Stockton and Sacramento Deepwater Ship Channel Maintenance Dredging Project 2008 Fish Community and Entrainment Monitoring Report

Prepared for

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Abbreviations

Abbreviation	Full Term or Name
BO	biological opinion
CDFG	California Department of Fish and Game
CESA	California Endangered Species Act
Corps	U.S. Army Corps of Engineers
CPUE	catch per unit effort
Delta	Sacramento and San Joaquin River Delta
DMP	dredged material placement
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	hypothesis
IEP	Interagency Ecological Program
IUCN	International Union for Conservation of Nature and Natural Resources
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NMFS	National Marine Fisheries Service
ppm	parts per million
ppt	parts per thousand
PODS	Pelagic Organism Decline Study
RISG	Ross Island Sand and Gravel
RM	river mile
SCP	scientific collecting permit
SD	standard deviation
SE	standard error
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 2008 fish community and fish entrainment monitoring for maintenance dredging in two deepwater ship channels: 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.

Bottom trawling was used to monitor the fish community in the active dredge area of the shipping channels. All trawl samples were performed up-current of the operating dredge.

Fish entrainment was monitored using a combination of the entrainment sampling cell method used in previous years and the mobile entrainment screen constructed in early 2008. The mobile entrainment screen was used in all dredged material disposal areas except those inaccessible by road (Decker Island) or where work was of short duration (Bradford Island).

Dredging commenced on August 1, 2008, and ended on November 25, 2008. 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 2008 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 2008 as in previous years.

The key findings from the 2008 fish community (trawl) sampling were:

- 7,359 individual fish, representing 25 fish species among the 40 or so species presently known to occur in the Sacramento and San Joaquin River Delta (the Delta) were collected during 2008 fish community monitoring.
- 46 trawl surveys were performed in 2008, compared to 13 in 2007. A total of 205 successful trawl replicates were conducted.
- Nine of the collected fish species are native to the Delta, and 16 are introduced.
- As in 2007, white catfish (*Ameiurus catus*) an introduced demersal (bottom-oriented) species, was the most commonly encountered species in fish community trawl samples accounting for 42.87% of the total catch.
- A total of 25 delta smelt (*Hypomesus transpacificus*) were collected from three of the eight project dredge reaches sampled. This species is listed as threatened under the ESA.
- A total of 21 longfin smelt (*Spirinchus thaleichthys*) were collected in 2008, all from the Decker Island area on the Sacramento River. As in 2006 and 2007, longfin smelt were not captured in the lower San Joaquin River.
- Eleven fish taxa occurred in both fish community and entrainment samples. Only one of these species was native, the Pacific staghorn sculpin (*Leptocottus armatus*).

- Non-native species accounted for 99.07% of the total catch, overall. Delta smelt were the most commonly encountered native fish during 2008 (0.33%), similar to 2007.
- Native fishes comprised 16.30% of total fishes collected from Sacramento River locations and 0.20% at all San Joaquin River locations, both higher than in 2007. In 2006, native fishes comprised 52.02% at Sacramento River sites and 0.18% over all San Joaquin River locations.

The key findings of the 2008 entrainment monitoring at the dredged material placement (DMP) sites were:

- A total of 278 individual fish from 12 different taxa were collected during entrainment monitoring.
- 46 entrainment surveys were completed (11 sample cell and 35 entrainment screen surveys), compared to eight sample cell surveys in 2007 and 31 sample cell surveys in 2006.
- Channel catfish (*Ictalurus punctatus*) was the most common fish species found in entrainment samples (62.23%).
- Lamprey were the most common native species collected in entrainment sampling (11.15%). Lamprey were not observed or collected in fish community sampling within the navigation channels. A total of 31 lamprey were observed in entrainment samples. Of these, 15 were identified to species as river lamprey (*Lampetra ayresii*). Unidentified lamprey could possible western brook lamprey (*Lampetra richardsoni*), Kern brook lamprey, (*L. hubbsi*) or Pacific lamprey (*Lampetra* [*Entosphenus*] *tridentata*).
- Lamprey and Pacific staghorn sculpin were the only native fish collected during entrainment sampling.
- No federal or state special-status species were collected in entrainment samples in 2008.
- Similar to 2006 and 2007, most entrained fish were demersal species that were also encountered during fish community monitoring, with white catfish and channel catfish comprising 76.25% of the total entrained catch.
- The mobile entrainment screen was used at all DMP sites, except Decker and Bradford Islands. The amount of dredged material sampled in 2008 was much higher than in previous years (4.4% of overall dredged material, compared to 0.35% in 2007 and 0.37% in 2006).
- As in 2005, 2006, and 2007, the sampling cell entrainment monitoring method, used at Decker and Bradford Islands, was effective at collecting entrained organisms but did not sample a large sample volume of the total daily output of the dredge. This was primarily due to the time required to drain and fill the sampling cells, and due to site constraints on sampling cell creation and maintenance.
- Slurry volume sampled varied from 0.49% of total deposited slurry volume at the Bradford DMP site to 6.41% at the Roberts Island DMP site.
- A total of approximately 468,272 cubic yards of dredged material was placed at the DMP sites during the 2008 maintenance dredging season. Approximately 342,959 cubic yards were dredged from the SSC and 125,313 cubic yards from the SRSC.
- Total sampled volume of dredged material was insufficient to accurately assess overall entrainment rates at the Decker and Bradford Island DMPs; extrapolated entrainment rates for individual species may not reflect actual rates of entrainment.

All data collected in 2008 were incorporated into the Microsoft 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 may also enable assessment of changes to the fish community resulting from management actions, anthropogenic influences, and/or environmental fluctuations/ perturbations.

Several special-status species designations and take allotments changed during the 2008 monitoring period. Longfin smelt were petitioned for California and federal ESA listing on August 8, 2007. The petition was accepted by the California Fish and Game Commission on February 7, 2008, and special protections have been enacted for the species until final listing determination occurs (longfin smelt 2084 regulation, California Code of Regulations 2008, No. 38 subsection 749.3). Delta smelt take allotments for the project were adjusted to 10 fish per week for the duration of the 2008 dredging operations. The August 7, 2008 U.S. Fish and Wildlife Service memorandum of understanding letter (Document Reference No. 81420-2008-F-1775-1) appended the *Formal Programmatic Consultation on the Issuance of Section 10 and 404 Permits for Projects with Relatively Small Effect on the Delta Smelt (Hypomesus transpacificus) and its Critical Habitat within the Jurisdiction of the Sacramento Fish and Wildlife Office of the U.S. Fish and Wildlife Service, California* (Service File Number 1-1-04-F-0345).

2 Introduction

This document provides a description of the third year of fish community monitoring and the fourth year of dredge entrainment monitoring conducted by SWCA Environmental Consultants (SWCA) for the Sacramento District of the U.S. Army Corps of Engineers (Corps) through its contract with Ross Island Sand and Gravel Company (RISG). The Corps has an ongoing need to maintain channel depth and levee integrity along the Sacramento River Deepwater Ship Channel (SRSC) and the Stockton Deepwater Ship Channel (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 Endangered Species Act (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 and 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 activities that are required to maintain the authorized channel depths in the Corps-maintained federal shipping channels

The Corps and NMFS have developed a 10-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 (BOs) and supplemental documents for the shipping channels (NMFS 2006a,b). Although the timing of dredging projects in the Sacramento and San Joaquin River Delta (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 set annual monitoring requirements, which SWCA designed and conducted, beginning in 2006. As in 2006 and 2007, SWCA's design for the monitoring activities conducted in 2008 was reviewed by the Corps and NMFS. These agencies determined that the design was 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).

The Corps has consulted with U.S. Fish and Wildlife Service (USFWS) on maintenance dredging of the deepwater ship channels (DWSCs), which resulted in a programmatic informal consultation with a not likely to adversely effect (NLAA) determination for delta smelt, which are under USFWS jurisdiction (Service File Number 1-1-04-F-0345). Following SWCA's collection of delta smelt during 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. A consultation letter from USFWS dated August 7, 2008 appended the Sacramento Deep Water Ship Channel and the Stockton Deep Water Ship Channel maintenance dredging to the formal programmatic consultation of December 1, 2004 (Service File Number 1-1-04-F-0345) to allow the monitoring project to proceed in 2008 with authorized incidental take for the listed delta smelt.

This monitoring program was developed to meet the requirements of Conservation Measure 12 of the NMFS BOs (2006a,b). The conservation measures developed through these 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). NMFS established these conservation measures after recognizing that additional protections and measures to monitor project impacts were needed to ensure that project actions would not jeopardize the viability and existence of protected species. In August 2008, in order to minimize potential effects to delta smelt, the USFWS appended the deepwater ship channel maintenance dredging projects to their formal 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 restricted from August 1 to November 30. Work windows for the longfin smelt were established by CDFG as August 1 through October 31, 2008 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, 2008 in the SSC between RM 31–32 and RM 36–40.

To convert the monitoring requirements into testable assumptions, the following hypotheses (H1 and H2) were developed prior to the initiation of the 2006 sampling:

- H1: Maintenance dredging of the SSC and SRSC will result in take of listed and other fishes through direct dredge entrainment.
- H2: There is a correlation between presence of fish in the dredging areas and entrainment by the dredge.
- H2a: 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 1, 2008, through November 25, 2008. 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 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. 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. The monitoring activities were also accountable to provisions of the California Endangered Species Act (CESA), which affords special status to some species that do not have federal protective status. The CESA-listed species relevant to monitoring activities consist of:

- Sacramento splittail (*Pogonichthys macrolepidotus*) – threatened status under CESA
- longfin smelt (*Spirinchus thaleichthys*) – threatened status under CESA
- delta smelt – status change from threatened to endangered under CESA

This project has also encountered 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). These species are:

- American shad (*Alosa sapidissima*)
- 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.

Recent state and federal petitions have requested a status change of the federal listing of delta smelt from threatened to endangered. An official decision by the USFWS remains pending; the USFWS closed the comment period on this issue on February 9, 2009. In the absence of a final determination, the dredging process has been governed by new interim protections that were provided to delta smelt on December 14, 2007, through the Delta Smelt/OCAP decision in *NRDC* v. *Kempthorne*. Delta smelt were encountered during November and December 2007, which led to a mandatory shift in dredging locations and ultimately the suspension of the remaining 2007 dredge operations in the SRSC. In 2008, dredging was started in the SRSC in August and finished in the SSC in November. Delta smelt were encountered from August 6 to September 21 in the SRSC, 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. The change in the dredging plan, in theory, resulted in potential reduced take of delta smelt in 2008. The state status of the delta smelt was recently changed from threatened to endangered under CESA.

The California Department of Fish and Game (CDFG) enacted protections for longfin smelt in 2008, which was at that time a CESA candidate species. Incidental take of longfin smelt was restricted. Longfin smelt encountered in 2008 were reported to agency representatives within 24 hours of collection. The level of take authorized by CDFG for 2009 will be 150 juveniles and 150 adults for the entire year. The status of longfin smelt under CESA as threatened was unanimously accepted by the CDFG Fish Commission (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 is initiating a status review for the entire longfin smelt population from Alaska to California.

Species likely to occur in the project area that do not currently have any special state or federal status or conservation requirements, but that are considered to be in need of greater conservation efforts and/or are likely to be awarded special status during the lifetime of this project include:

- Pacific and river lamprey
- white sturgeon (*Acipenser transmontanus*)
- Central Valley fall/late fall-run Chinook salmon (*Oncorhynchus tshawytscha*)
- hardhead (*Mylopharodon conocephalus*)
- Sacramento-San Joaquin tule perch (*Hysterocarpus traskii traskii*)

Notably, there is a potential for future listings of Pacific and river lamprey. These lamprey are known to occur in the Delta and river lamprey have been encountered during monitoring. Although not currently protected under ESA or CESA, lamprey are recognized by USFWS and others as species that require greater conservation efforts. Both species were petitioned for listing under the ESA in 2004 but 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. The lamprey collected in the fish community samples (in 2006 and 2007) and fish entrainment samples (in 2006, 2007, and 2008) have been confirmed as river lamprey, a rare species that has not been well studied. Lamprey specimens from 2008 sampling have been submitted to the USFWS for ongoing genetic analyses. Nearly half of all lamprey were positively identified as river lamprey in 2008, with the remaining specimens identifiable only to the genus or family level.

Reporting requirements for the 2008 monitoring effort included reporting to both the Corps and the Interagency Ecological Program (IEP) on a regular basis, including midseason catch summaries, weekly reporting of ESA catch, and annual monitoring reports. Reporting requirements are further discussed in Section 3.6. Midseason catch summaries were provided to the Corps at their request. Weekly reporting of ESA catch, including weeks when no sampling occurred, was made to IEP via the ESA reporting website for research projects in the Bay-Delta region (CDFG 2008a). Resource agencies including NMFS, USFWS, and CDFG have access to the IEP database for the weekly updated ESA catch reports. Annual monitoring reports are provided to the Corps and CDFG. The license and revenue branch of CDFG requires an annual collection summary in order to renew the state scientific collecting permits (SCP) every two years, which is submitted to Paul Roberts or Russ Bellmer at CDFG (Sacramento). Additional reporting requirements have been added to the renewal of 2008 SCPs.

This report describes fish species collected at each dredging location and compares sites based on simple assessments of catch per unit effort (CPUE), species composition, and overall numbers of fish collected. Although species that do not have special status under federal law are outside the monitoring requirements for dredging in 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.

3 Materials and Methods

3.1 Sampling Methods Overview

Sampling methods for the 2008 SRSC and SSC maintenance dredging monitoring program followed those presented in the fish entrainment and fish community monitoring plan (FMP) for 2007–2008 (SWCA 2007). The following methods were used based on their appropriateness for sampling the dredging locations (i.e., dredging in deep water mid-channel locations with water column depths greater than 20 feet). The methods used were:

- Bottom trawling against the current, to monitor the fish community in the active dredge area of the shipping channels. Water quality parameters were measured in conjunction with the bottom trawling.
- Entrainment sampling cell method, to monitor fish entrained by the dredging operation.
- Entrainment monitoring using the portable entrainment monitoring screen.

Timing of 2008 dredging operations did not extend outside the approved work window; consequently observational monitoring 24 hours a day aboard the dredge was not necessary as in 2006 and 2007.

All fish collected in the bottom trawl or entrainment screen and nets were counted and identified to the species level, with some exceptions. Twelve juvenile lamprey and five post-larval gobies were identified to genus level. Eight post-larval fish were collected and identified to family level as Centrarchidae (bass and sunfishes) or Moronidae (striped bass) eliminating the possibility of these fish being special-status species. Some of the unidentified lamprey were observed in entrainment but escaped sampling gear prior to further species determination. Other lamprey were damaged severely following entrainment by the dredge and could not be properly identified. Preserved lamprey specimens were shipped to USFWS taxonomy experts in Arcata, California, for inclusion in ongoing genetic studies and further species identification. Invertebrates were identified to the highest taxonomic resolution feasible in the field, usually genus.

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-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 dredged material placement (DMP) sites is often an indicator 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 prey for sea lions.

3.2 Sampling Effort, Timing, and Sampling Locations

An overview of the 2008 fish community and entrainment sampling locations corresponding to dredging locations is provided in Figure 1. Location data and activity periods are also summarized in Table 1. Prior to the 2008 dredge season, RISG provided SWCA with a tentative dredging schedule. The schedule included the approximate timing and location of each channel location (dredge reach) to be dredged. Due to the inherent uncertainty regarding exact timing of initiation of dredging, fish community sampling was initiated within 24 hours of when dredging actually commenced. Entrainment sampling was usually conducted on the second day of dredging at each dredge reach. As a result, fish community and entrainment sampling typically occurred on alternate days.

The methods defined in the fisheries monitoring plan 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. Ten of 47 trawl surveys were conducted during low light or nighttime conditions. Most entrainment observations occurred during daylight hours due to logistical, operational, and safety issues. Seven of 46 entrainment samples were conducted in low light or nighttime conditions.

Entrainment sampling ponds were constructed at the Bradford Island and Decker Island DMP sites; a mobile entrainment screen was used at all other DMP sites. Both methods were effective in sampling the dredge discharge slurry passing through the screen or net into the DMP site. Figures 2 through 10 show locations of the individual DMP sites used in 2008 and corresponding trawl track information. Effort levels for 2008 are summarized by monitoring method and presented in Tables 2 and 3. These tables present the level of effort attempted versus achieved during both entrainment and community sampling. Entrainment sampling was disrupted on several occasions in 2008, usually the result of unexpected dredge shutdowns (related to dredge operations, not monitoring activities). The goal for entrainment sampling was to sample at least 5% of the overall dredge output based on an average dredge run time of 20 hours per day. Overall success was much higher than in 2007 because of the mobile entrainment screen. Overall, 4.4% of total dredge output was sampled in 2008 compared to 0.35% in 2007 and 0.37% in 2006. In these two previous years, only the sample cell method was used. Each sampling attempt was considered successful in 2008 because at least some portion of the dredge output was monitored on all occasions.

Trawling locations within each dredging reach were either directly upriver of the dredge during an outgoing or ebb tide or directly downriver during and incoming or flood tide. Figures 2 through 10 display the 2008 trawling locations and the corresponding dredging reaches. Unsuccessful trawl tows, such as those experienced on three occasions in the Port of Stockton, were the result of the net hanging up on large wood or other debris, 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 would be noted as unsuccessful in the database and excluded from further analyses. Unsuccessful trawl attempts were repeated until a successful sample was made.

Table 1. Stockton and Sacramento Deepwater Ship Channel 2008 Maintenance Dredging Locations

River Channel	Dredge Reach	Dredge Area (River Mile)		Excavated Dry Material (cy)	Estimated Material % of Slurry	Estimated Total Slurry Volume (gal)	DMP Site	Time Frame	
		From	To					Start	End
Sacramento	Man-made Channel	32.86	33.92	42,844	15.0	49,042,099	S-31	Aug 1	Aug 7
Sacramento	Rio Vista	10.14	10.34	14,910	12.5	21,082,740	Sandy Beach	Aug 10	Aug 13
Sacramento	Decker Island	6.02	8.33	67,559	10.0	122,822,262	Decker Island	Aug 18	Sept 6
San Joaquin	West Island Antioch Bridge	5.49	9.51	79,390	10.0	144,331,020	Scour Pond	Sep 11	Sept 27
San Joaquin	Light 19 Reach	10.97	11.34	30,188	12.5	42,685,832	McCormick Pit	Sept 30	Oct 4
San Joaquin	Bradford	13.45	13.64	18,957	12.5	26,805,198	Bradford Island	Oct 7	Oct 13
San Joaquin	Port of Stockton	36.72	38.45	106,964	15.0	122,438,125	Roberts Island	Oct 16	Nov 7
San Joaquin	Sediment Trap	39.73	39.96	107,460	12.5	151,948,440	Roberts Island	Nov 9	Nov 25

Table 2. 2008 Entrainment Monitoring Effort at DMP Sites

DMP Site Name, River	Date Start	Date End	Sampling Days	Sampling Attempts	Successful Events	Material Type	Sampled Vol. (gal)	Dredge Slurry Vol. (gal)	Sample %
S-31, SRSC	Aug. 1	Aug. 7	3	3	3	Mud	1,235,989	57,695,474	2.14%
Sandy Beach, SRSC	Aug. 10	Aug. 13	2	2	2	Sand	690,683	24,094,173	2.87%
Decker Island, SRSC	Aug. 18	Sept. 6	7	8	8	Sand	1,045,058	136,467,425	0.77%
Scour Pond, SSC	Sept. 11	Sept. 27	9	11	11	Sand	8,362,443	160,365,738	5.21%
McCormick Pit, SSC	Sept. 30	Oct. 4	2	2	2	Sand	2,572,943	48,783,024	5.27%
Bradford Island, SSC	Oct. 7	Oct. 13	3	3	3	Sand	150,852	30,634,020	0.49%
Roberts I, SSC Port of Stockton	Oct. 16	Nov. 7	8	8	8	Mud	9,234,223	144,042,075	6.41%
Roberts I, SSC Sediment Trap	Nov. 9	Nov. 25	9	9	9	Sand	10,813,011	173,652,569	6.23%
Total							34,105,201	775,734,498	4.40%

Table 3. 2008 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 – Port of Sacramento	SRSC	S-31	Aug. 1	Aug. 7	3	6	6	3,094
Rio Vista	SRSC	Sandy Beach	Aug. 10	Aug. 13	2	10	10	4,998
Natural Channel	SRSC	Decker Island	Aug. 19	Sept. 7	8	30	30	15,624
Antioch – West Island – Antioch Bridge	SSC	Scour Pond	Sept. 11	Sept. 27	9	42	42	21,822
Light 19 Reach	SSC	McCormick Pit	Sept. 30	Oct. 4	3	15	15	7,647
Sherman-Bradford	SSC	Bradford Island	Oct. 7	Oct. 13	4	18	18	9,229
Port of Stockton – Rough & Ready Island	SSC	Roberts Island	Oct.16	Nov. 8	8	40	39	19,861
Port of Stockton – Sediment Trap	SSC	Roberts Island	Nov. 9	Nov. 25	9	47	45	22,141

3.3 Fish Community Sampling

Fish community sampling followed all relevant regulations and protocols to ensure ESA 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 2007-113. Prior to the onset of the 2008 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. Prior to each trawling effort for fish community sampling, the U.S. Coast Guard (USCG) and San Francisco Bay Vessel Traffic Information were made aware of SWCA's activities to help ensure the safety of the sampling vessel and other vessels in the area. Communication with the dredge was maintained through use of VHF marine band radio to ensure that the timing, methods, and location of trawling efforts did not hinder or compromise the dredge's operations or endanger personnel. The USCG required one VHF radio dedicated to the Vessel Traffic Information Channel; thus, two VHF radios were operated during all trawl sampling events, one to monitor vessel traffic and one to remain in constant communication with the dredge. 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 2008 sampling was a green, funnel-shaped net constructed with a 7-meter-long floating headrope, a weighted footrope, and doors attached just ahead of the net mouth to spread the net (Figure 11). The mouth of each trawl net used in 2008 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% of the maximum stretched mouth area. The stretched mouth area was calculated as a rectangular shape totaling 9.875 square meters, with an 80% 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 vessel was modified to include an A-frame and electronic windlass to aid in net deployment and retrieval (Figure 12). The A-frame allowed 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 in 2007 and 2008 resulted in fewer net twists and unsuccessful tows than in 2006. The A-frame system provided the crew with increased ability to observe and control the net as it was deployed, and it increased the speed at which the net and bridle material could be managed.

A 250-foot-long bridle was used between the net and the vessel in order to achieve a 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 were conducted for each fish community sampling event. The direction of each individual tow was determined by 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 Lowrance global positioning system (GPS) chart plotter that logged vessel position, distance, bearing, and other information. Information from the GPS unit was uploaded in real time to a portable Toughbook computer (see Figure 12) running NobleTec navigation software to create vessel tracks of the trawl locations. The NobleTec software also displayed real-time (predicted) tidal information that was recorded for each trawl, including current velocity and direction.

The length in meters of each tow was the distance that the net was fished along the river bottom measured using the vessel track information collected from the GPS. Tracking began when the otter trawl encountered the bottom and ended when the trawl tow was stopped prior to the vessel retrieving the net, providing an accurate measure of the real time and distance that the net was fished on the channel bottom. The vessel speed during net deployment was adjusted so that the vessel did not move forward over the bottom until the net was on the bottom. During retrieval, the vessel was maneuvered directly over the net's position on the bottom, and field personnel hauled the net directly upward through the water column. These methods were employed to concentrate on demersal species and minimize collection of fish associated with the water column and the surface.

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 (see Figure 12). Assessment involved a quick inspection and then rapid removal of the most fragile species to minimize mortality. Data were collected on individual fish specimens, which were then released back to the river outside the assessed channel area.

Trawl catch was sorted and counted as described above. Special-status species were quickly documented and, if alive, were released prior to documenting the remaining catch. Some special-status species—delta smelt, longfin smelt and lamprey—were required to be vouchered for research purposes, regardless of capture disposition. Additional data recorded for each trawl included GPS waypoints for beginning and end of tow; tow duration; date and time; sampling depth; tidal phase; current speed and direction; boat speed and engine rpm; bird activity; direction of water flow (upstream or downstream); and channel location. Water quality data were collected (upstream from the dredge) before the first and last tows of each fish community sampling event. Water quality monitoring and methods are described further in Section 2.5.

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 mobile entrainment screen was completed and used at all DMP sites, with the exception of the Bradford and Decker Island sites.

3.4.1 Sampling Cells

The sampling cell method used for fish entrainment monitoring is based on a method employed by Buell (1992). Entrainment monitoring with the sampling cell method involves discharging the slurry flowing from the dredge pipeline into a relatively small sampling cell. The cell is isolated from the overall DMP site pond by a temporary berm (Figure 13). Sampling cells varied in size from 0.12 acres at Bradford Island DMP site to 0.24 acres at Decker Island 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. At Decker Island, the cell method was used in sampling 0.77% of the overall dredge output. At Bradford, 0.49% of the dredge output was sampled. For each DMP site, the 2008 sampling rate was higher than the average proportion of 0.35% sampled using this method in 2007. The overall proportion of dredge output sampled at sites using only the cell method was 0.62% of the total volume in 2008.

A splitter valve was employed at the Bradford and Decker Island DMP sites to transfer the entire volume of the dredge slurry to the sampling cell (Figure 14). The entrainment sampling process was initiated by switching the Y-valve lever to direct flow through the sampling cell. When the sampling cell approached full capacity, the valve was switched to direct flow back to the main DMP site pond. The duration of discharge into the sampling cell was timed in order to calculate the volume of material sampled based on the dredge pumping rate.

One or two weir box structures with 30-inch culverts were installed at the downstream end of the sampling cells at the DMP sites. Stop boards were placed in each weir structure to control volume and velocity of the slurry leaving the sampling cell. The outlet of each culvert/weir structure was at the level of the bottom of the sampling cell, allowing the pond to drain completely to the main DMP site when the stop boards were removed. The number of weirs used varied according to DMP site constraints. The use of two weirs allowed for quicker draining of the sample cell and processing of material. At the Decker Island DMP site, only one weir could be used; consequently, the volume of material sampled was lower than at Bradford Island. Two weirs were used at the Bradford Island DMP site.

The cells were filled with dredged material from the discharge pipe and allowed to drain through the weirs into a sock-shaped hoop net attached to the back of the weir(s). The specially designed net (see Figure 13) was attached to the terminus of each culvert discharge pipe to capture any entrained fish moving over the weir structure and through the culvert with the slurry material. The net ensured that any dredge-entrained organisms were collected in the nets before entering the main DMP site. The entrainment sampling nets were cylindrical in shape, 15 feet in length (4.57 meters), and 3 feet (0.914 meter) in diameter at the mouth tapering to 1.5 feet (0.457 meter) in diameter at the cod end. The nets were constructed of soft, knotless mesh to minimize damage to fish. Mesh size of the nets ranged from 0.5 inch (12.7 mm) at the mouth to 0.25 inch (6.35 mm) at the cod end. A zipper through the 0.25-inch portion of the net was installed to allow removal of debris, sediment, and entrained organisms. A canvas collar was sewn onto the opening of the net to allow the net to be secured to the culvert outlet. Nets were secured to the culvert with a stout rope or a ratcheting nylon strap.

The material retained in the net was closely examined and any organisms removed. Fish and invertebrates were identified and enumerated. Live fish were placed in plastic totes filled with river water and returned to the river after processing the catch. It is possible that some fish or invertebrates were damaged and were not identifiable in the net. It is also possible that some live organisms were mired in the bottom of the cell and not enumerated. The bottom of the cell was observed after each filling and emptying cycle to attempt to account for these organisms. One fish was collected from the sampling cell bottom over the course of the 2008 entrainment sampling, and it is unlikely that a substantial number of entrained organisms were buried and retained in the cells.

A portable, high-pressure water pump fitted with a screened inlet and 0.75-inch outlet hose delivered fresh river water to the sampling cell site for use in sample washing and processing. Bird activity was noted and a visual survey was performed during each sampling event to determine if any specimens were remaining in the DMP site that were not captured in the net or the screen.

The length of time required to process each entrainment sample varied according to the capacity of the sampling cell and the length of time needed to drain the cell dredge slurry material after filling. Deposition of sediments occurred with each cell filling cycle thus decreasing the capacity of the sampling cell during subsequent fill cycles. Stop boards were removed one by one to allow the slurry to pass over the weir at a rate slow enough to prevent clogging of the small mesh in the nets. In areas where substrates were dominated by sand, the steps of draining the cell, sorting through the material, and processing the samples required approximately two hours. When high volumes of organic material were encountered, sample processing times were generally three to five hours.

Mobile Entrainment Screen

The mobile entrainment screen (screen) was put into action during the 2008 monitoring season with the goal of retaining all life stages of entrained organisms, except larval fishes, while also allowing large volumes of sediment to pass through the mesh.

The screen unit is mounted on trailer axles and can be transported by road from site to site. Once on site, the screen was positioned in a stable location that cantilevered over the DMP site (Figure 16). The dredge output pipe was connected to the top of the screen with a Y-valve (see Figure 14) operated by the dredge's on-shore 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 (Figure 17). Heavy equipment was used to clear material periodically below the screen to avoid erosion under the axles and direct the slurry into the DMP site.

The screen operates 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 percent of dredge output sampled. 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 or the dredge itself shut down. Biologists manipulated and sorted the screened materials with large rubber squeegees, small nets, and various rakes and shovels, allowing for longer periods of continuous monitoring of the discharge stream.

The screen surface is 20 feet long by 6 feet wide (Figure 15). Design adaptations were made during the 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
- Install a round-hole screen mesh to minimize loss of small organisms, reduce debris clogging, and increase survival of entrained fish

Two types of screen grating were used during 2008 monitoring. Initially, a ⅜-inch mesh woven steel wire with alternating ⅜-inch squares and ⅜-inch by 4-inch rectangles (Figure 18) was used. The woven wire screen was used between August 1 and October 20 at S-31, Sandy Beach, Scour Pond, McCormick Pit, and the first two entrainment samples at the Roberts 1 DMP site. The 11-gauge wire (0.12-inch-diameter) screen had a variable open area of approximately 50% to 60%. The refined version of the entrainment screen was installed and used for the remainder of the season at the Roberts DMP site (see Figure 18). The screen consists of ½-inch smooth perforated stainless steel plate with staggered ⅜-inch-diameter round holes with an effective open area of 51%.

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 YSI MP-556 portable water quality meter (Figure 19). Parameters measured included water temperature, dissolved oxygen, pH, conductivity, and salinity. Turbidity samples were collected from the surface and near the bottom using a Van Dorn-style water sampler. Turbidity was measured using a calibrated Hanna Model HI93703 turbidity meter. Water clarity during daytime sampling events was measured using a Secchi disk. Sampling was performed upstream from dredging activities to avoid dredge influence on water quality measurements.

3.6 Data Analysis, Reporting, Quality Assurance, and Quality Control

3.6.1 Fish Entrainment

Overall entrainment rates were estimated for each species by extrapolating the numbers of entrained fish observed in the sampling, to the overall volume of pumped material. 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 estimates that final deposited material comprised 10% to 15% of total slurry volume per DMP site.

Entrainment rates for specific species were extrapolated for each location where entrainment occurred during 2008 monitoring. This data should be assessed cautiously considering the small percentage of the dredge output used to calculate the overall entrainment rates. This caution is particularly relevant for data obtained using the sampling cell method. The overall percentage of dredge material sampled in 2008 increased to 4.4% from 0.35% in 2007. Extensive statistical modeling would help predict future entrainment rates, but at this time, there is not sufficient data available from this study. Furthermore, the fish populations of the Delta change rapidly, which further limits the creation of such models.

3.6.2 Fish Community Sampling

Relative population abundance for each sampled location, each channel, and both channels combined was determined by ranking each species based on total numbers of individuals collected in all trawls. The CPUE was determined by comparing numbers of individual fish collected to distance trawled.

3.6.3 Mortality Estimation

Percent mortality was calculated by comparing the observed mortality for each species to the total number of mortalities across all species. 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 Section 6 and Section 7 of this report.

3.6.4 Reporting

Reporting requirements for the 2008 monitoring effort included reporting to both the Corps and the IEP on a regular basis. Midseason catch summaries were provided to the Corps at their request. Weekly reporting of ESA catch, including weeks when no sampling occurred, was made to IEP via the ESA reporting website for research projects in the Bay-Delta region (CDFG 2008a). Resource agencies including NMFS, USFWS, and CDFG have access to the IEP database for the weekly updated ESA catch reports. Annual monitoring reports are provided to the Corps and CDFG. The license and revenue branch of CDFG requires an annual collection summary in order to renew the state SCPs every two years, which is submitted to Paul Roberts or Russ Bellmer at CDFG (Sacramento). Additional reporting requirements have been added to the renewal of 2008 SCPs. A report of rare native species is submitted to the California Natural Diversity Database. Reporting requirements under IEP have been modified for 2009 to incorporate new take restrictions for program elements under their jurisdiction.

3.6.5 Data Management

Data were documented in the field on paper data sheets and in the customized SWCA Dredge Monitoring Database created with Microsoft Access 2003. 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 the analytical tools to assess the data based on CPUE, species composition, and the overall number of fish collected.

Statistical Analysis

Catfish Entrainment and Community Sampling

Channel catfish and white catfish lengths were analyzed using unequal variance t-tests to determine if there was a significant difference in the size of fish entrained by the suction dredge and fish collected during community sampling. Separate tests were performed on each species. This test assumes the following: the sample size (n) is of sufficient size, the distribution is approximately normal, and the data do not contain outliers (Moore 1995). Also, both populations should have approximately similar variances and should be sampled independently. A non-parametric Mann-Whitney Rank Sum Test was performed to validate the results of the t-test when the data did not pass the Shapiro-Wilk normality test. A Mann-Whitney Test is useful when data are not normally distributed and is tested in terms of the median rather than the mean (Moore and McCabe 1993).

Demersal and Non-demersal Fish

A z-test for proportions was performed to determine if there was a significant difference in the proportion of demersal (bottom-oriented) species entrained by the suction dredge (sample) compared to the proportion of demersal fish in the community (population). The population proportion was determined by fish community (trawl) sampling and was compared to the total proportion observed in entrainment monitoring across all sites. Site specific analyses were conducted for sites with sufficient sample size. The sample size was considered sufficient when $(np) > 10$ and $n(1-p) > 10$. The z-test also assumes a simple random sample (Moore and McCabe 1993). A Yates Correction Factor was applied to the z-test, which makes the test more conservative and reduces the chance of a false positive conclusion.

Quality Assurance and Quality Control

In addition to saving time in the field, the project database provides a key step in quality assurance and quality control. Data entry forms were created to ensure consistency in data collection. These entry forms restrict the type of information being entered into the database, through focused user inputs and menus. In previous years, hardcopy data forms were used in conjunction with electronic entry forms created in the database.

In addition to focused inputs and menus to control data entry, Microsoft 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. The database was also backed up nightly on an external computer drive and copied to an office computer to further ensure integrity of collected data. Field crews were trained on the data collection forms before monitoring or sampling was carried out. Paper data collection forms will continue to be used for data verification when time is an issue or another form of documentation is needed (i.e., the collected specimen portion of the trawl survey).

Starting in 2007, all data were recorded on paper forms, as well as directly into the database while in the field. In 2006 all field data were collected on paper and, at a later date, entered into the database. Data entered into the database were cross-checked against paper forms collected in the field (SWCA 2007). As samplers became more confident with the electronic entry forms, all data (except specimen data for each trawl replicate) were recorded directly in the database while in the field. Field crews also made daily checks to ensure that the data were entered directly and accurately into the database without redundant paper copies, as specified in the 2007–2008 FMP (SWCA 2007).

Data verification was performed for specimen, trawl mortality, and water quality information. Over 90% of the specimen data entered electronically into the database was cross-checked with the specimen data collected on paper data sheets in the field. Several transcription errors were identified and corrected through this data verification process.

Water quality database results were checked against paper copies for three water quality data collection events. The final summary reports for water quality data were cross-checked by the biologists who collected the data to ensure the data fell within the acceptable range for parameters of the subject waterbody. Dates were checked against associated trawl data entries since water quality data were collected only on days when trawl surveys were conducted.

Specimen data, consisting of species of organism, enumeration, length, anomalies, life history stage, and disposition, were collected on paper field forms, because speedy data collection was often required when large numbers of fish and invertebrates were encountered. These data were entered into the database at a later time. 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 SWCA's office in Portland, Oregon.

Field GPS data identifying boat location were logged continuously by the Lowrance GPS and stored on the portable field computer running NobleTec navigation software. The vessel tracks of the trawl locations were recorded in a separate database to determine trawl distance and location. The vessel tracks were checked to ensure accuracy and identify anomalies that may skew the data. The real-time data associated with the trawl tracks were then cross-referenced with the continuous vessel tracking system to provide concurrence of location and supplemental information for any gaps in data for the collected vessel tracks.

4 Results

4.1 Fish

A total of 7,637 individual fish representing 26 species were collected and identified during the fish community and entrainment sampling events in 2008 (Table 4). Of the 26 species encountered, 16 were introduced and 10 were native. Native fishes made up 0.88% of the total number of fish collected. The three most abundant species were white catfish, threadfin shad, and striped bass. All three species are non-native and accounted for 78.84% of the total catch.

Delta smelt was the most abundant native species encountered during trawling in 2008 and was represented by 25 individual fish, followed by longfin smelt with 21 individuals. Thirty-one lamprey were encountered during sampling, all of which were collected during entrainment sampling. Sixteen of the lamprey were unidentified and 15 have been positively identified as river lamprey. Of the unidentified lamprey, those that could be identified were all resolved to genus *Lampetra*. Within the Sacramento and San Joaquin River basins, this genus is represented by three species: river lamprey (*L. ayresii*), western brook lamprey (*L. richardsoni*), and Kern brook lamprey (*L. hubbsi*). In contrast, within this same geographic region, the genus *Entosphenus* is represented by one species: Pacific lamprey (*E. tridentata*). All identifiable juvenile lamprey collected in 2007 as well as those collected in 2006, were positively identified as river lamprey.

Table 4. Ranked List of All Fish Collected from All Locations during 2008 Fish Community and Entrainment Monitoring

Rank	Percent	Number	Common Name	Genus	Species	Origin	Rule: Status *
1	42.87	3,274	white catfish	*Ameiurus*	*catus*	Introduced	
2	21.29	1,626	threadfin shad	*Dorosoma*	*petenense*	Introduced	
3	14.68	1,121	striped bass	*Morone*	*saxatilis*	Introduced	
4	9.28	709	American shad	*Alosa*	*sapidissima*	Introduced	
5	8.17	624	channel catfish	*Ictalurus*	*punctatus*	Introduced	
6	0.64	49	yellowfin goby	*Acanthogobius*	*flavimanus*	Introduced	
7	0.52	40	shokihaze goby	*Tridentiger*	*barbatus*	Introduced	
8	0.33	25	delta smelt	*Hypomesus*	*transpacificus*	Native	ESA: FT CESA: SE IUCN: EN
8	0.33	25	shimofuri goby	*Tridentiger*	*bifasciatus*	Introduced	
9	0.27	21	longfin smelt	*Spirinchus*	*thaleichthys*	Native	CESA: ST DFG: SSC
10	0.24	18	wakasagi	*Hypomesus*	*nipponensis*	Introduced	
11	0.20	15	river lamprey	*Lampetra*	*ayresii*	Native	DFG: SSC
12	0.18	14	starry flounder	*Platichthys*	*stellatus*	Native	MSA: MEC-EFH
13	0.14	11	blue catfish	*Ictalurus*	*furcatus*	Introduced	
14	0.13	10	unidentified lamprey	*unknown*	*unknown*	Native	
15	0.10	8	warmouth	*Lepomis*	*gulosus*	Introduced	
16	0.09	7	brown bullhead	*Ameiurus*	*nebulosus*	Introduced	
16	0.09	7	white sturgeon	*Acipenser*	*transmontanus*	Native	IUCN: LC
17	0.08	6	lamprey	*Lampetra*	spp.	Native	
17	0.08	6	Pacific staghorn sculpin	*Leptocottus*	*armatus*	Native	
18	0.07	5	unidentified goby spp.	all	spp.	Introduced	
19	0.05	4	bluegill	*Lepomis*	*macrochirus*	Introduced	
19	0.05	4	Sacramento splittail	*Pogonichthys*	*macrolepidotus*	Native	DFG: SSC IUCN: EN
20	0.03	2	prickly sculpin	*Cottus*	*asper*	Native	
20	0.03	2	Sacramento blackfish	*Orthodon*	*microlepidotus*	Native	
21	0.01	1	bigscale logperch	*Percina*	*macrolepida*	Introduced	
21	0.01	1	common carp	*Cyprinus*	*carpio*	Introduced	
21	0.01	1	Inland silverside	*Menidia*	*beryllina*	Introduced	
21	0.01	1	tule perch	*Hysterocarpus*	*traskii*	Native	
Total Fish:		7,637					

* 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
DFG: 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

Other native fish collected in 2008 that were not encountered in 2007 were Sacramento blackfish, tule perch, Pacific staghorn sculpin, and prickly sculpin. Photos of native species collected during community sampling are shown in Figure 20. One Sacramento blackfish, 61 tule perch, and 25 prickly sculpin were collected in 2006. Two green sturgeon and one Sacramento pikeminnow were collected in 2006, but none have been encountered since that time. New non-native fish captured in 2008, but not in 2007, consisted of shokihaze goby, wakasagi, warmouth, bluegill, bigscale logperch, and inland silverside. Black crappie was the only fish caught in 2007 that was not observed in 2008.

The most common fish in the community monitoring was the white catfish (43.96%); however, the most common fish observed in entrainment monitoring was channel catfish (62.2%). Channel catfish comprised only 6.13% of the catch during community sampling. Photos of specimens collected during entrainment monitoring are presented in Figure 21.

Introduced species of fishes dominated the catch from all locations in 2008 as in 2007. As in 2006 and 2007, very few native fish were collected in the Port of Stockton reach (Figure 22). In 2008, Decker Island had the highest proportion of native species, as in 2006. In 2007, the Scour Pond area had the highest native fish percentage. The variation found at these sites is discussed in more detail in Section 4.3.

4.1.1 Special-status Species

Ten species of native fish were collected in 2008, compared to six species in 2007. Longfin smelt and delta smelt were both encountered in 2008 and have received CESA or ESA status (CDFG 2008b,c). Catch data for both of these species is provided in Appendix D. Many of the other native species encountered are afforded special status by other entities or are presently petitioned for special status under ESA, CESA, or both (see 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.

Delta smelt was the only federally listed fish species captured during 2008 fish community monitoring. Delta smelt and longfin smelt were the most commonly collected special-status species. Twenty-one longfin smelt were captured during trawl surveys, all from the Sacramento River near Decker Island, during late August to early September.

Starry flounder was the thirteenth most commonly encountered fish species in 2008 and the fourth 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).

No federally listed fish species were encountered during 2008 entrainment monitoring, although two native fish species, lamprey and Pacific staghorn sculpin, were observed. Together, there were 33 specimens of these two species encountered during entrainment monitoring.

4.2 Entrainment Monitoring

Entrainment monitoring for 2008 was completed using two methods, the sample cell method and the mobile entrainment screen. The sample cell method was used at the Decker Island and Bradford DMP sites. A total of 16 fish were captured using the sample cell method (14 lamprey and two white catfish). The entrainment screen was used at all other sites and greatly increased the sampling efficiency over the sample cell method. A total of 262 fish were captured using the entrainment screen. The results from 2008 entrainment screen and sample cell catch were combined (Table 5).

Table 5. Ranked List of All Fish Collected During 2008 Entrainment Monitoring

Rank	Percent	Total	Common Name	Genus	Species	Native
1	62.23	173	channel catfish	*Ictalurus*	*punctatus*	Introduced
2	14.03	39	white catfish	*Ameiurus*	*catus*	Introduced
3	5.40	15	river lamprey	*Lampetra*	*ayresii*	Native
4	3.60	10	unidentified lamprey	unknown	unknown	Native
5	3.24	9	yellowfin goby	*Acanthogobius*	*flavimanus*	Introduced
6	2.52	7	shokihaze goby	*Tridentiger*	*barbatus*	Introduced
7	2.16	6	shimofuri goby	*Tridentiger*	*bifasciatus*	Introduced
7	2.16	6	lamprey	*Lampetra*	spp.	Native
8	1.44	4	brown bullhead	*Ameiurus*	*nebulosus*	Introduced
8	1.44	4	striped bass	*Morone*	*saxatilis*	Introduced
9	0.72	2	Pacific staghorn sculpin	*Leptocottus*	*armatus*	Native
10	0.36	1	bluegill	*Lepomis*	*macrochirus*	Introduced
10	0.36	1	threadfin shad	*Dorosoma*	*petenense*	Introduced
10	0.36	1	warmouth	*Lepomis*	*gulosus*	Introduced
Total		278				

As listed in Table 1, a total of approximately 468,272 cubic yards of dredged material was placed at the DMP sites during 2008. Approximately 342,959 cubic yards were dredged in the SSC and 125,313 cubic yards in the SRSC. All material was dredged using RISG Dredge No. 7, a hydraulic cutterhead suction dredge with an 18-inch (inside diameter) discharge pipe. The total overall estimated water output from the dredge was 681 million gallons. The approximate average pumping rate by location varied from 5,802 to 10,337 gallons per minute.

Overall, 278 fish were observed during entrainment monitoring in 2008. Table 6 shows the extrapolated counts based on observed catch as a function of overall percentage of the dredge output sampled at each location. Based on these extrapolations, a total of approximately 6,483 fish may have been entrained by dredging operations in 2008. Channel catfish were estimated to be 42.99% of the total predicted catch. Lamprey species had the second highest predicted entrainment, with a predicted 33.60% of the total extrapolated catch. In 2007, 3,286 fish were predicted in entrainment from extrapolated counts, with channel catfish again, making up the bulk of the catch. Lamprey were not observed in entrainment in 2007 though lamprey macropthalmia were collected in trawl sampling that year.

S-31 (SRSC): Substrates in the man-made reach of the SRSC were primarily light mud. Approximately 1,235,988 gallons, or 2.14% of the total slurry volume, were sampled during the three entrainment events conducted at this site. A total of four fish were observed in the entrainment monitoring, one each of the following: channel catfish, striped bass, lamprey (unidentified), and shimofuri goby. Therefore, it is predicted that approximately 188 fish may have been entrained by the dredge at this site in 2008.

Sandy Beach (SRSC): Substrates in the Rio Vista reach of the SRSC were primarily sand. Approximately 690,683 gallons, or 2.87% of the total slurry volume, were sampled during the two entrainment events conducted at this site. One lamprey of the genus *Lampetra*, one unidentified lamprey, and one white catfish were observed in the entrainment monitoring, therefore it is predicted that approximately 105 fish may have been entrained by the dredge at this site in 2008.

Table 6. Extrapolated Fish Entrainment Catch for 2008 by Location and Species

	SRSC			SSC					Total
	S-31	Sandy Beach	Decker Island	Scour Pond	McCormick	Bradford	Roberts - Port of Stockton	Roberts - Sediment Trap	
%Sampled	2.14	2.87	0.77	5.21	5.27	0.49	6.41	6.23	4.40
bluegill							16		16
brown bullhead							32	32	64
channel catfish	47						826	1,914	2,787
lamprey (unidentified)	47	35	393	19				80	574
lamprey (*Lampetra* spp.)		35	131				16	48	230
river lamprey			1,310					64	1,374
Pacific staghorn sculpin				38					38
shimofuri goby	47						94		141
shokihaze goby				115			16		131
striped bass	47			38					85
threadfin shad							16		16
warmouth							16		16
white catfish		35	262				453	112	862
yellowfin goby				38			63	48	149
Total	188	105	2,096	248	0	0	1,548	2,298	6,483

Note: Gray shading indicates introduced species.

Decker Island (SRSC): Substrates in the Decker Island reach of the SRSC varied from sand to silty sand. Approximately 1,045,058 gallons, or 0.77% of the total slurry volume, was sampled during the eight entrainment events conducted at this site. A total of 16 fish (lamprey and white catfish) were observed in the entrainment monitoring; therefore it is predicted that approximately 2,096 fish may have been entrained by the dredge at this site in 2008. The sample cell method was used at this location because the mobile screen could not be transported to the DMP site.

Scour Pond (SSC): Substrates in the Antioch / West Island reach of the SSC were primarily sand. Approximately 8,362,442 gallons, or 5.21% of the total slurry volume, were sampled during the 11 entrainment events conducted at this site. A total of 13 fish were observed in the entrainment monitoring, including native lamprey and sculpin, and non-native striped bass, shokihaze and yellowfin goby. Extrapolation predicted that approximately 248 fish may have been entrained by the dredge at this site in 2008.

McCormick Pit (SSC): Substrates in the Light 19 reach, just upstream from Antioch, in the SSC were primarily sand. Approximately 2,572,942 gallons, or 5.27% of the total slurry volume, was sampled during the two entrainment events conducted at this site. No fish were observed in the entrainment monitoring, therefore it is predicted that zero fish were entrained by the dredge at this site in 2008.

Bradford Island (SSC): Substrates in the Bradford Island reach of the SSC were primarily sand. Approximately 150,852 gallons, or 0.49% of the total slurry volume, were sampled during the three entrainment events conducted at this site. No fish were observed in the entrainment monitoring; therefore it is predicted that zero fish were entrained by the dredge at this site in 2008. The sample cell method was used at this location in 2008, resulting in lower overall sample size.

Roberts – Port of Stockton (SSC): Substrates in the Port of Stockton-Rough and Ready Island reach of the SSC were primarily mud, with some organic material. Approximately 9,234,222 gallons, or 6.41% of the total slurry volume, were sampled during the eight entrainment events conducted at this site. A total of 99 fish from nine different non-native species and one native lamprey were observed in entrainment samples (see Table 6). The greatest number of fish species was encountered during entrainment monitoring from this lower reach near the Port of Stockton. It is predicted that approximately 1,548 fish may have been entrained by the dredge at this site in 2008.

Roberts – Sediment Trap (SSC): Substrates in the Port of Stockton / Sediment Trap reach of the SSC were primarily sand, with some organic material. Approximately 10,813,010 gallons, or 6.23% of the total slurry volume, was sampled during the nine entrainment events sampling the upper Port of Stockton reach. A total of 143 fish were observed in the entrainment monitoring; therefore it is predicted that approximately 2,298 fish may have been entrained by the dredge at this site in 2008.

4.3 Fish Community Monitoring

The following sections describe the fish community sampling results for both shipping channels and individual dredge locations (see Table 4). Figure 22 depicts the percentage of native versus non-native fish collected during fish community sampling in each dredging reach in 2006, 2007, and 2008. Table 7 summarizes the catch and effort data for fish collected by trawling in 2008 and provides a description of fish density at the trawl locations through the CPUE metric of number of fish collected per linear meter towed along the bottom.

Table 7. Summary Data of Catch and Effort for Fish Collected in 2008 Fish Community Trawl Surveys

River	Location	Trawl Tows	Distance Towed(m)	Cubic Meters Sampled	% of Total Trawl Effort	Number of Fish	% of Total Catch	CPUE (fish/m)	CPUE (fish/ 10,000m^3)
San Joaquin	Port of Stockton	39	19,861	156,902	19.02	2,343	31.84	0.118	149.33
San Joaquin	Sediment Trap	45	22,141	174,914	21.20	3,709	50.40	0.168	212.05
San Joaquin	Scour Pond	42	21,822	172,394	20.90	579	7.87	0.027	33.59
San Joaquin	Bradford	18	9,229	72,909	8.84	84	1.14	0.009	11.52
San Joaquin	McCormick	15	7,647	60,411	7.32	239	3.25	0.031	39.56
Sacramento	Decker Island	30	15,624	123,430	14.96	254	3.45	0.016	20.58
Sacramento	S-31	6	3,094	24,443	2.96	78	1.06	0.025	31.91
Sacramento	Sandy Beach	10	4,998	39,484	4.79	73	0.99	0.015	18.49
Total		205	104,416	824,886		7,359		0.07	89.21

Comparisons are given between 2006, 2007, and 2008 sampling, simply as a frame of reference. Caution should be applied when comparing the data across years, as timing, exact locations, effort, and environmental factors all varied. In 2007, sampling and dredging began in the SSC in November and finished in the SRSC in December. In 2008, dredging movements were reversed from the two prior years; that is, the SRSC was dredged first, between August 1 and September 6, while the reaches within the SSC were dredged later in the season with completion on November 25 (Table 1 provides the specific period of activity for each river reach). There was little overlap in timing of work in dredge reaches from year to year, except at the Port of Stockton; therefore it is not possible to apply rigorous statistical analyses to changes in population structure between years. A multi-year comparison for the Roberts-Port of Stockton reach is presented in Section 5.5.

4.3.1 Stockton Shipping Channel (SSC) – San Joaquin River

White catfish was the most abundant of the 21 fish species collected within the SSC and accounted for 45.38% of the total catch (Table 8). White catfish was also most abundant in 2007, comprising 89% of the total catch. The five most common species (white catfish, threadfin shad, striped bass, American shad, and channel catfish) are introduced and together represented 98.92% of the catch, a composition similar to 2007. Of the 21 species collected, only six are natives, represented by 14 individual fish; together these native species comprised only 0.20% of the total number of fish collected at these sites. In 2007, 0.14% of the total species collected were native. Three individual ESA-listed fish, all delta smelt, were encountered in the SSC during 2008. All three delta smelt were caught in a night trawl near Antioch, on September 21.

Species observed in 2008 that were not found in the SSC during 2007 were Sacramento blackfish, tule perch, inland silverside, bigscale logperch, warmouth and bluegill. Only three native species were collected in both the SRSC and SSC: delta smelt, starry flounder, and Pacific staghorn sculpin.

Table 8. Ranked Catch of Fish from 2008 Trawl Monitoring for All San Joaquin River Sites

Rank	Percent	Number	Common Name	Origin
1	45.38	3,156	white catfish	Introduced
2	23.37	1,625	threadfin shad	Introduced
3	14.09	980	striped bass	Introduced
4	10.02	697	American shad	Introduced
5	6.05	421	channel catfish	Introduced
6	0.45	31	yellowfin goby	Introduced
7	0.12	8	shimofuri goby	Introduced
8	0.10	7	warmouth	Introduced
9	0.07	5	shokihaze goby	Introduced
10	0.06	4	Sacramento splittail	Native
11	0.04	3	delta smelt	Native
11	0.04	3	bluegill	Introduced
11	0.04	3	brown bullhead	Introduced
11	0.04	3	starry flounder	Native
12	0.03	2	Sacramento blackfish	Native
13	0.01	1	Pacific staghorn sculpin	Native
13	0.01	1	tule perch	Native
13	0.01	1	inland silverside	Introduced
13	0.01	1	common carp	Introduced
13	0.01	1	blue catfish	Introduced
13	0.01	1	bigscale logperch	Introduced
Total		6,954		

Roberts I / Port of Stockton (SSC): Maintenance dredging and fish community monitoring occurred within the deepwater navigation channel between RM 36.72 and 38.45, near Rough and Ready Island in the Port of Stockton. White catfish was the most abundant fish species collected in trawl sampling, representing 66.03% of the catch (Table 9). No native fish species were encountered.

Roberts I / Sediment Trap (SSC): Maintenance dredging and fish community monitoring were conducted within the deepwater navigation channel between RM 39.73 and 39.96 near the mouth of Old River and upstream from Rough and Ready Island in the Port of Stockton. White catfish were the most abundant species encountered here in 2008, representing 43.38% of the total overall catch (Table 10). Seven native fish were captured including four Sacramento splittail, two Sacramento blackfish and one starry flounder. Overall, native fish made up 0.19% of the total fish captured at this location. This location had the highest fish density of all locations sampled in 2008 (CPUE = 0.168 fish/meter).

Table 9. Summary of Fish Collected in 2008 Trawl Monitoring near Roberts I / Port of Stockton

Rank	Percent	Number	Common Name	Origin
1	66.03	1,547	white catfish	Introduced
2	22.96	538	threadfin shad	Introduced
3	4.74	111	American shad	Introduced
4	4.18	98	striped bass	Introduced
5	1.79	42	channel catfish	Introduced
6	0.13	3	warmouth	Introduced
7	0.04	1	yellowfin goby	Introduced
8	0.04	1	brown bullhead	Introduced
9	0.04	1	shimofuri goby	Introduced
10	0.04	1	blue catfish	Introduced
Total		2,343		

Table 10. Summary of Fish Collected in 2008 Trawl Monitoring near Roberts I / Sediment Trap

Rank	Percent	Number	Common Name	Origin
1	43.38	1,609	white catfish	Introduced
2	27.74	1,029	threadfin shad	Introduced
3	15.85	588	striped bass	Introduced
4	10.19	378	channel catfish	Introduced
5	1.70	63	American shad	Introduced
6	0.62	23	yellowfin goby	Introduced
7	0.11	4	warmouth	Introduced
7	0.11	4	Sacramento splittail	Native
8	0.08	3	bluegill	Introduced
9	0.05	2	brown bullhead	Introduced
9	0.05	2	Sacramento blackfish	Native
10	0.03	1	inland silverside	Introduced
10	0.03	1	common carp	Introduced
10	0.03	1	bigscale logperch	Introduced
10	0.03	1	starry flounder	Native
Total		3,709		

Scour Pond / Antioch (SSC): Maintenance dredging and fish community monitoring were conducted in the main navigation channel from RM 5.49 to 9.51, between Sherman Island and West Island as well as upstream of Antioch Bridge. American shad was the most abundant fish species collected from this reach, representing over 66% of the total catch (Table 11). Three delta smelt were encountered in this reach. In 2007, striped bass were the most abundant fish, representing 27.0% of the catch. Overall, introduced species represented 98.9% of the total catch, up from 77.8% in 2007.

Table 11. Summary of Fish Collected in 2008 Trawl Monitoring near Scour Pond

Rank	Percent	Number	Common Name	Origin
1	66.15	383	American shad	Introduced
2	25.73	149	striped bass	Introduced
3	5.01	29	threadfin shad	Introduced
4	0.86	5	yellowfin goby	Introduced
5	0.69	4	shokihaze goby	Introduced
6	0.52	3	delta smelt	Native
7	0.35	2	starry flounder	Native
7	0.35	2	shimofuri goby	Introduced
8	0.17	1	channel catfish	Introduced
8	0.17	1	tule perch	Native
Total		579		

4.3.2 McCormick Pit / Light 19 Reach (SSC):

Dredging and fish community monitoring occurred in the lower SSC reach upstream of the Antioch Bridge between Jersey Island and Sherman Island, from RM 10.97 to 11.34. Table 12 provides a summary of the fish collected during community sampling. Striped bass was the most abundant fish species collected from this reach, at over 51% of the total catch. Only one native species, a Pacific staghorn sculpin, was collected. Introduced species represented 99.6% of the total catch. This reach was not sampled in 2007.

Table 12. Summary of Fish Collected in 2008 Trawl Monitoring near McCormick Pit

Rank	Percent	Number	Common Name	Origin
1	51.88	124	striped bass	Introduced
2	42.68	102	American shad	Introduced
3	2.51	6	threadfin shad	Introduced
4	1.26	3	shimofuri goby	Introduced
4	0.84	2	yellowfin goby	Introduced
5	0.42	1	Pacific staghorn sculpin	Native
5	0.42	1	shokihaze goby	Introduced
Total		239		

Bradford Island (SSC): Fish community monitoring occurred in the main navigation channel from RM 13.45 to 13.64 on the lower SSC reach adjacent to Bradford Island, near False River. Table 13 provides a summary of the fish collected during community sampling. American shad was the most abundant fish species collected in trawl sampling from this reach, representing over 45% of the total catch. In 2007, this area was not sampled. Overall, introduced species represented 100% of the total catch. There were no native species or ESA-listed fish encountered during trawling from the Bradford SSC dredge location in 2008.

Table 13. Summary of Fish Collected in 2008 Trawl Monitoring near Bradford Island

Rank	Percent	Number	Common Name	Origin
1	45.24	38	American shad	Introduced
2	27.38	23	threadfin shad	Introduced
3	25.00	21	striped bass	Introduced
4	2.38	2	shimofuri goby	Introduced
Total		84		

4.3.3 Sacramento River Shipping Channel (SRSC)

The SRSC locations sampled in 2008 presented a fairly different species composition than the SSC, similar to observations in 2007. The SRSC sites were dominated by striped bass and catfish (Table 14). The four most abundant species were introduced, and together represented 67.65% of the catch, down from 2007, when the top four comprised 91.53% of the total catch. Overall, native fish represented 16.30% of the catch, up from 2007, when they only made up 6.04% of the total catch. Of the 16 species collected, six were natives. In the SSC, native fish only made up 0.20% of the fish community sampling catch. Of the 25 delta smelt encountered during fish community monitoring in 2008, 22 came from SRSC sites. Of the 76 native specimens collected in 2008, 86.84% of them came from the SRSC. White sturgeon, longfin smelt, prickly sculpin and the non-native wakasagi were encountered only on the SRSC in 2008, and not the SSC. Only three native species were collected in both the SRSC and SSC: delta smelt, starry flounder and Pacific staghorn sculpin.

Table 14. Ranked Catch of Fish from 2008 Trawl Monitoring for all Sacramento River Sites

Rank	Percent	Number	Common Name	Origin
1	33.83	137	striped bass	Introduced
2	19.51	79	white catfish	Introduced
3	7.41	30	channel catfish	Introduced
4	6.91	28	shokihaze goby	Introduced
5	5.43	22	delta smelt	Native
6	5.19	21	longfin smelt	Native
7	4.44	18	wakasagi	Introduced
8	2.96	12	American shad	Introduced
9	2.72	11	Starry flounder	Native
9	2.72	11	shimofuri goby	Introduced
10	2.47	10	blue catfish	Introduced
11	2.22	9	yellowfin goby	Introduced
12	1.73	7	white sturgeon	Native
13	1.23	5	unidentified goby spp.	Introduced
14	0.74	3	Pacific staghorn sculpin	Native
15	0.49	2	prickly sculpin	Native
Total		405		

Decker Island / Natural Channel (SRSC): Dredging and monitoring occurred in the Natural Channel reach from RM 6.02 to 8.33 offshore of Sherman Island and downstream of the Decker Island DMP site. Longfin smelt and delta smelt were the most abundant native fishes in this reach, each representing 8.27% of the overall catch (Table 15). Striped bass were the most abundant non-native fish represented over 32.28% of the individual fish collected from the trawl tows conducted at this site in 2008. Native species represented 25.59% of the total catch, up from 6.41% of the overall catch in 2007.

Table 15. Summary of Fish Collected in 2008 Trawl Monitoring near Decker Island

Rank	Percent	Number	Common Name	Origin
1	32.28	82	striped bass	Introduced
2	11.42	29	channel catfish	Introduced
3	11.02	28	shokihaze goby	Introduced
4	8.27	21	longfin smelt	Native
4	8.27	21	delta smelt	Native
5	7.09	18	white catfish	Introduced
6	4.33	11	starry flounder	Native
7	3.15	8	American shad	Introduced
7	3.15	8	yellowfin goby	Introduced
8	2.76	7	white sturgeon	Native
9	1.97	5	blue catfish	Introduced
9	1.97	5	goby, unidentified	Introduced
10	1.57	4	shimofuri goby	Introduced
11	1.18	3	Pacific staghorn sculpin	Native
12	0.79	2	wakasagi	Introduced
12	0.79	2	prickly sculpin	Native
Total		254		

S-31 / Man-made Channel (SRSC): Dredging and monitoring took place in the Sacramento River Man-made Channel downstream from the Port of Sacramento between RM 32.86 and 33.92. One out of seven species encountered was native, a single delta smelt (Table 16). White catfish were the most abundant fish, comprising 50% of the total catch, a composition similar to 2007. This site had the highest CPUE (0.025 fish/meter) of fish specimens collected for all SRSC sampling locations.

Table 16. Summary of Fish Collected in 2008 Trawl Monitoring near S-31

Rank	Percent	Number	Common Name	Origin
1	50.00	39	white catfish	Introduced
2	20.51	16	wakasagi	Introduced
3	15.38	12	striped bass	Introduced
4	8.97	7	shimofuri goby	Introduced
5	2.56	2	American shad	Introduced
6	1.28	1	delta smelt	Native
6	1.28	1	yellowfin goby	Introduced
Total		78		

Sandy Beach (SRSC): Dredging and monitoring took place near Sandy Beach and Rio Vista in the SRSC, between RM 10.14 and 10.34. None of the five species encountered in 2008 were native (Table 17). Striped bass were the most abundant fish, at 58.90% of the total catch. This site was not sampled in 2007.

Table 17. Summary of Fish Collected in 2008 Trawl Monitoring near Sandy Beach

Rank	Percent	Number	Common Name	Origin
1	58.90	43	striped bass	Introduced
2	30.14	22	white catfish	Introduced
3	6.85	5	blue catfish	Introduced
4	2.74	2	American shad	Introduced
5	1.37	1	channel catfish	Introduced
Total		73		

4.3.4 Larval / Post-larval Fish Collection

The trawl net used for this study is not designed to catch larval fish; however, larval fish were collected on three occasions, all near Decker Island on the SRSC. Larvae were attached to macroalgae/vegetation that was caught in the net mesh. A total of 14 larval fish were collected over three trawls between August 22 and September 5, 2008. Larval fish were not encountered in previous years.

The entrainment monitoring screen and sample cell net are also not designed to collect larval fish; therefore, it is unknown if these fish are being entrained by dredge operations. All post-larval fish collected were vouchered for further lab identification. Five fish were identified to the genus *Tridentiger* or *Acanthagobius* (gobies) and one fish was narrowed to Moronidae or Centrarchidae (striped bass or bass/sunfish, respectively). One fish was damaged too heavily to identify. The remaining seven vouchered post-larval fish were turned over to CDFG by the Corps on August 25, 2008, for further identification. Final identifications have not been made; however, based on our observations, these were similar to the individuals identified to family Moronidae or Centrarchidae. All post-larval fish were in the 10 to 20 mm range. The unidentified larval/post-larval fish are not included in this report's analysis.

4.4 Fish Length

For 19 of the 25 species encountered during trawling, 100% of fish collected were measured for length (Table 18). Overall, 1,932 fish out of 7,354 (26.27%) were measured for length (total length [TL], standard length, or fork length, depending on species). The longest fish was a striped bass (722 mm TL), and the shortest was a shokihaze goby (18 mm TL). Of five unidentified post-larval gobies, which are not included in this table, the smallest measured 14 mm.

Overall, 225 fish out of 262 fish collected during 2008 entrainment screen monitoring (85.88%) were measured for length (Table 19). Channel catfish were the most common fish entrained by the dredge and comprised 66.03% of the total catch observed on the entrainment screen. The longest fish measured was a channel catfish with a total length of 308 mm, and the shortest was a shokihaze goby with a total length of 47 mm. Measurements were not made for fish that escaped through the screen or were lost into the DMP site during transfer to the live well. Lamprey and Pacific staghorn sculpin were the only native species collected during entrainment monitoring. Lamprey ammocoetes occasionally escaped through the screen.

During 2008, the entrainment cell method was used only at Decker Island and Bradford Island DMP sites, where the mobile screen was unavailable; 100% of specimens collected using the cell method were measured. Only lamprey and white catfish were encountered during entrainment cell monitoring (Table 20). Of the 14 lamprey collected, 10 were positively identified as river lamprey, three were unidentifiable, and one was from the genus *Lampetra*, which represents three possible species occurring in the Delta. The lamprey ranged from 106 to 152 mm (TL). The two catfish had total lengths of 50 and 289 mm. Lamprey were the only native species encountered during the entrainment cell sampling.

Table 18. Summary Size Statistics for Fish Collected during 2008 Fish Community (Otter Trawl) Surveys

Common Name	Length (mm) Minimum	Length (mm) Maximum	SD of Mean	Mean Total Length (mm)	n Measured	n Collected	% Measured
Native Species							
delta smelt	46	69	5.40	60.24	25	25	100
longfin smelt	38	94	14.18	63.19	21	21	100
Pacific staghorn sculpin	85	126	16.99	103	4	4	100

Table 18 (continued). Summary Size Statistics for Fish Collected during 2008 Fish Community (Otter Trawl) Surveys

Common Name	Length (mm)		SD of Mean	Mean Total Length (mm)	n Measured	n Collected	% Measured
	Minimum	Maximum					
prickly sculpin	68	68	0	68	2	2	100
Sacramento blackfish	345	372	19.09	358.5	2	2	100
Sacramento splittail	304	370	30.00	333.75	4	4	100
starry flounder	84	306	77.87	201.43	14	14	100
tule perch	194	194		194	1	1	100
white sturgeon	365	600	75.19	517.71	7	7	100
Introduced Species							
American shad	47	362	46.09	118.47	248	709	34.98
bigscale logperch	114	114		114	1	1	100
blue catfish	43	89	14.84	57.5	8	11	72.73
bluegill	24	98	37.75	56.67	3	3	100
brown bullhead	135	162	15.04	152.33	3	3	100
channel catfish	35	348	82.98	202.97	199	451	44.12
common carp	680	680		680	1	1	100
inland silverside	71	71		71	1	1	100
shimofuri goby	24	74	15.20	46.00	19	19	100
shokihaze goby	18	65	11.47	40.73	33	33	100
striped bass	32	722	65.94	139.66	456	1,117	40.82
threadfin shad	34	195	38.80	117.44	453	1,625	27.88
wakasagi	75	99	6.03	89.78	18	18	100
warmouth	33	180	50.91	141.57	7	7	100
white catfish	32	360	51.93	177.59	362	3,235	11.19
yellowfin goby	87	193	31.13	150.5	40	40	100
Total					1,932	7,354	26.27

Table 19. Summary Size Statistics for Fish Collected during 2008 Entrainment Screen Monitoring

Common Name	Length (mm)		SD	Mean Total Length (mm)	n Measured	n Collected	% Measured
	Minimum	Maximum					
Native Species							
river lamprey	149	170	13.43	154.6	5	5	100
lamprey (*Lampetra* spp.)	140	156	6.81	150	4	5	80
lamprey (unidentified)	na	na		na	0	7	0
Pacific staghorn sculpin	95	106	7.78	100.5	2	2	100
Introduced Species							
bluegill	192	192		192	1	1	100
brown bullhead	138	180	19.90	155	4	4	100
channel catfish	69	308	52.49	183.27	158	173	91.33
white catfish	69	220	40.78	143.25	28	37	75.68
yellowfin goby	126	201	23.58	166.22	9	9	100
shimofuri goby	52	75	11.53	63	3	6	50
shokihaze goby	47	109	20.65	64.14	7	7	100
striped bass	50	120	49.50	85	2	4	50
threadfin shad	68	68		68	1	1	100
warmouth	126	126		126	1	1	100
				Total	225	262	85.88

Table 20. Summary Size Statistics for Fish Collected during 2008 Entrainment Cell Monitoring

Common Name	Length (mm) Minimum	Length (mm) Maximum	SD	Mean Total Length (mm)	n Measured	n Collected	% Measured
Native Species							
river lamprey	118	152	11.33	131.6	10	10	100
lamprey (unidentified)	105	115	5.51	108.67	3	3	100
lamprey (*Lampetra* spp.)	122	122		122	1	1	100
Introduced Species							
white catfish	50	289	169.00	169.5	2	2	100
Total					16	16	100%

4.5 Invertebrates

Invertebrates were collected in both fish community and entrainment sampling during 2008 (Table 21). Although assessing impacts on invertebrates is not a specific monitoring requirement, invertebrates were commonly observed in most samples and consequently their presence is discussed briefly. Species encountered in 2008 that were not observed in 2007 consisted of native freshwater mussels (*Anondonta* spp.), leeches (unknown), native oysters (*Ostrea lurida*), mud crabs (*Rithropanopeus harrisii*), native marine mussels (*Mytilus* spp.), and one aquatic snail (unknown). A total of 136,937 invertebrates were collected during trawl and entrainment sampling in 2008; 126,823 of these specimens were collected in entrainment monitoring and 10,114 were collected in the trawl. Native marine mussels and oysters identified in entrainment samples were shells only and were not live specimens. All other counts are for live specimens.

Table 21. Ranked List for All Invertebrates Collected during 2008 Entrainment Monitoring and Fish Community Sampling

Rank	Percent	Total	Common Name	Genus	Species	Origin
1	89.66	122,771	Asian clam	*Corbicula*	*fluminea*	Introduced
2	5.95	8,141	Siberian prawn	*Exopalaemon*	*modestus*	Introduced
3	2.04	2,788	freshwater shrimp	all	spp.	Introduced
4	1.19	1,633	overbite clam	*Corbula*	*amurensis*	Introduced
5	0.68	929	jellyfish	all	spp.	Unknown
6	0.34	453	mussel, unidentified freshwater species	*Anondonta*	spp.	Native
7	0.14	185	leech	Unknown	spp.	Unknown
9	0.01	20	native oyster*	*Ostrea*	*lurida*	Native
11	0.00	3	mud crab	*Rithropanopeus*	*harrisii*	Introduced
12	0.00	2	saltwater mussel*	*Mytilus*	spp.	Native
13	0.00	1	aquatic snail spp.	unknown	unknown	Unknown
Total		136,926				

* Dead shell only collected

Freshwater shrimp, including the introduced *Palaemon macrodactylus* and *Exopalaemon modestus,* native mysids (ghost shrimp), and at least one other unidentified species, were collected in both the SRSC and SSC. The Asian clam (*Corbicula fluminea*) was frequently collected from all 2008 dredge locations. The clam counts were based on estimates while enumeration of other invertebrate species was based on actual counts of individual organisms.

Most shrimp were collected during fish community sampling, while the majority of clams and mussels were collected in entrainment sampling. The Siberian prawn comprised 67.6% of the shrimp species from community sampling but accounted for 96.5% of the entrained shrimp species. Jellyfish were the only invertebrates caught in community sampling that were not observed in entrainment monitoring.

Nearly all of the mussels were collected at the Port of Stockton-Rough and Ready Island and Sediment Trap reaches (Roberts DMP). Two unidentified mussels (*Anondonta* spp.) were collected during entrainment monitoring at S-31 in the SRSC. All other mussels were captured in the SSC. With the exception of two native marine mussels (*Mytilus* spp.) captured near Antioch (Scour Pond), all the mussel captured in the SSC were specimens of *Anondonta* (n=453) observed near Stockton at the Roberts DMP site. Most were returned to the river alive immediately following collection and prior to species identification. SWCA field staff vouchered a subset of these specimens, which have been submitted to mussel experts at the Center for Integrated Biosystems in Logan, Utah, for further research. One shell specimen was sent to the CDFG Bay-Delta Office for analysis. No quagga mussels or other non-native mussels were encountered during fish community or entrainment monitoring.

Total extrapolated counts predict that 2,907,391 invertebrates were entrained by the dredge in 2008 (Table 22). The introduced Asian clam was the dominant taxon at all DMP sites. Asian clams accounted for 96.83% of the predicted total of entrained invertebrates. Native oysters and unidentified saltwater mussels collected in the SSC were all dead shells. Dead shell counts were recorded only when the more rare native oysters and saltwater mussels were encountered, since sampling was taking place outside of their known habitat range. Therefore, dead shells were not recorded for Asian or overbite clams. The freshwater mussel data is based almost solely on individuals that were alive before entrainment.

Table 22. Extrapolated Invertebrate Entrainment Catch for 2008 by Location and Species

	S-31	Sandy Beach	Decker Island	Scour Pond	McCormick	Bradford	Roberts Port of Stockton	Roberts Sediment Trap	Total
River	SRSC	SRSC	SRSC	SSC	SSC	SSC	SSC	SSC	
% Sampled	2.14	2.87	0.77	5.21	5.27	0.49	6.41	6.23	4.40
Asian clam	887,850	156,794	48,442	910,940	40,797	11,633	655,226	103,531	2,815,213
Siberian prawn	1,822		1,039	77			24,805	13,965	41,708
saltwater mussel				38					38
overbite clam			9,610	28,599	38				38,247
freshwater shrimp			130	499			1,014		1,643
mud crab				58					58
native oyster				345	38				383
aquatic snail spp.				19					19
leech							546	2,408	2,954
unidentified mussel (freshwater)	47						6,006	1,075	7,128
Total	889,719	156,794	59,221	940,575	40,873	11,633	687,597	120,979	2,907,391

Note: Gray shading indicates introduced species.

The overbite clam was found in both the lower SRSC and SSC in 2008. They were most abundant in the Scour Pond – Antioch and Decker Island reaches. The highest abundance of delta smelt and longfin smelt were also found in these reaches.

As a rough calculation, in the Port of Stockton reach of the SSC, where *Anondonta* densities were highest, RISG dredged 106,964 cubic yards of material. Assuming the average depth of dredging was three feet deep, then the density of native freshwater mussels was approximately 0.056 mussels per square yard (or 0.047 per square meter). In comparison, using a similar depth of three feet at the Scour Pond DMP site, where Asian clam density was highest, Asian clam density was 11.47 per square yard (or 9.59 per square meter). Dredging depths were often greater than or less than three feet; therefore, these numbers are merely an exercise of how this data can be used to estimate approximate population abundance and density in dredged areas.

4.6 Comparison of Monitoring Method Results

Analyses of relationships between the results of fish community and entrainment monitoring were made where enough data existed. Differential usage of the water column provides an area where comparisons can be made between both monitoring methods. Fish were categorized into demersal and non-demersal fishes as previously described.

Demersal species comprised 52% of the population in the fish community trawl catch, varying by dredge location, from 2.4% at Scour Pond and Bradford to over 60% at S-31 and the Port of Stockton reaches (Table 23). The percentage of demersal fishes encountered in entrainment sampling was much higher at all locations where fish were collected, except at S-31 (Figure 25). In areas where there were fewer demersal fishes encountered in the fish community sampling, there were fewer fish entrained.

Eleven species were collected in both community sampling and entrainment monitoring. Fish community presence did not always correlate to rates of entrainment for all species. The most glaring anomaly was observed with catfish. Channel catfish accounted for 62.2% of the entrainment catch, while only comprising 6.1% of the trawl catch. The most common fish in the community monitoring was the white catfish (44.0%), which only made up 14.0% of the observations in entrainment monitoring (Table 24).

Table 23. Percent Demersal Fishes by Location in the Trawl and Entrainment Sampling

Location	Method	Entrainment		Trawl		
		Average Richness	% Demersal	Average CPUE (fish/100m)	Average Richness	% Demersal
S-31	Screen	1.33	75.00	1.95	3.08	60.26
Sandy Beach	Screen	1.00	100.00	1.47	1.90	38.36
Decker I	Cell	0.88	100.00	1.75	3.45	47.24
Scour Pond	Screen	0.91	84.60	3.16	1.76	2.40
McCormick	Screen	no fish collected		3.17	1.67	2.93
Bradford	Cell	no fish collected		0.99	1.73	2.40
Robert-Port	Screen	3.50	96.00	10.37	2.90	68.00
Roberts-Sediment	Screen	2.33	100.00	17.87	4.98	54.30

Table 24. Community and Entrainment Percentage for Species Observed in Both Sampling Methods

Overall Rank	Trawl Count	Percent Community	Percent Entrainment Screen	Entrainment Count	Common Name	Origin
1	3,235	43.96	14.03	39	white catfish	Introduced
2	1,625	22.08	0.36	1	threadfin shad	Introduced
3	1,117	15.18	1.44	4	striped bass	Introduced
5	451	6.13	62.23	173	channel catfish	Introduced
6	40	0.54	3.24	9	yellowfin goby	Introduced
7	33	0.45	2.52	7	shokihaze goby	Introduced
9	19	0.26	2.16	6	shimofuri goby	Introduced
16	7	0.10	0.36	1	warmouth	Introduced
17	3	0.04	1.44	4	brown bullhead	Introduced
18	4	0.05	0.72	2	Pacific staghorn sculpin	Native
20	3	0.04	0.36	1	bluegill	Introduced
Total	6,537	88.83	88.85	247		

4.7 Water Quality Monitoring

Surface and bottom measurements were acquired for all parameters except Secchi depth and were taken twice during each fish community sampling event. The water quality data discussed below are bottom measurements.

Dissolved oxygen measurements ranged between 69.5% and 98.4% with several readings dropping below 80% (both surface and bottom). On average, the lowest dissolved oxygen measurements were found in the Port of Stockton and Sediment Trap reach in November. The maximum water temperature recorded for 2008 was 23.15°C near Decker Island in late August, and the minimum temperature was 14.76°C in the Port of Stockton on the final day of sampling, November 24. Salinity levels varied from 0.18 parts per thousand (ppt) at Rio Vista during a low tide sample to 4.62 ppt at Decker Island during a high tide sample. Additional water quality data can be downloaded at the California Data Exchange Center (CDWR 2009) for Rio Vista, Antioch, Rough and Ready Island and other areas in the Delta. Data on the website include river stage, pH, temperature, dissolved oxygen, conductivity, turbidity and other parameters taken on an hourly basis. Surface water quality data, along with complete bottom data are presented in Appendix B.

4.8 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 25) were based on the estimates developed for the Stockton DWSC and the Sacramento DWSC BOs (NMFS 2006a,b). Take allotments have recently been revised by the IEP for 2009. The original estimated mortality was based on NMFS estimates for the maintenance dredging program in the Stockton and Sacramento DWSCs. It was assumed that exposure of listed fish to sampling gear would be less than 25% 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 three years.

Table 25. Original Estimated Incidental Take Established in 2006 and Updated IEP Allotments for 2009

Potential annual incidental take for fish community sampling in the Stockton DWSC 2006–2008				
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	25 juveniles and adults combined (2% = 1 mortality)			
Potential annual take for fish community sampling in the Sacramento River DWSC 2006–2008				
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	25 juveniles and adults combined (2% = 1 mortality)			
IEP-ESA incidental annual take allotments for fish community sampling in the Sacramento River and Stockton DWSC 2009				
Species	Juveniles		Adults	
	non-lethal	lethal	non-lethal	lethal
Sacramento River winter-run Chinook salmon	100	0	1	0
Central Valley spring-run Chinook salmon	80	0	1	0
Central Valley steelhead	2	0	1	0
longfin smelt	150		150	
delta smelt	100 total lethal and non-lethal, no life history differentiation			
North American green sturgeon	4 juveniles and adults combined (non-lethal only)			

* ESU = evolutionarily significant unit DPS = distinct population segment

Estimates of take of the threatened delta smelt or the candidate species 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 10 delta smelt per week during normal dredging operational windows. Incidental and lethal take for fish community sampling were authorized under Program Element Number 2008-113 for inclusion in the amended IEP Scientific Collecting Permit 1440. The IEP has included delta smelt and longfin smelt in their take allotment for 2009 monitoring for this project.

None of the species listed above were collected or observed during dredge entrainment monitoring in 2008. Other than delta smelt, and the then candidate longfin smelt collected during fish community monitoring, no other ESA-listed fish were encountered in 2008. Twenty-five delta smelt were collected in August and September of 2008, from three different dredge reaches spanning the SRSC and the lower SSC (Table 26 and Appendix D). None of these delta smelt encounters had an impact on dredging. All 25 delta smelt were vouchered, as requested by the IEP, and delivered to the Corps, Sacramento District and then transferred to CDFG, Bay-Delta Region. This collection of vouchered delta smelt was made to augment the small numbers of scientifically available specimens for research and to provide positive laboratory identification of collected specimens considering the poor probability for post-release survival of captured delta smelt. Initial species identifications between wakasagi and delta smelt for specimens collected in early August from the Man-made Channel were provided by staff at CDFG, Bay-Delta Regional office in Stockton.

Table 26. Delta Smelt Encounters in 2008

Date	Trawl ID	Trawl Time	n Indiv.	DWSC	Location	Secchi Depth (cm)	Bottom Salinity (ppt)
Aug. 6	3_3	13:59–14:06	1	SRSC	Man-made Channel, downstream from Port of Sacramento	34	0.4
Aug. 20	6_2	18:11–18:21	4	SRSC	Natural Channel, Decker Island dredge reach. Navigation lights 17-18 adjacent to Decker Island in the navigation channel	49	0.71
Aug. 24	8_2	13:39–13:43	6	SRSC	Natural Channel, Decker Island dredge reach. Navigation lights 17-18 adjacent to Decker Island in the navigation channel	58	0.61
Aug. 29	10_1	11:15–11:24	1	SRSC	Natural Channel, Decker Island dredge reach. Navigation lights 17-18 adjacent to Decker Island in the navigation channel	67	0.24
Aug. 29	10_5	10:20–10:38	3	SRSC	Natural Channel, Decker Island dredge reach. Navigation lights 17-18 adjacent to Decker Island in the navigation channel	65	0.67
Sept. 5	12_4	15:34–15:41	1	SRSC	Natural Channel, Decker Island dredge reach. Below Horseshoe Bend, downstream of Decker Island in the navigation channel	81	1.24
Sept. 6	13_1	21:51–21:58	6	SRSC	Natural Channel, Decker Island dredge reach. Below Horseshoe Bend, downstream of Decker Island in the navigation channel	NA (dark)	4.62
Sept. 21	19_2	20:00–20:10	3	SSC	West Island dredge reach. Navigation light 7 off NW end of West Island in navigation channel	83	1.79

As discussed in Section 2, CDFG has imposed take restrictions for the longfin smelt. A total of 21 longfin smelt, a CESA-listed fish, were collected in the 2008 monitoring effort. Catch data for these longfin smelt is provided in Appendix D. A February 2, 2009 letter from CDFG specifically addressed take of smelt for this project. In an amendment to the current Section 2081(a) Permit authorizing the take of CESA-listed longfin smelt, take restrictions were modified for the upcoming 2009 sampling period. The amendment states that all Osmerids (smelt) shall be returned to the natural system; however, if those species perish during sampling, they shall be preserved and delivered to CDFG. Allowable take for longfin smelt changed to 150 juveniles (20–84 mm FL) and 150 adults (>84 mm FL) for 2009. In the future, all healthy Osmerids that are captured shall be released unharmed, if possible.

4.9 Sampling Mortality

Mortality of certain species was an unavoidable during fish community and entrainment sampling (Table 27 and Table 28). It should be noted that delta smelt, longfin smelt and all lamprey species were required to be vouchered under mandates from the IEP. These were the only native fish species that incurred sampling mortality. Vouchered specimens are not reported in this section but are discussed in Section 4.10. All delta smelt and longfin smelt were captured during community (trawl) sampling. All lamprey were collected during entrainment monitoring.

Table 27. Total Mortality for Community Sampling

Common Name	Total Mortalities	Percent Trawl Mortality	Origin
American shad	55	12.79	Introduced
bluegill	0	0	Introduced
brown bullhead	0	0	Introduced
channel catfish	4	0.93	Introduced
lamprey	0	0	Native
shimofuri goby	2	0.47	Introduced
shokihaze goby	0	0	Introduced
striped bass	77	17.91	Introduced
threadfin shad	284	66.05	Introduced
wakasagi	1	0.23	Introduced
white catfish	5	1.16	Introduced
yellowfin goby	2	0.47	Introduced
Total	430		

Table 28. Total Mortality for Entrainment Sampling

Common Name	Total Mortalities	Percent Entrainment Mortality	Origin
American shad	0	0	Introduced
bluegill	1	0.87	Introduced
brown bullhead	2	1.74	Introduced
channel catfish	80	69.57	Introduced
lamprey	7	6.09	Native
shimofuri goby	3	2.61	Introduced
shokihaze goby	3	2.61	Introduced
striped bass	4	3.48	Introduced
threadfin shad	1	0.87	Introduced
wakasagi	0	0	Introduced
white catfish	9	7.83	Introduced
yellowfin goby	5	4.35	Introduced
Total	115		

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. Other entrainment mortalities were limited to 11 non-native fish species. Channel catfish had the highest entrainment mortality rates (80 individuals), accounting for 69.57% of all entrainment mortalities. Overall, entrainment monitoring resulted in 115 mortalities, 41.37% of the fish entrained by the dredge. Native fish (lamprey) comprised 1.28% of all sampling mortality, not including vouchered specimens.

A total of 430 individuals, or 5.84% of the total catch, were recorded as mortalities during fish community sampling. The highest mortality rates were observed among threadfin shad. Channel catfish, striped bass, and American shad made up the majority of the remaining mortalities. These four species accounted for 92.66% of total mortality during community sampling (not including vouchered specimens).

Delta smelt, longfin smelt and lamprey species were vouchered immediately upon collection. Some smelt appeared healthy enough for release; however, each specimen was euthanized under mandates by the IEP for further laboratory analysis. Hybridization of wakasagi and delta smelt has become an important ecological concern and careful examination of these species was required before making a species determination. The delta smelt's physiology makes this species less likely to survive once being captured and handled than other "less fragile" species (Moyle 2002). It was determined that greater scientific benefit could be gained from vouchering these species than could be gained from their release and impending low probability of survival.

4.10 Vouchered Specimens

Overall, 92 fish specimens were vouchered in 2008 including 25 delta smelt and 19 longfin smelt. Additionally, 24 lamprey specimens were vouchered for further identification and have been submitted to the USFWS in Arcata, CA (Table 29). All other vouchered specimens were non-native and required further laboratory analysis for positive identification. A single unknown larval fish (15 mm) has yet to be identified to species, but is likely from the family Moronidae or Centrarchidae, making it a member of the bass or sunfish family. The unidentified gobies were identified to the genus level and are likely shimofuri, yellowfin, or shokihaze gobies. Seven additional post-larval fish caught at Decker Island were transferred to the Corps for transport to CDFG on August 22, 2008. It is unknown if these fish have been identified.

Table 29. Vouchered Specimens Collected during 2008 Monitoring

Species	Total Vouchered	River	Method of Collection	Reason	Location	Origin
delta smelt	25	SRSC, SSC	Otter Trawl	Required	CDFG Bay-Delta office	Native
goby, unidentified spp.	5	SRSC	Otter Trawl	Positive ID	SWCA Portland	Introduced
inland silverside	1	SSC	Otter Trawl	Positive ID	SWCA Portland	Introduced
longfin smelt	19	SRSC	Otter Trawl	Required	CDFG Bay-Delta office	Native
shimofuri goby	1	SRSC	Otter Trawl	Positive ID	SWCA Portland	Introduced
wakasagi	14	SRSC	Otter Trawl	Positive ID	CDFG Bay-Delta office	Introduced
unknown post-larval fish	1**	SRSC	Otter Trawl	Positive ID	SWCA Portland	Introduced
unknown post-larval fish	7	SRSC	Otter Trawl	Positive ID	CDFG Bay-Delta office	Introduced
lamprey, unidentified spp.*	3	SRSC, SSC	Cell/Screen	Positive ID	USFWS-Arcata office	Native
river lamprey	15	SRSC, SSC	Cell/Screen	Positive ID	USFWS-Arcata office	Native
lamprey, *Lampetra* spp.*	6	SRSC, SSC	Cell/Screen	Positive ID	USFWS-Arcata office	Native
Total	92					

* Genetic analysis underway to determine species of unidentified individuals
** Likely from the family Moronidae or Centrarchidae

4.11 Sampling Design Efficiency

The increased sampling effort in 2008 allowed more detailed assessment of whether the sampling design is effective at assessing the fish community structure around the dredge. Species richness (the number of different fish species collected during each sample) and CPUE (the number of fish per meter or fish per 10,000 meters) were selected as parameters for comparing the fish community sampling design. We analyzed whether the daily trawl effort of five replicate trawls was efficient at assessing the community structure for each site in terms of diversity and abundance.

4.11.1 Species Richness

Species richness was determined for each individual trawl replicate based on the number of different specimens collected. An average for each trawl sample, consisting of one to five replicates, was calculated (Figure 23). Species richness varied among replicate samples, from zero at several locations to nine on one occasion at Decker Island. Overall species richness for all sites was 2.96, or an average of roughly three different species per trawl replicate.

Deviation from the overall mean species richness for each trawl survey was calculated after each consecutive replicate sample. Trawl samples with less than five replicates were not considered. The overall mean for each trawl survey is based on the average across all five replicate samples. The results showed the deviation from the mean decreasing with each successive tow; therefore, as effort increases, so does the ability to assess species richness. For example, the average deviation (across all sites), after one replicate tow, was ±1.049 species. The average deviation from the mean after the fourth replicate tow was ±0.185 species.

The data indicate that performing only one or two trawls would reduce the opportunity to encounter an average of one additional species at each site. The graph (see Figure 23) indicates that species richness is more often underestimated after only one trawl. Increasing the sampling effort increases the likelihood of encountering a rarer, less abundant species.

4.11.2 Catch per Unit Effort

For each individual trawl replicate, CPUE was calculated based on the number of specimens caught, divided by the total distance trawled. The average trawl length was 500 meters. An average for each trawl sample, consisting of one to five replicates, was calculated (Figure 24). Among sites, CPUE varied considerably, with several areas having zero catch; the highest catches coming from the Port of Stockton area on the San Joaquin River. The highest CPUE of 1.75 fish per meter towed occurred near Stockton at the Sediment Trap dredge site on November 18. The average CPUE across all sites in 2008 was 0.067 fish per meter.

The deviation from the overall mean CPUE was calculated after each consecutive replicate sample for each trawl survey. Only trawl surveys with five complete replicate tows were used for this analysis. The overall mean and deviation for each trawl survey was calculated in a manner similar to the species richness data. The average deviation for CPUE decreased with each consecutive replicate tow indicating increased accuracy as a function of increased sampling effort. The average deviation across all sites, after one replicate tow, was ±644 fish per 10,000 meters. The average deviation from the mean after the fourth replicate tow was ±110 fish per 10,000 meters. The average deviation was higher after one tow when species abundance was also high, as was noted for Roberts-Port of Stockton and Sediment Trap sites.

Average CPUE across all sites was 670 fish per 10,000 meters towed. In contrast, if only the first replicate trawl for each survey were used, the average CPUE was 537 fish per 10,000 meters, an underestimate. If all CPUEs for the second replicate tows are averaged, the result is 936 fish per 10,000 meters, an overestimate. It is likely that these numbers are being driven by the high catches in the Stockton area. If these catches are removed from the analysis, the total average CPUE for all other locations is 222 fish per 10,000 meters, with the first replicate trawl averaging 300 fish per 10,000 meters, a narrower margin of error. It is likely that with increased fish abundance there is an increased likelihood for variability within the catch in terms of overall numbers.

4.12 Statistical Analysis of Fish Size

Twenty-six fish species were collected from trawl and entrainment sampling in 2008. However, only two species contained sufficient sample sizes to perform valid statistical analyses: channel catfish and white catfish. Some young-of-the-year catfish were collected in trawl sampling in the Sacramento River in August and September 2008 but were not detected in significant numbers in entrainment. Four catfish were observed in entrainment at all SRSC sites in 2008. No catfish were observed during entrainment in the lower SSC in 2008. The Roberts DMP site accounted for 97.2% of all channel and white catfish encounters.

4.12.1 Channel Catfish

Entrained channel catfish were only collected at the Roberts DMP site; therefore, analyses were limited to fish captured only at this site.

A length frequency distribution shows the variation in size of channel catfish caught during entrainment and community monitoring at the Roberts DMP site (Figure 28). Channel catfish were compared to determine if there was a difference in size between the fish entrained by the dredge and those collected from the fish community in the area of the dredge during dredge operations. The result from unequal variance t-test indicates a significant size difference between fish caught in the trawl and those entrained by the dredge ($p<0.001$). The mean size of channel catfish caught in the trawl at the Roberts DMP site was 226.9 mm TL, while the mean size of the fish observed in entrainment sampling was 181.6 mm TL. Channel catfish data displayed a slightly non-normal distribution; however the large sample size ($n=299$) was sufficient to perform a test of significance. Data transformations did not result in normalizing the data.

During 2008 sampling at the Roberts DMP site in 2008, smaller channel catfish were more likely to become entrained by dredging activities. This difference is likely more pronounced than can be illustrated with this data. Anecdotal information received from anglers, direct observation of sea lion predation, and trawl capture of large channel catfish that had been bitten in half (likely by sea lions), indicates that larger channel catfish are present in the sampling area, yet avoid capture in the trawl net.

4.12.2 White Catfish

White catfish were entrained at three DMP sites in 2008: Roberts ($n=27$), Sandy Beach ($n=1$), and Decker Island ($n=2$). Due to insufficient entrainment sample sizes at Sandy Beach and Decker Island, analysis was only performed on white catfish caught at the Roberts DMP site. A total of 297 white catfish were measured during trawl sampling at the Roberts DMP site. Results from the unequal variance t-test indicates there was a statistically significant difference between the size of white catfish caught in the trawl and those entrained by the dredge ($p<0.001$). The mean size of white catfish caught in the trawl at Roberts was 183.2 mm TL, and the mean size of the fish observed in entrainment sampling was 143.8 mm TL. The data displayed a slightly non-normal distribution, and the sample size of entrained fish ($n=27$) was slightly less than the preferred minimum for a statistically significant test. However, the skewness measure (−0.05) was close to zero, indicating an approximately normal data set. (Skewness measures the symmetry above and below the mean. A skewness of zero indicates a normally distributed bell-shaped curve.) These data are slightly negatively skewed (to the left) due to the presence of the smaller age class of fish in the population. For this data, skewness falls within the acceptable range for assuming an approximately normal distribution. Data transformations were not successful in normalizing the data. A Mann-Whitney Rank Sum test was performed to determine if the non-normal distribution caused an error in rejecting the null hypothesis. This test also rejected the null hypothesis, indicating that the difference in the median values between the two groups is greater than would be expected by chance and that this difference is statistically significant

($p<0.001$). Note that the Mann-Whitney test analyzes the median, rather than the mean, resulting in a slight change to the hypotheses. Nonetheless, both tests were significant.

During sampling at the Roberts DMP site in 2008, smaller white catfish were more likely to become entrained by dredging activities. Numbers of white catfish collected in entrainment monitoring at other sites during 2008 were too small to test for significance.

4.12.3 Special-status Length Data

The lack of special-status fishes collected in entrainment sampling and low sample sizes of these fish collected in fish community monitoring prevented comparative statistical analyses. Length measurements were collected for all special-status species to provide useful data for agency managers and researchers. Length data gathered for longfin and delta smelt collected during trawling is displayed as a length frequency histogram in Figure 29.

4.12.4 Demersal and Non-demersal Fish

Statistical analyses were performed to determine if demersal fish were more likely to become entrained by the dredge than non-demersal fish (Table 30). In 2008, 97.5% (n=278) of fish observed during entrainment monitoring were demersal, and the majority of these fish were channel and white catfish. Three goby species, lamprey, sculpin, and brown bullhead were also encountered in entrainment sampling. In the fish community monitoring conducted in 2008, demersal species comprised 52% of the total catch (see Figure 25).

Table 30. Results from One Sample Proportion Z-test for Difference in Demersal and Non-demersal Species Observed in Entrainment and Fish Community Sampling

		Entrainment		Trawl		Z-test			
Location	Method	Sample Size (n)	Sample Proportion Demersal (p)	Sample Size (n)	Population Proportion Demersal (p)	SE	z-stat	P	Sig. Difference
S-31	Screen	4	0.75	78	0.603	sample size too small to perform test			
Sandy Beach	Screen	3	1.00	73	0.384				
Scour Pond	Screen	13	0.85	579	0.024				
Decker Island	Cell	16	1.00	254	0.472	0.129	3.836	<0.001	yes
McCormick	Screen	0	na	239	0.029	no fish collected in entrainment			
Bradford	Cell	0	na	84	0.024				
Roberts-Port of Stockton	Screen	99	0.96	2,343	0.680	0.047	5.796	<0.001	yes
Roberts-Sediment Trap	Screen	143	1.00	3,709	0.543	0.042	10.717	<0.001	yes
TOTAL	All	278	0.97	7,359	0.520	0.031	14.708	<0.001	yes

A z-test for proportions was used to determine if there was a significant difference in the proportion of entrained demersal fish species and demersal fish in the community. Analyses were conducted for individual sites with sufficient sample size and for all (total) sites combined (see Table 30). Overall, a significantly higher proportion ($p<0.001$) of demersal fish were entrained than were observed during fish community sampling. In addition, significantly higher proportions ($p<0.001$) of demersal fish were entrained at the Port of Stockton (Roberts) and the Sediment Trap (Roberts) than were observed during fish community sampling at those sites individually. Site-specific statistical analyses were not performed on data collected at S-31, Sandy Beach, Decker Island, Scour Pond, McCormick, or Bradford due to insufficient sample size. Some texts state the minimum requirement to perform this test is (np) > 5 and n(1−p) > 5 (Dean and Illowsky 2009). However, a more conservative approach of (np) > 10 and n(1−p) > 10 was selected, following Moore and McCabe (1993). The Decker Island site is included in Table 30 for illustrative purposes; however, it falls within the less conservative range (np=7.5, n(1−p)=8.4) and should be interpreted with caution.

5 Discussion

5.1 Hypotheses

The following hypotheses were developed prior to the initiation of 2006 monitoring as the means to convert the monitoring requirements into heuristically testable assumptions and questions:

- H1: Maintenance dredging of the SSC and SRSC will result in take of listed and other fishes through direct dredge entrainment.
- H2: There is a correlation between presence of fish in the dredging areas and entrainment by the dredge.
- H2a: 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.

H1: This hypothesis was tested during 2006, 2007, and 2008 monitoring. In 2008, H1 again proved to be partially correct. Fish species were entrained, though none were listed species. In 2008, the overall amount of dredge discharge sampled during entrainment monitoring increased substantially. At the same time that effort increased, greater species diversity and abundance were observed. The sampled proportion of dredged material increased from 0.35% to 4.4%, with a total of 278 fish observed from 11 distinct taxa, of which lamprey (n=31) and Pacific staghorn sculpin (n=2) were native.

If these numbers are extrapolated, based on percent of total dredge output sampled in 2008, the total number of all fish entrained from this project across all sites is approximately 6,483 fish (see Table 6). This figure is likely to vary from year to year as the number and composition of species changes; as a result of future unforeseeable environmental perturbations/changes, and as a result of (planned) changes to the monitoring methods, effort, and locations. The sampled slurry volume increased dramatically in 2008. The very low fish entrainment rates observed (including the results of 2006 and 2007 sample cell entrainment monitoring) appear to be indicative of overall dredging impacts to Delta fish.

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 effects other than direct entrainment. Fish community monitoring has shown that listed fish species do occasionally occur within the dredging reach (although in relatively low numbers) and are therefore potentially subjected to take in the form of harm or harassment from dredge and monitoring activities.

H2 and H2a: The data set has gained strength through the use of the mobile entrainment screen sampling unit. Several factors, primarily lack of corresponding samples during corresponding dates, did not allow comparison of fish community structure between years. In 2008, SRSC dredging began in August and ended in early September. Dredging in the SSC commenced in mid-September and ended in late November. These changes in timing of dredging activities were better suited to the in-water construction windows allowed for the various species of concern.

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 are likely to affect migratory, diel, and feeding behavior of fishes with potential for greater overlap of pelagic and demersal behaviors (Feyrer and Healey 2002, 2003; Norbriga et al. 2005).

In 2006 and 2007 no fish species were entrained that were not also collected in the fish community sampling. All fish species entrained during these years (channel catfish, white catfish, yellowfin goby, shokihaze goby, and river lamprey) were demersal (bottom-oriented) fishes. This relationship did not entirely hold true in 2008, perhaps due to the influence of the increased entrainment sampling effort and use of the mobile screen unit. Four striped bass, one bluegill, one warmouth, and one threadfin shad were observed in entrainment sampling in 2008. These primarily pelagic species comprised only 2.5% of the catch associated with entrainment sampling in 2008; therefore, demersal fishes still dominate the entrainment catch. Other demersal fishes not previously encountered in entrainment were Pacific staghorn sculpin, shimofuri goby, and brown bullhead.

Also, river lamprey and other unidentified lamprey were observed in entrainment sampling but not in community sampling. This difference is presumably due to their burrowing nature and the larger mesh size of the trawl net, although one specimen was collected in 2007 using the same net. No lamprey were observed in entrainment in 2007. Thus, for lamprey, it can be assumed that the community monitoring, as currently designed, may not be capable of establishing a relationship between community structure and entrainment rates.

In addition, several demersal species were collected during community sampling that were not observed in entrainment sampling in 2008. These species consisted of white sturgeon, starry flounder, prickly sculpin, and common carp. This difference may be due to a very low occurrence of these species, low sampling efficiency at the corresponding DMP site, the general size of these fish, and/or avoidance behavior around the dredge. Together, these fish only made up 0.33% of the total fish collected in trawl sampling (24 individuals). The white sturgeon (n=7), starry flounder (n=14), and common carp (n=1) were consistently some of the larger fish collected with mean lengths ranging from 201 mm to 680 mm (see Table 18), while the average mean length of fish collected in entrainment was 128.5 mm. There were only two prickly sculpins collected during trawl sampling, with an average size of 68 mm. Both specimens were collected at Decker Island, where the sample cell was used and overall dredge output sampled was only 0.77%. Most of the starry flounder and all of the white sturgeon were also collected during trawl surveys at this site.

Figure 26 shows a graphical representation of the mean size of fish species that were observed in both the community and entrainment monitoring. The standard deviation is also shown. For most of the species, with the exception of channel catfish and white catfish, the sample size for lengths from entrainment fish is low (see Table 19). 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 the community sampling. 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. This relationship is also likely stronger than reported, as extremely large catfish are not caught in the trawl likely due to their ability to avoid sampling gear. Reports from fisherman and observations of sea lion predation indicated that larger catfish are present in the areas sampled.

In order to fully test H2a, more knowledge of the fishes 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, and recent studies initiated by IEP's Pelagic Organism Decline (POD) work team. These and other studies will 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, as well as substantial data gaps 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 also 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 26 fish species collected in 2008, the 17 species in 2007, and the 26 species in 2006, approximately half can be readily defined as demersal rather than pelagic. These species include sculpin, goby, catfish, sturgeon, flounder, lamprey, carp, and others. The non-demersal species tend to use most, or all, of the water column, and some engage in diurnal migrations to the surface or bottom. Within species, behavior differences based on life stage also hamper a 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 specific use of areas of the Delta by individual species and of seasonal fluctuations of species presence in the shipping channel. However, many gaps exist 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).

5.1.1 Sampling Design Efficiency

The magnitude of increase in percent of total volume sampled by entrainment sampling from prior years can be attributed to the use of the mobile entrainment screen device. As a result of adding the pneumatic-assisted splitter-valve in 2008 and refinement of its operation during initial uses, the dredge did not have to slow its pumping rate when the discharge stream was switched between the DMP site and the sampling cell or screen, as was the case in prior years' entrainment sampling. This improvement furthered the efficiency of the dredging operations by substantially decreasing incidences of slowing the pumping rate, or temporarily shutting the pump down, while the Y-valve was manually switched.

The arbitrary entrainment sampling goal of 5% of dredge output was reached fairly consistently at Scour Pond, McCormick, and Roberts (see Table 2). The lower sampling percentages at S-31 and Sandy Beach were due primarily to logistical issues during initial operation of the screen at each site. The low sampling percentages at Decker Island and Bradford Island were the result of using the sample cell method when the screen was not available. Dredge slurry with abundant organic debris, at times, created a short-duration build-up of mixed sediment and debris on the screen's surface that required rapid management of material by screen operators. Occasionally, an overwhelming flow of organic material would cause the discharge to over-top the sides of the screen and/or run off the dump-end of the screen. These infrequent incidences of over-topping were short-lived, usually lasting between 15 seconds and one minute, during which the discharge stream could not be adequately screened or observed for potential organisms. During these occurrences, the screen operators noted the duration of the event and reduced the total sample time for that entrainment event accordingly.

A maximum of five daily trawls were performed during each alternating day trawl survey. No additional trawls were conducted at any sites. Future sampling should incorporate periodic increased sampling effort to clarify the question of sampling efficiency with absolute certainty. Sampling efficiency is likely to vary by site from a variety of confounding factors. It is the goal of this monitoring project to minimize harm to fish from sampling, while maximizing the accuracy of assessing the community structure. Increased sampling effort will result in more precise and powerful data but will also result in increased sampling mortality of fish species. It is currently assessed 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. Any increases to sampling frequency, tow duration, or change of sampling location must first be approved by ESA administrator Kelly Souza (CDFG).

This monitoring study is not designed to conform within the specifications of a scientific study to model populations or determine absolute abundance. Modifications to the sampling design and corresponding sampling efforts could potentially help answer such questions. However, the current scope of monitoring for the maintenance dredging program is not designed to model populations and determine abundance.

Improvements to entrainment sampling techniques in 2009 and beyond should improve the predictive ability of the sampling. More robust entrainment estimates will help identify trends and further test the study’s hypotheses. Changes to the entrainment sampling methodology are discussed in the adaptive management and recommendations sections.

5.1.2 Statistical Analysis

The results of the statistical tests for size and type of fishes indicate that demersal, and particularly smaller fishes, are more vulnerable to entrainment than the larger and non-demersal fishes present in the navigation channels during active dredging. These results confirm H2a, in that fish associated with the channel bottom are entrained at higher levels than species associated with the water column. An additional but related hypothesis is that smaller, or juvenile fishes, are likely to be entrained at greater rates than larger or adult fishes. This related hypothesis was confirmed for channel catfish and white catfish by statistical tests of these data sets (at least for locations where sample sizes were robust enough), showing that smaller fishes are 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 collected in entrainment, the results imply that juveniles are more vulnerable to dredge entrainment than adult fish (see Figure 26). Results of these statistical tests also underscore the continued need to collect length data for all fishes encountered in entrainment, and that the current proportion of fishes measured for length from trawl sampling appears adequate to test significance of relationships based on fish size.

Future monitoring should be directed toward increasing the sample size of fish collected in entrainment monitoring if statistically significant data is desired. The amount of fish collected in entrainment sampling cannot be predicted or controlled; however, if the monitoring crew is approaching a critical sample size for a target species, adaptive management could be employed to increase sampling effort to potentially meet that target. The target sample size is difficult to establish until monitoring has commenced, depending heavily on other population characteristics and amount of required dredging at a location. Monitoring staff should be aware of when these sample size thresholds are within sight and should increase sampling effort accordingly. Conversely, maintaining relatively equal sampling effort across all sites is desirable to increase strength of comparative analyses. Additionally, where monitoring effort is adequate, small numbers of fishes collected during entrainment translates to low impact from dredging operations. Low sample size of fishes collected is not necessarily correlated to sampling design or effort. For instance, Bradford and McCormick dredge reaches contained less than 3% of fish that were classified as demersal in the community sampling, with no fish collected during entrainment sampling. At these sites it is unlikely that increased entrainment monitoring effort would result in increased numbers of entrained fishes.

5.2 Overview

The fish species encountered during 2008 and earlier 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 that were not encountered during 2008 and earlier monitoring for this project are species with the following traits: populations that are known to be very low, such as Sacramento perch (extirpated) and hardhead; 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 observed in the trawl but rarely observed in entrainment monitoring. Although 10 different native species were found in the community sampling, only two were observed in the entrainment monitoring (lamprey species and Pacific staghorn sculpin).

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

- The introduced shokihaze goby was not previously described as inhabiting the upper Delta in (Moyle 2002), but this species ranked seventh in overall abundance in 2008 and twelfth overall during 2006 monitoring.
- The white sturgeon to green sturgeon ratio was approximately 40:1 in 2006, much higher than the 5:1 ratio described by Moyle (2002), due to much lower numbers of green sturgeon. In 2007, eight white sturgeon were collected but no green sturgeon. In 2008, seven white sturgeon were collected but again, no green sturgeon were encountered.
- The ranking of longfin smelt from lower Sacramento River locations was still very high in 2006 (895 were collected, ranked first among native species and fourth among all species), as opposed to other locations in the Delta and San Francisco Bay estuary where steep declines had recently been observed (Thomas Greiner, CDFG, personal communication). In 2007, only two longfin smelt were collected, 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

collected, all from the SRSC in late August and early September. The summer tow net survey (CDFG 2009b) documented presence of longfin smelt primarily from lower bay sites between June and mid-August, and only up to the lower end of Sherman Island during the last week in July. The Bay Study (CDFG 2009c) conducted both midwater trawl and otter (bottom) trawl surveys throughout the Bay and Delta over each month of the year. For the months overlapping with this monitoring study, the Bay Study's midwater trawl survey found areas of higher longfin smelt abundance occurred at or downstream of Chipps Island in October and November, but with presence at Decker Island in October; the otter trawl survey found longfin smelt distributed downstream of Sherman Lake until November with presence near Decker Island in December.

- The 2007 PODS progress report (IEP 2008) reported the highest (worst) bloom on record of the algae *Microcystis aeruginosa* for 2007, centered near Antioch. Significant monitoring efforts from this study 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. Results for the 2008 PODS progress report are not yet available.
- In 2008, 25 delta smelt were captured during community sampling; 22 of the specimens were caught in the SRSC from August to early September. Of these 22 specimens, 21 were in the vicinity of Decker Island, and the other was from the Man-made Channel early in August. The remaining three individuals were collected on the San Joaquin River near Antioch during a single night tow on September 21. Delta smelt were not encountered by this study during 2006; however, in 2007, 11 delta smelt were collected during fish community monitoring in November and December. Of these 11 individuals, nine were from locations near the confluence of the San Joaquin and Sacramento rivers, and two were from the Sacramento River Man-made Channel near the Port of Sacramento. In comparison, the 2008 Fall Midwater Trawl Survey team collected 12 delta smelt in November and 4 in December (CDFG 2009a). The 2008 Fall Midwater Trawl delta smelt index was even lower than 2007 and is the lowest recorded index since inception of the study in 1967. The Bay Study did not report collection of any delta smelt throughout the entire 2008 sampling in either their monthly midwater trawl or 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).
- These studies referenced above indicate that delta smelt and longfin indices remain very depressed. However, when delta smelt are collected from the lower Sacramento River, particularly near Decker Island, and to a lesser extent between Antioch and Bradford Island in the lower San Joaquin River, these areas are shown to be relative strongholds for the species. Monitoring for this project also indicates that delta smelt occur in the Sacramento River Man-made Channel (early August in 2008 and early December in 2007), which is not indicated in the aforementioned studies. The dredge project and its monitoring activities are likely to encounter delta smelt during the approved dredge activity windows within the SRSC, especially near Decker Island, and to a smaller extent in the lower SSC downstream of Bradford Island.

5.3 Discussion of Entrainment Monitoring

Overall, entrainment monitoring in 2008 resulted in a much higher sampling effort compared to previous years. Sampling was still constrained slightly by availability and reliability of equipment, delays in sampling cell construction, and transport of the mobile entrainment screen between DMP locations. The specific constraints by DMP site are as follows.

As described in the 2007–2008 fish monitoring plan (SWCA 2007), it was intended that a new screen device designed to assess entrainment rates would be used at some or all of the DMP sites in 2007. The purpose of this device is to allow sampling of a greater percentage of dredge output. However, this device was not available as planned, and all 2007 entrainment assessments were conducted as in 2006 and 2005, using the sampling cell approach. In 2008, the mobile entrainment screen was completed and used at all DMP locations except Bradford Island and Decker Island, which used the sampling cell method of previous years. The sampling cell approach used for entrainment monitoring at two sites in 2008 resulted in assessment of 0.62% of the total dredge output. The extrapolated entrainment rates are therefore less accurate than they could have been, had they been based on assessments of a higher percentage of the dredged material. The entrainment screen allowed sampling of approximately 5.41% of the total dredge output, nearly an order of magnitude higher than the sample cell method. This allowed for a greater overall accuracy of extrapolated entrainment rates in 2008.

The use of the mobile entrainment screen device increased sampling effort by an order of magnitude over the sampling cell method. This estimate was based on sampling two or more hours of the dredge's daily output during the course of an eight-hour work day. This scenario resulted in sampling from 2.14% to 6.41% of the overall dredge output, as opposed to the 0.35% that was sampled in 2007 using the sample cell approach only.

5.3.1 Entrainment Screen

Overall, the entrainment screen was an extremely useful tool for sampling the dredge output. Certain locations were more difficult to sample, primarily due to the composition of the material being dredged. Dredging output, primarily sand, was the material that passed most easily through the screen. Samples with high mud content or those with greater percentage of organic materials made sampling more difficult. If the screen became overwhelmed with debris, the Y-valve was switched to stop flow to the screen. The material was then removed and sampling would commence by switching the Y-valve back.

Initially, the most difficult operational task involving operation of the screen was developing a way to prevent the wheels and axles from being undermined. The sheer volume of water moving through the screen (~10,000 gallons per minute) causes severe erosion directly below the screen, with the 10% to 15% dry material settling out just beyond the screen. A berm was constructed around the screen at each DMP site to direct the water and material away from screen into the DMP area. This created an eddy-like effect just under the screen, which increases erosion. The resulting erosion can cause a breaching of the berm and lead to instability of the sampling screen. Each site varied based on elevation, proximity to the DMP area and soil composition. In most cases, an excavator or bulldozer worked the area intermittently during the entrainment sampling in order to remove depositing material and maintain the stability of the screen. At Sandy Beach, Scour Pond, and McCormick DMP sites, plywood or plastic was installed directly below the screen to further help reduce erosion under the axles. The average time for which the screen could be run before the screen axles became undermined or the surrounding berm was breached was approximately two hours. At the Roberts DMP site, the screen was placed adjacent to the levee, where the soil was much more compacted and direct erosion under the screen was less of an issue.

At the Scour Pond site, large pieces of wood occasionally became trapped at the Y-valve, not fully allowing the valve to switch into a fully open position. First, an attempt to clear the jam was made by working the valve back and forth, with the hope that this action would dislodge the material. In one case, the jam could not be removed via this method, and the dredge was shut down periodically so the crew could remove the access panel and physically remove the blockage.

It was possible that some organisms fell through the screen due to their small size or were forced through due to the high volume and pressure before they could be observed by biologists. Six lamprey ammocoetes were observed passing through the screen before they could be collected, and one was lost in transfer from the screen to an aerated holding container. A juvenile striped bass, two unidentified gobies, and three juvenile catfish were observed passing through the woven wire screen that was used at S-31, Sandy Beach, Scour Pond, McCormick, and the first two entrainment sampling days at Roberts 1 DMP site. The perforated round screen had equal escapement for lamprey as the woven-wire screen (three lamprey escaped through each screen type); however, the round-holed screen was more efficient at retaining fish in general. Other than lamprey juveniles, no other fish were observed passing through the perforated screen before they could be collected. Both screens were equally efficient at passing material and capturing large fish. The perforated screen was more conducive to cleaning debris and sorting material due to the smooth surface. It was expected that the perforated round-holed screen would increase survival of fish species being entrained, but this hypothesis was not tested because it was only used at one site and fish community structured varied greatly between sites.

5.3.2 Entrainment Cells

At Decker Island and Bradford Island, the screen was not used. Sample cells were constructed by the dredging crew in a similar manner as 2007. A double weir system was used at Bradford and a single weir system was used at Decker Island. Occasionally a bulldozer (used for managing material at DMP sites) was used to re-grade the sample cell and exit channel. On one instance at the Decker Island DMP site, this excavation compacted the cell floor below the elevation of the weir box, which caused residual water to remain in the sample cell once emptied. Fisheries biologists surveyed this pool for specimens after the cell had finished draining, finding no additional specimens other than Asian clams (*Corbicula fluminea*).

At the Bradford DMP site, logistical difficulties were encountered, including very windy conditions, heavy vessel traffic from a bass fishing tournament, dredge pump repairs, and pipeline breakage. These necessitated many adjustments by the dredge and monitoring crews to the operations schedule and in the level of effort needed to achieve project and monitoring objectives successfully. The sample cell method was a far less efficient method as demonstrated by the difference between the proportion of dredge slurry sampled between cell and screen methods of entrainment monitoring.

5.4 Discussion of Fish Community Monitoring

Fish community composition was effectively monitored in 2006, 2007, and 2008 by otter trawling in the vicinity of the dredging operations. Data acquired by the fish community monitoring portion of this study, along with data from other Delta fish studies, will help clarify trends and changes to the fish community of the Delta; determine what linkages, if any, may be created between community sampling and entrainment rates; provide the regulatory agencies with the information and feedback needed to evaluate the efficacy of the monitoring requirements; and help determine if the dredging work windows continue to effectively protect ESA-listed and other sensitive species.

One setback to the monitoring effort occurred on October 8. While performing trawl sampling at night near Bradford Island, high winds caused breakage of the navigation lights after the third trawl. The fourth and fifth trawls and final corresponding water quality sample were not performed as had been planned, as it was decided that this further sampling could not be performed safely without proper lighting.

Delta smelt were encountered during bottom trawl surveys in three of the eight dredge locations during 2008 maintenance dredging operations. Collection of delta smelt early in a daily trawl survey prompted the sampling crew to reduce or eliminate additional replicates to avoid exceeding weekly take allotments instituted in 2008. Early in August both wakasagi and delta smelt were encountered in the Man-made Channel reach. Non-native wakasagi and native delta smelt, both Osmerid fishes, can hybridize making initial field identification problematic. Sampling effort was reduced in the Man-made Channel until it was determined that the majority of these fish were not listed delta smelt (see Table 26). Reduction of replicate tows occurred twice at Decker Island and once at Scour Pond when delta smelt were collected and weekly take was at risk of being exceeded.

Trawl sampling in the Port of Stockton's Rough and Ready Island and Sediment Trap reach documented a much higher density of fishes than any other location, as was also the case in 2006 and 2007. However, nearly all of the catch at the Port of Stockton were introduced species, with dominance by white catfish and threadfin shad. After some very large catches of catfish occurred here during early trawl replicates on November 6 and again on November 18, the target distance trawled was lowered to approximately 350 meters to avoid the need to subsample and reduce processing time, thereby decreasing fish mortality. Unlike in 2007 when even larger catches of catfish were encountered, the target trawl distance was shortened only for the duration of the daily trawl survey and returned to the target of 500 meters on subsequent surveys to better maintain consistency of effort and avoid sampling bias for this location.

5.5 Inter-annual Variation

Several general locations were sampled on an annual basis beginning in 2006. The timing of the sampling varied from year to year, so it is difficult to assess changes in population structure inter-annually. Changing environmental factors from year to year can also have profound impacts on population structure. Data from the Port of Stockton have been compared, since it is the only location with corresponding sampling dates across all three years (Table 31).

Table 31. Dredge Monitoring Sampling Locations by Date and Location

Sacramento River				San Joaquin River			
Year	Man-made Channel	Rio Vista	Decker Island	Antioch West Island	McCormick	Bradford Island	Port of Stockton
2006		Dec. 6–13,15–17	Nov. 16–Dec. 4			Oct. 17–26	Sept. 30–Oct. 6: Nov. 1–9
2007	Dec. 8–11		Dec. 2 only	Nov. 24–29			Nov. 2–13
2008	Aug. 1–7	Aug. 10–13	Aug. 18–Sept. 6	Sept. 11–27	Sept. 30–Oct. 4	Oct. 7–13	Oct. 16–Nov. 25

Shaded background indicates multiple years with overlapping sampling data

Although sampling dates do not overlap entirely, CPUE has been compared for the top five most common species (white catfish, threadfin shad, striped bass, channel catfish and American shad) across the three years of sampling for the Roberts Island and Port of Stockton dredge reach (Figure 27). Sampling methods were identical across all three years. In 2008, this area was split into two sections, the Port of Stockton and Sediment Trap reaches. For the purpose of this comparison, these two reaches were combined from 2008, as these areas were not differentiated in previous years.

5.5.1 Bird Activity Monitoring

As a monitoring requirement for this project, bird activity in the dredge area and DMP site must be observed and recorded. It has been established that bird activity in the dredge area may be correlated to fish being disturbed or injured by dredging activities. Bird activity in the DMP site is theorized to 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. Several species of birds were observed at nearly all locations during 2008 sampling. Sea lions were also noted in the Bradford, Decker, Antioch Bridge, and Port of Stockton navigation channels while conducting trawl surveys. On three different occasions during October and November, in the Port of Stockton reaches, sea lions were observed actively consuming large fish; the first occasion likely involved a salmonid, as pink flesh was observed. In the remaining two of these occurrences the fish were identified as adult white catfish. Notes were kept regarding primarily fish-eating bird activity within approximately a half-mile around the dredge. It did not appear that any bird activity was directly correlated to fish being injured or entrained by the dredge. Additionally, no observations of Swainson’s hawk (a listed bird species) were made near any of the DMP sites during monitoring activities.

5.5.2 Survival of Entrained Fish

Approximately 58.63% of the fish species observed in entrainment monitoring, using the screen, were collected alive. The species collected alive were measured and released (after being held in aerated tanks until properly revived) or were vouchered upon collection. There is potential to use the entrainment screen as a tool to increase fish survival during entrainment. Survival after release is unknown for the individual fish that were released alive; however, certain species had better survival rates than others. Table 32 shows the percent mortality for fish collected using the entrainment screen and sample cell method in 2008. All of the fish listed in the table were collected using the entrainment screen, except for two white catfish collected in the sample cell, one of which was a mortality. The 24 lamprey collected and vouchered were not included in this table, as all lamprey specimens captured were euthanized and preserved for transfer to the USFWS. Seven additional lamprey escaped through the screen before they could be collected and were counted as mortalities in this table. No ESA-listed species or other native species of concern were collected during entrainment in 2008; however, the proper aeration tanks were maintained for live specimens.

Scientific collection is also another aspect of entrainment monitoring that can be a useful tool for the scientific community. If it is determined that collection of a species is desired, sampling intensity or frequency can be increased when it is determined that the species is present. Previous encounters of river lamprey in 2006 and 2007 prompted the USFWS to request that all lamprey collected in 2008 be vouchered for further examination, identification and genetic analysis in the lab. The collection of native freshwater mussels near the Port of Stockton in 2008 has also piqued the interest of USFWS and CDFG biologists, which may lead to future studies in the area.

Table 32. Survival of Entrained Fish Collected During Entrainment Monitoring in 2008

Common Name	Mortalities	Total	% Mortality	Native
channel catfish	80	173	46.24	Introduced
white catfish	9	39	23.08	Introduced
yellowfin goby	5	9	55.56	Introduced
shokihaze goby	3	7	42.86	Introduced
unidentified lamprey	7	7	100.00	Native
shimofuri goby	3	6	50.00	Introduced
brown bullhead	2	4	50.00	Introduced
striped bass	4	4	100.00	Introduced
Pacific staghorn sculpin	0	2	0.00	Native
bluegill	1	1	100.00	Introduced
threadfin shad	1	1	100.00	Introduced
warmouth	0	1	0.00	Introduced
Total	115			

6 Adaptive Management

Adaptation of monitoring methods will likely continue in subsequent sampling years as sampling needs, fish community information needs, and sampling and dredging permit requirements change.

6.1 Entrainment Monitoring

Modifications to monitoring methods for the 2008 monitoring incorporated the following recommendations from the 2007 monitoring report (SWCA 2008):

- The mobile entrainment device was used successfully at all DMP sites with suitable access, increasing the overall sampling of dredge output by nearly an order of magnitude.

- Some of the modifications to the sample cell approach suggested in the 2007–2008 Fisheries Monitoring Plan (SWCA 2007) were implemented resulting in improved monitoring. Sample cells at Decker Island and Bradford Island were increased in size to accommodate larger sample volume, plywood pads were used underneath the weir outlets and nets to minimize scour and associated maintenance of the outflow channel, sampling frequency was increased, and the elevations of the sample cells were designed to prevent backwatering of the entrainment area.

- A splitter valve was employed as needed. The entrainment cell that was previously used at the Decker Island DMP site did not have an additional weir box installed prior to sampling during 2008. Other recommendations that were incorporated included using a Y-valve when necessary and locating the cell away from the main DMP zone to eliminate breaching of either area into or out of the sample cell.

- An on-site water pump provided ambient river water to the DMP site that helped clear sediment and aided in inspection of the material and organisms entrained in the sample cell net or on the screen. The pump also provided fresh river water for holding live organisms collected during entrainment monitoring.

- Water pumps were rigged in tandem to provide the water pressure needed to supply the added height of the mobile screen work area.

- The ⅜-inch round-hole screen material was more effective than the woven wire screen at retaining small bony fishes. The ⅜-inch round-hole screen replaced the woven screen at the Roberts 1 DMP site in November.

As in previous years, the high composition of fine materials and organic content of the dredge slurry, particularly near the bottom of the entrainment sampling cell, presented sampling challenges. Alternative methods of draining the sampling cell were explored to reduce the amount of time necessary to sort through a sample. The sampling cells used at Decker Island and Bradford Island DMP sites in 2008 had larger capacity and were generally deeper than those used in previous years. A minimum of two weir boxes are needed to efficiently process the slurry at these larger cells. Occasionally during the draining process, it was necessary to stop flow through one culvert while either emptying or processing a full net or removing blockages from the other. A single weir box was available for use at Decker Island.

The mobile entrainment screen has the potential to be used as a fish conservation device. It was noted that not all organisms passing through the dredge and pipeline were dead when collected on the screen. With minor adaptations, the screen device could be used effectively as a collection device to retain live fish and invertebrates.

Early life history forms of lamprey have slender bodies that can pass through a ⅜-inch screen. If retention of all lamprey becomes a priority or recommended conservation measure in the future, it may be necessary to reduce the diameter of the screen mesh to ¼ inch. Smaller diameter openings are likely to be problematic for sediment; a smaller mesh may require lengthening of the screen surface or reduction in pumped discharge volume. These changes would require additional engineering analysis and design modifications.

6.2 Fish Community Monitoring

The following modifications to fish community monitoring methods were incorporated in 2008:

- A specimen labeling scheme was implemented in 2008 at the request of CDFG and in coordination with the Corps, primarily for collection of longfin and delta smelt specimens retained by the agencies.

- Lamprey specimens were carefully preserved and vouchered for later identification.

- Subsampling was used to estimate the larger catches of shrimp and clams.

- Subsampling of individual fish length data was employed to reduce stress and mortality when high densities of fish were encountered.

- Targeted trawl distance was reduced when necessary to reduce negative impacts to collected fish.

- Aeration and increased frequency of ambient water exchange were used to minimize injury or stress to collected fish during warm air and water conditions.

7 Recommendations

7.1 Entrainment Monitoring

The following steps should be taken to improve the effectiveness of entrainment monitoring:

- Coordination with CDFG and USFS/Center for Integrated Biosystems should be carried out regarding entrainment monitoring schedules and collection of native mussels of the genus *Anondonta*.
- Observation of bird activity at DMP sites should be limited to fish-eating birds and any birds of special concern to the project.
- Information from the dredging contractor, including overall surface area dredged at each site and accurate GPS locations of each discrete dredged area, would be helpful for developing estimates of lamprey and invertebrate density, along with habitat alteration. Researchers can use this data to help study how dredging impacts the benthic community, how quickly the areas can be recolonized and how these species react to changing habitat conditions. It is likely that in 2009, freshwater mussels will be studied more closely if dredging occurs in the Port of Stockton reach of the San Joaquin River.

The following modifications are recommended for the entrainment screen device:

- Install a device to direct flow away from the base of the screen. Such a device would prevent erosion under the axles. This device may need to be removable for transport and be re-installed at each DMP site.
- Install removable side-splash boards along the first screen section to prevent water splashing over the side. These boards can be made of plywood; however, there needs to be a way to attach them.
- Install a high-pressure capacity air tank available to the pneumatically controlled Y-valve splitter. Such a tank would allow for on-demand switching capability, eliminating the existing need to wait for a generator-powered pump to reach high pressure prior to switching discharge flow between the screen and DMP cell.
- Install a waterproof and extendable control switch for the pneumatic Y-valve that can be quickly reached by monitoring staff stationed on the screen device.
- 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.
- Repair the stretched tailgate cable to allow the tailgate to be raised and locked into its fully closed position again and install incremental locking positions to allow the tailgate screen section to be locked in more than one raised position.
- Extend the entrainment screen device, or have a removable section that can be added for areas with high pumping volumes or when heavy debris clogs the screen quickly.

The entrainment screen device (see Figures 15 to 17) should be used at all DMP sites. The screen device works well in all areas with sandy substrate, but it requires more labor when used at sites with very high organic loads and/or adhesive, fine sediments that easily clog the screen. It is likely that constraints at individual DMP sites such as access, geomorphology, and dredged material characteristics will prevent use of the screen device at all DMP sites. As a result, the sampling cell methodology will be retained during future monitoring events even if the screen is successful at most locations.

If the entrainment screen device does not prove efficient at a particular DMP site, then the following points are recommended to improve the efficiency of the sample cell methodology:

- Enlarge the size of the sampling cell as much as possible to accommodate a greater volume of dredge slurry. The cell should not become so large that the monitoring crew cannot keep pace with settling, draining, and sample processing times.
- Increase sample frequency to increase overall sampled volume of the dredges output. Greater effort will require increased labor efforts for monitoring.
- Ensure that the elevation of the sampling cell and work area at the sampling cell discharge location are sufficiently high to prevent backwatering of the DMP site pool into the entrainment work area.
- Flush the sampling cell (remove all stop boards and direct flow through the sampling cell) occasionally to remove buildup of fine sediments and organic material on the bottom of the cell to maintain its capacity.
- When using the sampling cell, use a splitter valve to direct flow into or around the cell.
- Use a Y-valve splitter or locate the sample cell a sufficient distance from the DMP site to reduce breach risks. As occurred in 2007 at the Scour Pond DMP site, locating the sample cell too close to the primary discharge location at the DMP site is likely to increase the risk of breaching into the sample cell.
- Use more than one weir box and outflow for sample cells to increase speed of sample cell drainage, sample processing, and turnaround time to increase sampling capability using this method.

7.2 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:

- During periods of high flow velocities or high debris content, the long segment of fine mesh tends to catch debris and create additional drag in such conditions. Therefore, the monitoring team may reduce the length of the fine mesh, cod-end inner liner of the otter trawl to maintain the ability of the net to reach the target sampling depth (bottom). Testing should also be done to assess changes in fish retention based on the reduced length of the cod-end inner liner.
- Frequent changes of water and aeration of holding bins will be used when sensitive and ESA-listed species are encountered.
- If difficult-to-identify species (particularly juvenile lamprey) are collected, additional specimens will be preserved and vouchered for further laboratory identification and confirmation.
- In future collections of lamprey, particularly of the genus *Lampetra*, specimens will be carefully preserved for morphological examination, with a portion of body tissue collected for submittal to USFWS for mitochondrial DNA analysis to improve taxonomy and field identification characteristics.

- On-water observation of bird activity at specific dredge reaches will be limited to fish-eating birds and any birds of special concern to the project.
- The sample design efficiency will be tested by increasing replicate iterations per trawl survey, preferably once per dredge reach location or when the risk of encountering ESA-listed fishes is low.
- The individual specimen label system will continued to be used, with further refinements to meet project needs. The project database will be modified to prompt for real-time data collection of specimen label identification information. These steps will increase the efficiency of future data management.

8 Conclusions

Key conclusions of the 2008 monitoring program were:

- Fisheries monitoring requirements stipulated by the NMFS BOs (NMFS 2006a,b) for the SSC and SRSC were successfully met during the 2008 dredge season.

- Collection and take of delta smelt occurred during fish community monitoring in the Antioch reach (Scour Pond Island DMP site) of the SSC, and the natural channel (Decker Island) and Man-made Channel (S-31) reaches of the SRSC.

- Collection and take of longfin smelt occurred during fish community monitoring in the Decker Island reach of the SRSC.

- No collection or take of listed salmonid species occurred in 2008.

- No take of listed fish species occurred during entrainment monitoring events at any of the DMP sites in 2008.

- Demersal species dominated entrainment catch at all DMP sites in 2008.

- For fish species where enough data existed to compare (white and channel catfish) a higher proportion of smaller sized fish were encountered in entrainment monitoring than were encountered in fish community monitoring.

- Entrainment sampling efficiency and the quantitative capability of entrainment monitoring was increased substantially by use of the mobile entrainment screen.

- Initiating dredging earlier in the season (August) in the SRSC appears to reduce the likelihood of encountering juvenile salmonids, delta smelt, and longfin smelt.

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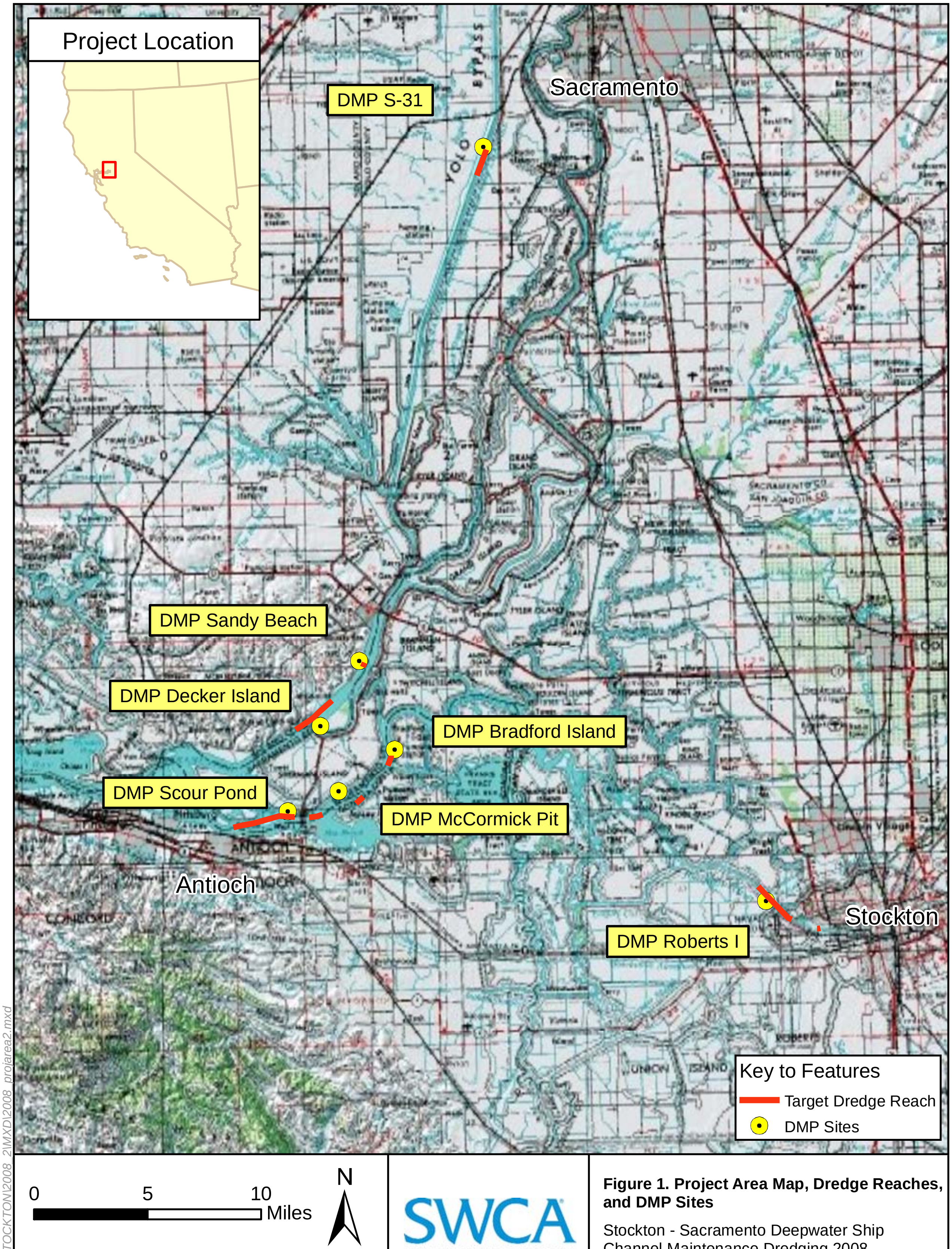

Source:
USGS 7.5 Minute Topographic Quadrangles.

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

Stockton - Sacramento Deepwater Ship Channel Maintenance Dredging 2008 Fish Monitoring Report

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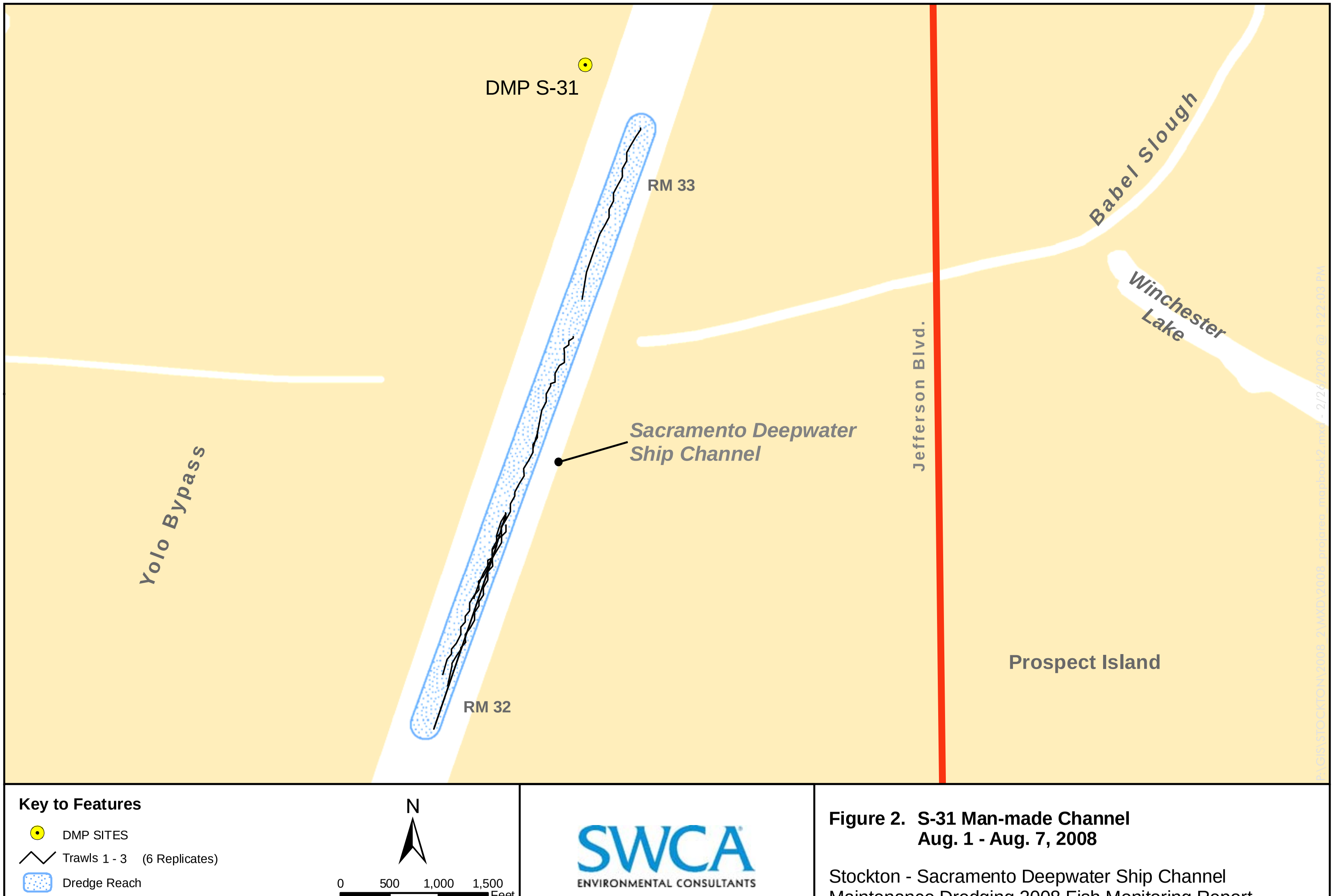

Source:
Base map data provided by ESRI Data & Maps, ESRI Redlands, CA. 2004.

Figure 2. S-31 Man-made Channel
Aug. 1 - Aug. 7, 2008

Stockton - Sacramento Deepwater Ship Channel
Maintenance Dredging 2008 Fish Monitoring Report

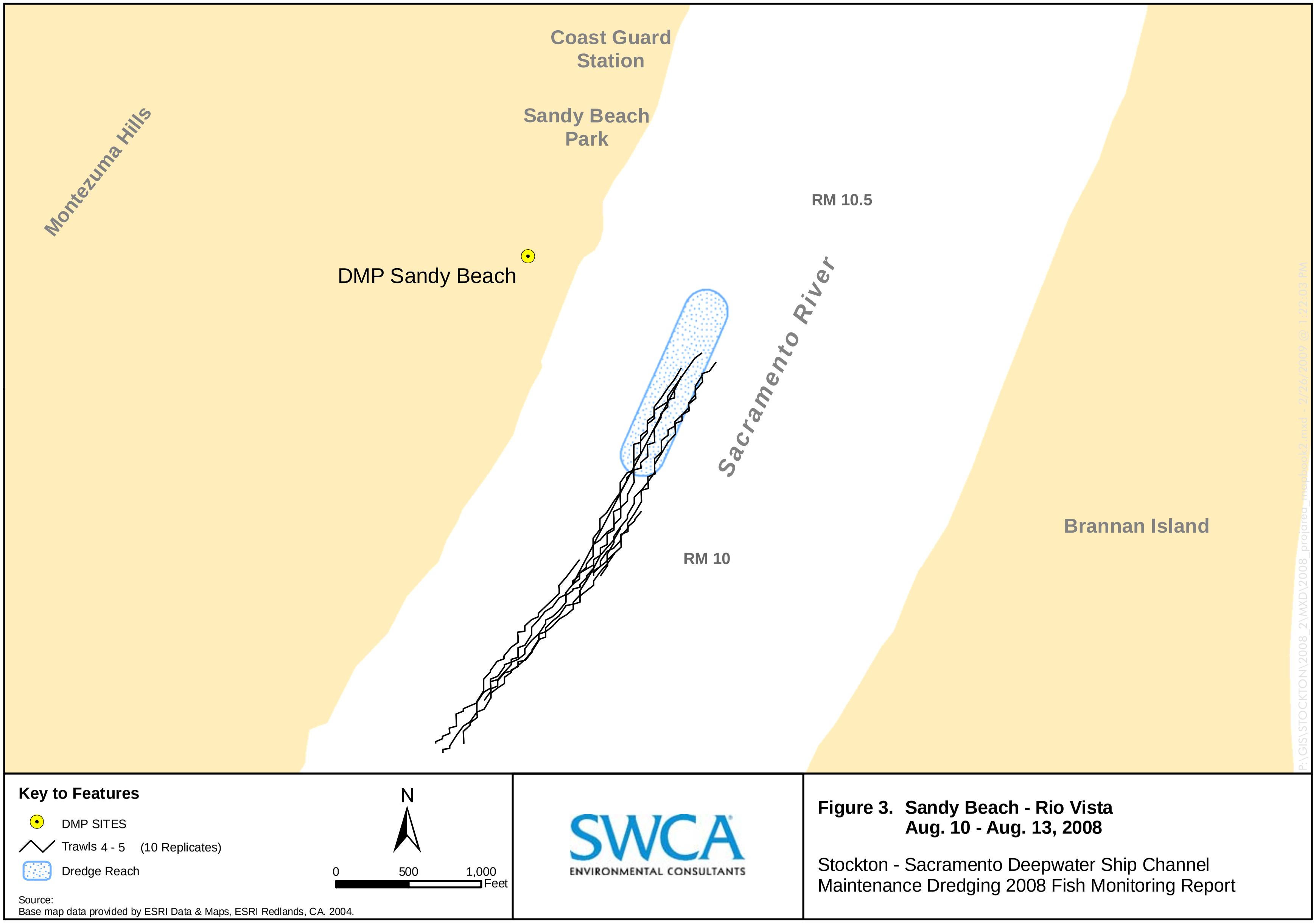

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Figure 3. Sandy Beach - Rio Vista
Aug. 10 - Aug. 13, 2008

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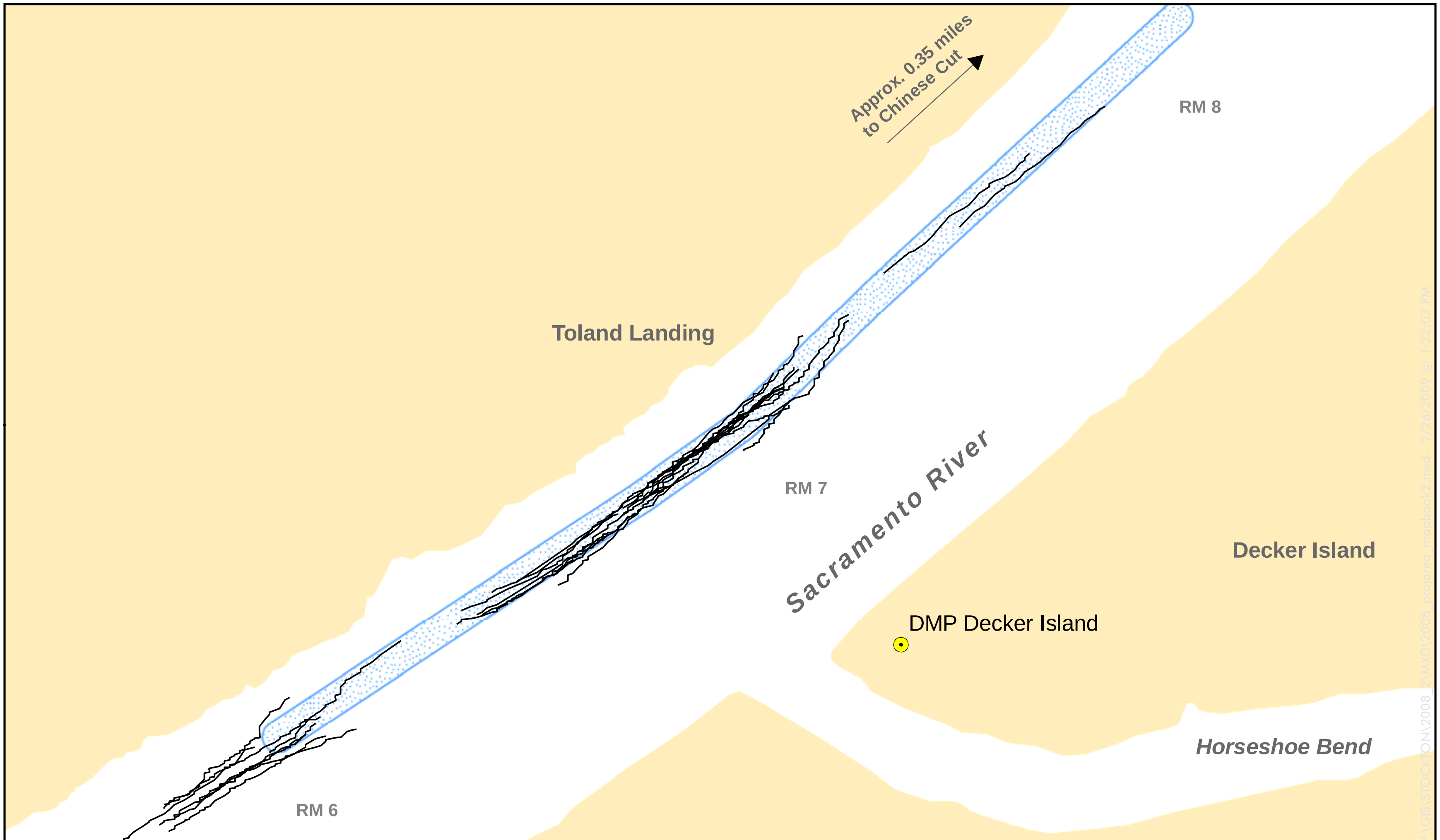
Maintenance Dredging 2008 Fish Monitoring Report



Key to Features

- DMP SITES
- Trawls 6 - 13 (30 Replicates)
- Dredge Reach

N

0 500 1,000 1,500 Feet

Source:
Base map data provided by ESRI Data & Maps, ESRI Redlands, CA. 2004.

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Figure 4. Decker Island - Natural Channel
Aug. 19 - Sept. 7, 2008

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Maintenance Dredging 2008 Fish Monitoring Report

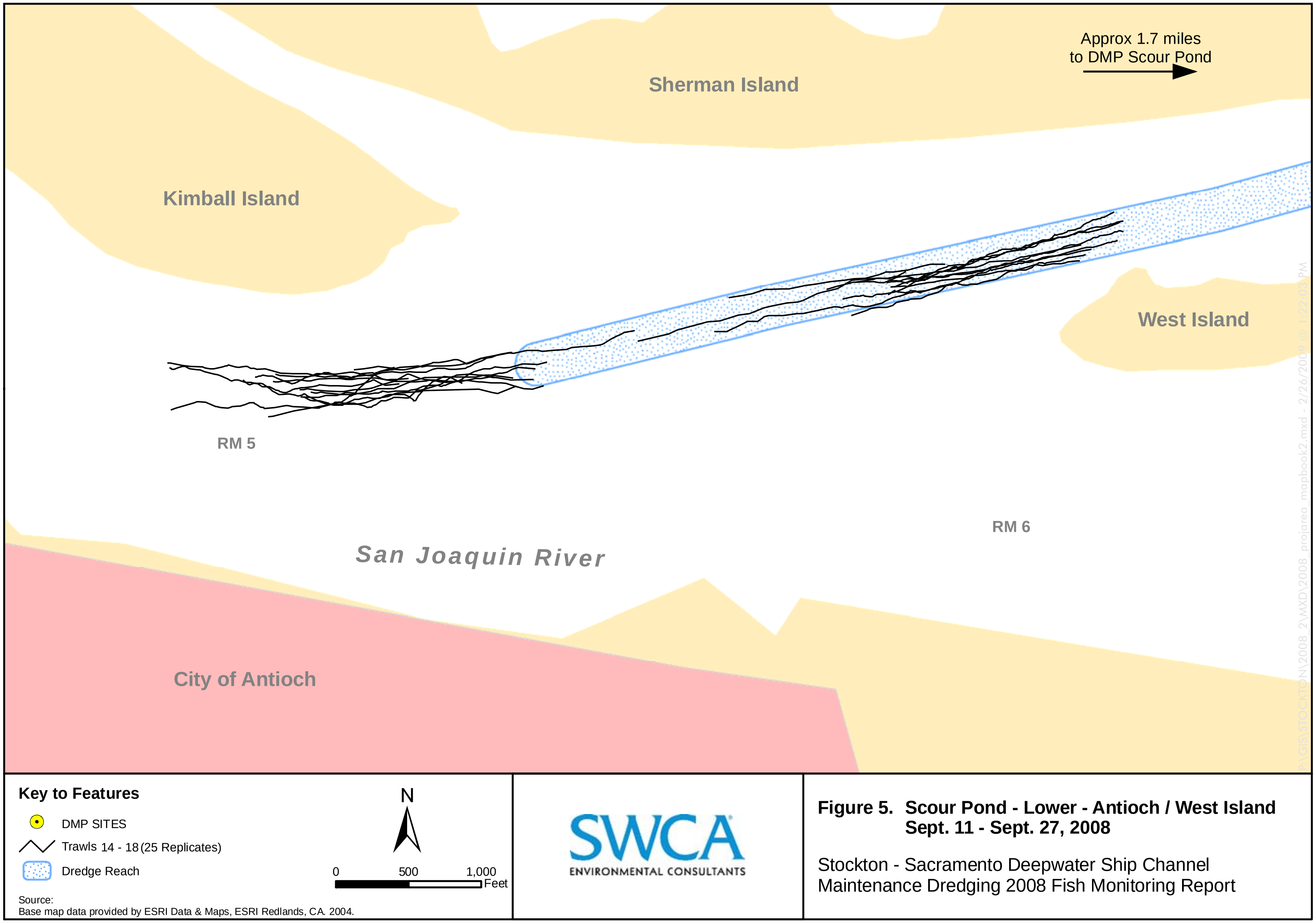

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Figure 5. Scour Pond - Lower - Antioch / West Island Sept. 11 - Sept. 27, 2008

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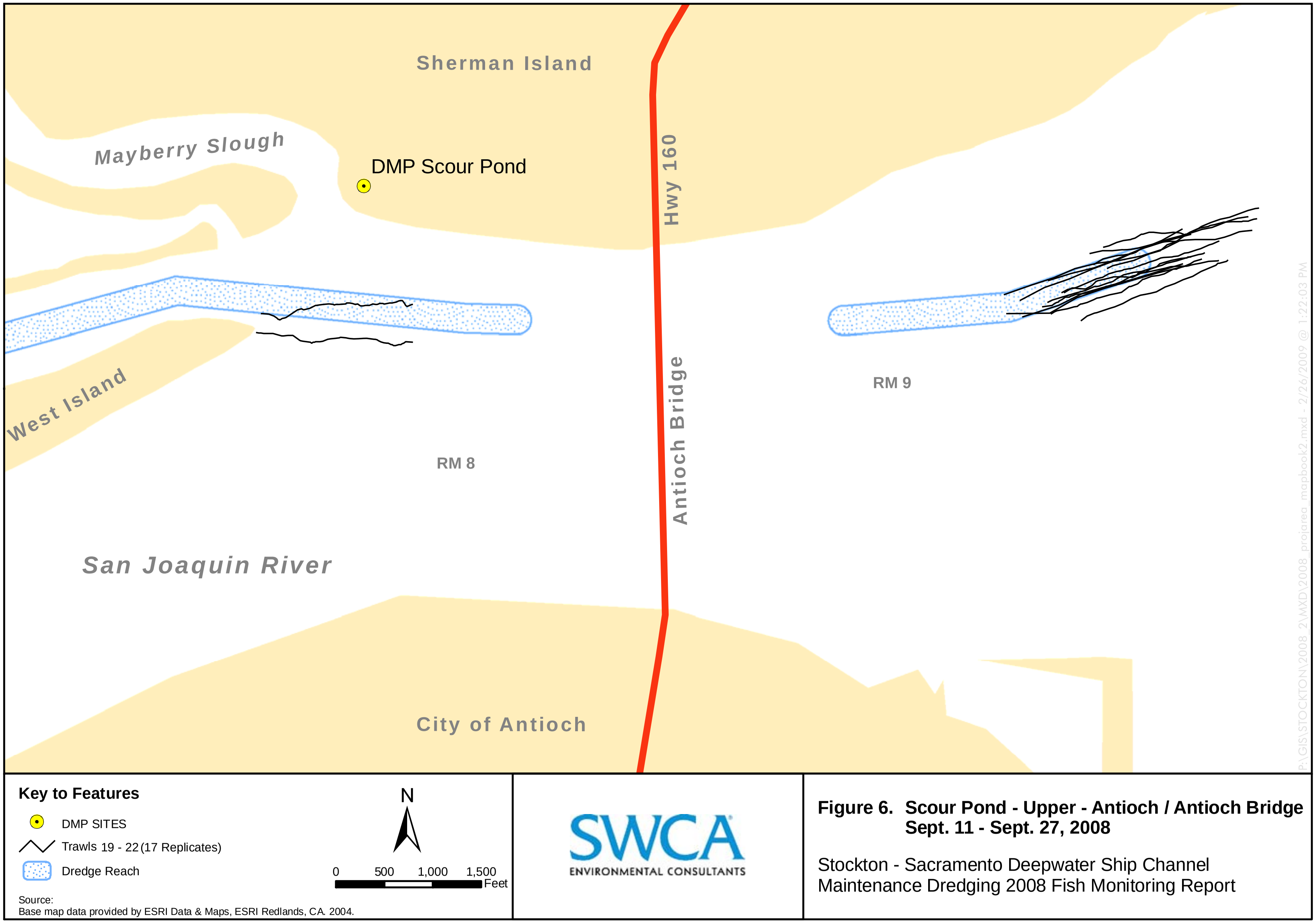

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Figure 6. Scour Pond - Upper - Antioch / Antioch Bridge
Sept. 11 - Sept. 27, 2008

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Maintenance Dredging 2008 Fish Monitoring Report

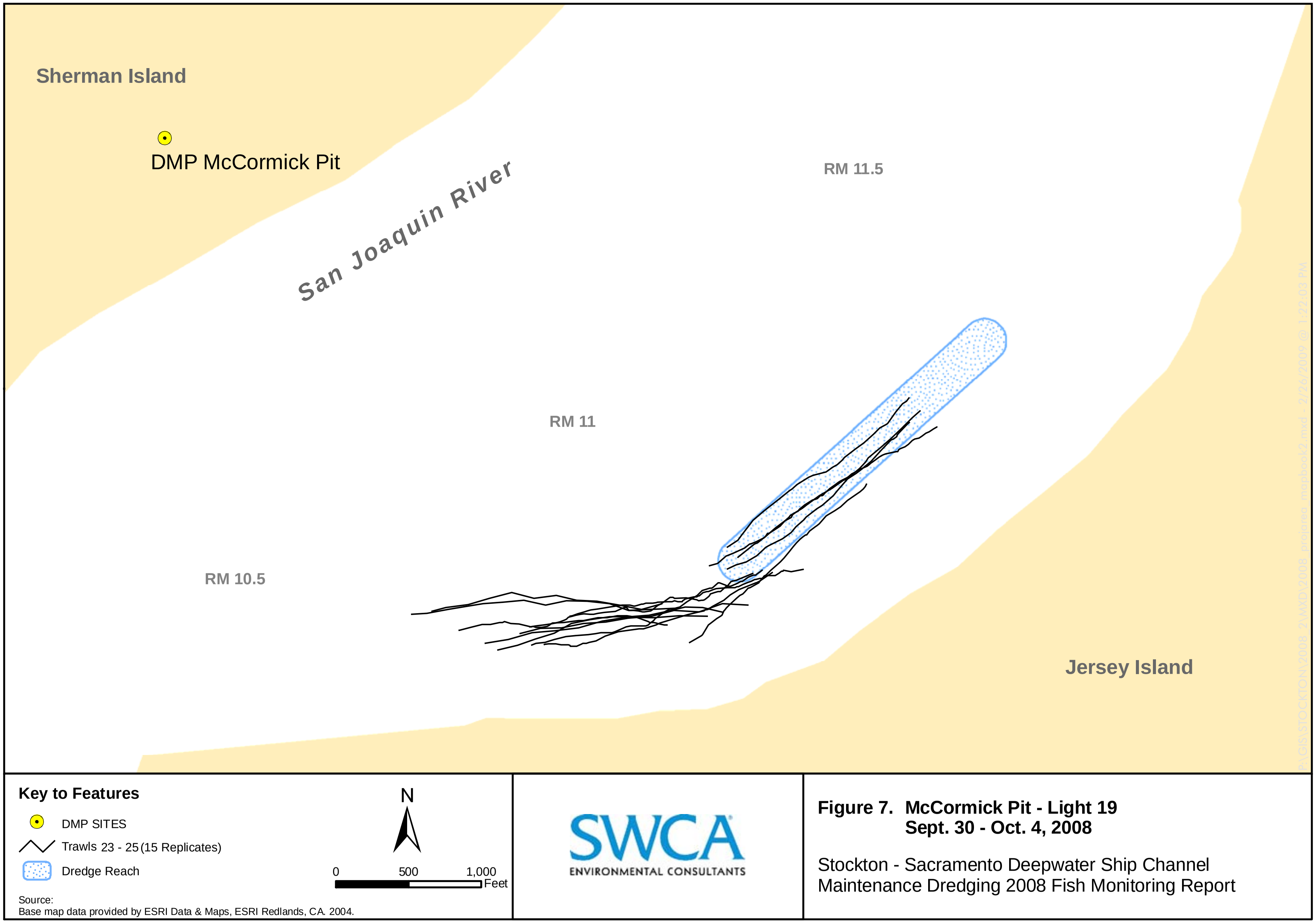

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Figure 7. McCormick Pit - Light 19
Sept. 30 - Oct. 4, 2008

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Maintenance Dredging 2008 Fish Monitoring Report

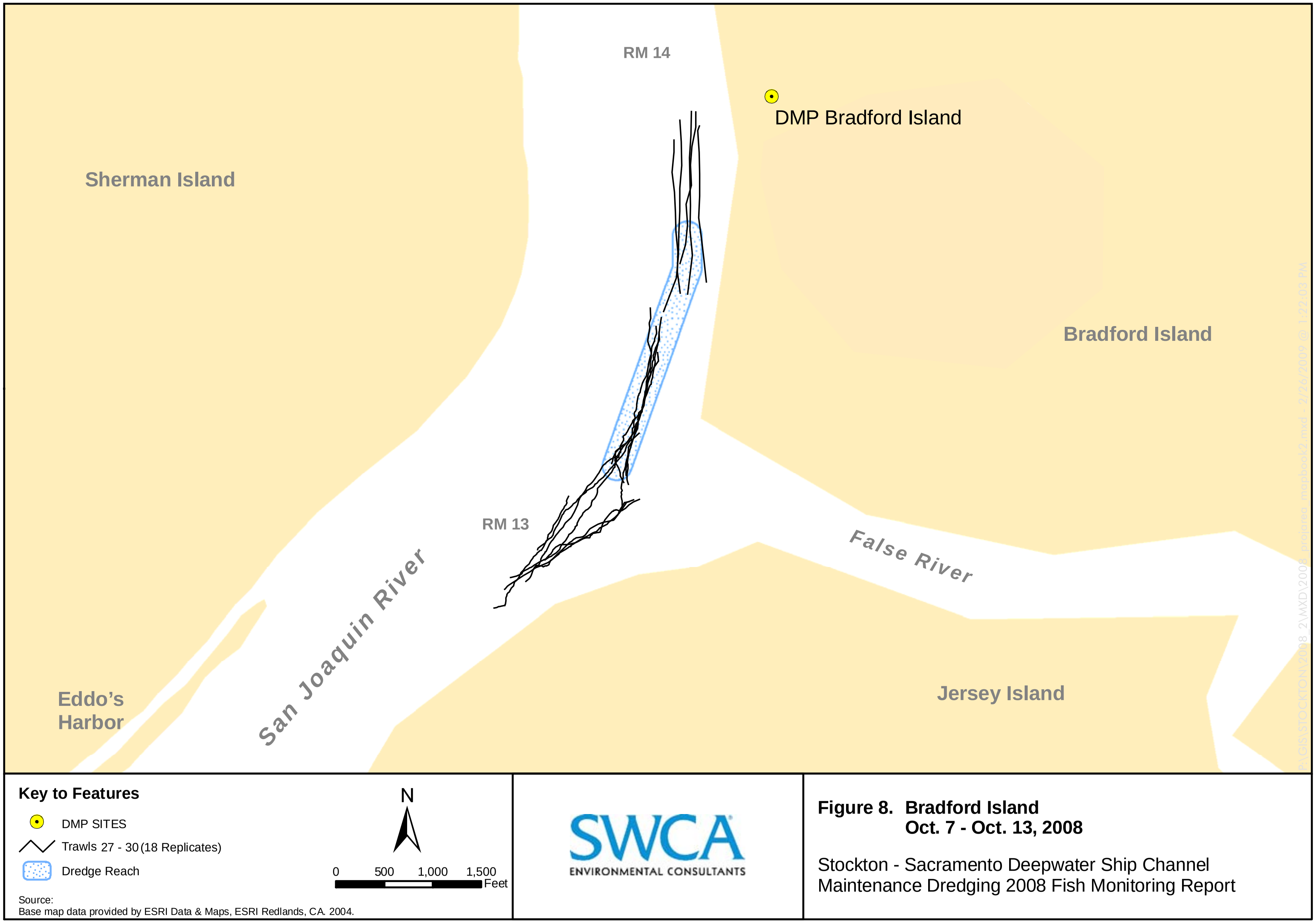

Figure 8. Bradford Island
Oct. 7 - Oct. 13, 2008

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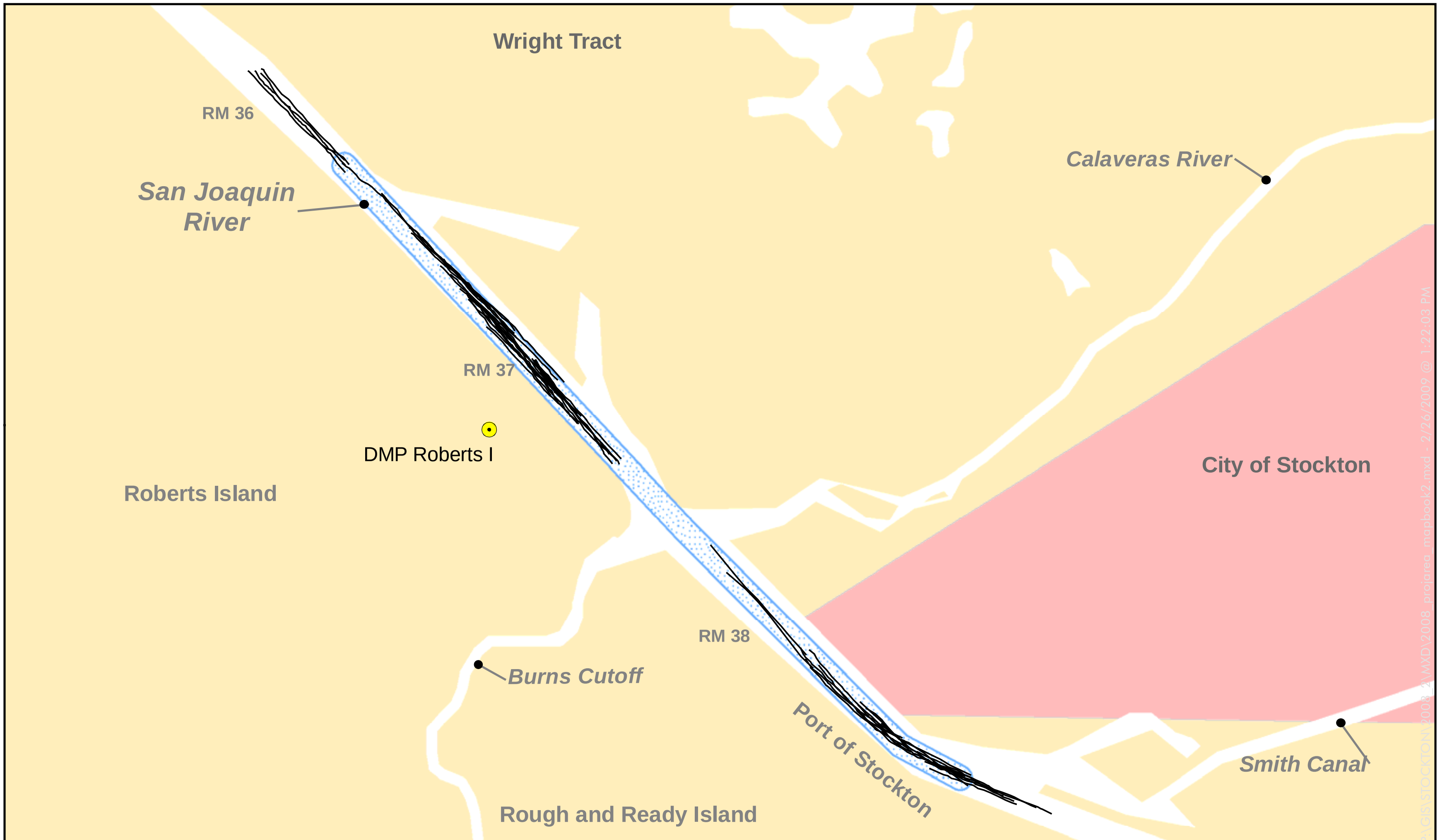
Maintenance Dredging 2008 Fish Monitoring Report



Source:
Base map data provided by ESRI Data & Maps, ESRI Redlands, CA. 2004.

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Figure 9. Roberts - Port of Stockton
Oct. 16 - Nov. 8, 2008

Stockton - Sacramento Deepwater Ship Channel
Maintenance Dredging 2008 Fish Monitoring Report

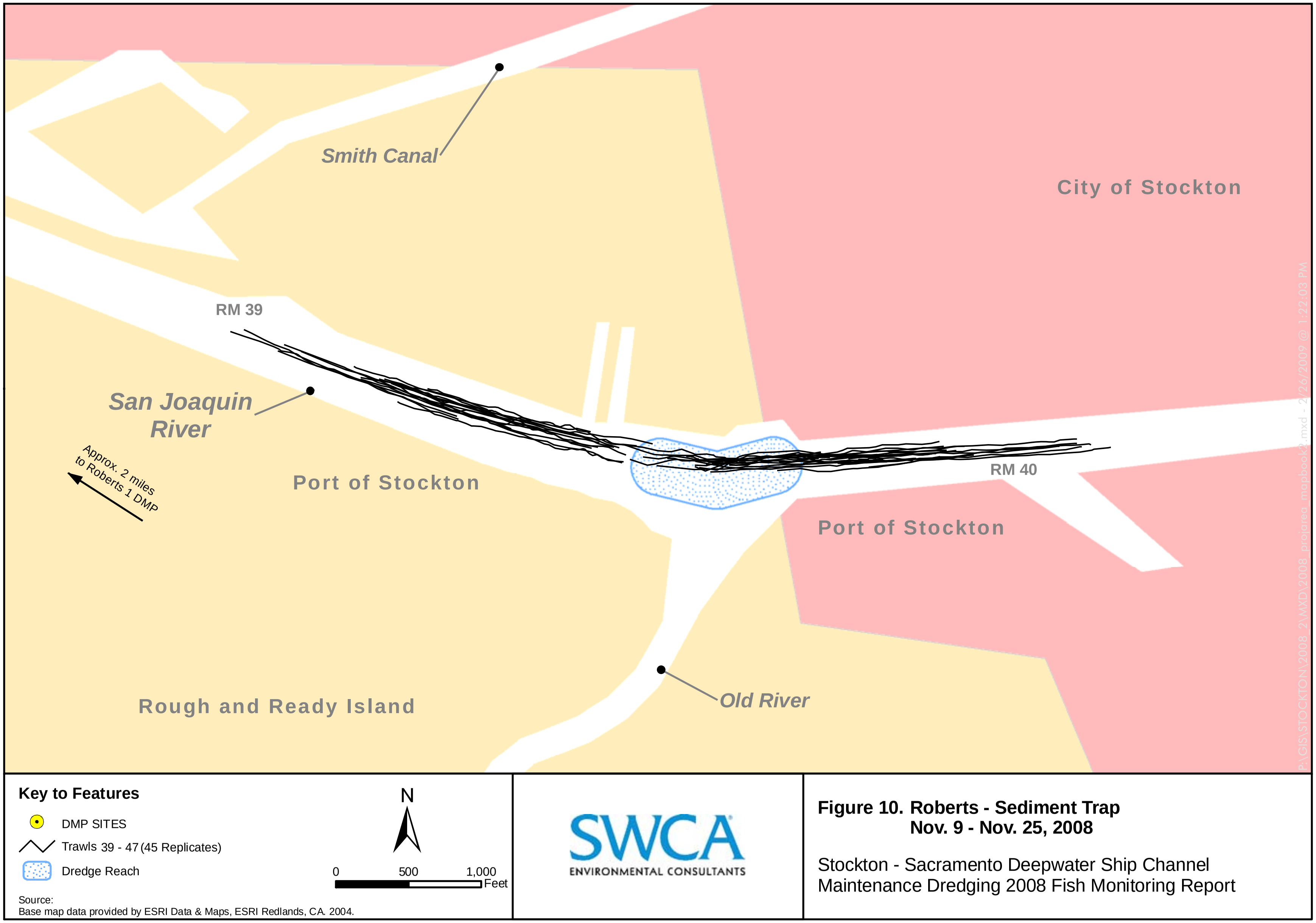

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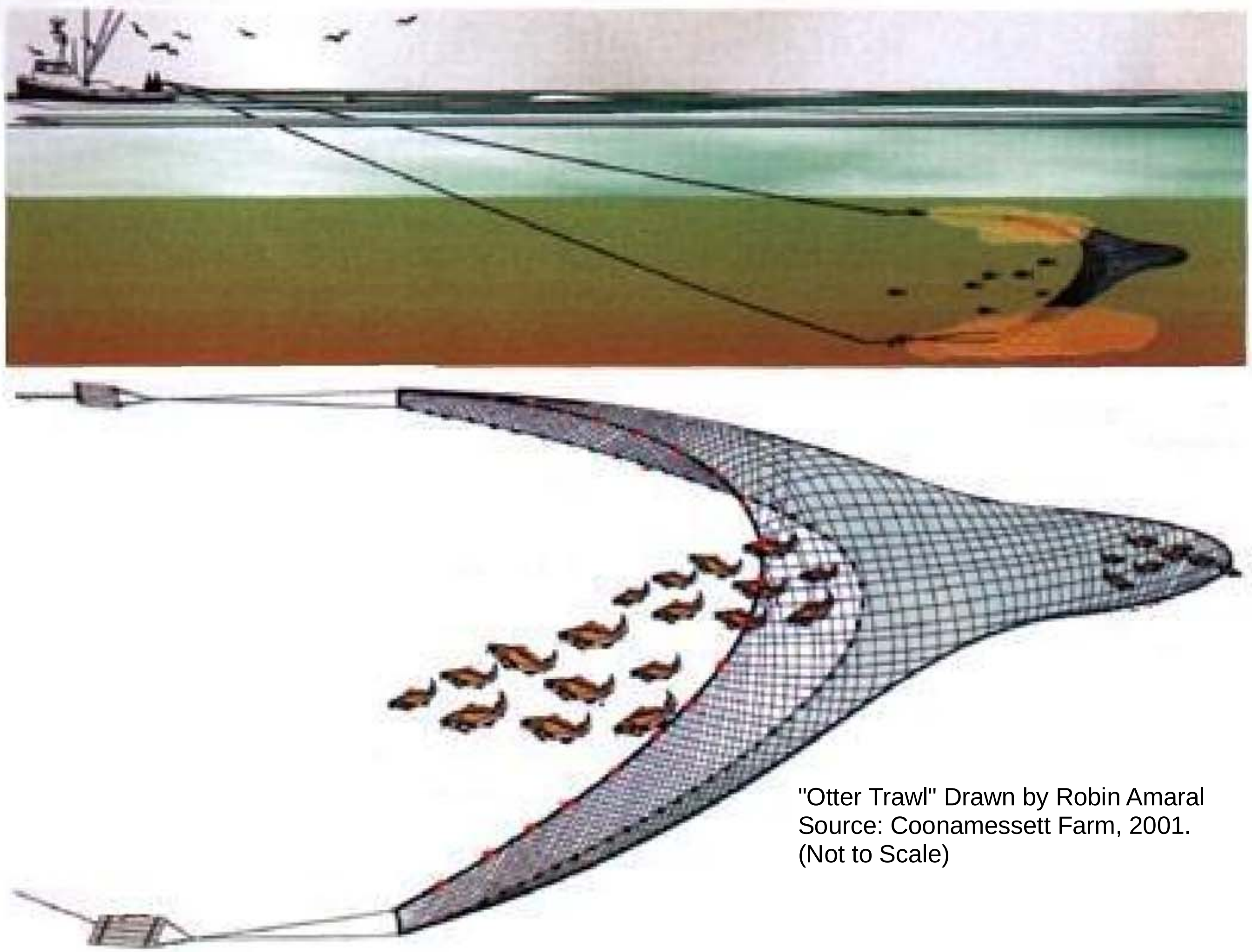
Figure 10. Roberts - Sediment Trap
Nov. 9 - Nov. 25, 2008

Stockton - Sacramento Deepwater Ship Channel
Maintenance Dredging 2008 Fish Monitoring Report



"Otter Trawl" Drawn by Robin Amaral
Source: Coonamessett Farm, 2001.
(Not to Scale)

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Channel Maintenance Dredging Program
2008 Fish Monitoring Report

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Figure 11. Otter Trawl Diagram


Processing the Catch


Data Logging Computer

Trawl Vessel RV Karen M at Bradford Island


Retrieving the Otter Trawl at the Port of Stockton

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Figure 12. Fish Community Sampling

Step 1:
Fill the Sample
Cell

Step 2:
Release Water
Through Weir.

Step 3:
Monitor

Step 4:
Survey Empty
Cell for Fish.

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2008 Fish Monitoring Report

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Figure 13. Entrainment Sampling Cell at Decker Island DMP Site

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Figure 14. Discharge Pipeline Splitter Valve at Roberts Island DMP

Figure 15. Mobile Entrainment Collection Screen System

Figure 16. Mobile Entrainment Screen at Roberts Island DMP

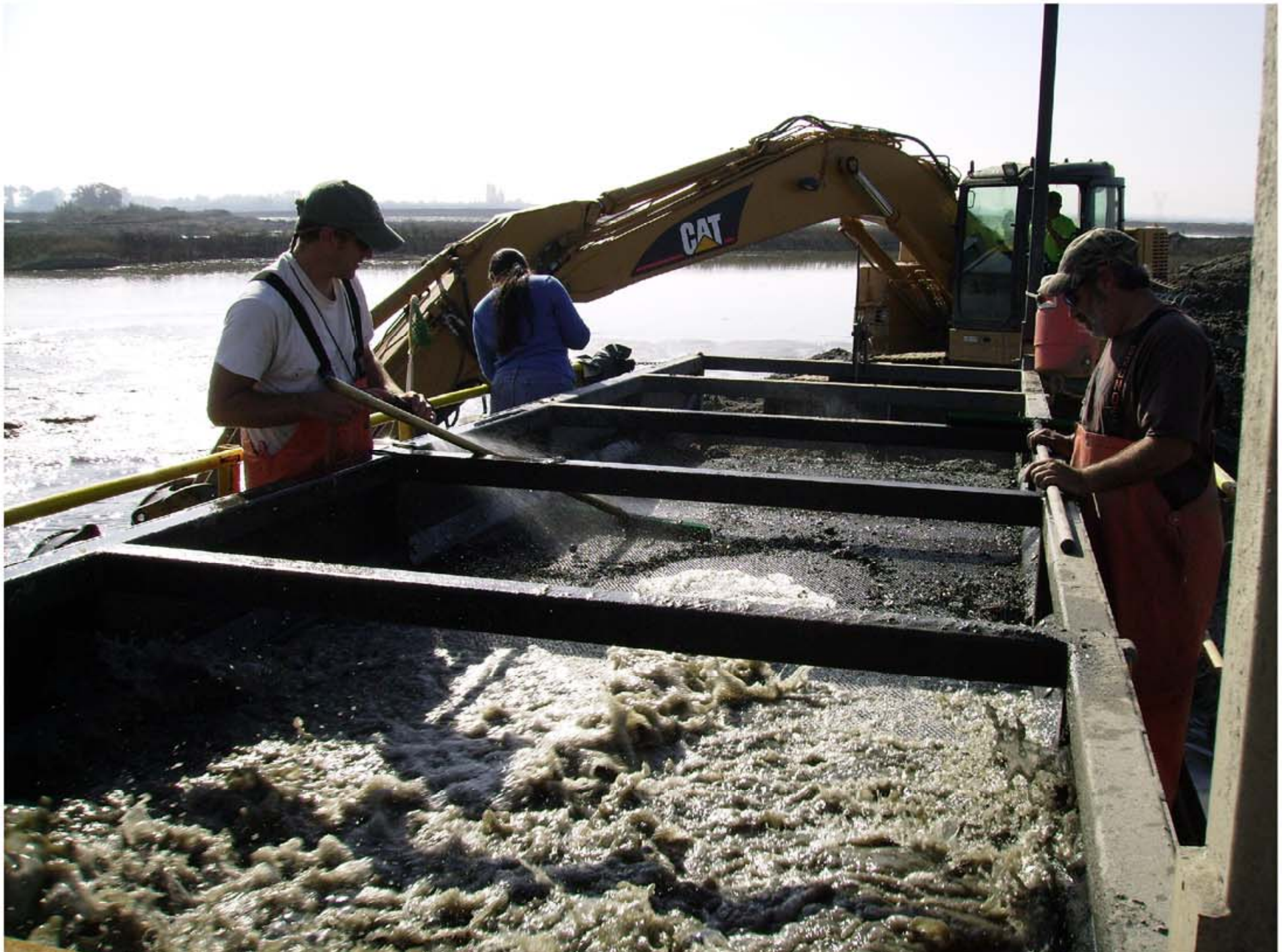

Figure 17. Mobile Entrainment Screen at Roberts Island DMP

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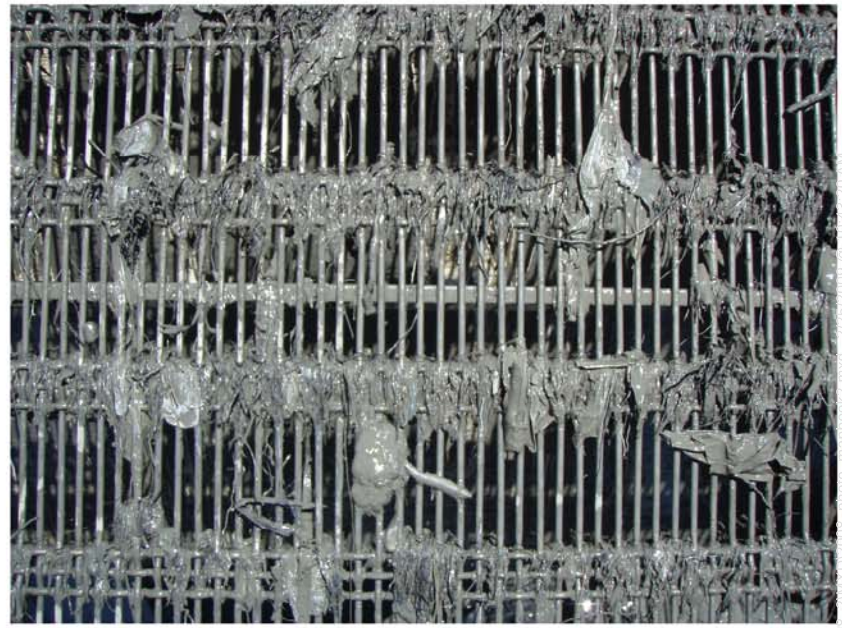
Perforated Round Screen



Woven Wire Screen

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Figure 18. Two Types of Screen Used for Entrainment Screen Sampling in 2008

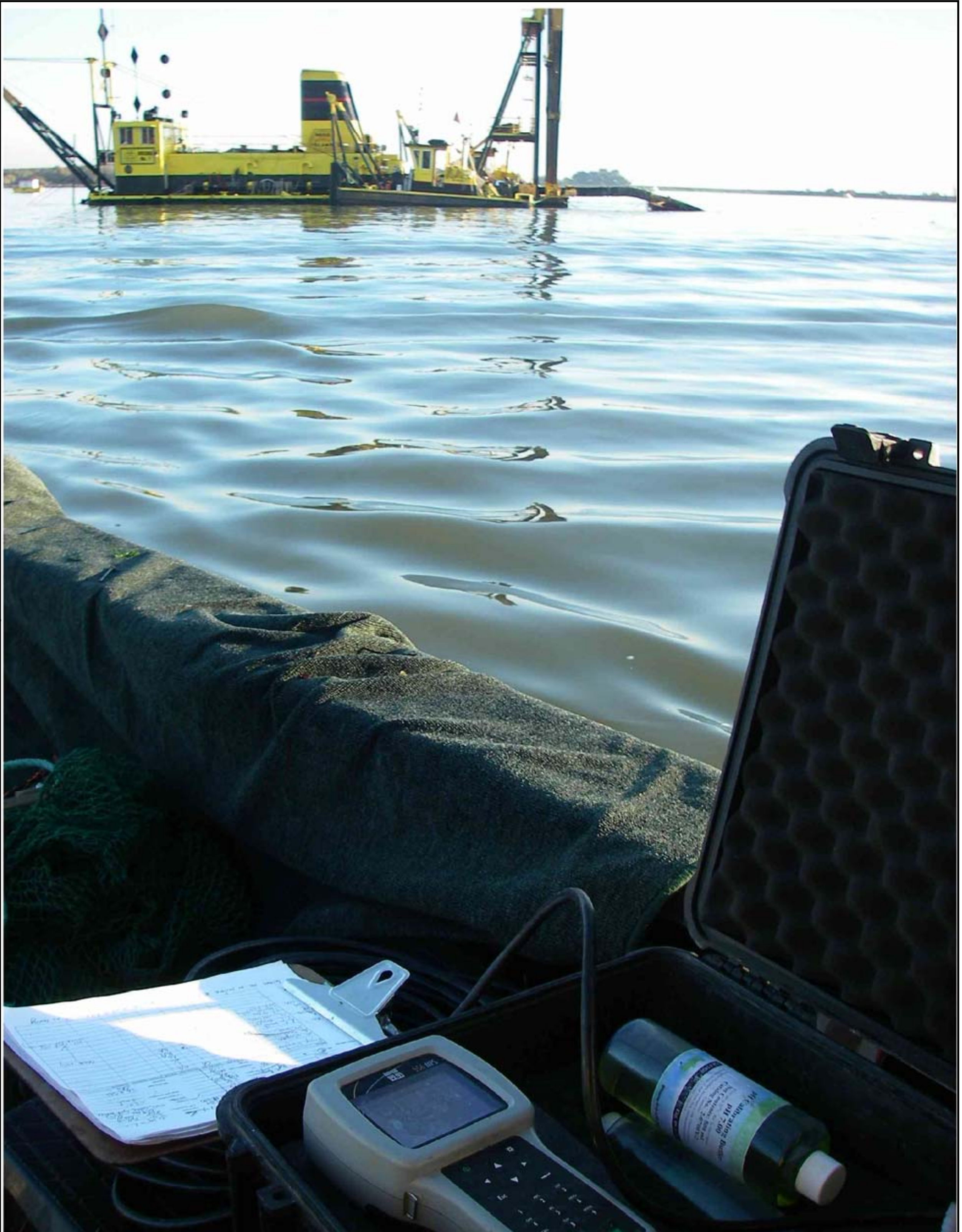

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Figure 19. Water Quality Monitoring (YSI-556/MPS) During Fish Community Sampling RISG Dredge No. 7 in the Background

P:\GIS\STOCKTON\2008_2\MXD\Water_Quality_Monitoring_NonMap.mxd

Starry Flounder

Tule Perch

White Sturgeon

Sacramento Blackfish

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Shrimp and Asian Clams

Catfish and Other Invertebrates

Freshwater Mussles, Bluegill, and Catfish

River Lamprey

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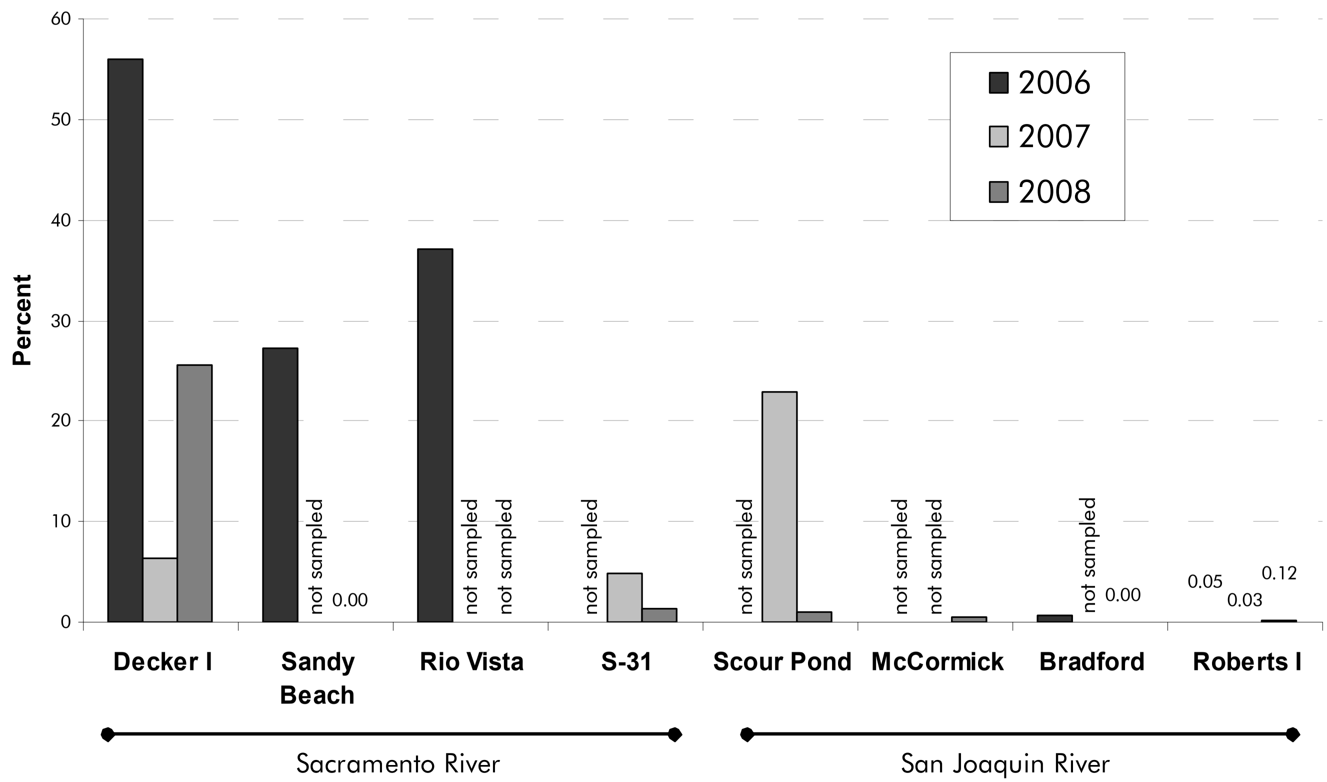
Figure 21. Specimens Collected During Entrainment Sampling



Not Sampled: Dredging activities and corresponding monitoring did not occur at these locations.

Note: In 2006, sampling occurred October to December, in 2007, sampling occurred November to December, in 2008 sampling occurred from August to November.

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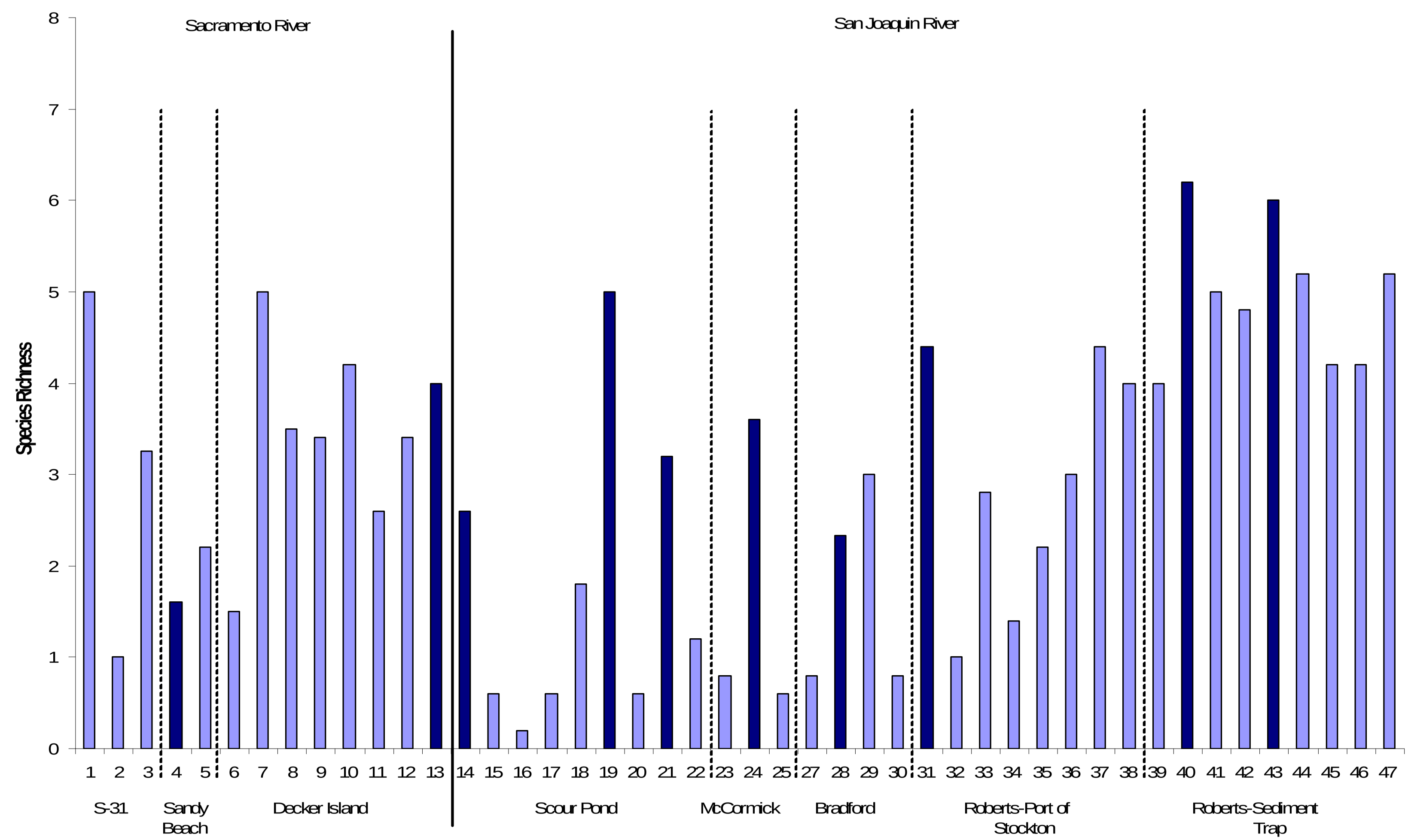
Figure 22. Percent Native Fish Collected at Each Fish Community Monitoring Location



Note: Shaded bar indicates night/dawn/dusk survey.

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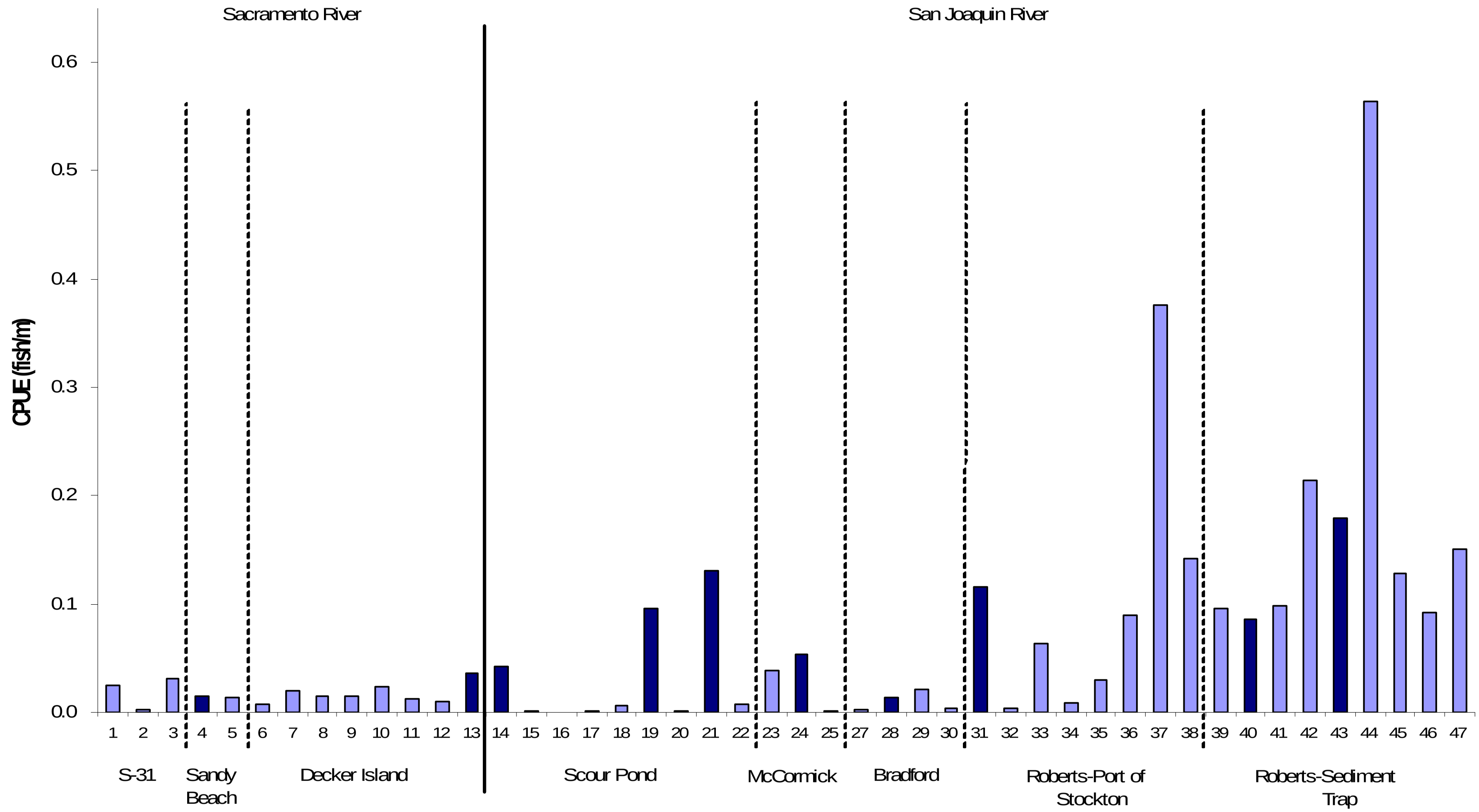
Figure 23. Average Species Richness for Each Fish Community Survey



Note: Shaded bar indicates night/dawn/dusk survey.

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Figure 24. Average CPUE for Each Fish Community Survey

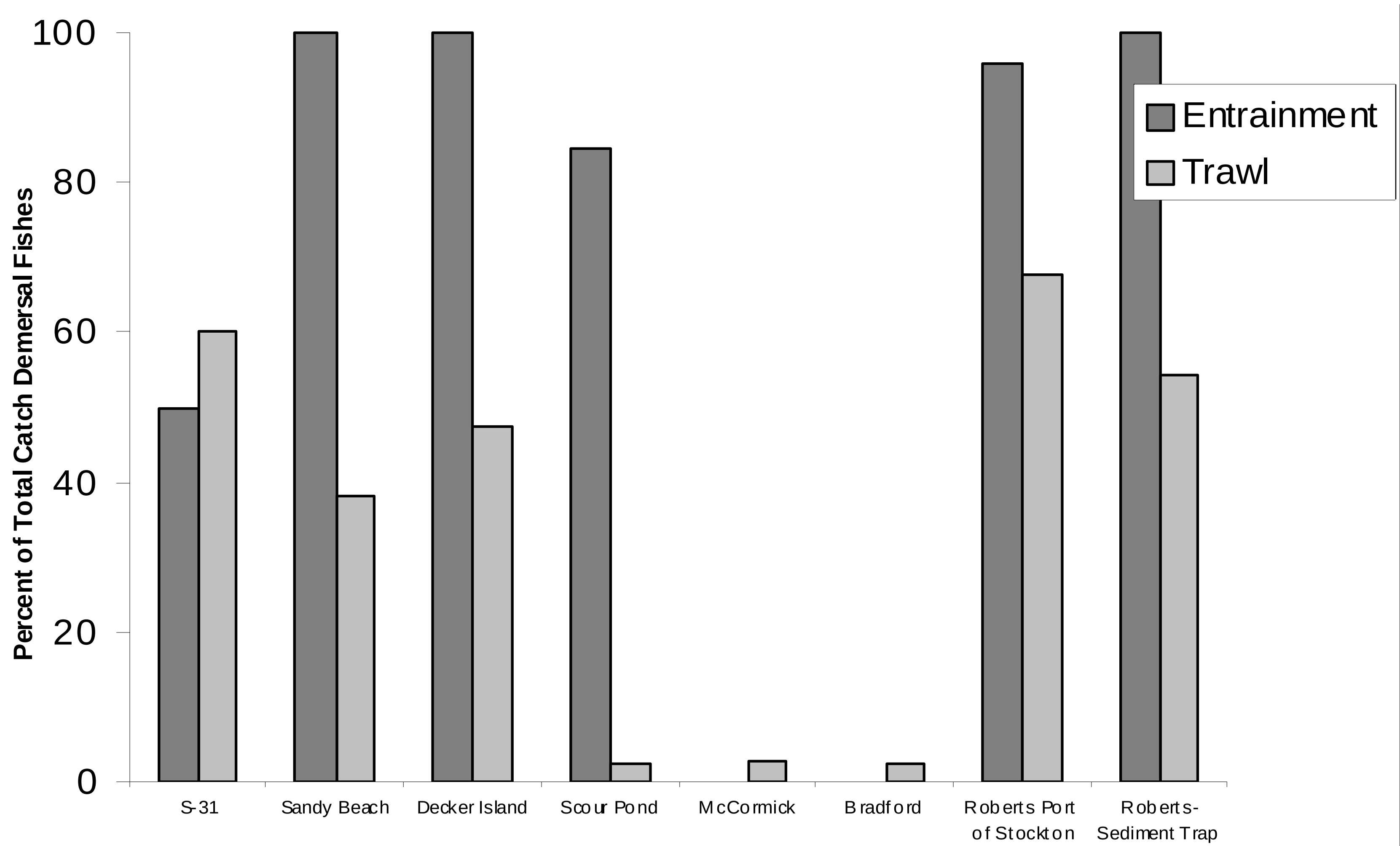

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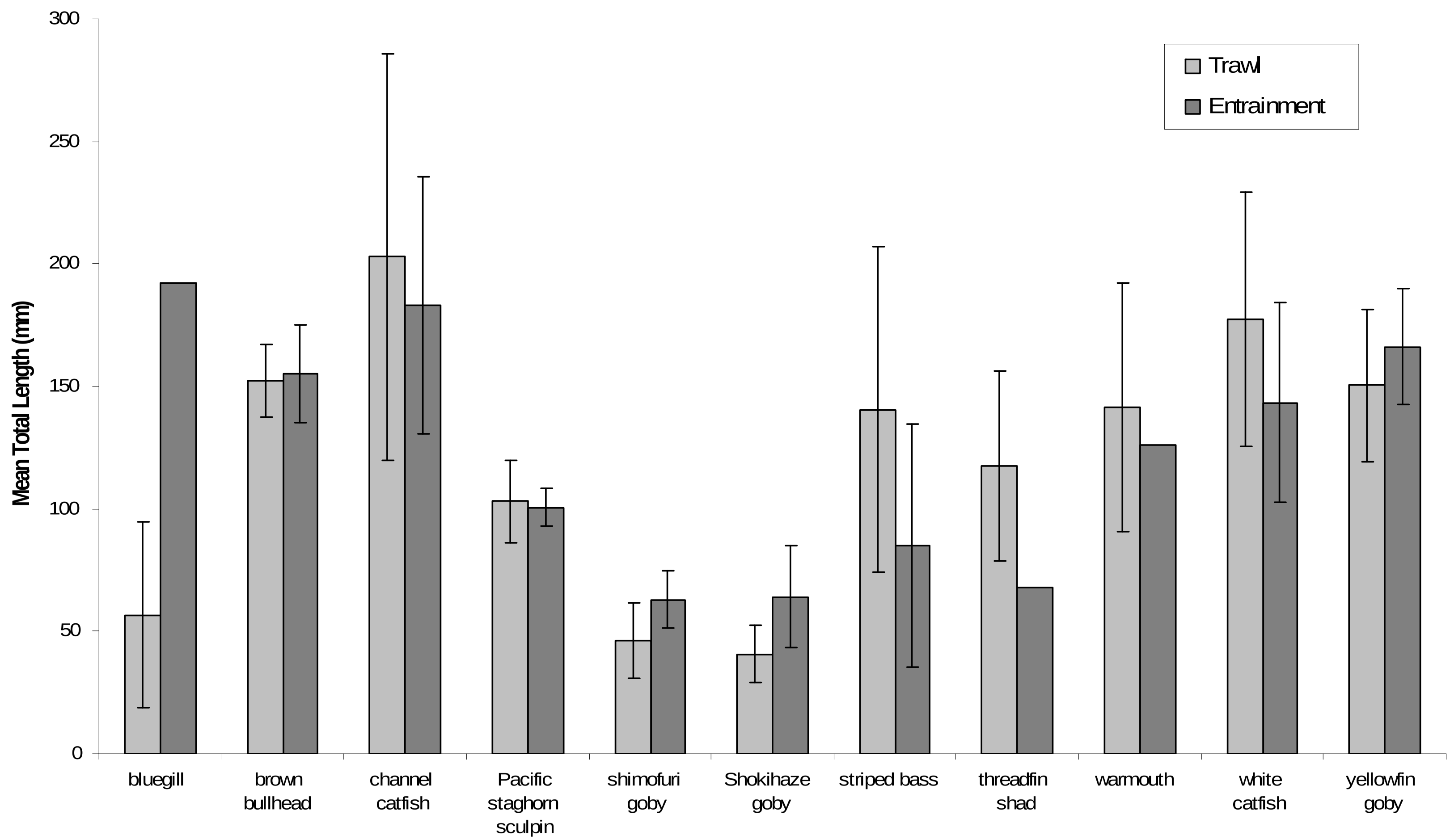
Figure 25. Percent Demersal Fishes in Overall Catch



Note: Bars without errors indicate only one specimen collected.

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Figure 26. Mean Size of Fish Species Collected in Both Trawl and Entrainment in 2008 (+/- one standard deviation)

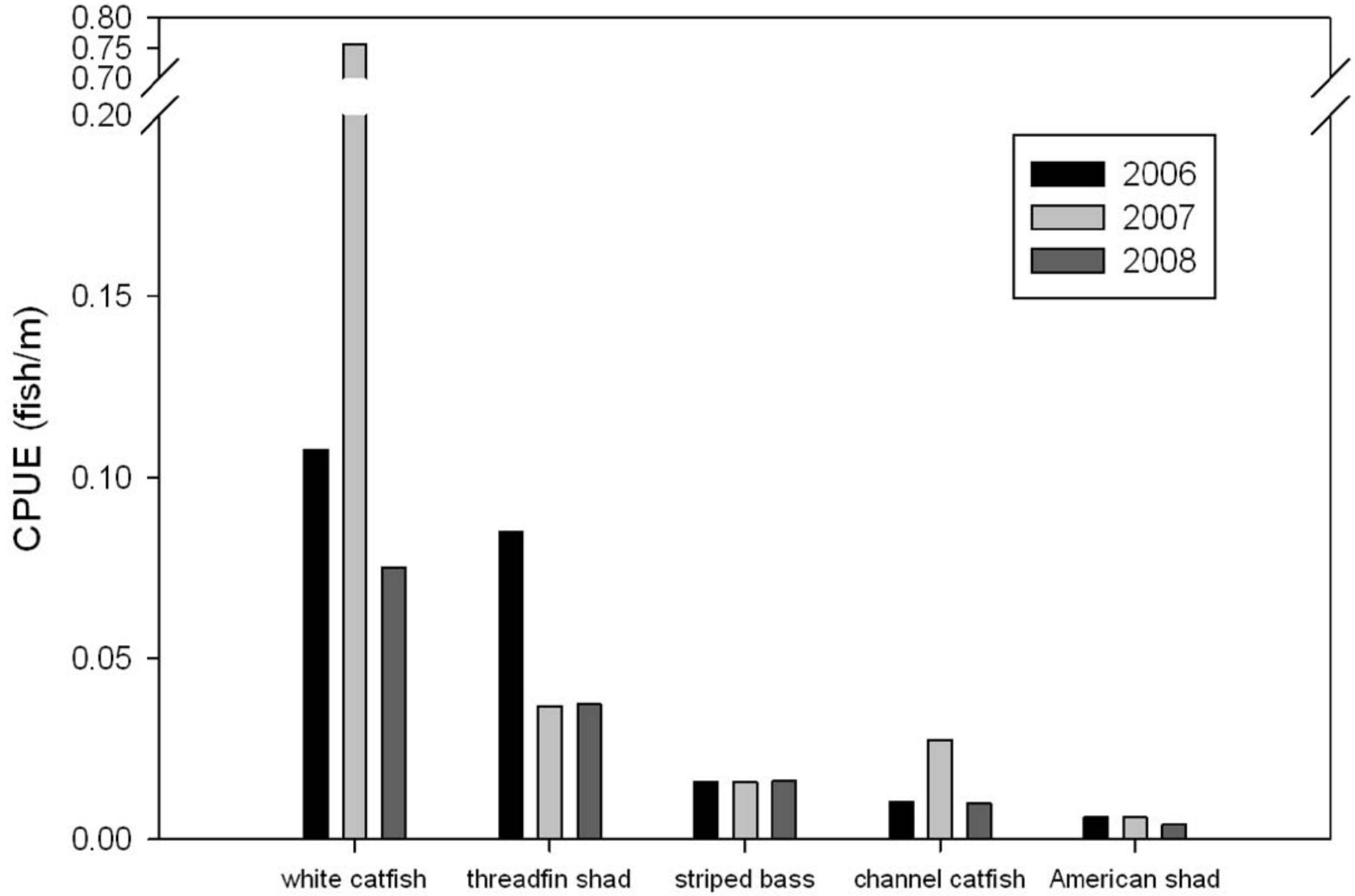

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Figure 27. Roberts (Port of Stockton)
Multi-year Comparison
November Trawls

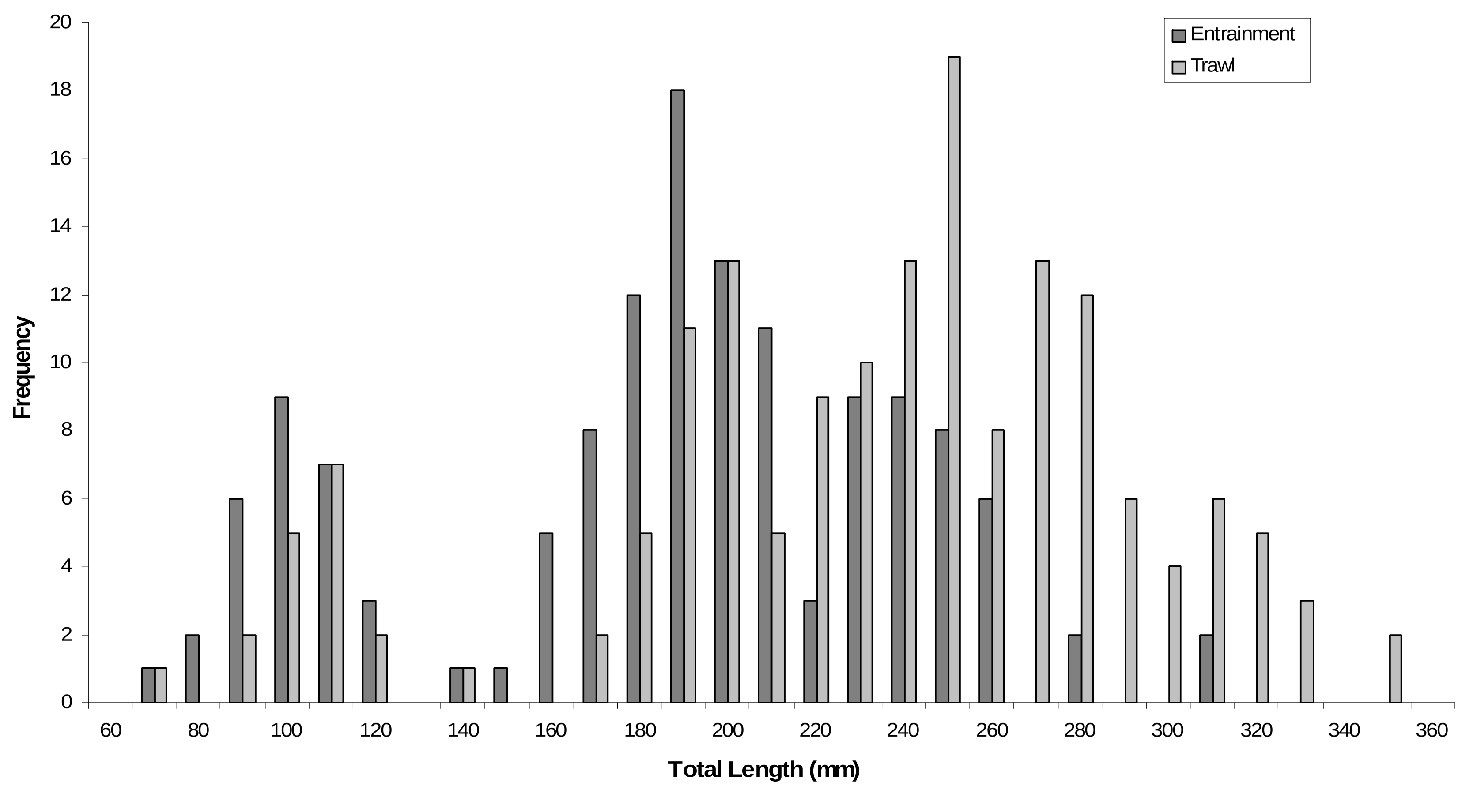

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Figure 28. Length Frequency Distribution of Channel Catfish at Roberts DMP in 2008

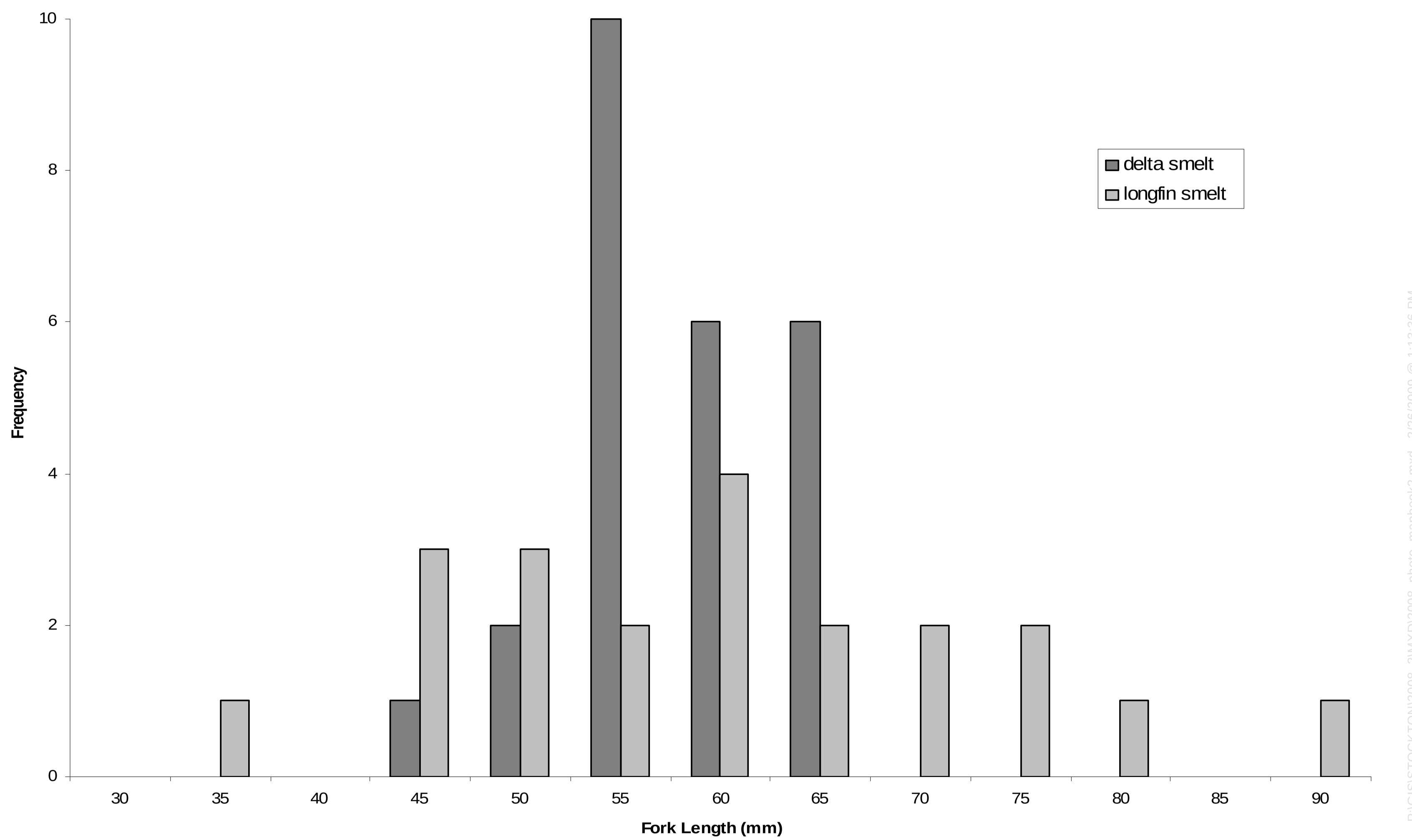

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Figure 29. Length Frequency Distribution of Delta Smelt and Longfin Smelt Caught in the SRSC and the Lower SSC in Aug. and Sept. 2008

Appendix A. Special Status Species Life History Information

Appendix A. Special Status Species Life History Information

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 the 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 designation has been proposed. The delta smelt was reclassified from threatened to endangered under CESA (March 4, 2009). The delta smelt has been petitioned to be reclassified from threatened to endangered, under the ESA. That decision remains under review. The delta smelt has designated critical habitat that includes the action area of the project. The longfin smelt, previously petitioned for listing under the ESA and CESA, was listed as threatened under CESA (March 4, 2009) but denied listed under the ESA (April 9, 2009). Other key species of interest that are at least seasonally present in the action area include: Sacramento splittail, 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 parr-juveniles 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. The delta smelt is not present in waters over 25˚C, and is rarely found in water temperatures above 22˚C.

Delta smelt spawn in deadened 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. The 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. The smelt swim in large schools. 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.

The delta smelt was listed as threatened under the ESA on March 5, 1993 (FR 58, 12854). Final critical habitat designation for the 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 the 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 Proposed
California Status: none
Sources: Adams et al. 2002; CDFG 2009; CalFed 2005; Fry 1973; Radtke 1966; Wang 1986

The little-studied green sturgeon occurs in 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. In September 2008, critical habitat was proposed for the Southern DPS of the green sturgeon, which includes the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California (50 CFR 226).

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. Developmental biology of this species is essentially unstudied. Little is known about the age and growth of the green sturgeon but 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.

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 upper portions of the Delta affected by the project. These species have also been 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 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 lower 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. Juveniles occur on the bottom in the lower portion of the SSC and SRSC and have been encountered in trawl monitoring of dredging operations each of the past 3 years. .

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 since these fish were encountered by the fish community and or entrainment monitoring conducted in 2008.

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. Both species are lumped together here due to the difficulty in discriminating between the two species in the field at the life stage encountered during monitoring efforts. 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. Lamprey encountered during the 2006, 2007 and 2008 sampling were at lengths and displayed characteristics of the macropthalmic life-history stage. Macropthalmia are transforming or newly transformed adults that undergo physiological and morphological changes that allow them to shift from a freshwater to saltwater environment. 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. All lamprey collected in 2008 were vouchered for identification and research purposes. In 2008, 15 of the 31 total lamprey observed were positively identified as river lamprey. Six specimens were damaged and could only be identified to the genus Lampetra, which could possibly make them river, western brook or kern brook lamprey. The remaining ten specimens either escaped through the entrainment sampling screen or were damaged too heavily to identify. All specimens were collected in entrainment in 2008, none were observed in trawl sampling, as in 2007. The specimens are currently being genetically analyzed by biologists at the USFWS in Arcata, CA.

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.

The vouchered and preserved lamprey specimens from 2006 and 2007 were macropthalmia. Identification for these specimens was confirmed by USFWS and Western Fishes taxonomic experts as *Lampertra ayresii* (river lamprey). Fifteen, of the 24 vouchered specimens in 2008, were positively identified as river lamprey. Newly developed field identification techniques based on mitochondrial DNA analysis will aid in positive field identification of macropthalmia and ammocoetes collected in future monitoring.

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 there and elsewhere in 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 into 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. The USFWS was petitioned to list longfin smelt as endangered under the ESA in 1992. The petition was denied in 1993. Longfin smelt were again petitioned for federal listing on August 8, 2007, and recently denied (April 9, 2009) on the basis that the San Francisco Bay-Delta longfin smelt did not constitute a “distinct population segment”. The longfin smelt was petitioned under the California Fish and Game Code for listing as endangered. On March 4, 2009 the California Fish and Game Commission accepted the longfin smelt for listing under CESA as a threatened species.

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Appendix B. Water Quality Data

2008 Water Quality Monitoring

				Surface Measurements								Bottom Measurements							
Trawl Survey ID	WQ Location	WQ Date	Secchi Depth (cm)	Time	Temp [C]	DO [PPM]	DO %	pH	Cond [uS]	Sal [ppt]	Turb [ntu]	Depth [ft]	Temp [C]	DO [PPM]	DO %	pH	Cond [uS]	Sal [ppt]	Turb [ntu]
1	S-31	2-Aug	58	1030	23.1	7.42	87.5	7.46	797	0.4	28.7	21	22.54	6.97	80.4	8.07	826	0.4	53
2	S-31	4-Aug	33	1235	23.2	8.09	95	8.18	807	0.41	32.5	31	22.39	7.66	88.5	8.11	798	0.41	56
3	S-31	6-Aug	39	1233	23.13	7.4	86.8	8.14	787	0.4	44.56	31	22.35	7.09	80.9	8.13	766	0.4	445
3	S-31	6-Aug	34	1530	24.62	7.88	94.8	8.2	809	0.4	56	32	22.34	7.05	81.3	8.14	782	0.4	395
4	Rio Vista	10-Aug	75	1815	23.35	7.65	89.8	7.61	335	0.16	12.3	25	21.65	7.07	80.4	7.36	367	0.19	23.8
4	Rio Vista	10-Aug	*	2028	22.37	7.37	84.9	7.81	369	0.19	14.2	28	21.48	7.2	81.6	7.73	567	0.3	21.5
5	Rio Vista	11-Aug	76	1314	22.38	7.63	88.1	7.52	353	0.18	19.56	26	22.27	7.6	87.4	7.37	355	0.18	28.42
5	Rio Vista	12-Aug	66	1550	22.49	7.77	90.2	7.64	740	0.38	20.02	27	21.98	7.66	87.8	7.61	869	0.45	27.86
6	Decker Island	20-Aug	49	1718	21.45	8.25	93.7	7.75	1144	0.61	35.32	28	21.39	8.23	93.5	7.74	1297	0.71	41.73
7	Decker Island	22-Aug	99	1620	23.32	8.03	94.3	7.78	439	0.22	16.01	26	22.25	7.73	88.9	7.65	408	0.21	26.51
7	Decker Island	22-Aug	66	1912	21.47	7.85	89.7	7.56	2699	1.51	24.27	28	21.43	7.79	89	7.59	2786	1.56	30.32
8	Decker Island	24-Aug	58	1255	22.57	7.72	89.6	7.79	1148	0.6	25.42	25	21.74	7.64	87.3	7.71	1149	0.61	28.05
9	Decker Island	27-Aug	70	850	22.5	7.55	87.3	7.7	466	0.24	23.42	24	22.52	7.55	87.3	7.65	440	0.22	23.55
9	Decker Island	27-Aug	77	1113	22.95	7.56	88.1	7.62	251	0.12	19.72	25	22.55	7.61	88.1	7.55	671	0.34	24.4
10	Decker Island	29-Aug	67	1010	23.19	7.24	84.9	7.71	464	0.23	32.5	30	23.15	7.21	84.4	7.67	486	0.24	44.15
10	Decker Island	29-Aug	65	1327	23.77	7.69	91.2	7.76	608	0.3	21.4	28	22.64	7.56	87.8	7.56	1308	0.67	77
11	Decker Island	3-Sep	66	1558	23.59	7.76	91.6	7.61	760	0.38	21.25	23	21.87	7.37	84.5	7.45	1510	0.81	61
11	Decker Island	3-Sep	82	1849	22.71	7.7	90.5	7.66	3853	2.1	17.55	32	21.76	7.44	86	7.61	4606	2.64	70
12	Decker Island	5-Sep	84	1302	22.85	7.46	87	7.54	1129	0.59	16.2	32	22.12	7.16	82.8	7.42	2923	1.61	27.44
12	Decker Island	5-Sep	81	1559	23.5	7.44	88.5	7.69	894	0.45	17.28	28	22.18	7.21	83.3	7.52	2272	1.24	43.72
13	Decker Island	6-Sep	*	2135	22.58	7	82.7	7.75	6674	3.88	16.84	32	22.24	6.79	80.3	7.61	7885	4.62	28.22
14	Scour Pond	11-Sep	*	2115	21.28	7.9	90.3	7.86	4119	2.37	7.7	36	21.34	7.88	90.2	7.85	4232	2.43	13.61
14	Scour Pond	11-Sep	*	2349	21.06	7.94	90.8	7.85	5423	3.16	7.28	33	21.03	8	91.9	7.8	6716	4.01	
15	Scour Pond	13-Sep	100	1022	20.5	8.28	92.8	7.9	2636	1.5	12.25	30	20.5	8.24	92.3	7.94	2692	1.54	15.39
15	Scour Pond	13-Sep	140	1243	20.71	8.39	94.6	7.98	3076	1.76	11.01	35	20.51	8.35	93.7	7.97	3163	1.82	16.96
16	Scour Pond	15-Sep	97	1531	20.36	8.54	95.6	7.96	3554	2.09	13.67	24	20.15	8.49	94.8	7.9	3686	2.16	17.1
16	Scour Pond	15-Sep	94	1757	20.44	8.54	95.9	7.99	4142	2.43	11.32	41	19.88	8.22	92.1	7.9	5897	3.59	28.11
17	Scour Pond	17-Sep		920	19.22	8.24	90.2	7.94	3128	1.86	22.92	35	19.21	8.23	90.1	7.94	3117	1.85	31.03
17	Scour Pond	17-Sep	88	1128	19.3	8.32	91	8.03	2362	1.38	21.8	38	19.3	8.28	90.5	8	2362	1.38	26.33
18	Scour Pond	19-Sep	80	1130	18.58	8.61	92.9	8.01	2540	1.53	16.34	36	18.51	8.52	91.8	7.94	2640	1.58	18.11
18	Scour Pond	19-Sep	82	1342	18.81	8.68	93.9	7.97	2143	1.26	14.65	40	18.66	8.52	91.9	7.95	2221	1.31	19.8
19	Scour Pond	21-Sep	83	1910	19.24	7.07	77.4	7.96	2846	1.7	15.17	41	19.21	7.03	76.9	7.86	3016	1.79	14.29
20	Scour Pond	23-Sep	100	1317	19.81	8.73	95.9	7.95	1530	0.85	9.3	32	19.5	8.58	93.9	7.95	1769	1.01	12.93
20	Scour Pond	23-Sep	110	1509	20.08	8.12	89.8	8.06	1920	1.09	9.56	29	19.45	7.84	86.1	7.94	2041	1.18	14.76
21	Scour Pond	25-Sep	*	2009	20.2	8.05	89.3	8.06	1331	0.74	11.76	38	20.22	7.99	88.7	7.77	1332	0.74	16.83
21	Scour Pond	25-Sep	*	2233	20.15	8.01	88.5	8.06	1322	0.73	11.39	38	20.17	7.93	87.8	7.93	1333	0.74	19.64
22	Scour Pond	28-Sep	98	940	20.5	7.77	86.5	7.95	897	0.49	12.42	40	20.49	7.71	85.9	7.93	893	0.48	12.29
22	Scour Pond	27-Sep	110	1148	20.75	7.87	88	7.9	812	0.43	8.68	38	20.55	7.74	86.3	7.86	811	0.44	10.73
23	McCormick	30-Sep	91	1055	20.41	6.68	74.2	8.17	902	0.49	12.13	12	20.4	6.62	73.6	7.96	896	0.49	10.42
23	McCormick	30-Sep	108	1256	20.62	8.99	100.1	8.01	824	0.44	8.4	39	20.34	8.86	98.4	7.96	779	0.42	12.17
24	McCormick	2-Oct	*	450	20.56	8.11	90.4	8.36	923	0.5	11.73	40	20.56	8.06	89.9	8.09	942	0.51	13.71
24	McCormick	2-Oct	99	748	20.25	7.99	86.3	8.1	1566	0.88	11.8	40	20.25	7.84	84.8	7.96	1734	0.97	13.24
25	McCormick	4-Oct	102	745	20.08	7.3	80.7	8.17	1266	0.7	12.74	17	20.07	7.22	79.8	7.97	1274	0.71	15.3
25	McCormick	4-Oct	100	945	19.95	8.05	89	7.96	1732	0.98	10.84	39	19.9	8.14	89.8	7.93	1932	1.1	11.45
27	Bradford	7-Oct	120	1630	20.39	8.67	95.5	8.09	832	0.45	7.9	38	19.88	8.28	91.2	7.93	1032	0.57	8.28
27	Bradford	7-Oct	130	1859	20.45	8.61	95.6	7.97	745	0.4	4.82	27	20.03	8.37	92.3	7.92	937	0.51	8.32
28	Bradford	8-Oct	*	2156	20.1	8.53	94.3	8.09	1132	0.62	7.89	40	20.13	8.49	93.9	7.97	1163	0.64	10.24

2008 Water Quality Monitoring (Continued)

				Surface Measurements								Bottom Measurements							
Trawl Survey ID	WQ Location	WQ Date	Secchi Depth (cm)	Time	Temp [C]	DO [PPM]	DO %	pH	Cond [uS]	Sal [ppt]	Turb [ntu]	Depth [ft]	Temp [C]	DO [PPM]	DO %	pH	Cond [uS]	Sal [ppt]	Turb [ntu]
29	Bradford	10-Oct	100	1135	18.67	7.81	83.8	8.18	640	0.36	11.5	28	18.59	7.8	83.6	7.97	648	0.36	10.63
29	Bradford	10-Oct	78	1441	18.56	7.74	83	8.09	986	0.56	12.25	32	18.55	7.76	83.2	8.04	1057	0.6	12.17
30	Bradford	13-Oct	96	1335	16.37	9.25	94.7	7.91	734	0.43	13.4	32	16.36	9.19	94.1	7.91	738	0.44	15.1
30	Bradford	13-Oct	63	1557	16.36	8.9	91.2	8.05	1034	0.62	15.65	36	16.3	8.94	91.5	8	1094	0.66	47.65
31	Roberts I	16-Oct	120	1824	17.37	8	83.6	7.69	567	0.32	7.6	35	17.17	7.97	82.8	7.64	559	0.32	33.8
31	Roberts I	16-Oct	*	2121	17.39	7.38	77.2	7.8	568	0.33	9.19	34	16.54	7.86	80.7	7.82	525	0.31	46.72
32	Roberts I	18-Oct	118	1650	17.23	8.3	86.6	7.8	532	0.3	7.26	38	16.93	7.93	82.2	7.65	522	0.3	12.09
33	Roberts I	20-Oct	140	1328	17.38	8.64	90.3	7.76	495	0.28	6.13	39	16.63	8.18	84.1	7.68	482	0.28	6.18
33	Roberts I	20-Oct	105	1604	17.33	9.36	97.7	7.83	480	0.27	9.43	30	16.69	8.5	87.5	7.67	473	0.27	13.08
34	Roberts I	26-Oct	115	1349	17.98	9.77	103.5	8.03	561	0.31	8.55	29	17.47	9.07	94.9	7.9	554	0.32	13.42
34	Roberts I	26-Oct	140	1614	17.87	8.87	93.6	7.83	544	0.31	6.51	39	17.44	8.64	90.4	7.79	543	0.31	7.06
35	Roberts I	30-Oct	123	1440	17.67	8.97	94.3	7.88	568	0.32	8.19	38	17.67	8.93	93.9	7.87	570	0.32	10.49
35	Roberts I	30-Oct	144	1650	17.66	8.74	91.8	7.81	567	0.32	7.32	39	17.68	8.71	91.6	7.78	568	0.32	6.49
36	Roberts I	1-Nov	123	1134	17.47	7.96	83.3	7.8	620	0.36		35	17.48	8	83.8	7.77	620	0.36	
36	Roberts I	1-Nov	*	1918	17.49	7.88	82.4	7.79	592	0.34		40	17.49	7.79	81.9	7.74	591	0.34	
37	Roberts I	3-Nov		1214	17.03	7.17	74.5	7.58	696	0.4	9.8	39	17.02	6.84	71	7.57	702	0.41	37.43
37	Roberts I	3-Nov	102	1519	17.01	7.17	74.4	7.72	689	0.4	8.77	39	17.03	7.14	74.1	7.69	689	0.4	76
38	Roberts I	6-Nov	120	1344	16.43	7.34	75.2	7.84	690	0.41	7.2	38	15.97	6.85	69.5	7.72	682	0.41	15.41
38	Roberts I	6-Nov	102	1555	16.45	7.7	78.9	7.79	690	0.41	9.07	39	15.71	7.48	75.5	7.74	696	0.42	13.08
39	Roberts I	8-Nov	116	1120	16.02	7.93	80.6	7.91	693	0.41	7.9	39	15.81	7.34	74.2	7.83	693	0.42	9.6
39	Roberts I	8-Nov	100	1339	15.97	7.15	72.4	7.82	688	0.41	9.79	28	15.92	7.38	74.8	7.75	690	0.41	16.7
40	Roberts I	10-Nov	70	1612	15.86	8.56	86.7	7.84	699	0.42	2.96	44	15.28	8.36	83.6	7.79	706	0.43	164
40	Roberts I	10-Nov	*	1842	15.25	8.41	84.1	7.79	709	0.43	7.81	41	15.27	8.49	84.9	7.75	711	0.43	15.98
41	Roberts I	12-Nov	99	1010	15.11	8.65	86	7.83	716	0.44	10.28	39	14.94	8.52	84	7.8	713	0.44	34.49
41	Roberts I	12-Nov	101	1858	15.58	8.72	87.7	7.79	716	0.43	21.82	44	15.05	8.65	86.1	7.67	716	0.44	19.49
42	Roberts I	14-Nov	92	1040	15.37	8.52	85.4	7.79	730	0.44	26.92	34	15.32	8.23	82.4	7.83	730	0.44	36.65
42	Roberts I	14-Nov	90	1405	15.88	8.93	90.5	7.72	732	0.44	16.97	41	15.28	8.42	84.2	7.62	729	0.44	26.42
43	Roberts I	16-Nov	*	1813	15.82	7.59	76.8	7.62	732	0.44		38	15.57	7.5	75.8	7.53	739	0.45	
43	Roberts I	16-Nov	*	2054	15.76	7.72	78	7.64	736	0.44		41	15.49	7.53	75.7	7.59	736	0.45	
44	Roberts I	18-Nov	110	958	15.76	7.68	77.5	7.76	753	0.45	8.77	37	15.54	7.89	78.9	7.75	758	0.46	0.85
44	Roberts I	18-Nov	115	1340	16.55	9.52	97.8	7.81	755	0.45	7.38	39	15.54	7.93	79.6	7.71	755	0.46	11.75
45	Roberts I	20-Nov	101	1340	15.93	8.56	87.6	7.26	751	0.45	9.15	45	15.47	8.27	83.3	7.27	747	0.45	11.36
45	Roberts I	20-Nov	97	1621	15.77	8.17	82.6	7.44	738	0.44	8.98	40	15.49	7.91	79.3	7.4	741	0.45	26.6
46	Roberts I	22-Nov	80	904	15.05	8.84	88.1	7.61	746	0.469	12.92	41	15.03	8.75	86.8	7.65	744	0.46	11.9
46	Roberts I	22-Nov	90	1145	15.5	8.39	84.3	7.5	745	0.45	10.49	43	15.14	8.44	84.2	7.53	747	0.46	13.21
47	Roberts I	24-Nov	98	755	14.89	8.41	83.4	7.44	735	0.45	7.54	43	14.9	8.22	81.6	7.48	739	0.45	26.84
47	Roberts I	24-Nov	99	1030	15.02	8.59	85.3	7.55	733	0.45	6.74	43	14.76	8.59	84.9	7.57	742	0.46	8.65

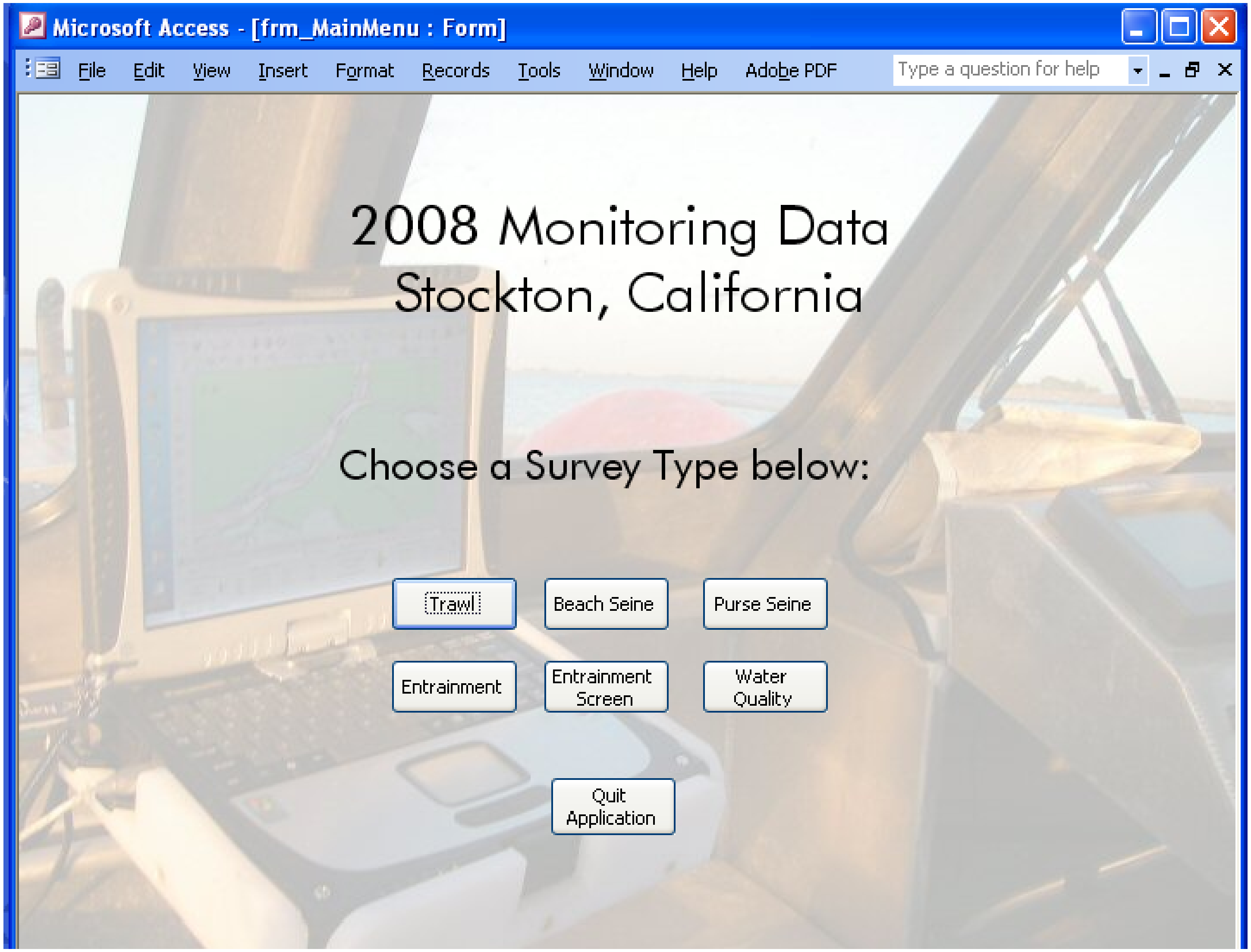
* Night survey, no secchi depth taken

Note: Bottom water quality measurements taken immediately following surface measurements

Note: Bottom water quality taken approximately one foot above the river bottom

Note: Surface water quality taken one foot below the surface

Appendix C. Field Data Collection Forms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Stockton, California
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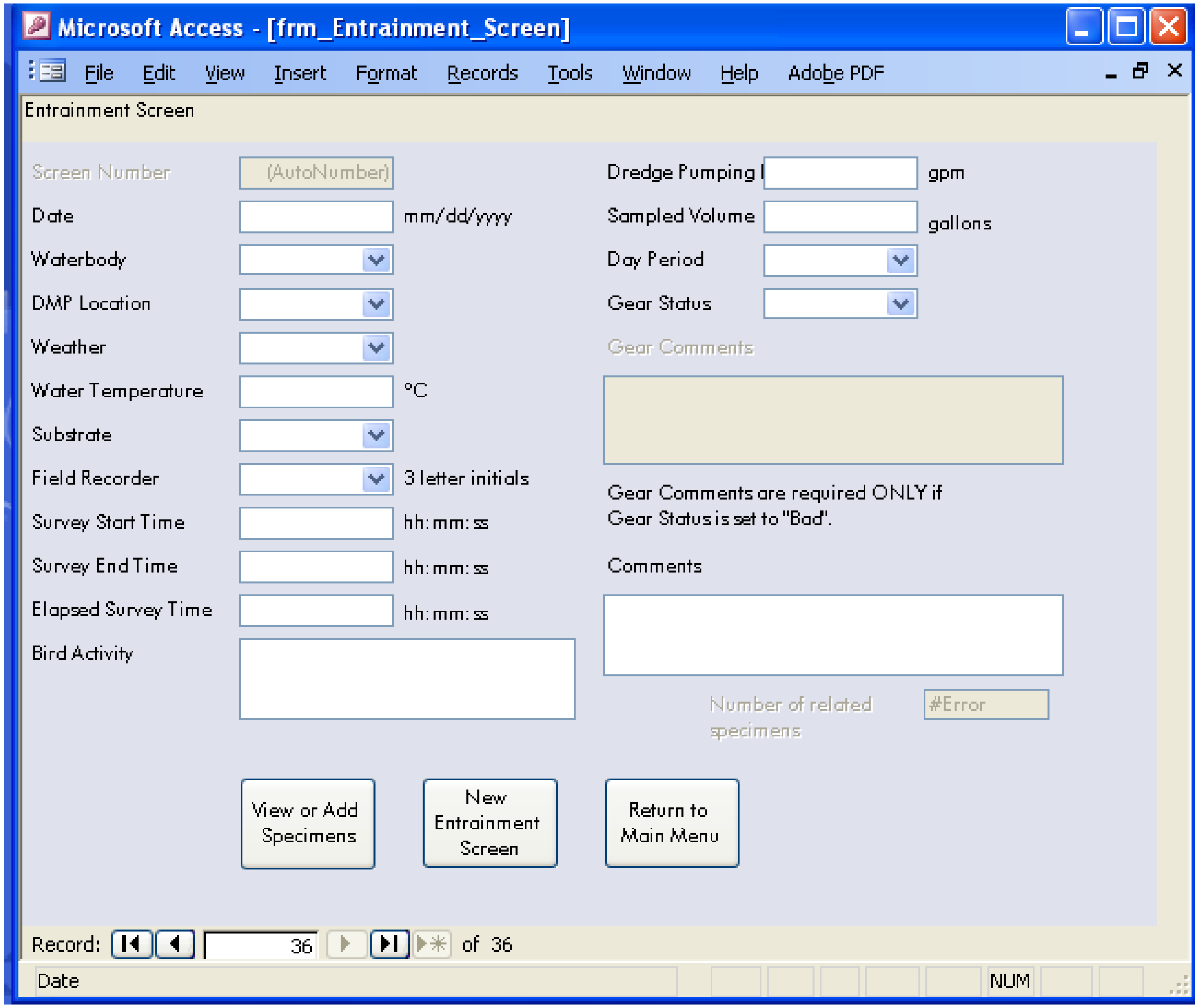
Beach Seine
Purse Seine
Entrainment
Entrainment Screen
Water Quality
Quit Application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Dredge Pumping I
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Sampled Volume
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Day Period
Gear Status
Gear Comments
Gear Comments are required ONLY if Gear Status is set to "Bad".
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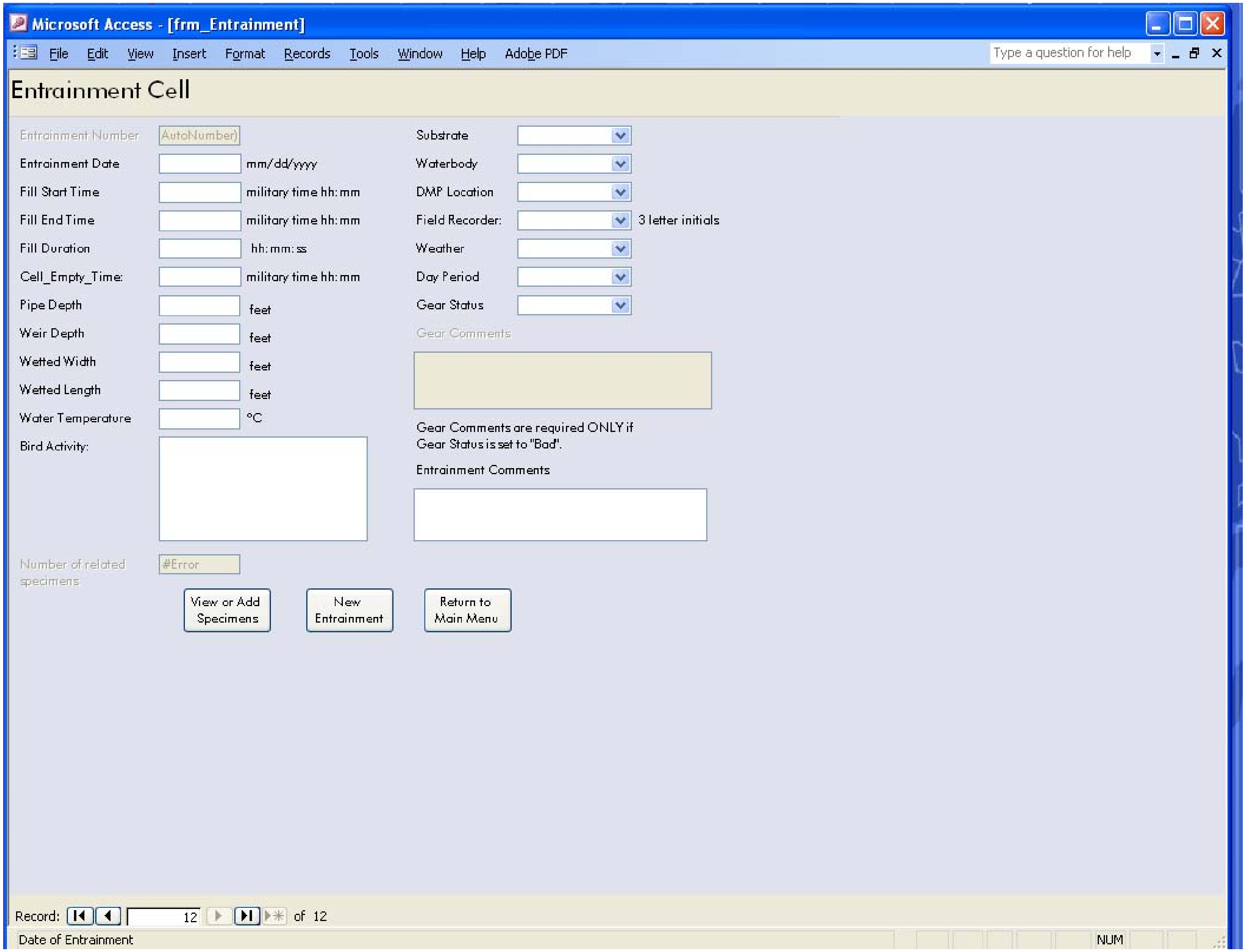
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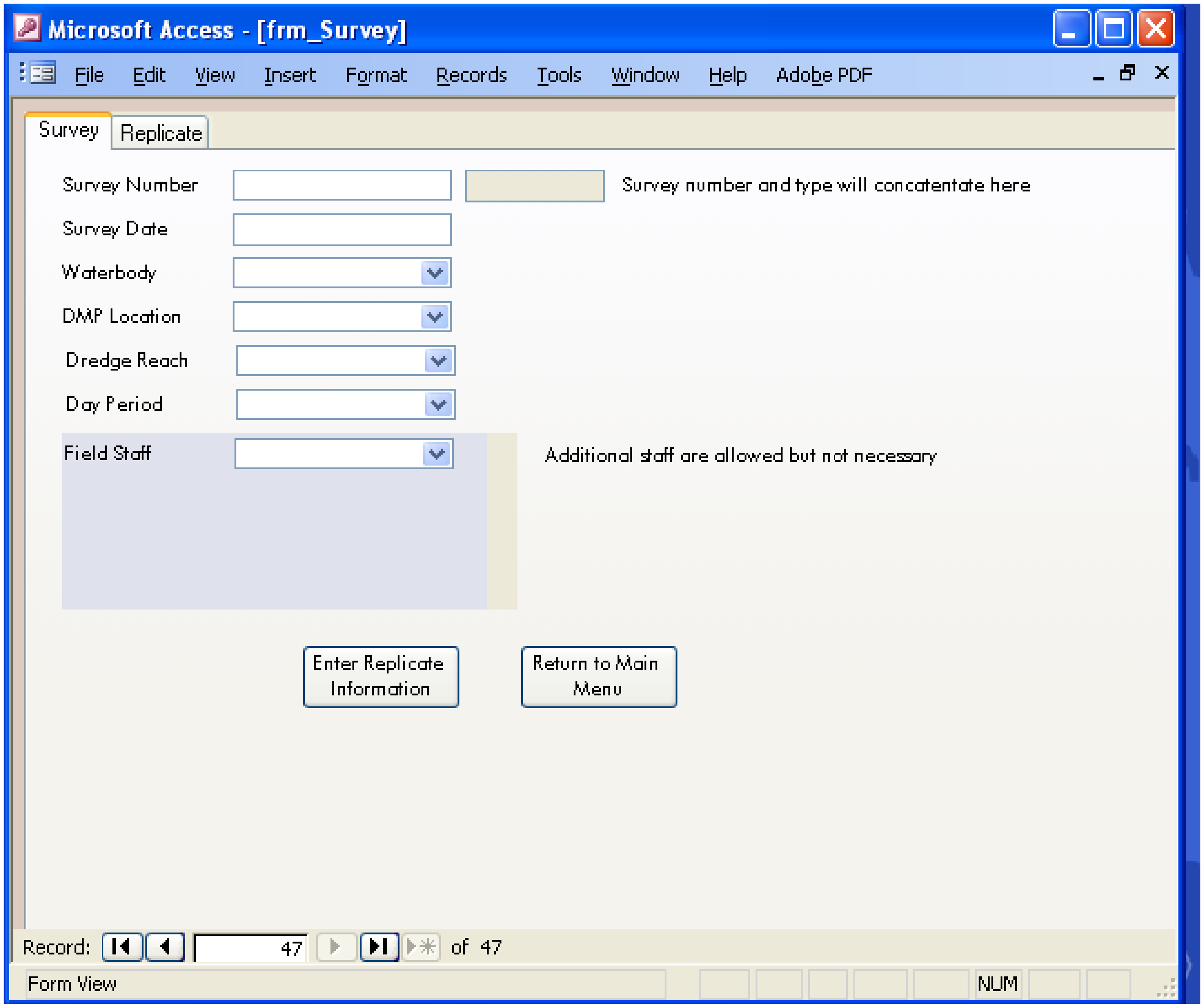
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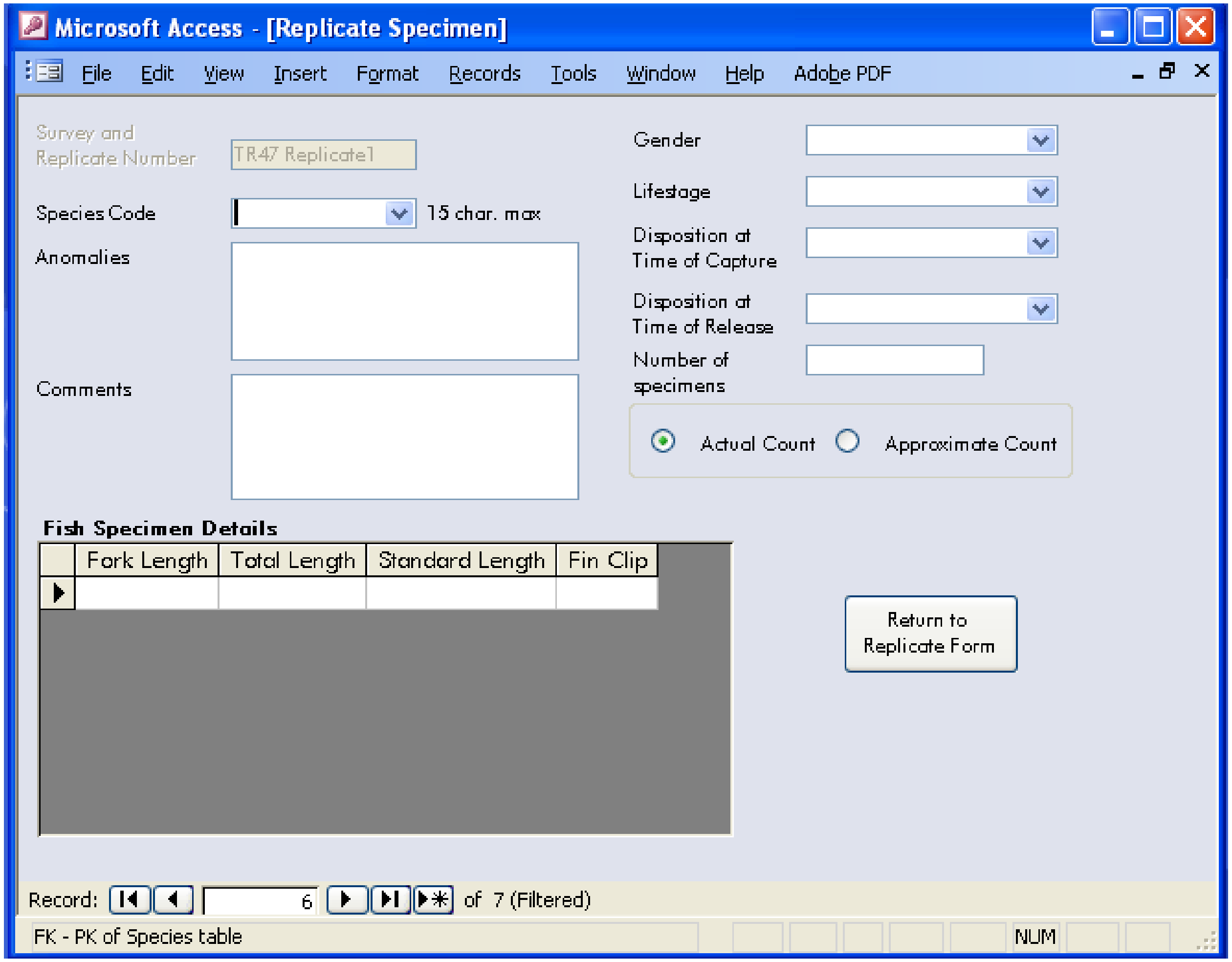
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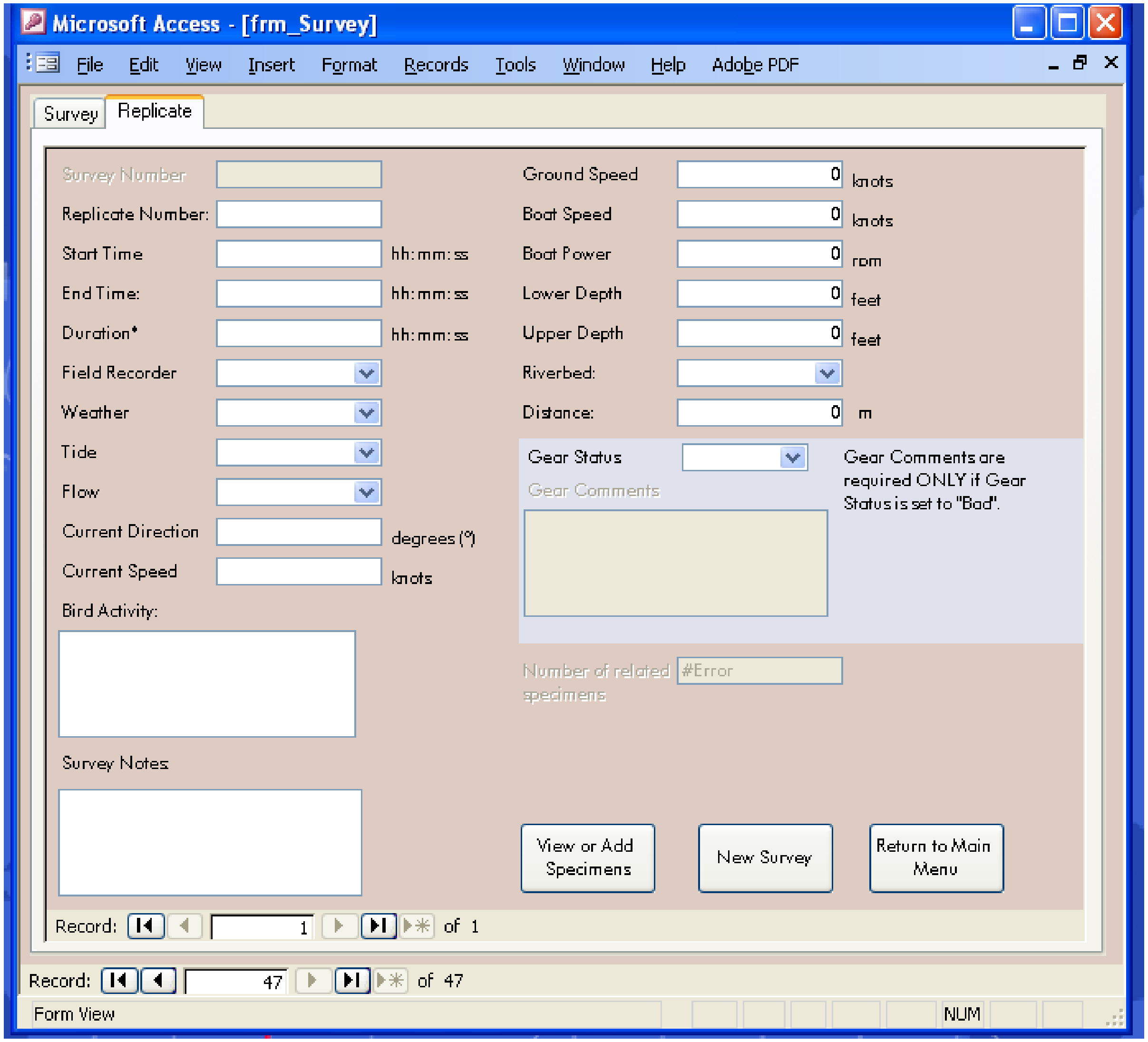
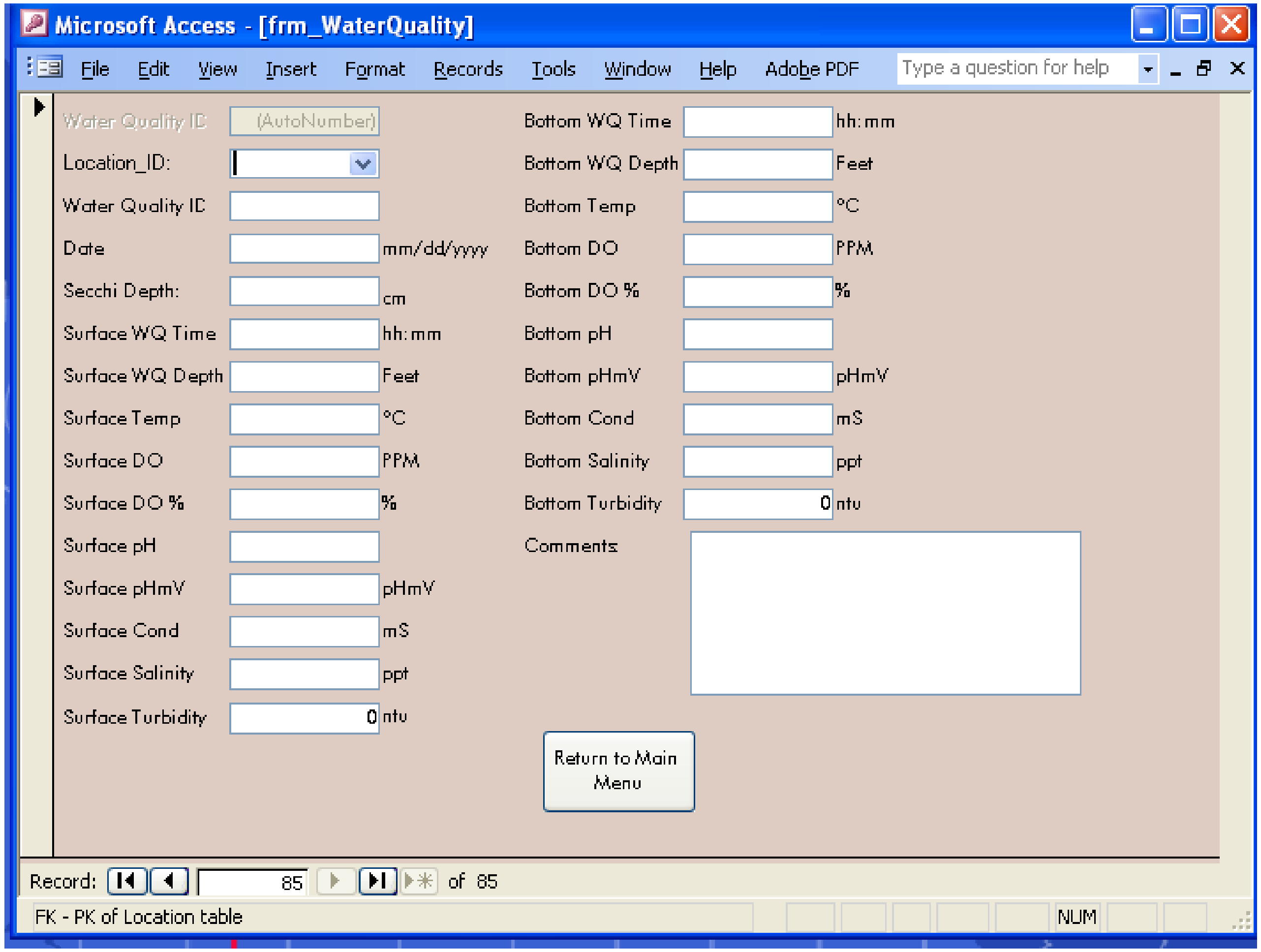
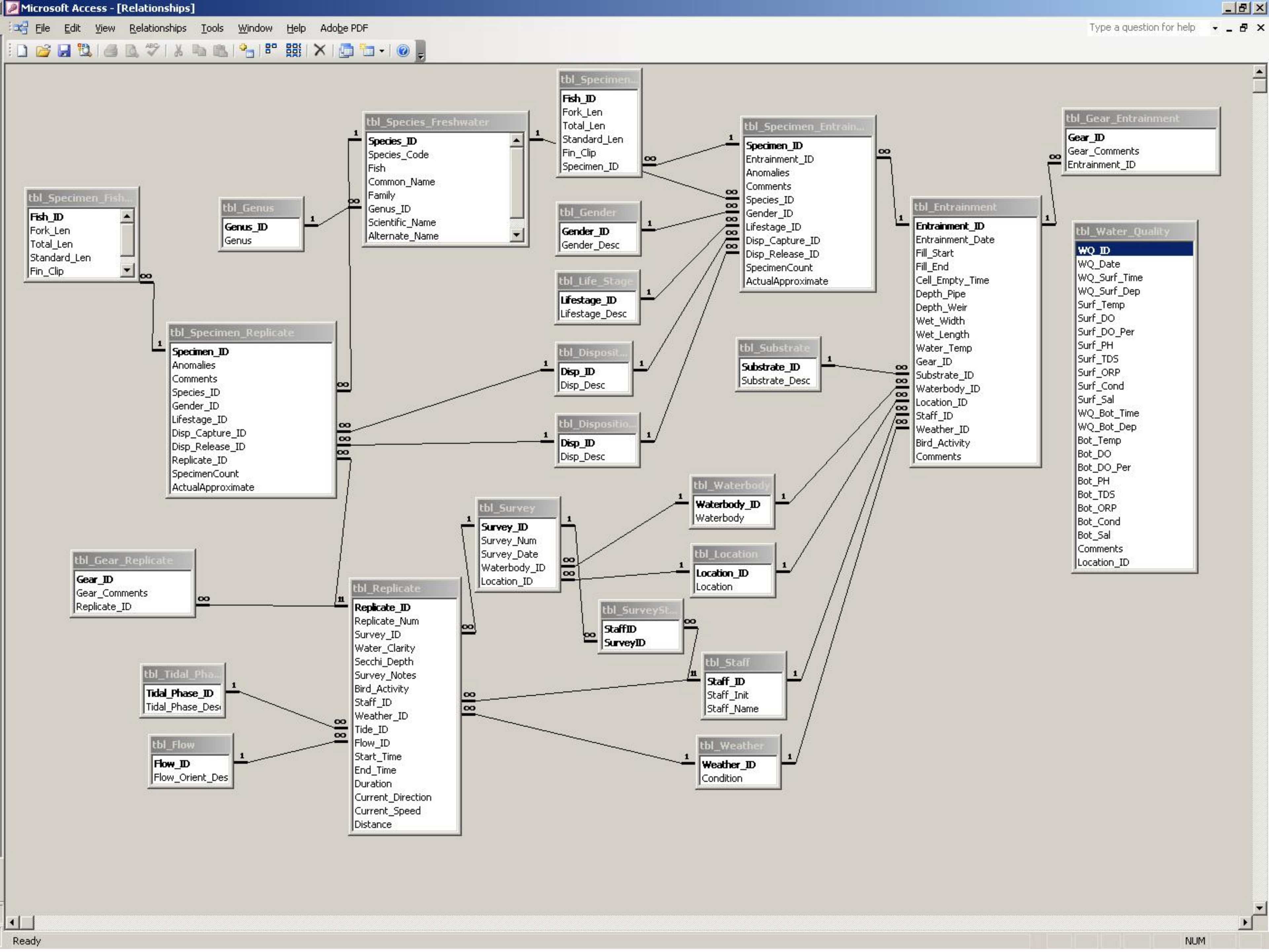


Microsoft Access - [frm_Survey]
File Edit View Insert Format Records Tools Window Help Adobe PDF
Survey
Replicate
Survey Number
Replicate Number:
Start Time
hh:mm:ss
End Time:
hh:mm:ss
Duration*
hh:mm:ss
Field Recorder
Weather
Tide
Flow
Current Direction
degrees (°)
Current Speed
knots
Bird Activity:
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
tbl_Specimen_Fish...
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...
Fish_ID
Fork_Len
Total_Len
Standard_Len
Fin_Clip
Specimen_ID
tbl_Specimen_Entrain...
Specimen_ID
Entrainment_ID
Anomalies
Comments
Species_ID
Gender_ID
Lifestage_ID
Disp_Capture_ID
Disp_Release_ID
SpecimenCount
ActualApproximate
tbl_Gear_Entrainment
Gear_ID
Gear_Comments
Entrainment_ID
tbl_Gender
Gender_ID
Gender_Desc
tbl_Entrainment
Entrainment_ID
Entrainment_Date
Fill_Start
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
WQ_ID
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_Life_Stage
Lifestage_ID
Lifestage_Desc
tbl_Specimen_Replicate
Specimen_ID
Anomalies
Comments
Species_ID
Gender_ID
Lifestage_ID
Disp_Capture_ID
Disp_Release_ID
Replicate_ID
SpecimenCount
ActualApproximate
tbl_Disposit...
Disp_ID
Disp_Desc
tbl_Substrate
Substrate_ID
Substrate_Desc
tbl_Dispositio...
Disp_ID
Disp_Desc
tbl_Waterbody
Waterbody_ID
Waterbody
tbl_Survey
Survey_ID
Survey_Num
Survey_Date
Waterbody_ID
Location_ID
tbl_Location
Location_ID
Location
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_SurveySt...
StaffID
SurveyID
tbl_Staff
Staff_ID
Staff_Init
Staff_Name
tbl_Tidal_Pha...
Tidal_Phase_ID
Tidal_Phase_Des
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 2008

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:	yes / no	Current Speed [kts]:	____________
If No GPS, describe problem	____________	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	Bird Activity:	____________
* Subsample percent (estimate):	____________	River bed description:	____________
Gear Status:	good / bad	Sampling Staff / Recorder (circle):	____________
Gear Comments	____________		

Entrainment Sampling Data Sheet (Screen)

Page ____of_____

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:	______		

Entrainment Sampling Data Sheet (Sample Cell)

Date:	______________________	Sample Cell Fill Start Time:	______________________
Sample ID:	______________________	Sample Cell Full Time:	______________________
DMP Location:	______________________	Sample Cell Empty End Time:	______________________
GPS	______________________	Dredge Pumping Rate [gpm]:	______________________
GPS location at DMP:	______________________	Sampled Volume [gal]:	______________________
Weather:	______________________	Approx. Avg. Wetted Width [ft]:	______________________
Water Temperature:	______________________	Approx. Avg. Wetted Length [ft]:	______________________
Substrate Description:	______________________	Approx. Avg. Area of Cell [ft]:	______________________
Sampling Staff:	______________________	Sample Cell Description:	______________________
Recorder:	______________________	Bird Activity:	______________________

Gear Status / Notes: ____

Specimen Collection Datasheet (2008)

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 (2008)

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:

Appendix D. Delta smelt and longfin smelt Catch Data

Appendix D-1. Delta Smelt Encounters in 2008 and Bottom Water Quality Measurements

Date	Trawl ID	Trawl Time	n Indiv.	Location (River)	FL	TL	Secchi Depth (cm)	Salinity (ppt)	Temp [C]	D.O. ppm %	pH	Cond (uS)	Turbidity (ntu)	Longitude (dec. deg.)	Latitude (dec. deg.)	Depth (ft)	Tide
8/6/2008	3_3	13:59-1406	1	S-31 (SRSC)	54	59	34	0.4	22.34	7.05, 81.3	8.14	782	395	-121.600	38.438099	28-35	Ebb
8/20/2008	6_2	18:11-18:21	4	Decker Island (SRSC)	54 59 55 50	57 64 60 55	49	0.71	21.39	8.23, 93.5	7.74	1297	41.73	-121.737	38.092499	31-35	Flood
8/24/2008	8_2	13:39-13:43	6	Decker Island (SRSC)	63 54 57 44 54 52	67 56 60 46 57 55	58	0.61	21.74	7.64, 87.3	7.71	1149	28.05	-121.732	38.096901	33-35	Ebb
8/29/2008	10_1	11:15-11:24	1	Decker Island (SRSC)	52	56	67	0.24	23.15	7.21, 84.4	7.67	486	44.15	-121.743	38.089001	31-34	Ebb
8/29/2008	10_5	10:20-10:38	3	Decker Island (SRSC)	57 52 54	63 57 59	65	0.67	22.64	7.56, 87.8	7.56	1308	77	-121.755	38.082699	31-33	Ebb
9/5/2008	12_4	15:34-15:41	1	Decker Island (SRSC)	63	69	81	1.24	22.18	7.21, 83.3	7.52	2272	43.72	-121.745	38.087799	32-36	Low Slack
9/6/2008	13_1	21:51-21:58	6	Decker Island (SRSC)	56 50 63 57 54 57	60 55 68 63 58 62	NA (dark)	4.62	22.24	6.79, 80.3	7.61	7885	28.22	-121.757	38.082001	33-35	Flood
9/21/2008	19_2	20:00-20:10	3	Scour Pond Antioch	62 62 61	66 67 67	83	1.79	19.21	7.03, 76.9	7.86	3016	14.29	-121.762	38.027417	36-44	Flood

Appendix D-2. Longfin Smelt Encounters in 2008 and Bottom Water Quality Measurements

Date	Trawl ID	Trawl Time	n Indiv.	Location (River)	FL	TL	Secchi Depth (cm)	Salinity (ppt)	Temp [C]	D.O. ppm %	pH	Cond (uS)	Turbidity (ntu)	Longitude (dec. deg.)	Latitude (dec. deg.)	Depth (ft)	Tide
8/22/2008	7_3	17:35-17:45	3	Decker Island (SRSC)	50 72 34	54 77 38	66	1.56	21.43	7.79 89	7.59	2786	30.32	-121.739	38.091400	32-36	Flood
8/22/2008	7_5	18:44-18:53	1	Decker Island (SRSC)	55	57	66	1.56	21.43	7.79 89	7.59	2786	30.32	-121.74	38.091099	32-36	Flood
9/3/2008	11_1	16:14-16:23	3	Decker Island (SRSC)	88* 45 46	94* 49 50	66	0.81	21.87	7.37 84.5	7.45	1510	61	-121.756	38.083000	26-33	Flood
9/3/2008	11_2	16:44-16:52	2	Decker Island (SRSC)	59 51	62 54	66	0.81	21.87	7.37 84.5	7.45	1510	61	-121.756	38.082500	32-35	Flood
9/3/2008	11_3	17:12-17:22	5	Decker Island (SRSC)	79* 65 58 47 41	83* 71 63 56 44	82	2.64	21.76	7.44 86	7.61	4606	70	-121.754	38.082901	32-34	Flood
9/3/2008	11_4	17:44-17:54	2	Decker Island (SRSC)	73 67	80 73	82	2.64	21.76	7.44 86	7.61	4606	70	-121.754	38.082901	32-34	Flood
9/3/2008	11_5	18:14-18:25	4	Decker Island (SRSC)	70 62 58 45	77 67 64 49	82	2.64	21.76	7.44 86	7.61	4606	70	-121.755	38.082901	33-35	Flood
9/5/2008	12_3	15:03-15:10	1	Decker Island (SRSC)	59	65	81	1.24	22.18	7.21 83.3	7.52	2272	43.72	-121.745	38.087799	32-35	Ebb

* Fish released alive