Appendix I. Fish Survey Report

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Appendix I

Sears Point Restoration Project Fisheries Monitoring

Results of ARIS Camera and Traditional Sampling Surveys

February 2018 | DUI-01

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Appendix I

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EXECUTIVE SUMMARY

The Sears Point Wetland Restoration Project (Project) is one of the largest tidal marsh restoration projects along the Pacific Coast and has resulted in a 1,000-acre tidal marsh basin that, until recently, was diked off from San Francisco Bay (Bay) for over 140 years. Project partners (Sonoma Land Trust, National Oceanic and Atmospheric Administration [NOAA], National Marine Fisheries Service [NMFS], United States Fish and Wildlife Service [USFWS], and Ducks Unlimited [DU]) incorporated several novel design features (e.g., marsh mounds, sidecast ridges, rootwads, flooded remnant terrestrial vegetation) to decrease restoration time (via sediment accretion) and provide habitat complexity for a broad range of wetland organisms. The Project partners also incorporated a strong scientific basis into the design and restoration of the Project, emphasizing monitoring to evaluate restoration success and address uncertainties. This document describes results of fish monitoring activities conducted in 2017 with the overall goal of determining the relative abundance, habitat use, and species assemblage of the fish community in the recently restored subtidal habitat. To address this goal, several objectives were identified, which included:

- Use ARIS technology to determine relative abundance of fish in various subtidal habitats throughout the Project;
- Use traditional fish sampling methods to identify and describe fish species present and their relative abundance for comparison to ARIS results; and
- Interpret fish survey data from the current Project and compare with other restored wetland habitat restoration projects in the Bay.

Dual methodology sampling was conducted using an Adaptive Resolution Imaging Sonar (ARIS) camera as well as traditional sampling (seine and trawl) methods in the spring (May) and fall (October) of 2017. Sampling was designed to encompass five subtidal habitat types: sidecast ridge, marsh mound, levee transition slope, flooded remnant terrestrial vegetation, and rootwads. Monitoring consisted of both stationary (nine sites) and transect survey (eight transects) methods; each site and transect consisted of sampling initially with the ARIS, immediately followed by the deployment of traditional sampling gear (i.e., beach seine or otter trawl). In both cases, the ARIS continued to operate throughout the traditional sampling efforts to characterize fish avoidance behavior and relative capture efficiency. Water quality measurements were recorded at each sampling location and included water temperature, dissolved oxygen, salinity, pH, and turbidity.

During ARIS monitoring, a total of 14,358 fish was observed over the course of two sampling events at the Project. Substantially higher fish abundance was observed in fall (n = 12,766) compared to spring (n = 1,592). Over both sampling events, more fish were observed during stationary surveys (n = 10,062) than during transect surveys (n = 4,296), which was in part due to the longer duration of stationary surveys. However, despite the longer duration, more fish were observed per minute during stationary surveys (14.0 fish per minute) than during transect surveys (9.0 fish per minute).

A total of 1,568 fish (18 fish species) was collected by beach seine and otter trawl over the course of two seasonal sampling events; more fish were collected during beach seine surveys (n = 1,342) than during otter trawl surveys (n = 226). Three crustacean species were also collected (n = 2,831). Fish were more abundant during the fall sampling event (n = 977) compared to the spring sampling event (n = 591). While the beach seine catch in fall (n = 901) was nearly double the spring catch (n = 441), the otter trawl catch in fall (n = 76) was about half that of the spring catch (n = 150).

Eighteen fish species and three crustacean species were collected during the beach seine and otter trawl monitoring program. The fish community in spring was dominated by native Bay Goby, Starry Flounder, Topsmelt, and Pacific Staghorn Sculpin. Non-native gobies (Chameleon, Shimofuri, Shokihaze, and Yellowfin) and Striped Bass were also abundant. In fall, the native Topsmelt and Pacific Herring accounted for about 88 percent of the entire fish catch. Striped Bass was the most abundant non-native fish, followed by Chameleon and Yellowfin gobies. Two additional fish species, White Sturgeon (Green Sturgeon not likely) and Bat Ray, were visually observed by field crews but were never collected. Native fish species were most abundant in the beach seine catch (89.1 percent and 95.2 percent of all individuals in the spring and fall, respectively) as compared with the otter trawl catch, with only 31.3 percent and 39.5 percent of all individuals in the spring and fall, respectively. The differences depended upon the habitat where the species were observed (shallow, channel margin habitat vs. deep water habitat).

The results of this study indicate that the Project is already providing valuable aquatic habitat for a variety of native and non-native species. Fish were observed using multiple sampling gear types in a variety of different habitats throughout the Project area. Substantially higher fish abundance was observed during the fall sampling event compared to the spring sampling event for both ARIS and traditional sampling methods.

Sidecast ridges and levee transition slope sites appeared to provide the best habitat for fish as observed by both the ARIS and traditional sampling gear. Overall, fish presence at all habitat types during early phases of habitat restoration signifies the benefits of habitat complexity. This is consistent with findings at other restored areas in the Bay such as the Tolay Creek Restoration Project and the Napa Plant Site Restoration Project.

As the Project area continues the trajectory of accumulating sediments, more plants, invertebrates and other aquatic organisms will begin to occupy the Project area and complex habitats will mature, all of which will provide improved conditions for the fish community. It is expected that nursery habitats (i.e., juvenile rearing) will continue to improve for fishes such as Starry Flounder, California Halibut, Pacific Herring, gobies, Topsmelt, and crangonid shrimp, all species that depend upon this currently limited habitat for increased production. Many of these species, such as Topsmelt, gobies, and crangonid shrimp, provide important forage for larger, mobile fishes such as Striped Bass, Green Sturgeon, White Sturgeon, and Chinook Salmon which will likely increase utilization of the Project in years to come.

The dual sampling methodology described in this document is a novel approach to sampling in the San Francisco Bay and Delta. This methodology allowed for an in-depth examination of the fish fauna throughout the variety of subtidal habitats. For example, greater abundance of fish (especially larger individuals) was observed with the ARIS camera than with traditional sampling techniques, which is at least partially illustrative of the differences in capture (or detection) efficiency between the two sampling methods. Additionally, the ARIS was able to detect species in habitats (i.e., flooded remnant vegetation) that was difficult to sample with traditional sampling gear. Conversely, the traditional sampling gear was more effective in collecting data on smaller fish species that were much more abundant in shallow water and channel margin habitat. Furthermore, traditional sampling was necessary for identifying species and examining native vs non-native species assemblages.

1.0 INTRODUCTION

There has been a dramatic reduction in tidal wetlands around the San Francisco Bay (hereafter, the Bay) since the late 1800's. More than 85 percent of historical tidal wetlands in the bay have been lost due to extensive diking to 'reclaim' the land for farming, ranching, and urbanization. Over the last few decades, efforts have been made to restore some of these areas to increase biodiversity and reestablish important ecosystem functions of bay wetlands. The Sears Point Wetland Restoration Project (hereafter, the Project) is one of the largest tidal marsh restoration projects along the Pacific Coast and has resulted in a 1,000-acre tidal marsh basin that, until recently, was diked off from the Bay for over 140 years. The newly restored estuarine habitat (breached in October 2015), offers several significant benefits to the Bay ecosystem including the creation of critical habitats for endangered and native fish species.

Recent restoration projects have focused on the importance of habitat complexity in restored tidal wetlands. The Project is a good example of this approach as Project partners (Sonoma Land Trust, National Oceanic and Atmospheric Administration [NOAA], National Marine Fisheries Service [NMFS], United States Fish and Wildlife Service [USFWS], and Ducks Unlimited [DU], incorporated several novel design features (e.g., marsh mounds, sidecast ridges, rootwads, flooded remnant terrestrial vegetation) to decrease restoration time (via sediment accretion) and provide various habitats for a broad range of wetland organisms. Additionally, a focus on incorporating a topographic gradient into the design will facilitate the establishment of a variety of plant species. Together, these design features will allow for suspended sediment to be continually deposited by tidal action, eventually leading to the development of shallow marsh habitat mosaic with a diverse plant community and a highly complex network of tidal channels. Fully restored tidal marshes provide a variety of habitats for a diverse and abundant fish community including several threatened, endangered and native fish species.

The Project partners have also made a concerted effort to incorporate a strong scientific basis into the design and restoration of the Project, emphasizing monitoring to evaluate restoration success and address uncertainties. As such, fish monitoring was conducted to determine the relative abundance and habitat use of fish in the recently restored habitats. Although this measure of relative abundance does not provide an estimate of exactly how many fish are in the Project area, it does give an indication of the relative diversity and number of fish in different habitats and locations within the Project area and can also be compared to data from other monitoring efforts elsewhere in the Bay. Ultimately, these data will help to elucidate the effectiveness of Project methods and design features towards providing habitat for the Bay fish community.

Monitoring of fish resources (abundance and distribution) within restored subtidal habitat presents several challenges. Traditional fish sampling techniques are often difficult to perform in complex subtidal habitats with uneven substrate, and submerged aquatic and terrestrial vegetation or may have biases that make the results difficult to interpret. For example, seine net sampling can provide an assessment of the fish community and relative abundance, especially for epibenthic species (fish that reside on or just above the bottom sediments). However, sampling must be conducted near the shore and the net can be hard to deploy in places with uneven and complex substrate (i.e., rocks and debris) or dense vegetation. In addition, seine nets may not provide an accurate representation of pelagic (open-water) or migratory fish species that opportunistically utilize nearshore habitats for feeding, as this type of sampling better represents the littoral fish community (i.e., fish residing near the shore) and many large or fast-swimming species are not as vulnerable to capture. The otter trawl was selected for use in this study to sample the epibenthic fish community in deeper water habitat; however the trawl is easily avoided by strong-swimming fish species, like Striped Bass, and schooling/migratory species, like American Shad and Threadfin Shad, as well as juvenile salmonids. This is largely due to the relatively slow trawling speeds (typically 1.5 to 3 knots) necessary to keep the gear in contact with the benthos.

Recent advancements in technology provide alternative or complementary methods for studying fish populations in the form of hydro-acoustics. This tool has proven to be effective at monitoring abundance, distribution, and behavior of fish species at various spatial scales and offers several advantages compared to traditional sampling methods. Hydro-acoustics provide a continuous view of the water column, are less selective (i.e., able to sample a wide variety of species throughout several habitat types), have less impact on the environment, and allow for sampling to be conducted in areas where the effectiveness of standard tools may be limited. One of the most innovative and cutting-edge hydro-acoustic sampling methods available today is the Adaptive Resolution Imaging Sonar (ARIS) camera (Sound Metrics Inc.). Based on Dual-Frequency Identification Sonar (DIDSON) technology, the ARIS can produce near-video-quality imagery in high turbidity and zero-light conditions. Additionally, ARIS software allows the camera user to retrieve range and size information from the footage. However, as with any sampling method, there are limitations with this technology, such as the limited ability to detect species that are closely associated with the bottom (epibenthic species), as well as smaller fish. In addition, it is very difficult to identify fish to species with the ARIS, and therefore, inferences must be made based upon a variety of factors including body shape, movement patterns, behavior(s), and habitats in which the observation was made.

The use of the ARIS acoustic camera was combined with traditional sampling (seine and trawl) methods to monitor the fish community and improve the understanding of fish habitat use at the Project. Pairing technologies can be a simple and inexpensive way to overcome technological limitations and enhance fisheries sampling capabilities. In each case, the capabilities of the separate sampling techniques are greatly enhanced by the ability to verify findings with an additional method. Pairing an ARIS camera with traditional sampling gear allowed for a more accurate view of fisheries abundance at the restoration site as well as a more in-depth examination of the fish fauna in a variety of habitats. Additionally, operating the ARIS camera before and during traditional sampling events allowed for an examination of avoidance behavior around the nets. Pairing an ARIS camera with conventional sampling gear that is used extensively throughout the estuary and Delta may yield important information about detection rates of larger, more mobile fishes.

2.0 OBJECTIVES

The overall goal of this study was to estimate the relative abundance (overall and by habitat type) and understand the species assemblage of the fish community within newly restored subtidal habitat. To address this goal, several objectives were identified, which include:

- Use ARIS technology to determine relative abundance of fish in various subtidal habitats throughout the Project;
- Use traditional sampling methods to identify and describe fish species present and their relative abundance for comparison to ARIS results; and
- Interpret fish survey data from the current Project and compare with other restored wetland habitat restoration projects in the Bay.

3.0 METHODS

Dual-method sampling was conducted in the spring (May) and fall (October) of 2017. Each sampling event was conducted over a period of five days and consisted of both stationary (n = 18) and transect (n = 24) surveys that were designed to cover the various subtidal habitat types within the Project (see Project map in Appendix A). These habitat types included:

Sidecast ridges – Consisting of both constructed earthen 'comma-shaped' ridges and remnant pre-construction dredged material (spoils) piles (sometimes with remnant vegetation) from adjacent channel dredging actions, sidecast ridges were primarily included to provide high tide refuge for wildlife. Typically larger in size (roughly 6 feet wide with crest elevations above MHHW) and less abundant (a total of 12 were constructed) than marsh mounds, sidecast ridge haver inner channel bank slopes graded at 5:1 and outer slopes at 7:1, resulting in low to moderate relief mudflats extending from the base of these structures to adjacent channels.

- Stationary monitoring sites – S1, S2, S3
- Transect monitoring sites – T1, T2

Marsh mounds – Approximately 500 non-engineered earthen mounds were constructed throughout the Project to dissipate wave energy, create dispersal loci for establishing vegetation, and accelerate sedimentation. Marsh mounds were typically 10-foot in diameter at their base and graded at 5:1 side slopes, with crest elevations at or below MHHW. Low to moderate relief mudflats surround these structures.

- Stationary monitoring sites – S4, S5
- Transect monitoring sites – T5, T8

Levee transition slope - A variable, gently sloped levee (slopes graded to 10:1) was constructed in various Project locations, and in particular for protection against breaching to Tolay Creek. The resulting low relief mudflats adjacent to these levees extended directly to dredged channels and afforded excellent seining opportunities with no debris or submerged vegetation.

- Stationary monitoring sites – S8, S9
- Transect monitoring sites – N/A

Flooded remnant terrestrial vegetation – This portion of the Project area was previously vegetated by terrestrial shrubs (primarily coyote brush) prior to breaching. The vegetation was not disturbed during restoration and remains in place. In comparison, the rest of the Project area was graded and de-vegetated.

- Stationary monitoring sites – S6, S7
- Transect monitoring sites – T6, T7

Rootwads – Eucalyptus trees in the Project area were cut down, and their rootwads were weathered over 2 years prior to being keyed into various channel margins to provide fish cover (see Appendix A).

- Stationary monitoring sites – N/A
- Transect monitoring sites – T3, T4

Sampling at both stationary and transect surveys consisted of sampling first with the ARIS (Model 1800, 0.7 – 35-meter range), immediately followed by the deployment of traditional sampling gear (i.e., beach seine and otter trawl). In both cases, the ARIS continued to operate throughout the traditional sampling efforts to characterize fish avoidance behavior and relative capture efficiency. Water quality measurements were collected at each site prior to sampling.

3.1 STATIONARY SURVEYS

Nine stationary sampling locations (sites) were chosen to represent the key subtidal habitat types found at the Project (Appendix A). Habitat types that were examined with stationary surveys included sidecast ridges, marsh mounds, flooded remnant vegetation, and levee transition slopes. During stationary surveys, the ARIS was deployed for a set amount of time at each site (20 minutes) and focused to capture any important habitat features (i.e., rootwads or flooded remnant vegetation). Immediately following the ARIS survey, the site was sampled with a beach seine (75 ft. in length and 8 ft. in height with ¼ inch stretched mesh delta weave, equipped with float line and lead line with 25 ft. hauling lines) that was deployed parallel to the shoreline at approximately 25 ft. and then hauled to shore by land-based personnel (see photos in Appendix G). The ARIS continued to operate throughout the duration of the seine sampling, and when possible, the ARIS was focused on the open end of the seine net. The use of the ARIS camera throughout the seining effort allowed for a better understanding of the efficiency of the seining effort and behavioral avoidance and helped to inform fish identification from ARIS images of captured species. All fish captured in the beach seine were identified to species, enumerated, and up to 30 individuals of each species were measured. If less than 30 individuals of a particular species were collected, then all individuals of that species were measured. Stationary surveys were replicated twice at each site between May 7-8, 2017 and between October 3-4, 2017. All sites were sampled consecutively to facilitate comparisons of the fish community between habitat types. Due to the time needed for sampling, habitats were sampled during different tide stages within the same day, although wherever possible, sampling was begun during flood tide and extended through high slack tide.

3.2 TRANSECT SURVEYS

Eight transects of approximately 500 meters in length were chosen to represent the key Project habitat types (see Appendix A). Habitat types that were sampled during transect surveys included sidecast ridges, marsh mounds, rootwads, and flooded remnant vegetation. During transect surveys, the ARIS was deployed for a set amount of time (10 minutes) along a fixed transect. Immediately following the ARIS survey, the same transect was subsampled with a 12 ft. (mouth width) otter trawl (5 minutes bottom time), equipped with side doors and bottom chain, and a ¼ inch stretch mesh Delta Weave cod end. Both ARIS and otter trawls were conducted on the channel side of sidecast ridges and marsh mounds to ensure adequate water depths for sampling. During the otter trawl, the ARIS was focused on the opening of the net to characterize capture efficiency and avoidance behavior around the net. The use of the ARIS camera throughout the otter trawl allowed for a better understanding of the efficiency of the trawl and behavioral avoidance and helped to inform fish ID from ARIS images of captured species. All fish captured in the trawl were identified to species, enumerated, and up to 30 individuals of each species were measured. If less than 30 individuals of a particular species were collected, then all individuals of that species were measured. Trawl surveys were sampled in triplicate between May 9-11, 2017 and between October 1-6, 2017. All eight transects were sampled consecutively to facilitate comparisons of the fish community between habitat types, and where possible, during the period of flood tide through high slack tide.

3.3 WATER QUALITY

Water quality measurements were recorded at each sampling location, immediately prior to fish sampling activities, using a YSI Pro Plus© multi-parameter water quality meter. Parameters measured included water temperature, dissolved oxygen, salinity, pH, and turbidity. Water quality measurements were collected just below the water surface in the general area of each otter trawl and beach seine sampling location.

3.4 SAMPLE PROCESSING IN THE FIELD

All fish and crustaceans collected from each trawl and seine sample were identified, counted and measured (mm). Although carapace length is the typical length measurement for crustaceans, total length (rostrum to telson) was collected because of the objective to compare results with the organism length measurement as determined by the ARIS. If a sample contained over 30 individuals of a single species, length measurements (to the nearest millimeter) were collected from a representative subsample of 30 individuals. Photos were taken of most fish species. After processing, fish and crustaceans were released near the site of capture.

3.5 SAMPLE PROCESSING OF ARIS FOOTAGE

All ARIS footage was organized by date, survey type, and location. ARIS video files were reviewed in their entirety and all fish observed from the footage were manually counted and measured using built-in measuring features on the ARIS software. The time of each fish observation was recorded and any interesting behavior(s) was noted. At two of the sites, small fish (i.e., <10 cm) were too numerous to manually count each fish. The abundance of small fish at these sites was determined by reviewing two randomly selected one-minute subsets of the footage and extrapolating these numbers to the entire 20 minutes. This sample footage was still viewed in its entirety to enumerate all large fish (i.e., >10 cm).

3.6 DATA ANALYSIS AND SUMMARY

The data from each sampling event were compiled based on habitat type to provide a relative abundance of fish in each habitat type during each sampling event. Detection and observation rates were not accounted for, and therefore, all abundance data presented herein, should be considered an index of abundance and not a measure of absolute abundance in the Project area. Data were also presented as an average for each survey, due to the replicate sampling that occurred during both the spring and fall. The number of fish observations per minute (fish per minute) was produced by dividing the total number of fish observations during a given number of surveys, by the total survey time.

4.0 WATER QUALITY RESULTS

In general, water quality parameters during the spring and fall were typical of San Francisco Bay estuarine conditions with high Delta outflow (spring) and moderate Delta outflow (fall) prior to the onset of winter storm events. Temperature, salinity, and turbidity measurements exhibited the most striking difference between the two seasons, and as would be expected in the estuary, water temperatures in fall were somewhat cooler, salinities were substantially greater, and turbidity was moderately reduced from those in spring. Average water temperatures from all seine and otter trawl sampling locations in spring were 18.3 ºC and 19.8 ºC, respectively, while average salinities were 7.5 and 8.7 parts per thousand (ppt). Average water temperatures from all seine and otter trawl sampling locations in fall were 16.8 ºC and 17.0 ºC, respectively, while average salinities were 19.9 and 21.8 ppt, respectively.

In spring, turbidity values averaged 51.3 and 60.6 Nephelometric Turbidity Units (NTUs) at seine and otter trawl locations, respectively. In fall, turbidity values were reduced from spring values, averaging 17.6 NTUs and 23.5 NTUs at seine and otter trawl locations, respectively.

Average dissolved oxygen concentrations from all seine and otter trawl sampling locations in spring were 8.86 parts per million (ppm) and 8.42 ppm, respectively, while average pH values were 7.81 and 7.77. Dissolved oxygen concentrations from all seine and otter trawl sampling locations in fall were somewhat reduced from spring values (7.48 and 7.55 ppm, respectively), while average pH values were slightly increased over those in spring (7.90 and 7.97, respectively).

All water quality measurements recorded during both May and October 2017 sampling events are presented in Appendix B.

5.0 ARIS SURVEY RESULTS

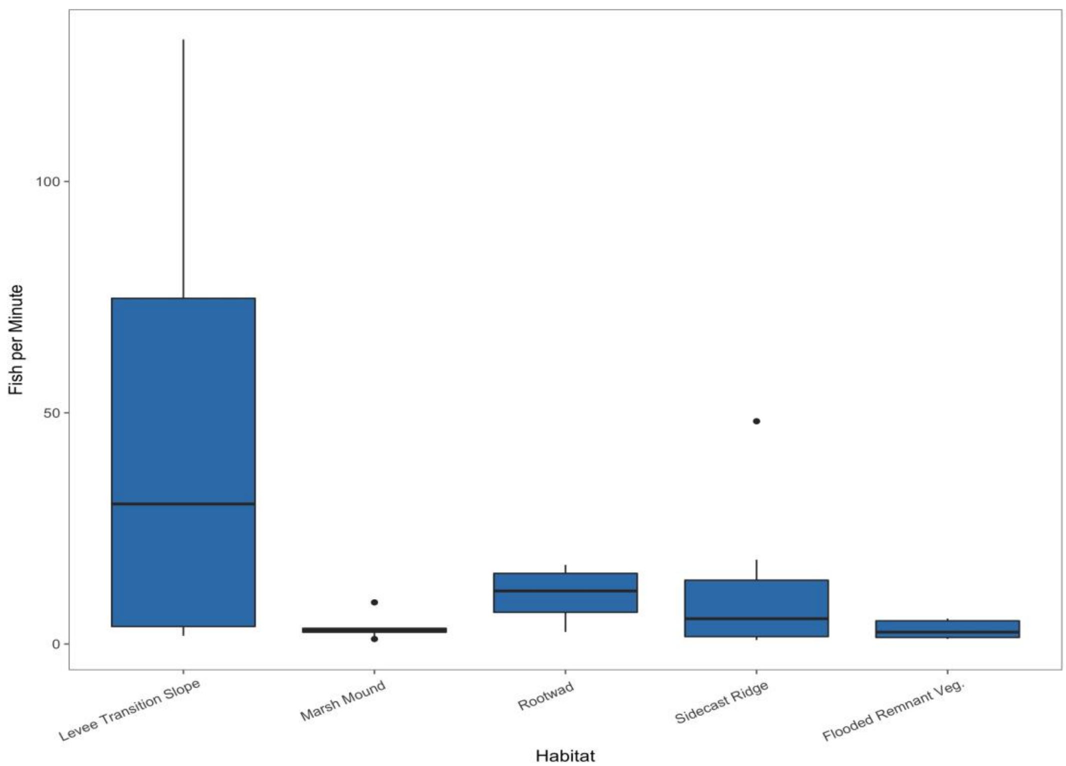
This section (Section 5.0 and all subsections) reports solely on the results of ARIS surveys. During ARIS monitoring, a total of 14,358 fish was observed over the course of two sampling events at the Project. Substantially higher fish abundance was observed during the fall sampling event (n = 12,766) compared to the spring sampling event (n = 1,592). Over both sampling events, more fish were observed during stationary surveys (n = 10,062) than during transect surveys (n = 4,296), which was in part due to the longer duration of stationary surveys. However, despite the longer duration, more fish were observed per minute during stationary surveys (14.0 fish per minute) than during transect surveys (9.0 fish per minute; Appendix C; Figure C-9).

Throughout both surveys, the majority of fish were observed at levee transition slopes, followed by sidecast ridges, marsh mounds, rootwads, and flooded remnant vegetation. In terms of the average abundance per survey and the number of fish observed per minute, most fish were observed at levee transition slopes, followed by rootwads, sidecast ridges, marsh mounds, and flooded remnant vegetation (Table 1; see Appendix A).

Table 1.
FISH ABUNDANCE BY HABITAT TYPE OBSERVED DURING ARIS SURVEYS AT THE SEARS POINT RESTORATION PROJECT DURING MAY 7-11 AND OCTOBER 1-6, 2017

Habitat Type	Spring Total	Spring Avg. per Survey	Fall Total	Fall Avg. per Survey	Total	Avg. per Survey
Sidecast Ridge	458	38.2	3,173	264.4	3,631	151.3
Marsh Mound	301	30.1	604	60.4	905	45.3
Levee Transition Slope	249	62.3	7,473	1868.3	7,647	965.3
Flooded Remnant Vegetation	258	25.8	563	56.3	821	41.1
Rootwad	326	54.3	953	158.8	1,279	213.2
TOTAL	**1,592**	**37.9**	**12,766**	**304.0**	**14,358**	**170.9**

Figure 1[1]
FISH OBSERVATIONS PER MINUTE OBSERVED WITH THE ARIS DURING BOTH SURVEY METHODS AT THE SEARS POINT RESTORATION PROJECT



[1] The blue box represents the 25th and 75th percentile of observations and the solid black line represents the mean number of observations in each habitat type. Error bars represent the 95th percentile.

Fish sizes ranged from a minimum of 5 cm to a maximum of 130 cm over both sampling events. The average fish size was higher during transect surveys (avg. = 17.0 cm) than during stationary surveys (avg. = 14.9 cm). Although many more large fish (i.e., ≥60 cm) were observed during fall sampling than during spring sampling, the average fish size decreased from the spring (avg. = 21.6 cm; median = 21) to the fall (avg. = 14.8 cm; median = 15 cm). During spring sampling, only one fish was observed that was 60 cm or greater, however, 127 fish that were 60 cm or greater were observed during fall sampling. Fish sizes varied only slightly by habitat type, with the largest fish observed near marsh mounds, followed by sidecast ridges, flooded remnant vegetation, levee transition slopes, and rootwads (Table 2). Length frequencies of all observed fish are presented in Appendix C.

Table 2
FISH SIZE (TOTAL LENGTH IN CM) BY HABITAT TYPE OBSERVED DURING ALL ARIS SURVEYS AT THE SEARS POINT RESTORATION PROJECT

Habitat Type	Spring		Fall		Overall	
	Average	Median	Average	Median	Average	Median
Sidecast Ridge	22.0	21	18.7	15	19.1	15
Marsh Mound	22.9	22	20.9	15	21.6	20
Levee Transition Slope	21.0	20	12.4	10	12.7	10
Flooded Remnant Vegetation	21.3	20	17.6	15	18.7	15
Rootwad	20.6	19	14.6	10	16.2	10
Overall	21.6	21	14.8	10	15.5	15

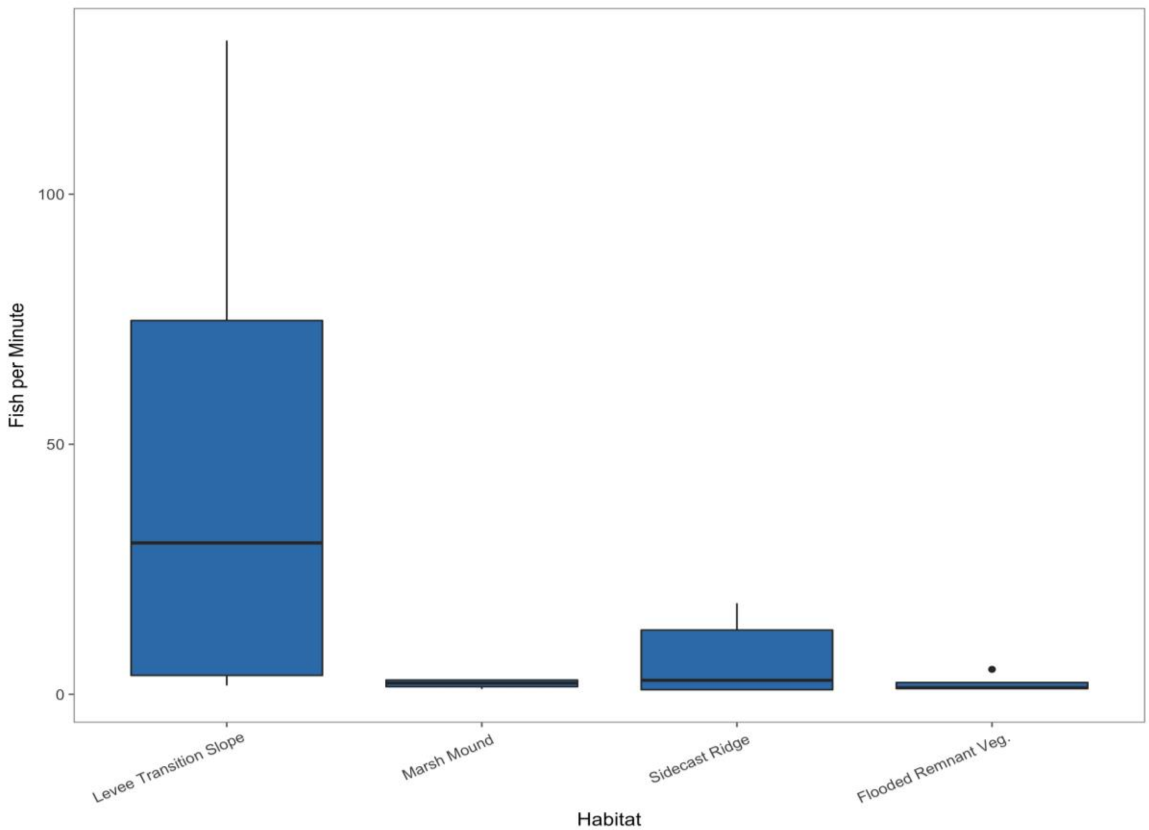
5.1 STATIONARY SURVEYS

A total of 10,062 fish was observed with the ARIS camera during both stationary sampling events; with 574 fish observed during the spring sampling event and 9,488 fish observed during the fall sampling event (Table 3). Approximately 77 percent of all fish were observed at levee transition slopes, followed by sidecast ridges (16%), flooded remnant vegetation (4%), and marsh mounds (3%). Fish abundance by habitat type was relatively similar during the spring and the fall, with most fish observed at levee transition slopes during both surveys. However, a greater proportion of fish were observed at sidecast ridges during the fall than during the spring (Table 3).

Table 3
FISH ABUNDANCE BY HABITAT TYPE OBSERVED DURING ARIS STATIONARY SURVEYS AT THE SEARS POINT RESTORATION PROJECT

Habitat Type	Spring Total	Spring Average	Fall Total	Fall Average	Total	Average
Sidecast Ridge	111	18.5	1,537	256.2	1,648	137.3
Marsh Mound	110	27.5	232	58	342	42.8
Levee Transition Slope	249	62.3	7,473	1,868.3	7,722	965.3
Flooded Remnant Vegetation	104	26	246	61.5	350	43.8
TOTAL	**574**	**31.9**	**9,488**	**522.9**	**10,062**	**279.5**

Figure 2[1]
FISH OBSERVATIONS PER MINUTE OBSERVED WITH THE ARIS DURING STATIONARY SURVEYS AT THE SEARS POINT RESTORATION PROJECT



[1] The blue box represents the 25th and 75th percentile of observations and the solid black line represents the mean number of observations in each habitat type. Error bars represent the 95th percentile.

5.1.1 Fish Size

Fish sizes ranged from a minimum of 8 cm to a maximum of 114 cm over both sampling events, with an average size of 14.9 cm. The average fish size decreased from the spring (avg. = 22.7 cm; median = 22 cm) to the fall (avg. = 14.4 cm; median = 12 cm); however, many more large fish (i.e., ≥60 cm) were observed during fall sampling (n = 79) than during spring sampling (n = 1). During spring sampling, fish sizes varied only slightly by habitat type; however, fish sizes during fall sampling varied substantially between habitat types, with the largest fish observed near marsh mounds, followed by sidecast ridges, flooded remnant vegetation, and levee transition slope (Table 4).

Table 4
FISH SIZE (TOTAL LENGTH IN CM) BY HABITAT TYPE OBSERVED DURING ARIS STATIONARY SURVEYS AT THE SEARS POINT RESTORATION PROJECT

Habitat Type	Spring		Fall		Overall	
	Average	Median	Average	Median	Average	Median
Sidecast Ridge	24.5	24	22.1	17	22.3	18
Marsh Mound	24.3	24	28.1	20	26.8	22
Levee Transition Slope	21.0	20	12.4	10	12.7	10
Flooded Remnant Vegetation	23.3	22	15.5	14	17.8	15
Overall	22.7	22	14.4	12	14.9	15

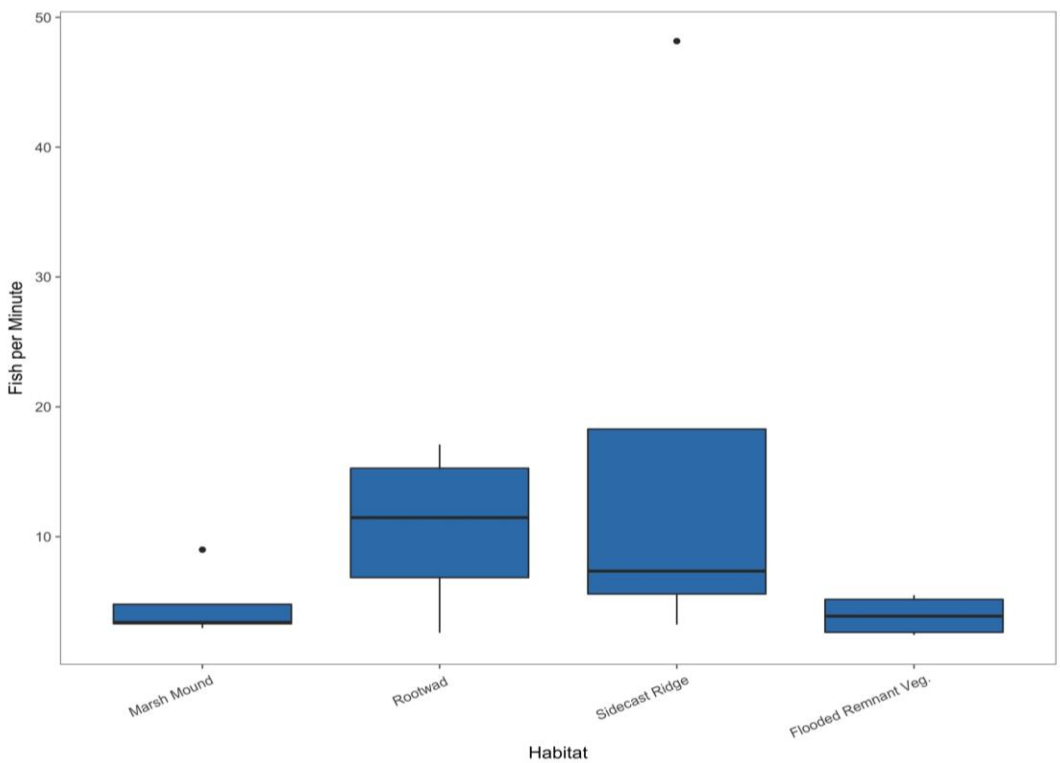
5.2 TRANSECT SURVEYS

A total of 4,296 fish was observed with the ARIS camera during both transect sampling events; with 1,018 fish observed during the spring sampling event and 3,278 fish observed during the fall sampling event (Table 5). Most fish were observed at sidecast ridges (46% of all observations), followed by rootwads (30%), marsh mounds (13%), and flooded remnant vegetation (11%). Fish abundance by habitat type was similar in the spring and the fall, although proportionally, many more fish were observed at sidecast ridges during the fall (Table 5).

Table 5.
FISH ABUNDANCE BY HABITAT TYPE OBSERVED DURING ARIS TRANSECT SURVEYS AT THE SEARS POINT RESTORATION PROJECT

Habitat Type	Spring Total	Spring Average	Fall Total	Fall Average	Total	Average
Sidecast Ridge	347	86.8	1,636	409	1,983	247.9
Marsh Mound	191	47.8	372	93	563	70.4
Rootwad	326	81.5	953	238.3	1,279	159.9
Flooded Remnant Vegetation	154	38.5	317	79.3	471	58.9
TOTAL	**1,018**	**63.6**	**3,278**	**204.9**	**4,296**	**134.3**

Figure 3[1]
FISH OBSERVATIONS PER MINUTE OBSERVED WITH THE ARIS DURING TRANSECT SURVEYS AT THE SEARS POINT RESTORATION PROJECT DURING MAY 9-10 AND OCTOBER 5-6, 2017



[1] The blue box represents the 25th and 75th percentile of observations and the solid black line represents the mean number of observations in each habitat type. Error bars represent the 95th percentile of the data.

5.2.1 Fish Size

Fish sizes as determined by ARIS ranged from a minimum of 8 cm to a maximum of 130 cm over both sampling events with an average size of 17.0 cm. The average fish size decreased from the spring (avg. = 21.0 cm; median = 20 cm) to the fall (avg. = 15.7 cm; median = 10 cm); however, all the large fish (i.e., ≥60 cm) were observed during fall sampling (n = 48). During spring sampling, fish sizes varied only slightly by habitat type, ranging between 22.1 and 19.9 cm. During fall sampling, fish sizes were more variable among habitat types, with the largest fish observed near flooded remnant vegetation, followed by marsh mounds, sidecast ridges, and rootwads (Table 6).

Table 6
FISH SIZE (BY HABITAT TYPE OBSERVED DURING ARIS TRANSECT SURVEYS AT THE SEARS POINT RESTORATION PROJECT DURING MAY 9-10 AND OCTOBER 5-6, 2017

Habitat Type	Spring		Fall		Overall	
	Average	Median	Average	Median	Average	Median
Sidecast Ridge	21.2	20	15.5	15	16.5	15
Marsh Mound	22.1	21	16.5	15	18.4	17
Flooded Remnant Vegetation	19.9	20	19.2	15	19.4	17
Rootwad	20.6	19	14.6	10	16.2	10
Overall	21.0	20	15.7	10	17.0	15

6.0 TRADITIONAL SAMPLING SURVEY RESULTS

This section (Section 6.0 and all subsections) reports solely on the results of traditional sampling (net) surveys. A total of 1,568 fish was collected by beach seine and otter trawl over the course of two seasonal sampling events at the Project. Eighteen fish species and three crustacean species were collected during the beach seine and otter trawl monitoring program (Table 7). Two additional fish species, White Sturgeon (Green Sturgeon not likely) and Bat Ray, were observed by field crews but were never collected. These observations are not included in any fish counts but are listed in Table 7. Fish were more abundant during the fall sampling event (n = 977) compared to the spring sampling event (n = 591). While the beach seine fall catch (n = 901) was nearly double the spring catch (n = 441), the otter trawl fall catch (n = 76) was nearly half that of the spring catch (n = 150). Over both sampling events, more fish were collected during beach seine surveys (n = 1,342) than during otter trawl surveys (n = 226).

Table 7
FISH AND CRUSTACEAN SPECIES COLLECTED BY BEACH SEINE AND OTTER TRAWL SURVEYS FOR SEARS POINT RESTORATION PROJECT FISHERIES MONITORING[1]

Species		Total Spring Catch		Total Fall Catch	
Common Name	**Scientific Name**	**Seine**	**Trawl**	**Seine**	**Trawl**
Bay Goby	*Lepidogobius lepidus*	211	25	1	9
Chameleon Goby	*Tridentiger trigonocephalus*	25	1	2	15
Shimofuri Goby	*Tridentiger bifasciatus*	3	59	0	1
Shokihaze Goby	*Tridentiger barbatus*	0	16	0	1
Yellowfin Goby	*Acanthogobius flavimanus*	12	7	11	13
Pacific Staghorn Sculpin	*Leptocottus armatus*	34	6	0	0
Striped Bass	*Morone saxatilis*	5	20	13	15
Topsmelt	*Atherinops affinis*	68	0	688	0
Shiner Surfperch	*Cymatogaster aggregata*	1	0	0	0
Silver Surfperch	*Hyperprosopon ellipticum*	0	1	0	0
Northern Anchovy	*Engraulis mordax*	0	0	0	1
Pacific Herring	*Clupea pallasi*	0	2	127	14
American Shad	*Alosa sapidissima*	3	0	0	0
Threadfin Shad	*Dorosoma petenense*	0	0	16	0
Starry Flounder	*Platichthys stellatus*	63	9	13	3
California Halibut	*Paralichthys californicus*	2	1	0	4
Sacramento Splittail	*Pogonichthys macrolepidotus*	9	2	0	0
Threespine Stickleback	*Gasterosteus aculeatus*	5	1	0	0
Palaemon Shrimp	*Palaemon macrodactylus*	63	628	4	16
Crangon Shrimp	*Crangon spp.*	5	0	35	2,069
Hemigrapsus Crab	*Hemigrapsus oregonensis*	3	6	0	2
Sturgeon (white or green)[2]	*Acipenser spp.*	0	0	0	0
Bat ray[2]	*Myliobatis californica*	0	0	0	0

[1] The authors of this report follow the guidelines published by the American Fisheries Society (2013) in its most recent edition of *Common and Scientific Names of Fishes from the United States, Canada, and Mexico, 7th Edition* (Special Publication 34), in particular, the capitalization of all portions of the common names of fish species.

[2] Sturgeon and Bat Ray were often observed in the Project area by the field crews but neither species were ever collected or observed with either ARIS or traditional sampling methods.

Throughout both surveys, fish abundance was greatest at sidecast ridge and levee transition slope sites, followed by marsh mounds and rootwads (channel edge habitat). Density of fish appeared to be lower at flooded remnant vegetation sites, at least partially a function of sampling difficulty pulling gear through and within vegetation.

6.1 STATIONARY SURVEYS (BEACH SEINE)

A total of 1,312 fish was collected by beach seine during both sampling events; with 441 fish collected during the spring sampling event and 871 fish collected during the fall sampling event. Total catch and average number of fish collected by seine haul are presented by habitat and by season in Table 8. In spring, fish were most abundant at sidecast ridge sites followed by levee transition slope and marsh mound sites, and in fall, fish were most abundant at levee transition slope sites, followed by sidecast ridge sites. Fish abundance at marsh mound sites was seasonally variable and lowest at flooded remnant vegetation sites.

Table 8
FISH ABUNDANCE BY HABITAT TYPE COLLECTED BY BEACH SEINE SURVEY AT THE SEARS POINT RESTORATION PROJECT

Habitat Type	Spring Total	Spring Average	Fall Total	Fall Average	Total	Average
Sidecast Ridge	193	32.0	165	41.3	358	36.7
Marsh Mound	109	27.3	5	1.3	114	14.3
Levee Transition Slope	112	27.8	693	180.8	805	104.3
Flooded Remnant Vegetation	27	7.3	8	2.0	35	4.7
TOTAL	**441**	**24.5**	**871**	**56.3**	**1,312**	**40.4**

6.1.1 Fish Communities by Habitat Type

In spring, 13 fish species were collected by beach seine (See Table 7 and Appendix D; Table D-1). Over 90 percent of the fish catch (n = 441) consisted of Bay Goby (47.6%), Topsmelt (15.5%), Starry Flounder (15.5%), Pacific Staghorn Sculpin (7.7%) and Chameleon Goby (5.7%). Adult Sacramento Splittail accounted for 2.0% of the catch and two juvenile California Halibut were also collected. The Bay Goby was most abundant at sidecast ridge and marsh mound sites; Topsmelt was most abundant at levee transition slope and flooded remnant vegetation sites; Starry Flounder, Pacific Staghorn Sculpin, and Chameleon Goby were all most abundant at sidecast ridge sites. The non-native shrimp, *Palaemon macrodactylus.*, was relatively abundant (n = 63) at marsh mound and levee transition slope sites, while the native crangonid shrimp species group (potentially consisting of three species: *Crangon franciscorum, C. nigricauda, and C. nigromaculata*), was nearly absent from the catch. The reproductive season for C. *franciscorum*, likely the most abundant species of the species group, extends from December through June, with the first major cohort of juvenile shrimp often appearing in May or June in San Pablo Bay (*Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco estuary, California*; Interagency Ecological Program for the Sacramento-San Joaquin Estuary, 1999).

A total of 393 (89.1%) native fish (eight fish species) and 48 (10.9%) non-native fish (five fish species) were collected by beach seine in spring. Bay Goby accounted for over half (53.7%) of the native fish species abundance, followed by Topsmelt (17.3%), Starry Flounder (16.0%), Pacific Staghorn Sculpin (8.7%), Sacramento Splittail (2.3%), Threespine Stickleback (1.3%), California Halibut (0.5%), and Shiner Surfperch (0.3%). Chameleon Goby accounted for over half of the non-native fish species (53.7%), followed by Yellowfin Goby (25.0%), Striped Bass (10.4%), Shimofuri Goby (6.3%) and American Shad (6.3%).

In fall, eight fish species were collected by beach seine (see Table 7 and Appendix D; Table D-3). Nearly 80 percent of the fish catch (n = 871) consisted of Topsmelt, followed by Pacific Herring (14.1%), Threadfin Shad (1.7%), Striped Bass (1.4%), Starry Flounder (1.4%), and Yellowfin Goby (1.2%). Bay Goby and Chameleon Goby together accounted for less than one percent of the catch. Topsmelt and Pacific Herring were most abundant at levee transition slope sites and relatively abundant at sidecast ridge sites. In contrast to the spring survey results, the native crangonid shrimp species group (*Crangon spp.*), consisting of the 2017 cohort, was relatively abundant (n = 36) at sidecast ridge and marsh mound sites, while the non-native shrimp, *P. macrodactylus* was nearly absent.

In fall, 829 (95.2%) native fish (four fish species) and 42 (4.8%) non-native fish (four fish species) were collected by beach seine. Topsmelt dominated the native fish catch (83.0%), followed by Pacific Herring (15.3%), Starry Flounder (1.6%), and Bay Goby (0.1%). Threadfin Shad (38.1%), Striped Bass (31.0%), and Yellowfin Goby (26.2%) accounted for over 95 percent of the non-native fish species. Chameleon Goby accounted for 4.8 percent of the catch.

6.1.2 Length Frequency Analysis

Minimum and maximum length ranges of each species collected by beach seine and potentially vulnerable to being observed by the ARIS camera are presented in Table 9. Based on sizes of fishes observable by the ARIS camera, seven species collected by beach seine were likely observed by the ARIS in spring 2017, and six species were likely observed by the ARIS in fall 2017. All goby species were included as a group for this analysis. A full description of length frequencies for all species collected by beach seine in spring and fall 2017, are presented in Appendix E.

Table 9
FISH SPECIES AND THEIR LENGTH RANGES COLLECTED BY BEACH SEINE AT THE SEARS POINT RESTORATION PROJECT[1]

Fish species (beach seine catch) potentially observed by the ARIS (>7 cm length) in spring, 2017	Topsmelt	California Halibut	Pacific Staghorn Sculpin	Sacramento Splittail	American Shad	Gobies	Striped Bass
Minimum Length (cm)	5.5	20.0	3.5	6.0	13.0	3.5	10.0
Maximum Length (cm)	18.0	21.0	9.0	19.5	15.0	15.0	19.5
Fish species (beach seine catch) potentially observed by the ARIS (>5 cm length) in fall, 2017	**Topsmelt**	**Starry Flounder**	**Pacific Herring**	**Threadfin Shad**	**Gobies**	**Striped Bass**	
Minimum Length (cm)	5.5	6.5	6.5	8.0	3.0	9.5	
Maximum Length (cm)	16.0	10.5	9.5	13.0	14.5	53.0	

[1] Fish species that could be observed by the ARIS camera based on observable minimum size by season.

6.2 TRANSECT SURVEYS (OTTER TRAWL)

A total of 226 fish were collected by otter trawl survey during both sampling events; 150 fish were collected during the spring sampling event and 76 fish were collected during the fall sampling event. Total catch and average number of fish collected by trawl set are presented by habitat and by season in Table 10. Fish abundance was greatest at sidecast ridge and rootwad sites. Fish abundance was somewhat lower at marsh mound and flooded remnant vegetation sites.

Table 10.
FISH ABUNDANCE BY HABITAT TYPE COLLECTED BY OTTER TRAWL SURVEY AT THE SEARS POINT RESTORATION PROJECT

Habitat Type	Spring Total	Spring Average	Fall Total	Fall Average	Total	Average
Sidecast Ridge	55	9.2	28	4.7	83	6.3
Marsh Mound	29	4.3	9	1.5	38	3.5
Rootwad	43	6.6	22	3.7	65	5.3
Flooded Remnant Vegetation	23	3.8	17	2.8	40	3.4
TOTAL	**150**	**6.3**	**76**	**3.2**	**226**	**4.8**

6.2.1 Fish Communities by Habitat Type

In spring, 13 fish species were collected by otter trawl (See Table 7 and Appendix D, Table D-2). The fish catch (n = 150) was dominated by Shimofuri Goby (39.3%), followed by Bay Goby (16.7%), Striped Bass (13.3%), Shokihaze Goby (10.7%), and Starry Flounder (6.0%). Sacramento Splittail and California Halibut were collected in low abundance. The Shimofuri Goby was most abundant at sidecast ridge and rootwad sites; Bay Goby, Striped Bass, and Starry Flounder were present in similar abundance at all habitat types. The non-native shrimp, *P. macrodactylus*, dominated the catch (n = 557) over all habitat types, while the native shrimp species group (*Crangon spp*.) was absent from the otter trawl catch.

A total of 47 (31.3%) native fish (eight species) and 103 (68.7%) non-native fish (five species) were collected by otter trawl in spring. Bay Goby accounted for over half (53.2%) of the native fish species abundance, followed by Starry Flounder (19.1%), Pacific Staghorn Sculpin (12.8%), Pacific Herring (4.3%), Sacramento Splittail (4.3%), California Halibut (2.1%), Threespine Stickleback (2.1%), and Silver Surfperch (2.1%). The non-native fish catch was comprised of Shimofuri Goby (57.3%), Striped Bass (19.4%), Shokihaze Goby (15.5%), Yellowfin Goby (6.8%), and a single Chameleon Goby.

In fall, 10 fish species were collected by otter trawl (n = 76) (See Table 7 and Appendix D, Table D-4). Over half the fish catch (n = 76) consisted of three species; Chameleon Goby (19.7%), Striped Bass (19.7%), and Pacific Herring (18.4%). Yellowfin Goby (17.1%) and Bay Goby (11.8%) were also relatively abundant. Chameleon Goby and Pacific Herring were present in all habitat types and Striped Bass was most abundant in sidecast ridge sites. In contrast to the spring survey results, crangonid shrimp dominated the overall catch (n = 2,069) at all habitat types. The non-native shrimp, *P. macrodactylus*, was collected in low abundance.

A total of 31 (40.8%) native fish (five species) and 45 (59.2%) non-native fish (five species) were collected by otter trawl in fall. Pacific Herring (45.2% of native fish) and Bay Goby (29.0%) were the most abundant native fish species in the catch, followed by California Halibut (12.9%), Starry Flounder (9.7%), and Northern Anchovy (3.2%). The non-native fish catch was comprised largely of Chameleon Goby (33.3% of non-native fish), Striped Bass (33.3%), and Yellowfin Goby (28.9%). Shimofuri Goby and Shokihaze Goby were collected in low abundance.

6.2.2 Length Frequency Analysis

Minimum and maximum length ranges of each species collected by otter trawl and potentially vulnerable to being observed by the ARIS camera are presented in Table 11. Based on sizes of fishes observable by the ARIS camera, five species collected by otter trawl were likely observed by the ARIS in spring, 2017, and six fish species and one crustacean species were likely observed by the ARIS in fall, 2017. All goby species were included into one species group for this analysis. A full description of length frequencies for all species collected by otter trawl in spring and fall, 2017, are presented in Appendix E.

Table 11
FISH SPECIES AND THEIR LENGTH RANGES COLLECTED BY OTTER TRAWL AT THE SEARS POINT RESTORATION PROJECT[1]

Fish species (otter trawl catch) potentially observed by the ARIS (>7 cm length) in spring, 2017	Topsmelt	California Halibut	Sacramento Splittail	Gobies	Striped Bass		
Minimum Length (cm)	5.5	>7.0	>7.0	3.5	12.0		
Maximum Length (cm)	18.0	19.5	16.5	15.5	21.0		
Fish and crustacean species (otter trawl catch) potentially observed by the ARIS (>5 cm length) in fall, 2017	**Starry Flounder**	**California Halibut**	**Sacramento Splittail**	**Gobies**	**Striped Bass**	**Crangon Shrimp**	**Pacific Herring**
Minimum Length (cm)	6.0	30.0	6.0	3.0	10.5	2.5	6.5
Maximum Length (cm)	22.5	52.0	19.5	14.0	25.5	6.5	10.0

[1] Fish species that could be observed by the ARIS camera based on observable minimum size by season.

7.0 DISCUSSION

7.1 SEASONAL DIFFERENCES

Fish sampling at the Project resulted in high totals for both observed catch and species diversity, indicating extensive use of the newly restored habitat by a variety of fish species. The difference in fisheries abundance between the spring and fall sampling events (as observed by the ARIS) was remarkable and may be explained by many factors. First, habitat usage of several species may differ between the spring and the fall. Many estuarine species travel between habitats (i.e., near shore and pelagic) and may be likely to be found in nearshore tidal areas during the fall. The majority of fish observed by the ARIS camera during fall sampling were smaller (i.e., ~10-15 cm) pelagic species that are often found in large schools (i.e., Pacific Herring, Threadfin Shad, and Topsmelt) that were either not present (in the case of Threadfin Shad) or were present but in low abundance (Pacific Herring and Topsmelt) during spring. Second, life histories are temporally variable among small estuarine fish and it may be that several of the abundant species had simply grown large enough between the spring and the fall to be more easily detectable by the ARIS camera. For example, both Pacific Herring and Threadfin Shad spawn during the spring. Both species were commonly observed in seine hauls during the fall but not during spring, suggesting that they were likely not in the Project area during the time of spring sampling (Threadfin Shad) or they were generally too small to be captured by seine or trawl net and too small to be observed by the ARIS camera (e.g., only two Pacific Herring were collected in spring and were only 32-37 mm in length). In contrast, American Shad were present and observed in spring (135-149 mm in length) but not in fall due to their migratory seasonality. Third, the Project area is accumulating sediment and becoming more naturalized. It is expected that as this occurs more plants, plankton and invertebrates will begin to occupy the Project area which may provide better conditions for the fish community. Lastly, detectability of fish by the ARIS camera depends on several factors including fish size, weather conditions (i.e., wind and wave patterns), camera settings, and camera placement. While efforts were made to ensure consistency throughout all replicates and between sampling seasons, it is inevitable that some camera footage is more focused and clear allowing for increased detectability of fish.

7.2 HABITAT USE

Overall, differences in fish abundance between various habitat types were relatively minimal, potentially due to the proximity and uniformity of many of the sampling sites. Habitat is generally considered to be the immediate surroundings, including numerous physical factors (i.e., water quality, temperature, light, etc.), of an individual within its habitat. For this study, we treated sidecast ridges, marsh mounds, and levee transition slope sites as different microhabitats that may support different fish communities. However, with the absence of an established plant community as well as identical substrates and sediment, the only real difference between these 'habitats' is the location within the Project area (and proximity to channels) and the topographical slope of the substrate. With respect to the fish community, these 'habitats' are remarkably similar. Additionally, differences in abundance and diversity of different habitats may be heavily biased by sampling gear. Traditional sampling gears showed higher differences in abundance between habitat types than the ARIS, likely reflecting the difficulty of sampling and the lower capture efficiency in certain habitat types (i.e., flooded remnant vegetation). Lastly, tidal fluctuations likely influenced both the abundance and diversity of the fish community at all sampling locations. Sampling was targeted to occur at similar tidal conditions (flood tide and high tide) among sites and sampling events, but timing of sampling at specific sites was sometimes altered due to sampling constraints at individual sites (i.e., marsh mounds become inundated as the flood tide progresses, precluding the ability to conduct seining). Therefore, daily differences in fish abundance among sites were at least partially influenced by the tidal condition at the time of sampling, as fish are more concentrated in the channels during lower tides.

Sidecast ridges and levee transition slope sites, however, did seem to provide the best habitat for fish as observed by both the ARIS and traditional sampling gear. This could be due to several factors including the shallow sloping topography in these habitats, and the fact that sidecast ridge habitats are much larger than the marsh mounds. However, many other factors may contribute to the abundance of fish observed including the location of sidecast ridges and sampling locations within the Project area. For example, two of the sidecast ridges that were sampled were near the main breach and may have had an increased abundance of fish due to fish swimming into and out of the Project area. Additionally, the levee transition slope locations were located in the 'fish tail' and may have had higher fish abundance due to the location at the back of the Project area far away from the two breaches with potentially reduced populations of predators (i.e., the most sheltered location in the Project area).

7.3 NATIVE VS. NON-NATIVE SPECIES

Much of the species abundance observed during beach seining and trawling could be attributed to just a handful of species. No state- or federally-listed fish species (e.g., Delta Smelt, Longfin Smelt, Green Sturgeon, Central Valley Steelhead, Central Valley Spring-run Chinook Salmon, or Sacramento River Winter-run Chinook Salmon) were collected during sampling; this result was not surprising given the relatively low abundance of these species (especially Delta Smelt, Longfin Smelt, and Green Sturgeon), habitat use patterns (smolt Steelhead and Chinook Salmon have recently been shown to migrate rapidly through the Bay, largely through the primary channel) and the timing of surveys (few smolt Chinook Salmon would be expected to be present during the fall surveys, while juvenile Chinook Salmon of all races may be expected during the spring, however, they tend to out-migrate rapidly and through the primary channel).

However, surveys did reveal the presence of Sacramento Splittail, a sensitive native minnow, and two important commercial species (California Halibut and Pacific Herring) were present in both the beach seine and otter trawl catches. Though not collected, sturgeon (likely White Sturgeon, but could not positively discern between Green or White Sturgeon) were infrequently observed breaching by boat -based field technicians during sampling events. Native species were most abundant in the beach seine catch (89.1 percent and 95.2 percent of all individuals in the spring and fall, respectively, were native species) as compared with the otter trawl catch, with only 31.3 percent and 39.5 percent of all individuals in the spring and fall, respectively, being native species. The differences depended upon the habitat where the species were observed (shallow, channel margin habitat vs. deep water habitat). Beach seine surveys are focused in shallow channel margin habitat (typically <2 meters in depth) where juvenile, native fish species are generally most abundant. Non-native fish species are often not as abundant in this type of habitat due to daily variation in water depth and temperature, including tidal fluctuations that often result in complete loss of water. Native fish species have evolved to live in this type of habitat whereas non-native fish species often prefer more stable habitat conditions such as occurs in deeper channels. The loss of shallow-water subtidal habitat in the Bay as a result of extensive reclamation likely contributed to a reduction in native fish abundance and highlights the need for additional restoration of these habitats.

In spring, the most abundant fish species that were observed with the ARIS camera at rootwad and sidecast ridge transects were likely native Topsmelt and Sacramento Splittail, and non-native Striped Bass and American Shad. In fall, the abundant smaller species (i.e., ~10-15 cm) that were especially abundant at levee transition slope transects with the ARIS camera were likely native Topsmelt and Pacific Herring, and non-native Threadfin Shad. The larger species (>15 cm) were likely non-native Striped Bass. These are pelagic species that were particularly abundant at levee transition slope stations during beach seine surveys, and all three have lengths that are comparable to the median length observed by the ARIS (10 cm).

7.4 COMPARISON WITH OTHER RESTORED WETLANDS IN THE SAN FRANCISCO ESTUARY

One of the goals of this project is to compare the results to other tidal marsh restoration projects. In short, Project species composition was generally consistent with the documented catch from other tidal marsh and wetland habitats in the Bay. The most appropriate tidal marsh restoration project with available and comparative data to the Project is the Tolay Creek Restoration Project (TCRP), immediately adjacent to the Project. The TCRP, located south of Highway 37 near the Hwy 37/121 junction, is located on lands managed by the San Pablo Bay National Wildlife Refuge and the Napa-Sonoma Marshes State Wildlife Management Area. The objective of this project was to restore 2 ½ miles of Tolay Creek to tidal influence, open an additional 117 acres of former field to tidal influence, and increase the cordgrass/pickleweed marsh and slough channel habitat preferred by California Clapper, Ridgeway's Rail, and Black Rail, Salt Marsh Harvest Mouse, and sensitive fish species such as the Sacramento Splittail and juvenile salmonids. Engineered habitats were generally not included in TCRP, other than dredged channels with dredge material sidecast adjacent to the channels, and levee transition slope. Habitat types sampled were levee transition slope and channel margin, often with submerged vegetation. All sampling was conducted by bag beach seine (100 ft. in length and 10 ft. in height with ¼ inch stretched mesh delta weave, equipped with float line and lead line with 25 ft. hauling lines).

The goal of the TCRP fish monitoring plan was to describe fish and other aquatic species assemblage and abundance usage within the subtidal habitat of the restored wetland, to document year to year changes in fish species assemblage and abundance, and to compare the results to other subtidal restoration projects. Initial post-construction sampling efforts in 1999 indicated that 7 species of fish were using engineered habitats in addition to natural habitats. Low to high elevation marsh habitat was beginning to become established through sediment accretion, including the upstream-most lagoon area adjacent to Highway 37; however, most of the restoration marsh was still subtidal habitat. Fish monitoring was conducted by the co-author of this report (Thomas Keegan) for Ducks Unlimited, using beach seine (typically 5-8 hauls) in spring (May-June) and fall (November-December) in 2002, 2003, 2004 and 2005. Supplemental sampling was also conducted in June 2007. Summary results of the TCRP native vs. non-native species total catch, by spring and fall seasons, are provided along with Sears Point Project results in Appendix F; Figures F-1 and F-2. The Project otter trawl catch for spring and fall, though not directly comparable, is also included for reference. Native fish catch in spring at Tolay Creek ranged from 116 fish to 857 fish (averaging 450 fish over the 5 spring seasons of record), compared with 391 fish at the Project; Native fish catch at Tolay Creek in fall ranged from 6 fish to 94 fish (averaging 33 fish), compared with 859 fish at the Project. Non-native fish catch in spring at Tolay Creek ranged from 76 fish to 566 fish (averaging 450 fish over the 4 fall seasons of record), compared with 48 fish at the Project; non-native fish catch at Tolay Creek in fall ranged from 1 to 39 fish (averaging 18 fish), compared with 42 fish at the Project. High numbers of non-native fish species in Tolay Creek from 2002 through 2005 were largely due to the extreme high abundance of Yellowfin Goby during that time. The number of colonizing species (11 – 13 fish species in spring 2002 and 2003) during the initial years following completion of construction and overall fish abundance at Tolay Creek is relatively similar to that at the Project (13 fish species in spring 2017). In general, the more abundant species collected in Tolay Creek were also abundant at the Project, except for the Yellowfin Goby.

The longer-term Tolay Creek dataset shows high annual and seasonal variation in both numbers and species, generally due to interannual differences in Delta outflow. It is difficult to compare one year of data (even with two seasons) from one site against multiple years of data from another site. This is especially true when the catch is dominated by a few species whose abundance is largely determined by winter and spring Delta outflow. High spring Delta outflow in 2017 likely resulted in greater spawning and larval production for species like Pacific Herring and Starry Flounder, as well as crangonid shrimp, in San Francisco Bay. Topsmelt and the gobies also show various responses to high Delta outflow. For example, Yellowfin Goby are generally more abundant in years with lower than average Delta outflow, resulting in higher than average salinity, during winter and spring. Nonetheless, the spring and fall 2017 fish catch, combined with the ARIS results, show high fish utilization of both engineered and ‘natural’ (i.e., flooded remnant vegetation and sidecast ridge) habitat types at the Sears Point Project. It is difficult to tease out differences in fish utilization between the various engineered habitats (e.g., rootwads, marsh mounds), but it appears that most fish preferred the channel margin habitats associated with all sampling locations. Some fish species strongly prefer lower gradient beach/mudflat habitat (Starry Flounder, Bay Goby and other gobies), while some fish species utilize both low gradient and sharper edge channel edge habitat (Pacific Herring, Striped Bass, Topsmelt, and others) presumably because of the abundance of prey items in the channel margin and the protection afforded both by depth within the channel and the channel edge. The abundance of fish at all engineered habitats observed during the short-term sampling events suggests the positive, year-round benefit of habitat complexity afforded by the incorporation of several habitat types.

Shannon Diversity indices (Appendix F; Figures F-3 and F-4) were calculated both for fish only (Fish SDI) and for fish and crustaceans (*SDI all*) for the same sampling events in Tolay Creek and the Project in both spring and fall. In spring, Fish SDI ranged from 0.82 to 1.55 in Tolay Creek compared to 1.67 at the Project. In fall, Fish SDI ranged from 1.02 to 1.95 in Tolay Creek, compared to 0.54 at the Project. The lower Project value in fall was likely due to the high abundance of two native species, Topsmelt and Pacific Herring. When comparing fish and crustacean (*SDI all*) indices to Fish SDI indices, spring values were somewhat higher over all years. However in fall, *SDI all* values in Tolay Creek were lower likely due to the combination of generally lower abundance of fish in fall along with high abundance of only one crustacean species (more correctly, species group), crangonid shrimp (*Crangon spp.*). Fish were more abundant at the Sears Point Project than in Tolay Creek during fall, and crangonid shrimp were present in moderate number, therefore the diversity index remained higher. In spring, fish diversity appears to be greater at the Project than in Tolay Creek, largely due to the extreme numbers of only one species, Yellowfin Goby, in Tolay Creek. In fall, Project fish diversity appears to be lower than in Tolay Creek, again, a function of the high abundance of only one species, in this case Pacific Herring, at the Project.

Another tidal marsh restoration project with data comparable to the Sears Point Project is the Napa Plant Site Restoration Project. Sampling was conducted in April, July and September in 2010 and 2011 soon after construction was completed. The number of native fish species collected by beach seine and otter trawl ranged from 5 to 9 species, while the number of non-native species ranged from 5 to 7 species. Native fish species were most dominant in April and June, while non-native fish were dominant in September; this in contrast to the Project where native fish were dominant in both spring and fall. An apparent difference in specificity of native to non-native catch to the sampling gear was observed; otter-trawl catch was native fish dominated, while the seine catch was non-native dominated. This observation is apparently in opposition to Project results; however, the non-native Inland Silverside was the most dominant fish collected by beach seine at the Napa Plant Site. Inland Silverside was not collected at the Project, although smaller juveniles are sometimes difficult to identify in the field, being very similar to juvenile Topsmelt. Pacific Herring, Topsmelt, Sacramento Splittail, Pacific Staghorn Sculpin, American Shad, Threadfin Shad, Starry Flounder, Threespine Stickleback, Striped Bass, and several species of gobies, were all at least seasonally abundant at both the Project and at the Napa Plant Site. In contrast, Tule Perch, Prickly Sculpin, Inland Silverside, Mosquitofish and Chinook Salmon were collected at Napa Plant Site and not at the Project; most likely a function of the proximity and connection of the Napa Plant Site to the Napa River, and the more freshwater condition. The relatively high abundance and diversity of the fish catch at Napa River Plant Site, along with presence of both engineered and natural habitats, confirms the similarity in results with the Sears Point Project. It is difficult to determine specific differences in fish diversity and abundance among habitats due to inherent variability, other than the fish community in general prefers the complexity of the habitat mosaic afforded by both projects.

7.5 GEAR CAPTURE EFFICIENCY

The higher abundance of fish observed by the ARIS camera in comparison to the number of fish collected by traditional sampling gear is at least partially illustrative of the differences in capture efficiency between traditional sampling gear and hydro-acoustic methods. Comparable estimates of capture efficiency for the two gear types are difficult to quantify due to many factors, including difficulty observing the entire seine area with the ARIS, difficulty tracking the net during otter trawls, and propeller wash from the boat. In addition, the duration of sampling time was longer during ARIS surveys. However, on a per minute basis, many more fish were observed with the ARIS camera (n= 9.0 fish per minute) than with traditional sampling gear (n= 0.9 fish per minute) during transect surveys. Seine surveys were not timed and therefore could not be compared on a per minute basis. Despite the differences in gear, greater numbers of fish were observed with the ARIS camera than were captured with traditional sampling methods (see Appendix C; Figures C-5 and C-6).

Notable avoidance behaviors of larger fish species to both beach seine and otter trawl sets were frequently observed after review of the ARIS footage, thus limiting comparisons of the data between the ARIS and each active sampling method. Avoidance behavior and capture efficiency were more easily visible during transect surveys than during stationary surveys and multiple instances were recorded of fish swimming in front of or into the trawl net before swimming off. Fish observations from the ARIS camera during the spring otter trawl surveys were compared to the otter trawl catch data to evaluate capture efficiency. The observations made by the ARIS represent fish that were either swimming near the trawl net during the survey or fish that were captured in the net. In many habitats, the catch totals were similar; however, 81 percent more fish were observed with the ARIS than were captured by the otter trawl during the same surveys. However, these data should be treated with caution (due to the many factors listed above) and do not provide a true capture efficiency of the otter trawl gear type.

Many of the fish that were observed avoiding the net were larger in size (likely Striped Bass) that appeared to be looking for opportunities to feed on fish and crustaceans that were forced into the water column due to the action of the trawl making contact with the substrate. Few large fish were captured during trawl surveys, which is common since larger fish can swim much faster than the speed of the boat during otter trawl deployment (i.e., > 1.5 knots). At some sampling locations, fish could be seen swimming out of the trawl net when the transect was over and the net was being pulled into the boat. However, larger Striped Bass individuals (>50 cm) were collected by beach seine, suggesting that the larger fish observed by ARIS included Striped Bass. Based on lengths of fish collected by otter trawl in spring, fish species observed by ARIS could also have included Topsmelt and Sacramento Splittail (see Table 11).

8.0 CONCLUSIONS

The results of this fisheries monitoring indicate that the Project is already providing valuable aquatic habitat for a variety of native and non-native species. Fish were observed using multiple sampling gear types in a variety of different habitats throughout the Project area. Substantially higher fish abundance was observed during the fall sampling event compared to the spring sampling event for both ARIS and traditional sampling methods. This was likely due to seasonal fluctuations in the fish community as well as changes in the aquatic habitats; in fall, water temperatures were somewhat cooler, salinities were substantially greater, and turbidity was moderately reduced from those recorded in spring. Over both sampling events, more fish were observed during stationary (beach seine) surveys than during transect (otter trawl) surveys.

The fish community in spring was dominated by native Bay Goby, Starry Flounder, Topsmelt, and Pacific Staghorn Sculpin. Non-native gobies (Chameleon, Shimofuri, Shokihaze, and Yellowfin) and Striped Bass were also abundant. In fall, the native Topsmelt and Pacific Herring accounted for about 88 percent of the entire fish catch. Striped Bass was the most abundant non-native fish, followed by Chameleon and Yellowfin gobies.

Based on the size ranges of fish observed by the ARIS and collected by the traditional gear, the most abundant fish species that were observed with the ARIS camera were likely native Topsmelt and Pacific Herring and non-native Threadfin Shad and Striped Bass. Together, these species likely accounted for the high abundance of fish observed by the camera, particularly at levee transition slope sampling locations located in the 'fish tail' of the Project area.

Fish were observed at all habitat types, but abundance fluctuated seasonally and was greater in the fall. In spring, fish abundance was generally similar among all habitat types (as observed by the ARIS), but in the fall, abundance was an order of magnitude greater at sidecast ridge and levee transition slope sites. Fish collected from the traditional gear were in greater abundance at rootwad and sidecast ridge sites in spring and at rootwad, levee transition slope, and sidecast ridge sites in fall. Fish abundance was lowest at the flooded remnant vegetation sites in spring and at marsh mound habitat in fall. Overall, fish presence at all habitat types during early phases of habitat restoration signifies the benefits of habitat complexity. This is consistent with findings at other restored areas in the Bay such as the Tolay Creek Restoration Project and the Napa Plant Site Restoration Project.

As the Project area continues the trajectory of accumulating sediments, more plants, invertebrates and other aquatic organisms will begin to occupy the Project area and complex habitats will mature, all of which will provide improved conditions for the fish community. It is expected that nursery habitats (i.e., juvenile rearing) will continue to improve for fishes such as Starry Flounder, California Halibut, Pacific Herring, gobies, Topsmelt, and crangonid shrimp, all species that depend upon this currently limited habitat for increased production. Many of these species, such as Topsmelt, gobies, and crangonid shrimp, provide important forage for larger, mobile fishes such as Striped Bass, Green Sturgeon, White Sturgeon, and Chinook Salmon which will likely increase utilization of the Project in years to come.

Utilization of the dual sampling gear methodology allowed for a more in-depth examination of the fish fauna throughout the variety of subtidal habitats. For example, greater abundance of larger fish was observed with the ARIS camera than with traditional sampling techniques. Additionally, the ARIS was able to detect species in habitats (i.e., flooded remnant vegetation) that was difficult to sample with traditional sampling gear. Conversely, the traditional sampling gear was more effective in collecting data on smaller fish species that were much more abundant in shallow water and channel margin habitat. Traditional sampling is key for identifying species and addressing native vs non-native species assemblages. Pairing an ARIS camera with traditional sampling gear that is currently used extensively throughout the estuary and Delta would provide important information on the presence of larger, more mobile fishes. Currently, only a small percentage of larger, mobile fish that are tagged with acoustic transmitters are being monitored in the Bay; further, these fish are only being monitored where acoustic receivers have been deployed. The dual sampling methodology described in this document is a novel approach to sampling for the San Francisco Bay and Delta and if applied to many of the current long-term trawl and seine programs that exist for this region (e.g., fall midwater trawl, spring Kodiak trawl, seine surveys) would provide value-added information on fishes that are currently being under-sampled.

Appendix A

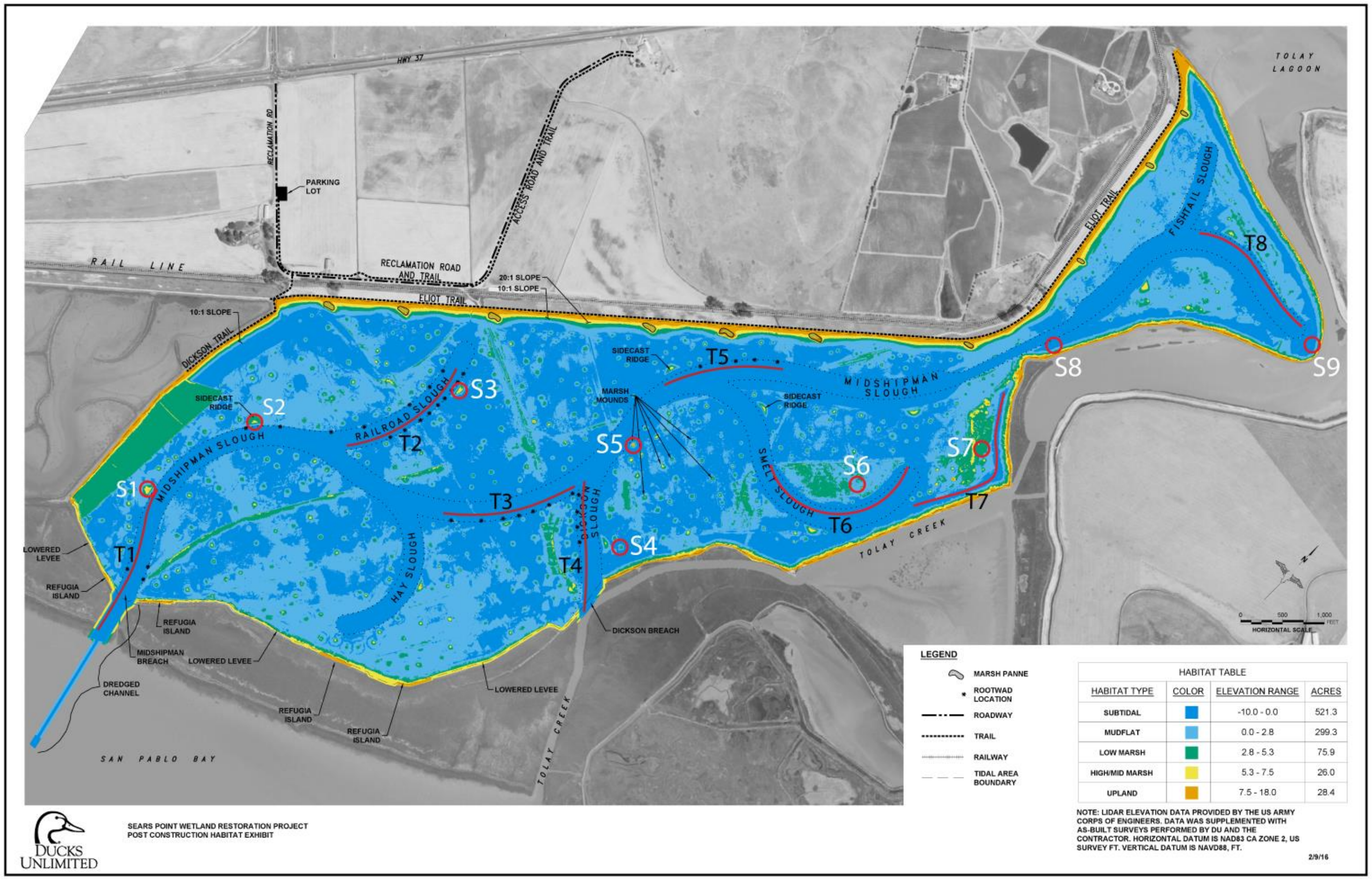
Map of the Sears Point Restoration Project

Appendix A

Map of the Sears Point Restoration Project

Figure A-1

MAP OF THE SEARS POINT RESTORATION PROJECT SHOWING BOTH STATIONARY (S) AND TRANSECT (T) SAMPLING LOCATIONS



Appendix A (cont.)

Map of the Sears Point Restoration Project

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Appendix B

Water Quality Data

Appendix I

Appendix B

Water Quality Data

Table B-1
SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; WATER QUALITY, SPRING, 2017

Site ID	Date	Time	Water Temp (°C)	DO (mg/L)	DO %	Salinity (PPT)	pH	ORP	Turbidity (NTU)
S5 MM2	5/7/2017	15:13	18	9.17	100.9	6.88	7.87	134.7	35.7
	5/8/2017	8:53	18.1	8.63	95.83	7.21	7.57	115.3	42.3
S4 MM1	5/7/2017	16:01	18.9	9.54	107.2	6.8	7.94	192.2	37.6
	5/8/2017	8:00	17.7	8.24	90.5	7.41	7.62	161	40.5
S1 SCR1	5/7/2017	9:00	16.8	8.52	91.3	6.83	7.89	107.8	142.7
	5/8/2017	12:20	18.7	8.6	97.5	9.46	7.97	198.3	78
S3 SCR3	5/7/2017	14:00	18.8	9.17	102.6	7.05	7.93	165.7	38.4
	5/8/2017	11:48	18.1	8.54	95.8	9.38	7.95	188.5	119.5
S2 SCR2	5/7/2017	14:30	18.8	9.23	104.2	8.67	8.09	172.5	31.3
	5/8/2017	11:15	19.3	8.66	98.4	8.15	7.75	184.7	34.6
S6 SV1	5/7/2017	10:05	16.8	8.54	91.5	6.57	7.69	139.5	37.3
	5/8/2017	10:00	18.5	9.42	104.9	7.4	7.85	177.6	41.5
S7 SV2	5/7/2017	12:30	17.7	8.7	95.2	6.92	7.8	171.9	38
	5/8/2017	10:20	19	9.43	106.2	7.34	7.73	180.6	26.4
S8 LWN	5/7/2017	10:12	17.1	8.55	92.3	6.65	7.59	112.7	69.5
	5/8/2017	13:02	19.1	8.8	99.5	7.72	7.82	190.6	31.9
S9 LWFT	5/7/2017	11:13	18.4	9.12	101	6.76	7.72	157.3	37.5
	5/8/2017	13:28	18.8	8.7	97.5	6.93	7.71	162.9	42.1
T1 SCR1	5/9/2017	10:45	18.8	8.32	94.5	9.46	7.95	221.7	109.2
	5/10/2017	14:50	20.4	8.23	96.4	9.22	7.93	222.5	50.2
	5/11/2017	14:41	18.9	7.96	90.7	9.35	7.88	203.5	79.9
T2 SCR2	5/9/2017	11:18	20.4	8.11	94.4	8.26	7.79	189.3	46.7
	5/10/2017	12:02	19.3	7.91	90.8	9.62	7.89	243.9	166.9
	5/11/2017	11:40	18.7	8.08	91.7	9.2	7.65	196.6	46.4
T3 RW1A	5/9/2017	11:53	19.8	8.08	92.9	8.27	7.67	180.2	55.9
	5/10/2017	12:28	19.9	7.91	91.6	8.66	7.63	206.6	53.7
	5/11/2017	11:58	19	7.99	90.8	8.76	7.47	157.9	22.6
T4 RW1B	5/9/2017	12:14	19.8	8.38	96.2	8.51	7.8	199.4	49.6
	5/10/2017	12:47	19.4	8.34	95.5	8.94	7.83	199.7	95.8
	5/11/2017	12:13	19.25	8.02	91.8	9.11	7.81	182.2	140.4
T5 SCR/RW2	5/9/2017	12:53	20	8.69	100.4	8.3	7.76	193.4	36.6
	5/10/2017	13:11	19.5	8.35	95.9	9.01	7.85	211.9	105.3
	5/11/2017	12:45	19.1	7.94	90.7	9.19	7.82	173.2	145.2
T6 SV1	5/9/2017	13:23	20	8.73	101.3	8.71	7.98	190.3	39.7
	5/10/2017	13:35	20.6	9.16	107	8.44	7.64	205.9	23.4
	5/11/2017	13:18	19.8	8.12	93.7	8.87	7.55	172.7	36.9

Appendix B (cont.)

Water Quality Data

Table B-1 (cont.)
SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; WATER QUALITY, SPRING, 2017

Site ID	Date	Time	Water Temp (°C)	DO (mg/L)	DO %	Salinity (PPT)	pH	ORP	Turbidity (NTU)
T7 SV2	5/9/2017	14:01	21.2	9.64	113.8	8.24	7.96	200.7	26.4
	5/10/2017	13:58	20.3	9.21	107.3	8.5	7.85	177.5	22.9
	5/11/2017	13:35	18.9	8.19	93	8.79	7.6	176	20.7
T8 MM	5/9/2017	14:30	21.8	9.76	116.2	7.63	7.89	196.3	23
	5/10/2017	14:24	20.4	8.75	101.8	7.97	7.68	202.3	20.5
	5/11/2017	13:57	19.6	8.19	94.2	8.77	7.6	185.8	36.2

Appendix B (cont.)

Water Quality Data

Table B-2
SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; WATER QUALITY, FALL, 2017

Site ID	Date	Time	Water Temp (°C)	DO (mg/L)	DO %	Salinity (PPT)	pH	ORP	Turbidity (NTU)
S4 MM1	10/2/2017	8:22	16.3	6.56	76.6	22.38	7.95	128.3	39.1
	10/4/2017	10:00	16	7.66	87.4	19.5	7.99	125.6	17.6
S5 MM2	10/2/2017	9:10	16.4	7.22	82.1	16.6	7.99	99.9	18.9
	10/4/2017	9:08	15.8	7.38	84	19.55	7.85	111.9	18.5
S1 SCR1	10/2/2017	11:55	18.6	7.9	94.4	18.86	8.29	191.4	11.6
	10/4/2017	8:00	15.7	7.48	84.7	19.36	7.99	134.6	15
S2 SCR2	10/2/2017	11:34	18.6	7.82	91.8	16.19	8.27	155.2	16.2
	10/4/2017	12:40	17.7	8.12	97	21.12	8.2	186	7.1
S6 SV1	10/2/2017	9:40	16.5	7.31	83.3	17.91	7.69	78.5	16
	10/4/2017	10:43	16	7.37	84.3	19.93	7.81	117	32.1
S7 SV2	10/2/2017	9:54	-	-	-	-	-	-	-
	10/4/2017	10:55	16.3	7.92	91.4	20.11	7.72	74.7	13.1
S8 LWN	10/2/2017	10:30	16.8	7	82.5	22.28	7.65	92.4	17.3
	10/4/2017	11:16	16.3	7.57	87.2	20.19	7.78	107.2	21.9
S9 LWFT	10/2/2017	10:49	17.6	7.26	87.1	22.57	7.62	126.5	11.2
	10/4/2017	12:00	17	7.63	90.2	22.01	7.71	126	8.6
T1 SCR1	10/1/2017	8:21	18.6	7.07	86.2	21.9	8.18	60.4	42.4
	10/5/2017	10:14	16.2	7.29	84.6	21.79	8.1	140.2	46.3
	10/6/2017	9:58	16	7.45	86.3	21.84	7.97	153.6	40
T2 RW/SCR	10/1/2017	8:55	18.5	7.15	86.9	21.98	8.22	93.5	38.4
	10/5/2017	10:42	16.1	7.62	88.4	21.5	8.16	154	46.3
	10/6/2017	10:20	15.2	7.6	86.4	21.55	7.92	152.8	22.7
T3 RW1A	10/1/2017	9:21	18.2	7.06	85.5	22.18	8.12	109.1	29.2
	10/5/2017	11:09	16.4	7.58	88.2	21.65	8.17	140.5	44.4
	10/6/2017	10:50	16.1	7.66	89.1	21.74	7.98	178	58.6
T4 RW1B	10/1/2017	9:44	17.7	6.86	82.3	22	8.02	96.4	14.1
	10/5/2017	11:36	16.2	8.01	92.9	21.67	7.97	106.6	13.7
	10/6/2017	11:23	16.1	7.9	91.3	21.6	7.99	137.8	13.5
T5 SCR/RW2	10/1/2017	11:20	18.2	7.19	87	21.82	7.98	98.2	9
	10/5/2017	13:24	17.3	8.19	96.7	21.4	8.14	138.3	9.3
	10/6/2017	12:50	16.8	8.01	93.9	21.5	7.99	147.5	12.7
T6 SV1	10/1/2017	10:07	17.4	6.79	81.2	22.2	7.98	103.8	16.7
	10/5/2017	12:00	16.4	7.96	93	21.59	8.06	141.3	14.3
	10/6/2017	11:44	16.6	8.1	94.7	21.63	7.95	166.9	14.4
T7 SV2	10/1/2017	10:26	17.9	6.85	82.5	22.43	7.71	74.4	14.1
	10/5/2017	12:25	17	8.05	95.4	21.7	7.77	63.2	11.8
	10/6/2017	12:04	16.5	8.2	95.7	21.74	7.78	92.7	13.7
T8 MM	10/1/2017	10:52	18.14	6.67	80.7	22.49	7.67	84.4	12.3
	10/5/2017	12:58	17.2	7.91	93.7	21.85	7.77	124.2	11.4
	10/6/2017	12:27	16.2	7.92	92	21.83	7.71	118.9	13.9

Appendix B (cont.)

Water Quality Data

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Appendix C

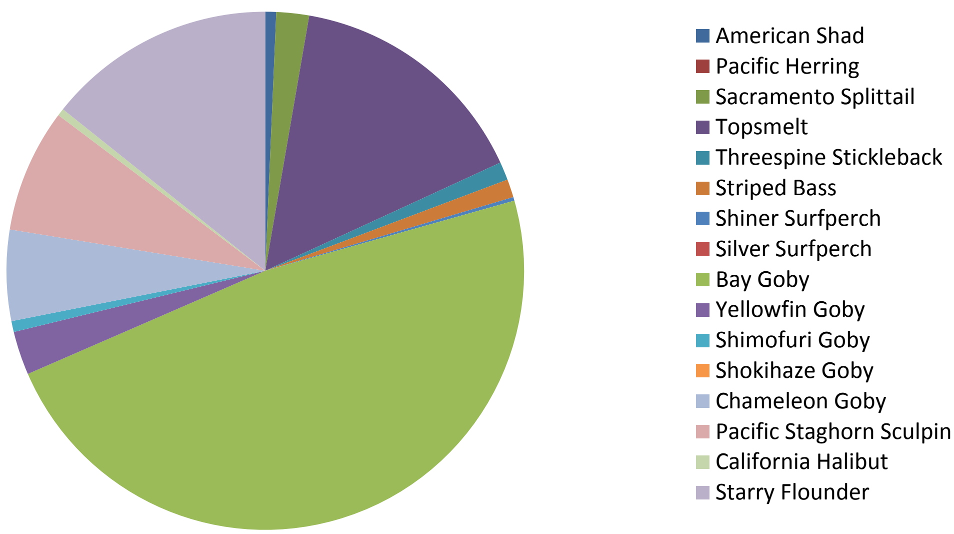
ARIS and Traditional Sampling Fish Catch Figures

Appendix C

ARIS and Traditional Sampling Fish Catch Figures

Figure C-1*

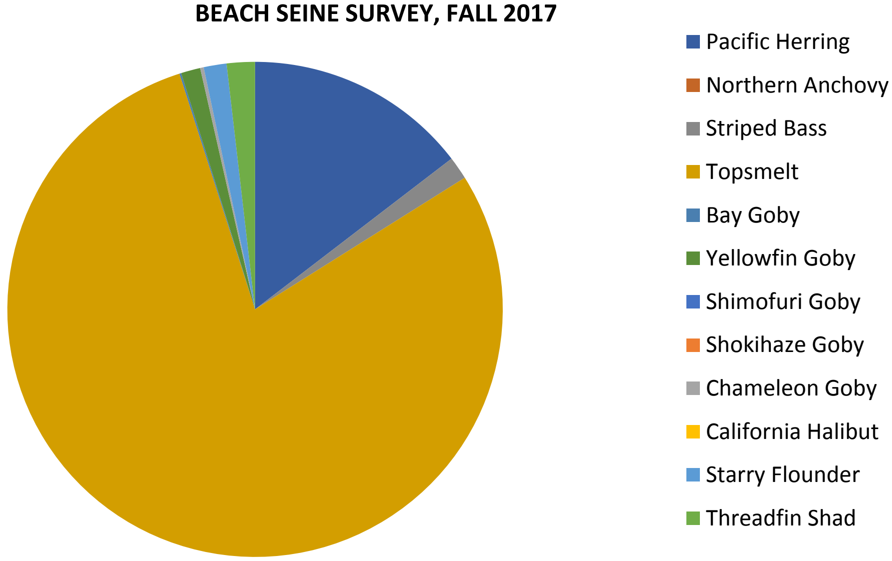
SEARS POINT RESTORATION PROJECT
BEACH SEINE SURVEY, SPRING 2017



* Beach Seine Catch during Spring 2017.

Figure C-2*

SEARS POINT RESTORATION PROJECT
BEACH SEINE SURVEY, FALL 2017



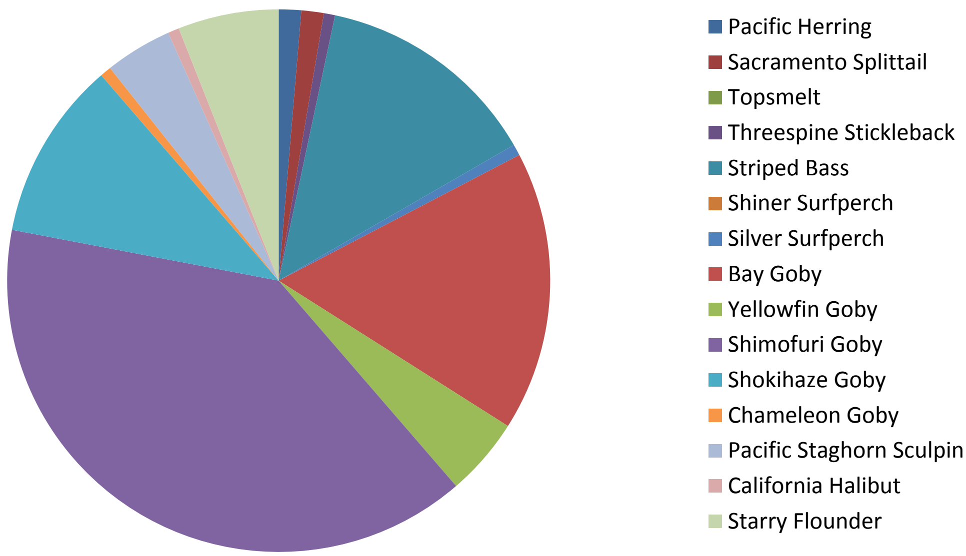
* Beach Seine Catch during Fall 2017.

Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-3*

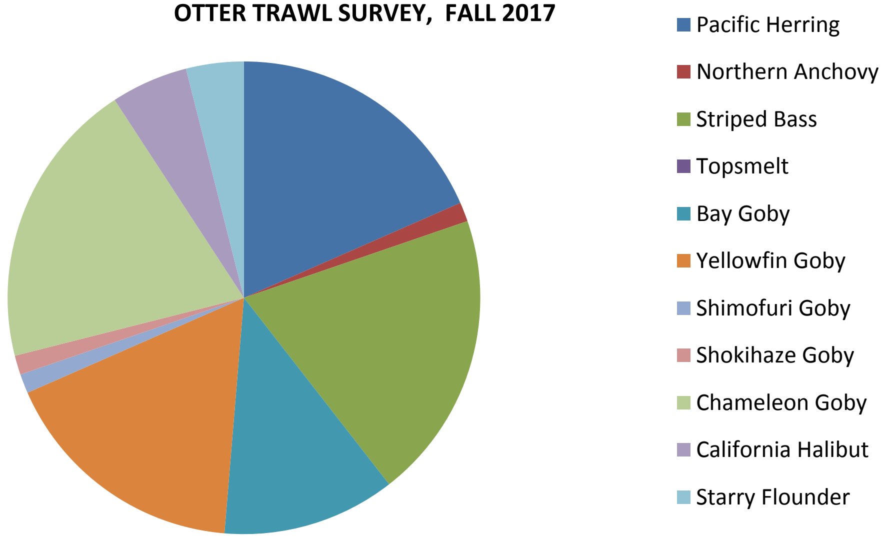
SEARS POINT RESTORATION PROJECT
OTTER TRAWL SURVEY, SPRING 2017



* Otter Trawl Catch during Spring 2017.

Figure C-4*

SEARS POINT RESTORATION PROJECT
OTTER TRAWL SURVEY, FALL 2017



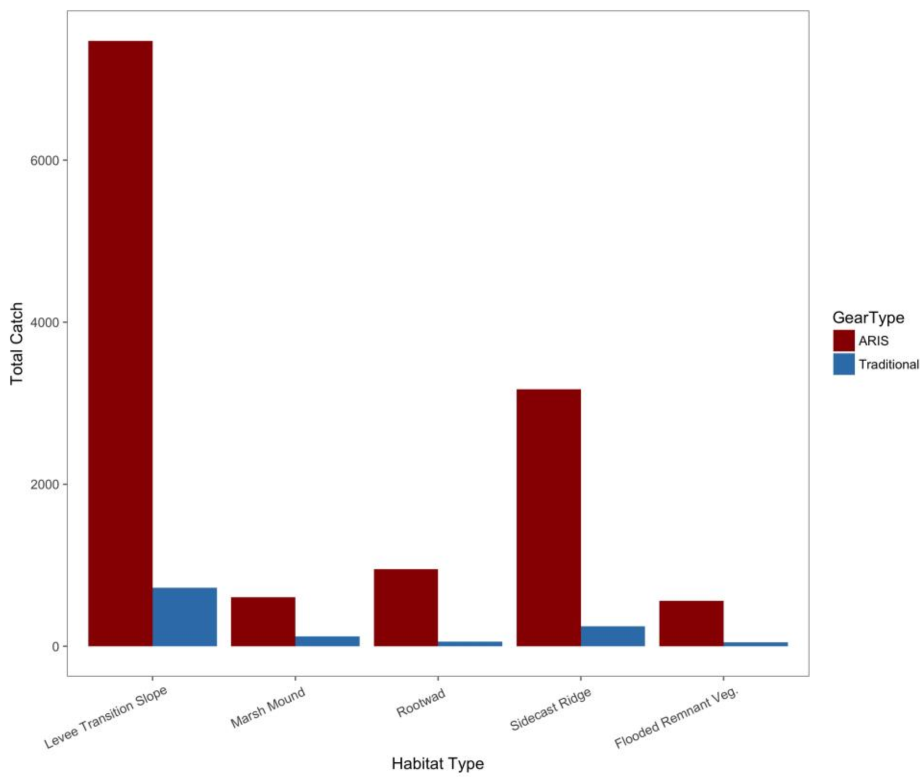
* Otter Trawl Catch during Fall 2017.

Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-5

COMPARISON OF FISH OBSERVATIONS MADE BY THE ARIS AND TRADITIONAL SAMPLING METHODS

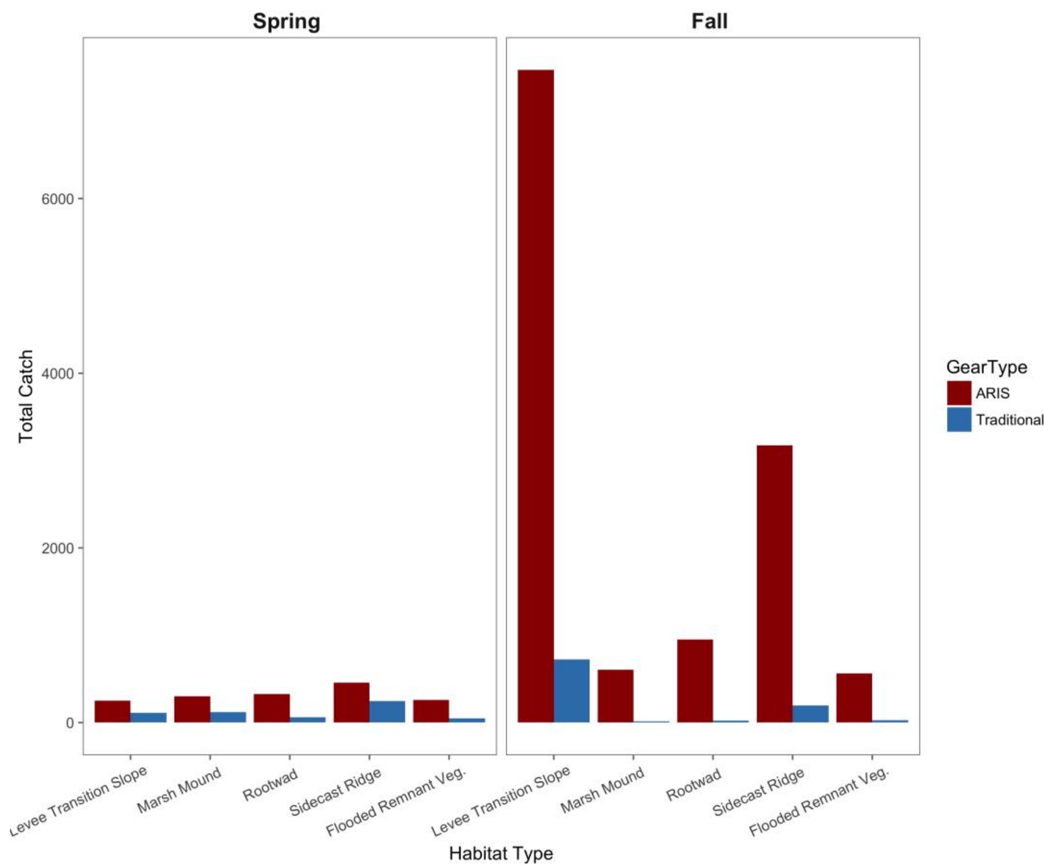


Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-6

COMPARISON OF FISH OBSERVATIONS MADE BY THE ARIS AND TRADITIONAL SAMPLING METHODS DURING THE SPRING AND FALL SAMPLING EVENTS

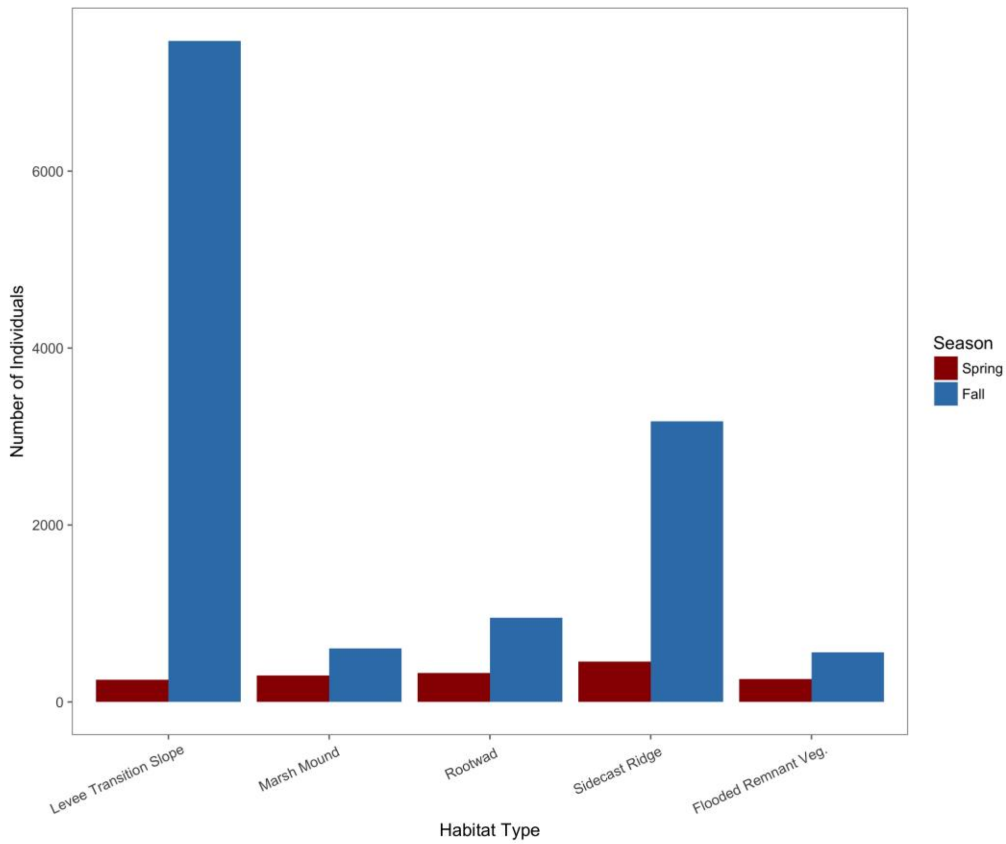


Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-7

FISH ABUNDANCE BY HABITAT TYPE OBSERVED DURING ALL ARIS SURVEYS

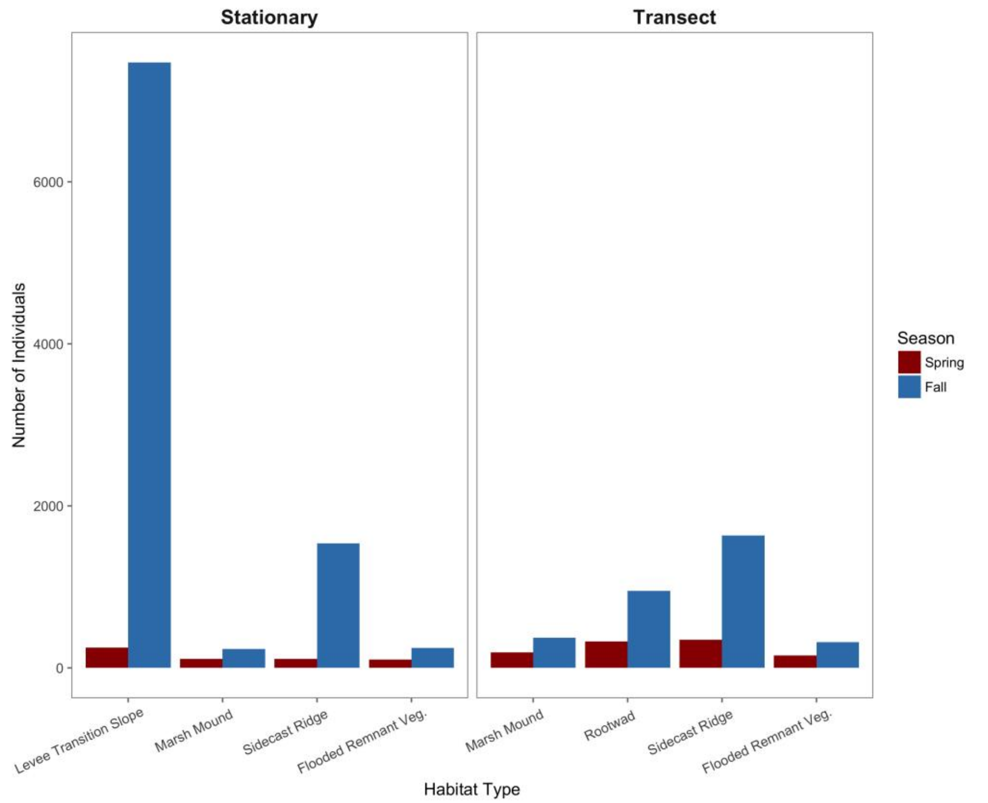


Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-8

FISH ABUNDANCE BY HABITAT TYPE OBSERVED DURING ARIS STATIONARY AND TRANSECT SURVEYS

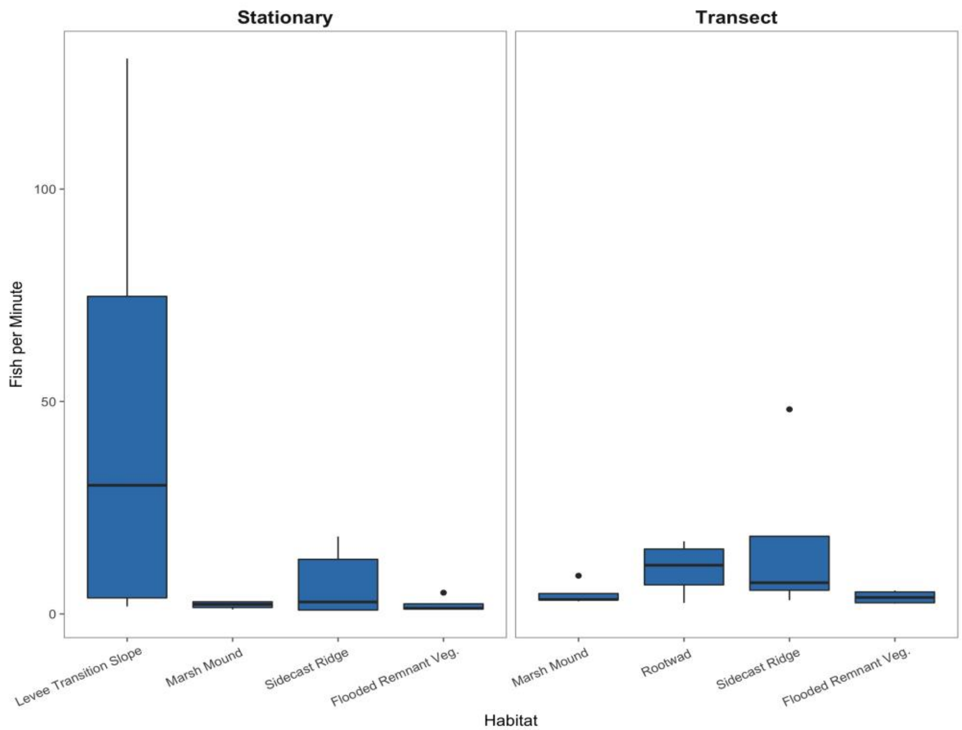


Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-9*

FISH OBSERVATIONS PER MINUTE OBSERVED WITH THE ARIS AT THE VARIOUS HABITATS OF THE SEARS POINT RESTORATION PROJECT



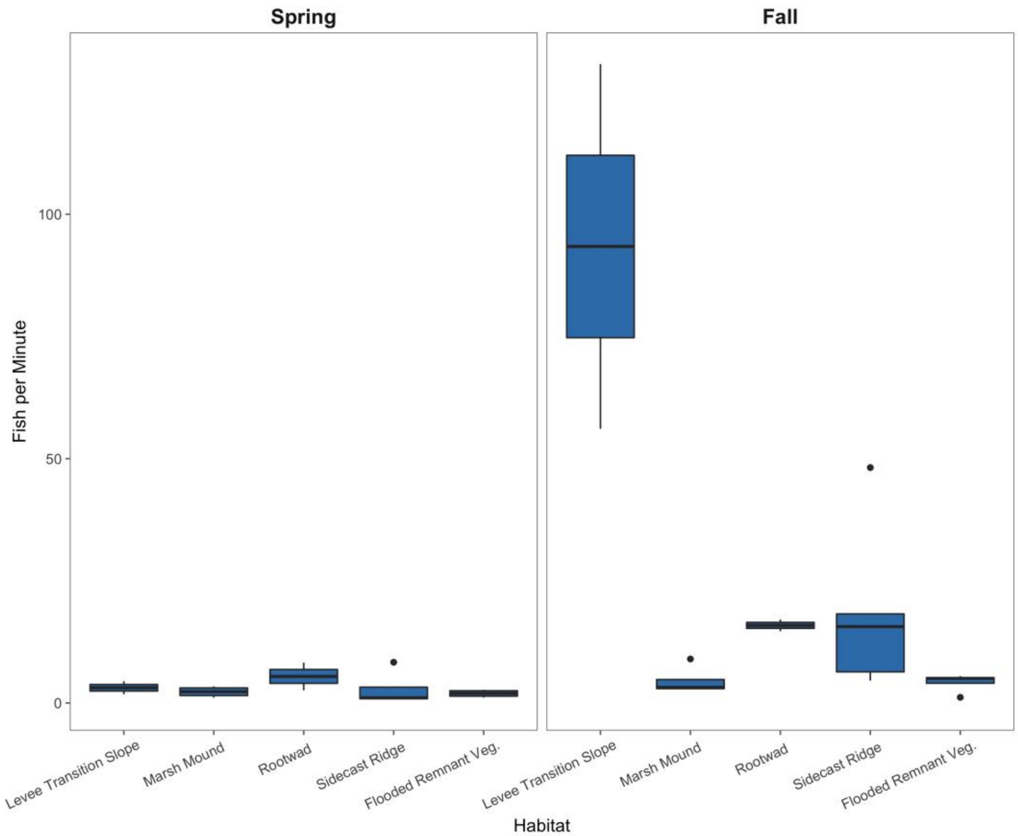
* The blue box represents the 25th and 75th percentile of observations and the solid black line represents the average number of observations in each habitat type. Error bars represent the 95th percentile.

Appendix C (cont.)

ARIS and Traditional Sampling Fish Catch Figures

Figure C-10*

FISH OBSERVATIONS PER MINUTE OBSERVED WITH THE ARIS AT THE VARIOUS HABITATS OF THE SEARS POINT RESTORATION PROJECT



* The blue box represents the 25th and 75th percentile of observations and the solid black line represents the average number of observations in each habitat type. Error bars represent the 95th percentile.

Appendix D

Fish Catch Data

Appendix D

Fish Catch Data

Table D-1

SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; BEACH SEINE DAILY CATCH, SPRING 2017

				Fish Species													Crustacean Species		
Site ID	**Date**	**Time**	**Tide**	**Bay Goby**	**Chameleon Goby**	**Shimofuri Goby**	**Yellowfin Goby**	**Pacific Staghorn Sculpin**	**Striped Bass**	**Topsmelt**	**Shiner Surfperch**	**American Shad**	**Starry Flounder**	**California Halibut**	**Sacramento Splittail**	**3 Spine Stickleback**	**Palaemon Shrimp**	**Crangon Shrimp**	**Hemigrapsus Crab**
S5 MM2	5/7/2017	15:13	Ebb	44			2	1									1		
	5/8/2017	8:53	Flood	34	1	1	5						2				11	5	2
S4 MM1	5/7/2017	16:01	Ebb	6	1	0				1		3			2		2		1
	5/8/2017	8:00	Flood	1		2		1							2		16		
S1 SCR1	5/7/2017	8:26	Flood	6															
	5/8/2017	12:20	Flood	9			1	2					19				1		
S3 SCR3	5/7/2017	14:30	Ebb	1			1			1	1		1		2				
	5/8/2017	11:15	Flood	10	1			2					5				2		
S2 SCR2	5/7/2017	14:00	Ebb	5	10				1	1			1				3		
	5/8/2017	11:48	Flood	52	3		2	23					31	1		1			
S6 SV1	5/7/2017	9:42	Flood																
	5/8/2017	10:00	Flood	2	3			1		10									
S7 SV2	5/7/2017	12:30	Flood																
	5/8/2017	10:20	Flood	3					2	2			3		1		4		
S8 LWN	5/7/2017	10:12	Flood	10	1			1	2					1			3		
	5/8/2017	13:02	Flood	1	3		1	3		2			1				9		
S9 LWFT	5/7/2017	11:13	Flood	4	1					32					2		1		
	5/8/2017	13:28	Flood	23	1					19						4	10		
			TOTAL ORGANISMS	**211**	**25**	**3**	**12**	**34**	**5**	**68**	**1**	**3**	**63**	**2**	**9**	**5**	**63**	**5**	**3**

Appendix D (cont.)

Fish Catch Data

Table D-2

SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; OTTER TRAWL DAILY CATCH, SPRING 2017

				Fish Species													Crustacean Species	
Site ID	Date	Time	Tide	Bay Goby	Chameleon Goby	Shimofuri Goby	Shokihaze Goby	Yellowfin Goby	Pacific Staghorn Sculpin	Striped Bass	Silver Surfperch	Pacific Herring	Starry Flounder	California Halibut	Sacramento Splittail	3 Spine Stickleback	Palaemon Shrimp	Hemigrapsus Crab
T1 SCR1	5/9/2017	10:45	Flood		1	1	7		1	1			2				170	
	5/10/2017	15:22	Ebb	1		5											5	
	5/11/2017	14:46	Flood			25	2						1	1		1	73	
T2 SCR2	5/9/2017	11:18	Flood				1			1							7	
	5/10/2017	12:02	Flood	1													3	
	5/11/2017	11:40	Flood	2				1									10	
T3 RW1A	5/9/2017	11:53	Flood	1						1			1		1		1	
	5/10/2017	12:28	Flood	2		1											4	
	5/11/2017	11:58	Flood							2							2	
T4 RW1B	5/9/2017	12:15	Flood				3			2							8	.
	5/10/2017	12:47	Flood			9	1		3								30	
	5/11/2017	12:13	Flood	1		13	1		1								84	2
T5 MM	5/9/2017	12:53	Hi Slack							3							12	1
	5/10/2017	13:11	Flood	6		5			1				1				157	
	5/11/2017	12:45	Flood														5	
T6 SV1	5/9/2017	13:23	Hi Slack	3			1	2			1	1					11	
	5/10/2017	13:35	Flood					1				1					5	
	5/11/2017	13:18	Flood	1						1							2	2
T7 SV2	5/9/2017	14:01	Hi Slack							3			1				6	
	5/10/2017	13:58	Flood	2						1			1					1
	5/11/2017	13:35	Flood							2			1				6	
T8 MM	5/9/2017	14:30	Ebb	3						1			1				8	
	5/10/2017	14:24	Hi Slack					1							1		1	
	5/11/2017	13:57	Hi Slack	2				2		2							18	
TOTAL ORGANISMS				**25**	**1**	**59**	**16**	**7**	**6**	**20**	**1**	**2**	**9**	**1**	**2**	**1**	**628**	**6**

Appendix D (cont.)

Fish Catch Data

Table D-3
SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; BEACH SEINE DAILY CATCH, FALL 2017

				Fish Species								Crustacean Species	
Site ID	**Date**	**Time**	**Tide**	**Bay Goby**	**Chameleon goby**	**Yellowfin Goby**	**Striped Bass**	**Topsmelt**	**Pacific Herring**	**Threadfin Shad**	**Starry Flounder**	**Palaemon Shrimp**	**Crangon Shrimp**
S4 MM1	10/2/2017	8:30	Flood				1		1				
	10/4/2017	10:00	Flood										3
S5 MM2	10/2/2017	9:10	Flood					2					
	10/4/2017	9:08	Flood	1									18
S1 SCR1	10/2/2017	11:55	Hi Slack			2	1	29			1		1
	10/4/2017	8:00	Flood			1		39	3				9
S2 SCR2	10/2/2017	11:34	Flood			2		65	7		4		
	10/4/2017	12:40	Flood			4		1	3		3		
S6 SV1	10/2/2017	9:40	Flood		1								
	10/4/2017	10:43	Flood				1						3
S7 SV2	10/2/2017	9:54	Flood					3					
	10/4/2017	10:55	Flood						3				
S8 LWN	10/2/2017	10:25	Flood				2	90	36	8			
	10/4/2017	11:16	Hi Slack		1			67	35	2		1	
S9 LWFT	10/2/2017	10:49	Flood			1	4	147	35	6	2	2	
	10/4/2017	12:00	Hi Slack			1	4	245	4		3	1	1
			TOTAL ORGANISMS	**1**	**2**	**11**	**13**	**688**	**127**	**16**	**13**	**4**	**35**

Appendix D (cont.)

Fish Catch Data

Table D-4

SEARS POINT RESTORATION PROJECT FISHERIES MONITORING; OTTER TRAWL DAILY CATCH, FALL 2017

				Fish Species										Crustacean Species		
Site ID	Date	Time	Tide	Bay Goby	Pacific Herring	Starry Flounder	California Halibut	Chameleon goby	Shimofuri Goby	Shokihaze Goby	Yellowfin Goby	Striped Bass	Northern Anchovy	Palaemon shrimp	Crangon Shrimp	Hemigrapsus Crab
T1 SCR1	10/1/2017	8:21	Flood				2								278	
	10/5/2017	10:14	Flood			1	1	1	1			2		4	148	
	10/6/2017	9:58	Flood					2			1	1		3	164	
T2 SCR2	10/1/2017	8:55	Flood		1						1	1		1	148	
	10/5/2017	10:42	Flood	2							1	3			277	
	10/6/2017	10:20	Flood		1						1	5			145	
T5 MM/SCR	10/1/2017	11:20	Hi Slack								1				58	
	10/5/2017	13:24	Hi Slack												15	
	10/6/2017	12:50	Flood												10	
T3 RW1A	10/1/2017	9:21	Flood	1	3			1		1	2				188	
	10/5/2017	11:09	Flood	2	1							1			127	
	10/6/2017	10:50	Flood		1			1			1	1			120	
T4 RW1B	10/1/2017	9:44	Flood				1	1			1				53	
	10/5/2017	11:36	Flood					1				1			11	2
	10/6/2017	11:23	Flood								1			1	8	
T6 SV1	10/1/2017	10:07	Flood	2	1			3						1	48	
	10/5/2017	12:00	Flood								2				39	
	10/6/2017	11:44	Flood												2	
T7 SV2	10/1/2017	10:26	Flood	1	2			4			1			3	27	
	10/5/2017	12:25	Flood											1	6	
	10/6/2017	12:04	Flood		1										7	
T8 MM	10/1/2017	10:52	Hi Slack	1	2	1		1					1		83	
	10/5/2017	12:58	Flood												22	
	10/6/2017	12:27	Flood		1	1								2	85	
TOTAL ORGANISMS				**9**	**14**	**3**	**4**	**15**	**1**	**1**	**13**	**15**	**1**	**16**	**2069**	**2**

Appendix E

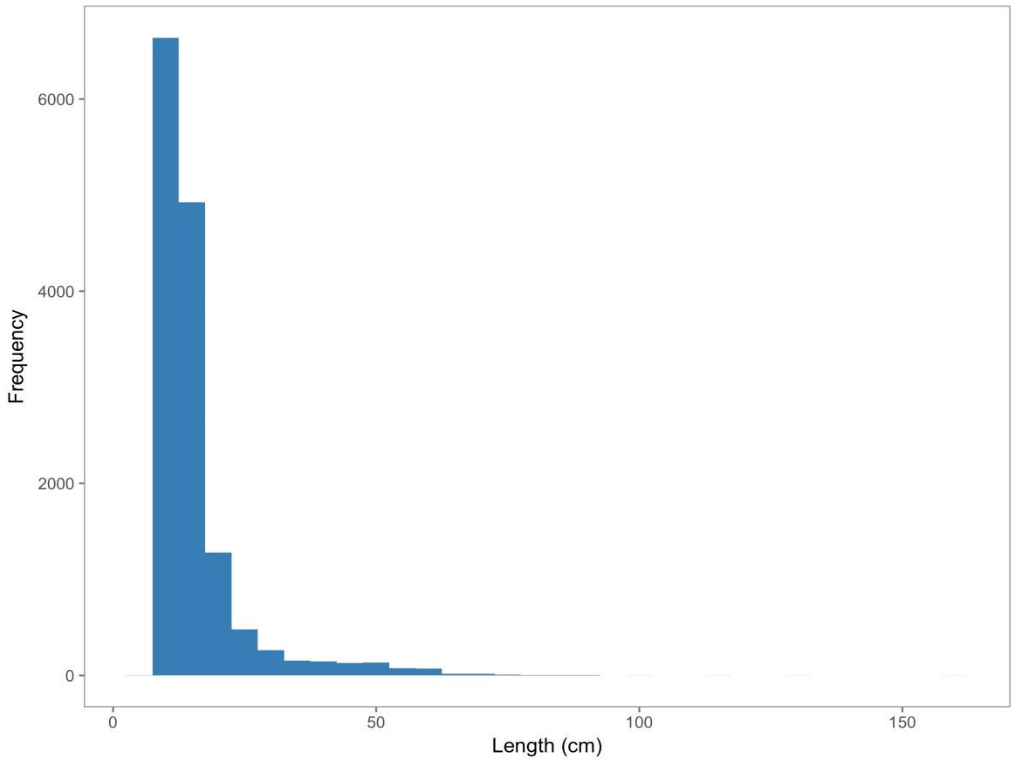
Length Frequency Figures

Appendix E

Length Frequency Figures

Figure E-1

LENGTH FREQUENCIES OF ALL FISH OBSERVED DURING ARIS SAMPLING AT THE SEARS POINT RESTORATION PROJECT

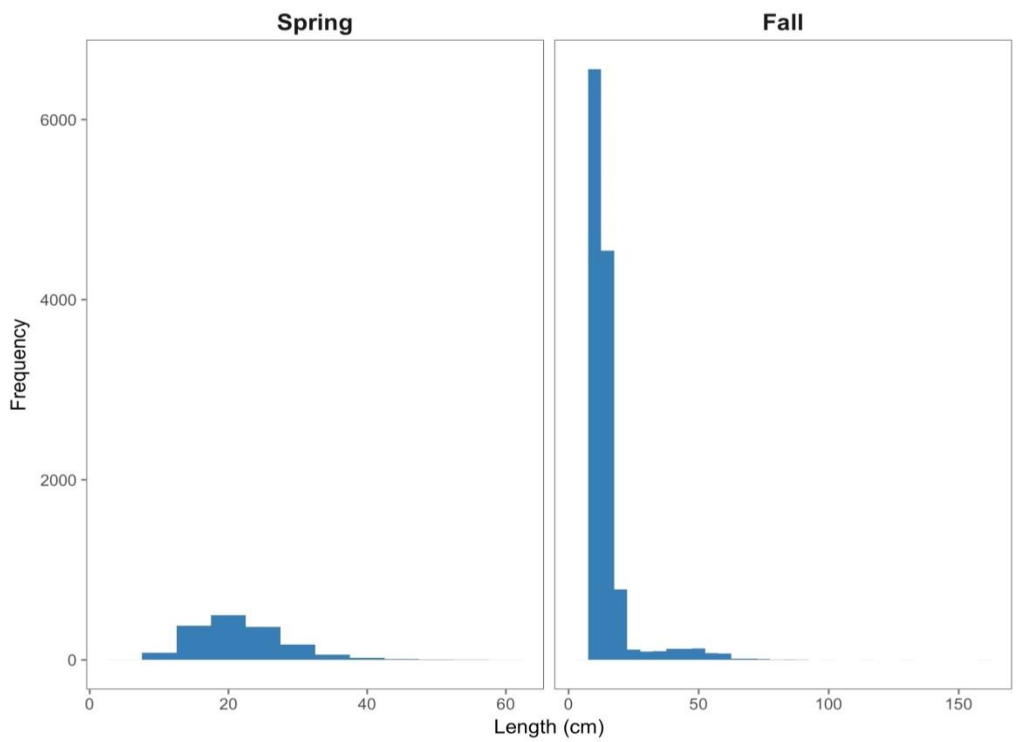


Appendix E (cont.)

Length Frequency Figures

Figure E-2

LENGTH FREQUENCIES OF ALL FISH OBSERVED DURING ARIS SAMPLING IN THE SPRING AND FALL AT THE SEARS POINT RESTORATION PROJECT.

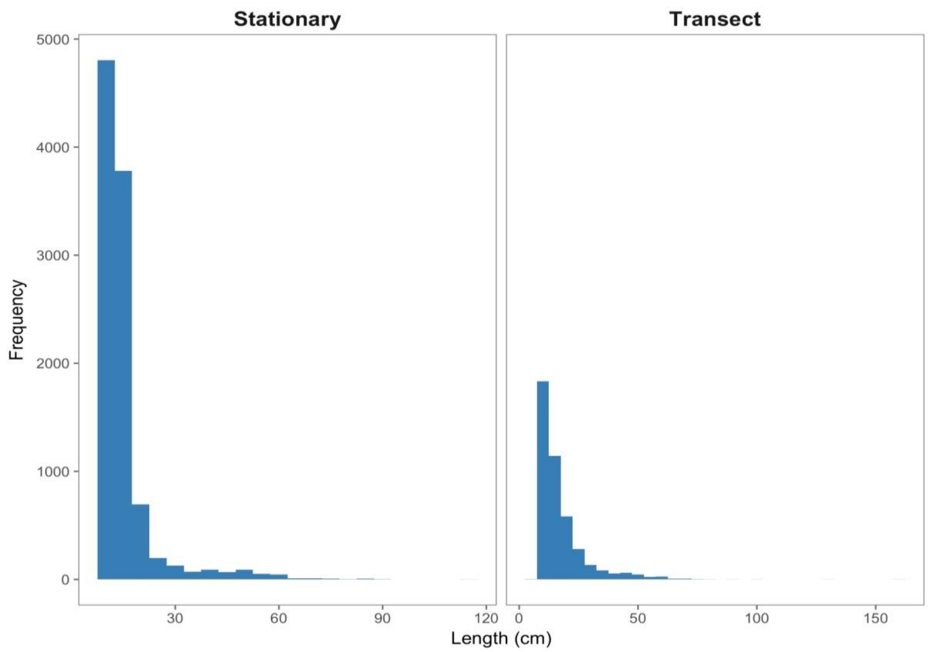


Appendix E (cont.)

Length Frequency Figures

Figure E-3

LENGTH FREQUENCIES OF ALL FISH OBSERVED DURING ARIS SAMPLING AT STATIONARY AND TRANSECT SURVEYS AT THE SEARS POINT RESTORATION PROJECT

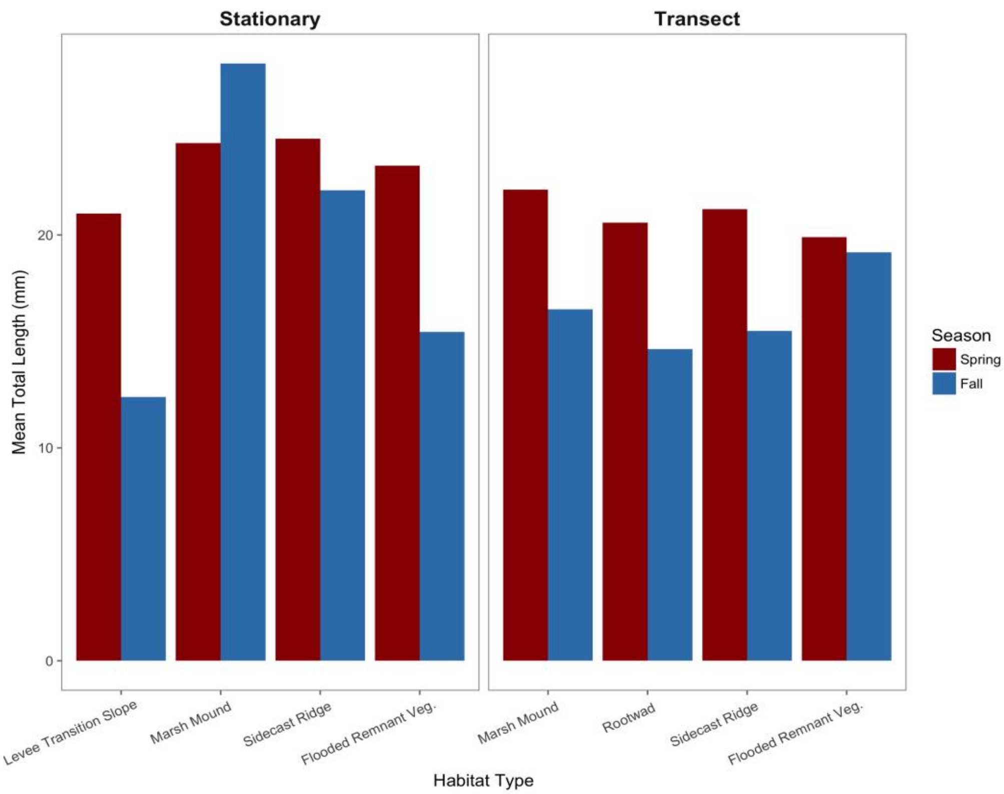


Appendix E (cont.)

Length Frequency Figures

Figure E-4

AVERAGE LENGTHS OF ALL FISH OBSERVED DURING ARIS SAMPLING BY HABITAT AT THE SEARS POINT RESTORATION PROJECT

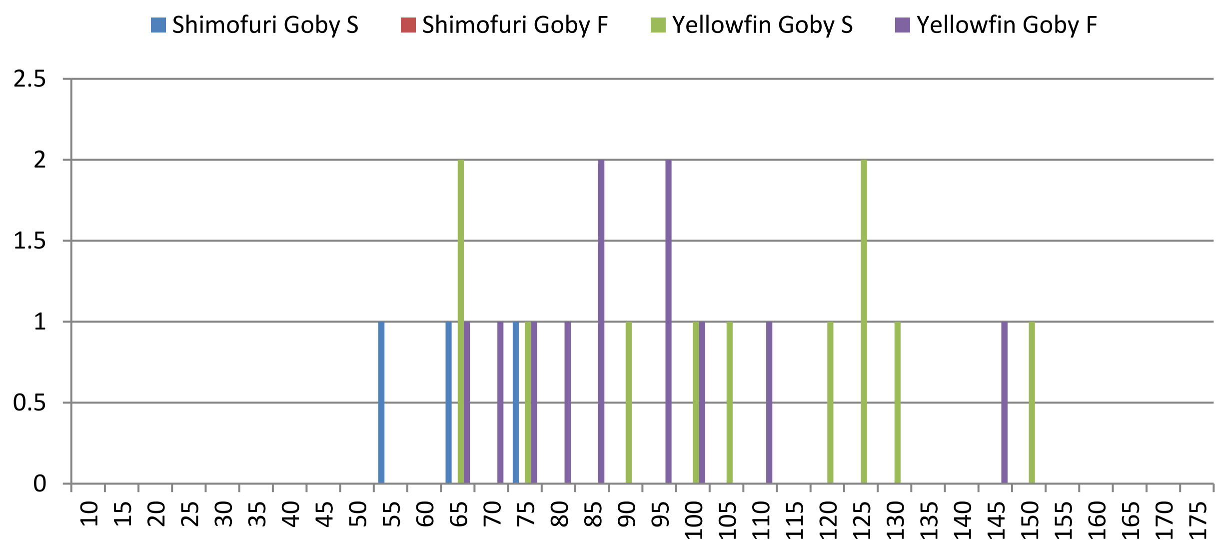


Appendix E (cont.)

Length Frequency Figures

Figure E-5

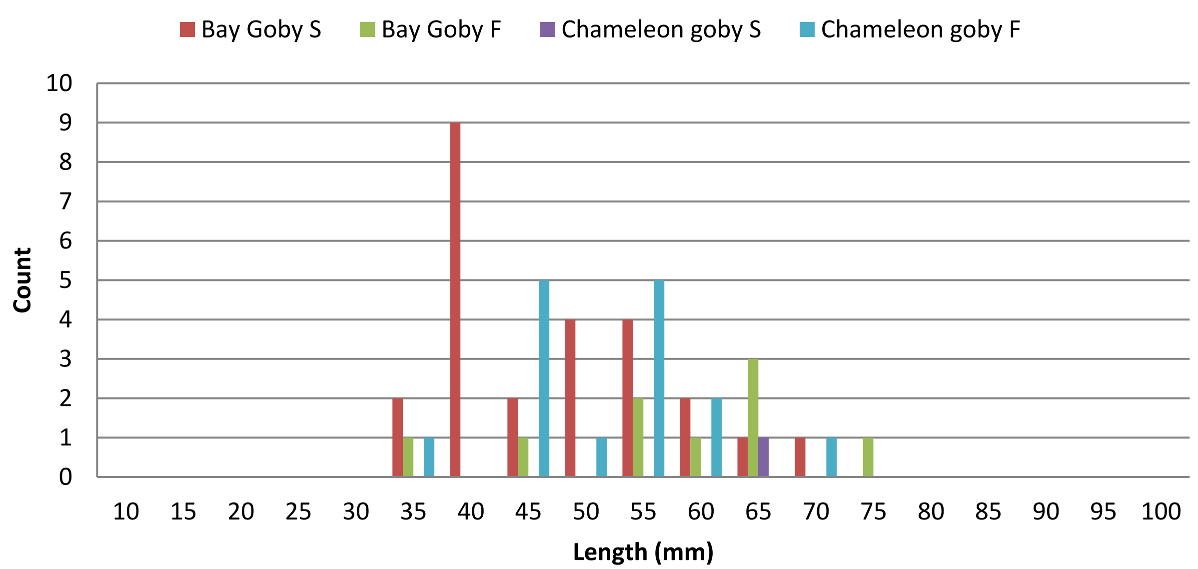
BEACH SEINE LENGTH FREQUENCIES FOR SHIMOFURI AND YELLOWFIN GOBIES, SPRING (S) AND FALL (F) 2017



* Lengths of Shimofuri and Yellowfin Gobies collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.

Figure E-6

OTTER TRAWL LENGTH FREQUENCIES FOR BAY AND CHAMELEON GOBIES, SPRING (S) AND FALL (F) 2017



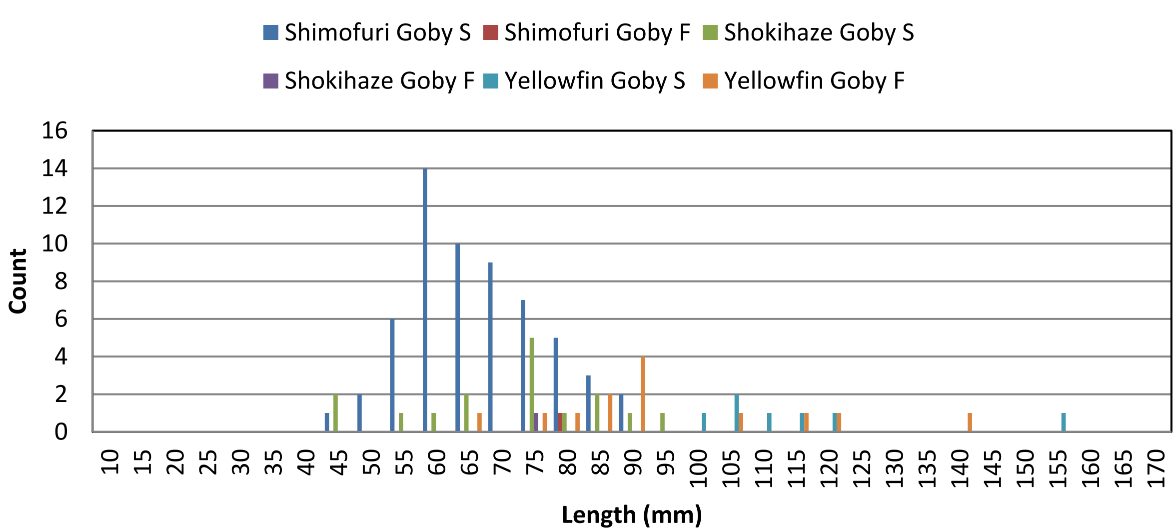
* Lengths of Bay and Chameleon Gobies collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures

Figure E-7*

OTTER TRAWL LENGTH FREQUENCIES FOR SHIMOFURI, SHOKIHAZI AND YELLOWFIN GOBIES, SPRING (S) AND FALL (F) 2017



* Lengths of Shimofuri, Shokihaze, and Yellowfin Gobies collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.

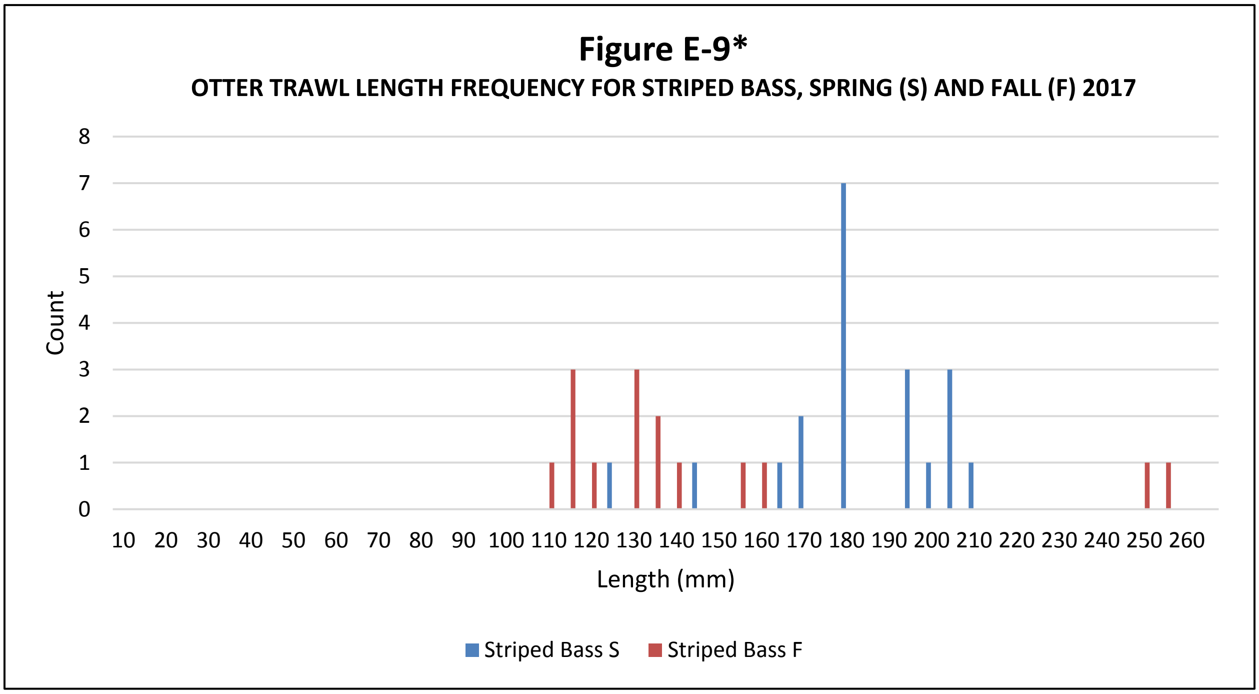
Figure E-8*

BEACH SEINE LENGTH FREQUENCY FOR STRIPED BASS, SPRING (S) AND FALL (F) 2017

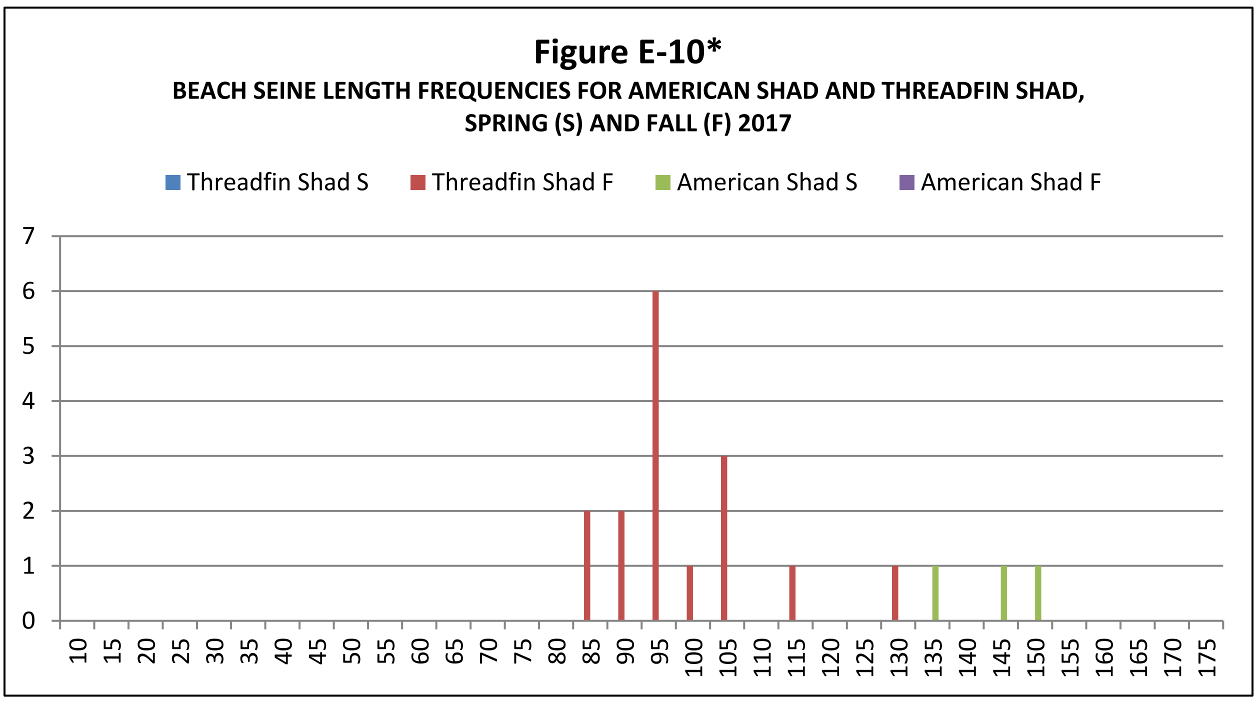
* Lengths of Striped Bass collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures



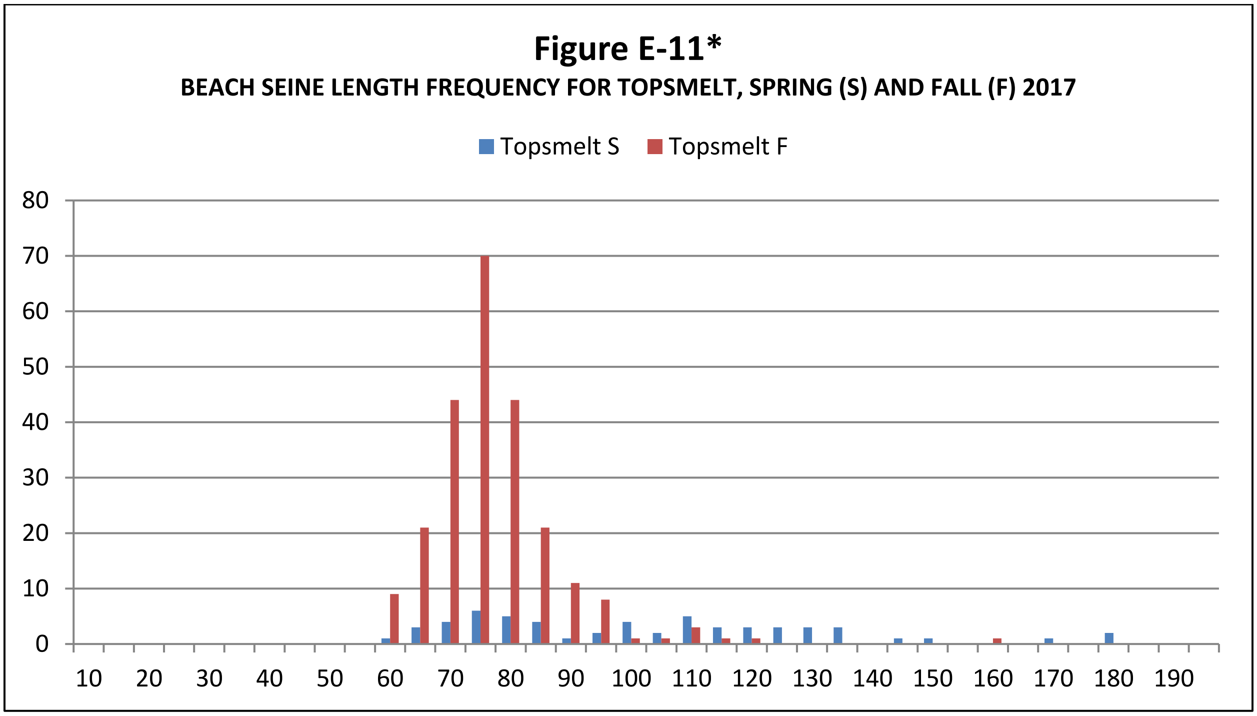
* Lengths of Striped Bass collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.



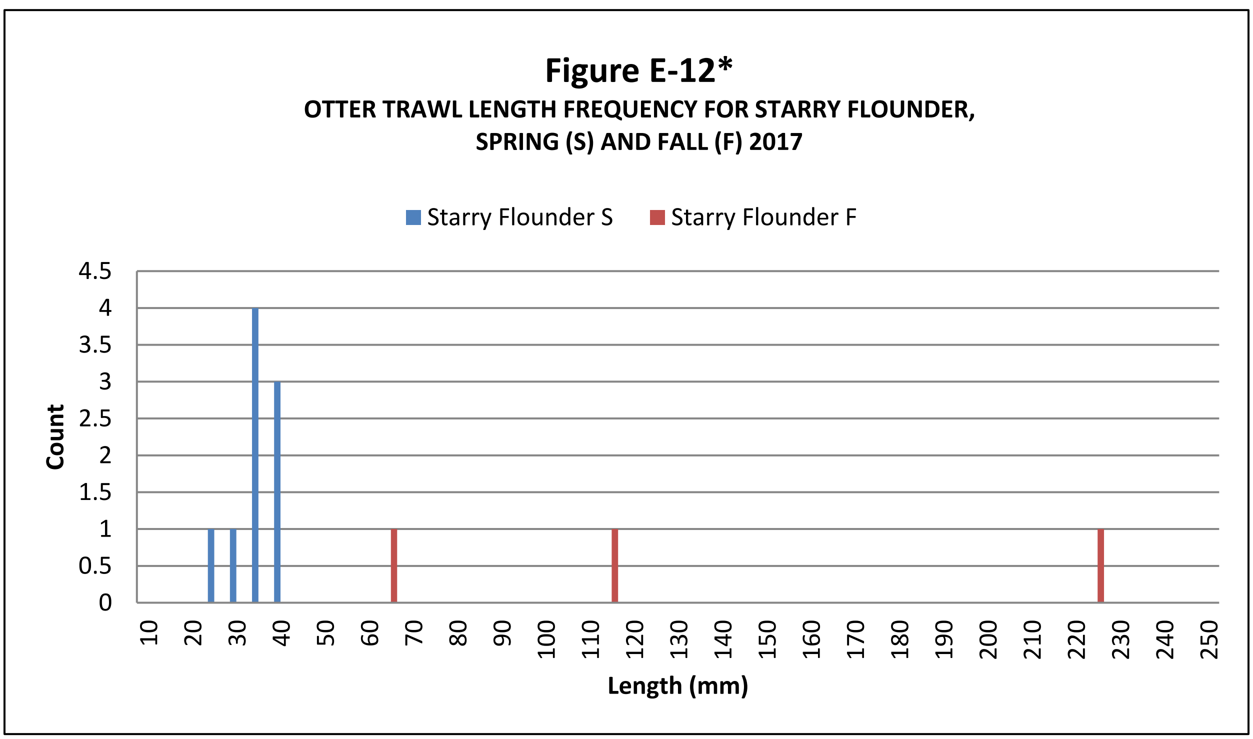
* Lengths of American Shad and Threadfin Shad collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures



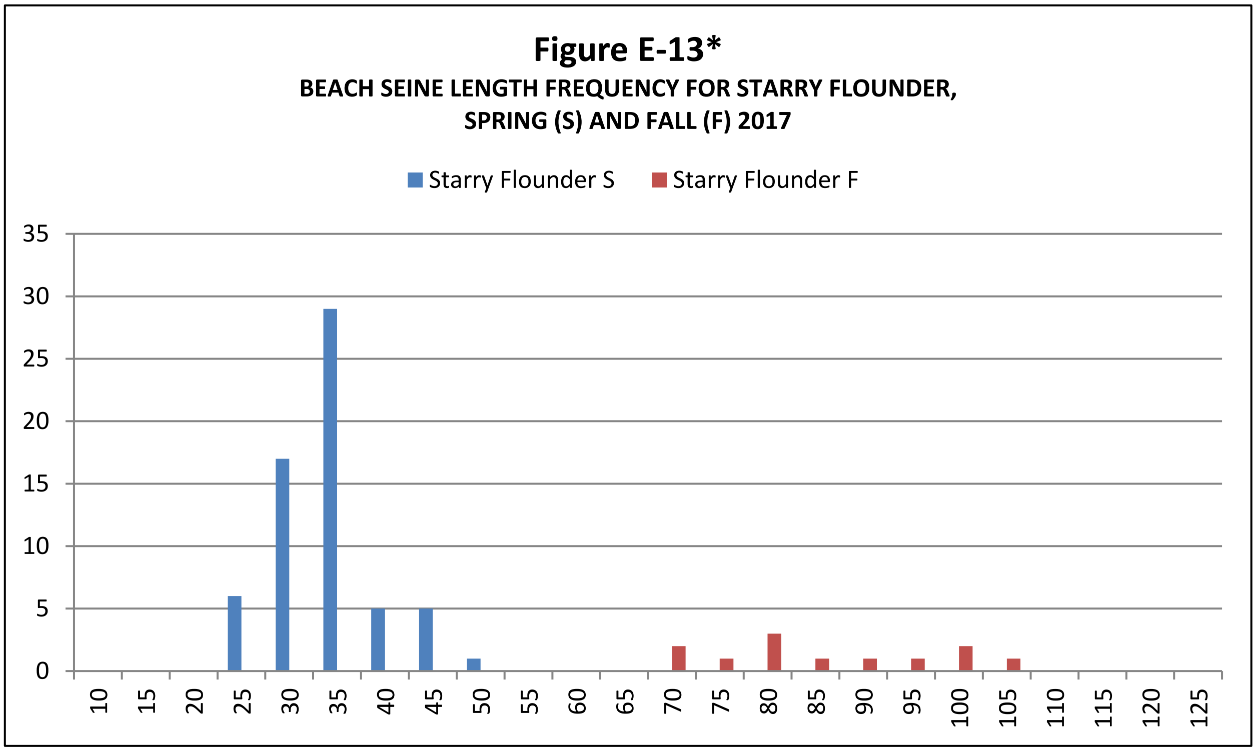
* Lengths of Topsmelt collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.



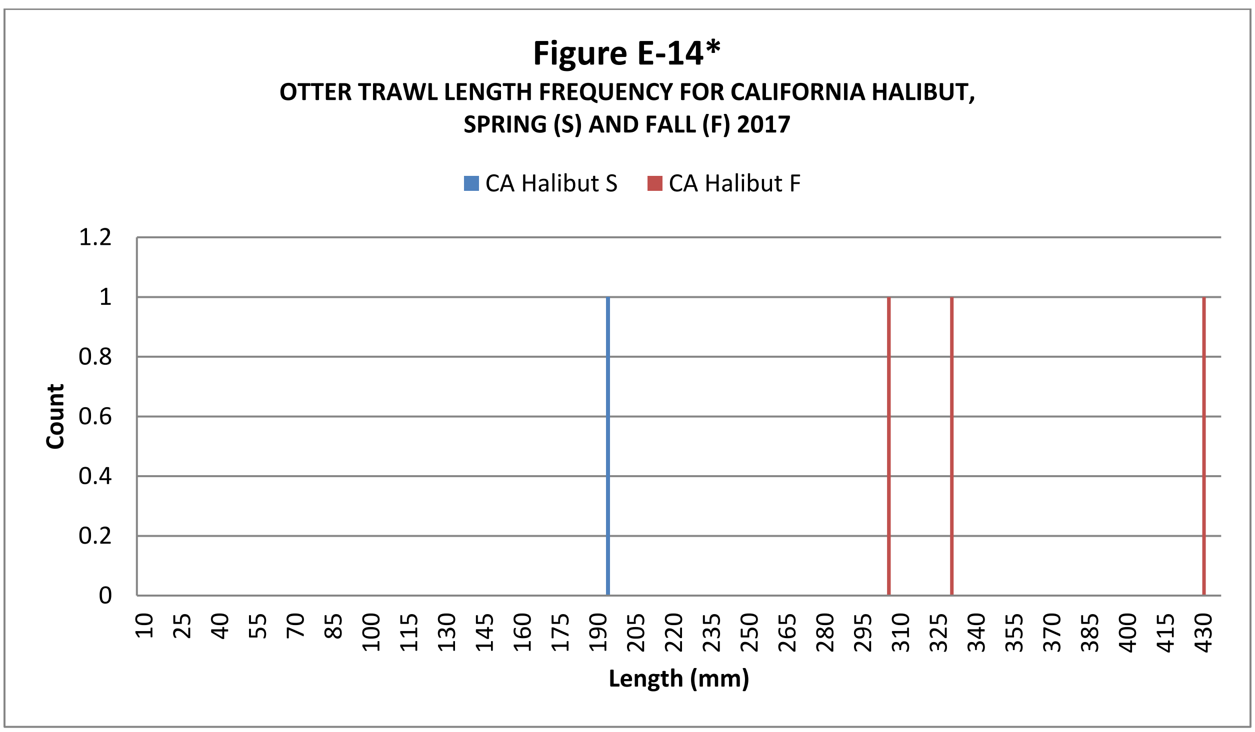
* Lengths of Starry Flounder collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures



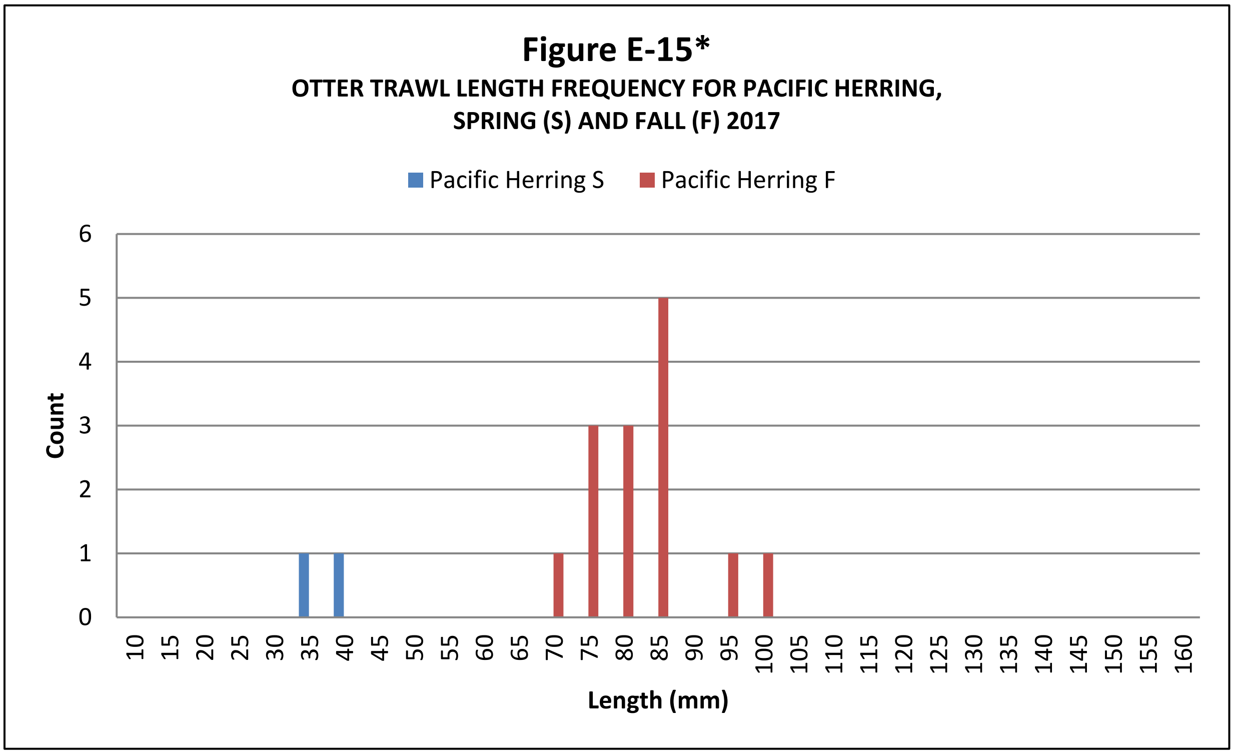
* Lengths of Starry Flounder collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.



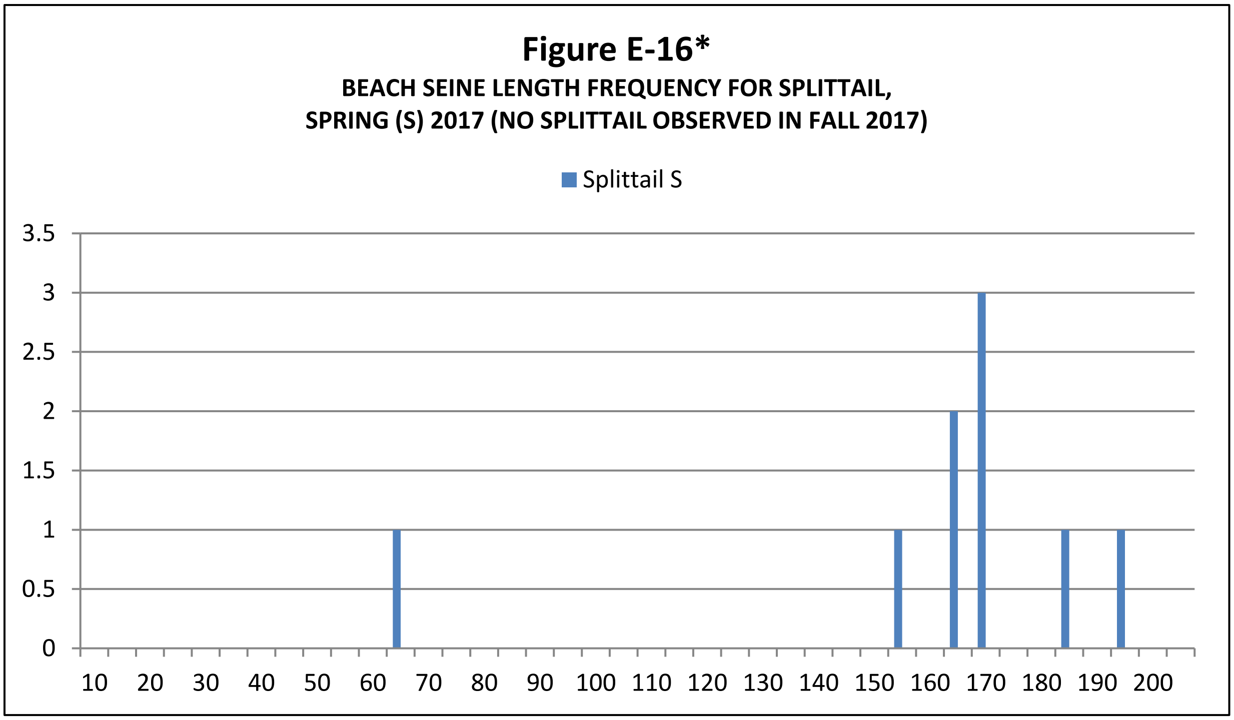
* Lengths of California Halibut collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures



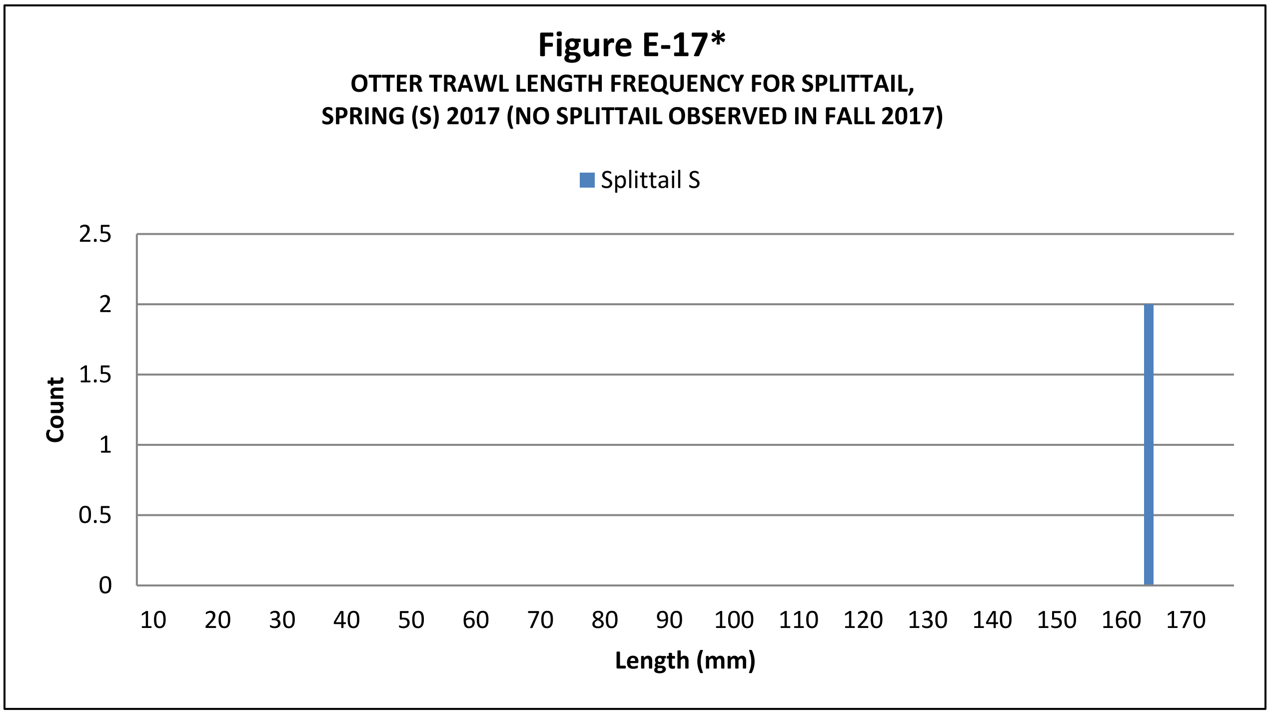
* Lengths of Pacific Herring collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.



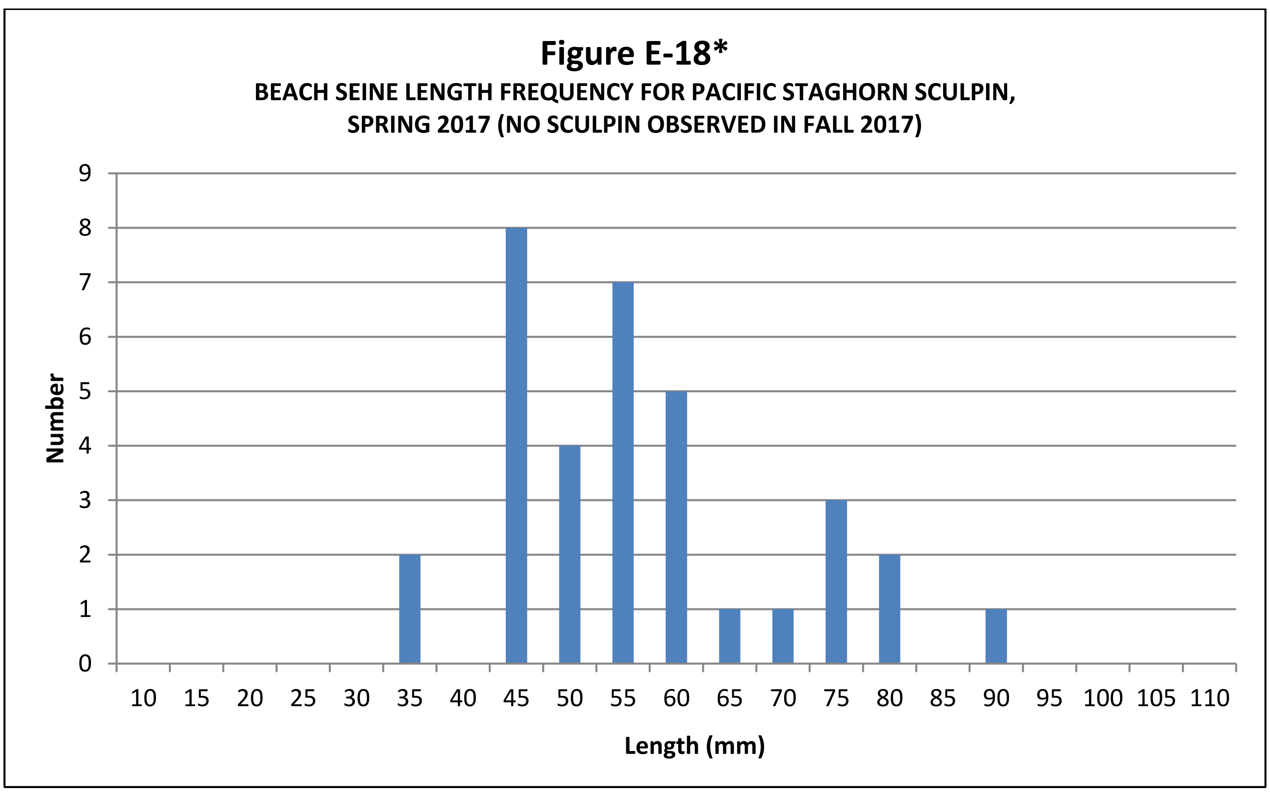
* Lengths of Sacramento Splittail collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures



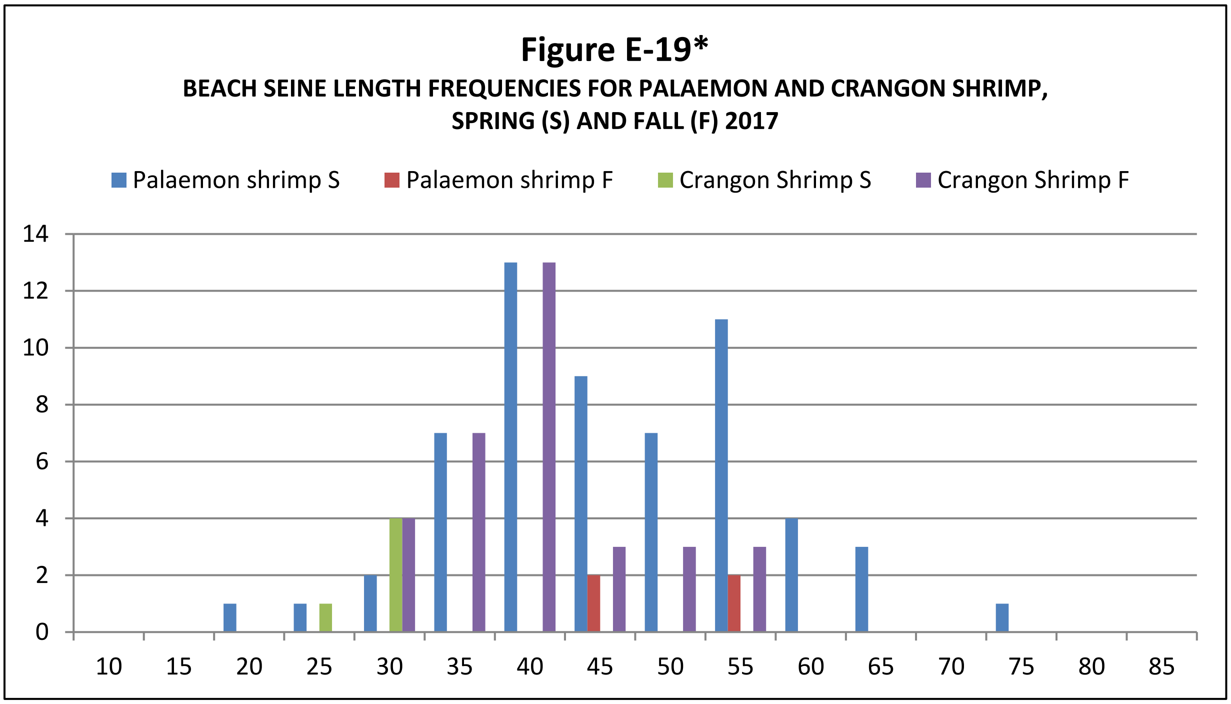
* Lengths of Sacramento Splittail collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.



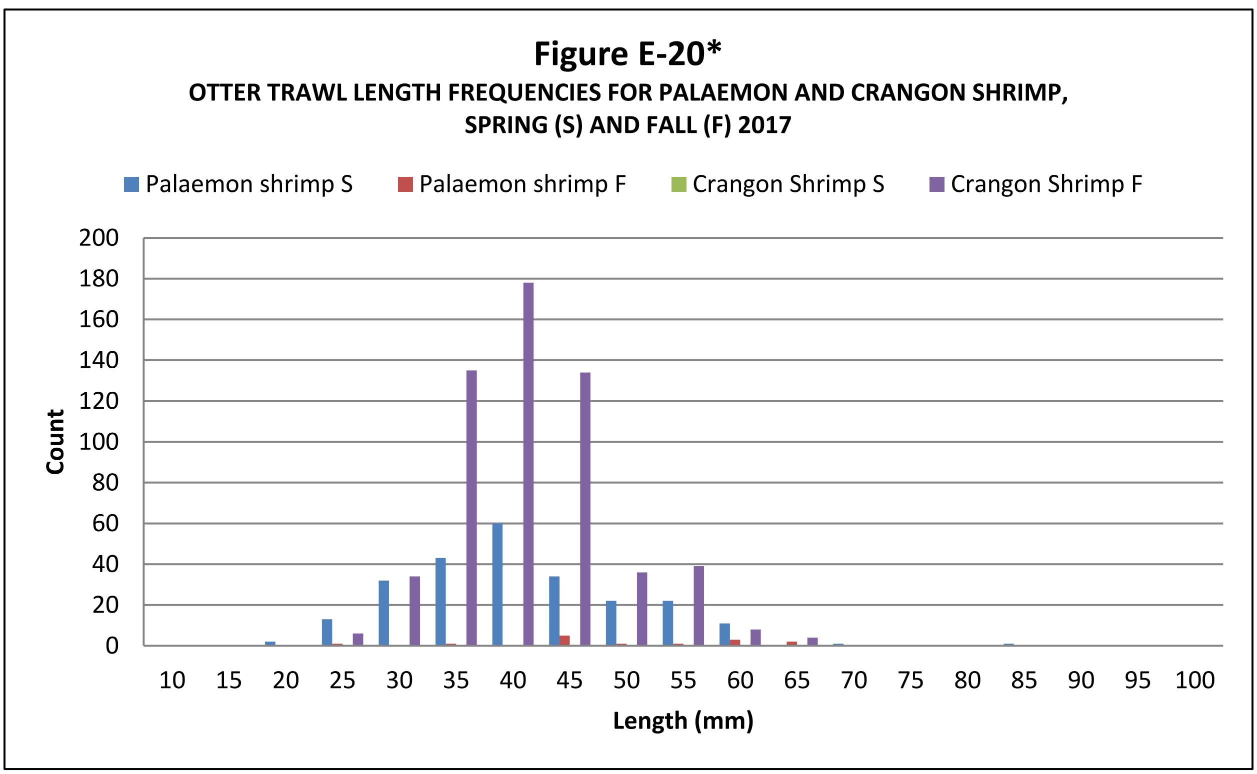
* Lengths of Pacific Staghorn Sculpin collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.

Appendix E (cont.)

Length Frequency Figures



* Lengths of Palaemon and Crangon Shrimp collected by beach seine during spring and fall 2017 at the Sears Point Restoration Project.



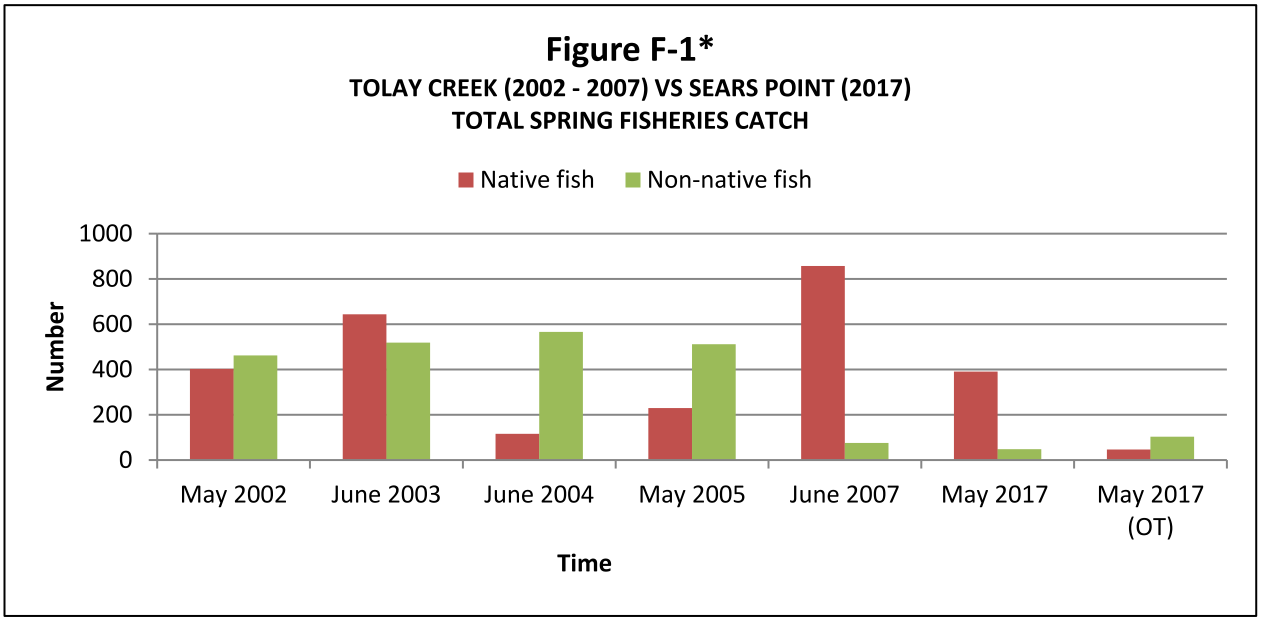
* Lengths of Palaemon and Crangon Shrimp collected by otter trawl during spring and fall 2017 at the Sears Point Restoration Project.

Appendix F

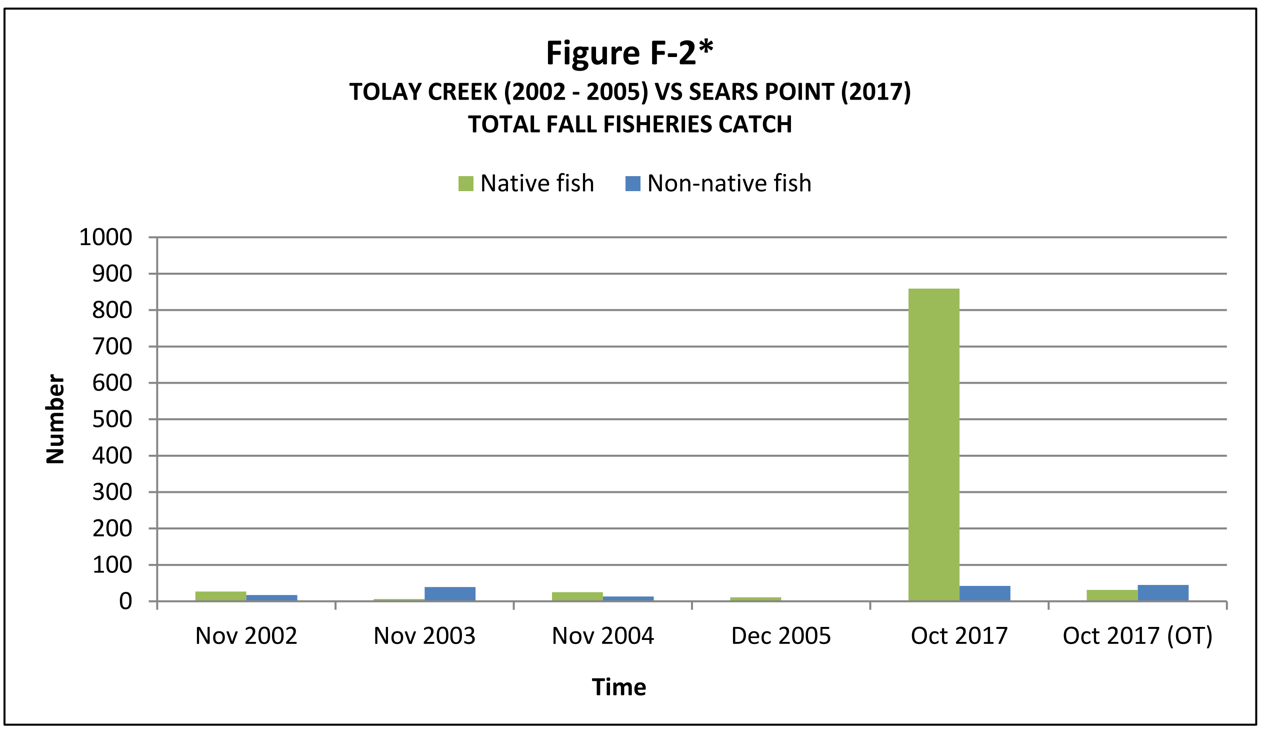
Comparison of Fish Catch at The Sears Point Restoration Project and Other Restored Areas in The Bay

Appendix F

Comparison of fish catch at the Sears Point Restoration Project and other restored areas in the Bay



* Abundance of native vs. non-native fish collected by beach seine during spring at the Tolay Creek Restoration Project (2002 - 2007) and the Sears Point Restoration Project (May 2017). OT indicates the otter trawl catch at Sears Point Restoration Project in May 2017.



* Abundance of native vs. non-native fish collected by beach seine during fall at the Tolay Creek Restoration Project (2002 -2005) and the Sears Point Restoration Project (Oct 2017). OT indicates the otter trawl catch at Sears Point Restoration Project in Oct 2017.

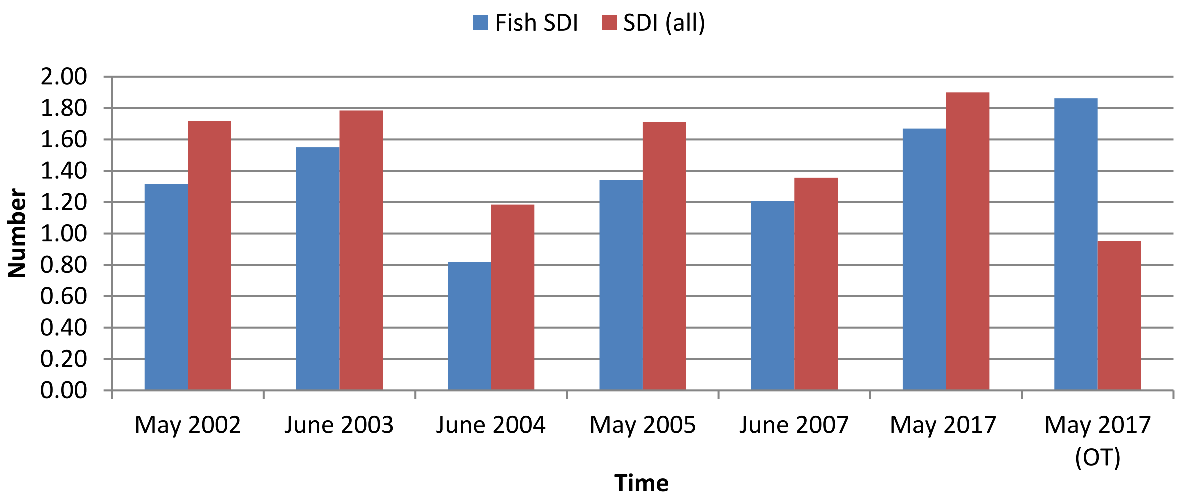
Appendix I

Appendix F

Comparison of fish catch at the Sears Point Restoration Project and other restored areas in the Bay

Figure F-3

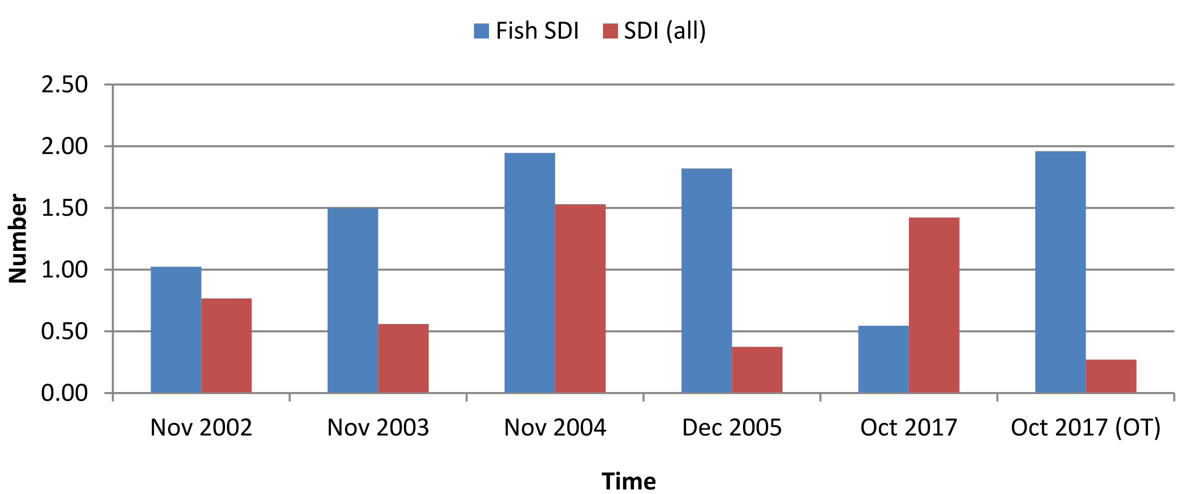
SHANNON DIVERSITY INDICES FOR THE TOLAY CREEK (2002 - 2007) AND SEARS POINT (2017) SPRING FISHERIES CATCH



* Shannon Diversity indices for fish collected by beach seine during spring at the Tolay Creek Restoration Project (2002 -2007) and the Sears Point Restoration Project (May 2017). Fish SDI includes fish only, SDI all includes fish and crustaceans. OT indicates the otter trawl catch at Sears Point Restoration Project in May 2017.

Figure F-4

SHANNON DIVERSITY INDICES FOR THE TOLAY CREEK (2002 - 2005) AND SEARS POINT (2017) FALL FISHERIES CATCH



* Shannon Diversity indices for fish collected by beach seine during fall at the Tolay Creek Restoration Project (2002 -2005) and the Sears Point Restoration Project (Oct 2017). Fish SDI includes fish only, SDI all includes fish and crustaceans. OT indicates the otter trawl catch at Sears Point Restoration Project in Oct 2017.

Appendix G

Sampling Photos

Figure G-1. ARIS camera attached to the stationary stand with transect mount attached to the boat behind.

Figure G-2. Pacific herring and threadfin shad captured with seine nets at the Sears Point Restoration Project.

Figure G-3. Conducting an ARIS survey with the stationary mount visible in the background.

Figure G-4. Monitoring beach seine efforts with the ARIS camera.

Figure G-5. Processing the seine haul.

Figure G-6. Retrieving a seine haul.

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Figure G-7. Processing the seine haul

Figure G-8. Setting and processing the seine net

Figure G-9. Measuring a striped bass from a seine haul.

Figure G-10. Retrieving a seine haul from seine site S1, Sidecast Ridge.

Figure G-11. Processing a striped bass collected in fall from seine site S8.

Figure G-12. Processing a California Halibut collected from trawl site T1 in fall, near the Midshipman Slough breach.