Final Report

2011 Longfin Smelt Monitoring During Dredging By The USACE Hopper Dredge Essayons In The San Francisco Bay Area

Contract # W912P7-11-P-0032

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Submitted to:

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Acknowledgements

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1. Executive Summary

The entrainment monitoring conducted for USACE in 2011 was similar to the monitoring conducted in 2010, as it was done on the same dredge, the *Essayons,* and used the “crab basket” as the primary method of monitoring fish entrainment. The monitoring in 2011 did, however, differ from 2010 in several important ways: (1) the biologists conducting the monitoring differed; (2) a higher proportion of hopper loads were monitored (100% in 2011[1] vs. 52% in 2010); and (3) additional entrainment monitoring methods were employed.

Monitoring was conducted in a variety of locations in San Pablo Bay, Central San Francisco Bay, and Suisun Bay in July and August, 2011. This monitoring project was the first hopper dredge monitoring project in the San Francisco Estuary to document entrainment of delta smelt, listed under the Federal Endangered Species Act (FESA), and longfin smelt, listed under the California Endangered Species Act (CESA) and currently under review by USFWS under FESA, as well as large species such as California halibut and brown smoothhound sharks. In all, twenty species of fish and thirty species of invertebrates were documented as having been entrained during dredging operations.

Documentation of the take of longfin smelt prompted changes to the dredging operations in an effort to minimize take. In addition to describing the monitoring that was conducted and the efforts designed to minimize take of ESA and CESA listed fish, this report also includes suggestions for changes to the monitoring methods that will enable future monitoring efforts to assess a higher percentage of the dredged material.

[1] Each hopper load was monitored during hopper loading, flushing, or, in the vast majority of cases, both.

2. Background

Monitoring of dredging impacts, and more specifically, assessing take of state and or federally listed species, is limited to a few recent projects in the San Francisco Estuary and Sacramento / San Joaquin River Delta (Delta). These projects include 2010 USACE monitoring efforts (McGowan, 2010); monitoring conducted annually since 2006 in the Delta's federal shipping channels (Gold and Novotny, 2010, 2011 and SWCA, 2007-2009); and monitoring conducted at the Port of Sonoma (NMFS, unpublished manuscript).

There are several reasons for this lack of monitoring effort. ESA and CESA fish species listed as threatened or endangered that are present within the San Francisco Estuary and Delta include longfin smelt and delta smelt, the species prompting this work, as well as winter-run Chinook salmon, Central Valley steelhead, and green sturgeon. All of these species listings have been fairly recent and there has been an inevitable lag in the promulgation of regulations and mandates requiring impacts investigations centered on assessments of take. Another significant reason for the limited amount of monitoring or research has been the general assumption that the direct entrainment of fish by dredge (drag arm, cutter-head, clamshell, etc.) is limited due to the ability of fish to avoid entrainment by swimming out of the way. While many fish undoubtedly do avoid entrainment in this manner, this monitoring project and the projects listed above have demonstrated that regulatory agency concern over take of listed and other species is reasonable. This view is corroborated by work done in the 1970s, 80s and 90s in a variety of locations in the Pacific Northwest, reviewed by Reine and Clarke (1998). These studies documented entrainment of many species of fish including longfin smelt and Columbia River smelt (Eulachon, *Thaleichthys pacificus*), both of which are currently listed (CESA for longfin and ESA for Eulachon) but were not listed at the time that these older studies were conducted. In fact, one study (McGraw and Armstrong, 1990) concluded that up to 2.5% of the total population of juvenile English sole, a demersal (bottom-oriented) fish, would be entrained during proposed suction dredging of Gray's Harbor, WA.

The monitoring described herein is a result of California Department of Fish and Game (CDFG), California State Regional Water Quality Control Board (RWQCB), and Bay Conservation and Development Commission (BCDC) dredging permit conditions resulting from their concerns about dredging impacts to longfin smelt.

3. Introduction

This report provides the methods and results of the 2011 San Francisco Estuary fish entrainment monitoring conducted onboard the federal hopper dredge *Essayons*, a double-arm draghead suction dredge. It also provides suggestions for future monitoring. Additional analysis and interpretation of the results may be provided by the San Francisco District of the US Army Corps of Engineers (USACE).

Dredging and monitoring was conducted from July 16 through August 11, 2011 in three separate locations within the San Francisco Estuary: (1) Pinole shoal in San Pablo Bay, conducted July 16th through 19th; (2) Richmond Harbor and Southampton Shoal in San Francisco Bay, conducted July 19th through 31st, and two additional hopper loads collected on August 11th; and (3) several dredge reaches in Suisun Bay, stretching from just upstream of the Carquinez Strait to New York Slough near Pittsburg, conducted August 1st through 10th.

The purpose of this project was to monitor entrainment of longfin smelt during the annual maintenance dredging of the San Francisco Estuary's federal navigation channels. In addition to entrainment of longfin smelt and delta smelt, this report provides details of all entrained species of fish and invertebrates observed as well as the water temperature and salinity at all dredging locations. Description of the invertebrates encountered was not required by USACE or other involved agencies. It is provided out of interest of the investigators and is based on their assessment of the usefulness of the information.

3.1. Reporting Requirements

The reporting requirements associated with this project as described in the designated biologist's 2081(a) permit provided by Mr. Carl Wilcox, Regional Manager of the California Department of Fish and Game (CDFG) Bay Delta Region (CDFG, July 29, 2011) include submittal of several work products. Each of these is described below. It should be noted that reporting associated with take of delta smelt was not part of the original scope of work for this project; this information is, however, presented in the narratives and tabular results that follow due to their protected status.

3.1.1. Annual Report, Designated Biologist

As a permit condition for approval of the designated biologist's application for a 2081(a) incidental take permit associated with implementation of the fish monitoring, the designated biologist is required to submit an annual report describing monitoring activities. Requirements associated with this report are excerpted below.

> *1. Mr. Jordan Gold shall provide a project summary report on all activities performed under this CESA MOU. The report shall include all activities of a given calendar year and be due no later than December 31 of the year of completion. Copies of the annual report shall be sent to:*
>
> *Ms. Corinne Gray, Bay Delta Region,*
> *7329 Silverado Trail, Napa, California 94558*
> *Telephone: (707) 944-5526, Email: cgray@dfg.ca.gov*
>
> *Mr. Jim Starr, Bay Delta Region,*

4001 N. Wilson Way, Stockton, California 95205
Telephone: (209) 941-1944, Email: jstarr@dfg.ca.gov

3.1.2. Summary Report

In addition, CDFG requires submittal of a summary report of dredging activities. Requirements for that report are described below. The submittal of this report fulfills the requirements of the Summary Report. Delays in the CDFG confirmation of fish species identification performed by project biologists resulted in delays in the reporting. These delays were approved by Vicki Frey of CDFG (Vicki Frey, personal communication).

G. Within 15 working days after the end of dredging activities, the contractor will submit a summary report to DFG of all observations, inspections, survey results, and monitoring results including data. The report will include a table showing when mitigation and minimization measures were implemented, all available information about project-related incidental take of longfin smelt and Delta smelt, other project impacts to longfin smelt and Delta smelt, an estimate of level of take of longfin smelt and delta smelt associated with the project, assessment of effectiveness of mitigation and minimization measures, and recommendations for changes that would more effectively minimize and mitigate impacts of future projects on longfin smelt and Delta smelt."

3.1.3. Monthly Compliance Report

In addition to the 2081(a) permit requirements, Mr. Carl Wilcox, Regional Manager of the CDFG Bay Delta Region provided USACE additional requirements in the form of a letter sent to the Mr. Laurie Suda on July 15, 2011 (CDFG, July 15, 2011). Condition 11 of the Notification and Reporting section of this letter is as follows:

11. Monthly Compliance Report: The Designated Biologist shall be on-site daily while dredging operations are taking place to minimize take of longfin smelt and Delta smelt and to check for compliance will all mitigation and avoidance measures. The Designated Representative or Designated Biologist shall prepare daily written observation and inspection records summarizing oversight activities and compliance inspections; observations of longfin or Delta smelt among entrainment monitoring survey results; and monitoring activities required by these measures. These inspections shall be compiled into a Monthly Compliance Report and submitted to DFG's regional representatives George Isaac (gisaac@dfg.ca.gov) and Jim Starr (jstarr@dfg.ca.gov). If no activities take place during a given month, Corps shall provide a letter stating such and submit it to DFG's regional representatives. DFG may at any time increase the timing and number of compliance inspections. If DFG determines the reporting schedule is inadequate, DFG will notify the Corps by letter of the new reporting requirements.

The daily reports that were sent via email to the individuals listed above satisfy the daily reporting requirements for daily compliance reports. USACE will provide the Monthly Compliance Reports based upon information provided by the designated biologist.

3.1.4. Annual Report, USACE

As referenced in Section 3.2.1 above, CDFG provided additional reporting requirements associated with this project. Condition 14 of the Notification and Reporting section of this letter is as follows:

> *14. Annual Report: No later than December 31, 2011, Corps shall provide DFG with an Annual Report. The Annual Report shall be prepared by the Designated Biologist and shall include at a minimum: 1) a table with notes showing when and where each of the measures was implemented; 2) all available information about Project-related incidental take of longfin smelt and Delta smelt; 3) information about other Project impacts on longfin smelt and Delta smelt; 4) operation dates; 5) an assessment of the effectiveness of these measures in minimizing Project impacts; 6) recommendations on how measures might be changed to more effectively avoid, minimize and mitigate the impacts of future projects on longfin smelt and Delta smelt; and 7) any other pertinent information related to the level of take of longfin smelt and Delta smelt associated with the Project."*

It is anticipated that the information provided within daily reports and this project report will provide the necessary information to USACE so that they can complete the Annual Report required by condition 14 above.

4. Methods

The following sections describe methods employed to conduct monitoring and estimate potential impacts based upon findings.

4.1. Monitoring Equipment

The fish entrainment monitoring methods utilized were determined by the equipment available on the *Essayons*. The monitoring device is referred to as the "crab basket" as it was originally designed to investigate entrainment of crab larvae at Pacific Northwest dredging locations. The crab basket is a large, roughly rectangular shaped basket. Its walls are made of thin steel mesh with approximately 6.4 mm holes throughout to allow for drainage of water and dredged material. Images of the crab basket and other ship's equipment are provided separately from this report due to the large size and number of images.

The flow of material into the crab basket is regulated through use of a hydraulic gate valve that was operated by the designated and assistant biologists. Material that accumulated in the basket while monitoring was sorted by tilting the basket (with hydraulic rams) to allow access. The biologists then entered the basket and flushed the accumulated material with water from a hose to force the remaining sediment through the mesh of the basket. Once cleaned, the material was sorted and the organisms were removed, examined, and documented.

4.2. Monitoring Scheme

In 2010, longfin smelt monitoring was conducted from the *Essayons* using a scheme wherein the drag arms were initially positioned within three feet of the bottom, and the pumps were started as the drag arms were lowered to touch the bottom,[2] with dredged material diverted to the crab basket for monitoring (McGowan, 2010). The diversion to the crab basket was discontinued as the crab basket reached capacity. Start times for monitoring were recorded as the time that the hydraulic valve was triggered open and stop times were recorded as the time that the valve was triggered closed. Sampling times ranged from 15 to 244 seconds, with the majority within a range of 30 to 60 seconds (McGowan, 2010).

Monitoring conducted in 2011 differed from that of 2010 in several ways, as described in the following sections.

4.2.1. Initial Monitoring Design

Similar to 2010, the initial monitoring methodology provided by USACE in the scope of work for 2011 monitoring operations (USACE, 2011) was designed to monitor fish entrained during two phases of the dredging cycle: (1) the period of time that the drag-arm pumps are running and the drag arms are waiting to be dropped down onto the bay bottom (load or fill), and (2) when the drag-arms are lifted at the end of the hopper filling cycle and the pumps are lifted above the bottom in order to clear the remaining material from the pumps (flush). In each case, drag arms were to be held within three feet of the bottom for approximately two minutes, a duration thought long enough to provide a reasonable amount of monitoring time.

[2] Estimated by USACE as a two to three second process.

This monitoring scheme was designed in this manner for several reasons. First, based upon prior monitoring results, USACE assumed that fish were not vulnerable to entrainment when the drag arms were on the bottom, actively pumping dredged material (a commonly-held view). Second, previous use of the crab basket by other researchers resulted in over-filling and damage to the basket. USACE desired to avoid a repetition of this by only diverting material to the crab basket while water, rather than sediment, was being pumped.

There are, however, drawbacks to using this monitoring methodology. This could artificially increase the likelihood of fish entrainment by increasing the overall pumping time per hopper load. It may also have increased entrainment because it altered typical dredging practices by prolonging the length of pumping time with the drag arms off the bottom, and, as has been mentioned, the prevailing thought is that the likelihood of entrainment of species that are found throughout the water column is higher when the pumps are on with the drag arms positioned slightly above the bottom. This may be true, however, it cannot be proven given the available monitoring methodology.

Another reason that increasing the pumping time with the drag arms off the bottom is problematic is that, due to capacity issues, pumping time per hopper load is strictly limited in locations including Pinole Shoal and Richmond Harbor. Artificially increasing the pumping time to enable time for monitoring decreases dredging efficiency by decreasing the amount of dredged material in each hopper load. This is because more water is pumped into the hopper than would otherwise be necessary. When the dredged material (including this water) starts to pour out of the ship's scuppers, the ship is limited to 15 more minutes of dredging (over-flow dredging). This is done in an effort to reduce increases in turbidity associated with dredging activities.

The planned monitoring methodology was implemented with the initial hopper load on July 16th (hopper ID 787). Monitoring of the beginning of each hopper load began when the pumps were started and typically continued for approximately two minutes. Monitoring while flushing the pumps at the end of each hopper load was also conducted for approximately two minutes, though this period was shortened in an effort to avoid the pitfalls mentioned above, and also because flushing the pumps was not necessary until the dredge reached Suisun Bay.[3]

Monitoring continued with the original methodology through the early morning of July 18th, when the first longfin smelt was entrained (hopper ID 806). This happened to coincide with the weekly shift change, a period when the Captain of each shift (Captains Holcroft and Nyberg) were both on the vessel. They discussed the situation with the designated biologist and with their operations personnel from the Portland District and the San Francisco District of USACE, and with the CDFG and proposed that the monitoring methodology be revised in an effort to minimize take of longfin smelt.

4.2.2. Modified Sampling Design

After discussion with project participants, it was decided that rather than start monitoring with the drag arms positioned within 3 feet of the bottom, the pumps would be started with the drag arms

[3] Suisun Bay contains sandy substrates that require flushing from the pumps at the end of each hopper load to avoid binding of the pump impellers.

already touching the bottom, and the biologists would carefully monitor how much material was in the basket in an effort to avoid overfilling it. This change could be undertaken due to the ship's ability to assess pumping conditions and monitor pump temperatures and other parameters. Evidence of conditions that may have damaged the pumps did not appear.

This new methodology, initially implemented July 19th, 2011 (beginning with hopper ID 819) worked well, though some additional problems arose that necessitated changes to the ship's hydraulic system. The hydraulic pump that was initially used to power the valve that delivered dredged material to the crab basket was also used for several other important systems on the ship. As a result of this, to avoid overheating this critical pump, power to the valve needed to be reset by the ship's officers every 90 seconds. This proved to be very unwieldy and resulted in overfilling the crab basket on several occasions. This situation was not resolved until August 3, when a new pump was brought online to service the crab basket valve. The new pump was not critical to any other ship's functions so use of this valve could be completely under the control of the biologists. This meant that control over the timing and duration of the monitoring was entirely at the discretion of the biologists. The result of this change is that monitoring periods were extended due to the ability of the biologists to monitor the amount of material in the basket and to close the valve prior to overfilling. Overfilling did occur on several occasions and was problematic, though it did not have any significant impact on the monitoring.

4.2.3. Opportunistic Monitoring

The general scheme of monitoring with the crab basket at the beginning and end of each hopper load did occasionally vary. There were a series of hopper loads from the Richmond Harbor area where the drag arms were lifted in the middle of the hopper loads in order to allow the ship to turn. When this initially occurred, additional monitoring was conducted. However, after consulting with the Captain it was determined that monitoring was not necessary in the middle of the loads as long as the pumps were shut off prior to lifting the drag arms off the bottom and not restarted until the arms were back on the bottom. There were also a series of very long hopper loads in Suisun Bay. This allowed the biologists to do some opportunistic mid-load monitoring during several Suisun Bay hopper loads.

Additionally, though it was not initially addressed within the monitoring plan, monitoring during water calibration and hopper flushing events was also conducted. Changes in water density that result from salinity and temperature changes require frequent calibration of the hopper. This is conducted by filling the hopper with water pumped by the drag arm pumps. The hopper is also flushed with water pumped through the drag arms before moving to new sites in an effort to avoid transporting organisms from site to site. The initial calibration and flushing events were not monitored due to the initial lack of knowledge of these events. Once these dredging operations were observed and discussed, it was determined that monitoring should be undertaken when they occurred. In general, the entire water calibration and hopper flush periods could be monitored using the crab basket, as water rather than sediment was pumped, and thus it did not overfill with material on these occasions.

Several other monitoring methodologies were opportunistically employed when there was time available during hopper loading events that was not spent processing material from the crab basket. Namely, observing the water around the ship, particularly the amidships region, for fish that may have been entrained and then exited the hopper via the ship's scuppers or hopper de-watering devices.

The other methodology was directly observing the hopper via the hopper observation area. The majority of the hopper is covered with deck plating, mesh decking, or piping or other deck equipment, thus obscuring the hopper's surface from view. There is a hopper observation area just in front of the ship's super-structure that is surrounded by a railing but is open to the hopper. The surface of the dredged material within the hopper can be reached with a long handled net when the hopper is full or nearly full. Fish and especially invertebrates were commonly seen and frequently could be netted from the hopper when observed. It was also common to see fish but be unable to net them, as they would appear only briefly in the turbulent flow while the hopper was being filled. Organisms were most easily netted after the hopper was full and flow had ceased. This opportunistic sampling yielded many fish, including a delta smelt that was netted from the hopper during a hopper-flushing event. The level of effort expended in direct hopper observation varied markedly among individual hopper loads, as did its efficacy, which was undoubtedly higher during daylight monitoring. It also varied significantly based on the amount of time expended during processing of the material from the crab basket. Unfortunately, given the opportunistic nature of the direct hopper observation methodology, it is problematic to incorporate entrained fish observed in this manner into the required extrapolations of numbers of fish entrained.

4.3. Species Identification

Fish and invertebrates found in the hopper or crab basket were identified to species, whenever feasible, based on prior experience of the lead and assistant biologists. Dichotomous keys and field guides were used to identify unfamiliar species and to confirm the distinguishing characteristics of longfin smelt and delta smelt. The publications used for fish identification included: Eschmeyer (1983), Kramer (1995). Miller and Lea (1972), Moyle (2002), and Wang (2007). The publications used for invertebrate identification included: Brusca (2001), Jensen (1995), Morris, Abbott, and Hadderlie (1980), and SCAMIT (2008). When useful or necessary, hand-held magnifying lenses and or a dissecting microscope was utilized. Common names are used throughout this report except for species for which only scientific names are available, as is the case for many of the invertebrates. All fish and most of the invertebrates were identified to the species level.

Digital images were taken of all longfin smelt and delta smelt and all dead fish. Images were also taken of live fish prior to returning them to the water. Additionally, images were taken of some of the invertebrates and of the entrainment monitoring and other shipboard operations. These images are referenced in the results section.

Several invertebrate species were not identified to the species level due largely to lack of the necessary mandate from USACE or the regulatory agencies. Also, due to the very large number of invertebrates present in the dredged material, a considerable effort would be required to enumerate each invertebrate individually. For many of the hopper loads, hundreds and sometimes thousands of invertebrates such as shrimp and clam species were present. Out of necessity, the counts of invertebrates from the individual hopper loads were estimated, except for those species that were either large, or appeared in low numbers.

4.4. Monitoring Locations

The latitude and longitude of the beginning and end of each hopper load was provided by the ship. This information is provided for each hopper load in the Results section. The starting position for each hopper load was plotted onto National Oceanographic and Atmospheric Administration (NOAA) nautical charts using MacENC® charting software, to provide a graphic depiction of the dredging locations. The graphic depictions of the dredging locations are found in the Results section. A .kml file is also provided with this report for use with GoogleEarth®.

4.5. Water Quality Monitoring

During each monitoring event using the crab basket, a water sample was acquired by filling a bucket using the ship's wash-down hose for the source water for sampling. The water supplying this hose came directly from the ship's raw water intake (sea chest) located near the bottom of the hull. Water temperature was determined using a digital thermometer, and salinity was determined by using a hand-held refractometer.

5. Results

Detailed data from this monitoring project is presented in a spreadsheet format consistent with the daily reports that were sent to interested parties via email. All daily reports were combined into this final spreadsheet. Some of the data and comments were altered for clarity, and some of the photo references were changed. This data report consists of six individual pages: (1) the screen sheet, (2) fish data sheet, (3) invertebrate data sheet, (4) fish species list, (5) invertebrate species list, and (6) a dredging and monitoring images list. Each of these pages is described in more detail in Appendix A:

Results for the monitoring project are summarized below.

5.1. Summary of Monitoring Results

As described previously, monitoring was conducted on multiple types of dredging-related activities, including loading, active dredging, flushing, water calibration, etc. As described below, we have summarized all monitoring data generated through this project split between two distinct categories: (1) monitoring conducted during standard dredging practices (i.e., normal drag arm lowering, dredging, and flushing); and (2) all other monitoring. As described in the following sections, more detailed information is available within the referenced spreadsheets. It should be noted that for all images that follow, icons representing specific hopper loads indicate the starting point of dredging associated with that hopper load.

5.1.1. Monitoring Results, Pinole Shoal Area

Dredging and associated monitoring activities in the Pinole Shoal region were initiated on July 16th, 2011, and concluded on July 19th, 2011, encompassing all or parts of four days. A summary of all fish entrained during Pinole Shoal dredging operations is presented in Table 1. This list includes all fish observed by monitors, including those captured within the crab basket and those observed within the hopper itself.

Dredged areas are indicated in Figure 1, and actual hopper IDs are shown in finer scale in Figure 2. All monitoring was conducted using the original methodology, where samples of near-bottom water was diverted into the crab basket for approximately two minutes upon loading and flush.

Table 1. Monitoring Results of All Fish Entrained During Pinole Shoal Monitoring Operations. Includes fish observed within both crab basket and hopper. Hopper loads for which longfin smelt or Delta smelt were observed are indicated by LS and DS, respectively.

Hopper ID	Date	Species	No.	LS	DS
787	7/16/2011	anchovy	4		
788	7/16/2011	anchovy	6		
789	7/16/2011	anchovy	7		
790	7/17/2011	anchovy	2		
791	7/17/2011	none	0		
792	7/17/2011	anchovy	2		
793	7/17/2011	anchovy	3		
794	7/17/2011	anchovy	4		
795	7/17/2011	anchovy	2		
796	7/17/2011	anchovy	1		
797	7/17/2011	none	0		
798	7/17/2011	anchovy bay goby	1 1		
799	7/17/2011	anchovy bay goby	2 1		
800	7/17/2011	anchovy	2		
801	7/17/2011	anchovy	3		
802	7/17/2011	anchovy	4		
803	7/18/2011	anchovy	5		
804	7/18/2011	anchovy	7		
805	7/18/2011	anchovy staghorn sculpin	1 2		
806	7/18/2011	longfin smelt	3	3	
807	7/18/2011	anchovy	4		
808	7/18/2011	anchovy	4		
808		plainfin midshipman	1		
809	7/18/2011	anchovy	1		
809		three-spine stickleback	1		
810	7/18/2011	none	0		
811	7/18/2011	bay goby	1		
812	7/18/2011	anchovy	2		
812		plainfin midshipman	1		
813	7/18/2011	none	0		
814	7/18/2011	anchovy	7		
815	7/18/2011	anchovy	5		
816	7/19/2011	anchovy	8		
817	7/19/2011	anchovy	2		
818	7/19/2011	anchovy	1		
Total			101	3	0

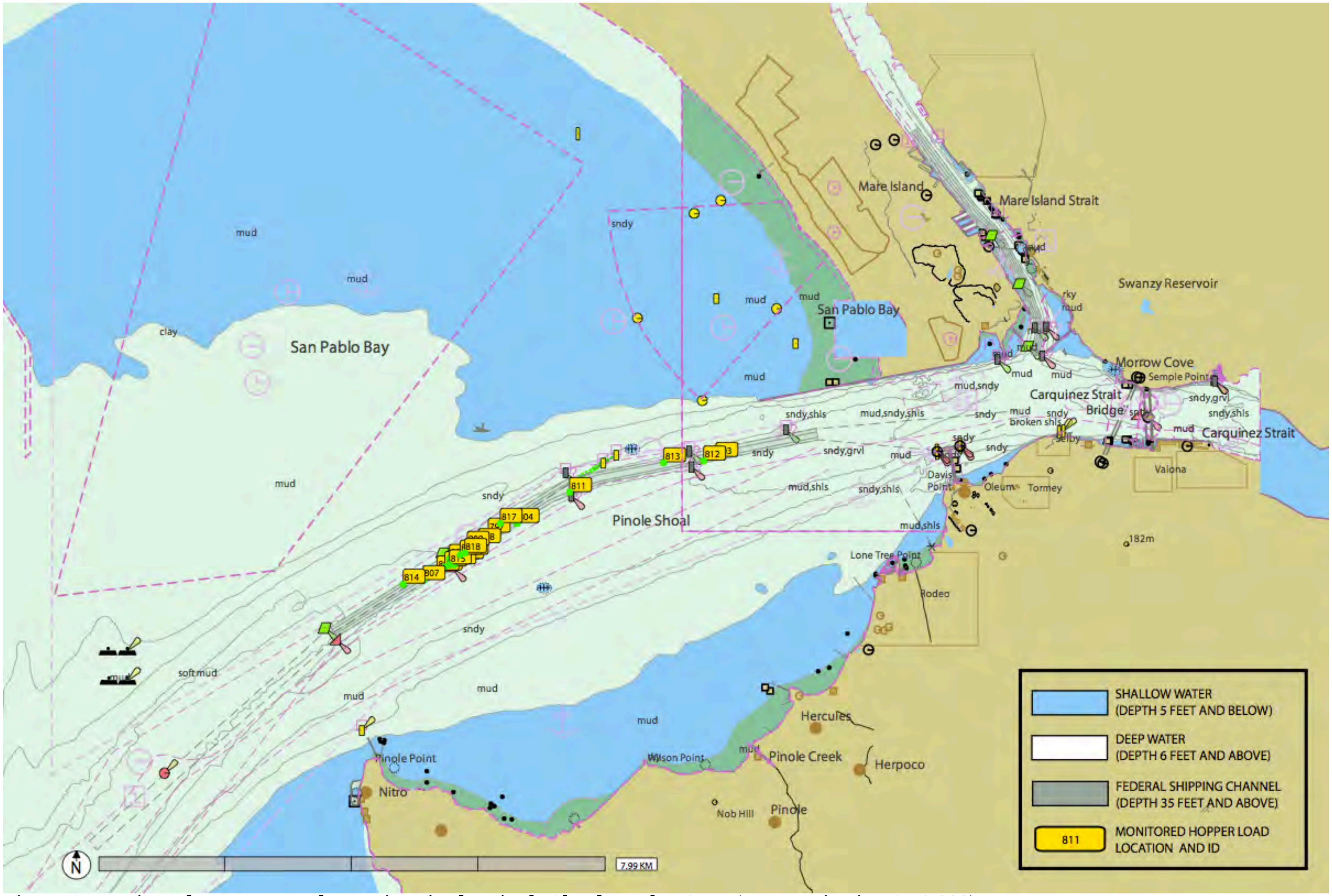

Figure 1. Monitored Hopper Load Locations in the Pinole Shoal Dredge Area (map projection 1:50,000)

Figure 2. Detailed Image of Hopper Loads Collected During Pinole Shoal Dredging Operations, July 16th, 2011 through July 19th, 2011.

5.1.2. Monitoring Results, Richmond Area

Dredging and associated monitoring activities in the Richmond Shoal area were initiated on July 19th, 2011, and concluded on July 31st, 2011. An additional two hopper loads (hopper IDs 1015 and 1016) were collected on August 11th, 2011. Total dredged time within the Richmond area therefore encompassed all or parts of fourteen days.

A summary of all fish entrained during dredging operations in the Richmond area is presented in Table 2. This list includes all fish observed by monitors, including those captured within the crab basket and those observed within the hopper itself.

Dredged areas are indicated in Figure 3, and actual hopper IDs are shown in finer scale in Figure 4 (Chevron Richmond Long Wharf area) and Figure 5 (Southampton Shoal). All monitoring was conducted using the revised methodology, where dredging was initiated with the drag arms at or very near the bottom.

Table 2. Monitoring Results of All Fish Entrained During Richmond Shoal Monitoring Operations. Includes fish observed within both crab basket and hopper. Hopper loads for which longfin smelt or Delta smelt were observed are indicated by LS and DS, respectively.

Hopper ID	Date	Species	No.	LS	DS
819	7/19/2011	staghorn sculpin	1		
		bay goby	1		
		plainfin midshipman	1		
820	7/19/2011	bay goby	3		
821	7/19/2011	longfin smelt	2	2	
822	7/19/2011	bay goby	7		
		longfin smelt	1	1	
823	7/20/2011	none	0		
824	7/20/2011	none	0		
825	7/20/2011	staghorn sculpin	1		
826	7/20/2011	bay goby	1		
827	7/20/2011	bay goby	1		
828	7/20/2011	bay goby	1		
829	7/20/2011	none	0		
830	7/20/2011	none	0		
831	7/20/2011	none	0		
832	7/21/2011	none	0		
833	7/21/2011	none	0		
834	7/21/2011	none	0		
835	7/21/2011	brown smoothhound shark	1		
		staghorn sculpin	1		
836	7/21/2011	none	0		
837	7/21/2011	none	0		
838	7/21/2011	none	0		
839	7/21/2011	bay goby	1		
840	7/21/2011	none	0		
841	7/21/2011	none	0		
842	7/21/2011	none	0		
843	7/22/2011	none	0		
844	7/22/2011	none	0		
845	7/22/2011	anchovy	1		
		bay goby	1		
846	7/22/2011	anchovy	1		
847	7/22/2011	none	0		
848	7/22/2001	none	0		
849	7/22/2011	none	0		
850	7/22/2011	none	0		
851	7/22/2011	plain midshipman	1		
852	7/22/2011	none	0		
853	7/22/2011	none	0		
854	7/23/2011	none	0		
855	7/23/2011	none	0		
856	7/23/2011	bay goby	1		
857	7/23/2011	staghorn sculpin	1		
858	7/23/2011	none	0		
859	7/23/2011	anchovy	2		
860	7/23/2011	none	0		
861	7/23/2011	none	0		

Hopper ID	Date	Species	No.	LS	DS
862	7/23/2011	none	0		
863	7/23/2011	none	0		
864	7/24/2011	none	0		
865	7/24/2011	none	0		
866	7/24/2011	none	0		
867	7/24/2011	none	0		
868	7/24/2011	none	0		
869	7/24/2011	none	0		
870	7/24/2011	none	0		
871	7/24/2011	staghorn sculpin	2		
872	7/24/2011	none	0		
873	7/24/2011	none	0		
874	7/25/2011	none	0		
875	7/25/2011	none	0		
876	7/25/2011	Pacific sanddab rock sole	1 1		
877	7/25/2011	none	0		
878	7/25/2011	none	0		
879	7/25/2011	none	0		
880	7/25/2011	none	0		
881	7/25/2011	bay goby	5		
882	7/25/2011	bay goby	1		
883	7/25/2011	none	0		
884	7/26/2011	none	0		
885	7/26/2011	none	0		
886	7/26/2011	bay goby	1		
887	7/26/2011	none	0		
888	7/26/2011	none	0		
889	7/26/2011	none	0		
890	7/26/2011	anchovy	1		
891	7/27/2011	anchovy	3		
892	7/27/2011	anchovy longfin smelt white croaker	2 1 1	 1 	
893	7/27/2011	none	0		
894	7/27/2011	none	0		
895	7/27/2011	none	0		
896	7/27/2011	bay goby Pacific sanddab staghorn sculpin	1 1 1		
897	7/27/2011	rock sole	1		
898	7/27/2011	bay goby	2		
899	7/27/2011	none	0		
900	7/27/2011	none	0		
901	7/28/2011	none	0		
902	7/28/2011	anchovy	1		
903	7/28/2011	none	0		
904	7/28/2011	bay goby	1		
905	7/28/2011	longfin smelt	1	1	
906	7/28/2011	none	0		
907	7/28/2011	none	0		

Hopper ID	Date	Species	No.	LS	DS
908	7/28/2011	longfin smelt staghorn sculpin	3 1	3	
909	7/28/2011	bay goby	4		
910	7/28/2011	none	0		
911	7/29/2011	bay goby	1		
912	7/29/2011	none	0		
913	7/29/2011	anchovy staghorn sculpin	1 1		
914	7/29/2011	none	0		
915	7/29/2011	none	0		
916	7/29/2011	bay goby staghorn sculpin	1 2		
917	7/29/2011	rock sole bay goby	5 1		
918	7/29/2011	bay goby	1		
919	7/29/2011	rock sole	1		
920	7/29/2011	bay goby	1		
921	7/29/2011	longfin smelt bay goby Pacific sanddab Rock sole	1 1 1 3	1	
922	7/30/2011	staghorn sculpin	1		
923	7/30/2011	none	0		
924	7/30/2011	none	0		
925	7/30/2011	none	0		
926	7/30/2011	none	0		
927	7/30/2011	bay goby white croaker staghorn sculpin	1 1 1		
928	7/30/2011	staghorn sculpin	1		
929	7/30/2011	plain midshipman	1		
930	7/30/2011	none	0		
931	7/30/2011	staghorn sculpin	1		
932	7/30/2011	bay goby	1		
933	7/31/2011	none	0		
934	7/31/2011	staghorn sculpin plainfin midshipman	1 1		
935	7/31/2011	staghorn sculpin	2		
936	7/31/2011	none	0		
937	7/31/2011	plain midshipman	1		
938	7/31/2011	longfin smelt	1	1	
939	7/31/2011	none	0		
940	7/31/2011	staghorn sculpin white croaker	1 1		
941	7/31/2001	none	0		
942	7/31/2011	none	0		
1015	8/11/2011	none	0		
1016	8/11/2011	Anchovy Jacksmelt	2 1		
Total			109	10	0

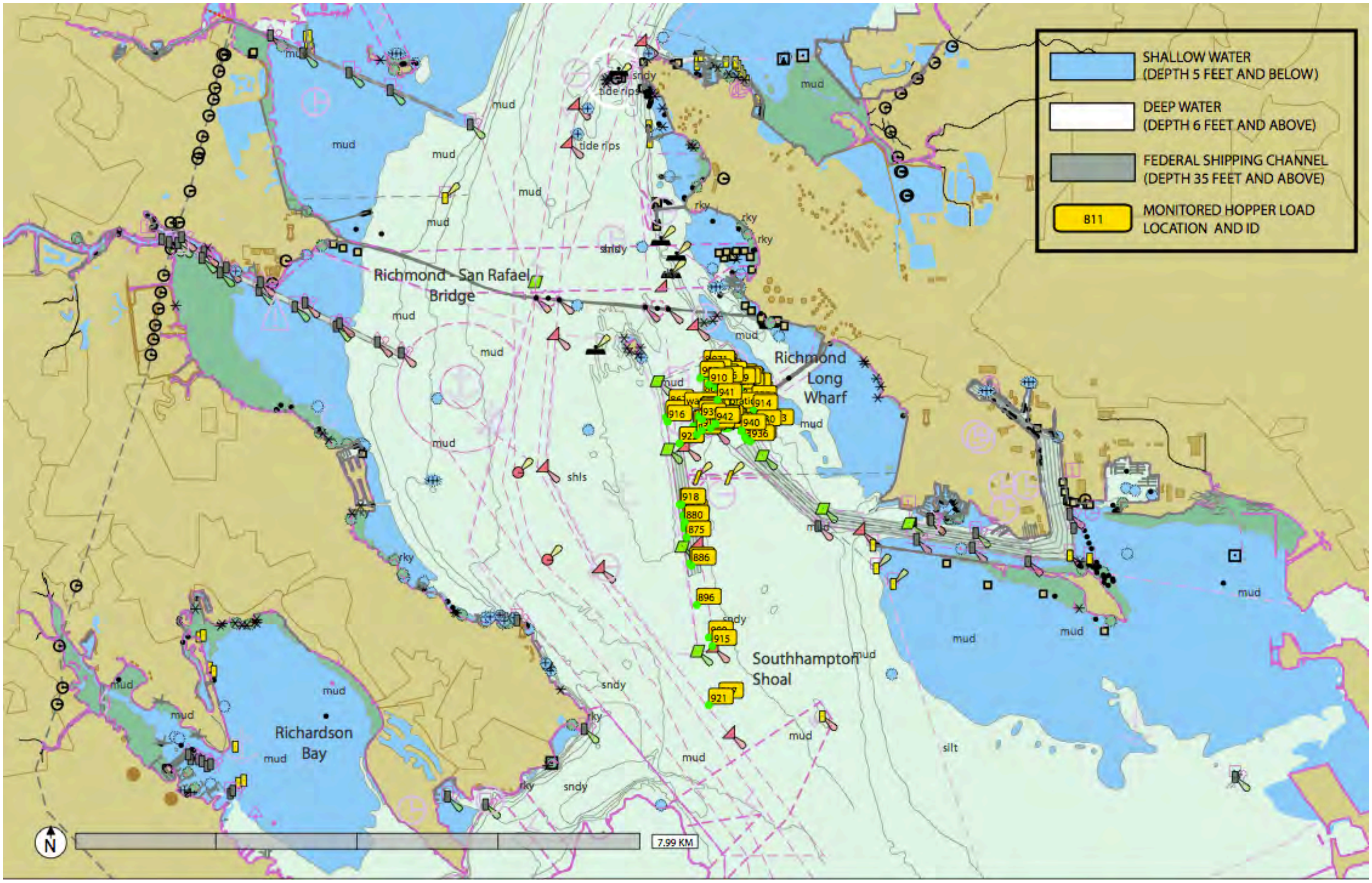

Figure 3. Monitored Hopper Load Locations in the Richmond Shoal Dredge Area (map projection 1:50,000)

Figure 4. Detailed Image of Hopper Loads Collected During Richmond Long Wharf Dredging Operations, July 19th, 2011 through July 31st, 2011.

Figure 5. Detailed Image of Hopper Loads Collected During Southampton Shoal Dredging Operations, July 27th, 2011 through July 29th, 2011.

5.1.3. Monitoring Results, Suisun Bay Area

Dredging and associated monitoring activities were initiated on August 1st, 2011, and concluded on August 10th, 2011, a period encompassing all or parts of ten days. A summary of all fish entrained during dredging operations in the Richmond area is presented in Table 7. This list includes all fish observed by monitors, including those captured by the crab basket and those observed within the hopper itself.

Areas dredged in West Suisun Bay are indicated in Figure 6, and areas within East Suisun Bay are indicated Figure 7. Actual hopper IDs are shown in finer scale in Figure 8 (Suisun Bay proper) and Figure 9 (New York Slough). All monitoring was conducted using the revised methodology, where dredging was started with the drag arms at or very near the bottom.

Table 3. Monitoring Results of All Fish Entrained During Monitoring Operations in Conducted in West Suisun Bay. Includes fish observed within both crab basket and hopper. Hopper loads for which longfin smelt or Delta smelt were observed are indicated by LS and DS, respectively.

Hopper ID	Date	Species	No.	LS	DS
943	8/1/2011	striped bass	2		
		longfin smelt	1	1	
944	8/1/2011	none	0		
945	8/1/2011	none	0		
946	8/1/2011	none	0		
947	8/1/2011	none	0		
948	8/1/2011	none	0		
949	8/1/2011	none	0		
950	8/1/2011	none	0		
951	8/1/2011	none	0		
952	8/1/2011	none	0		
953	8/1/2011	none	0		
954	8/1/2011	striped bass	4		
955	8/2/2011	none	0		
956	8/2/2011	none	0		
957	8/2/2011	none	0		
958	8/2/2011	none	0		
959	8/2/2011	none	0		
960	8/2/2011	none	0		
961	8/2/2011	none	0		
962	8/2/2011	none	0		
963	8/2/2011	none	0		
964	8/2/2011	none	0		
965	8/2/2011	none	0		
966	8/3/2011	American shad	1		
967	8/3/2011	none	0		
968	8/3/2011	none	0		
969	8/3/2011	none	0		
970	8/3/2011	none	0		
971	8/3/2011	staghorn sculpin	1		
972	8/3/2011	staghorn sculpin	1		

Hopper ID	Date	Species	No.	LS	DS
973	8/3/2011	none	0		
974	8/3/2011	staghorn sculpin	1		
		striped bass	1		
975	8/4/2011	striped bass	2		
976	8/4/2011	staghorn sculpin	2		
		striped bass	3		
		American shad	2		
		bay goby	1		
		Sacramento splittail	1		
977	8/4/2011	striped bass	2		
		bay goby	1		
		staghorn sculpin	1		
978	8/4/2011	staghorn sculpin	4		
978	8/4/2011	striped bass	1		
979	8/4/2011	staghorn sculpin	1		
980	8/4/2011	none	0		
981	8/4/2011	staghorn sculpin	1		
982	8/4/2011	anchovy	2		
		river lamprey	2		
		staghorn sculpin	1		
983	8/4/2011	none	0		
984	8/4/2011	none	0		
985	8/5/2011	none	0		
986	8/5/2011	staghorn sculpin	2		
		striped bass	1		
987	8/5/2011	none	0		
998	8/7/2011	shokihaze goby	1		
999	8/8/2011	striped bass	2		
		delta smelt	1		1
1000	8/8/2011	none	0		
1001	8/8/2011	delta smelt	1		1
		longfin smelt	1	1	
1002	8/8/2011	none	0		
1006	8/9/2011	none	0		
1007	8/9/2011	staghorn sculpin	2		
1008	8/9/2011	anchovy	1		
1009	8/9/2011	striped bass	2		
		American shad	1		
		staghorn sculpin	1		
1010	8/10/2011	river lamprey	1		
1011	8/10/2011	striped bass	2		
1012	8/10/2011	striped bass	1		
		longfin smelt	1	1	
1013	8/10/2011	none	0		
1014	8/10/2011	none	0		
Total			42	3	2

Table 4. Monitoring Results of All Fish Entrained During Monitoring Operations in Conducted in East Suisun Bay (New York Slough). Includes fish observed within both crab basket and hopper. Hopper loads for which longfin smelt or Delta smelt were observed are indicated by LS and DS, respectively.

Dredged Area	Hopper ID	Date	Species	No.	LS	DS
New York Slough	988	8/5/2011	striped bass	1		
New York Slough	989	8/5/2011	none	0		
New York Slough	990	8/5/2011	delta smelt	1		1
New York Slough	991	8/6/2011	striped bass river lamprey	1 1		
New York Slough	992	8/6/2011	none	0		
New York Slough	993	8/6/2011	striped bass American shad	2 2		
New York Slough	994	8/6/2011	delta smelt American shad	1 2		1
New York Slough	994	8/7/2011	none	0		
New York Slough	996	8/7/2011	none	0		
New York Slough	997	8/7/2011	none	0		
New York Slough - East	1003	8/8/2011	striped bass	1		
New York Slough - East	1004	8/8/2011	striped bass	1		
New York Slough - East	1005	8/9/2011	striped bass	1		
Total				14	0	2

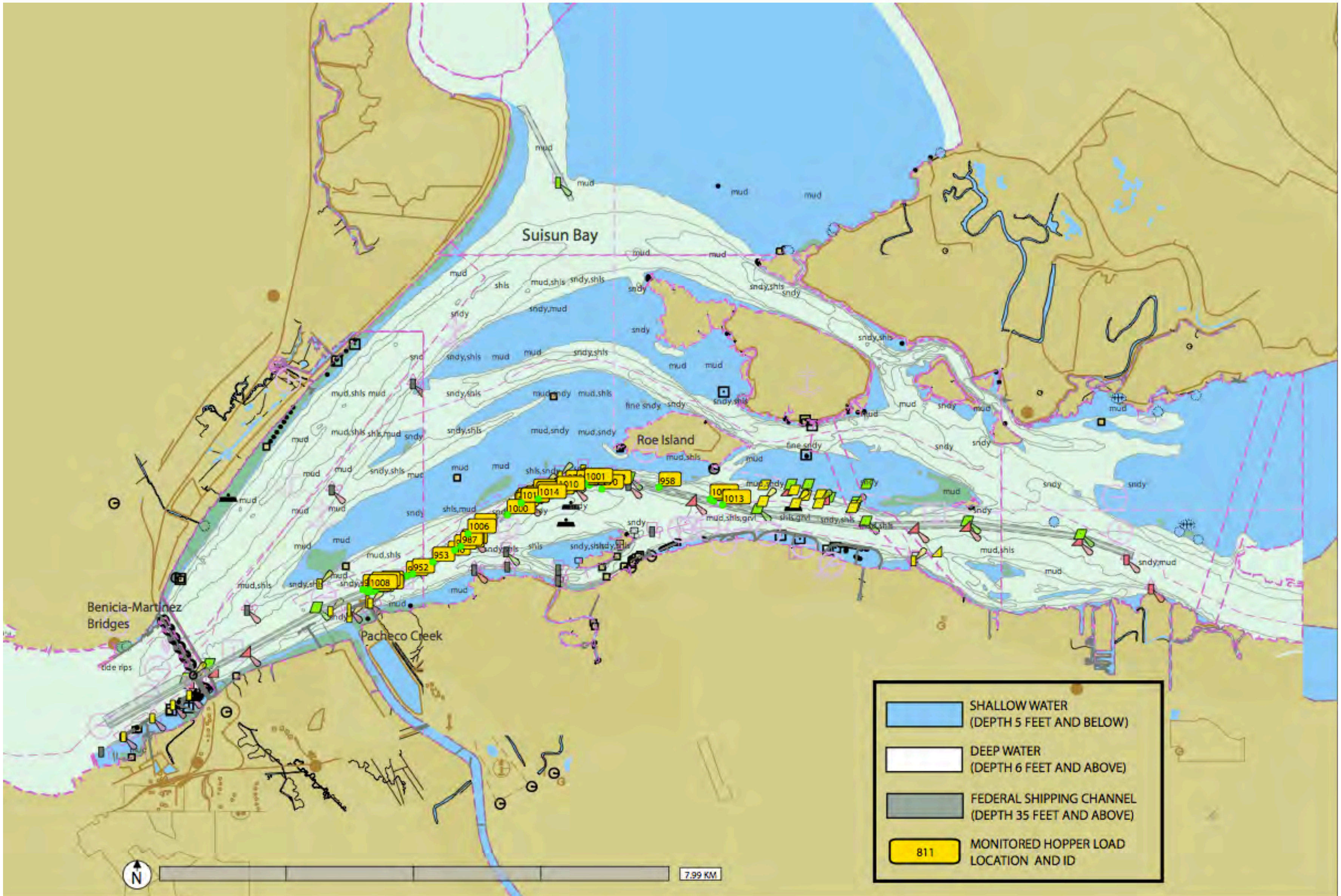

Figure 6. Monitored Hopper Load Locations in the West Suisun Bay Dredge Area (map projection 1:50,000)

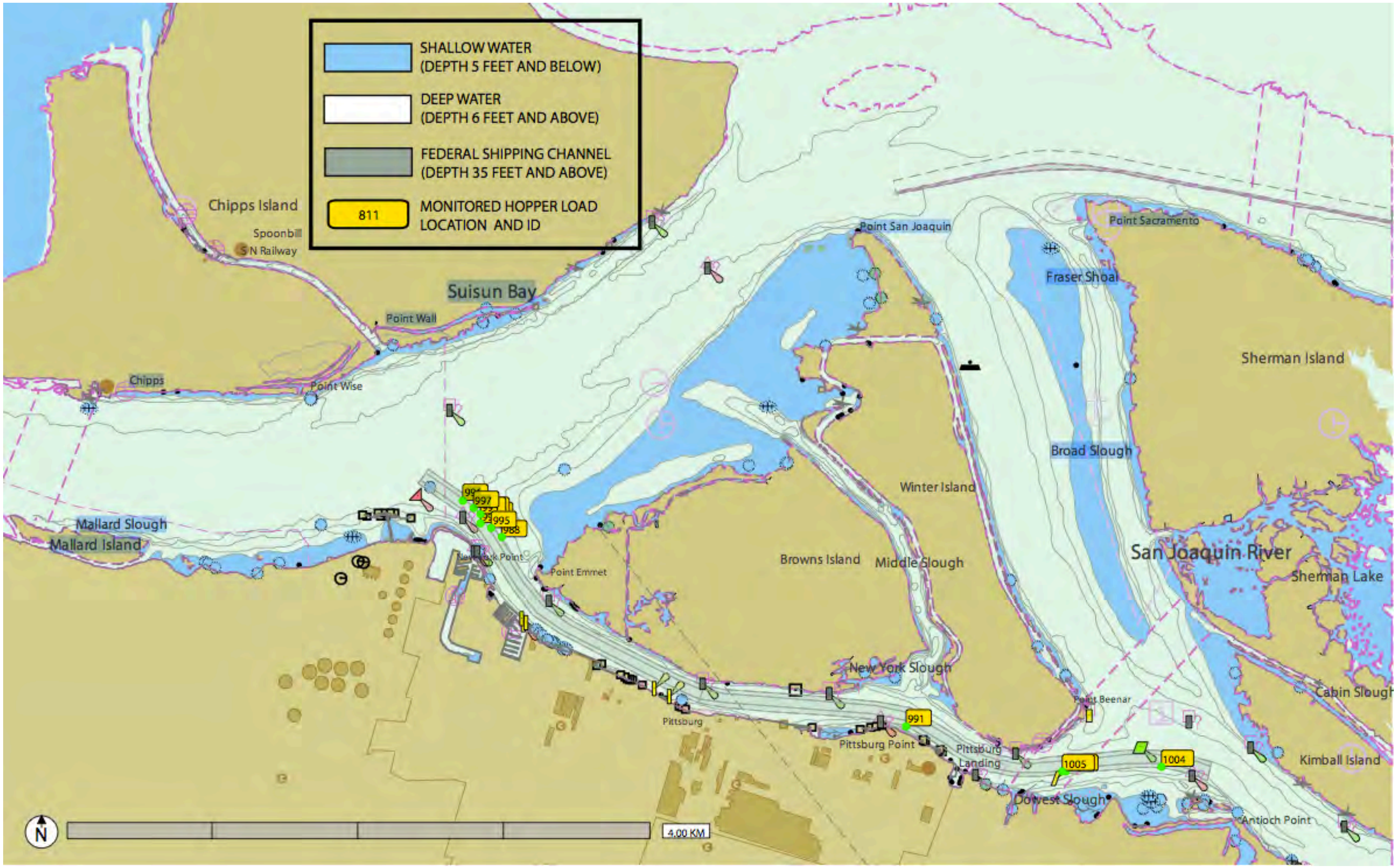

Figure 7. Monitored Hopper Load Locations in the New York Slough / East Suisun Bay Dredge Area (map projection 1:25,000)

Figure 8. Detailed Image of Hopper Loads Collected During Suisun Bay Dredging Operations, August 1st, 2011 through August 5th, 2011, and August 9th, 2011 through August 10th, 2011.

Figure 9. Detailed Image of Hopper Loads Collected During East Suisun Dredging Operations, August 5th, 2011 through August 9th, 2011.

Table 5. Monitoring Results of All Fish Entrained During Monitoring Operations in Conducted in East Suisun Bay. Includes fish observed within both crab basket and hopper. Hopper loads for which longfin smelt or Delta smelt were observed are indicated by LS and DS, respectively.

Dredged Area	Hopper ID	Date	Species	No.	LS	DS
New York Slough	988	8/5/2011	striped bass	1		
New York Slough	989	8/5/2011	none	0		
New York Slough	990	8/5/2011	delta smelt	1		1
New York Slough	991	8/6/2011	striped bass river lamprey	1 1		
New York Slough	992	8/6/2011	none	0		
New York Slough	993	8/6/2011	striped bass American shad	2 2		
New York Slough	994	8/6/2011	delta smelt American shad	1 2		1
New York Slough	994	8/7/2011	none	0		
New York Slough	996	8/7/2011	none	0		
New York Slough	997	8/7/2011	none	0		
New York Slough - East	1003	8/8/2011	striped bass	1		
New York Slough - East	1004	8/8/2011	striped bass	1		
New York Slough - East	1005	8/9/2011	striped bass	1		
Total				14	0	2

5.1.4. Monitoring Results, Special Situations

As discussed previously, monitors were able to opportunistically sample situations that were part of regular dredging operations, but not associated with active dredging of bottom sediments. These situations included water calibration, sample pump rate tests, and hopper flushing events. These events were conducted in different parts of the Bay and distributed over the course of dredging operations. Results of these events are shown in Table 6. It should be noted that one delta smelt was entrained associated with these special situations (hopper flush on August 10, 2011).

Table 6. Monitoring Results of All Fish Entrained During Monitoring Operations Conducted Associated with Special Situations. Includes fish observed within both crab basket and hopper. Hopper loads for which longfin smelt or Delta smelt were observed are indicated by LS and DS, respectively.

Dredged Area	Event	Date	Species	No.	LS	DS
Richmond - SH	water calibration	7/28/2011	none	0		
Richmond - SH	water calibration	7/29/2011	none	0		
Richmond - LW	water calibration	7/30/2011	anchovy	1		
New York Slough	sample pump rate test	8/7/2011	none	0		
Suisun Bay	hopper flush	8/10/2011	delta smelt striped bass anchovy American shad Yellowfin goby	1 3 1 1 1		1
Richmond - LW	hopper flush	8/11/2011	none			
Total				8	0	1

5.1.5. Monitoring Results, Combined

The combined monitoring results for areas dredged during 2011 are presented in Table 7. Figures 10 through 12 illustrate approximate longfin smelt and delta smelt entrainment locations for Pinole Shoal, Richmond Harbor and Southampton Shoal, and East and West Suisun Bay, respectively.

Table 7. Summary of Presence / Absence of Entrained Longfin Smelt (LS) and Delta Smelt (DS) within Each Hopper Load by Dredged Area. Results do not include fish entrained during special situation monitoring identified above.

	Pinole	Richmond	West Suisun	East Suisun	All Areas
No. Hopper Loads	32	124	45	27	228
No. Loads with LS	1	7	3	0	10
% Loads with LS	3.1%	5.6%	6.7%	0	4.4%
No. Loads with DS	0	0	2	2	2
% Loads with DS	0%	0%	4.4%	7.4%	0.9%

Figure 10. Approximate Location of Hopper Loads with Entrained Fish, Pinole Shoal. All fish entrained were longfin smelt.

Figure 11. Approximate Location of Hopper Loads with Entrained Fish, Richmond and Southampton Shoal. All fish entrained were longfin smelt.

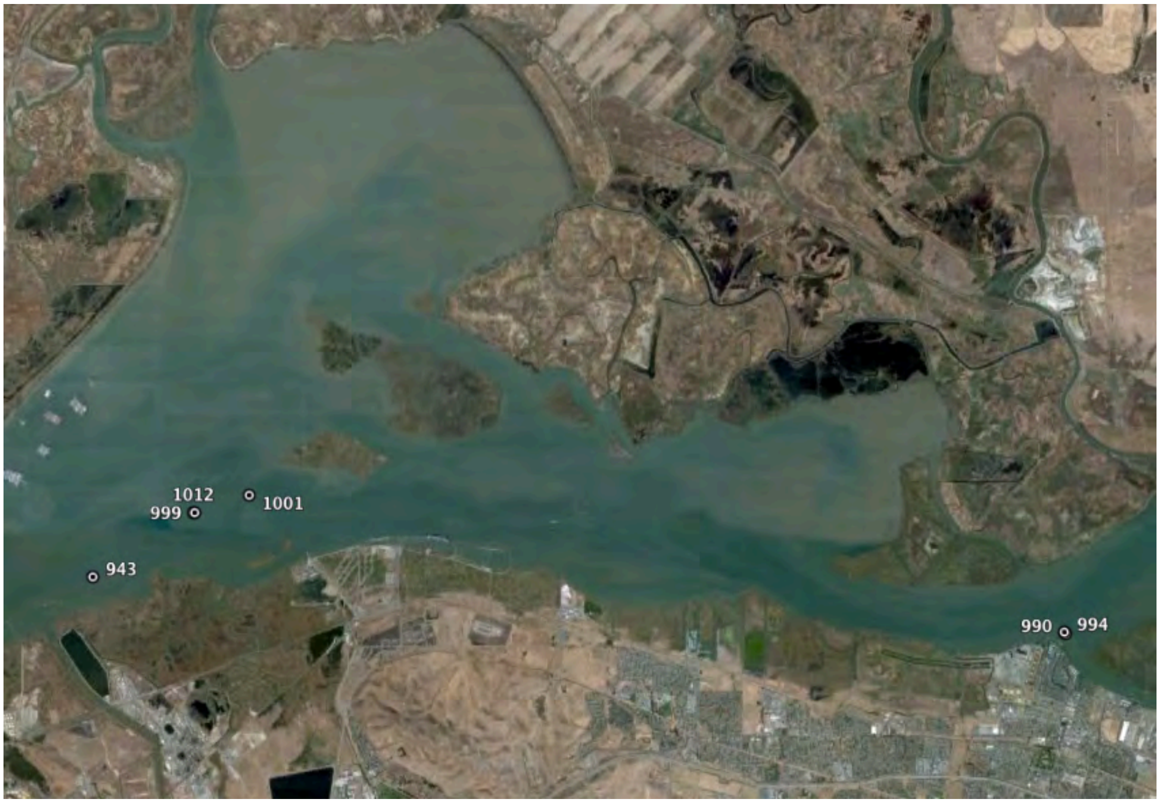

Figure 12. Approximate Location of Hopper Loads with Entrained Fish, Suisun Region. Hopper loads 943, 1001, and 1012 entrained longfin smelt; hopper loads 990, 994, 999, and 1001 entrained delta smelt.

6. Estimates of Entrainment

At the request of CDFG, dredging effort and monitoring data were used to develop rough estimates of entrainment associated with dredging operations. The methods used to perform these extrapolations are described below.

Two simple approaches are taken here to extrapolate the total numbers of fish entrained. The first extrapolation method assumes that entrained species were equally distributed in each embayment (Pinole Shoal, Richmond Harbor, including Southampton Shoal, and all of the locations within Suisun Bay) in which they were entrained. This assumption allows the following extrapolation equation:

$$N = n\,(V/v)$$

Where:

Where:	N	=	total number of entrained fish
	n	=	number of fish entrained in all hopper loads
	V	=	total volume of material dredged (calculated as total dredge pumping time multiplied by 66,000 gallons / minute, the base dredged pumping rate)
	v	=	total volume of dredged material monitored (monitoring time multiplied by 3,480 gallons / minute, the pumping rate for the crab basket)

The numbers of individual fish within each species that are estimated to have been entrained using this extrapolation methodology is determined by calculating the proportion of each species entrained within the total number of all fish entrained, and multiplying that proportion by the total number of fish extrapolated.

The assumption that the fish are equally distributed is no doubt flawed. Some species were far more common than others, which itself begins to describe the un-equal distribution of species as well as susceptibility to entrainment. However, assuming that species were not present in hopper loads in which they were not documented in the crab basket is also flawed. Not only does the small proportion of material assessed challenge that assumption, but equally challenging is the fact that species were documented via hopper observation that were not documented in the crab basket during the same hopper load, or, as is the case for some species, they were not documented in the crab basket at all.

This leads to the second method of extrapolation. This method is largely based on the idea that the monitoring methodology roughly describes not only the size of the population, but also the unequal distribution of species within each embayment. It assumes that species were only entrained in the hopper loads in which they were captured within the crab basket. This method is represented by the following equation:

$N_1 = n_1 (V_1/v_1)$

Where:	N_1	=	total number of fish of each species entrained
	n_1	=	total number of fish of each species documented in an individual hopper load
	V_1	=	total amount of material dredged during that hopper load
	v_1	=	volume of material monitored during that hopper load (flush or fill)

Using this methodology, entrainment estimates are calculated for each hopper load in which a species occurs, and added together for the totals for each embayment. This method is significantly challenged for the same reasons as the first method. Only longfin smelt and delta smelt numbers are extrapolated using this method, although estimates of other species may be performed based upon the results of monitoring.

Fish that were opportunistically observed and netted from the hopper were documented, but total entrainment numbers were not calculated using these fish. This is due to lack of an appropriate multiplier from which to extrapolate. Put simply, this data is non-quantitative, and thus cannot be used for extrapolation in a scientifically defensible manner. This is significant for several reasons. Both listed and non-listed species were observed in this manner, and several species, including the largest individuals observed, were only documented in the hopper, and not in the crab basket. So, we know that several species were entrained by documenting them from hopper observations, but due to the inherent monitoring constraints, we are unable to use this data to estimate the total numbers of individuals of these species that may have been entrained.

For each methodology, the calculations rely upon estimates of volume of total material dredged and volume diverted to the crab basket provided by ship's crew. The two drag arm pumps typically produced 66,000 gallons per minute of dredged material; Captain Nyberg estimated that the crab basket receives approximately 3,480 gallons per minute (Captain Nyberg, personal communication). These two pumping rates are multiplied by pumping and monitoring durations in combination with entrained fish to extrapolate total numbers of entrained fish.

6.1. Estimated Entrainment, Pinole

The estimates of entrainment prepared for the dredged areas within the vicinity of the Pinole Shoal are provided in Table 8 (Methodology 1) and Table 9 (Methodology 2). As shown in the results above, only longfin smelt were entrained associated with the Pinole Shoal dredging operations. Only results from dredging activities using the originally planned monitoring methodology are represented within the tables.

Table 8. Entrainment Estimated Based Upon All Fish Entrained within All Sampling Events and the Proportion of Longfin and Delta Smelt to All Entrained Fish (Methodology 1), Pinole Region. Extrapolations include only extended water column monitoring conducted on hopper loads using original monitoring methodology.

Dredge Area	Pinole
Proportion of Dredged Material Monitored (%)	0.70
Total Fish Encountered	101
Estimated # Total Fish for All Dredging Events	14,620
Proportion of Total, Longfin Smelt (%)	3
Estimated # Longfin Smelt	434
Proportion of Total, Delta Smelt (%)	0
Estimated # Delta Smelt	0

Table 9. Estimated Entrainment of Longfin Smelt (LS) and Delta Smelt (DS) Based Upon Hopper Loads with Longfin and / or Delta Smelt Entrained (Methodology 2), Pinole Region. Extrapolations include only extended water column monitoring conducted on hopper loads using original monitoring methodology.

Species	Hopper ID	# Fish Entrained	Proportion of Hopper Load Monitored (%)	Subtotal
LS	806	3	0.6657	451
	`			
	Total			451

6.2. Estimates of Entrainment, Richmond

The estimates of entrainment prepared for the dredged areas within the vicinity of the Richmond Long Wharf and Southampton Shoal are provided in Table 10 (Methodology 1) and Table 11 (Methodology 2). All estimates were prepared using only monitoring data collected associated with the modified monitoring protocols (i.e., dredging and monitoring initiated with drag arms at the bottom). As with Pinole Shoal, only longfin smelt were entrained associated with the dredging operations in the Richmond Area.

Table 10. Entrainment Estimated Based Upon All Fish Entrained within All Sampling Events and the Proportion of Longfin and Delta Smelt to All Entrained Fish, Richmond and Suisun Regions. Extrapolations include only monitoring associated with modified sampling methodology.

Dredge Area	Richmond
Proportion of Dredged Material Monitored (%)	0.24
Total Fish Encountered	109
Estimated # Total Fish for All Dredging Events	44,936
Proportion of Total, Longfin Smelt (%)	9
Estimated # Longfin Smelt	4,123
Proportion of Total, Delta Smelt (%)	0
Estimated # Delta Smelt	0

Table 11. Estimated Entrainment of Longfin Smelt (LS) and Delta Smelt (DS) in Richmond Region Based Upon Hopper Loads with Longfin and / or Delta Smelt Entrained. Extrapolations include only monitoring associated with modified monitoring methods.

Species	Hopper ID	# Fish Entrained	Proportion of Hopper Load Monitored (%)	Estimated # Fish Entrained
LS	821	2	0.3667	545
LS	822	1	0.3466	288
LS	892	1	0.1412	708
LS	905	1	0.1933	517
LS	908	3	0.3308	907
LS	921	1	0.2856	350
LS	938	1	0.1291	775
Total				4,091

6.3. Estimates of Entrainment, Suisun Bay

The estimates of entrainment prepared for the dredged areas within the Suisun Bay area are provided in Table 10 (Methodology 1) and Table 11 (Methodology 2). All estimates were prepared using only monitoring data collected associated with the modified monitoring protocols (i.e., dredging and monitoring initiated with drag arms at the bottom). As with Pinole Shoal, only longfin smelt were entrained associated with the dredging operations in the Richmond Area.

Table 12. Entrainment Estimated Based Upon All Fish Entrained within All Sampling Events and the Proportion of Longfin and Delta Smelt to All Entrained Fish, Suisun Region. Extrapolations include only monitoring associated with modified monitoring methods.

Dredge Area	Suisun
Proportion of Dredged Material Monitored (%)	0.24
Total Fish Encountered	70
Estimated # Total Fish for All Dredging Events	28,841
Proportion of Total, Longfin Smelt (%)	4
Estimated # Longfin Smelt	1,236
Proportion of Total, Delta Smelt (%)	4
Estimated # Delta Smelt	1,236

Table 13. Estimated Entrainment of Longfin Smelt (LS) and Delta Smelt (DS) in Suisun Bay Region Based Upon Hopper Loads with Longfin and / or Delta Smelt Entrained. Extrapolations include only monitoring associated with modified monitoring methods.

Species	Hopper ID	# Fish Entrained	Proportion of Hopper Load Monitored (%)	Estimated # Fish Entrained
LS	943	1	0.2371	422
LS	1001	1	0.4287	233
LS	1012	1	0.4905	204
Total	N/A	3	N/A	859
DS	994	1	0.1449	690
DS	998	1	0.4860	206
DS	1001	1	0.4287	233
Total	N/A	3	N/A	1,129

6.4. Estimates of Entrainment, Combined

Extrapolating the total numbers of fish entrained based on the percentage of material monitored was conducted as described in the methods section. The first method calculates total numbers of all fish entrained, and then numbers of entrained longfin and delta smelt are derived based on their proportion of the total. Using this method, it is estimated that approximately 15,000, 43,000, and 29,000 fish (all species) were entrained in the Pinole, Richmond, and Suisun Bay locations respectively. This resulted in an estimated take of approximately 400 longfin smelt in Pinole, 4,000 in Richmond, and 1,000 in Suisun Bay, and an estimated take of 1,000 delta smelt in Suisun Bay.

Using the second method, in which only hopper loads in which longfin smelt and / or delta smelt were entrained were used for extrapolations, take of longfin smelt was estimated at approximately 500, 4,000, and 1,000 at Pinole, Richmond, and Suisun Bay, respectively. Estimated take of delta smelt in Suisun Bay using this second method was approximately 1,000.

As noted previously, dredging operations were adjusted following the take of the first longfin smelt (hopper ID 806) to minimize potential take of sensitive species. Monitoring protocols were adjusted so that dredging (and concurrent load monitoring) was initiated with drag arms at the bottom, as opposed to pumping water two to three feet above the sea floor for one to two minutes prior to dropping the drag arms to the sea floor. This change in dredging operations was implementing following completion of all Pinole Shoal dredging, with the second hopper load collected in the vicinity of the Chevron Richmond Long Wharf (LW) facility (hopper ID 819). For this reason, the entrainment estimates for Pinole Shoal and all other areas are kept separate.

7. Discussion

Individual aspects of the monitoring and modeling efforts are described in more detail below.

7.1. Quality Assurance

For the 2011 monitoring, the designated biologist was tasked by USACE with monitoring a minimum of 80% of the individual hopper loads. The biologists successfully monitored 100% of all hopper loads over the course of the dredging operations, on either the load (fill), flush, or both portions of the dredging cycle. Of the 228 hopper loads that were obtained in all of the dredging locations, on only four loads were the load or flush not monitored. In three of the four cases when a load or flush was missed, it was due to not having been informed by the ship that the event was occurring. In the fourth case, the flush was not monitored because the ship had to move without flushing the pumps first, due to ship traffic.

All dead fish entrained within the crab basket were vouchered for archival and will be archived frozen for a period of one year at AMS's Livermore facility. In August 2011, CDFG personnel conducted confirmation identifications of all field identifications of longfin smelt and delta smelt made by monitoring personnel. In each case, results of these identifications confirmed original identifications.

7.2. Uncertainty of Entrainment Estimates

Although estimates of entrainment generated through the two methodologies presented in the Methods above are very close, this should not be interpreted as suggesting that either method is especially representative of environmental conditions present or overall number of fish entrained by this dredging project. Although each hopper load was monitored, both the dredging time and dredged volume are several orders of magnitude greater than the monitoring time and monitored volume; overall, only 0.367 % of the dredge's total output of pumped material was assessed. This suggests that any uncertainty associated with the results of monitoring and how representative these results are of actual entrainment will be magnified by the extrapolations.

As evidence of this inherent uncertainty associated with large extrapolations, we can describe the effect of the single longfin smelt that was observed within the dredge hopper on July 21, 2011 (hopper ID #839). As this individual was not captured by the crab basket, it was not included in estimates of overall entrainment. However, had the fish been captured by the basket, it would have increased our estimate of entrained longfin smelt in the Richmond Long Wharf area by approximately 400 individuals, or approximately ten percent of all longfin smelt entrained in this region. Based on the limited monitoring periods, dredging volumes monitored, and the probable patchiness of fish presence and abundances during dredging events, the only conclusive statement that can be made about fish entrainment from *Essayons* dredging activity, is that entrainment of listed and other species was documented. The results of this extrapolation exercise should be viewed within this context.

7.3. Minimization Measures

As presented in the Introduction, there are several permit requirements that require reporting of mitigation and minimization measures implemented over the course of the project. Table 14 provides the details of the minimization measures implemented. Mitigation measures were not employed while monitoring.

The lack of minimization measures employed reflects the lack of measures available. After the initial adjustment to the methods that occurred shortly after the first longfin smelt was taken, the only other method available was to move the dredge and work elsewhere. Moving was only done once, due to lack of areas to move to during most of the occurrences of entrainment of listed fish.

Effectiveness of the minimization measures cannot really be addressed in any scientifically defensible manner. However, given the decreased pumping time resulting from the minimization measure, it is likely that it did decrease take of listed species.

Table 14. Minimization Measures Employed when Longfin and Delta Smelt were Entrained.

Date	Location	Minimization Measure
7/18/11	Pinole Shoal	see methods section
7/19/11	Richmond LW (Long Wharf)	none
7/27/11	Richmond LW	none
7/28/11	Richmond LW	none
7/28/11	Richmond LW	none
7/29/11	Richmond SH (Southampton Shoal)	none
8/5/11	Suisun Bay (New York Slough)	none
8/6/11	Suisun Bay (New York Slough)	Ship moved to new location
8/8/11	Suisun Bay (Preston Reach)	none
8/8/11	Suisun Bay (Preston Reach)	none
8/10/11	Suisun Bay (Preston Reach)	none
8/10/11	Suisun Bay (hopper-flush)	none

7.4. Recommendations for Future Monitoring

Our recommendation is to provide a monitoring methodology that will allow future monitoring efforts to assess a much higher portion of the dredged material. Doing so will help provide far more robust assessments of entrainment of listed and other species and will allow for a more meaningful and effective discussion of minimization of fish entrainment and ultimately take of protected species, and the appropriate mitigations that will result in reduced take. USACE may consider building a screen similar to the screen being used to assess dredge entrainment in the Delta's Ship Channels. Use of such a device would likely allow an order of magnitude increase in the amount of dredged material that could be assessed.

Assessment of a greater amount of dredged material will allow greater confidence in future efforts to extrapolate total numbers of fish entrained during dredging projects. However, this alone does not suffice when questions arise about differential susceptibility of entrainment among species. Nor does it allow definitive conclusions about lack of listed or other species susceptibility based on lack of entrainment. Concurrent community monitoring efforts should be considered in order to answer such questions, as they describe the fish community that could be impacted.

8. References

Brusca, R. C., V. Coelho and S. Taiti, 2001. A Guide to the Coastal Isopods of California. http://tolweb.org/notes/?note_id=3004

California Department of Fish and Game, July 29, 2011. 2081(a) Memorandum of Understanding, California Endangered Species Act, Take of Longfin Smelt and Delta Smelt for Entrainment Monitoring of the Essayons in the Suisun Bay Channel.

California Department of Fish and Game, July 7, 2011. Section 2081(a) permit Authorizing Take of California Endangered Species Act (CESA) Listed Longfin Smelt for 2011 Activities.

California Department of Fish and Game, July 21, 2011. Amendment to Section 2081(a) permit Authorizing Take of California Endangered Species Act (CESA) Listed Longfin Smelt for 2011 Activities.

California Department of Fish and Game, July 15, 2011 Letter to Mr. Laurie Suda, Chief of Environmental Section B San Francisco District of the U.S. Army Corps of Engineers.

Eschmeyer, W. N., Herald, E. S., and Hammann, H., 1983. A Field Guide to the Pacific Coast Fishes of North America.

Jensen, G.C. 1995. Pacific Coast crabs and shrimps. ISBN 0-930118-20-0. Sea Challengers. Monterey, California.

Kramer, D. E., Barss, H., Paust, B. C., and Bracken B. E., 1995. Guide to Northeast Pacific Flatfishes Families *Bothidae, Cynoglossidae, and pleuronectidae.* Alaska Sea Grant college Program Universty of Alaska Fairbanks. Marine Advisory Bulletin No. 47.

Mari-Gold Environmental Consulting and Novo Aquatic Sciences, 2011. Stockton and Sacramento Deepwater Ship Channel Maintenance Dredging 2010 Fish Community, Entrainment and Water Quality Monitoring Report. Prepared for U.S. Army Corps of Engineers, Sacramento District 1325 J Street Sacramento, California 95814.

Mari-Gold Environmental Consulting and Novo Aquatic Sciences, 2010. Stockton and Sacramento Deepwater Ship Channel Maintenance Dredging 2009 Fish Community, Entrainment and Water Quality Monitoring Report. Prepared for U.S. Army Corps of Engineers, Sacramento District 1325 J Street Sacramento, California 95814.

McGowan, M., 2010. Longfin Smelt Monitoring During Dredging of the Pinole Shoal Channel in San Pablo Bay, California in June 2010. Report Prepared for U. S. Army Corps of Engineers, San Francisco.

McGraw, K., and Armstrong, D., 1990. "Fish entrainment by dredges in Grays Harbor, Washington." Effects of dredging on anadromous Pacific Coast fishes. C. A. Simenstad, ed., Washington Sea Grant Program, University of Washington, Seattle.

Miller, D. J., and R. N. Lea, 1972. Guide to the coastal marine fishes of California. California Fish Bulletin No. 157.

Morris, R. H., Abbott, D. P., and E. C. Hadderlie, 1980. Intertidal invertebrates of California. Stanford University Press. Stanford, California. 690 pp.

Moyle, P. B., 2002. Inland fishes of California, revised and expanded. University of California Press. Berkeley.

National Marine Fisheries Service (NMFS). Unpublished manuscript.

Reine, K., and Clarke, D., 1998. "Entrainment by hydraulic dredges–A review of potential impacts." Technical Note DOER-E1. U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/elpubs/pdf/doere1.pdf

SCAMIT, 2008. A Taxonomic Listing Of Macro - and Megainvertebrates from Infaunal and Epifaunal Monitoring and Research Programs in the Southern California Bight. Prepared by The Southern California Association of Marine Invertebrate Taxonomists Donald B. Cadien and Lawrence L. Lovell, editors.

SWCA Environmental Consultants, 2007. Stockton and Sacramento deepwater ship channel maintenance dredging project 2006 fish community and entrainment monitoring report. Report to U.S. Army Corps of Engineers, Sacramento District. Submitted to IEP/CDFG and USACE July 31, 2007. SWCA, Portland.

SWCA Environmental Consultants, 2008. Stockton and Sacramento deepwater ship channel maintenance dredging project 2007 fish community and entrainment monitoring report. Report to U.S. Army Corps of Engineers, Sacramento District. Submitted March 2008. SWCA, Portland.

SWCA Environmental Consultants, 2009. Stockton and Sacramento deepwater ship channel maintenance dredging project 2008 fish community and entrainment monitoring report. Report to U.S. Army Corps of Engineers, Sacramento District. Submitted March 2008. SWCA, Portland.

USACE, 2011 Scope of Work (SOW) For 201l Longfin Smelt Monitoring During Dredging by the USACE Hopper Dredge *Essayons* In the San Francisco Bay Area. June 2011. U.S. Army Corps of Engineers San Francisco District Planning Branch Environmental Section B.

Wang, J.C.S., 2007. Spawning, early life stages, and early life histories of the Osmerids found in the Sacramento-San Joaquin Delta of California. Tracy Fish Collection Facility Studies. Volume 38. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service.

9. Appendix A – Description of Worksheets Containing Detailed Monitoring Data

Screen Page

This page provides the basic details of the monitoring of each hopper load, water calibration, and hopper flush. It provides the timing and volume of material that was monitored as well as the timing and volume of material for each hopper load. Beginning and ending locations for each hopper load were provided by the ship. The timing of the monitoring was documented by the biologists,[4] and the timing for each hopper load was provided by the ship. The amount of material dredged and monitored during each hopper load is provided by multiplying the duration of these events by the established pumping rates. It provides a description of the dredged material and the water temperature and salinity determined while monitoring. Notes are provided to indicate fish presence during individual hopper loads, and to provide other cogent information. The alternating white and grey bands provide a visual key to differentiate hopper loads. Yellow and light blue highlighting indicates hopper loads during which longfin smelt or delta smelt were present. Medium blue highlighting in the gear status/notes section indicate hopper loads where either the load or flush monitoring did not take place due to communication issues with the ship.

Fish Data Page

This page provides the species and sizes of fish encountered. The white and grey bands again provide a visual key to differentiate between hopper loads, and the light yellow and blue highlighting indicates longfin smelt and delta smelt. Image references are provided and the method of observation is stated. Notes provide other cogent information. The referenced images are provided on a separate computer disk.

Invert Data Page

This page provides details of the invertebrates encountered during monitoring. White and grey bands are used in the same manner as previously. Images of some invertebrates are referenced and the images are provided on a separate computer disk.

Fish Species List Page

This page provides the scientific and common names of all species of fish that were encountered, and provides a description of each species as either native or introduced. It also describes each species as either demersal or not. This description is a general one, and for some species does not really fit very well. For instance, longfin smelt are generally considered to be non-demersal, though at times they do utilize demersal habitats (Moyle, 2002).

[4] Recorded as the mid-point between the gate valve being actuated and fully opening or closing, an interval that takes approximately ten seconds to complete.

Invert Species List Page

This page provides the scientific names of all invertebrates that were identified, and also provides the common names when available. The type of invertebrate is provided, as is its origin (native or introduced).

Dredging and Monitoring Images Page

This page provides a reference to and a description of images of dredging and monitoring provided on a separate CD-ROM.