FINAL REPORT

FISHERIES IN RESTORED SOUTH BAY WETLANDS AND ADJACENT HABITATS

Prepared for
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March 2008

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In recent history 80-95% of tidal wetland in the San Francisco Bay-Delta Estuary was reclaimed for urban development, agriculture, and salt production. In South San Francisco Bay (South Bay) commercial salt production begun in approximately 1894 ultimately converted 26,000 acres to solar evaporation ponds. Restoration of more than 15,000 acres of former South Bay salt ponds will occur over the next decades. Salt pond restoration goals include creating multiple habitat types such as intertidal flats, tidal marshes, tidal channels and managed ponds (Goals Project 1999). The National Oceanic and Atmospheric Administration (NOAA) Restoration Center sponsored this study to learn more about fish use of restored South Bay wetlands, particularly wetlands created in former salt ponds, to inform the design of future restoration efforts.

Fish habitats in the South Bay include the deep bay channels, shallow open water, submerged aquatic vegetation beds, hard substrate rocks or reefs, river mouths, intertidal flats, tidal marshes, tidal channels, and managed ponds (Goals Project 1999). The conditions in these habitats are influenced by many factors including the generally shallow bathymetry of South San Francisco Bay, seasonal fluvial outflow, limited water circulation, easily warmed water temperatures, and turbidity generated by wind/wave suspended sediment.

Habitat suitability for fish species and life history stages may be influenced by a number of factors including: channel depth, channel and marsh plain hydroperiod, drainage basin area and characteristics (floodplains are a source of primary productivity and food for fish); the species and percent cover of marsh vegetation; the substrate type and slope of the channel sides, which may influence spawning habitat; water temperature and salinity which may be influenced by water residence time and freshwater inputs, as well as other water quality parameters.

This report discusses data from multiple studies of nearshore habitats, defined as intertidal flats, tidal marshes, tidal channels, and managed ponds. The report’s first part presents results of a study conducted by URS in 2006 for NOAA that surveyed fish and abiotic characteristics of tidal channels in four South Bay restored wetlands. Fish were sampled in spring, summer, late summer, and fall of 2006, at multiple sites within 4 restored salt ponds. Data on abiotic habitat characteristics were also collected during sampling. Empirical data are presented and correlations discussed between microhabitat characteristics such as channel width and fish species presence and relative abundance.

The second part of the report reviews and analyses several South Bay fisheries datasets from a continuum of shallow nearshore habitats in the South San Francisco Bay including intertidal mudflats, tidal marshes, tidal channels, and managed ponds.

The multi-habitat analysis includes data from the following studies:

- NOAA tidal wetland study described in part 1 of this report;
- Woods (1984) Cogswell Marsh study immediately post breaching collected monthly otter trawl data in June 1980-May 1981;
- US Geological Survey (USGS) study of tidal channels and managed former salt ponds, conducted in March, June, September and November of 2004 and March and June of 2005 (USGS 2006); and
- California Department of Fish and Game (CDFG) (Baxter et. al. 1999), 1980-1986, beach seine data collected from South Bay intertidal mud flats.

A comprehensive list of field sampling lessons learned is provided to inform future fisheries biologists monitoring in restored habitats.

1.1 STUDY OBJECTIVES

The three primary study objectives are to identify fish use in wetlands restored in former South Bay salt ponds and to identify the habitat features associated with fish species occurrence and abundance (utilization). Specifically, the following questions are addressed:

- Are there relationships between habitat characteristics, in particular channel bathymetry (top width, depth, and side slope) and drainage area and fish species relative abundance and use?
- Is fish species presence or abundance influenced by site or season, e.g., varying seasonal patterns of life stage use?
- What can be learned about fish use across habitats and how does a mature wetland support the greater fisheries of the bay?

1.2 STUDY AREA

Study sites for the sampling effort were selected from a list of ten restored tidal wetlands (Appendix A) after a field visit with NOAA staff on February 9, 2006, Figure 1-1. Site selection criteria were: former salt ponds, large surface area, South Bay east and west shoreline locations, number of years and habitat development since breaching (presence of wetland vegetation and subtidal channels), proximity to other sampling programs (e.g., USGS salt pond and slough study) or previous fisheries surveys. Sites considered for the study but not sampled were: La Riviere Marsh and Bayside Business Park in Fremont, Charleston Slough and Cooley Landing in Palo Alto, Pond 3 in Union City, and Oro Loma Marsh in Hayward. Reasons for not including these sites were distance to the bay, poor access, lack of wetland features development, incompatibility with available sampling equipment. The sites selected for the sampling were Bair Island, Cargill, Cogswell Marsh, and Faber Tract (Figures 1-2 to 1-5). Sites included in the cross-study data analysis were selected based on location in the South Bay, and/or at the sampling sites, comparable methods and habitats, or complementary habitats. These datasets will be described in detail in Section 3.

1.2.1 Bair Island

The Bair Island, Figure 1-2, complex comprised of Inner, Middle, and Outer Bair Islands and segments of Redwood Creek, Steinberger Slough, Corkscrew Slough, and Smith Slough is located on the west side of the South Bay in Redwood City, California. Bair Island was historically part of a large complex of tidal marshes and mudflats prior to diking in the late 1800s and early 1900s for agricultural uses. In 1946, Bair Island was converted to salt evaporation ponds until 1965 when the ponds were drained and abandoned.

Restoration of Outer Bair Island, an 800-acre salt pond owned by California Department of Fish and Game (CDFG), began when tides breached the levee in 1975, then in 1979 the levee was breached on the west end, and another breach was constructed on the east end of the levee in 1983. Current breach widths measured using aerial images and GIS were: 459 and 643 feet to the South Bay, 94 feet to Steinberger Slough (located approximately 2,950 ft from the bay), and a

154 foot wide breach to Corkscrew Slough (located approximately 2,450 feet from Redwood Creek). Outer Bair's slough channel network is not comprised of a typical dendritic pattern because of the multiple breaches and perimeter sloughs, instead many channels flood and drain in two directions. (This unique hydrology made it impossible to define drainage area for specific sampling stations.) The restoration required limited channel excavation to improve tidal circulation and limited planting of cordgrass. Natural recruitment of cordgrass (*Spartina foliosa*) and pickleweed (*Salicornia* spp.) resulted in 70% vegetation cover by 1990 (15 years after the first breach). An approximately 3,000-ft wide intertidal mudflat is located adjacent to Outer Bair Island. Shallow water extends offshore to the deepwater shipping channel through the South Bay approximately 6,000 ft offshore of Outer Bair.

1.2.2 Cargill Mitigation Marsh

The Cargill Mitigation Marsh, Figure 1-3, is located on the east side of the South Bay near Union City, California, immediately in-board of Whale's Tail Marsh. Cargill created the 49-acre site by constructing a levee to separate it from a salt evaporation pond as mitigation required for salt facility operation, repair, and construction. The goal of the mitigation was to create a self-sustaining tidal wetland within the former salt evaporation pond with subtidal, intertidal mudflats, tidal channels, and vegetated marsh habitats. Native vegetation was planted in portions of the site, but rapid colonization by the non-native cordgrass also occurred at the upper elevations. The outer levee was breached in two locations in 1996 and 1999 to introduce tidal action to the mitigation site. The wider southern breach (138 feet, Figure 1-3) connects to South San Francisco Bay by an approximately 1,700 foot channel compared with the smaller northern breach (12 ft) located 2,200 feet from the South Bay. Old Alameda Creek flows into the South Bay immediately north of the site, but does not directly influence the hydrology of the Cargill Mitigation Marsh.

1.2.3 Cogswell Marsh

Cogswell Marsh, formerly known as Hayward Marsh, Figure 1-4, is located north of the Hayward-San Mateo Bridge on the east side of the South San Francisco Bay. The 200-acre former salt evaporation pond was breached in1980 as mitigation for wetland impacts associated with Dumbarton Bridge construction. Cogswell Marsh is part of East Bay Regional Park District's Hayward Regional Shoreline which is comprised of 1,697 acres of salt, fresh, and brackish water marshes, seasonal wetlands, and public trails. Cogswell Marsh is comprised of three distinct areas, the north unit, south unit, and east unit. The north and south breaches are 767 feet and 259 feet, respectively. The east unit is connected to the north unit by a channel. Each unit includes multiple habitats, e.g., intertidal mudflats, tidal channels, and vegetated marsh habitat. At the beginning of the study the main subtidal channel in the south unit received flow from the marsh located immediately south of Cogswell Marsh.

1.2.4 Faber Tract Marsh

Faber Tract Marsh, Figure 1-5, is located on the west side of the South San Francisco Bay near East Palo Alto, California. The 90-acre site, owned by the United States Fish and Wildlife Service (USFWS), differs from the other three study sites because it was not a former salt pond. Faber Tract Marsh was a diked wetland that received dredged materials excavated from the Palo

Alto Yacht Harbor until restoration began by breaching the levee in July 1971. Cordgrass (450 plugs) was planted soon after the site was breached, however, 90% of the plugs planted above mean high water (MHW) did not survive, and after three years pickleweed had naturally colonized 75% of the site below MHW. The marsh was fully vegetated in 2006. Tides flow through a single 159 foot wide breach. The marsh is adjacent to the Palo Alto airport and San Francisquito Creek; however, there is no surface hydrological connection between the creek and marsh except through the bay.

1.2.5 Site Characteristics

The NOAA study sampled tidal marsh channels, the network distributing, and draining tides to the vegetated marsh plain. The system of tidal channels in a tidal marsh can vary in size (topwidth and drainage area) and complexity; including the number of tributary channels, channel density, sinuosity, bathymetry, and the number of outlets to the bay. Tidal channel types can be broken down into channels that always contain water (subtidal) and channels that drain completely (intertidal). The presence or absence of fluvial (freshwater) flow into the channel is also an important factor influencing the habitat characteristics of tidal channels and marshes.

Basic physical parameters were measured to characterize the sites, Table 1-1. Air and water temperature were measured at each sampling location with an alcohol thermometer. Dissolved oxygen was measured with a YSI 51B field meter and pH was measured using an Oakton Instruments pHTestr 1 probe at each wetland. Water temperatures ranged from 14-19^{o}Centigrade (°C) in spring and peaked at 29^{o}C at Faber Tract Marsh in summer. Dissolved oxygen was generally measured at greater than 5 milligrams per liter (mg/l) which is established by the Regional Water Quality Control Board's Basin Plan (CRWQCB 2007) as protective of beneficial uses. However, two measurements dipped to 4.6 and 4.7 mg/l in association with the high July temperature recorded at Faber Tract Marsh. The pH range was from 7.6 to 8.8 units among the sites. Water salinity exhibited typical San Francisco estuarine variation ranging from 9 parts per thousand (ppt) in March and increasing to 31 ppt in September and October.

Table 1-1 Site Air and Water Temperature, Dissolved Oxygen, pH and Salinity

Site	Date	Water Temp. (^{o}C)	Air Temp (^{o}C)	Dissolved Oxygen (mg/L)	pH (units)	Salinity (ppt)
Bair Island	3/29/2006	14	18	9.5	8.3	18
Bair Island	6/29/2006	26	25	6.7	8.0	18
Bair Island	9/5/2006	21	19	7.5	7.7	27
Bair Island	10/18/206	17	21	6.1	8.0	30
Cargill	3/13/2006	16	No data	9.2	8.2	16
Cargill	6/9/2006	21	26	6.6	7.6	22
Cargill	9/6/2006	18	27	7.0	8.1	31
Cargill	10/3/2006	23	No data	9.4	8.3	30
Cogswell	3/23/2006	19	18	13.2	8.8	9

Table 1-1 Site Air and Water Temperature, Dissolved Oxygen, pH and Salinity

Site	Date	Water Temp. (°C)	Air Temp (°C)	Dissolved Oxygen (mg/L)	pH (units)	Salinity (ppt)
Cogswell	6/23/2006	24	21	5.8	7.8	19
Cogswell	6/23/2006	27	No data	6.4	8.0	17
Cogswell	9/20/2006	21	No data	4.6	8.4	26
Cogswell	11/6/2006	17	18	6.8	8.2	27
Faber	4/10/2006	15	No data	10.0	8.3	10
Faber	7/25/2006	29	29	4.7	7.7	18
Faber	9/19/2006	No data	22	6.0	7.9	25
Faber	10/19/2006	16	No data	5.6	7.8	24

1.2.6 Subsites

Within each wetland site, several sampling stations "subsites" were selected and the subsite locations are shown in Figures 1-2 to 1-5. Subsite selection was influenced by the following criteria:

a) sample a variety of channel widths and distances from the breach,

b) avoid impacts to sensitive species and their habitats: adjacency to steelhead (*Oncorhynchus mykiss*) spawning streams was avoided and affects to the federally endangered California clapper rail (*Rallus longirostris obsoletus*) were minimized by:

    i) not sampling in narrow channels in Faber Tract Marsh, Cogswell Marsh, and Bair Island where rails are known to occur, or until after nesting season;

    ii) minimizing walking across the wetland vegetation by walking on unvegetated channel banks and working from a boat whenever feasible; and,

    iii) working the beach seine when the tide is low enough to expose beach/mudflat for haul-out to avoid walking on vegetation.

c) ability to use standard fish sampling equipment, e.g.:

    i) beach seine sites with an unobstructed bottom surface and a large enough area to haul the seine onto relatively gentle unvegetated slope

    ii) channels with maximum synergy and efficiency among trawl width, mesh size, boat motor power and few submerged obstructions, such as snags

d) accessibility to launch facilities or a suitable levee slope and surface for launching a boat or canoe.

Figure 1-6 Small channels in northwest corner of Faber Tract, not sampled until October to avoid disturbing California clapper rail habitat

The NOAA study sampled tidal marsh channels, the network distributing, and draining tides to the vegetated marsh plain. Table 1-2 presents the sampling schedule and equipment for each sampling subsite, gear, and channel characteristics: slope, channel top width, and depth**.** The tidal channel network in a tidal marsh can vary in size (topwidth and drainage area) and complexity; including the number of tributary channels, channel density, sinuosity, bathymetry, and the number of breaches connecting the marsh to the bay. Each of the marsh study sites contained both subtidal channels and intertidal channels. The presence or absence of fluvial (freshwater outflow from upstream in the watershed) flow into the wetland influences marsh and channel habitat. Bathymetry for three cross sections at each study site is displayed in Figure 1-7. Channel slopes ranged from steeply sloped sides at 1:1 (e.g., Bair Island Station 8) to very gentle slopes of 11:1 at Station 47 in Cogswell Marsh. Some channels included an incised thalweg (e.g., Cargill Station 22) and some were too deep even at lower low water to collect cross section data. The vast majority of sampling subsites had unconsolidated fine mud substrates, up to a foot in depth. The exception was at subsites 9 and 73 where the substrate was comprised of sand with shell fragments.

Table 1-2 Sampling Site, Subsites, Haul Types, Dates, Slope, Channel Top Width, and Depth

Marsh	Sampling Event	Equipment	Month and Day 2006	Vegetation at channel cross section terminus	Slope, Left Bank	Slope, Right Bank	Channel Top Width (ft.)[b]	Depth at Thalweg (ft.)
Bair Island	1,2,3,4,5,	Otter Trawl	3/29	*Salicornia virginica*			66, 64, 77, 89, 88	
	6, 12, 15	Seine	6/29, 9/5, 10/	*S. virginica*	1:1	Nd	**21**	0.6
	7	Gillnet #1	6/29	*a) S. virginica, Jaumea carnosa, b) Spartina sp.*	3:1	4:3	**50**	3.4
	10	Gillnet #1	9/5		6:1	14:5	**75**	4.6
	8, 11, 14	Gillnet #2	6/29	*a) S. virginica, Jaumea carnosa, b) Spartina sp.*	1.5:1	9:4	**46**	4.3
	8, 11, 14	Gillnet #2	9/5		10:3	4:1.5	**42**	2.2
	9	Otter Trawl	9/5				c	
Cargill	20	Seine	3/13	*Spartina sp.*			121	
	22	Seine	8/29[a]	*Spartina sp. Then S. virginica*	2:1	10:3	**33**	4.3
	25, 27	Seine	8/29[a]	*Spartina sp.*	16:3	1:1	**34**	3.4
	21	Seine	8/29[a]	*Spartina sp. Then S. virginica*	9:2	5:2	31	3.1
	23	Gill net	6/9				32	
	24	Gill net #1	9/6		4:3	6:1	**28**	3.6
	26	Seine	9/6					
	28	Seine	10/3	*Spartina sp.*			48	
	29	Seine	10/3				36	

Table 1-2 Sampling Site, Subsites, Haul Types, Dates, Slope, Channel Top Width, and Depth

Marsh	Sampling Event	Equipment	Month and Day 2006	Vegetation at channel cross section terminus	Slope, Left Bank	Slope, Right Bank	Channel Top Width (ft.)[b]	Depth at Thalweg (ft.)
Cogswell	40	Seine	3/23	*Spartina sp.* Then *S. virginica*	6:1	9:1	**56**	.7
	42, 43, 44, 45	Otter trawl	6/23	Not applicable	d			
	41, 46, 50	Gillnet	3/23, 6/23, 9/20	*Spartina sp.* Then *S. virginica*	3:1	1:1	**18**	1.6
	47	Seine	6/23		11:1	4:1	**62**	1
	48, 51	Seine	3/23		N/A	6:1	**29**	.5
	52	Otter Trawl	11/6				D	
	53	Gill net	11/6				50	
	54	Seine	11/6				15	
Faber Tract	60, 64, 67, 72	Seine across 2 channels	4/10, 7/25, 9/19, 10/19	*Spartina sp.* Then *S. virginica*	3:1 3:1	2:1 1:2	**46** **15**	2.76 2.37
	61, 62	Gill net	4/10		5:1	9:1	61	5.07
	63	Gill net	7/25				121	
	65	Gill net	9/19				52	
	66	Gill net	9/19				94	
	68 (e)	Seine	10/19				30	
	69	Gill net	10/19	*Spartina* sp.			135	
	70	Gill net	10/19	*Spartina sp.* Then *S. virginica*			127	
	71	Gill net	10/19	*Spartina sp.* Then *S. virginica*			29	
	73	Seine	10/19	*Spartina sp.* Then *S. virginica*			65	

a = Channel cross section data not collected during a sampling event
b =Channel width measured in field (bolded) or from 2004 High
c = Otter trawl was deployed through edge of the bay, width not applicable
d = Otter trawl was deployed through an embayment at mouth of Cogswell Marsh, channel width is not applicable

1.2.7 Acknowledgements

Site access was authorized and facilitated by numerous agency land managers. Their cooperation was essential to the field survey work and their assistance is gratefully acknowledged.

- Joy Albertson and Clyde Morris - U.S. Fish and Wildlife Service for reconnaissance access, permission to sample at Bair Island and Faber Tract Marsh, and for California clapper rail consultation,
- Mark Taylor, Pete Alexander, Joe DiDonato – East Bay Regional Park Service for sampling permission at Cogswell Marsh, boat use for otter trawling and for allowing us to wash equipment at park headquarters,
- John Krause and Kathy Heib – California Department of Fish and Game for access to Cargill and Bair Island and for providing fisheries study data,
- Daren Anderson – City of Palo Alto for access to Faber Tract Marsh,
- Mike Saiki and Francine Mejia – USGS for providing fisheries study data,
- John Fritz for access and boat assistance at Bair Island,
- Natalie Cosantino-Manning and Gillian O’Doherty – NOAA Restoration Center for study support and review.

The following four pages, Figure 1-7, display three channel cross sections from each site: Bair Island, Cargill Mitigation Marsh, Cogswell Marsh, and Faber Tract Marsh.

0 2.5 5 10 Miles

N

L:\Projects\NOAA_Fisheries_26815264\Maps\sampling_stations.mxd

URS	NOAA Fish Model 26815264	SOUTH BAY SITES OVERVIEW	Figure 1-1

0 800 1,600

1 inch equals 1,000 feet

URS

NOAA Fisheries
Bair Island
Sample Subsites

Figure 1-2

November 2007

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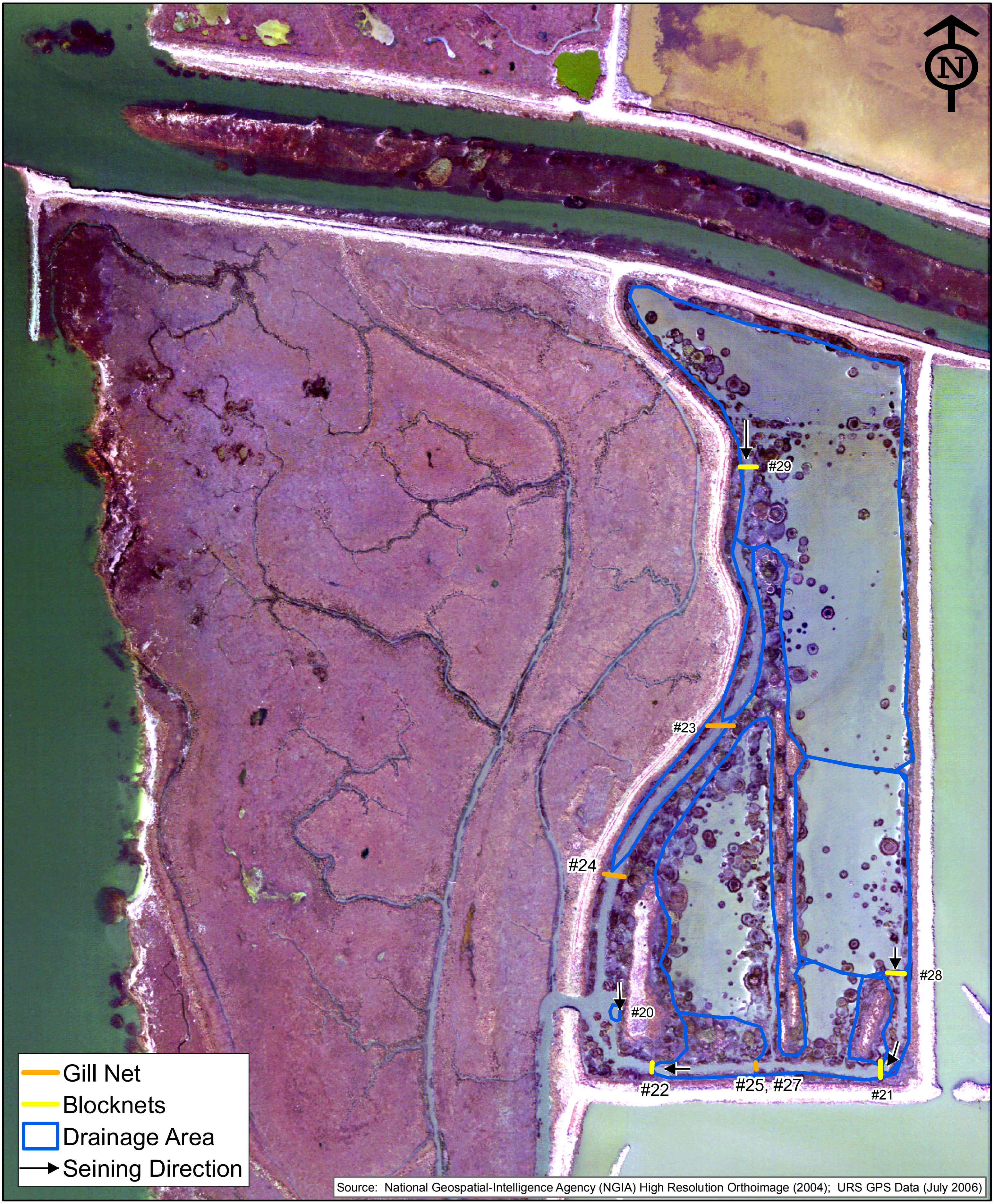

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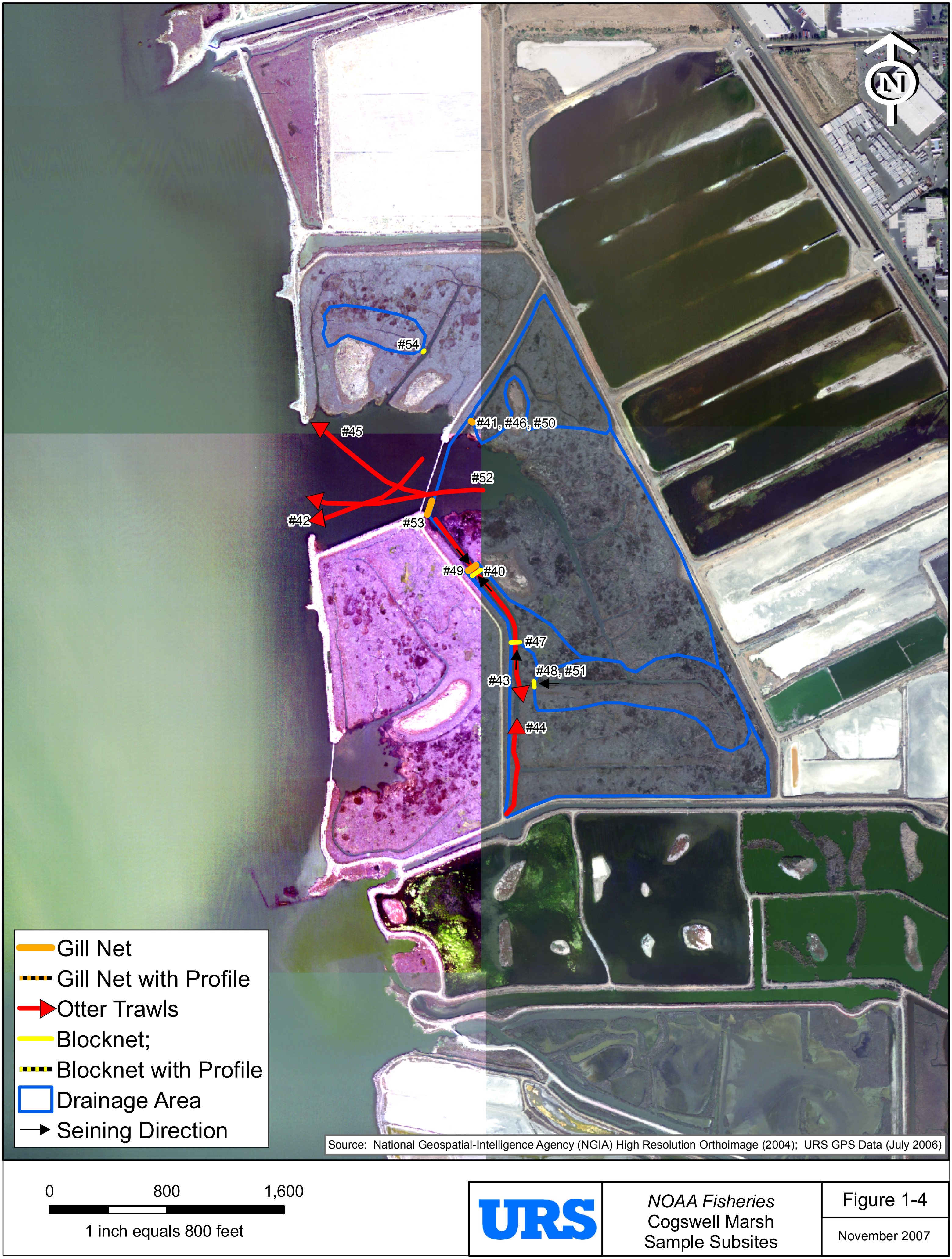
0 200 400 800

1 inch equals 400 feet

URS	*NOAA Fisheries* Cargill Mitigation Marsh Sample Subsites	Figure 1-3 November 2007



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URS	*NOAA Fisheries* Cogswell Marsh Sample Subsites	Figure 1-4 November 2007

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0 200 400 800

1 inch equals 400 feet

URS

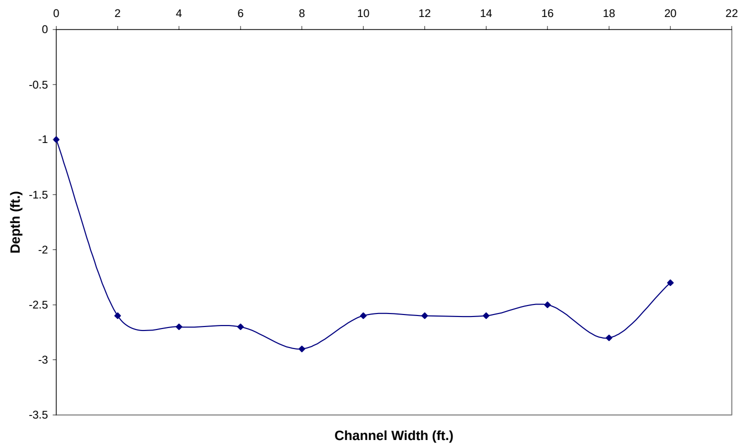
NOAA Fisheries
Faber Tract
Sample Subsites

Figure 1-5

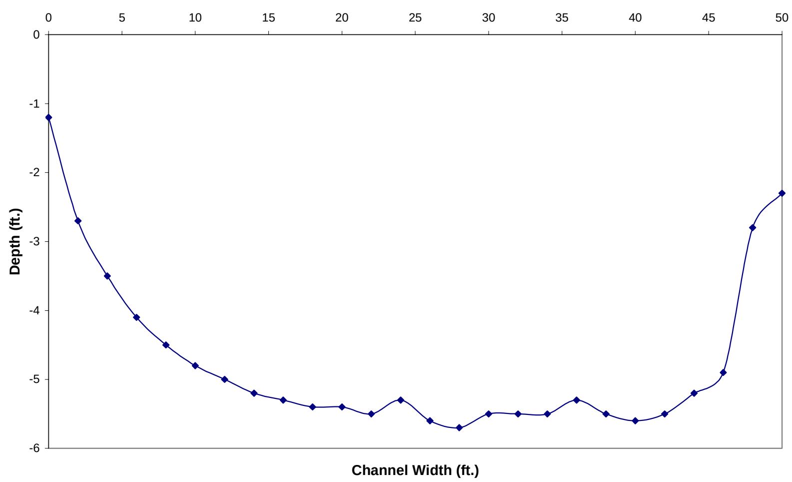
November 2007

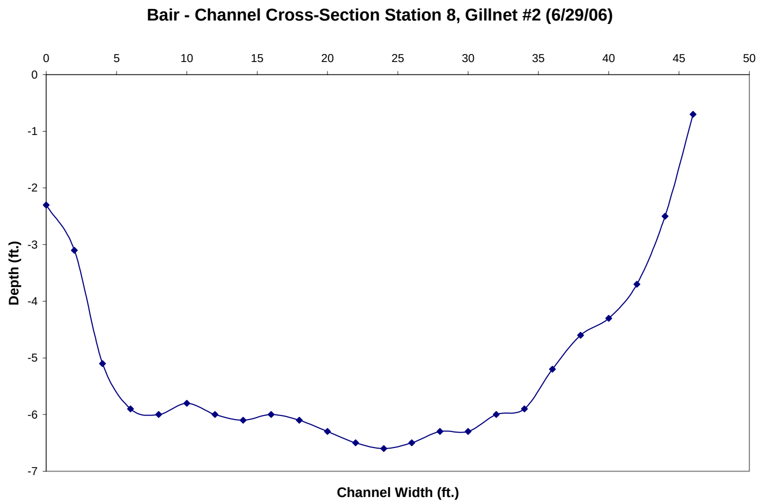
Figure 1-7 Channel Bathymetry (3 cross sections each: Bair, Cargill, Cogswell, Faber)

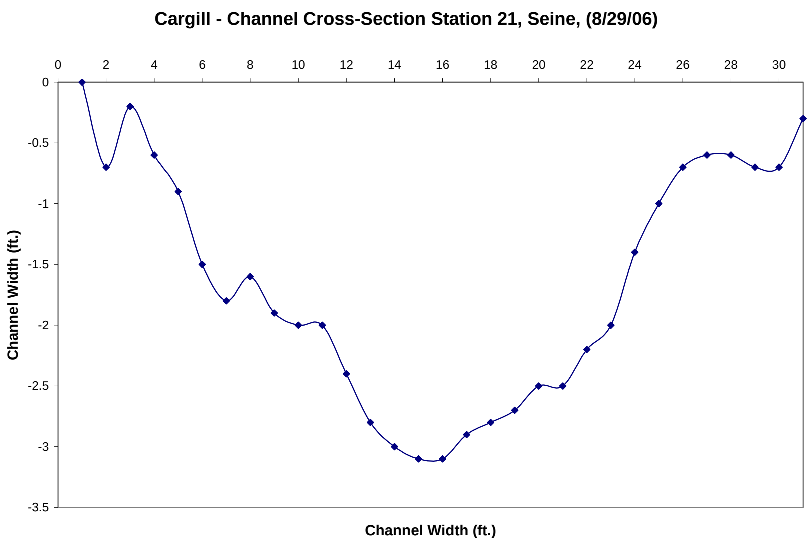
Bair - Channel Cross-Section, Station 6, Seine #3 (6/29/06)

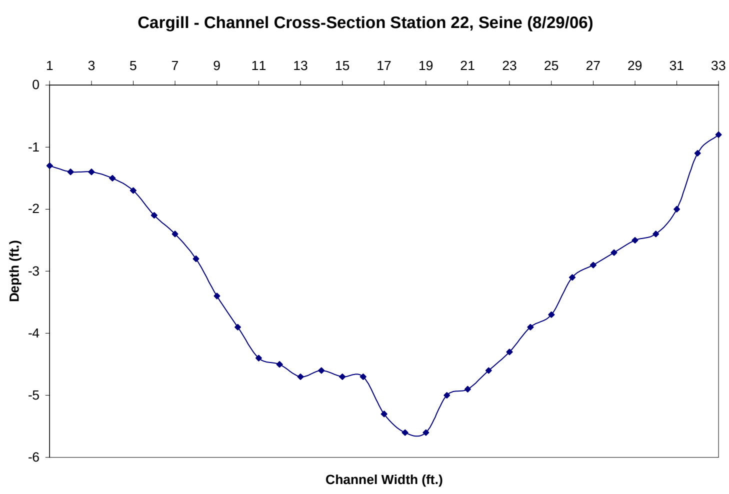


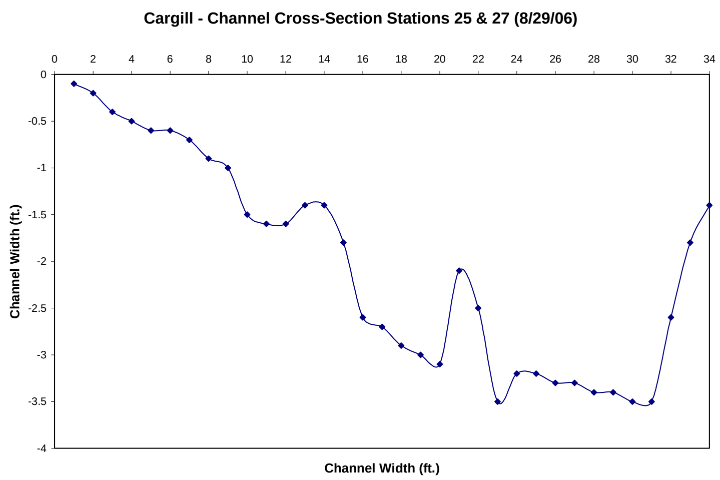
Bair - Channel Cross-Section, Station 7, Gillnet #1 (6/29/06)

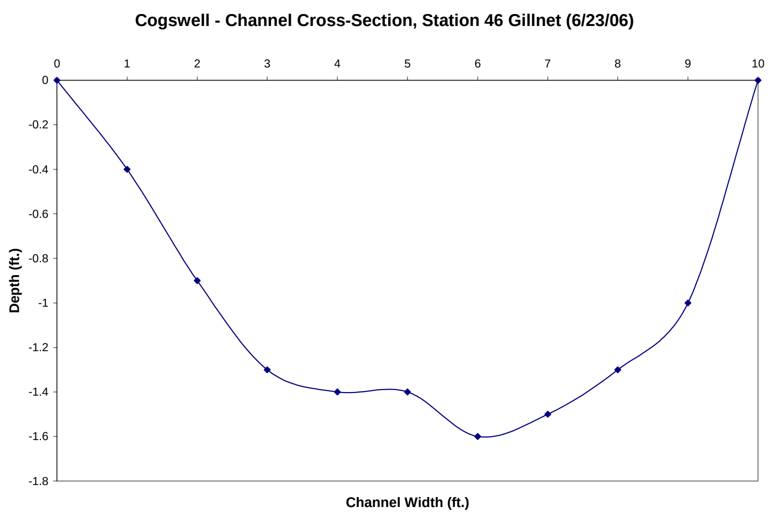


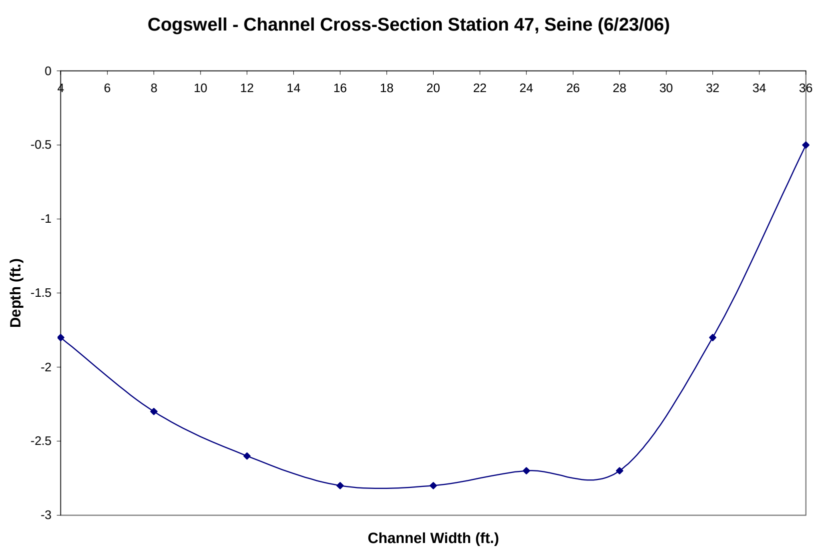

Bair - Channel Cross-Section Station 8, Gillnet #2 (6/29/06)
0
5
10
15
20
25
30
35
40
45
50
0
-1
-2
-3
-4
-5
-6
-7
Depth (ft.)
Channel Width (ft.)


Cargill - Channel Cross-Section Station 21, Seine, (8/29/06)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
Channel Width (ft.)
Channel Width (ft.)

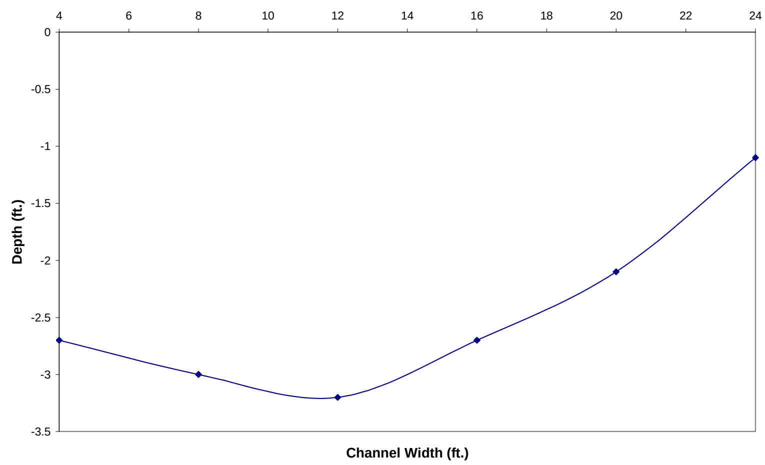

Cargill - Channel Cross-Section Station 22, Seine (8/29/06)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
0
-1
-2
-3
-4
-5
-6
Depth (ft.)
Channel Width (ft.)


Cargill - Channel Cross-Section Stations 25 & 27 (8/29/06)
Channel Width (ft.)
Channel Width (ft.)

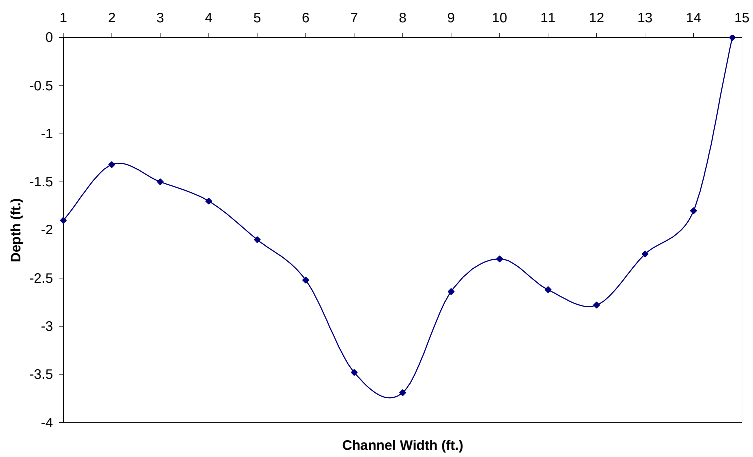

Cogswell - Channel Cross-Section, Station 46 Gillnet (6/23/06)
Depth (ft.)
Channel Width (ft.)


Cogswell - Channel Cross-Section Station 47, Seine (6/23/06)
Depth (ft.)
Channel Width (ft.)

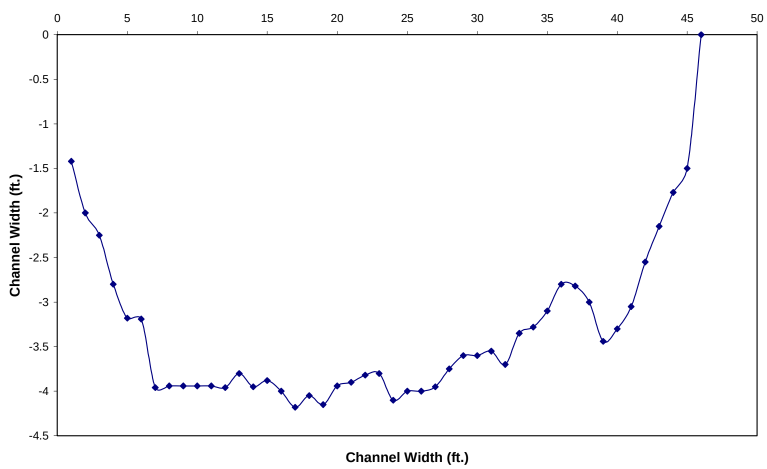
Cogswell - Channel Cross-Section Station 48, Seine (6/23/06)



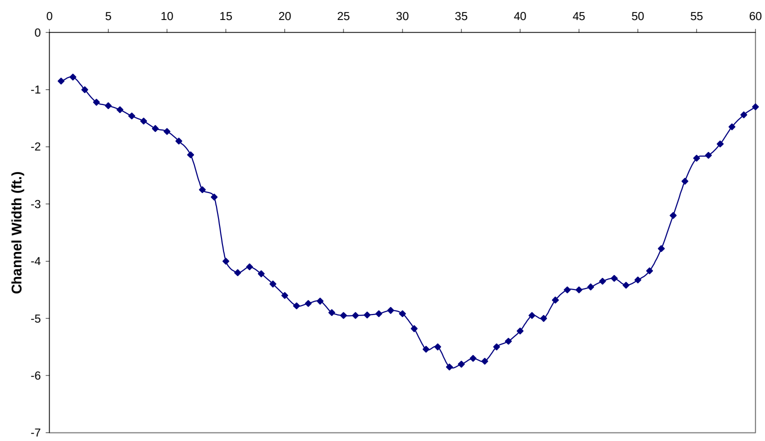
Faber Tract - Channel Cross-Section Station 60a, Seine (4/10/06)



Faber Tract - Channel Cross-Section Station 60b, Seine (4/10/06)



Faber Tract - Channel Cross-Section Station 61, Gill net (4/10/06)



Section 2 describes the field data collection and sampling program methods, gear types, fish processing, sampling limitations, and the data analysis methods.

2.1 SAMPLING METHODS

Sampling was conducted at multiple subsites in each wetland site using several sampling methods as described below for beach seine, gill nets, and otter trawl. Sampling schedule was selected to match the USGS fisheries study schedule. Table 2-1 lists gear type and number of deployments at each wetland site during each seasonal sampling event. The locations of each deployment and gear type are depicted on Figures 1-2 to 1-5.

2.1.1 Gear Types

Beach seine – Beach seines, ¼ inch mesh, 25 feet long by 3 feet in height and 30 feet long by 4 feet tall were generally deployed in conjunction with block nets to facilitate capture in channels. Beach seines were occasionally used without block nets, for example to capture leopard sharks observed at the edge of the bay. Block nets (1/8 inch mesh by 5 feet in height) were set on the outgoing tide by wading and by boat in deeper water habitat. In subtidal channels the beach seine was used once the water was low enough to work the channel efficiently, usually 3 to 5 hours after setting the block net, Figure 2-6. Seine pulls were for distances varying from 25 meters to 50 meters towards the block net. One to two sets were performed during each sampling. In intertidal channels fish were processed from behind the block net without seining, and immediately returned to downstream flows. Invasive sampling on the marsh plain was prohibited because of the need to protect California clapper rails and their habitat. Therefore fish use of the marsh plain was estimated by setting a block net in the mouth of small intertidal channels and collecting fish confined by the blocknet's 1/8th inch mesh on the ebbing tide.

Figure 2-1 Beach seine worked toward block net on ebbing tide at Cargill mitigation marsh site

Gill nets – Three gill net mesh sizes were used to collect fish in both large and small channels. The nylon monofilament nets were 6 feet in height by 50 feet long. Each net had one size mesh: half inch, three-quarters of an inch and 2 inches, depending on the net. The gill nets were set by boat in strategic locations across channels just after the flood tide had turned and begun to ebb. The gill nets were retrieved 2 to 5 hours later. The short set times minimized impacts to the captured fish. The nets did not always span the entire channel width. In wider channels the gill nets were often set with different mesh sizes adjacent to each other stretching across a single cross section and in a narrower channel one net with one mesh size spanned the entire channel.

Figure 2-2 Gill net deployed at Cargill mitigation site breach

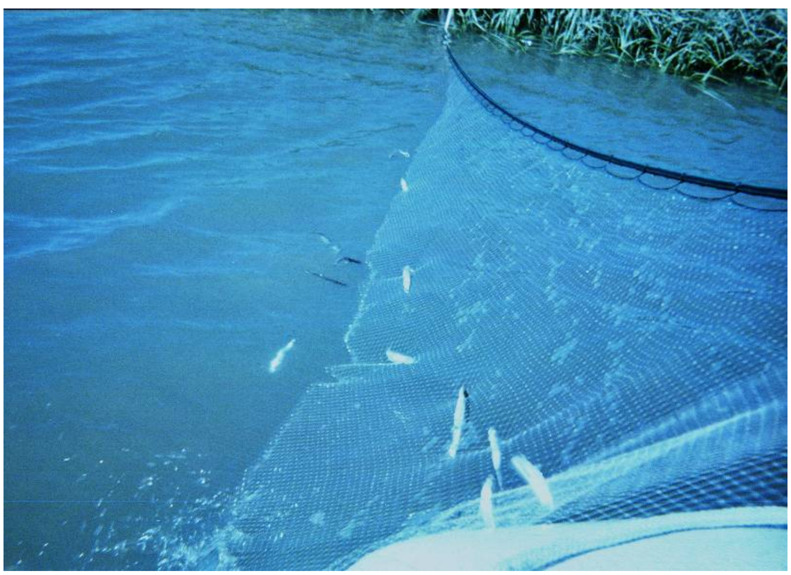


Figure 2-3 Gill net with topsmelt

Otter trawl – A 2.4 meter otter trawl was pulled behind a boat for 2 to 4 minutes, various distances, ranging from approximately 250 ft to 2,000 ft depending on conditions. The otter trawl consisted of nylon 0.625cm bar mesh throughout with a 0.313 cm bar mesh in the cod end. The otter boards were 50 cm by 26.25 cm and the bridle was 8.4 meters on each side. The otter trawl was pulled with a boat with a 25 horsepower engine.

2.1.2 Fish Processing

All fish captured were identified to species, except as noted, measured or counted as described below and released. Some larval gobies were recorded as goby species because of their small size and development stage. Both juvenile topsmelt (*Atherinops affinis*) and Mississippi silversides (*Menidia beryllina*) may have been recorded as topsmelt due to the difficulty in identification of smaller individuals. Other similar studies (USGS 2006) have used size as a way to differentiate between the two species. However, this method did not seem appropriate for this study, therefore no distinction was made. The fish of each species captured were measured in standard length, to the nearest 1 mm interval. After measuring a minimum of 20 individuals of a species, then the total number of fish was recorded, except if unrepresented size classes of fish were observed, then, their standard length was also measured and recorded. Gravid females were noted and lesions, parasites or other abnormalities were noted.

Figure 2-4 Identifying, measuring standard length and returning fish to channel, from the canoe

At each site abiotic variables were measured in the field. A Trimble GPS unit (GeoExplorer 1 and 3) was used to record the location of each subsite sampling location. Channel top width was measured in the field and from GIS aerial images, distance from the sampling subsite to the bay, and drainage area (acres of marsh plain draining to a sampling subsite) were measured using ArcGIS. At each sampling subsite channel cross section was characterized by stretching a line across the channel and at 1 foot intervals, measuring depth in feet and tenths. Vegetation species at each terminus of each cross section were observed and recorded.

Sampling schedule and gear use is presented in Table 2-1 and described below.

Bair Island: A total of 9 subsite locations were sampled using beach seine, gill net, or otter trawl 4 times throughout the year (March, June, September, and October). A beach seine was used to sample 1 location, 3 times throughout the year (June, September, and October). Gill nets were used to sample at two locations, 3 times throughout the year (June, September, and October). An otter trawl was used to sample 5 locations in March and 1 location in September.

Cargill Mitigation Marsh: A total of 7 subsite locations were sampled using either beach seine or gill net at 4 times throughout the year (March, June, September, and October). The beach seine was used at 5 locations (1 location was sampled once in October, 2 locations were sampled once in June, and 2 locations were sampled once in October). Gill nets were used at 2 locations (1 location was sampled once in September and 1 location was sampled twice in September and October).

Cogswell Marsh: A total of 12 subsite locations were sampled using beach seine, gill net, or otter trawl at 4 times throughout the year (March, June, September, and November). A beach seine was used at 4 locations (3 locations were sampled once in March, June, or November; and 1 location was sampled twice in June and September). An otter trawl was used at 5 locations (4 locations sampled in June and 1 location sampled in November).

Faber Tract Marsh: A total of 9 locations were sampled using either beach seine or gill net at 4 times throughout the year (April, July, September, and October). A beach seine was used at 3 locations (1 location was sampled 4 times in April, July, September, and October; and 2 locations were sampled 1 time in October. Gill nets were used at 6 locations (1 location was sampled twice and 5 locations were sampled once in July, September, or October).

2.1.3 Sampling Limitations

A variety of difficulties were encountered using each gear type. Minnow traps baited with dry and wet cat food and pickleweed did not catch fish. Towing the otter trawl with a 25 horse power engine put significant drag on the boat so that faster fish escaped. A small engine was used to decrease disturbance and to match the Woods protocol. Ebbing tidal velocities and flow volume sometimes ripped block nets off their moorings.

Highest tides flood the marsh plain making setting nets and maneuvering difficult. In addition vegetation entrained in outflow can overwhelm nets causing blowouts. Block nets set in channels were sometimes overtopped or had to be set after the tide receded enough to safely set the nets.

An assumption was made in fish sampling methodology that fish utilizing channels would be collected during ebbing tides. Because small channels could rarely be directly sampled, a method was devised to infer fish using small channels. To infer the fish using small channels, a block net was put in place near slack just before high tide, and then fish were sampled downstream of the net. The ability of these data to represent fish using small channels depends on two assumptions 1) fish using small channels are in small channels at slack just before high tide, which assumes that fish do not use and leave the channels before slack before high tide and 2) that there are no refugial pools or remaining channel water (such as would be found if at a relatively high low tide) in which fish could remain as the tide recedes.

The presence of special status species affected the sampling strategy. Sites known to support salmonid passage were avoided. Sampling in first order, narrow channels was minimized to avoid impacts to California clapper rail, which nests near small channels in marshes.

Table 2-1 Site, Season, Collection Gear and Number of Sets in Field Surveys

	Method	Spring (March/April)	Summer (June/ July)	Late Summer (Sept.)	Fall (Oct/Nov)	Total
Bair Island	Beach Seine	0	1	2	1	4
	Gill Net	0	2	2	2	6
	Otter Trawl	6	0	1	0	7
Cargill Mitigation Marsh	Beach Seine	1	2	1	2	6
	Gill Net	0	1	2	2	5
Cogswell Marsh	Beach Seine	2	2	1	2	7
	Gill Net	3	2	2	3	10
	Otter Trawl	0	6	0	1	7
Faber Tract Marsh	Beach Seine	1	1	1	3	6
	Gill Net	2	2	2	3	9
Totals	**Beach Seine**	**4**	**6**	**5**	**8**	**23**
	Gill Net	**5**	**7**	**8**	**10**	**30**
	Otter Trawl	**6**	**6**	**1**	**1**	**14**

2.2 DATA ANALYSIS METHODS

Two types of data analysis methods were used: Canonical Correspondence Analyses and statistical analysis using JMP.

Canonical Correspondence multi-variate analysis using PC-ORD (Version 4.41) was performed to identify relationships among habitat features and species presence and length. This method was used to identify relationships among multiple abiotic features related to fish habitat use. Various combinations of abiotic variables: channel top width, distance from breach, channel slope, drainage area, and season were evaluated to identify relationships with fish length, species and topsmelt length. The strongest relationships were then analyzed statistically as described in the next section.

Statistical analyses were conducted in JMP 7.0. Each haul or set (as depicted on Figures 2-2 to 2-5 and listed in Table 2-1) was considered a single data point Dependent variables included number of species; number of adult topsmelt; number of juvenile topsmelt; median length of adult topsmelt; median length of juvenile topsmelt. For the analyses, topsmelt < 75 millimeter (mm) standard length were considered young of the year (YOY), and topsmelt > 75 mm standard length were considered 2nd year juveniles or adults. This distinction was based on the length frequency curves for all topsmelt collected in this study (discussed in detail below). Juveniles ranged in length from 18.5 to 120 mm and matured in their 2^{nd} or 3^{rd} year (Saiki 2000). Topsmelt between 75 to 125 mm were assumed to be second year juveniles.

The data were not normally distributed therefore the non-parametric Wilcoxon test was used for one-way analyses of variance (ANOVA). If the one-way ANOVA was significant, a Tukey-Kramer Honestly Significant Difference (HSD) test was used to determine which groups were significantly different. Data were transformed to rank average using the "Rank Average" function in JMP. Median was calculated by hand.

Continuous independent variables were converted to categorical variables due to the small number of data points. The categories were defined as follows:

- Subsite: combined data from all hauls and all seasons, deployed at a single subsite; e.g., gill net hauls 8, 11, 14 at Bair Island were from the same location in June, September and October respectively, Figures 2-2 thru 2-5;
- Season: four sampling seasons were defined as field events conducted during spring, (March and April); summer, (June and July); late summer (September); and fall (October – November);
- Channel top width categories were: narrowest, less than 30 ft; narrow, 30 – 40 ft; medium, 50 – 80 ft; wide, > 80 ft; as derived from Table 2-2;
- Channel depth categories were subtidal and intertidal.

Section 3 presents the results of the 2006 sampling at four tidal wetlands located in South San Francisco Bay. Species richness, relative abundance, topsmelt size classes, and life stage use of the wetlands, and relationships among the abiotic habitat variables are discussed. Appendix B contains a summary of the fish captured from each sampling event, from all gear types, at all stations, in each wetland.

3.1 SPECIES RICHNESS, SEASONALITY, AND RELATIVE ABUNDANCE

A total of 15 species of fish, 10 of which are native, were collected. Table 3-1 summarizes species caught and key characteristics including: 10 were native species, 10 species were listed as 'key fish' species for San Francisco Bay by the Goals Project (1999), presence by capture site and season, and total number sampled in this study. Goby *spp.* included juvenile fish of uncertain Gobiidae species, likely longjaw mudsuckers (*Gillichthys mirabilis)* and or yellowfin gobies (*Acanthogoius flavimanus)*. One flatfish was captured but escaped from the net prior to identification. Invertebrates incidentally collected in fish nets were not identified to species, but included crabs, snails, mussels, shrimp, water boatmen, and backswimmers.

The number of species captured was highest in spring and decreased in summer, late summer, and fall, Figure 3-1. The number of species captured was significantly higher in the spring than in the fall (Chi-squared = 8.6947, degrees of freedom (df) 3, $P = 0.0336$; Tukey-Kramer HSD season and mean number of species: spring 3.5, fall 1.57), but not different among the other seasons. Several species were only observed in the spring including common carp (*Cyprinus carpio)*, cheekspot goby (*Ilypnus gilberti)*, diamond turbot (*Hypsopsetta guttulata)*, and shiner perch (*Cymatogaster aggregata)*. The total number of species captured at each of the four sites ranged from 8 to 11.

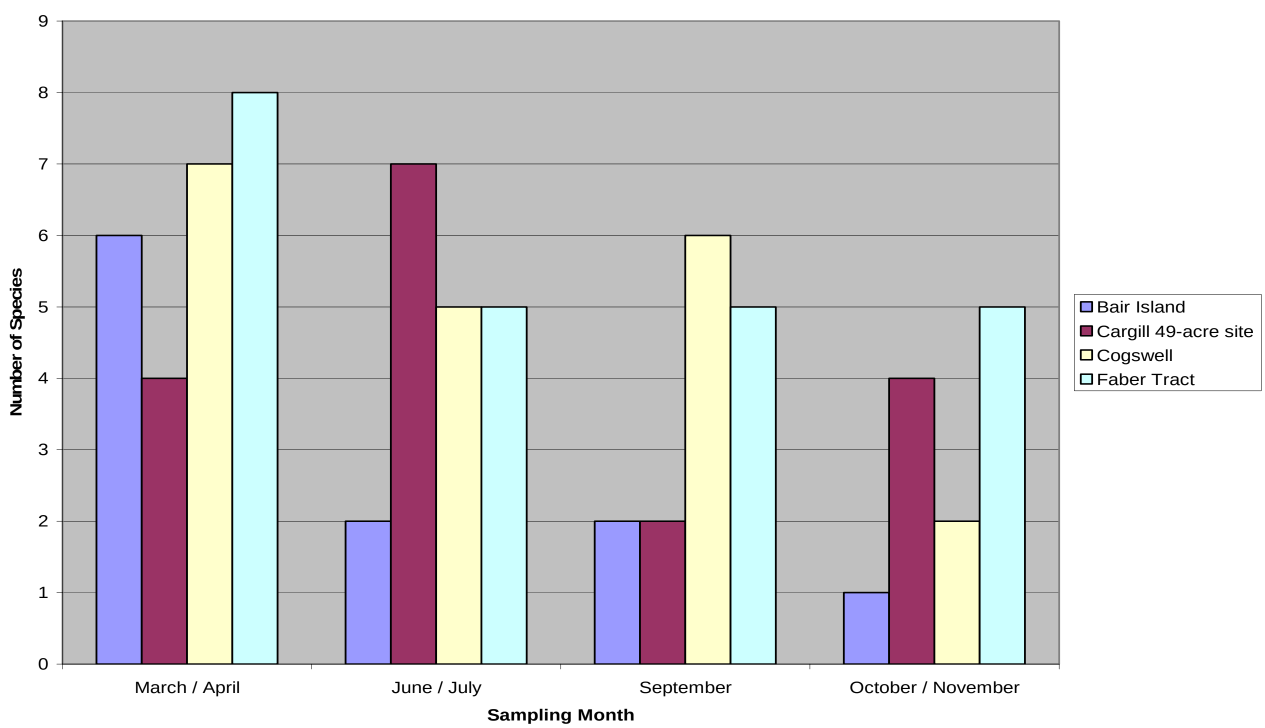


Figure 3-1 Number of species by season

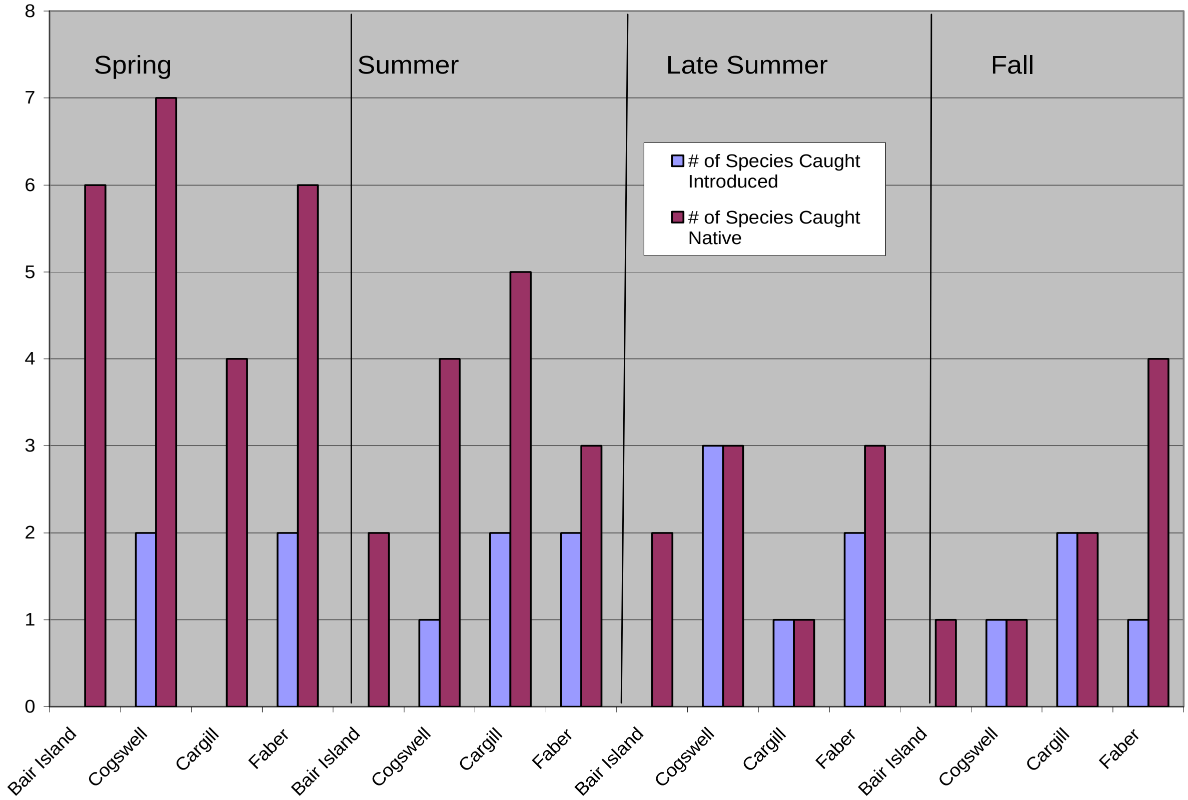


Figure 3-2 Number of Native and Introduced Species by Season

Relative abundance: The vast majority of the **total fish catch** was topsmelt (86%), a total of 4,237 fish, followed by threespine stickleback (*Gasterosteus aculeatus)* (5% of the total catch), northern anchovy (*Engraulis mordax*) (3%), and rainwater killifish (*Lucania parva*) (2%). Additionally, small numbers of individuals, <60 of each of 12 species were collected. The predominance of topsmelt in the catch was consistent with sampling in many Pacific Coast estuaries (Frey 1971). Topsmelt form schools of similar-sized fishes at the surface in shallow water (Baxter et al. 1999). Adults move to shallow sloughs and mudflats from late spring to summer to spawn (Baxter et al. 1999). The following species were relatively abundant in **each season sampled**: longjaw mudsucker, rainwater killifish, yellowfin goby, and topsmelt. There were relatively small numbers of individuals (< 14) of common carp, cheekspot goby, diamond turbot, and shiner perch. Leopard shark (*Triakis semifasciata)*, Figure 3-3, was collected close to the breach at Faber Tract Marsh and at the edge of the bay at Bair Island. Sampling inefficiencies, number of events, and gear bias affected catch totals, restricting discussion to relative abundance. While gear bias most likely affected the relative abundance of fish species collected during the study, it is still an effective method of determining fish species present within the project area, and their relative abundance at the time. Obtaining population estimates is a difficult and time consuming process and was not possible during this study. Therefore, relative abundance was used to analyze trends in fish populations and diversity.

Figure 3-3 Leopard shark collected in gill net at mouth of Faber Tract Marsh

Table 3-2 lists species collected by gear type: otter trawl, seine with blocknet, and gill nets. Longjaw mudsucker, shiner perch, topsmelt, and yellowfin goby were collected in all three gear types. Leopard shark was collected by seine and gill net; cheekspot goby and rainwater killifish were only captured in beach seines; common carp, striped bass (*Morone saxatilis*) and threadfin shad (*Dorosoma petenense*) only in gill nets; diamond turbot and Pacific herring (*Clupea harangues*) only in the otter trawl; northern anchovy, threespine stickleback, and Pacific staghorn sculpin (*Leptocottus armatus*) were captured in beach seine and otter trawl.

Table 3-2 Species collected by gear type and season

Common Name	Scientific Name	Beach Seine	Gill nets	Otter trawl	Season Collected	Native or Introduced
Common carp	*Cyprinus carpio*		X		March/April	Introduced
Cheekspot goby	*Ilypnus gilberti*	X			March/April	Native
Diamond	*Hypsopsetta*			X	March/April	Native

Table 3-2 Species collected by gear type and season

Common Name	Scientific Name	Beach Seine	Gill nets	Otter trawl	Season Collected	Native or Introduced
turbot	*guttulata*					
Leopard shark	*Triakis semifasciata*	X	X		September, October/November	Native
Longjaw mudsucker	*Gillichthys mirabilis*	X	X	X	All 4 events	Native
Northern anchovy	*Engraulis mordax*	X		X	March/April September	Native
Pacific herring	*Clupea pallasii*			X	March/April	Native
Rainwater killifish	*Lucania parva*	X			All 4 events	Introduced
Shiner perch	*Cymatogaster aggregata*	X	X	X	March/April	Native
Pacific staghorn sculpin	*Leptocottus armatus*	X		X	March/April June/July	Native
Striped bass	*Morone saxatilis*		X		June/July September October/November	Introduced
Threadfin shad	*Dorosoma petenense*		X		June/July	Introduced
Threespine stickleback	*Gasterosteus aculeatus*	X		X	March/April June/July October/November	Native
Topsmelt	*Atherinops affinis*	X	X	X	All 4 events	Native
Yellowfin goby	*Acanthogobius flavimanus*	X	X	X	All 4 events	Introduced

The following species were expected to occur in the habitats sampled, based on the habitat type associations described in the Goals Project (1999) but were not collected in this study: bat ray (*Myliobatis californica*); other flatfish, prickly sculpin (*Cottus asper*), jack smelt, (*Atherinopsis californiensis*), longfin smelt (*Spirinchus thaleichthys*)and brown rockfish (*Sebastes auriculatus*). The limited number of sampling events and gear bias are potential reasons why species were not observed, particularly solitary species. Three species of flatfish were expected to be captured in the surveys including starry flounder (*Platichthys stellatus)*, English sole *(Pleuronectes vetulus)* and California halibut (*Paralichthys californicus*). At least one and possibly two species were collected, diamond turbot and a flatfish that escaped from the net before it was identified to species. Chinook salmon (*Oncorhynchus tshawytscha)* and steelhead (*Oncorhynchus mykiss*) were also not found, but juvenile rearing and smoltification habitat was not included in the study sites. Therefore they were not expected to occur.

A series of canonical correspondence analyses were run. They showed that species presence was related to channel topwidth and date and that fish length was related to channel topwidth. In addition, these analyses showed that the variables of distance to bay and drainage area were not useful predictors of fish presence. The variable "distance to bay" was adapted from work done on avian habitats in South Bay salt ponds and wetlands (Stralberg et. al., 2003). It did not prove to be as useful for analyzing fish species presence and habitat because other factors proved dominant, e.g., channel topwidth. This is because of physical conditions in the restoration sites e.g., confined by levees, influenced by original breach location and excavation bathymetry, and that both large and small channels can be located near breaches. These results were used to guide the direction of the statistical analyses.

The canonical correspondence multi-variate analysis figure below graphs length of all fish species, at all sites, grouped in 5 mm classes. Length classes were analyzed with date, channel topwidth, distance of capture location to bay, and drainage area (except Bair Island because drainage area is not available for Bair Island sites). It shows a relationship between longer fish and channel topwidth.

Table 3-1 Characteristics of Species Captured, Presence By Season and Site, and Abundance

Common

Species				Season				Site					
Common Name	**Scientific Name**	**Native or Introduced**	**'Key Fish' species [1]**	**Spring (March/April)**	**Summer (June/ July)**	**Late Summer (September)**	**Fall (October/ November)**	**Bair**	**Faber**	**Cogswell**	**Cargill**	**No. fish captured**	**Percent of total catch**
Common carp	*Cyprinus carpio*	Introduced	No	X					X			1	< 1%
Cheekspot goby	*Ilypnus gilberti*	Native	No	X							X	9	< 1%
Diamond turbot	*Hypsopsetta guttulata*	Native	No	X				X				1	< 1%
Flatfish	unidentified									X		1	< 1%
Leopard shark	*Triakis semifasciata*	Native	Yes			X	X	X	X			6	< 1%
Longjaw mudsucker	*Gillichthys mirabilis*	Native	Yes	X	X	X	X		X	X	X	60	1%
Northern anchovy	*Engraulis mordax*	Native	Yes	X		X		X				160	3%
Pacific herring	*Clupea pallasii*	Native	Yes	X				X	X	X	X	7	< 1%
Rainwater killifish	*Lucania parva*	Introduced	Yes	X	X	X	X		X	X	X	78	2%
Shiner perch	*Cymatogaster aggregata*	Native	Yes	X				X	X			13	< 1%
Staghorn sculpin	*Leptocottus armatus*	Native	Yes	X	X			X				8	< 1%
Striped bass	*Morone saxatilis*	Introduced	Yes		X	X	X		X	X		4	< 1%
Threadfin shad	*Dorosoma petenense*	Introduced	No		X				X			1	< 1%
Threespine stickleback	*Gasterosteus aculeatus*	Native	Yes	X	X		X	X	X	X	X	264	5%
Topsmelt	*Atherinops affinis*	Native	Yes	X	X	X	X	X	X	X	X	4237	86%
Goby spp.[2]	NA	NA	NA	X	X				X	X	X	61	1%
Yellowfin goby	*Acanthogobius flavimanus*	Introduced	No	X	X	X	X			X	X	26	1%
Total number of identified fish species				12	9	7	7	8	11	9	8	4937	100%

[1]Goals Project (1999)

[2]fish were too young to be identified to species

C Table 3.5 in Goals Project (1999)

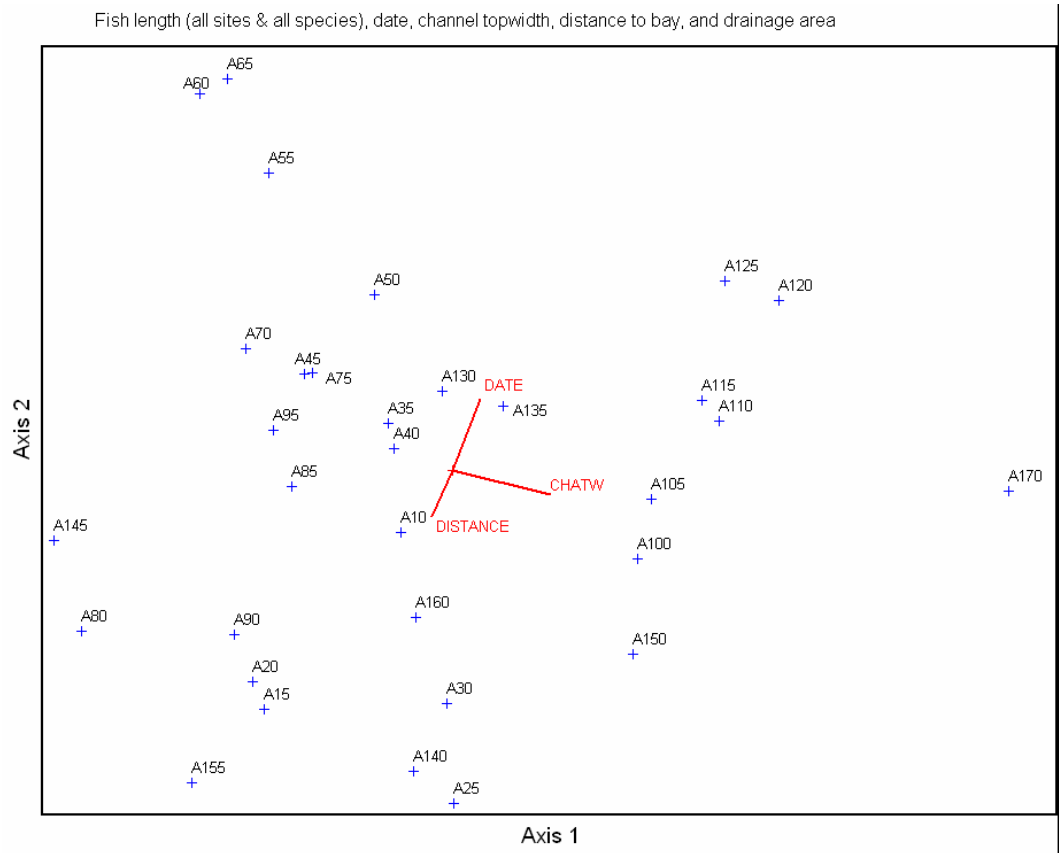


Figure 3-4 Canonical correspondence graph of fish length, date, channel topwidth, distance to bay and drainage area

3.2 TOPSMELT: LENGTH, HABITAT, AND SEASONAL USE

Due to the large number of topsmelt captured, further analysis of fish length (as a proxy for life history stages) and habitat characteristics was conducted on topsmelt. Topsmelt were present in channels of restored salt marshes in all four seasons sampled. Individuals captured ranged in length from 10 mm to 160 mm. Juvenile characteristics are formed at 18.5 mm (Wang 1986), maximum adult length is 366 mm total length (TL) (Miller and Lea 1972) and topsmelt live to 7 – 8 years of age (Gregory 1992). Juveniles grow fastest in their first year attaining half their adult size (Baxter et al 1999).

Two generations of fish (first year, and second year) fish can be detected by interpreting data in plots of frequency of topsmelt by fish length for the four seasons sampled, Figure 3-5. It is possible that many of these fish were Mississippi silversides. However due to the overlap in sizes both species were considered as topsmelt. In the first year fish, two cohorts (early and late) of young of the year (YOY) can be detected. In the spring, there were a few relatively large first year fish and very few adults. In the summer, there was a very large recruitment of adults (frequency peak was 105 mm) to tidal marsh channels, and the first cohort of young (frequency peak was approximately 25 mm). In the late summer, adults grew in size, as indicated by the shift in frequency peak from 105 to 120 mm; abundance dropped presumably due to adults leaving the tidal marsh and returning to the bay or ocean, and in the fall adults did not increase further in size from late summer but appear to leave the tidal channels as indicated by the reduction in abundance of peak frequency. The number of adult topsmelt (rank average) was significantly higher in both summer and late summer than spring (Chi-squared = 13.1037 df=3, *P* = 0.0044; Tukey-Kramer HSD season and mean rank: summer 33.75, late summer 29.458, spring 14.05).

Topsmelt YOY appeared to grow from 25 to 45 mm from summer to late summer, and continued to increase in size to the fall from 45 to 60 mm. The median length of juvenile topsmelt (rank average) was significantly longer in late summer than in summer (Chi-squared 8.98, df = 3 *P* = 0.0296; Tukey-Kramer HSD season and mean rank average of juvenile length: late summer 21 mm, summer 10.6 mm). A second cohort was detected from the small summer peak at approximately 20 mm, more apparent in the fall where there was a second peak between 25-35 mm.

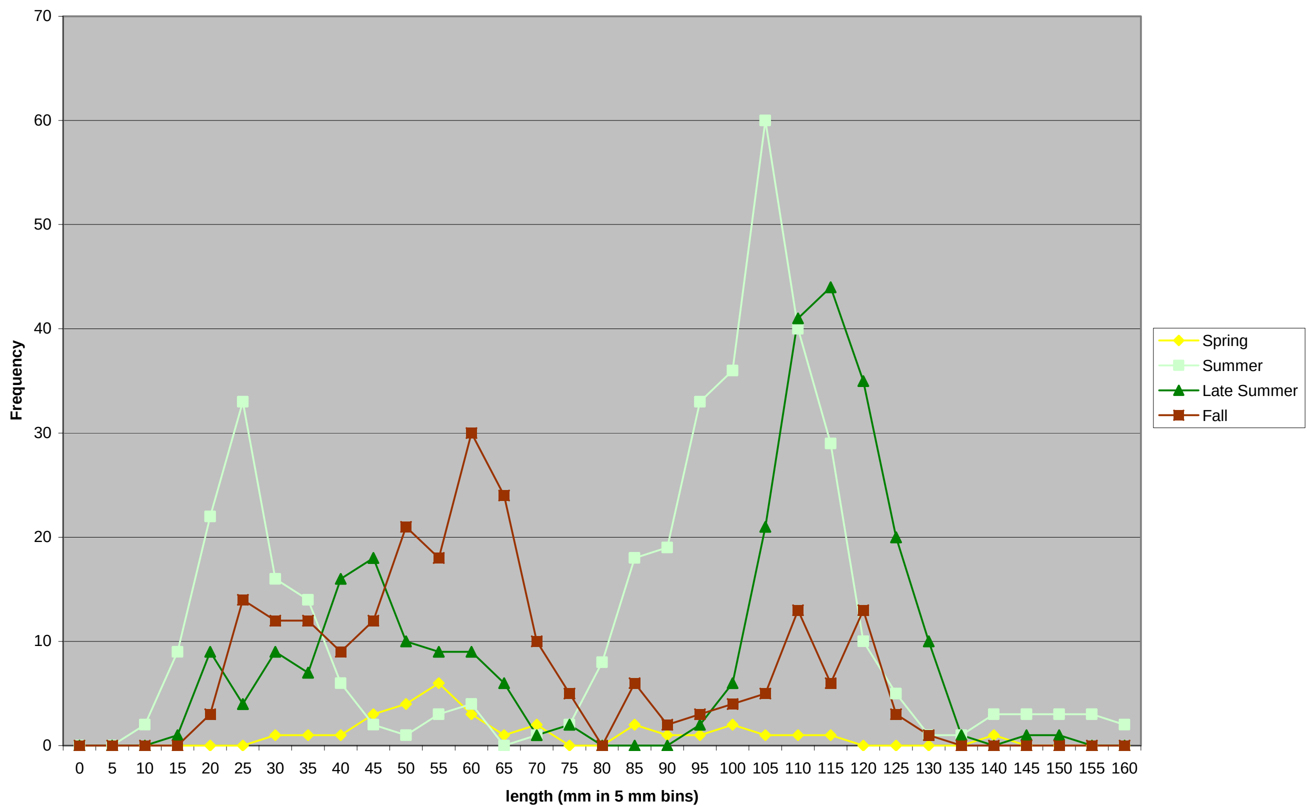


Figure 3-5 Topsmelt abundance and length for each sampled season

The median length of juvenile topsmelt (rank average) is significantly longer at Bair Island (mean length 53 mm) and Faber Tract (mean length 50 mm) than at Cogswell Marsh (mean length 28 mm) (statistics using rank average were Chi-squared 11.99, df =3, *P* = 0.0074; Tukey-Kramer HSD). This may be related to the larger size channels (comparing top widths of subsites sampled) sampled at Bair Island and Faber Tract Marshes.

The number of juvenile topsmelt (rank average) was significantly different across channel widths (Chi-squared 7.9088, df = 3, P =0.0479). The difference was not significant at the Tukey Kramer test for an alpha of 0.05, but the trend is that narrowest and narrow channels (less than 40 ft topwidth) had a significantly higher number of juveniles than both wide and medium channels (Tukey-Kramer HSD channel width category and mean rank average number of juveniles: narrowest 30.45, narrow = 29.57; wide = 19.43; medium 18.86).

3.3 RELATIONSHIPS AND RECOMMENDATIONS AMONG ABIOTIC CHARACTERISTICS

Several abiotic characteristics are typically correlated including distance to bay, channel topwidth, stream order, and channel depth. Channel topwidth was measured in the field and using GIS on aerial photos and correlated with drainage area for subsites from 3 of our four wetlands, Figure 3-6. The exception was at Bair Island the metrics 'distance to bay' and 'drainage basin area' were confounded due to the presence of multiple breaches. Multiple breaches affected the plan-form channel network, i.e., instead of the typical dendritic channel structure Bair Island has a flow-through channel network. Similarly, defining drainage basin area in Cogswell Marsh was complicated because of the freshwater input from Hayward Marsh during the first sampling events of the study. Figure 3-7 shows a trend of increased number of species in larger channels as well as the increased number of species in spring and summer.

Field experience shows that some measures of abiotic characteristics are more repeatable than others. This knowledge is critical both for interpretation of the collected data, and for developing efficient long term monitoring protocols. Repeatable measures offer the most value for illuminating and quantifying relationships between fish and abiotic site characteristics. Experience measuring abiotic characteristics in the field indicates that channel topwidth is a repeatable measure of abiotic characteristic. A methodology for measuring channel topwidth needs to be defined to maintain consistency and repeatability. The uncertainty or variability comes from the need to define endpoints; e.g., to the edge of emergent vegetation or grade breaks, or how to treat channels with calved blocks.

Developing a plan that includes standard sampling techniques, multiple gear types, identifies long term sampling locations across multiple habitat types, and incorporates a schedule to assess annual and inter-annual temporal variability will facilitate a comprehensive assessment of wetland use by fish as the South Bay Salt Pond restoration project progresses.

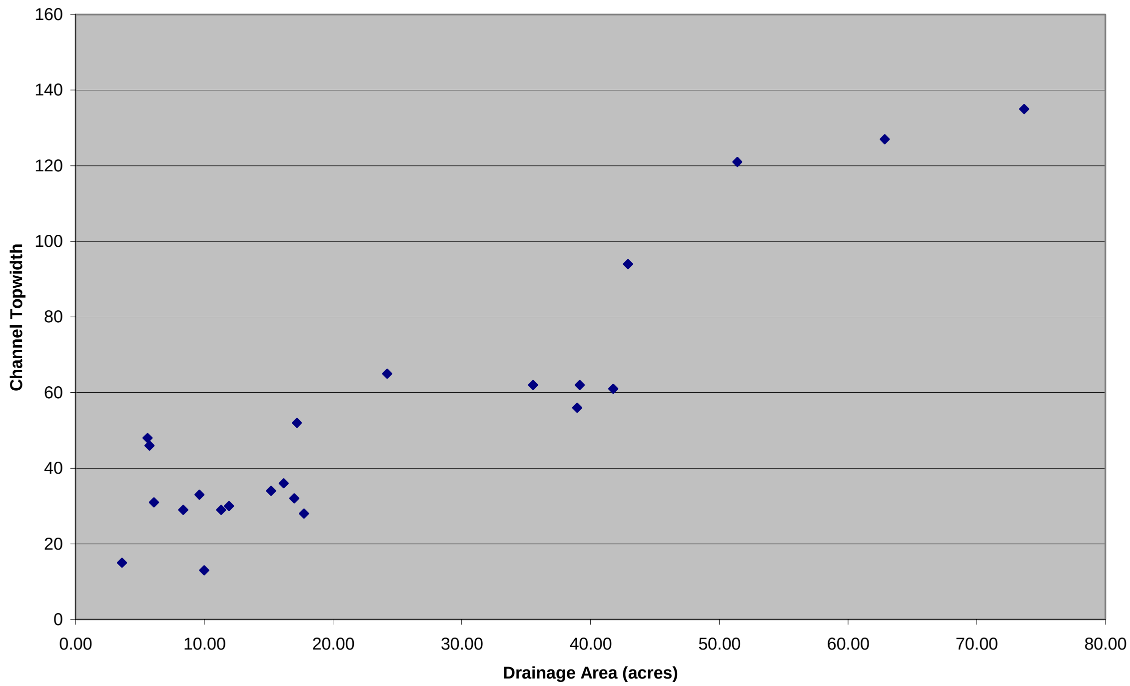


Figure 3-6 Channel Topwidth vs. Drainage Area (Faber, Cogswell, Cargill)

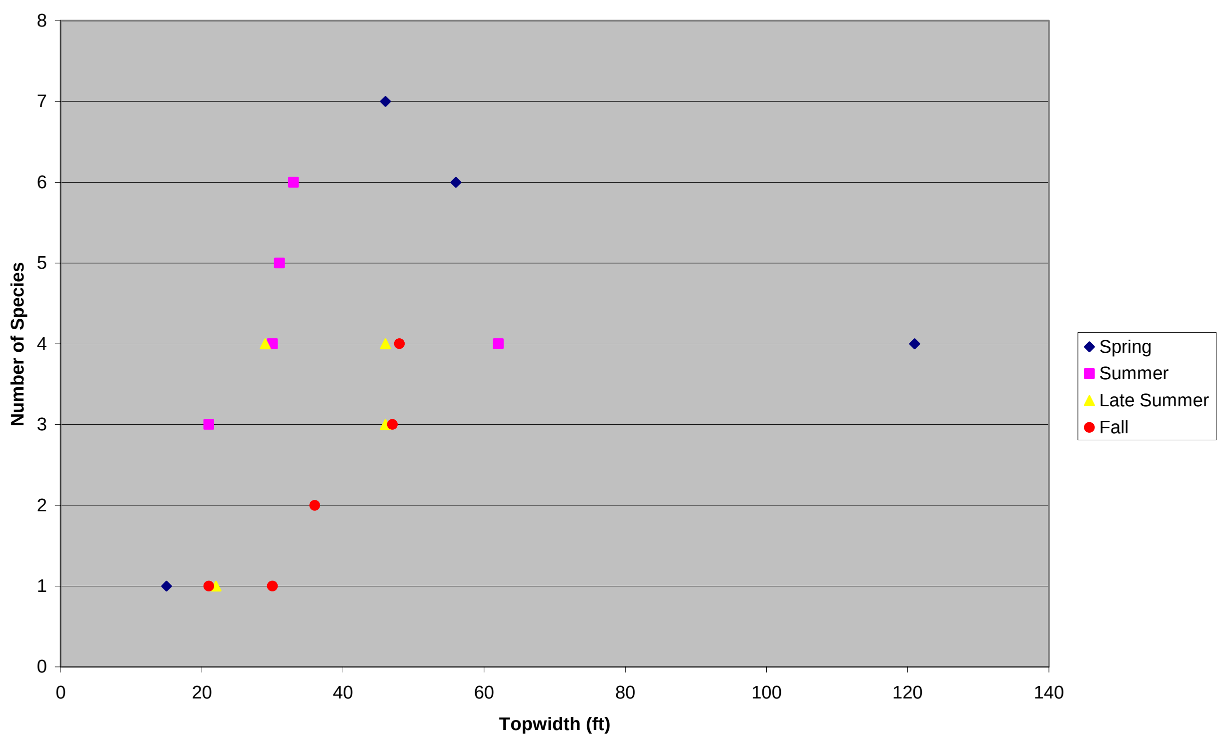


Figure 3-7 Number of Species Collected by Channel Topwidth and Season

Section 4 discusses fish use across a continuum of habitats; first by defining expectations and then evaluating data from South Bay fisheries studies conducted along a continuum of habitats and spanning a 25 year temporal change at a single site.

The South San Francisco Bay fish community is comprised of many guilds using a diversity of habitats during various life stages. Fish habitats in the South Bay include deep bay, shallow open water, beds of submerged aquatic vegetation, hard substrate rocks or reefs, river mouths, intertidal mud and sand flats, tidal marshes, tidal channels, and managed ponds (Goals Project 1999). Table 4-1 was prepared during the initial stages of the project prior to the field study to identify potential fish species of interest and their habitat. The Goals Project (1999) key fish species and a list of potential salt pond species formed the basis of the list.

Wherever possible, quantifiable habitat characteristics were determined for each species and life stage. If no quantifiable habitat characteristics were identified (e.g., for northern anchovy), the species was removed from the list. In other words, only species or life stages that showed a quantifiable habitat preference were included. Additionally, key habitat variables for each species and life stage included on the list were developed based upon the quantifiable habitat characteristics (preferences). In particular, vegetative cover, salinity, depth and turbidity are consistent habitat variables associated with these species.

Table 4-1 Fish Species, Life Stage, and Habitat Preferences

Species	Life stage[1]	Habitat Utilized[2]	Timing[3]	Quantifiable Habitat Characteristics	Key Habitat Variables for Model	'Key Fish' species and their Standardized Selection Criteria [4]
Arrow goby	A	SB, TF, LTM	S	Tidal marshes, mudflats near large order channels	Channel size (nearest channel), distance to channel	Community Indicator, Habitat Indicator, Dominant Species, Practical Species
Staghorn sculpin	A, J	SB, TF, LTM, MTM, HTM	Year round	Associated with mudflats, sandflats and eelgrass	Substrate, % veg cover, veg type	Economic Indicator, Dominant Species, Practical Species
Leopard shark	A, J	SB, TF	Year round	Sandy/muddy bottoms, high salinity pref.,	Substrate, salinity	Community Indicator, Protected Species, Dominant Species, Practical Species NOAA Trust Species
Starry flounder	A, J	SB, TF, LTM	Year round (spawn in ocean, larvae drift into bay)	Shallow to deep subtidal mud and sand flats, deeper and more saline is preferred by adults	Substrate, salinity	Habitat Indicator, Economic Indicator, Dominant Species, Practical Species
California halibut	A, J	SB, TF	Sp, S, F	Sandy bottoms, high water temp tolerant (juveniles)	Substrate, temperature	Habitat Indicator, Economic Indicator, Dominant Species, Practical Species

Table 4-1 Fish Species, Life Stage, and Habitat Preferences

Species	Life stage[1]	Habitat Utilized[2]	Timing[3]	Quantifiable Habitat Characteristics	Key Habitat Variables for Model	'Key Fish' species and their Standardized Selection Criteria [4]
Longjaw mudsucker	A	TF, LTM. MTM, HTM	S	Complex tidal channels, large order channels, salt ponds	Channel size, incision	Habitat Indicator, Economic Indicator, Dominant Species, Practical Species NOAA Trust Species
Prickly sculpin	A, J	LTM, MTM, HTM	Sp, S	Structure (rootwads), and salinity <10ppt	% cover (instream), salinity	Dominant Species, Practical Species
Threespine stickleback	A, J	LTM, MTM, HTM	Year round	Cover and clear water	Turbidity, % veg cover, veg type	Dominant Species, Practical Species
Topsmelt	S	SB, TF,	Sp, S, F	Submerged vegetation	% veg cover, veg type	Habitat Indicator, Economic Indicator, Dominant Species, Practical Species
	A, J	SB, TF, LTM, MTM, HTM	Year round	Prefer salinity less than 30ppt	Salinity	NOAA Trust Species
	L	SB, TF	S, F	Prefer shallow open-water tidal basins	Depth	
Shiner perch	J	SB, TF	S, F	Intertidal and subtidal flats and seagrass beds, sand gravel and rock substrate	Depth, substrate	Habitat Indicator, Economic Indicator, Dominant Species, Practical Species NOAA Trust Species
Brown rockfish	A, J	SB	Year round	Structure, salinity >20ppt	% cover (structure), salinity	Habitat Indicator, Economic Indicator, Dominant Species, Practical Species

[1] A=Adult L=Larvae, J=Juvenile, S=Spawning
[2] SB=Shallow bay or channel, TF=Tidal flat, LTM=Low tidal marsh, MTM=Mid tidal marsh, HTM=High tidal marsh
[3] Sp=Spring, S=Summer, F=Fall, W=Winter
[4] Goals Project, 1999

4.1 COMPARATIVE FISHERIES STUDIES

This section of the report presents meta-analysis of data collected in a number of studies on fish use of shallow water habitats in South San Francisco Bay. The 2006 NOAA fisheries wetland channel habitat data discussed in Sections 2 and 3 is evaluated in combination with fisheries data from other South Bay habitats including USGS's (2006) study of managed ponds and sloughs, CDFG's beach seine data from South Bay intertidal flats (Baxter et. al., 1989), and data from an earlier study at Cogswell Marsh (Woods 1984) that was conducted immediately post breaching and before vegetation establishment.

4.1.1 USGS Survey: 2004-2005 Fishes of Selected Salt Ponds and Sloughs on the Don Edwards San Francisco Bay National Wildlife Refuge

This study surveyed fish in tidal sloughs and managed former salt ponds in March, June, September and November 2004 and March and June 2005. Managed ponds sampled in the Eden Landing Unit were B1, B2, B4, B5, B6C, B7 and sloughs sampled in that unit were Old Alameda Flood Control Channel and Coyote Hills Slough. In the Alviso Restoration Unit ponds A-9, A10, A-11, A-12, A2W, A2E and Stevens Creek, Alviso Slough, and Coyote Creek were sampled, Figure 1-1. Data collected from 506 hauls in tidal sloughs and 650 hauls in restored salt ponds is used in the comparisons below. The distinction between the tidal sloughs sampled in the USGS study and the tidal sloughs sampled in the NOAA study is that the former also receive fluvial outflow, whereas the later do not. The water source for the NOAA sites is tidal action from the bay.

The managed ponds were former salt evaporation ponds. Water control structures were installed in the former salt ponds to manage tidal exchange, maintain water depth and salinity as described in the Initial Stewardship Plan (Life Science! 2003). The muted tidal exchange can affect managed pond water quality resulting in fluctuating temperatures and periodically low dissolved oxygen. The presence of water control structures has potential to entrap fish. Managed pond operation is an interim step while the management team determines where full tidal action will be restored and where managed pond operation will continue (PWA et al. 2006).

4.1.2 CDFG Beach Seine Data. 1980-1986

This extensive fisheries study included seining intertidal mud flats throughout the bay. Beach seine data for South Bay stations, from CDFG's San Francisco Bay Study and the Interagency Ecological Program for the San Francisco Estuary, was provided courtesy of Kathryn Hieb (pers. comm., October 5, 2007). Fisheries data from beach seine surveys between 1980 – 1986 was compared from the following locations in the South San Francisco Bay:

- 169, Coyote Point (sand, exposed);
- 170, San Mateo west (oyster shell);
- 171, San Mateo east (mud);
- 172, Hetch Hetchy (mud, pickleweed).

Some tows had two hauls, in which case the catch size was averaged by species. For comparative purposes, data were limited to February through November, to coincide with in NOAA and USGS sampling dates.

4.1.3 Woods, E. M. 1984. A Survey of Fishes Utilizing a Marsh Restoration Site in San Francisco Bay. San Francisco State University

The Woods survey was conducted in 1980-81 in Cogswell Marsh, less than 1 year after breaching and prior to vegetation establishment. The 229 acre area was comprised of intertidal mudflats, subtidal channels, and islands. Woods described it as being completely inundated except for islands during high tide and having extensive exposed mudflats with limited vegetation during low tide. The area was partially protected by (breached) exterior levees but was similar to the intertidal flats sampled by CDFG. The presence of a mud sill, (sediment at the breach) prevented complete site drainage at low tide (Woods 1984). Fish were collected using an otter trawl, monthly from June 1980 through May 1981, except for January. For comparative purposes, data were limited to February through November, to coincide with sampling in NOAA data; this resulted in the removal of two species; *Clupea harengus* (Note: Woods cited the scientific name for Atlantic herring, however Pacific herring would be more likely) and *Microstomus pacificus* which was captured once in December.

4.2 RESULTS AND DISCUSSION

This section discusses species richness among the studies and among the years included within the CDFG beach seine study. The interannual variation among the data sets is evaluated in comparison with the Marine Sciences Institute (MSI) midwater trawl data. The two datasets at Cogswell Marsh offer a unique opportunity to evaluate the effects of temporal variation and habitat variation on species presence. Finally, the section presents a discussion on the relative abundance of fish species among the studies.

4.2.1 Species Richness

The fisheries data from over 1,845 hauls collected in a continuum of South Bay habitats identified 37 species of fish; 8 of these species were uncommon (uncommon was defined as one individual fish collected for a species), Table 4-2. The fish were collected from intertidal flats, tidal sloughs, tidal wetlands, and managed ponds. The shallow intertidal flats sampled by CDFG contained 33 species. The Woods study temporally overlapped with the CDFG study and included similar habitats. Twenty species were identified during the pre-vegetation establishment at Cogswell Marsh. Tidal sloughs sampled by USGS hosted 14 species. Fifteen species were collected in the NOAA tidal wetland channels, and 13 species were collected in the managed ponds.

The 37 species were comprised of 23 families, as follows: Anchovies, Carp, Drums and Croakers, Eagle Rays, Gobies, Ground Shark, Herring, Large-tooth Flounders, Minnow, Pipefishes and Seahorses, Righteye Flounders, Salmon and Trout, Sculpins, Silversides, Silversides (Old World), Smelts, Sticklebacks, Suckers, Surfperches, Temperate Bass, Toadfishes, and Topminnows and Killifish. Families with the highest number of species observed included the Surfperches (6 species) and at least 5 species of Gobies (some larval individuals were not identified).

Five species were found in all habitats: northern anchovy, rainwater killifish, staghorn sculpin, topsmelt, and yellowfin goby, Table 4-2. Leopard shark, longjaw mudsucker, striped bass, threespine stickleback, shiner perch, American shad, and starry flounder were captured in 4 of the 5 surveys. Leopard shark was not collected by CDFG in the intertidal flats, however, it was collected in this habitat in 2006, just off the Bair Island oyster shell flats. Threespine stickleback, shiner perch, and striped bass were not found in managed ponds. Starry flounder was not collected in tidal wetland channels nor in tidal sloughs. Thirteen species were only collected in the intertidal bay flats; bat ray was only collected in tidal sloughs.

Table 4-2 Species distribution among habitats

Study		**CDFG Beach Seine**	**Woods**	**NOAA, URS**	**USGS sloughs**	**USGS ponds**
Sampling Year(s)		1980-86	1980-81	2006	2004-05	2004-05
Number of hauls		616	>50	73	506	650
Common Species Name	**Native or Introduced**	**Intertidal flats**	**Intertidal, no vegetation**	**Tidal marsh channels**	**Tidal sloughs**	**Managed ponds**
Topsmelt	N	■	■	■	■	■
Yellowfin goby	I	■	■	■	■	■
Staghorn sculpin	N	■	■	■	■	■
Rainwater killifish	I	■	■	■	■	■
Northern anchovy	N	■	■	■	■	■
Striped bass	I	■	■	■	■	
Longjaw mudsucker	N	■	■	■		■
Leopard shark	N		■	■	■	■
Threespine stickleback	N	■	■	■	■	
Shiner perch	N	■	■ 1	■	■	
Starry flounder	N	■	■			■
American shad	I	■ 1	■ 1		■	■
Bay pipefish	N	■	■		■	
Diamond turbot	N	■	■ 1	■ 1		
Jacksmelt	N	■	■		■	
Threadfin shad	I	■ 1		■ 1		
Arrow goby	N	■	■			
Barred surfperch	N	■	■			
Pacific herring	N	■		■		
Common carp	I			■ 1	■ 1	
Cheekspot goby	N	■		■		
Chameleon goby	I	■				■ 1
Pile Perch	N	■				
Mississippi (Inland) silverside	I	■				■
Chinook salmon	N	■				
Sacramento splittail	N	■				
Bat ray	N				■ 1	
Longfin smelt	N	■				
White perch	N		■			
Dwarf perch	N	■				
Plainfin midshipman	N	■ 1				
White croaker	N	■				
Walleye perch	N	■				
Surf smelt	N	■				
Sacramento blackfish	N	■ 1				
California halibut	N	■ 1				
English sole	N	■				
Native species/ study		26	14	10	9	6
Total species/study		33	18	15	14	11

Note:
Species present in habitats with colored shading
Color shaded cells with a "1"means a single fish of that species was collected
NOAA Trust Species are indicated by bolded species names

To evaluate the commonality of species use among the habitats the presence/absence of species at pairs of sites were examined. Overall, each pair of sites shared between 9 and 16 species. Early stage Cogswell Marsh and the CDFG intertidal bay flats had 16 species in common, which may be due to the habitat similarity of these sites. Greater than 10 species were shared among the following pairs of habitats: tidal marsh channels and intertidal flats (12 species); intertidal flat and managed ponds (11 species); and early Cogswell and tidal sloughs (12). The rest of the pairs of sites shared between 9 – 10 species. This provides evidence of fish species using a variety of shallow bay habitats.

4.2.2 Species Common to CDFG Surveys in 1980-1986

For all the fish surveys, the number of species collected at any one site in one year ranged from 14-18. Over 7 years, 33 species were collected in CDFG trawls, with the annual number of species captured ranging from 14-26 with a mean of 19 species. Eight species were found in all CDFG surveys from 1980-1986: arrow goby, bay pipefish, staghorn sculpin, jacksmelt, topsmelt, threespine stickleback, dwarf perch, and shiner perch. Three fish were found in 6 of the 7 years: striped bass, northern anchovy, yellowfin goby; and Pacific herring, diamond turbot, English sole were collected in 5 out of 7 years. The following six species were collected in one year during the 1980-86 sampling period: American shad, California halibut, Mississippi silverside, plainfin midshipman, Sacramento blackfish, and threadfin shad.

4.2.3 Year of Fish Survey

Fish surveys discussed in this report were conducted over a 26 year period (1980-2006). The variation in these data is compared with the variation in data collected in a single habitat over a similar time period. The MSI's (MSI 2002) midwater trawl data was examined to identify population abundance trends in fish species in the subtidal portion of the South Bay. The purpose was to qualitatively examine whether species presence in a single, specific habitat may be confounded by a change in abundance in surveys of different microhabitats. MSI data are ideal because they were collected using standard methodology over a 26 year period near the beginning (1973-1982) and during the end (1992-2002) of the period of surveys examined in this review.

Nine species were found in both the midwater trawls and nearshore habitats: northern anchovy, shiner perch, leopard shark, staghorn sculpin, Pacific herring, white croaker, bat ray, California halibut, and dwarf perch. Three species were found in the MSI midwater trawls but not the nearshore habitats (black perch, Dover sole, and white perch).

The directional change in abundance recorded in midwater trawls does not strikingly correspond with presence/absence in surveys of nearshore habitats recorded in different years. Species-specific presence/absence may be related to change in abundance over decades. For example, the abundance of northern anchovy and shiner perch declined by half from 1973-1982 and 1992-2002, but were present in all nearshore habitats collected over different years. Increases in California halibut and white croaker did not correspond with increased detection in 2004-2006. For Pacific herring, leopard shark, bat ray, dwarf perch and staghorn sculpin a potential relationship exists, but cannot be detected with this methodology. These data provide support for the implicit assumption in this analysis, which is that the presence or absence of fish in a nearshore microhabitat is not influenced by the year of the fish survey.

4.2.4 Temporal and Habitat Variation at Cogswell Marsh: Tidal Mudflats (1981) and Tidal Marsh (2006)

Subtidal and intertidal channels were surveyed at Cogswell Marsh by Woods in 1980-81, the first year the salt pond levees were breached to restore tidal action, and again in 2006 by NOAA/URS. In 1981 the habitat consisted of intertidal mudflats, subtidal channels and islands whereas 26 years later the pickleweed and cordgrass marsh plain was fully developed, including intertidal and subtidal channel segments and a broad intertidal flat near the main breach. Eight species were observed in Cogswell Marsh in both stages of habitat development (1981 tidal mudflat and in 2006 tidal marsh): longjaw mudsucker, rainwater killifish, staghorn sculpin, striped bass, threespine stickleback, topsmelt, northern anchovy, and yellowfin goby. Except for the threespine stickleback, all of these fish were found in every fish survey. Several species were present in the tidal mudflats which were not captured 26 years later when the site had evolved to a fully vegetated tidal marsh habitat, including: American shad, arrow goby, barred perch, bay pipefish, diamond turbot, jacksmelt, leopard shark, shiner perch, starry flounder, and white perch.

The greater species richness documented immediately after the introduction of tidal action may be partially attributable to the greater sampling effort in 1980-81 study. Woods trawled one channel in each of 3 marsh units and set minnow traps every month and deployed gill nets every three months (3), for a total of more than 50 hauls. The data used in this analysis was from February to November. The 14 URS Cogswell Marsh sampling hauls (spring, summer, late summer, fall) were comprised of: 5 seine to block net hauls, 5 otter trawl tows, and 4 gill net sets. The 7 years of CDFG studies show that increases in sampling effort result in increased detection of diversity.

Figure 4-1 compares the relative abundance by species between the two studies at Cogswell Marsh. Topsmelt was the most abundant fish in both studies, threespine stickleback was the second most numerous in 2006, whereas arrow goby was the second most numerous in the earlier study. The relative abundance of yellowfin goby and longjaw mudsucker is similar between the studies.

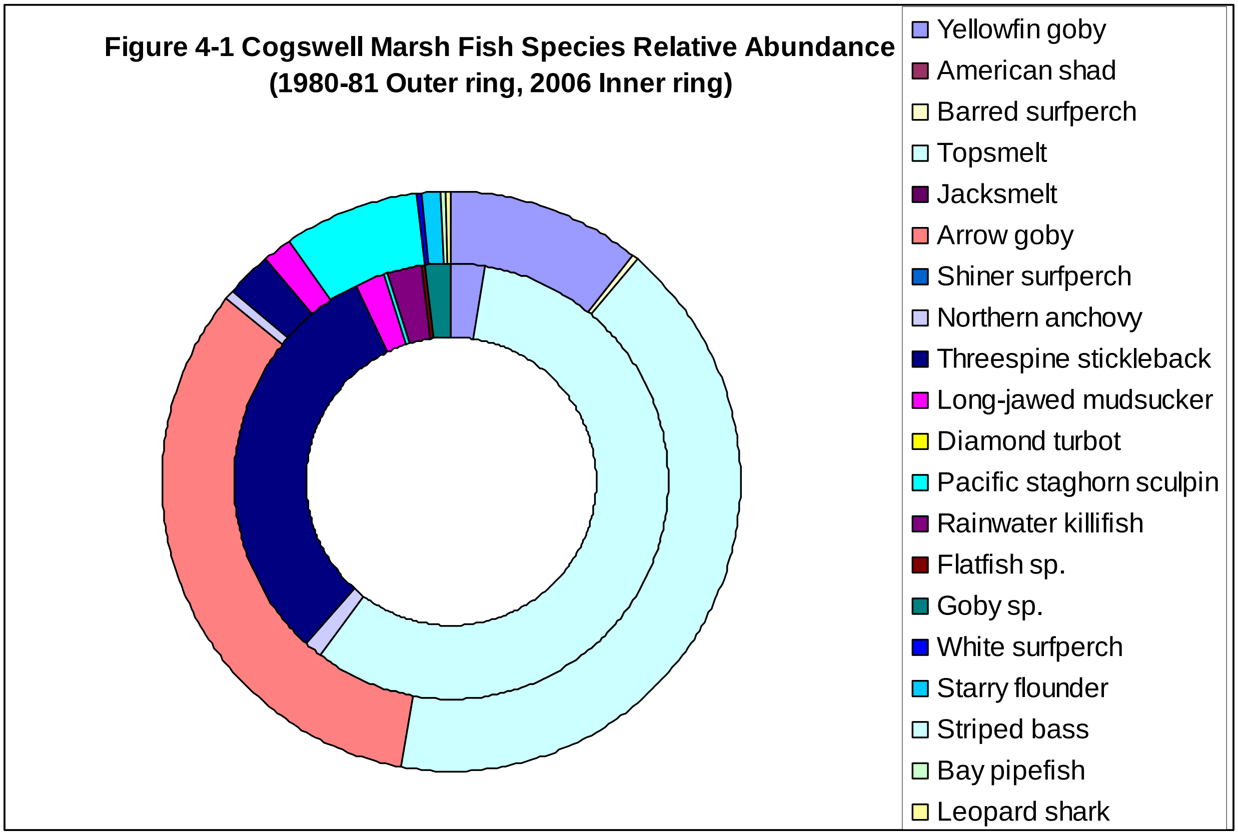


Figure 4-1 Cosgwell Marsh Fish Species Relative Abundance (1980-81 Outer ring, 2006 Inner ring)

4.2.5 Relative Abundance among Habitats

The relative abundance of fish species comprising more than one percent of the total catch is displayed in Figure 4-2, including data from 14 of the total 37 species collected. Topsmelt, a schooling species, is the most numerous species in all habitats except the managed ponds where rainwater killifish was most abundant. This is likely due to the behavior of topsmelt, entering and leaving with the tides, thus their movement is impeded by the water control structures on the managed ponds. Yellowfin goby is another relatively abundant species among the habitats. CDFG's long data record displays the most diversity of abundant species. NOAA embarked on this study because of the relative lack of data on fish use of restored wetlands. It is difficult to know if the greater diversity and relative abundance observed in the intertidal margins of the bay is related to actual fisheries use, the long term data set, or a combination.

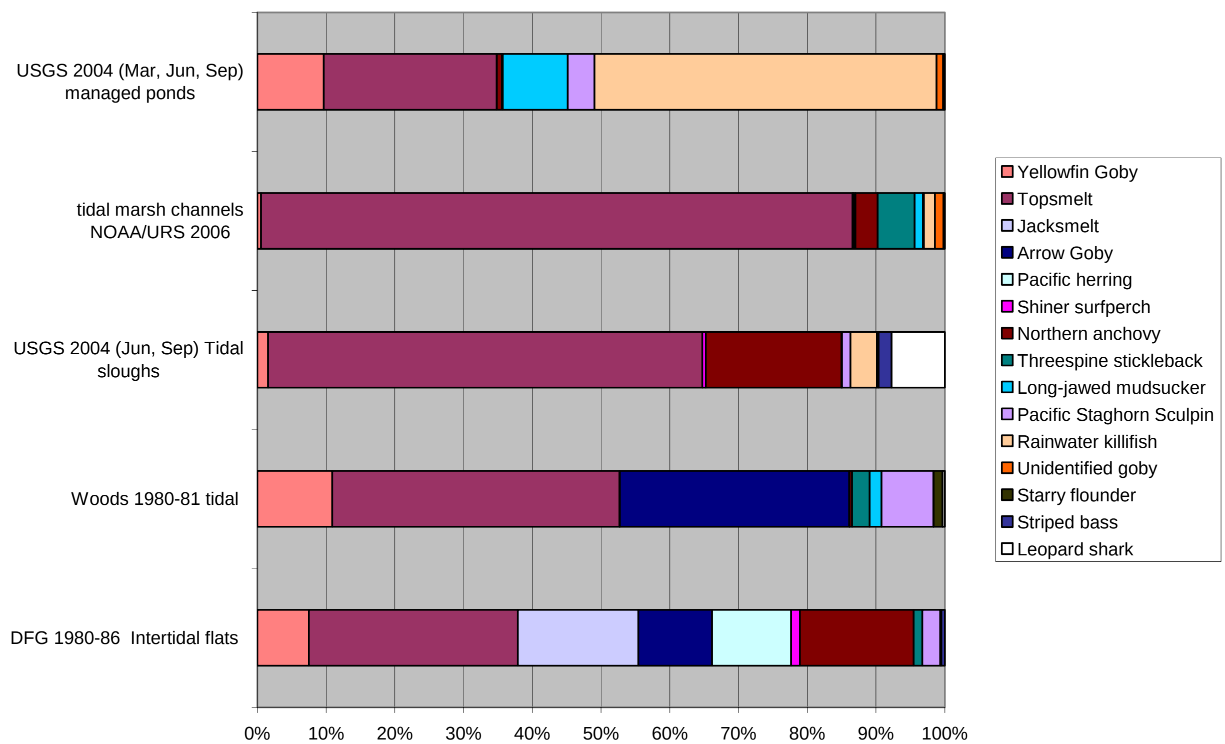


Figure 4-2 Relative Abundance of Species with > 1% Total Catch, by Habitat

4.2.6 NOAA Trust Resources

NOAA acts on behalf of the U.S. Department of Commerce as a trustee for natural resources. Three goals guide NOAA in carrying out its responsibilities as a trustee:

- Reducing threats to coastal resources and human health through planning and prevention;
- Protecting coastal resources and human health by recommending and implementing appropriate response actions; and

- Restoring injured trust resources.

NOAA is a trustee for coastal and marine resources, including:

- Commercial and recreation resources;
- Anadromous species;
- Catadromous species;
- Marine mammals;
- Endangered and threatened marine species and their habitats;
- Marshes, mangroves, seagrass beds, coral reefs, and other coastal habitats; and
- Resources associated with National Marine Sanctuaries and National Estuarine Research Reserves.

San Francisco Bay's estuarine environment provides nursery, adult, and spawning habitat for many NOAA trust resources (Table 4-1). The southern bay area is used primarily as a seasonal nursery ground. Smelt and herring spawn in the Bay's central areas and use the nearshore estuaries for juvenile growth. Several flatfish species also use the nearshore areas as juvenile nursery grounds and as adult habitat. Sea perch use the Bay year-round and can often be found just beyond the intertidal zone. Leopard sharks, dogfish, and bat rays are relatively shallow-water carnivores that feed on smaller fish and benthic invertebrates along the mud flats during high tide. Commercially important shrimp species also are found in San Francisco Bay, with juveniles present in nearshore waters and adults in the central areas. Pacific salmon and steelhead trout use San Francisco Bay as a migratory route (NOAA 2007).

Several of the species collected during the 2006 sampling effort are considered NOAA trust species, Table 4-2. These include leopard shark, longjaw mudsucker, northern anchovy, shiner perch, striped bass, threespine stickleback, staghorn sculpin, and topsmelt. Many of these species are common and were collected in all of the studies. These species can be good long-term indicators of fish community composition and the response to changing conditions in the restored wetlands.

In addition to NOAA trust species, several species collected were fish with commercial importance. In particular, this included northern anchovy and Pacific herring. While these species were collected in low numbers, their commercial importance makes them a valuable resource for monitoring.

4.3 SUMMARY AND RECOMMENDATIONS

Fish use within South San Francisco Bay is complex and dynamic. Many variables affect fish populations in the South Bay, including the tides, water temperatures, turbidity and salinity, as well as invasive species introductions and other conditions. The primary study objectives were to identify fish use in wetlands restored in former South Bay salt ponds and to identify the habitat features associated with fish species occurrence and abundance. The three primary questions cited in Section 1 are addressed below.

Are there relationships between habitat characteristics, channel bathymetry (top width, depth, and side slope, drainage area, fish species relative abundance and use?

Canonical correspondence multi-variate analyses incorporating length classes, date, channel topwidth, distance of capture location to bay, and drainage area were conducted. Species presence was related to channel topwidth and date (e.g., increased number of species in spring and summer). The number of species and fish length increased in channels with a wider topwidth. In addition, the number of small fish (short fish and juvenile fish) is higher in narrower channels.

Several abiotic characteristics are typically correlated including distance to bay, channel topwidth, stream order, and channel depth. These analyses suggest that channel topwidth was the most useful for predicting fish use in restored wetlands in the South Bay and that the variables of distance to bay and drainage area were not useful predictors of fish presence because of numerous confounding factors.

Is fish species presence or abundance influenced by site or season, e.g., are there varying seasonal patterns of life stage use in restored wetlands?

A total of 15 species of fish (10 natives) were collected in this study, ranging from 8 to 11 species identified at each of the 4 wetlands. The number of species captured was 1) highest in spring, 2) significantly higher in the spring than in the fall, and 3) decreased in summer, late summer, and fall. Common carp, cheekspot goby, diamond turbot, and shiner perch were only observed in spring. The vast majority of the **total fish catch** was topsmelt (86%), followed by threespine stickleback (5% of the total catch), northern anchovy (3%), and rainwater killifish (2%). The following species were relatively abundant in **each season sampled**: longjaw mudsuckers, rainwater killifish, yellowfin goby, and topsmelt.

Multiple life stages of topsmelt use wetland channels. In the spring there are a few relatively large first year fish and very few adults. In the summer, there is recruitment of adults (frequency peak 105 mm) to tidal marsh channels. In the late summer, adults grow in size (frequency peak increases to 120 mm) and abundance drops presumably due to adults returning to the bay or ocean, finally, in fall adults do not increase further in size from late summer.

The number of adult topsmelt (rank average) was significantly higher in both summer and late summer than spring. The median length of juvenile topsmelt was significantly longer at Bair Island and Faber Tract (mean 53 mm and 50 mm respectively) than at Cogswell Marsh (mean 28 mm). This may be related to the larger size channels sampled at Bair Island and Faber Tract Marshes.

Two cohorts of YOY topsmelt were identified. The first cohort of YOY had a frequency peak of approximately 25 mm in length. YOY growth increased significantly from (25 to 45 mm) from summer to late summer, and continued to increase in size during the fall from 45 to 60 mm. A second cohort was detected from the small summer peak at approximately 20 mm, more apparent in the fall where there was a second peak between 25-35 mm. The number of juvenile topsmelt (rank average) was significantly higher in channels with top widths less than 40 ft than the number of juveniles in the larger channels surveyed.

Topsmelt abundance and use of multiple habitat types makes them a good candidate species for long term trend monitoring.

What can be learned about fish use across habitats and how does a mature wetland support the greater fisheries of the bay?

Many fish species use multiple habitats, e.g., spawn in one habitat, rear in another, and live as adults somewhere else. This occurs at different times of the year and in some cases, not every year (e.g., grunion, salmon). Fisheries data from multiple habitats were examined to assess the potential future benefit of South Bay Salt Pond restoration on fish. One difficulty in comparing these data sets is that they are temporally disparate, spanning the years from 1980-2006. The fisheries data from over 1,845 hauls collected in a continuum of South Bay habitats identified 37 species of fish (27 native species) from 23 families; 8 of these species were uncommon. Surfperches (6 species) and at least 5 species of Gobies (5 species) were the families with the highest number of species. Species richness among habitats was as follows:

- 33 species (26 native) - intertidal bay flats,
- 18 species (14 native)- Cogswell Marsh breached salt pond, pre-vegetation establishment
- 14 species (9 native) - tidal sloughs (with fluvial input)
- 15 species (10 native) - tidal wetland channels (restored ponds with no fluvial input)
- 11 species (6 native) - managed ponds.

Topsmelt was the most abundant fish in both studies at Cogswell Marsh, threespine stickleback was the second most abundant in 2006, whereas arrow goby was the second most abundant in the 1981 Cogswell study. The relative abundance of yellowfin goby and longjaw mudsucker is similar between the studies.

Eight species were observed in Cogswell Marsh in two stages of habitat development (tidal mudflat in 1981 and tidal marsh in 2006): long-jawed mudsucker, rainwater killifish, staghorn sculpin, striped bass, threespine stickleback, topsmelt, northern anchovy, and yellowfin goby. These are the same 8 species found in all habitats reviewed suggesting a potential parallel relationship between the habitat continuum from open bay to wetlands and the developmental trajectory in an individual wetland unit. This hypothesis could be explored further in future studies by identifying sampling stations representing the spatial variability across habitats and conducting the sampling over a time period spanning wetland establishment to quantify temporal evolution and variation.

The Eden Landing complex may provide opportunities to conduct this type of investigation. The Eden Landing former salt ponds are less subsided than the Alviso complex ponds, thus the marsh plain will form and revegetate more rapidly. Therefore developing a comprehensive monitoring program at this location would provide information that could frame expectations for the other south bay restoration complexes and more completely characterize fishery use across multiple evolving habitats.

Existing baseline data in or adjacent to the Eden Landing complex includes the following parts of the spatial/habitat trajectory:

- Intertidal bay flats as monitored at DFG beach seine location 171 (Figure 1-1)
- Tidal wetland channels in Cargill mitigation site

- Tidal sloughs with fluvial input, in Old Alameda Creek/Coyote Hills Slough and Alameda Flood Control Channel
- Managed ponds (data from ponds 1, 2, 4, 5, 6C, and 7 in the Eden Landing complex)

The Eden Landing complex includes all the habitats of interest and includes wetlands at multiple stages of development:

- salt ponds newly opened to muted tidal action as managed ponds,
- early stage marsh plain development, i.e., low percent cover by vegetation on the marsh plain at Cargill Mitigation site

The Whale's Tail Marsh is an undisturbed, remnant mature emergent marsh located at the mouth of Old Alameda Creek/Coyote Hills Slough adjacent to these other sites. Whale's Tail Marsh and channels are visible in Figure 1-3, immediately west of the Cargill Mitigation site. Fisheries monitoring data has not been collected here to our knowledge. It could be added to this group of sites, representing the bay's climax wetland stage. In addition, DFG has recently introduced tidal action to former salt ponds north of Old Alameda Creek/Coyote Hills Slough, that are larger than the Cargill Mitigation site and that provide opportune monitoring locations.

Sampling issues and recommendations

Sampling fisheries in South Bay wetlands is challenging because of the physical conditions in the marshes and the need to avoid impacts to special status species. The following recommendations are offered based on observations made during this study.

- More sampling events are needed to understand the complex temporal and spatial relationships and variability. Long term, intensive sampling can help define trends not observed during short, quick sampling efforts.
- Multiple gear types, e.g., Fyke nets in addition to the gear types used, may increase the ability to effectively sample diverse habitats and species.
- Increased sampling at fixed sites is required to quantify fish use of near shore habitats. The number of surveys in this study was small relative to other fish studies. The data here indicate that increased sampling increases the number of uncommon or less abundant species detected, and therefore species numbers in different habitats is confounded by sampling effort.
- Characterization of fish use of channels of different orders (which can also be measured as stream width or channel depth) requires the ability to sample in small channels. Such data may be critical to restoration designs in which channels are artificially constructed.
- Conduct consultation with U.S. Fish and Wildlife Service regarding California clapper rail to obtain a permit to sample in small channels.
- Collection of additional channel habitat data: cross sections with vegetation, slopes, topwidths, depths (high/low tide) over time to document channel evolution would be useful for correlating with species presence and absence.
- Protocols need to be developed for field measurements of channel cross-section bathymetry and channel slope, (without expensive topographic survey equipment) for implementation in **unconsolidated sediments**. Issues include difficulty walking in soft sediments at low tide

and when taking measurement at high tide from a boat it is difficult to discern the channel's bottom surface.

Literature Cited

Baxter, R., Hieb, K., DeLeon, S., Fleming, K., and J. Orsi. 1999. Report on the 1980-1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary, California. California Department of Fish and Game. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Technical Report 63. 503 pp.

California Department of Fish and Game Technical Report 63. Ed. James Orsi. Interagency

Cargill Pond B-1 Tidal Wetland Restoration, Union City. Wetlands Research Associates, Inc.

(CRWQCB) California Regional Water Quality Control Board. 2007. San Francisco Bay Basin (Region 2), Water Quality Control Plan (Basin Plan).

Ecological Program for the Sacramento-San Joaquin Estuary, California Department of Fish and Game, and California Department of Water Resources, and National Marine Fisheries Service.

(Goals Project 1999) U.S. EPA and SF RWQCB (1999). Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U.S. Environmental Protection Agency, San Francisco CA/ S.F. Bay Regional Water Quality Control Board, Oakland, CA

Gregory, P. A. (1992) California's living marine resources and their utilization. Pages 78-79 in W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California Department of Fish and Game, Sacramento, CA.

Life Science! 2003. South Bay Salt Ponds Initial Stewardship Plan. Submitted to US Fish and Wildlife Service and California Department of Fish and Game.

Miller, D. J. and R. N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157.

(MSI) Marine Sciences Institute. 2002 Trends in South San Francisco Bay Fish Populations from 1972 to 2002. Discovering Our Bay. Marine Science Institute 500 Discovery Parkway Redwood City, CA 94063-4715.

NOAA. 2007. San Francisco Bay Watershed Database and Mapping Project. Available: http://mapping.orr.noaa.gov/website/portal/sanfranciscobay/index.html

Pearson, D.E. 1989. Survey of fishes and water properties of South San Francisco Bay, California, 1973-82. NOAA Tech. Rep. NNMFS 78. U.S. Dept. Commerce. 21 pp.

(PWA) Philip Williams & Associates, H.T. Harvey & Associates, EDAW, Brown & Caldwell. 2006. Final Restoration Alternatives. Report submitted to California State Coastal Conservancy, US Fish and Wildlife Service, California Department of Fish and Game.

San Francisco Foundation. 1990. Ecological Restoration in the San Francisco Bay Area. A Descriptive Directory and Sourcebook.

Stralberg, Diana; Warnock, Nils; Nur, Nadav; Spautz, Hildie; Page, Gary. 2003. Predicting the effects of habitat change on South San Francisco Bay bird communities: An Analysis of bird –habitat relationships and evaluation of potential restoration scenarios. Habitat

Conversion Model: Phase One. Prepared by PRBO Conservation Science for California Coastal Conservancy.

The Bay Institute of San Francisco. 1987. Citizens' Report on the Diked Historic Baylands of San Francisco Bay. 196 pgs.

USFWS, CDFG. 2004. Draft Environmental Impact Statement/Environmental Impact Report. Bair Island Restoration and Management Plan Don Edwards San Francisco Bay National Wildlife Refuge Bair Island Ecological Reserve. August, 2004.

USGS. 2006. Fishes of Selected Salt Ponds and Sloughs on the Don Edwards San Francisco Bay National Wildlife Refuge.

Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Technical Report 9.

Woods, E. M. 1984. A Survey of Fishes Utilizing a Marsh Restoration Site in San Francisco Bay. Master's Thesis, San Francisco State University. 81 pp.

Appendix A
List of Potential Sampling Sites

Sites for February 9, 2006 Field Visit

Natalie Cosentino-Manning, Gillian O'Daugherty, Francesca Demgen

1. Cogswell Marsh
    a. Ownership: EBRPD, Contact: Mark Taylor (510) 783-1066
    b. 229 acres, breached in 1980
    c. 880 to W. Winton Ave, take it to the bay.
    d. Good for sampling
        i. Several mid-large channels
        ii. Nice shallow bay area
    e. Clapper rail is an issue
2. Pond 3
    a. Ownership: EBRPD, Contact: Alameda Creek trail office (Eric) 510-790-2612
    b. 110 acres, breached in 1975
    c. Enter north levee trail through stables. Will need permit for fish sampling
    d. Not good for sampling (no good channels)
3. Cargill Mitigation Marsh
    a. Excellent for sampling
        i. A few good channels
        ii. One nice breach area for gill or fyke netting
    b. Clapper rail issue
4. La Riviere Marsh
    a. Ownership: USFWS, Contact: Clyde Morris (510) 792-0222
    b. 117.6 acres, restricted flow in 1982 and 1988
    c. Thornton Ave and Gateway Blvd., Fremont
    d. Decent for sampling
        i. A few channels
        ii. Good access
        iii. Upstream too far, may not be representative
5. Bayside Business Park
    a. Ownership: USFWS, Contact: Clyde Morris (510) 792-0222
    b. 271 acres, breached in 1986
    c. 880 to Fremont Blvd south, to Clipper Ct..
    d. Not good for sampling
        i. Mostly open water
6. Charleston Slough
    a. Ownership: City of Mountain View, Contact: Paula Bettencourt
    b. 101.3 acres, (60 according to our list), restricted flow 1998
    c. 101 to East Bayshore Rd
7. Faber Tract Marsh
    a. Ownership: USFWS, Contact: Clyde Morris (510) 792-0222
    b. 87.3 acres, breached in 1971
    c. 101 to University Ave to Runnymede St
    d. Good site for sampling
        i. Several large to mid-size channels
        ii. Decent access
        iii. Good locations

8. Cooley Landing
    a. Ownership: MROSD, Contact: Cindy Roessler (650) 691-1200
    b. 118.4 acres, breached in 2000
    c. 101 to University Ave to Bay Road
    d. Not good for sampling
        i. No defined channels formed yet
9. Bair Island
    a. Ownership: USFWS, Contact: Clyde Morris (510) 792-0222
    b. 800 acres, breached in 1975 and 1979
    c. Access difficult.
        i. Boat required
        ii. Strong currents in area.
    d. 101 to Whipple Rd east.
    e. May be ok for sampling but will require boat
        i. Inner bair is not representative
        ii. Middle and Outer Bair may work. Need to see sloughs
10. Seal Slough
    a. City of San Mateo, Contact: Bob Batha BCDC
    b. 43 acres, breached approx. 1982
    c. access off 3rd Avenue, San Mateo
    d. Did not visit but doesn’t look good

Appendix B

Data Summary

2006 Sampling

Fish Captured From All Methods in 2006

	March/April 2006				June/July 2006				September 206				October/November 2006			
Common name	**Bair Island**	**Cogswell**	**Cargill**	**Faber**	**Bair Island**	**Cogswell**	**Cargill**	**Faber**	**Bair Island**	**Cogswell**	**Cargill**	**Faber**	**Bair Island**	**Cogswell**	**Cargill**	**Faber**
Topsmelt	1	2	4	510	660	212	307	191	624	163	6	227	21	54	299	945
Pacific herring	7															
Thread finned shad								1								
Staghorn Sculpin	5	1	1				1									
Carp				1												
Shiner surfperch	2			11												
Northern Anchovy	2		145	1						11		1				
Rainwater killifish		5		2			15			15		2			22	17
Stickleback		10		4	1	221	23									4
Cheekspot goby			9													
Goby sp.							1	1								
Longjaw mudsucker		1		41		15	25	2		1		2			8	6
Unknown goby #2		2		4												
Unknown goby #1		5				7										
Yellowfin goby		2				13	3			3	1				4	
Striped bass								1		1		1		1		
Diamond turbot	1															
Flatfish		1														
Leopard shark									5							1