus)* was the most common fish species found in entrainment samples and comprised 64.76% of the entrained individuals.
- Lamprey (*Lampetra* spp.), comprising 4.71% of the entrained individuals, were the most common native species encountered in entrainment sampling. Lamprey were not observed or encountered in the fish community sampling within navigation channels. A single pacific lamprey (*Entosphenus tridentata)* was entrained. Lamprey and prickly sculpin (*Cottus asper)* were the only native fish encountered during entrainment sampling.
- No federal or state special-status species were encountered in 2009 entrainment samples.
- Similar to previous years, the majority of fish entrained were demersal species that were also encountered during fish community monitoring. For the first time, shimofuri goby, rather than white catfish (*Ameiurus catus*) or channel catfish, was the most commonly entrained fish.
- No entrainment sampling was conducted at the Scour Hole DMP site because the dredge was working in this reach for less than 24 hours. Fish community monitoring was conducted.

- The volume of slurry (dredged water and sediment) sampled throughout 2009 monitoring varied from 3.35% of total deposited slurry at the Windmill Cove dredge reach / Roberts 1 DMP site to 8.99% at the Upper Turning Basin dredge reach / Roberts 2 DMP site. A total of 34,932,127 gallons of slurry was sampled in 2009 surveys.
- A total volume of approximately 619,899,702 gallons of slurry was placed at DMP sites during the 2009 maintenance dredging season. Of this total, approximately 125,085,921 gallons of slurry were dredged from the SRSC and 494,813,781 gallons were dredged from the SSC.

The key findings from the 2009 fish community (trawl) sampling were:

- A total of 6,240 individual fish were encountered during 2009 trawl surveys. These fish represented 22 of the approximately 40 species presently known to occur in the Sacramento River and San Joaquin River Delta (the Delta).
- Twenty-seven trawl surveys were performed in 2009. A total of 96 successful trawl tow replicates were conducted. Total trawled distance was 50,822 meters.
- Six of the encountered fish species are native to the Delta and 16 are introduced.
- As in previous years, white catfish, an introduced demersal (bottom-oriented) species, was the most commonly encountered species in trawl samples and accounted for 55.02% of the total catch in 2009.
- Special status fish species (CESA or ESA threatened or endangered) were not encountered in 2009, unlike previous years when green sturgeon, delta smelt, and longfin smelt were encountered.
- Non-native species accounted for 99.65% of the fish encountered during community sampling. Delta smelt were the most commonly encountered native fish during 2008 (0.33%), similar to 2007. In 2009, however, starry flounder and white sturgeon were the most commonly encountered native fish each comprising 0.11% of the catch.
- Native fishes comprised 1.78% of total fish encountered from the single SRSC location and 0.24% of fish from all the SSC locations.
- Twelve of the 22 species encountered during fish community monitoring were also encountered during entrainment monitoring. Only one of the species encountered during both types of monitoring in 2009 was native: the prickly sculpin.

All data collected in 2009 were incorporated into the Microsoft (MS) Access database constructed for this project in 2006. The database provides data integrity for this large and growing data collection, streamlines electronic field data entry, and can enable examination of the complex relationships between fish presence and other environmental factors such as seasonality, water quality, tidal phase, presence/absence of other species and additional variables. It enables assessment of changes to the fish community resulting from management actions, anthropogenic influences, and/or environmental fluctuations/ perturbations.

Several special-status species designations changed during the 2009 monitoring period. Longfin smelt was petitioned for California and federal ESA listing on August 8, 2007. The California Fish and Game Commission accepted the petition on February 7, 2008, and longfin smelt were listed as threatened under California Endangered Species Act (CESA) on June 25, 2009. On April 8, 2009, the US Fish and Wildlife Service (USFWS) concluded that the San Francisco (SF) Bay - Delta population of longfin smelt did not meet the legal criteria for protection as a species subpopulation or distinct population segment (DPS). The USFWS is currently conducting a status review of all West Coast longfin smelt populations. Delta smelt were accepted as state candidates for up-listing from

threatened to endangered status under CESA on January 16, 2009. Take allotments for delta and longfin smelt encountered by this monitoring program remained unchanged during 2009.

Notable amongst the non-listed native fish species encountered by this monitoring program are Sacramento splittail (*Pogonicthys macrolepidotus)* and lamprey species. Sacramento splittail*,* a native minnow, have been encountered every year that this monitoring has been conducted, including 2009. On January 22, 2010, the Center for Biological Diversity won a lawsuit requiring the USFWS to make a new finding by September 30, 2010 on whether listing splittail as threatened or endangered is warranted. The possible listing of splittail in 2010 is unlikely to affect the 2010 dredging season, but could affect the 2011 season.

Two species of lamprey are known to occur in the project area: Pacific lamprey (*Entosphenus tridentata)* and river lamprey (*Lampetra ayresii)*. Though Western brook lamprey (*Lampetra richardsoni)* and Kern brook lamprey (*Lampetra hubbsi)* may be present in the Delta, Brown and Moyle (1993) described both species as utilizing higher elevation portions of the San Joaquin River If either species is present in the project area, it is more likely the western brook lamprey as this species is known to inhabit larger river systems than the Kern brook lamprey. Although not currently protected under ESA or CESA, these species are recognized by USFWS and others (Moyle 2002, Goodman et al. 2009) as species that require greater conservation efforts. Lamprey have been encountered during each year of the study in both the fish community and entrainment samples.

All plans and reports stemming from this monitoring program since its inception are now available through a link from the following web address: http://www.mari-gold.biz.

2 Introduction

This document provides a description of the fourth year of fish community monitoring and the fifth year of dredge entrainment monitoring conducted for the Sacramento District of the Corps through its contract with Ross Island Sand and Gravel Company (RISG). The Corps is authorized and required to maintain channel depth and levee integrity along the SRSC and the SSC. This monitoring program was mandated by the National Marine Fisheries Service (NMFS) through formal consultation with the Corps to:

- Ensure compliance with applicable environmental laws and regulations including Section 7 of the ESA and the Clean Water Act.
- Quantify the level of incidental take of special-status fish species.
- Assess linkages between the fish community around the dredge reach and the numbers and types of fish species entrained by the dredge.
- Provide feedback to the Corps and other agencies to assess and implement adaptive strategies designed to diminish negative environmental effects of the long-term dredging and dredged material management.

The Corps and NMFS have developed a ten-year programmatic approach to maintain the SRSC and SSC to their authorized depths via maintenance dredging and levee stabilization, as described in the biological opinions (BO) and supplemental documents for the shipping channels (NMFS 2006a,b). Although the timing of dredging projects in the Delta is regulated through area-specific dredging windows, NMFS recognized in these BOs that additional protections for ESA-listed fish (salmon, steelhead, and sturgeon) were needed. To that end, NMFS tasked the Corps with developing and conducting fisheries monitoring associated with Delta ship channel maintenance dredging. SWCA Environmental Consultants, Inc. (SWCA) designed and conducted this monitoring from 2006 through 2008. In 2009, a new contractor, Mari-gold Environmental Consulting Inc. (MEC), was selected by RISG to conduct this work. Jordan Gold, who provided the research vessel and much of the scientific expertise utilized by this monitoring program since its inception, founded MEC. The Corps and NMFS annually review the plans and reports for this project to determine that they are consistent with and appropriate for the requirements of the BOs (i.e., monitoring the effects of maintenance dredging and bank protection on fish in the SSC and SRSC).

This monitoring program was developed to meet the requirements of Conservation Measure 12 of the NMFS BO's (2006a,b – Note: Conservation Measures 1 through 11 address dredging operations rather than fisheries monitoring). NMFS is required to ensure that project actions do not jeopardize the viability and existence of protected species (steelhead, salmon and green sturgeon) under their jurisdiction. The conservation measures developed through the ESA consultations augment the established in-water work windows that regulate the timing of Delta dredging projects. The established annual work windows for maintenance dredging are from June 1 through December 31 for the SSC, and between June 1 and February 27 for the SRSC (restricted to upstream areas in the Man-made Channel beginning December 1).

Following the collection of delta smelt during (this study's) fish community monitoring in November and December 2007, the Corps' Sacramento District requested clarification and guidance from the USFWS regarding incidental take of delta smelt during future maintenance dredging and monitoring activities. In August 2008, in order to minimize potential effects to delta smelt, the USFWS appended the deepwater ship channel maintenance dredging projects to their programmatic consultation on the issuance for Section 10 and 404 permits (Service File Number 1-1-04-F-0345). Under the appended

consultation, the normal in-water work window for protection of delta smelt was then further restricted from August 1 to November 30. Additionally, each week of the permitted dredging season a maximum of ten delta smelt may be collected during monitoring.

Work windows prescribed by the California Department of Fish and Game (CDFG) for the protection of longfin smelt were established due to their threatened status under CESA. These two work windows are: August 1 through October 31 in the SRSC from river mile (RM) 5-10 and RM 31-34 and in the SSC between RM 5-10; and August 1 through November 30, in the SSC between RM 31-32 and RM 36-40.

To convert the NMFS mandated monitoring requirements into testable assumptions. The following hypotheses (H^1 and H^2) were developed prior to the initiation of the 2006 sampling:

H^1: Maintenance dredging of the SSC and SRSC will result in take of listed and other fishes through direct dredge entrainment.

H^2: There is a correlation between presence of fish in the dredging areas and entrainment by the dredge.

H^2a: Differential use of the water column will result in different entrainment levels among fishes present in the project areas; that is, demersal fish that are associated with the channel bottom (benthic and epibenthic species) will be entrained at higher levels than pelagic fish, which are associated with the water column.

This report presents the results of sampling activities conducted from August 16, 2009, through October 16, 2009. These activities consisted of fish entrainment sampling and fish community sampling. The entrainment monitoring was designed to quantify the level of incidental take of special-status and other (fish) species by the dredging operation. The fish community monitoring was designed to assess which species are present in dredge areas during active dredging and are therefore potentially vulnerable to entrainment by the dredging operation.

The monitoring requirements are focused on species that are listed as threatened or endangered under the ESA, due to the impact that these species can have on annual maintenance dredging of the SSC and SRSC. This report therefore includes information on the following federal special-status species that occur in the SSC and SRSC:

Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) – endangered
Central Valley spring-run Chinook salmon (*O. tshawytscha*) – threatened
Central Valley steelhead (*O. mykiss*) – threatened
delta smelt (*Hypomesus transpacificus*) – threatened
green sturgeon (*Acipenser medirostris*) – threatened

It is important to note that special-status species designations are not limited to the federal ESA nor are they fixed. These monitoring activities are also accountable to provisions of CESA. The CESA-listed species relevant to these monitoring activities consist of:

longfin smelt (*Spirinchus thaleichthys*) – threatened
delta smelt (*Hypomesus transpacificus*) – endangered
winter-run Chinook salmon (*Oncorhynchus tshawytscha*) – endangered
Central Valley spring-run Chinook salmon (O. tshawytscha) – threatened

CDFG also maintains a list of fish Species of Special Concern. This list contains species that have experienced declines in population levels, have limited ranges, and/or are vulnerable to continuing threats of extinction. Some of these species have not yet been awarded any other state or federal status, and have not impacted this monitoring program as of yet. However, the authors feel that it is prudent to list them here due to the likelihood of these fish species having an impact on monitoring and/ or dredging during the lifetime of this monitoring study. These species include:

Chinook salmon – Central Valley fall / late fall-run *(Oncorhynchus tshawytscha)* ESU
river lamprey *(Lampetra ayresii)*
Pacific lamprey *(Entosphenus tridentata*)
hardhead *(Mylopharodon conocephalus)*
Sacramento splittail *(Pogonicthys macrolepidotus)*

River lamprey have been encountered in both shipping channels during each year that monitoring has been conducted. Pacific lamprey (an ammocoete) was encountered for the first time in 2009. This species, along with five other lamprey species endemic to California, were petitioned for listing under the ESA in 2003 but all were denied (USFWS 2004). Future petitions for CESA and/or ESA listing of these species are likely, with attendant implications for dredging and monitoring, should listing occur. This monitoring program has encountered lamprey during both fish community and entrainment sampling. The lamprey encountered in the fish community samples from 2006 and 2007 and fish entrainment samples from 2006, 2007, and 2008 have been confirmed as river lamprey – a rare species that has not been well studied. Lamprey specimens from 2008 sampling were submitted to the USFWS for ongoing genetic analyses. Nearly half of all lamprey encountered in 2008 were positively identified as river lamprey, with the remaining specimens identifiable only to the genus or family level. Twenty lamprey were encountered during 2009. Only one was vouchered for morphologic and genetic analyses and was determined to be a Pacific lamprey.

The 19 lamprey encountered in 2009 that did not undergo genetic analyses are assumed to be mostly, if not all, river lamprey. For 2009 and previous study years, all lamprey of genus *Lampetra* are considered as a single species: the river lamprey (*L. ayresii*). A possibility exists that Pacific lamprey, western brook lamprey and Kern brook lamprey have been among the lamprey previously encountered, and incorrectly identified due to the difficulty in resolving these fish to species level when in the ammocoete stage (such as most of the individuals encountered). Goodman et al. (2009) describes morphological characters that allow differentiation between *Entosphenus* and *Lampetra* in the field, though determining the species of *Lampetra* ammocoetes encountered in the future may still require genetic analysis.

There are several other native fishes that utilize the Delta channels and have been, or could be, encountered while conducting this monitoring program – some imperiled to one degree or another. These species have been awarded special status by several entities not yet mentioned, such as the

American Fisheries Society (AFS), the USFWS, and The World Conservation Union (IUCN). This information is continually refined and updated by CDFG and is reported in The California Natural Diversity Database (CNDDB) special animals list. CDFG also produces a frequently updated list of state and federally listed endangered and threatened animals of California. The July 2009 CNDDB and January 2010 CDFG lists were the latest available at the time of this writing. Both lists are available at: www.dfg.ca.gov/biogeodata/cnddb/.

This project has also encountered and documented non-native fish species that are currently a major focus of the Pelagic Organism Decline Study (PODS) due to their rapidly declining populations and their importance to the Delta ecosystem (IEP 2008). Though unable to receive special status (listing) due to the fact that they are not native fishes, their recent major population declines are of significant concern. Though encountering these species will not alter dredging or monitoring operations in the foreseeable future, the data from this annual monitoring program includes information about relative population levels of fish species in multiple Delta (channel) locations. This information is delivered to Interagency Ecological Program (IEP), CDFG, and other parties in order to satisfy permit requirements and for research interests. Use of this information on these and other species is an indirect benefit of this monitoring program. These species are:

threadfin shad (*Dorosoma petenense*)
striped bass (*Morone saxatilis*)

Dredging and monitoring activities are affected by proposed listings, new listings, and indications of likely future listings of special-status species. The dynamic nature of listing status had a direct effect on dredging and associated monitoring activities in 2007 and 2008, due to changes in the CESA status of delta smelt and longfin smelt that resulted in shortening of the dredging windows. There were no impacts due to status change during 2009.

Recent state and federal petitions have requested that delta smelt be up-listed from threatened to endangered under CESA and ESA. California up-listed delta smelt to endangered status on March 4, 2009 (Final Statement issued on November 10, 2009). USFWS had not yet commented on the petition to up-list delta smelt from threatened to endangered status at the time of this writing, though they did announce the initiation of a five-year status review on March 24, 2009.

During 2007 fish community sampling, one delta smelt was encountered on November 21 in the SSC, and ten delta smelt were encountered between December 2 and December 12 in the SRSC. This led to a mandatory shift in dredging locations and then the suspension of remaining 2007 dredge operations in the SRSC. In 2008, dredging was started in the SRSC in August and finished in the SSC in November. Twenty-two delta smelt were encountered from August 6 to September 6 in the SRSC, and three were encountered on September 21 near the upstream end of West Island in the SSC. No delta smelt were found upstream of Antioch Bridge in the SSC from late September to late November 2008, when dredging operations were completed. No delta smelt were encountered during 2009 fish community or entrainment monitoring.

The California Fish and Game Commission enacted protections for longfin smelt in 2008, which was a CESA candidate species at that time. Incidental take of longfin smelt while conducting fish community monitoring was restricted to 150 juveniles and 150 adults for the entire year. Longfin smelt were accepted as threatened under CESA by the Commission on March 4, 2009. Federal protection of the longfin smelt was recently denied by the USFWS following review of the petition to list the longfin smelt under the ESA (April 9, 2009). The USFWS found that the San Francisco Bay-Delta longfin smelt did not qualify as a distinct population segment (DPS). The USFWS has initiated (April

9, 2009) a status review for the entire longfin smelt population from Alaska to California. No longfin smelt were encountered during 2009 fish community or entrainment monitoring.

This annual monitoring report is submitted to the Corps and CDFG as a reporting requirement for fish monitoring of federal ship channel maintenance dredging activities. Collection details of any ESA-listed fish is reported within 24-hours to the Corps Sacramento District's Environmental Scientist and RISG's Project Manager; subsequent notifications are then made by the Corps to the regulatory agencies of NMFS, USFWS, and/or CDFG. Additional requirements include reporting of sampling activities and ESA fish collections on a weekly basis to the ESA Reporting Website of IEP, a requirement for research projects conducted in the SF Bay-Delta region (CDFG 2008a). Resource agencies including NMFS, USFWS, and CDFG may access the IEP database for updated ESA catch reports. The license and revenue branch of CDFG requires an annual collection summary for review and renewal of state scientific collecting permits (SCP) held by the investigative biologists conducting the fish monitoring. The SCP collections summaries are submitted to Paul Roberts or Russ Bellmer at CDFG (Sacramento) and now require a review period of 28 weeks prior to renewal of permits. CDFG also requires reporting of all state Endangered, Threatened, and Special Concern species to the California Natural Diversity Database. All longfin smelt (California Code of Regulations - Longfin Smelt 2084 Regulation), and sturgeon collection data are sent to biologists at the Bay-Delta Branch of CDFG as detailed in specific measures of the SCPs.

This report describes fish species encountered at each dredging location and compares sites based on simple assessments of catch per unit effort (CPUE), species composition, and overall numbers of fish. Although species that do not have special status under federal law are outside the monitoring requirements for dredging in the SRSC and SSC, the sampling methods used for monitoring yielded information on these species. Since species status determinations are ongoing and any changes in status could affect dredging and monitoring activities, this report includes data on all species encountered. Comparisons with data from previous years are made when sufficient data are available. This report also discusses the efficacy of the monitoring methods, efforts to minimize sampling mortality, and adaptive management measures with suggestions for future monitoring.

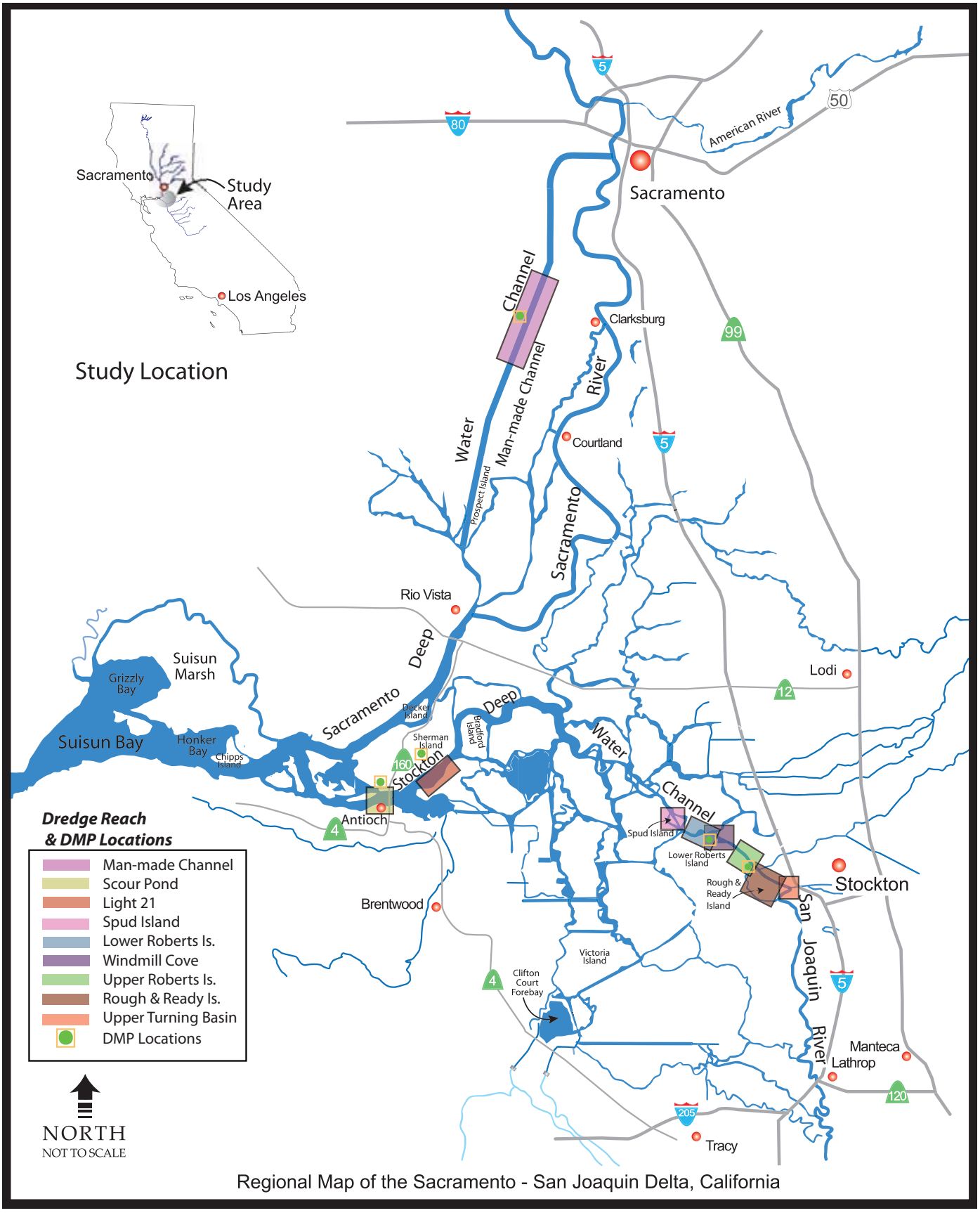

Figure 1. Project Area Map, Dredge Reaches, and DMP Sites

Adapted from USACE - SF District, LTMS Program Map

3 Methods

3.1 Sampling Methods Overview

The sampling methods followed for fish community and entrainment monitoring during the 2009 SRSC and SSC maintenance dredging were those presented in the Fish Entrainment and Fish Community Monitoring Plan (FMP) for 2007–2008 (SWCA 2007). Methods were based on their appropriateness for sampling the dredging locations (i.e., dredging in deepwater mid-channel locations with water column depths greater than 20 feet). The methods were:

- Bottom trawling against the current, to monitor the fish community in the active dredge area of the shipping channels (the channel bottom), with water quality parameters measured in conjunction with bottom trawling.
- Entrainment monitoring (end of pipe) using the portable entrainment monitoring screen.

Timing of 2009 dredging operations did not extend beyond the approved work window. As a result, observational monitoring 24 hours a day aboard the dredge was not necessary as in 2006 and 2007.

All fish encountered in the bottom trawl or entrainment screen samples, with some exceptions, were counted and identified to the species level. Preserved lamprey specimens were shipped to USFWS taxonomy experts in Arcata, California, for inclusion in ongoing genetic studies and further species identification.

Fish were identified, counted, and classified by life history stage. A subset of each fish species was measured for length. As many individual fish as possible were released back to the water with minimal harm. Stressed fish, or fish species easily injured by trawling activities, were quickly counted and released without further processing. Gross body abnormalities, injuries, fin clips, or other markings were noted. Fish were sometimes vouchered for further assessments or due to permit requirements. Fish-eating bird and sea lion activity was closely observed while monitoring during daylight sampling. Bird congregations over open water often indicate fish presence, and feeding activity by birds in DMP sites is often an indicator of the presence of entrained fish or other prey organisms. Sea lion activity is often indicative of the presence of adult salmon or other large fish that are likely sea-lion prey.

Invertebrates were, in most cases, identified to species level, and their numbers were directly counted or estimated depending on species abundance.

3.2 Sampling Effort, Timing, and Sampling Locations

An overview map of the project area including the sampling locations associated with each dredge reach is provided in Figure 1. Location data and activity periods are also summarized in Table 1. Prior to the 2009 dredge season, RISG provided MEC with a tentative dredging schedule. The schedule included the approximate timing and location of each channel location (dredge reach) to be dredged. Sampling was conducted during every day of active dredging. In general, fish community and entrainment sampling were conducted on alternating days. Due to inherent uncertainty regarding the exact timing of active dredging, fish community sampling was initiated within 24-hours of when active dredging actually commenced. Entrainment sampling was usually conducted on the second day of

dredging at each dredge reach. Both types of sampling continued at each dredge reach until dredging at that reach was completed.

Table 1. SRSC & SSC 2009 Maintenance Dredging Locations

River Channel	Dredge Reach	Dredge Area (RM) From	Dredge Area (RM) To	Excavated Dry Material (cy)	Estimated Material % of Slurry	Estimated Total Slurry Volume (gal)	DMP Site	Time Frame Start	Time Frame End
Sacramento	Man-made Channel	30.87	32.86	65,008	9.5	125,095,921	S-31	Aug 16	Aug 26
San Joaquin	Scour Pond	8.81	8.90	4,454	8.5	9,685,092	Scour Hole	Aug 28	Aug 29
San Joaquin	Light 21 Reach	11.65	12.22	35,734	10.0	64,964,412	McCormack Pit	Aug 31	Sept 5
San Joaquin	Spud Island	31.65	32.20	30,579	15.0	35,002,762	Roberts 2	Sept 11	Sept 14
San Joaquin	Lower Roberts Island	32.20	32.95	34,890	15.0	39,937,420	Roberts 2	Sept 14	Sept 17
San Joaquin	Windmill Cove Area	33.62	34.09	30,153	12.5	42,636,342	Roberts 2	Sept 17	Sept 20
San Joaquin	Upper Roberts Island	34.66	36.72	100,624	10.0	182,934,432	Roberts 1	Sept 20	Oct 4
San Joaquin	Rough & Ready Island	38.48	39.32	61,223	12.5	86,569,322	Roberts 1	Oct 5	Oct 11
San Joaquin	Upper Turning Basin	40.08	40.64	28,894	15.0	33,073,999	Roberts 1	Oct 12	Oct 16
Total				**391,559**		**619,899,702**			

The methods defined in the FMP were designed to sample as many diel/tidal regimes as possible. Consequently, sampling times were varied so that diurnal fish movements, as well as tidal elevation and river flow changes, would be reflected in the sampling results, and differences in species composition and entrainment based on diurnal or tidal rhythms might be assessed. A random sample design was not employed since it was necessary for entrainment monitoring to coincide with active dredging. Sampling was performed under a variety of light conditions. Twenty-seven total trawl surveys were successfully completed. Ten were conducted during low light or nighttime conditions. Twenty-seven entrainment surveys were performed and most occurred during daylight hours due to logistical, operational, and safety issues. Seven entrainment samples were successfully conducted in low light or nighttime conditions.

As listed in Table 1, a total of approximately 391,559 cubic yards of total dredged material was placed at DMP sites during 2009. Approximately 326,551 cubic yards were dredged in the SSC and 65,008 cubic yards in the SRSC. All material was dredged using RISG Dredge No. 7, a hydraulic cutter-head suction dredge with an 18-inch (inside diameter) discharge pipe. The total estimated overall slurry output from the dredge was 620 million gallons. The approximate average pumping rate varied by location from 10,275 gallons per minute at Scour Pond DMP site to 15,588 gallons per minute at Roberts 2 DMP site.

The mobile entrainment screen was used at all DMP sites for the first time in 2009. Effort levels for 2009 are summarized by monitoring method and presented in Tables 2 and 3. These tables present the level of effort attempted versus results achieved during both entrainment and trawl sampling. Entrainment sampling was disrupted on several occasions in 2009, usually the result of unexpected dredge shutdowns unrelated to fish monitoring activities. The goal for entrainment sampling was to sample at least 5 percent of the overall dredge output based on an expected average dredge run time of 20 hours per day. An overall total of 5.64 percent of the dredge output was sampled in 2009, representing a significant increase over previous years; 4.4 percent of overall dredged material was sampled in 2008, compared to 0.35 percent in 2007 and 0.37 percent in 2006. Rather than an increase in sampling effort, this increase is due to abandonment of the sampling cell method entirely in 2009, due to its inability to assess significant portions of the dredge output.

Trawl survey locations within each dredging reach were either directly upriver of the dredge during an outgoing (ebb) tide or directly downriver during an incoming (flood) tide. Trawl surveys, DMP sites, and corresponding dredge reaches are displayed in Figures 13 through 21. Unsuccessful trawl tows, experienced on twelve occasions in five different dredge reaches, were usually the result of large wood or other debris hung up in the net, preventing a full 500-meter tow. In these instances, the net was hauled in prior to completion of the 500-meter target distance. If the field staff determined that a trawl was unsuccessful, any associated data was noted in the database as unsuccessful and excluded from CPUE calculations and analyses. After unsuccessful trawls, further attempts were repeated until a successful sample was made, except when the trawl net was damaged beyond the ability to affect an on-board repair.

Table 2. 2009 Entrainment Monitoring Effort at DMP Sites

DMP Site	Dredge Reach	Date Start	Date End	Sampling Days	Sampling Attempts	Material Type	Sampled Vol. (gal)	Dredge Slurry Vol. (gal)	Sample %
S-31	Man-made Channel	Aug 17	Aug 25	5	5	Mud	6,190,680	125,095,921	4.95
Scour Hole *	Scour Pond	--	--	0	0	Sand	0	9,685,092	0
McCormack Pit	Light 21	Sept 1	Sept 5	3	4	Sand	4,292,682	64,964,412	6.61
Roberts 2	Spud Island	Sept 12	Sept 14	2	2	Mud	2,692,860	35,002,762	7.70
Roberts 2	Lower Roberts Island	Sept 16	Sept 16	1	1	Mud	1,988,568	39,937,420	4.98
Roberts 2	Windmill Cove Area	Sept 18	Sept 18	1	1	Mud/Silt	1,431,480	42,636,342	3.35
Roberts 1	Upper Roberts Island	Sept 20	Oct 3	8	8	Mud/Silt	8,791,632	182,934,432	4.81
Roberts 1	Rough & Ready Island	Oct 5	Oct 11	4	4	Mud	6,569,674	86,569,322	7.49
Roberts 1	Upper Turning Basin	Oct 14	Oct 15	2	4	Mud	2,974,521	33,073,999	8.99
Total				26	29		34,932,127	619,899,702	5.64

* Scour Hole dredge operations less than 24 hours total duration. Monitored fish community by otter trawl sampling only, entrainment screen monitoring not conducted.

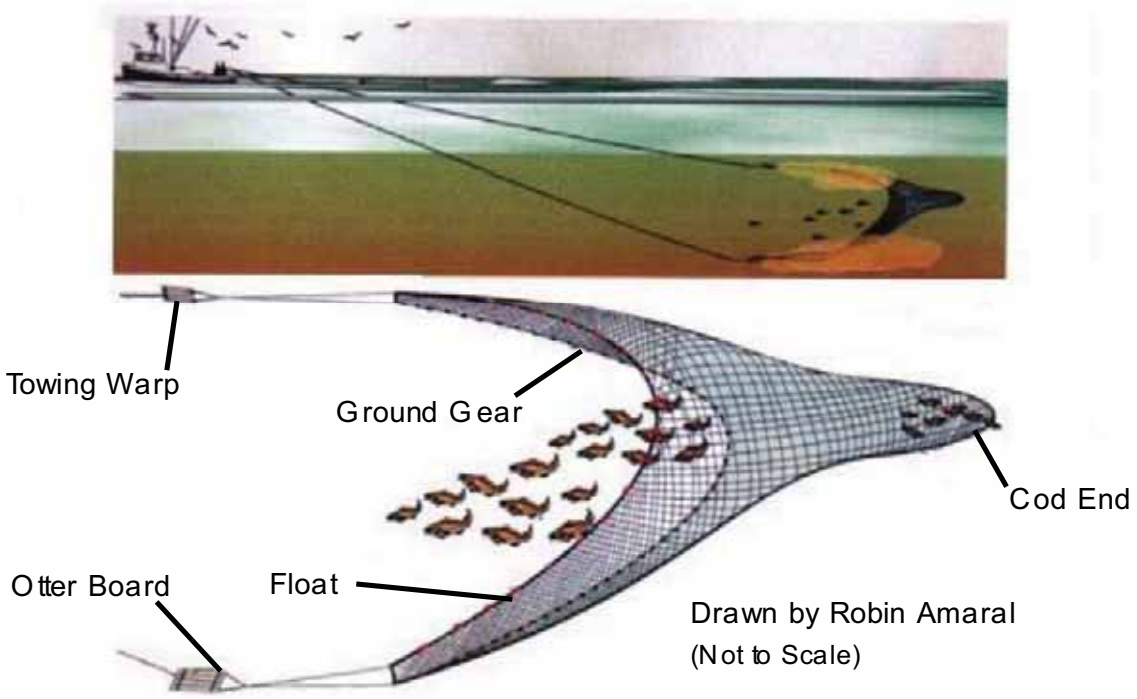

Figure 2. Otter Trawl Net Diagram

Source: Coonamessett Farm, 2001

Table 3. 2009 Fish Community Monitoring Effort by Dredging Reach

Dredge Reach	River Channel	DMP Site	Time Frame		Sampling Days	Trawl Tows		Distance Towed (m) *
			Start	End		Attempted	Successful	
Man-made Channel	SRSC	S-31	Aug 16	Aug 26	6	17	16	9,480
Scour Pond/Antioch	SSC	Scour Hole	Aug 28	Aug 29^	1	5	5	2,760
Light 21	SSC	McCormack Pit	Aug 31	Sept 4	3	15	15	7,295
Spud Island	SSC	Roberts 2	Sept 12	Sept 15	3	14	9	4,917
Lower Roberts Island	SSC	Roberts 2	Sept 17	Sept 19	2	6	5	3,046
Windmill Cove Area	SSC	Roberts 2	Sept 21	Sept 21	1	5	5	3,004
Upper Roberts Island	SSC	Roberts 1	Sept 23	Oct 4	5	18	16	8,652
Rough & Ready Island	SSC	Roberts 1	Oct 6	Oct 12	4	20	20	9,621
Upper Turning Basin	SSC	Roberts 1	Oct 14	Oct 16	2	7	5	2,047
				Totals:	27	107	96	50,822

* Successful trawl tows only ^ Night sampling began night of Aug 28 and ended early morning of Aug 29

3.3 Fish Community Sampling

Fish community sampling followed all relevant regulations and protocols to ensure ESA and CESA compliance, prevent accidents, and avoid in-channel obstructions. These practices are summarized below. Required federal and state scientific research permits were obtained from CDFG and the IEP through IEP Program Element Number 2009-113. Prior to the onset of the 2009 dredge season, CDFG wardens were notified of the intended collection schedule and planned collection locations. Notification requirements for ESA-listed species contact followed those in Appendix F of the FMP (SWCA 2007) and included weekly reporting through the IEP website. Communication with the dredge was maintained on fish community sampling days through use of VHF marine band radio or cell phone to ensure that the timing, methods, and location of trawling efforts did not hinder or compromise the dredge's operations or endanger personnel. Other information exchanged included vessel traffic, tidal phase, and any other important details concerning the sampling effort. An additional VHF radio monitored USCG and Vessel Traffic Information channels for the duration of surveys. The channel bottom in each dredge location was briefly surveyed using sonar and National Oceanographic and Atmospheric Administration charts to attempt to identify and avoid potential obstructions that might foul the net.

Fish community sampling was conducted up current of the working dredge, in the main navigation channel. An otter trawl, which is a semi-balloon type shrimp and fish trawl, was fished on the riverbed to target fish species assumed to be most susceptible to entrainment by the dredge. Each otter trawl used for 2009 sampling was a green, funnel-shaped net constructed with a 7-meter-long floating head-rope, a weighted foot-rope, and otter-doors attached just ahead of the net mouth to spread the net (Figure 2). The mouth of each trawl net used in 2009 measured approximately 1.25 by 7.9 meters with the body stretched; the mesh of each trawl net was 3 centimeters square, with a cod-end inner liner of 1 centimeter (stretched) mesh. The inner liner was composed of a soft nylon delta-style weave designed to be protective of fish scales and slime. The volume of water fished was determined as the product of net mouth area and overall linear distance towed, under the assumption that the mouth

area during a tow is 80 percent of the maximum stretched mouth area. The stretched mouth area was calculated as a rectangular shape totaling 9.875 square meters, with an 80 percent sampling size of 7.9 square meters.

The 27-foot-long RV *Karen M*., a custom aluminum jet boat, was used to conduct the trawling operations. The *Karen M* utilizes an A-frame and davit equipped with electronic windlasses for net deployment and retrieval (Figure 3). The A-frame (built in 2007) allows the crew to deploy the net from the stern without the need to haul the otter doors in and out on each trawl replicate. Use of the A-frame results in fewer net twists, and increases control and speed of net deployment.

A 250-foot-long bridle was used between the net and the vessel in order to achieve a minimum five-to-one scope (bridle length versus water depth) and ensure that the otter trawl would stay on the channel bottom while moving at efficient trawling speeds of 2 to 3 knots over water. Typically, five replicate trawl tows (trawls) were conducted for each survey. The direction of each individual trawl was determined by river current direction and was initiated as close as safely possible to the dredge's location. The net was towed along the river bed for approximately 500 meters from the starting point determined by a MacBook Pro portable computer running MacENC software (version 7.0) with a USB 20 channel SiRF III global positioning system (GPS) receiver that logged vessel position, track, bearing, and other information. Vessel tracks of trawls were displayed in real-time with a nautical chart overlay (see Figures 13-21). GPS vessel tracking information accurately measured the length (meters) and time (minutes and seconds) of each trawl that the net was fished along the channel bottom; tracking from when the net encountered the bottom to when the tow stopped, prior to retrieval.

The vessel speed during net deployment was adjusted so that the net did not move forward until it had reached the channel bottom. During retrieval, the vessel was maneuvered over the net's position on the bottom, and then hauled directly upward through the water column. These methods were employed to concentrate on demersal species and minimize collection of pelagic fish (fish associated with the water column and the surface, rather than the bottom).

Following retrieval, the cod end of the net was placed in a cooler filled with river water and the trapped fish, invertebrates, and debris were released into it. Large debris was removed and the catch was then quickly assessed (Figure 4). Assessment involved a quick inspection and then rapid removal of the most fragile species to minimize mortality (e.g., listed fishes, shads, striped bass). Data were collected on all individual fish specimens or on a subset of the catch, based on the number of fish encountered, their condition, and the desire to minimize mortality to the maximum extent possible. Fish and invertebrates were then released back to the river a short distance away from the assessed channel area.

Trawl catch was sorted and counted as described above. In previous years, some special-status species (green sturgeon, longfin and delta smelt) were quickly documented and, if alive, were released prior to documenting the remaining catch (no special status species were encountered in 2009). Some species are required to be vouchered for research purposes, regardless of capture disposition. Additionally collected trawl data includes: tow duration; date and time; sampling depth; tidal phase; current speed and direction; boat speed and engine rpm; bird/sea lion presence; direction of water flow (upstream or downstream); ship activity; and channel location. Water quality data were generally collected (upstream from the dredge) before the first and last replicate tow of each fish community survey. Water quality monitoring and methods are described in detail in Section 3.5.

Figure 3. *Karen M* Research Vessel

Figure 4. Examples of Fish Community Survey Tools and Methods

Trawl survey and water quality data was entered into the customized MS Access database running on a second MacBook Pro portable computer as the information was acquired. Large catches of fish during individual trawls required the use of paper forms (Appendix C) to document the catch as the need to minimize fish mortality outweighed the need to document the data electronically. When this occurred, the catch data was entered into the database at a later date.

3.4 Entrainment Sampling

Entrainment monitoring methods were selected based on the likelihood of their success to:

- Avoid and minimize take (damage or mortality) to entrained fish, particularly ESA-listed species.
- Quantitatively sample the dredge disposal stream, which is not uniform throughout the discharge pipe cross-section.
- Avoid or minimize dredge shutdowns or head loss resulting from sampling.

Two entrainment monitoring alternatives were presented in the 2007-2008 FMP (SWCA 2007). Both alternatives were modifications of methods that have been used to successfully monitor fish entrainment in Pacific Northwest dredging projects. The two alternatives were the sampling cell method and the collection basket (screen) method. In 2008, the prototype mobile entrainment screen was completed and used at all DMP sites, except the Bradford and Decker Island sites. In 2009, all of the entrainment sampling was conducted using the mobile entrainment screen. It is the intention to use this device at all sites during future monitoring efforts, as this prototype has proven its efficacy during the last two sampling seasons. However, there are DMP sites with access issues that may make it difficult to utilize the screen. If there are active sites in future years where the mobile entrainment screen cannot be used, then the sampling cell method will again be utilized at these sites. Information on this sampling cell method is only briefly presented in this year's report, as the method was not used during 2009. However, interested parties can read the 2006-2008 annual reports or FMPs for more information on this method. The mobile entrainment screen system addresses goals stated above in the following ways:

- The grain size of the majority of dredged material is small enough to pass through the screen while fish and invertebrates are retained. Organisms not apparently damaged by their passage through the dredge are easily collected and returned alive to the shipping channel.
- The entire output of the dredge is passed over the screen, effectively sampling all cross-sections of the discharge pipe.
- Operating the valve that switches the dredge discharge from the main DMP pond to the screen does not normally require any action by the dredge, thus minimizing dredge shutdowns or head loss resulting from sampling.

3.4.1 Sampling Cells

The sampling cell method used for fish entrainment monitoring was based on a method employed by Buell (1992). Entrainment monitoring with the sampling cell method involved discharge of the dredge slurry into a relatively small earthen cell isolated from the overall DMP site pond by a temporary berm. Sampling cells used prior to 2009 varied in size from 0.055 acres at the SRSC Sandy Beach DMP site to 0.57 acres at the SSC Roberts 1 DMP site. Overall sampling cell geometry, size, and placement were determined by the geography of the DMP site, its storage capacity, and the logistics of material placement. Due to inherent inefficiencies of the sampling cell method, only a small

percentage of the dredge's overall output was sampled this way: 0.35 percent and 0.62 percent in 2007 and 2008, respectively. Use of the mobile sampling screen allows an order of magnitude more dredged material to be assessed than with the sample cell method, given a similar level of effort. Due to the increased efficiency of the mobile entrainment screen, sampling cells will only be used for future monitoring if DMP sites preclude the use of the mobile screen due to access issues.

3.4.2 Mobile Entrainment Screen

The prototype mobile entrainment screen system was used at most of the DMP sites during the 2008 monitoring season. This system was used with the project goals of retaining all life stages of entrained organisms, except larval fishes, while also allowing large volumes of sediment to pass through the mesh. It achieved these goals last season (SWCA 2009) and so was also used at all sites during the 2009 maintenance dredging season.

The screen was built on trailer axles, enabling transport by road from site to site. Once on site, the screen was positioned in a stable location appropriate for discharge of the dredged material (Figure 5). The dredge output pipe was connected to the top of the screen with a Y-valve (Figure 6) operated by the dredge's on-shore (fill) crew. When the dredge output was not directed to the screen, it flowed directly to the DMP site pond. When in use, the slurry passes over the screen to allow sorting and observation of all entrained materials and organisms that do not pass through the screen. Track hoes and or bulldozers were used to clear material below the screen at DMP sites where necessary due to large grain size of material, lack of sufficient elevation for material flow, or other logistical considerations.

An entrainment survey began by switching the Y-valve to direct the entire dredge discharge onto the screen. The length of time that the valve directed flow to the screen was used to calculate the sampled percentage of dredge output. Two biologists trained in handling ESA-listed fish were stationed on either side of the screen to observe and collect organisms as the slurry stream filtered through the screen mesh. Dredged material was allowed to flow over the screen until the screen clogged with material, the sampling period expired, or the dredge itself shut down. Small pumps, with intakes in the river, supply the screen with pressure water to wash the accumulated material and organisms that do not pass through the 3/8-inch diameter screen. Large rubber squeegees, small nets, and various rakes and shovels are also employed to keep the screen clear, thereby allowing longer periods of continuous monitoring of the discharge stream without directing the flow back to the main DMP pond. After the accumulated material is sorted, it is swept off the end of the screen.

The ability of the screen to pass dredged material through the mesh is dependent on the grain size of the dredged material. A general description of the dredged material at each dredge location in 2009 is provided in Table 2. For the most part, the dredged sediments consist of sand and silt sized particles. However, a high degree of overall variation in grain size exists among dredge reaches as well as within each dredge reach. The commonly found "U" shape of the channel in cross-section can explain the within-channel variation in sediment load experienced on the entrainment screen. The dredge does not vary the height of the cutter head as it sweeps across the bottom, effectively dredging more material from each side of the channel due to its "U" shape. This results in pulses of heavy sediment loads on the screen corresponding to the dredge being near the side of the channel that are then interspersed with lighter sediment loads combined with more shell and debris from the surface.

Figure 5. Mobile Entrainment Screen Collection System

Figure 6. Photographs of Discharge Pipeline Y-valve

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There are vast shoals of Asian clams (*Corbicula fluminea)* in many locations in both channels, with wide variation in shell size and live to dead (empty shell) clam ratio. All but the smallest of the shells are retained by the screen. Many locations also have a percentage of larger grain size sediments in addition to the predominant sand or silt, ranging from pea gravel to large rock. Trash, bones, clay balls, golf balls, fishing gear and other items are among the things that do not pass through the screen. In 2009, more than in previous years, Brazilian water weed (*Egeria densa)* was very common among the retained material.

All of the material retained by the screen was sorted through to determine and document what organisms were present. This process could be completed without diverting the material flow back to the main DMP pond as long as the grain size was appropriate and the percentage of retained material to organisms was low. When this process could not be completed because the grain size was inappropriate or the percentage of retained organisms was high (example shown in Figure 7), the flow was diverted until the screen was cleared.

High dredge pumping rates also overwhelmed the screen on occasion during 2009, generally when the dredge was working very close to the DMP site and using a short discharge pipe. When this occurred, it was usually only for a small but significant portion of the dredge's swing across the channel bottom. These periods were timed, and not counted as sampling time, as any entrained organisms could have been carried off the end of the screen by the high flows and undocumented.

The screen surface is 20 feet long by 6 feet wide. Modifications to the prototype screen were made during the 2008 season to:

- Maximize the length of time the screen could be operated without powering down the dredge.
- Prevent erosion under the axles.
- Prevent splashing over the sides of the screen box.
- Replace the mesh style screen with punched steel plate to minimize loss of small organisms, reduce debris clogging, and increase survival of entrained fish.

The 3/8-inch woven wire mesh screen that was initially used during 2008 monitoring was replaced with 3/8-inch punch-hole steel plate, with an effective open area of 51 percent (Figure 8). The punched plate did not clog as quickly as the woven wire mesh and remained in use throughout 2009. In addition to clogging less quickly, the punched plate is smoother and easier to clear. It appears to be more fish friendly as well, as the entrained fish slide easily along the smooth plate, rather than bumping over wire-mesh. Additional improvements to the screen were suggested in the 2008 Fish Monitoring Report (SWCA 2009) and should be incorporated prior to initiation of sampling in 2010. These improvements are further discussed in the recommendations section of this report.

All fish either retained by the screen or observed passing through it were documented (a few lamprey and gobies were observed but not netted before escaping). Both live and dead retained fish were collected, examined, measured, and then released back into the river or vouchered for further examination.

3.5 Water Quality Monitoring

In situ water quality data were collected from the surface and near bottom twice during each trawl survey event, generally prior to the first and after the final trawl replicates of the day. Measurements were made and collected using a Horiba U-52 portable water quality meter (Figure 9). Parameters

measured included water temperature, dissolved oxygen (DO), pH, conductivity, turbidity, and salinity. The comparative measure of percent DO was later calculated from the direct DO (ppm) and temperature measures using a nomogram (Hutchinson *in* Bell 1991). Water quality readings were made within the same channel area as the trawl surveys.

3.6 Reporting, Data Management, Quality Assurance and Quality Control

3.6.1 Fish Entrainment

Overall entrainment rates were estimated for each species by extrapolating from the numbers of entrained fish per gallon of dredge slurry sampled, to the total number of gallons of slurry deposited at each DMP site. Pumping rate and volume information were provided by RISG. Conversion from dry dredged material amount to end of pipe slurry volume was made using the RISG provided estimate that final deposited material comprised 8.5 percent to 15 percent of total slurry volume per DMP site.

Entrainment rates for specific species were extrapolated for each location where entrainment occurred during 2009 monitoring. This data should be assessed cautiously considering the small percentage of dredge output used to calculate the overall entrainment rates. The overall percentage of dredged sediment from both shipping channels that was sampled in 2009 was 5.64 percent, versus 4.4 percent in 2008 and 0.35 percent in 2007.

3.6.2 Fish Community Sampling

Relative population abundance by species was assessed by simply ranking each species based on numbers of individuals encountered for: each sampled location, each channel, and both channels combined. The CPUE was determined by comparing numbers of individual fish caught to distance trawled. Mean CPUE for a survey was derived from the mean average of all successful trawl replicates for that day's trawl survey.

3.6.3 Mortality Estimation

Percent mortality among fish encountered during fish community sampling and fish encountered during entrainment sampling was calculated by comparing the observed or estimated mortality for each species to the total number of individuals of that species that were encountered. Mortality numbers were estimated in large trawl catches. It is possible that some fish initially counted as mortalities actually recovered after release. It is also likely that an unknown number of fish that appeared healthy at release subsequently died due to unobserved injury, predation or stress. A small number of fish were vouchered for further examination, resulting in immediate mortality of these individuals. Several adjustments to the collection and data acquisition methods designed to reduce mortality in future collections are discussed in the adaptive management and recommendations portions of the discussion section of this report.

3.6.4 Data Management

Data were documented in the field on portable computers directly into the Dredge Monitoring Database created with MS Access 2003 (upgraded in 2009 to MS Access 2007), and on paper data sheets. This database was created in 2006 to provide a streamlined data entry and management system for this study. This relational database allows sizeable amounts of information to be entered, stored, managed, verified, analyzed, and retrieved. It also provides a common framework for

managing and analyzing the information from this multi-year project. The database stores information on aquatic organisms potentially vulnerable to impacts of dredge operations and provides analytical tools to assess the data based on CPUE, species composition, and overall number of fish.

3.6.5 Quality Assurance and Quality Control

The MS Access database for the project provides structured, data entry forms for consistent data collection on field laptop computers. These entry forms restrict the type of information being entered into the database through focused user inputs and menus.

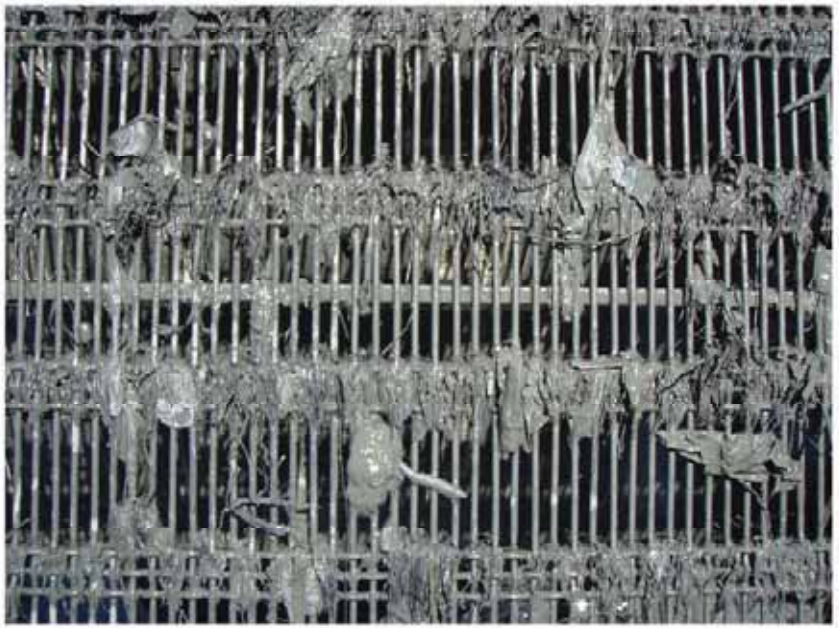
In addition to focused inputs and menus to control data entry, MS Access has user restrictions that provide a safeguard against multiple editors manipulating and changing the same tables and fields. These safeguards provide checks to ensure database tables and relationships are not compromised. Regular database backups were made to an external computer storage drive and copied to an additional project computer to further ensure integrity of collected data. Field crews were trained on the data collection forms before monitoring or sampling was carried out. Waterproof paper data collection forms continued in use for data verification purposes, foul weather/rough conditions, and for efficiency reasons in the case of specimen data collection. During 2009, approximately ten percent of the physical and water quality survey information was collected on paper forms providing a means to directly cross check duplicate data inputs. Few transcription errors were identified and corrected through this data verification process. Field crews made daily checks of the database to ensure accurate collection when redundant paper copies were not collected - an additional QA/QC measure specified in 2007–2008 FMP (SWCA 2007). Project biologists responsible for collecting the data checked database outputs.

As in past years, specimen data from each sampling event (species, length, anomalies, developmental stage, and disposition) were collected on waterproof paper field forms, because rapid data collection was often required when large numbers of fish and invertebrates were encountered in wet/dusty sampling conditions. These data were later entered into the MS Access database. Individual trawl replicates that had few specimens were entered directly into the database and checked for accuracy prior to leaving the survey location. Sample paper data entry and database forms are presented in Appendix C. Original field data sheets are archived at the MEC office in Canby, Oregon.

Vessel location while trawling was logged at 15-second intervals using GPS and a portable Macintosh computer running MacENC navigation software (V 7.0). The start and stop times and distance of individual vessel tracks from each trawl location were directly recorded into the MS Access database to document trawl distance and duration. The vessel tracks were checked to ensure accuracy and identify anomalies that could skew the data. Vessel tracks are documented in this report using MacENC GPX NavX software to display the tracks overlaid on raster scanned versions of NOAA navigation charts. In conjunction with this printed report, kml-formatted files from Google Earth are available at http://www.mari-gold.biz and provide an interactive display of the 2009 trawl survey locations and DMP sites using satellite imagery.

Figure 7. Example of Substrate Debris Collected during Entrainment Screen Collection

Perforated Round Screen



Woven Wire Screen

Figure 8. Two Types of Screen Used for Entrainment Screen Sampling in 2008

Figure 9. Horiba U-52 Multi-parameter Portable Water Quality Meter

(Manufacurer's Image)

4 Results

4.1 Fish

A total of 6,643 individual fish representing 24 species were encountered and identified during the fish community and entrainment sampling events in 2009 (Table 4). 403 of these fish were encountered during entrainment monitoring, accounting for 6.06 percent of the total number of fish encountered overall during 2009 sampling. The rest of the fish were encountered during fish community monitoring. The fish encountered during entrainment monitoring were collected while assessing 5.4 percent of the overall output of the dredge. Extrapolated totals for each entrained species observed are presented further on in the results section of this document.

Of the 24 species encountered, 16 were introduced and 8 were native. Native fishes made up 0.66 percent of the total number of fish encountered. The three most abundant species in order of abundance were white catfish, striped bass, and threadfin shad. All three species are non-native and accounted for 82.84 percent of the total.

Lampreys were the most common native fish encountered during 2009 sampling (n = 20), all of which were encountered during entrainment sampling. Several of the individuals were clearly identified as lamprey, but eluded capture and escaped through the entrainment screen. All but one of the live encountered lampreys were released back to the river channel as a conservation measure. The retained ammocoete was vouchered and was later positively identified through morphological analysis as a Pacific lamprey. This was the first positively identified Pacific lamprey encountered during this study.

Table 4. Ranked List of Fish Encountered from All 2009 Sites from Trawl & Entrainment Monitoring

Rank	Percent	Number	Common Name	Genus	Species	Origin	Demersal / Pelagic	Rule: Status
1	52.46	3,485	white catfish	*Ameiurus*	*catus*	Introduced	Demersal	
2	21.29	1,414	striped bass	*Morone*	*saxatilis*	Introduced	Pelagic	
3	9.09	604	threadfin shad	*Dorosoma*	*petenense*	Introduced	Pelagic	
4	4.88	324	channel catfish	*Ictalurus*	*punctatus*	Introduced	Demersal	
5	4.40	292	shimofuri goby	*Tridentiger*	*bifasciatus*	Introduced	Demersal	
6	3.70	246	American shad	*Alosa*	*sapidissima*	Introduced	Pelagic	
7	2.06	137	wakasagi	*Hypomesus*	*nipponensis*	Introduced	Pelagic	
8	0.62	41	yellowfin goby	*Acanthogobius*	*flavimanus*	Introduced	Demersal	
9	0.50	33	shokihaze goby	*Tridentiger*	*barbatus*	Introduced	Demersal	
10	0.29	19	lamprey	*Lampetra*	*spp.*	Native	Demersal	*
11	0.15	10	warmouth	*Lepomis*	*gulosus*	Introduced	Pelagic	
12	0.11	7	starry flounder	*Platichthys*	*stellatus*	Native	Demersal	MSA: MEC-EFH
12	0.11	7	white sturgeon	*Acipenser*	*transmontanus*	Native	Demersal	IUCN: LC
13	0.06	4	splittail	*Pogonichthys*	*macrolepidotus*	Native	Pelagic	DFG: SSC; IUCN: EN
13	0.06	4	bluegill	*Lepomis*	*macrochirus*	Introduced	Pelagic	
13	0.06	4	brown bullhead	*Ameiurus*	*nebulosus*	Introduced	Demersal	
13	0.06	4	prickly sculpin	*Cottus*	*asper*	Native	Demersal	
14	0.03	2	common carp	*Cyprinus*	*carpio*	Introduced	Demersal	
15	0.01	1	black crappie	*Pomoxis*	*nigromaculatus*	Introduced	Pelagic	
15	0.01	1	largemouth bass	*Micropterus*	*salmoides*	Introduced	Pelagic	
15	0.01	1	Pacific lamprey	*Entosphenus*	*tridentata*	Native	Demersal	AFS:VU
15	0.01	1	redear sunfish	*Lepomis*	*microlophus*	Introduced	Pelagic	
15	0.01	1	Sac. pikeminnow	*Ptychocheilus*	*grandis*	Native	Pelagic	
15	0.01	1	tule perch	*Hysterocarpus*	*traskii*	Native	Pelagic	
Total Fish:		6,643						
Native Composition: 0.66%, Native Species: 8, Introduced Species: 16								
*Unidentified individuals of genera *Lampetra* are treated as one species under common name lamprey. Likely species and respective status listings include: western brook lamprey (*Lampetra richardsoni);* river lamprey (*Lampetra ayresii)* AFS:VU & DFG:SSC; and Kern brook lamprey (*Lampetra hubbsi)* AFS:TH; DFG:SSC; IUCN:NT.*;*								

*** Status Key**

ESA: federal Endangered Species Act	FPT Federally proposed for listing as Threatened FT Federally listed as Threatened
CESA: California Endangered Species Act	ST State-listed as Threatened SE State-listed as Endangered
CDFG: California Dept of Fish and Wildlife	SSC Species of Special Concern
MSA: Magnuson-Stevens Sustainable Fisheries Act	MEC-EFH Marine Estuarine Composite – designated Essential Fish Habitat
IUCN: International Union for Conservation of Nature	EN Endangered LC Least Concern
AFS: American Fisheries Society	TH Threatened VU vulnerable

Including fish that this monitoring is mandated to assess, native fish captured during 2009 sampling continued to comprise a very small percentage of fish encountered. There are also several species of native fish that were encountered in previous years but were absent this year. Those species are: green sturgeon, longfin smelt, delta smelt, Sacramento blackfish (*Orthodon microlepidotus*), and Pacific staghorn sculpin (*Leptocottus armatus).* Some of the species encountered during 2009 community sampling are shown in Figure 10.

One juvenile largemouth bass represented the only new fish species captured in 2009 that had not been encountered in prior years' monitoring. By comparison, new non-native fish species captured in 2008, but not in 2007, consisted of: shokihaze goby, wakasagi, warmouth, bluegill, bigscale logperch (*Percina macrolepida*), and Mississippi silverside (*Menidia beryllina*).

The most common fish in the trawl monitoring was the white catfish (55.02%). However, the most common fish observed in entrainment monitoring was the shimofuri goby (64.76%). Shimofuri goby comprised only 0.5 percent of the trawl monitoring samples.

Introduced species of fishes have dominated the fish community samples from almost all locations during all years of this study (2006-2009). The top five species (white catfish at 57.33%, threadfin shad at 15.67%, striped bass at 9.61%, American shad at 6.96% and channel catfish at 4.67%) are all introduced and together comprise 94.24 percent of the catch. SRSC and lower SSC locations continue to have higher percentages of native fish than upper SSC locations. Figure 11 graphs the percentage of native fishes encountered in each dredge reach during 2009 fish community surveys.

4.1.1 Special-status Species

Eight species of native fish were encountered in 2009, compared to ten species in 2008, six in 2007, and nine in 2006. Green sturgeon have not been encountered since 2006. Longfin smelt were encountered in 2006, 2007, and 2008, and delta smelt were encountered in 2007 and 2008, but neither was encountered in 2009. Table 41 provides location and additional information for these encounters. CNDDB status information for all special status species encountered in 2009 is provided in Table 4. Additional status and life history information for these species and all other special-status species that use the DWSCs during some or all of their life cycle is provided in Appendix A.

No state or federally threatened or endangered fish was encountered during either fish community or entrainment sampling during 2009, as has occurred during all the previous years of this study.

Starry flounder was the twelfth most commonly encountered fish species in 2009 and the second most common native fish. Starry flounder is a special-status species under the Magnuson-Stevens Fishery Conservation and Management Act, as an estuarine composite species with essential fish habitat within the project area as described in Amendment 11 of the Pacific Coast Groundfish Fisheries Management Plan (PFMC 1998).

4.2 Entrainment Monitoring

Entrainment monitoring was conducted with the mobile entrainment screen at all sites for the first time in 2009, dispensing with the sample cell method due to its inability to sample significant amounts of the dredge's output. A total of 403 fish were captured using the entrainment screen while assessing 5.64 percent of dredge output and thus achieving the project goal of sampling at least 5 percent of dredge output. Table 5 presents a ranked list of all fish encountered during 2009 entrainment monitoring, while Tables 6 and 7 present the list of fish segregated by river channel. Shimofuri goby

were the most commonly entrained species in 2009, comprising almost 64.76 percent of the entrained individuals, and white catfish and channel catfish were second and third. In 2008, channel catfish and white catfish were first and second, while shimofuri goby were a distant seventh, comprising only 2.16 percent of all fish encountered.

Table 5. Ranked List of Fish Encountered From All Sites During 2009 Entrainment Monitoring

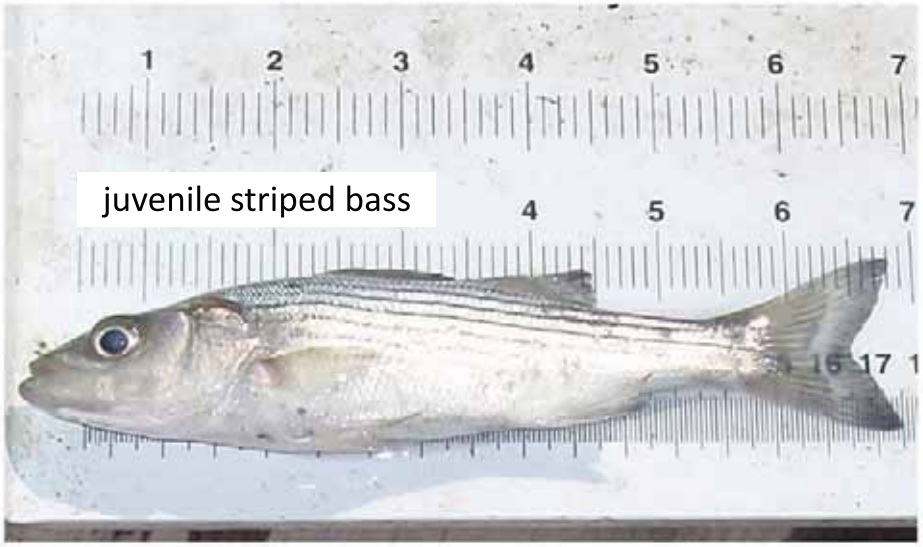
Rank	Percent	Number	Common Name	Genus	Species	Native
1	64.76	261	shimofuri goby	*Tridentiger*	*bifasciatus*	Introduced
2	12.90	52	white catfish	*Ameiurus*	*catus*	Introduced
3	7.44	30	channel catfish	*Ictalurus*	*punctatus*	Introduced
4	4.96	20	shokihaze goby	*Tridentiger*	*barbatus*	Introduced
5	4.71	19	lamprey	*Lampetra*	*spp.	Native
6	2.98	12	yellowfin goby	*Acanthogobius*	*flavimanus*	Introduced
7	0.50	2	prickly sculpin	*Cottus*	*asper*	Native
8	0.25	1	American shad	*Alosa*	*sapidissima*	Introduced
8	0.25	1	bluegill	*Lepomis*	*macrochirus*	Introduced
8	0.25	1	brown bullhead	*Ameiurus*	*nebulosus*	Introduced
8	0.25	1	Pacific lamprey	*Entosphenus*	*tridentata*	Native
8	0.25	1	striped bass	*Morone*	*saxatilis*	Introduced
8	0.25	1	wakasagi	*Hyposmesus*	*nipponensis*	Introduced
8	0.25	1	warmouth	*Lepomis*	*gulosus*	Introduced
Total		403				

Native Percent: 5.46%, Native Species: 3, Introduced Species: 11, **Lampetra* species are lumped as in Table 4

Table 6. Summary Results of Entrainment Monitoring Events for All SSC Locations

Rank	Percent	Number	Common Name	Origin
1	65.06	216	shimofuri goby	Introduced
2	15.06	50	white catfish	Introduced
3	9.04	30	channel catfish	Introduced
4	5.42	18	shokihaze goby	Introduced
5	2.71	9	yellowfin goby	Introduced
6	0.60	2	lamprey	Native
6	0.60	2	prickly sculpin	Native
7	0.30	1	American shad	Introduced
7	0.30	1	bluegill	Introduced
7	0.30	1	brown bullhead	Introduced
7	0.30	1	striped bass	Introduced
7	0.30	1	warmouth	Introduced
Total		332		

Native Percent = 1%, Native Species = 2, Introduced Species = 10



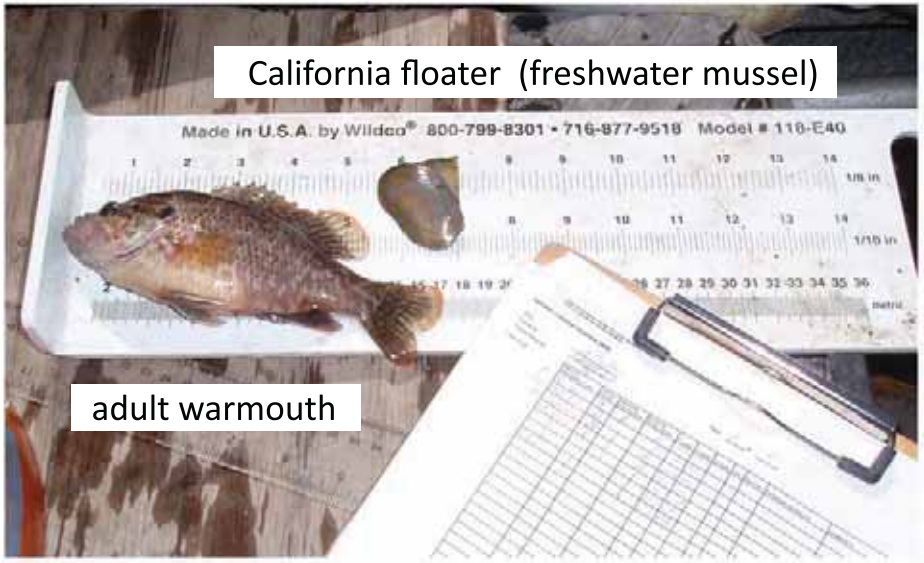


Figure 10. Examples of Specimens Collected during 2009 Fish Community Surveys

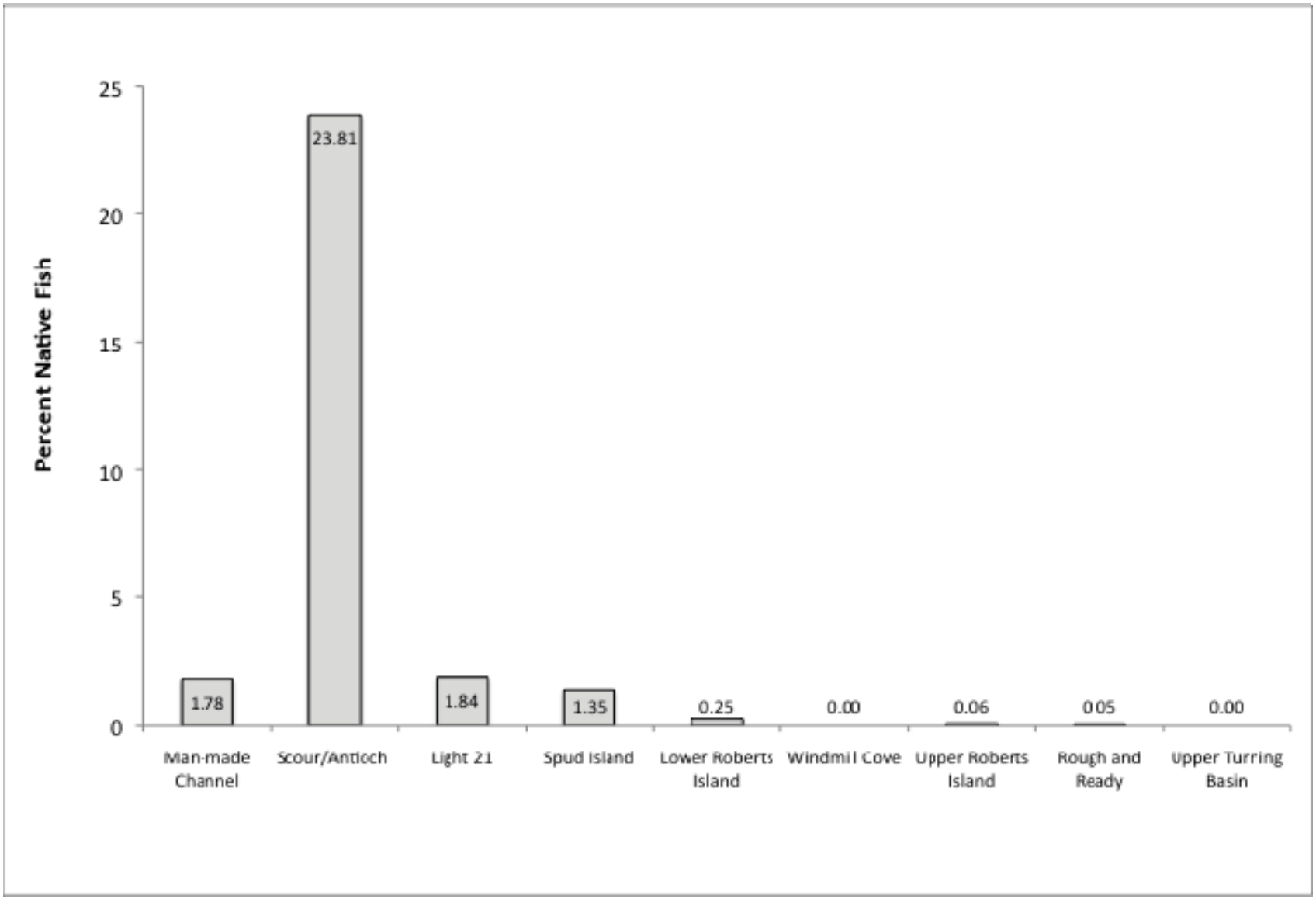


Figure 11. Percent Native Fish Collected at Each Fish Community Monitoring Location in 2009

Table 7. Summary Results of Entrainment Events for SRSC, Man-made Channel — S-31 DMP Site

Rank	Percent	Number	Common Name	Origin
1	63.38	45	shimofuri goby	Introduced
2	25.35	18	lamprey	Native
3	4.23	3	yellowfin goby	Introduced
4	2.82	2	white catfish	Introduced
4	2.82	2	shokihaze goby	Introduced
5	1.41	1	wakasagi	Introduced
Total		71		

Native Percent = 25%, Native Species = 1, Introduced Species = 5

Entrainment rates and sampling characteristics are discussed by dredge reach and DMP site in more detail below.

4.2.1 Sacramento River Shipping Channel Locations

Man-made Channel – S-31 DMP Site: The Man-made Channel reach near the S-31 DMP site was the only SRSC reach that was dredged in 2009. This section of the channel was dredged for the first time in 2009, adjacent and downstream of the Man-made Channel reach dredged in 2008. Substrates in this portion of the SRSC were primarily mud. Approximately 6,190,680 gallons, or 4.95 percent of the total slurry volume produced at this site, was sampled during the five entrainment sampling events conducted there. A total of 71 fish were observed during entrainment monitoring at S-31 (Table 7). Notably, lamprey comprised 25 percent of the entrained fish at this site. 2008 entrainment catch at S-31 also included lamprey. The single wakasagi collected in 2009 is also notable due to its similarity to delta smelt.

4.2.2 Stockton Shipping Channel Locations

Scour Pond/Antioch – Scour Hole DMP Site: This section of the channel was dredged for the first time in 2008 and a small portion of it again in 2009. Substrates in the Scour Pond/Antioch reach of the lower SSC were primarily sand. Approximately 9,685,092 gallons of slurry were produced at this site during a period of less than 24 hours. Due to the short duration of dredging at the Scour Pond location, RISG requested that only fish community monitoring be conducted, and that the mobile entrainment screen be mobilized at the subsequent DMP site. Low numbers of fish were encountered in trawl surveys of this area in both 2008 and 2009. Eleven screen sampling events were conducted in 2008 with a total result of 13 fish collected, including native lamprey.

Light 21 – McCormack Pit DMP Site: This section of the channel was dredged for the first time in 2009. It is located upstream from Antioch between Jersey Island and Sherman Island in the SSC. Substrates in the Light 21 reach were primarily sand. Approximately 4,292,682 gallons, or 6.61 percent of the total slurry volume produced at this site, was sampled during the three entrainment sampling events conducted at this site. Table 8 provides the results for the entrainment sampling conducted at this site in 2009. A total of three fish were encountered at this location. In 2008, entrainment sampling occurred a few weeks later at the adjacent Light 19 dredge reach where no fish were encountered.

Table 8. Summary Results of Entrainment Events at Light 21 — McCormack Pit DMP Site

Rank	Percent	Number	Common Name	Origin
1	33.33	1	lamprey, unidentified species	Native
1	33.33	1	prickly sculpin	Native
1	33.33	1	striped bass	Introduced
Total		3		

Native Percent = 66.7%, Native Species = 2, Introduced Species = 1

Spud Island – Roberts 2 DMP Site: This section of the channel was dredged for the first time during 2009. Substrates from this dredge reach were primarily mud. Approximately 2,692,860 gallons, or 7.70 percent of the total slurry volume produced at this site, was sampled during the two entrainment sampling events conducted. Table 9 provides the results for the entrainment sampling conducted at this site in 2009.

Table 9. Summary Results of Entrainment Events at Spud Island — Roberts 2 DMP Site

Rank	Percent	Number	Common Name	Origin
1	54.22	45	shimofuri goby	Introduced
2	39.76	33	white catfish	Introduced
3	3.61	3	channel catfish	Introduced
4	2.41	2	yellowfin goby	Introduced
Total		83		

Native Percent = 0%, Native Species = 0, Introduced Species = 4

Lower Roberts Island – Roberts 2 DMP Site: This section of the channel was dredged for the first time during 2009. Substrates from this dredge reach were primarily mud. Approximately 1,988,563 gallons, or 4.98 percent of the total slurry volume deposited at this site, was sampled during one entrainment sampling event. Table 10 displays the results of entrainment sampling conducted at this reach in 2009.

Table 10. Summary Results of Entrainment Events at Lower Roberts Island — Roberts 2 DMP Site

Rank	Percent	Number	Common Name	Origin
1	66.67	2	shimofuri goby	Introduced
2	33.33	1	white catfish	Introduced
Total		3		

Native Percent = 0%, Native Species = 0, Introduced Species = 2

Windmill Cove – Roberts 2 DMP Site: This section of the SSC was dredged for the first time during 2009. Substrates from this dredge reach were primarily mud and silt. In 2009, approximately 1,431,480 gallons, or 3.35 percent of the total volume of dredged slurry, was sampled during the single entrainment event. Table 11 provides the results for 2009 entrainment sampling conducted at this site.

Table 11. Summary Results of Entrainment Events at Windmill Cove — Roberts 2 DMP Site

Rank	Percent	Number	Common Name	Origin
1	76.47	26	shimofuri goby	Introduced
2	11.76	4	white catfish	Introduced
3	8.82	3	shokihaze goby	Introduced
4	2.94	1	yellowfin goby	Introduced
Total		34		

Native Percent = 0%, Native Species = 0, Introduced Species = 4

Upper Roberts Island – Roberts 1 DMP Site: This channel section was dredged for the first time during 2009. Substrates from this dredge reach were primarily mud and silt. Approximately 8,791,632 gallons, or 4.81 percent of the total slurry volume produced, was sampled during the eight entrainment surveys conducted at this site. Table 12 provides the 2009 entrainment sampling results for this dredge reach.

Table 12. Summary Results of Entrainment Events at Upper Roberts Island — Roberts 1 DMP Site

Rank	Percent	Number	Common Name	Origin
1	86.00	129	shimofuri goby	Introduced
2	6.00	9	white catfish	Introduced
2	5.33	8	shokihaze goby	Introduced
3	2.00	3	yellowfin goby	Introduced
4	0.67	1	prickly sculpin	Native
Total		150		

Native Percent = 0.67%, Native Species = 1, Introduced Species = 4

Rough and Ready Island – Roberts 1 DMP Site: This section of the channel was first dredged in 2006 and then again in 2009. Substrates from this dredge reach were primarily mud and silt. In 2009 approximately 6,569,674 gallons, or 7.49 percent of the total dredged slurry volume, was sampled during the four entrainment sampling events conducted at this site. Table 13 displays the results for the entrainment sampling conducted at this site in 2009.

Table 13. Summary Results of Entrainment Events at Rough & Ready Island —Roberts 1 DMP Site

Rank	Percent	Number	Common Name	Origin
1	35.71	15	channel catfish	Introduced
2	26.19	11	shimofuri goby	Introduced
3	16.67	7	shokihaze goby	Introduced
4	7.14	3	white catfish	Introduced
4	7.14	3	yellowfin goby	Introduced
5	2.38	1	bluegill	Introduced
5	2.38	1	brown bullhead	Introduced
5	2.38	1	warmouth	Introduced
Total		42		

Native Percent = 0%, Native Species = 0, Introduced Species = 8

Upper Turning Basin – Roberts 1 DMP Site: This section of the channel was dredged for the first time in 2009. It is adjacent to the East Complex of the Port of Stockton. Substrates from this dredge reach were primarily mud. Approximately 2,974,521 gallons, or 8.99 percent of the total slurry volume

produced at this site, was sampled during the two entrainment sampling events conducted. Table 14 provides the entrainment sampling results for the surveys conducted at this site in 2009.

Table 14. Summary Results of Entrainment Events at Upper Turning Basin — Roberts 1 DMP Site

Rank	Percent	Number	Common Name	Origin
1	70.59	12	channel catfish	Introduced
2	17.65	3	shimofuri goby	Introduced
3	5.88	1	American shad	Introduced
3	5.88	1	Pacific lamprey	Native
Total		17		

Native Percent = 5.88%, Native Species = 1, Introduced Species = 3

Extrapolated entrainment totals for each species encountered in each dredge reach enables estimation of overall numbers of fish entrained. These extrapolations were created by simply dividing the number of individuals encountered in each dredge reach by the percentage of material sampled in that reach. The totals were estimated without regard to the high likelihood of fish density patchiness throughout the length of each dredge reach, simply assuming that the fish density (or entrainment likelihood) for each species for the entire reach was the same as that in the sub-set of material assessed from that reach. Table 15 displays the extrapolated counts for each species for each dredge reach in 2009.

Table 15. Extrapolated Fish Entrainment Catch for 2009 by Event Location & Fish Species

River	SRSC	SSC								
	Man-made Channel	Scour Pond	Light 21	Spud Island	Lower Roberts Island	Windmill Cove	Upper Roberts Island	Rough & Ready Island	Upper Turning Basin	
	S-31	Scour Hole	McCormack Pit	Roberts 2	Roberts 2	Roberts 2	Roberts 1	Roberts 1	Roberts 1	Total
[% Sampled]	[4.95%]	DNS	[6.61%]	[7.70%]	[4.98%]	[3.35%]	[4.81%]	[7.49%]	[8.99%]	[5.64%]
shimofuri goby	909			584	40	776	2,682	147	33	5,171
white catfish	40			429	20	119	187	40		835
lamprey spp.	364		16							380
shokihaze goby	40					90	166	93		389
channel catfish				39				200	133	372
yellowfin goby	61			26		30	62	40		219
prickly sculpin			16				21			37
wakasagi	20									20
striped bass			16							16
warmouth								13		13
bluegill								13		13
brown bullhead								13		13
American shad									11	11
Pacific lamprey									11	11
Total	1,434	DNS	48	1,078	60	1,015	3,118	559	188	7,500

Note: Gray shading indicates introduced species.

Based on these extrapolations, a total of approximately 7,500 fish may have been entrained by dredging operations in 2009. Shimofuri goby comprised the vast majority of the entrained individual fish, making up 65 percent of the estimated entrained fish while white catfish comprised 11 percent. Lamprey species combined comprised 5 percent and prickly sculpin, the only other native species

entrained in 2009, comprised 0.5 percent. Channel catfish comprised 5 percent of the encountered fish in 2009. In 2008, they comprised 62 percent while white catfish comprised 14 percent of encountered fish.

4.3 Fish Community Monitoring

The following sub-sections describe the fish community sampling results for all locations and by shipping channel and individual dredge reach/DMP site. Table 16 summarizes the catch. Figure 11 graphs the percentage of native fish encountered during 2009 fish community sampling in each dredging reach. Table 17 summarizes the effort data for 2009 fish community sampling and provides a description of relative fish density at the trawl locations through the CPUE metric of number of fish collected per linear meter towed along the bottom. A graph of the mean CPUE for each trawl survey by dredge reach and river is provided in Figure 12.

2009 data are compared with previous years when relevant. Caution should be applied, though, when comparing the data across years as timing, exact locations (dredge reaches), effort, and environmental factors all varied significantly. In 2009, only 10.7 percent of the locations (river miles) had been previously dredged since monitoring began in 2006. Comparisons within DMP sites are made between years even though the exact dredging reaches and trawl locations change from year to year for each DMP site.

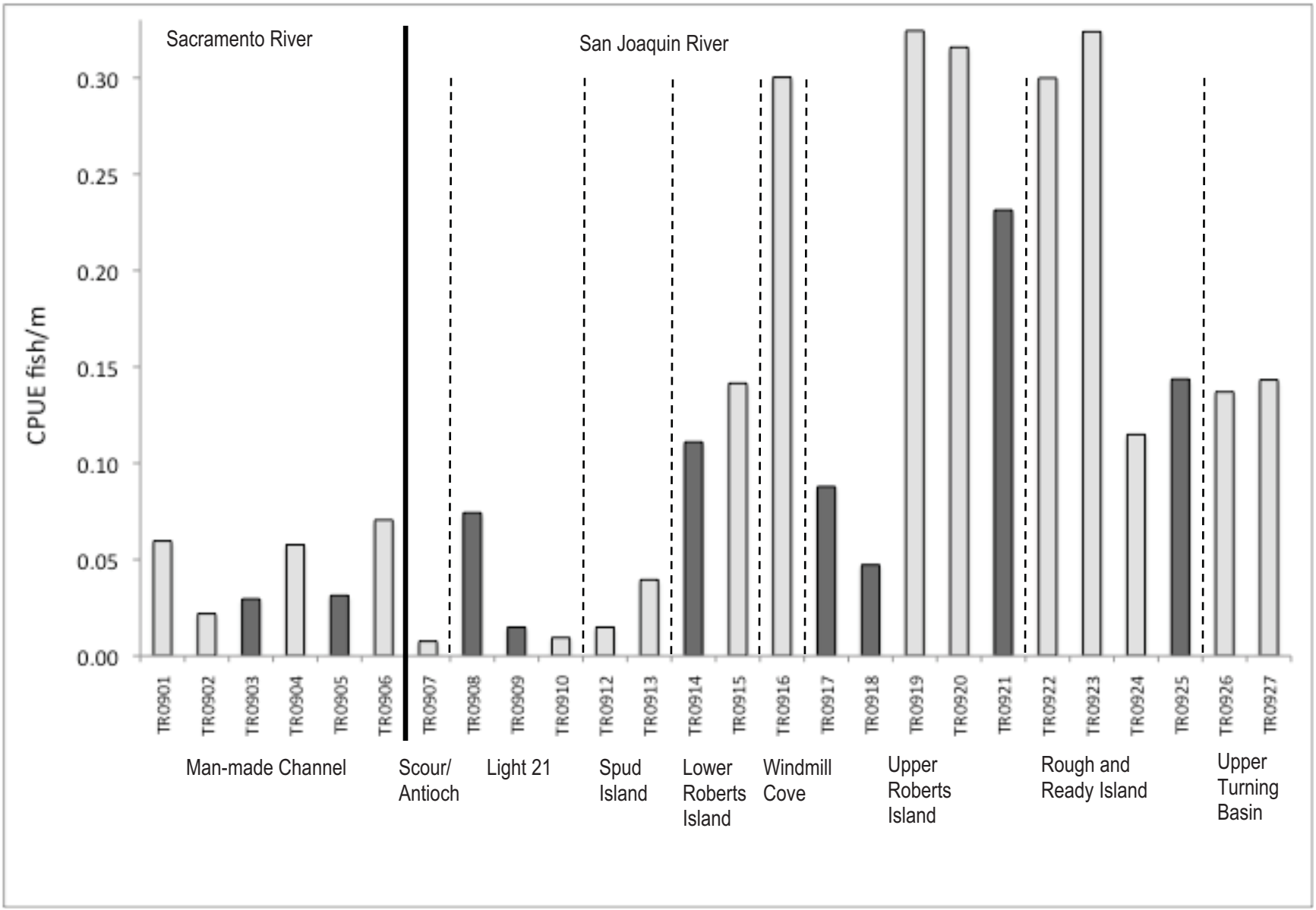


Figure 12. Mean CPUE for Each Fish Community Survey (Note: Shaded bars indicate dusk/night/dawn surveys)

Table 16. Ranked Catch of Fish from All Sites during 2009 Trawl Monitoring Surveys

Rank	Percent	Number	Common Name	Origin
1	55.02	3,433	white catfish	Introduced
2	22.64	1,413	striped bass	Introduced
3	9.68	604	threadfin shad	Introduced
4	4.71	294	channel catfish	Introduced
5	3.93	245	American shad	Introduced
6	2.18	136	wakasagi	Introduced
7	0.50	31	shimofuri goby	Introduced
8	0.46	29	yellowfin goby	Introduced
9	0.21	13	shokihaze goby	Introduced
10	0.14	9	warmouth	Introduced
11	0.11	7	starry flounder	Native
11	0.11	7	white sturgeon	Native
12	0.06	4	splittail	Native
13	0.05	3	bluegill	Introduced
13	0.05	3	brown bullhead	Introduced
14	0.03	2	common carp	Introduced
14	0.03	2	prickly sculpin	Native
15	0.02	1	black crappie	Introduced
15	0.02	1	largemouth bass	Introduced
15	0.02	1	redear sunfish	Introduced
15	0.02	1	Sacramento pikeminnow	Native
15	0.02	1	tule perch	Native
Total		6,240		
Native Percent = 0.35%, Native Species = 6, Introduced Species = 15				

Table 17. Summary Catch & Effort Data for Fish Encountered in 2009 Trawl Monitoring Surveys

River	Dredge Reach	CPUE Trawl Tows	CPUE Trawl Distance (m)	Cubic Meters Sampled	% Total Trawl Effort	Number of Fish	% of Total Catch	CPUE (fish/m)	CPUE (fish/ 10,000m^3)
Sacramento	Man-made Chan	17	9,480	74,892	18.7	450	7.3	0.05	60
San Joaquin	Scour/Antioch	5	2,760	21,804	5.4	21	0.3	0.01	10
	Light 21	15	7,295	57,631	14.4	217	3.5	0.03	38
	Spud Island	9	4,917	38,844	9.7	148	2.4	0.03	38
	Lower Roberts	5	3,046	24,063	6.0	401	6.5	0.13	167
	Windmill Cove	5	3,004	23,732	5.9	902	14.6	0.30	380
	Upper Roberts	16	8,652	68,351	17.0	1,656	26.8	0.19	242
	Rough & Ready	20	9,621	76,006	18.9	2,094	33.9	0.22	276
	Upper Turn Basin	5	2,047	16,171	4.0	287	4.6	0.14	177
Total	9	97	50,822	401,494		6,176			

4.3.1 Sacramento River Shipping Channel Locations

Man-made Channel – S-31 DMP Site: Dredging and monitoring took place in this section of the Sacramento River Man-made Channel downstream from the Port of Sacramento, between RM 30.87 and 32.86, just downstream of last year's reach. Figure 13 displays the trawl surveys and DMP site for this sampling location. This section of the channel was sampled for the first time in 2009. Two of

twelve species encountered were native: white sturgeon and splittail (Table 18). White catfish were the most abundant fish, comprising 49 percent of the total catch, a composition similar to 2007 and 2008. White catfish, wakasagi (an introduced smelt), and striped bass were the most common fish respectively in 2009 and 2008. The CPUE (described as number of fish per meter trawled) in 2009 was 0.05, an increase from 0.025 measured in 2008 and 0.03 measured in 2007.

Table 18. Ranked Fish Catch from 2009 Trawl Surveys in SRSC Man-made Channel – S-31 DMP Site

Rank	Percent	Number	Common Name	Origin
1	48.67	219	white catfish	Introduced
2	28.67	136	wakasagi	Introduced
3	10.89	49	striped bass	Introduced
4	3.33	15	shimofuri goby	Introduced
5	1.78	8	channel catfish	Introduced
6	1.56	7	American shad	Introduced
7	1.11	5	yellowfin goby	Introduced
7	1.11	5	white sturgeon	Native
8	0.67	3	splittail	Native
9	0.22	1	threadfin shad	Introduced
9	0.22	1	shokihaze goby	Introduced
9	0.22	1	common carp	Introduced
Total		450		

Native Percent = 1.78%, Native Species = 2, Introduced Species = 10

4.3.2 Stockton Shipping Channel Locations

White catfish was the most abundant of the 21 fish species encountered within the SSC and accounted for 56 percent of the total individual fish encountered (Table 19). White catfish was also most abundant in all other monitoring years as well. Threadfin shad was second most abundant fish in all years except 2009 when it slipped to third. Striped bass has gone from fifth most abundant in 2006 to second most abundant in 2009. Channel catfish and American shad, fourth and fifth in 2009, have also been among the top five most abundant fish in all other years. All of these species are introduced and together represented 98.54 percent of the catch, a composition similar to previous years. Of the 21 species encountered, only six are natives, represented by 14 individual fish; together these native species comprised only 0.24 percent of the total number of fish caught at these sites, also similar to previous years.

Species observed in 2009 that were not found in the SSC during 2008 were: prickly sculpin, largemouth bass, and Sacramento pikeminnow. Only two native species were encountered from both the SRSC and SSC in 2009: white sturgeon and splittail.

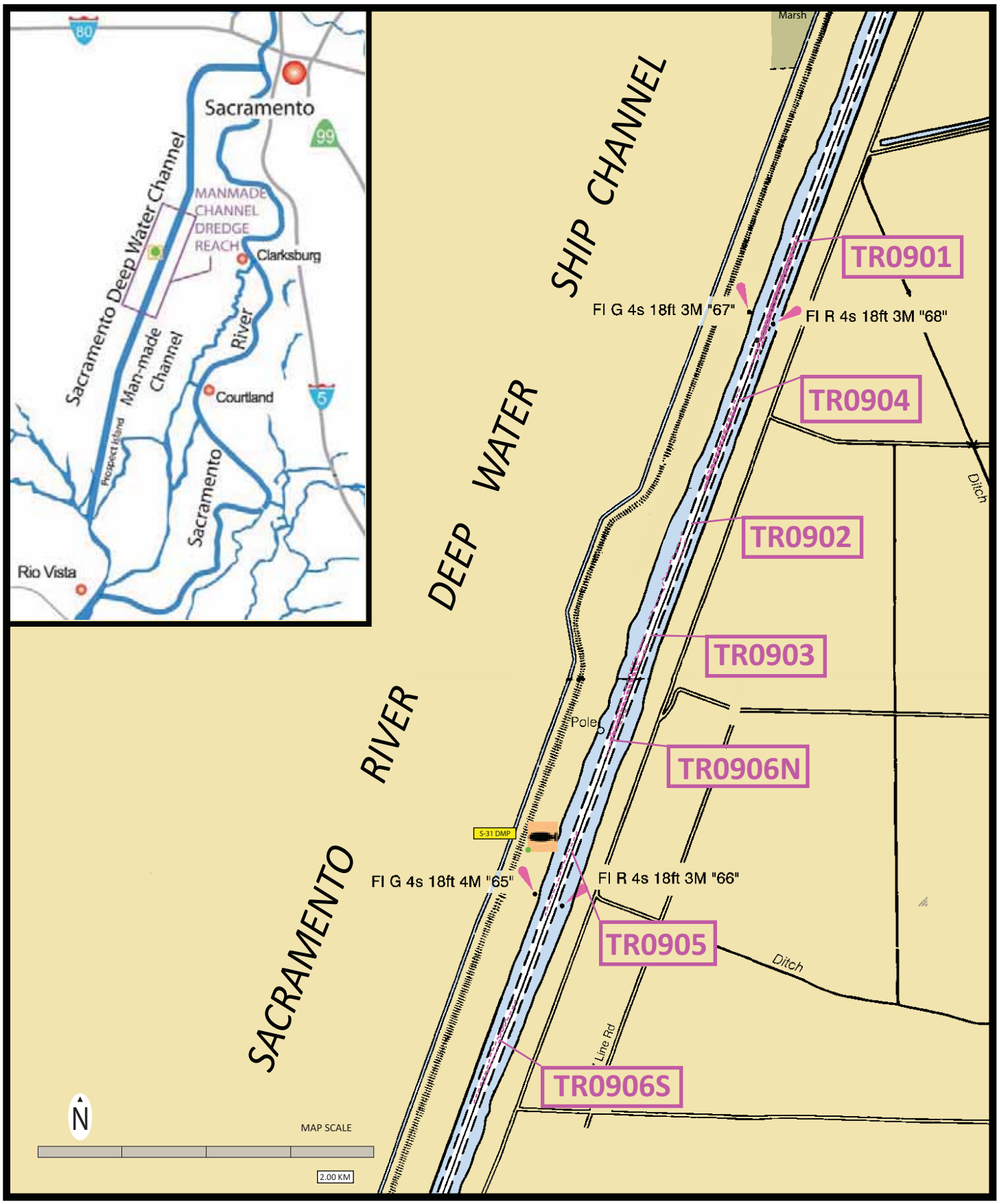


Figure 13. 2009 Fish Community Surveys for Man-made Channel Dredge Reach and S-31 DMP Site

Map projection 1:25,000

Table 19. Ranked Fish Catch from 2009 Trawl Surveys at All SSC Sites

Rank	Percent	Number	Common Name	Origin
1	56.13	3214	white catfish	Introduced
2	23.44	1342	striped bass	Introduced
3	10.08	577	threadfin shad	Introduced
4	4.75	272	channel catfish	Introduced
5	4.14	237	American shad	Introduced
6	0.40	23	yellowfin goby	Introduced
7	0.28	16	shimofuri goby	Introduced
8	0.21	12	shokihaze goby	Introduced
9	0.16	9	warmouth	Introduced
10	0.12	7	starry flounder	Native
11	0.05	3	bluegill	Introduced
11	0.05	3	brown bullhead	Introduced
12	0.03	2	white sturgeon	Native
12	0.03	2	prickly sculpin	Native
13	0.02	1	black crappie	Introduced
13	0.02	1	common carp	Introduced
13	0.02	1	largemouth bass	Introduced
13	0.02	1	redear sunfish	Introduced
13	0.02	1	Sacramento pikeminnow	Native
13	0.02	1	splittail	Native
13	0.02	1	tule perch	Native
Total		5,726		

Native Percent = 0.24%, Native Species = 6, Introduced Species = 15

Scour Pond/Antioch – Scour Hole DMP Site: Maintenance dredging and fish community monitoring were conducted in the main navigation channel from RM 8.81 to 8.90, between Light 16 and Light 18, upstream of Antioch Bridge (Figure 14). This section of the channel was sampled for the first time in 2009. American shad was the most abundant fish species caught in this reach, representing over 47 percent of the total catch (Table 20). American shad was also most abundant at this site in 2008. Three delta smelt were encountered nearby in 2008, and one each of delta smelt and longfin smelt in 2007. Smelt were not encountered in 2009. Native fish comprised a higher percent of the overall catch in both 2007 and 2009 than 2008, mostly due to the high numbers of starry flounder relative to the other (introduced) species. This reach was not sampled in 2006. Few fish have been encountered in all years of trawl and entrainment monitoring of the SSC near the Antioch Bridge and Scour Pond. Salinity here is consistently the highest recorded at any of the SSC dredge locations. The CPUE for the Scour Pond reach in 2009 was 0.01 fish/m, the lowest of all SSC reaches. While a greater number of trawl surveys were conducted near Scour Pond in prior years, the CPUE was also lowest at this site in 2007 and second lowest in 2008.

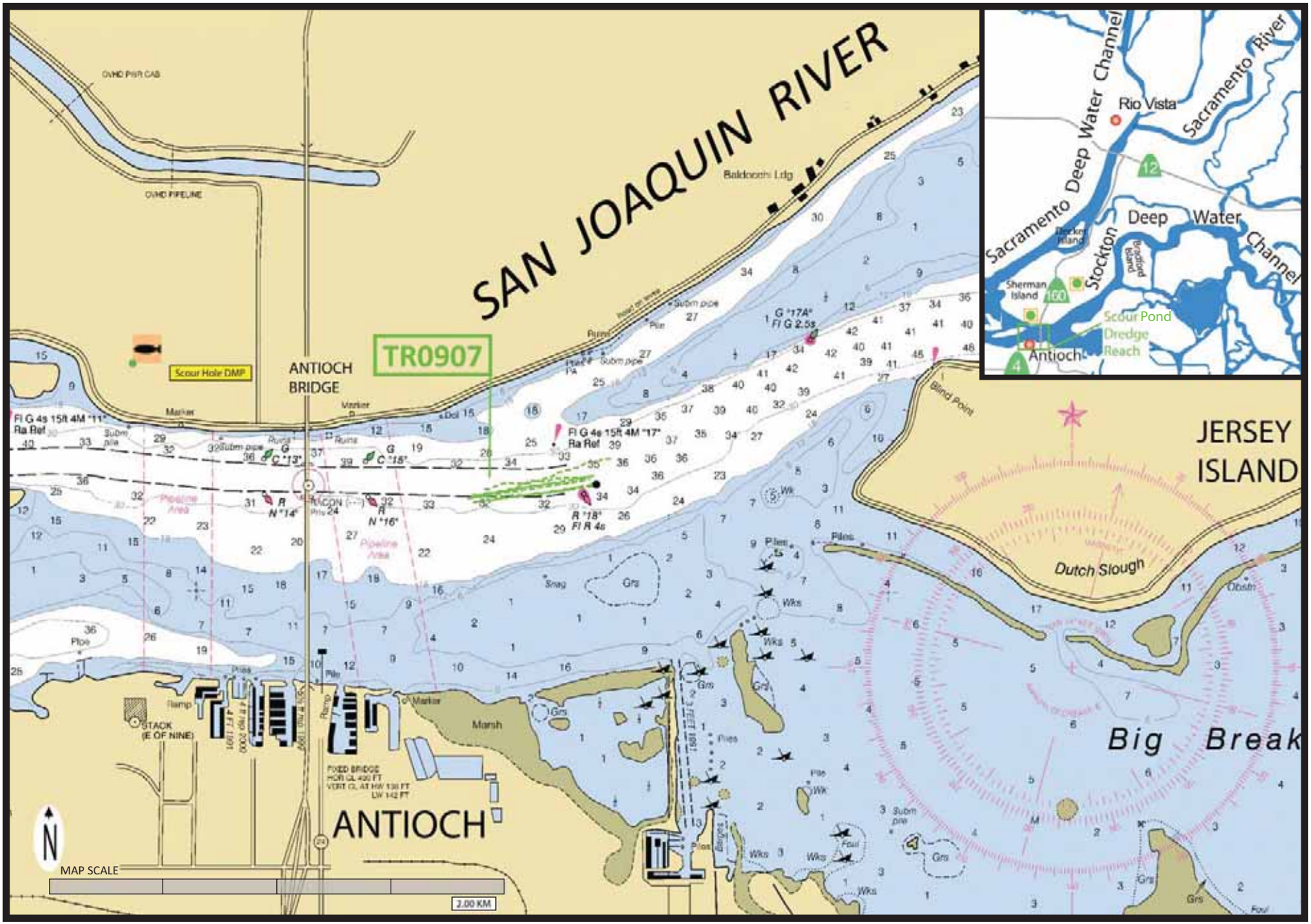


Figure 14. 2009 Fish Community Survey for Antioch / Scour Pond Dredge Reach and Scour Hole DMP Site

Map projection 1:15,000

Table 20. Summary Results of Trawl Surveys at Scour Pond/ Antioch — Scour Hole DMP Site

Rank	Percent	Number	Common Name	Origin
1	47.62	10	American shad	Introduced
2	23.81	5	starry flounder	Native
3	19.05	4	striped bass	Introduced
4	4.76	1	channel catfish	Introduced
4	4.76	1	threadfin shad	Introduced
Total		21		

Native Percent = 24% Native Species = 1, Introduced Species = 4

Light 21 – McCormack Pit DMP Site: Dredging and fish community monitoring were conducted upstream of the Antioch Bridge between Jersey Island and Sherman Island, from RM 11.65 to 12.22 in the SSC (Figure 15). This section of the channel was sampled for the first time in 2009. Table 21 provides a summary of the fish encountered during community sampling. American shad was the most abundant fish species captured in this reach, comprising over 51 percent of the total catch. Two native species, white sturgeon and starry flounder, were encountered. Introduced species represented over 98.5 percent of fish encountered, very similar to 99.6 percent collected at the nearby Light 19 reach in 2008. This reach was sampled in 2008, but not prior. CPUE at this site during 2009 and 2008 was 0.03, among the lowest in the SSC.

Table 21. Summary Results of Trawl Surveys at Light 21 — McCormack Pit DMP Site

Rank	Percent	Number	Common Name	Origin
1	51.29	139	American shad	Introduced
2	23.25	63	striped bass	Introduced
3	1.85	5	threadfin shad	Introduced
4	1.48	4	white catfish	Introduced
5	0.74	2	starry flounder	Native
5	0.74	2	white sturgeon	Native
6	0.37	1	yellowfin goby	Introduced
6	0.37	1	channel catfish	Introduced
Total		271		

Native Percent = 1.5% Native Species = 2, introduced Species = 6

Spud Island – Roberts 2 DMP Site: Dredging and fish community monitoring were conducted from RM 31.65 to 32.20 (Figure 16). This year was the first time that the Roberts 2 DMP site has been used since fish community monitoring commenced in 2006; thus, background fish monitoring data for nearby portions of the channel is not available. Table 22 provides a summary of the fish encountered during fish community sampling near the Spud Island dredge reach. Striped bass was the most abundant species encountered, comprising nearly 59 percent of the total catch. Two native species were encountered: tule perch and prickly sculpin. The single tule perch was the only one encountered at any location in 2009. In prior years, only four of the 62 encountered tule perch were from SSC trawl locations. The prickly sculpin was one of two encountered in 2009. The 27 previously encountered prickly sculpin were found in the SSC. CPUE at this site during 2009 was 0.03 fish/m, among the lowest in the SSC.

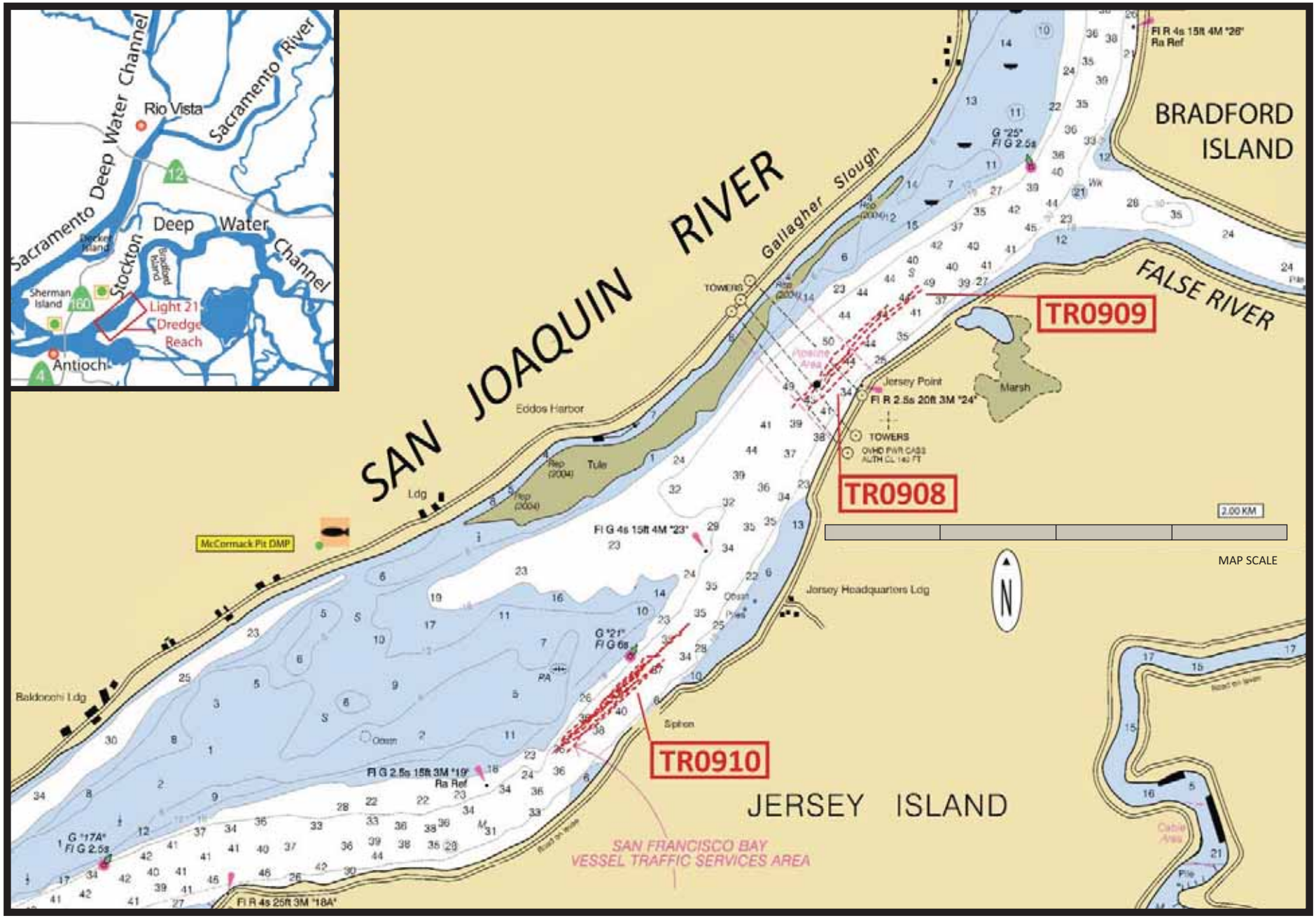


Figure 15. 2009 Fish Community Surveys for Light 21 Dredge Reach and McCormack Pit DMP Site

Map projection1:15,000

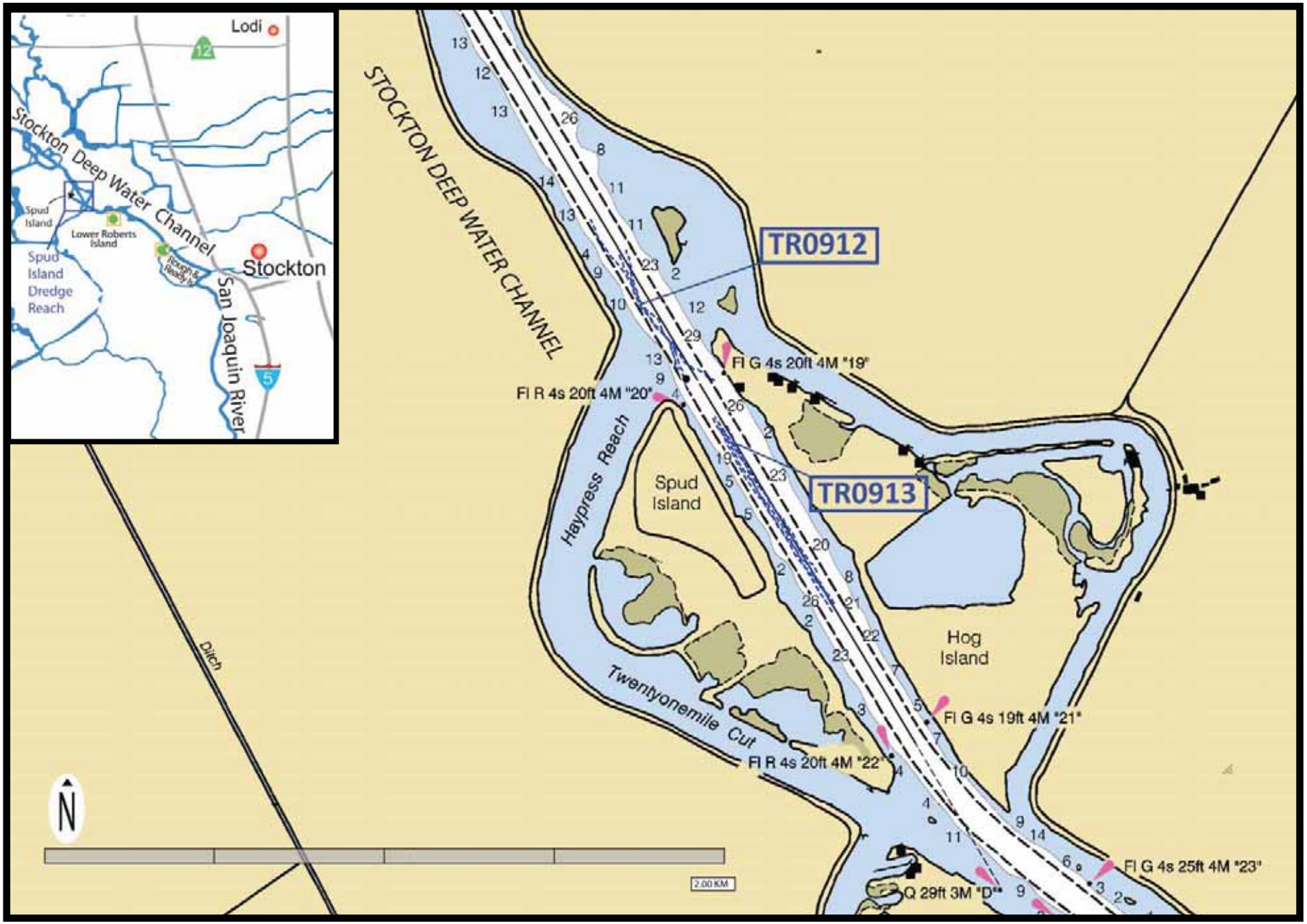


Figure 16. 2009 Fish Community Surveys for Spud Island Dredge Reach

Map projection1:10,000

Table 22. Summary Results of Trawl Surveys at Spud Island — Roberts 2 DMP Site

Rank	Percent	Number	Common Name	Origin
1	58.78	87	striped bass	Introduced
2	23.65	35	white catfish	Introduced
3	7.43	11	American shad	Introduced
4	2.70	4	channel catfish	Introduced
4	2.70	4	shimofuri goby	Introduced
5	2.03	3	bluegill	Introduced
6	0.68	1	largemouth bass	Introduced
6	0.68	1	prickly sculpin	Native
6	0.68	1	shokihaze goby	Introduced
6	0.68	1	tule perch	Native
Total		148		

Native Percent = 1.4% Native Species = 2, introduced Species = 8

Lower Roberts Island – Roberts 2 DMP Site: Dredging and fish community monitoring were conducted from RM 32.20 to 32.95, upstream from the Spud Island reach (Figure 17). This year was the first time Roberts 2 DMP site has been used since fish community monitoring commenced in 2006, so prior bottom trawl data for this reach is not available. Table 23 provides a summary of the fish encountered during community sampling. White catfish was the most abundant species collected, comprising 79 percent of the total catch. One Sacramento pikeminnow was the only native fish encountered at this trawl location. Pikeminnow have been extremely rare in the trawl catch, with only one previously encountered from the SRSC. CPUE at this site was 0.13 fish/m.

Table 23. Summary Results of Trawl Surveys at Lower Roberts Island — Roberts 2 DMP Site

Rank	Percent	Number	Common Name	Origin
1	79.05	317	white catfish	Introduced
2	15.71	63	striped bass	Introduced
3	3.24	13	threadfin shad	Introduced
4	1.00	4	channel catfish	Introduced
5	0.50	2	shimofuri goby	Introduced
6	0.25	1	Sacramento pikeminnow	Native
6	0.25	1	American shad	Introduced
Total		401		

Native percent = 0.25% Native species = 1, introduced species = 6

Windmill Cove – Roberts 2 DMP Site: Dredging and fish community monitoring were conducted from RM 33.62 to 34.09 with material placed at the Roberts 2 DMP site (Figure 18). Prior fish community monitoring of dredge operations has not occurred in this reach. Table 24 provides a summary of the fish encountered during community sampling. White catfish was the most abundant species encountered, comprising nearly 96 percent of the total catch. CPUE was 0.30 fish/m, the highest density of fish among all trawl locations in 2009. Native fish species were absent from the trawl catch at this location.

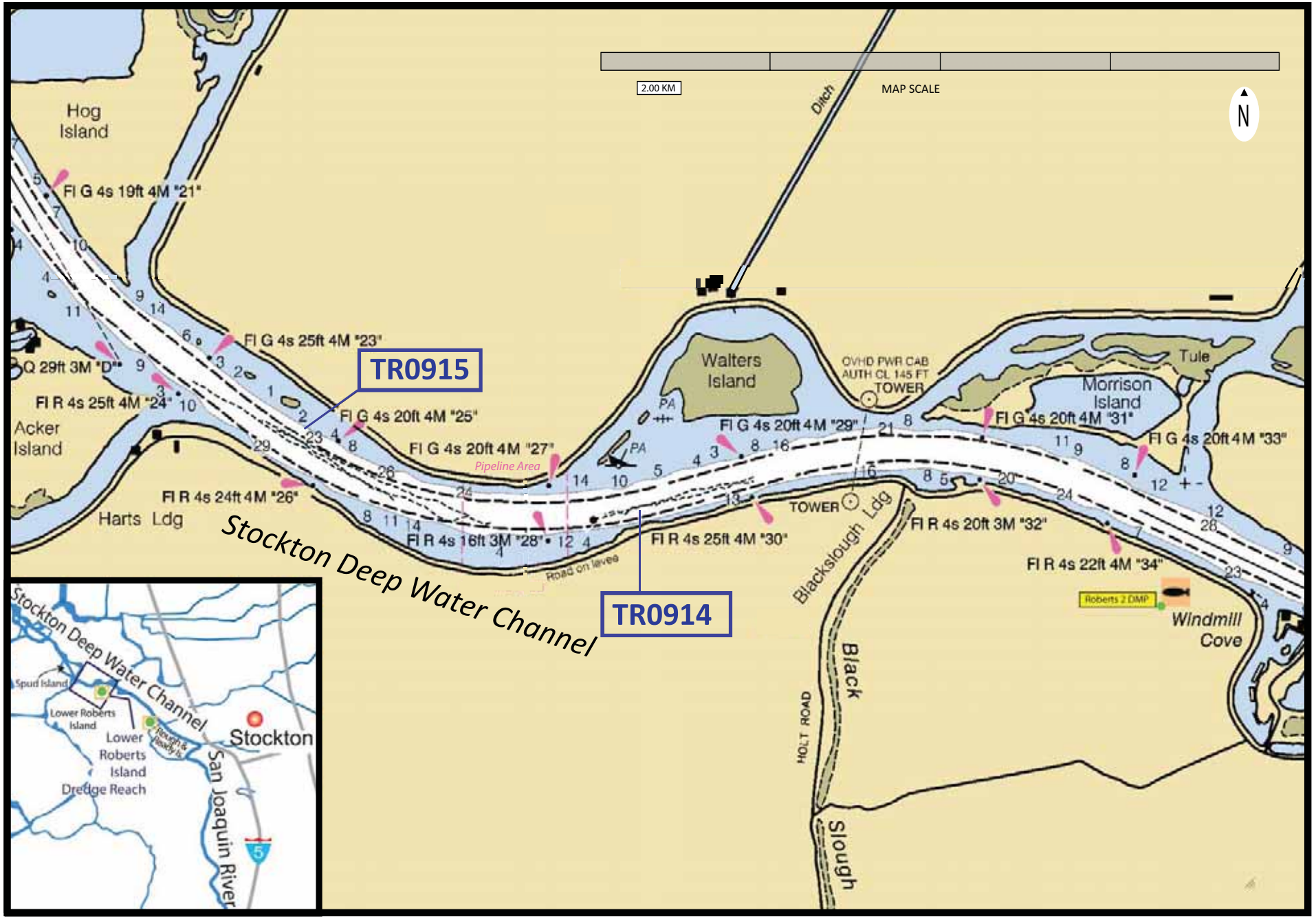


Figure 17. 2009 Fish Community Surveys for Lower Roberts Island Dredge Reach and Roberts 2 DMP Site

Map projection 1:15,000

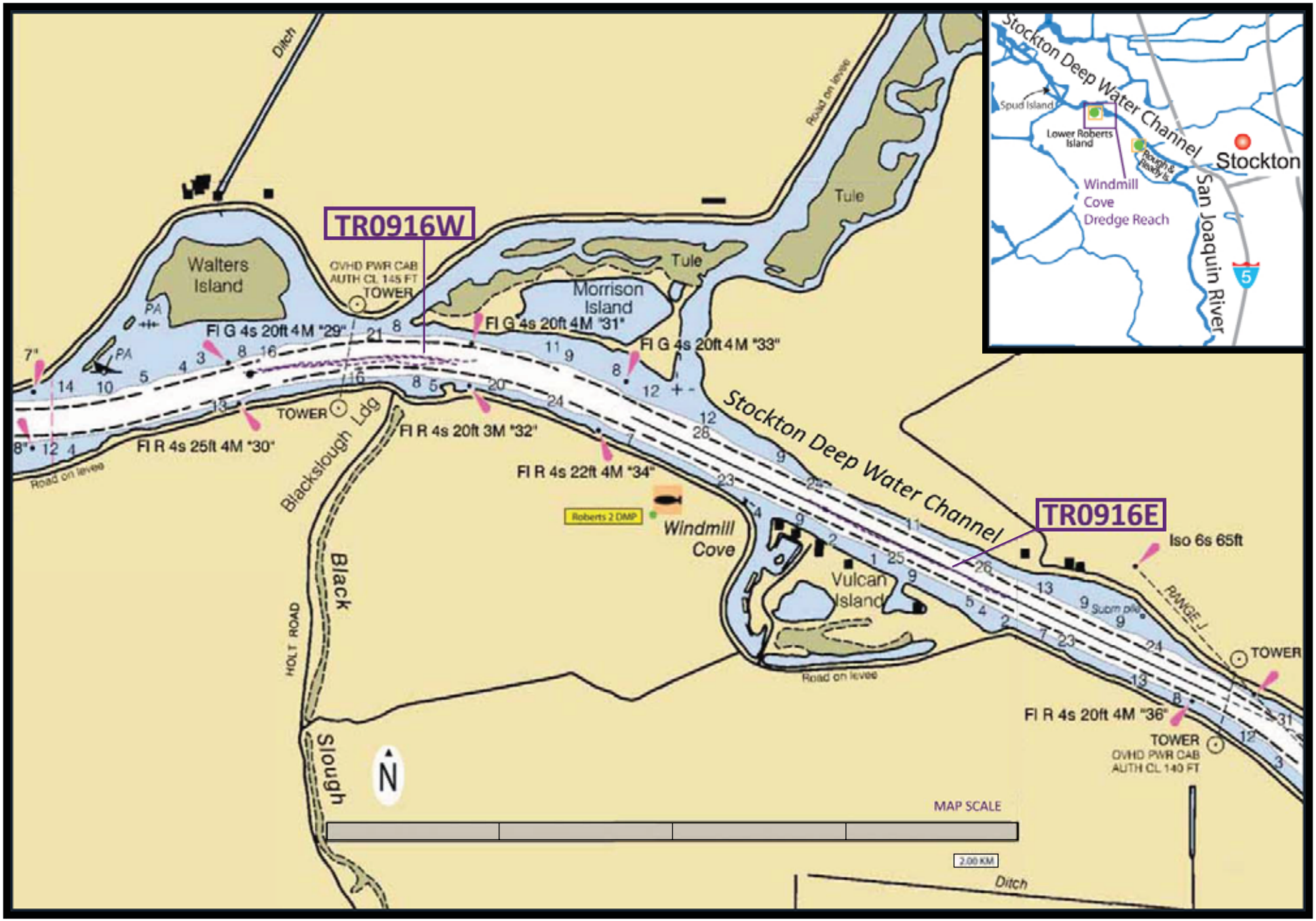


Figure 18. 2009 Fish Community Surveys for Windmill Cove Dredge Reach and Roberts 2 DMP Site

Map projection 1:10,000

Table 24. Summary Results of Trawl Surveys at Windmill Cove — Roberts 2 DMP Site

Rank	Percent	Number	Common Name	Origin
1	95.68	863	white catfish	Introduced
2	3.55	32	striped bass	Introduced
3	0.33	3	shimofuri goby	Introduced
4	0.22	2	channel catfish	Introduced
5	0.11	1	threadfin shad	Introduced
5	0.11	1	yellowfin goby	Introduced
Total		902		

Native Percent = 0% Native Species = 0, introduced Species = 6

Upper Roberts Island – Roberts 1 DMP Site: Dredging and fish community monitoring were conducted from RM 34.66 to 36.72 (Figure 19). This year was the first time that this section of the channel was sampled, though nearby channel areas have been sampled in previous years. The Roberts 1 DMP site has been used each year since fish community monitoring commenced in 2006. Table 25 provides a summary of the fish encountered during community sampling. White catfish was the most abundant species encountered, comprising nearly 79 percent of the total catch. White catfish has been the most abundant species at dredge reaches using the Roberts 1 DMP site since sampling commenced in 2006. CPUE at this location in 2009 was 0.19 fish/m. Native species were represented by a single splittail, the only one encountered in the SSC among the four caught in 2009. Splittail have been encountered in all years in both shipping channels, though never in high numbers.

Table 25. Summary Results of Trawl Surveys at Upper Roberts Island — Roberts 1 DMP Site

Rank	Percent	Number	Common Name	Origin
1	78.62	1302	white catfish	Introduced
2	12.74	211	striped bass	Introduced
3	3.80	63	channel catfish	Introduced
4	1.87	31	threadfin shad	Introduced
4	1.87	31	American shad	Introduced
5	0.36	6	warmouth	Introduced
6	0.30	5	shimofuri goby	Introduced
7	0.24	4	yellowfin goby	Introduced
8	0.06	1	splittail	Native
8	0.06	1	redear sunfish	Introduced
8	0.06	1	Shokihaze goby	Introduced
Total		1,656		

Native Percent = 0.06% Native Species = 1, introduced Species = 10

Rough and Ready Island – Roberts 1 DMP Site: Maintenance dredging and fish community monitoring occurred within the deepwater navigation channel between RM 38.48 and 39.32, near Rough and Ready Island in the West Complex of the Port of Stockton (Figure 20). This portion of the channel was sampled once before in 2006, and a portion sampled in 2008. Table 26 provides a summary of the fish encountered during community sampling. Striped bass was the most abundant fish species encountered in trawl sampling, representing almost 38 percent of the catch, followed closely by white catfish. The CPUE at this location was 0.22 fish/m, second highest of all locations in 2009. Native species were represented by a single prickly sculpin, the second of two captured in the SSC in 2009.

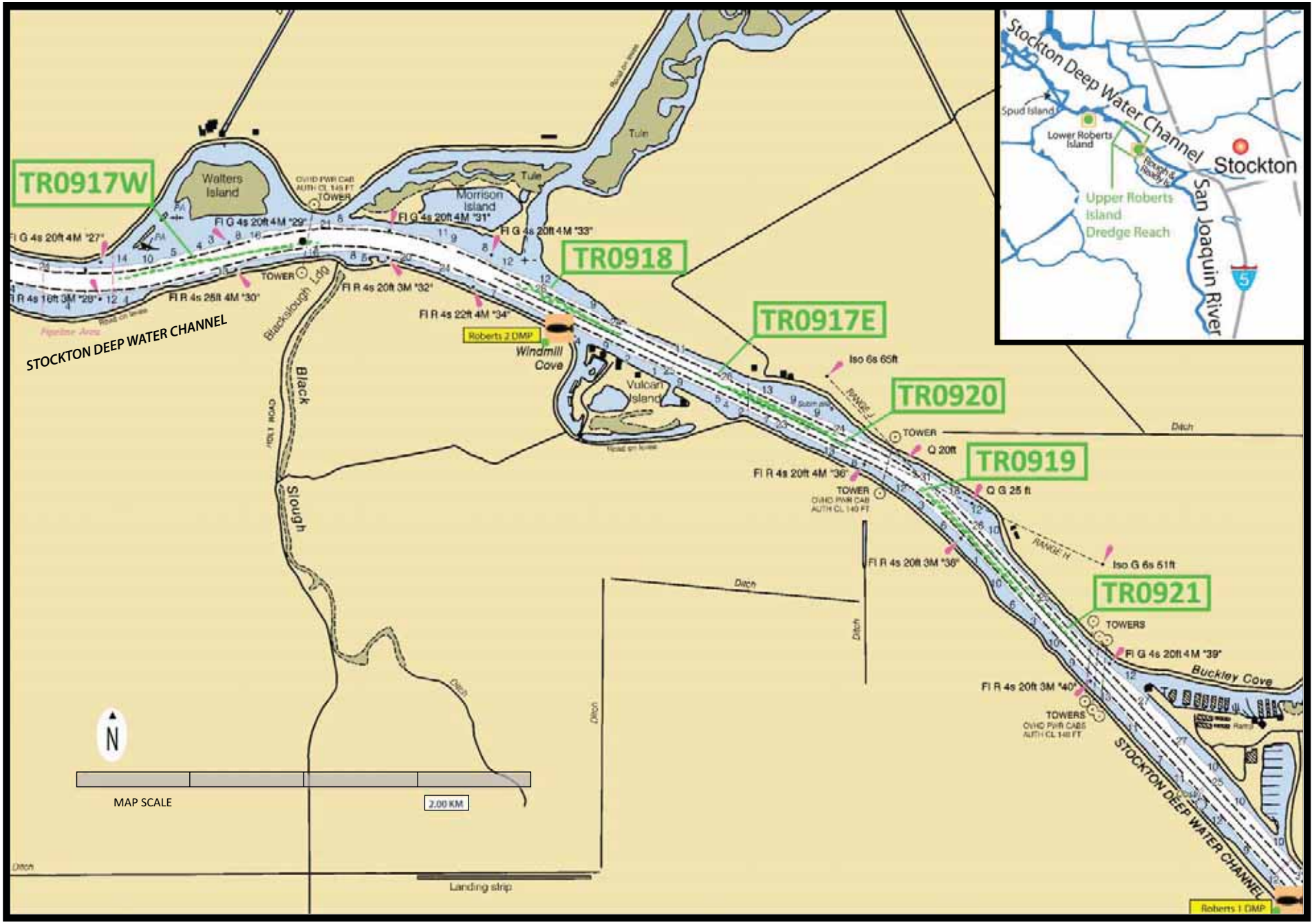


Figure 19. 2009 Fish Community Surveys for Upper Roberts Island Dredge Reach, Roberts 1 and Roberts 2 DMP Sites

Map projection 1:15,000

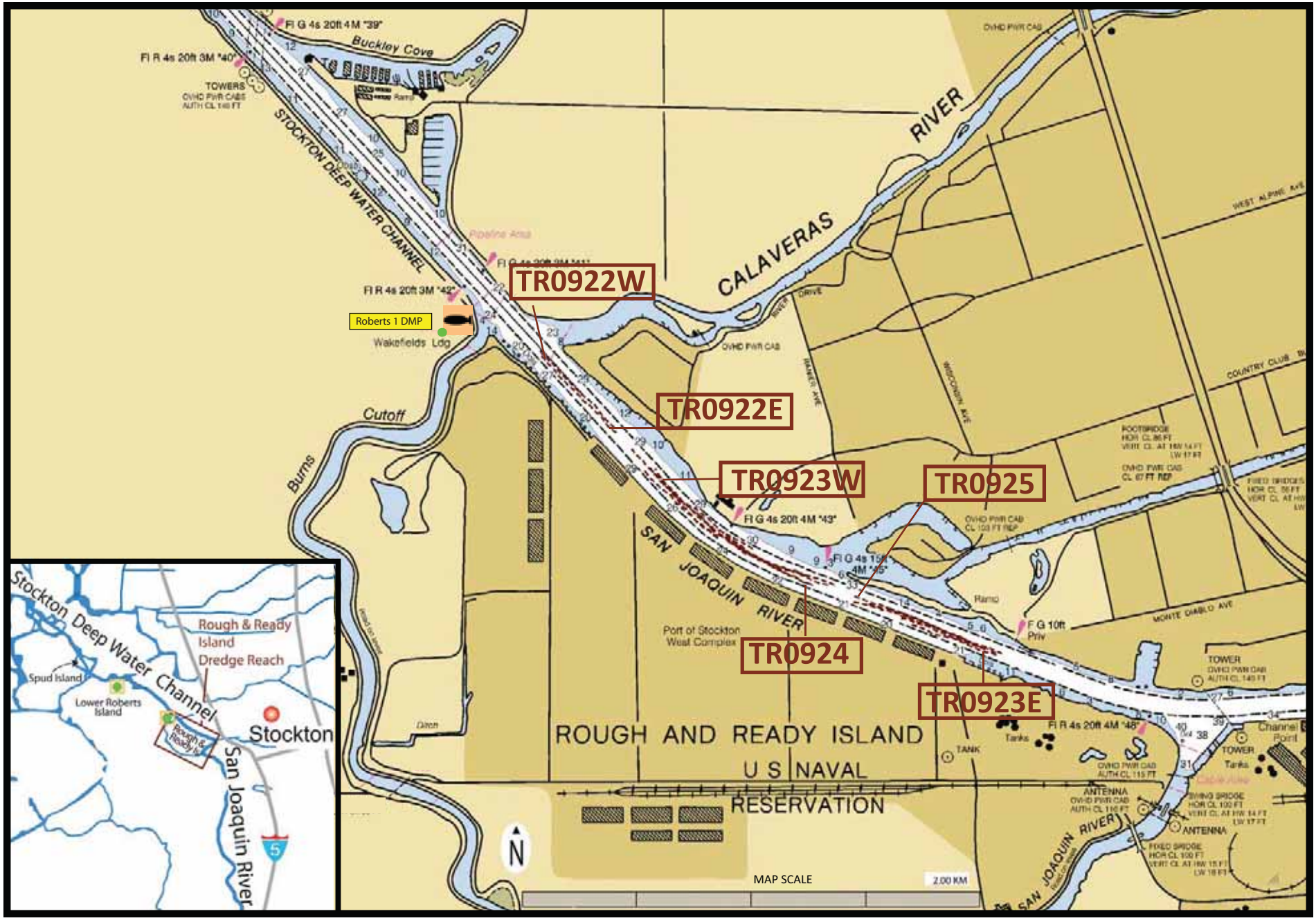


Figure 20. 2009 Fish Community Surveys for Rough and Ready Island Dredge Reach and Roberts 1 DMP Site

Map projection 1:15,000

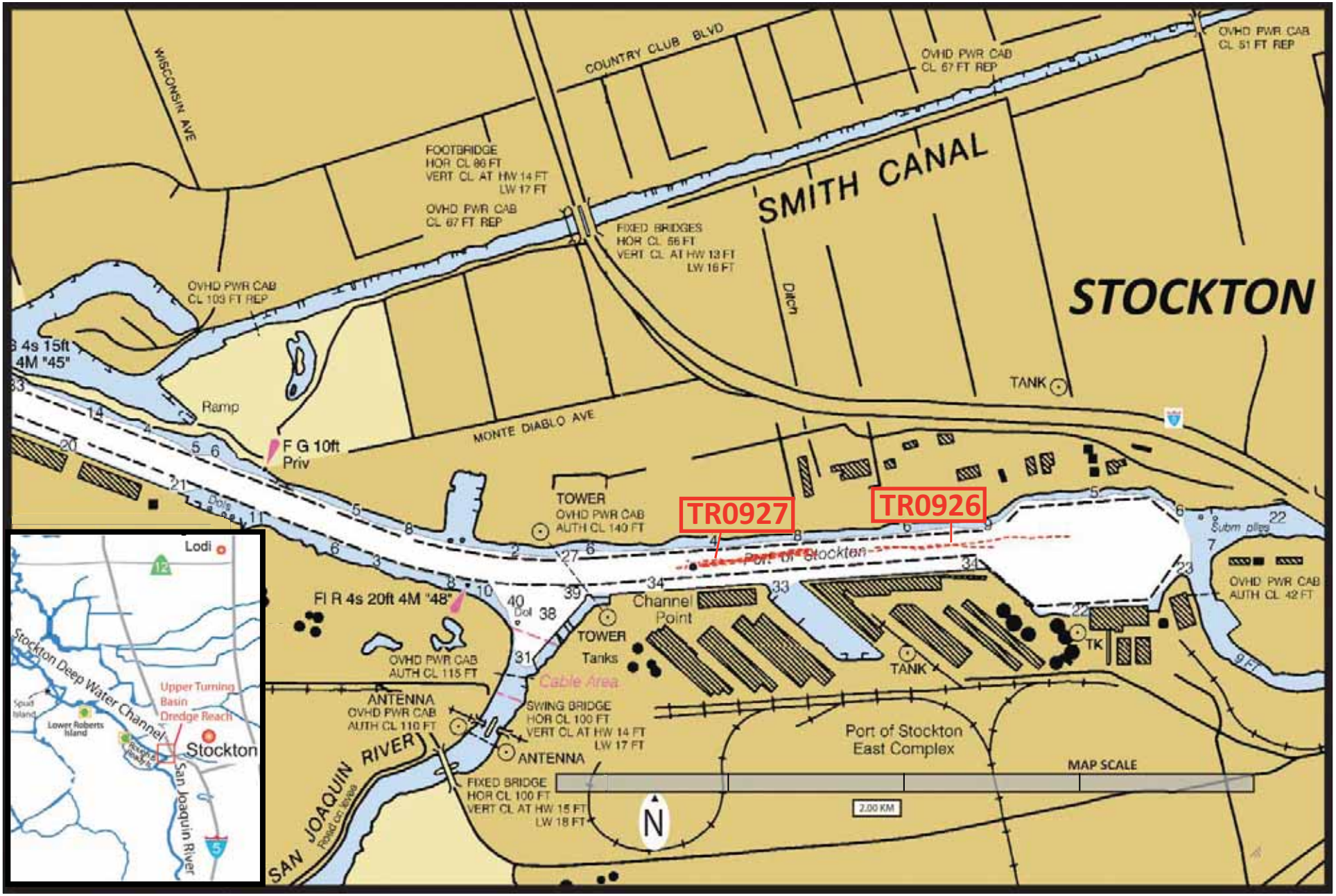


Figure 21. 2009 Fish Community Surveys for Upper Turning Basin Dredge Reach

Map projection 1:10,000

Table 26. Summary Results of Trawl Surveys at Rough & Ready Island — Roberts 1 DMP Site

Rank	Percent	Number	Common Name	Origin
1	37.78	791	striped bass	Introduced
2	32.33	677	white catfish	Introduced
3	19.10	400	threadfin shad	Introduced
4	8.02	168	channel catfish	Introduced
5	1.24	26	American shad	Introduced
6	0.76	16	yellowfin goby	Introduced
7	0.48	10	shokihaze goby	Introduced
8	0.01	2	shimofuri goby	Introduced
9	0.005	1	warmouth	Introduced
9	0.005	1	common carp	Introduced
9	0.005	1	brown bullhead	Introduced
9	0.005	1	prickly sculpin	Native
Total		2,094		

Native Percent = .005% Native Species = 1, introduced Species = 11

Upper Turning Basin – Roberts 1 DMP Site: Maintenance dredging and fish community monitoring were conducted within the deepwater navigation channel between RM 40.08 and 40.64 off the West Complex of the Port of Stockton (Figure 21). This is the furthest upstream area to have yet been assessed. Table 27 provides a summary of the fish encountered during community sampling. Threadfin shad and striped bass were the most abundant fish species encountered at this dredging location in 2009, representing almost 44 percent and 32 percent of the overall catch, respectively. CPUE at this location was 0.14 fish/m. Native fish were not encountered at this location in 2009.

Table 27. Summary Results of Trawl Surveys at Upper Turning Basin — Roberts 1 DMP Site

Rank	Percent	Number	Common Name	Origin
1	43.90	126	threadfin shad	Introduced
2	31.71	91	striped bass	Introduced
3	10.10	29	channel catfish	Introduced
4	6.62	19	American shad	Introduced
5	5.57	16	white catfish	Introduced
6	0.70	2	brown bullhead	Introduced
6	0.70	2	Warmouth	Introduced
7	0.35	1	yellowfin goby	Introduced
7	0.35	1	black crappie	Introduced
Total		287		

Native Percent = 0% Native Species = 0, introduced Species = 9

4.4 Fish Length

For 13 of the 21 species encountered during fish community monitoring, 100 percent of the fish encountered were measured for length prior to release. Species encountered in large numbers such as striped bass, white catfish, and threadfin shad are sub-sampled to determine the sizes of the encountered fish. This is done to minimize mortality by returning fish to the river as quickly as possible. Table 28 provides the summary length statistics for all measured fish encountered in the 2009 trawl surveys. Overall, 1,242 fish out of 6,240 (20%) were measured for length (total length [TL], standard length, or fork length, depending on species).

Table 28. Summary Size Statistics for Fish Encountered during 2009 Trawl Surveys

Common Name	Length (mm) Minimum	Maximum	SD of Mean	Mean Total Length	n Measured	n Captured	% Measured
Native Species							
prickly sculpin	114	126	8.49	120.00	2	2	100
Sacramento pikeminnow	224	224		224.00	1	1	100
splittail	104	386	147.04	246.50	4	4	100
starry flounder	95	241	52.35	130.71	7	7	100
tule perch	215	215		215.00	1	1	100
white sturgeon	525	670	45.28	617.00	7	7	100
Introduced Species							
American shad	45	310	68.74	127.18	97	245	40
black crappie	213	213		213.00	1	1	100
bluegill	135	152	12.02	143.50	2	3	67
brown bullhead	119	332	111.05	207.33	3	3	100
channel catfish	45	460	84.85	223.67	116	294	39
common carp	330	670	240.42	500.00	2	2	100
largemouth bass	85	85		85.00	1	1	100
redear sunfish	183	183		183.00	1	1	100
shimofuri goby	24	87	19.37	53.86	29	31	94
Shokihaze goby	25	107	23.07	87.85	13	13	100
striped bass	44	690	72.24	158.27	319	1,413	23
threadfin shad	52	198	31.85	125.82	129	604	21
wakasagi	63	130	8.86	94.05	120	136	88
warmouth	124	194	20.09	169.22	9	9	100
white catfish	15	506	67.67	174.65	349	3,433	10
yellowfin goby	73	194	24.19	131.10	29	29	100
Total					1,242	6,240	20

The majority of entrained fish were retained, examined, measured and returned to the river. Occasionally, fish were observed but not measured. There were a few reasons why individual entrained fish went unmeasured. There were fish that were visually identified to species but escaped collection over the end of the entrainment screen or through the screen mesh. These fish were documented in the entrainment results. Typically, they were individuals of the most common species (gobies and catfish), for which an abundance of length data has been collected. A few fish were dropped on their way to the collection bucket and there were also a few partial (un-measurable) fish showing signs of damage from the dredge. Table 29 provides the summary length statistics for all entrained fish that were measured. Overall, 75 percent of fish encountered during 2009 entrainment screen monitoring were measured prior to release or vouchering.

Table 29. Summary Size Statistics for Fish Encountered during 2009 Entrainment Screen Events

Common Name	Length (mm) Minimum	Maximum	SD	Mean Total Length	n Measured	n Collected	% Measured
Native Species							
lamprey (undet. spp.)	103	147	12.8	137	20	20	100
prickly sculpin	52	123	50.2	87.5	2	2	100
Introduced Species							
shimofuri goby	26	83	12.4	51.6	189	261	72.4
white catfish	37	170	31.2	77.8	47	52	90.4
channel catfish	55	248	63.7	137	30	30	100
shokihaze goby	34	108	26	71	19	20	95
yellowfin goby	107	166	19.4	136	12	12	100
American shad	75	75	--	--	1	1	100
bluegill	134	134	--	--	1	1	100
brown bullhead	180	180	--	--	1	1	100
striped bass	267	267	--	--	1	1	100
wakasagi	91	91	--	--	1	1	100
warmouth	167	167	--	--	1	1	100
				Total	303	403	75.2

4.5 Invertebrates

Invertebrates have been encountered during both fish community and entrainment sampling since the project's inception, even though the sampling methods employed were designed specifically for collection of fish. Information on the numbers and species of invertebrates encountered continues to be collected due to its potential utility in assessments of the indirect impacts of maintenance dredging in the shipping channels. A total of 139,523 invertebrates were encountered during entrainment sampling in 2009 and 10,001 were encountered during fish community monitoring. These numbers are estimates (as described in the methods) for most invertebrate species. Estimates are necessitated in large part due to the large number of individuals encountered and the practical need to focus on fish as opposed to invertebrates as the project's central objective.

The most commonly encountered species for both types of sampling were, as in previous years, Asian clams and Siberian prawns (*Exopalaeomon modestus)*, both introduced species. Large populations of these clams and shrimp exist in many of the sampled locations in the shipping channels. Clam shells persist long after death and are frequently a large percentage of the detritus left on the entrainment screen or mixed with the fish in the cod-end of the trawl. Live clams and shrimp are also very common on the screen and in the cod-end of the trawl net. The S-31 reach in the SRSC was remarkable for both the number and large size of the clams in the entrainment samples, as well as the amount of shell. The SSC Light 21 reach off the McCormack Pit DMP site was remarkable for the high numbers of small *Corbicula* with very little other detritus whatsoever.

More crayfish were captured than in previous years, with presence at the Spud Island and Upper Roberts Island reaches. The crayfish were of two species: the native Californian, or signal, crayfish (*Pacifasticus leniusculus)* and the red swamp crayfish (*Procambarus clarkii)* not previously documented by this sampling program. The individual species were not documented in the field and so crayfish are grouped in the data. However, the two species were of approximately equal density.

The increased abundance of crayfish seemed to coincide in these locations with noticeably more Brazilian pond weed (*Egeria densa)* in sampling gears.

The California floater (*Anodonta californiensis),* a native freshwater mussel, was again encountered in the entrainment samples from Man-made Channel reach in the SRSC, but more often from the upper reaches of the SSC. This mussel species is a federal species of concern. Samples of these mussels were provided to Dr. Jeanette Howard of the Nature Conservancy for genetic analyses. Mussels collected from the upper SSC are most closely related to other central coast populations and populations in the lower Sacramento River coastal streams of the Bay Area, south of the Russian River (Howard 2010 – in press). The presence of the native mussels in our sampling coincides with large numbers of leeches (in the SSC), lamprey ammocoetes, and fine, organic and detritus rich sediments.

The introduced overbite clam (*Corbula amurensis)* was found in the lower reaches of SSC in 2009. These clams are estuarine and the lower reaches of the channels are at the freshest end of their salinity tolerance. These clams were previously encountered in the lower reaches of both shipping channels. An unidentified species of jellyfish was once again present in these areas as well.

Other species of invertebrates such as mud crabs (*Rhithropanopeus harrisii*), and the Chinese mitten crab (*Eriocheir sinensis*) have been encountered previously but were not in 2009. One introduced mud snail (*Cipangopaludina japonica)* was entrained in 2009. These snails were observed in very low numbers in 2008 as well. Shells of native but displaced bivalves such as the bay mussel (*Mytilus edulus)* and the oyster (*Ostrea conchaphila*) are occasionally found in the entrainment samples but they have not been enumerated in 2009 as in previous years. The probable source of these shells is transfer via ship bottom. These organisms likely arrive in the fresher portions of the channel on vessel hulls, fall or are scraped off as the ships rub bottom, then die and leave their shells behind.

Invertebrates encountered in 2009 are listed in Table 30 and Table 31 by respective sampling type.

Table 30. Ranked List for Invertebrates Encountered during 2009 Entrainment Monitoring

Rank	Percent	Total	Common Name	Genus	Species	Origin
1	97.8	136,500	Asian clam	*Corbicula*	*fluminea*	Introduced
2	1.5	2,078	Siberian prawn	*Exopalaemon*	*modestus*	Introduced
3	0.3	478	leech	Unknown	spp.	Unknown
4	0.2	229	California floater (mussel)	*Anodonta*	*californiensis*	Native
5	0.1	205	freshwater shrimp	undetermined	spp.	unknown
6	0.02	25	overbite clam	*Corbula*	*amurensis*	Introduced
7	0.005	7	signal crayfish and red swamp crayfish	*Pacifasticus* *Procambarus*	*Leniusculus* *clarkii*	Native introduced
8	~0	1	mud snail	*Cipangopaludina*	japonica	introduced
Total		139,523				

Table 31. Ranked List for Invertebrates Encountered during 2009 Trawl Surveys

Rank	Percent	Total	Common Name	Genus	Species	Origin
1	70.7	7071	Siberian prawn	*Exopalaemon*	*modestus*	Introduced
2	23.6	2360	Asian clam	*Corbicula*	*fluminea*	Introduced
3	5.0	500	amphipods**	unknown	unknown	Unknown
4	0.5	55	shrimp, freshwater	all	spp.	Unknown
5	0.1	10*	signal crayfish red swamp crayfish	*Pacifasticus* *Procambarus*	*Leniusculus clarkii*	Native introduced
6	0.04	4	freshwater mussel	*Anodonta*	*californiensis*	Native
7	0.01	1	jellyfish	undetermined	spp.	Unknown
Total		10,001				

* Species about equally split. **The amphipods were on a piece of wooden piling that was stuck in the trawl

Based on the collected data, the authors extrapolate the total numbers of entrained invertebrates as well as entrained fish, and provide the details in Table 21. The extrapolation is presented because indirect impacts of dredging are in part based on impacts to the benthic ecology such as community disturbance and prey removal. Though not directly addressed by this sampling program, entrainment rates of invertebrates by dredge may be useful to assess indirect impacts. Total extrapolated counts predict that 2,437,184 invertebrates were entrained by the dredge operations in 2009 (Table 32) and the introduced Asian clam was the dominant taxon at all DMP sites. Asian clams accounted for almost 98 percent of the predicted total of entrained invertebrates, very similar to the 97 percent predicted in 2008.

These extrapolated data are based on numbers of invertebrates per gallon of dredged material sampled, and have not been converted into organisms per square meter (or other density measurement). The extrapolated numbers are in some cases very large. However, they describe the estimated number of entrained invertebrate organisms across the entire dredge reach.

Table 32. Extrapolated Invertebrate Entrainment Catch for 2009 by Location & Species

River	SRSC	SSC								
	Man-made Channel	Scour Pond	Light 21	Spud Island	Lower Roberts Island	Windmill Cove	Upper Roberts Island	Rough & Ready Island	Upper Turning Basin	
	S-31	Scour Hole	McCormack Pit	Roberts 2	Roberts 2	Roberts 2	Roberts 1	Roberts 1	Roberts 1	Total
[% Sampled]	[4.95]	DNS	[6.61]	[7.70]	[4.98]	[3.35]	[4.81]	[7.49]	[8.99]	[5.64]
Asian clam	468,687		756,430	129,870			914,760	86,782	31,146	2,387,675
Siberian prawn	14,444			2,597	60		8,731	6,341	4,060	36,253
leech				325	161		1,975	267	3,671	6,399
California Floater	101						728	2,363	133	3,325
freshwater shrimp			3101							3,101
overbite clam			378							378
crayfish				39			83			122
mud snail							21			21
Total	483,232	DNS	759,909	132,831	221	0	926,298	95,753	39,010	2,437,184

Note: Gray shading indicates introduced species.

4.6 Bird Activity Observations

Observations of piscivorous birds were made at all 2009 trawl and DMP site locations during active monitoring periods. Few, if any piscivorous birds were observed during either entrainment or trawl surveys at the Man-made Channel, Scour Pond, Light 21, Spud Island, Lower Roberts, and Windmill Cove dredge reach locations and their associated DMP sites. Observations of piscivorous gulls and terns, cormorants, and an occasional western griebe or heron became more numerous at the end of September at Upper Roberts Island. Larger flocks (12-50 individuals) of gulls and terns were commonly observed perched on Port of Stockton buildings or drifting in the channel during trawl surveys at the Rough and Ready Island and the Upper Turning Basin dredge reaches. One brown pelican was observed on the last day of monitoring for the season in the Upper Turning Basin reach. Swainson's hawks were not observed during monitoring activities.

Piscivorous wading birds (egrets and herons of 1-10 birds) were more frequently observed in the Roberts 1 DMP site for the Upper Roberts, Rough and Ready, and Upper Turning Basin dredge reaches. During two different entrainment surveys at the Roberts 1 DMP site large mixed flocks of approximately 100-200 gulls, terns, crows, egrets and herons were observed at the far end of the DMP site ½ to ¾ miles distant from the pipeline discharge point. On these occasions, bare soils had been newly exposed in preparation to receive additional decanting water from the DMP site. Piscivorous birds were absent or rare at all other DMP sites and their associated dredge reaches prior to late September.

One sea lion was observed at the Scour Pond dredge reach hauled out on a navigation buoy near the Antioch Bridge in late August. Sea lions were observed in the channel and hauled out, for nearly the full duration of trawl sampling, at Rough and Ready Island dredge reach in the SSC. In one instance, 3 sea lions had hauled out together under Berth B on Rough and Ready Island.

4.7 Comparison of Monitoring Method Results

Assessments of relationships between the species, habits, and relative abundance of the fish encountered in the community and entrainment monitoring are made where enough data exists. Making these comparisons helps answer questions about the suitability of the fish community sampling methodology for testing the hypotheses about the subset of species most susceptible to entrainment.

Fish were categorized into demersal (benthic and epi-benthic) and non-demersal (pelagic) fish types based descriptions in Moyle (2002), Wydoski and Whitney (2003), Nobriga et al. (2005), and Brown and May (2006). During 2009, demersal species comprised 62 percent of the individual fish in the fish community trawl catch, varying by dredge location from 4.6 percent at Light 21 to over 96 percent at Windmill Cove (Table 33). The percentage of demersal fishes in the entrainment samples was much higher than in the fish community catch at all locations where both sampling methods were conducted (Figure 22). This was true for 2008 as well. Only five of the 403 entrained fish in 2009 (1.24%) were pelagic species.

Table 33. Percent Demersal Fishes by Location in 2009 Trawl & Entrainment Sampling

Location	Entrainment	Trawl	
	% Demersal	Mean CPUE (fish/100m)	% Demersal
Man-made Channel/S-31	98.6	5	56.4
Scour Pond	not sampled	1	33.3
Light 21/McCormack	66.7	3	4.6
Spud Island	100	3	42.6
Lower Roberts Island	100	13	80.8
Windmill Cove	100	30	96.3
Upper Roberts Island	100	19	83.0
Rough and Ready Island	95.3	22	41.8
Upper Turning Basin	94.1	14	16.7

Presence in the fish community samples predicates presence in the entrainment samples with few exceptions as might be expected. However, relative abundance of species in the fish community samples does not directly correlate with relative abundance in the entrainment samples. In 2009, lamprey (n = 20, 4.96% of entrainment) were the only fish to be encountered in entrainment, but not in fish community monitoring. They have been part of the fish community catch in the past, though never in high numbers (one in 2007 and 13 in 2006). Ten additional fish species were encountered in community monitoring but not in entrainment, which included: threadfin shad, starry flounder, white sturgeon, splittail, common carp, black crappie, largemouth bass, redear sunfish, Sacramento pikeminnow, and tule perch. The more pelagic striped bass, shads, and wakasagi have been entrained, but rarely (only once each in 2009). Additionally, demersal species that are rare in the entrainment samples tend to be rare in the community samples. Pelagic species are also rare in the entrainment samples overall. Only two fish species, the introduced shimofuri and shokihaze gobies (both demersal), were more common in the entrainment samples than in the community samples. Shimofuri goby was also the most commonly entrained fish species for the first time in 2009. Table 34 provides additional details about species encountered during both types of sampling. American shad and wakasagi were added to this list in 2009. Though the relative abundances changed between years, the fish species encountered in both types of sampling were the same in 2008 with the exception of threadfin shad in place of American shad.

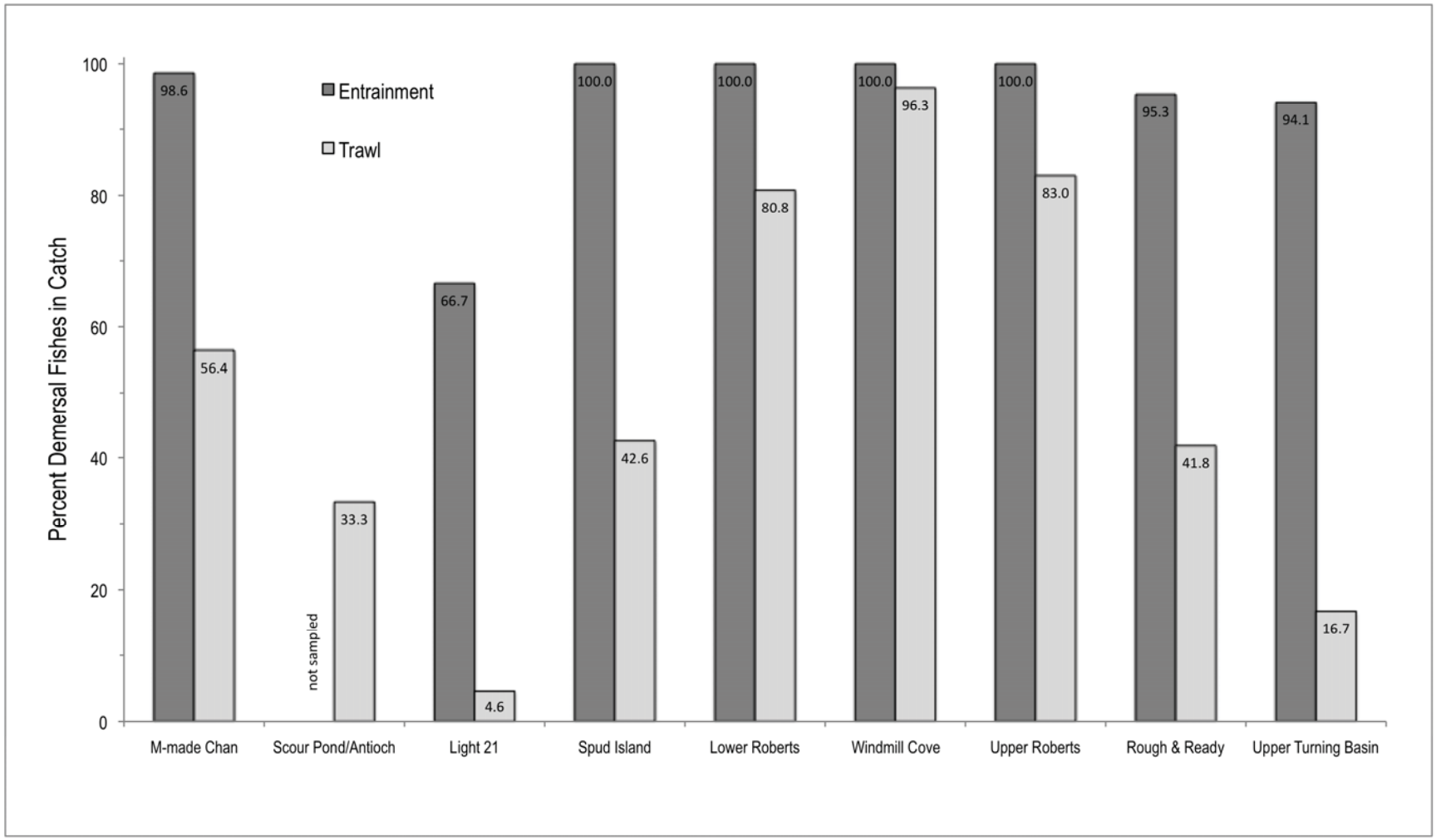


Figure 22. Percent Demersal Fishes in Overall Catch by Survey Method for Each Dredge Reach

Table 34. Trawl & Entrainment Percentage for Fish Species Observed in Both Sampling Methods

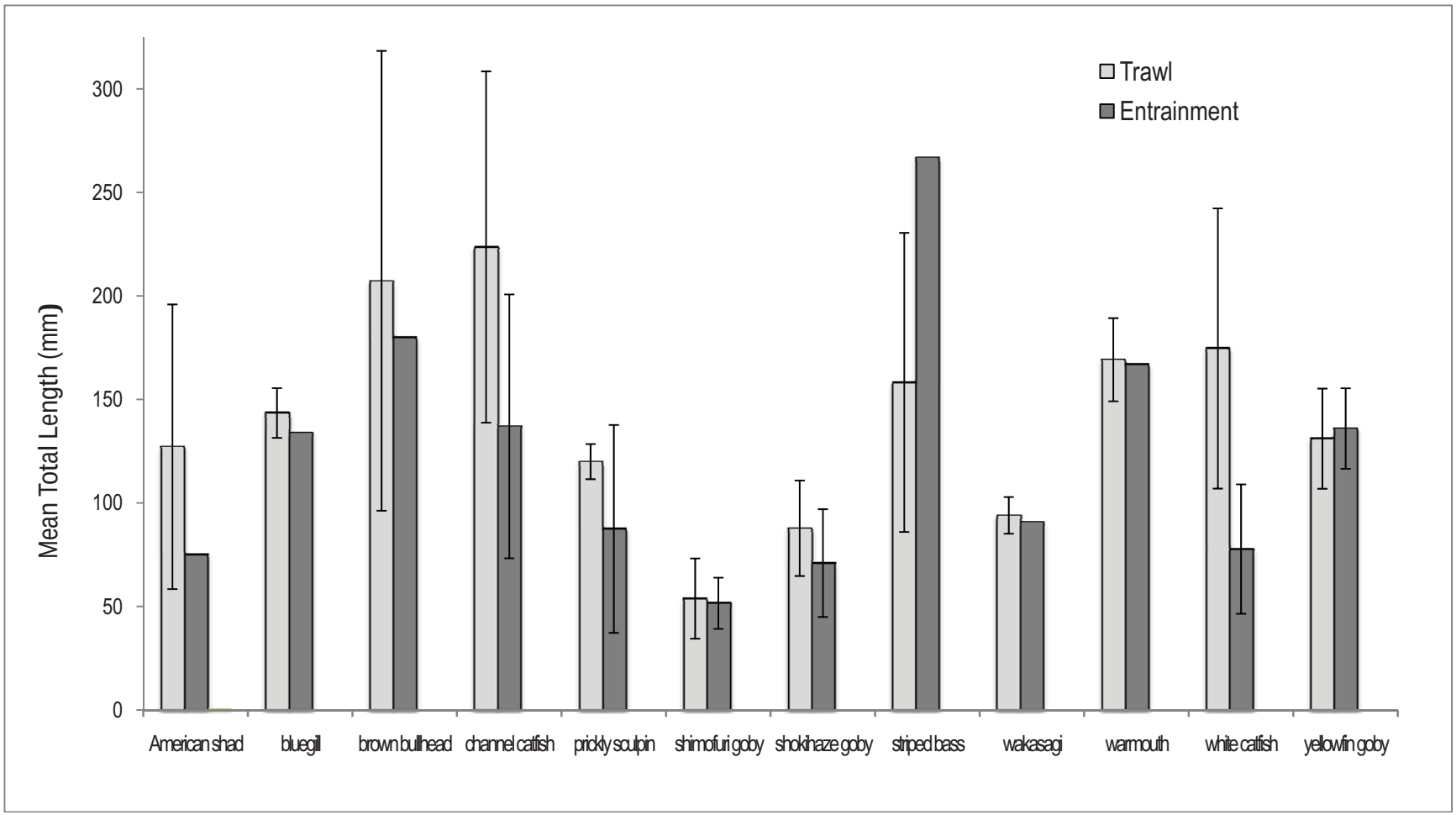
Trawl Count	Percent Catch of Trawl	Percent Catch of Entrainment	Entrainment Count	Common Name	Origin	Demersal/ Pelagic
3,433	55.02	12.90	52	white catfish	Introduced	Demersal
1,413	22.64	0.25	1	striped bass	Introduced	Pelagic
294	4.71	7.44	30	channel catfish	Introduced	Demersal
31	0.51	64.76	261	shimofuri goby	Introduced	Demersal
245	3.93	0.25	1	American shad	Introduced	Pelagic
136	2.18	0.25	1	wakasagi	Introduced	Pelagic
29	0.46	2.98	12	yellowfin goby	Introduced	Demersal
13	0.21	4.96	20	shokihaze goby	Introduced	Demersal
9	0.14	0.25	1	warmouth	Introduced	Pelagic
2	0.03	0.50	2	prickly sculpin	Native	Demersal
3	0.05	0.25	1	brown bullhead	Introduced	Demersal
3	0.05	0.25	1	bluegill	Introduced	Demersal

The total lengths of fishes were collected in both entrainment and fish community monitoring. The difference in mean size among species encountered in both survey types allows testing of correlations between the size of fish present around the dredge and the likelihood of entrainment. In 2009, twelve fish species were encountered in both monitoring methods. However, for entrainment monitoring, six species of fish were represented by only one individual each. Figure 23 displays a bar chart comparison of the mean size of fishes encountered by survey type.

4.8 Water Quality Monitoring

Surface and bottom measurements were acquired for all parameters except Secchi depth and were generally taken at the beginning and end of each fish community sampling event. A total of 40 surface and 37 bottom water quality readings were made in 2009. The complete multi-parameter results are presented in Appendix B. The water quality data discussed below are near bottom measurements.

Dissolved oxygen measurements ranged between 77 percent and 115 percent with two bottom readings below 80 percent (Light 21 and Lower Roberts Island dredge reaches). Bottom water temperature readings exceeded 20°C in all monitoring locations until October. The maximum water temperature recorded for 2009 was 25.36°C in the Upper Roberts Island reach on September 23. The minimum temperature of17.92°C was found in the Upper Turning Basin, recorded on October 14th, two days prior to completion of 2009 monitoring. Salinity readings near 1.0 salinity units showed slightly brackish conditions at the two lowest SSC dredge reaches of Scour Pond and Light 21 with freshwater readings below 0.3 at all other reaches. The highest turbidity readings (generally above 100 ntu) were recorded in the Man-made Channel reach. Additional water quality data can be downloaded at the California Data Exchange Center (CDWR 2009) for Antioch, Rough and Ready Island and other areas in the Delta. Data on the website include river stage, pH, temperature, DO, conductivity, turbidity and other parameters taken on an hourly basis.



Note: Error bars represent one standard deviation based on the measured number of individuals; no bars indicate only one specimen collected

Figure 23. Mean Size of Fish Species Collected in both Trawl and Entrainment in 2009 (+/- one standard deviation)

4.9 Level of Take

A stated objective of the monitoring program is to improve take estimates for maintenance dredging operations in the Delta. Original take estimates for the 2006 FMP (Table 35) were based on the estimates developed for the Stockton DWSC and the Sacramento DWSC maintenance dredging BOs (NMFS 2006a,b). It was assumed that exposure of listed fish to sampling gear would be less than 25 percent of the potential exposure to dredging activities and associated shipping, a very conservative overestimate, since no salmon or steelhead, and only two green sturgeon have been encountered during monitoring of dredging operations over the past four years.

Table 35. ESA & CESA Incidental Take Allotments for 2009 & 2010

Potential annual incidental take for NMFS jurisdiction listed fish for fish monitoring of the Stockton DWSC Maintenance Dredge Project (original estimate 2006)

Species	Juveniles		Adults	
	No.	% of Total ESU/DPS*	No.	% of Total ESU/DPS*
Sacramento River winter-run Chinook salmon	650	0.85	1	<1
Central Valley spring-run Chinook salmon	1,250	0.32	1	<1
Central Valley steelhead	70	0.15	2	<1
North American green sturgeon, Southern DPS	25 juveniles and adults combined (2% = 1 mortality)			

Potential annual incidental take for NMFS jurisdiction listed fish for fish monitoring of the Sacramento DWSC Maintenance Dredge Project (original estimate 2006)

Species	Juveniles		Adults	
	No.	% of Total ESU/DPS*	No.	% of Total ESU/DPS*
Sacramento River winter-run Chinook salmon	650	0.85	1	<1
Central Valley spring-run Chinook salmon	1,250	0.32	1	<1
Central Valley steelhead	70	0.15	2	<1
North American green sturgeon, Southern DPS	25 juveniles and adults combined (2% = 1 mortality)			

Incidental take for USFWS jurisdiction listed fish for fish monitoring of the SRSC and SSC

Species	Juveniles		Adults	
	non-lethal	lethal	non-lethal	lethal
delta smelt	10 per week, lethal and non-lethal, no life history differentiation			

IEP-ESA incidental annual take allotments for fish community sampling in the SRSC and SSC 2010

Species	Juveniles		Adults	
	non-lethal	lethal	non-lethal	lethal
longfin smelt	150		150	

* ESU = evolutionarily significant unit . DPS = distinct population segment.

Estimates of take of delta smelt and longfin smelt were not included in the original take estimates, as NMFS does not provide take estimates for these fish species, nor were they established during previous informal consultations with the USFWS. Additional consultation with USFWS resulted in a letter amendment (reference number 81420-2008-F-1775-1) to the prior USFWS Informal Consultation decision for maintenance dredging (Service File Number 1-1-04-F-0345), allowing the take of up to ten delta smelt per week during normal dredging operational windows. Incidental and lethal take for longfin smelt during fish community monitoring was authorized under Program Element

Number 2009-113 for inclusion in the amended IEP Scientific Collecting Permit 1440. The IEP permit allowed 150 adults and 150 juvenile longfin smelt in this study's take allotment for 2009 monitoring.

None of the listed species above were encountered or observed while conducting fish community or dredge entrainment monitoring in 2009.

Sampling Mortality

Some mortality among encountered fish is an unavoidable result of fish community and entrainment sampling, although in the case of the entrainment sampling, all entrained fish are assumed to die as a result of being entrained and then placed in a DMP site. De-watering of DMP sites is not conducted in an effort to save entrained fish that are still alive when de-watering occurs. Rather, it is conducted out of necessity to remove the water from the sites. Entrainment sampling probably reduces overall dredge entrainment mortality as live fish collected during sampling are returned to the river. In this sense, documentation of entrainment mortality serves a separate purpose than that of community sampling mortality.

Estimation of mortality during fish community sampling is presented due to the interest in documenting the "costs" of sampling. Many types of fisheries sampling methods result in mortality to some or all of the sampled fish. Sampling mortality is weighed and justified from the standpoint of research need, government mandate, species conservation measures, as well as cultural and ethical considerations. The investigators conducting this monitoring program seek to minimize sampling mortality wherever and whenever possible, and have in some cases decided to reduce the amount of data gathered based on the desire to minimize mortality to non-target species. Data gathered by this monitoring study on non-special status species may prove useful to this and other studies. However, in large part, this data is not central to the requirement to conduct the monitoring. The monitoring mandate is related to a very small subset of the species encountered due to, and required by their currently rare occurrence in the environment. The project faces an area of compromise between gathering data and increasing the mortality of encountered fish by delaying their release. The investigators address this by sorting the catch based on data needs, data availability from this and other studies, and interspecies variability in survival rate. The result is that the field biologists immediately remove and return to the river (without measuring) most striped bass, American shad, threadfin shad, and channel and white catfish. In the case of the catfish, the field biologists continue to gather ample data on a subset of these abundant introduced fishes. In the case of the other fishes that rapidly exhibit handling stress, only a quick return to the river can help minimize mortality. No rare and or special status species (if not vouchered) is ever returned to the river without acquiring length measurements and making other observations. Mortality is estimated by directly counting dead fish with a re-correction after observing released fish. Table 36 provides the mortality data for fish from the fish community samples and Table 37 provides the mortality data from the entrainment samples.

Lamprey experienced some mortality during entrainment sampling. Seven unidentified lamprey fell through the entrainment screen or escaped upon transfer to the live-well and were counted as mortalities. Shimofuri goby had the highest entrainment mortality rates (63 individuals), accounting for 64 percent of all entrainment mortalities. Overall, entrainment monitoring resulted in 99 mortalities, or 24.6 percent of the fish entrained by the dredge. Native fish (lamprey) comprised 1.28 percent of all sampling mortality, not including vouchered specimens.

A total of 598 individuals, or 9.58 percent of the total catch, were recorded as mortalities during fish community sampling. The highest mortality rates were observed among striped bass, threadfin shad,

wakasagi, and American shad. These four species accounted for 94.4 percent of total mortality during community sampling (not including vouchered specimens).

Portions of the man-made channel of the SRSC and possibly other delta channel locations may contain populations of delta smelt, wakasagi, and or hybrids of the two. Field identification and differentiation is possible but non-trivial following Wang, 2007. Hybridization of wakasagi and delta smelt has become an important ecological concern. It is a regulatory concern also, as hybrids are not due special status while delta smelt are. Minimizing fish community sampling effort when these fish are present due to the difficulty of positive differentiation in the field was employed in 2008 and 2009. All delta smelt, potential hybrids and wakasagi are now required to be vouchered for further analysis by CDFG. In 2009, nine smelts were vouchered for such additional analysis and identification. All of these fish were determined to be wakasagi by CDFG. The vouchered wakasagi are included in the mortality data presented in Table 36.

Table 36. Total Mortality for 2009 Fish Community Sampling

Common Name	Total Mortalities	Percent Trawl Mortality	Origin
striped bass	226	37.8	Introduced
threadfin shad	136	22.7	Introduced
wakasagi	119	19.9	Introduced
American shad	84	14.0	Introduced
white catfish	17	2.8	Introduced
shimofuri goby	8	1.3	Introduced
yellowfin goby	6	1.0	Introduced
bluegill	1	0.2	Introduced
shokihaze goby	1	0.2	Introduced
Total	598		

Table 37. Total Mortality for 2009 Entrainment Sampling

Common Name	Total Mortalities	Percent Entrainment Mortality	Origin
shimofuri goby	63	64	Introduced
channel catfish	11	11	Introduced
white catfish	8	8	Introduced
lamprey, unidentified species	4	4	Native
shokihaze goby	3	3	Introduced
American shad	1	1	Introduced
bluegill	1	1	Introduced
striped bass	1	1	Introduced
wakasagi	1	1	Introduced
Total	99		

Vouchered Specimens

Overall, 11 fish specimens were vouchered in 2009 (Table 38). One Pacific lamprey ammocoete was preserved for further examination and submitted to the USFWS in Arcata, CA. Nine wakasagi were sent to CDFG for positive identification and examination. California floaters were provided to The Nature conservancy for inclusion in an investigation of West Coast mussels being conducted for the US Forest Service. (Howard 2010). One prickly sculpin and one mud snail were also retained for further examination and confirmation of identification.

Table 38. Vouchered Specimens Collected during 2009 Monitoring

Species	Total Vouchered	River	Method of Collection	Reason	Location	Origin
wakasagi	9	SRSC	Otter Trawl	Positive ID, further study	CDFG Stockton, CA	Introduced
prickly sculpin	1	SSC	Screen	Positive ID	Mari-Gold Environmental	Native
Pacific lamprey, ammocoete	1	SSC	Screen	Positive ID	USFWS-Arcata office	Native
California floater (mussel)	45	SSC	Screen	Genetic Study	Dr. J. Howard, Nature Conservancy - SF	Native
Mud snail	1	SSC	Screen	Positive ID	Dr. J. Howard, Nature Conservancy - SF	Introduced
Total	57					

4.10 All Years Combined Data

Tables 39 and 40 present the combined fish community and entrainment catch for all years (2006-2009) without regard to inter-annual differences in effort, location, method or timing. The basic information presented in this manner provides a description of the Delta fish species that have been present in the shipping channels while maintenance dredging was occurring, and the subset of those species most susceptible to entrainment. Introduced species greatly outnumbered natives both by species and by number of individuals. The proportion of demersal to pelagic species was higher both in species and in numbers of individuals in the entrainment samples than it was in the fish community samples. All native species entrained were demersal, while half of the native species encountered in the fish community samples were pelagic.

Table 39. Combined Fish Catch for Entrainment Sampling during All Years of Study

Rank	Number	Proportion	Common Name	Origin	Demersal/Pelagic
1	267	0.3683	shimofuri goby	Introduced	Demersal
2	226	0.3117	channel catfish	Introduced	Demersal
3	92	0.1269	white catfish	Introduced	Demersal
4	67	0.0924	lamprey spp.	Native	Demersal
5	29	0.0400	Shokihaze goby	Introduced	Demersal
6	23	0.0317	yellowfin goby	Introduced	Demersal
7	5	0.0069	brown bullhead	Introduced	Demersal
7	5	0.0069	striped bass	Introduced	Pelagic
8	2	0.0028	bluegill	Introduced	Pelagic
8	2	0.0028	Pacific staghorn sculpin	Native	Demersal
8	2	0.0028	prickly sculpin	Native	Demersal
8	2	0.0028	warmouth	Introduced	Pelagic
9	1	0.0014	American shad	Introduced	Pelagic
9	1	0.0014	threadfin shad	Introduced	Pelagic
9	1	0.0014	wakasagi	Introduced	Pelagic

Total:	725	90.21% introduced
Species:	15	(3 Native)

Table 40. Combined Fish Catch for Trawl Sampling during All Years of Study

Rank	Number	Proportion	Common Name	Origin	Demersal/Pelagic
1	18,383	0.5733	white catfish	Introduced	Demersal
2	5,025	0.1567	threadfin shad	Introduced	Pelagic
3	3,082	0.0961	striped bass	Introduced	Pelagic
4	2,233	0.0696	American shad	Introduced	Pelagic
5	1,499	0.0467	channel catfish	Introduced	Demersal
6	918	0.0286	longfin smelt	Native	Pelagic
7	154	0.0048	wakasagi	Introduced	Pelagic
8	137	0.0043	yellowfin goby	Introduced	Demersal
9	106	0.0033	white sturgeon	Native	Demersal
10	94	0.0029	shokihaze goby	Introduced	Demersal
11	89	0.0028	shimofuri goby	Introduced	Demersal
12	72	0.0022	starry flounder	Native	Demersal
13	63	0.0020	tule perch	Native	Pelagic
14	36	0.0011	delta smelt	Native	Pelagic
15	29	0.0009	prickly sculpin	Native	Demersal
16	19	0.0006	splittail	Native	Pelagic
17	17	0.0005	warmouth	Introduced	Pelagic
18	15	0.0005	common carp	Introduced	Demersal
19	14	0.0004	blue catfish	Introduced	Demersal
20	13	0.0004	lamprey spp.	Native	Demersal
21	10	0.0003	Sacramento blackfish	Native	Pelagic
22	9	0.0003	bluegill	Introduced	Pelagic
22	9	0.0003	brown bullhead	Introduced	Demersal
23	5	0.0002	unidentified goby	Introduced	Pelagic
24	4	0.0001	Pacific staghorn sculpin	Native	Demersal
25	3	0.0001	black crappie	Introduced	Pelagic
25	3	0.0001	white crappie	Introduced	Pelagic
26	2	0.0001	green sturgeon	Native	Demersal
26	2	0.0001	redear sunfish	Introduced	Pelagic
26	2	0.0001	Sacramento pikeminnow	Native	Pelagic
27	1	0.0000	bigscale logperch	Introduced	Demersal
27	1	0.0000	Mississippi silverside	Introduced	Pelagic
27	1	0.0000	largemouth bass	Introduced	Pelagic

Total:	32,067	95.97% introduced
Species:	33	(12 Native)

Green sturgeon, longfin smelt and delta smelt are the only special status (listed) species that have been encountered over all years of this monitoring program. White sturgeon collection data are included here as surrogate data due to lack of green sturgeon data. Encounters with special status species are further detailed in Table 41. All of these fish were encountered during fish community sampling.

Table 41. Special Status Species List for All Years of Study

Year	DMP	Rank	n	Proportion	Species
2006	Decker Island	17	2	0.0003	green sturgeon
2006	Bradford Island	5	2	0.016	longfin smelt
2006	Decker Island	1	881	0.4772	longfin smelt
2006	Sandy Beach	5	8	0.0412	longfin smelt
2006	Rio Vista	7	4	0.0252	longfin smelt
2006	Decker Island	5	75	0.0406	white sturgeon
2006	Sandy Beach	9	3	0.0155	white sturgeon
2006	Roberts I	8	1	0.0002	white sturgeon
2006	Bradford Island	5	2	0.0016	white sturgeon
2006	Rio Vista	8	3	0.0189	white sturgeon
2007	Scour Pond	6	1	0.0208	longfin smelt
2007	Decker Island	5	1	0.0053	longfin smelt
2007	Scour Pond	6	1	0.0208	delta smelt
2007	Decker Island	3	8	0.0428	delta smelt
2007	S-31	5	2	0.0328	delta smelt
2007	Scour Pond,	5	3	0.0625	white sturgeon
2007	Roberts I	7	2	0.002	white sturgeon
2007	Decker Island	4	2	0.0107	white sturgeon
2007	S-31	6	1	0.0164	white sturgeon
2008	Scour Pond	8	25	0.0033	delta smelt
2008	Decker Island	9	21	0.0027	longfin smelt
2008	Decker Island	16	7	0.0009	white sturgeon
2009	S-31	7	5	0.0111	white sturgeon
2009	McCormack Pit	5	2	0.0074	white sturgeon

Species are listed by year and location of occurrence. Rank is based on relative numbers of each species.

California Delta fish species are well documented by Turner and Kelly (1966), McGinnis (1984), Moyle (2002) and others. Some information gaps exist in details of life history and present range, but for the vast majority of the almost 70 species of fish that now occur in the Delta, presence or absence in the channel bottom habitat is well understood. Given that one of the central and ongoing themes of monitoring programs is the assessment of the efficacy of the methods in answering the research questions (or in this case, the monitoring mandate), the authors have spent considerable effort in describing the fish species that have been encountered in the community and entrainment sampling. An alternate approach is to examine the species that have not been encountered, and for each of these species, to describe to its rarity and the likelihood of its utilization of the channel bottom. Table 42 provides these details for all species not encountered during the lifetime of this project. Five species emerge from this assessment. Steelhead and Chinook salmon have never been encountered by this study, though they are not extirpated from the sampling locations. They are however very rare, and are not often observed using channel bottom habitat (NMFS 2006a,b). A similar scenario exists for hitch and hardhead. Though known to occur in the Delta, No specific information has been found that documents their presence in the channel bottom habitat that the investigators are assessing. Finally, black bullhead have not been encountered, though they are present in the Delta. Specific documentation of their occurrence in the channel bottom habitat is lacking, though it would not be a surprise if they did utilize this habitat. It is possible that the investigators have encountered them and have misidentified them as brown bullhead. All other species known to occur in the Delta are rare and/or unlikely to utilize the channel bottom habitat, thus decreasing the likelihood of encountering them during trawl or entrainment sampling.

Table 42. Delta Fish Species Not Encountered in Trawl or Entrainment Sampling during Lifetime of Study

Species	Origin	Utilizes Channel Bottom Habitat	Rare in the Delta
Sacramento sucker *Catostomus occidentalis*	Native	No	No
steelhead *Oncorhynchus mykiss*	Native	No	Yes
Chinook *salmon Oncorhynchus tshawytscha*	Native	No	Yes
hitch *Lavinia exilicauda*	Native	No	Yes
riffle sculpin *Cottus gulosus*	Native	No	No
hardhead *Mylopharodon conocephalus*	Native	No	Yes
threespine stickleback *Gasterosteus aculeatus*	Native	No	No
topsmelt *Atherinops affinis*	Native	No	No
California roach *Hesperoleucus symmetricus*	Native	No	No
speckled dace *Rhinichthys osculus*	Native	No	No
American eel *Anguila rostrata*	Introduced	Questionable	Yes
black bullhead *Ameiurus melas*	Introduced	Questionable	No
pumpkinseed *Lepomis gibbosus*	Introduced	No	No
green sunfish *Lepomis cyanellus*	Introduced	No	No
smallmouth bass *Micropterus dolemieu*	Introduced	No	No
spotted bass *Micropterus punctulatus*	Introduced	No	No
goldfish *Carrasius auratus*	Introduced	No	No
western mosquitofish *Gambusia affinis*	Introduced	No	No
rainwater killifish *Lucania parva*	Introduced	No	No
fathead minnow *Pimephales promelas*	Introduced	No	No
red shiner *Cyprinella lutrensis*	Introduced	No	No
golden shiner *Notemigonus crysoleucas*	Introduced	No	No

5 Discussion

5.1 Hypotheses

This monitoring program's methodologies were developed to assess the assumptions in the NMFS BO's incidental take statement for listed salmonids and green sturgeon. NMFS assumed that take of these species would be low and required that a monitoring program be developed and conducted to determine level of take. This monitoring program allows the continued development of measures to avoid, minimize, and monitor the impacts of maintenance dredging on listed salmonids, green sturgeon and their habitat.

The hypotheses were developed prior to the initiation of 2006 monitoring as the means to convert the monitoring requirements into heuristically testable assumptions and questions. They are repeated here again for clarity:

- **H^1:** Maintenance dredging of the SSC and SRSC will result in take of listed and other fishes through direct dredge entrainment.
- **H^2:** There is a correlation between presence of fish in the dredging areas and entrainment by the dredge.
- **H^2a:** Differential use of the water column will result in different entrainment levels among fishes present in the project areas; that is, demersal fish that are associated with the channel bottom (benthic and epibenthic species) will be entrained at higher levels than pelagic fish, which are associated with the water column.

H^1: This hypothesis has been tested during all years of this monitoring program. In 2009, H^1 again proved to be partially correct. Fish species were entrained, though none were listed species. In 2009, the overall amount of dredge discharge sampled during entrainment monitoring again increased substantially. At the same time that effort increased, greater species diversity and abundance were observed. The sampled proportion of dredged material increased from 4.4 percent in 2008 to 5.64 percent in 2009. A total of 403 fish from 14 different taxa were observed in 2009, an increase from 11 in 2008, including three natives – lamprey from genus *Lampetra,* Pacific lamprey, and prickly sculpin.

When these numbers are extrapolated, based on percent of total dredge output sampled, the total number of fish entrained from this project across all sites is approximately 7,500 fish. This figure is likely to vary from year to year as both the number and composition of species change. These changes may come about as a result of future unforeseeable environmental perturbations/changes, and as a result of (planned) changes to the monitoring methods, effort, and locations. The low fish entrainment rates observed since the inception of monitoring continue to indicate low overall impacts (via direct effects) from direct entrainment of special status and other Delta species.

To date, no listed species have been observed in entrainment. This does not ensure that listed species have not been entrained over this time period, nor does it guarantee that listed species have not been subjected to take from dredging impacts other than direct entrainment. Fish community monitoring has shown that listed fish species occasionally occur within the dredging reach, although in relatively low numbers. Therefore, these fish are potentially subjected to take in the form of harm or harassment from dredge and monitoring activities.

H^2 and H^2a: These hypotheses are important because a goal of this monitoring program is to provide information to management agencies about both susceptibility to entrainment and presence of listed

and other species utilizing the dredged areas. The data set has gained strength through the use of the mobile entrainment screen by allowing assessment of an order of magnitude more of the dredge's output than was previously possible with the sampling cell method. Increasing the amount of dredge material sampled increases the accuracy of the comparison between the species utilizing the channel bottom and those that are entrained. Fish community assessments conducted in conjunction with entrainment monitoring provides information useful for determining the likelihood of entrainment. Simply stated, rarity in the environment decreases entrainment rates. However, rarity in the environment also confounds our ability to assess likelihood of entrainment based on described behavioral differences among species of interest. The investigators have been faced so far with interpreting potential for incidental take based on data from of non-special status species. NMFS predicted that take of green sturgeon would be higher than listed salmonids based partly on the differential (demersal vs. non-demersal or pelagic) habits of these fish. Thus, H^2 and H^2a provide the framework to assess whether demersal fish actually are entrained at higher rates than pelagic fish.

Classification of fish species as demersal or pelagic was based on general feeding habit and habitat preferences, following Moyle (2002), Wydoski and Whitney (2003), Nobriga et al. (2005), and Brown and May (2006). Other environmental factors that may affect whether a species occupies demersal habitat, such as altered habitat and altered predator-prey relationships, were not considered due to lack of site specific information. These altered environmental and ecological factors may affect migratory, diel, and feeding behavior of Delta fishes with potential for greater overlap of pelagic and demersal behaviors (Feyrer and Healey 2002, 2003; Norbriga et al. 2005).

With the exception of lamprey, entrained fish continue to represent a subset of those species observed in the community samples, though relative abundance of species varies dramatically between entrained species and species utilizing the channel around the dredge. Pelagic fish are comparatively rare in the entrainment samples, but not in the fish community samples.

River lamprey, Pacific lamprey and other lamprey spp. were again observed in entrainment sampling but not in fish community sampling. Ammocoete stage lamprey may be buried in the sediment with only their heads sticking out to filter-feed. This might result in the trawl passing over rather than entrapping them as it moves by. Some of the lampreys encountered have exhibited characteristics of the free swimming macropthalamic juvenile phase of development as well. These fish, though smaller than adults, share some of their characteristics: large, well developed eyes, developing teeth, white/silver side and ventral coloration and bluish to black dorsal coloration. Most importantly, they are strong swimmers and an ideal size and shape to escape through the trawl mesh. Although one specimen was encountered in 2007 using the same-sized trawl net, the mesh size of the trawl net is larger than the hole size of the entrainment screen. This may increase the odds of small lampreys escaping through the trawl that would be retained by the entrainment screen. Thus, for lamprey it can be assumed that fish community monitoring, as currently conducted, may not be capable of establishing a relationship between abundance in the channel and entrainment rates.

In addition, several demersal species were encountered during community sampling that were not observed in entrainment sampling in 2009. These species consisted of white sturgeon, starry flounder, and common carp. This difference between entrainment and fish community sampling may be due to: a low occurrence of these species; low sampling efficiency at the corresponding DMP site; and/or avoidance behavior around the dredge. Together, these fish only made up 0.17 percent of the total fish encountered in trawl sampling (ten individuals). Only one white sturgeon has been observed as entrained since 2006. This fish was observed by one of RISG's crew during 2006 operations at the Bradford Island DMP site. The fish appeared unharmed after traveling through the dredge pipeline and was returned to the river by the fill crew. No sturgeon, starry flounder, or common carp have

been observed during entrainment sampling. During fish community sampling, starry flounder are occasionally encountered, and common carp are rarely encountered. Both of these species are considered demersal, though the flounder probably is more demersal than the carp. Because both species are strong swimmers, they may be able to avoid the dredge and both can grow large enough to afford some protection from entrainment as well.

In 2009, among all of the more commonly encountered entrained fish species, mean length was smaller than that of those same species encountered in fish community sampling. In 2008, a test of significance was performed for channel catfish and white catfish to determine if the size of the fish being entrained was significantly different from the size of fish in trawl sampling (SWCA 2009). An unequal variance t-test was performed and indicated a significant difference in sizes. According to the data, smaller channel catfish and white catfish were more susceptible to entrainment than larger fish of the same species (SWCA 2009). This relationship is also likely to be stronger than reported, as the larger catfish are more able to avoid the trawl net and thus are not represented in the fish community data. Reports from fisherman and observations of sea lion predation have indicated that larger catfish are present in the areas sampled.

In order to fully test H^2a, more knowledge of the fish inhabiting the dredging sites is needed. This knowledge will be provided by future sampling efforts from this monitoring program and by other studies of Delta fish. The IEP sponsors several long-term status and trends studies, such as the Estuarine and Marine Fish Abundance and Distribution Survey and the Fall Midwater Trawl Survey. There are also other recent studies such as those initiated by the Pelagic Organism Decline (POD) work team. These and other studies will continue to be used to assess the vulnerability of Delta fishes to dredge entrainment. Comparing data across studies will always be problematic since there are substantial differences in sampling timing, methods, and locations. Substantial data gaps still exist in many critical areas of the life history and population biology of listed and other Delta fish species. The lack of basic biological information for some Delta species is compounded by the rapid changes (declines) that some populations are currently experiencing (Bennett 2005; IEP 2008).

Several other factors add additional complications to the hypothesis testing and analysis of vulnerability to entrainment. Among the 33 fish species encountered in all years, only 15 can be readily defined as demersal rather than pelagic. These species include: sculpin, goby, catfish, sturgeon, flounder, lamprey, and carp. The trawl net samples from the channel bottom up into the water column while it is open during the tow. The exact height of the cork-line above the bottom has not been determined, but may approach one-third of the total water column height at times and so reach into the zone that pelagic fish may be utilizing. In comparison, the dredge cutter head stays buried in or very close to the channel bottom while entrainment sampling is conducted. The pelagic species may utilize the entire water column in some cases and others may engage in diurnal migrations to the surface or the bottom. Within species, behavioral differences based on life stage also hamper generalized discussion of water column usage. Additionally, the described behaviors for individual species are often based on observations from all of the inland California water bodies in which they occur (Moyle 2002), rather than at specific Delta locations. There is some knowledge of which specific areas of the Delta are used by individual species and of how seasonal fluctuations impact species presence in the shipping channel. Yet, many gaps remain for specific Delta locations and groups of fishes (Moyle 2002; Feyrer and Healey 2002, 2003; Bennett 2005; Nobriga et al. 2005; Brown and May 2006).

5.2 Sampling Design Efficiency

The magnitude of increase in percent of total volume sampled by entrainment sampling compared to prior years may be attributed to the exclusive use of the entrainment screen in 2009 at all DMP sites. With continued use of the pneumatic-assisted Y-valve (installed in 2008) and refinement of its operation during initial uses in 2009, the dredge's pumping rate could usually remain unaltered while the output was diverted from the DMP site to the monitoring screen. The efficiency of entrainment monitoring has thus improved over prior years; when there was more need to idle the dredge to divert material for entrainment monitoring.

The entrainment sampling goal of 5 percent of dredge output was not achieved at all sites, though an average 5.64 percent of the overall output was sampled. Dredge slurry with abundant organic debris created, at times, a short-term build-up of mixed sediment and debris on the screen's surface. Occasionally, the flow of organic material caused the discharge to over-top the sides and/or run off the dump-end of the screen. Also in 2009, there were several occurrences of rapid overwhelming of the screen due to excessive volume of clams and clam shells, clay balls, and at times gravel and rock. These incidences of over-topping or overwhelming were infrequent and short-lived, usually lasting between 15 to 60 seconds in the case of the over-topping. Because the discharge stream could not be adequately screened or observed for potential organisms during these occurrences, screen operators noted the duration of the event and reduced the total time for that entrainment sample accordingly. During incidences of overwhelming, the dredge material was diverted and sampling discontinued until the screen could be cleared and sampling resumed.

Improvements to the entrainment screen slated for 2010 should improve the predictive ability of the sampling. More robust entrainment estimates will help identify trends and further test the study's hypotheses. Improvements slated for the sampling screen and changes related to these improvements are discussed in the adaptive management and recommendations sections.

A maximum of five daily trawls were performed during each day that fish community sampling was conducted. No additional trawls were conducted at any sites. Based on an assessment of the species that have not been encountered during fish community surveys, we believe that five trawls accurately sample the community structure in the shipping channel, recognizing the possibility that sampling on a more random basis, or across a broader time window may help understand the changes to fish community that are continually occurring. Increases to the level of effort would increase our understanding of the presence of the rare species, as well as refine our understanding of relative abundance and other population parameters of fishes that utilize the shipping channels. However, any increase in fish community sampling effort would increase sampling costs as well as increase mortality among sampled fish. Any increases to sampling frequency, tow duration, or change of sampling location must first be approved by CESA administrator Kelly Souza (CDFG).

Statistical tests conducted in 2008 indicated that demersal, and particularly smaller fishes, were more vulnerable to entrainment than the larger and non-demersal fishes present in the navigation channels during active dredging. These results helped confirm H^2a, in that fish associated with the channel bottom (demersal) were entrained at higher levels than species associated with the water column (pelagic). The percentage of demersal fish entrained in 2009 was higher than 2008, again lending strength to this hypothesis. An additional but related hypothesis is that smaller and/or juvenile fishes are likely to be entrained at greater rates than larger and/or adult fishes. This related hypothesis was first confirmed in 2008 for channel catfish and white catfish by statistical tests of these data sets (at least for locations where sample sizes were robust enough). Smaller fishes were shown to be significantly more vulnerable to entrainment than larger fishes. Though the relationship

between juvenile and adult life history stages for each species encountered was not examined due to low numbers of individuals entrained, the results implied that juveniles were more vulnerable to dredge entrainment than adult fish. Results of these statistical tests underscored the continued need to collect length data for all fishes encountered in entrainment and also demonstrated that the current proportion of fishes measured for length from trawl sampling appeared adequate to test the significance of sampling relationships based on fish size.

These analyses were not repeated in 2009 for two primary reasons: 1) Comparatively lower numbers of channel and white catfish decreased the ability of investigators to repeat the analyses. 2) Potential bias in size of fish selected for sub-samples used in 2008 may have resulted in over-representation of larger fish within the length frequency data set. The high catch of shimofuri goby for the first time in 2009 corroborates the idea that smaller fishes are subject to higher entrainment rates than larger fish. Nonetheless, investigators feel that repetition of size assessment analyses, if requested, will need to be accompanied by changes in the sub-sampling protocol to ensure all size classes are equally represented.

5.3 Overview

The fish species encountered during 2009 and previous year's fish community and entrainment monitoring are a subset of those described by Moyle (2002) for the Central Valley subprovince. The majority of the species described by Moyle as being present in the Delta but have not been encountered while monitoring are species with the following traits: rare species; species not known to inhabit the channel bottoms, such as largemouth bass, red shiner, and western mosquitofish; or species not known to occur in the areas being dredged, such as Sacramento sucker or topsmelt. Pelagic fish species with relatively high abundances in the Delta (i.e., striped bass and threadfin shad) have been commonly encountered during fish community monitoring but are rarely observed in the entrainment samples. Although 14 different native species including river lamprey and other possible but unconfirmed *Lampetra spp.* have been encountered in the community sampling, the only native fish so far observed in the entrainment samples have been river lamprey and possibly other *Lampetra spp.*, Pacific lamprey, Pacific staghorn sculpin and prickly sculpin.

Recent precipitous population declines in several species of Delta fish such as delta smelt, longfin smelt, threadfin shad, striped bass (CDFG 2009a,b,c), listed salmonids, and green sturgeon (NMFS 2006a,b) document the need for ongoing assessments of Delta fish populations. Since the 2006 inception of fish community monitoring for this study, several findings have come to light that either corroborate similar observations or, instead, contrast with those of others. These trends, observations, and monitoring outcomes are listed below.

- The introduced shokihaze goby was not previously described as inhabiting the upper Delta by Moyle (2002), but this species ranked seventh in overall abundance in 2008 and twelfth overall during 2006 monitoring. In 2009, it was the ninth most common fish. The introduced shimofuri goby was eighth most common fish in 2008 and advanced to fifth most common in 2009.
- The white sturgeon to green sturgeon ratio was approximately 40:1 in 2006, much higher than the 5:1 ratio described by Moyle (2002). No green sturgeon have been encountered since 2006 and white sturgeon have been less common as well. Encounters with white sturgeon have occurred in both channels near the confluence of the two river systems, at Roberts I in the SSC and at S-31 in the SRSC (Man-made Channel). This may provide useful surrogate data for the presence of green sturgeon in these locations.

The ranking of longfin smelt from lower SRSC locations was very high in 2006 (895 were encountered, ranked first among native species and fourth among all species), as opposed to other locations in the Delta and SF Bay estuary where steep declines had been observed. In 2007, only two longfin smelt were encountered, mirroring the low catch of the Fall Midwater Trawl Survey (CDFG 2008d). The 2006 sampling appears to have coincided with the reported center of abundance of spawning adults near Rio Vista (Moyle 2002). In 2008, 21 longfin smelt were encountered, all from the SRSC in late August and early September. The (CDFG) summer tow net survey (CDFG 2009b) documented presence of longfin smelt primarily from lower SF Bay sites between June and mid-August, and as well as up to the lower end of Sherman Island during the last week in July. The Bay Study (CDFG 2009c) conducted both mid-water and otter (bottom) trawl surveys throughout the SF Bay and in limited Delta locations over each month of the year. There are three months that the Bay Study overlaps with this monitoring study. The Bay Study's mid-water trawl survey found areas of higher longfin smelt abundance occurred at, or downstream of, Chipps Island in October and November, with presence at Decker Island in October. In contrast, the trawl surveys of this project found longfin smelt distributed downstream of Sherman Lake until November with presence near Decker Island in December.

- No longfin smelt were encountered in 2009. The Bay Study data showed that longfin smelt were present downstream of dredging locations during the 2009 season. Some longfin smelt did move into the western Delta area that corresponds with some dredging locations in both channels in January of 2010, but had moved downstream again in February. This data set is available at: http://www.dfg.ca.gov/delta/projects.asp?ProjectID=BAYSTUDY
- In 2007 the PODS progress report (IEP 2008) described the highest (worst) bloom on record of the algae (*Microcystis aeruginosa)* centered near Antioch. Significant efforts from the fish monitoring for maintenance dredging also took place in this region during fall 2007, and the CPUEs were at least an order of magnitude lower than previously measured by this study at any other location. The 2008 CPUE at the Antioch dredge reach was higher than that of 2007 and similar to other lower river sites monitored this year. In 2009, very little monitoring was conducted in these locations, however CPUE's were again lowest among all sites.
- The 2008 CDFG Fall Midwater Trawl Survey collected 12 delta smelt in November and 4 in December (CDFG 2009a). The 2008 Fall Midwater Trawl delta smelt index was the lowest recorded index since inception of the study in 1967. The Bay Study did not report collection of any delta smelt throughout 2008 sampling either in their monthly midwater trawl or in otter trawl surveys (CDFG 2009c). The summer tow net survey, which sampled earlier in the summer, found relatively higher abundances at their survey stations in the SRSC near Decker Island and occasionally in the SSC downstream of Bradford Island (CDFG 2009b).
- No delta smelt were encountered in 2009. In 2008, 25 delta smelt were encountered during community sampling; 22 of the specimens were caught in the SRSC between August and early September. Of these 25 specimens, 21 were caught in the vicinity of Decker Island, one was from the Man-made Channel early in August, and the remaining three individuals were encountered near Antioch during a single night tow on September 21. Delta smelt were not encountered during 2006. However, in 2007, 11 delta smelt were encountered during November and December trawls. Of these 11 individuals, nine were from locations near the confluence of the San Joaquin and Sacramento rivers, and two were from the SRSC Man-made Channel near the Port of Sacramento. In comparison, the delta smelt index produced from CDFG's Fall Midwater trawl survey is down again in 2009 and has

once reached a new low of 17 individual fish. This data set is available at: http://www.dfg.ca.gov/delta/projects.asp?ProjectID=FMWT

- The studies referenced above indicate that delta smelt and longfin smelt populations remain very depressed and are typically found further downstream in the SF Bay-Delta system. However, documented presence in the lower river miles of both channels and areas of the Man-made Channel indicates the potential their continued presence during maintenance dredging operations.
- The absence of listed salmonid encounters is not surprising given their very low populations, and the timing and location of maintenance dredging during 2006-2009.
- The novel (for 2009) assessment of species present in the Delta but not encountered during monitoring provided additional confidence in the appropriateness of the monitoring methods.

5.4 Bird Activity Monitoring

As a monitoring requirement for this project, observation of bird activity in the dredge area and DMP site must be documented. Piscivorous bird activity in the dredge area is an indication of the presence of near surface fish or potentially fish being disturbed or injured by dredging activities. Fish or invertebrates entering the DMP site via dredge operations are thought to attract predaceous birds. Sea lion presence has also been documented, since their presence in large freshwater rivers can indicate presence of large fish not successfully sampled by the trawl, such as salmonids. This is particularly true if feeding behavior can be observed.

Bird activity in the DMP site may also be a result of fish or other invertebrates being entrained by the dredge. However, it may also be an attraction response to sources of flowing water, or, as was observed in 2008, predation of birds on newly displaced terrestrial prey previously occupying the DMP site, such as rodents or insects. In 2009 the largest congregations of piscivorous gulls, egrets, herons, and crows were again observed on newly tilled terrestrial areas over ½ mile from the pipeline's discharge into the DMP site. A few egrets and an occasional heron were observed near the entrainment screen for sampling at Roberts 1 for the Upper Roberts, Rough and Ready, and Upper Turning Basin dredge reaches. Trawl sampling CPUE values for these same reaches were also relatively high.

Piscivorous bird activity increased in dredge reaches as the dredge season progressed. Few of these birds were observed until reaching the Upper Roberts Island dredge reach in late September. Piscivorous gulls, terns, cormorants, and an occasional heron, were more frequently observed and numerous in the Rough and Ready Island and Upper Turning Basin dredge reaches.

Sea lions were present during most of the monitoring at the Rough and Ready Island dredge reach. Up to three sea lions were observed hauled out under Berth B on Rough and Ready Island. While trawling in the upstream end of Rough and Ready Island a large head of a carp was recovered, apparently the result of sea lion predation.

5.5 Adaptive Management Strategies

NMFS requires that adaptive management strategies be employed and discussed as part of this monitoring program. This has been done since the project's inception with focus on testing and

improving the project methodologies through constant evaluation while monitoring is underway, followed by careful analysis of the annual monitoring results that includes comparisons with other available data. Adaptive management in past years specifically focused on improvements to the entrainment monitoring methods and responding to presence of delta smelt and longfin smelt in the fish community samples.

5.5.1 Entrainment Monitoring

Modifications to monitoring methods for the 2009 monitoring incorporated the following recommendations from the 2008 monitoring report (SWCA 2009):

- The mobile entrainment device was used successfully at all DMP sites, dispensing completely with the entrainment cell methodology and allowing a significant increase in sampled dredge output with no increase in sampling effort.
- Two of the cross bars on the screen were removed based on analysis of structural integrity impacts of removal that were deemed minimal versus vastly improved ease in material clearance off the screen.

5.5.2 Fish Community Monitoring

The following modifications to fish community monitoring methods were incorporated in 2009:

- Upgrades were made to the sampling vessel's computers and software, allowing improved navigation in the shipping channels and improved data acquisition and manipulation.
- A water quality meter capable of high precision turbidity measurements was utilized. While providing synoptic measurements of turbidity at both surface and bottom this meter streamlined the water quality sampling through elimination of Secchi depth measurements and use of an additional turbidity meter.

5.6 Recommendations

5.6.1 Entrainment Monitoring

The following steps should be taken to improve the effectiveness of entrainment monitoring. Specific recommendations for entrainment sampling screen improvements have been provided previously and are provided here again for clarity and continuity. When implemented, these improvements should allow an assessment of an increased percentage of the dredge output without increasing sampling effort or cost. They will also provide significantly greater ease of use and allow much needed increases in nighttime sampling:

- The first section of screen was removed and replaced with steel plate early during 2008 sampling due to washout of the axles under the screen by slurry dropping down from this forward section of the device. This decreased the effective area of the screen by approximately 20 percent. Frequent entrainment screen over-loading in some locations during 2009 sampling demonstrated the need to return to the originally engineered screen capacity. This section of plate should be removed and replaced with the current screen type. Additional modifications to channel the dredge slurry away from the trailer axels will also be required.

- Install hinged steel plate lids on the forward sections of the screen to eliminate splash-over during periods of high discharge. These lids need to be hinged so that they can be opened during periods of low discharge and for cleaning the organic debris that accumulates on the screen- a daily maintenance chore.
- Install a new valve to replace the y-valve currently in use. While this valve does work, is sometimes problematic and does not allow rapid diversion of the slurry to the main DMP. This became a serious problem and limited sampling effort at times during 2009 due to frequent screen inundation at some locations. The new valve will be controllable by the biologists working on the device and will allow seamless switching of the slurry flow between the screen and the main DMP without requiring attention or activity by the dredge or DMP site (fill) crew.
- Install a second lifting arm for the tailgate/final screen section on the other side of the tailgate section to allow for both monitoring staff to lift this screen section safely and efficiently when under a load.
- Re-work the dump gate at the end of the screen allowing it to be raised and locked into its fully closed position again and devise and install a device allowing incremental locking positions for the dump-gate to be easily locked in more than one raised position.
- Improve the lighting system on the screen. 2009 nighttime sampling again demonstrated the inadequacy of the current lights. The light plant provided by RISG while very bright, cannot be placed directly over the top of the screen. The result is substantial areas of shadow in the corners of the screen. These shadowed areas do not allow confidence that all entrained fish are documented.
- Provide a high pressure water system that will allow use of a variety of hoses and sprayers for cleaning and clearing the accumulated material off of the screen. This system need to be adjustable due to the variety and volume of material.
- Conduct mortality studies on entrained fish such as holding them in a tank full of recirculating river water for 24 hours prior to release to provide greater accuracy to the estimation of mortality to entrained fish. This would provide information cogent to the evaluation of use of the entrainment screen as a conservation tool via salvage and return of entrained fish. This may prove important for conservation of lamprey as well as other entrained species.
- Develop specific sampling metrics and triggers for management change through coordination with USACE and NMFS prior to 2010 monitoring to determine the appropriate level of entrainment sampling effort required to meet agency needs.

5.6.2 Fish Community Monitoring

The following recommendations are made in order to maximize sampling efficiency, gather better information about the sampling target area, minimize impacts to ESA-listed and sensitive species, and increase the potential for future statistically valid comparisons of fish community monitoring data:

- Frequent changes of water and aeration of holding bins will be used when sensitive and ESA-listed species are encountered.
- In future collections of lamprey, particularly of the genus *Lampetra*, specimens will be carefully preserved for morphological examination, with a portion of, or all, body tissue

collected for submittal to USFWS for mitochondrial DNA analysis to improve taxonomy and field identification characteristics.

- The individual specimen label system will continued to be used and further refined to meet project needs. The project database will continue to be modified for ease of real-time data collection, including specimen label identification information. These steps will increase the efficiency of future data acquisition and management.
- A dissecting microscope has been purchased and will be present on the research vessel to allow clear distinction between introduced wakasagi and listed delta smelt in the field. During 2009, presence of wakasagi and lack of confidence in the field differentiation between the two species resulted in some curtailment of fish community monitoring at S-31 in the Man-made Channel of the SRSC. The increased ability to differentiate these species in the field should allow us to better manage sampling effort. This microscope will also be used to differentiate lamprey species (*Entosphenus vs. Lampetra)* and other difficult to identify species.

5.7 Conclusions

Key conclusions of the 2009 monitoring program were:

- Fisheries monitoring requirements stipulated by the NMFS BOs (NMFS 2006a,b) for the SSC and SRSC were successfully met during the 2009 dredge season.
- The fish community in the Delta continues to be dominated by non-native fish and the fish community and entrainment monitoring data continues to exhibit significant inter-annual variation.
- Entrainment sampling efficiency and the quantitative capability of entrainment monitoring was increased substantially by use of the mobile entrainment screen.
- Take of listed and other species during future dredging events may be predicted by presence of these species in the fish community samples.
- Lamprey species are particularly susceptible to dredge entrainment and should be a focus of management agency attention due to their sensitive status. Though not currently listed, likelihood of future listing is high.

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Appendix A. Special Status Species Life History Information

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Designated Critical Habitat
The designated critical habitat of Sacramento River winter-run Chinook salmon occurs at the origin of the SRSC adjacent to Kimball, Browns, and Winter Islands near RM 4 of the San Joaquin River and is inclusive of the aquatic habitat below the ordinary high water mark surrounding these islands. The winter-run Chinook ESU has designated critical habitat in the SRSC beginning at Chipps Island, the western margin of the Sacramento-San Joaquin Delta. Designated critical habitat for Central Valley spring-run Chinook salmon borders the northern edge of the San Joaquin River from the confluence of the Mokelumne River west to the boundaries of Suisun Bay and the Delta hydrologic sub units at approximately RM 4 of the San Joaquin River. This includes the waters of Three Mile Slough and New York Slough. Critical habitat for CV Chinook salmon includes the Sacramento River from Keswick Dam in Shasta County through the San Francisco Bay. Individuals of both Chinook salmon Evolutionarily Significant Units (ESUs) can occupy waters within the SSC and SRSC action area. Designated critical habitat for the Central Valley steelhead ESU occurs along the entire length of the SSC and SRSC below the ordinary high water mark. The recently listed Southern Distinct Population Segment (DPS) of green sturgeon's critical habitat Final Rule was published in the Federal Register (74 FR 52300) on October 9, 2009 and includes the entire Sacramento and San Joaquin Delta.

Recent state and federal petitions have requested that delta smelt be up-listed from threatened to endangered under CESA and ESA. California up-listed delta smelt to endangered status on March 4, 2009 (Final Statement issued on November 10, 2009). USFWS had not yet commented on the petition to up-list delta smelt from threatened to endangered status at the time of this writing, though they did announce the initiation of a five-year status review on March 24, 2009.

The California Fish and Game Commission enacted protections for longfin smelt in 2008, which was a CESA candidate species at that time. Incidental take of longfin smelt while conducting fish community monitoring was restricted to 150 juveniles and 150 adults for the entire year. Longfin smelt were accepted as threatened under CESA by the Commission on March 4, 2009. Federal protection of the longfin smelt was recently denied by the USFWS following review of the petition to list the longfin smelt under the ESA (April 9, 2009). The USFWS found that the San Francisco Bay-Delta longfin smelt did not qualify as a distinct population segment (DPS). The USFWS has initiated (April9, 2009) a status review for the entire longfin smelt population from Alaska to California. Other key species of interest that are at least seasonally present in the action area include: Sacramento splittail, and Pacific and river lamprey.

Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*)
ESA status: Endangered, critical habitat designated
California status: Endangered
Sources: CalFed 2005; Fry 1961, 1973; Hallock and Fry 1967; Hallock et al. 1970; Miller and Lea 1972; Moyle 1976; Sasaki 1966; Wang 1986

Use of project area waters by this ESU of Chinook salmon is primarily for adult spawning migrations, and juvenile rearing and outmigrations. Winter-run Chinook adults migrate upstream from December to July with spawning in accessible upper reaches of the Sacramento River basin occurring from April through July. Chinook alevins have been collected from Suisun Bay in January and February. Larger parrjuveniles have been found from April to June. Juvenile life stages are commonly found inshore, in

shallow water and throughout estuarine habitat. Some Chinook salmon delay their downstream migration until the early smolt stage. Juvenile outmigration peaks from May to June. Juvenile Chinook salmon feed primarily on various aquatic and terrestrial insects, crustaceans, chironomid larvae and pupae, and caddisflies when they are in fresh water. When found in saline waters, the Chinook smolt diet changes to mainly Neomysis spp., Gammarus spp., and Crangon spp. Juvenile salmon are prey for many animals, including birds and other fishes.

Central Valley spring-run Chinook salmon (*O. tshawytscha*)
ESA status: Threatened, critical habitat designated
California status: Threatened
Sources: CalFed 2005; Fry 1961, 1973; Hallock and Fry 1967; Hallock et al. 1970; Miller and Lea 1972; Moyle 1976; Sasaki 1966; Skinner 1972; Wang 1986

Uses of the project areas by spring-run Chinook salmon are of the same types as described for the winter-run ESU. Spawning migration timing differs with spring-run Chinook moving upstream from April to October, and spawning from August through October. Juvenile usage in the areas of concern is similar to that described for winter-run Chinook.

Central Valley steelhead (*O. mykiss*)
ESA Status: Threatened, critical habitat designated.
Sources: CalFed 2005; Hallock et al. 1970; Hallock and Fry 1967; Moyle 1976; Wang 1986

After an ocean residence of 2–3 years, anadromous adults of the Central Valley steelhead ESU make their upstream migrations beginning in July (peaking in September and October), and spawn from December through April. Steelhead primarily use the project areas as a migration corridor, with some juvenile rearing overlapping with their smoltification and outmigrations. Spawning and incubation, along with the majority of rearing, occurs farther upstream than for Chinook salmon. Juveniles feed on diverse aquatic and terrestrial insects and other small invertebrates, primarily occupying the water column and near surface when over deeper waters. Though juvenile Central Valley steelhead outmigrate to the ocean from December through August, most are found migrating through the project areas in spring.

Delta smelt (*Hypomesus transpacificus*)
ESA status: Threatened, critical habitat designated
California status: Endangered
Sources: Bennett 2005; CDFG 2009, CalFed 2005; Ganssle 1966; Herald 1961; McAllister 1963; Messersmith 1966; Moyle 1976, 2002; Moyle et al.1995; Radtke 1966; Wang 1986

The endemic delta smelt is a euryhaline fish that ranges from the lower reaches of the Sacramento and San Joaquin Rivers, through the Delta, and into Suisun Bay. They have been found in the SRSC and SSC in low abundance. The abundance of this fish is closely associated with salinities between 0 and 7 practical salinity units (psu), with an upper tolerance of 19 psu and a significant preference centered near or upstream of the 2 psu zone. They are not present in waters over 25°C, and are rarely found in water temperatures above 22°C. Delta smelt spawn in dead-end sloughs, near-inshore areas of the Delta, and shallow fresh water channels of the Delta and Suisun Bay. In the fall, prior to spawning, delta smelt congregate in upper Suisun Bay and the lower reaches of the Delta. The spawning period is estimated to be from February to June. Eggs are demersal and adhesive. Delta smelt may prefer spawning over vegetation, if present, but often deposit their eggs over submerged tree branches and stems, or in open water over sandy and rocky substrate, and may even use the

shallower areas of Delta levees. Newly hatched larvae float near the surface of the water column in both inshore and channel areas. Larval movements are variable and follow tides and discharge. Data from trawl and trap net catches show that larger juveniles and adults are abundant during spring and summer in Suisun Bay and the Delta. Seasonal migrations occur within a short section of the upper estuary. Juvenile smelt move downstream to San Pablo Bay and Carquinez Strait before turning back to Suisun Bay or upstream sloughs for spawning. During average and high outflow years, delta smelt congregate from upper Suisun Bay to the Sacramento River near Decker Island. During low outflow and drought years their pre-spawning congregations are centered in the channel of the Sacramento River and are rarely further downstream in Suisun Bay. Juvenile delta smelt primarily eat planktonic crustaceans, small insect larvae, and mysid shrimp. Delta smelt mature quickly, with most adults dying after spawning their first year. The few adults that survive to their second year have vastly higher fecundity. Delta smelt was listed as threatened under the ESA on March 5, 1993 (FR 58, 12854). Final critical habitat designation for delta smelt (Federal Register 59, 65256; December 19, 1994) includes the Stockton and Sacramento DWSCs. On March 24, 2009, the USFWS initiated a five-year status review of delta smelt. The state status of delta smelt under CESA was recently elevated from threatened to endangered (March 4, 2009).

Green sturgeon (*Acipenser medirostrus*)
ESA status: Threatened (July 6, 2006), Southern DPS, Critical Habitat designated on October 9, 2009
California Status: none
Sources: Adams et al. 2002; CDFG 2009; CalFed 2005; Fry 1973; Gisbert (2006); Klimley 2007; NOAA 2009; Radtke 1966; Van Eenenaam (2005); Wang 1986.

The little studied green sturgeon occurs within the project area the Sacramento and San Joaquin Rivers and the Delta. The Southern DPS consists of fish in the San Francisco Bay and Delta that spawn in the Sacramento River basin. A number of presumed spawning populations of green sturgeon have been lost since the 1960s and 1970s — from the Eel River, South Fork Trinity River, and San Joaquin River. Green sturgeon inhabit near shore oceanic waters, bays, and estuaries. Early life-history stages(<4 years old) reside in fresh water, with adults returning to freshwater to spawn when they are more than 15 years of age and more than 130 cm in size. Spawning occurs in spring and summer in reported locations of the upper Sacramento River and tributaries to the Sacramento River such as the Feather, Yuba, and American Rivers. Recent studies have improved the knowledge of the biology and ecology of this fish, though substantial gaps still exist regarding its habits in the project area and elsewhere in its range. Juveniles of two apparent size groups (fork length range of 20–58 cm) have been collected in the Sacramento and San Joaquin Rivers and Suisun Bay. The diet of juvenile sturgeon consists mostly of amphipods and mysid shrimps in the Delta. Additional information on green sturgeon is available at NMFS web site (http://www.nmfs.noaa.gov/pr/species/fish/greensturgeon.htm).

Estuarine Composite Species with Essential Fish Habitat

The following fishes, though not listed under ESA, are included here as they are part of the estuarine composite species with essential fish habitat (EFH) protections under the Magnuson- Stevens Fishery Conservation and Management Act (MSA); and are the most likely of their composite to utilize the portions of the Delta within the project area. These species were included in the EFH assessment for the Stockton SSC Maintenance Dredging and Levee Stabilization Project (NMFS 2006a).

Starry flounder (*Platyichthys stellatus*)
ESA status: None,
MSA species, estuarine composite EFH

Sources: CalFed 2005; Fry 1973; PFMC 1998; McCain et al. 2005; NMFS 2006; Radtke 1966; Wang 1986; Wydoski and Whitney 2005

The starry flounder is a marine flatfish with both eyes on the same side of its head. Starry flounder are white on the ventral side and have conspicuous ventral black and orange bands on their dorsal and anal fins. They have a tolerance for a variety of salinities and are found along the coast and in estuaries and the lower portions of rivers. Juveniles and adults are demersal and prefer sandy to muddy substrates. Starry flounder have been recorded at a depth of 900 feet. Studies have shown starry flounder can move a considerable distance between estuarine and ocean habitats (440 nautical miles). Juveniles and sub-adult life stages extend the upstream freshwater use to the Bay and lower reaches of the Delta. Adults may reach a length of 3 feet and a weight of 20 pounds. Females grow faster than males and are heavier at a given length. Males mature at 2 years and females at 3 years. They spawn in winter with water temperatures averaging 11°C (51.8°F). Eggs and larvae are epipelagic and occur near the surface over water that ranges from 20 to 70 m (65 to 30 feet) deep. They feed on copepods, amphipods and annelid worms and, as adults, include crabs, mollusks, and echinoderms. Feeding slows in winter as temperatures drop. Starry flounder provide both recreational and commercial fisheries. One juvenile flounder was collected near the Port of Stockton in 2009 and this may represent an extension of its known range in the Delta.

English sole (*Pleuronectes vetulus*)
ESA status: None
MSA species, estuarine composite EFH
Sources: McCain et al. 2005; NMFS 2006; PFMC 1998; Wang 1986; Wydoski and Whitney 2005

English sole are an inner shelf-mesobenthal flatfish species that ranges from Mexico to Alaska and is abundant in the San Francisco Bay-Estuary system. Adults generally spawn during late fall to early spring in inshore waters over soft mud bottoms to 70 m (230 feet). Epipelagic larvae are carried by wind and near-surface tidal currents into bays and estuaries where they metamorphose to demersal juveniles. Juveniles rear in the inshore areas and in the bays and estuaries moving offshore as they age. Juvenile English sole seek food and shelter in shallow near-shore, inter-tidal, and estuarine waters. Prey items include small crustaceans (e.g., copepods and amphipods) and polychaete worms. English sole provide commercial and recreational fisheries. Bottom-oriented juveniles may occur in the lower portion of the SSC and SRSC. However, none have been encountered during monitoring of dredge operations.

Species of Special Concern

The following fishes, though not listed under ESA, nor protected under the MSA, have been listed or petitioned for listing in the recent past, and are presently considered species of special concern by the State of California. Information on these species is being sought by NMFS and USFWS. This background information is provided here because these species were encountered during fish community and or entrainment monitoring.

Lamprey, Pacific and river (*Lampetra* (*Entosphenus*) *tridentata* and *L. ayresii*, respectively)
ESA status: Not warranted (decision 2005)
California Status: Watch list – river lamprey
Sources: Kostow 2002; Moyle 2002; Wydoski and Whitney 2005

Anadromous Pacific and river lamprey co-occur in SSC and SRSC. Little is known about population trends for the river lamprey at the southern end of its distribution. Most records of this species in

California are from the Feather River and the lower Sacramento-San Joaquin River system. Adult lamprey of both species migrate upstream in early spring and spawn during late spring and early summer in gravel substrates upstream of the Delta and lower Sacramento-San Joaquin river system. Adult Pacific lamprey generally hibernate for a year in freshwater after their initial spawning migration. During this time they hide in substrates near their spawning area and do not feed prior to spawning the following year. The filter-feeding ammocoetes develop for years burrowed into soft substrates in freshwater. River lamprey begin their transformation from ammocoete to adult form at about 120 mm total length, Pacific lamprey at approximately 140 to 160 mm. Metamorphosis lasts from 9 to 10 months in river lamprey, the longest known in this family of fishes. During this time, both lamprey species congregate close to the saltwater-freshwater interface in estuaries. Macropthalmia have large, well-developed eyes, and their body coloration is silvery on the lateral and ventral aspects with blue to dark gray coloration along the dorsal aspect. During this stage, mouth dentition forms adult teeth used to prey or parasitize other fishes. It is noted in Pacific lamprey that full development of the middle tooth of the supraoral lamina develops during the transforming adult stage, complicating field identification at the macropthalmic stage. Following complete transformation, macropthalmia migrate downstream to the ocean, likely in the winter and spring, when outflow is high. River lamprey may spend their entire life history in freshwater and are more parasitic in freshwater than Pacific lamprey. Adult river lamprey spend less time in the ocean, migrating back to freshwater in the fall and winter. Adult Pacific lamprey generally migrate from stream to spawning areas in winter and spring.

Sacramento splittail (*Pogonichthys macrolepidotus*)
ESA status: species of concern (2003), formerly listed as threatened (1999)
Sources: Moyle 2002; USFWS 2003; Wang 1986

The Sacramento splittail is found only in California's Sacramento-San Joaquin Delta, streams of the Central Valley, and the Napa and Petaluma rivers. This native minnow (family Cyprinidae) received protection as a threatened species in February 1999 (64 FR 5963). The USFWS delisted the splittail on September 22, 2003 (68 FR 55140). The relatively long-lived splittail (up to 9 years) can grow up to 400 mm long. The upper part of the tail is enlarged and appears to be split, hence its common name. Historically, the splittail occurred in the Sacramento River as far north as Redding, as far south in the San Joaquin River as Friant Dam near Fresno, and as far west as the Petaluma River. They are adapted to living in estuarine systems and are tolerant of salinities from 10 to 18 ppt. Young-of-year and yearling splittail are most abundant in shallow water and are able to swim in strong current. Adults exhibit slow upstream movement during winter and spring to forage and spawn in flooded areas. Their small, subterminal mouth with barbels and pharyngeal teeth, along with the large upper tail lobe, reflect their preference for feeding on bottom invertebrates in low to moderate current strength. Splittail reach adulthood at approximately 170 mm in their second year. Splittail populations have declined as dams and diversions have prevented fish from access to upstream areas of large rivers. Reclamation and modification of flood basins also have reduced the species' spawning grounds.

Longfin smelt (*Spirinchus thaleichthys*)
ESA status: none, Bay-Delta DPS denied petitioned for listing
California status: State Threatened
Sources: CDFG 2009, 2007, 2000; Moyle 2002; Moyle et al. 1995

Longfin smelt are a euryhaline and anadromous fish that was historically one of the most abundant fish in the San Francisco estuary and the Delta, but have since declined precipitously throughout its range. Longfin smelt can be distinguished from other California smelts by their long pectoral fins,

which reach or nearly reach the base of their pelvic fins. These fish reach a maximum size of about 150 mm (total length) and mature near the end of their second year. As they mature in the fall, adults found throughout San Francisco Bay migrate to brackish or freshwater in Suisun Bay, Montezuma Slough, and the lower reaches of the Sacramento and San Joaquin Rivers. They congregate for spawning at the upper end of Suisun Bay and in the lower and middle Delta, especially in the Sacramento River channel and adjacent sloughs. In April and May, juveniles are believed to migrate downstream to San Pablo Bay; juvenile longfin smelt are collected throughout the Bay during the late spring, summer, and fall and occasionally venture offshore as far as the Gulf of the Farallones. Juveniles tend to inhabit the middle and lower portions of the water column. Their decline is likely due to multiple factors including: reduction in outflows, entrainment losses to water diversions, climactic variation, toxic substances, predation and introduced species.

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Appendix B. Water Quality Data

Surface Water Quality Readings

Survey_ID	Dredge Reach	Date (m/d/year)	Time (hh:mm)	Depth (ft)	Temp (*C)	DO (ppm)	DO (%)	pH	ORP (mV)	Cond (uS)	Sal (ppt)	Turb (ntu)
WQ0901	Man-made Channel	8/16/2009	15:45	2	24.63	8.58	106	8.17	77	776	0.2	44.4
WQ0902	Man-made Channel	8/16/2009	19:54	2	24.68	9.40	114	8.26	66	816	0.2	
WQ0903	Man-made Channel	8/18/2009	14:58	3	24.15	8.08	99	7.99	108	740	0.2	61.8
WQ0904	Man-made Channel	8/24/2009	18:12	2	22.75	8.85	115	8.16	177	577	0.3	122.0
WQ0905	Man-made Channel	8/26/2009	11:07	2	22.40	8.22	98	8.24	152	595	0.3	114.0
WQ0906	Scour/Antioch	8/28/2009	15:35	2	23.51	9.21	116	8.12	168	2110	1.1	11.8
WQ0907	Scour/Antioch	8/28/2009	17:55	2	23.43	9.78	120	8.13	162	1880	1.0	11.9
WQ0908	Light 21	8/31/2009	19:07	2	22.84	7.38	88	8.11	157	1540	0.8	9.9
WQ0909	Light 21	8/31/2009	21:37	2	22.83			8.25	162	1170	0.6	8.3
WQ0910a	Light 21	9/2/2009	19:27	2	23.07			7.95	156	1430	0.7	12.6
WQ0910b	Light 21	9/2/2009	17:08	2	23.16	8.56	104	7.81	163	1400	0.7	10.1
WQ0911	Light 21	9/4/2009	12:45	2	22.83	8.33	101	7.92	198	104	0.5	9.7
WQ0912	Light 21	9/4/2009	15:04	2	22.90	8.65	106	8.03	200	126	0.6	11.0
WQ0913	Spud Island	9/12/2009	19:17	2	24.05	7.06	90	7.65	189	260	0.1	4.8
WQ0914	Spud Island	9/12/2009	21:22	2	23.49			7.58	192	260	0.1	5.9
WQ0915	Spud Island	9/13/2009	14:36	2	23.79	7.38	91	7.37	207	262	0.1	7.6
WQ0916	Spud Island	9/13/2009	17:15	2	23.67	7.72	97	7.69	209	262	0.1	7.5
WQ0917	Lower Roberts Island	9/15/2009	12:56	2	24.51	10.34	122	7.29	187	390	0.2	8.4
WQ0918	Lower Roberts Island	9/15/2009	15:49	2	24.24	6.91	89	7.18	212	281	0.1	9.4
WQ0919	Lower Roberts Island	9/19/2009	13:40	2	25.35	6.46	84	7.42	210	521	0.2	14.3
WQ0920	Windmill Cove	9/21/2009	10:52	2	25.06			7.27	195	531	0.3	13.7
WQ0921	Windmill Cove	9/21/2009	17:17	2	25.69	6.87	89	7.21	210	465	0.2	13.6
WQ0922	Upper Roberts Island	9/23/2009	8:59	2	24.82	6.20	101	7.17	167	497	0.2	12.8
WQ0923	Upper Roberts Island	9/23/2009	12:10	2	26.15	7.41	99	7.54	247	531	0.3	13.9
WQ0924	Upper Roberts Island	9/26/2009	19:41	2	26.08	10.81	135	7.04	225	533	0.3	17.5
WQ0925	Upper Roberts Island	9/30/2009	8:31	2	23.63	9.56	117	6.74	191	519	0.2	16.1
WQ0926	Upper Roberts Island	10/2/2009	12:39	2	22.95	10.18	112	7.70	148	501	0.2	16.3
WQ0927	Upper Roberts Island	10/2/2009	15:33	2	23.47	9.04	107	7.50	153	517	0.2	17.5
WQ0928	Upper Roberts Island	10/4/2009	16:10	2	21.66	9.55	111	7.85	146	502	0.2	20.0
WQ0929	Rough & Ready Island	10/6/2009	11:03	2	19.70			7.98	131	492	0.2	21.4
WQ0930	Rough & Ready Island	10/6/2009	14:02	2	20.83			7.91	183	485	0.2	19.0
WQ0931	Rough & Ready Island	10/8/2009	13:08	2	19.65	8.81	100	7.43	171	468	0.2	16.7
WQ0932	Rough & Ready Island	10/8/2009	16:06	2	20.32	10.81	124	7.61	166	474	0.2	16.1
WQ0933	Rough & Ready Island	10/10/2009	11:25	2	19.12	8.49	97	7.62	171	477	0.2	28.5
WQ0934	Rough & Ready Island	10/10/2009	15:47	2	20.05	9.16	105	7.73	170	468	0.2	17.0
WQ0935	Rough & Ready Island	10/12/2009	15:24	2	19.36	9.10	105	7.91	115	474	0.2	15.8
WQ0936	Rough & Ready Island	10/12/2009	17:42	2	19.36	9.90	111	7.98	171	479	0.2	14.8
WQ0937	Upper Turning Basin	10/14/2009	14:35	2	19.23	8.58	96	7.93	136	471	0.2	6.4
WQ0938	Upper Turning Basin	10/16/2009	12:03	2	19.08	7.38	84	7.19	146	459	0.2	9.0
WQ0939	Upper Turning Basin	10/16/2009	14:12	2	19.54	7.44	87	7.52	134	466	0.2	14.6

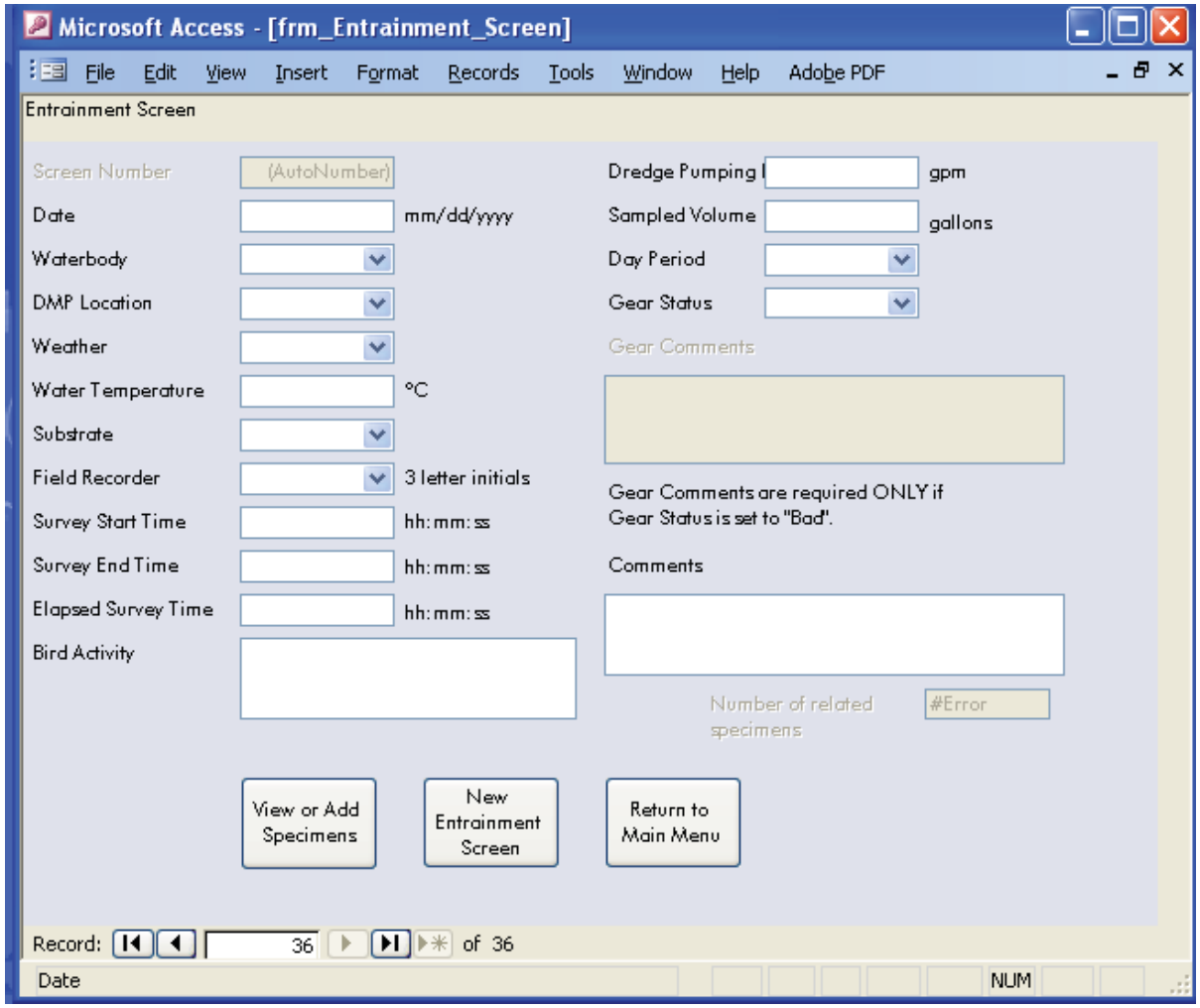
Bottom Water Quality Readings

Survey ID	Dredge Reach	WQ_Date	Time (hh:mm)	Depth (ft)	Temp (*C)	DO (ppm)	DO (%)	pH	ORP (mV)	Cond (uS)	Sal (ppt)	Turb (ntu)
WQ0901	Man-made Channel	8/16/2009										
WQ0902	Man-made Channel	8/16/2009										
WQ0903	Man-made Channel	8/18/2009										
WQ0904	Man-made Channel	8/24/2009	18:09	31	22.71	9.53	115	8.21	171	580	0.3	119
WQ0905	Man-made Channel	8/26/2009	11:11	30	22.22	8.52	102	8.16	163	600	0.3	112
WQ0906	Antioch	8/28/2009	15:39	37	22.04	9.39	112	7.94	172	2360	1.2	16.6
WQ0907	Antioch	8/28/2009	17:58	33	22.08	8.38	100	7.97	163	2240	1.1	15.2
WQ0908	Light 21	8/31/2009	19:12	37	22.85	6.13	77	8.11	154	1560	0.8	11.9
WQ0909	Light 21	8/31/2009	21:43	45	22.86			8.08	174	1190	0.6	10.5
WQ0910a	Light 21	9/2/2009	19:31	45	23.11			7.94	161	1480	0.7	11.2
WQ0910b	Light 21	9/2/2009	17:13	38	23.10	7.36	92	7.87	172	1840	0.9	13.1
WQ0911	Light 21	9/4/2009	12:49	45	22.82	9.19	110	7.93	190	100	0.5	9.8
WQ0912	Light 21	9/4/2009	15:07	36	22.90	8.25	100	7.93	199	123	0.6	10.5
WQ0913	Spud Island	9/12/2009	19:20	33	23.83	8.27	103	7.58	192	258	0.1	13.9
WQ0914	Spud Island	9/12/2009	19:24	38	23.58	7.12	90	7.48	202	263	0.1	4.4
WQ0915	Spud Island	9/13/2009	14:48	36	23.44	7.09	87	7.42	217	260	0.1	7.3
WQ0916	Spud Island	9/13/2009	17:13	34	23.47	7.23	89	7.30	33	261	0.1	6.4
WQ0917	Lower Roberts Island	9/15/2009	13:01	38	23.67	6.11	77	7.56	190	336	0.2	13.8
WQ0918	Lower Roberts Island	9/15/2009	15:53	36	23.51	6.90	85	7.58	187	281	0.1	10.5
WQ0919	Lower Roberts Island	9/19/2009	13:44	30	24.90	6.98	89	7.50	237	520	0.2	19.7
WQ0920	Windmill Cove	9/21/2009	10:56	30	24.78			7.28	187	532	0.3	28.9
WQ0921	Windmill Cove	9/21/2009	17:19	30	24.99	6.11	82	7.13	217	494	0.2	16.0
WQ0922	Upper Roberts Island	9/23/2009	9:02	30	24.81	6.02	80	7.20	141	499	0.2	13.6
WQ0923	Upper Roberts Island	9/23/2009	12:13	30	25.36			7.30	258	531	0.3	26.8
WQ0924	Upper Roberts Island	9/26/2009	19:45	35	25.28	9.12	115	7.15	215	531	0.3	18.5
WQ0925	Upper Roberts Island	9/30/2009	8:35	31	23.72	8.79	108	7.10	179	521	0.3	17.2
WQ0926	Upper Roberts Island	10/2/2009	12:45	35	22.50	9.74	116	7.41	175	500	0.2	21.4
WQ0927	Upper Roberts Island	10/2/2009	15:31	35	22.75	8.79	107	7.30	162	513	0.2	24.6
WQ0928	Rough & Ready Island	10/4/2009	16:18	36	21.43	9.49	112	7.17	191	510	0.2	17.7
WQ0929	Rough & Ready Island	10/6/2009	11:07	35	19.06			7.59	175	490	0.2	47.5
WQ0930	Rough & Ready Island	10/6/2009	14:06	36	19.37			7.79	193	487	0.2	27.4
WQ0931	Rough & Ready Island	10/8/2009	13:11	36	18.45	8.77	98	7.34	179	459	0.2	38.7
WQ0932	Rough & Ready Island	10/8/2009	16:10	37	18.94	8.64	100	7.48	168	472	0.2	16.0
WQ0933	Rough & Ready Island	10/10/2009	11:27	37	18.99	8.23	95	7.53	181	480	0.2	68.0
WQ0934	Rough & Ready Island	10/10/2009	15:49	37	19.12	9.09	102	7.48	182	475	0.2	43.9
WQ0935	Rough & Ready Island	10/12/2009	15:27	38	18.83	9.15	103	7.69	130	492	0.2	15.9
WQ0936	Rough & Ready Island	10/12/2009	17:44	35	18.62	9.20	104	7.72	177	490	0.2	15.9
WQ0937	Upper Turning Basin	10/14/2009	14:45	37	17.92	9.84	107	7.59	147	444	0.2	27.6
WQ0938	Upper Turning Basin	10/16/2009	12:09	35	18.06	7.00	100	7.17	148	471	0.2	36.2
WQ0939	Upper Turning Basin	10/16/2009	14:15	35	18.04			7.20	142	466	0.2	60.1

Water Quality Comments

Survey ID	Dredge Reach	Date (m/d/year)	Comments
WQ0901	Man-made Channel	8/16/2009	No near bottom measurement due to rental unit cable only 2m long.
WQ0902	Man-made Channel	8/16/2009	No near bottom reading as rental unit cable was only 2 m long.
WQ0903	Man-made Channel	8/18/2009	No bottom measurement due to too short of probe cable on rental unit. Associate w/ TR0902-01
WQ0904	Man-made Channel	8/24/2009	First reading with new Horiba Model 52 multi-parameter WQ meter.Associate w/ TR0905-1
WQ0905	Man-made Channel	8/26/2009	Asssociate w/ TR0906-01
WQ0906	Antioch	8/28/2009	
WQ0907	Antioch	8/28/2009	Associate w/ TR0907-04 and -05.
WQ0908	Light 21	8/31/2009	QC the DO on
WQ0909	Light 21	8/31/2009	Dark; associate w/ TR0908, DO readings suspect
WQ0910a	Light 21	9/2/2009	DO not reading correctly, will check.
WQ0910b	Light 21	9/2/2009	Assoc w/ TR0909
WQ0911	Light 21	9/4/2009	WQ meter cleaned/DO repaired and fully recalibrated; San Joaquin Green Light 21; Associate with TR0910-1
WQ0912	Light 21	9/4/2009	Associate with TR0910
WQ0913	Spud Island	9/12/2009	WQ recalibrated, however DO not w/in range. Assoc w/ TR 0911
WQ0914	Spud Island	9/12/2009	Assoc w/ TR0911-04 and -05. Note DO not calibrated w/in range; all other parameters calibrated prior
WQ0915	Spud Island	9/13/2009	Assoc w/ TR0912 at Spud Island Red Light 20.
WQ0916	Spud Island	9/13/2009	Assoc w/ TR0912-03 and -04. Near high slack tide.
WQ0917	Lower Roberts Island	9/15/2009	Associate w/ TR0913 (replicate 1 & 2)
WQ0918	Lower Roberts Island	9/15/2009	Assoc w/ TR0913 rep 04&05
WQ0919	Lower Roberts Island	9/19/2009	reach location is Walters Island; rechecked 1st set of measurements for 2' depth
WQ0920	Windmill Cove	9/21/2009	reach location is Windmill Cove; DO probe has bubble, so no DO readings taken
WQ0921	Windmill Cove	9/21/2009	reach location is Windmill Cove
WQ0922	Lower Roberts Island	9/23/2009	reach location is Upper Roberts but near Windmill Cove
WQ0923	Lower Roberts Island	9/23/2009	reach location is Upper Roberts but near Windmill Cove, bottom DO out of range.
WQ0924	Lower Roberts Island	9/26/2009	Dark. Associate w/ TR091, Upper Roberts near Windmill Cove
WQ0925	Lower Roberts Island	9/30/2009	Associate w/ TR0919, Upper Roberts, Red Light 36, approximately 100 yds upstream of Dredge 7. Weak outgoing tide (shifts around 10:00).
WQ0926	Lower Roberts Island	10/2/2009	Assoc w TR0920, reps 1 & 2
WQ0927	Lower Roberts Island	10/2/2009	Associate w/ TR0920, replicates 3 & 4.
WQ0928	Rough & Ready Island	10/4/2009	Dredge 7 just finished dredging this reach and will move up to Rough & Ready (Port Stockton W). Associate w/ TR0921.
WQ0929	Rough & Ready Island	10/6/2009	1st trawl sampling at d/s end of Rough & Ready; Assoc w/ TR0922, reps 1-3. DO reading in question. Slack tide. Ship "Star Kirkeness" recently passed u/s
WQ0930	Rough & Ready Island	10/6/2009	Assoc w/ TR0922, reps 4 & 5. DO not reading correctly.
WQ0931	Rough & Ready Island	10/8/2009	Meter calibrated prior to use today. Port of Stockton Berth B area; Associate with TR0923, reps 1 & 2
WQ0932	Rough & Ready Island	10/8/2009	Assoc w. TR0923, reps 3 - 5; Near Green Light 43.
WQ0933	Rough & Ready Island	10/10/2009	Ship "Star Kirkenes" just departed Stockton within 10 minutes of this reading. Associate w/ TR0924, rep 1.
WQ0934	Rough & Ready Island	10/10/2009	Assoc w/ TR0924, reps 2-5.
WQ0935	Rough & Ready Island	10/12/2009	Assoc w/ TR0925, reps 1&2; Dredge 7 currently mobilizing to Sed Trap reach.
WQ0936	Rough & Ready Island	10/12/2009	Assoc w/ TR0925, reps 3-5.
WQ0937	Upper Turning Basin	10/14/2009	Upstream of Sediment Trap/Old San Joaquin River in Port of Stockton water along concrete plant/ship "Golden Arrow 1"; Associate w/ TR0926; Recorded on Horiba meter
WQ0938	Upper Turning Basin	10/16/2009	Last day of dredge ops for 2009; Dredge 7 finished at 11:40. Assoc w/ tr0927, reps 1-3; wq PROBE CALIBRATED AND CHECKED W/IN RANGE.
WQ0939	Upper Turning Basin	10/16/2009	Associate with TR0927, replicates 4 and 5. DO reading on bottom not available;

Appendix C. Field Data Collection Forms and Database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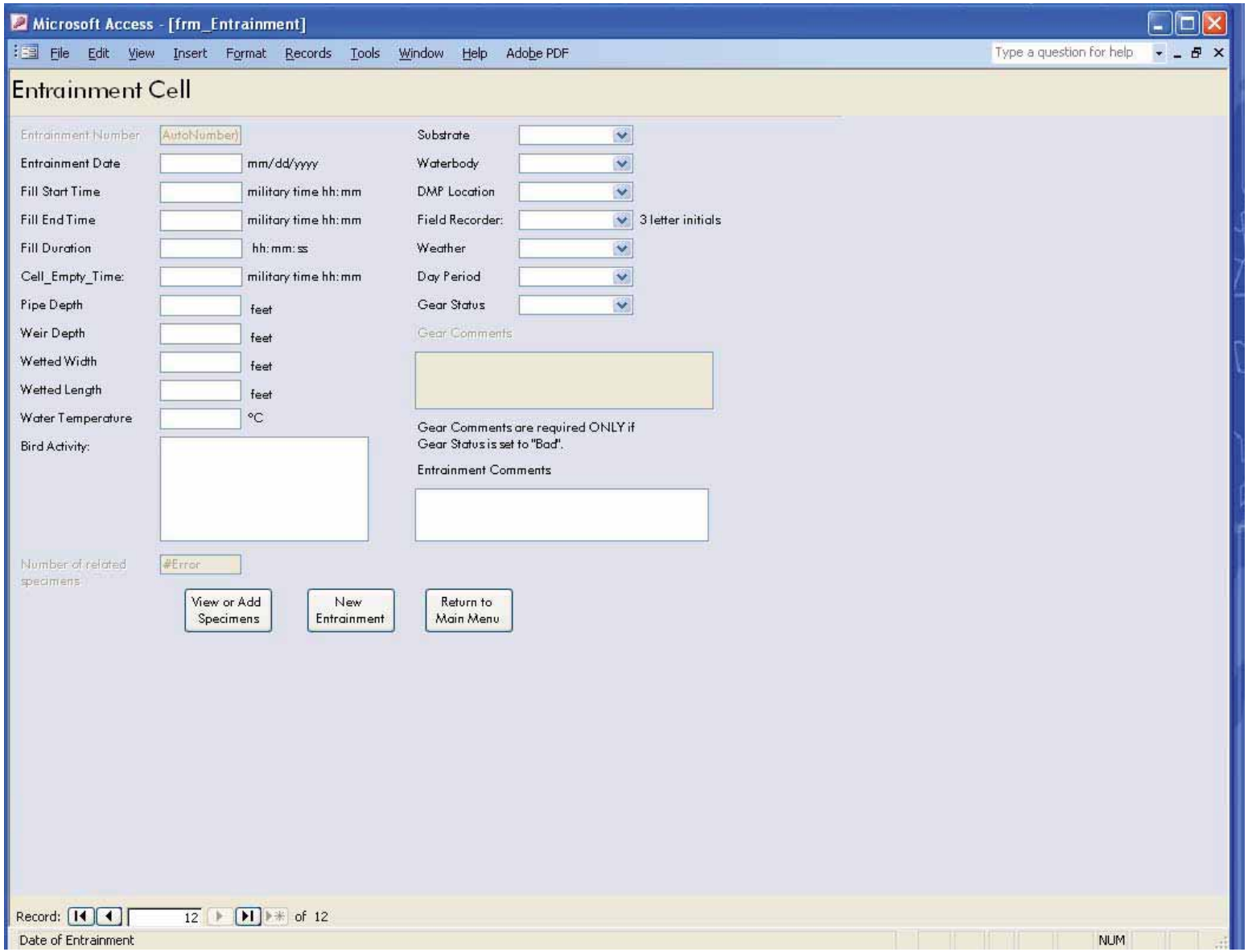
Entrainment Screen
Screen Number
(AutoNumber)
Date
mm/dd/yyyy
Waterbody
DMP Location
Weather
Water Temperature
°C
Substrate
Field Recorder
3 letter initials
Survey Start Time
hh:mm:ss
Survey End Time
hh:mm:ss
Elapsed Survey Time
hh:mm:ss
Bird Activity
Dredge Pumping I
gpm
Sampled Volume
gallons
Day Period
Gear Status
Gear Comments
Gear Comments are required ONLY if Gear Status is set to "Bad".
Comments
Number of related specimens
#Error
View or Add Specimens
New Entrainment Screen
Return to Main Menu
Record:
36
of 36
Date
NUM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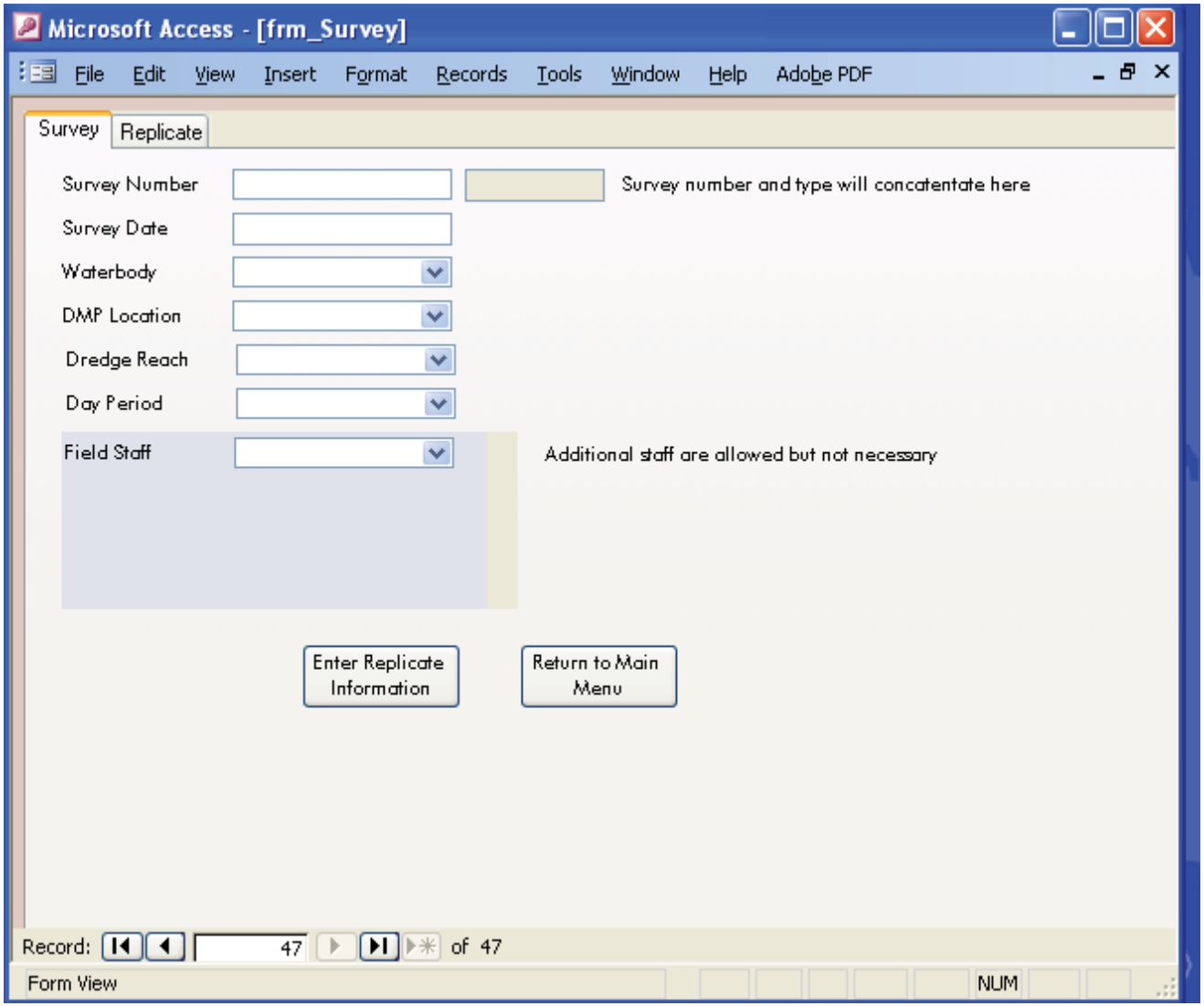
Entrainment Number
AutoNumber)
Entrainment Date
mm/dd/yyyy
Fill Start Time
military time hh:mm
Fill End Time
military time hh:mm
Fill Duration
hh:mm:ss
Cell_Empty_Time:
military time hh:mm
Pipe Depth
feet
Weir Depth
feet
Wetted Width
feet
Wetted Length
feet
Water Temperature
°C
Bird Activity:
Number of related specimens
#Error
Substrate
Waterbody
DMP Location
Field Recorder:
3 letter initials
Weather
Day Period
Gear Status
Gear Comments
Gear Comments are required ONLY if Gear Status is set to "Bad".
Entrainment Comments
View or Add Specimens
New Entrainment
Return to Main Menu
Record: 12 of 12
Date of Entrainment
NUM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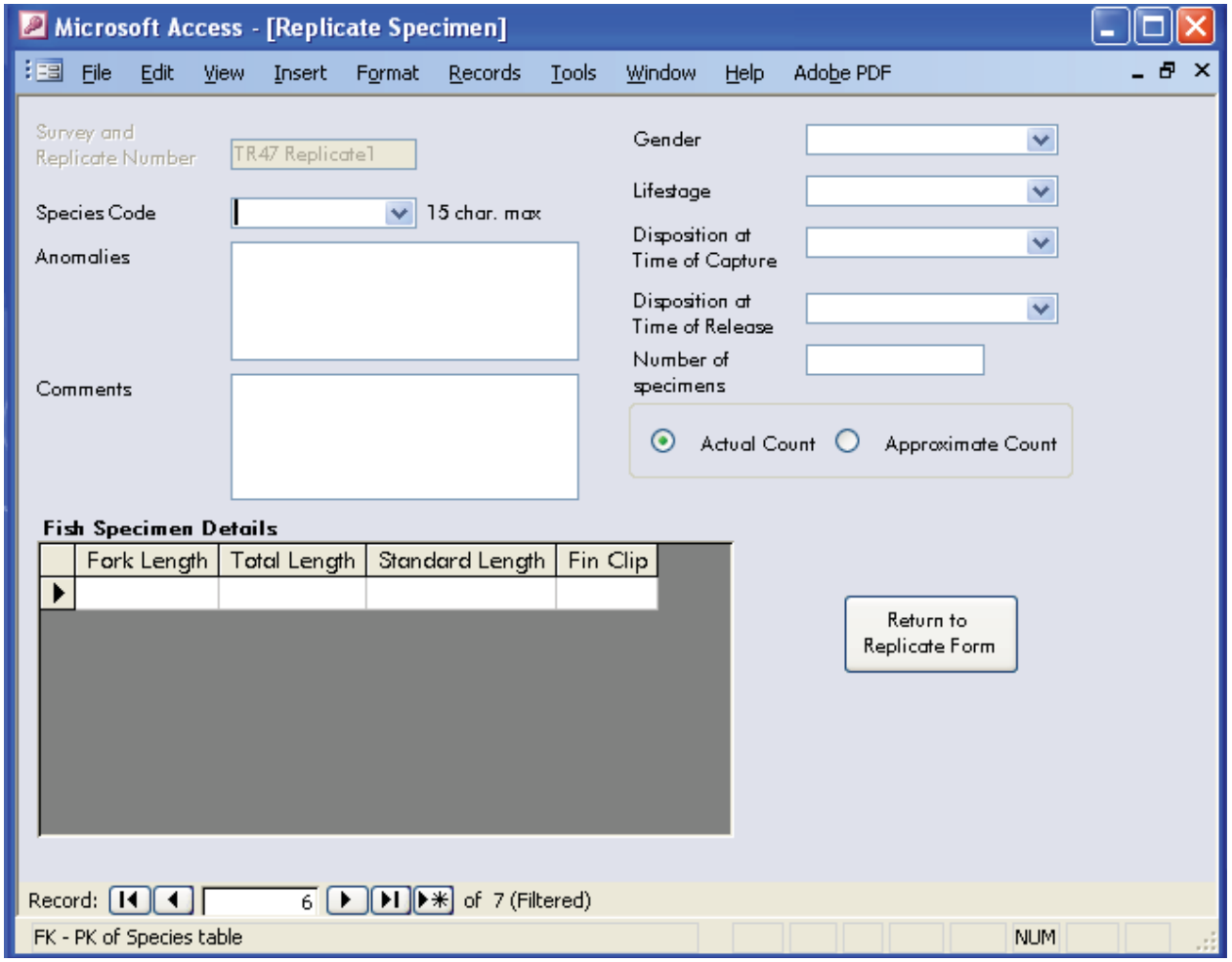
Survey
Replicate
Survey Number
Survey number and type will concatentate here
Survey Date
Waterbody
DMP Location
Dredge Reach
Day Period
Field Staff
Additional staff are allowed but not necessary
Enter Replicate Information
Return to Main Menu
Record: 47 of 47
Form View
NUM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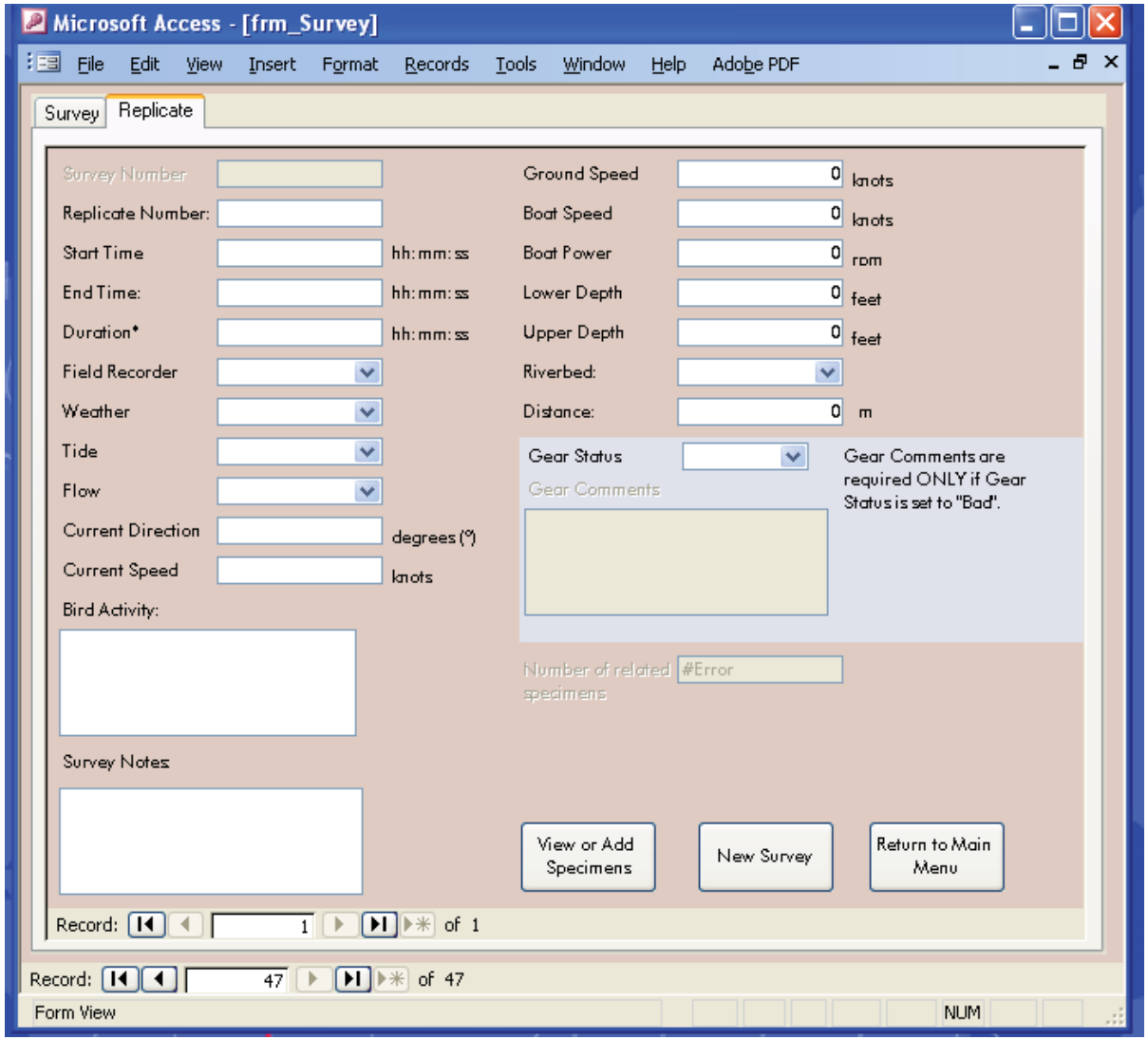
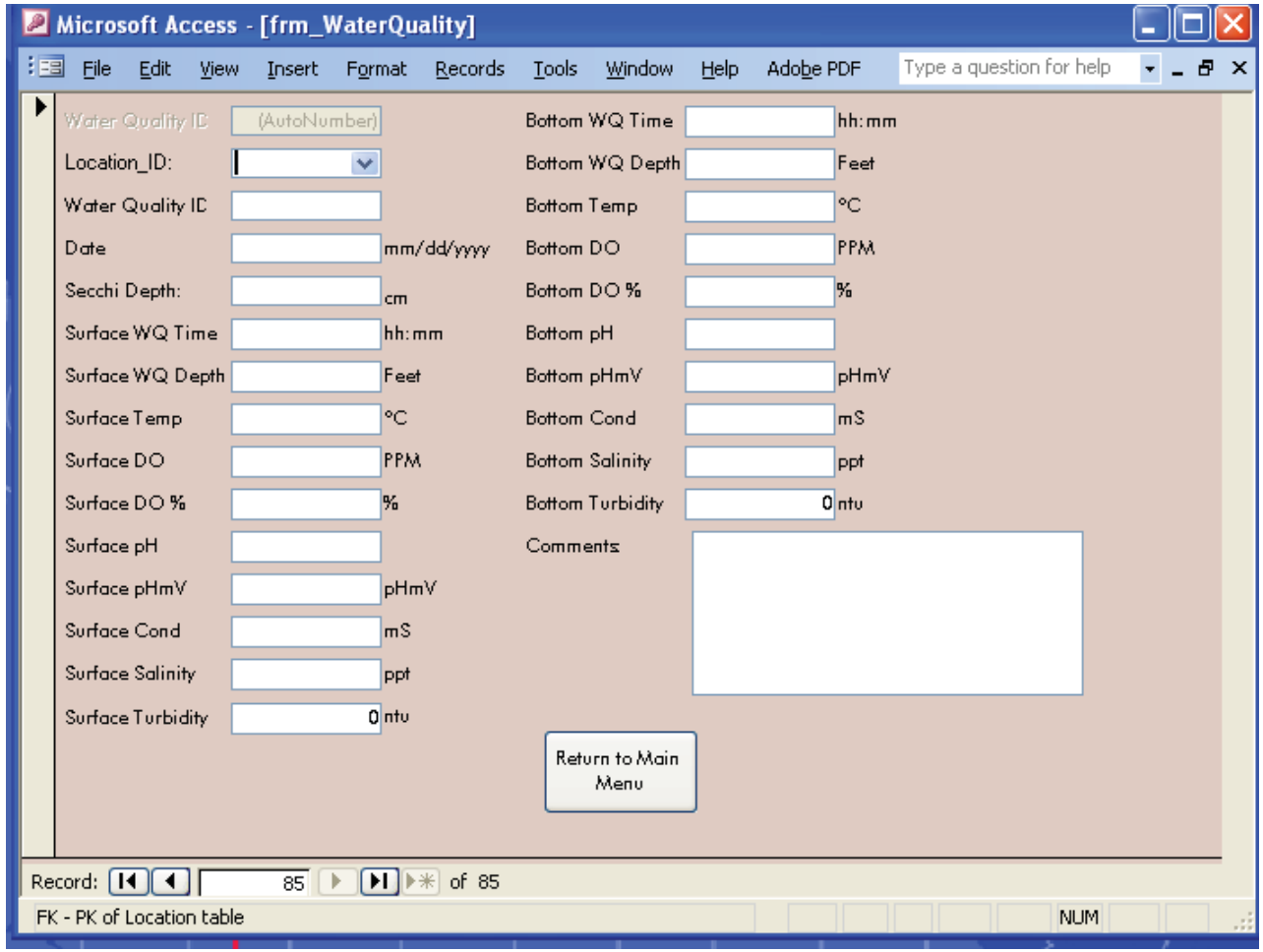
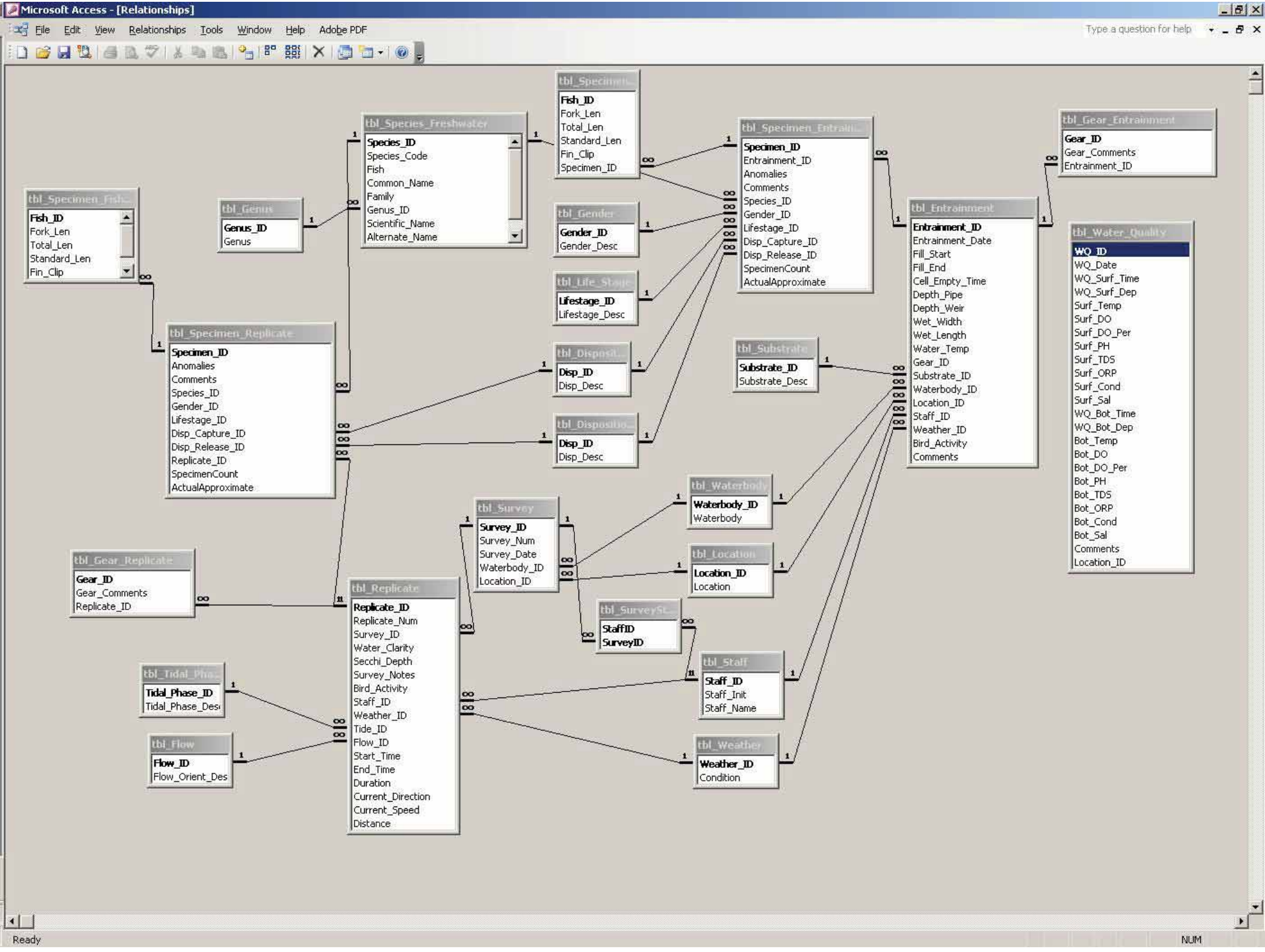
File Edit View Insert Format Records Tools Window Help Adobe PDF
Survey and Replicate Number
TR47 Replicate1
Species Code
15 char. max
Anomalies
Comments
Gender
Lifestage
Disposition at Time of Capture
Disposition at Time of Release
Number of specimens
Actual Count
Approximate Count
Fish Specimen Details
Fork Length
Total Length
Standard Length
Fin Clip
Return to Replicate Form
Record: 6 of 7 (Filtered)
FK - PK of Species table
NUM


Microsoft Access - [frm_Survey]
File Edit View Insert Format Records Tools Window Help Adobe PDF
Survey
Replicate
Survey Number
Replicate Number:
Start Time
hh:mm:ss
End Time:
hh:mm:ss
Duration*
hh:mm:ss
Field Recorder
Weather
Tide
Flow
Current Direction
degrees (°)
Current Speed
knots
Bird Activity:
Survey Notes:
Ground Speed
0
knots
Boat Speed
0
knots
Boat Power
0
rpm
Lower Depth
0
feet
Upper Depth
0
feet
Riverbed:
Distance:
0
m
Gear Status
Gear Comments
Gear Comments are required ONLY if Gear Status is set to "Bad".
Number of related specimens
#Error
View or Add Specimens
New Survey
Return to Main Menu
Record:
1
of 1
Record:
47
of 47
Form View
NUM


Microsoft Access - [frm_WaterQuality]
File Edit View Insert Format Records Tools Window Help Adobe PDF
Type a question for help
Water Quality ID
(AutoNumber)
Location_ID:
Water Quality ID
Date
mm/dd/yyyy
Secchi Depth:
cm
Surface WQ Time
hh:mm
Surface WQ Depth
Feet
Surface Temp
°C
Surface DO
PPM
Surface DO %
%
Surface pH
Surface pHmV
pHmV
Surface Cond
mS
Surface Salinity
ppt
Surface Turbidity
0
ntu
Bottom WQ Time
hh:mm
Bottom WQ Depth
Feet
Bottom Temp
°C
Bottom DO
PPM
Bottom DO %
%
Bottom pH
Bottom pHmV
pHmV
Bottom Cond
mS
Bottom Salinity
ppt
Bottom Turbidity
0
ntu
Comments
Return to Main Menu
Record:
85
of 85
FK - PK of Location table
NUM


Microsoft Access - [Relationships]
File Edit View Relationships Tools Window Help Adobe PDF
Type a question for help
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Fish_ID
Fork_Len
Total_Len
Standard_Len
Fin_Clip
tbl_Genus
Genus_ID
Genus
tbl_Species_Freshwater
Species_ID
Species_Code
Fish
Common_Name
Family
Genus_ID
Scientific_Name
Alternate_Name
tbl_Specimen_Replicate
Specimen_ID
Anomalies
Comments
Species_ID
Gender_ID
Lifestage_ID
Disp_Capture_ID
Disp_Release_ID
Replicate_ID
SpecimenCount
ActualApproximate
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Fork_Len
Total_Len
Standard_Len
Fin_Clip
Specimen_ID
tbl_Gender
Gender_ID
Gender_Desc
tbl_Life_Stage
Lifestage_ID
Lifestage_Desc
tbl_Disposit
Disp_ID
Disp_Desc
tbl_Disposition
Disp_ID
Disp_Desc
tbl_Specimen_Entrain
Specimen_ID
Entrainment_ID
Anomalies
Comments
Species_ID
Gender_ID
Lifestage_ID
Disp_Capture_ID
Disp_Release_ID
SpecimenCount
ActualApproximate
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Substrate_ID
Substrate_Desc
tbl_Gear_Entrainment
Gear_ID
Gear_Comments
Entrainment_ID
tbl_Entrainment
Entrainment_ID
Entrainment_Date
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Fill_End
Cell_Empty_Time
Depth_Pipe
Depth_Weir
Wet_Width
Wet_Length
Water_Temp
Gear_ID
Substrate_ID
Waterbody_ID
Location_ID
Staff_ID
Weather_ID
Bird_Activity
Comments
tbl_Water_Quality
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WQ_Date
WQ_Surf_Time
WQ_Surf_Dep
Surf_Temp
Surf_DO
Surf_DO_Per
Surf_PH
Surf_TDS
Surf_ORP
Surf_Cond
Surf_Sal
WQ_Bot_Time
WQ_Bot_Dep
Bot_Temp
Bot_DO
Bot_DO_Per
Bot_PH
Bot_TDS
Bot_ORP
Bot_Cond
Bot_Sal
Comments
Location_ID
tbl_Waterbody
Waterbody_ID
Waterbody
tbl_Survey
Survey_ID
Survey_Num
Survey_Date
Waterbody_ID
Location_ID
tbl_Location
Location_ID
Location
tbl_SurveySt
StaffID
SurveyID
tbl_Staff
Staff_ID
Staff_Init
Staff_Name
tbl_Gear_Replicate
Gear_ID
Gear_Comments
Replicate_ID
tbl_Replicate
Replicate_ID
Replicate_Num
Survey_ID
Water_Clarity
Secchi_Depth
Survey_Notes
Bird_Activity
Staff_ID
Weather_ID
Tide_ID
Flow_ID
Start_Time
End_Time
Duration
Current_Direction
Current_Speed
Distance
tbl_Tidal_Phas
Tidal_Phase_ID
Tidal_Phase_Desc
tbl_Flow
Flow_ID
Flow_Orient_Des
tbl_Weather
Weather_ID
Condition
Ready
NUM

Appendix C. Database and Paper Data Entry Forms

Paper Data Entry Forms

Fish Sampling Data Sheet 2009

Sampling Method (survey type):		Dredge Reach:	
Sample ID:		DMP Site:	
Tow Replicate:		Location Markers/Aids:	
Date:		Tidal Phase:	ebb / flood / slack
Start Time:		Flow Direction:	upstream / downstream
End Time:		Current Direction [° True North]:	
GPS: Track ID start #		Current Speed [kts]:	
Track ID end #		Boat Speed [kts]:	
Survey Depth_Lower [ft]:		Speed over ground [kts]:	
Survey Depth_Upper [ft]:		Boat Power [rpms]:	
Tow distance [m]:		Weather:	
Subsample?	yes / no	Piscivorous Bird Activity:	
* Subsample percent (estimate):		River bed description:	
Gear Status:	good / bad	Daylight Conditions:	
		Sampling Staff / Recorder (circle):	

Gear Comments

Entrainment Sampling Data Sheet (Screen)

Date:		Sample Area Description:	
DMP Location:		Survey Start Time:	
GPS		Survey End Time:	
GPS location at DMP:		Total Elapsed Survey Time [hh:mm:ss]:	
Weather:		Dredge Pumping Rate [gpm]:	
Water Temperature:		Sampled Volume [gallons]:	
Substrate Description:			
Sampling Staff / Recorder:		Bird Activity at DMP Site:	

Gear Status / Notes: _____

Specimen Collection Datasheet (2009)

Date ______________ Page ______ of ______

Survey ID ______________

Survey Replicate

[tally_count]

SPECIES_ SPECIMEN_CODE	LIFE HX STAGE	CAPTURE DISPOSITION	RELEASE DISPOSITION	FL (mm)	TL (mm)	SL (mm)	SEX	FIN CLIP	EXTERNAL ANOMALIES	COMMENTS

Notes:

Water Quality Monitoring Datasheet (2009)

Location:
Sampling Crew:
Recorder:
Associated Survey ID:
Date:
Secchi Depth [cm]:

	Near Surface	Near Bottom
WQ Time:		
WQ Depth:		
Temp [°C]:		
DO [ppm]:		
DO [% saturation]:		
pH:		
Conductivity [µm]:		
Salinity:		
ORP [mV]:		
TDS [g/L]:		
Turbidity [ntu]:		

Gear Status / Notes:

Location:
Sampling Crew:
Recorder:
Associated Survey ID:
Date:
Secchi Depth [cm]:

	Near Surface	Near Bottom
WQ Time:		
WQ Depth:		
Temp [°C]:		
DO [ppm]:		
DO [% saturation]:		
pH:		
Conductivity [µm]:		
Salinity:		
ORP [mV]:		
TDS [g/L]:		
Turbidity [ntu]:		

Gear Status / Notes: