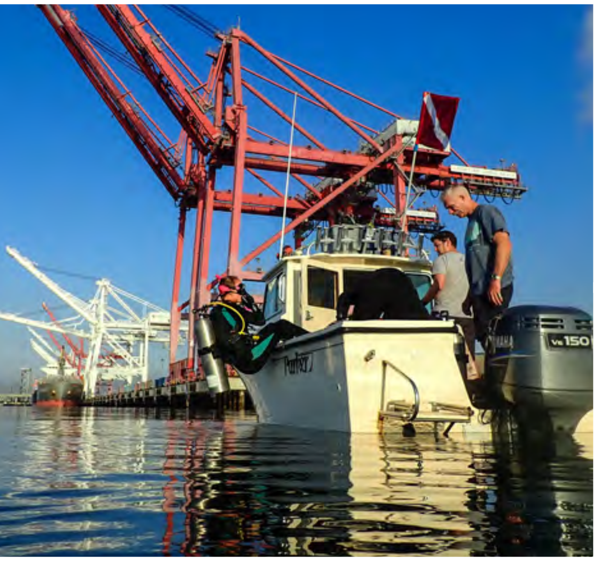
2018 Biological Surveys

Los Angeles and Long Beach Harbors





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2018 BIOLOGICAL SURVEYS OF THE LOS ANGELES AND LONG BEACH HARBORS

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LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

%	percent
°C	degree(s) Celsius
µg/kg	microgram(s) per kilogram
µg/L	micrograms(s) per liter
µm	micrometer(s)
µS/cm	microsiemen per centimeter
AHA	Accident Hazard Analysis
ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
APP	Accident Prevention Plan
ASTM	American Society for Testing and Materials
Biosurvey(s)	Biological Survey(s)
BRI	Benthic Response Index
CA	California
CalCOFI	The California Cooperative Oceanic Fisheries Investigations
CANOD	California Aquatic Non-Native Organism Database
CDFW	California Department of Fish and Wildlife
CFR	Code of Federal Regulations
CIQ	*Clevelandia*, *Ilypnus*, *Quietula*
cm	centimeter(s)
CO_2	Carbon Dioxide
COC	chain-of-custody
CPS	Coastal Pelagic Species
CTD	Conductivity-Temperature-Depth
DCE	Dancing Coyote Environmental
DGPS	differential global positioning system
DO	dissolved oxygen
DQO	Data Quality Objectives
EFH	Essential Fish Habitat
EI	Ecological Index
ENSO	El Niño Southern Oscillation
FL	Fork length
FMP	Fishery Management Plan
g	gram(s)
GIS	Geographic Information System
HDSP	Health and Dive Safety Plan
hr	hour(s)
IBI	Index of Biotic Integrity
ID	identification
ITIS	Integrated Taxonomic Information System
IUCN	The International Union for Conservation of Nature
kg	kilogram(s)

ACRONYMS AND ABBREVIATIONS (Continued)

L	liter(s)
LA	Los Angeles
m	meter(s)
M&A	Merkel & Associates, Inc.
m^2	square meter(s)
m^3	cube meter(s)
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
$MgSO_4$	Magnesium sulfate, Epsom salts
mL	milliliter(s)
MLLW	mean lower low water
mm	millimeter(s)
MQO	method quality objectives
N/A	not applicable
NEMESIS	National Exotic Marine and Estuarine Species Information System
nMDS	Non-metric Multidimensional Scaling
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
ONI	Oceanic Niño Index
OT	Otter Trawl
PCG	Pacific Coast Groundfish
PDO	Pacific Decadal Oscillation
pH	potential of hydrogen
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
POLA	Port of Los Angeles
POLB	Port of Long Beach
Port Complex	Ports of Los Angeles and Long Beach
Ports	Ports of Long Beach and Los Angeles
PRIMER	Plymouth Routines in Multivariate Ecological Research
PSU	Practical Salinity Unit
PT	pressure/ temperature
QA	Quality Assurance
QC	Quality Control
RMC	Regional Monitoring Coalition
ROV	Remotely operated vehicle
SCAMIT	Southern California Association of Marine Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
Seaventures	Seaventures, Inc.
SIMPER	Similarity Percentages
SIMPROF	Similarity Profile

ACRONYMS AND ABBREVIATIONS (Continued)

SL	Standard length
SM	Standard Methods
SOP	standard operating procedure
sp.	species
SQO	Sediment Quality Objectives
SST	Sea Surface Temperature
SWH	Shallow water habitat
SWRCB	State Water Resources Control Board
TL	Total Length
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
U.S.	United States
USC	University of Southern California
UPC	Uniform Point Contact
USEPA	United Stated Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WoRMS	World Register of Marine Species
WQO	Water Quality Objective
WRAP Model	Water Resources Action Plan Model
Wood	Wood Environment & Infrastructure Inc.
yr	year

EXECUTIVE SUMMARY

I. INTRODUCTION

The biological communities of San Pedro Bay represent an important element of the coastal marine biological resources of Southern California. These communities co-exist with and are affected by the operations of the nation's largest port complex: the ports of Los Angeles and Long Beach. As discussed in more detail below, this report describes both the current state of those communities and how those communities have changed over the past 40 years in response to federal and state regulatory programs and the robust environmental initiatives of the two ports.

The Long Beach-Los Angeles Port Complex today (Figure ES-1) consists largely of deep channels and basins for the navigation of cargo vessels and other watercraft, and dry land to support marine cargo terminals and other water-related uses. Most of the shoreline is protected by rock dikes, rock revetments, and sheet-pile or concrete bulkheads, and lined by pile-supported wharves and piers. Virtually none of the original coastal features on which the ports were built over the past 100+ years – tidal marshes, mudflats, sandy beaches, and tidal channels -- are still present. Small stretches of sandy beach and small areas of shallow water are present, largely as by-products of past development or as mitigation efforts undertaken by the ports.

The ports are charged by various laws both with accommodating maritime commerce, navigation, and fisheries and with managing and protecting the marine resources of the harbors for the people of California. As part of that stewardship, the ports have conducted periodic, comprehensive biological surveys (Biosurveys). Early studies focused on one port or the other but starting in 2000 the Biosurveys covered the entire Port Complex. Other studies, sponsored by state and local agencies and public utilities, have provided additional information on conditions in the Port Complex over the past 70 years. The earliest studies documented seriously degraded conditions in the harbor, including areas virtually devoid of marine life, as a result of essentially unchecked pollution from the urbanized greater Los Angeles area. Since the mid-1970s, however, conditions have steadily improved as a result of pollution control efforts mandated by the Clean Water Act of 1972.

The latest harbor wide Biosurvey, conducted between April 2018 and March 2019, is the primary subject of this report. Sampling stations are shown in Figure ES-2. It supplements and updates the information provided by the three previous harbor wide Biosurveys (2000, 2008, 2013). Like those surveys, this study, on the basis of field sampling and observation, describes physical conditions and the marine biota of the Port Complex, including:

- the pelagic (open water) zone,
- the harbor's soft bottom habitats (including eelgrass beds),
- hard substrate habitats (riprap and boulder shorelines, pilings, breakwaters, kelp beds), and
- the birds and marine mammals of the Port Complex.

This study, like the previous Biosurveys, has four key objectives:

1) to describe the biological communities of the various habitats in the Port Complex;
2) to describe how those communities have changed over time;
3) to describe how those communities compare among different habitats and sub-regions within the Port Complex and to the greater Southern California coastal region and;
4) to document the occurrence of non-native species in the Port Complex.

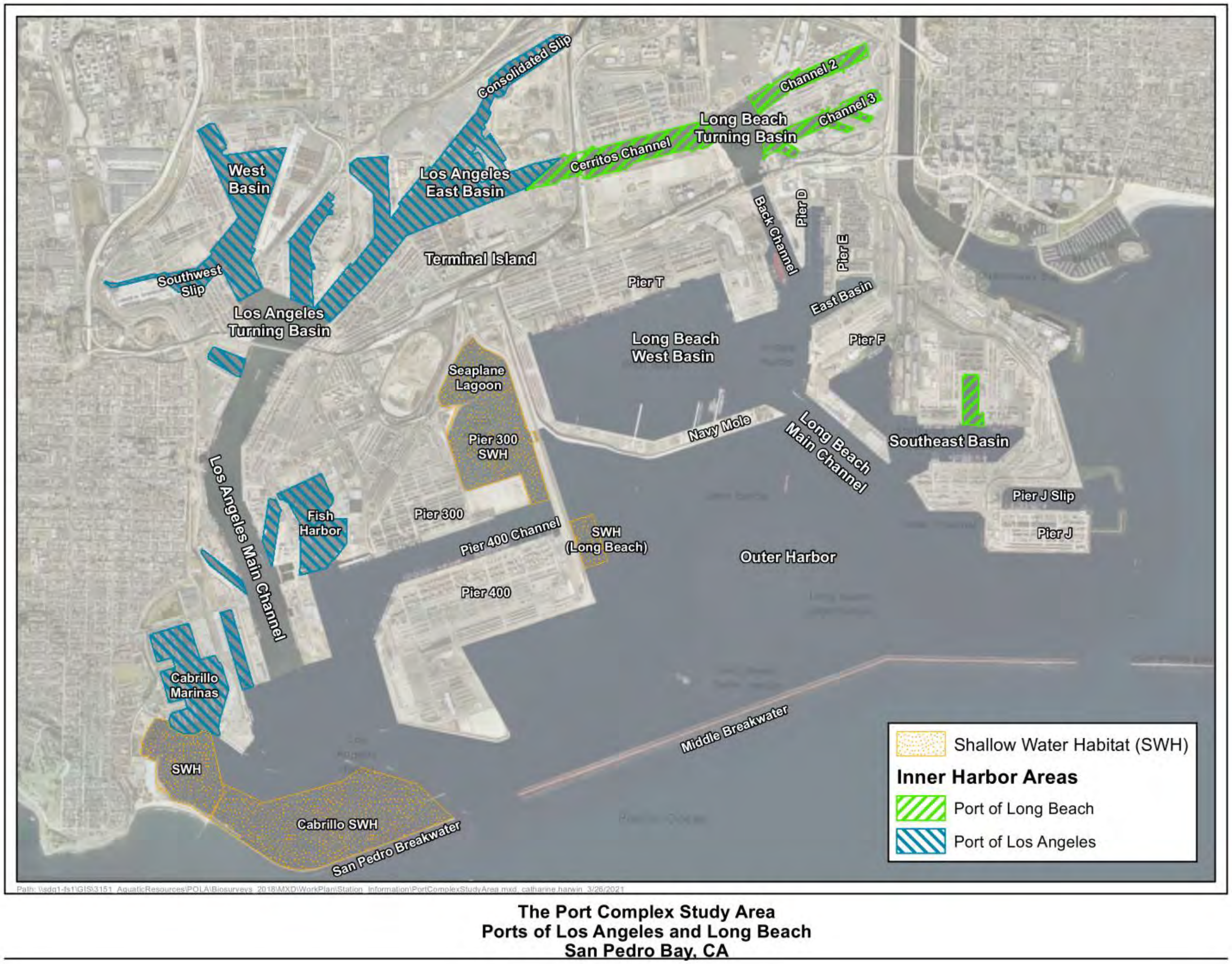
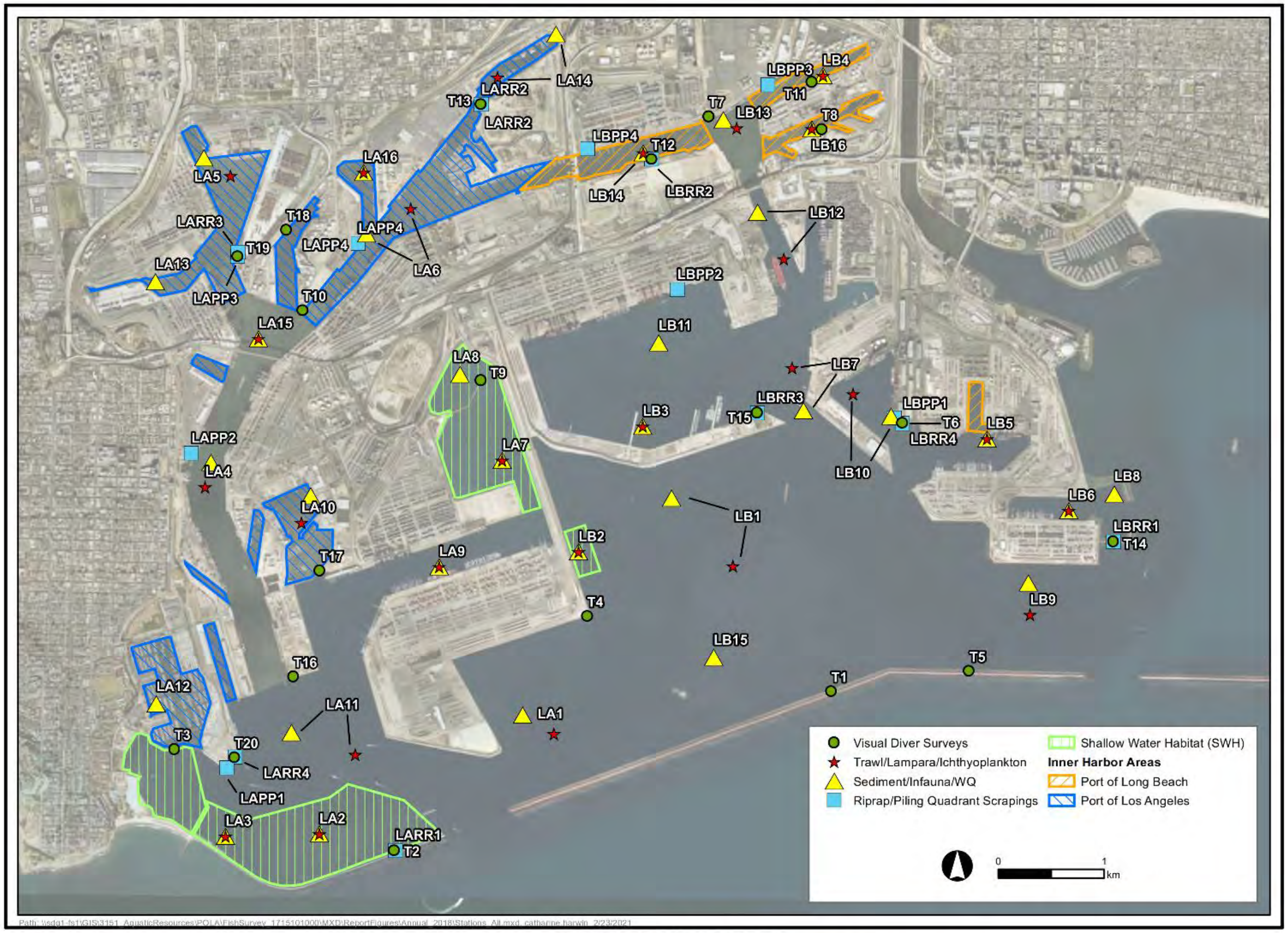


Figure ES-1. The Los Angeles and Long Beach Port Complex



Sampling Station Locations
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure ES-2. Sampling Stations Within the Los Angeles and Long Beach Port Complex

To achieve these objectives, the study design closely resembled the design of the three previous Biosurveys. Changes from those previous studies included:

- Altering some elements of the hard substrate sampling effort to better align with regional efforts and to increase the emphasis on the biota of pilings;
- Refining the technique for collecting fish eggs and larvae;
- Redesigning the surveys on riprap for kelp and macroalgae to make the methodology consistent with similar region-wide kelp monitoring programs and to include an assessment of invertebrates and the presence of fish;
- Adding some sampling stations and relocating others to reflect the changes in the hard-substrate sampling effort; and
- Refining the bird survey technique to better reflect the actual habitats used by birds.

Sampling was conducted at stations throughout the Port Complex (Figure ES-2), the number and location of stations varying with the type of sampling. In general, the sampling effort was equally divided between the two ports, although in the case of certain study elements (i.e., beach seines and eelgrass), the absence of beaches and scarcity of shallow-water habitat in the Port of Long Beach resulted in sampling being concentrated on the Port of Los Angeles side of the harbor.

II. PHYSICAL CONDITIONS

The physical conditions in the Port Complex profoundly influence which plants and animals live in harbor waters and how their abundances and distributions change over time. As general examples:

- Areas with consistently low dissolved oxygen (DO), which can be indicative of organic enrichment and/or pollution, are often populated by only those few species that can tolerate such conditions.
- Water clarity can limit photosynthesis by marine plants (eelgrass, attached seaweeds, and pelagic phytoplankton).
- Composition of sediments (sand, silt, clay) and organic carbon content can influence the suitability for the establishment of eelgrass and the composition of benthic infauna that can burrow and forage in that area.

The physical parameters of water temperature, dissolved oxygen concentration, water clarity and turbidity, pH, chlorophyll-a concentration (as a measure of planktonic algae), and salinity were measured in May and August of 2018 and January of 2019. Sediment characteristics (grain size and total organic carbon [TOC] content) were sampled in spring and summer.

Water temperatures varied by season and depth, with summer surface temperatures reaching 21.9^{o} C. Surface temperatures did not show large differences between Inner Harbor and Outer Harbor, although bottom temperatures in spring and summer were lower at Outer Harbor Stations compared to Inner Harbor and SWH stations. The past three Biosurveys (2000, 2008 and 2013) occurred during cool oceanic regimes, according to the Oceanic Niño Index (ONI) and sea-surface temperature records for the last 20 years in San Pedro Bay. Conversely, the 2018 Biosurvey occurred during a warm regime, in addition to following a large marine heatwave event that persisted in the Southern California Bight from 2014-2016. The signal from the marine heatwave within the Port Complex was also recorded in monthly CTD monitoring from 2008-2018 within POLA at Inner and Outer Harbor stations at the surface and the bottom.

DO concentrations were above the Basin Plan water quality objective of 5.0 mg/L at every station in all three seasons with two exceptions: the concentration at the bottom of the water column at the Fish Harbor station was 3.6 mg/L in spring and summer. Fish Harbor has a history of low DO concentrations at depth, which have been attributed to restricted circulation and the presence of historical fish processing wastes in the sediments.

Water clarity at Outer Harbor stations showed little variation with either season or depth, but at some Inner Harbor stations clarity fell to as low as 20% light transmittance, as opposed to typical values elsewhere in the Port Complex of 60-80%. According to monthly CTD surveys within POLA from 2009-2018, Inner and Outer Harbor stations showed modest improvement in average water clarity (measured as transmittance and turbidity) in 2015-2018 compared to 2010-2014.

pH values in the Port Complex varied little with season, depth, or location, and were consistent with typical coastal ocean waters. The average pH values harbor wide across all seasons ranged from 8.09-8.47.

Salinity in the Port Complex varied little in spring and summer with depth or location, and values were typical of the nearshore coastal ocean (33.5 PSU). In winter, however, lower salinity occurred in the surface layers at numerous stations as a result of stormwater runoff from the Los Angeles Basin, with salinity ranging from 30.9-33.4 PSU.

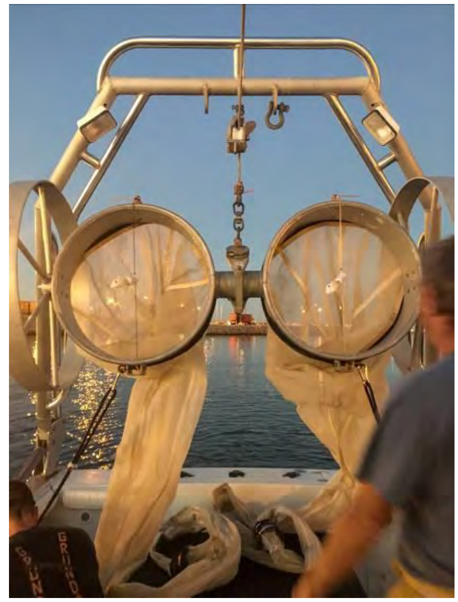
Chlorophyll concentrations were similar in summer and winter throughout the Port Complex (1.2-2.1 µg/L), but values were higher in spring (average of 3.7 µg/L at the surface and 4.4 µg/L near the bottom), reflecting the typical "spring bloom" of planktonic algae. As would be expected in a coastal embayment such as San Pedro Bay, concentrations were generally somewhat higher than in nearby open coastal waters, which average 1-2 µg/L.

Soft-bottom sediments in 2018 in the Outer Harbor were composed largely of silt and sand, whereas sediments in Inner Harbor areas were muddier, containing an average of over 60% silt and clay (% fines). This pattern reflects the more energetic environment of the Outer Harbor, which results in less deposition of fine sediments. Total organic carbon measured in 2018 was greater on average at Inner Harbor stations (4.28%) compared to Outer Harbor stations (1.54%).

III. PELAGIC HABITAT

The pelagic habitat is the water column that extends from just above the sea bottom to the water surface. It is the most widespread habitat type throughout the Port Complex, totaling some 3,600 hectares (8,900 acres) of water area. Unlike static habitats such as sediments and riprap, the pelagic habitat consists of a dynamic, three-dimensional, moving environment of open water.

Pelagic organisms of particular concern to the Biosurveys are the fish species managed by NOAA Fisheries under the Coastal Pelagics Fisheries Management Plan (FMP) through the Magnuson-Stevens Fisheries Management Act. The common Coastal Pelagics in the Port Complex are northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax caeruleus*), Pacific (chub) mackerel (*Scomber japonicus*), and jack mackerel (*Trachurus symmetricus*). In addition to juvenile and adult pelagic fish species, the 2018 Biosurvey sampled the eggs and larvae (referred to as "ichthyoplankton") of pelagic fish. The ichthyoplankton and juvenile/adult pelagic fish were sampled at 26 stations in spring and summer, with samples collected both day and night.



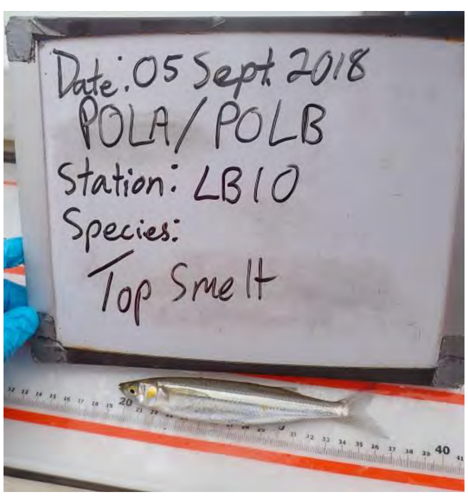
Ichthyoplankton "bongo" nets

Ichthyoplankton

Many of the pelagic and bottom-dwelling (demersal) adult fishes that live in the Port Complex also spawn there by broadcasting their eggs into the water column, where their larvae begin life as part of the plankton. Some of those species, such as blennies and gobies, are common in the Port Complex but are not usually caught in the lampara and trawl nets used to sample adult and juvenile fish because they live associated with structures, such as breakwaters, or are burrowing or otherwise cryptic species. Accordingly, sampling the ichthyoplankton can provide a more complete picture of the diversity of fish living in the Port Complex.

Fish eggs were collected in every sample but one, with a mean density of 34,079 eggs/100 m^3 of seawater per station. The eggs belonged to four groups: unidentified eggs, which accounted for 96% of the eggs, turbot (*Pleuronectes* spp., 2.5%), the anchovy family (Engraulidae, 1.3%), and the silversides family (Atherinidae, 0.03%). Fish eggs were about four times as abundant in winter and spring as in summer, but there were no obvious trends in abundance with location in the Port Complex.

The ichthyoplankton sampling effort collected 8,461 fish larvae belonging to 45 taxa, with a mean of 332 larvae/100 m^3 per station. Most taxa, however, were represented by fewer than ten individuals, and the top four taxa accounted for nearly 85% of the total catch: gobies in the CIQ species complex, combtooth blennies, northern anchovy (*Engraulis mordax*), and tripletooth gobies. Larval fishes were approximately ten times as abundant in spring and summer as in winter. The ichthyoplankton included larvae of two non-native demersal fish species: yellowfin goby (*Acanthogobius flavimanus*) and a species of tripletooth goby (assumed on the basis of the presence of adults in the Port Complex to be chameleon goby (*Tridentiger trigonocephalus*).



Topsmelt was the most abundant species captured in lampara nets

Pelagic Fish

Although the sampling caught 23 species of pelagic fish, three species (topsmelt [*Atherinops affinis*], California grunion [*Leuresthes tenuis*], and northern anchovy) overwhelmingly dominated the catch, accounting for 95% of the 18,336 individuals captured (Table ES-2). Half of the remaining species were represented by a single individual. Very large catches, primarily of grunion and northern anchovy, at just five of the 26 stations accounted for over half of the total catch.

Spring sampling caught 70% of the total abundance of pelagic fish, although the difference between seasons was not statistically significant because of the high variability in the catch of just a few species. Night sampling caught two-thirds of the fish, with substantially greater species richness compared to daytime sampling, with differences between day and night catches statistically significant. The pattern of substantially larger catches at night has been consistent throughout the four Biosurveys and may reflect diurnal patterns of habitat use within the Port Complex by some species.

Of the four Coastal Pelagics FMP species, northern anchovy was by far the most abundant; in addition to nearly 5,000 anchovies captured in the pelagic sampling effort (Table ES-1), nearly 15,000 were captured in the trawl samples of demersal fish (see Table ES-4). Population assessment for length at maturity revealed that the majority of the ten most abundant pelagic fish species were juveniles, suggesting the habitats present within the Port Complex constitute viable nursery habitat for these species that, once they become adults, head for deeper waters offshore.

Most of the total biomass of pelagic fish was made up by three species: topsmelt (40% of the biomass), grunion, and Pacific sardine. As with abundance, biomass was concentrated at a few stations where either very large numbers of small fish or a single large individual were caught.

Stations located in the SWHs on average supported more abundant, diverse, and balanced communities of pelagic fish species than stations located in deeper water or other parts of the Port Complex. However, multivariate analysis revealed few statistically significant differences among station groupings, likely because of the overwhelming dominance at all stations by just three species.

Table ES-1. Ten Most Abundant Pelagic Fish Species Captured in Lampara Nets During the 2018 Biosurvey

Common Name	Scientific Name	Number Caught	% of Total Catch	Biomass (kg)	% Juveniles
Topsmelt	*Atherinops affinis*	7802	42.6	77.0	98
Northern anchovy	*Engraulis mordax*	4884	26.6	11.9	92[a]
California Grunion	*Leuresthes tenuis*	4727	25.8	31.0	86
Pacific Sardine	*Sardinops sagax caeruleus*	540	2.95	30.9	50
Jack Mackerel	*Trachurus symmetricus*	151	0.82	9.88	96
Jacksmelt	*Atherinopsis californiensis*	130	0.71	3.73	92
Barracuda	*Syphyraena argentea*	45	0.25	14.1	Males[b]: 27% Females[b]: 100%
Queenfish	*Seriphuus politus*	20	0.11	0.56	24a
Pacific Mackerel	*Scomber japonicus*	12	0.07	1.40	100
Slough Anchovy	*Anchoa delicatissima*	7	0.04	0.02	NA[c]

[a] - Percentages combine catch from lampara and otter trawls
[b] - Due to inability to determine sex in the field and differing male and female ages at maturity, % Juveniles was calculated twice, assuming either an all-male or all-female population
[c] - Not analyzed for length at maturity due to low number caught (7)

The dominant species of pelagic fish, in terms of abundance, in the Port Complex have remained fairly stable over the four Biosurveys. Northern anchovy, grunion, and topsmelt, the three most abundant species in the 2018 Biosurvey, were always among the five most abundant species in previous Biosurveys. Other dominant pelagic species have included jacksmelt (*Atherinopsis californiensis*), Pacific mackerel, barracuda (*Sphyraena argentea*), and Pacific sardine, although the latter species has declined precipitously in abundance since the 2000 Biosurvey, a regional trend attributed to overexploitation of the fishery.

IV. SOFT-BOTTOM HABITATS

Most of the Port Complex's water area – over 8,000 acres -- consists of soft-bottom habitats: silty sediments of open-water areas, sandy sediments of beaches and shallow nearshore areas, and sandy-silt eelgrass beds. These habitats are inhabited by eelgrass growing in shallow areas throughout the Port Complex, invertebrates living in the sediments (benthic infauna) and on the sediment surface (epibenthic invertebrates), fish associated with the bottom (demersal fish), and fish in shallow subtidal areas near beaches. The soft-bottom habitats are important resources for adult and juvenile fishes, especially for those managed by NOAA under the Pacific Coast Groundfish (PCG) FMP.

Eelgrass, benthic invertebrates, and demersal fish were surveyed twice, in spring and summer, and subtidal fish were sampled in spring, summer, and fall. Eelgrass surveys covered the entire Port Complex, benthic invertebrates were sampled at 32 stations and demersal fish at 28 stations throughout the Port Complex, and subtidal fish were sampled at two locations: Cabrillo Beach and Seaplane Lagoon (both in the Port of Los Angeles).

Eelgrass

Eelgrass (*Zostera marina*) is a community-structuring seagrass, typically growing in beds in silty sand sediments, that in recent years has become abundant in shallow areas of the Port Complex. Eelgrass beds support a rich detrital food web and provide structure, food, and nursery habitat for a diverse range of fish, invertebrates, and birds, including commercially and recreationally important fish species. Given their diverse biological functions, eelgrass has been designated as a Habitat Area of Particular Concern (HAPC) under the Magnuson-Stevens Act resulting in the development of a formal mitigation policy for minimizing adverse impacts of development projects.

Eelgrass was found at twelve locations throughout the Port Complex in 2018 (Table ES-2; Figure ES-3). Over 99.5 percent of the eelgrass in the Port Complex occurs between +0.5 and -15 feet Mean Lower Low Water (MLLW). Two sites -- the Cabrillo Beach area and Pier 300 Basin (including Seaplane Lagoon) -- contained more than 95 percent of all of the eelgrass within the Port Complex during both seasons of survey. This spatial pattern of occurrence has been consistent through all of the past Biosurveys, although the 2018 Biosurvey identified eelgrass at two new locations. The density of eelgrass plants within beds varied, with the densest growth off Cabrillo Beach (a shallow area with some tidal exchange) and the lowest in the Consolidated Slip (a deeper area with restricted water movement).

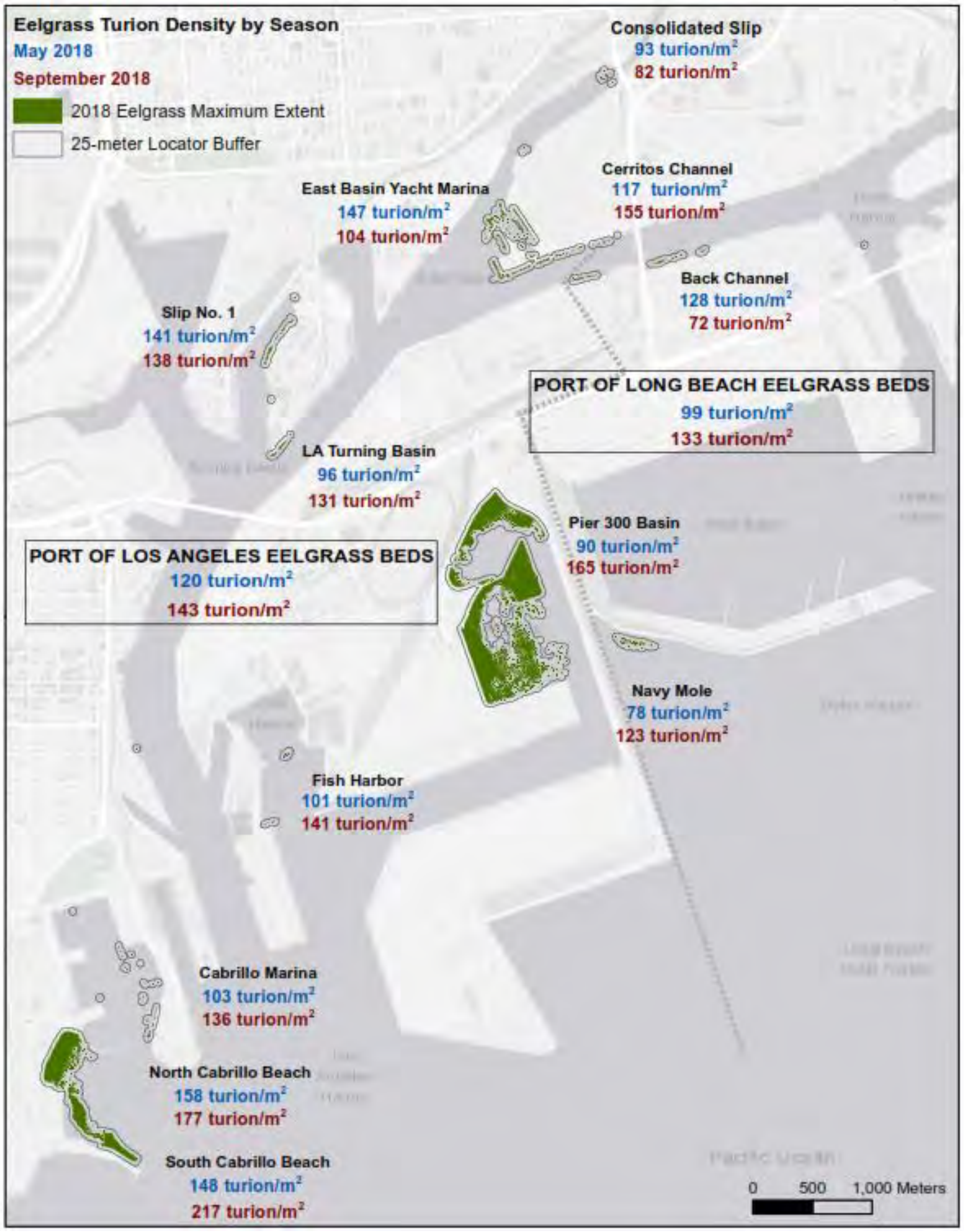


Figure ES-3. Turion Density of Eelgrass (*Zostera marina*) in the Port Complex

Current eelgrass distribution in the Port Complex is likely the result of colonization from outside areas (e.g., Alamitos Bay) and the transplantation efforts that have occurred since the early 1980s. Until the early 2000s, eelgrass in the Port Complex was only known to occur at Cabrillo Beach and the Pier 300 SWH, but the last three Biosurveys have documented small beds of eelgrass at numerous other locations, including patches on the Long Beach side of the Port Complex (Table ES-2). In addition, eelgrass occurred at greater depths in 2018 than in 2013. These changes suggest that physical conditions favorable to eelgrass, particularly water clarity and overall water quality, have continued to improve.

Table ES-2. Distribution of Eelgrass Within the Port Complex in 2018

Location of Eelgrass Beds		Spring 2018		Summer 2018	
		Acres	% of Total	Acres	% of Total
Port of Los Angeles	Pier 300 Basin	48.7	69.2%	62.0	72.1%
	North Cabrillo Beach	11.4	16.2%	12.1	14.1%
	South Cabrillo Beach	7.2	10.3%	7.8	9.1%
	East Basin Marinas	1.8	2.6%	2.3	2.7%
	Cabrillo Marina	0.1	0.2%	0.2	0.2%
	Fish Harbor	0.1	0.1%	0.1	0.2%
	Consolidated Slip	<0.1	0.1%	<0.1	<0.1%
	LA Turning Basin	0.1	0.1%	<0.1	<0.1%
	Slip No. 1	0.4	0.6%	0.5	<0.4%
	Total	**69.8**	**99.4%**	**85.3**	**99.2%**
Port of Long Beach	Navy Mole	<0.1	<0.1%	0.3	0.4%
	Cerritos Channel	0.4	0.6%	0.4	0.4%
	Back Channel	<0.1	<0.1%	<0.1	<0.1%
	Total	**0.4**	**0.60%**	**0.7**	**0.8%**
	Total Port Complex	**70.2**	**100%**	**86.0**	**100%**

Benthic Infauna

Benthic infaunal communities in the Port Complex are comprised of a diverse array of invertebrates with differing life histories and feeding strategies that live within the sediments. Benthic organisms are an important link between primary producers and higher trophic levels of the food web (e.g., fish and birds), and perform crucial ecological functions such as water filtration, nutrient cycling, and bioturbation of sediments. These organisms vary in tolerance to physical and chemical stressors from both natural and anthropogenic sources, and as a result can be valuable indicators of habitat quality.

Over 16,000 benthic infaunal organisms comprising 369 unique taxa were collected in sediment grab samples. There was very little significant seasonal variation in any of the summary measures used to characterize biological communities (abundance, biomass, species numbers, diversity) except that species richness was greater in summer than in spring. The phylum Annelida (principally, polychaete worms) dominated the infauna, comprising approximately half of total abundance. Arthropoda (crustaceans such as amphipods) was the second most abundant phylum, accounting for approximately one-third of total abundance. Nine of the ten most abundant benthic infauna species in each season (Table ES-3) were polychaete worms and amphipods, and they comprised nearly half of total abundance. The pollution-sensitive amphipod *Amphideutopus oculatus* was the most abundant species in both seasons. Four non-native species (two polychaete worms and two amphipods) were among the most dominant.

In terms of biomass, however, the phyla Mollusca (principally clams) in the spring and Annelida in the summer were dominant, largely because these phyla have species wherein a single large individual in a sample can outweigh numerous small individuals of other phyla. The other abundant phylum, Echinodermata (primarily brittle stars) rarely accounted for more than a few percent of total abundance or biomass. A number of other taxonomic groups were combined in the category "Other Taxa," composed of Chordata (mostly tunicates), Porifera (sponges), Cnidaria (anemones), Nemertea (ribbon worms), and several minor phyla.

There were no statistical differences in abundance, biomass, species richness, and diversity among the habitat types (Shallow-Water Habitat [5 stations], Inner Harbor [10 stations], Outer Harbor [17 stations]) although, on average, abundances were greater at the SWH stations than at Inner Harbor and Outer Harbor stations and diversity was greater at the Outer Harbor stations than within the other two habitats.

The exception was that two Inner Harbor stations (Cabrillo Marina [LA12] and Consolidated Slip [LA14]) had the highest abundances in both spring and summer. These stations, both characterized by restricted water circulation and runoff from land, were dominated by large numbers of pollution-tolerant species such as oligochaetes and by non-native polychaete worms and amphipods. Multivariate analysis clustered these two stations together, emphasizing how different they were from the other stations. Arthropoda (primarily amphipods) made up a notably higher proportion of abundance at SWH stations than at the other habitats, and this may have been due to the presence of eelgrass, which is known to attract amphipods.

Table ES-3. Ten Most Abundant Benthic Infauna Collected Across all Stations - Spring and Summer, 2018

Spring 2018		Summer 2018	
Taxon	**Percent of Total**	**Taxon**	**Percent of Total**
Amphideutopus oculatus[1]	12.0%	*Amphideutopus oculatus*[1]	8.3%
*Pseudopolydora paucibranchiata**	11.4%	*Cossura* sp. A	7.9%
Cossura sp. A	4.7%	*Pseudopolydora paucibranchiata**	6.2%
Zeuxo normani complex	4.0%	*Theora lubrica**	5.0%
Mediomastus sp.	3.6%	*Kirkegaardia siblina*	4.2%
*Sinocorophium heteroceratum**	2.8%	*Oligochaeta*	3.9%
Kirkegaardia siblina	2.8%	*Eochelidium* sp. A	2.8%
*Grandidierella japonica**	2.7%	*Mediomastus* sp.	2.2%
Oligochaeta	2.6%	*Euchone limnicola*	2.2%
Phtisica marina	2.5%	*Dorvillea longicornis*	2.0%

[1] Denotes sensitive, pollution-intolerant species. * Denotes non-native species

The location type station groups (Basin, SWH, Channel, Slip, Outer Harbor) also revealed few clear differences except that, as with the habitat types, mean abundance was greatest at the SWH stations. Stations grouped by depth showed clearer patterns: abundance was higher at Shallow stations (8 of the 32 stations) than at the Deep (21) and Very Deep (3) stations, but diversity and species numbers were highest at the Very Deep stations. Multivariate analysis of the abundance data generally confirmed the patterns revealed by the summary measures: the three habitat types were distinctly different from one another, forming separate groups in multivariate space; the Shallow stations were different from the Deep and Very Deep stations; and the location groups did not greatly differ from one another. These findings suggest that the benthic infauna assemblages within the Port Complex are influenced more by habitat type and depth than by location.

The 2018 Biosurvey applied a commonly used pollution tolerance index, the Benthic Response Index (BRI), to the benthic infauna data to evaluate the degree of stress, whether natural or anthropogenic, experienced by the communities at the sampling stations. The BRI was calculated in the 2013 Biosurvey but not in previous Biosurveys. The results identified 5 of the 32 stations as stressed to some degree; the remainder (85% of the stations) were scored as "Reference", meaning that they were similar to unpolluted sites. Three stations, LA10 (Fish Harbor), LA12 (Cabrillo Marina), and LA14 (Consolidated Slip), were considered to represent moderately disturbed communities in at least one season. Stations LA10 and LA14 have historically been considered impacted benthic communities and have elevated chemical concentrations in their sediments. No stations were considered to reflect highly disturbed benthic communities.

The 2018 Biosurvey documented a benthic community that shows the continued improvement in environmental conditions over the past six decades. For example, sampling in the 1950s identified only 70 species of benthic infauna, most of them pollution-tolerant Annelida, and found areas with no infauna at all. Sampling in the Port of Los Angeles in the mid-1970s found benthic infauna at all stations but identified large areas of the Inner Harbor and the Consolidated Slip as severely stressed by pollution. A study in the late 1980s identified several hundred taxa and concluded that sediments, even in the Consolidated Slip, were less contaminated than observed in earlier studies. The four Biosurveys from 2000 to 2018 have documented a steady decrease in the abundance of a key pollution indicator species, the polychaete *Capitella capitata*: it was one of the ten most abundant infauna species from the 1950s into the 1980s, but only 18 individuals were collected in 2018.

Epibenthic Invertebrates

Epibenthic invertebrates include highly mobile animals such as shrimp, crabs, lobsters, and snails, and sessile animals such as tunicates (sea squirts), bryozoans, sea pens, and scallops. These organisms are an important food source for a variety of fish, particularly demersal fish such as juvenile halibut and other flatfish, and also serve as an important trophic link.

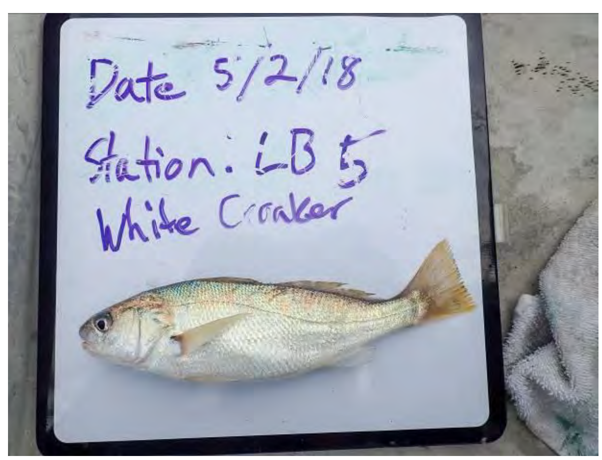
A total of 14,028 epibenthic invertebrates belonging to 121 species were collected in the otter trawls (93% of the individuals) and beach seine sampling (7%). There were no significant differences by either day/night or by season in the number of species collected, but there were statistically significant differences in total abundance: roughly twice as many animals were captured in trawls at night as during the day (beach seining only occurred during the day) and in spring as opposed to summer. There were few distinct patterns in the summary measures (abundance, species richness, biomass, and diversity) among the station groupings by habitat, location, or depth.

The most abundant species captured in trawls were target shrimp (*Sicyonia penicillata*), tunicates (sea squirts, *Ciona sp*), and blackspotted shrimp (*Crangon nigromaculata*); bryozoans are colonial and cannot be enumerated but two species were commonly caught. The most abundant epibenthic species captured in beach seines were green shrimp (*Hippolyte clarki*), western mud nassa snail (*Nassarius tiarula*), and purple olivella snail (*Calianax biplicata*).

The epibenthic species assemblage in the 2018 Biosurvey was generally consistent with those described by past Biosurveys and regional sampling programs. However, in the 2000 and 2008 surveys the community was dominated by the blackspot shrimp and the tuberculate pear crab, *Pyromaia tuberculata*, but 2013 and 2018 saw a dramatic shift in dominance to target shrimp. This shift appears to be partly a result of the target shrimp population shifting its distribution northward in response to recent warm-water events and changes in coastal current dynamics. These climatic forces may explain the increase in species richness for benthic infauna and epibenthic invertebrates, which over time may gain more subtropical species. While changes in the demersal fish community are less apparent in this study, invertebrate communities, with shorter life cycles and more passive distribution of larvae, may be more sensitive to and indicative of these larger oceanographic changes. Future Biosurveys and regional monitoring programs will be able to assess the persistence, magnitude, and impacts of such changes.

Demersal Fish

Trawl sampling for demersal fish collected a total of 59 species comprised of 28,491 individuals. The ten most abundant species (Table ES-4) accounted for nearly 98% of the total catch. All ten of those species were widely distributed throughout the Port Complex, being caught in at least two-thirds of the trawls. The abundance of northern anchovy, a pelagic species that nevertheless accounted for over half of the total otter trawl catch, is likely due to large schools tightly shoaling in deep areas of the Port Complex during the day, resulting in their capture in otter trawls. White croaker (*Genyonemus lineatus*) was by far the most abundant demersal fish species captured in the 2018 Biosurvey and also dominated the biomass, accounting for nearly half of the total weight of fish captured. The demersal species are, on average, much larger than anchovies, so despite the overwhelming abundance of anchovies, five of the most abundant demersal species accounted for 82% of the biomass, whereas anchovies only made up 2.8%.



White croaker was the most abundant demersal fish species captured in otter trawls

Other commonly caught demersal species not among the ten most abundant included shiner surfperch (*Cymatogaster aggregata*), fantail sole (*Xystreurys liolepis*), plainfin midshipman (*Porichthys notatus*), California scorpionfish (*Scorpaena guttata*), spotted sand bass (*Paralabrax maculofasciatus*), diamond turbot (*Hypsopsetta guttulata*), and hornyhead turbot (*Pleuronichthys verticalis*).

Size analysis of the most abundant demersal fish suggests that there are self-sustaining populations of mature adult queenfish and white croaker within the Port Complex, likely spawning and recruiting locally, although fish tracking studies suggest there is connectivity with nearshore populations outside the Port Complex as well. Most of the sand bass and halibut captured were juveniles, suggesting the value of the Port Complex as a nursery area for recreationally and commercially valuable fish species.

Table ES-4. Ten Most Abundant Fish Species Collected in Otter Trawls, 2018

Common Name	Scientific Name	Number Caught	% of Total Catch	Biomass (kg)	% Juveniles
Northern anchovy	*Engraulis mordax*	14,883	52.2	17.9	92a
White croaker	*Genyonemus lineatus*	8,231	28.9	317	83
Queenfish	*Seriphus politus*	2,201	7.7	67.9	24a
Barred sand bass	*Paralabrax nebulifer*	519	1.8	44.1	99
California tonguefish	*Symphurus atricauda*	509	1.8	6.7	NA[c]
Specklefin midshipman	*Porichthys myriaster*	444	1.6	3.2	NA[c]
California lizardfish	*Synodus lucioceps*	389	1.4	12.9	NA[c]
Speckled sanddab	*Citharichthys stigmaeus*	175	0.6	2.5	NA[c]
Round stingray	*Urolophus halleri*	166	0.6	54.1	NA[c]
California halibut	*Paralichthys californicus*	162	0.6	47.6	Males[b]: 39 Females[b]: 95

[a] - Percentages combine catch from lampara and otter trawls
[b] - Due to inability to determine sex in the field and differing male and female ages at maturity, % Juveniles was calculated twice, assuming either an all-male or all-female population
[c] - Not analyzed for length at maturity

The analysis of station groups showed that the SWH stations had, on average, higher numbers of demersal fish species, higher total biomass, and higher diversity than Inner Harbor and Outer Harbor station groups, and that Inner Harbor stations had the lowest total abundance and biomass of the three habitat groups (Figure ES-4). The station groupings by location type and depth range showed a similar result for diversity but did not show any other clear patterns. Multivariate analyses of the station groupings also revealed the four SWH stations to be distinctly different from any other station groups and that the differences were statistically significant but did not show any of the other station groupings to be markedly distinct from one another. Cluster analysis suggested that the SWH stations were distinguished by relatively high abundances of round stingray and California halibut, which were not major components of the fish assemblage in any other station group.

Trawl sampling across the four 2018 Biosurveys captured a total of 100 different fish species, although species richness has remained similar during each sampling year between 59 to 62. About a third of those species have been captured in every survey year, and although some of those are never abundant, there are nine species that are consistently common and can be considered the core species assemblage characteristic of the Port Complex. These nine species -- barred sand bass, California halibut, California lizardfish, California tonguefish, fantail sole, northern anchovy, queenfish, specklefin midshipman, and white croaker -- accounted for at least 75% of the total abundance of trawl-caught fish in every Biosurvey, and thus dominated the fish assemblage.

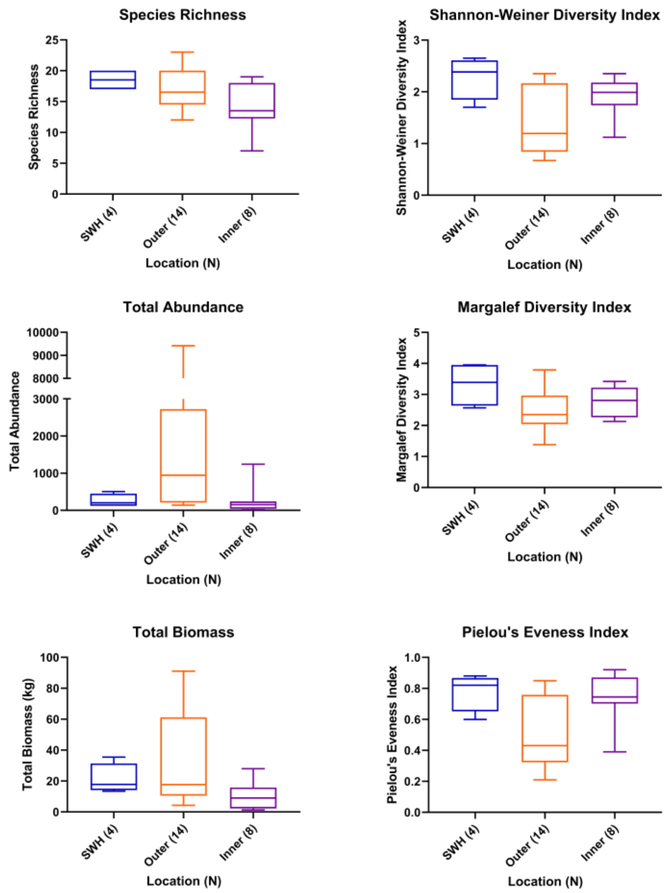


Figure ES-4. All Seasons Station Habitat Group Summaries
(Box plots show the median, range, and quartiles for each dataset)

Eight of the species managed under the Pacific Coast Groundfish Fishery Management Plan were captured in otter trawls during the 2018 Biosurvey. Multiple individuals of California scorpionfish, vermillion rockfish (*Sebastes miniatus*), Big skate (*Raja binoculata*), and gopher rockfish (*Sebastes carnatus*) were captured but only single individuals of bocaccio (*Sebastes paucispinis*), brown rockfish (*Sebastes auriculatus*), English sole (*Parophrys vetulus*), and Pacific sanddab (*Citharichthys sordidus*). Past Biosurveys have documented 16 managed species, although their abundances are relatively low and vary from year to year.

Shallow Subtidal Fish

Sampling at Cabrillo Beach and Seaplane Lagoon using a beach seine identified 23 species of fish totaling 1,352 individuals. Topsmelt, gobies, unidentified atherinids (topsmelt, jacksmelt, and grunions), and juvenile queenfish were the most abundant species, but several species rarely captured by other sampling methodologies were caught in appreciable numbers, including pipefish (*Syngnathus* spp.) and kelpfish (*Heterostichus rostratus*). Some of the species represented by large individuals in trawls were abundant in the beach sampling as early juveniles (e.g., California halibut, diamond turbot, and surfperches), highlighting the value of the shallow subtidal as nursery habitat. The proximity of large eelgrass beds to the beaches where sampling took place likely contributed to the abundance and species richness in these areas.

V. HARD SUBSTRATE ASSOCIATED COMMUNITIES

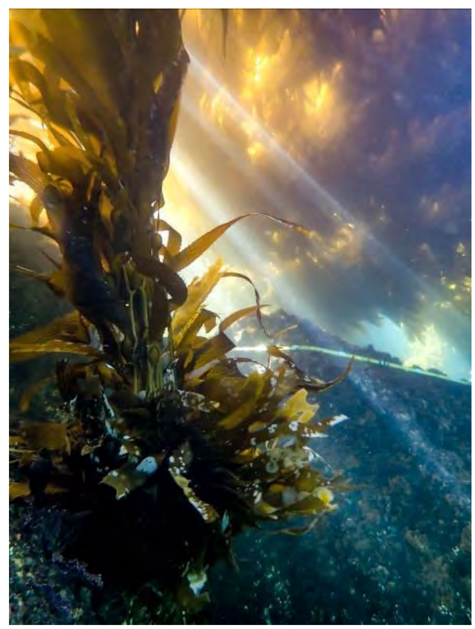
Most of the shoreline of the Port Complex consists of rock dikes known as riprap; the remainder is formed by steel, concrete, or wooden bulkheads. Along with extensive breakwaters and jetties, the Port Complex's riprap habitat represents over 50 miles of rocky shoreline. Much of the riprap supports extensive stretches of canopy-forming algae (chiefly giant kelp, *Macrocystis pyrifera*, but also including feather boa kelp, *Egregia menziesii*), various understory and encrusting algae, a diverse assemblage of invertebrates, and a number of reef-associated fish species. The boulders characteristic of riprap, particularly the breakwaters and Outer Harbor riprap, provide substantial surface area for algal and invertebrate recruitment and substantial interstitial space that helps capture drift algae and provides refuge from predators and habitat for invertebrates. Kelp forest on riprap also creates vertical structure in the water column that can be used by fish and marine mammals.

Tens of thousands of concrete, wood, and steel pilings support the wharfs and docks of the Port Complex. These pilings constitute another hard substrate that supports diverse assemblages of algae and invertebrates, depending on depth, current regime, degree of shading, and piling material. Encrusting algae and fleshy red, brown and green algae and a variety of attached and motile invertebrates such as tunicates, bryozoans, sponges, tube worms, barnacles, mussels, and sea stars, form growths on pilings that are often quite dense.

The 2018 Biosurvey characterized the riprap and piling communities using some methods similar to those used in past Biosurveys for macroalgae, while incorporating new methodology to survey invertebrates and fishes consistent with those used in regional surveys of rocky reefs. Additionally, the sampling methodologies were modified from previous Biosurveys by placing additional emphasis on pilings, which were not well studied in previous biosurveys.

Kelp Canopy and Other Algae

Kelp canopy covered 118 acres of the Port Complex in the spring and 114 acres in the summer of 2018. As in previous Biosurveys, kelp canopy was oriented along the linear features of breakwaters, jetties, shoreline riprap, and underwater dikes in the Outer Harbor. Giant kelp was not observed in the channels, basins, and slips of the Inner Harbor, which is consistent with its requirement for an energetic current regime to ensure adequate nutrient supply and with the seasonally higher temperatures in Inner Harbor areas, which can prevent recruitment and growth of existing kelp. However, drifting giant kelp and submerged kelp detritus was observed at Inner Harbor stations throughout the Port Complex, suggesting that there is connectivity between Outer Harbor kelp forests and Inner Harbor benthic communities that can augment secondary production in these areas.



Giant kelp in the Outer Harbor with canopy visible at the surface

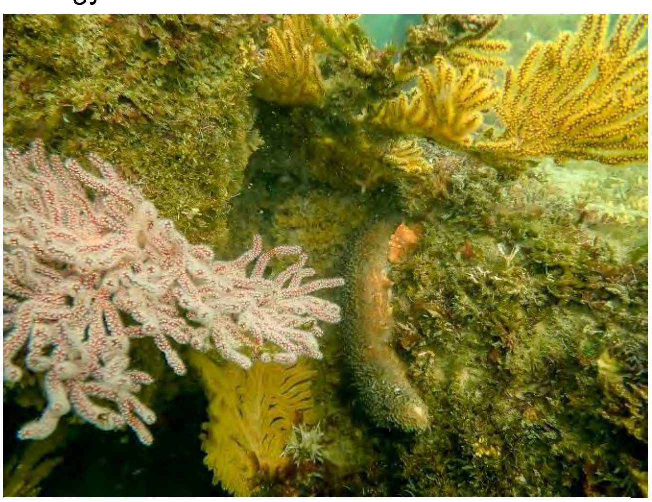
The extent of kelp canopy has increased steadily since the 2000 Biosurvey. In summer, 2018 coverage was more than twice that observed in any other survey, and in 2018, unlike previous years, there was little decrease from spring to summer.

Four understory species are found on riprap and pilings in the Port Complex: *Sargassum horneri, Sargassum muticum, Undaria pinnatifida*, and *Stephanocystis osmundacea*. The two *Sargassum* species and *Undaria* are non-native species that are considered invasive. At least one of the four species was found at every one of the riprap stations sampled by divers except the station at Los Angeles Berth 48, which was devoid of any but encrusting algae, likely due to very high densities of sea urchins. *Sargassum* and *Undaria* were substantially more abundant at the Inner Harbor riprap stations than at Outer Harbor stations, whereas *Stephanocystis* was only observed at Outer Harbor stations. *Sargassum horneri* was present at similar densities on riprap in spring and summer; but *S. muticum* and *Undaria* were far less abundant in summer than in spring. Interestingly, *Undaria* was observed on pilings at similar densities in both seasons, suggesting that pilings may be a more favorable habitat for the species.

Both riprap and piling substrates supported a variety of encrusting and low-growing algae. These were primarily coralline red algae (e.g., *Corallina* spp.) but included a number of species of red (*Ceramiaceae and Pterocladia*), brown (*Colpomenia*) and green algae (*Ulva)*.

Invertebrates

Riprap: Surveys observed marked differences between Outer Harbor and Inner Harbor stations in the composition of the invertebrate species assemblages. Specifically, Outer Harbor stations commonly consisted of predators such as spiny lobster (*Panulirus interruptus*), filter feeding gorgonians (*Muricea* spp.) and large anemones which are consistent with increased wave energy and currents in the Outer Harbor. Inner Harbor stations were dominated by bat stars (*Patiria miniata*) and sea cucumbers (*Apostichopus parvimensis*). The primary herbivores in the Port Complex were urchins, primarily purple urchins (*Strongylocentrotus purpuratus*), although abalone were also present in the Outer Harbor. UPC surveys of percent cover showed that Inner Harbor stations on average had higher percentages of bare substrate, reflecting higher sedimentation at depth, and of *Sargassum muticum*, and lower percentages of gastropod molluscs (i.e., snails), gorgonians, and coralline algae, than at Outer Harbor stations.



Gorgonians and a warty sea cucumber in the Outer Harbor

Although abalone have been reported anecdotally within the Port Complex, the 2018 Biosurvey was the first to document the presence of three particular species. A few individuals of green and pink abalone (*Haliotus fulgens* and *H. corrugata*) and one individual of the endangered white abalone (*H. sorenseni*) were found on Outer Harbor breakwaters and riprap during dive surveys. Green and pink abalone observed in these areas consisted of a mix of juveniles and individuals likely to be mature adults (50% adults for green abalone, 66% for pink abalone), suggesting that populations in the Port Complex could be self-sustaining in addition to augmentation through larval transport from nearby coastal populations.

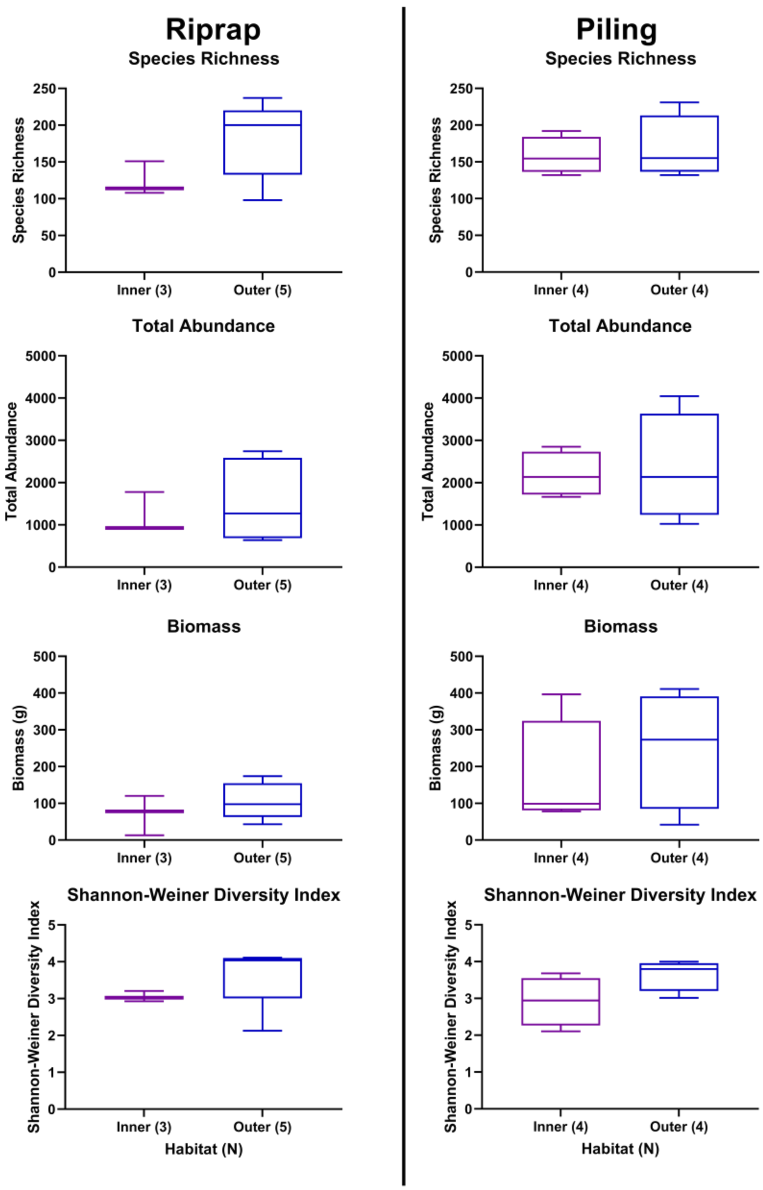


Figure ES-5. Species Richness, Abundance, Biomass and Diversity Index Values for Riprap Between Inner and Outer Harbor Habits

Finally, the scraped quadrat methodology, in which divers removed all the organisms from a small area at eight riprap stations, provided high-resolution taxonomy of the animals living at three tidal levels (upper intertidal, lower intertidal, and subtidal) on the riprap. A total of 491 species (459 invertebrate species and 32 algae species) were identified across all riprap stations; the average number of species at individual riprap stations was 160 and the average number of individuals was 1,427. Outer Harbor stations had more species and higher total abundance, biomass, and diversity than Inner Harbor stations (Figure ES-5). As is typical of rocky shorelines, the upper intertidal zone had significantly fewer species and individuals (mostly barnacles, which were much less abundant at lower tidal levels, and the bivalve mollusc *Lasaea adansoni*) than the lower tidal levels, reflecting the few species that are adapted to the harsh conditions of the upper intertidal.

Epifaunal community growing on piling

Two Inner Harbor riprap stations – one in Los Angeles West Basin and one near the Consolidated Slip – were distinctly different from all other stations due in part to the presence of the disturbance-tolerant non-native worm *Pseudopolydora paucibranchiata*. These are areas of historical sediment contamination, and this finding is consistent with their presence in the benthic infauna, described above.

The four Biosurveys since 2000 suggest a trend of increasing species richness and may suggest a concomitant increase in abundances on riprap, although methodological differences among the Biosurveys in terms of number of stations sampled make definitive statements problematic.

Pier Pilings: UPC surveys showed that pilings had higher percent cover by chordates, bivalves, and cnidaria compared to riprap stations, that the percent of bare substrate was much lower than at riprap stations, and that pilings appear to support an overall denser, more productive community than does riprap. Inner and Outer Harbor pilings showed only subtle differences in community composition, which were not statistically significant.

Scraped quadrats on pilings identified a total of 435 species (412 invertebrate and 23 algae species) with an average of 172 species and 2,541 individuals per station, substantially greater abundance than that observed for riprap stations, as well as an average biomass value twice that of riprap stations (Figure ES-5). The piling community differed from the riprap community in having generally a higher proportion of molluscs (e.g., mussels, *Mytilus galloprovincialis*) and lower proportion of arthropods (e.g., barnacles). Pilings also had more green and fleshy red algae than riprap, which tended to be dominated by coralline red algae.

Outer Harbor stations had, on average, substantially higher species numbers, total abundances, biomass, and diversity values than Inner Harbor stations (Figure ES-5). Multivariate analysis grouped the four Inner Harbor stations and one Outer Harbor station together as being significantly different in terms of species composition and abundances from the other three Outer Harbor stations.

Tidal height had a significant effect on the composition of the invertebrate communities found on both riprap and pilings, with lower species richness and diversity in the upper intertidal, which is expected due to the harsh and variable conditions compared to lower intertidal and subtidal areas. Riprap showed more variability in abundance between tidal heights with the highest average abundance in the lower intertidal zone, followed by the subtidal, while communities on pilings were relatively similar across all tidal heights.

The 2018 Biosurvey is the first to sample more than one piling station, so it is not possible to draw conclusions on historical trends in that substrate type.

Juvenile garibaldi sheltering in riprap

Fish of the Riprap and Piling Habitats

A total of 29 fish species were observed during the sampling at the riprap and piling stations. This was the first Biosurvey to include presence/absence of fish at these habitats. All of the species were seen associated with riprap but only seven were observed at piling stations. Kelp bass and barred sand bass were the most commonly encountered species at both riprap and piling stations. Several of the species observed in the hard-substrate sampling are not normally recorded from the Port Complex because, being closely associated with rock substrates or kelp forests, they are not captured by trawl or lampara sampling. These include garibaldi (*Hypsypops rubicundus*), sheephead (*Semicossyphus pulcher*), and opaleye (*Girella nigricans*), which were among the most common fish observed with new methodology in 2018 but were not observed in the three previous Biosurveys.

VI. BIRDS

The Port Complex features an assortment of habitats that provide shelter, foraging, and nesting opportunities for a wide variety of avian species, including waterfowl, shorebirds, gulls, aerial fish foragers, upland birds, and raptors. As in previous Biosurveys, marine mammals were recorded as they were observed during the bird surveys.

In these Biosurveys, birds are also considered through a concept called “guilds”, which groups bird species according to habitat usage and foraging patterns rather than taxonomic groupings (e.g., Aerial Fish Foragers, Waterfowl, Raptors). The study recorded the presence of birds on a variety of physical features throughout the Port Complex, such as open water, breakwaters, docks/pilings, barges, sandy beach, etc., in order to assess the value of such features to various bird guilds.

Great blue heron in the Outer Harbor

A total of 48,754 individual birds belonging to 87 species in 28 families were observed in the Port Complex during the 2018 Biosurvey. Monthly species numbers ranged from 35 in May 2018 to 54 in February 2019. Abundance was highly seasonal, with bird numbers peaking during the fall migration and winter, and at their lowest during the summer. This pattern was driven primarily by the abundance of overwintering Waterfowl (ducks, grebes, cormorants) and Aerial Fish Foragers (terns and pelicans).

However, 26 of the species observed are likely year-round residents because they were present during at least 10 of the 12 survey events.

As in previous Biosurveys, the ten most abundant bird species (Table ES-5) accounted for 90% of all observations, and the top three species – western gull, western grebe, and elegant tern -- accounted for over half of total bird abundance. Nine of these species have been numerically dominant in all four Biosurveys, indicating a consistent and stable species assemblage. Only one of the ten most abundant species was an upland species: rock pigeon (*Columba livia*), which are closely associated with structures such as docks, warehouses, and marina structures. All of the ten most abundant species, except the elegant tern, are year-round residents of the Port Complex, and five of those (western gulls, rock pigeons, great blue heron, Brandt's cormorant, and double-crested cormorant) are known to breed and nest in the Port Complex.

Abundant Bird Guilds: The most abundant guild was Gulls, which represented 37.6% of all birds observed during the survey period, and by far the most abundant gull (and the most abundant species observed in the Port Complex) was the western gull (Table ES-5). The Waterfowl guild accounted for 29.1% of total bird sightings, and four of the ten most abundant species were in this guild. The large expanses of open water in the Port Complex are attractive to grebes, scoters, and migratory ducks, which often form large rafts in the Outer Harbor. Aerial Fish Foragers accounted for 18.4% of observations and were most abundant in late spring and summer. Large numbers of elegant terns, as well as lower numbers of other terns, including the endangered California least tern, *Sternula antillarum*, arrive in the Port Complex in late spring, nest on Pier 400 in the Port of Los Angeles, and then depart in August for their overwintering grounds. Brown pelicans, the sixth-most abundant bird, return to the Port Complex in summer from their offshore island breeding grounds. The other five guilds were minor components of the overall bird assemblage, except for rock pigeons (9.2% of all birds) and, during the fall migration and winter, Small Shorebirds such as plovers, sandpipers, and turnstones that either stop over during their migration or overwinter in the Port Complex.

Table ES-5. Ten Most Abundant Bird Species In the Port Complex, 2018-2019

Species		Percent of Total	Guild
Western Gull	*Larus occidentalis*	32.4	Gulls
Western Grebe	*Aechmophorus occidentalis*	12.2	Waterfowl
Elegant Tern	*Thalasseus elegans*	10.5	Aerial Fish Foragers
Rock Pigeon	*Columba livia*	9.2	Upland Birds
Brandt's Cormorant	*Phalacrocorax penicillatus*	8.0	Waterfowl
Brown Pelican	*Pelecanus occidentalis*	5.7	Aerial Fish Foragers
Double-Crested Cormorant	*Phalacrocorax auritus*	3.9	Waterfowl
Heermann's Gull	*Larus heermanni*	3.6	Gulls
Surf Scoter	*Melanitta perspicillata*	3.1	Waterfowl
Great Blue Heron	*Ardea herodias*	1.4	Wading/Marsh Birds
TOTAL		90.0	

Rare and Special-Status Birds: Two of the species observed in the 2018 Biosurveys are rare in Southern California: a single American oystercatcher (*Haematopus palliates*) was observed on the eastern leg of the Middle Breakwater during several survey events, and a single black scoter (*Melanitta americana*) was observed in POLB's Southeast Basin during one survey event. In addition, 18 special-status species (i.e., species protected by state or federal regulations or otherwise listed as having a special status) were observed during the 2018 Biosurvey. Ten of these species are known to nest in the Port Complex (Table ES-6), and for them the harbor is an important habitat resource. For a number of other special-status species that do not nest within the Ports the harbor may be valuable for foraging and resting. These include the brown pelican, California gull (*Larus californicus*), long-billed curlew (*Numenius americanus*), whimbrel (*Numenius phaeopus*), marbled godwit (*Limosa fedoa*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), and common loon (*Gavia immer*).

In the 2018 Biosurvey, brown pelicans (2,780 observations) comprised only 5.7% of total observations, whereas in previous Biosurveys it has made up nearly 10% of the birds in the Port Complex (7,320 observations in 2013). This decline may reflect recent collapses of nesting colonies and/or the generally warmer ocean conditions along the coast of California and Baja Mexico.

Table ES-6. Special-Status Bird Species Nesting in Los Angeles-Long Beach Harbor

Species		Status	Abundance
California Least Tern	*Sterna antillarum brownii*	FE, SE, FP	Abundant
Peregrine Falcon	*Falco peregrinus*	BCC, FP	Common
Elegant Tern	*Thalasseus elegans*	WL	Abundant
Caspian Tern	*Hydroprogne caspia*	BCC	Common
Black Skimmer	*Rhyncops niger*	BCC, SCC	Common
Great Blue Heron	*Ardea herodias*	SA	Abundant
Black-crowned Night Heron	*Nycticorax*	SA	Common
Double-crested Cormorant	*Phalacrocorax auritus*	WL	Abundant
Black Oystercatcher	*Haematopus bachmani*	BCC	Common
Osprey	*Pandion halieatus*	WL	Occasional

Note: BCC = Bird of Conservation Concern; SA= Special Animal; SSC = Species of Special Concern; FP = Fully Protected; FE = Federally Endangered; WL = Watch List; SE = State Endangered

<u>Habitat Utilization</u>: Seven survey zones in the Outer Harbor, two in the Shallow Water Habitats in the Port of Los Angeles, and the Fish Harbor survey zone consistently supported large numbers of birds, and these zones accounted for over half of all the observations. The Outer Harbor zones, in particular, had large numbers of Aerial Fish Foragers and Waterfowl due to their proximity to the Pier 400 nesting site used by terns in spring and summer and to the large rafts of grebes and surf scoters in the winter. The Outer Harbor zones that included the Middle Breakwater had large numbers of birds due primarily to the cormorants, pelicans, and gulls roosting on the boulders. The Shallow Water Habitat zones had the highest species numbers, largely because of the variety of physical features – sandy beach, riprap, open water, dredge pipe – available. Fish Harbor attracted large numbers of gulls, likely because of the presence of the commercial fishing fleet, and of rock pigeons, possibly because of the large number of shoreline structures there.

These geographic patterns are consistent with the results of previous Biosurveys, as are the patterns in types of physical features used by birds. Open water, riprap, and dock/pilings have continually been the most heavily used physical features in the Port Complex. In all four Biosurveys, no less than 70% of observations have occurred in these three types of features, which is not surprising given that these are the dominant physical features of the water areas of the Port Complex.

Dolphins near Queen's Gate

VII. MARINE MAMMALS

Pinnipeds that are commonly observed within the Port Complex include harbor seal (*Phoca vitulina*) and California sea lion (*Zalophus californianus*), which forage on harbor waters and rest on the shoreline and structures in the harbor. Cetaceans known to occur within the Port Complex include common bottlenose dolphin (*Tursiops truncatus)* and common dolphins (*Delphinus* spp.), which forage in harbor waters. The gray whale (*Eschrichtius robustus*) is a rare visitor to the Port Complex but is commonly observed nearshore along coastal California during migration periods.

A total of 1,015 marine mammals observations belonging to five species were recorded during the 2018 Biosurvey. California sea lion accounted for 58.8% of total marine mammal observations and was present year-round. They were typically seen resting on buoys, docks, riprap shoreline, and the bulbous bows of large container ships in the Outer Harbor, and were especially abundant in the Long Beach West Basin. Previous Biosurveys also found California sea lions to be the most abundant marine mammal in the Port Complex. Harbor seals, the second most abundant marine mammal, were most commonly observed resting or foraging along riprap shorelines.

Common dolphin was the most abundant of the three cetacean species observed, but all of them occurred in a single pod. On the other hand, common bottlenose dolphins were observed several times in small groups throughout the Port Complex. The third cetacean species was a single gray whale observed in the Outer Harbor.

VIII. NON-NATIVE SPECIES

Species identified for each element of the 2018 Biosurvey and the historical Biosurveys (2000-2013) were cross referenced to determine their status with web-based databases and scientific literature including:

- Non-native status determined from National Exotic Marine and Estuarine Species Information System (NEMESIS) database, which was compiled with information previously held in the California Aquatic Non-Native Organism Database (CANOD) and used in previous Biosurveys.
- Cryptogenic species, defined by Carlton (1996) as "a species that is not demonstrably native or introduced" and has insufficiently documented life history or native range to

allow characterization as either native or introduced, were determined using the CDFW report "Introduced Aquatic Species in California Bays and Harbors 2011 Survey"

In total, 46 non-native species were identified in the current study (Table ES-7), which is an increase over the 27 species observed in 2013, 19 species in 2008 and 25 species in 2000. Of the 1,003 total fish, invertebrate and algal taxa observed during the 2018 survey, non-natives made up 4.6%, a similar relative contribution compared to past Biosurveys. The expanded methods and habitat types surveyed in 2018 may have contributed to the increase in non-native species detected, in addition to the possibility of climate-mediated changes in invertebrate communities resulting in new species appearing in new locations as their ranges expand with increasing water temperatures and events such as marine heatwaves.

Table ES-7. Number of Non-Native Species by Community Type in 2018

Phyla		# Non-Native Species	Ichthyo-plankton	Demersal Fishes	Epibenthic Invert-ebrates	Benthic Infauna	Riprap Epifauna	Piling Epifauna
Chordates	Fishes	2	2	1				
	Sea Squirts	12			2	2	8	12
Invertebrates	Annelids	4				2	4	4
	Arthropods	12			1	7	6	7
	Bryozoa	4			1	1	2	2
	Cnidaria	2				2		
	Mollusca	7			3	5	3	2
Macroalgae	Ochrophyta	3					3	2
Total Non-Native Species		**46**	**2**	**1**	**7**	**19**	**26**	**29**

The majority of non-native species, and all of the species not observed in previous Biosurveys, were invertebrates. Most species observed for the first time were represented by only a few individuals, and their persistence within the Port environment will require further monitoring to determine if they become established. The number of non-native fish species has remained consistent across the past four Biosurveys, with only two species (yellowfin goby [*Acanthogobius flavimanus*] captured in trawl sampling and a tripletooth goby species *Tridentiger* sp., most likely *T. trigonocephalus* [chameleon goby] captured in ichthyoplankton sampling) have been observed in all four Biosurveys captured in the ichthyoplankton and in benthic trawls and are the only non-native fish species captured to date. The non-native macroalgae, namely *Sargassum horneri*, *Sargassum muticum*, and *Undaria pinnatifida*, have been present on riprap and pilings throughout the Port Complex in all four Biosurveys, with highest densities at Inner Harbor areas.

Epifaunal communities on riprap and benthic infauna had similar relative percentages of non-native invertebrate species (5.29% and 5.15%, respectively), while epifaunal communities on pilings had the highest relative percentage of non-natives (6.67%). In terms of relative abundance, however, riprap and pilings were similar (8.12% and 8.85%, respectively) and less than half of the relative abundance of non-natives in soft-bottom habitats (18.0%). The Biosurveys have also identified a number of cryptogenic (i.e., of uncertain origin) species; these appear not to have changed substantially over the course of the Biosurveys. Benthic infauna had the highest percentage of cryptogenic species (11.7%) and relative abundance of cryptogenic species (9.07%), while pilings and riprap had a considerably lower number of cryptogenic species (5.52% and 4.28%, respectively). However, piling and riprap had considerably higher abundance of cryptogenic species, meaning that although there are relatively fewer cryptogenic species on hard substrates than in soft-bottom habitats, they are present in greater abundances.

Regional studies of non-native species in Southern California embayments show that the Port Complex is similar to or on the low end of the range compared to other embayments and marinas in terms of the percentage of non-native species compared to total species observed in each habitat. This is true for both soft-bottom habitats, and riprap and piling communities.

While non-native and cryptogenic species are present in most anthropogenically influenced coastal habitats in Southern California, it does not appear that they are disproportionately displacing native species within the Port Complex, as the diversity and abundance of fish, invertebrates, and algae has remained high across the habitats examined in this study.

IX. CONCLUSION

Results of the 2018 Biosurvey suggest that the Port Complex continues to support healthy and robust biological communities and documented the greatest biodiversity of any Biosurvey to date. While climatic events such as the 2014-2016 marine heatwave do not appear to have had a measurable influence on the composition of demersal fish assemblages, there has been a notable shift in the epibenthic invertebrate community with the establishment of target shrimp as the dominant species. For the second survey in a row, a pollution-sensitive infaunal species was the most abundant species collected in sediments within the Port Complex, an indication of good sediment quality. Pelagic and demersal fish continue to use the Port Complex to forage for prey, and many of the most abundant species utilize the Port Complex as a nursery habitat. Critical habitat such as kelp and eelgrass are key resources for numerous species, and in the case of eelgrass there appears to be an expansion into Inner Harbor areas that may be a result of continued improvements in water clarity in these areas. New survey methods on riprap and pilings have catalogued numerous algae, invertebrate and fish species (some for the first time as part of the Biosurveys) and has shown that these habitats can support a diverse and productive epifaunal community. The Port Complex continues to support numerous bird species that forage in the open water and utilize various port structures for nesting, including several special status species. Marine mammals are common, especially sea lions and harbor seals, while dolphins and seasonal visitors such as gray whales can occasionally be spotted in Outer Harbor areas.

Sunrise over Angel's Gate

1.0 INTRODUCTION

The biological communities of San Pedro Bay represent an important element of the coastal marine biological resources of Southern California. These communities co-exist with, and are affected by, the operations of the nation's largest port complex: the ports of Los Angeles and Long Beach. As discussed in more detail below, this report describes both the current state of those communities and how those communities have changed over the past 40 years in response to federal and state regulatory programs and the environmental initiatives of the two ports.

The ports of Long Beach and Los Angeles are located in the western portion of San Pedro Bay, which is bounded by the City of Los Angeles communities of San Pedro and Wilmington on the north and west and by the City of Long Beach on the north and east (Figure 1-1). Both ports are departments of their respective city governments having jurisdiction over harbor land and water areas, consistent with the provisions of the State of California Tidelands Trust Act and the California Coastal Act. Both of those laws charge the ports primarily with accommodating and promoting maritime commerce, navigation, and fisheries, but also with managing and protecting the marine resources of the harbors for the benefit of the people of California. As part of that stewardship, over the past four decades the ports have conducted periodic, comprehensive biological surveys of the Long Beach-Los Angeles Port Complex.

The first large-scale biological surveys were performed in the late 1970s under USC's Harbors Environmental Project, and a series of reports from those surveys (e.g., HEP-USC, 1979; HEP-USC, 1979) provided an overview of oceanographic and marine biological conditions at that time. In the early 1980s the Ports commissioned biological baseline studies of their respective harbors (MBC Applied Environmental Sciences, 1984; MEC Analytical Systems, 1988). Recognizing that both they and the governmental agencies that oversee marine wildlife resources would benefit from a comprehensive, simultaneous survey of the entire Port Complex, the ports collaborated to commission the year 2000 baseline biological survey (Biosurvey) (MEC Analytical Systems, 2002), and agreed to repeat the Biosurvey on a regular basis. The next Biosurvey was conducted in 2008 (SAIC, 2010), and the third Biosurvey was conducted in 2013 (MBC Applied Environmental Sciences et al., 2016).

This report documents the results of the fourth collaborative harbor-wide Biosurvey, conducted over three seasons in 2018-2019. Because this Biosurvey used similar techniques to the prior three Biosurveys, it supplements and updates the information provided by those previous Biosurveys. Like the previous harbor-wide Biosurveys, this study, by means of systematic field sampling and observation spaced throughout an entire year, describes basic physical factors (e.g., water quality and sediment types) as well as the marine biota in a variety of habitats.

The marine biota studied by the Biosurveys conducted over the past four decades constitutes the major biological elements of the Los Angeles-Long Beach Port Complex. These include the invertebrates living in, on, and immediately above the bottom sediments (the benthic infauna and epifauna); bottom-dwelling and open-water fish, including their eggs and larvae (the ichthyoplankton); the animals and plants living on the rock dikes and pilings (hard substrate associated epifauna and macroalgae); eelgrass and kelp; marine mammals; and seabirds and shorebirds.

1.1 Overview of the Study Area

Physical Configuration

The Los Angeles-Long Beach Port Complex (Figure 1-1) occupies the western half of San Pedro Bay, a semi-enclosed embayment at the southeastern corner of Los Angeles County. The harbors are protected by a 14-kilometer (nine-mile)-long series of three breakwaters constructed in the first half of the 20th Century. Prior to the 20th Century, the Port Complex was an estuarine system at the mouth of the San Gabriel and Los Angeles rivers, with extensive mudflats and marsh areas protected by barrier beaches. The estuary's shallow waters, mudflats, and beaches provided habitat for a wide variety of fish, invertebrates, and seabirds.

Rapid urbanization of the region starting in the 1890s led to a need for commercial harbor facilities, and the resultant dredging of channels and basins, filling of marshes, open water areas, and mudflats to create land, and construction of port facilities has wholly altered the area. In addition, the Los Angeles River no longer flows directly into the harbor. As a result of this change and the changes caused by the development of the ports, the harbor area is no longer a true estuary. Today, the Port Complex consists largely of deep channels and basins for the navigation of cargo vessels, and dry land to support marine cargo terminals. Most of the shoreline is lined by rock dikes and revetments and sheet-pile bulkheads. As a result of those developments, very little sandy beach or tidal marsh habitat remains. On the other hand, the placement of shoreline structures, such as bulkheads, riprap, and pier pilings, has greatly increased the hard substrate available for species characteristic of rocky shores, such as mussels, barnacles, and macroalgae. The open-water areas are largely characterized by muddy bottoms, as were the former tidal marshes, but now most of the soft-bottom habitat is in deeper water.

Today, the Los Angeles-Long Beach Port Complex is one of the major commercial port facilities in the world and a major gateway to Pacific Rim economies. In 2018, the 3,916 vessels that called at the marine terminals of the two ports conveyed approximately one-third of the cargo entering and leaving the United States. The two ports are similar in physical size, sharing approximately 7,860 acres of water area, including anchorage and maneuvering areas in open waters behind the breakwaters, navigational channels, slips, turning basins, and berthing areas farther inside the Port Complex. On the basis of the past Biosurveys, the ports and the wildlife resource agencies recognize three ecological zones in the Port Complex (Figure 1-1): Outer Harbor, consisting of deep open-water areas and most of the deep channels and basins; Shallow-Water Habitat, consisting of areas in the outer harbor less than 20 feet deep; and Inner Harbor, consisting largely of dead-end slips and other areas in the interior reaches of the Port Complex.

Climate and Oceanography

Southern California lies in a climatic regime defined as Mediterranean, characterized by mild winters and warm, dry summers. Annual average rainfall is approximately 31 cm (12 inches), most of which falls between November and April.

The Port Complex is located in approximately the center of the geographical feature known as the Southern California Bight, which extends from Point Conception in the north to the Mexican border in the south. Winds in the area produce a weak, generally onshore southerly flow of air (Dailey et al. 1993). Near the shoreline, a diurnal onshore land breeze is typical, particularly during summer, driven by a thermal low over the deserts to the east of the Los Angeles area. On occasion, a high-pressure area develops over the Great Basin that causes strong, dry, offshore winds in the coastal areas. These Santa Ana winds are most common in late summer and fall but can occur any time of year.

Tides along the coast of Southern California are classified as mixed semi-diurnal, with two unequal high tides (high water and higher high water) and two unequal low tides (low water and lower low water) each lunar day (approximately 24.5 hours). Since 2000, water level extremes in Outer Los Angeles Harbor (NOAA Buoy 9410660) ranged from -0.71 m to +2.41 m (-2.34 ft to + 7.92 ft) above Mean Lower Low Water (MLLW; NOAA 2019). These tides are the primary drivers of water circulation in the Port Complex, although strong wind events can affect circulation in the Outer Harbor.

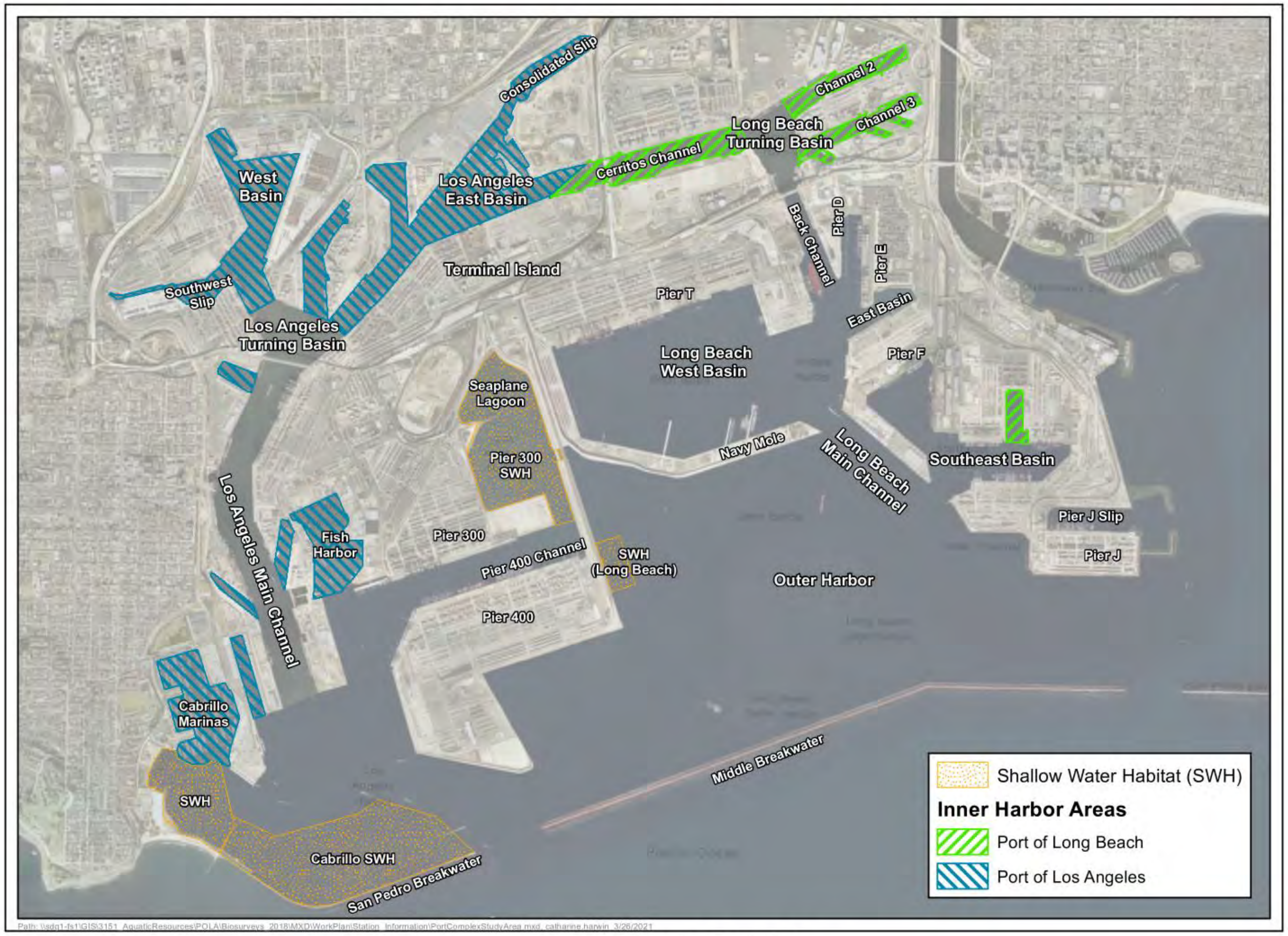
Hydrodynamic modeling by the U.S. Army Corps of Engineers has described circulation in the Port Complex (Figure 1-2). Strong flood tide currents enter the Port Complex through the Angel's Gate and Queen's Gate, and weaker currents enter through the opening between the tip of the breakwater and the shoreline of eastern Long Beach. Flood currents passing through Angel's Gate flow to either side of Pier 400 while those passing through Queen's Gate flow to either side of Pier J.

During ebb tide, the flow in the harbor is drawn from all directions toward the exits through the breakwater. Ebb currents leaving the Port of Los Angeles flow mainly through the Angel's Gate. In the Port of Long Beach, ebb currents exit either through the Queen's Gate or the eastern opening at the tip of the breakwater. As Figure 1-2 shows, tidal currents within the Ports of Los Angeles and Long Beach are generally weak (less than 0.15 m/second (0.5 ft/second)) except in the main navigational channels (LA's Main Channel and Long Beach's Back Channel). As a result, many areas of the Port Complex, particularly Inner Harbor slips and basins, are characterized by limited tidal circulation.

1.2 Port Development Since 2013

Over the past four decades the ports have changed their configuration, sometimes dramatically, as port facilities were expanded or redeveloped. These changes have affected the marine ecology of the ports by altering water circulation, water depth, and substrate types. The most substantial changes in recent times occurred between approximately 1990 and 2010, when both ports undertook major fill projects to create new land for terminals and deepened their main channels to accommodate rapidly increasing ship sizes. The latest report (MBC 2016) listed several such projects that had occurred between 2008 and 2013.

Between 2013 and the present, however, port development has focused largely on landside projects. With the exception of minor fills to complete the Port of Long Beach Middle Harbor terminal, the configuration of the water area of the ports is little changed from 2013. Some shoreline work has occurred (maintenance, berth deepening, and wharf and dike improvements), but neither the configuration nor the character of the shoreline have been substantially changed. Accordingly, the current physical environment of the Port Complex is very similar to the 2013 environment.



The Port Complex Study Area
Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 1-1. The Los Angeles and Long Beach Port Complex

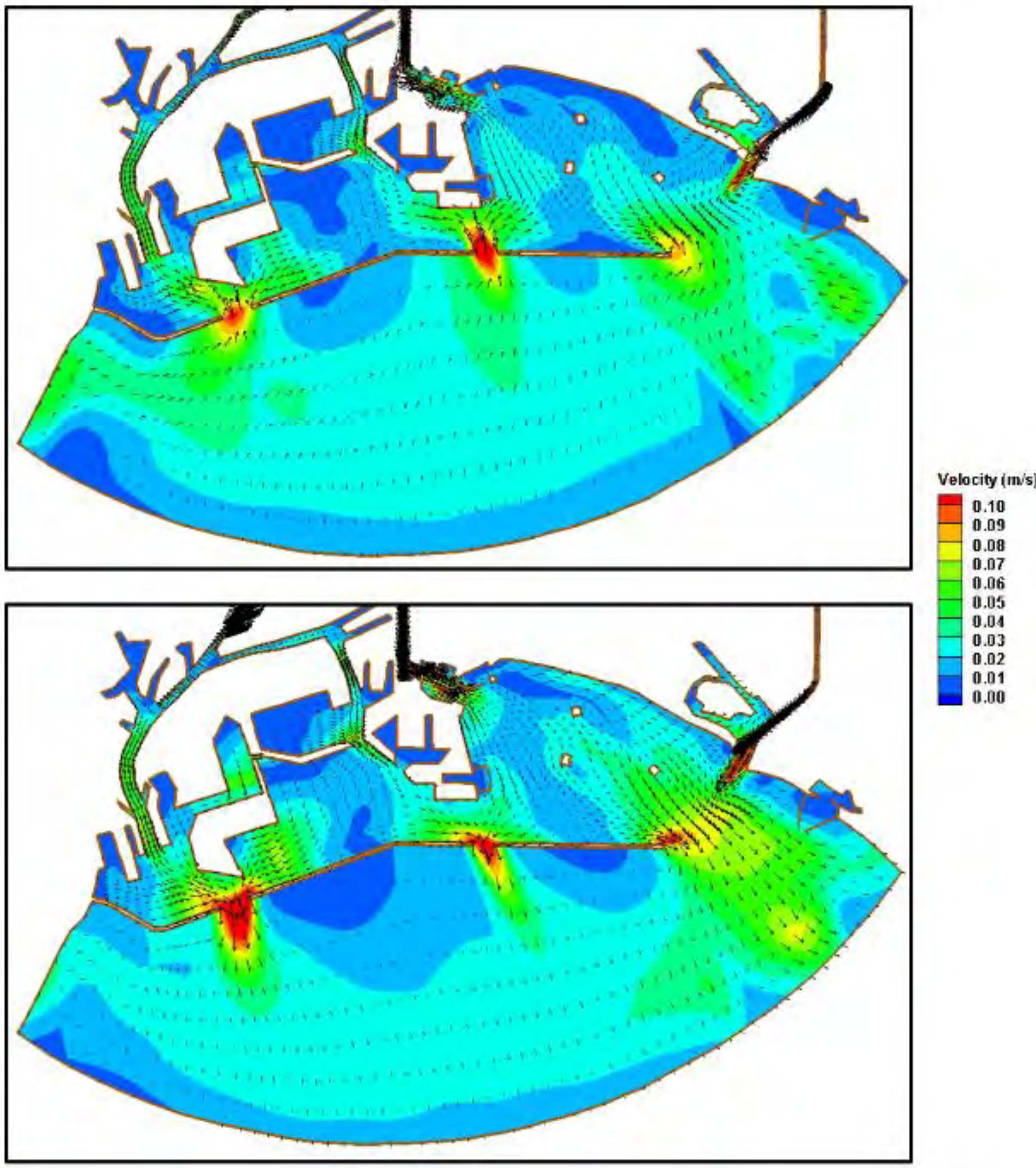


Figure 1-2. Current Patterns in the Ports of Los Angles and Long Beach Predicted by the WRAP Model (POLA and POLB 2009)

Top: Typical flood tide currents. Bottom: Typical ebb tide currents.

1.3 Previous Biological Studies in the Port Complex

Marine habitat and associated biological communities within the Ports have been periodically studied since the 1950s. In addition to the systematic, harbor-wide Biosurveys summarized above, a number of other physical and biological studies unrelated to the harbor-wide studies have been conducted.

Physical and biological sampling by the State Department of Public Health and the California Department of Fish and Game performed within the ports (State Department of Public Works, 1952) and Reish (1959) found areas within the harbors with low dissolved oxygen and high bacterial counts that supported virtually no animals, although other areas, such as the Outer Harbor, had enough dissolved oxygen to support fairly diverse invertebrate populations. At that time, harbor waters were subject to untreated discharges from storm drains, industrial sources such as refineries, and domestic/sanitary discharges. The discharge of oil refinery wastes was prohibited in 1968, and by 1970 improvements to water quality and species diversity were documented (Reish, 1972); in the years following the passage of the Clean Water Act (PL 92-500) in 1972, untreated discharges to the harbor were further reduced.

Physical, chemical, and marine biological monitoring studies were also carried out in association with the Long Beach Generating Station (EQA and MBC, 1978), the Los Angeles Harbor Generating Station, and the Terminal Island Treatment Plant in Los Angeles Harbor. The Port of Los Angeles conducted a Biological Baseline study in 1986-87 (MEC 1988) following Port development since the prior surveys in 1978. Finally, sampling has been conducted in the Port Complex as part of the Southern California Coastal Water Research Project's (SCCWRP) periodic Southern California Bight regional monitoring program in 1998, 2003, 2008, 2013, and 2018.

1.4 Study Objectives

The key objectives of this study, as with the previous studies, is to describe how key biological community metrics vary among different sub-regions and habitat types within the Port Complex, how those metrics may have changed over time, how the biological communities of the Port Complex compare to those throughout the Southern California region, and how prevalent non-native species are throughout the Port Complex.

To achieve those objectives, this study evaluated the following elements:

- Physical characteristics (water quality and sediment grain size);
- Benthic infauna and epibenthic macroinvertebrates;
- Ichthyoplankton;
- Demersal, pelagic, and shallow-water fishes;
- Hard substrate-associated communities (i.e., giant kelp, other macroalgae, fish and invertebrates associated with the riprap, concrete pier pilings, and other hard structures in the Port Complex);
- Eelgrass;
- Birds and marine mammals.

1.5 Study Design

The study design for the 2018 program was similar to those used during the 2000, 2008, and 2013 studies. The California Department of Fish and Wildlife (CDFW), National Marine Fisheries Service (NFMS), and U.S. Fish and Wildlife Service (USFWS) reviewed and provided comments on the study plan. The most notable changes in 2018 from the previous study included:

- Creation of a separate piling study sub-element documenting biological communities on pier pilings; this element expands upon the piling work done in previous studies as part of the riprap study effort.
- Elimination of the seasonality element of the riprap study, with scrapings performed only in summer rather than semi-annually. This change was based on analysis of prior Biosurveys in which very few additional species were collected during the winter survey and enabled the creation of the piling community study element.
- Co-location of the riprap stations with the kelp and macroalgae transect stations to provide a more robust dataset with which to assess community relationships between invertebrates and algae. This required moving a number of stations, as described below.
- Inclusion of Uniform Point Contact (UPC) survey methods on riprap and pier pilings to complement scrapings data with percent cover data as a rapid assessment tool.
- Elimination of neuston (water/air interface) sampling with manta nets from the ichthyoplankton element. Analysis of past Biosurveys indicated that, with the exception of greater abundance of fish eggs, neuston sampling collected very few additional species than the bongo net effort.
- Redesign of the former Kelp and Macroalgae element to better align with methods used by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) to obtain density data on macroalgae and invertebrates on coastal rocky reefs.
- Revision of the bird survey zones to add a “Hard Substrate” habitat type to each zone in addition to the “Open Water” habitat type.

For most project elements, an equal number of stations was sampled in each port (e.g., water quality, infauna, fish, ichthyoplankton, and riprap; Table 1-1), but some project elements involved one port more than another (e.g., shallow-water fish, eelgrass). Station maps for each project element (e.g., physical characteristics, riprap, kelp and macroalgae, shallow-water fish, eelgrass, and birds) are provided in the respective report sections. Several stations were changed since the 2013 study to provide better representation of the various habitat types and allow better comparisons of biological metrics between stations:

- Assigned eight study stations for both the riprap and piling studies (previous riprap surveys included seven riprap stations and one piling station through an artifact of an in-the-field decision made during the 2008 Biosurvey).
- Made all pier piling station locations unique to the 2018 study; renamed 2013 pier piling station LARR3 to LAPP3 and relocated it to coincide with LARR3 in POLA’s West Basin near Berths 147-148.
- Relocated three riprap stations: LARR1 to the Cabrillo Shallow-Water Habitat Phase 2 breakwater, LARR2 to just south of the Consolidated Slip near Berths 200Y-200Z, and LBRR2 to the Cerritos Channel near Berths S106-S108;

- Relocated five rocky reef-associated community stations: T6 to coincide with LBRR4 in the Southeast Basin near Berth G230; T7 to the POLB Inner Harbor Turning Basin near Berth A88, T9 to the northern end of the riprap groin within Seaplane Lagoon, T15 to coincide with LB3 at the Navy Mole near Gull Park, and T19 to coincide with LARR3 in the POLA West Basin near Berths 147-148.

Table 1-1. Sampling Dates for Spring 2018, Summer 2018 and Winter 2019

Survey Type	Spring 2018 Sampling Dates	Summer 2018 Sampling Dates	Winter 2019 Sampling Dates
Physical Characteristics (Water)	May 10-11	August 22-23	January 28-29
Physical Characteristics (Sediment) and Benthic Infauna[1]	Not Sampled	August 7-14	Not Sampled
Ichthyoplankton	May 9-10	September 18-19	January 22-23
Demersal Fishes and Epibenthic Invertebrates (Otter Trawl)	Day: April 30-May 4 Night: May 7-11	Day: August 20-24 Night: August 27-31	Not Sampled
Pelagic Fishes (Lampara Net)	Day: May 14-18 Night: May 21-25	Day: September 3-7 Night: September 10-14	Not Sampled
Shallow-water Fishes (Beach Seines)	April 25	September 24 *Additional Sampling November 6	Not Sampled
Swath and UPC Diver Surveys on Riprap and Pier Pilings	April 9-13	August 13-17, 24	Not Sampled
Riprap and Pier Piling Quadrat Sampling	Not Sampled	August 13-17	Not Sampled
Eelgrass	May 7-11	September 3-7	Not Sampled
Birds and Marine Mammals	Monthly for 12 months; April 2018-March 2019		

[1] Sampling conducted by Anchor QEA

1.6 Survey Methods

Field sampling and laboratory processing methods used in this study are summarized here; detailed descriptions are presented in Appendix A. In general, the field methodology of this study was consistent with the previous studies, but departures from previous techniques are noted below and in Appendix A.

1.6.1 Physical Characteristics

Water Quality

As in the previous studies, continuous vertical profiles of temperature, conductivity (as a measure of salinity), pH, light transmittance (as a measure of water clarity), and dissolved oxygen in the water column were collected at 32 stations. Data were stored in real time to a field laptop computer. For consistency with previous Biosurveys, transparency of the surface waters was also measured at each station using a Secchi disk. Water quality surveys were conducted in May 2018 (spring), August 2018 (summer), and February 2019 (winter).

Sediments

Sediment data used in this study were generated by Anchor QEA as part of a separate program (the Harbor Toxics TMDL program, described in Section 1.6.2, below). Samples were collected at 32 stations using a Van Veen grab, and sediment from the top 5 centimeters of each grab sample was used for grain size and total organic carbon (TOC) analysis.

1.6.2 Benthic Infauna and Epibenthic Invertebrates

Sampling to characterize the benthic infaunal community was conducted by Anchor QEA, in coordination with the Greater Harbor Waters Toxic TMDL Regional Monitoring Coalition (RMC) program. Sampling was conducted in spring (April 2018) and summer (August 2018) at 32 stations. Sediment samples were collected using a 0.1-meter square (m^2) Van Veen grab sampler and sieved through a 1.0-mm screen to collect infauna.

Epibenthic macroinvertebrates (the larger invertebrates that dwell on and just above the sediment surface) were collected in the benthic trawls used to collect demersal fish (see Section 1.6.4, below).

1.6.3 Ichthyoplankton

Ichthyoplankton collections were made at 26 stations (13 in each harbor). Surveys were performed in the spring (May 2018), summer (September 2018), and winter (January 2019), and were performed only at night to minimize visual net avoidance by the larger larvae.

Ichthyoplankton were collected from both the epibenthic (near-bottom) habitat and the water column using a bongo net array (two one-meter-diameter nets mounted side by side); the nets had a 0.333-mm mesh and a removable cod end. The epibenthic sampling utilized a weighted, wheeled bongo net apparatus that suspended the nets just above the bottom and allowed them to be towed along the bottom. Water column sampling utilized the bongo net towed in an oblique pattern from near-bottom to the surface, retrieved at a constant rate over the length of the tow.

Deployment of bongo nets for ichthyoplankton collection

Each station yielded four samples: one from each of the paired nets of each tow (epibenthic and oblique). Accordingly, each seasonal survey yielded 52 samples, for a total of 156 samples over the course of the study. Samples were fixed in 10% buffered formalin then transferred to 70% ethanol for subsequent laboratory analysis.

1.6.4 Demersal, Pelagic, and Shallow-water Fish

Juvenile and adult fish were collected with three types of gear:

- Otter trawls were used to sample demersal (bottom-associated) fish;
- Lampara nets were used to collect pelagic (open-water) fish;

- Beach seines were used to collect shallow subtidal fish.

Deployment of beach seine at Cabrillo Beach

Both trawling and lampara sampling were conducted during both the day and night, in spring (April-May 2018) and summer (August-September 2019) at the same 26 stations sampled for ichthyoplankton. Beach seine sampling was conducted at or near low tide during the day in spring (April 2018), summer (August 2018) and fall (November 2018) at two stations in Los Angeles Harbor (Cabrillo Beach and at the Pier 300 Shallow Water Habitat).

Collection and processing methodology for the demersal fish sampling were consistent with the prior harbor-wide Biosurveys but with minor additional procedures consistent with the Bight '18 Regional Monitoring program to make data as regionally comparable as possible. With all three gear types, the number of fish of a given species collected varied considerably; Table 1-2 describes the procedures for processing large samples (note that epibenthic invertebrates were weighed but not measured).

The Ecological Index (EI) is a metric based on the percentage of individual fish collected, the percentage of biomass, and the percentage of frequency of occurrence (VRG, 2009). This index is indicative of the relative importance of each species to the energy flow within each habitat (Allen et al. 2002, Williams et al. 2015). This is the first time this metric has been used in the Port's Biosurvey.

- **Index of Ecological Importance for Individual Fish:** Calculated by (number of fish as a % of catch + weight of the fish as a % of catch) × (% frequency of catch).

Table 1-2. Procedures for Measuring and Weighing

Abundance of Single Taxon	Measured to Nearest cm by Individual	Weighed to the Nearest 0.1kg	Comments
0-30	Yes	Individually	
31-250	Yes	Batch Weight	
251+	No	Batch Weight	Batch weights can be done based on size classes

1.6.5 Hard Substrate Associated Communities

As indicated in sections 1.4 and 1.5, the 2018 Biosurvey included a revised approach to the biota associated with the various hard substrate habitats in the Port Complex. The riprap and pier piling surveys had three sub-elements – kelp canopy, riprap, and pier pilings. The methodology for each sub-element was similar to the methods used in past Biosurveys, except as noted in Section 1.5. The methods are summarized here, while species lists and an example site schematic can be found in Chapter 5.

Kelp Canopy: Canopy-forming kelp species are associated with riprap (the boulders used for shoreline protection) and other hard structures such as submerged rock dikes throughout the Port Complex. The extent of kelp canopy visible at the water surface was assessed using aerial infrared photographs collected as part of the Central Region Kelp Survey Consortium program, which takes downward-looking photographs of the area during optimum conditions. Aerial imagery and GIS were applied to the photographs to determine the spatial and temporal coverage of kelp canopy within the Port Complex.

Riprap: Hard-substratum biota on riprap were sampled by certified divers in three depth zones (upper intertidal, lower intertidal, subtidal) using scraped quadrats, band transect surveys, and photography at 20 riprap station (8 of which had quadrat scrapings) and 8 pier piling station.

A diver collecting data on riprap

At each of the eight riprap stations designated for quadrat sampling (four in each port), divers deployed a transect along the depth contour of three depth zones: upper intertidal, lower intertidal, and subtidal. The three depth zones sampled were delineated based on a combination of biological and tidal factors: upper intertidal (the high tide zone characterized by barnacles), lower intertidal zone (the mid- to low-tide zone characterized by mussels), and subtidal zone (the deepest extent of the riprap). The depths at the upper intertidal and lower intertidal zones remained consistent across all stations. The subtidal zone was located at the deepest extent of the riprap, approximately 1 meter (m) above the soft-bottom interface, in order to minimize the influence of sedimentation on organism recruitment.

At each station, duplicate quadrat scrapings (a quadrat was 7.5 centimeters (cm) by 15 cm, i.e., 0.01- m^2) were collected at two random locations along each of the three depth zones (i.e., six samples per station). Photos were taken of each quadrat prior to scraping. Samples were fixed in 10% buffered formalin then transferred to 70% ethanol for subsequent laboratory analysis.

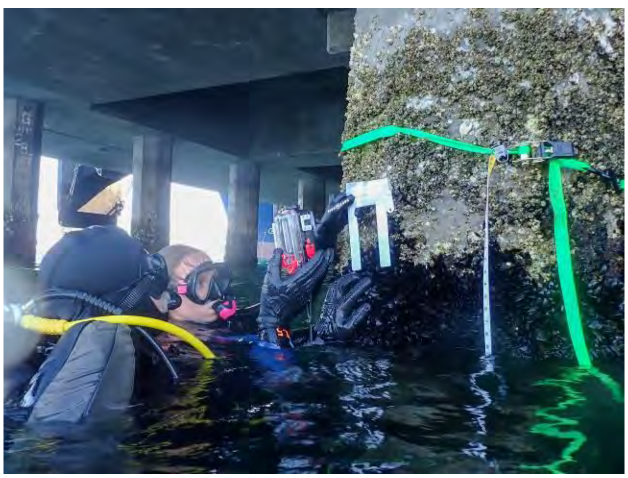
In addition to scraped quadrats, a rapid assessment method for comparison was employed along each riprap transect depth zone, using 10-m-long band transects and a uniform point contact (UPC) method to determine percent cover of algae and invertebrates (see Appendix A for details of the UPC method). The divers used a modified species list prepared and utilized by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) to classify cover type.

The epifuanal community on riprap was also assessed by diver surveys using UPC and swath surveys to determine percent cover and density of invertebrates and algae (see Appendix A for details of the field methods and how they differed from those utilized in 2013 Biosurveys). At the eight riprap stations and at 12 additional stations established specifically for this element, divers surveyed two to three depth zones (depending on station depth) along band transects using the

UPC method to estimate percent cover of algae and invertebrates every 0.2 meters, for a total of 50 points per depth zone.

In addition to the UPC survey, a swath survey along each transect was conducted to quantify macroalgae and invertebrates based on functional community groups (canopy-forming kelp, understory kelp, non-native algae, herbivores, filter feeders, and carnivores) and to catalog larger, mobile invertebrates that may not be captured using the UPC method. This community-based assessment provided density estimates of key biological communities present on riprap habitat, as well as site-specific verification of canopy-forming kelp species density identified via aerial imagery. In particular, canopy-forming kelp is more widely distributed in the Port Complex than indicated by the aerial survey method, and the3 swath technique provided an indication of the extent of that wider distribution.

While a quantitative fish survey was not conducted as part of this element, fish species observed on site were noted at each station to document species that are rocky reef-associated and would not be captured during otter trawl, lampara, and beach seine surveys.



Divers preparing to collect quadrat scraping in upper intertidal zone on pier piling

Pier Pilings: Hard-substratum biota on concrete pilings that support wharves throughout the Port Complex were sampled at eight piling stations (four in each port) by certified divers in three depth zones (upper intertidal, lower intertidal, subtidal) using scraped quadrats, band transect surveys, and photography. The methodology was identical to the methods used on the riprap, except that the transect extended vertically down each piling from 0 ft mean lower low water (MLLW) to the bottom of the piling near the mudline. Also, divers conducted the UPC survey vertically, classifying the cover type at every 0.2 meters along the transect.

1.6.6 Eelgrass

Consistent with the methodology of the 2013 Biosurvey (MBC 2016), eelgrass surveys were conducted using a combination of acoustic techniques (interferometric sidescan sonar), diver-ground truth surveys (if necessary), and ROV surveys. Acoustic surveys of all shorelines and waters shallower than 30 feet mean lower low water (MLLW) within the Port Complex were conducted during spring (early April 2018) and at the height of the summer growing season (mid-September 2018) to detect seasonal variability in eelgrass areal extent and density.

1.6.7 Birds and Marine Mammals

Surveys to enumerate birds and marine mammals were conducted monthly from April 2018 through March 2019. Surveys recorded species composition, abundance, behavior, and location of birds and marine mammals in 54 pre-designated zones throughput the Port Complex. Methods were similar to those used in the 2013 Biosurvey and consisted of saturation surveys, conducted by boat, in all zones. The survey team consisted of a boat captain, an observer, and a recorder; the observer and recorder were both trained ornithologists. The observer was responsible for species identification and counts, and the recorder was responsible for assisting with bird counts and for completing and managing data sheets. Marine mammals were noted as they were encountered and were recorded according to the zone in which they were observed.

The only modification from previous Biosurveys was that the habitat type “Hard Structure” was added as a strata type separate from “Open Water”. This modification helps to better quantify the effect that physical structures and human activity have on the presence and behavior patterns of birds.

1.7 Data Analysis

Laboratory and data analysis methods appropriate to each study element were applied to the field-collected data and samples (see Appendix A for descriptions of laboratory sample processing, data analytical, and QA/QC methodologies). In the case of some elements (e.g., water quality, birds, and marine mammals) no laboratory processing was necessary. In the case of benthic infauna, ichthyoplankton, and the scraped quadrats of the riprap element, however, extensive laboratory processing was necessary to separate, sort, identify, and weigh the organisms collected in the samples.

Task-generated data included enumeration data (e.g., from trawls, marine mammal surveys, seabird surveys, benthos, etc.), continuous data (physical water quality, analytical data, etc.), metadata, and more. To ensure data quality and usability, these data, as well as data from previous Biosurveys, were synthesized into a single project-specific database after undergoing a thorough QA/QC review according to established internal procedures.

Data were analyzed with the key objective of identifying and describing spatial and temporal trends in the various natural resource elements studied in these harbor-wide Biosurveys. Relevant indicators of spatial and temporal trends include selected measures of abundance, biomass, and other metrics such as dominance, diversity, and the Benthic Response Index used in previous Biosurveys.

1.8 References

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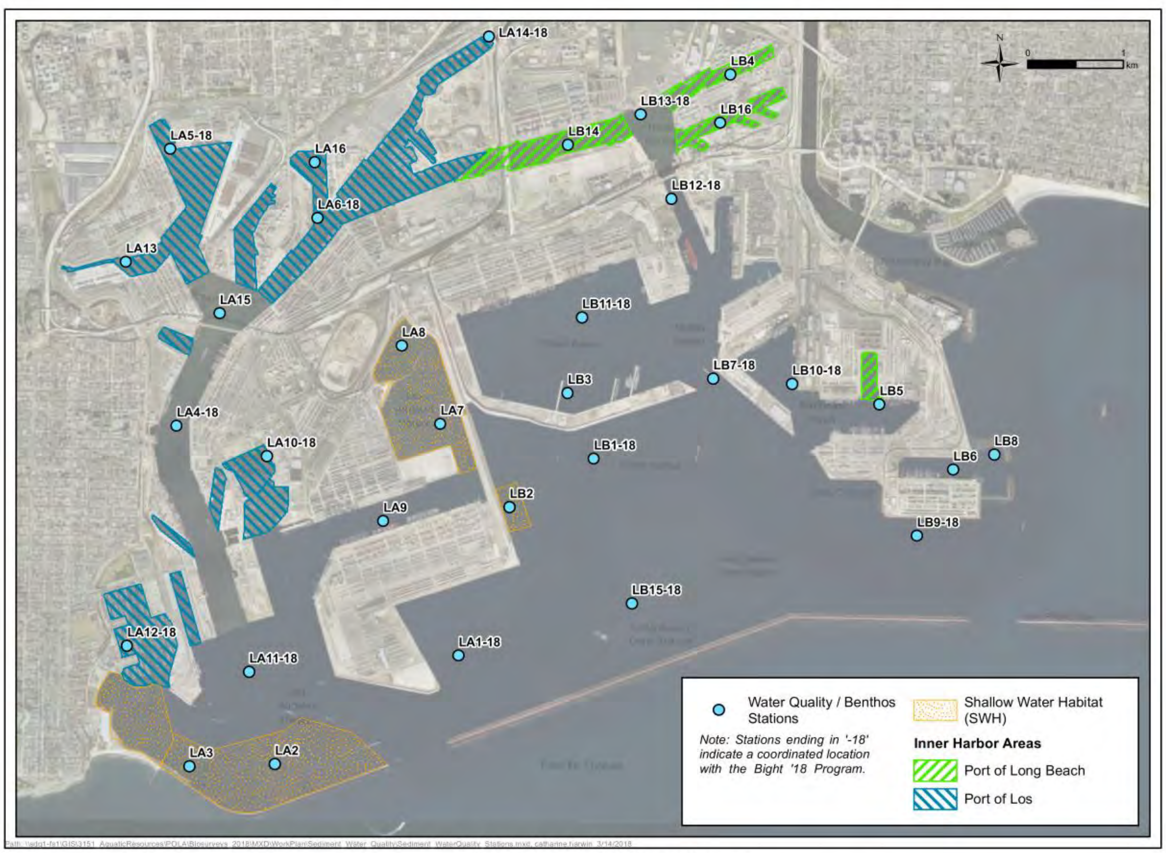
2.0 PHYSICAL CHARACTERISTICS

2.1 Summary of Physical Parameters

A suite of physical water quality parameters (i.e., temperature, dissolved oxygen, clarity, pH, and chlorophyll concentration) was measured at 32 stations in the Port Complex (Figure 2-1) during three monitoring periods in 2018/2019: May 10-11, 2018 (Spring), August 22-23, 2018 (Summer), and January 28-29, 2019 (Winter). Grain size data from the Regional Monitoring Coalition (RMC) was available from 18 stations in the summer of 2018, with 13 of those stations aligned with benthic infauna stations. TOC data from the RMC was available for 13 stations. These physical characteristics provide information that can be used to help interpret biological results, including factors potentially related to changes in species abundances and occurrences observed over time. Results of these monitoring efforts are provided in this Chapter.



Sediment and Water Quality Stations
2018 Biological Surveys of the Ports of Los Angeles and Long Beach / Bight '18
San Pedro Bay, CA

Figure 2-1. Locations of Water Quality and Benthic Sampling Stations

Table 2-1. Physical Water Quality Parameters by Season

Parameter		Spring			Summer			Winter		
		Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Temperature (°C)	Surface	19.0	14.6	16.5	23.8	20.2	21.9	15.8	14.6	15.2
	Bottom	18.7	11.6	13.5	21.3	16.8	18.9	15.2	14.5	14.9
Dissolved Oxygen (mg/L)	Surface	12.1	8.1	10.0	9.0	7.4	8.5	9.0	6.7	8.0
	Bottom	10.6	3.6	7.0	8.8	3.6	7.2	8.7	6.9	7.7
Light Transmission (%)	Surface	87.4	45.7	64.1	80.4	59.3	68.9	79.1	63.6	73.1
	Bottom	76.4	38.6	62.4	72.0	21.4	56.7	78.1	47.2	64.5
Turbidity (NTU)	Surface	1.9	0.3	1.1	4.6	0.7	2.7	7.4	0.4	1.0
	Bottom	4.9	0.8	2.1	9.1	0.7	2.8	9.4	0.7	1.8
pH	Surface	8.37	7.96	8.17	8.26	7.94	8.13	8.59	8.10	8.47
	Bottom	8.31	7.95	8.09	8.23	7.91	8.09	8.57	8.29	8.46
Chlorophyll A (ug/L)	Surface	4.4	3.1	3.7	4.7	0.7	1.6	4.6	0.6	2.1
	Bottom	9.6	3.4	4.4	3.1	0.0	1.2	3.4	0.7	1.5
Salinity (PSU)	Surface	33.7	33.0	33.5	33.7	33.2	33.5	33.4	30.9	33.2
	Bottom	33.7	33.5	33.6	33.6	33.5	33.6	33.6	33.0	33.4

With regard to these water quality measurements, it is important to note that values recorded represent a single point in time during each sampling event. Given inherent temporal and spatial variability, particularly for water quality parameters such as temperature and clarity, the values recorded cannot be regarded as representing overall average conditions or upper or lower bounds throughout each season at each site. Interpretation of the results of this sampling effort must take this point into consideration.

Temperature

Temperature varied by season and by depth. Summer showed the warmest water temperatures (surface average of 21.9 °C), followed by spring (surface average of 16.5 °C), and winter (surface average of 15.2 °C). Surface temperatures were generally higher than bottom temperatures across all sampling periods.

The range of temperatures across the entire sampling period was relatively large, with the coldest temperatures observed near the bottom at the Outer Harbor stations during spring (average of 12.7 °C) and the warmest temperatures at the surface at Inner Harbor stations during the summer (average of 21.9 °C). Winter temperature measurements reflected only small differences between the surface and bottom, especially at the Shallow Water Habitat (SWH) stations, where there is less distance between surface and bottom (Figure 2-2).

In waters deeper than a few meters, a thermocline can develop wherein the warm upper layer of water abruptly transitions to substantially cooler water below. This phenomenon is caused when the surface water warms quicker than the bottom layer can mix with it. The occurrence of thermoclines can vary by both season and station depth, becoming most common in the spring when the warm air increases the sea surface temperature but cannot reach deeper waters. In the case of the Port Complex, a number of the stations in the Inner Harbor and SWH areas were too shallow for a steady thermocline to develop. However, thermoclines were observed at several locations, especially at the Outer Harbor stations (Appendix B).

In spring, surface water temperatures ranged from 14.6 °C at Station LA3 to 19.0 °C at Station LA8, and bottom temperatures from a low of 11.6°C at Station LB9 the high of 18.7 °C at Station LA8. The highest water temperatures occurred in summer. Surface temperatures ranged from 20.2 °C at Station LA11 to 23.8 °C at Station LB8, and bottom temperatures were slightly lower, ranging from 16.8 °C at Station LA1 to 21.3 °C at Station LA14. Winter temperatures were substantially lower than in spring and summer. Surface temperatures ranged from 14.6 °C at Station LB8 to 15.8 °C at Station LB13 and bottom temperatures from 14.5 °C at Station LA11 to 15.2 °C at Station LB16. The small range in temperatures compared to spring and summer (evident in Figure 2-2) indicates the absence of thermoclines in winter.

Salinity

Salinity in the Port Complex varied little in spring and summer with depth or location (33.0-33.7 PSU), and values were typical of the nearshore coastal ocean. In winter, however, lower salinity occurred in the surface layers at numerous stations as a result of stormwater runoff from the Los Angeles Basin with a range of 30.9-33.4 PSU. Salinity near the bottom during the winter fell within the range of spring and summer.

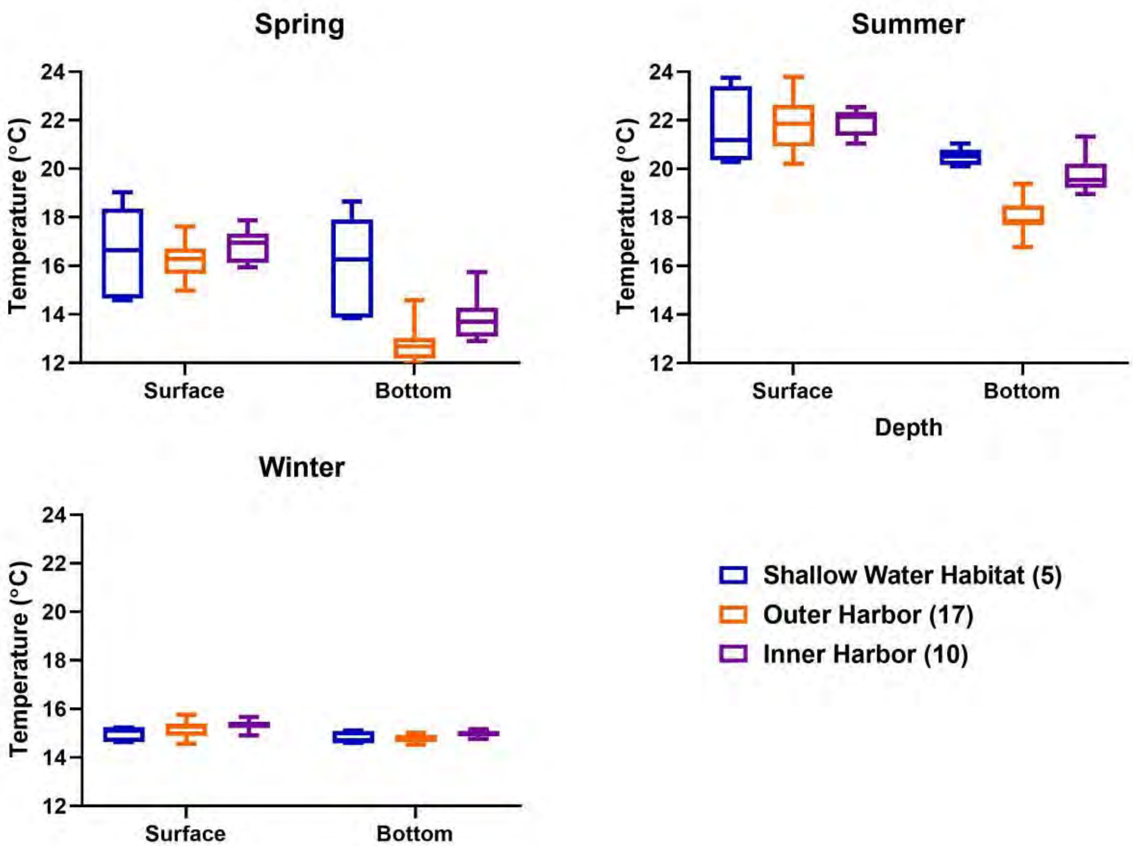


Figure 2-2. Temperature Boxplots Across All Sampling Stations, with Respect to Habitat Type and Depth Strata

Dissolved Oxygen

To survive in marine habitats, aquatic animals must have sufficient concentrations of dissolved oxygen (DO) in the seawater. Therefore, the DO concentration at a location can be an important factor defining the biological community living there, and sustained decreases in DO can lead to complex alterations in marine habitats (National Ocean Service, 2020). Generally, DO concentrations are inversely influenced by salinity and temperature (because cold water can hold more oxygen than warm water). Further, factors such as photosynthetic activity, organic matter decomposition, animal respiration, and ocean mixing can affect local DO concentrations. In Southern California, nearshore waters generally do not fall below the Basin Plan Water Quality Objective (WQO) of 5.0 mg/L, due to mixing between ocean and harbor waters and wave action. Concentrations above the Basin Plan WQO are expected to be supportive of all aquatic species in this region. During the 2018 Biosurvey, seasonal and depth fluctuations were observed across all stations, as shown in Figure 2-3.

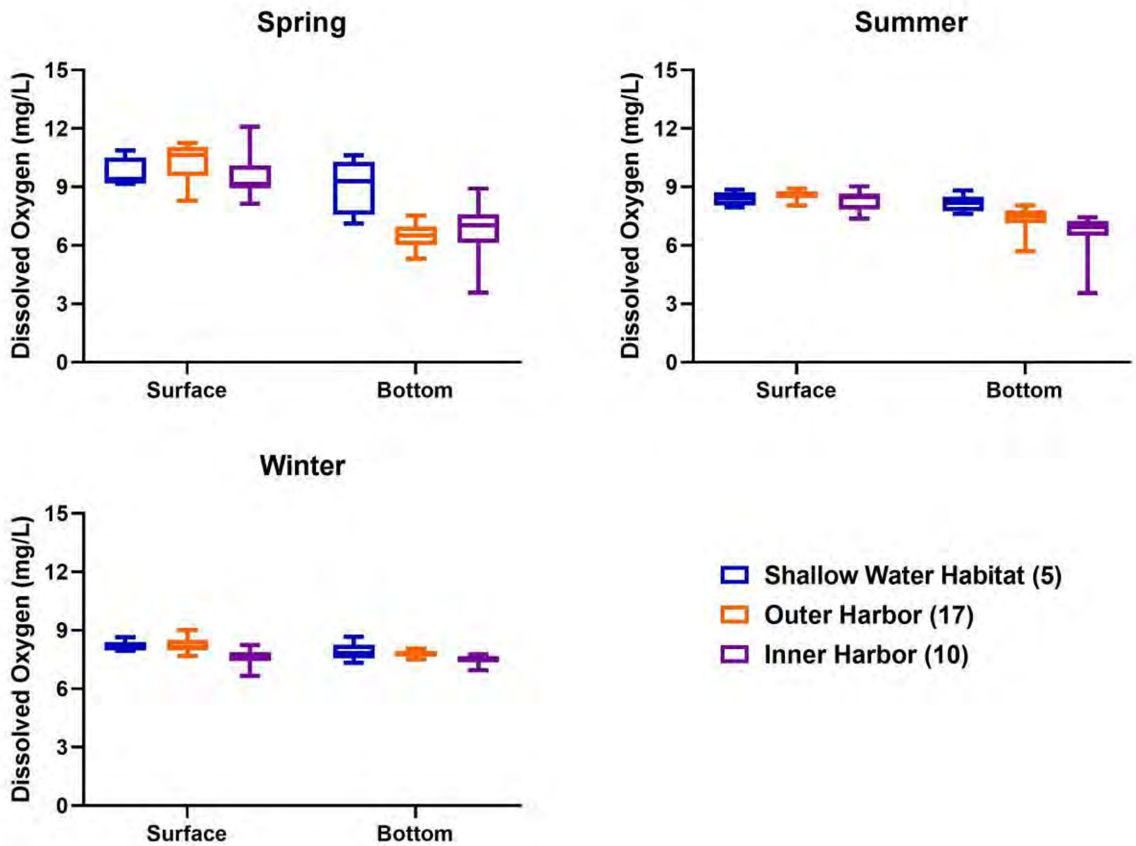


Figure 2-3. Dissolved Oxygen Boxplots Across All Sampling Stations, with Respect to Habitat Type and Depth Strata

In the spring, DO was relatively high at the surface, generally decreasing towards the bottom of the profiles. Surface DO concentrations ranged from 8.1 mg/L at Station LA14 in Consolidated slip to 12.1 mg/L at Station LA10 in Fish Harbor. Bottom concentrations ranged from 3.6 mg/L at Station LA10 to 10.6 mg/L at Station LB2 in LB SWH. The LA10 bottom concentration was the only measurement in the spring sampling that fell below the Basin Plan WQO. Fish Harbor also had the largest difference in DO between the surface and bottom (12.1 mg/L to 3.6 mg/L).. This large difference is noteworthy given that Fish Harbor is relatively shallow (7 m) and is consistent with Fish Harbor's history of low DO concentrations, which have been attributed to the residual fish processing wastes in the sediments and the restricted circulation in the basin.

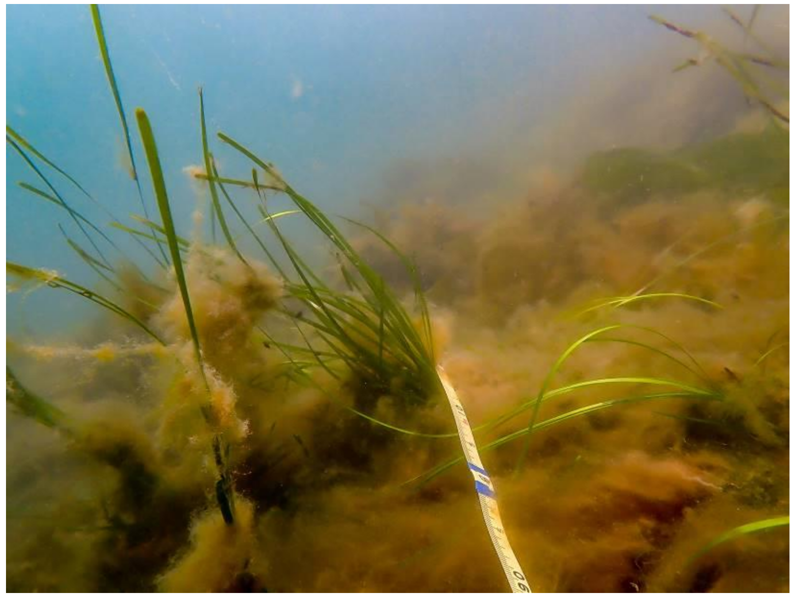
DO concentrations were slightly lower in the summer than in spring, likely attributable to the lower solubility of oxygen at higher temperatures. There was also less difference between surface and bottom concentrations, likely due to the lack of a significant thermocline in the summer months. Surface concentrations ranged from 7.4 mg/L at Consolidated Slip to 9.0 mg/L at Berth 118 (LA13), and bottom concentrations ranged from 3.6 mg/L at Fish Harbor to 8.8 mg/L at LB SWH. As in spring, the bottom concentration at Fish Harbor was the only measurement in the summer sampling that fell below the Basin Plan WQO.

DO concentrations in winter were generally similar to those in summer, despite generally cooler water temperatures. Surface DO ranged from 6.7 mg/L at Consolidated Slip to 9.0 mg/L at

Outer Harbor Anchorages (LB15) and bottom DO concentrations ranged from 6.9 mg/L at Consolidated Slip to 8.7 mg/L at LB SWH. No measurements in winter fell below the Basin Plan WQO.

Water Clarity

Water clarity has important implications for the diversity and productivity of aquatic ecosystems because it is a key abiotic factor affecting plants and algae – both attached vegetation such as eelgrass and kelp, and pelagic primary producers such as phytoplankton. Low clarity can limit photosynthesis, thereby affecting a habitat's biological diversity and productivity. Fluctuations in water clarity can be attributed to factors such as input of suspended particles from urban watersheds and storm drains, resuspension of sediments, tidal currents, and wave action.



Eelgrass growing in the Inner Harbor

In this study, water clarity was evaluated using both light transmission (%) and turbidity (NTU) measurements. However, this discussion focuses on transmittance, as being a more direct measure of light available for biological activity; NTU values are presented in the detailed water quality data included in Appendix B. In general, transmission values at Outer Harbor and Shallow Water Habitat stations varied little with season and depth (Figure 2-4): median values were in the range of 60 to 75%. However, Inner Harbor stations exhibited considerable variability, with water clarity at some stations falling as low as 16% in the winter while others were as high as 87% in the spring. Water clarity at the bottom of the water column tended to be lower than at the top at most stations. Outer Harbor stations during the spring sampling were an exception to this trend, however, as transmission at most stations increased with depth.

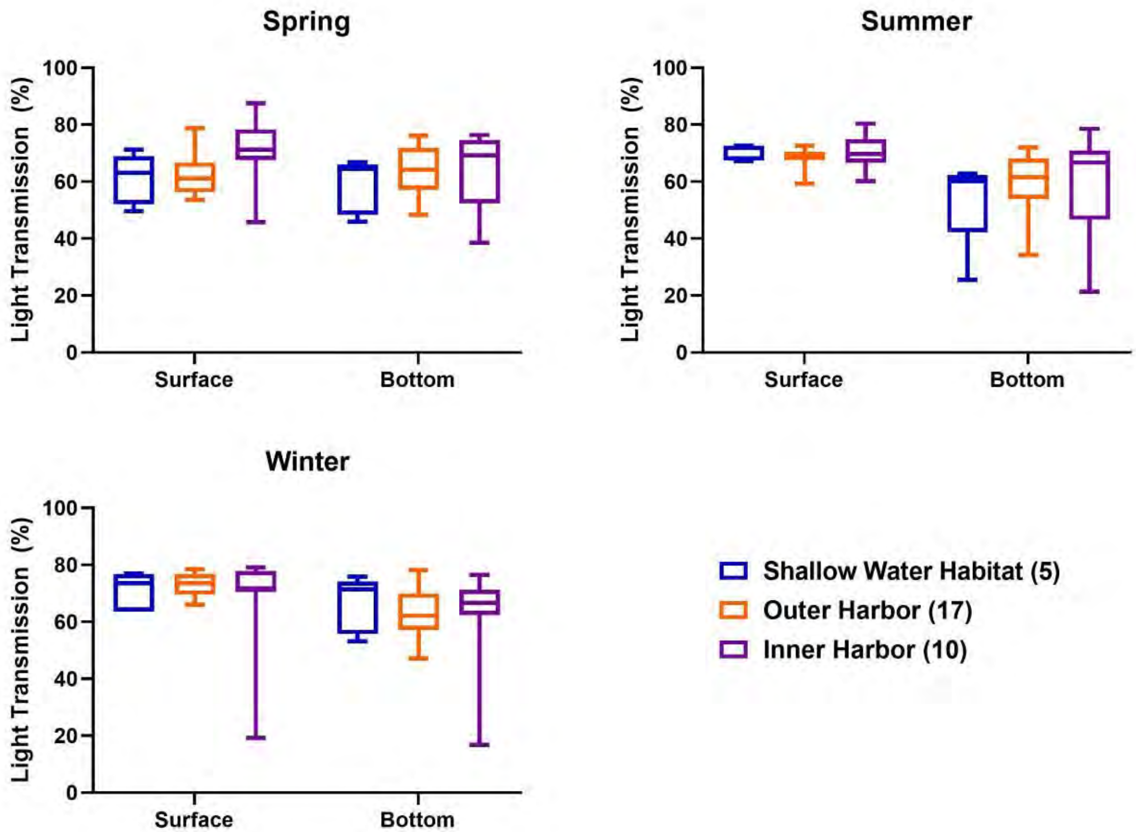


Figure 2-4. Light Transmission Boxplots Across All Sampling Stations, with Respect to Habitat Type and Depth Strata

pH

Overall, seawater tends to be slightly alkaline (pH > 7.8) and remains in a narrow range of values with a global mean of 8.1 (Chan 2014). Measuring pH provides useful information regarding the acidity of seawater, which can have significant effects on some organisms living in the water column. As an example, ocean waters are acting as a sink for increased atmospheric concentrations of carbon dioxide (CO_2), thereby lowering the pH of oceans around the globe. This trend is particularly notable along the west coast of the United States (NOAA 2014 and Busch 2014). Lower pH has been implicated as causing challenges for cultured shellfish and planktonic snails (pteropods) along the West Coast. Both of these classes of organisms, along with other gastropods, bivalves, and coral reefs around the world, rely on the formation of calcium carbonate shells or skeletons, which are unable to form properly when pH drops too low (Hales 2012 and Chan 2017). Aquatic organisms are influenced by pH at differing thresholds and impact should be assessed on a species-by-species basis. For example, *Crassostrea virginica*, native to the east coast of North America, experiences an increase in juvenile mortality, and decreases in growth in a pH of 7.5 (Beniash 2010). Conversely, *Mytilus edulis* experiences reduced shell length only once pH has been decreased to 7.3 (Fitzer 2014).

In this study, pH in the Port Complex varied little with season, depth, or location. Highest values occurred in winter (range 8.10 – 8.59) and lowest in summer (range 7.91 – 8.26). On average, pH was slightly lower near the bottom than near the surface, but the trend was not pronounced. The values measured in the Port Complex were typical of coastal ocean waters in the region and do not appear to be low enough to cause concern for local species. The differences between seasons, depths, and locations are likely due to variations in temperature, biological activity, and availability of nutrients in the surrounding waters.

Chlorophyll

Phytoplankton (single-celled planktonic algae) is the base of the marine food web and chlorophyll is present in most marine algal cells, enabling them to conduct photosynthesis. Accordingly, the concentration of chlorophyll in ocean water provides a good measure of the amount of phytoplankton present. Measurements of chlorophyll can also identify harmful algal blooms which may result from enhanced nutrient loading and bioavailability. A healthy ecosystem will sustain a certain level of algal productivity, but too much nutrient loading and availability may also result in algal blooms which can have a wide range of detrimental impacts on marine ecosystems (Heisler et al. 2008).

Concentrations of chlorophyll throughout the Port Complex were similar in the summer and winter sampling periods, with surface values generally slightly higher (1.6 ug/L average in summer and 2.1 ug/L average in winter) than bottom values (avg. 1.2 ug/L average in summer, 1.5 ug/L average in winter) (Table 2-1; Figure 2-5). Spring measurements were different, however: average concentrations were substantially higher than in summer and winter and tended to be highest near the bottom (Table 2-1). The higher chlorophyll concentrations in spring are attributable to the “spring bloom,” a typical feature of temperate oceans in which increasing light levels and day length allow phytoplankton to utilize the nutrients that accumulate during the winter to support rapid growth.

By way of comparison chlorophyll-a concentrations measured in the nearshore environment off of Scripps pier in San Diego, CA between 1983–2010 are typically around 1–2 ug/L, although occasionally, during a massive algal bloom, concentrations can exceed 100 ug/L (McGowan et al. 2017). While concentrations within the Port Complex were on average slightly higher than 1-2 ug/L, this is to be expected within a coastal embayment with reduced circulation and increased nutrient concentrations compared to a nearshore environment.

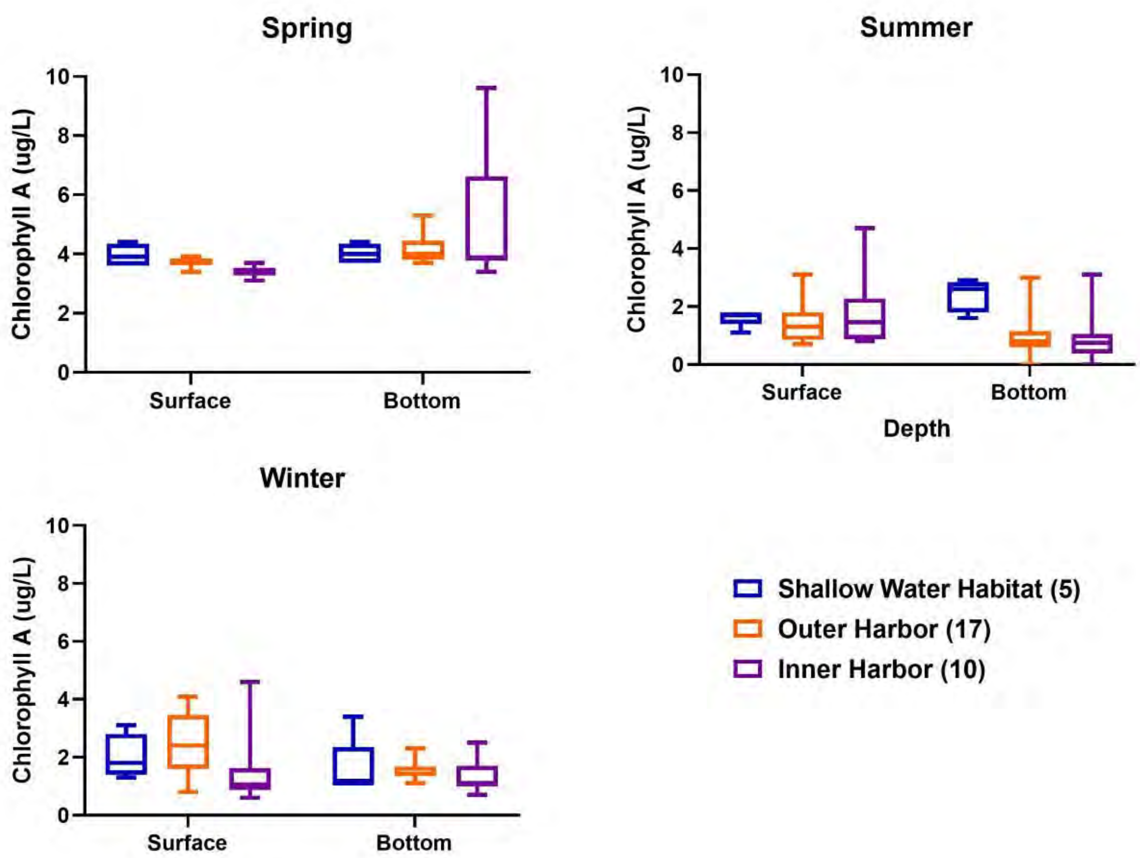


Figure 2-5. Chlorophyll-a Boxplots Across All Sampling Stations, with Respect to Habitat Type and Depth Strata

Historical Water Quality Parameters of Interest

The Port of LA conducts regular monthly water quality monitoring using a CTD at 33 stations throughout the harbor. Monthly averages of turbidity, transmissivity, and temperature at the surface and bottom were compared across years at Outer Harbor stations (Figure 2-5), and Inner Harbors stations (Figure 2-6). Turbidity and transmissivity data go back to 2009, while temperature goes back to 2008. Historical turbidity, transmissivity, and temperature data were chosen as select water quality proxies due to their influence on distribution of habitats of particular concern such as kelp and eelgrass. The historical average of each parameter at Inner and Outer Harbor stations within POLA is shown in Table 2-2.

Table 2-2. Historical average from 2008/2009-2018 within POLA at Inner and Outer Harbor Stations

Parameter	Inner Harbor		Outer Harbor	
	Surface	Bottom	Surface	Bottom
Temperature (°C)	17.1	16.2	17.0	15.7
Turbidity (NTU)	5.55	3.66	6.81	3.32
Transmissivity (%)	67.2	64.9	63.2	65.0

When the historical averages on the monthly averages within each year (Figures 2-6 and 2-7), trends for above and below average years can be examined. Temperature showed an increase at Inner and Outer harbor stations from 2014-2016 which was seen at the surface and the bottom before returning to near average in 2017 and 2018. Water clarity measurements (turbidity and transmission) showed larger differences between surface and bottom measurements, although patterns were consistent between Inner and Outer Harbor stations. Surface turbidity measurements in the Inner and Outer Harbors both had spikes (i.e., lower water clarity) which likely result from rainfall events that bring suspended particles into the water or from plankton blooms that can seasonally reduce water clarity. However, on average there was a trend of decreasing turbidity (i.e., better water clarity) in 2016-2018 compared to 2009-2015. Inner and Outer Harbor Stations also showed trends toward lower turbidity over the same time period at the bottom of the water column. Surface transmissivity was also highest (i.e., best water clarity) at both Inner and Outer Harbor stations in 2018 compared to the previous few years, although the trend over time is likely confounded by similar events as turbidity. Bottom transmissivity at Inner and Outer Harbor stations showed a clearer trend, with the average yearly transmissivity above the historical average from 2015-2018 with previous years below the historical average. This suggests that water clarity at the bottom of the water column at both Inner and Outer Harbor stations has shown modest improvement over the last 3-4 years, while water clarity at the surface is more variable although it does suggest improving conditions over time.

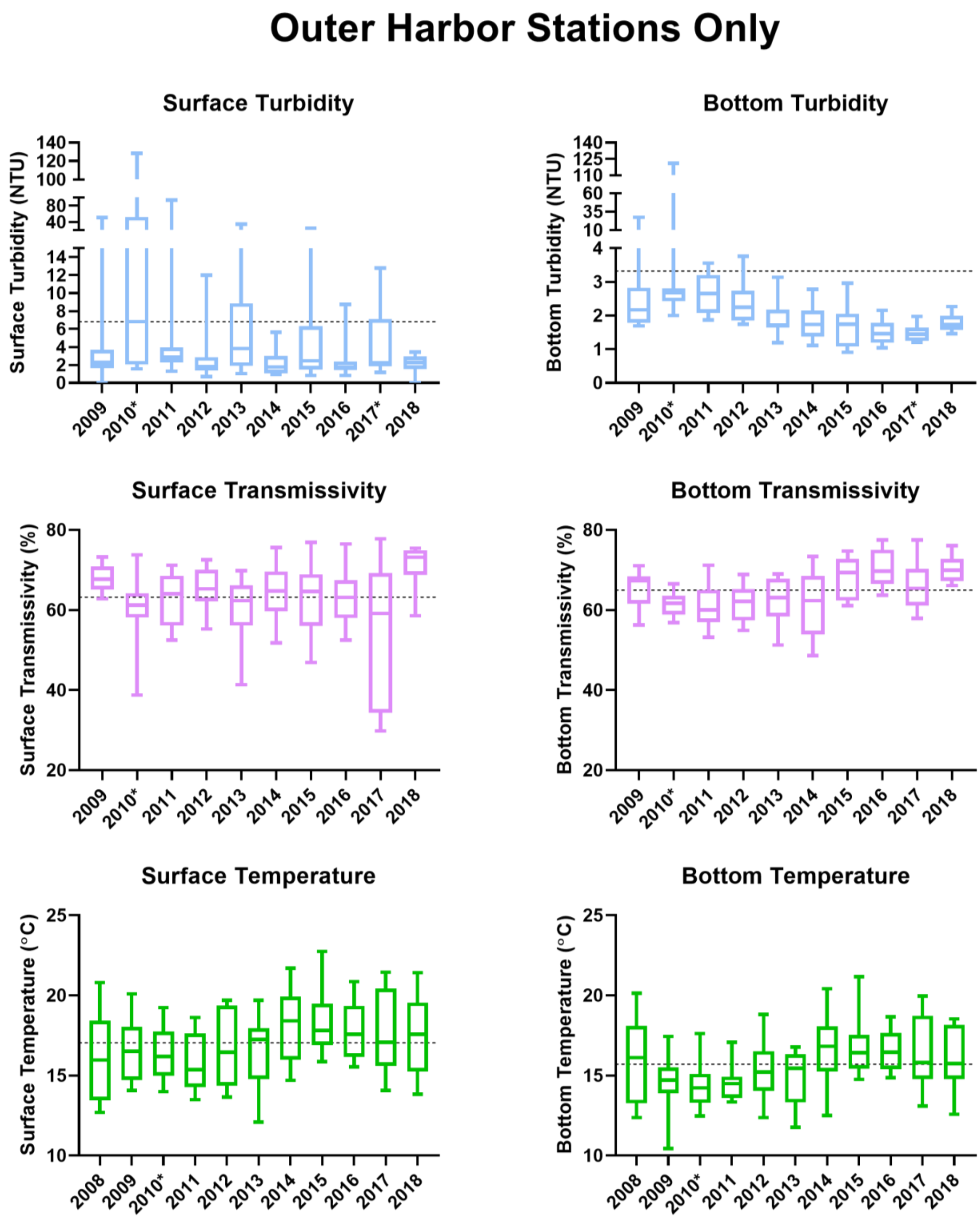


Figure 2-6. POLA Monthly Average Surface and Bottom Turbidity, Transmissivity, and Temperature Boxplots at Outer Harbor Sampling Stations

* = 2010 missing January data, 2017 for turbidity missing June-November. Whiskers represent the range, boxes represent one quartile around the mean and the line represents the median. Dotted lines represent the historical average.

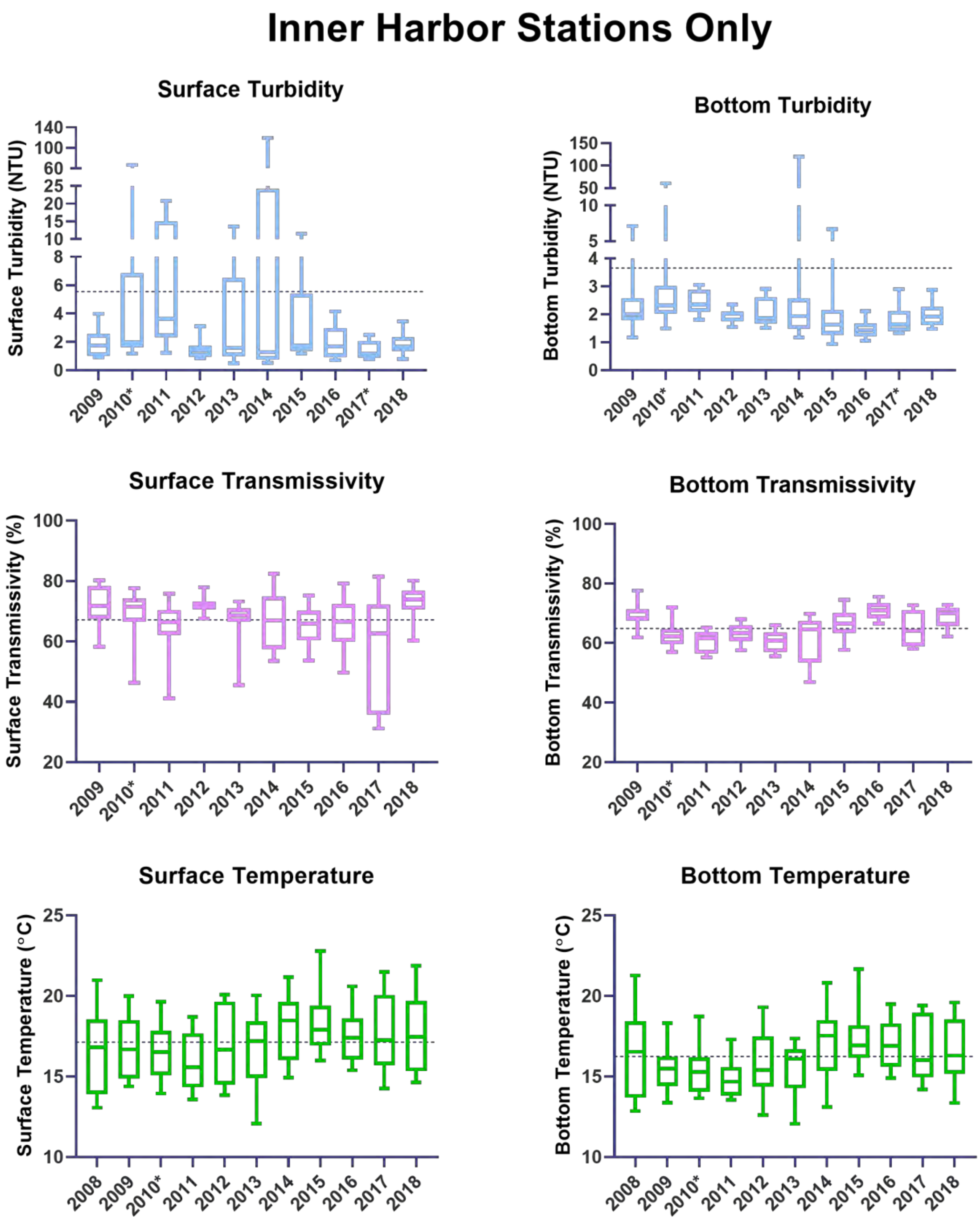


Figure 2-7. POLA Monthly Average Surface and Bottom Turbidity, Transmissivity, and Temperature Boxplots at Inner Harbor Sampling Stations

* = 2010 missing January data, 2017 for turbidity missing June-November Whiskers represent the range, boxes represent one quartile around the mean and the line represents the median. Dotted lines represent the historical average.

Regional Climate Trends

The coastal ocean of the Southern California Bight, including the Port Complex, is heavily influenced by two cyclical trends in the oceanography of the Pacific Ocean. The El Niño Southern Oscillation (ENSO) is a cyclical environmental condition that occurs across the Pacific Ocean (Lindsey, 2013). ENSO is actually comprised of two different conditions, known as "El Niño" and "La Niña," and is measured by the Oceanic Niño Index (ONI). El Niño occurs when the Pacific Ocean develops warmer waters than average, but easterly winds are weaker than normal and can actually reverse direction to become westerly. When that happens, warmer-than-normal water often moves as far north as the coast of California, bringing unusual conditions to local habitats. La Niña, the opposite phase of El Niño in the ENSO climate pattern, produces strong winds and cooler ocean waters. ENSO takes place approximately every 3-5 years. In Southern California, El Niños often cause above-average rainfall, reduced upwelling, and increased water temperatures. Alternately, La Niñas can result in an increased upwelling of nutrient-rich water, enhancing fisheries activities along the coast of Southern California (Zhang, 1997).

Similarly, the Pacific Decadal Oscillation (PDO) is also a cyclical trend that influences sea surface temperatures, sea-level pressures, and winds across the Pacific Ocean. However, the PDO can be distinguished from ENSO because, while ENSO is felt primarily near the equator, the PDO originates in the northern waters of the Pacific. Additionally, the climate regimes brought on by the PDO are more persistent than those of ENSO, sometimes lasting 20-30 years before alternating (Hare and Mantua, 2001).

The ENSO and PDO cycles in Southern California over the last 20 years are depicted below, using the ONI and PDO Index, respectively (Figure 2-8). Historical Biosurvey sampling events are represented with arrows for comparison. Red arrows represent warming trends and blue arrows represent cooling trends. In the ENSO, margins are displayed at +/- 0.5 to reflect the neutral temperatures. When values fall above this zone, it is considered to be an "El Niño" condition and when values fall below this zone it is considered to be a "La Niña" condition. An assessment of regional climate patterns can assist with the interpretation of biological community data with knowledge of temperature tolerances for certain species, or general associations (e.g., the presence of tropical species expanding their range as water temperature increases). Over the course of the historical Biosurveys in 2000, 2008 and 2013, the ENSO reflects warmer waters in 2000 and colder waters in 2008 and 2013. This is contrasted by the historical PDO cycles, which reflect cool water regimes in all three historical Biosurveys. In the current Biosurvey (2018), the ENSO reflects warm waters within the neutrality zone (+/- 0.5), while the PDO reflects slightly cool waters. While these are opposing trends, the indices are relatively neutral and neither demonstrate a significant warming or cooling trend in 2018.

Local ocean surface temperature data were furnished by the Coastal Data Information Program, Integrative Oceanography Division, operated by the Scripps Institution of Oceanography from an oceanographic buoy located in approximately 483 m of water near San Pedro. Monthly sea surface temperature (SST) data from 1998-2018 show similar trends in local SST to those observed with ENSO and PDO over the same time period (Figure 2-9). Buoy data shows that the lowest SST in summer (July-September) occurred in 2013, with temperatures increasing thereafter with the arrival of the warm water anomaly that persisted through 2016. That anomaly produced peak summer SSTs in 2014 and 2015 of 22-23° C (Cavole et al. 2016, Jacox et al.

2019). In 2017-2018, SST decreased and looked more consistent with 2013 although summer temperatures in 2018 were approximately 1-2 °C warmer than in 2013. This mild cooling pattern in local SST is similar to the trend observed in the ENSO and PDO following the warm water anomaly.

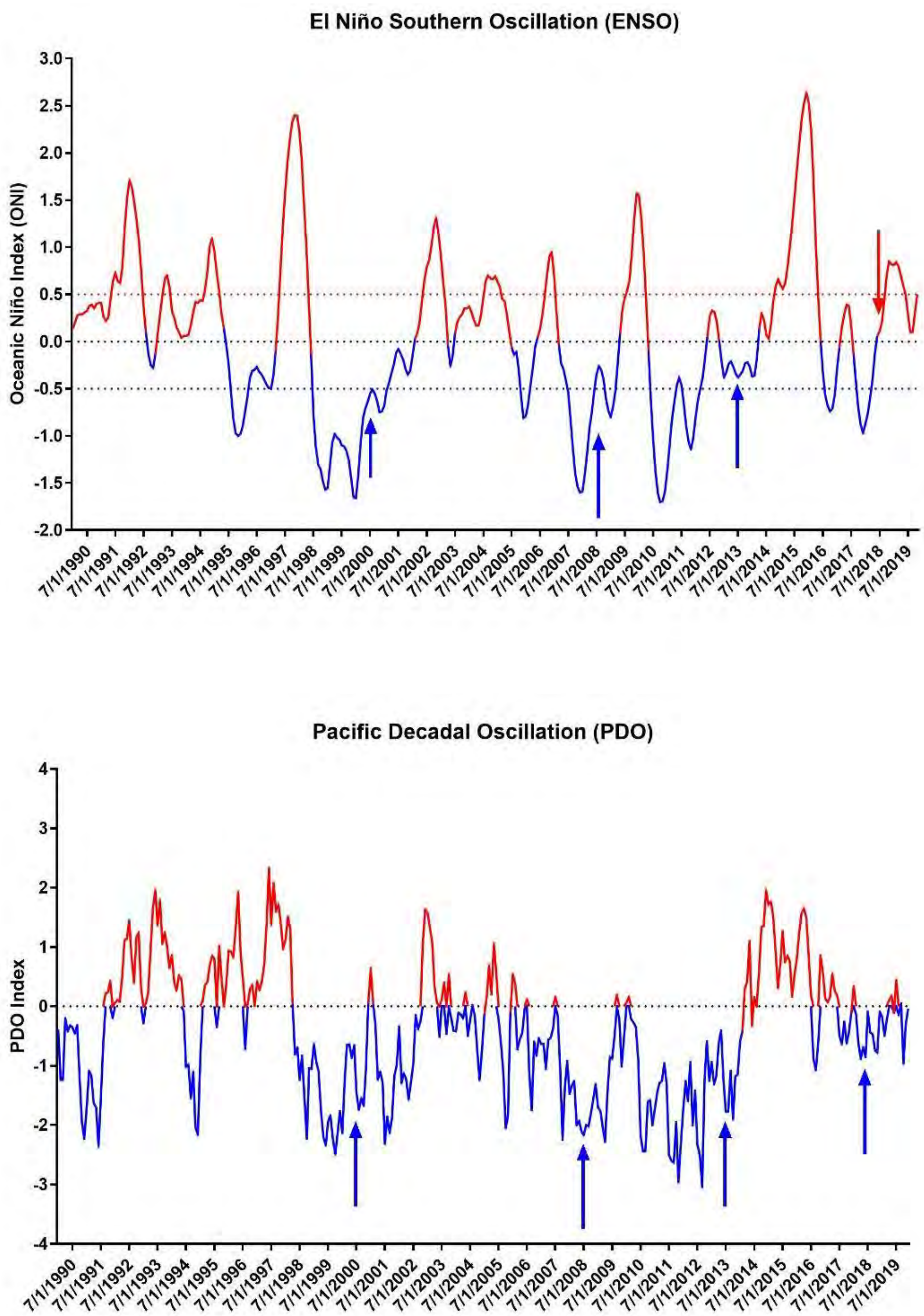
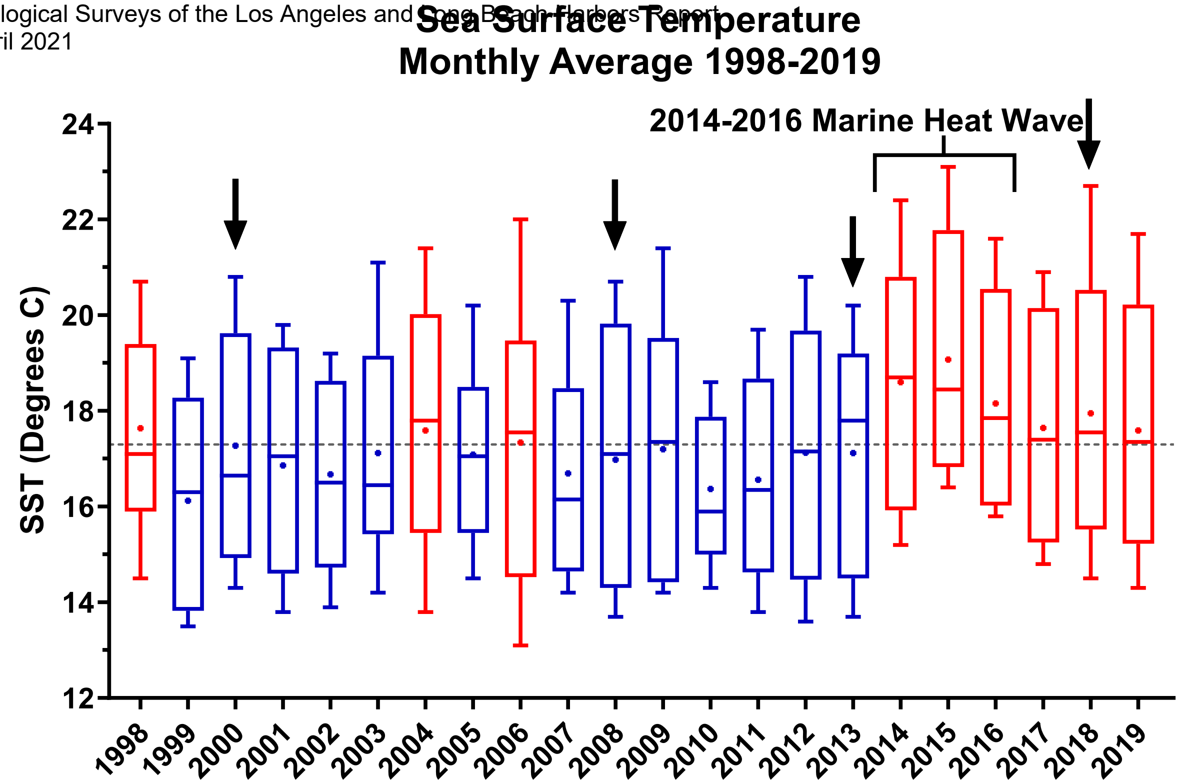


Figure 2-8. Regional Climate Trends Between the Years 1990 and 2019 and Depicted by Both the Oceanic Niño Index (ODI) and the Pacific Decadal Oscillation (PDO)

Warm periods are depicted by red lines and cold periods are depicted by blue lines. Historical Biosurvey sampling years are represented by arrows.



Data from Coastal Data Information Program, Integrative Oceanography Division, operated by the Scripps Institution of Oceanography Buoy 092 - San Pedro (Lat: 33.61779, Long: -118.317). Dotted line is average temperature from 1998 to 2019 (17.3 degrees C). Annual average temperatures below the 21-year average are denoted as blue, while annual average temperatures above the 21-year average are red. Black arrows represent the four historical Biosurvey years. Whiskers represent the min-max, the line represents the median and the dot represents the average.

Data from Coastal Data Information Program, Integrative Oceanography Division, operated by the Scripps Institution of Oceanography Buoy 092 - San Pedro (Lat: 33.61779, Long: -118.317). Dotted line is average temperature from 1998 to 2019 (17.3 degrees C). Annual average temperatures below the 21-year average are denoted as blue, while annual average temperatures above the 21-year average are red. Black arrows represent the four historical Biosurvey years. Whiskers represent the min-max, the line represents the median and the dot represents the average.

Figure 2-9. Sea Surface Temperature Monthly Average 1998-2018

2.2 Physical Characteristics of Sediment (TOC and Grain Size)

The physical characteristics of the sediments in the Port Complex (sediment total organic carbon [TOC] and grain size) are summarized in Table 2-3, and the complete dataset is provided in Appendix B. Grain size and TOC data are used to help interpret benthic community composition. Grain size data from the Regional Monitoring Coalition (RMC) was available from 18 stations in the summer of 2018, with 13 of those stations aligned with benthic infauna stations. TOC data from the RMC was available for 13 stations. Grain size data from the 2013 Biosurvey is also presented to give grain size context for all 32 stations where benthic infauna were collected, and a comparison between 2013 and 2018 data is provided below.

Table 2-3. Summary of Grain Size and Total Organic Carbon (TOC) Results Across All Habitat Types (Shallow Water Habitat, Inner Harbor and Outer Harbor)

Parameter		SWH (1)	Inner Harbor (5)			Outer Harbor (12)		
			Max	Min	Avg	Max	Min	Avg
Grain Size	Clay	5.83	12.4	6.60	9.47	12.1	0.690	7.94
	Silt	37.2	58.6	44.0	52.1	73.7	2.82	41.6
	Percent Fines (Clay + Silt)	43.0	69.3	50.6	61.6	84.1	3.51	49.5
	Fine Sand	39.1	45.0	24.7	33.5	58.8	11.9	33.6
	Coarse Sand	17.9	10.5	0.300	4.89	84.6	< 0.010	15.3
	Gravel	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total Organic Carbon		SWH (0)	Inner Harbor (4)			Outer Harbor (9)		
			Max	Min	Avg	Max	Min	Avg
		--	6.60	1.30	4.28	4.50	0.17	1.54

*TOC and grain size results were available for only a subset of stations monitored for water quality and benthic infauna and these two parameters were also not always paired. The minimum and maximum values listed for each grain size class are not necessarily from the same sample. Due to this, Percent Fines (Clay + Silt), and the sum of all grain size classes are not equal to 100%. The number of study sites surveyed per habitat type are denoted in parentheses.

Grain Size

The three habitats (SWH, Inner Harbor, and Outer Harbor) were generally similar in terms of grain size percentages except that the SWH station had somewhat more sand and less silt and clay than the deeper habitats; that pattern reflects the origins of the SWH areas, which were created with dredged fine sands. Percent fines (clay plus silt) across habitats was relatively similar, although Inner Harbor stations on average had higher percentages of fines compared to Outer Harbor stations, which had a wide range of sediment composition (Table 2-3).

Total Organic Carbon

Total Organic Carbon (TOC) was measured in sediments from 13 locations, 4 at Inner Harbor stations, and 9 at Outer Harbor stations. Stations in the Inner Harbor had higher average percent TOC (4.28%) compared to Outer Harbor stations (1.54%; Table 2-3).

Historical Grain Size Comparisons

The utility in comparing grain size data across Biosurvey years has multiple purposes: 1) there was a subset of stations (n=18) sampled in 2018 compared to those sampled in 2013 (n=32) (Table 2-4), 2) seasonal metrics were not collected in 2018 (Figure 2-10, and 3) it is essential to understand how sediment size characteristics change over time and may affect community composition. Percent fines (clay plus silt) across all habitats were lower on average compared in Summer 2018 compared to Summer 2013 (Figure 2-10).

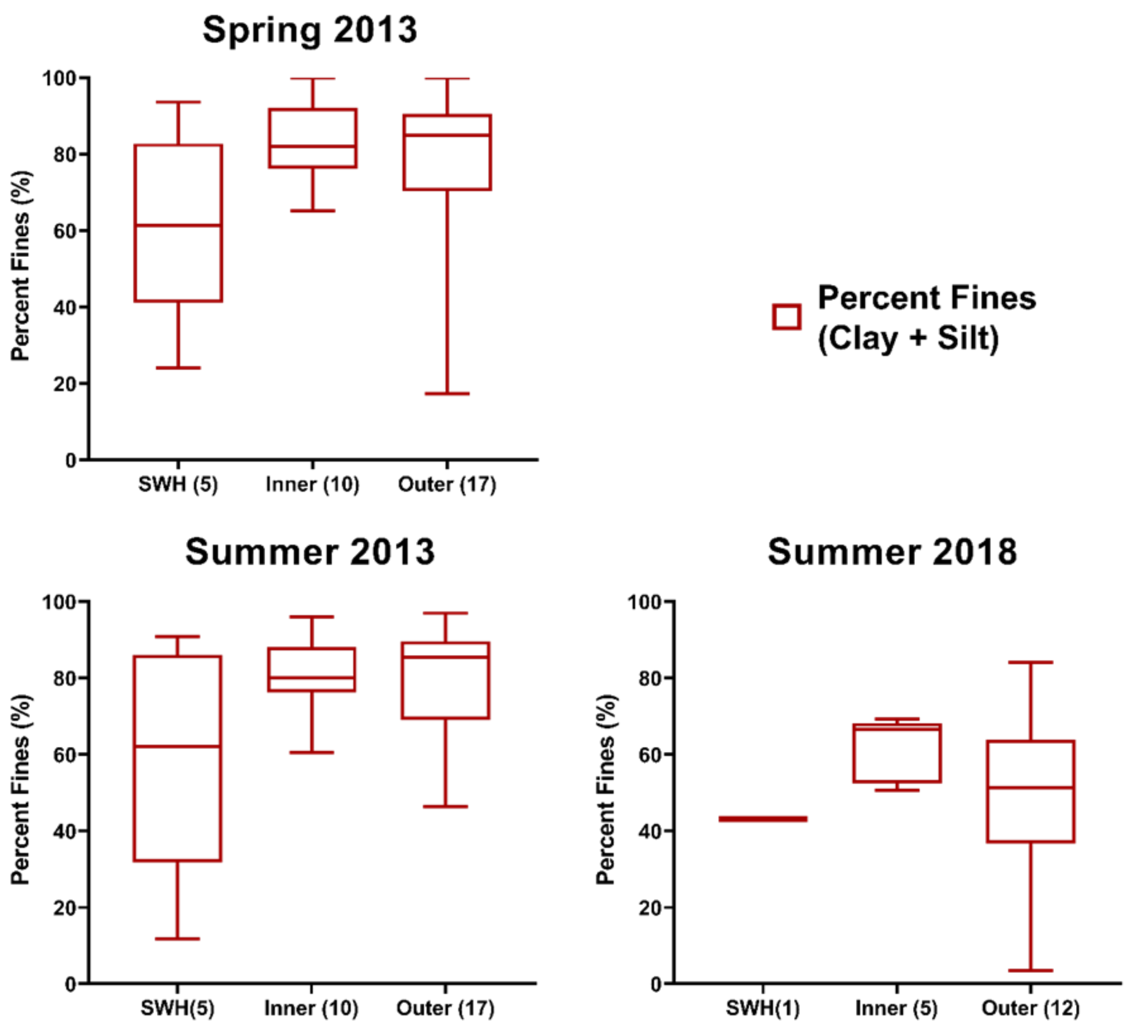


Figure 2-10. Percent Fines (Clay +Silt) by Habitat Tyle (Shallow Water Habitat, Inner Harbor, and Outer Harbor) during Spring and Summer 2013 and Summer 2018

Table 2-4. Average Grain Size across 2013 (Spring + Summer)

Station ID	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
LA1	20.5	**65.1**	14.4	0
LA2	5.56	29.3	**65.1**	0
LA3	17.3	**70.1**	12.6	0
LA4	11.9	26.5	**61.6**	0
LA5	25.7	**62.7**	11.7	0
LA6	23.7	**62.7**	13.7	0
LA7	12.5	**49.2**	38.3	0
LA8	16.5	**64.9**	18.7	0
LA9	17.2	**46.1**	36.8	0
LA10	21.5	**63.1**	15.5	0
LA11	24.3	**65.6**	10.1	0
LA12	26.5	**67.3**	6.2	0
LA13	22.2	**62.7**	15.0	0
LA14	20.5	**61.3**	18.2	0
LA15	27.8	**60.5**	11.4	0.390
LA16	26.0	**53.3**	20.8	0
LB1	12.5	43.6	**43.9**	0
LB2	6.66	31.2	**62.1**	0
LB3	20.6	**65.9**	13.5	0
LB4	22.1	**56.0**	21.8	0
LB5	21.4	**61.7**	17.0	0
LB6	27.4	**61.2**	11.4	0
LB7	27.6	**67.1**	5.4	0
LB8	25.9	**59.7**	14.4	0
LB9	12.9	**53.4**	33.6	0
LB10	26.2	**64.7**	9.1	0
LB11	22.3	**62.5**	15.2	0
LB12	28.6	**64.3**	7.1	0
LB13	17.5	**45.5**	37.1	0
LB14	20.9	**57.1**	22.1	0
LB15	20.3	**52.7**	27.0	0
LB16	17.5	**45.3**	37.2	0

Note: Bold denotes the highest percent grain size category per station.

2.3 Riprap Substrate

In the course of the riprap sampling effort (see Section 1.6.6), divers collected data on the physical structure that comprised the riprap habitat based on the size of the substrate encountered. While the designations of sand (<0.5 cm), cobble (0.5 - 15 cm), boulder (15 cm - 1 m), and reef (>1 m) are generally descriptive, they are more accurately thought of as a measure of the potential for the substrate to be disturbed. Large substrates such as reef and boulders would only be disturbed by an extreme event, whereas sand and cobble may be disturbed by winter storms, anchor scour, or propwash scour. The category “Other” represents substrates such as rope, cable, concrete, or trash. Data were collected at 20 stations, including two in the SWH areas and the remainder on the Inner and Outer Harbor habitats, during the spring and summer surveys.

The character of riprap substrate throughout the Port Complex was similar between spring and summer, with reef representing the highest percentage of substrate across all habitat types (Figure 2-9). SWH and Outer Harbor sites were characterized primarily by reef, followed by boulder and cobble in nearly even percentages. Inner Harbor sites differed in that they on average had more boulder and less reef as the dominant substrate, and a higher percentage of cobbles and sand. The small seasonal differences observed were likely due to two factors: the calmer conditions in summer allowing more sand to settle on the riprap, and variations in the exact location of diver transects between sampling events. The high-relief boulder habitat in the Port Complex is more similar to the reefs found around the Channel Islands than to the shelf-like, low-relief rocky reefs found along the mainland coast (Pondella et al. 2015).

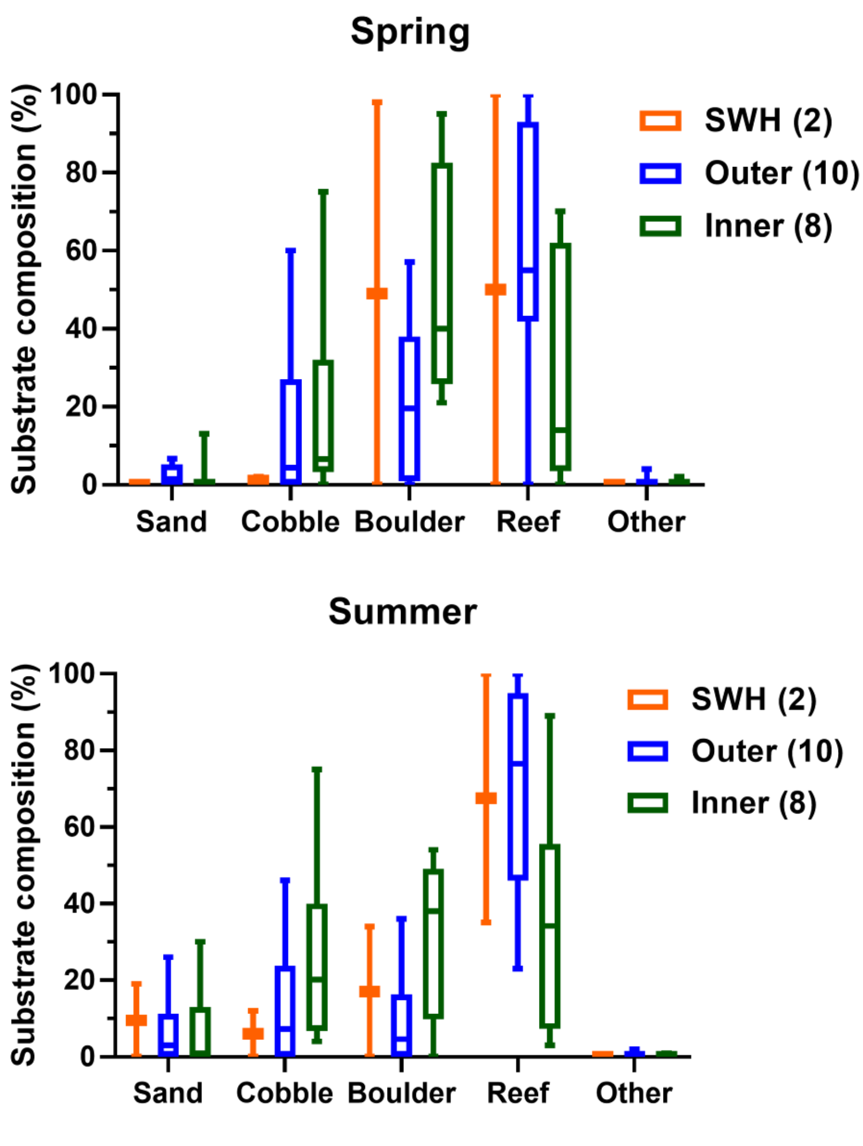


Figure 2-11. Riprap Substrate by Habitat Type Sampled during Spring and Summer

Note: For the purpose of this report, substrate composition groups are defined as follows: sand (<0.5 cm), cobble (0.5 - 15 cm), boulder (15 cm - 1 m), and reef (>1 m)

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3.0 PELAGIC HABITAT

Pelagic habitat consists of the water column that extends from just above the sea bottom to the water surface and is the most widespread habitat type throughout the Port Complex, totaling some 3,600 hectares (8,900 acres) of water.

3.1 Habitat Characteristics

The pelagic habitat is unique compared to others within the Port Complex because it is typically more dynamic relative to more stable benthic habitats (Dickey-Collas et al. 2017). Defining and delineating this habitat is important to aid in the assessment, targeted management, and communication of relevant issues. Hyrenbach et al. (2000) categorize pelagic habitat as having static, persistent and ephemeral aspects. Static aspects include fixed bathymetric and coastal features, persistent aspects include hydrographic and climatic features that can vary seasonally, and ephemeral aspects are short-lived and less predictable gradients and other variations in water quality.

Many fish and invertebrate species inhabit the pelagic zone either throughout their life cycle or during some stage of it. One important component of the pelagic habitat are plankton, a diverse group of animals that is generally divided into several subcategories. Small animals, typically invertebrates that are moved by currents rather than their own efforts are the zooplankton. Planktonic animals that spend their entire life cycle in the pelagic habitat are the holoplankton, whereas those only present during certain life stages (i.e., larval forms of benthic organisms such as worms, echinoderms, and some bottom-dwelling fish) are the meroplankton.

Pelagic sampling in this study focuses primarily on pelagic fishes and their meroplanktonic larvae (the ichthyoplankton). It therefore provides information on coastal pelagic species (CPS) and essential fish habitat (EFH) managed under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), 50 CFR 600 (added by the interim final rule published at 62 Fed. Reg. 66531; December 19, 1997). EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Several species that are managed under the CPS Fishery Management Plan (FMP) are common within the Port Complex, namely northern anchovy, Pacific sardine, Pacific (chub) mackerel, and jack mackerel. These species along with other fish species sampled during the 2018 Biosurvey are discussed below.

Station IDs and associated characteristic identifiers (habitat, location, and depths) used for analysis of pelagic fishes and ichthyoplankton groupings highlighted in the following sections are summarized in Table 3-1.

Data analysis included grouping stations according to habitat (inner, outer, SWH), location (Outer, SWH, Channel, Basin, Slip), and depth stratum (Shallow [0-7 m], Deep [7.1-18 m], Very Deep [18+ meters]). Station designations and the grouping of stations for analysis are shown in Tables 3-1.

Table 3-1. Station Analysis Groups for Pelagic Fishes and Ichthyoplankton

POLA/POLB 2018 Biosurvey - Fish/Ichthyoplankton Station Groups

Station	Port	Habitat	Location	Station Descriptor	Station Depth (m)	Depth Strata
LB1	POLB	Outer	Outer	Outer Harbor Anchorages	13	Deep
LB2	POLB	SWH	SWH	POLB SWH	7	Shallow
LB3	POLB	Outer	Basin	West Basin	15.5	Deep
LB4	POLB	Inner	Slip	Channel 2	14	Deep
LB5	POLB	Outer	Basin	SE Basin East	17.5	Deep
LB6	POLB	Outer	Slip	Pier J South Slip	16.5	Deep
LB7	POLB	Outer	Channel	POLB Main Channel - Pilot Station	24.5	Very Deep
LB9	POLB	Outer	Outer	POLB Outer Main Channel	24.5	Very Deep
LB10	POLB	Outer	Basin	SE Basin West	18	Deep
LB12	POLB	Outer	Channel	POLB Main Channel - Police Station	23	Very Deep
LB13	POLB	Outer	Basin	Inner Harbor Turning Basin	20	Very Deep
LB14	POLB	Inner	Channel	Cerritos Channel	18	Deep
LB16	POLB	Inner	Slip	Channel 3	16.5	Deep
LA1	POLA	Outer	Outer	Outer Pier 400	24	Very Deep
LA2	POLA	SWH	SWH	LA SWH East	6	Shallow
LA3	POLA	SWH	SWH	LA SWH West	6	Shallow
LA4	POLA	Outer	Channel	LA Main Channel	18	Deep
LA5	POLA	Inner	Basin	West Basin	16.5	Deep
LA6	POLA	Inner	Basin	LA East Basin	17.5	Deep
LA7	POLA	SWH	SWH	Seaplane Lagoon	3.5	Shallow
LA9	POLA	Outer	Channel	Pier 300 Channel	18	Deep
LA10	POLA	Inner	Basin	Fish Harbor	7.5	Deep
LA11	POLA	Outer	Outer	LA Outer Channel	25	Very Deep
LA14	POLA	Inner	Slip	Consolidated Slip	7.5	Deep
LA15	POLA	Outer	Basin	LA Turning Basin	17.5	Deep
LA16	POLA	Inner	Slip	Bannings Landing	14	Deep

3.2 Ichthyoplankton

Many species of adult fishes both live and spawn in the Port Complex. Some species lay eggs that attach to hard surfaces while others rear and protect their young within nests. Many, however, are considered broadcast spawners, meaning that they release their eggs into the water column, and the eggs hatch directly into the plankton as larvae, i.e., ichthyoplankton. These broadcast spawners may include a number of cryptic, reef-associated, or burrowing species that, as adults, are ineffectively surveyed by standard sampling methods such as otter trawl or lampara net. Therefore, a survey of the ichthyoplankton provides a more complete picture of the diversity of fish living in the ports' waters and those that use it only for a portion of their life cycle. Several features of the Port Complex may be important for planktonic larvae such as warmer waters and decreased turbulence compared to the open coast which is more readily utilized by adults (MBC 2011). Seasonally timed surveys focused on the ichthyoplankton may also provide an indication of overall spawning activity and recruitment to adult fish stocks.

For this study, the ichthyoplankton survey was performed at the same 26 stations as the benthic and pelagic fish surveys in order to provide comprehensive spatial coverage of the Port Complex. Samples were collected using a bongo net apparatus, which has paired cylinder-cone nets with a 70-cm diameter opening, 0.333 mm mesh Nitex netting, and a removable cod-end. Samples collected from the tows were placed in sample jars and preserved with a mixture of

Collecting ichthyoplankton sample from bongo nets

10% buffered formalin in filtered seawater. Fish eggs and larvae were sorted from the samples, identified to the lowest practicable taxon, and counted. Surveys were conducted during the same months as in the 2013 study (i.e., May, September, and January). To maximize comparability of data with the previous Biosurvey, the sampling vessel and crew, bongo nets, and trawling techniques used were identical to those used during the 2013 study (MBC 2016) and are summarized in Appendix A.1.5 of this report.

3.2.1 Results

A complete summary of all fish eggs and larvae collected is presented in Table 3-2. A variety of parameters were evaluated to assess their impact on observed capture including tow type (oblique versus epibenthic), season (spring, summer, winter), habitat type, location, and depth strata. Statistical comparisons found some seasonal differences in taxonomic richness for fish larvae and seasonal differences in abundance for both fish eggs and larvae, as well as differences based on habitat type and depth for fish larvae. There were no statistically significant differences in taxonomic composition based on tow type. Additional raw data and graphics, separated by survey, depth strata and station location/habitat, are provided in Appendix C.

Table 3-2. Total Abundance of Ichthyoplankton Larvae and Eggs Collected in Long Beach and Los Angeles Harbors, May, September, and January, 2018-19

Stage	Common Name	Species	Oblique (#/100 m^3)	Epibenthic (#/100 m^3)	All Tow Types Combined (#/100 m^3)	% of Total
Eggs	Fish Egg	Fish Egg	17907	14867	32774	96.17
	Turbot	Pleuronichthys sp	495	367	862	2.53
	Anchovy sp	Engraulidae	322	110	432	1.27
	Silverside sp	Atherinidae	11	0	11	0.03
		Total Eggs	**18734**	**15344**	**34079**	**100.00**
Larvae	Clevlandia/Ilypnus/Quietula Goby Complex sp	CIQ goby	2761	2041	4802	55.57
	Combtooth blennies	Hypsoblennius sp	988	626	1613	18.67
	Northern Anchovy	Engraulis mordax	244	211	455	5.26
	Tripletooth Goby	Tridentiger sp	195	233	428	4.95
	Bay Goby	Lepidogobius lepidus	173	79	252	2.92
	Blennies	Chaenopsidae	87	89	176	2.03
	Goby sp	Gobiidae	75	69	144	1.67
	White Croaker	Genyonemus lineatus	73	61	133	1.54
	California Clingfish	Gobiesox rhessodon	32	58	90	1.04
	Yellowfin Goby	Acanthogobius flavimanus	48	28	76	0.88
	Roughcheek Sculpin	Ruscarius creaseri	36	37	73	0.84
	Longjaw Mudsucker	Gillichthys mirabilis	16	30	46	0.53
	fish unid	fish unid	24	23	47	0.55
	Kelpfishes and Blennies	Labrisomidae	16	19	35	0.41
	Yellowchin Sculpin	Icelinus quadriseriatus	10	20	30	0.34
	Giant Kelpfish	Heterostichus rostratus	16	11	27	0.31
	Kelpfish sp	Gibbonsia sp	18	8	26	0.30
	Mussel Blenny	Hypsoblennius jenkinsi	16	4	20	0.23
	Woolly Sculpin	Clinocottus analis	7	11	18	0.20
	Sculpin sp	Cottidae	12	5	17	0.20
	Blackeye Goby	Rhinogobiops nicholsii	4	9	13	0.15
	Silverside sp	Atherinidae	4	5	9	0.10
	California Halibut	Paralichthys californicus	5	4	8	0.10
	Snubnose Pipefish	Cosmocampus artcus	4	4	8	0.09
	Anchovy sp	Engraulidae	2	5	7	0.08
	California Grunion	Leuresthes tenuis	6	1	7	0.08
	Clingfish sp	Rimicola sp	7	0	7	0.08
	Jacksmelt	Atherinopsis californiensis	2	4	6	0.07
	Ronquil sp	Rathbunella sp	1	5	6	0.07
	Bluebanded Goby	Lythrypnus dalli	3	3	6	0.07
	Ronquil sp	Bathymasteridae	4	2	6	0.07
	Rockfish sp	Sebastes sp	0	5	5	0.06
	Shortspine Combfish	Zaniolepis frenata	2	3	5	0.06
	Topsmelt	Atherinops affinis	2	2	5	0.05
	Zebra Goby	Lythrypnus zebra	4	0	4	0.05
	Spotted Turbot	Pleuronichthys ritteri	1	3	4	0.04
	Pacific Sardine	Sardinops sagax	1	3	4	0.04
	Slender Sole	Lyopsetta exilis	3	0	3	0.04
	Hornyhead Turbot	Pleuronichthys verticalis	2	1	3	0.04
	Pipefish sp	Syngnathus sp	2	0	2	0.03
	Blind Goby	Typhlogobius californiensis	0	2	2	0.02
	Bluebanded/ Zebra Goby	Lythrypnus sp	2	0	2	0.02
	Diamond Turbot	Pleuronichthys guttulata	1	0	1	0.02
	Blenny sp	Labrisomus sp	0	1	1	0.02
	Pygmy Poacher	Odontopyxis trispinosa	0	1	1	0.01
	English Sole	Parophrys vetulus	0	1	1	0.01
	Pacific Sanddab	Citharichthys sordidus	1	0	1	0.01
	Croaker sp	Sciaenidae	1	0	1	0.01
	Deepwater Blenny	Cryptotrema corallinum	1	0	1	0.01
	Reef Finspot	Paraclinus integripinnis	1	0	1	0.01
	Longspine Combfish	Zaniolepis latipinnis	0	1	1	0.01
	Pacific Staghorn Sculpin	Leptocottus armatus	1	0	1	0.01
		Total Larvae	**4915**	**3726**	**8641**	**100**

Fish Eggs Summary

Fish eggs were collected in every haul but one, with abundances that ranged from 0 to 146 eggs per haul, equivalent to 0 to 2,919 eggs per 100m^3 of water; the mean concentration per haul was 1,311 eggs/100m^3 (Table 3-2). Capture of eggs at a given station (i.e., with all hauls and seasons at a station combined) was also quite variable with a mean abundance per station ranging from 72 to 1,611 eggs/100m^3. The greatest abundance of fish eggs was observed at Stations LA5, LA9, and LA1 spanning both the inner and outer harbor with no clear spatial trend (Appendix D).

Unidentified fish eggs accounted for 96% of the total catch. Turbot (*Pleuronichthys* sp.) eggs accounted for 3%, northern anchovy (*Engraulis mordax*) accounted for 1%, and silversides (Atherinidae) accounted for less than 1% of the total catch. Turbot and anchovy eggs were collected at all but two stations (LA7 and LB3 for both taxa), while silverside eggs were collected at only two stations (LA9 and LB9).

Fish eggs showed a seasonal pattern of abundance, with the abundances considerably higher in the spring and winter (mean per station of 568 eggs/100m^3 and 560 eggs/100m^3, respectively) than in summer (182 eggs/100m^3).

Larval Fish Summary

The ichthyoplankton sampling effort identified a total of 45 larval fish taxa in the Port Complex (Table 3-2). The actual number of species was likely higher due to numerous determinations that were left at family or genus level, some of which likely comprised more than one species (e.g., the family-level taxon “Chaenopsidae”). Larvae were collected in every haul at abundances that ranged from 1 to 139 larvae per haul, equivalent to 2 to 980 larvae/100m^3 across all stations and surveys (Appendix C), which indicated widespread year-round abundance. The overall mean concentration (all samples at a station combined) was 332 larvae/100m^3 with the greatest abundance observed at Stations LA10, LA14, and LB2, which ranged from 299 to 412 larvae/100m^3.

Dominant Larval Fish Taxa

The CIQ (*Clevelandia*, *Ilypnus*, *Quietula*) goby complex was the most frequently encountered and most abundant taxon over the three seasons combined (Table 3-3, Figure 3-1). CIQ gobies were collected at every station and accounted for 55.6% of the total abundance, nearly three times the second most abundant taxon (*Hypsoblennius* sp., combtooth blennies) and ten times the third most abundant taxon (*Engraulis mordax*, northern anchovy). CIQ gobies were most abundant at Stations LA10 (945 larvae/100m^3), LA7 (786 larvae/100m^3), and LB3 (698 larvae/100m^3) (Appendix C). Combtooth blennies were also distributed relatively evenly throughout the Port Complex, while northern anchovies were generally more abundant at stations within the inner Long Beach Harbor stations with a mean of 28.2 larvae /100m^3 compared to a mean of 17.5 larvae/100m^3 for all 26 stations within the Port Complex. The fourth most abundant taxon, *Tridentiger* sp. (most likely *T. trigonocephalus*, chameleon goby), was patchily distributed, collected at six of the stations, and one sample (LA14 in May) accounted for 80.2% of the total catch.

Table 3-3. Ten Most Abundant Larval Fish Collected from All Tows and All Seasons Combined

Species		Total Density (#/100 m^3) per Taxa	% of Total Density
Common Name	Scientific Name		
CIQ goby	*Clevlandia ios/Ilypnus gilberti/Quietula y-cauda*	4,802	55.6
Combtooth blennies	*Hypsoblennius* sp.	1,613	18.7
Northern anchovy	*Engraulis mordax*	455	5.3
Tripletooth goby	*Tridentiger* sp.	428	5.0
Bay goby	*Lepidogobius lepidus*	252	2.9
Blennies	*Chaenopsidae*	176	2.0
Goby	*Gobiidae*	144	1.7
White croaker	*Genyonemus lineatus*	133	1.5
California clingfish	*Gobiesox rhessodon*	90	1.0
Yellowfin goby	*Acanthogobius flavimanus*	76	0.9

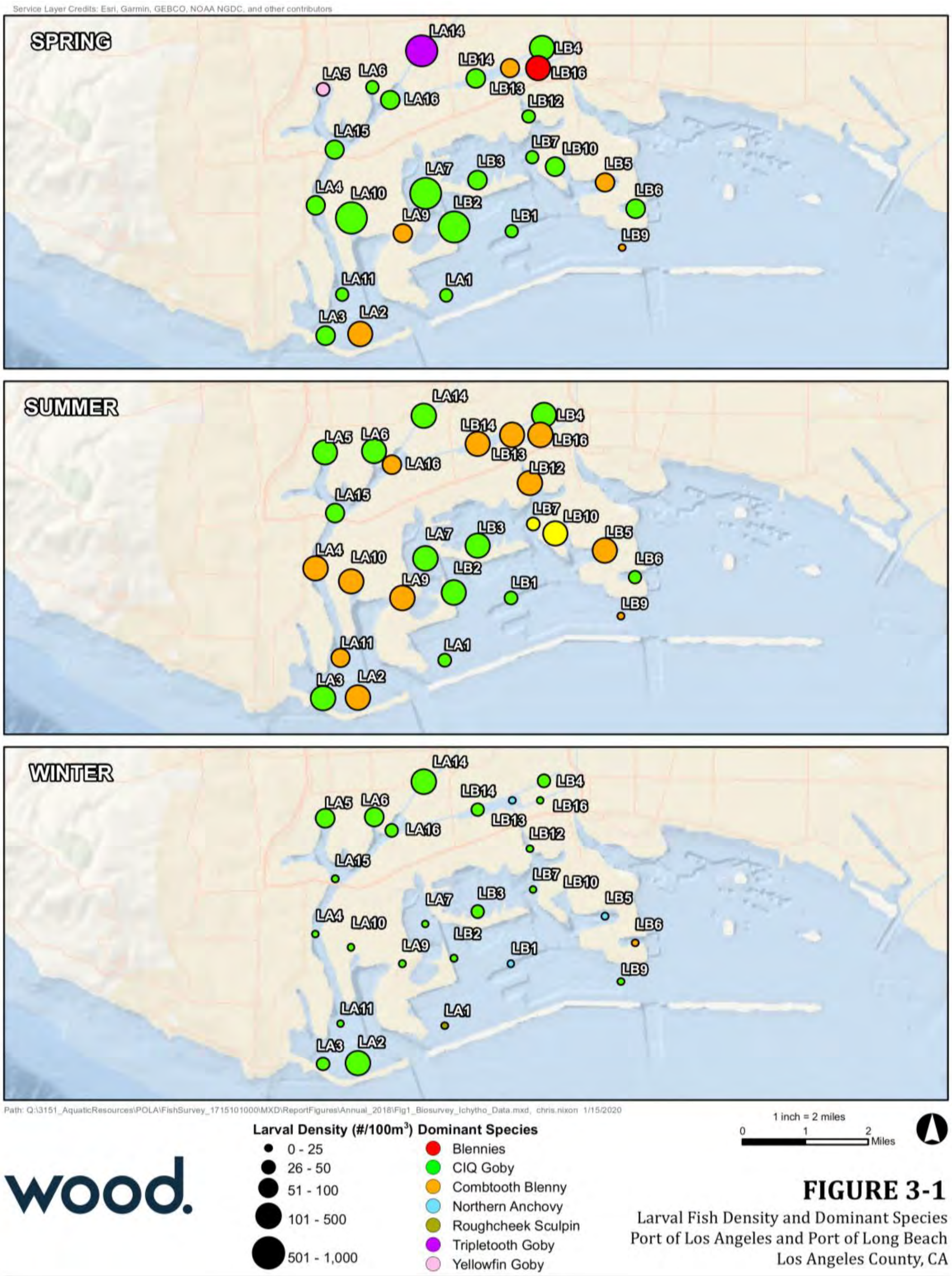


Figure 3-1. Seasonal Variation of Larval Density by Station and the Most Abundant Larval Fish Species Collected in 2018

Seasonality

As shown in Figure 3-2, there were seasonal differences in the richness and abundance of fish larvae: both measures were highest in spring and lowest in winter. These differences were most pronounced for abundance, which was substantially lower in winter.

Individual taxa, particularly those that were more abundant, showed a similar seasonal pattern of abundance; highest larval abundances occurred in the spring survey, while lowest larval abundances occurred in the winter survey. For example, CIQ goby had a mean abundance per station of 107 larvae/100m^3 in spring, 64 larvae/100m^3 in summer, and 14 larvae/100m^3 in winter. However, several taxa were most abundant in the summer survey, including combtooth blennies, northern anchovies, and bay goby (*Lepidigobius lepidus*). Bay goby was the only frequently caught larva present in more or less consistent abundances throughout the year.

Distribution by Depth and Habitat Types

In order to assess patterns of larval distribution within the Port Complex, stations were grouped according to habitat type (SWH, Outer Harbor, Inner Harbor), location (SWH, Outer Harbor, Basin, Channel, Slip), and depth (Shallow 0-7 m, Deep 7.1-18 m, Very Deep 18+ meters). Differences in larval species richness, abundance, and diversity indices were then assessed across these station groups and are shown graphically on Figures 3-3 through 3-5 (Pielou's evenness index is not included in the figures because of redundancy with the Shannon Weiner index).

Groupings of stations by habitat type showed that the SWH group differed from the other habitat groups by having lower Shannon-Wiener and Pielou's diversity and higher abundances (significantly so compared to the Outer Harbor group; Figure 3-3). Likewise, the SWH location group had statistically significant differences in abundance (higher) and Shannon-Wiener and Peilou's diversity (lower) than all other location groups (Figure 3-4). The same differences were noted for the depth strata groups, with the SWH group having significantly higher abundances and lower diversity than the deep and very deep groups (Figure 3-5). Details are presented in Appendix D.

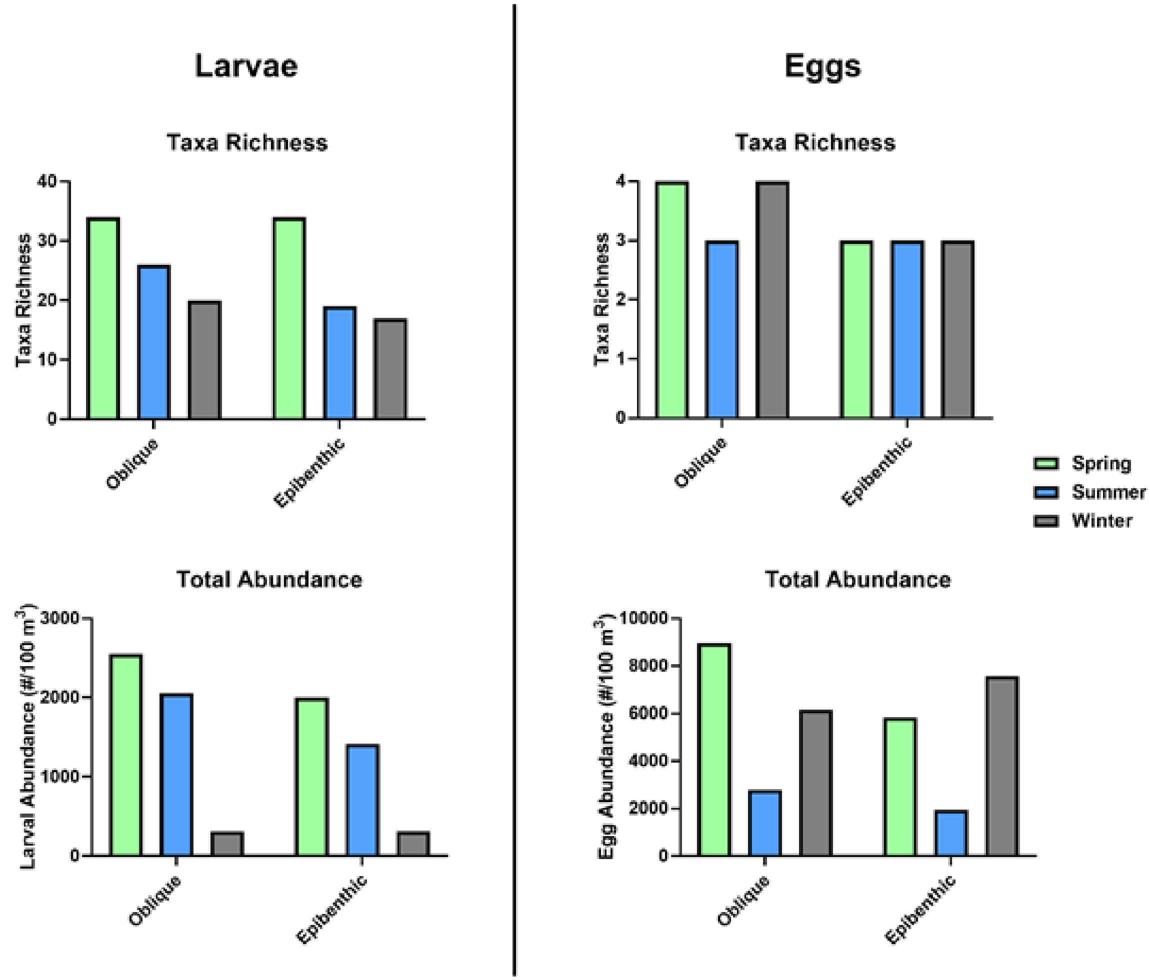


Figure 3-2. Ichthyoplankton and Egg Abundance Based on Tow Type and Season for all Stations Combined

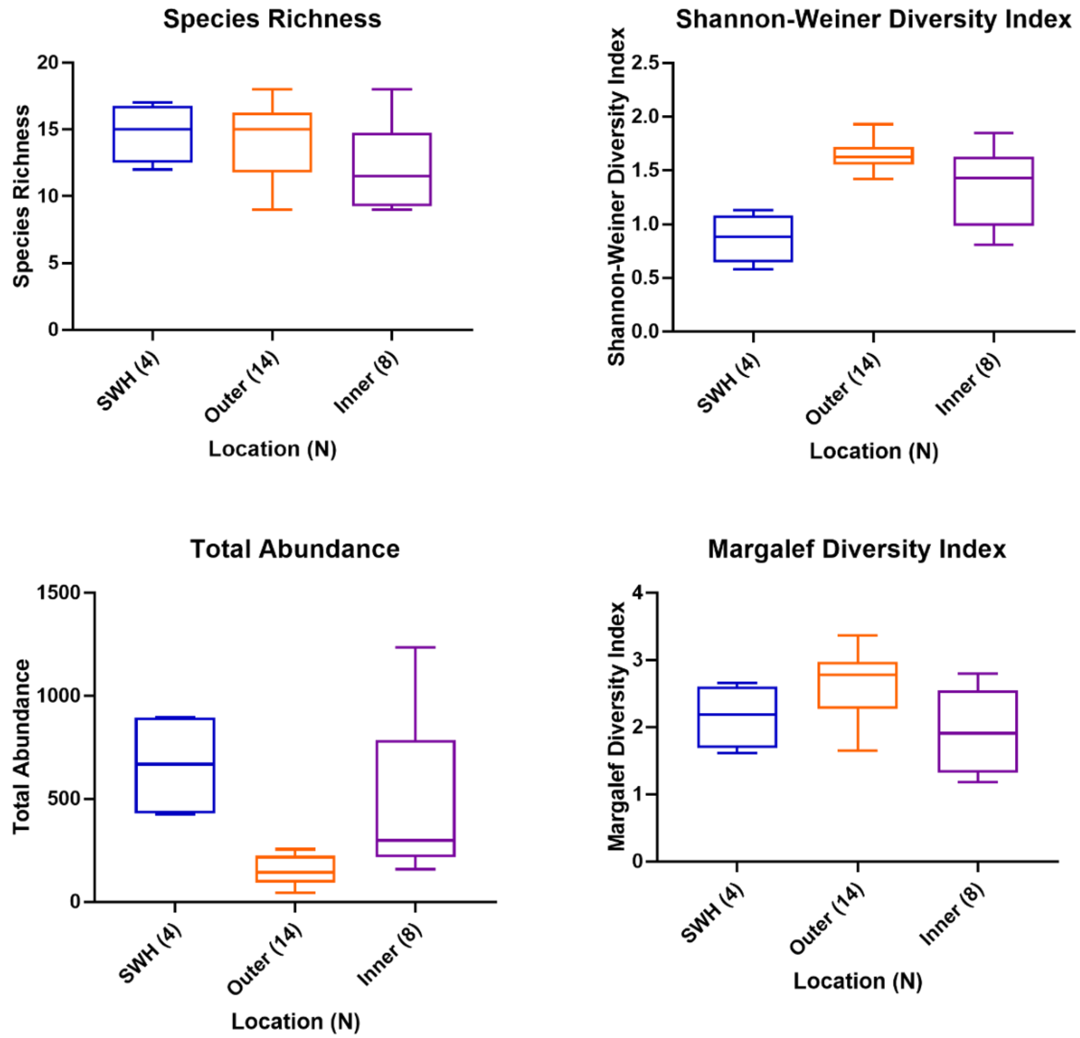


Figure 3-3. Larval Fish Species Abundance, Richness and Diversity Among Habitat Types – All Tows and Seasons Combined, 2018

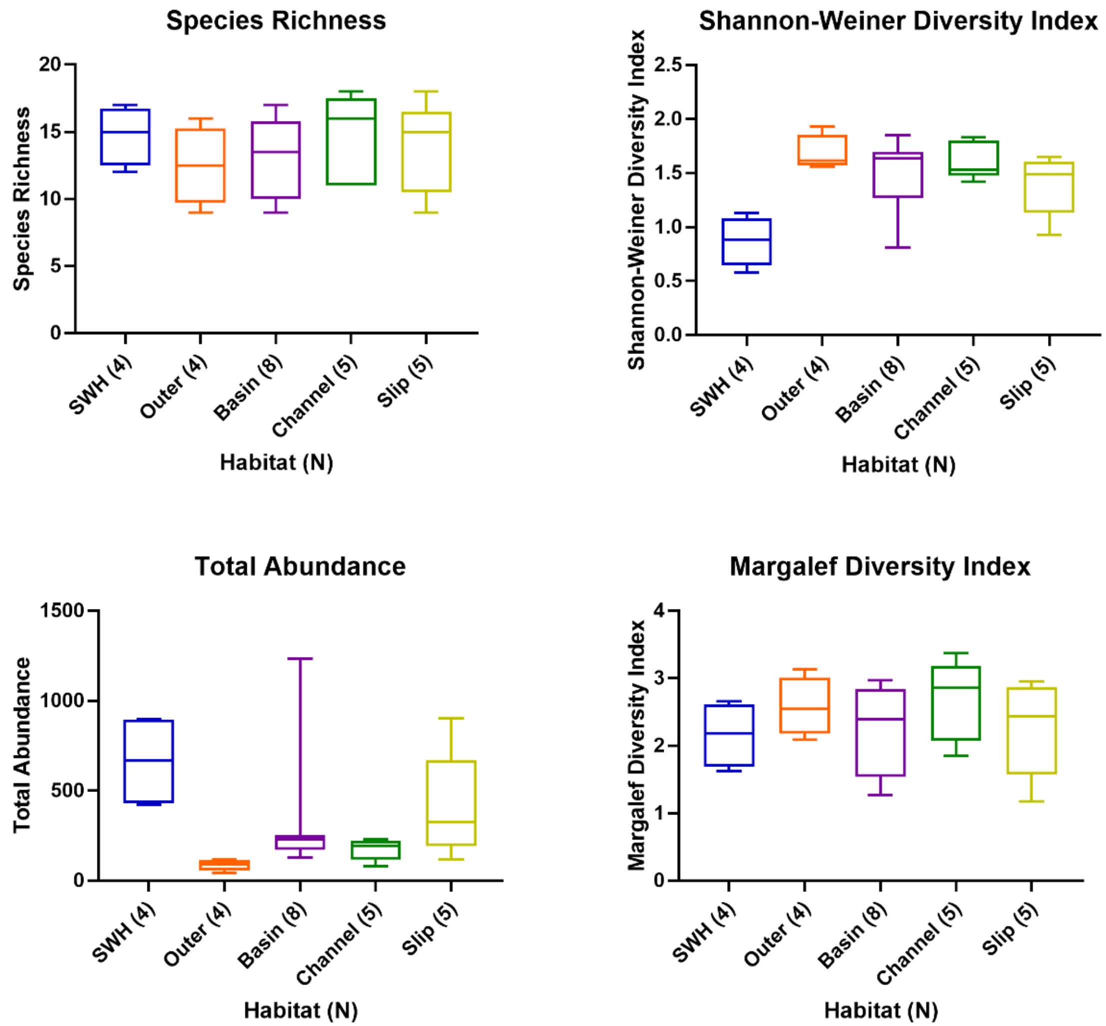


Figure 3-4. Larval Fish Species Abundance, Richness and Diversity Among Location Types – All Tows and Seasons Combined, 2018

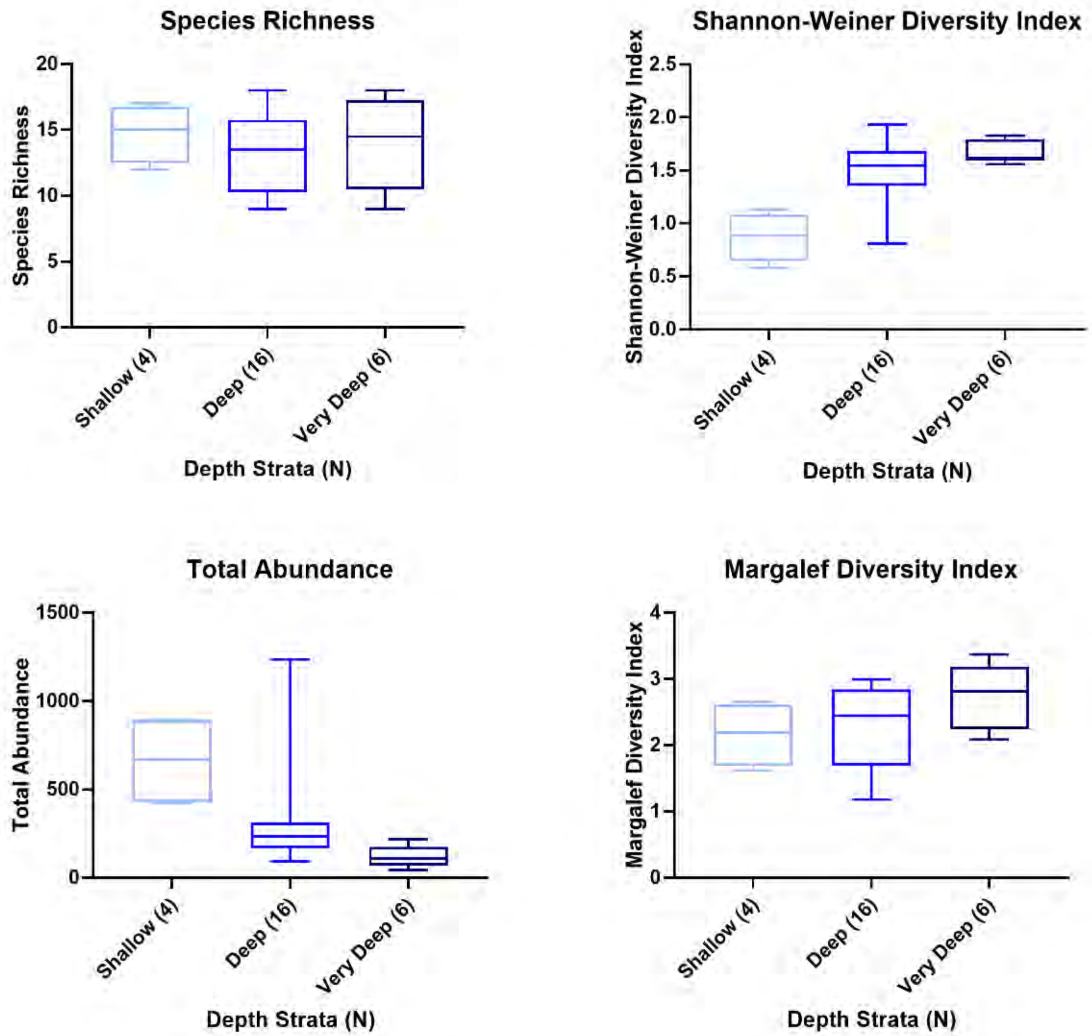


Figure 3-5. Larval Fish Species Abundance, Richness and Diversity Based on Depth – All Tows and Seasons Combined, 2018

Distributional Patterns of Larval Fish using Multivariate Analyses

Multivariate analysis of larval fish abundance (per 100 m^3) data combined across all sampling events provided an integrated analysis of larval community patterns throughout the Port Complex (see Appendix A for a description of the analytical methodology). These analyses, like those presented above, found significant differences among habitat types and depth strata (Figures 3-6 and 3-7), but not among location types. The SWH station group was significantly different from the Outer and Inner station groups, and the shallow stations were distinct from the deep and very deep stations (which did not differ significantly from one another). These results support the results of the comparisons of abundance, species richness, and diversity presented above that suggest that the larval fish assemblages in shallow-water areas of the Port Complex had a distinctive pattern of abundance and composition compared to deeper areas. nMDS plots, shade plots and SIMPER analysis figures and tables for location, habitat, and depth strata groups can be found in Appendix C.

Cluster analysis of the larval fish taxonomic data identified four clusters of stations (Figure 3-8). However, 19 of the 26 stations were in a single cluster, and two clusters were comprised of a single station each. Overall, this analysis did not appear to identify any major differentiation of larval community structure in any specific area of the Port Complex and, most notably, the shallow-water stations did not cluster together. This result was likely driven by the planktonic nature of larval fish and their distribution likely due to tidal and wind-driven currents and mixing (Robins 2013). Results of the cluster analysis are presented in Appendix C.

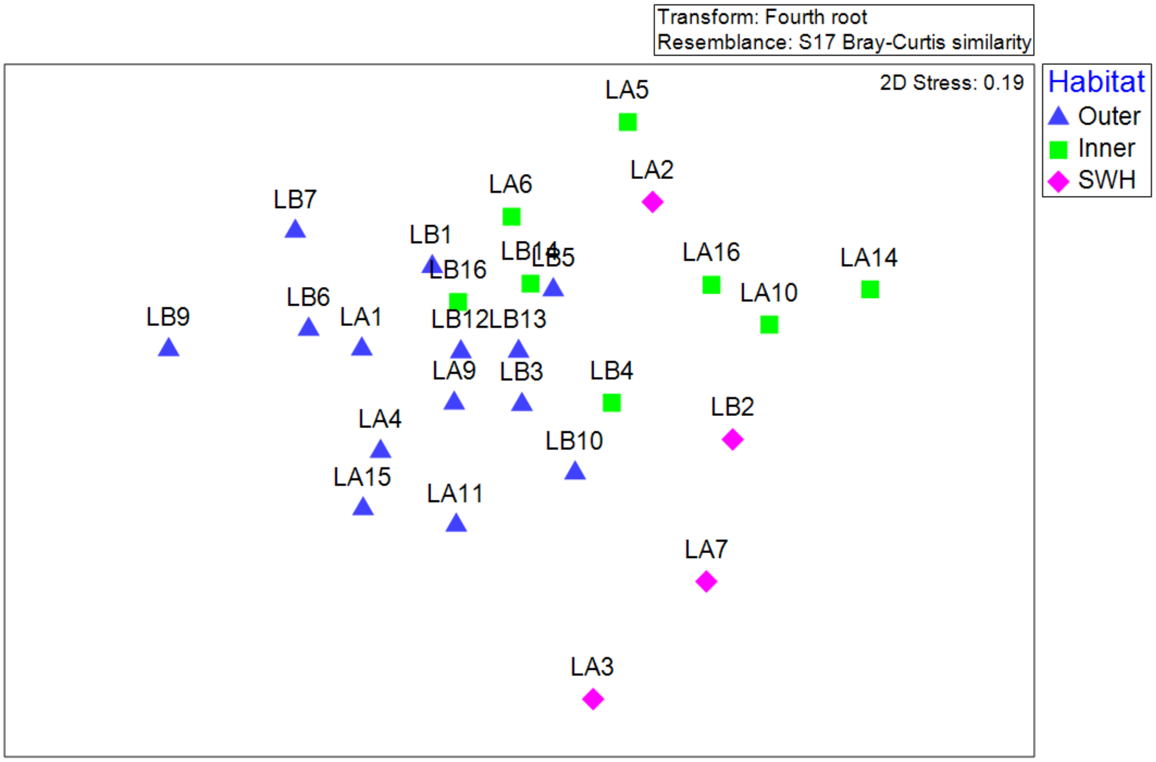


Figure 3-6. Multivariate nMDS Plot Showing the Relationship Among Larval Fish Populations Based on Habitat Grouping - All Seasons Combined

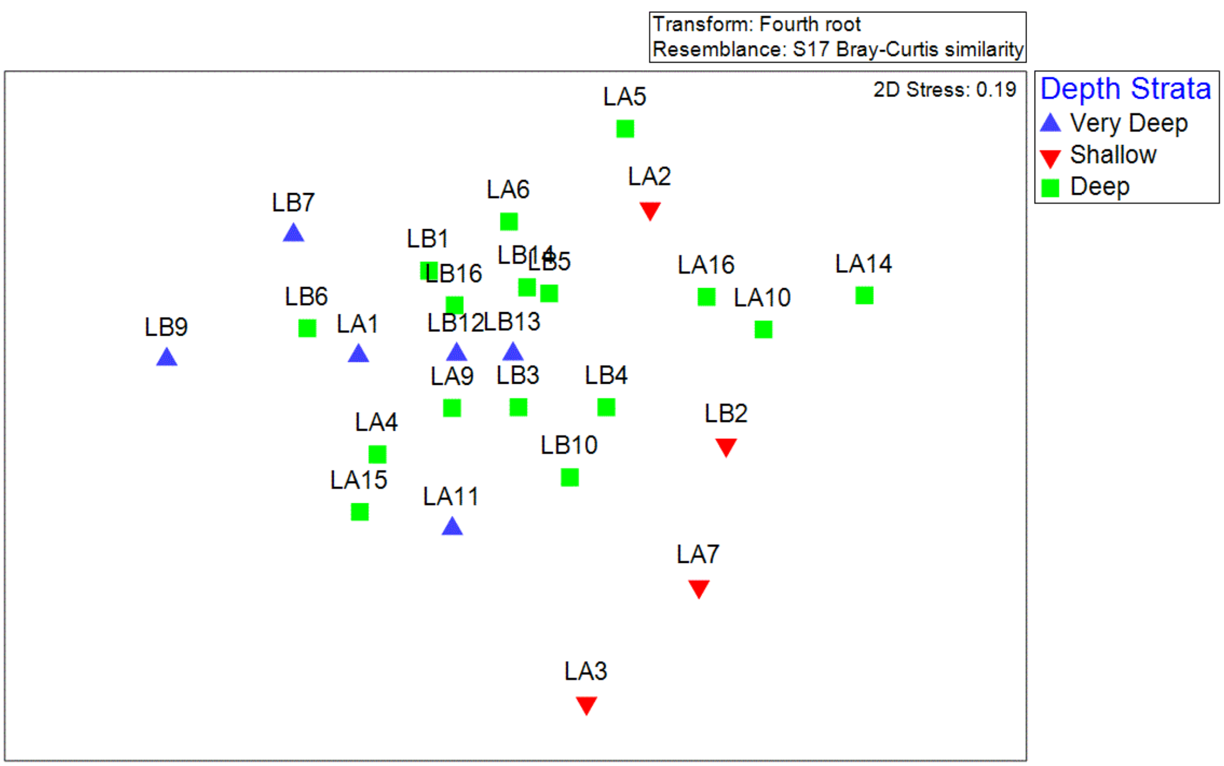
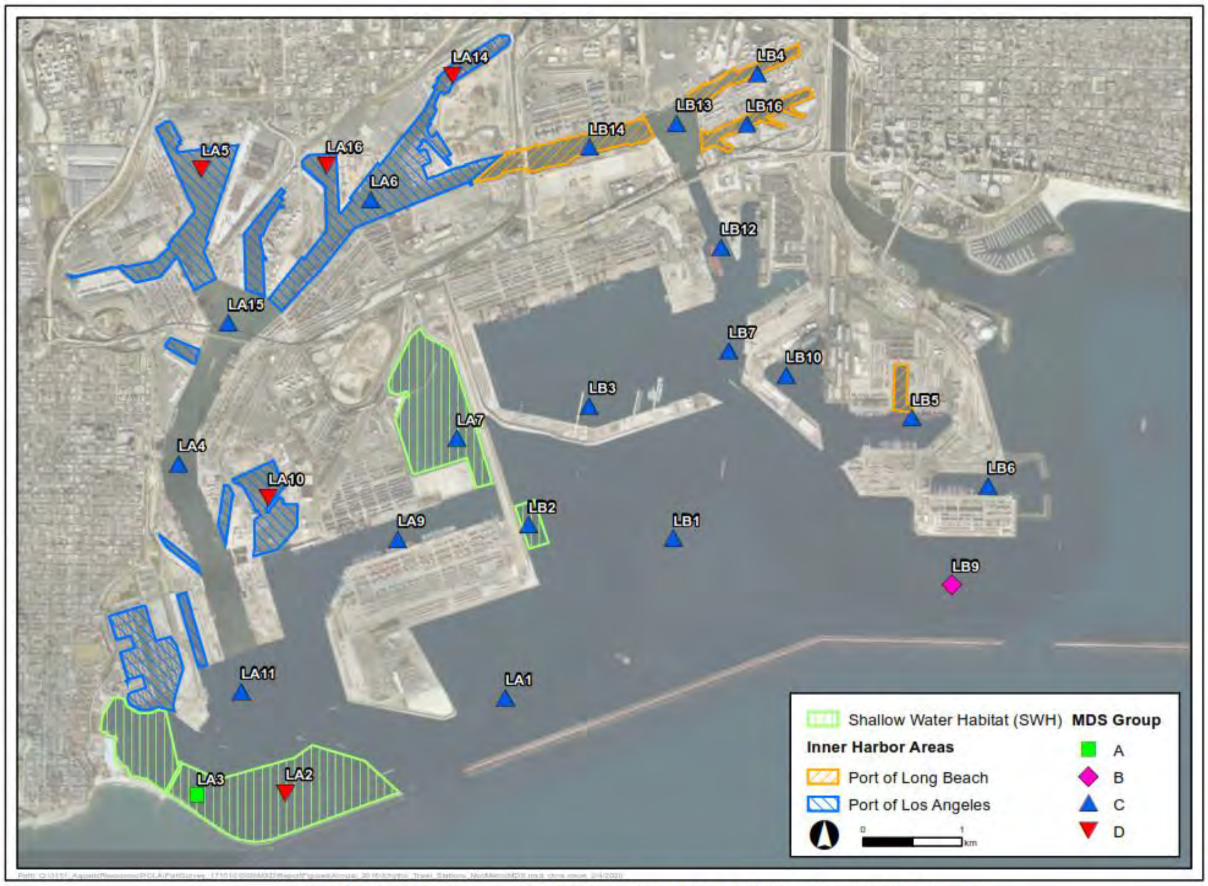


Figure 3-7. Multivariate nMDS Plot showing the Relationship Among Larval Fish Populations Based on Depth - All Seasons Combined



Ichythoplankton Abundance By Trawl Station (Non-Metric Multidimensional Scaling Groups)
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 3-8. Similarity Profile Analysis Showing the Distribution of Cluster Groupings for Larval Fish Populations Across All-Seasons

3.2.2 Historical Comparisons

Prior ichthyoplankton surveys in the Port Complex (MEC 2002, SAIC 2010, MBC 2016) have utilized similar sampling gear and fishing techniques to the 2018-19 Biosurvey. There have been some differences in the number and location of stations and laboratory sample processing, but when the data are standardized to number of larvae per water volume and to account for methodological differences, comparisons between Biosurveys are possible. In the 2018-19 Biosurvey, the neuston sampling of the surface layer was discontinued, and so neuston data from prior Biosurveys were eliminated from these analyses. Additionally, estimates of total species richness per Biosurvey did not count non-distinct taxa (e.g., determinations made to family level were not considered unique from genus or species level determinations within that family).

Species richness varied from 42 unique taxa collected in 2000 to 58 unique taxa in 2013 (Table 3-4). The 2018 Biosurvey collected 45 unique taxa. Mean station abundance has shown a decline from 2000, when the mean per station was 1,653 larvae/100m^3 to 2018, when the mean was 332 larvae/100m^3 (Table 3-4). This trend may reflect an overall regional decline in nearshore ichthyoplankton abundance, as was documented in a long-term monitoring program in nearby King Harbor (Pondella et al., 2012), where surveys conducted from 1974-2009 showed steady declines in abundance, diversity, and total plankton sample volume. This gradual decline could be possibly due to numerous cumulative factors such as red tide, the strength of ENSO, and shifts in oceanographic conditions including a transition to warmer, nutrient-deficient waters along the Southern California Bight since the 1970s (Parnell et al., 2010). In particular, water temperatures along the Southern California coast were very high in the summer of 2018, with one Santa Monica buoy experiencing the longest duration of continuous positive anomalies (Thompson et al. 2018) which could explain low larval abundance.

Many of the most abundant larvae have remained consistent over the four Biosurveys, including CIQ goby (the most abundant taxon in every Biosurvey), combtooth blenny, bay goby, and white croaker (Table 3-5, Figure 3-9). Anchovy and queenfish have been variable; anchovy did not make the top ten list in 2008, and queenfish was in the top ten in 2000 and 2013 but was not collected at all in 2008 and 2018. Croakers (Family Sciaenidae) had lower diversity and abundance in 2018 than in all previous Biosurveys, with white croaker the only sciaenid identified in 2018.

Within the Southern California Bight, fish larvae that prefer warm water have been very abundant in Southern California since 2014 (Thompson 2019), while species preferring cooler waters have been in decline (Parnell et al., 2010). In 2018, anchovy larvae were identified as being the most abundant in Southern California since the 1960s most likely due to these warm water conditions (Thompson et al. 2018). Record high larval anchovy abundance continued into 2019 (Thompson 2019) as warm water circumstances persisted. In addition to rising larval anchovy abundance, goby and garibaldi larvae have remained constant (Pondella 2012). While most larval fish species have experienced declines in Southern California recently, both gobies and anchovy found in this current report have been identified recently in other independent regional assessments described above which substantiates observations within the Port Complex.

Table 3-4. Historic Comparison of Larval Fish Metrics per Biosurvey - Summation of All Seasons, Oblique and Epibenthic Tows

Metric	2000	2008	2013	2018
	18 Stations	19 Stations	26 Stations	26 Stations
Total Larval Taxa Richness	42	55	58	45
Total # Larvae/100 m3	29,753	15,610	22,400	8,641
Mean # Larvae/100m3 per station	1,653	822	862	332
Mean # Eggs/100m3 per station	42,734	50,643	112,543	34,079

Table 3-5. Historical Comparison of the Top Ten Larval Fish Taxa Collected from 2000 to 2018, Summation of All Seasons, Oblique and Epibenthic Tows

2000	2008	2013	2018
CIQ goby	CIQ goby	CIQ goby	CIQ goby
Bay goby	Combtooth blenny	Unidentified anchovy	Combtooth blenny
Northern anchovy	Bay goby	Combtooth blenny	Northern anchovy
California clingfish	Clingfish	White croaker	Tripletooth goby
Queenfish	Unidentified larvae	Northern anchovy	Bay goby
Combtooth blenny	Yellowfin goby	Bay goby	Blenny
White croaker	White croaker	Unidentified yolk sac	Goby
Yellowfin goby	Roughcheek sculpin	Yellowfin goby	White croaker
Unidentified goby	Snubnose sculpin	Queenfish	California clingfish
California grunion	Fragmented larvae	Jacksmelt	Yellowfin goby

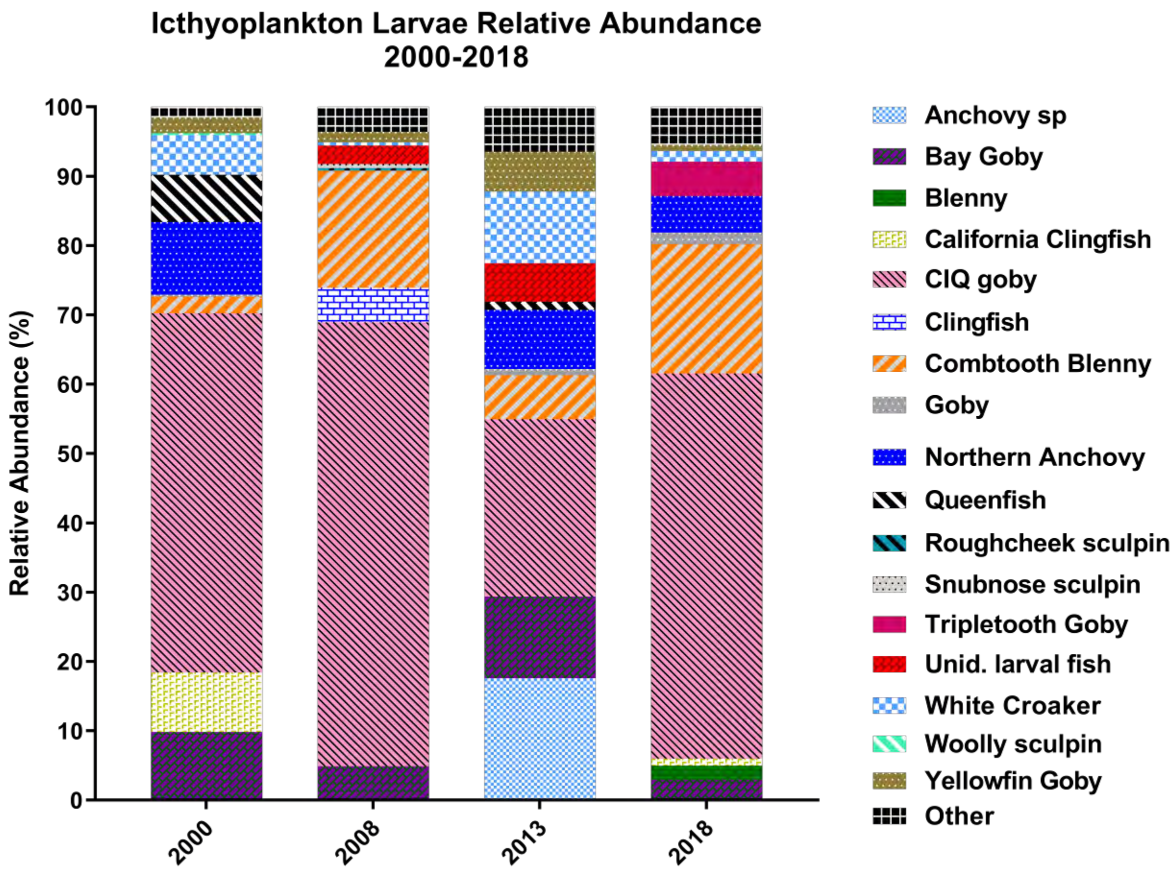


Figure 3-9. Historical Comparison of Relative Abundance of the Top Ten Larval Fish Taxa Collected from 2000 to 2018-19 - Summation of All Seasons, Oblique and Epibenthic Tows

3.3 Pelagic Fish

Adult pelagic fishes were sampled using lampara net in the spring and summer at 26 stations throughout the Port Complex (Figure 3-10). Day and night sampling was performed during each season for a total of four sampling events at each station throughout the study period and a total of 104 individual sampling events. Maps of the lampara sampling locations at each station are provided for reference in Appendix C. The overall diversity and biomass results for the two seasonal sampling events are combined in the results summary below because statistical analysis determined there was no significant difference between seasons when data for all species is combined. Seasonal differences were noted however for certain individual species as highlighted in the following section describing size class relationships for select species.

Ichthyoplankton, Trawl, Lampara, and Beach Seine Stations
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

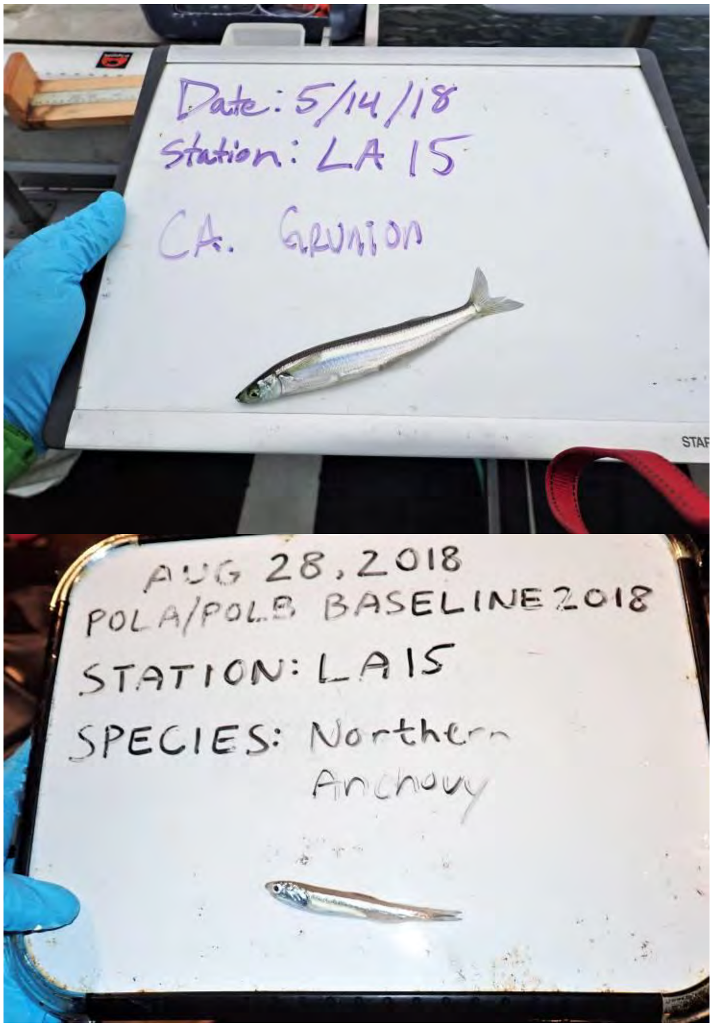
Figure 3-10. Locations of Fish and Ichthyoplankton Sampling Stations

3.3.1 Species Comparisons

Abundance

Lampara sampling captured a total of 18,336 fish comprised of 23 species across all sampling events (Table 3-6). More fish were caught in the summer compared to the spring (12,986 individuals and 16 species versus 5,350 individuals and 15 species, respectively), although the difference in abundance and species numbers between the two seasons was not statistically significant. While there was no statistical difference as a whole, some notable differences between seasons were observed such as topsmelt (*Atherinops affinis*; 5,675 in summer versus 2,127 in spring), California grunion (*Leuresthes tenuis*; 4,180 versus 547), and Pacific sardine (*Sardinops sagax caeruleus*; 536 versus 4). The seasonal difference in California grunion can be partially attributed to their annual spawning runs that begin in March and peak during June-September in Southern California.

A paired two-tailed t-test of natural-log-transformed abundance data determined that there was a statistically significant difference between day and night sampling (p=0.045, see Appendix C). Day sampling captured 5,921 fish comprised of eight species, while night sampling captured 12,415 comprised of 21 species. The species that showed the largest differences between day



California grunion (top) and northern anchovy (bottom) collected in lampara net

and night were northern anchovy (*Engraulis mordax*; 180 versus 4,704, respectively), Pacific sardine (2 versus 538), jack mackerel (*Trachurus symmetricus*; 0 versus 151), and jacksmelt (*Atherinopsis californiensis*; 5 versus 125). Topsmelt, California grunion, and northern anchovy comprised 99.7% of the 5,918 fish caught during the day; the other five species captured only accounted for 14 individuals. The same three species also dominated the night catch, making up 92.7% of the total abundance, but there was more diversity at night, with an additional 18 species that added 906 individuals. Only two species were captured during the day that were not captured at night: a single bay pipefish (*Syngnathus leptorhynchus*) and a single juvenile yellowtail (*Seriola dorsalis*).

Fish captured at five stations (LA3, LA7, LA10, LB7 and LB12) made up 56.9% of the total abundance across all sampling events. This was driven primarily by large catches of California grunion and northern anchovy at these stations. Topsmelt were present in high abundances at a few stations, but topsmelt were also the only species that was captured at all stations.

Biomass

Lampara sampling captured a total of 191 kg of fish biomass (Table 3-6), 71.7 kg in the spring and 120 kg in the summer. Similar to total abundance, a paired t-test was used to determine there was a statistical difference between total biomass collected during the day (60.0 kg) versus the night (131 kg).

Of any individual fish species, topsmelt accounted for the most biomass (77.0 kg, 40.3% of total), followed by California grunion (31.00 kg, 16.2%) and Pacific sardine (30.9 kg, 16.1%). While northern anchovy made up a large percentage of the total abundance (26.6%), their small size meant that they accounted for only 6.23% of the total biomass. Barracuda (*Syphyraena argentea*; 7.39%), bat ray (*Myliobatis californica*; 5.46%), jack mackerel (5.17%) and jacksmelt (1.95%) were the only other species that accounted for more than 1% of the total biomass.

Five stations (LA3, LA5, LA7, LA10 and LB6) accounted for 50.3% of the total fish biomass collected across all sampling events. These large biomass values were usually the result of one large individual or a large catch of a single species. Site LA5 had the greatest total biomass (26.5 kg), which was the result of one large bat ray (10.4 kg) and a large catch of Pacific sardines (13.5 kg). LA7 had the highest diversity of any station, but much of its high biomass (20.9 kg) was the result of the large catch of 38 barracuda (12.0 kg) at that station. LB6 (18.8 kg) was dominated by a large catch of Pacific sardine (17.1 kg), while the high biomasses at LA3 (15.1 kg) and LA10 (14.9 kg) were driven by large catches of California grunion and topsmelt.

Ecological Index

The Ecological Index (EI) is a metric included for the first time for the Ports Biosurvey Project. The EI utilizes the percent of total abundance, percent of total biomass and frequency of trawl capture to calculate a unitless index value (Table 3-6; see discussion in Section 1.7 and Appendix A). This weighted approach emphasizes species that were abundant and caught at many stations such as topsmelt and northern anchovy, but also gives weight to solitary larger species that were caught at only a few stations such as bat rays. The “rank” by EI determines the relative importance of each species to how energy flows within the food web of the Port ecosystem (Allen et al. 2002). Because the EI incorporates frequency of catch, this index provides a good measure of what the overall community looks like over time.

EI values for lampara sampling ranged from 0.02 for three small species occurring as single individuals to 8,280 for topsmelt, which was the overwhelming dominant species in terms of abundance and biomass as well as being captured at all sampling stations. California grunion (2,907) and northern anchovy (2,402) were the next highest scoring species. An additional seven species had EI values above 1 (Table 3-6): Pacific sardine (440), jack mackerel (323), jacksmelt (92.0), barracuda (88.1), bat ray (21.0), Pacific mackerel (18.5) and Queenfish (*Seriphus politus*; 4.61).

Table 3-6. Pelagic Fish Caught by Lampara, in Order of Ecological Index (All Seasons Combined)

Species		Total Abundance per Taxa	% of Total Abundance	Total Biomass per Taxa (kg)	% of Total Biomass	Total Density (#/100 m^2)	Frequency of Trawl Capture (%)	Ecological Index
Common Name	**Scientific Name**							
Topsmelt	*Atherinops affinis*	7802	42.6	77.0	40.2	88.9	100	8280
California Grunion	*Leuresthes tenuis*	4727	25.8	31.0	16.2	53.9	69.2	2907
Northern Anchovy	*Engraulis mordax*	4884	26.6	11.9	6.23	55.7	73.1	2402
Pacific Sardine	*Sardinops sagax caeruleus*	540	2.95	30.9	16.1	6.16	23.1	440
Jack Mackerel	*Trachurus symmetricus*	151	0.82	9.88	5.17	1.72	53.8	323
Jacksmelt	*Atherinopsis californiensis*	130	0.71	3.73	1.95	1.48	34.6	92.0
Barracuda	*Syphyraena argentea*	45	0.25	14.1	7.39	0.51	11.5	88.1
Bat Ray	*Myliobatis californica*	1	0.01	10.4	5.46	0.01	3.85	21.0
Pacific Mackerel	*Scomber japonicus*	12	0.07	1.40	0.73	0.14	23.1	18.4
Queenfish	*Seriphus politus*	20	0.11	0.56	0.29	0.23	11.5	4.61
Slough Anchovy	*Anchoa delicatissima*	7	0.04	0.02	0.01	0.08	7.69	0.35
California Lizardfish	*Synodus lucioceps*	2	0.01	0.06	0.03	0.02	7.69	0.32
White Croaker	*Genyonemus lineatus*	1	0.01	0.13	0.07	0.01	3.85	0.28
Pacific Butterfish	*Peprilus simillimus*	1	0.01	0.05	0.03	0.01	3.85	0.13
Salema	*Xenistus californiensis*	1	0.01	0.05	0.03	0.01	3.85	0.13
Deepbody Anchovy	*Anchoa compressa*	4	0.02	0.01	0.01	0.05	3.85	0.11
Halfmoon	*Medialuna californiensis*	2	0.01	0.01	0.00	0.02	7.69	0.11
Giant Kelpfish	*Heterostichus rostratus*	1	0.01	0.02	0.01	0.01	3.85	0.05
Bocaccio	*Sebastes paucispinis*	1	0.01	0.01	0.01	0.01	3.85	0.04
Yellowtail (juvenile)	*Seriola dorsalis*	1	0.01	0.00	0.00	0.01	3.85	0.03
Pacific Seahorse	*Hippocampus ingens*	1	0.01	0.00	0.00	0.01	3.85	0.02
Sharpchin Flyingfish	*Fodiator acutus*	1	0.01	0.00	0.00	0.01	3.85	0.02
Bay Pipefish	*Syngnathus leptorhynchus*	1	0.01	0.00	0.00	0.01	3.85	0.02
Total Abundance/Biomass		18336		191.3				
Total Species Richness		23						

Size Classes

Size class analysis was performed for the top seven pelagic species, chosen for a combination of high EI values, status as coastal pelagic species managed under NOAA EFH guidelines, and in the case of barracuda, to include a high trophic-level pelagic predator. Although the species discussed here were collected primarily through lampara sampling, some species such as topsmelt are considered pelagic yet were also captured with benthic gear (i.e. otter trawling and beach seines) and those data are included in this size class analysis. Length at maturity information is provided for species where this information is available.

Topsmelt (8,409 total across all gear types) ranged from 3-24 cm standard length (Figure 3-11). Topsmelt captured during the spring were generally larger: 79% of the 2,129 individuals were in the 10-12 cm range, whereas in the summer 67% were in the 7-10 cm range. The largest individual topsmelt were also captured in the spring, with 10 individuals ranging from 19-24 cm, while no topsmelt in the summer were larger than 18 cm. Topsmelt captured by beach seine in the shallow subtidal were substantially smaller than those captured by lampara or trawls, ranging from 3-16 cm with 52% in the 5-6 cm range. Maturity of Pacific topsmelt occurs when fish reach approximately 1-year of age (10 cm TL), with nearly all fish mature at 2-3 years of age with a length of approximately 15 cm (Love 2011). Based on the average of this range (12.5 cm) approximately 10% of the Topsmelt caught during the spring could be considered mature adults while 17% caught during the summer could be considered adults. Topsmelt are a pelagic species and those caught in beach seines were separated from these metrics. Only approximately 2% of Topsmelt caught in beach seines may be considered mature.

California grunion (4,742 total across all gear types) ranged in size from 4-17 cm standard length (Figure 3-12), and there was a marked difference in size classes between the spring and summer catches. During the spring there was a bimodal distribution of size classes, with 22% of the fish in the 5-6 cm size class and 67% in the 12-14 cm size class. The summer catch was predominantly one size class group, with 89% of the measured fish in the 6-10 cm size class. This difference in size classes across seasons is notable when considering the length at maturity for female grunion is 11.9 cm (Shanks and Eckert 2005). While no information for length at maturity for males is currently available, if size at maturity is the same for both sexes it would indicate that 74% of the California grunion caught during the spring could be considered mature adults while only 6% caught during the summer could be considered adults (14% mature across both seasons).

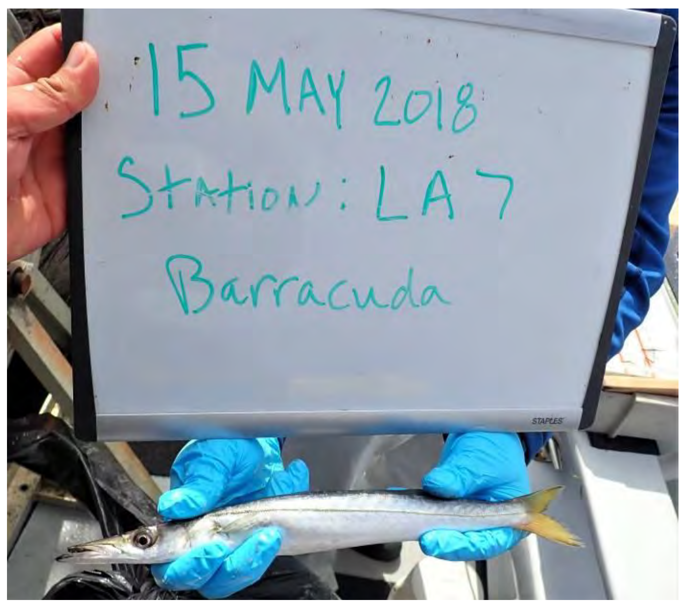
Northern anchovy was the most abundant pelagic species (19,768 total across all gear types, with most caught in the otter trawls because anchovy schools tend to occupy the entire water column) and ranged in size from 3-10 cm during the spring, and from 3-9 cm in the summer (Figure 3-13). Size class distribution in both seasons was centered around 6-7 cm. Given that the length at maturity for females is 9.6 cm (Hunter and Macewicz 1980), adult northern anchovy were only captured during the spring and made up only 8% of the total population sampled (885 total caught in spring). Of the total northern anchovy captured across both seasons, only 0.37% were mature adults.

Pacific sardine (540 total) were scarce in the spring, with only four individuals ranging from 7-18 cm standard length, but abundant in summer, with 536 individuals ranging from 11-21 cm (Figure 3-14). The population sampled in the summer was bimodal in distribution, with one peak around 12-13 cm and the other around 17-19 cm. Using the length at maturity of 14.5 cm (Butler et al. 1996), about 50% of the population could be considered mature adults.

Jack mackerel ranged in size from 11-24 cm (Figure 3-15). The majority of jack mackerel were captured during spring sampling (155 of 161 total captured), but in both spring and summer the size class distribution was centered around the 16-19 cm range. Jack mackerel mature at an age of approximately 1 year ranging in length from 20-23. cm (Love 2011). Based on the average of this range (21.5 cm) approximately 4% of the population captured in the Port Complex in 2018 may be considered mature.

Jacksmelt had a large range in standard length: from 10-32 cm, although only four individuals were larger than 20 cm (Figure 3-16). While far fewer jacksmelt were captured in the spring (22) than in the summer (108), they were markedly larger: 15-18 cm in the spring versus 11-13 cm in the summer. Jacksmelt mature around 2-3 years of age ranging in length from 15-20 cm (Love 2011). Based on the average of this range (17.5 cm) approximately 8% of the population captured in the Port Complex in 2018 may be considered mature.

Barracuda (45 total) were only captured in the spring and ranged from 29-46 cm (Figure 3-17). The majority (67%) of the barracuda captured fell within the 38-41 cm range. Maturity of Pacific barracuda occurs in males between 1 and 2 years of age with a length range of 33 – 45 TL cm. More than 50% of females are mature at 2-3 years of age (49 cm), and nearly all are mature at 55 cm (Love 2011). If the population within the Ports was assumed to be all males then 73% would be mature adults using average maturity TL (39 cm), while the same assumption for all females would result in no mature adults.



Barracuda in spring lampara sample

Pacific mackerel were scarce with only five individuals captured in the spring and seven in the summer and ranged from 18-25 cm SL. Approximately 50% of pacific mackerel are mature by 3 years of age (33.5 cm fork length [FL]), with nearly all mature by 6 years of age (38.8 cm FL; Knaggs and Parrish 1973). Pacific mackerel reach a mean length of 27.2 cm FL by year one (Knaggs and Parrish 1973), which indicates that all individuals captured within the Port Complex were juveniles less than one year of age.

A key observation from this analysis shows that a high fraction of the fish captured are using the harbor complex as a nursery ground prior to adulthood at which time many will head to deeper offshore environments.

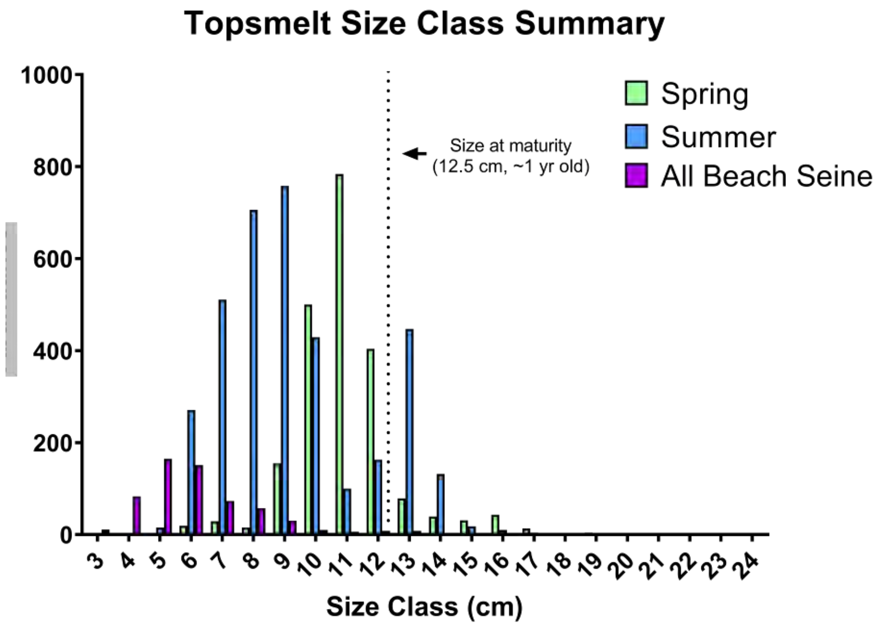


Figure 3-11. Topsmelt Size Class Distribution from Lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note: 2,108 topsmelt from the summer survey were not sized and are not included in this graph (only first 250 from each species in each trawl were sized). Length at maturity from Love 2011. Catch data for beach seines is shown separately due to the much smaller class size captured using this method. Seasonal data using beach seine were combined due to the similarity in class sizes captured between seasons.

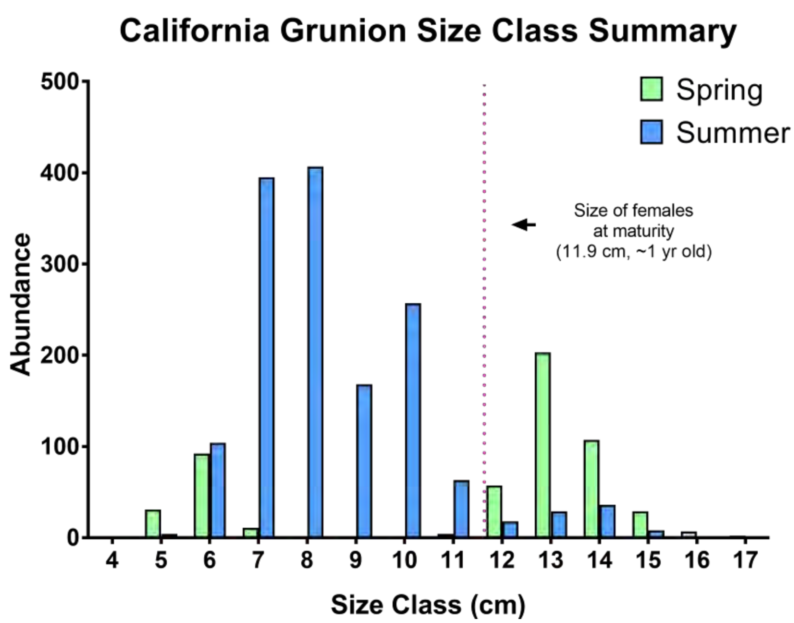


Figure 3-12. California Grunion Size Class Distribution from Lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note: 2,704 California grunion from the summer survey were not sized and are not included in this graph (only first 250 from each species in each trawl were sized). Length at maturity from Shanks and Eckert 2005

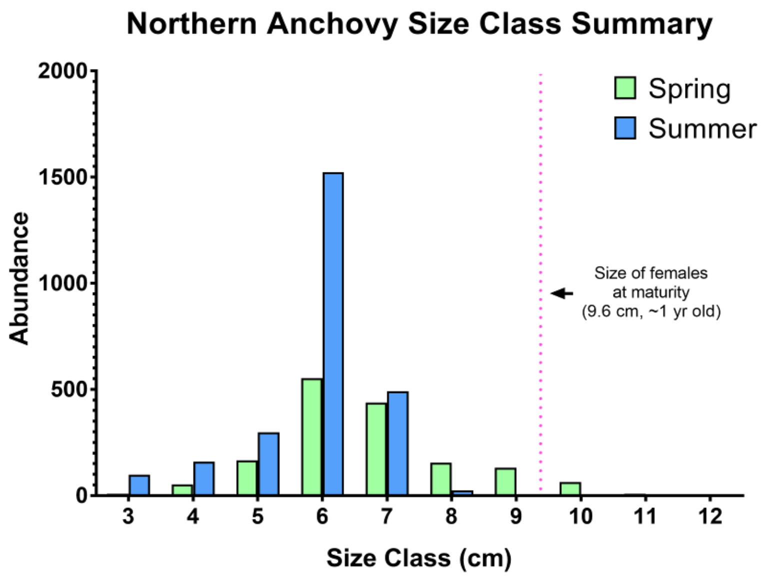


Figure 3-13. Northern Anchovy Size Class Distribution from Lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note:885 northern anchovy from the spring survey and 14,709 northern anchovy from the summer survey were not sized and are not included in this graph (only first 250 individuals from each species in each trawl were sized). Length at maturity from Hunter and Macewicz 1980.

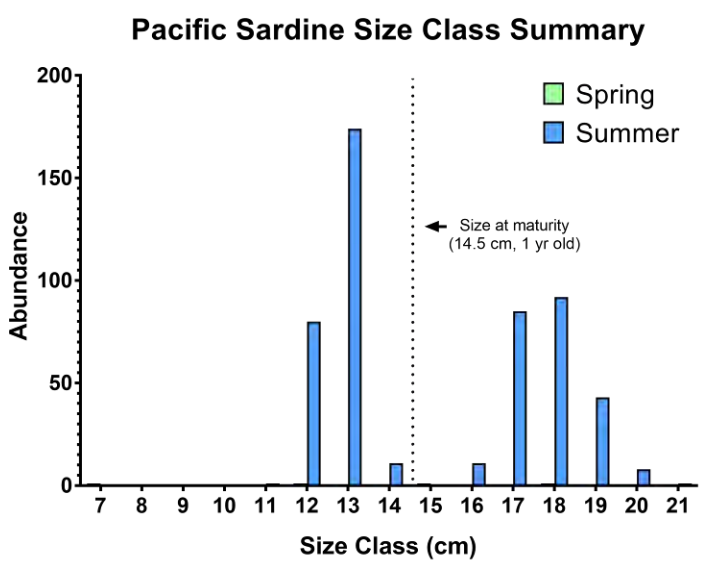


Figure 3-14. Pacific Sardine Size Class Distribution from lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note: 30 Pacific sardines from the summer survey were not sized and are not included in this graph (only first 250 individuals from each species in each trawl were sized). Length at maturity from Butler et al. 1996.

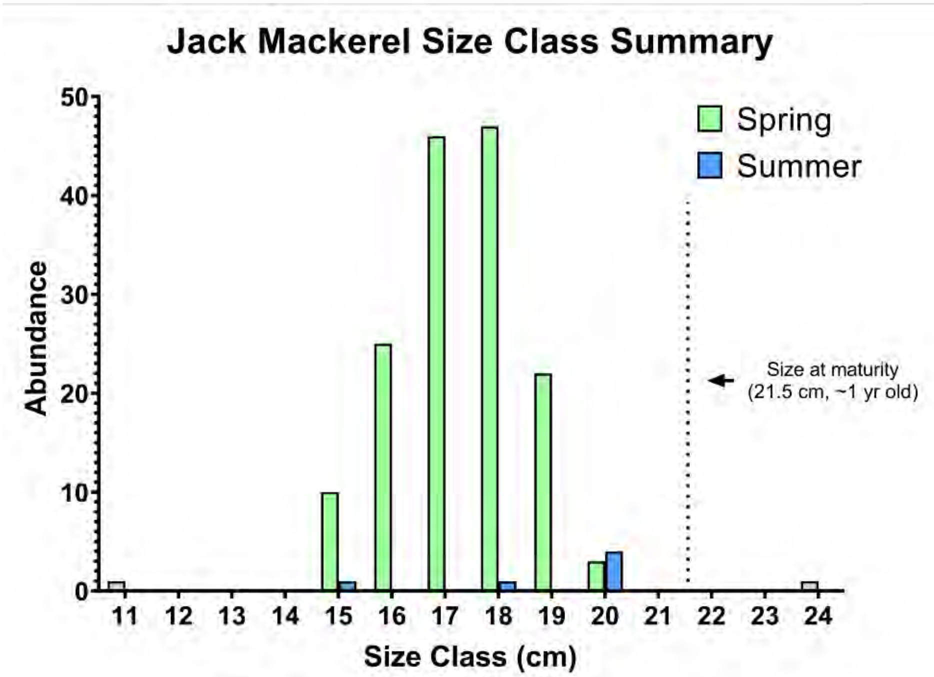


Figure 3-15. Jack Mackerel Size Class Distribution from lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note: Length at maturity from Love 2011

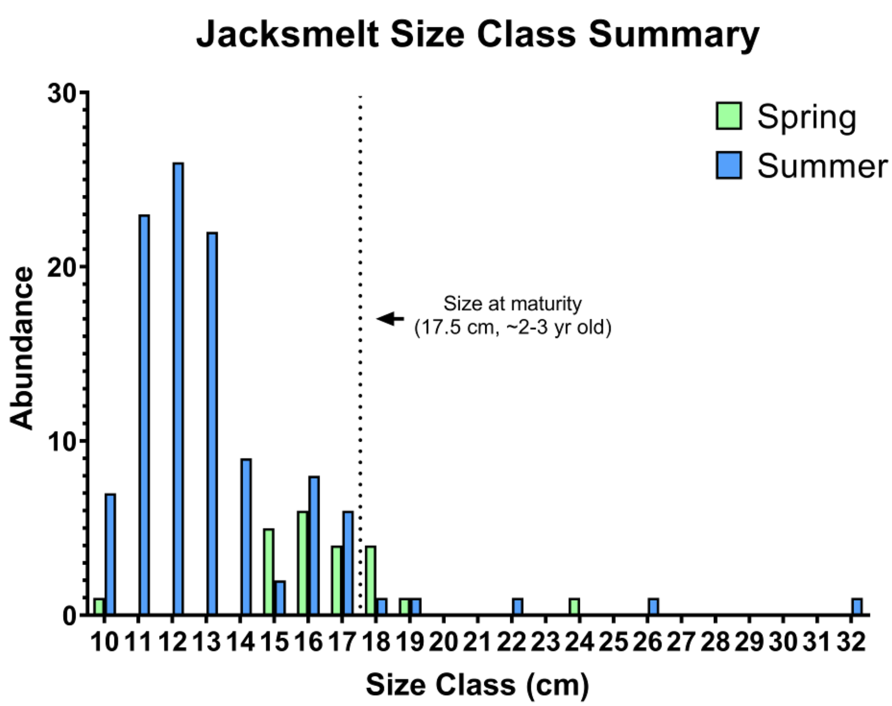


Figure 3-16. Jacksmelt Size Class Distribution from lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note: Length at maturity from Love 2011

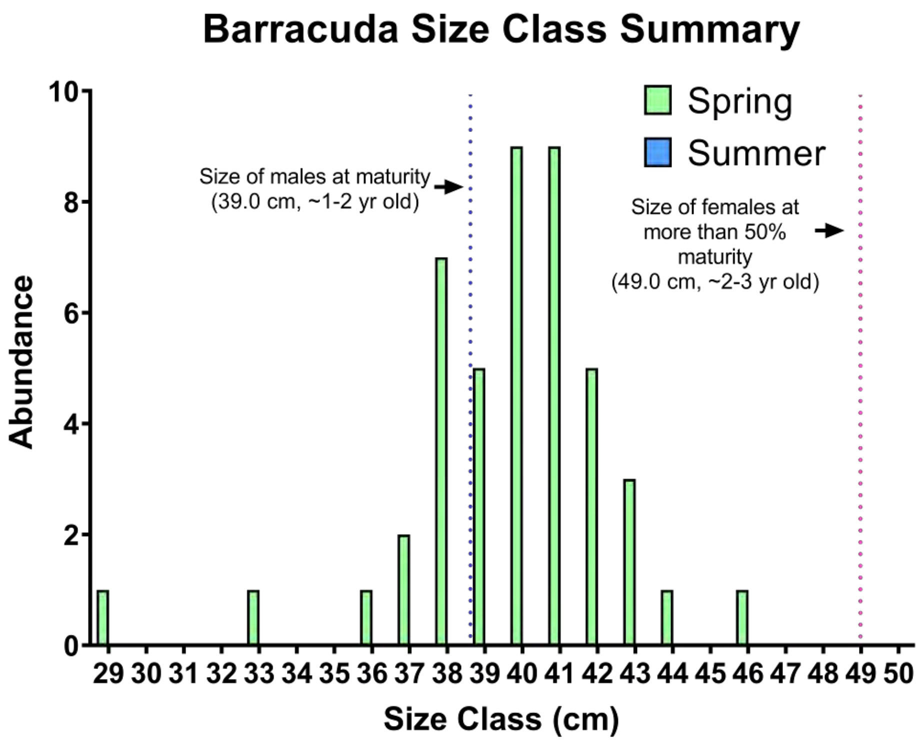


Figure 3-17. Barracuda Size Class Distribution from lampara, Trawl and Beach Seine Sampling during Spring and Summer 2018

Note: Length at maturity from Love 2011

3.3.2 Station Comparisons

Species Richness

Lampara net deployment at night

A total of 23 species were collected by lampara net sampling events. Species richness was similar between spring and summer (15 and 16, respectively), yet there was a marked contrast in species richness between day and night sampling (8 and 21, respectively). When all sampling events were combined (day/night and spring/summer) for each station, species richness among stations ranged from 1 to 11 (Table 3-7). Bannings Landing (LA16) was the only station where only one species was caught, and at four stations only two species were caught. The most species (11) were caught at Seaplane Lagoon (LA7), followed by the LB SWH (LB2) with 8 and LA SWH West (LA3) with 7. In general, SWH stations as a group had the greatest species richness, but the fact that LA SWH East (LA2) was one of the stations where only two species were captured highlights the variability between stations with similar habitat types.

Diversity and Evenness Indices

Diversity indices provide information about biological communities by combining species richness, abundance, and relative abundances (or evenness) into one measure. While there are numerous indices to choose from, two common indices have been used in previous Biosurveys: the Shannon-Weiner index and the Margalef index. For both of these indices, higher values represent higher quality communities. Margalef is the more basic of the two, considering only species richness and abundance, while Shannon-Weiner also factors in the relative abundance of each species. Another community measure, "evenness," has also been evaluated in these Biosurveys using the Pielou's evenness index. Similar to the Shannon-Weiner index, Pielou's index gives higher values to communities that are more evenly balanced (highest score of 1) and not highly dominated by only one or a few species (lowest score of 0), much as the Shannon-Wiener index operates. Caution should be used when using only one index to "rank" stations in terms of diversity or evenness; rather, all indices should be considered when evaluating a given station.

Overall, Shannon-Weiner index values at individual stations ranged from 0 to 1.36, while the Margalef index ranged from 0 to 1.53 (Table 3-7). Both indices scored the slip station near Bannings Landing (LA16) as a 0 because only one species was caught. The only other station that ranked in the bottom three for both indices was LA East Basin (LA6). Outer Pier 400 (LA1) had the highest Shannon-Weiner score, while LB SWH (LB2) had the highest Margalef score. While LA1 did not have especially high species richness or total abundance, the four species that were caught were similar in abundance, which is more heavily weighted in the Shannon-Weiner index. As previously discussed, Margalef only considers the species richness and abundance while Shannon-Weiner includes the relative abundance. It is not surprising, then, that the two stations with the highest species richness received two of the highest Margalef scores, even though LB2 had relatively low total abundance (97, the second lowest total among all stations).

Pielou's evenness index ranged from 0, at LA16, where only one species was captured, to 0.98, at LA1, where although only four species were captured their abundances were nearly equal (Table 3-7). Other stations that received very low Pielou scores, such as Consolidated Slip (LA14) and Channel 2 (LB6), were largely dominated by one species. Pielou's index does not account for species richness or abundance, so a station like SWH East (LA2), which had only two species, relatively low abundance, and scored on the low end of the diversity indices had a high Pielou's evenness index score since the two species were caught in similar numbers. These examples illustrate why considering more than one index is helpful when evaluating stations for diversity and evenness.

Table 3-7. Pelagic Fish Catch Summary by Station Using the Lampara Net (Both Seasons Combined)

Station	Station Descriptor	Habitat	Location	Depth Strata	Taxa Richness	Total Abundance per Station	Total Biomass per Station (kg)	Shannon-Wiener Diversity Index	Margalef Diversity Index	Pielou's Eveness Index
LA1	Outer Pier 400	Outer	Outer	Very Deep	4	503	7.05	1.36	0.48	0.98
LA2	LA SWH East	SWH	SWH	Shallow	2	145	3.67	0.63	0.20	0.92
LA3	LA SWH West	SWH	SWH	Shallow	7	2014	15.12	0.72	0.79	0.37
LA4	LA Main Channel	Outer	Channel	Deep	3	302	4.89	0.42	0.35	0.38
LA5	West Basin	Inner	Basin	Deep	6	427	26.52	0.81	0.83	0.45
LA6	LA East Basin	Inner	Basin	Deep	2	222	3.35	0.07	0.19	0.10
LA7	Seaplane Lagoon	SWH	SWH	Shallow	11	2697	20.94	0.66	1.27	0.27
LA9	Pier 400	Outer	Channel	Deep	5	496	2.89	0.66	0.64	0.41
LA10	Fish Harbor	Inner	Basin	Deep	6	3023	14.87	0.89	0.62	0.50
LA11	LA Outer Channel	Outer	Outer	Very Deep	4	70	1.08	0.63	0.71	0.45
LA14	Consolidated Slip	Inner	Slip	Deep	3	327	3.17	0.04	0.35	0.04
LA15	LA Turning Basin	Outer	Basin	Deep	6	381	5.99	0.46	0.84	0.26
LA16	Bannings Landing	Inner	Slip	Deep	1	326	3.29	0.00	0.00	0.00
LB1	Outer Anchorages	Outer	Outer	Deep	6	249	1.92	0.62	0.91	0.35
LB2	LB SWH	SWH	SWH	Shallow	8	97	2.39	1.05	1.53	0.50
LB3	West Basin	Outer	Basin	Deep	2	642	2.73	0.30	0.15	0.44
LB4	Channel 2	Inner	Slip	Deep	5	783	6.26	0.09	0.60	0.06
LB5	SE Basin East	Outer	Basin	Deep	4	549	1.97	0.40	0.48	0.29
LB6	Pier J	Outer	Slip	Deep	6	402	18.76	0.70	0.83	0.39
LB7	Main Channel Pilot Station	Outer	Channel	Very Deep	5	1347	7.05	1.09	0.56	0.67
LB9	Outer Channel	Outer	Outer	Very Deep	4	283	5.10	0.40	0.53	0.29
LB10	SE Basin West	Outer	Basin	Deep	5	247	4.58	0.54	0.73	0.34
LB12	Main Channel Police Station	Outer	Channel	Very Deep	6	1354	9.53	0.47	0.69	0.26
LB13	LB Turning Basin	Outer	Basin	Very Deep	4	339	8.87	0.72	0.51	0.52
LB14	Cerritos Channel	Inner	Channel	Deep	4	388	4.56	0.77	0.50	0.55
LB16	Channel 3	Inner	Slip	Deep	2	723	4.77	0.40	0.15	0.58

3.3.3 Station Groups

Stations were grouped according to habitat (Inner Harbor, Outer Harbor, SWH), location (Outer Harbor, SWH, Channel, Basin, Slip) and depth (Shallow [0-7 m], Deep [7.1-18 m], Very Deep [18+ m]) and compared using all of the metrics discussed above.

Stations grouped according to habitat showed that at the SWH stations, despite a wide range, on average had higher values of species richness, abundance, biomass, and diversity than either Inner Harbor or Outer Harbor stations (Figure 3-18). Evenness was similar on average between SWH and Outer Harbor stations, while evenness values at Inner Harbor stations were lower.

Stations grouped by location characteristics (SWH, Outer, Basin, Channel, and Slip) also showed that at the SWH stations on average higher values of species richness, abundance, biomass, and Margalef diversity were measured than other location types (Figure 3-19). In those metrics, there was no obvious pattern among the other Location groups. Shannon-Weiner diversity and Pielou's evenness were similar in that SWH, outer and channel stations had the highest values on average, and slips had the lowest values.

Stations grouped by depth followed a similar pattern, with the Shallow stations (made up entirely of SWH stations) having the highest average species richness, abundance, and biomass (Figure 3-20. There was little difference in these metrics between Deep and Very Deep station groups, although average values were slightly higher at the Very Deep stations. In terms of diversity, SWH stations had somewhat higher values than Deep, and Very Deep stations, and Very Deep stations had higher values than Deep stations. Pielou's evenness values were similar among all three depth groups, indicating the high variability among individual stations in the factors that comprise that metric.

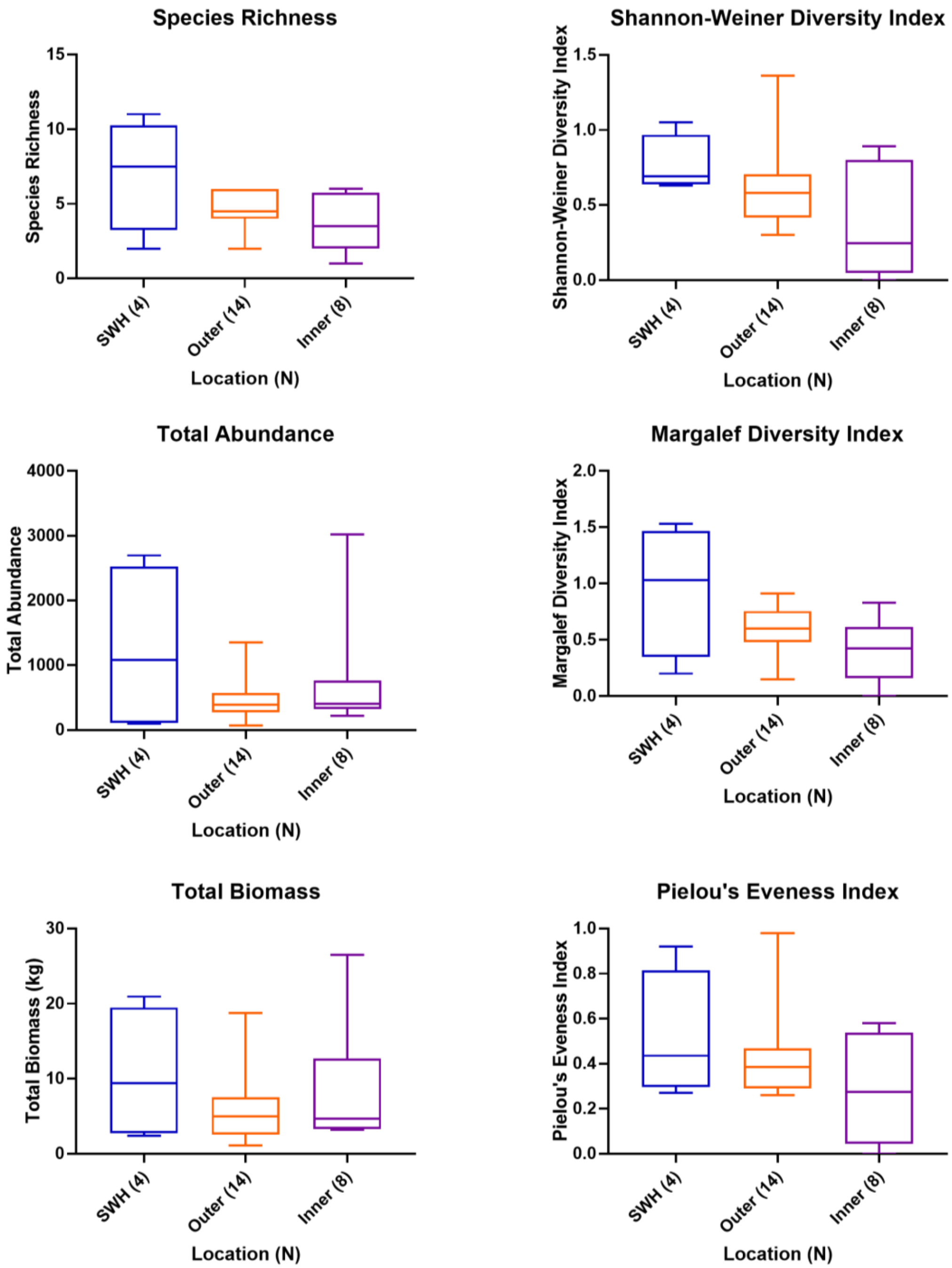


Figure 3-18. Station Habitat Group Summaries for Pelagic Fish Captured Using the Lampara Net (All Seasons Combined)

(Box plots showing the median, range, and quartiles for each dataset)

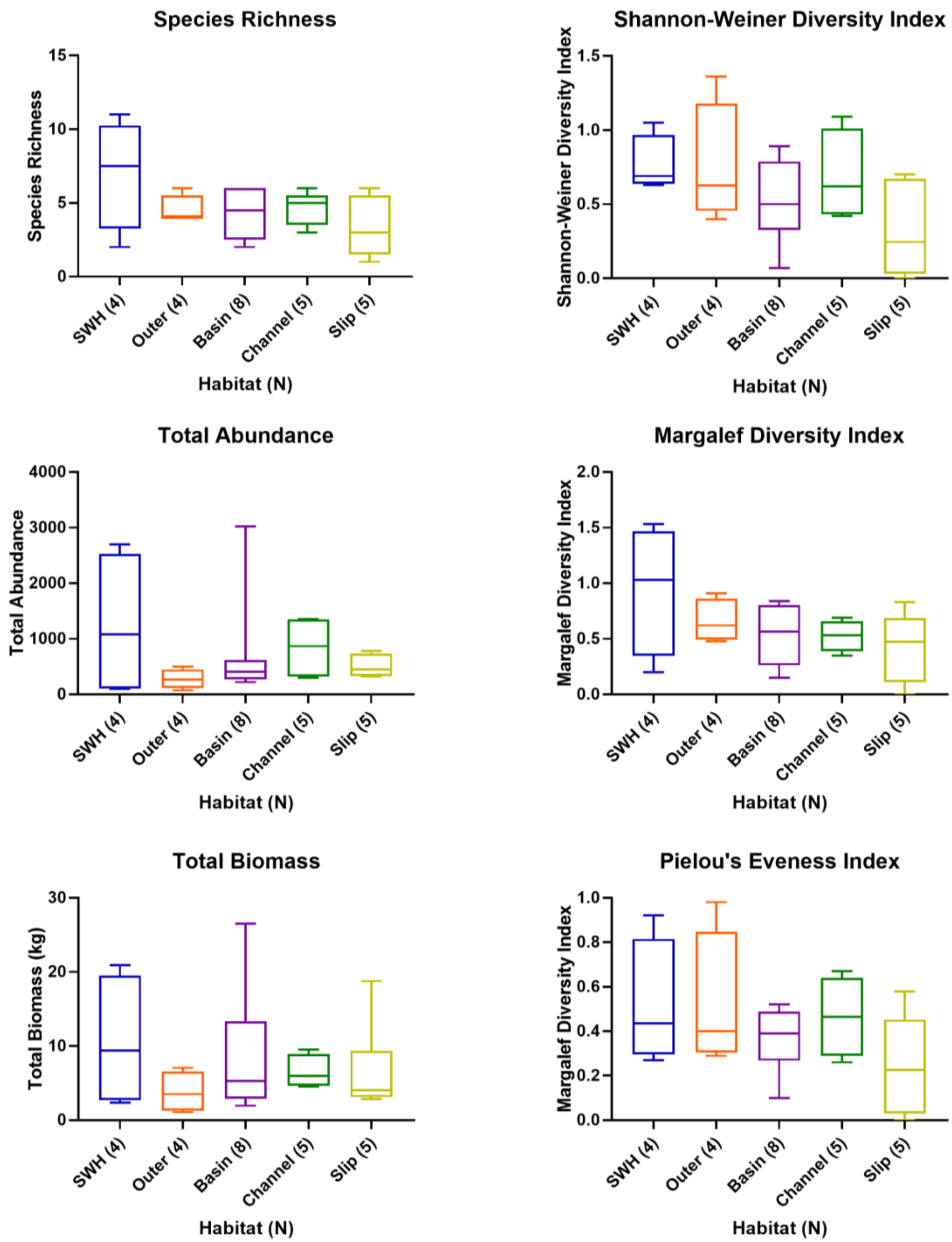


Figure 3-19. Station Location Group Summaries for Pelagic Fish Captured Using the Lampara Net (All Seasons Combined)

(Box plots showing the median, range, and quartiles for each dataset)

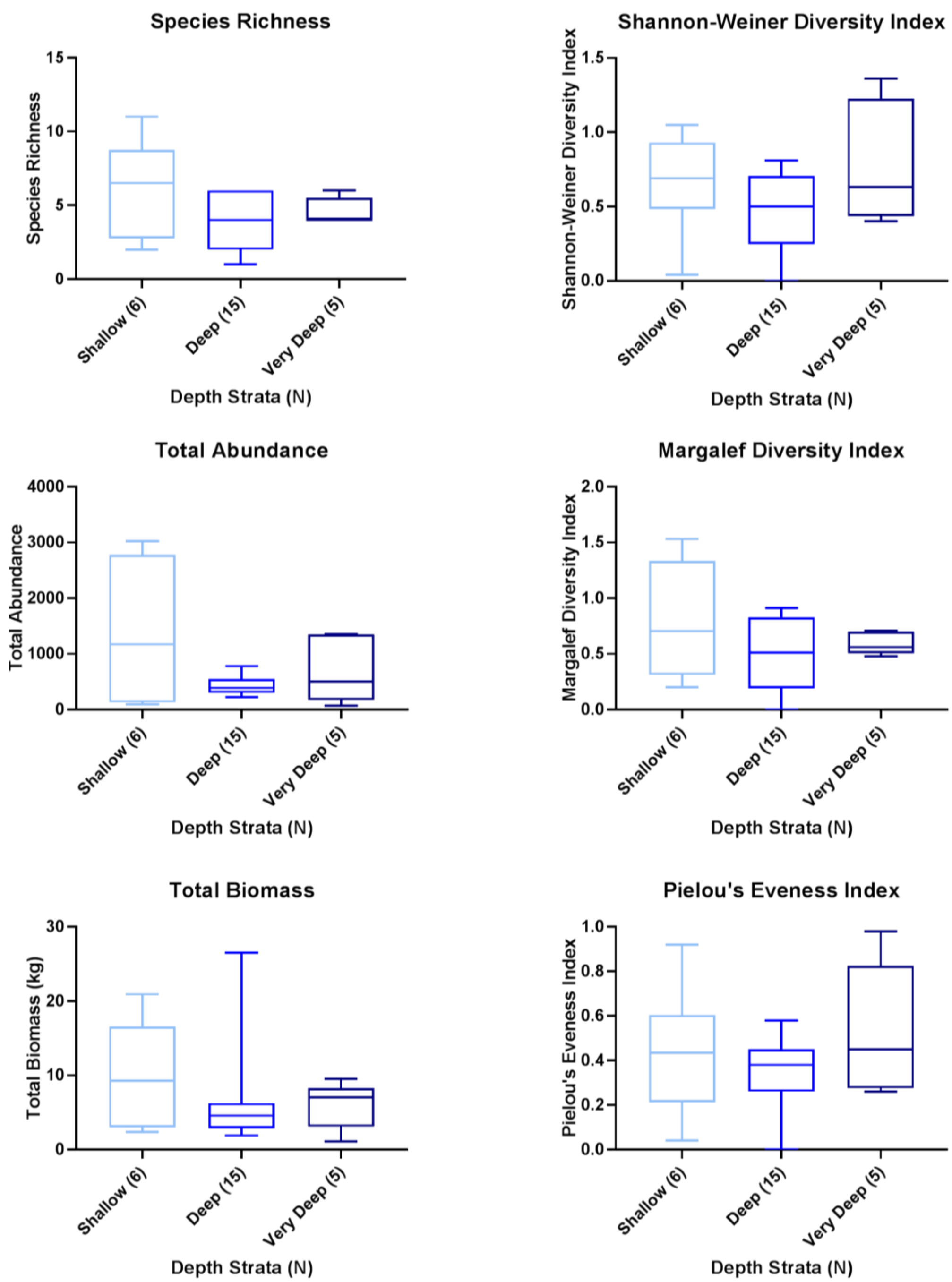


Figure 3-20. Station Depth Strata Group Summaries for Pelagic Fish Captured Using the Lampara Net (All Seasons Combined)

(Box plots showing the median, range, and quartiles for each dataset)
Note*: Shallow 0-7 m, Deep 7.1-18 m, Very Deep 18+ m*

Multivariate Analysis

Multivariate analysis of pelagic fish abundance data combined across all sampling events was performed using the PRIMER statistical package (see Section 1.7). This analysis provided an in-depth evaluation of station groups and patterns of pelagic fish communities across stations. Analysis of relationships among habitat, location, and depth strata station groups using ANOSIM (see Section 1.7) showed that there were significant differences for location and habitat groups but not for depth. Pairwise tests were able to show which pairs within each station type were the most distinct. Results not presented here can be found in Appendix C.

Habitat group pairwise tests revealed that Inner Harbor stations were statistically different from Outer Harbor and SWH stations. There was no statistical difference between Outer Harbor and SWH stations. This is shown using nMDS in Figure 3-21 by the Inner Harbor stations grouping together in the upper right quadrant, and that Outer Harbor and SWH stations mixed in the center left of the space. Even the statistically significant groups are the result of changing patterns of dominance by topsmelt, northern anchovy, and California grunion among them. A shade plot (see Section 1.7) of the relative abundance of each species at each station (Figure 3-22; grouped by habitat type) shows few discernable differences between groups. While core community members such as topsmelt, California grunion and northern anchovy are present in all groups, what may be driving the difference between Inner Harbor and SWH/Outer Harbor groups is the presence or absence of secondary species such as barracuda and jacksmelt and the distribution of rarely encountered species within the groups such as bat rays, Pacific seahorse, and slough anchovy.

Location group analysis showed that only slip and SWH stations had statistically different communities, while all other pairs were not statistically different (Figure 3-23). Overall, the low resolution of community type between station groups is not surprising considering the dominance of only a few species and the fact that relatively few secondary species differed among stations.

A similarity profile (SIMPROF) analysis to identify unique station groups based on community composition (ignoring the *a priori* station groups) showed that all stations were similar enough that there were no significant differences. This provides support to the conclusion that while statistically the station groups are different, there may be limited ecological implications attributed to the fact that the pelagic species are highly mobile and may not distribute according to habitat or location types.

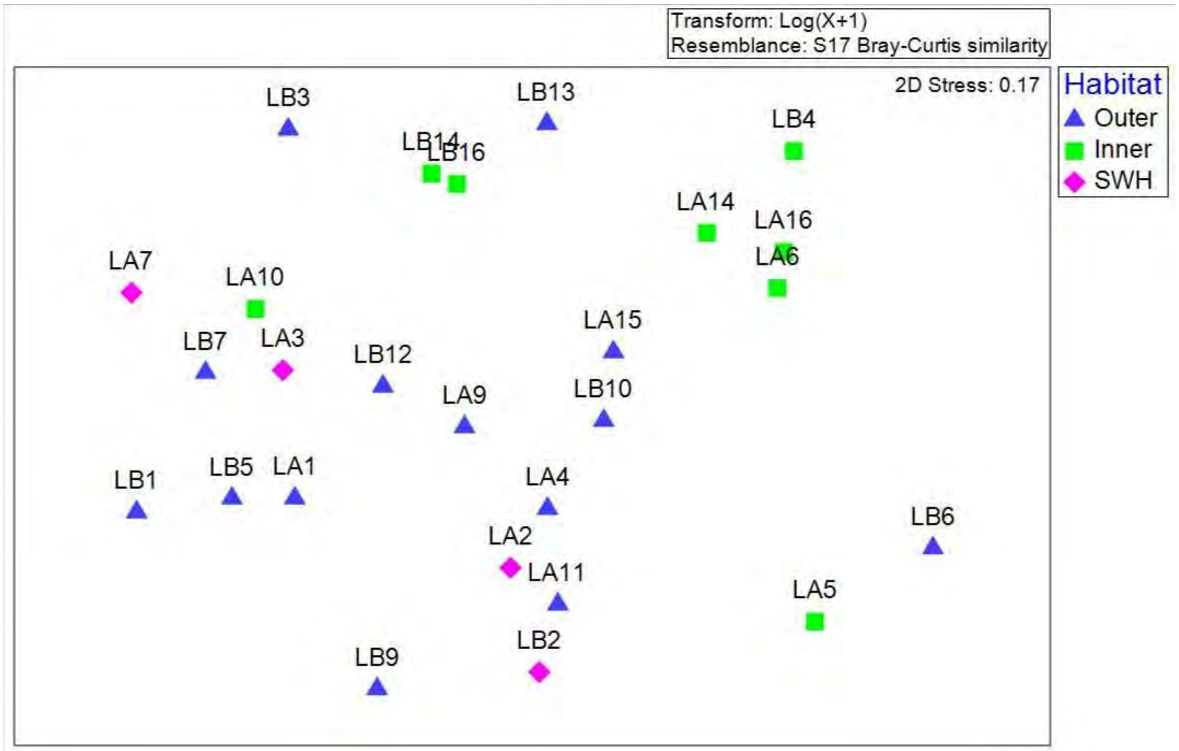


Figure 3-21. nMDS Habitat Group Plot for Pelagic Fish Captured using the Lampara Net

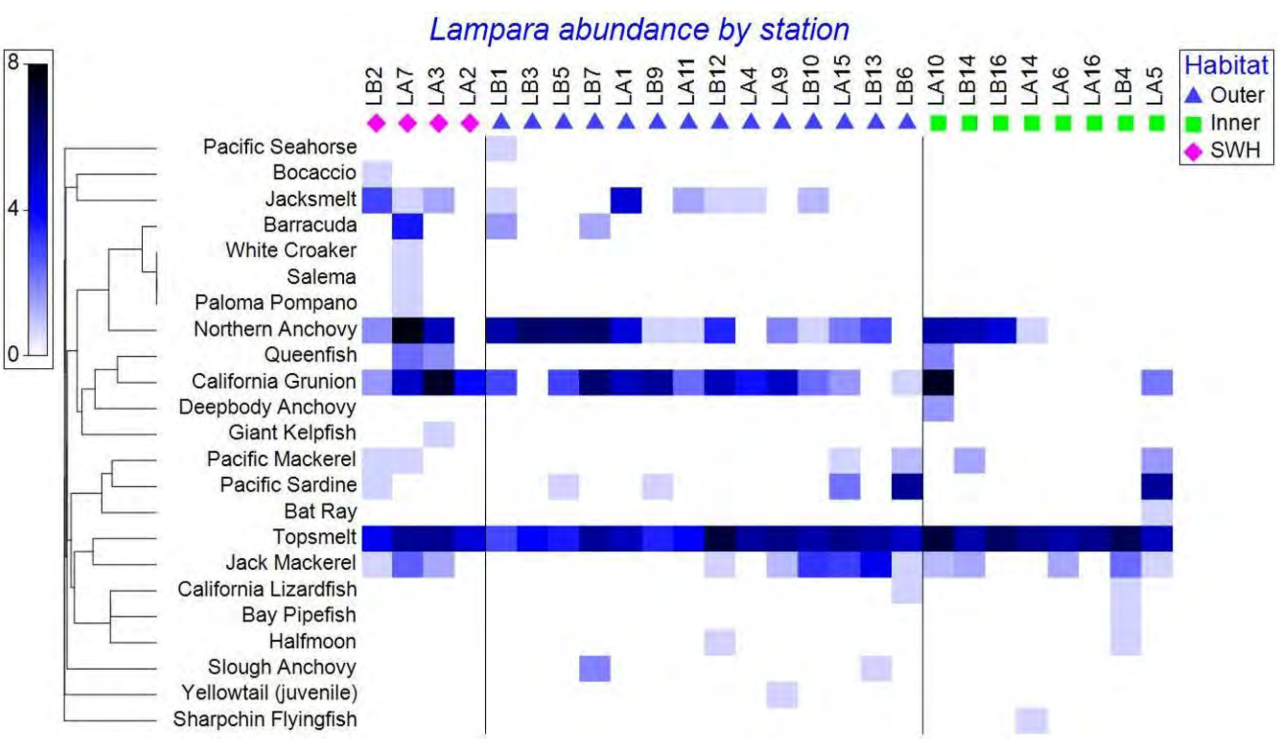


Figure 3-22. Shade Plot for Pelagic Fish Habitat Groups Assessed using the Lampara Net

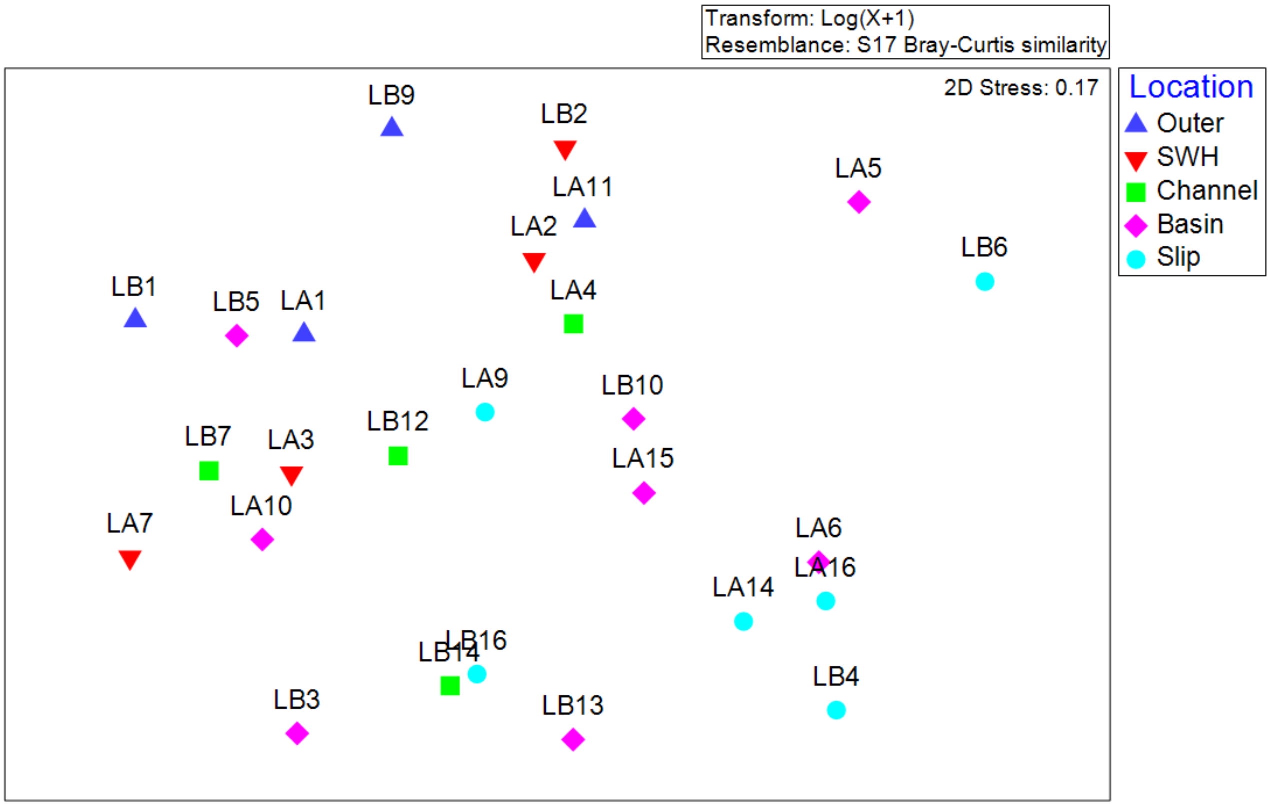


Figure 3-23. nMDS Plot for Pelagic Fish Habitat Groups Assessed using the Lampara Net

3.3.4 Fish Health

Overall, the fish captured appeared healthy and most specimens had normal color and energy. External anomalies such as lesions, tumors, fin erosion and spinal deformities were very rare, observed for only one California grunion which showed a spinal deformity (Table 3-8 and Figure 3-24). Combined with the white croaker caught in otter trawls that had a spinal deformity, this represents an anomaly rate of 0.00004% out of the 48,179 total fish captured during the 2018 Biosurvey. Fish anomalies have not been mentioned in past Biosurvey years, but the anomaly rate in the Port Complex is lower than that observed during regional monitoring in 2018 (Wisenbaker et al. 2021) which found a Southern California Bight-wide rate of 0.0002% and a 0.00009% rate within San Diego Bay.

Table 3-8. Fish Anomalies Identified from Lampara Sampling

Station	Location	Sample Date	Species	Common Name	Size Class (cm)	Anomaly
LA1	Outer Pier 400	9/12/18	Leuresthes tenuis	California Grunion	13.5	Spinal Deformity

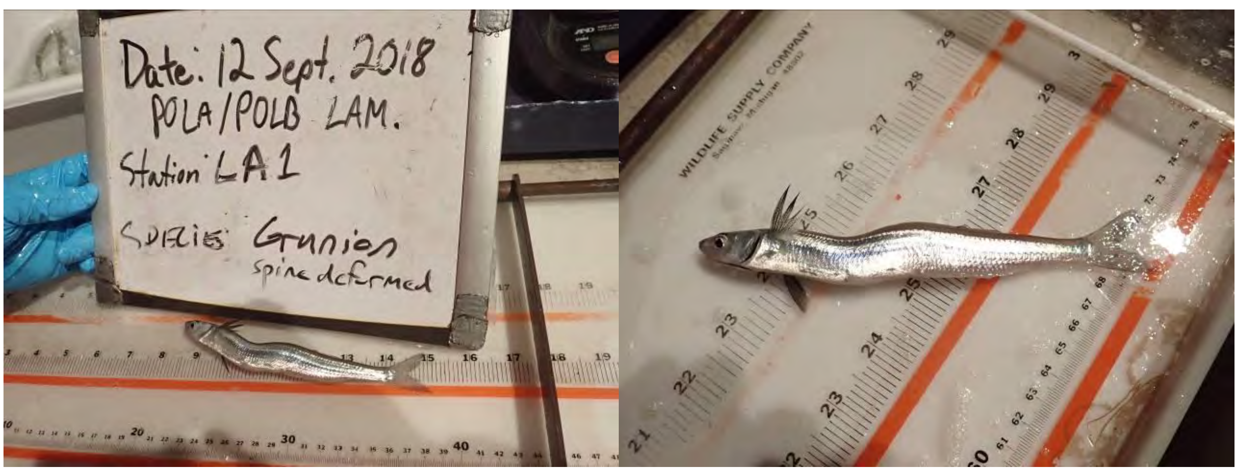


Figure 3-24. Spinal Deformity in California Grunion

3.3.5 Historical Comparisons

Lampara sampling across the 2000, 2008, 2013, and 2018 studies has revealed considerable variability in the abundance, species numbers, and biomass of pelagic fish in the Port Complex (Figure 3-25). The total number of species captured across all Biosurvey years is 63 and has ranged from 20 to 50 per year: 2018 was similar to 2008 (23 and 20 species, respectively), whereas substantially more species were captured in 2000 (50) and 2013 (36). Several species were captured for the first time in 2018, including bocaccio (*Sebastes paucispinis*), halfmoon (*Medialuna californiensis*), Pacific seahorse (*Hippocampus ingens*), sharpchin flying fish (*Fodiator acutus*) and yellowtail (*Seriola dorsalis*). The 2018 Biosurvey had the lowest mean abundance and biomass per station than in any previous Biosurvey. Some of this variability can be attributed to differences in sampling equipment used across Biosurveys, as past Biosurveys have used heavier lampara nets that inadvertently sampled benthic fishes in addition to pelagic fishes despite similar mesh size. This effect can be seen in the larger number of benthic species caught by lampara nets in earlier Biosurveys, such as white croaker (6,612 in 2000, 25 in 2008, 284 in 2013, 1 in 2018), queenfish (6,577 in 2000, 159 in 2008, 629 in 2013 and 20 in 2018), and California halibut (59 in 2000, 0 in 2008, 4 in 2013, and 0 in 2018). The lighter sampling equipment used during 2018 more effectively limited the sampling effort to the intended targeted pelagic communities, although some benthic species such as queenfish and Pacific seahorse were still captured at shallow stations, albeit in very low abundance compared to past Biosurveys. While differences between gear types such as weight on the bottom of the net has not been quantified across Biosurveys, historical comparisons across years does require this factor to be considered as it greatly influences abundance, biomass, and the number of species captured. The number of stations and seasons sampled is also a factor that has changed across Biosurvey years. While the 2018 and 2013 Biosurveys sampled the same number of stations (26) and seasons (spring and summer), the 2008 Biosurveys sampled 19 stations across three seasons while the 2000 Biosurvey sampled 14 stations across all seasons. The number of stations and their coverage of different habitat types likely has some unknown impact on the species sampled during the past Biosurveys.

The four Biosurveys were compared in terms of the composition of their pelagic fish species assemblages by identifying the top 10 species (by abundance or biomass) in each Biosurvey, combining all other species in an “other” category, and calculating the percent composition of each of the eleven species categories (Figures 3-26 and 3-27). In past Biosurveys, northern anchovy dominated the catch, accounting for 68% to 97% of abundance; no other single species totaled more than 6% of the catch. The catch in 2018 had a more balanced profile among the top three species: topsmelt (43%), northern anchovy (27%), and California grunion (26%). Four species (northern anchovy, Pacific sardine, queenfish and topsmelt) were in the 10 most abundant species across all Biosurveys.

Percent composition by biomass was more variable across Biosurveys because large, less numerous species such as bat rays and barracuda had an influence on biomass out of proportion to their abundance. The 2000 Biosurvey captured the most bat rays (332) and barracudas (646) of any Biosurvey, and the relative biomass of that Biosurvey was dominated by those two species (24% and 22%, respectively). Despite their small individual size, the large number of northern anchovy captured in 2008 and 2013 also led to them dominating biomass (57% and 66%, respectively). 2018 was the first Biosurvey to have topsmelt (40%) as the most dominant species followed by California grunion (16.2%), Pacific sardine (16.1%), and northern anchovy (6%). Only four species (bat ray, northern anchovy, queenfish, and topsmelt) were in the top 10 species by biomass across all Biosurveys.

The EI was chosen as a comparative method that might sufficiently overcome the variability in stations, gear and seasons to compare the structure of pelagic fish communities over the last 20 years of biological monitoring in the Port Complex. The top 15 species captured with lampara per Biosurvey year and ranked by EI are shown in Table 3-9, with species managed under the Coastal Pelagic FMP highlighted in each Biosurvey year. Except for Pacific mackerel in 2008 (where it ranked #16 by EI score), the four managed species occurred in the top 15 across all years. Northern anchovy was consistently among the highest ranked species, and Pacific sardine was never ranked lower than #9. Other species that consistently were ranked in the top 10 were topsmelt, bat rays and queenfish. Of the 63 species captured with lampara over the four different Biosurveys (full table with abundances in Appendix C), 13 species were captured during every Biosurvey (Table 3-10).

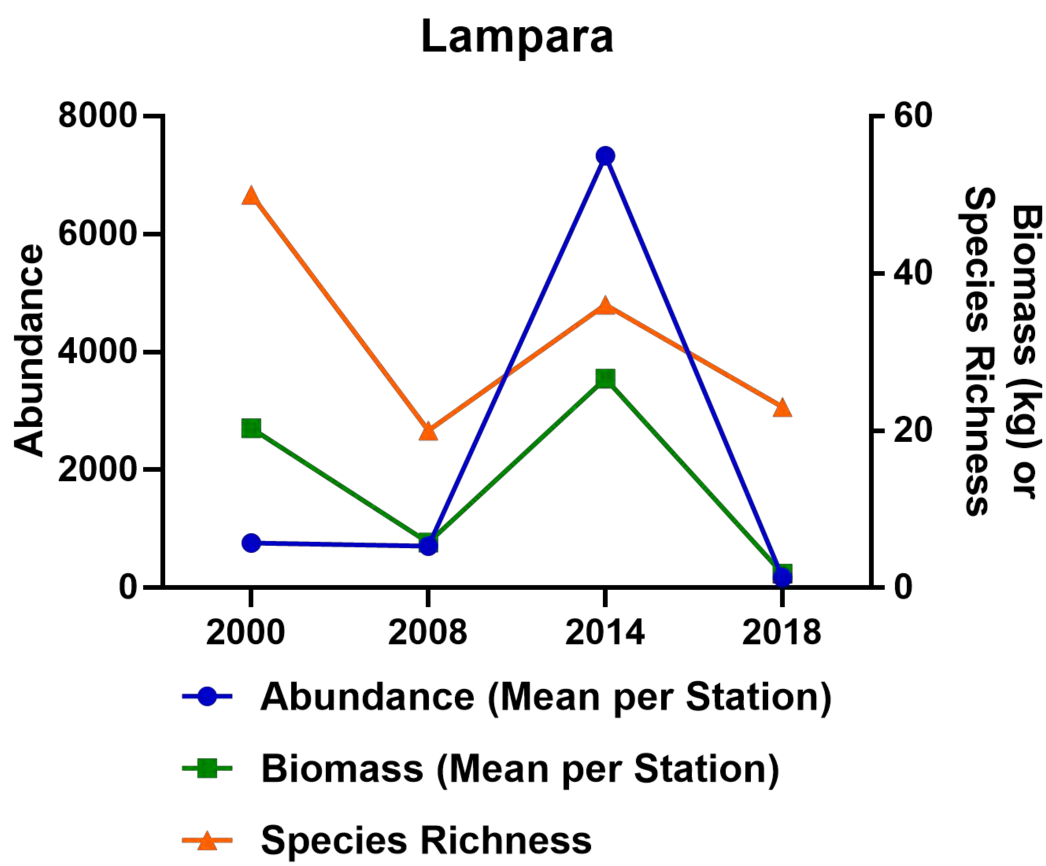


Figure 3-25. Mean Abundance, Mean Biomass and Total Pelagic Species Captured by Lampara Sampling 2000-2018

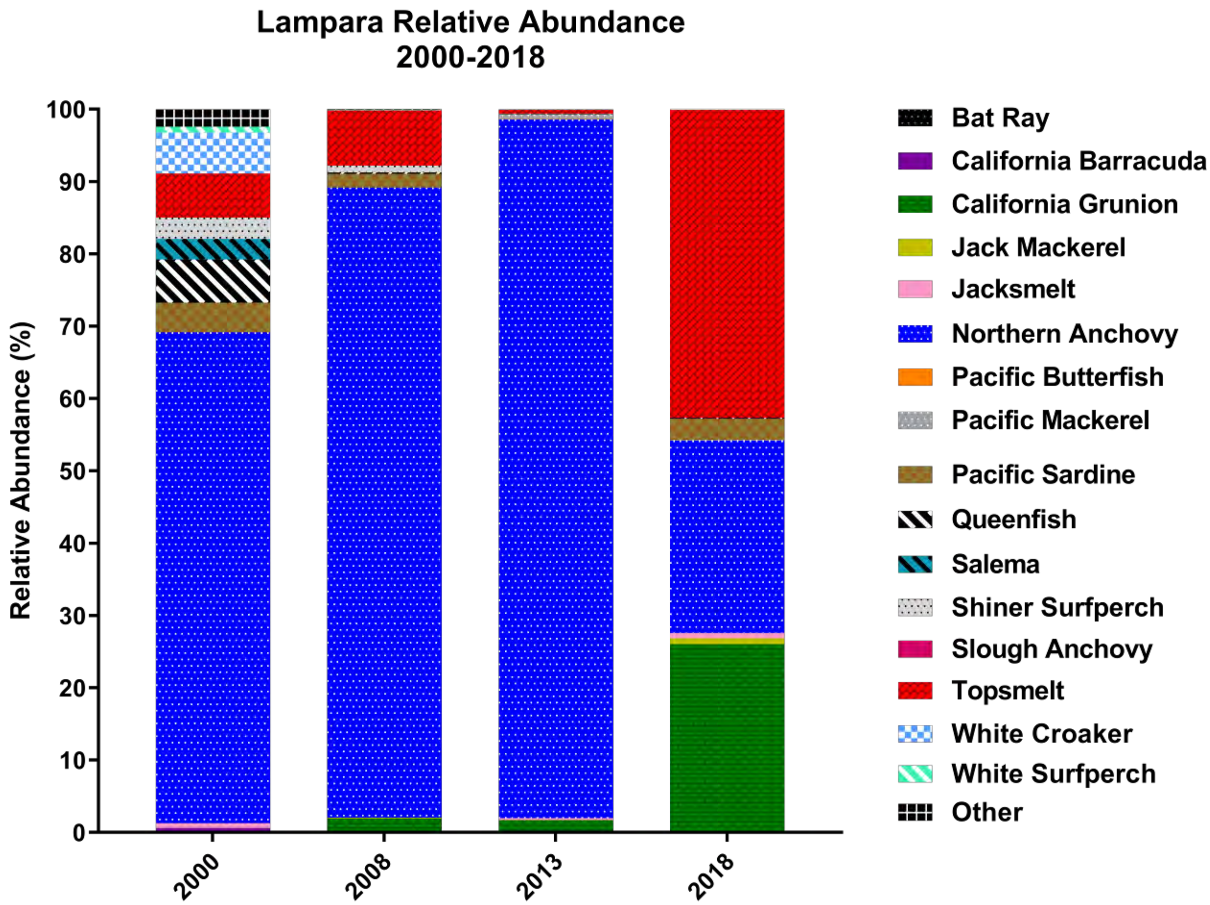


Figure 3-26. Historical Comparison of Species Composition by Abundance of Pelagic Fish Captured by Lampara

Note: Top 10 species are shown for each specific time period. Species listed alphabetically to aid species comparison between abundance and biomass

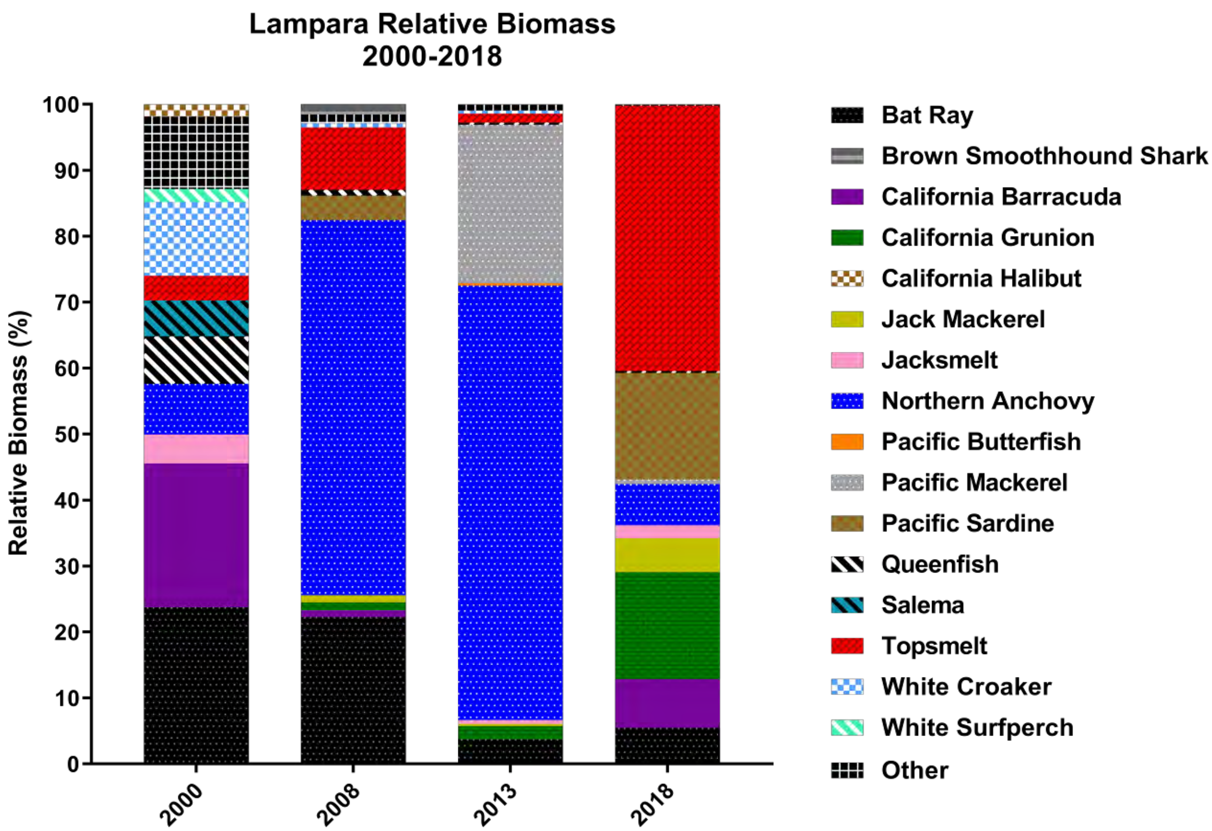


Figure 3-27. Historical Comparison of Species Composition by Biomass of Pelagic Fish Captured by Lampara

Note: Top 10 species are shown for each specific time period. Species listed alphabetically to aid species comparison between abundance and biomass

Table 3-9. Historical Summary of Fish Captured using the Lampara– Top 15 Species Ranked by the Ecological Index

2018 Lampara Fish Ecological Index — **23 Species Total**

Species		% of Total	% of Total	Frequency of	Ecological
Common Name	Scientific Name	Abundance	Biomass	Trawl Capture	Index
Topsmelt	*Atherinops affinis*	42.55	40.2	100	8280
California Grunion	*Leuresthes tenuis*	25.78	16.2	69	2907
Northern Anchovy	*Engraulis mordax*	26.64	6.23	73	2402
Pacific Sardine	*Sardinops sagax caeruleus*	2.95	16.1	23	440
Jack Mackerel	*Trachurus symmetricus*	0.82	5.17	54	323
Jacksmelt	*Atherinopsis californiensis*	0.71	1.95	35	92.0
California Barracuda	*Syphyraena argentea*	0.25	7.39	12	88.1
Bat Ray	*Myliobatis californica*	0.01	5.46	4	21.0
Pacific Mackerel	*Scomber japonicus*	0.07	0.73	23	18.4
Queenfish	*Seriphus politus*	0.11	0.29	12	4.61
Slough Anchovy	*Anchoa delicatissima*	0.04	0.01	8	0.35
California Lizardfish	*Synodus lucioceps*	0.01	0.03	8	0.32
White Croaker	*Genyonemus lineatus*	0.01	0.07	4	0.28
Pacific Butterfish	*Peprilus simillimus*	0.01	0.03	4	0.13
Salema	*Xenistus californiensis*	0.01	0.03	4	0.13

2013 Lampara Fish Ecological Index — **35 Species Total**

Species		% of Total	% of Total	Frequency of	Ecological
Common Name	Scientific Name	Abundance	Biomass	Trawl Capture	Index
Northern Anchovy	*Engraulis mordax*	96.6	65.8	100	16244
Pacific Mackerel	*Scomber japonicus*	0.683	24.0	54	1331
California Grunion	*Leuresthes tenuis*	1.69	1.96	88	322
Topsmelt	*Atherinops affinis*	0.542	1.36	96	183
Bat Ray	*Myliobatis californica*	0.004	3.76	31	116
Jacksmelt	*Atherinopsis californiensis*	0.272	0.61	92	81.9
Queenfish	*Seriphus politus*	0.084	0.31	88	35.1
White Croaker	*Genyonemus lineatus*	0.038	0.46	62	30.4
Pacific Sardine	*Sardinops sagax*	0.024	0.28	73	22.1
Pacific Butterfish	*Peprilus simillimus*	0.026	0.35	50	18.8
Jack Mackerel	*Trachurus symmetricus*	0.015	0.34	50	17.7
California Lizardfish	*Synodus lucioceps*	0.014	0.24	69	17.4
Diamond Turbot	*Pleuronichthys guttulatus*	0.001	0.06	12	0.72
Barred Sand Bass	*Paralabrax nebulifer*	0.002	0.03	19	0.68
White Surfperch	*Phanerodon furcatus*	0.003	0.03	19	0.54

2008 Lampara Fish Ecological Index — **20 Species Total**

Species		% of Total	% of Total	Frequency of	Ecological
Common Name	Scientific Name	Abundance	Biomass	Trawl Capture	Index
Northern Anchovy	*Engraulis mordax*	87.1	56.9	100	46034
Topsmelt	*Atherinops affinis*	7.65	9.45	100	6966
Bat Ray	*Myliobatis californica*	0.03	22.2	21	3072
Pacific Sardine	*Sardinops sagax*	1.86	3.74	74	1944
California Grunion	*Leuresthes tenuis*	1.89	1.17	89	858
Jack Mackerel	*Trachurus symmetricus*	0.13	1.09	74	538
Queenfish	*Seriphus politus*	0.20	0.87	63	373
California Barracuda	*Syphyraena argentea*	0.02	1.06	21	147
Shiner Surfperch	*Cymatogaster aggregata*	0.94	0.50	32	134
White Croaker	*Genyonemus lineatus*	0.03	0.58	16	60.3
Brown Smoothhound Shark	*Mustelus henlei*	0.00	1.54	5	53.2
White Surfperch	*Phanerodon furcatus*	0.07	0.14	21	20.8
White Seabass	*Atractoscion nobilis*	0.00	0.25	11	17.2
Jacksmelt	*Atherinopsis californiensis*	0.01	0.14	16	14.7
Spotfin Croaker	*Roncador stearnsii*	0.00	0.30	5	10.3

2000 Lampara Fish Ecological Index — **51 Species Total**

Species		% of Total	% of Total	Frequency of	Ecological
Common Name	Scientific Name	Abundance	Biomass	Trawl Capture	Index
Northern Anchovy	*Engraulis mordax*	67.9	7.65	100	7551
White Croaker	*Genyonemus lineatus*	5.68	11.1	100	1682
California Barracuda	*Sphyraena argentea*	0.59	21.7	72	1611
Queenfish	*Seriphus politus*	5.97	7.16	100	1314
Bat Ray	*Myliobatis californica*	0.30	23.7	50	1198
Topsmelt	*Atherinops affinis*	6.07	3.74	100	981
Salema	*Xenistius californiensis*	2.85	5.41	72	597
Pacific Sardine	*Sardinops sagax*	4.11	1.73	83	487
Jacksmelt	*Atherinopsis californiensis*	0.70	4.41	89	454
Shiner Surfperch	*Cymatogaster aggregata*	2.96	1.56	78	351
White Surfperch	*Phanerodon furcatus*	0.82	1.98	78	218
California Halibut	*Paralichthys californicus*	0.05	1.88	67	129
Jack Mackerel	*Trachurus symmetricus*	0.15	0.84	89	87.6
Barred Sand Bass	*Paralabrax nebulifer*	0.10	0.76	61	52.8
Pacific Mackerel	*Scomber japonicus*	0.11	0.67	67	52.2

Note: Managed species under the Coastal Pelagic FMP are in **BOLD**. Pacific mackerel ranked #16 in 2008. Values of 0.00 are <0.005. “Frequency of capture” is the percentage of sampling stations at which the species was captured.

Table ... Date

Histocial Lampara Fish Abundance

Common Name	Scientific Name	2018	2013	2008	2000
Bat Ray	*Myliobatis californica*	1	28	28	332
California Barracuda	*Sphyraena argentea*	45	4	19	646
California Grunion	*Leuresthes tenuis*	4727	12610	1531	410.5
Deepbody Anchovy	*Anchoa compressa*	4	1	4	127
Giant Kelpfish	*Heterostichus rostratus*	1	2	4	8
Jack Mackerel	*Trachurus symmetricus*	151	115	106	161
Jacksmelt	*Atherinopsis californiensis*	130	2036	7	769.5
Northern Anchovy	*Engraulis mordax*	4884	722008	70658	74719.5
Pacific Mackerel	*Scomber japonicus*	12	5104	2	124
Pacific Sardine	*Sardinops sagax caeruleus*	540	177	1509	4520
Queenfish	*Seriphus politus*	20	629	159	6577
Topsmelt	*Atherinops affinis*	7802	4049	6205	6687.5
White Croaker	*Genyonemus lineatus*	1	284	25	6259

3.4 Discussion

The decline of ichthyoplankton abundance in the Port Complex since 2000 continued in 2018 and may reflect an overall regional decline in nearshore ichthyoplankton abundance, as was documented in a long-term monitoring program in nearby King Harbor (Pondella et al., 2012). This gradual decline could be possibly due to numerous cumulative factors such as red tide, the strength of ENSO, and shifts in oceanographic conditions including a transition to warmer, nutrient-deficient waters along the Southern California Bight since the 1970s (Parnell et al., 2010). Within the Southern California Bight, fish larvae that prefer warm water have been very abundant in Southern California since 2014, while species preferring cooler waters have been in decline (Thompson 2019). Record high larval anchovy abundance has been recorded in the Southern California Bight beginning in 2015 through 2019 (Thompson 2019) as warm water circumstances persisted, which may help explain why this species remains the most dominant within the Ports. Connectivity between the Port Complex and nearshore environments may also explain why the density of eggs have not shown as dramatic of a reduction over the same timeframe. In addition to rising larval anchovy abundance, goby and garibaldi larvae have remained constant (Pondella 2012). While most larval fish species have experienced declines in Southern California recently, both gobies and anchovy found in this current report have been identified recently in other independent regional assessments described above which substantiates observations within the Port Complex. Additionally, ichthyoplankton abundance, species richness, and diversity were all highest in shallow-water areas of the Port Complex compared to deeper areas. This most likely occurred due to the increased diversity of pelagic and demersal fishes in the area that may spawn in these areas, as well as the potential for increased predation on larval fishes in open water areas compared to shallow areas with eelgrass that may provide shelter and protection from predators (Heck and Orth 1980).

Lampara sampling results did not indicate a seasonal difference between the spring and summer fish communities, but there was a marked difference between day and the night in the number of species and the abundance of fish collected. This difference could be attributed to several factors, such as gear avoidance during the day, increased prey (e.g., plankton) abundance in the water column at night, and behavioral patterns of some pelagic fishes using the Port Complex only at night. The 2000 and 2008 Biosurveys found a similar pattern, with 28,422 fish (42 species) captured during the day versus 81,667 (46 species) at night in 2000 and 8,043 fish (12 species) captured during the day versus 73,041 (19 species) at night in 2008. In 2013 the opposite pattern was observed; however, that was driven by one abnormally large catch of northern anchovy during the day. The 2013 report pointed out that excluding that one station, the night catch of northern anchovy was 30 times greater at night than in the daytime and the day sampling captured fewer species than the night sampling (23 versus 33 respectively).

Changes in fish community composition across historical Biosurveys appear to be influenced by gear type, and the number of stations and seasons sampled. Other likely factors influencing the abundance and distribution of species include continued harbor development (e.g., the completion of the SWH areas in 2013) and broader regional climate trends that have occurred. An example of the latter is the marine heat wave in 2014-2016 (Jacox et al. 2019) that affected coastal fish populations and led to mass marine mammal strandings across Southern California (Cavole et al. 2016).

Pacific sardines have been steadily declining over the last decade, a regional trend thought to be attributable primarily to overexploitation; abundances were so low in 2014 that a moratorium that is still in effect was placed on the fishery (Hill et al. 2019). Pacific sardine abundance and biomass within the Port Complex from 2000-2018 reflected this decline (4,520 in 2000, 1,509 in 2008, 177 in 2013, 540 in 2018).

While anchovy abundance is typically higher during cooler periods (Cavole et al. 2016), that pattern was not apparent within the Port Complex, as the most northern anchovy of any Biosurvey to date was observed in 2013, when water temperatures were higher than normal due to the marine heat wave. The boom in anchovy adults and larvae during 2013 could also have been a lagging response to the strong coastal upwelling that resulted in cooler temperatures and high productivity in the Southern California Bight in 2012 through early 2013 (Leising et al. 2014), before the shift to warmer waters began in fall 2013. There is also the element of chance when sampling for schooling fish species, as seen in the 2013 Biosurvey when there was one extremely large catch of northern anchovy from one station that had a large influence on the historical comparisons.

A distinct and key observation noted as described above was the high prevalence of sub adult pelagic fish species captured indicating their use of the harbor complex as a critical and productive nursery habitat prior to moving towards deeper offshore environments.

Managed Species

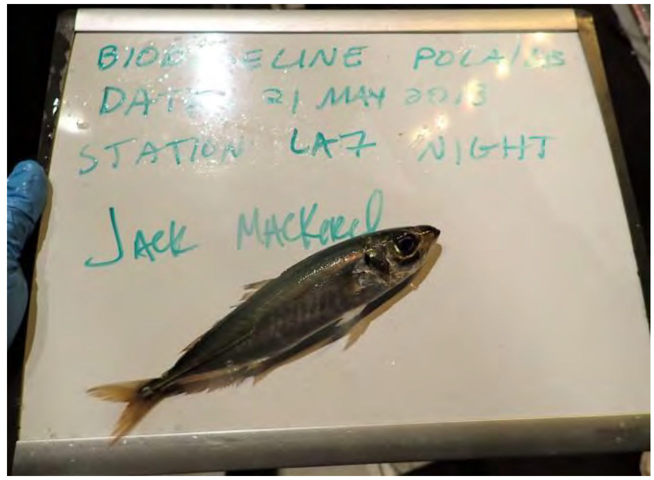
Several species managed under the Coastal Pelagic FMP were captured during the 2018 Biosurvey (Table 3-11). Northern anchovy was the most abundant and widespread FMP species, followed by Pacific sardine, jack mackerel and pacific mackerel.

Table 3-11. Coastal Pelagic FMP Species in Port of Long Beach/Port of Los Angeles

Common Name	Scientific Name	Comment
Coastal Pelagics FMP		
Northern Anchovy	*Engraulis mordax*	19,768 caught in 2018 Biosurvey
Pacific Sardine	*Sardinops sagax*	540 caught in 2018 Biosurvey
Pacific Mackerel	*Scomber japonicus*	12 caught in 2018 Biosurvey
Jack Mackerel	*Trachurus symmetricus*	161 caught in 2018 Biosurvey

Note: 2018 Biosurvey caught 48,179 fish between otter trawls, lampara net, and beach seine sampling conducted throughout the Port Complex.

Northern anchovy captured within the Port Complex during the 2018 Biosurvey exhibited a pattern that has been observed in populations of adults in central Baja California (Robinson et al. 1995), Monterey and Oregon (Kaltenberg and Benoit-Bird 2009). During the day, anchovy seek deeper water and form compact, discrete shoals near the bottom, then return to the surface at night in loosely-associated schools to feed. This behavior is thought to help avoid predation during the day from avian and piscivorous fish and is also correlated with a high concentration of prey (euphausiids) near the surface at night (Robinson et al. 1995).



Jack mackerel captured during night lampara

Of the 19,767 northern anchovy collected during the 2018 Biosurvey, 75% were collected near the bottom (using a trawl) during the day while 24% were collected near the surface (using a lampara net) at night. Most (62%) of the northern anchovy collected with trawls during the day were from stations categorized in the study as “Very Deep” (18+ m depth) and 37% were from “Deep” stations (7.1-18 m) (Figures 3-28 and 3-29). However, at night, 49% of fish collected with the lampara net (near the surface) were from shallow stations (0-7 m), 36% from deep stations, and only 15% from very deep stations. In addition, as Figures 3-28 and 3-29 show, anchovies were far more abundant in the open waters of the Outer Harbor than in the channels and basins of the Inner Harbor. Less than 1% of all northern anchovy were collected near the surface during the day and near the bottom at night. Similar patterns of day/night catches between lampara and trawls have been observed in the last four Biosurveys of the Port Complex (MEC 2002, SAIC 2010, MBC 2016); however, this is the first time this distribution has been linked to the behavior of the anchovy. This suggests that the behavior of northern anchovy described in Robinson et al. (1995) holds true in the Port Complex, which means that the lone Coastal Pelagics FMP species that utilize the Port Complex during the day may not occur in shallower, Inner Harbor habitats in order to avoid predation and to feed when prey is most abundant in the water column. In studies of visual thresholds for schooling in northern anchovy, Hunter and Nicholl 1985 suggest that light may not be necessary for successful filter feeding (the strategy employed by anchovies), although ambient light within the Port Complex may increase their ability to locate food at night.

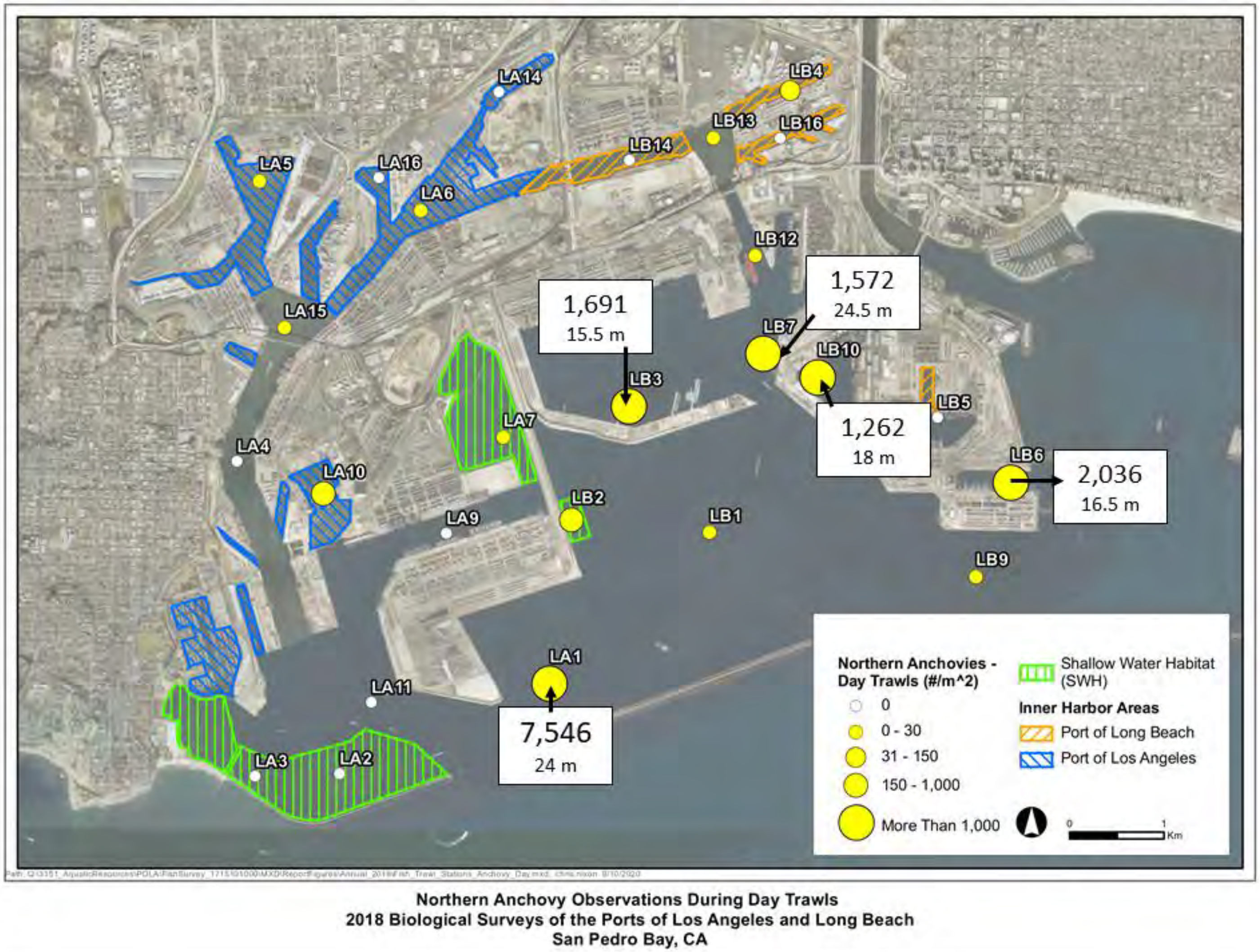


Figure 3-28. Abundance of Northern Anchovy from 2018 Daytime Bottom Trawls (Spring and Summer)

Note: Station callouts include abundance and station depth (m)

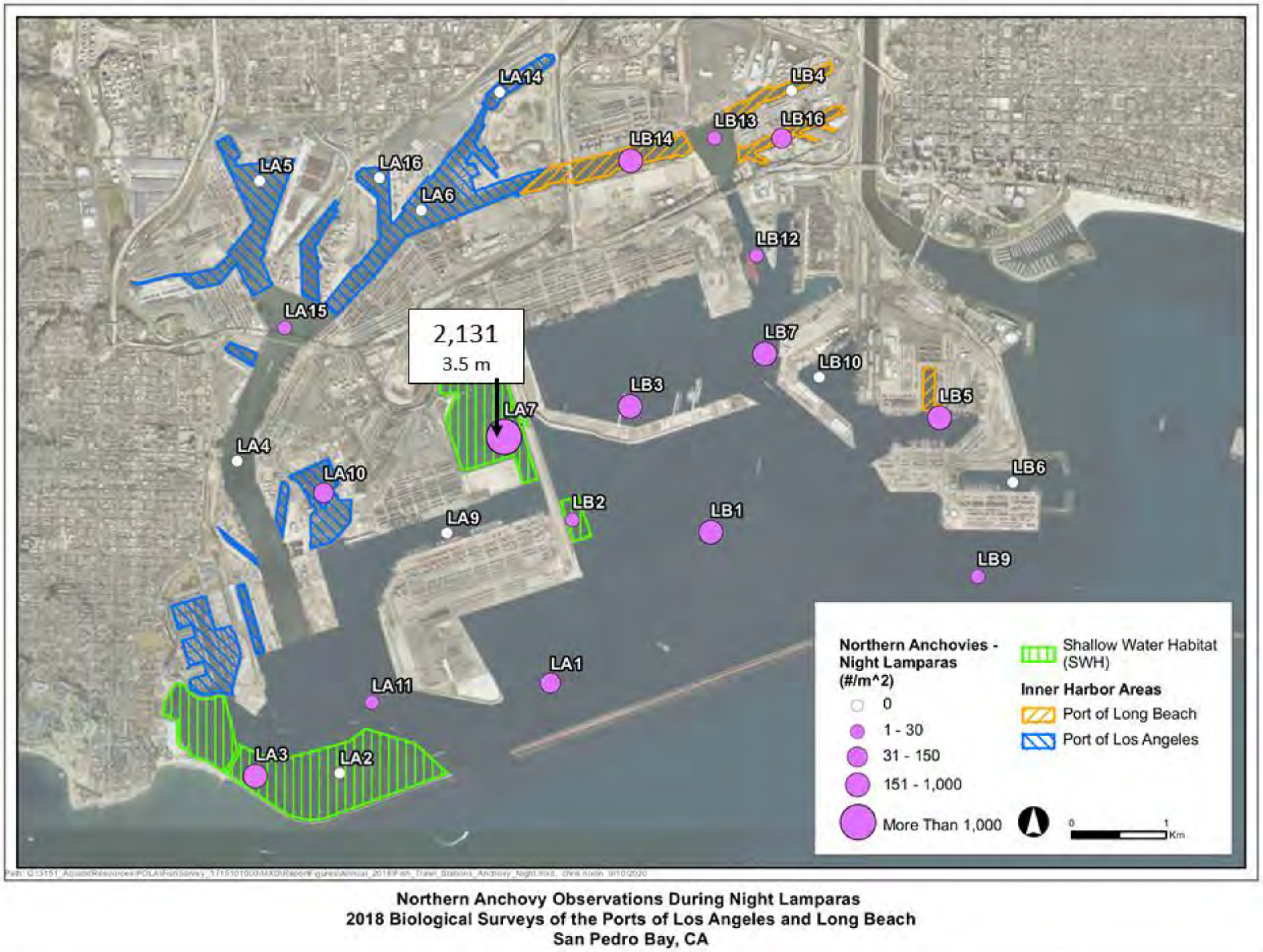


Figure 3-29. Abundance of Northern Anchovy from 2018 Nighttime Surface Lampara Net Sampling (Spring and Summer)

Note: Station callouts include abundance and station depth (m)

Non-Native Species

Two non-native species were detected in the ichthyoplankton: the yellowfin goby (*Acanthogobius flavimanus*) and a tripletooth goby species (*Tridentiger* sp., most likely *trigonocephalus* (chameleon goby)). Both species are demersal as juveniles and adults (their presence in the Port Complex is considered in Chapter 4 Soft Bottom Habitat), but their larvae are pelagic. Larvae of the chameleon goby were numerous (428 across all seasons, 5% of total larvae collected); most were captured at Consolidated Slip (LA14, 343 total) and Fish Harbor (LA10, 72 total), but some were captured at four other stations, none of which had more than 6 larvae.

The larvae of yellowfin goby were not as numerous as chameleon goby larvae (76 total, 0.9% of total abundance), but their abundance was spread more evenly across more stations (10). The most yellowfin goby larvae were captured at Fish Harbor (23) and West Basin (LA5, 21).

There were no non-native pelagic fish species caught during lampara net sampling.

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4.0 SOFT-BOTTOM HABITAT

Most of the Port Complex's water area – over 8,000 acres -- consists of Soft-Bottom Habitat: silty sediments of the deep channels, basins, and open-water anchorage and maneuvering areas; sandy sediments of shallow nearshore areas and a small amount of beach; and sandy-silt in nearshore eelgrass beds. This chapter describes the plants, fish and invertebrates that live just above, on, and in the sediments of the soft-bottom habitat of the Port Complex. The distribution and composition of eelgrass beds in soft-bottom habitat throughout the Port Complex are discussed in Section 4.2. The benthic infauna is discussed in Section 4.3, epibenthic invertebrates are discussed in Section 4.4, shallow subtidal fish near beaches in Los Angeles Harbor are discussed in Section 4.5, and demersal fish living just above the bottom in deep waters are discussed in Section 4.6.

Benthic infaunal and epibenthic communities are comprised of invertebrates that live within and on the surface of sediments, respectively. Sediments in the Port Complex support a diverse array of invertebrates with differing life histories and feeding strategies that respond differently to various habitat conditions. These organisms (or taxa) vary in tolerance to physical and chemical stressors from both natural and anthropogenic sources, and they also respond to habitat conditions such as sediment particle size and organic content. Benthic organisms are an important link between primary producers and higher trophic levels of the food web (e.g., fish and birds) and perform crucial ecological functions such as water filtration, nutrient cycling, and bioturbation of sediments. Multiple indices have been developed to assess the health of benthic infaunal communities (e.g., Benthic Response Index [BRI], Index of Biotic Integrity [IBI], etc.) that can provide an integrated measure of the overall condition of the community. While there are no similar established indices for epibenthic marine invertebrates in Southern California, commonly used metrics such a taxa richness, abundance, dominance, diversity, and biomass can be used to assess the relative health of this community across Biosurvey years and among different areas within the harbors.

4.1 Habitat Characteristics

Soft-bottom habitat supports several different biological communities. Soft bottom can include open-water areas that are predominantly sandy and influenced by tidal currents and wave action, as well as more protected areas that are more prone to sedimentation and have a higher proportion of fine-grained material (i.e., mud/silt) and a higher total organic carbon content. The assemblage of soft-bottom species at a given location will vary based on the site's physical characteristics and the species' adaptations to those conditions that allow them successfully to forage for food, find shelter from predators, and reproduce.

Soft-bottom habitats are also important for a wide variety of adult and juvenile fishes, especially those managed by NOAA under the Pacific Coast Groundfish (PCG) Fishery Management Plan (FMP) through the Magnuson-Stevens Act. Several of those managed species were captured during the most recent Biosurvey, including California scorpionfish, vermillion rockfish, gopher rockfish, brown rockfish, bocaccio, English sole and Pacific sanddab. Those species and others observed during the 2018 Biosurvey are discussed in more detail below.

Data on these communities were collected using a variety of methods, including side-scan sonar to map eelgrass, otter trawls to sample benthic fishes and epibenthic invertebrates, and sediment grabs for benthic infaunal organisms. Details of the field sampling and laboratory and data analysis are presented in Appendix A. For comparative analysis, stations were grouped according to habitat (Inner, Outer, SWH), location (Outer, SWH, Channel, Basin, Slip), and depth stratum (Shallow [0-7 m], Deep [7.1-18 m], Very Deep [18+ m]). Station designations and the grouping of stations for analysis are shown in Tables 4-1 and 4-2.

Table 4-1. Station Analysis Groups and Location Characteristics for Demersal Fishes and Epibenthic Invertebrates

Station	Port	Habitat	Location	Station Descriptor	Station Depth (m)	Depth Strata
LB1	POLB	Outer	Outer	Outer Harbor Anchorages	13	Deep
LB2	POLB	SWH	SWH	POLB SWH	7	Shallow
LB3	POLB	Outer	Basin	West Basin	15.5	Deep
LB4	POLB	Inner	Slip	Channel 2	14	Deep
LB5	POLB	Outer	Basin	SE Basin East	17.5	Deep
LB6	POLB	Outer	Slip	Pier J South Slip	16.5	Deep
LB7	POLB	Outer	Channel	POLB Main Channel - Pilot Station	24.5	Very Deep
LB9	POLB	Outer	Outer	POLB Outer Main Channel	24.5	Very Deep
LB10	POLB	Outer	Basin	SE Basin West	18	Deep
LB12	POLB	Outer	Channel	POLB Main Channel - Police Station	23	Very Deep
LB13	POLB	Outer	Basin	Inner Harbor Turning Basin	20	Very Deep
LB14	POLB	Inner	Channel	Cerritos Channel	18	Deep
LB16	POLB	Inner	Slip	Channel 3	16.5	Deep
Cabrillo Beach	POLA	SWH	SWH	Cabrillo Beach	2	Shallow
LA1	POLA	Outer	Outer	Outer Pier 400	24	Very Deep
LA2	POLA	SWH	SWH	LA SWH East	6	Shallow
LA3	POLA	SWH	SWH	LA SWH West	6	Shallow
LA4	POLA	Outer	Channel	LA Main Channel	18	Deep
LA5	POLA	Inner	Basin	West Basin	16.5	Deep
LA6	POLA	Inner	Basin	LA East Basin	17.5	Deep
LA7	POLA	SWH	SWH	Seaplane Lagoon	3.5	Shallow
LA9	POLA	Outer	Channel	Pier 300 Channel	18	Deep
LA10	POLA	Inner	Basin	Fish Harbor	7.5	Deep
LA11	POLA	Outer	Outer	LA Outer Channel	25	Very Deep
LA14	POLA	Inner	Slip	Consolidated Slip	7.5	Deep
LA15	POLA	Outer	Basin	LA Turning Basin	17.5	Deep
LA16	POLA	Inner	Slip	Bannings Landing	14	Deep
Pier 300	POLA	SWH	SWH	Seaplane Lagoon Beach	2	Shallow

Table 4-2. Station Analysis Groups and Location Characteristics for Benthic Infauna

Station	Port	Habitat	Location	Station Descriptor	CTD Bottom Depth (m)	Depth Strata
LB1	POLB	Outer	Outer	Outer Harbor Anchorages - Navy Mole	14	Deep
LB2	POLB	SWH	SWH	POLB SWH	5	Shallow
LB3	POLB	Outer	Basin	POLB West Basin - Navy Mole	15	Deep
LB4	POLB	Inner	Slip	Channel 2	14	Deep
LB5	POLB	Outer	Basin	SE Basin East	18	Deep
LB6	POLB	Outer	Slip	Pier J South Slip	17	Deep
LB7	POLB	Outer	Channel	POLB Main Channel - Pilot Station	22	Very Deep
LB8	POLB	Outer	Slip	Outer Pier J Breakwater	12	Deep
LB9	POLB	Outer	Outer	POLB Outer Main Channel	24	Very Deep
LB10	POLB	Outer	Basin	SE Basin West	18	Deep
LB11	POLB	Outer	Basin	POLB West Basin	17	Deep
LB12	POLB	Outer	Channel	POLB Main Channel - Police Station	17	Deep
LB13	POLB	Outer	Basin	Inner Harbor Turning Basin	20	Deep
LB14	POLB	Inner	Channel	Cerritos Channel	15	Deep
LB15	POLB	Outer	Outer	Outer Harbor Anchorages - Breakwater	17	Deep
LB16	POLB	Inner	Slip	Channel 3	14	Deep
LA1	POLA	Outer	Outer	Outer Pier 400	21	Very Deep
LA2	POLA	SWH	SWH	Cabrillo SWH Phase 1	5	Shallow
LA3	POLA	SWH	SWH	Cabrillo SWH Phase 3	6	Shallow
LA4	POLA	Outer	Channel	POLA Main Channel	18	Deep
LA5	POLA	Inner	Basin	POLA West Basin	16	Deep
LA6	POLA	Inner	Channel	POLA East Basin Channel	13	Deep
LA7	POLA	SWH	SWH	Pier 300 SWH	4	Shallow
LA8	POLA	SWH	SWH	Seaplane Lagoon SWH	4	Shallow
LA9	POLA	Outer	Channel	Pier 300 Channel	17	Deep
LA10	POLA	Inner	Basin	Fish Harbor	7	Shallow
LA11	POLA	Outer	Outer	POLA Outer Channel	18	Deep
LA12	POLA	Inner	Basin	Cabrillo Marina	3	Shallow
LA13	POLA	Inner	Slip	Berth 118	15	Deep
LA14	POLA	Inner	Slip	Consolidated Slip	6	Shallow
LA15	POLA	Outer	Basin	POLA Turning Basin	17	Deep
LA16	POLA	Inner	Slip	POLA Slip 5	11	Deep

4.2 Eelgrass

Seagrasses are recognized as one of the most productive ecosystems worldwide, and eelgrass is the most abundant and productive seagrass species in the northern hemisphere. Eelgrass is often referred to as a “foundation species” or “habitat architect” due to its role as a habitat-forming species. Eelgrass beds perform a multitude of ecosystem services (Orth et al. 2012, Waycott et al. 2009) and have been recognized and valued highly for their physical, chemical, and biological functions (Cole and Moksnes 2015).

Eelgrass beds function as habitat and nursery areas for marine fish and invertebrates, providing cover, forage opportunities, habitat complexity, and enhanced productivity.

Eelgrass of the genus *Zostera* is a community-structuring seagrass that in recent years has become abundant in shallow areas of the Port Complex, particularly on the Port of Los Angeles side. *Zostera* is a vascular monocot plant that spreads by rhizomatous clonal growth and seedling recruitment. It can form expansive meadows or small beds in both subtidal and intertidal habitats of shallow coastal bays and estuaries, as well as within semi-protected, shallow, soft-bottom environments of the open coast. Eelgrass in Southern California is typically limited to low intertidal elevations along its upper margin by desiccation stress and along its lower margin of growth by limitations on available photosynthetically active light. The elevation range of eelgrass is highly variable depending upon a number of factors including available soft bottom habitat, water clarity and suspended sediment load, bottom slope, wave energy and circulation, summer temperatures, as well as biotic factors of epiphytic loading, bioturbation, and disease.

Eelgrass is widespread in distribution, but highly restricted in its abundance both worldwide and within California. It is presently estimated that eelgrass covers less than 15,000 acres along the California coastline, with over 80 percent of the state’s eelgrass occurring in just five coastal systems (Merkel & Associates 2017). Documented eelgrass within the Southern California Bight totals slightly over 5,000 acres (Bernstein et al. 2011).

Regulatory Context of Eelgrass

Due to the important ecosystem functions it provides, eelgrass has special status designations under federal and state environmental laws and regulations. The U.S. Environmental Protection Agency (USEPA) has designated eelgrass beds as special aquatic sites under the Clean Water Act, affording them a higher level of protection under federal regulation and policy.

Under the Magnuson-Stevens Fishery Conservation and Management Act, eelgrass is recognized as a Habitat Area of Particular Concern (HAPC). While HAPCs are not afforded additional protections, they aid in prioritizing conservation efforts by the National Marine Fisheries Service (NMFS) and focusing coordination and consultation concerns under Essential Fish Habitat (EFH) consultations between federal agencies. Under the California Coastal Act, eelgrass is recognized as an Environmentally Sensitive Habitat Area (ESHA).

In 1991, NMFS adopted the Southern California Eelgrass Mitigation Policy (SCEMP, NMFS 1991). After 23 years of successful application and eleven revisions, the SCEMP was replaced in 2014 by NMFS' formal adoption of the California Eelgrass Mitigation Policy (CEMP, NMFS 2014) that retained much of the predecessor elements of the SCEMP. The CEMP has been subsequently employed by most state and federal agencies, including the Ports, as a standard for eelgrass management needs in California and is also being applied in Oregon and Washington as a regulatory guidance tool.

Common eelgrass (*Zostera marina*) is the most widespread of the three eelgrass species occurring in California and the only eelgrass species known to occur in the Port Complex. *Z. marina* typically grows in shallow-water, soft-bottom environments ranging from silts to fine gravels; however, the optimal growth medium is considered to be silty sands. Within the Port Complex, the distribution of shallow-water soft-bottom habitat is limited (see Eelgrass Depth Distribution discussion in Section 4.2.2) and thus the distribution of eelgrass is similarly restricted.

In addition to their critical resource values and ecosystem functions, eelgrass beds are uniquely suited to serve as a sentinel indicator of overall ecosystem health and condition. Eelgrass is easily monitored, widely distributed, and responds in a predictable way to natural and anthropogenic stressors that are chronic in nature. Despite seasonal fluctuations in environmental conditions, the presence of eelgrass is relatively consistent during its primary growing season in spring and summer and is resistant to changes driven by short-term environmental fluctuations within normal or near normal ranges. However, eelgrass is vulnerable to stressors that manifest over longer periods, such as persistently elevated water temperature and/or turbidity (e.g. El Niño Southern Oscillation [ENSO] events). Eelgrass may also respond rapidly to physical damage, episodic pollution, and disease (which itself may be facilitated by other stressors that can weaken the natural immunity of the eelgrass bed).

In the present Biosurvey, eelgrass surveys were conducted throughout the Port Complex during May and September 2018 using a combination of acoustic techniques (interferometric sidescan sonar), diver surveys, and remotely operated vehicle (ROV) surveys (see Appendix A for a detailed description of the methodology). The surveys were conducted at both the beginning (spring) and height of the growing season (summer), to assess potential short-term changes in eelgrass distribution and density. Sonographic surveys were undertaken in navigable waters of the Port Complex using an interferometric sidescan sonar system.

4.2.1 Eelgrass Distribution and Density

Eelgrass within the Port Complex was found at discrete locations in both the spring 2018 (Figure 4-1) and summer 2018 (Figure 4-2) surveys. In these figures, eelgrass is plotted with a 25-m locator buffer around all beds to make very small beds apparent, but it is important to note that this presentation results in a visual suggestion of more eelgrass than actually exists within small patches. The broad distribution of eelgrass was generally consistent with prior survey years; however, one new location of eelgrass not noted in 2013/2014 was identified within Slip No. 1 in the Los Angeles Inner Harbor. More detailed maps of the eelgrass beds in the Port Complex are provided in Appendix D. The density of eelgrass beds cannot be used to assess the extent of bottom coverage nor is the reciprocal true. Throughout the eelgrass section, density and bottom cover and percent coverage have explicit meaning and are not used interchangeably.

Seasonal Comparisons

Eelgrass in the Port Complex totaled approximately 70 acres in spring and 86 acres in summer (Table 4-3), a 22 percent increase. Over 99 percent of the eelgrass occurred on the Los Angeles side of the Port Complex in both spring and summer, a function of the much greater extent of shallow water on the Los Angeles side than on the Long Beach side. Two sites -- the Cabrillo Beach area and Pier 300 Basin (including Seaplane Lagoon) -- contained more than 95 percent of all of the eelgrass within the Port Complex during both seasons of this survey. This spatial pattern of occurrence has been consistent through all of the past Biosurveys.

Table 4-3. Distribution of Eelgrass within Port Complex by Survey Season

Location of Eelgrass Beds	Spring 2018		Summer 2018	
	acres	% of total	acres	% of total
Port of Los Angeles				
Pier 300 Basin	48.7	69.3%	62.0	72.1%
North Cabrillo Beach	11.4	16.2%	12.1	14.1%
South Cabrillo Beach	7.21	10.3%	7.76	9.02%
East Basin Yacht Marinas	1.85	2.63%	2.27	2.64%
Cabrillo Marina	0.14	0.20%	0.15	0.22%
Fish Harbor	0.08	0.11%	0.11	0.12%
Consolidated Slip	0.04	0.06%	0.08	0.09%
LA Turning Basin	0.10	0.13%	0.07	0.11%
Slip No. 1	0.38	0.55%	0.47	0.54%
Port of Los Angeles	**69.8**	**99.4%**	**85.3**	**99.1%**
Port of Long Beach				
Navy Mole	0.09	0.13%	0.31	0.37%
Cerritos Channel	0.33	0.75%	0.44	0.73%
Back Channel	<0.01	<0.01%	<0.01	<0.01%
Port of Long Beach	**0.422**	**0.60%**	**0.756**	**0.88%**
Total Port Complex	**70.2**	**100%**	**86.0**	**100%**

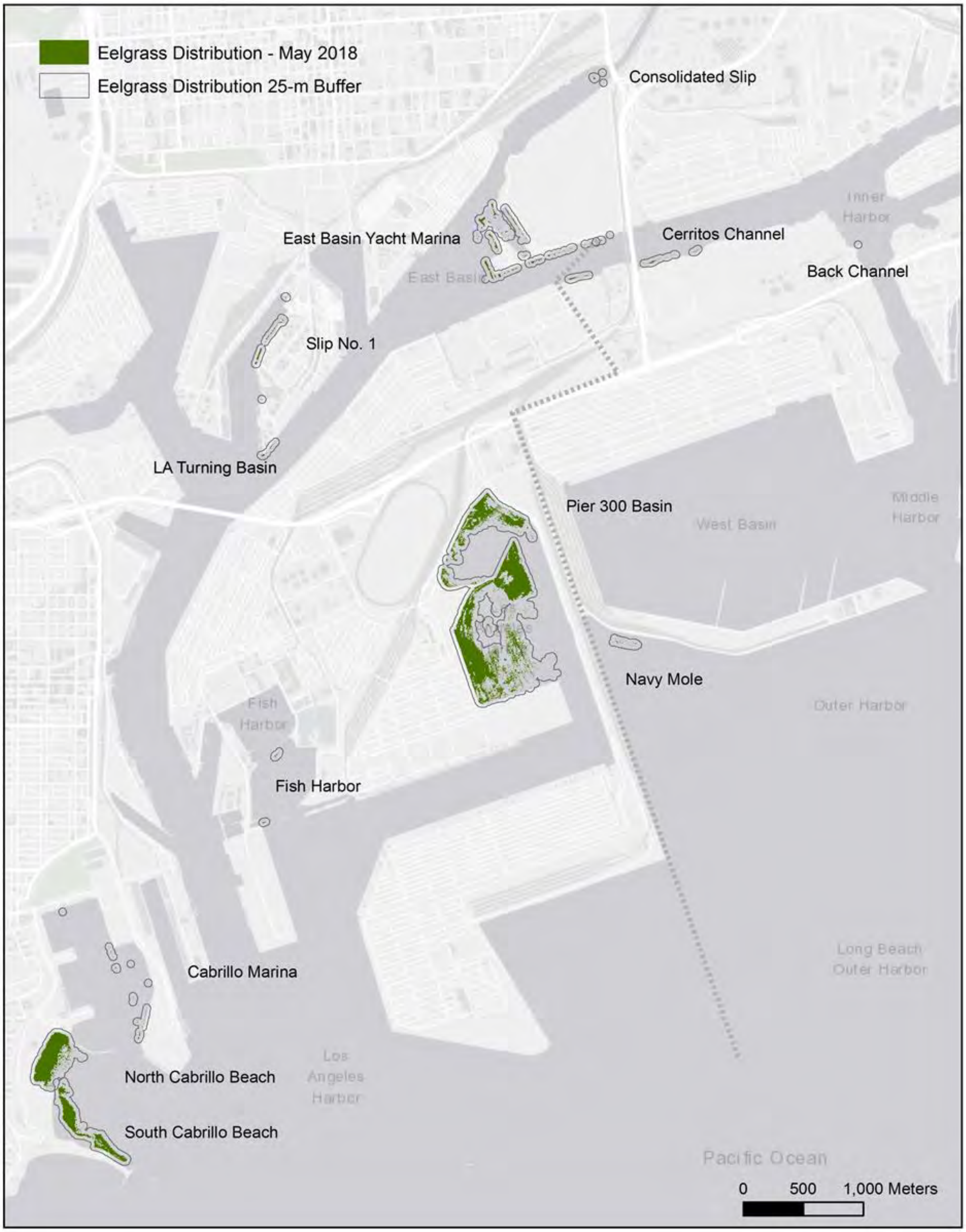


Figure 4-1. Spring Eelgrass Distribution within the Port Complex – (May 2018)

Figure 4-2. Summer Eelgrass Distribution within the Port Complex – (September 2018)

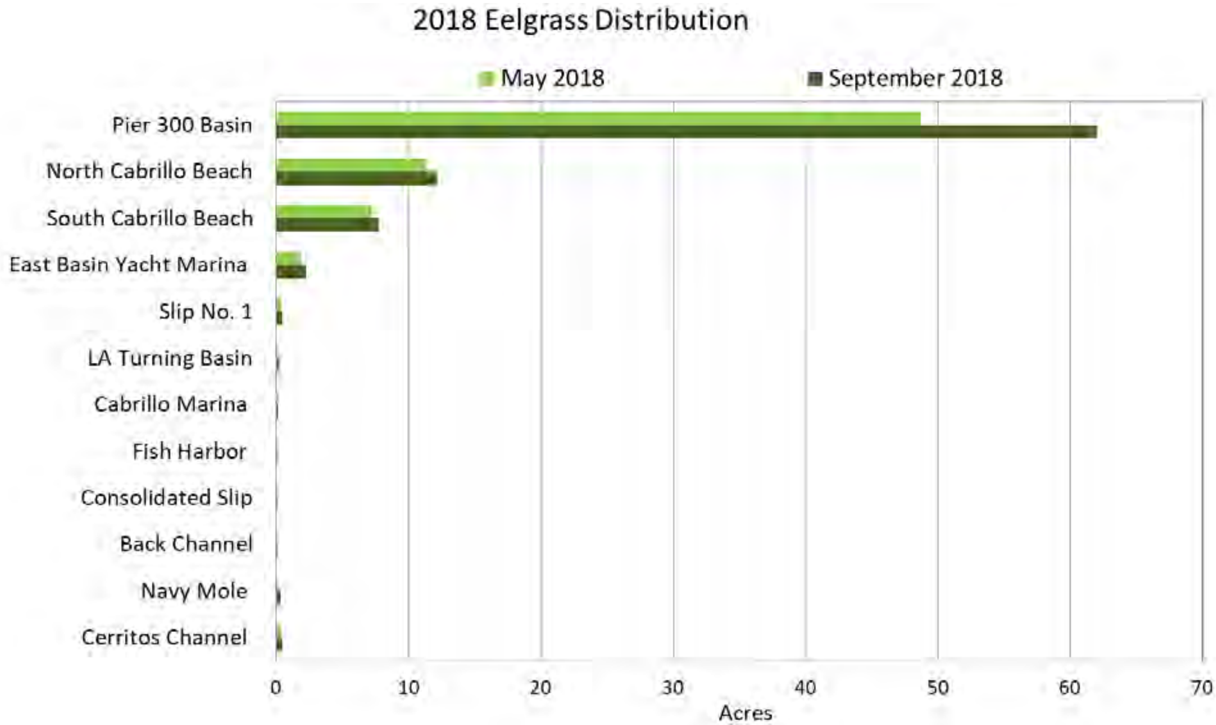


Figure 4-3. May and September 2018 Eelgrass Cover Area

Seasonal differences in the overall acreage of individual eelgrass beds provide a good indicator of the stability of an eelgrass bed throughout a year and help identify factors affecting eelgrass growth in different areas of the Port Complex. The change in the extent of eelgrass between May and September 2018 is shown graphically in Figure 4-4 for the Pier 300 area; figures for the other areas are included in Appendix D. The areas of change were determined by subtracting the area occupied by eelgrass in September 2018 from that in May 2018. The percentage changes in eelgrass beds between sampling seasons has been illustrated in Figure 4-5. As can be seen in Figure 4-4, a single bed may exhibit both increases and decreases in eelgrass between the seasons. Note that for even the most stable beds within the Port Complex, only about 60 to 80 percent of their total area remained unchanged with respect to the presence of eelgrass from spring to summer, although the sites occupied by eelgrass remained consistent between seasons. In the most dynamic bed (Navy Mole), less than 10 percent of the bed remained unchanged between seasons as a result of dramatic expansion in the beds between May and September. In general, the largest changes in the area of the larger

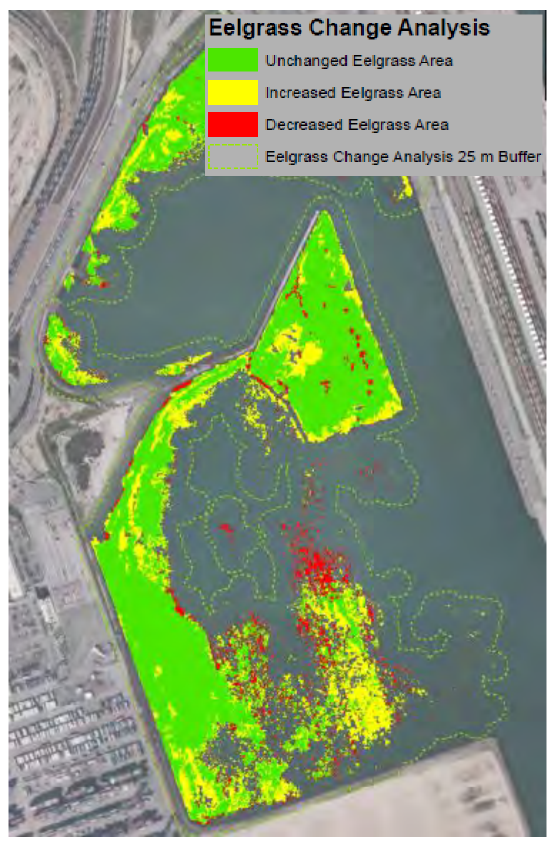


Figure 4-4. Change in Eelgrass Distribution Between May 2018 and September 2018

beds occurred at their deeper margins, although for smaller and patchy beds the changes occurred throughout the depth range. Some beds more than doubled in area between spring and summer (e.g., LA Turning Basin and Back Channel), although the increases were somewhat offset by patchy areas of decrease within the beds. In all cases, the net eelgrass coverage increased between the spring and summer surveys (Table 4-3 and Figure 4-5). The net change between spring and summer 2018 surveys was a 22.1 percent increase in eelgrass cover.

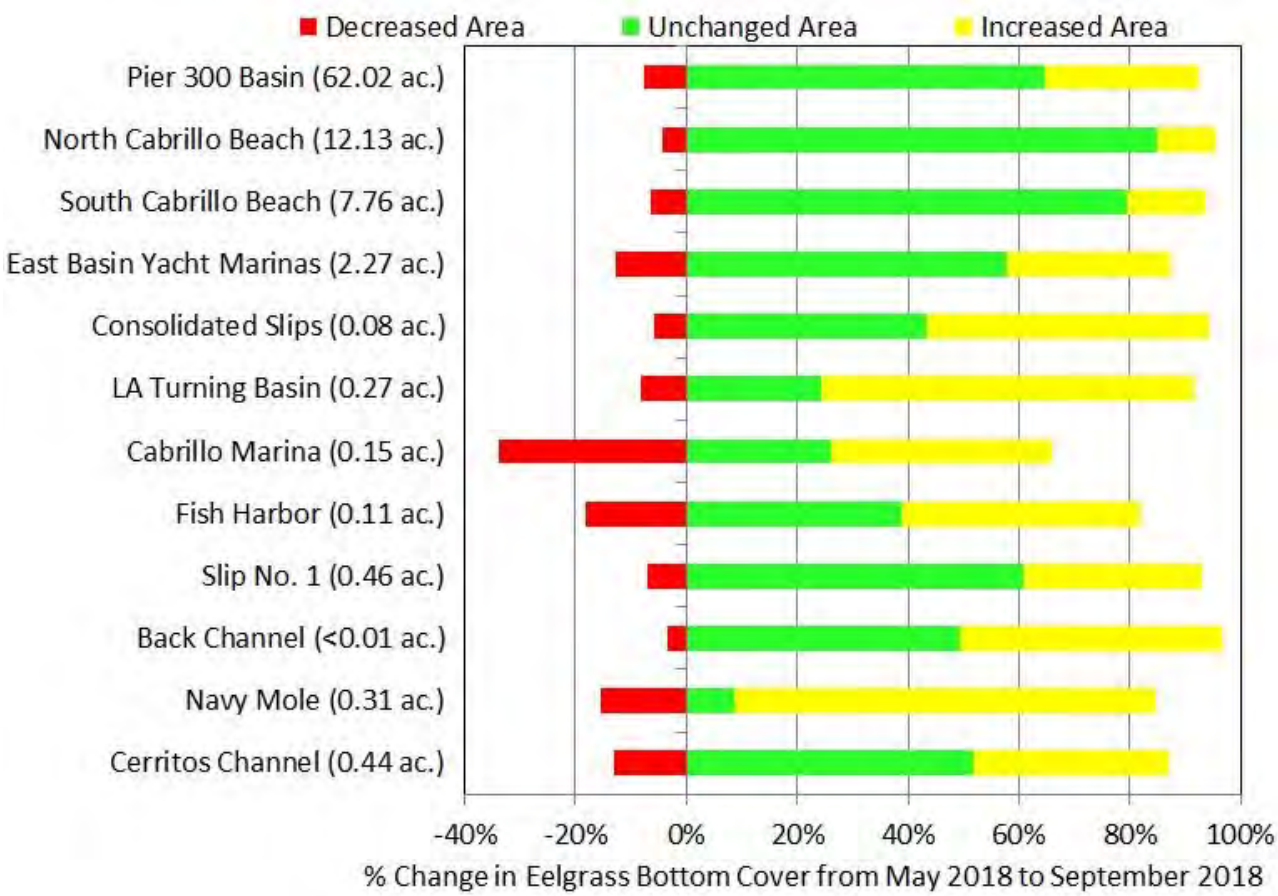


Figure 4-5. Change in Eelgrass Distribution between May and September 2018
Note: Acreage shown is for September 2018

Eelgrass Depth Distribution

During the winter, eelgrass typically experiences a reprieve from high summer temperatures and intense sunlight, and the upper margin of the bed moves higher into the intertidal and shallow subtidal margin (MBC and Merkel & Associates 2016). In spring and summer, eelgrass is pushed down from the intertidal margin, but more sunlight at depth allows the lower margin of the bed to expand downward. In addition, during the spring, eelgrass seedlings may germinate and grow at depths below those typically suited for long-term support of eelgrass. This occurs as a result of a combination of early-season high water clarity, supplemental energy stores in the seed, and seasonally enriched sediment nutrient levels. As a result, early growing season surveys often observe deeper bed margins made up of plants that typically do not survive through the entire growing season. This was observed to have occurred within the deeper margins of eelgrass beds within the Pier 300 Basin (Figure 4-4).

Over 99.5 percent of the eelgrass in the Port Complex occurs between +0.5 and -15 feet Mean Lower Low Water (MLLW). The depth distribution of eelgrass in the Port Complex is substantially different between the two ports, largely because of the very different water depth profiles of the two ports (Figure 4-6).

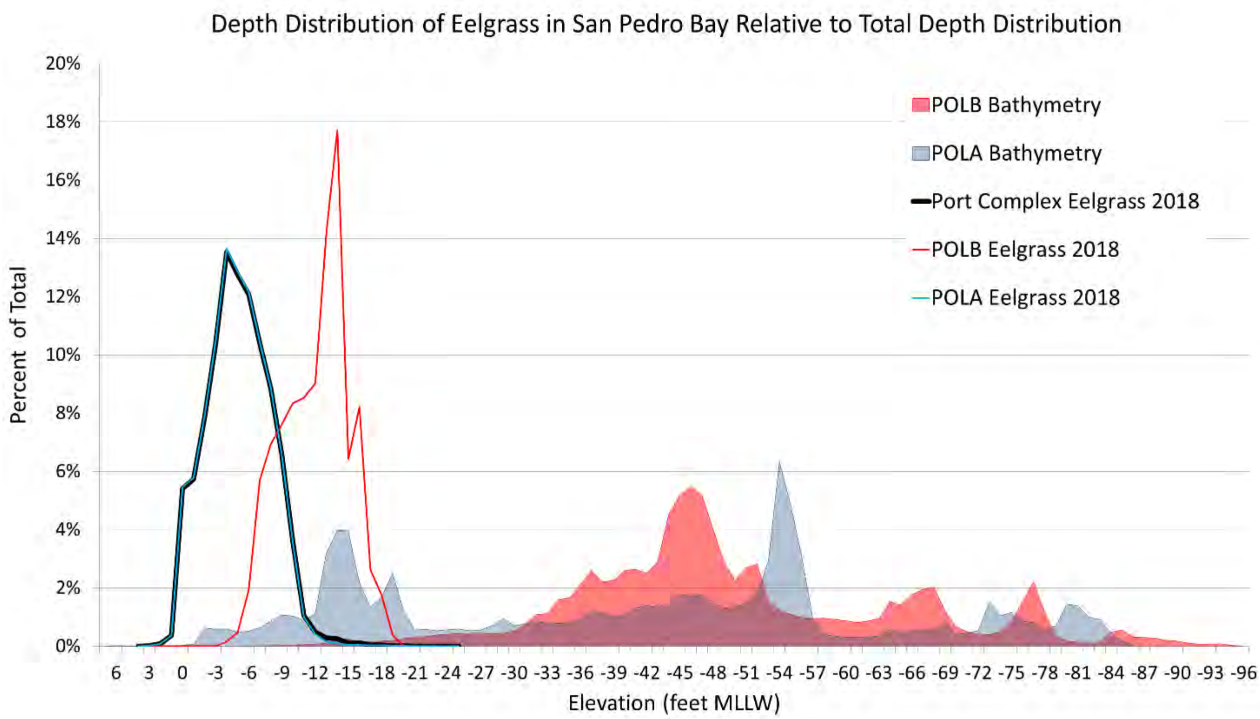


Figure 4-6. Depth Distribution of Eelgrass in Relation to Bathymetry in the Port Complex

Eelgrass Density

Eelgrass beds are characterized by the density of leaf shoot bundles (turions) arising from meristematic tissue at the rhizome tip. Turion density provides information on the overall bed condition and is useful in characterizing differences across beds and seasonally within beds. The raw density sampling data are presented in Appendix D. In Southern California, eelgrass turion densities in established beds typically range between 100 and 300 turions/m^2 with deviations from this norm typically occurring in stressful environments that either restrict turion count and increase plant height (e.g., light limitation) or increase turion count and reduce canopy height and leaf width (e.g., increased hydrodynamic energy). In the present survey, mean density across all samples was 116±49 turions/m^2 (±1SD, n=222) in spring and 142±66 turions/m^2 (±1SD, n=224) in summer.

Eelgrass density increased between spring and summer at eight of the twelve sites (Figure 4-7). Sites have been ordered in Figure 4-7 to generally reflect the most well flushed (i.e., replacement of water as result of tidal flow) to the least well flushed environments present in the

Port Complex and as such, tend to reflect Outer Harbor sites followed by Inner Harbor sites. The highest densities occurred off Cabrillo Beach, which has moderate tidal exchange, while the lowest densities occurred in the more restricted areas of Consolidated Slip (Figure 4-8). The greatest increase was observed at the Pier 300 Basin site, where of the 83 percent increase can be attributed principally to the emergence of new shoots of first-year seedlings in deeper water.

Overall, the greatest eelgrass densities occurred in uniformly shallow areas in the Outer Harbor that are more open to tidal exchange, while lower densities occurred in deeper areas with sloped embankments and lower circulation and/or less hydrodynamic energy.

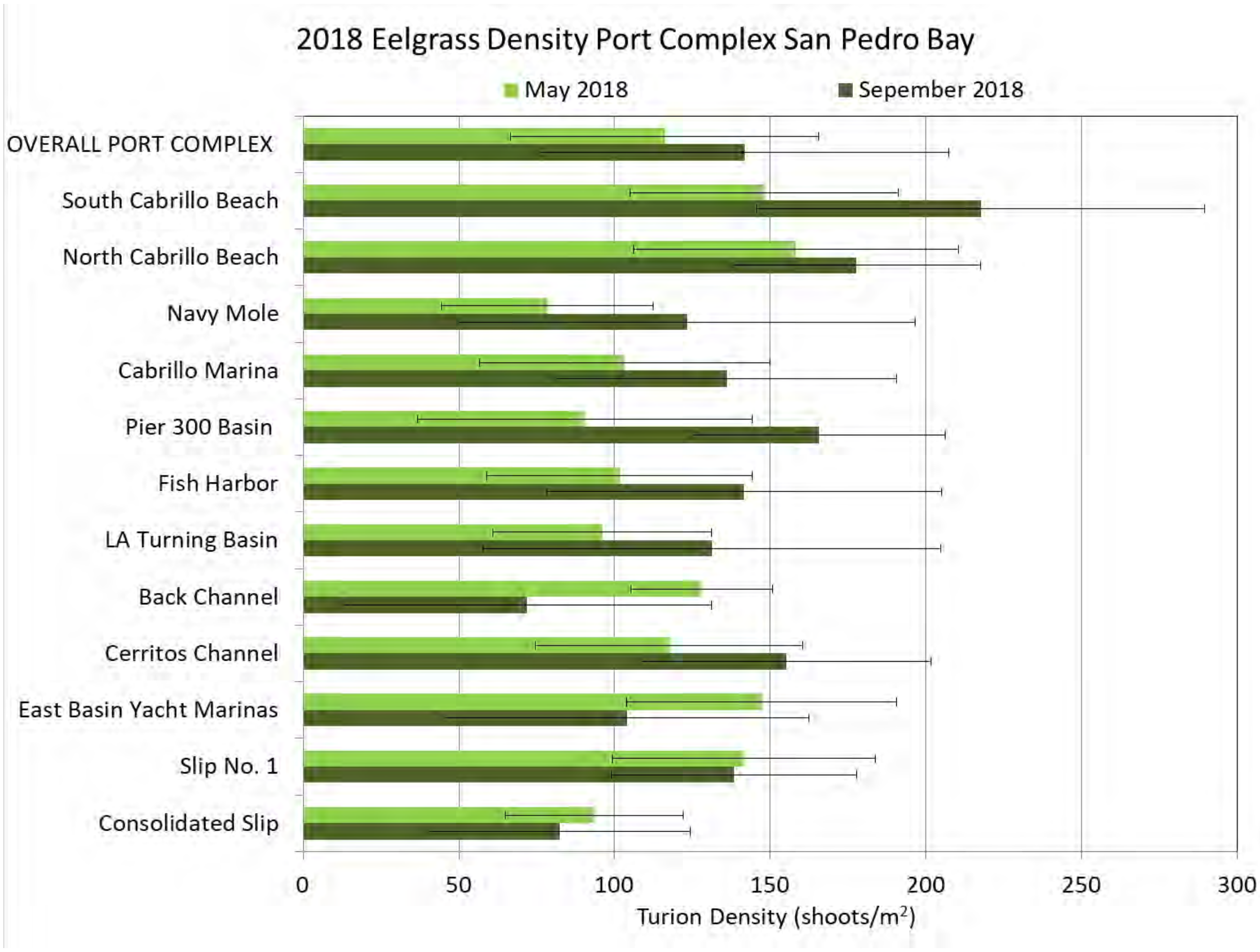


Figure 4-7. Mean Turion Density of Eelgrass in Spring (May 2018) and Summer (September 2018) (±1 Standard Deviation)

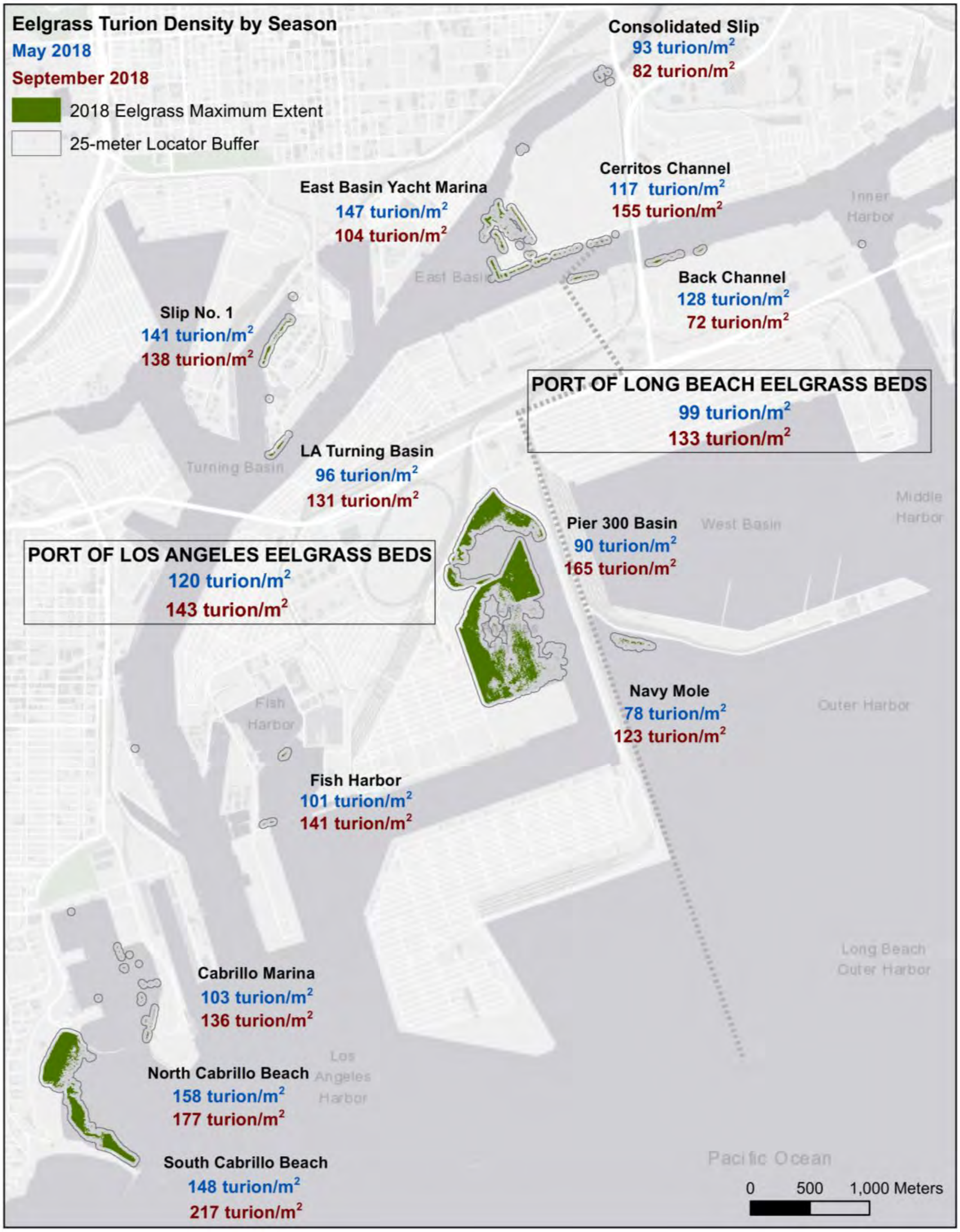


Figure 4-8. Eelgrass Turion Density Observed in Spring and Summer 2018

4.2.2 Eelgrass Health and Vigor

The health and vigor of eelgrass beds in the Port Complex were assessed on the basis of observations of canopy height, leaf color and turgidity, and epiphytic/sediment loading of leaves as an estimated percentage of the leaf surface area. In addition, the percentage of the plants exhibiting signs of wasting disease was noted (where evidence of disease was observed only on dead leaf tissues, the percent of disease was reported as zero because this is a natural pattern of decay of dead eelgrass). Finally, the characteristics of the surface sediments supporting eelgrass were noted (e.g., silt, mud, sand, shell hash). The observations are presented in Appendix D.

Canopy height in spring (0.2 and 1.2 meters) was typically lower than in summer (0.2 to 2.2 meters). The maximum summer canopy height, which was observed at South Cabrillo Beach, is exceptionally tall for eelgrass not only within the Port Complex but also in Southern California. It is not clear why the leaves reached such lengths during this survey and not during previous surveys.

Several coloration patterns of eelgrass were noted: the bright green coloration of rapidly growing tissues, normal medium green coloration, darker coloration of leaves richer in chlorophyll, and brown coloration (generally related to the presence of a biofilm on the leaves rather than pigmentation of the leaves themselves). Medium to bright green coloration was common in most of the beds during both seasons. The deeper beds within Cabrillo Marina, the East Basin Yacht Marinas, Consolidated Slip, and Back Channel all exhibited darker leaves, generally in sparse, light-limited beds.

Epiphytic loading of eelgrass leaves was typically lower during the spring than summer. Epiphytes were observed on 5 to 40 percent of the blades, with an average of approximately 20 percent in spring, but on 5 to 80 percent of blades, with an average of approximately 50 percent, in summer. Notably, during the Spring 2014 survey, epiphytes were present on more than 5 percent (0-20 percent) of the eelgrass blades in only five beds, despite surveys being completed at nearly identical times of the year. However, during the summer of 2013, the presence of epiphytes was more similar to that observed in the summer 2018. During both the summer and spring sampling periods in 2018, a considerable amount of macroalgae (*Ulva* sp., *Chaetomorpha* sp., and *Gracilaria* sp.) was present along the shallow margins of the eelgrass beds. This is similar to observations made in 2013/2014 and may have occupied the upper margin of eelgrass beds in some areas resulting in reduction in bed extent and/or density.

Sediment loading of eelgrass leaves is estimated as a percent cover of sediment over visible green plant tissue. It is important because heavy sediment loading precludes adequate light reaching the leaves to support photosynthesis. Sediment accumulation on eelgrass leaves was particularly low in most beds in the Ports throughout both study seasons. The exception was observed minor and persistent sediment loading at both beds within Cabrillo Beach and within the beds at Slip No. 1, as well as somewhat heavier (5-20 percent) loading within beds along the shoreline of the Los Angeles Turning Basin. None of the sediment loading was high enough to be judged substantively detrimental to the health of eelgrass.

Eelgrass in the Port Complex did not exhibit strong blemish and leaf erosion patterns of wasting disease during 2018, although there were blemishes on plants within several of the beds that might be indicative of a low level of disease.

4.2.3 Historical Comparisons

The earliest known efforts to quantify eelgrass in the Port Complex were undertaken in 1996 and 1999 by the Southern California Marine Institute. These studies surveyed eelgrass within specific portions of Los Angeles Harbor where eelgrass was known to exist. The 1996 survey only assessed the Cabrillo Beach area, while the 1999 survey looked at both Cabrillo Beach and the Pier 300 Shallow Water Habitat (Gregorio 1999). Survey methodology involved visual observations, fathometer readings, and diver transects. While these investigations provided insights into the distribution of the primary eelgrass present within the Port Complex, the methods applied provide less detailed and comprehensive data than the sidescan sonar methodology that has been employed in the Biosurveys conducted in 2000, 2008, 2013/2014, and the present study.

The last four Biosurveys include a total of eight seasonal surveys of eelgrass in the Port Complex, making it possible to examine the recent history of the occurrence of eelgrass through time. Although methodological differences between the Biosurveys -- aggregated density classes in 2000 and 2008 versus discrete bed mapping limits in 2013 and 2018 – limit the overall accuracy of numeric area comparison, it is nevertheless possible to evaluate the long-term stability of eelgrass beds within a given area by digitally overlaying the spatial data layers from each survey and determining how often eelgrass was reported for that area as a percentage of the survey intervals. As a result, when eelgrass was present during only one of eight surveys the occurrence frequency would be 13 percent, while presence of eelgrass during six of eight surveys would result in a 75 percent occurrence frequency. Because of a lack of comparability, data from the 1996 and 1999 surveys were omitted from this analysis.

This analysis confirms the persistence of eelgrass beds in the shallows of North and South Cabrillo Beach and in the Pier 300 Basin since 2000 (Figure 4-9). Eelgrass has persisted within portions of these three sites across all historical surveys, although the deeper margins of these areas exhibit dynamic conditions, with the frequency of occurrence ranging from 13 to 38 percent over much of the overall bed area. The occurrence frequency of eelgrass within Pier 300 Shallow Water Habitat was no more than 75 percent, because eelgrass was planted at the site after the completion of the first two surveys in 2000. Similarly, a low occurrence frequency was noted at the southeastern margin of Cabrillo Beach where eelgrass habitat was developed subsequent to the 2013/2014 surveys. Because of mapping scale, it is hard to see small patches of eelgrass with low frequency of occurrence that are scattered throughout the Port Complex. However, it is important to note that, in most instances, eelgrass beds outside of the Cabrillo Beach and the Pier 300 Basin (including Seaplane Lagoon) have rarely exceeded a 50 percent occurrence frequency due to non-persistence of individual plants as well as the recent emergence of beds within various locations.

Figure 4-9. Frequency of Eelgrass Occurrence During Eight System-wide Surveys Conducted in 2000, 2008, 2013–2014, and 2018

The current Port Complex-wide survey noted eelgrass in core areas as well as in areas where it has not previously been observed. However, eelgrass has been noted in small patches throughout the Port Complex during a number of Biosurveys. The first substantial expansion of eelgrass into areas not previously noted was in the mid-2000s, when eelgrass was documented in Consolidated Slip and the East Basin Yacht Marinas while investigating potential locations for positioning flow sensors for the Dominguez Channel Hydrodynamic and Water Quality Study (K. Merkel pers. obs., 2005), in the Cabrillo Marina Basin (Merkel & Associates 2009) and in 2011 along the Cerritos Channel east of the Heim Lift Bridge (MBC 2011). During the present survey, eelgrass was noted in Slip No. 1 and as small patches in a small cove north of the East Basin Yacht Marinas and along the San Pedro Public Market Promenade shoreline.

While the frequency of eelgrass occurrence map (Figure 4-9) provides a valuable tool to explore the persistence of eelgrass in the Port Complex, numeric comparisons between the present and prior eelgrass mapping efforts have intentionally not been made in this report due to the methodological inconsistencies noted above. The mapping methodologies have evolved from a three-class bottom coverage with a lower limit threshold at 5 percent bottom cover (2000), to a simplified two-class bottom coverage mapping classification without range definition (2008), to the present discrete plant boundary-mapping methods applied in 2013/2014 and the present 2018 surveys. These differences in methodology do not permit meaningful numeric interpretation of eelgrass extent, the application of the broader cover classes in 2000 and 2008 resulting in overestimating eelgrass relative to the discrete mapping applied in more recent surveys.

Notably, in 2018 deeper margins of eelgrass were generally located in Inner Harbor areas, such as along Cerritos Channel and within marina basins, as opposed to Outer Harbor areas as one might expect due to more oceanic influence and a general anticipation of greater water clarity and flushing. Similar observations of deep eelgrass beds have been made within the industrialized portions of San Diego Bay where it is believed that water clarity is enhanced by an inability to suspend sediment through wind waves, relatively slow water turn-over and thus continued settlement of suspended particulates, and trapping and removal of sediment by salps and filter-feeders as the water circulates through. This observation may point to greater average water clarity in the Inner Harbor than in the Outer Harbor, as seen in the historical surface turbidity and transmissivity data presented in Section 2. A change in water clarity within the Inner Harbor over the past two decades may also be a factor in the recent expansion of eelgrass within the Inner Harbor areas since 2008.

While the patterns of eelgrass depth distribution remain relatively similar between the surveys of 2013/2014 and present 2018 surveys, there has been a slight but detectable downward shift in the proportional distribution of eelgrass towards deeper waters in the Port Complex. This can be seen within a vertical range truncated adaptation of Figure 4-6 where data from 2013/2014 have been added for comparison with the 2018 data (Figure 4-10). The shift in depth within the Port of Los Angeles waters is related principally to expansion of eelgrass into deeper waters within the Pier 300 Basin while the overwhelmingly dominant extent of beds has remained consistent. A more substantial shift in depth was observed within the Port of Long Beach waters where the extremely limited and very patchy eelgrass allows for documentation of greater vertical range shifts even when a very small area and a small number of plants are involved in the change. While Figure 4-10 points to a greater vertical shift in eelgrass within the Port of Long Beach, this shift is likely less meaningful than the similar, but smaller shift within the Port of Los Angeles where significant expansion of eelgrass occurred into deeper waters of the Pier 300 Basin during 2018.

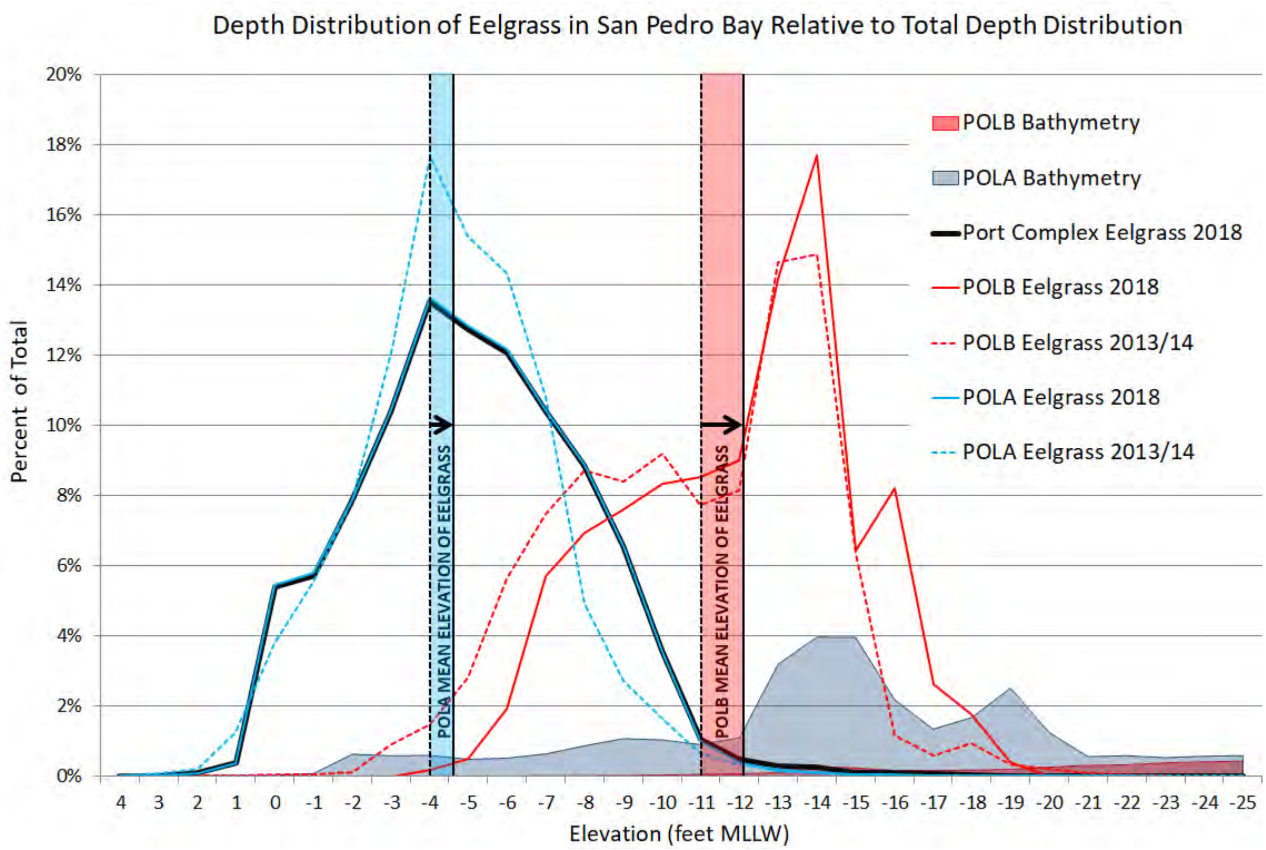


Figure 4-10. Downward Shift in Mean Elevation of Eelgrass Between 2013/2014 and 2018 Surveys

4.2.4 Discussion

Over 95 percent of the eelgrass in the Port Complex occurs in two areas: the Pier 300 Basin and the Cabrillo Beach area, including a total of 3.05 acres planted as mitigation in 2016 (Merkel and Associates 2020). These core areas have supported the vast majority of all eelgrass throughout the last four Biosurveys. Recent expansion of eelgrass has occurred within the Pier 300 Basin due to a pulse of seedling recruitment along the deeper margin of beds that has not been noted prior to 2018. It is unknown whether these plants will persist long-term. Other recent changes are the establishment of small beds within Slip No. 1 and the expansion of beds in the East Basin yacht marinas.

While changes in mapping methodologies over the past two decades limit the capacity to make robust numerical comparisons of eelgrass acreage over time, the changes in eelgrass distribution throughout the Port Complex clearly indicate the improving suitability of the Ports to support eelgrass. In 2000, eelgrass was limited to beds at Cabrillo Beach and Pier 300 Basin and a very small bed, probably a single plant, being reported along the northern shoreline of Pier A at Berth A88 within the Cerritos Channel (MEC 2002). In March 2000, a single floating leaf in the Port of Long Beach Back Channel suggested the presence of Pacific eelgrass (*Zostera pacifica*) in the area; however to date this species has not been found in the Port Complex and the leaf was likely derived from one of the small beds known to occur to the east of the Ports.

In 2008, eelgrass beds were again only mapped within the two core areas, but a small number of other beds were reported to exist based on referenced reports by other researchers (SAIC 2010). By 2013/2014 eelgrass was well represented as scattered plants in the limited shallow soft-bottom habitat present within the Port Complex (MBC and Merkel & Associates 2016). Finally, during the present 2018 surveys, eelgrass became well represented in persistent beds distributed widely through the suitable habitats of the Port Complex. However, because the extent of shallow soft bottom habitat is highly limited, the abundance of eelgrass is also limited.

The expansion of eelgrass through the Ports over the past several years has been notable and is likely a result of many factors. Primary among these are likely improving water and sediment quality conditions over time. A second likely important factor is deferred maintenance dredging in some of the shallower facilities within the inner harbor, such as the East Basin yacht marinas, allowing eelgrass habitat development as waters shallow due to sediment accretion. While periods of favorable conditions have likely contributed to expansion, long-term stressors such as warm water anomalies, ENSO events, and outbreaks of wasting disease have all resulted in eelgrass declines on timescales shorter than the historical Biosurveys. These events have impacted eelgrass within many systems along the Southern California coast, and all of these have had detectible effects on eelgrass dynamics within the Ports. These punctuated stressors create instability within eelgrass habitat and can lead to localized extirpation of eelgrass from marginal environments. As a result, it would not be unexpected to see some of the smaller stands of eelgrass within the Inner Harbor disappear over time, while others emerge due to random recruitment events. Concurrently, larger core areas may fluctuate substantially in area and intra-site distribution, but these beds are unlikely to disappear due to climatic instability and they will be important sources of seed for natural respreads of eelgrass following extirpations.

The bed dynamics observed in the Port Complex in 2018 underscore the relative plasticity of eelgrass between seasons. Perhaps the most notable shift in eelgrass distribution patterns on a seasonal basis is illustrated in Figure 4-4 where eelgrass seedlings present in deep water in May 2018 were absent in September 2018, but eelgrass seedlings in slightly shallower waters survived and filled in the previously sparse eelgrass beds. The patterns of eelgrass change are consistent with often recurrent patterns of recruitment and ultimate mortality of seedlings in water depths unsuited to survival and the tendency for bed coalescence over the course of a growing season. During winter months it is not uncommon to observe bed declines along the lower margins, the development of gaps within the bed, the reduction of bed boundaries, and expansion into shallower areas during the period when desiccation stress on plants is lowest. Changes in eelgrass beds follow a natural cycle as a consequence of seasonal variation in temperature, light availability, and other physical stressors such as winter storm events.

4.3 Benthic Infauna

To determine the overall condition of benthic infaunal communities, this study used multiple lines of evidence including the BRI for bays and harbors (Smith et al. 2003), which is an established multi-metric indicator. The BRI is one of three types of benthic indices recognized for biocriteria development by the U.S. Environmental Protection Agency. Others include the standard biological community metrics also used in Section 3 of this report such as abundance, richness, biomass, and various diversity indices. The individual metrics are useful to understand the characteristics of the benthic community, while the BRI provides a measure of overall biotic integrity.

4.3.1 Species Comparisons

Benthic Infauna Study Area Summary Metrics

Summing all samples, stations, and seasons, 16,436 organisms representing 369 unique taxa were identified (Appendix D). Total abundance and richness were very similar between seasons, with 8,227 organisms (294 unique taxa) collected in the spring, and 8,209 organisms (316 unique taxa) collected in the summer.

Abundance per station in spring ranged from 34 (Station LB6) to 1,028 (Station LA12) organisms per sample, while in summer it ranged from 83 (Station LB6) to 1,101 (Station LA14) organisms per sample (Figure 4-11; Appendix D). Species richness per station in spring ranged from 17 (Station LA4) to 75 (Station LB9) and in summer from 19 (Station LA10) to 66 (Station LB7).

Organism biomass for all stations and surveys combined totaled 323g, with a 192g in the spring survey and 141g in summer. Per-station biomass in spring ranged from 0.5g (Station LA15) to 29g (Station LA14) and in summer from 1.0g (Station LA10) to 19.9g (Station LB12) as shown in Figure 4-11.

Shannon-Wiener diversity ranged from 1.16 to 3.92 in the spring and from 1.13 to 3.63 in the summer (Figure 4-11).

When evaluating all samples and stations, there was no statistically significant difference between seasons for any of the metrics measured except taxonomic richness (Figure 4-11, $p=0.046$), which was significantly greater in summer despite substantial overlap among sites.

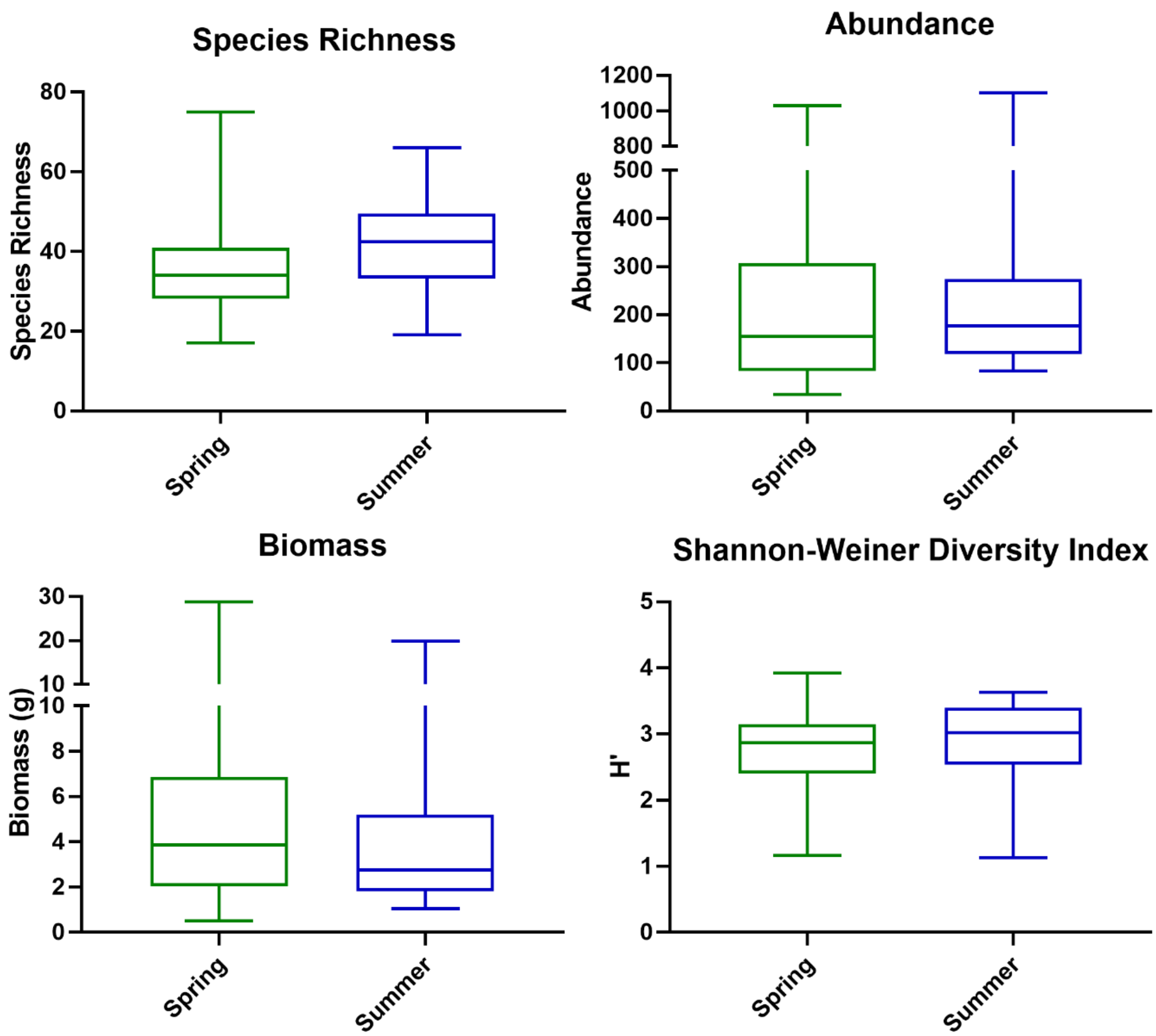


Figure 4-11. Median and Range of Benthic Infauna Community Metrics (per Site) in Spring and Summer - All Stations Combined

Whiskers represent the range, the line represents the median, and boxes represent the 1st quartile above and below the median

Taxonomic Composition by Major Phyla

Annelida (primarily polychaete worms) was the most abundant phylum, comprising 47% of the total abundance in the spring survey and 54% in summer (Figure 4-12, Appendix D). Arthropoda (crustaceans) was the second most abundant phylum, comprising 39% and 29% of the total abundance in spring and summer, respectively.

Biomass by major phyla showed somewhat different results than abundance in that there was a shift in the dominant biomass group between seasons. Mollusca had the highest biomass in spring with 42% of the total, while Annelida had the highest biomass in summer, comprising

39% of the total. Occasionally, one or a few large organisms can dominate the biomass in a single sample. Larger individuals of both Annelida and Mollusca were present in a few samples, resulting in substantially greater biomass than average. This was particularly evident in the LA14 sample collected in spring where two individual molluscs accounted for 49% of the sample biomass, and in the LB9 sample collected in summer where a single annelid worm accounted for 72% of the sample biomass. Echinodermata (primarily brittle stars) contributed the least biomass across both seasons, with 1.0% and 0.5% of the total in spring and summer, respectively.

Taxonomic richness varied little from spring to summer (Figure 4-12). Annelida was the most diverse major phylum and comprised 45% and 48% of the total taxa collected in spring and summer, respectively. Arthropoda and Mollusca had similar diversity values among seasons, with each comprising roughly 20% for both surveys. Echinodermata had the lowest diversity with 1.7% and 1.6% of the total and were primarily Ophiuroidea (brittle stars).

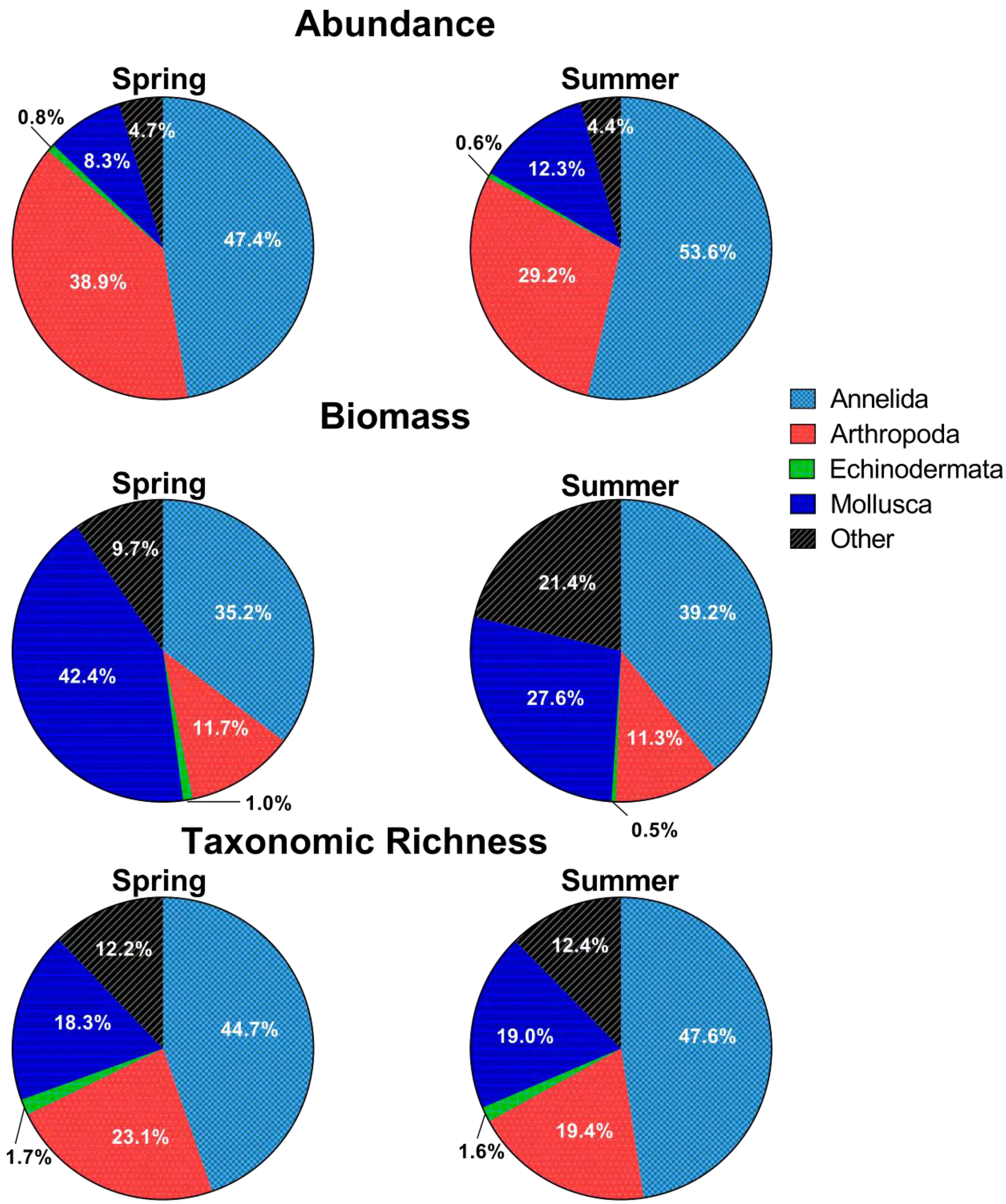


Figure 4-12. Relative Major Taxa Group Percentages for Benthic Infauna Abundance, Biomass and Richness in Spring and Summer Among All Stations Combined

4.3.2 Station Comparisons

Infauna Abundance, Biomass and Richness by Station

Figure 4-13 shows the mean and range of abundance, biomass and species richness separated by station and grouped by habitat. In general, the SWH stations had greater mean abundance than the Inner and Outer Harbor station groups, although two Inner Harbor stations, LA12 and LA14, had substantially greater abundance than all other stations in both spring and summer. Station LA12 in Cabrillo Marina was dominated by the non-native polychaete, *Pseudopolydora paucibranchiata* in both seasons (76% and 59% of the organisms present). Station LA14 in Consolidated Slip was dominated by the amphipods *Zeuxo normani* complex and *Grandidierella japonica*, and oligochaetes (segmented worms including aquatic and terrestrial earthworms) in the spring (61% combined of the organisms present), and oligochaetes and the polychaete *Dorvillea (Schistomeringos) longicornis* in summer (43% combined of the organisms present).

Aside from several outlier stations in the Inner and Outer Harbor, biomass was generally consistent throughout the Port Complex (within a range of 3g to 7g of biomass), and no habitat group exhibited consistently greater biomass. However, biomass at some stations was quite variable between seasons. For example, Station LA14 in the spring had 26g of molluscs, primarily the non-native mussel *Musculista senhousei* (n=84), while the summer sample only had 1.6g of molluscs with only 7 *M. senhousei* present. The higher biomass in spring was the result of the large number of *M. senhousei* and two large individual molluscs (*Philine auriformis and Venerupis philippinarum*) collected in this sample. The difference in the number of *M. senhousei* collected could have been the result of the known spatial patchiness of this particular taxon rather than an actual decrease in its abundance in summer.

Richness was similar to biomass in that it was generally consistent across sites with a few stations in the Outer Harbor (LB7, LB9, LB12 and LA11) and SWH (LA7) having above-average richness in both seasons. There was also large variability at some stations, particularly LA4, which had 17 species in the spring and 60 species in the summer.

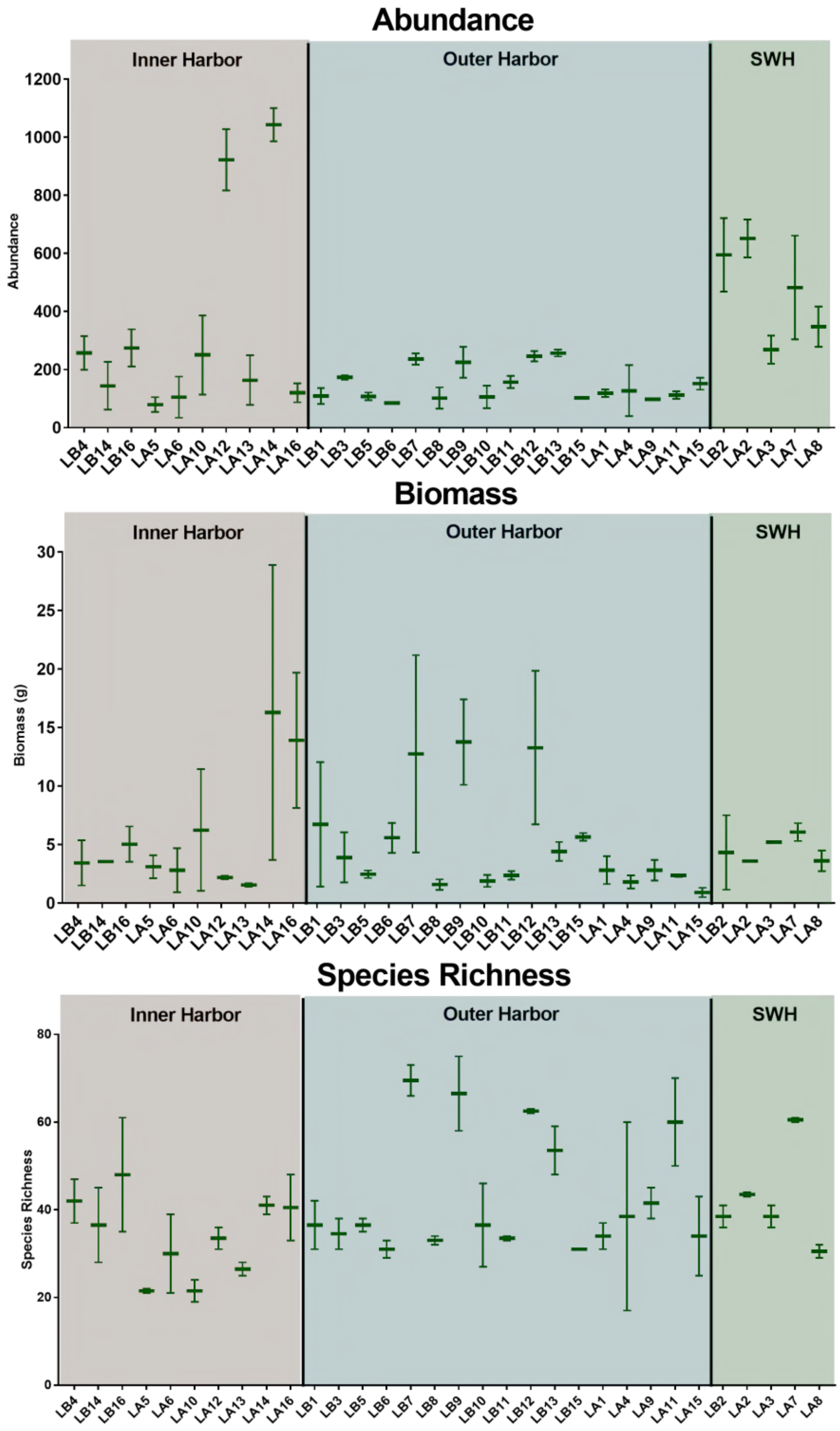


Figure 4-13. Mean and Range of Benthic Infauna Abundance, Biomass and Species Richness in Spring and Summer, Separated by Station

Vertical line represents range of sample values; horizontal bar represents the mean value

Dominant Benthic Infauna

For both the spring and summer surveys across all stations combined, the dominant taxon was the amphipod *Amphideutopus oculatus*, which comprised 12.0% and 8.3% of infaunal community abundance in spring and summer, respectively (Table 4-4). The polychaetes *Pseudopolydora paucibranchiata* and *Cossura* sp. A were the second and third most abundant taxa, switching ranks between spring and summer. Many of the most abundant taxa were unevenly distributed throughout the Port Complex (Appendix D). For example, in the spring survey, 97.5% of *A. oculatus* individuals were collected from three stations (LA2, LA7, and LB2), and 83.0% of *P. paucibranchiata* were collected from a single station (LA12). All but one of the ten most abundant taxa were either Annelids or Arthropods; the clam *Theora lubrica* was particularly abundant in summer. Note that three of the top ten species in spring and two of the top ten species in summer are non-natives.

Table 4-4. Ten Most Abundant Benthic Infauna Collected Across all Stations - Spring and Summer, 2018

Spring 2018		Summer 2018	
Taxon	**Percent Composition**	**Taxon**	**Percent Composition**
Amphideutopus oculatus[1]	12.0%	*Amphideutopus oculatus*[1]	8.3%
*Pseudopolydora paucibranchiata**	11.4%	*Cossura* sp. A	7.9%
Cossura sp. A	4.7%	*Pseudopolydora paucibranchiata**	6.2%
Zeuxo normani complex	4.0%	*Theora lubrica**	5.0%
Mediomastus sp.	3.6%	*Kirkegaardia siblina*	4.2%
*Sinocorophium heteroceratum**	2.8%	*Oligochaeta*	3.9%
Kirkegaardia siblina	2.8%	*Eochelidium* sp. A	2.8%
*Grandidierella japonica**	2.7%	*Mediomastus* sp.	2.2%
Oligochaeta	2.6%	*Euchone limnicola*	2.2%
Phtisica marina	2.5%	*Dorvillea (Schistomeringos) longicornis*	2.0%

[1] Denotes sensitive, pollution-intolerant species. *Denotes non-native species

Relative Abundance, Biomass, and Taxonomic Richness by Station

Figure 4-14 shows the relative proportions for abundance, biomass, and richness of each major phyla, separated by station (both surveys combined). The SWH stations consistently had a greater abundance of Arthropoda (primarily amphipods), and fewer Annelida than the Inner and Outer Harbor habitats. Echinoderms (primarily brittle stars) were the least abundant phylum and were found in greatest numbers at Station LA1 and several other Outer Harbor stations.

Biomass was dominated by Annelida at most of the Outer Harbor stations, while biomass at the Inner Harbor stations were dominated by a mix of molluscs and annelids. Biomass at the SWH stations was primarily arthropods and molluscs. Echinoderm biomass was very low at all stations.

While abundance and biomass of the major benthic infauna categories varied among stations and habitat type within the harbors, the relative taxonomic richness remained fairly consistent across all stations except at the SWH stations. Annelid taxa composed the largest percent of the total diversity at all stations except SWH Station LA8, at which arthropods contributed the most taxa. Inner and Outer Harbors locations overall were similar in terms of overall taxa richness, while the SWH stations had markedly fewer Annelid taxa but a greater number of Arthropod species than the other two location groups.

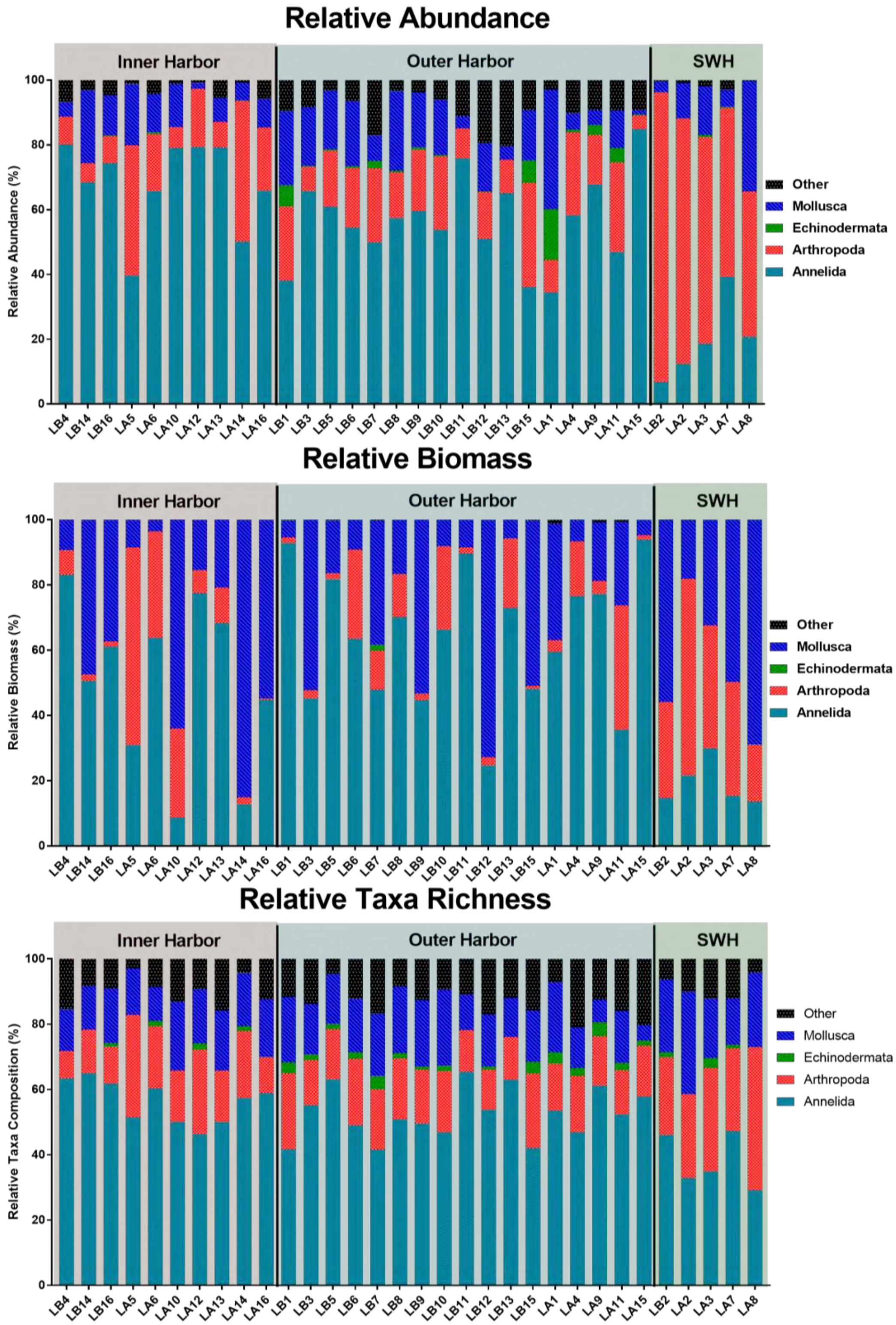


Figure 4-14. Relative Contribution by Major Phyla for Abundance, Biomass and Taxonomic Richness in Spring and Summer Combined

Benthic Infauna Characteristics by Habitat Type, Location, and Depth

To further assess spatial patterns of benthic infauna distribution within the Port Complex, stations were grouped according to habitat type (SWH, Outer Harbor, Inner Harbor), location (SWH, Outer Harbor, Basin, Channel, Slip) and depth (Shallow 0-7 m, Deep 7.1-18 m, Very Deep 18+ meters). Data from both sampling seasons were combined for this evaluation. Differences in diversity (taxonomic richness), abundance, and biomass were then assessed across these station groups. The results are shown in Figure 4-15 (habitat), Figure 4-16 (location), and Figure 4-17 (depth).

Species richness and biomass were similar across habitat types, but some separation was observed in mean abundance, which was highest in the SWH habitat (Figure 4-15). While all three diversity indicators showed a similar pattern, it is interesting to note that despite similar taxonomic richness, the Outer Harbor consistently exhibited the highest diversity index value. This reflects the fact that both the SWH and Inner Harbor habitats exhibited greater dominance by a few species; for example, three of the five SWH stations were overwhelmingly dominated by the amphipod *Amphideutopus oculatus*.

By location, mean species richness was similar everywhere except the Basin stations, which had somewhat lower taxonomic richness (Figure 4-16). Mean abundance was similar at all location groups except the SWH stations, which had greater mean abundance than all with the exception of a couple of outlier stations, one Basin (LA12) and one Slip (LA14). Mean biomass was similar across location types, although slightly lower at Basin stations.

Outer Harbor and Channel stations had highest species evenness and diversity compared to other stations while having the lowest abundance (Figure 4-16). As with habitat types, the SWH locations exhibited the lowest mean diversity index scores, particularly with Pielou's Evenness which is more sensitive to samples dominated by one or two taxa. Interestingly, despite the lower diversity, taxonomic richness at SWH stations was quite similar to Inner and Outer harbor areas.

When sorted by depth, species richness, diversity, and biomass were highest at the Very Deep stations, while abundance was highest at the Shallow stations (Figure 4-17).

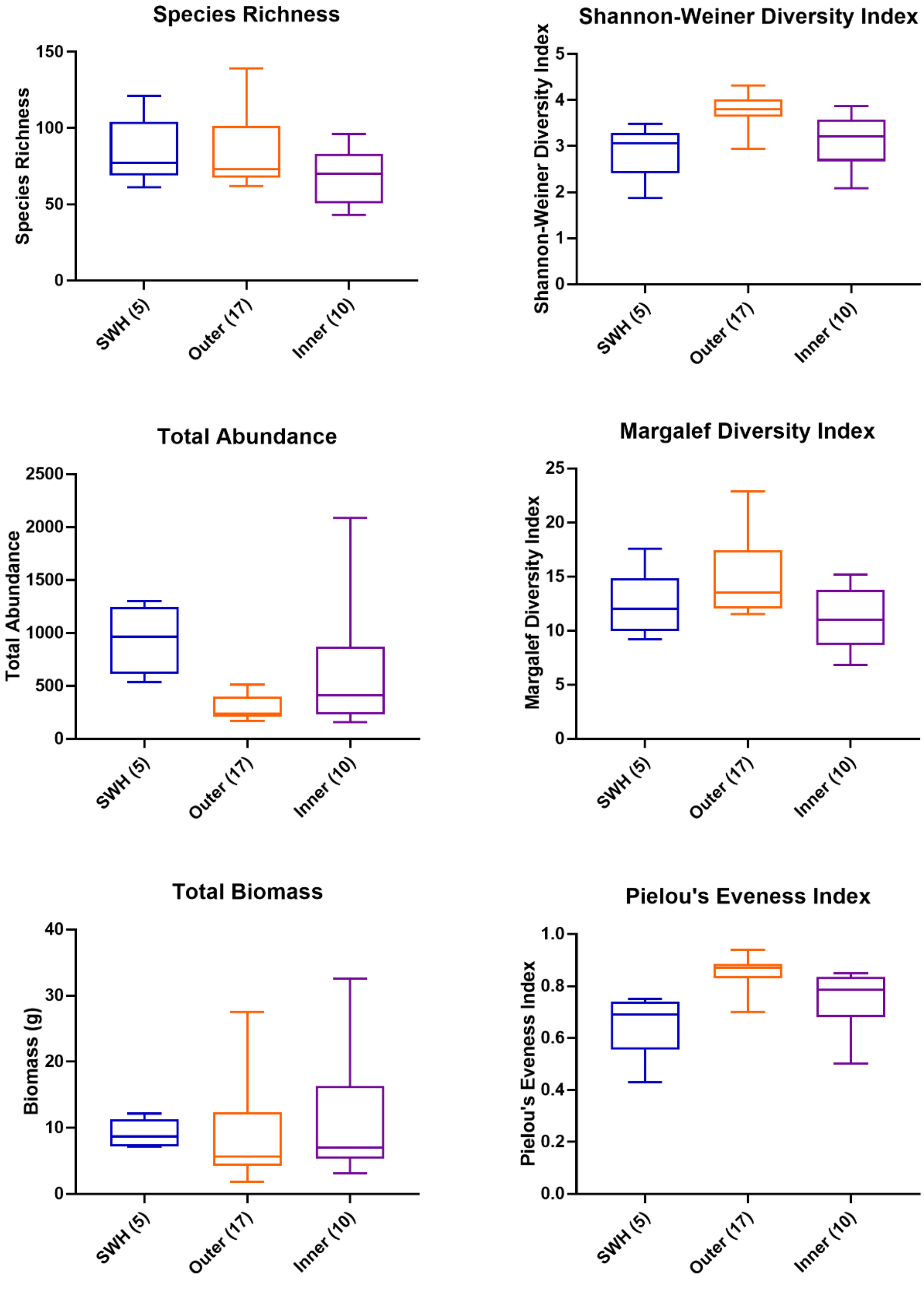


Figure 4-15. Benthic Infauna Summary Metrics by Station Habitats

Vertical lines depict the range of values, the horizontal line depicts the median of all values, and the boxes depict the 1st quartile above and below the median

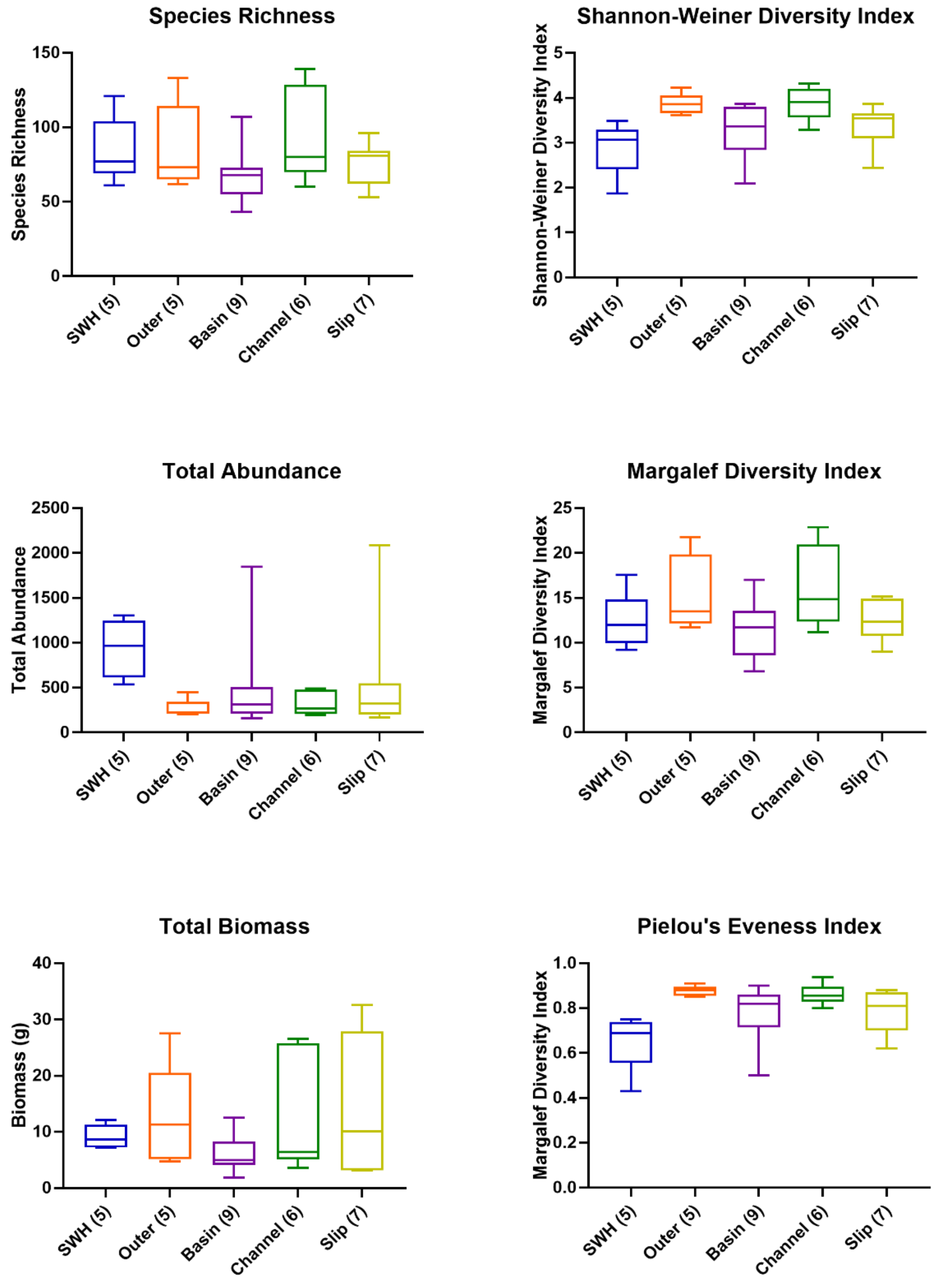


Figure 4-16. Benthic Infauna Summary Metrics by Station Locations

Vertical lines depict the range of values, the horizontal line depicts the median of all values, and the boxes depict the 1st quartile above and below the median

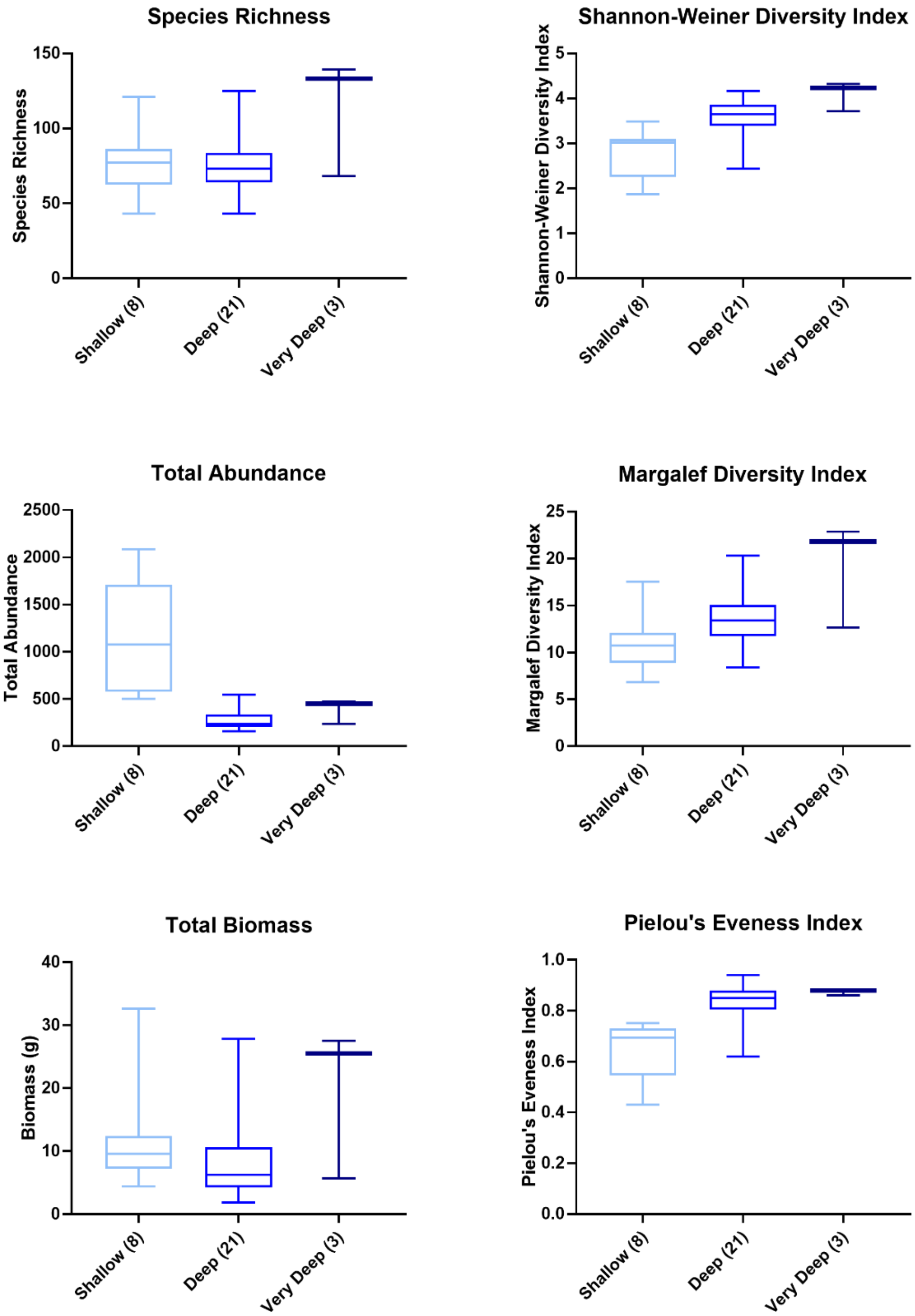


Figure 4-17. Benthic Infauna Summary Metrics by Station Depths

Vertical lines depict the range of values, the horizontal line depicts the median of all values, and the boxes depict the 1st quartile above and below the median

Distributional Patterns of Infauna Using Multivariate Analyses

Multivariate analysis of benthic infauna abundance data was performed by combining data across the spring and summer sampling events to assess potential differences in community composition patterns throughout the Port Complex (see Appendix A for a description of the analytical methodology). Additional shade plots, nMDS plots, and SIMPER analysis figures, as well as data tables for location, habitat, and depth strata groups, can be found in Appendix D. These analyses revealed the following primary patterns:

Benthic infaunal communities in the habitat groups were significantly different from one another. A few minor differences were noted within the location groups, but there was a limited degree of resolution overall. Benthic infaunal communities of the shallow areas were significantly different from the deep and very deep communities, which were not significantly different from one another. These patterns generally agree with those in the abundance, richness, and biomass discussion presented previously, and suggest that the benthic infauna assemblages within the Port Complex are influenced more by habitat type and depth than by location.

Cluster analysis using similarity profile (SIMPROF) grouping (see Appendix A for a description of the methodology) was performed on combined station abundance data from both seasons, and the resulting nMDS plot was overlaid on the station map (Figure 4-18) to examine spatial patterns. The resulting eleven station groups reveal a number of habitats within the Harbor Complex that have statistically different community composition, although the ecological implications of these groups are not well established. The shadeplot (Figure 4-19) and bar chart of relative phyla abundance (Figure 4-20) are useful tools to identify community differences between these groups.

The SWH stations (LA2, LA3, LA7, LA8, and LB2) formed two cluster groups (A and D) that were well separated from the other nine groups, which tended to overlap one another to a considerable extent (Figures 4-19 and 4-20). The high degree of separation is due to the dominance of amphipods, especially *Amphideutopus oculatus* and the relative scarcity, especially in Group A, of annelids. Of interest is the difference in grouping for SWH Stations LA2 (in Group A) and LA3 (in Group D) despite their physical proximity to each other. The main difference in the benthic infauna community appears to be the absence of some amphipod taxa from LA2, particularly S*inocorophium heteroceratum* (non-native), *Heterophoxus ellisi*, and *Eochelidium sp A*; *S. heteroceratum* made up 61% of the abundance for LA3 in the spring collection but was not found at all at LA2 in either collection event. Grain size from 2013 (Figure 4-21) indicates that there are also significant grain size differences that likely influence the different communities between the two groups. Stations LA2 and LB2 were predominantly sand (65% and 62%, respectively), while LA3, LA7 and LA 8 were predominantly silt (70%, 49% and 65%, respectively).

Despite their geographical separation, Consolidated Slip (LA14) and Cabrillo Marina (LA12) grouped together (Group C), which was likely due to the high abundance of the non-native polychaete *Pseudopolydora paucibranchiata*, the non-native amphipods *Grandidierella japonica and Zeuxo normani*, and oligochaetes (Figure 4-20). While the presence of non-natives may be expected in more degraded habitats, the relatively high abundances of *P. paucibranchiata* and *Theora lubrica* at SWH stations and may be a contributing factor to the shadeplot analysis placing these groups nearer to each other compared to other cluster groups that consisted of Channels, Slip and Outer Harbor stations (Figure 4-19).

Most groups followed readily apparent geographic patterns; for example, Group K consists of stations in the Inner Harbor/Back Channel areas of POLB, including the Turning Basin, Cerritos Channel, and Channels Two and Three. The largest group of stations (Group I) included most of the deep, Outer Harbor areas of the Port Complex, including the anchorages and adjacent channels and basins. Groups B (stations in the Main Channel of POLA) and G (Main Channel of POLB) were similar to one another in composition, which could be an indication of depth, as these six stations are all in the deep or very deep strata, or very possibly an indication of physical disturbance as a result of heavy vessel traffic. Group E was the only cluster to contain a single station (LA10, Fish Harbor). This station is a dead-end slip with little tidal flushing and was characterized by a unique assemblage of dominant or very abundant pollution-tolerant species.

Figure 4-18. Benthic Infauna Similarity Profile (SIMPROF) Analysis Groups (Both Seasons Combined)

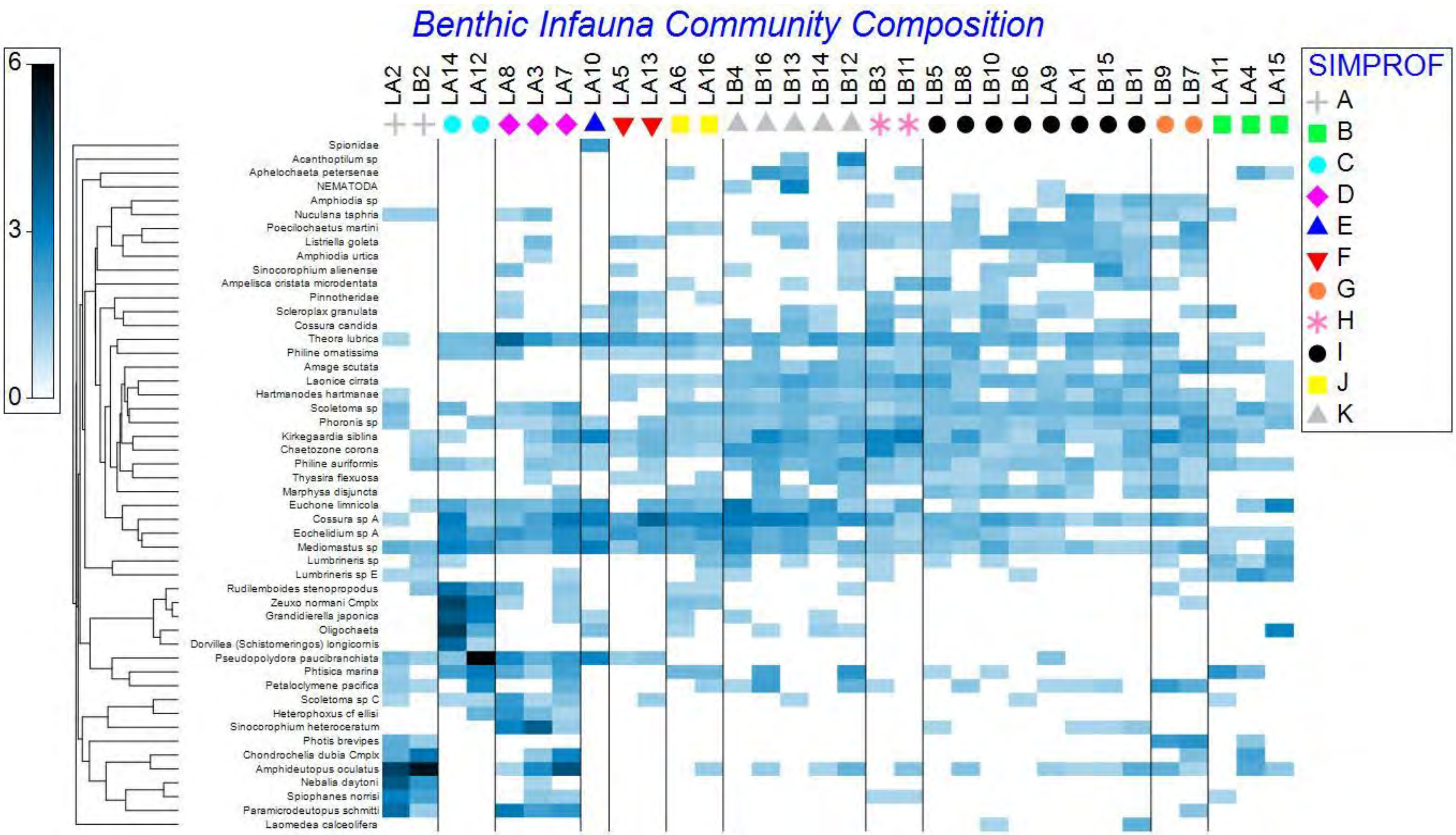


Figure 4-19. Benthic Infauna Community Shadeplot by SIMPROF Group – Top 50 Species (Both Seasons Combined)

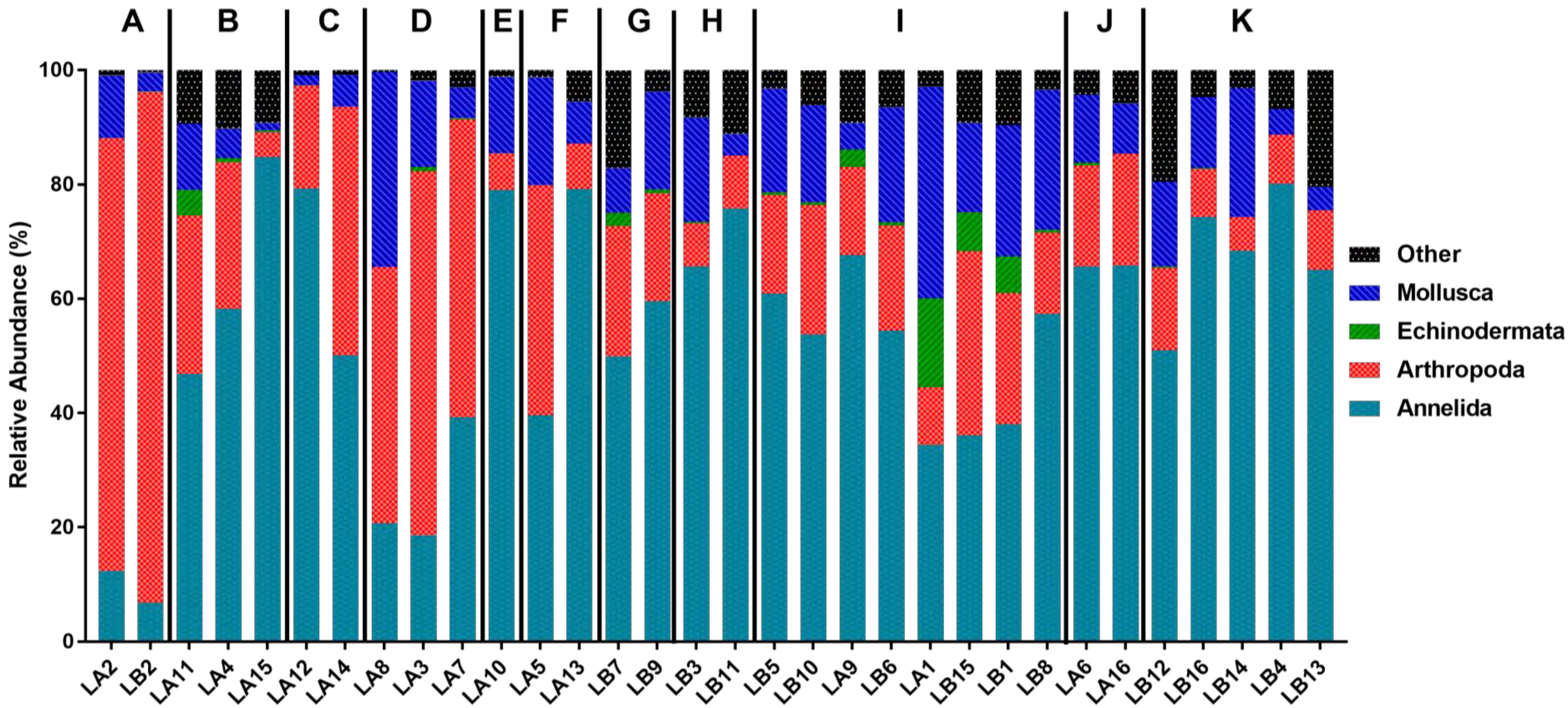


Figure 4-20. 2018 Benthic Infauna Phyla Relative Abundance by SIMPROF Group (Both Seasons Combined)

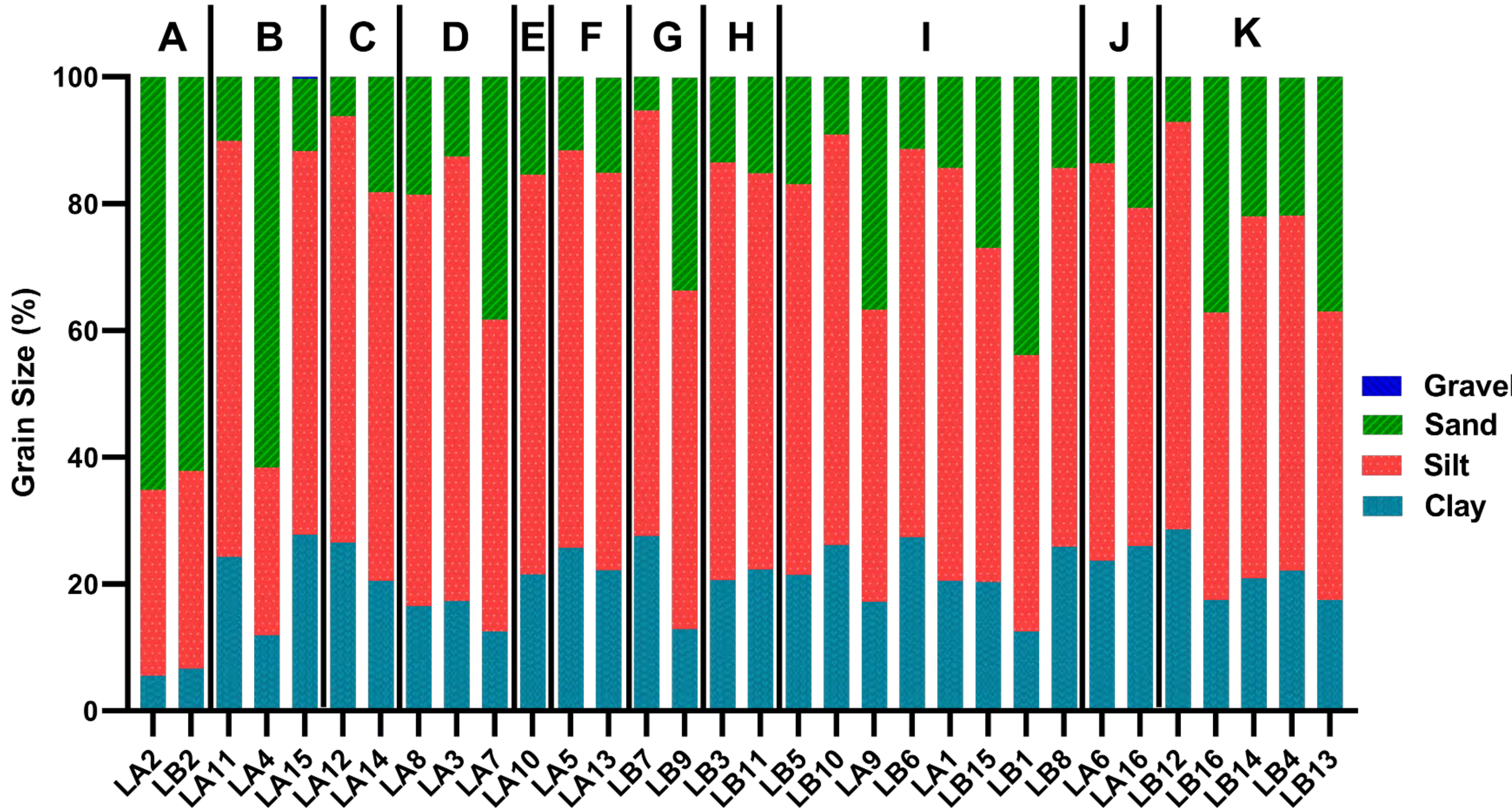


Figure 4-21. 2013 Grain Size (%) by SIMPROF Group (Both Seasons Combined)
Note: Grain size data overlaid on statistical grouping based on infauna community composition for comparison

4.3.3 Sediment Benthic Response Index (BRI) for Bays

The BRI (Smith et al. 2003) has assigned pollution tolerance values to 460 individual taxa collected from 341 sites in bays and harbors between Point Conception, California, and the U.S.-Mexico international border. These tolerance values are based on individual species frequency of abundance along a gradient between the most and least disturbed sites. (Species for which insufficient data was available [e.g., collected at only one site] were not assigned a pollution tolerance value.) The BRI is based on an abundance-weighted pollution tolerance score of the organisms present in a benthic sample. The higher the BRI score, the more degraded the benthic community represented by the sample. Two types of data are needed to calculate the BRI: the abundance of each species and its pollution tolerance score (P). A final BRI score was then defined as the abundance-weighted average tolerance value for all taxa in the sample (species without an associated pollution tolerance value are not included in the calculation). This average tolerance score is then compared to a set of thresholds that define the condition of the benthic community into four categories:

- Reference (BRI <39.96) - A community that would occur at a site in a similar habitat that is not pollution-stressed.
- Low Disturbance (BRI >39.96 to <49.15) - A community that may show signs of some stress but is within expected natural variability of the reference condition.
- Moderate Disturbance (BRI >49.15 to <73.27) - A community that shows clear signs of physical, chemical, natural, or anthropogenic stress.
- High Disturbance (BRI >73.27) - A clearly impacted community exhibiting a high magnitude of stress.

In this study, BRI was calculated for both the spring and summer surveys, although the index was developed with the recommendation that in Southern California sampling should occur in summer (July 1 – September 30; Smith et al. 2003). Regardless, the benthic infaunal communities at the majority of stations in the Port Complex were categorized as "Reference" in both the spring and summer surveys (84.4 and 90.6%, respectively; Table 4-5; Appendix D). The range of BRI scores between the two seasons was similar, with spring ranging from 4.3 (LA1) to 62.9 (LA12) and summer from -1.9 (LA1) to 53.4 (LA14).

Five stations in spring and three stations in summer were not scored as Reference, as shown in Table 4-6 and Appendix D. Stations LA10 (Fish Harbor), LA12 (Cabrillo Marina), and LA14 (Consolidated Slip) were not scored as Reference in both seasons. The BRI scores in LA10 and LA12 both decreased substantially between spring and summer collections, moving from the Moderately Disturbed category to Low Disturbance, while the BRI score at LA14 remained almost identical, in the Moderate Disturbance category. In examining the dominant taxa at these three sites, it is clear that LA14 contains a greater abundance of taxa considered to be pollution tolerant. The abundance-weighted mean tolerance value of the ten most abundant taxa (for those taxa that have an associated tolerance value) at Stations LA10 and LA12 were similar at 128 and 121 respectively, while Station LA14's tolerance value was 220. These stations with the highest BRI scores shared many of their most abundant species, including *Mediomastus sp*., *Pseudopolydora paucibranchiata*, *Grandidierella japonica*, and Oligochaetes, all of which have high pollution-tolerant values. Additionally, the taxonomic group with the second highest abundance-weighted pollution tolerance value (90.1) of the top ten dominant species (*Dorvillea*

(Schistomeringos) sp) was found almost exclusively at LA14 (200 individuals of the 225 found harbor-wide). Similarly, stations with the lowest BRI scores, including LB9 (POLB Outer Main Channel), LA1 (Outer Pier 400), LB1 (Outer Harbor Anchorages – Navy Mole), and LB7 (POLB Main Channel – Pilot Station) also shared many of the same taxa in their top 13 most abundant. These included the amphipods *Photis brevipes* and *Amphiodia sp*, the polychaetes *Laonice cirrata* and *Monticellina siblina*, and the bivalve *Theora lubrica*, all of which are considered highly or moderately sensitive to pollutants.

Table 4-5. Summary of BRI Scores and Condition Categories

Parameter	Spring	Summer
BRI Mean Score	24.3	20.9
BRI Score Range	4.3 to 62.9	-1.9 to 53.4
Categorical Ratings (% of stations)		
Reference	84.4	90.6
Low Disturbance	6.3	6.3
Moderate Disturbance	9.4	3.1
High Disturbance	0.0	0.0

Table 4-6. Summary of Sites Categorized as Non-Reference BRI

Condition Category	Spring	Summer
Low Disturbance	LA4, LA6	LA10, LA12
Moderate Disturbance	LA10, LA12, LA14	LA14
High Disturbance	None	None

4.3.4 Historical Comparisons

Benthic infauna communities have been sampled in the Port Complex dating back to 1954 (Reish 1959), although the configuration of the Port Complex and the sampling methodologies of the various studies have changed substantially over time. The initial surveys from the 1950s found that healthier areas were characterized by the polychaetes *Tharyx parvus*, *Cossura sp.*, and *Nereis procera*, while polluted areas were dominated in large numbers by the polychaete *Capitella capitata*. The most heavily polluted areas in the inner harbor had dissolved oxygen levels near zero at the bottom and no infauna were present. Only 70 species of benthic infaunal organisms were collected, the majority of which (45 species) were polychaetes.

In the four most recent biological surveys (2000-2018), between 258 and 369 species of benthic infauna have been identified within the Port Complex. The mean abundance across all stations over time declined from 4,100 individuals/m^2 in 2000 to 1,860 individuals/m^2 in 2008, to 1,215 individuals/m^2 in 2013 and then increased to 2,568 individuals/m^2 in 2018. Biomass has been quite variable, going from 49.7 g/m^2 in 2000 to 121 g/m^2 in 2008, to 37 g/m^2 in 2013, and 50.5 g/m^2 in 2018.

Table 4-7 shows the ten most abundant species of benthic infauna over ten historical surveys within the Port Complex, with the four most recent Biosurveys also noting total unique species and highlighting species that appear in the top ten at least three of four survey years. Studies between 1954 and 1996 do not include species richness due to substantial differences between studies in terms of sampling gear and taxonomic identification methods (MEC 1988).

The 2000, 2013, and 2018 Biosurveys identified similar numbers of species (344 to 369), while the 2008 Biosurvey only identified 258 species. However, the top ten species remained fairly consistent, with *Amphideutopus oculatus*, *Cossura sp A*, and *Theora lubrica* present in all four Biosurveys, and *Pseudopolydora paucibranchiata* was in the top ten in three of the four Biosurveys.

P. paucibranchiata and *T. lubrica*, which are considered non-native, have been among the most abundant benthic infauna species dating back as far as 1954 and 1986, respectively (Table 4-7). The annelid species *C. capitata* is a generalist feeder that has been noted to be tolerant of pollution (Dean 2008) and organic content enrichment (Thompson and Lowe 2004, Reish 1955), and has been observed to opportunistically colonize in areas with regular disturbance. This species was among the most abundant in studies from 1954, 1973-1974, and 1983, but has not been dominant in the infauna community since then. *C. capitata* has been observed during the last four Biosurveys, but its abundance across all seasons has decreased steadily from 325 in 2000, to 23 in 2008, 27 in 2013, and only 16 individuals at five stations in 2018, which is indicative of improving sediment conditions. The station with the highest abundance of *C. capitata* (eight individuals) was Cabrillo Marina (LA12), followed by the Outer Main Channel of POLA (LA11) and Channel 2 in POLB (LB4) with three individuals at each and Outer Main Channel of POLB (LB9) and Consolidated Slip (LA14) with one individual at each. This same increasing trend in condition can also be seen in that the number of relatively sensitive, pollution-intolerant taxa in the top ten most abundant taxa (Table 4-7) has also generally increased (with some variability) beginning with the 1994/1996 Biosurveys.

While the BRI was evaluated for the 2013 Biosurvey, it was not included in previous Biosurvey studies. Additionally, the method by which the BRI was calculated in the 2013 study was slightly different from that in the 2018 study (See Appendix A for details). While differences in BRI calculation methods have the potential to introduce bias, BRI results in the 2018 Biosurvey study are generally similar to those of the 2013 study, as discussed below.

Similar to the 2018 study, the vast majority of stations in the 2013 study were considered to have Reference condition infaunal communities in both spring and summer collections (94 and 97%, respectively). While no stations were rated as Moderately Disturbed in 2013 and only two were rated as Low Disturbance, those two were LA10 and LA14, both rated as Moderately Disturbed in 2018. While the BRI was not calculated in prior Biosurvey studies, both the 2000 (MEC 2002) and 2008 studies (SAIC 2010) indicate that Stations LA10 and LA14 were dominated by pollution-tolerant taxa, and cluster analysis showed that these two stations would often form their own single-station group or be grouped together.

In addition to the Biosurvey studies, the Bight Regional Monitoring program collected benthic infauna and calculated BRI scores for numerous stations throughout the Port Complex in 2003 (n=17), 2008 (n=33), 2013 (n=25), and 2018 (n=40; Ranasinghe 2007; Ranasinghe 2012). While the randomized design of the Bight surveys do not result in consistent samples taken year over year unlike the current 32 stations in the Biosurvey, they do provide context with which to interpret trends within the benthic infauna of the harbors. The Bight survey also includes samples in East San Pedro Bay, which is not sampled as part of the Biosurveys. In Bight 2003, 88% of the stations were categorized as having Reference condition infaunal communities, 6% as Low Disturbance (1 station); and 6% as Moderately Disturbed (1 station) (Table 4-8). In 2008, 97% of stations sampled in the Port Complex were considered Reference, 0% as Low Disturbance, and 3% as Moderately Disturbed (1 station). In 2013, 92% of stations sampled in the Port Complex were considered Reference, 4% as Low Disturbance (1 station), and 4% as Moderately Disturbed (1 station). Benthic infauna results are not yet available from the 2018 Bight Regional survey. In these five studies (i.e. Bight 2003, Bight 2008, Bight 2013, Biosurvey 2013, and Biosurvey 2018), no stations were classified as having Highly Disturbed infaunal communities, along with only a small percentage of Moderately Disturbed stations (Table 4-8), indicating that the overall benthic infaunal community condition in the Port Complex has been good.

Table 4-7. Historical Comparison of the Ten Most Abundant Benthic Infauna Taxa in the Port Complex, in Descending Order of Dominance

Year	1954	1973-1974	1978	1983	1986-1987	1994 and 1996	2000	2008	2013	2018
Source	Reish 1959	HEP 1976	HEP 1980	MBC 1984	MEC 1988	SAIC/MEC1997	MEC 2002	SAIC 2010	MBC 2016	Present Study
1	**Pseudopolydora paucibranchiata**	Tharyx parvus	Cossura candida	Cossura candida	Cossura candida	Cossura candida	**Pseudopolydora paucibranchiata**	**Theora lubrica**	Amphideutopus oculatus**	Amphideutopus oculatus**
2	Tharyx parvus	Capitita ambiseta	Mediomastus californiensis	Prinospio cirrifera	Prionospio lighti**	Leitoscoloplos pugettensis	Amphideutopus oculatus**	Nebalia pugettensis-complex	Cossura sp A	**Pseudopolydora paucibranchiata**
3	Cossura candida	Cossura candida	Tharyx sp	Capitella capitata	Mediomastus spp	Aphelochaeta multifilis Type 2	Cossura sp A	Cossura sp A	**Theora lubrica**	Cossura sp A
4	Capitella capitata	Capitella capitata	Prionospio cirrifera	**Pseudopolydora paucibranchiata**	Levinsenia gracilis	Chaetozone corona**	**Theora lubrica**	Streblosoma sp B	**Sinocorophium heteroceratum**	**Theora lubrica**
5	Cirriformia luxuriosa	Paraonis gracilis oculata	Capitella capitata	Polydora ligni	Euchone limnicola	Amphideutopus oculatus**	Euphilomedes carcharodonta**	Monticellina siblina	Euchone limnicola	Kirkegaardia siblina
6	Dorvillea articulata	Euchone limnicola	Paraonis gracilis oculata	Tharyx sp	**Theora lubrica**	Mediomastus sp	Monticellina siblina	Amphideutopus oculatus**	Paramage scutata**	Oligochaeta
7	Phoronids	Chaetozone corona**	Euchone limnicola	Mediomastus ambiseta	Tharyx sp C	Monticellina tesselata	Euchone limnicola	Scleroplax granulata	Aphelochaeta monilaris	Mediomastus sp
8	Nereis procera	Sigambra tentaculata	Haploscoloplos elongatus	Carinomella lactea	Nematoda	Monticellina sp 1	Mediomastus spp	Pista agassizi	Scleroplax granulata	Zeuxo normani Cmplx
9	Capitita ambiseta	Prionospio cirrifera	Sigambra tentaculata	Mediomastus californiensis	Tharyx sp A	Paraprionospio pinnata	Spiophanes berkeleyorum	**Pseudopolydora paucibranchiata**	Neotrypaea spp**	Eochelidium sp A
10	Macoma nasuta	Schistomeringos longicornis	Nephtys cornuta franciscana	Paraprionospio pinnata	Tharyx tesselata	Euclymene grossanewporti	Chaetozone corona**	Pista wui	Pista wui	Euchone limnicola
Species Richness	-	-	-	-	-	-	361 species	258 species	344 species	369 species
# Sensitive Taxa	0	1	0	0	1	2	3	1	3	1

Note: Species richness not provided for 1954-1996 due to inconsistent sampling and taxonomy methods between studies. Colors are provided in 2000-2018 to highlight species that appear in the top 10 in at least three of the four Biosurveys. Species in **bold** are classified by the CDFW NEMESIS database as non-native. Species followed by ** are considered relatively sensitive, pollution-intolerant taxa.

Table 4-8. Summary of Port Complex BRI Infauna Condition Categorical Ratings for Biosurvey and Bight Regional Surveys since 2003

BRI Condition Category	Bight 2003	Bight 2008	Biosurvey 2013[a] & Bight 2013[b]	Biosurvey 2018 [a,c]
	% of Sites Sampled			
Reference	88	97	96 (92)	88
Low Disturbance	6	0	4 (4)	6
Moderate Disturbance	6	3	0 (4)	6
High Disturbance	0	0	0	0

[a] These values are means of the spring and summer BRI survey values
[b] Values in parentheses are BRI results for Bight samples collected in summer 2013.
[c] BRI scores are not yet available for the 2018 Bight benthic infauna data

4.3.5 Discussion

In general, overall abundance, richness, biomass, and diversity were similar between spring and summer surveys. Some minor differences were noted, specifically a shift in the dominant biomass group from Mollusca in spring to Annelida in summer and a slight shift in abundance to more amphipods and slightly less annelids in summer. Of particular interest was the observation that abundances of infauna at Stations LA12 (Southwest Basin) and LA14 (Consolidated Slip) were substantially greater than at all other stations in both spring and summer. Both of these stations were also categorized as Moderately Disturbed based on the BRI. In previous studies LA14 has consistently exhibited elevated abundances, while LA12 has consistently been among the sites with the lowest abundances. This change in abundance at LA12 is due in large part to differences in the abundance of the spionid worm *Pseudopolydora paucibranchiata*: 39 individuals (out of a total abundance of 199) were observed in the 2013 Biosurvey, compared to 1,263 individuals (out of a total abundance of 1,844) in the 2018 Biosurvey. *P. paucibranchiata* is considered a pollution-tolerant species characteristic of disturbed environments, and its dramatic increased presence at LA12 in 2018, may indicate a decrease in sediment quality or increase in sediment disturbance at this particular location.

The most abundant species across the Port Complex in the 2018 Biosurvey were the amphipod *Amphideutopus oculatus* and the polychaete *P. paucibranchiata*; however, the vast majority of these individuals occurred in only a very few locations. *A. oculatus*, a pollution-sensitive species, was found almost exclusively at LA2, LA7 and LB2, while *P. paucibranchiata*, a pollution-tolerant species, was found predominantly at LA12.

It was apparent when evaluating the data by habitat, location, and depth strata, that depth (SWH, Deep, and Very Deep) and habitat (Inner Harbor, Outer Harbor, SWH) were the key factors influencing the benthic community's characteristics. The SWH stations typically exhibited higher abundance but reduced diversity relative to other sites, and nMDS analysis indicated a different community composition among the three habitat types. Among the depth strata, Very Deep stations had significantly greater species richness, biomass and diversity, while the Shallow stations had significantly greater abundance than the deeper stations. This is somewhat different from the 2013 Biosurvey results in which species richness, biomass, and diversity were all very similar among the three depth strata.

Cluster analysis of the benthic infauna communities showed that stations tended to group by location within the ports, with groups consisting of the back channel of POLB, outer anchorages, main channel of POLA, Seaplane Lagoon, Los Angeles West Basin, and Long Beach West Basin. Fish Harbor (Station LA10) was the only cluster to contain a single station based upon its unique combination of pollution-tolerant taxa. Consolidated Slip (LA14) and Cabrillo Marina (LA12) although not in close proximity, were within the same biological cluster, suggesting that they have closely related communities dominated by pollution-tolerant taxa.

Overall, the 2018 Biosurvey reaffirmed the findings of the 2013 Biosurvey, showing continued improvement of the benthic infauna community in that both Biosurveys showed a general reduction of pollutant-tolerant species, increasing species diversity, and a continued high percentage of sites categorized as Reference or Low Disturbance according to the BRI.

4.4 Epibenthic Invertebrates

Epibenthic invertebrates were captured with an otter trawl at 26 stations in the spring and summer of 2018 (Table 4-22). Detailed maps of trawl locations and tables that compare stations, species, day versus night, and spring versus summer can be found in Appendix D.

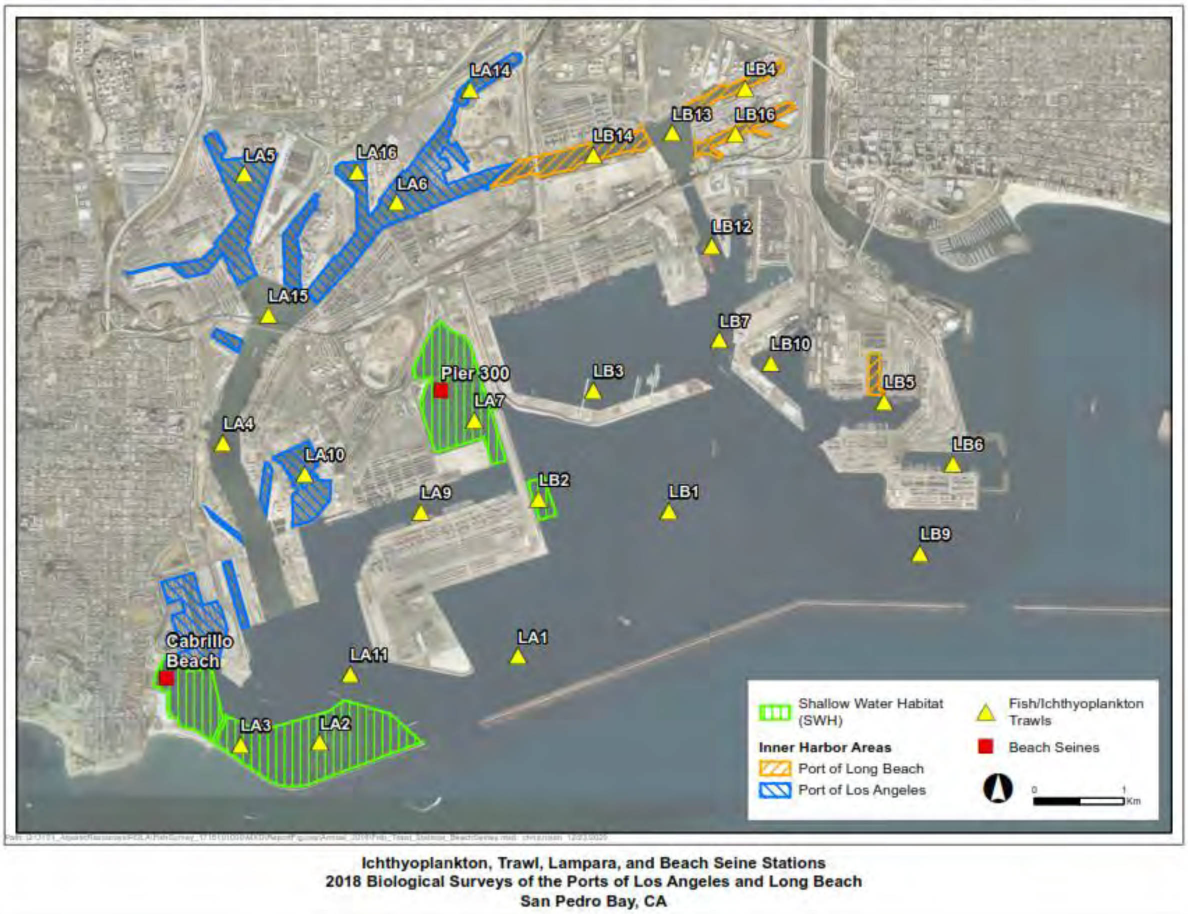


Figure 4-22. Locations for Epibenthic Invertebrate Sampling

4.4.1 Species Comparisons

Species Richness

A total of 121 epibenthic invertebrate species were collected in the otter trawl and beach seine sampling across all seasons. Otter trawls collected 111 unique species, beach seines collected another 5 unique species, and 5 species were collected using both otter trawl and beach seines.

Otter trawls collected 102 species in daytime sampling and 95 at night, and 99 species in spring compared to 81 in the summer; however, none of these differences was statistically significant. Across both seasons station LB9 (Outer Channel) had the lowest number of species with 12 while station LB12 (Main Channel – Police Station) had the highest number with 39.

Species richness of invertebrates collected at the two beach seine stations was similar: six species at Seaplane Lagoon and five at Cabrillo Beach. However, the species assemblages at the two locations were almost entirely different as only one species (the green shrimp, *Hippolyte clarki*) was captured at both stations.

Abundance

Across all seasons and stations, 12,989 epibenthic invertebrates were captured using otter trawls (Table 4-9) and 1,039 were captured using beach seines (Table 4-10). The two bryozoan species (*Amathia verticillata* and *Thalamoporella californica*) were not able to be quantified for abundance in the field and are excluded from abundance data.

Target shrimp captured in otter trawl

The most abundant species captured by otter trawls was the target shrimp (*Sicyonia penicillata;* 39% of total abundance), followed by tunicates (sea squirts, *Ciona sp.*; 7.98%), and the blackspot shrimp (*Crangon nigromaculata*; 6.8%). Invertebrates in otter trawls were more abundant at night than during the day (9,032 and 3,957 respectively) and more abundant in spring than in summer (8,985 and 3,999 respectively). Both the day-night and the seasonal differences were statistically different. Differences between day and night abundance were largely driven by increased capture rate across many species, which may be the result of increased foraging at night by the more mobile species such as shrimp, lobsters, and crabs. The difference between spring and summer abundance was in large part due to differences in the abundance of the two most common shrimp species, target shrimp and blackspot shrimp. Combined, the two species totaled 5,383 individuals in the spring but only 612 in the summer. Total abundance per station ranged from 123 at LB2 (LB SWH) to 1,646 at LB7 (Main Channel – Pilot Station).

The abundance of invertebrates collected by beach seines was variable across seasons and may also have been influenced by sampling occurring during different tidal heights and in somewhat different portions of the shallow eelgrass habitats (Appendix D). In total, 881 invertebrates were collected at Seaplane Lagoon compared to 158 at Cabrillo Beach. Seaplane Lagoon was dominated by green shrimp (72% of total abundance) and the western mud nassa snail (*Nassarius tiarula*; 28%). Cabrillo Beach was dominated by a single species, the purple Olivella snail (*Calianax biplicata*; 96% of total abundance)

Biomass

A total of 167 kg of epibenthic invertebrates was captured using otter trawls (Table 4-9) and 0.93 kg was captured using beach seines (Table 4-10). All species were weighed upon capture, which makes biomass the most representative metric for comparisons among day versus night, spring versus summer, and for multivariate analysis since it also included species which could not be enumerated such as bryozoans and sponges.

The species with the highest total biomass in trawls were target shrimp (35% of the total biomass), spaghetti bryozoan (*Amathia verticillata*; 23%), and California spiny lobster (*Panulirus interruptus*; 9.7%). Total biomass was greater during the night than day (109 kg and 58.0 kg, respectively), but was nearly equal in the spring and summer (83.5 kg and 83.6 kg, respectively). Across both seasons (Table 4-9), biomass per station ranged from 0.31 kg at LA14 (Consolidated Slip) to 25.3 kg at LB 7 (Main Channel – Pilot Station). There was no significant difference in invertebrate biomass between spring and summer, but there was a statistically significant difference between invertebrate biomass collected during the day and night (see Appendix D).

Total invertebrate biomass in beach seines (Table 4-10) was greater at Cabrillo Beach (710 g) than at Seaplane Lagoon (221 g). Seaplane Lagoon biomass was dominated by western mud nassa (67% of total biomass) and green shrimp (23%). At Cabrillo Beach only one California spiny lobster was captured, but it made up over half (67%) of the total biomass, and purple Olivella (32%) was the only other species to make up more than 1% of the total biomass.

Table 4-9. Epibenthic Invertebrate Collected with Otter Trawl Summary – Ranked by Ecological Index (Spring and Summer Events Combined)

Species			Total Abundance per Taxa	% of Total Abundance	Total Biomass per Taxa (kg)	% of Total Biomass	Total Density (g/100 m^2)	Frequency of Trawl Capture (%)	Ecological Index
Phylum	Common name	Scientific Name							
Arthropoda	Target shrimp	*Sicyonia penicillata*	5115	39.4	59.1	35.4	629	100	7474
Bryozoa	Spaghetti bryozoan	*Amathia verticillata*	NA	NA	38.1	22.8	406	42.3	965
Chordata	Sea squirt	*Ciona sp.*	1036	7.98	5.73	3.43	61.0	73.1	833
Arthropoda	Blackspot shrimp	*Crangon nigromaculata*	880	6.77	0.78	0.47	8.28	100	724
Arthropoda	Xantu's swimming crab	*Portunis xantusii*	454	3.50	7.63	4.56	81.2	88.5	713
Chordata	Warty tunicate	*Styela clava*	380	2.93	2.63	1.57	28.0	76.9	346
Arthropoda	California spiny lobster	*Panulirus interruptus*	25	0.19	16.3	9.73	173	30.8	305
Chordata	Tunicate A	*Tunicate Spp.*	750	5.77	1.78	1.07	19.0	42.3	289
Arthropoda	Tuberculate pear crab	*Pyromaia tuberculata*	337	2.59	0.21	0.13	2.27	100	272
Mollusca	Carinated dove snail	*Alia carinata*	983	7.57	0.03	0.02	0.34	30.8	233
Mollusca	Kelp scallop	*Leptopecten latiauratus*	324	2.49	0.18	0.11	1.93	76.9	200
Arthropoda	Ridgeback prawn	*Sicyonia ingentis*	250	1.92	1.48	0.89	15.8	53.8	151
Mollusca	Pacific oyster	*Crassostrea gigas*	149	1.15	2.40	1.44	25.6	57.7	149
Mollusca	White bubble snail	*Philine auriformis*	308	2.37	0.14	0.09	1.52	50.0	123
Mollusca	Mediterranean mussel	*Mytilus galloprovincialis*	200	1.54	0.76	0.46	8.10	46.2	92.1
Chordata	Mogula sp.	*Mogula sp.*	158	1.22	0.50	0.30	5.29	50.0	75.7
Arthropoda	Peruvian night shrimp	*Processa peruviana*	159	1.22	0.08	0.05	0.86	53.8	68.5
Chordata	Pleated tunicate	*Styela plicata*	77	0.59	1.23	0.73	13.1	46.2	61.3
Mollusca	Gould's bubble snail	*Bulla gouldiana*	139	1.07	1.54	0.92	16.4	26.9	53.6
Cnidaria	Sea pen	*Stylatula elongata*	336	2.59	1.23	0.74	13.1	15.4	51.2
Mollusca	Navanax	*Navanax inermis*	31	0.24	1.50	0.90	16.0	42.3	48.1
Echinodermata	California sea cucumber	*Apostichopus californicus*	18	0.14	4.70	2.81	50.0	11.5	34.0
Arthropoda	Yellowleg shrimp	*Farfantepenaeus californiensis*	20	0.15	0.85	0.51	9.06	42.3	28.1
Cnidaria	Sea pen	*Acanthoptilum sp.*	156	1.20	0.37	0.22	3.96	19.2	27.4
Echinodermata	Warty sea cucumber	*Apostichopus parvimensis*	10	0.08	1.35	0.81	14.4	26.9	23.8
Porifera	Yellow bay sponge	*Suberites sp.*	1	0.01	7.19	4.30	76.6	3.85	16.6
Mollusca	Hedgpeth's dorid	*Polycera hedgpethi*	56	0.43	0.02	0.01	0.20	26.9	11.9
Arthropoda	Yellow rock crab	*Cancer anthonyi*	5	0.04	1.20	0.72	12.8	15.4	11.7
Mollusca	Slipper snail	*Crepidula sp.*	62	0.48	0.05	0.03	0.49	23.1	11.7
Arthropoda	Alaska bay shrimp	*Crangon alaskensis*	39	0.30	0.03	0.01	0.27	34.6	10.9
Arthropoda	Broken back shrimp	*Heptacarpus sp.*	41	0.32	0.02	0.01	0.22	30.8	10.1
Mollusca	2 spot octopus	*Octopus bimaculoides*	5	0.04	0.70	0.42	7.49	19.2	8.84
Mollusca	California sea hare	*Aplysia californica*	2	0.02	1.69	1.01	17.9	7.69	7.87
Mollusca	Kellet's welk	*Kelletia kelletii*	15	0.12	0.37	0.22	3.92	19.2	6.45
Arthropoda	Sheep crab	*Loxorhynchus grandis*	3	0.02	0.81	0.49	8.63	11.5	5.86
Echinodermata	Spiny brittle star	*Ophiothrix spiculata*	30	0.23	0.03	0.02	0.28	23.1	5.69
Bryozoa	Bryozoan	*Thalamoporella californica*	NA	NA	0.49	0.29	5.20	19.2	5.61
Arthropoda	Black clawed crab	*Lophopanopeus bellus*	16	0.12	0.02	0.01	0.20	38.5	5.17
Mollusca	Keyhole limpet	*Megathura crenulata*	2	0.02	0.81	0.49	8.65	7.69	3.86
Mollusca	Opalescent sea slug	*Hermissenda opalescens*	13	0.10	0.02	0.01	0.18	34.6	3.82
Arthropoda	Graceful rock crab	*Metacarcinus gracilis*	6	0.05	0.31	0.19	3.30	15.4	3.56
Porifera	Yellow sponge 2	*Sponge Spp.*	2	0.02	0.64	0.38	6.80	7.69	3.06
Mollusca	Festive rock shell	*Pteropurpura festiva*	11	0.08	0.07	0.04	0.78	23.1	2.96
Mollusca	Spiny cup-and-saucer shell limpet	*Crucibulum spinosum*	18	0.14	0.01	0.01	0.10	19.2	2.77
Arthropoda	Stimpson's shrimp	*Heptacarpus stimpsonii*	21	0.16	0.01	0.01	0.12	15.4	2.59
Arthropoda	Spotwrist hermit	*Pagurus spilocarpus*	11	0.08	0.08	0.05	0.82	19.2	2.51
Mollusca	Wavy top turban	*Megastraea undosa*	2	0.02	0.49	0.29	5.23	7.69	2.38
Cnidaria	Proliferating anemone	*Epiactis prolifera*	25	0.19	0.02	0.01	0.18	11.5	2.34
Mollusca	Red octopus	*Octopus rubescens*	4	0.03	0.26	0.16	2.80	11.5	2.17
Arthropoda	Oriental shrimp	*Palaemon macrodactylus*	23	0.18	0.01	0.01	0.13	11.5	2.13
Arthropoda	Dock shrimp	*Pandalus danae*	21	0.16	0.01	0.01	0.10	7.69	1.29
Echinodermata	Bat star	*Patiria miniata*	6	0.05	0.18	0.11	1.91	7.69	1.18
Arthropoda	Barnacle	*Balanidae*	18	0.14	0.01	0.00	0.09	7.69	1.10
Arthropoda	Stout bodied shrimp	*Heptacarpus palpator*	8	0.06	0.01	0.00	0.07	15.4	1.01
Mollusca	San Diego Dorid	*Diaulula sandiegensis*	7	0.05	0.02	0.01	0.20	15.4	1.00
Mollusca	Santa Barbara janolus	*Janolus barbarensis*	6	0.05	0.01	0.00	0.09	19.2	0.98
Echinodermata	Red urchin	*Mesocentrotus franciscanus*	8	0.06	0.04	0.02	0.39	11.5	0.97
Echinodermata	Purple urchin	*Strongylocentrotus purpuratus*	6	0.05	0.06	0.03	0.61	11.5	0.93
Cnidaria	Cup coral	*Cup Coral spp.*	14	0.11	0.01	0.01	0.15	7.69	0.89
Mollusca	Channeled dog welk	*Caesia fossatus*	5	0.04	0.01	0.00	0.09	19.2	0.83
Arthropoda	Moss crab	*Loxorhynchus crispatus*	4	0.03	0.02	0.01	0.24	15.4	0.69
Mollusca	California cone snail	*Californiconus californicus*	5	0.04	0.03	0.02	0.36	11.5	0.68
Mollusca	Spotted triopha	*Triopha maculata*	7	0.05	0.01	0.00	0.07	11.5	0.67

Table 4-9 (continued). Epibenthic Invertebrate Collected with Otter Trawl Summary – Ranked by Ecological Index (Spring and Summer Events Combined)

Species			Total Abundance per Taxa	% of Total Abundance	Total Biomass per Taxa (kg)	% of Total Biomass	Total Density (g/100 m^2)	Frequency of Trawl Capture (%)	Ecological Index
Phylum	Common name	Scientific Name							
Mollusca	Hemphill's file shell	*Limaria hemphilli*	5	0.04	0.01	0.00	0.06	15.4	0.65
Mollusca	Milky venus	*Compsomyax subdiaphana*	4	0.03	0.02	0.01	0.18	15.4	0.63
Mollusca	Belcher's chorus shell	*Forreria belcheri*	1	0.01	0.25	0.15	2.61	3.85	0.59
Arthropoda	Stout coastal shrimp	*Heptacarpus brevirostris*	6	0.05	0.00	0.00	0.03	11.5	0.55
Mollusca	Hooded nudibranch	*Melibe leonina*	7	0.05	0.02	0.01	0.24	7.69	0.52
Mollusca	Egg cockle	*Laevicardium substriatum*	4	0.03	0.01	0.00	0.05	15.4	0.52
Mollusca	Market squid	*Loligo opalescens*	5	0.04	0.01	0.00	0.07	11.5	0.49
Echinodermata	Ophiuroid	*Ophionereis annulata*	5	0.04	0.01	0.00	0.05	11.5	0.48
Arthropoda	Crangonidae shrimp	*Crangon sp.*	14	0.11	0.01	0.01	0.11	3.85	0.44
Echinodermata	Sea star	*Astropecten ornatissimus*	2	0.02	0.07	0.04	0.72	7.69	0.43
Arthropoda	Kincaid coastal shrimp	*Heptacarpus kincaidii*	13	0.10	0.01	0.01	0.11	3.85	0.41
Arthropoda	Blacktail shrimp	*Crangon nigricauda*	6	0.05	0.01	0.00	0.06	7.69	0.38
Arthropoda	Shore crab	*Hemigrapsus oregonensis*	4	0.03	0.00	0.00	0.03	11.5	0.38
Mollusca	Native oyster	*Ostrea lurida*	4	0.03	0.03	0.02	0.30	7.69	0.37
Mollusca	Green zebra mussel	*Musculista senhousii*	10	0.08	0.01	0.01	0.11	3.85	0.32
Mollusca	Mollusk	*Hesperato vitellina*	3	0.02	0.00	0.00	0.04	11.5	0.29
Arthropoda	Crab	*Cancer sp.*	4	0.03	0.01	0.00	0.05	7.69	0.26
Arthropoda	Tube-dwelling pea crab	*Pinnixa tubicola*	4	0.03	0.01	0.00	0.05	7.69	0.26
Arthropoda	California rock crab	*Romaleon antennarium*	1	0.01	0.10	0.06	1.06	3.85	0.26
Mollusca	Dendronotid nudibranch	*Tritonia tetraquetra*	2	0.02	0.08	0.05	0.84	3.85	0.24
Mollusca	Mollusk	*Nassarius mendicas*	3	0.02	0.00	0.00	0.04	7.69	0.20
Arthropoda	Littoral pistol shrimp	*Synalpheus lockingtoni*	3	0.02	0.00	0.00	0.02	7.69	0.19
Mollusca	Sea snail	*Neosimnia avena*	5	0.04	0.01	0.01	0.12	3.85	0.17
Arthropoda	Ghost shrimp	*Neotrypaea biffari*	2	0.02	0.01	0.00	0.06	7.69	0.15
Mollusca	Sea snail	*Pteropurpura vokesae*	2	0.02	0.01	0.00	0.06	7.69	0.15
Mollusca	Nuculana sp.	*Nuculana sp.*	4	0.03	0.01	0.01	0.10	3.85	0.14
Arthropoda	Spined kelp crab	*Pugettia dalli*	2	0.02	0.00	0.00	0.02	7.69	0.13
Mollusca	Dorid nudibranch	*Thordisa rubescens*	1	0.01	0.04	0.02	0.39	3.85	0.11
Echinodermata	White urchin	*Lytechinus pictus*	3	0.02	0.01	0.00	0.06	3.85	0.10
Mollusca	Dorid nudibranch	*Doridoidea*	3	0.02	0.00	0.00	0.01	3.85	0.09
Mollusca	Bent nose clam	*Macoma nasuta*	2	0.02	0.01	0.00	0.09	3.85	0.08
Arthropoda	Red rock crab	*Cancer productus*	2	0.02	0.00	0.00	0.03	3.85	0.07
Echinodermata	Sea star	*Astropecten californicus*	2	0.02	0.00	0.00	0.03	3.85	0.07
Arthropoda	Shrimp	*Eualus sp.*	2	0.02	0.00	0.00	0.01	3.85	0.06
Echinodermata	Spiny sand star	*Astropecten armatus*	1	0.01	0.01	0.01	0.10	3.85	0.05
Mollusca	3 wing murex	*Pteropurpura trialata*	1	0.01	0.01	0.00	0.06	3.85	0.04
Mollusca	California jacknife clam	*Tagelus californianus*	1	0.01	0.01	0.00	0.06	3.85	0.04
Cnidaria	Red gorgonian	*Leptogorgia chilensis*	1	0.01	0.01	0.00	0.05	3.85	0.04
Mollusca	Pacific calico oyster	*Argopecten ventricosus*	1	0.01	0.01	0.00	0.05	3.85	0.04
Mollusca	California armina	*Armina californica*	1	0.01	0.01	0.00	0.05	3.85	0.04
Mollusca	Sea slug	*Dendrodoris sp.*	1	0.01	0.00	0.00	0.03	3.85	0.04
Mollusca	Snail	*Snail Spp.*	1	0.01	0.00	0.00	0.03	3.85	0.04
Mollusca	Pilsbry's piddock	*Zirfaea pilsbryi*	1	0.01	0.00	0.00	0.03	3.85	0.04
Arthropoda	California pistol shrimp	*Alpheus californiensis*	1	0.01	0.00	0.00	0.02	3.85	0.03
Arthropoda	Armed hermit crab	*Pagurus armatus*	1	0.01	0.00	0.00	0.02	3.85	0.03
Cnidaria	Brown gorgonian	*Muricea fructicosa*	1	0.01	0.00	0.00	0.02	3.85	0.03
Mollusca	Stearn's aeolid	*Austraeolis stearnsi*	1	0.01	0.00	0.00	0.02	3.85	0.03
Mollusca	Razor clam	*Ensis myrae*	1	0.01	0.00	0.00	0.02	3.85	0.03
Arthropoda	Grooved mussel crab	*Fabia subquadrata*	1	0.01	0.00	0.00	0.01	3.85	0.03
Arthropoda	Miniature shrimp	*Mesocrangon munitella*	1	0.01	0.00	0.00	0.01	3.85	0.03
Arthropoda	Toothshell hermit crab	*Orthopagurus minimus*	1	0.01	0.00	0.00	0.01	3.85	0.03
Arthropoda	Hermit crab	*Pagarus sp.*	1	0.01	0.00	0.00	0.01	3.85	0.03
Arthropoda	Arthropoda	*Paleomonella holmesii*	1	0.01	0.00	0.00	0.01	3.85	0.03
Mollusca	Aeolid nudibranch	*Aeolid sp.*	1	0.01	0.00	0.00	0.01	3.85	0.03
Mollusca	Giant nudibranch	*Dendronotus iris*	1	0.01	0.00	0.00	0.01	3.85	0.03
Mollusca	Monterey sea lemon	*Doris montereyensis*	1	0.01	0.00	0.00	0.01	3.85	0.03
Mollusca	Market squid	*Doryteuthis opalescens*	1	0.01	0.00	0.00	0.01	3.85	0.03
Mollusca	Red chiton	*Lepidozona mertensii*	1	0.01	0.00	0.00	0.01	3.85	0.03
Mollusca	Minute sea slug	*Placida dendritica*	1	0.01	0.00	0.00	0.01	3.85	0.03
Arthropoda	California green shrimp	*Hippolyte californiensis*	1	0.01	0.00	0.00	0.00	3.85	0.03
Total Abundance/Biomass			**12989**		**167.17**				
Total Number of Species					**116**				

Note: Values of 0.00 are <0.005

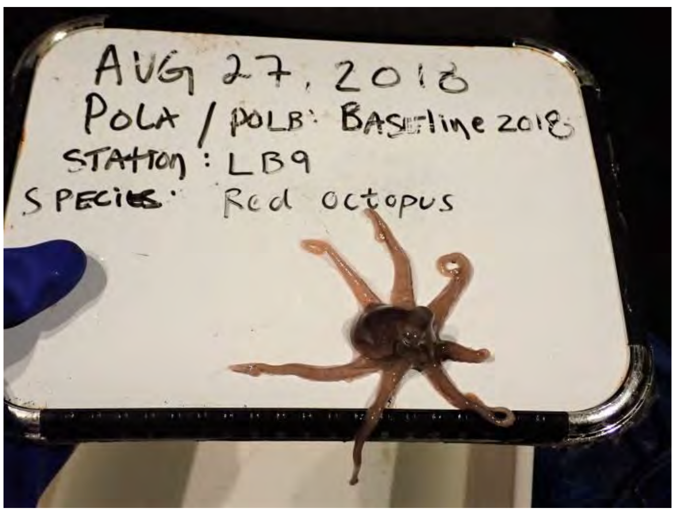
Table 4-10. Epibenthic Invertebrates Collected with Beach Seine Summary (Spring and Summer Events Combined)

Common Name	Species Name	Abundance			Biomass (g)		
		Seaplane Lagoon	Cabrillo Beach	Total Abundance	Seaplane Lagoon	Cabrillo Beach	Total Biomass
Western Mud Nassa	*Nassarius tiarula*	247	0	247	149	0	149
California Bubble Snail	*Bulla gouldiana*	1	0	1	15	0	15
Pacific Eggcockle	*Laevicardium substriatum*	1	0	1	0.2	0	0.2
Green Shrimp	*Hippolyte clarki*	630	2	632	51	1	52
Purple Olivella	*Callianax biplicata*	0	151	151	0	229	229
Pacific Sand Crab	*Emerita analoga*	0	3	3	0	4	4
Navinax	*Navinax inermis*	1	0	1	1	0	1
Spiny Lobster	*Panulirus interruptus*	0	1	1	0	475	475
Target Shrimp	*Sicyonia penicillata*	0	1	1	0	1	1
Pacific Calico Scallop	*Argopecten ventricosus*	1	0	1	5	0	5
Total		881	158	1039	221.2	710	931.2
Species Richness		6	5	10			
Shannon-Weiner Diversity		0.63	0.24	-			

4.4.2 Station Comparisons

To assess patterns of epibenthic invertebrate distribution within the Port Complex, stations were grouped according to habitat type (SWH, Outer Harbor, Inner Harbor), location (SWH, Outer Harbor, Basin, Channel, Slip) and depth (Shallow 0-7 m, Deep 7.1-18 m, Very Deep 18+ meters). Differences in invertebrate diversity, abundance, and biomass were then assessed across these station groups (Table 4-23).

Species richness and total abundance were greater at Outer Harbor and Inner Harbor stations than at SWH stations, while total biomass was similar across all three habitat groups (Figure 4-23). Diversity indices were highest at Inner Harbor stations and similar at Outer Harbor and SWH stations. These patterns were not statistically significant. Comparing total biomass and relative biomass by phylum (Table 4-8; Figure 4-24), SWH stations were composed primarily of arthropods and molluscs with only minor contributions from other phyla; this pattern likely contributed to the low diversity index scores. Most Outer Harbor stations were also dominated by arthropods (64%), although at several stations other phyla such as bryozoans (LB13), echinoderms (LB12), porifera (LA15) and chordates (LA9) were among the most dominant. Inner Harbor stations were the most variable in terms of composition as at half of them bryozoans were the dominant phylum, while at the other half almost no bryozoans were present, and the dominants were a mix of primarily arthropods, chordates (tunicates), and molluscs.



Red octopus captured in otter trawl

By location type, Channel and Basin stations had the greatest species richness, abundance, and biomass, while the other location types were similar to one another (Figure 4-25). Only abundance within Channels compared to SWH was determined to be statistically significant. Outer Harbor stations had slightly lower diversity index scores compared to other location types as they were generally dominated by a single species. Slip stations scored highly on the diversity index scores, although this pattern is driven by LA14 (Consolidated Slip), which despite having the lowest total biomass had a very even distribution of biomass across the 20 species caught there; that degree of evenness heavily influences the diversity indices.

Species richness was relatively even across all depth strata, while abundance and biomass were higher at Deep and Very Deep stations than at shallow stations (Figure 4-26). The abundance at Shallow stations was significantly lower than at Deep and Very Deep stations, while the species richness, biomass and diversity indices were not statistically significant. Shallow and Deep stations generally scored higher for the diversity indices than the Very Deep stations, and this was likely due to very Deep stations more often dominated by a single or small group of species such as target shrimp.

Table 4-11. Otter Trawl Invertebrates Station Summary (Spring and Summer Events Combined)

Station	Station Descriptor	Habitat	Location	Depth Strata	Taxa Richness	Total Abundance per Station	Total Biomass per Station (kg)	Shannon-Wiener Diversity Index	Margalef Diversity Index	Pielou's Eveness Index	Percent Of Total Biomass						
											Arthropoda	Bryozoa	Chordata	Cnidaria	Echinodermata	Mollusca	Porifera
LA1	Outer Pier 400	Outer	Outer	Very Deep	13	279	4.05	0.88	7.41	0.34	94.2	0	0	0	0.32	5.49	0
LA2	LA SWH East	SWH	SWH	Shallow	18	141	5.36	0.99	9.19	0.34	83.5	0	0	0.06	0.37	16.0	0
LA3	LA SWH West	SWH	SWH	Shallow	17	381	2.51	1.46	12.7	0.52	52.7	0	0	0	0	47.3	0
LA4	LA Main Channel	Outer	Channel	Deep	27	334	3.84	1.88	16.5	0.57	52.0	0	20.6	0	4.69	21.8	1.02
LA5	West Basin	Inner	Basin	Deep	31	845	15.5	1.33	10.7	0.39	15.0	63.9	18.4	0	0.08	0.41	2.21
LA6	LA East Basin	Inner	Basin	Deep	23	960	3.36	1.76	14.9	0.56	52.0	0	46.3	0	0	1.67	0
LA7	Seaplane Lagoon	SWH	SWH	Shallow	21	273	8.33	0.81	8.95	0.27	82.7	1.44	0.42	0	0	15.5	0
LA9	Pier 300 Channel	Outer	Slip	Deep	25	414	2.90	1.59	17.6	0.49	58.4	1.27	39.4	0.03	0	0.83	0
LA10	Fish Harbor	Inner	Basin	Shallow	21	238	2.73	2.18	15.2	0.72	49.2	2.93	8.97	0	4.36	34.5	0
LA11	LA Outer Channel	Outer	Outer	Very Deep	29	272	2.39	1.25	22.9	0.37	94.2	0	0.58	0.50	1.63	3.13	0
LA14	Consolidated Slip	Inner	Slip	Shallow	20	178	0.31	2.28	70.4	0.76	41.6	0	22.9	0	0.32	35.2	0
LA15	LA Turning Basin	Outer	Basin	Deep	27	691	10.1	1.54	10.8	0.47	20.5	0	15.7	0.15	0.01	8.47	55.2
LA16	Bannings Landing	Inner	Slip	Deep	28	380	8.89	1.32	11.8	0.40	3.54	63.0	14.1	0	0.51	1.02	17.8
LB1	Outer Anchorages	Outer	Outer	Deep	17	260	2.69	1.29	12.3	0.46	99.7	0	0	0	0	0.26	0
LB2	LB SWH	SWH	SWH	Shallow	15	123	2.19	1.49	12.1	0.55	72.2	0	0.37	0.18	3.06	24.2	0
LB3	West Basin	Outer	Basin	Deep	17	578	7.69	0.47	7.40	0.17	96.7	0	0.20	0.03	0	3.10	0
LB4	Channel 2	Inner	Slip	Deep	23	376	1.13	1.87	29.1	0.60	48.4	0.09	22.2	0	0.44	18.4	10.5
LB5	SE Basin East	Outer	Basin	Deep	26	255	6.83	1.59	12.1	0.49	42.7	28.8	0.38	0	15.7	12.4	0
LB6	Pier J	Outer	Slip	Deep	14	193	1.73	0.62	12.9	0.24	97.4	0	1.04	0	0	1.56	0
LB7	Main Channel Pilot Station	Outer	Channel	Very Deep	18	1646	25.3	0.73	5.20	0.25	89.4	3.39	0.07	0	1.04	6.06	0
LB9	Outer Channel	Outer	Outer	Very Deep	12	568	9.03	0.28	4.77	0.11	99.1	0	0	0	0.20	0.65	0
LB10	SE Basin West	Outer	Basin	Deep	24	304	2.77	1.62	17.3	0.51	45.2	42.5	4.76	0.18	1.48	3.68	2.24
LB12	Main Channel Police Station	Outer	Channel	Very Deep	39	883	10.2	1.83	15.7	0.50	47.1	0.66	6.49	0.35	42.8	1.68	0.92
LB13	LB Turning Basin	Outer	Basin	Deep	32	1274	11.1	1.35	12.4	0.39	11.5	64.6	0.83	13.8	0.02	9.24	0
LB14	Cerritos Channel	Inner	Channel	Deep	29	812	8.46	1.10	12.5	0.33	28.9	67.7	2.51	0.30	0	0.48	0.19
LB16	Channel 3	Inner	Slip	Deep	30	331	7.71	1.27	13.4	0.37	6.36	76.4	11.5	0.06	2.28	3.33	0

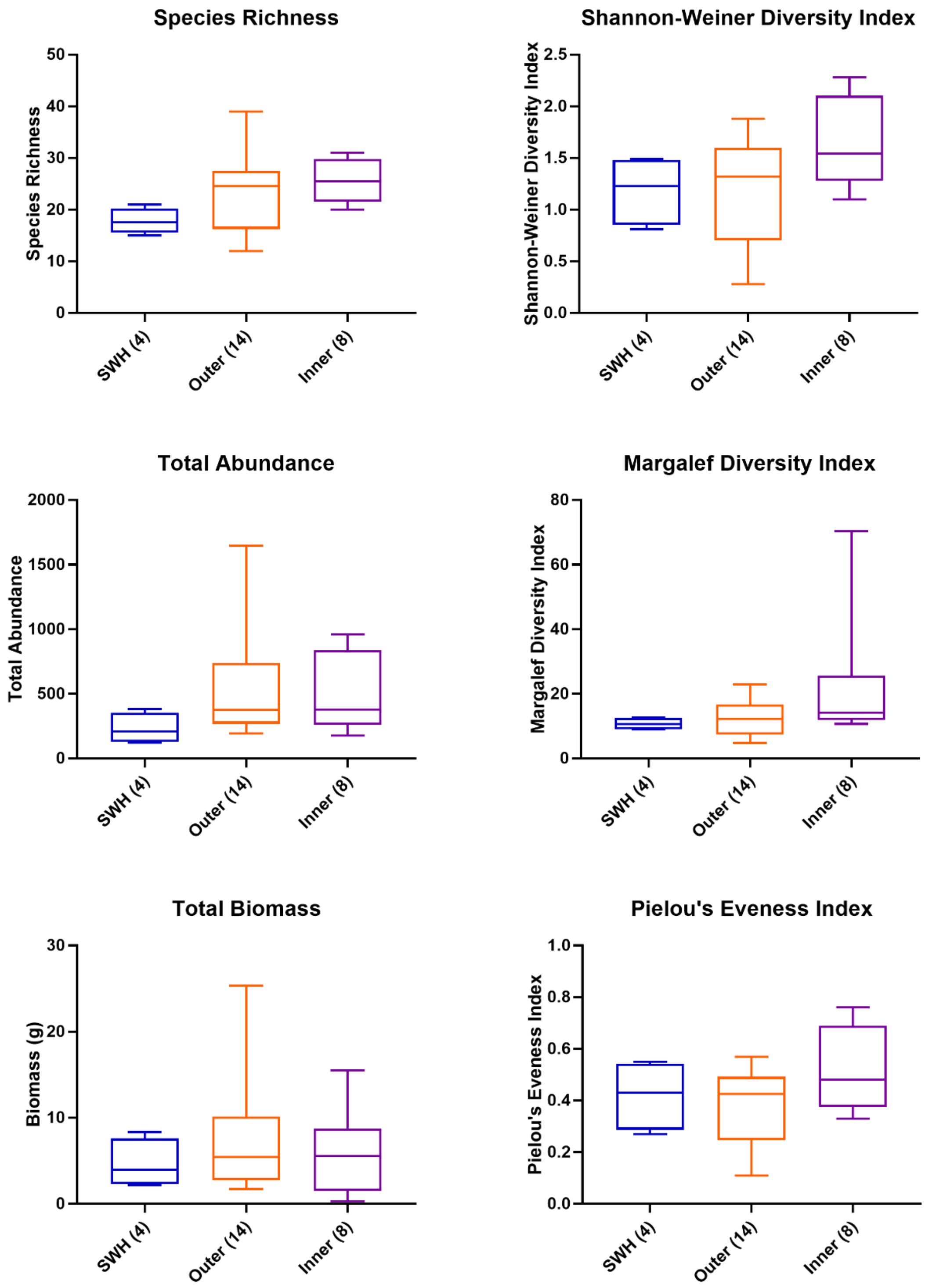


Figure 4-23. Epibenthic Invertebrate Summary Metrics by Station Habitats (Spring and Summer Events Combined)

Vertical lines depict the range of values, the horizontal line depicts the median of all values, and the boxes depict the 1st quartile above and below the median

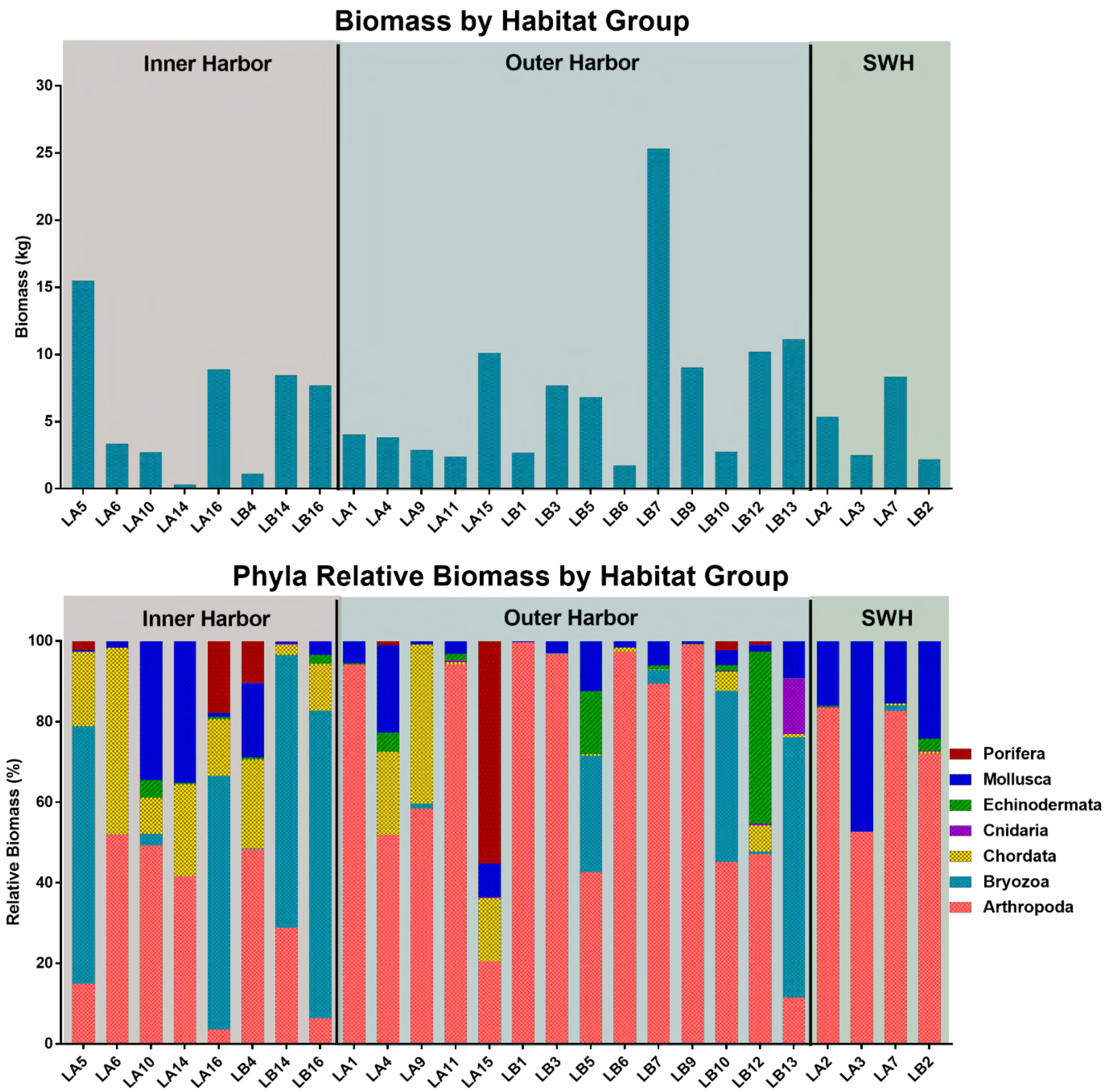


Figure 4-24. Epibenthic Invertebrate Station Biomass – Total and Relative Biomass by Phyla (Spring and Summer Events Combined)

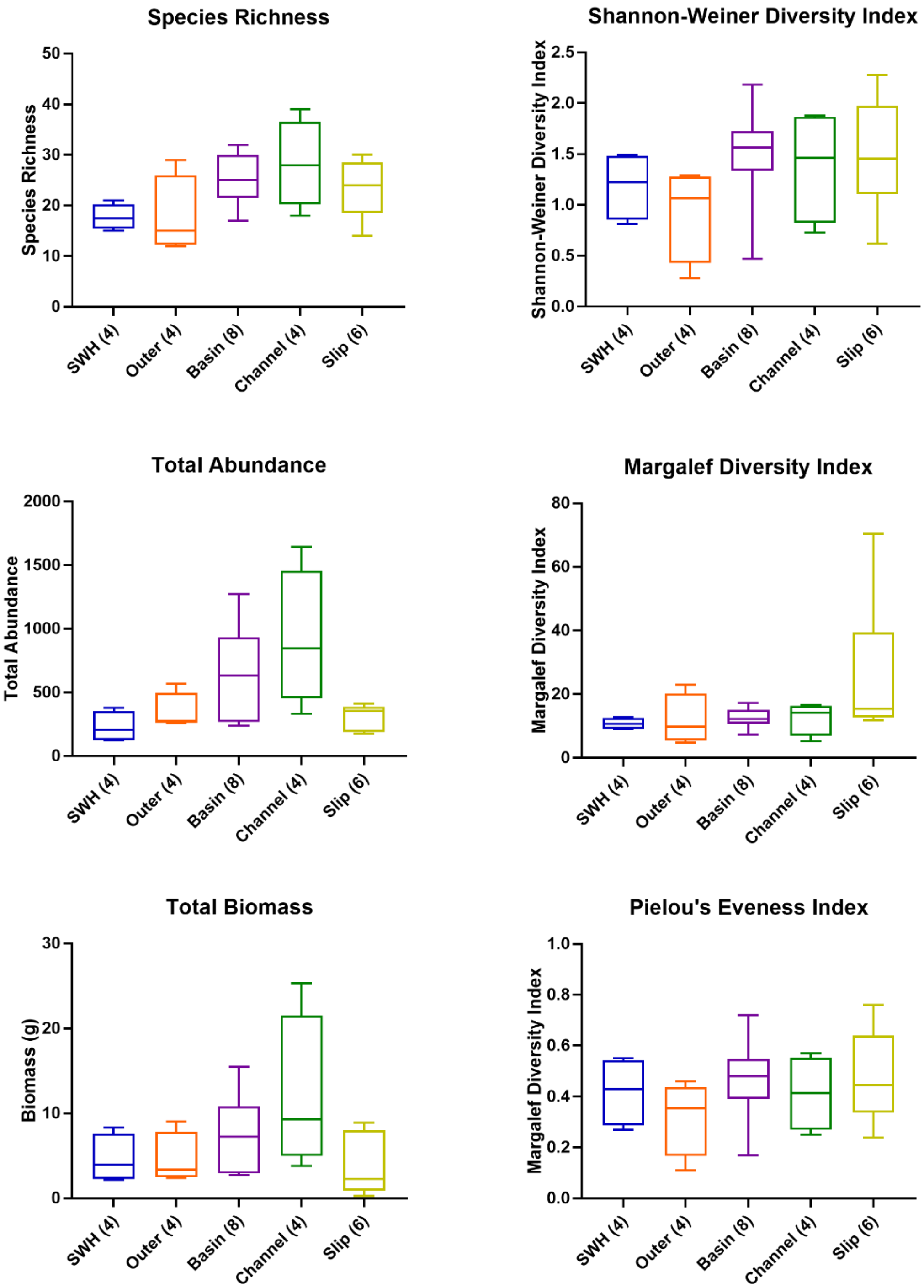


Figure 4-25. Epibenthic Invertebrate Summary Metrics by Station Locations (Spring and Summer Events Combined)

Vertical lines depict the range of values, the horizontal line depicts the median of all values, and the boxes depict the 1st quartile above and below the median

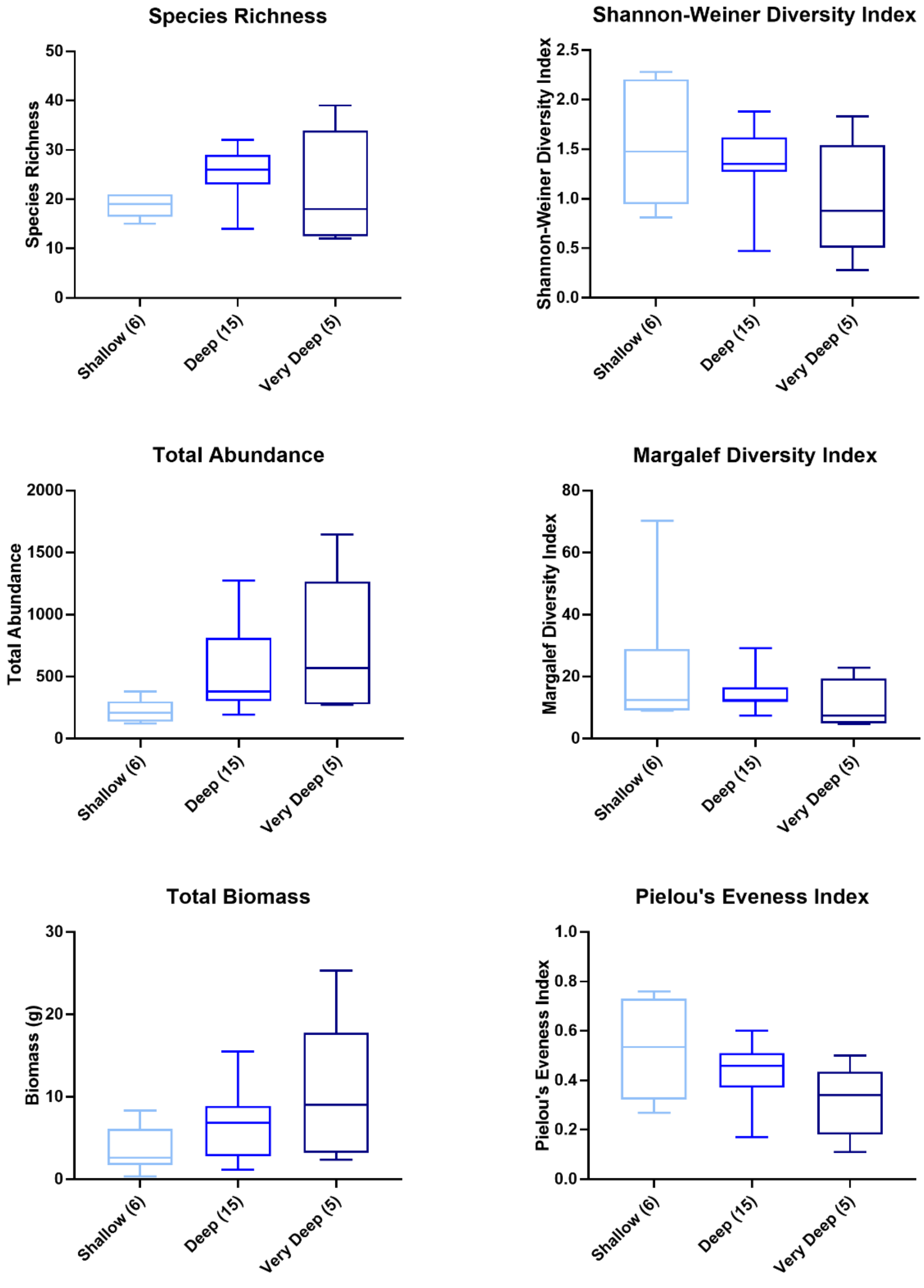


Figure 4-26. Epibenthic Invertebrate Summary Metrics by Station Depths (Spring and Summer Events Combined)

Vertical lines depict the range of values, the horizontal line depicts the median of all values, and the boxes depict the 1st quartile above and below the median

Multivariate Analysis

Multivariate analysis of epibenthic invertebrate biomass data combined across the spring and summer sampling events assessed community patterns throughout the Port Complex (see Appendix A for a description of the multivariate analytical methodology). Figures and analysis not shown here can be found in Appendix D. The analyses revealed the following primary patterns:

- Habitat group analyses showed that SWH was distinct from Inner and Outer Harbor stations but that there was no statistical difference between Inner and Outer Harbor.
- Location group analyses revealed that Outer Harbor and SWH stations were statistically different from all other location types. There was no significant difference between channel, basin, and slip stations.
- All depth strata station groups were significantly different from one another.

The station groups resulting from the similarity profile (SIMPROF) analysis were overlaid on the station map (Figure 4-27); the analysis also produced a heatmap of the 50 species that best resolve the groups (Figure 4-28). All of the Inner Harbor stations and several channel, basin, and the Seaplane Lagoon station group together in Group B. Group C was made up of Outer Harbor stations the SWH stations other than Seaplane Lagoon.

Group A consisted of one station (LB13) in the LB Turning Basin, which had a community assemblage that was unique in that it was dominated by the spaghetti bryozoan (65% of total biomass) and was the only station to have a large proportion of the community made up of cnidarians, primarily the sea pens *Stylatula elongata* (11%) and *Acanthoptilum sp.* (3.0%). Both sea pen species were observed at a handful of other stations, but not in the abundance at LB13, suggesting the habitat may support these large populations either through the availability of favorable substrate to anchor to and/or through adequate food in the form of plankton. It is also possible that their abundance may be the result of reduced predation pressure by sea stars, nudibranchs, and fish such as sand bass (*Paralabrax sp).*, which are known to ingest *S. elongata* (Davis et al. 1982), although predators such as spotted sand bass and the nudibranch *Navanax* were caught at this station.

Epibenthic Invertebrate Biomass By Trawl Station
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 4-27. Epibenthic Invertebrate Similarity Profile Groups

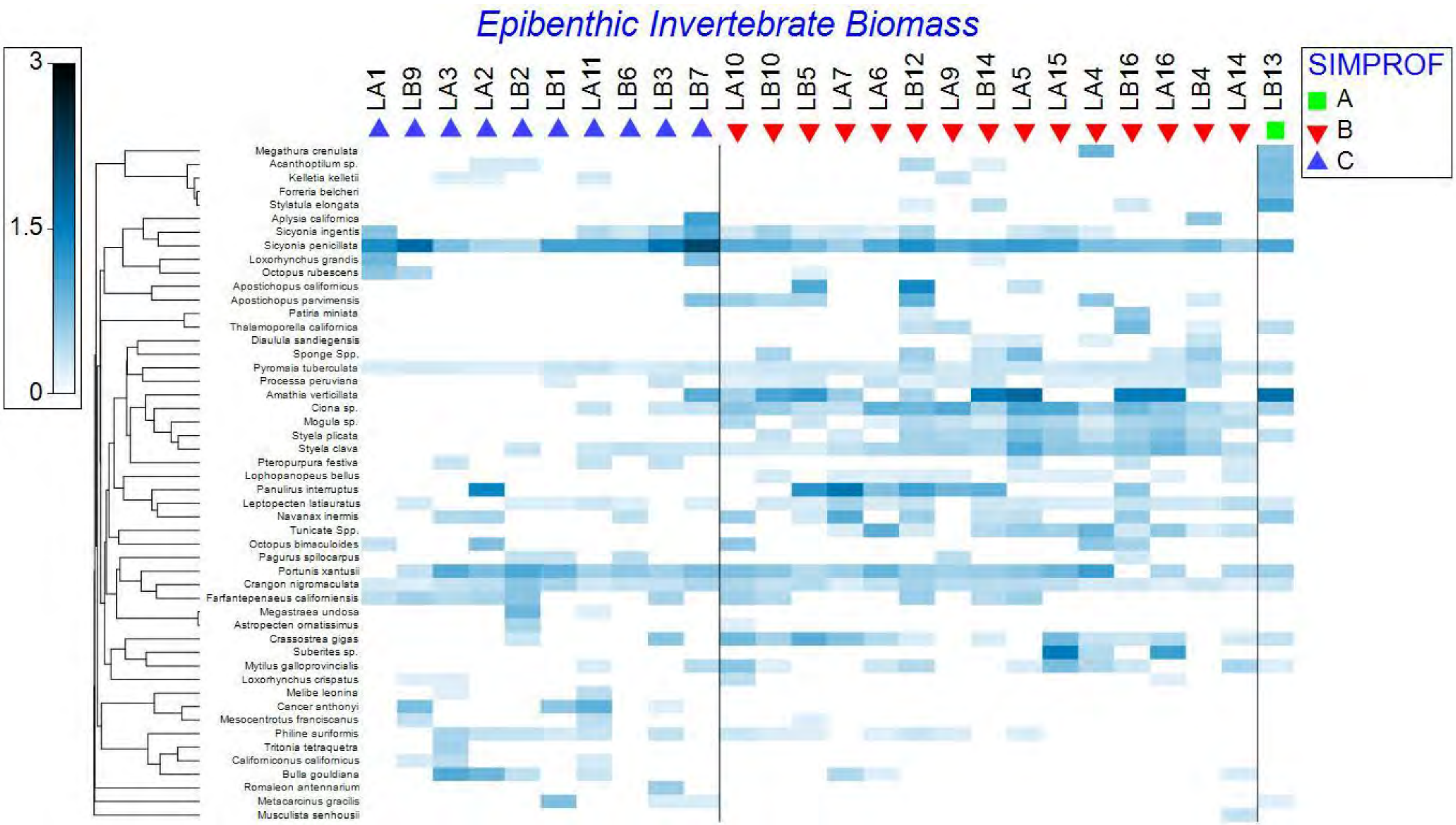


Figure 4-28. Epibenthic Similarity Profile Group Heatmap – Top 50 Species

4.4.3 Historical Comparisons

Despite differences in the number of stations and seasons sampled across study years, epibenthic invertebrate communities in the present study showed patterns that were consistent with the past three studies, especially increased abundance at night relative to daytime surveys. The 2018 and 2013 studies sampled during two seasons at 26 stations, whereas the 2008 study sampled during three seasons at 19 stations and the 2000 study sampled all four seasons at 14 stations. This discrepancy makes direct comparisons difficult, but measures such as mean biomass per trawl and mean abundance per trawl allow meaningful comparisons.

These comparisons (Table 4-12) are made on the basis of the ten most abundant epibenthic invertebrate species from the last four Biosurveys. The 2013 study noted a marked increase of 320 invertebrates per trawl -- approximately 2.5 times more than the previous two studies -- and the 2018 study showed a similar trend with 250 invertebrates per trawl. This held true for biomass as well (Table 4-12). The 2018 study caught 116 species of epibenthic invertebrates, an increase over the previous studies (110 species in 2013 and 61 species in both 2008 and 2000).

The changes in average biomass and abundance over the past four Biosurveys were driven largely by a shift in a few key shrimp species, principally the target shrimp (*S. penicillata*), which became the most abundant epibenthic invertebrate in 2013 and in 2018. *S. penicillata* historically has had its center of distribution in southern Baja California and the Gulf of California, but its range extension northward in western Baja was noted as early as 1986 (Estrada-Ramirez and Calderon-Aguilera 2001). The species was first noted off Palos Verdes in 1998 (Montagne and Cadien 2001) and it was first captured in the Port Complex in 2000 (although only 4 individuals). This range extension into San Pedro Bay was attributed to strong El Nino events in 1997/1998, but regional monitoring in the Southern California Bight (SCCWRP in prep.) and within the Port Complex did not see substantially increased populations until at least 2008 (Figure 4-29). Within the Port Complex, the increase in *S. penicillata* was most defined between 2008 and 2013, which may be a result of the warm water event that was underway at the time.

Regional studies found that the abundance of ridgeback prawn (*S. ingentis)* declined from 1998 to 2003 (Wisenbaker et al. 2021) but since has remained relatively stable, while blackspot shrimp (*C. nigromaculata)* is more variable (Figure 4-29). While a *S. ingentis* in the Port complex has stayed relatively stable, *C. nigromaculata* has decreased in abundance. *S. penicillata* is considerably larger than *C. nigromaculata*, and larger than the other two most abundant species in 2000 and 2008, Xantu's swimming crab *Portunus xantusii* and the tuberculate pear crab *Pyromaia tuberculata*, so the increased biomass in 2013 and 2018 is likely attributable to the dominance of the larger species in the two most recent Biosurveys.

In total, the past four Biosurveys have collected a total of 184 species, 24 of them collected in all four Biosurveys (Table 4-13). A total of 28 new species have been observed in 2013 and 2018 that were not present in the first two Biosurveys, including four non-native species (the tunicates *Styela clava* and *Styela plicata,* the Pacific oyster *Crassostrea gigas*, and the Mediterranean mussel *Mytilus galloprovincialis*). The 2018 Biosurvey found an additional 35 species that had not previously been recorded inside the Port Complex, including the non-native spaghetti bryozoan *Amathia verticillata*. Conversely, 18 species were captured only in 2000 and 14 species were captured in only 2008.

Epibenthic invertebrates were not reported for beach seine surveys during the 2000 or 2008 Biosurveys, so comparisons can only be made with the 2013 study. The 2018 Biosurvey found an increase in overall abundance and diversity at beach seine sites compared to 2013, with a total of 1039 individuals collected in 2018 across three seasons compared to only 74 in 2013 across two seasons. At Cabrillo Beach, a similar number of species was caught in 2018 (5) as in 2013 (6), although only the Pacific sand crab (*Emerita analoga*) was captured in both years. The greatest change at Cabrillo Beach was the dominance of the purple Olivella snail (*Callianax biplicata*), which made up 151 of the 158 individuals captured in 2018. In 2013 the only epibenthic species captured at Seaplane Lagoon was the fat western nassa snail (*Caesia perpinguis*), and then only two individuals. The 2018 Biosurvey found the community dominated by the green shrimp (*Hippolyte clarki*) and the western mud nassa (*Nassarius tiarula*), which combined made up 877 of 881 individuals captured. Due to the dominance of one species at Cabrillo Beach in 2018, the diversity score decreased from 1.48 in 2013 to 0.63 in 2018. With only one species at Seaplane Lagoon the diversity score in 2013 was zero and increased in 2018 to 0.24.

Table 4-12. Historical Top Ten Epibenthic Invertebrates

Year	2000		2008		2013		2018	
	Species	% Total Abundance	Species	% Total Abundance	Species	% Total Abundance	Species	% Total Abundance
1	*Crangon nigromaculata*	50.8	*Crangon nigromaculata*	38.4	*Sicyonia penicillata*	37.5	*Sicyonia penicillata*	39.4
2	*Pyromaia tuberculata*	27.9	*Sicyonia ingentis*	16.7	*Crangon nigromaculata*	17.3	*Ciona sp.**	7.98
3	*Portunus xantusii*	10.2	*Crangon nigricauda*	13.1	*Portunus xantusii*	10.3	*Alia carinata*	7.57
4	***Philine auriformis***	4.45	*Portunus xantusii*	10.9	*Pyromaia tuberculata*	6.60	*Crangon nigromaculata*	6.77
5	*Pagurus spilocarpus*	1.42	*Heptacarpus sp.*	7.62	*Sicyonia ingentis*	4.80	*Tunicate sp.*	5.77
6	*Cancer gracilis*	0.48	*Pyromaia tuberculata*	3.35	*Crangon nigricauda*	5.60	*Portunis xantusii*	3.50
7	*Bulla gouldiana*	0.36	*Crangon alaskensis*	3.15	*Heptacarpus sp.*	2.89	*Styela clava*	2.93
8	*Penaeus californiensis*	0.34	*Sicyonia penicillata*	1.14	*Crangon sp.*	3.81	*Pyromaia tuberculata*	2.59
9	*Navanax inermis*	0.32	*Penaeus californiensis*	0.70	***Philine auriformis***	1.20	*Stylatula elongata*	2.59
10	*Crangon alaskensis*	0.30	*Styela sp.**	0.69	*Cancer productus*	0.98	*Leptopecten latiauratus*	2.49
Total # of Trawls	56		57		52		52	
Species Richness	61		61		110		116	
Total Abundance	9182		6861		16615		12989	
Average Abundance per Trawl	164		120		320		250	
Average Biomass per Trawl (kg)	1.03		0.52		3.63		3.22	

* = Genus contains species in NEMESIS database known to be non-native in CA. Note: Shading follows species that appear in at least three Biosurvey years.

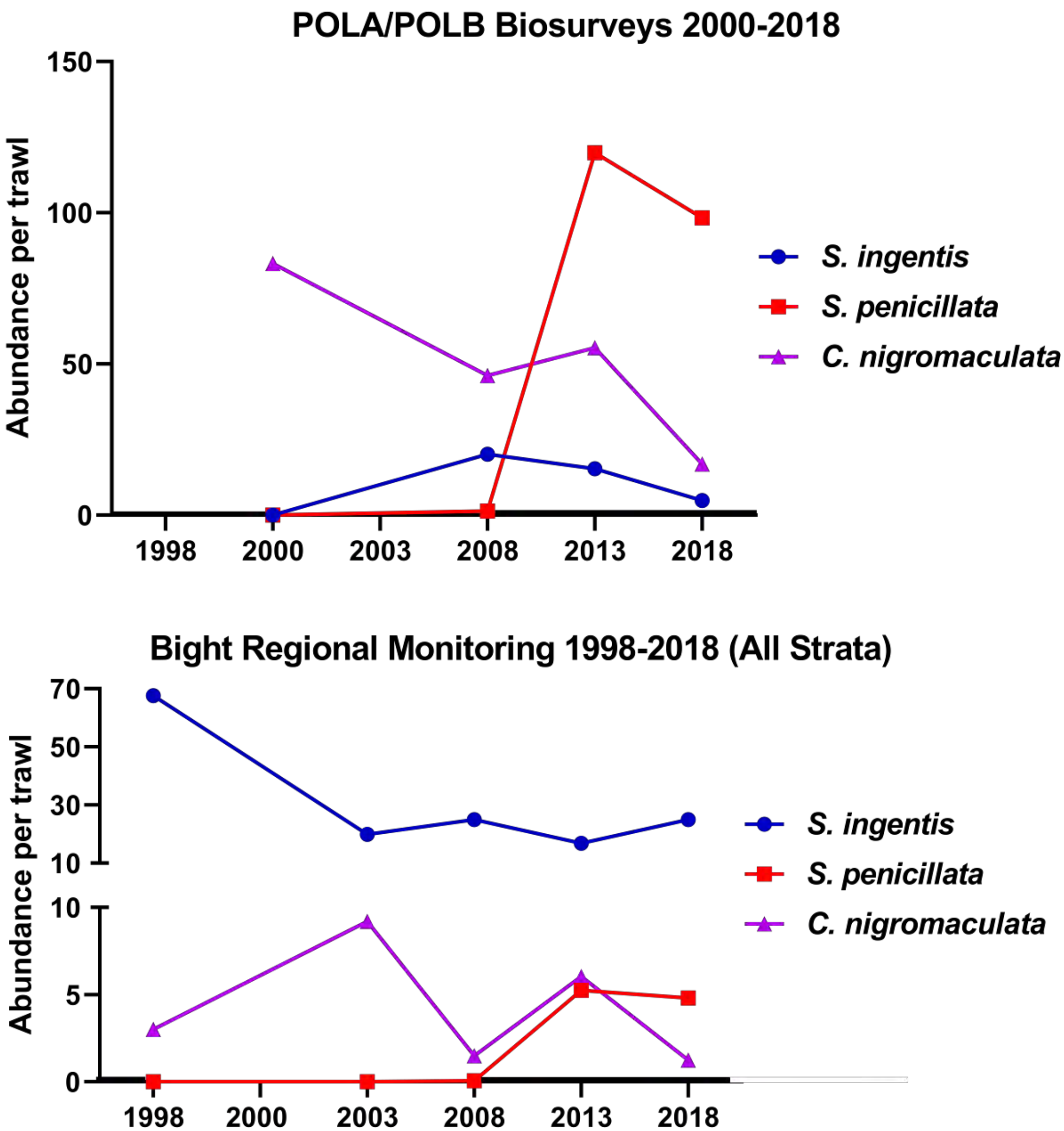


Figure 4-29. Abundance of Three Shrimp Species Measured by the Biosurveys and in All Strata (Bays and Harbors, Shelf and Slope Strata) of the Regional Bight Monitoring Program

Table 4-13. Epibenthic Invertebrate Species Captured During All Four Biosurvey Years

Phylum	Common name	Scientific Name	2000	2008	2013	2018
Arthropoda	Alaska bay shrimp	*Crangon alaskensis*	28	216	1	39
	Blacktail shrimp	*Crangon nigricauda*	11	899	931	6
	Blackspot shrimp	*Crangon nigromaculata*	4660	2632	2877	880
	Yellowleg shrimp	*Farfantepenaeus californiensis*	31	48	101	20
	Stout bodied shrimp	*Heptacarpus palpator*	1	6	26	8
	Stimpson's shrimp	*Heptacarpus stimpsoni*	16	46	16	21
	Moss crab	*Loxorhynchus crispatus*	3	1	1	4
	Sheep crab	*Loxorhynchus grandis*	5	2	10	3
	California spiny lobster	*Panulirus interruptus*	26	43	28	25
	Xantu's swimming crab	*Portunus xantusii*	933	747	1706	454
	Tuberculate pear crab	*Pyromaia tuberculata*	2561	230	1096	337
	Ridgeback prawn	*Sicyonia ingentis*	1	1148	797	250
	Target shrimp	*Sicyonia penicillata*	4	78	6230	5115
Echinodermata	California sea cucumber	*Apostichopus californicus*	12	5	55	18
	Warty sea cucumber	*Apostichopus parvimensis*	8	8	27	10
	Spiny sand star	*Astropecten armatus*	14	1	4	1
	Red urchin	*Mesocentrotus franciscanus*	1	2	2	8
	Bat star	*Patiria miniata*	16	2	29	6
	Purple urchin	*Strongylocentrotus purpuratus*	6	3	7	6
Mollusca	California sea hare	*Aplysia californica*	21	4	9	2
	Milky venus	*Compsomyax subdiaphana*	5	1	16	4
	Giant nudibranch	*Dendronotus iris*	5	2	98	1
	Navanax	*Navanax inermis*	29	12	56	31
	2 spot octopus	*Octopus bimaculoides*	1	1	18	5

4.4.4 Discussion

Epibenthic invertebrates sampled with beach seines showed that each station was largely dominated by one or two species. The very different results between stations and seasons may reflect the influence of tidal height on capture efficiency, as the summer sampling at high tide only caught one species at each station while the spring and fall sampling at low tide captured eight species in total, with six captured during spring and fall. Subsequent sampling efforts should target low tides, which allows the sampling gear to fully access the shallow eelgrass beds and sandy beach habitats at each station.

Epibenthic invertebrate communities sampled with trawls were most distinct across station habitat groups and depths: deep, Outer Harbor stations exhibited greater abundance and biomass compared to Inner Harbor and SWH stations. The Outer Harbor stations were most commonly dominated by a single species, most often the target shrimp *S. penicillata*, while Inner Harbor stations were more typically dominated by the bryozoan *A. verticillata*. Multivariate analysis identified two major groups, mostly Inner Harbor and Outer Harbor stations, while one station in the LB Turning Basin (LB13) had a unique community that was predominantly the sea pen *S. elongata*.

The composition of the epibenthic community has shifted over the course of the last four Biosurveys. In the 2000 and 2008 Biosurveys the community was dominated by the blackspotted shrimp, *C. nigromaculata*, and the tuberculate pear crab, *P. tuberculata*, before shifting dramatically in 2013 and 2018 to primarily the target shrimp, *S. penicillata*. This shift appears to be in part a result of the target shrimp shifting its distribution northward in response to warm water events that occur regularly in Southern California, although recent strong El Niños in 1997-1998 and the warm water event in 2013-2015 may have facilitated the persistence of a northern population (Estrada-Ramirez and Calderon-Aguilera 2001, Montagne and Cadien 2001). While these regional events may be landmarks of largescale shifts, there are also more persistent forces that facilitate the establishment of southern species such as the relaxation of the southward California Current, the intensification of the northward California Countercurrent, and the formation and persistence of offshore eddies in the Southern California Bight (Lluch-Belda et al. 2005). These climatic forces may explain the increase in species richness for both benthic infauna and epibenthic invertebrates, which over time may gain more subtropical species. While changes in the demersal fish community are less apparent in this study, invertebrate communities with shorter life cycles and larvae with more passive distribution may be more sensitive to, and correspondingly indicative of, these larger oceanographic changes. Continued monitoring of the invertebrate community within the Port Complex will be critical to assess any impact these new species, some of which could become dominant members of the community, may have on other biological communities.

4.5 Shallow Subtidal Fishes

Shallow subtidal habitat was sampled at two sandy beach and eelgrass locations: Cabrillo Beach and Seaplane Lagoon. At each location two stations were sampled using a beach seine during the spring, summer, and fall. The spring and fall sampling were conducted close to low tide, while summer sampling was performed close to high tide. This approach ensured that both tidal states were sampled and that representative samples were obtained near the outer edge of the eelgrass beds. The three sampling events were combined, as statistical analysis determined there was no significant difference in fish abundance across locations, replicates, and seasons based on total number of species and biomass (Appendix D). However, differences between seasons were noted for individual species as described further below.

4.5.1 Species Comparisons

Abundance

Beach seine sampling collected 1,352 fish comprised of 23 species across all sampling events (Tables 4-14 and 4-15, Figure 4-30). Notable differences were observed in the fish communities at the two locations sampled. For example, there were 160 small, unidentifiable juvenile Atherinidae captured at Seaplane Lagoon but none at Cabrillo Beach), 43 and 9 bay pipefish (*Syngnathus leptorynchus*), respectively, and 183 and 5 CIQ gobies, respectively. CIQ gobies consist of a complex of *Clevelandia ios, Ilypnus gilberti*, and/or *Quietula y-cuadadue* to their almost indistinguishable physical characteristics. Other species captured at Seaplane Lagoon that were not captured at Cabrillo Beach include arrow goby (*Clevelandia ios*), shovelnose guitarfish (*Rhinobatos productus*), snubnose pipefish (*S. arctus)*, spotted sand bass (*Paralabrax maculatofasciatus*), barred sand bass (*Paralabrax nebulifer*), staghorn sculpin (*Leptocottus armatus*), Blenny sp. (Blenniformes) and diamond turbot (*Hypsopsetta guttulata*). Some species were only observed at Cabrillo Beach: black surfperch (*Embiotoca jacksoni*), dwarf surfperch (*Micrometrus minimus*), queenfish (*Seriphus politus*), deepbody anchovy (*Anchoa compressa*), northern anchovy (*Engraulis mordax*) and round stingray (*Urolophus helleri*).

Six taxa made up 90.4% of the total abundance of all fish collected (Table 4-15): Topsmelt (*Atherinops affinis*; 44.7%), CIQ gobies (13.9%), queenfish (12.3%), Atherinidae (11.8%), giant kelpfish (*Heterostichus rostratus*; 3.9%), and bay pipefish (3.8%). Only five other species made up 1% or more of the remaining total abundance.

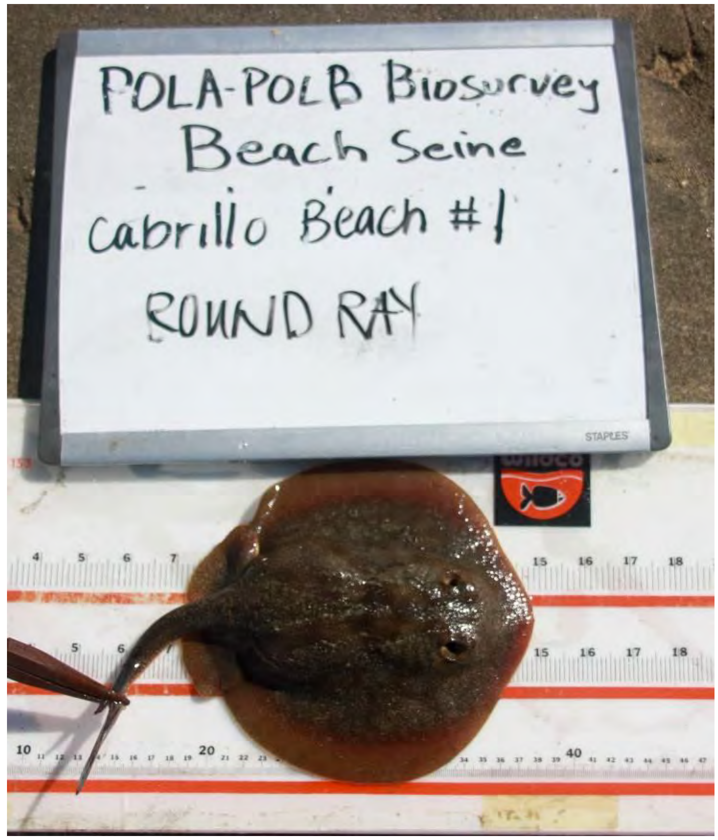
Table 4-14. Fish Catch Summary by Station using Beach Seines (Across all Seasons)

Location	Species Richness	Total Abundance	Total Biomass (kg)	Shannon-Weiner Diversity Index	Margalef Diversity Index	Pielou's Eveness Index
Seaplane Harbor	16	793	22.7	1.60	2.25	0.58
Cabrillo Beach	15	559	4.39	1.47	2.21	0.54

Biomass

During beach seine sampling a total of 27.1 kg of fish biomass was collected across all sampling events (Table 4-14), primarily due to five shovelnose guitarfish captured in the spring at Seaplane Lagoon which made up nearly three-quarters of the total biomass. Aside from the guitarfish, the two locations were very similar in terms of biomass, with a total of 2.83 kg at Seaplane Lagoon and 4.39 kg at Cabrillo Beach, respectively.

Not including shovelnose guitarfish, six other species accounted for more than 1% of the remaining total biomass (Table 4-15): topsmelt (7.4%), spotted sand bass (4.0%), California halibut (*Paralichthys californicus*; 3.6%), round stingray (3.6%), black surfperch (3.1%), and dwarf surfperch (1.1%).



Round ray captured in beach seine at Cabrillo Beach

Ecological Index

Fish species with the top five EI scores collected using the beach seines included topsmelt, shovelnose guitarfish, CIQ goby, queenfish, and Atherinidae as shown in Table 4-15.

Size Classes

To supplement otter trawl data, size class analysis was performed for queenfish, topsmelt and California halibut collected in the beach seines (Section 4.6.1). CIQ goby and Atherinidae were not analyzed due to their small size range. While topsmelt were caught in the beach seines, their size class distribution is presented with the rest of the pelagic species in section 3.3.1.

The size class analysis suggests that juveniles of all three species utilize the shallow beach and eelgrass habitat as nursery habitats. Their size distributions suggest smaller individuals utilize these habitats compared to the population sampled in deeper pelagic and soft-bottom habitat. Length at maturity information is not available for topsmelt, but no mature queenfish were caught in the beach seines and only one halibut was caught that could potentially be mature while the rest were juveniles.

Diversity and Evenness Indices

Diversity and evenness index values were very similar between Seaplane Lagoon and Cabrillo Beach (Figure 4-30), due to similar species richness and total abundance at the two locations. Seaplane Lagoon scored slightly higher than Cabrillo Beach in all three indices.

Table 4-15. Fish Catch Summary by Species using Beach Seines, in Order of Ecological Index (All Seasons Combined)

Common Name	Scientific Name	Total Abundance	% of Total Abundance	Total Biomass (kg)	% of Total Biomass	Frequency of Occurance (%)	Ecological Index
Topsmelt	*Atherinops affinis*	605	44.7	2.00	7.39	100	5214
Shovelnose Guitarfish	*Rhinobatos productus*	5	0.37	19.9	73.3	25	1843
CIQ Goby	*Gobiidae*	188	13.9	0.05	0.17	100	1407
Queenfish	*Seriphus politus*	166	12.3	0.22	0.83	50	655
Atherinidae	*Atherinidae*	160	11.8	0.02	0.07	50	595
California Halibut	*Paralichthys californicus*	19	1.41	0.97	3.59	100	500
Giant Kelpfish	*Heterostichus rostratus*	53	3.92	0.19	0.71	100	463
Bay Pipefish	*Syngnathus leptorhynchus*	52	3.85	0.07	0.26	100	411
Spotted Sand Bass	*Paralabrax maculatofasciat*	6	0.44	1.10	4.05	50	225
Black Surfperch	*Embiotoca jacksoni*	15	1.11	0.85	3.12	50	212
Round Stingray	*Urolophus halleri*	3	0.22	0.98	3.62	50	192
Staghorn Sculpin	*Leptocottus armatus*	16	1.18	0.06	0.21	75	105
Dwarf Surfperch	*Micrometrus minimus*	26	1.92	0.30	1.12	25	76.1
Diamond Turbot	*Hypsopsetta guttulata*	14	1.04	0.12	0.45	50	74.5
Shiner Surfperch	*Cymatogaster aggregata*	5	0.37	0.12	0.46	75	62.1
White Surfperch	*Phanerodon furcatus*	3	0.22	0.07	0.27	50	24.8
Snubnose Pipefish	*Syngnathus arctus*	5	0.37	0.01	0.02	50	19.4
Blenny spp	*Blennidae*	3	0.22	0.01	0.02	50	12.2
White Croaker	*Genyonemus lineatus*	2	0.15	0.01	0.05	50	10.0
Barred Sand Bass	*Paralabrax nebulifer*	2	0.15	0.06	0.21	25	9.06
Arrow Goby	*Clevelandia ios*	2	0.15	0.00	0.01	25	3.88
Deepbody Anchovy	*Anchoa compressa*	1	0.07	0.01	0.03	25	2.59
Northern Anchovy	*Engraulis mordax*	1	0.07	0.00	0.00	25	1.94
Total Abundance/Biomass		1352		27.1			
Total Species Richness		23					

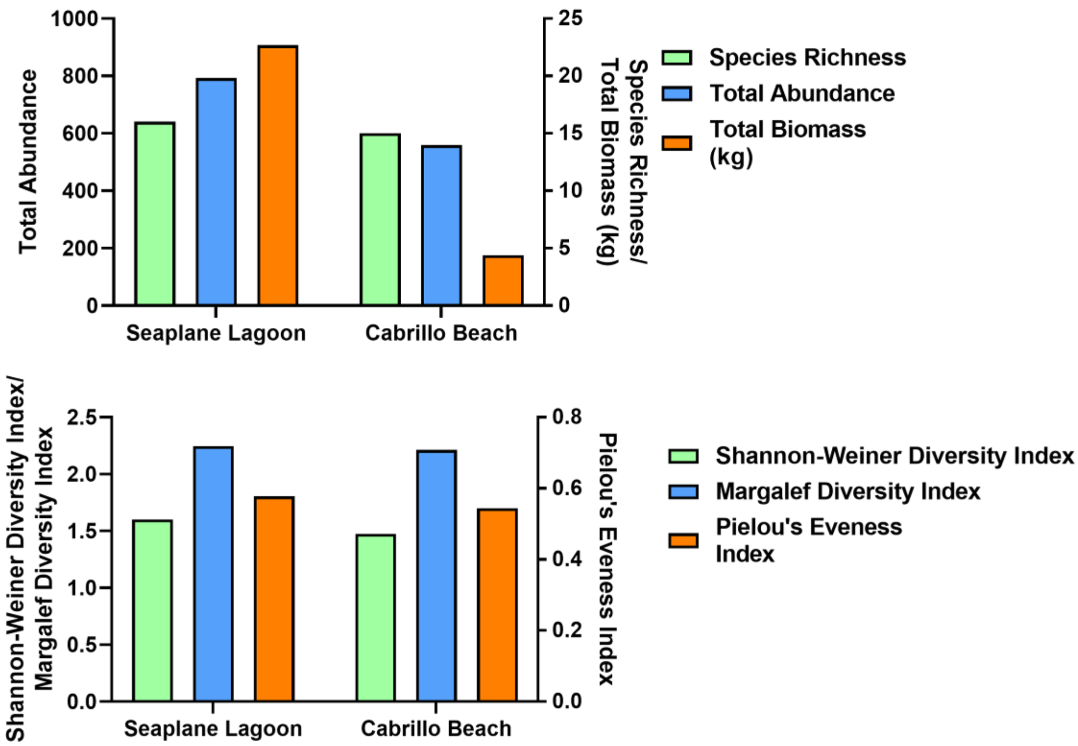


Figure 4-30. Fish Community Summaries for Seaplane Lagoon and Cabrillo Beach Captured using Beach Seines

4.5.2 Historical Comparisons

During the beach seine sampling in 2018, the greatest number of species (24) were caught of the four Biosurveys performed thus far (Figure 4-31). However, species richness in 2018 was only slightly greater than during the 2000 (21) and 2013 (20) Biosurveys, which had greater abundance. The mean abundance of fish per station was similar in all Biosurveys except for 2013, which had double the next highest abundance. The mean biomass per station was low in the 2000 and 2008 Biosurveys (0.37 kg and 0.17 kg respectively) relative to the 2013 and 2018 Biosurveys (6.5 kg and 4.5 kg respectively), likely due to the capture of a few large individual species such as guitarfish in some years but not others.

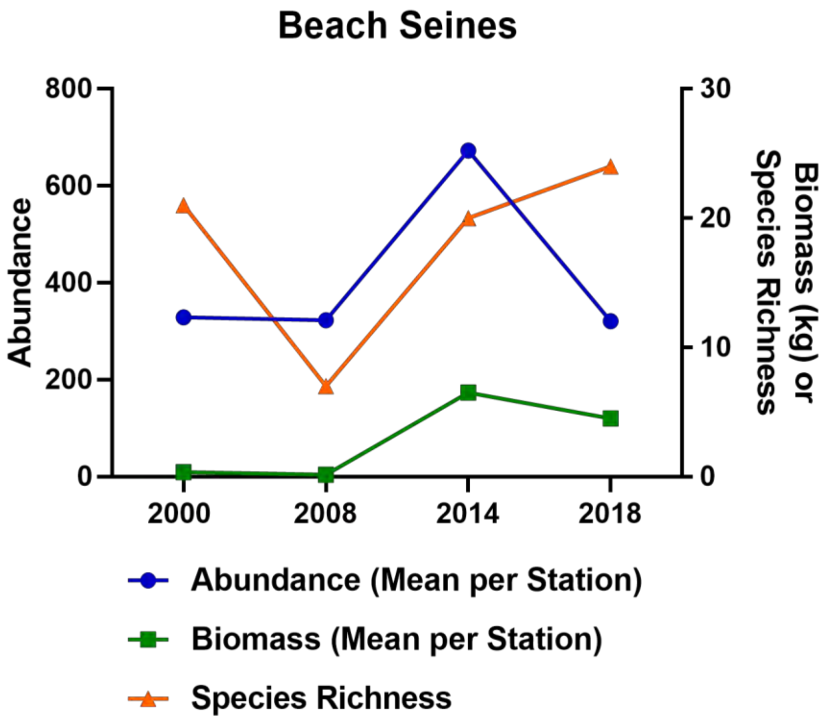


Figure 4-31. Historical Comparison of Species Richness, Mean Abundance and Mean Biomass Captured using Beach Seines at Seaplane Harbor and Cabrillo Beach

4.6 Demersal Fish

Demersal fish, those living on or near the ocean bottom, were sampled in the spring and summer at 26 stations throughout the Port Complex (Figure 4-22). Day and night sampling were performed using an otter trawl during each season for a total of 4 trawls at each station throughout the study period and a total of 104 individual trawl events. Detailed trawl tracks at each station can be found in the maps in Appendix D.

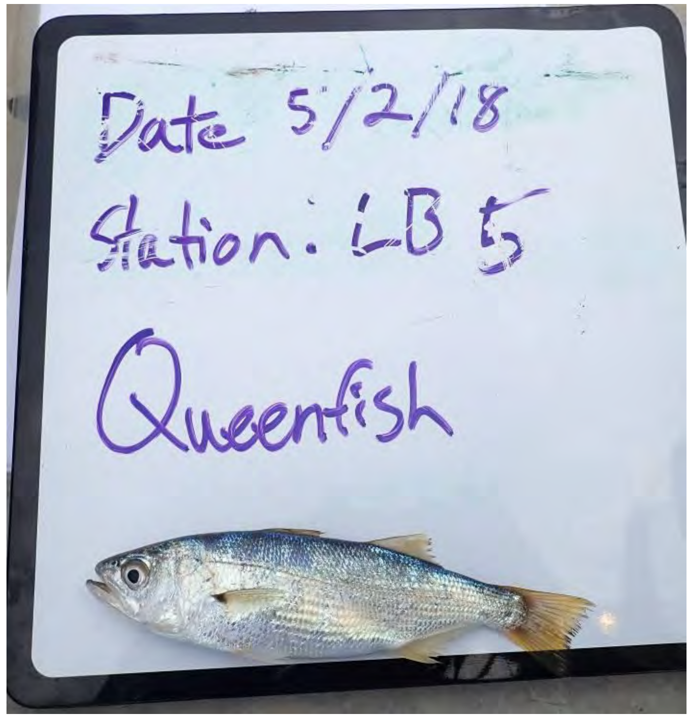
4.6.1 Species Comparisons

Abundance

Otter trawl sampling collected a total of 59 species comprised of 28,491 fish across all sampling events (Table 4-16). More fish were caught during the day (21,043) than at night (7,448) during the Biosurvey in 2018, but this difference was driven predominantly by a large capture of northern anchovy (*Engraulis mordax*) collected during the day (14,734) versus at night (149). Excluding the northern anchovy, the total catch in the day was 6,309 compared to 7,299 at night, showing a similar trend as that for pelagic fish caught using the lampara sampling during this Biosurvey, and both pelagic and benthic fish catches during prior Biosurveys in LA and Long Beach Harbors.

Large catches of northern anchovy also contributed heavily to differences in abundance observed between the spring (only 20 northern anchovies out of 5,880 fish caught) and summer (14,863 northern anchovies out of 22,611 fish caught). Across all sampling events, seven species made up 95.4% of the total abundance of all fish collected (Table 4-16): northern anchovy, white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), barred sand bass (*Paralabrax nebulifer*), California tonguefish (*Symphurus atricauda*), specklefin midshipmen (*Porichthys notatus*), and California lizardfish (*Synodus lucioceps*). The remaining 53 species represented only 4.6% of the total abundance.

Seven stations (LA1, LB3, LB6, LB7, LB9, LB10, and LB12) contained 82.6% of the total abundance of fish captured across all stations (See Appendix D). Large numbers of northern anchovy, white croaker, and queenfish were the main drivers of this pattern. These stations are all Outer Harbor stations that were classified as either deep or very deep, with depths ranging from 15.5-24.5 meters.



Queenfish captured in otter trawl

Table 4-16. Summary of Demersal Fish Captured using the Otter Trawl by Species, in Order of Ecological Index

Common Name	Scientific Name	Total Abundance per Taxa	% of Total Abundance	Total Biomass per Taxa (kg)	% of Total Biomass	Total Density (#/100 m^2)	Frequency of Trawl Capture (%)	Ecological Index
White Croaker	*Genyonemus lineatus*	8231	28.9	317	48.8	87.6	96.2	7474
Northern Anchovy	*Engraulis mordax*	14883	52.2	17.9	2.8	158	88.5	4866
Queenfish	*Seriphus politus*	2201	7.73	67.9	10.5	23.4	96.2	1749
Barred Sand Bass	*Paralabrax nebulifer*	519	1.82	44.1	6.8	5.53	92.3	796
California Halibut	*Paralichthys californicus*	162	0.57	47.6	7.3	1.72	92.3	729
Round Stingray	*Urolophus halleri*	166	0.58	54.1	8.3	1.77	65.4	583
California Lizardfish	*Synodus lucioceps*	389	1.37	12.9	2.0	4.14	84.6	284
California Tonguefish	*Symphurus atricauda*	509	1.79	6.70	1.03	5.42	92.3	260
Fantail Sole	*Xystreurys liolepis*	103	0.36	13.3	2.0	1.10	80.8	194
Specklefin Midshipman	*Porichthys myriaster*	444	1.56	3.19	0.49	4.73	80.8	166
California Scorpionfish	*Scorpaena guttata*	50	0.18	9.20	1.42	0.53	42.3	67.4
Speckled Sanddab	*Citharichthys stigmaeus*	175	0.61	2.49	0.38	1.86	53.8	53.7
Shiner Surfperch	*Cymatogaster aggregata*	138	0.48	2.34	0.36	1.47	61.5	52.0
Diamond Turbot	*Hypsopsetta guttulata*	16	0.06	3.40	0.52	0.17	46.2	26.8
Spotted Sand Bass	*Paralabrax maculatofasciatus*	44	0.15	2.80	0.43	0.47	34.6	20.3
Spotted Turbot	*Pleuronichthys ritteri*	35	0.12	1.71	0.26	0.37	42.3	16.4
Plainfin Midshipman	*Porichthys notatus*	98	0.34	0.42	0.06	1.04	38.5	15.7
Hornyhead Turbot	*Pleuronichthys verticalis*	30	0.11	1.46	0.23	0.32	46.2	15.3
Bat Ray	*Myliobatis californica*	5	0.02	8.31	1.28	0.05	11.5	15.0
California Corbina	*Menticirrhus undulatus*	11	0.04	2.18	0.34	0.12	23.1	8.66
Longspine Combfish	*Zaniolepis latipinnis*	45	0.16	1.29	0.20	0.48	23.1	8.23
California Skate	*Raja inornata*	6	0.02	2.51	0.39	0.06	19.2	7.84
Pacific Electric Ray	*Torpedo californica*	1	0.00	12.6	1.9	0.01	3.85	7.48
Thornback Ray	*Platyrhinoidis triseriata*	11	0.04	2.52	0.39	0.12	15.4	6.56
White Surfperch	*Phanerodon furcatus*	34	0.12	1.43	0.22	0.36	19.2	6.54
Basketweave Cusk-eel	*Otophidium scrippsi*	10	0.04	0.62	0.10	0.11	26.9	3.51
Yellowfin Croaker	*Umbrina roncador*	18	0.06	1.07	0.16	0.19	11.5	2.63
Black Sea Bass	*Stereolepis gigas*	1	0.00	4.40	0.68	0.01	3.85	2.62
Jack Mackerel	*Trachurus symmetricus*	10	0.04	0.62	0.09	0.11	15.4	2.00
Yellowchin Sculpin	*Icelinus quadreiseriatus*	22	0.08	0.06	0.01	0.23	23.1	1.98

Table 4-16 (continued). Summary of Demersal Fish Captured using the Otter Trawl by Species, in Order of Ecological Index

Common Name	Scientific Name	Total Abundance per Taxa	% of Total Abundance	Total Biomass per Taxa (kg)	% of Total Biomass	Total Density (#/100 m^2)	Frequency of Trawl Capture (%)	Ecological Index
Gopher Rockfish	*Sebastes carnatus*	3	0.01	0.58	0.09	0.03	11.5	1.15
Salema	*Xenistus californiensis*	8	0.03	0.19	0.03	0.09	19.2	1.10
Arrow Goby	*Clevelandia ios*	12	0.04	0.01	0.00	0.13	23.1	1.01
Longfin Sanddab	*Citharichthys xanthostigma*	6	0.02	0.42	0.07	0.06	11.5	1.00
Vermillion Rockfish	*Sebastes miniatus*	11	0.04	0.42	0.06	0.12	7.69	0.79
Black Surfperch	*Embiotoca jacksoni*	5	0.02	0.07	0.01	0.05	11.5	0.33
California Grunion	*Leuresthes tenuis*	15	0.05	0.14	0.02	0.16	3.8	0.28
Slender Sole	*Lyopsetta exilis*	5	0.02	0.26	0.04	0.05	3.8	0.22
Topsmelt	*Atherinops affinis*	2	0.01	0.13	0.02	0.02	7.69	0.20
Bay Goby	*Lepidogobius lepidus*	3	0.01	0.00	0.00	0.03	11.5	0.13
Pacific Butterfish	*Peprilus simillimus*	2	0.01	0.06	0.01	0.02	3.85	0.12
Black Croaker	*Cheilotrema saturnum*	1	0.00	0.15	0.02	0.01	3.85	0.10
Slough Anchovy	*Anchoa delicatissima*	3	0.01	0.01	0.00	0.03	7.69	0.09
Brown Rockfish	*Sebastes auriculatus*	1	0.00	0.10	0.02	0.01	3.85	0.07
Yellowfin Goby	*Acanthogobius flavimanus*	2	0.01	0.02	0.00	0.02	7.69	0.07
Rock Wrasse	*Halichoeres semicinctus*	1	0.00	0.07	0.01	0.01	3.85	0.06
English Sole	*Parophrys vetulus*	1	0.00	0.06	0.01	0.01	3.85	0.05
Kelp Bass	*Paralabrax clathratus*	1	0.00	0.06	0.01	0.01	3.85	0.05
Ocean Whitefish	*Caulolatilus princeps*	1	0.00	0.02	0.00	0.01	3.85	0.03
Pacific Sanddab	*Citharichthys sordidus*	1	0.00	0.02	0.00	0.01	3.85	0.02
Staghorn Sculpin	*Leptocottus armatus*	1	0.00	0.02	0.00	0.01	3.85	0.02
Deepbody Anchovy	*Anchoa compressa*	1	0.00	0.00	0.00	0.01	3.85	0.02
Bay Pipefish	*Syngnathus leptorhynchus*	1	0.00	0.00	0.00	0.01	3.85	0.02
Snubnose Pipefish	*Syngnathus arctus*	1	0.00	0.00	0.00	0.01	3.85	0.01
Goby (larval)	*Gobbidae*	1	0.00	0.00	0.00	0.01	3.85	0.01
Onespot Fringehead	*Neoclinus uninotatus*	1	0.00	0.00	0.00	0.01	3.85	0.01
Goby spp	*Gobiidae*	4	0.01	0.00	0.00	0.04	7.69	0.00
Kelpfish spp	*Clinidae*	1	0.00	0.00	0.00	0.01	3.85	0.00
Total Abundance/Biomass		28491		648.9				
Total Species Richness		59						

Biomass

The total biomass of demersal fish collected by otter trawl sampling was 649 kg across both seasons (Table 4-16). There was little difference in biomass between day (323 kg) and night (326 kg) and between spring (350 kg) and summer (299 kg) among all fish combined.

Across all sampling events, five species made up 81.8% of the total biomass of all fish collected. White croaker was the most dominant species, making up 48.8% of the total biomass. Queenfish (10.5%), round stingray (*Urobatis helleri*; 8.3%), California halibut (*Paralichthys californicus*; 7.3%) and barred sand bass (6.8%) were the only other species that made up more than 5% of the total biomass collected. Notably, northern anchovy, despite being the most abundant fish in otter trawls, represented only 2.8% of the total biomass, while some large species such as one Pacific electric ray (*Torpedo californica*; 1.9%) and five bat rays (*Myliobatis californica*; 1.3%) were well represented in the total biomass despite their low abundance.

Seven stations in the Outer Harbor (LA1, LB2, LB3, LB6, LB7, LB9 and LB12) made up 66.2% of the total biomass of fish captured across all stations.

Ecological Index

The range of EI values for trawl species ranged from 0.01 for a single kelpfish to 7,474 for white croaker which was nearly ubiquitous across the harbors (Table 4-16). The top five species based on the EI values were white croaker (7,474), northern anchovy (4,865), queenfish (1,749), barred sand bass (796) and California halibut (730). The “rank” by EI determines the relative importance of each species to how energy flows within the food web of the Port ecosystem (Allen et al. 2002). Because the EI incorporates frequency of catch, this index provides a good measure of what the overall community looks like over time across multiple trophic levels.

Size Classes

The four benthic fish species with the highest EI values (white croaker, queenfish, barred sand bass, and California halibut) as well as the most abundant Pacific Coast Groundfish FMP species (California scorpionfish) were analyzed by size class. Note that while northern anchovy were caught in the trawl, their size class distribution was analyzed with the rest of the pelagic species in Section 3.3.1. Beach seine data was incorporated into the size class analysis for queenfish and California halibut as those species were abundant in shallow subtidal habitats. Length at maturity information is provided for species where this information is available.

White croaker (8,234 total across all gear types) had the highest EI value of any species collected and ranged in size from 1 to 25 cm (Figure 4-32). Both spring and summer populations showed bimodal distributions. The spring population had a smaller size class centered around 2-5 cm and a larger size class between 13-18 cm. In the summer, the smaller size class was longer than in spring (7-9 cm range) and more abundant (1,938 individuals), but the larger size class was similar to the spring catch (14-17 cm). Maturity of 50% of the male and female white croaker population occurs when fish reach approximately 1-year of age (14 cm and 15 cm TL, respectively), and 100% of fish are mature at 3-4 years of age with a length of approximately 19 cm (Love 2011). Based on the average of this range (16.5 cm) approximately 16.6% of the population captured in the Port Complex in 2018 may be considered mature.

Queenfish (2,387 total) captured with otter trawls ranged in size from 1 to 24 cm and had a bimodal size distribution across both seasons (Figure 4-33). The spring population had a smaller size class centered around 7-9 cm and a larger size class from 13-15 cm. The summer population had a smaller size class around 5-7 cm and a larger size class from 12-16 cm. Beach seines captured small juveniles in the 3 cm size class in September 2019, which corresponds to the 2-3 cm size class observed in the otter trawls. Beach seines in November 2019 captured a large cohort of 4-5 cm juveniles at the same stations. Length-at-age studies from San Clemente and Oceanside populations suggest that females are mature at around 10-10.5 cm standard length (DeMartini and Fountain 1981), which would mean that approximately 76% of the total catch would be considered mature. A comparison of the size distribution of queenfish and white croaker captured within the Port Complex to maturity thresholds (Figures 4-1 and 4-2) suggests that there are self-sustaining populations of mature adult queenfish and white croaker within the Port Complex likely spawning and recruiting locally with connectivity to nearshore populations.

Barred sand bass (521 total) ranged from 4 to 29 cm, and in both seasons the modal size class was centered around 14-19 cm (Figure 4-34). Only five individuals over 23 cm were captured, and even the largest fish at 29 cm SL was smaller than the recreational fishing limit size of 14 inches total length (35.5 cm total length). Maturity of 50% of the male and female barred sand bass population occurs when fish reach approximately 3-years of age (22 cm and 24 cm TL, respectively), and 100% of fish are mature at 4-5 years of age with a length of approximately 26-27 cm (Love 2011). Based on the average of this range (24.5 cm), approximately 0.6% of the population captured in the Port Complex in 2018 may be considered mature.

California halibut (181 total) caught with otter trawls in spring ranged from 6-77 cm, while in the summer they ranged from 6-45 cm (Figure 4-35). This trend was notable because it is well established that halibut use bays and estuaries as nursery habitats (Lopez-Rasgado and Herzka 2009), with adults moving into shallow protected habitats between April and July to spawn. In the summer, the largest halibut caught were both 45 cm, while in the spring there were six halibut caught from 47-77 cm. The California Department of Fish and Wildlife considers California halibut a high priority species for life history research in order to help manage the fishery for long-term sustainability (Lesyna and Barnes 2016), and has established length- and age-at-maturity for California halibut in Central and Southern California. In Southern California, males are 50% mature at around 22.7 cm long (fork length) and about 1 year old, while females reach 50% maturity at 45.5 cm (fork length) and about 4 years old. Although the present study measured fish in standard length, these lengths

California halibut captured in otter trawls

can be used to conservatively estimate the juvenile and mature reproductive population of halibut within the Ports. Two-thirds of the California halibut captured across all seasons with otter trawl and beach seine were between 2-22 cm standard length, or what could be considered a first-year juvenile (Lesyna and Barnes 2016). Fifty-six individuals (31% of the total caught) were between 23-44 cm, which is a 1-4 year-old cohort that is likely a mix of juvenile and adult halibut, with most males in this size class already at maturity. There were eight individuals (4% of total abundance) above 45 cm, which represents a 4+ year old cohort that was almost entirely mature adults. The four individuals captured in the spring that were between 60-77 cm were likely adults that had moved back into shallower waters from offshore to spawn within the Ports.

California scorpionfish (50 total) ranged in size from 5 to 26 cm in the spring and 12 to 28 cm in the summer (Figure 4-36). In both seasons, the majority of fish were within the 14-20 cm size range (72% of the total). Maturity of 50% of California scorpionfish population occurs when fish reach approximately 2-years of age (17–18 cm TL), and 100% of fish are mature at 4 years of age with a length of approximately 22 cm (Love 2011). Based on the average of this range (19.5 cm) approximately 24.0% of the population captured in the Port Complex in 2018 may be considered mature.

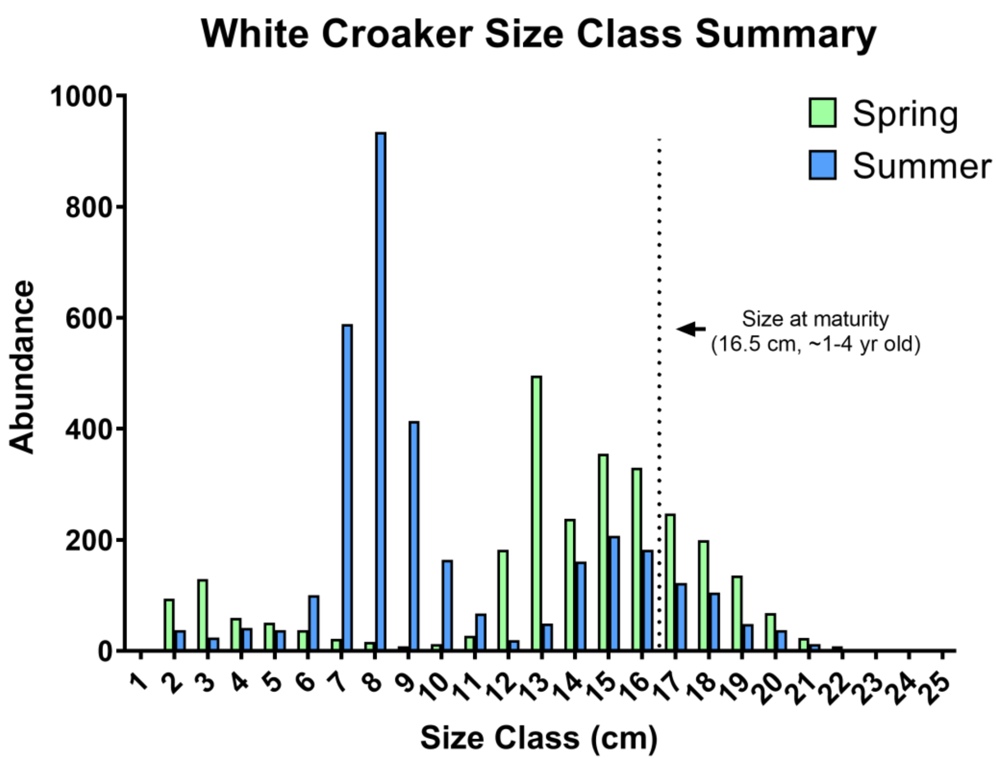


Figure 4-32. White Croaker Size Class Summary.

Note: 34 white croaker from the spring and 2,105 white croaker from the summer surveys were not sized and are not included in this graph (only first 250 individuals from each species in each trawl were sized). Length at maturity from Love 2011.

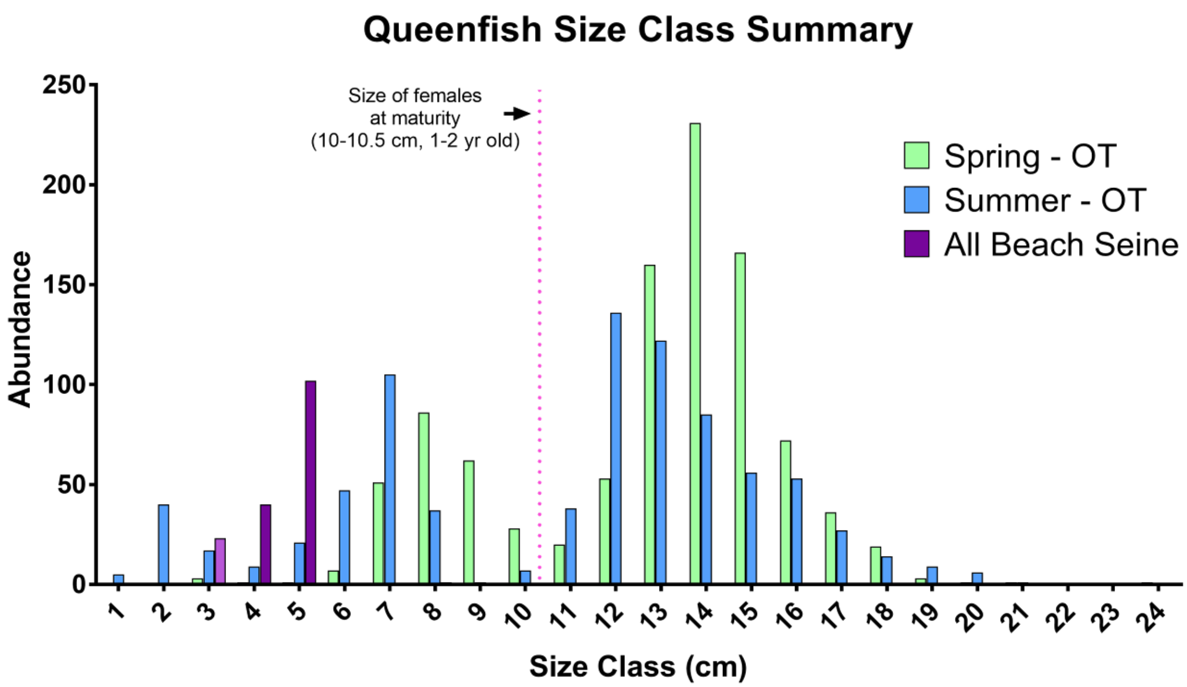


Figure 4-33. Queenfish Size Class Summary

Note: 383 queenfish from the spring survey were not sized and are not included in this graph (only first 250 individuals from each species in each trawl were sized). Length at maturity from Fountain 1981. Light purple bar represents all fish captured in September beach seines, dark purple represents all fish captured in November beach seines. April beach seines caught 1 fish at 8 cm standard length. OT = Otter Trawl.

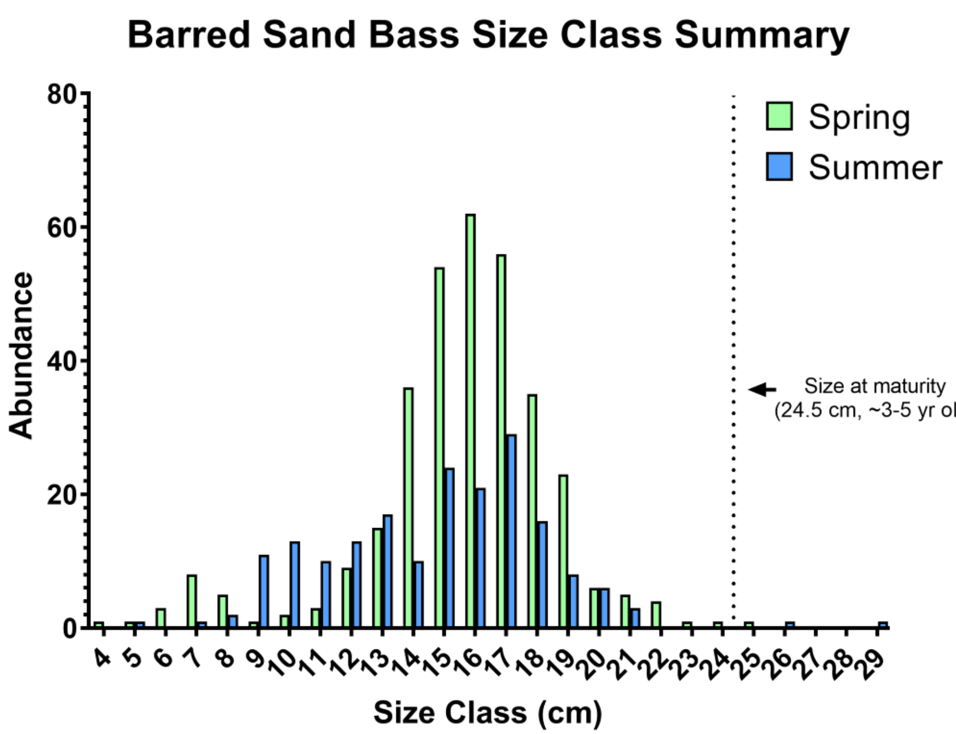


Figure 4-34. Barred Sand Bass Size Class Summary.

Note: Length at maturity from Love 2011

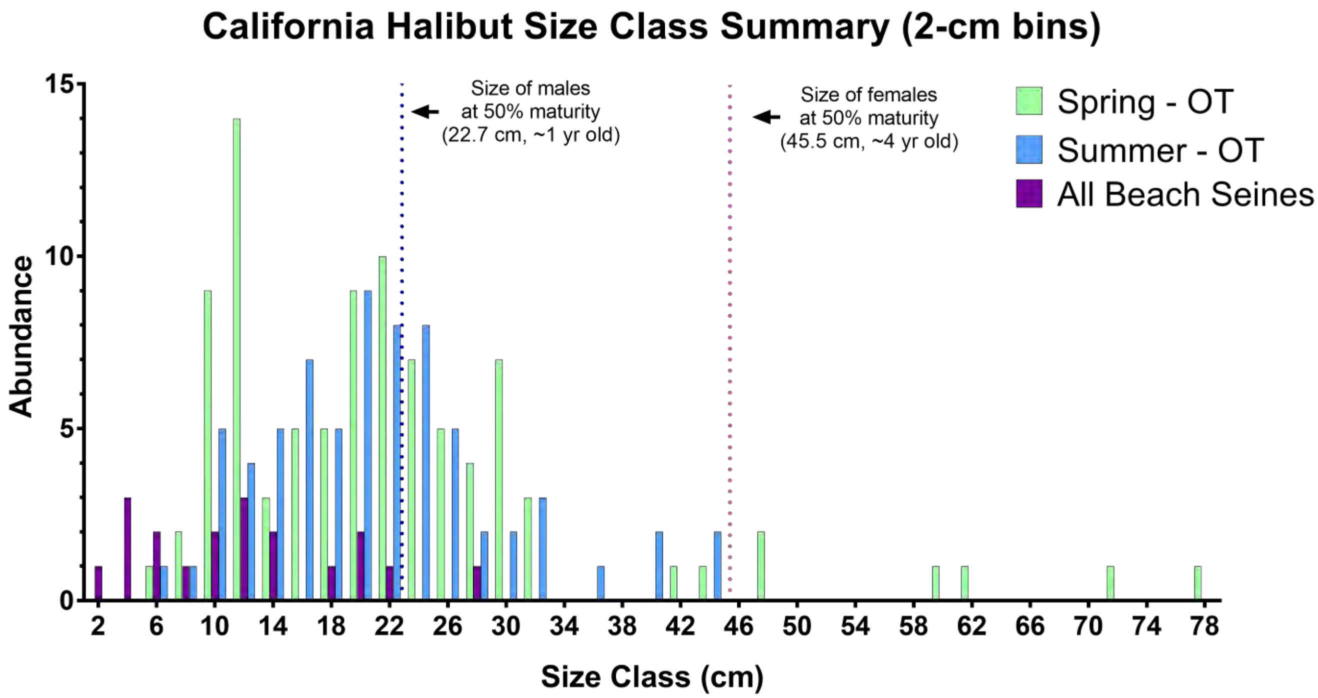


Figure 4-35. California Halibut Size Class Summary

Note: Length at maturity from Lesyna and Barnes 2016, which uses fork length while standard length is reported in this study. Therefore, these estimates can be considered conservative for the number of mature halibut as the standard length at maturity is shorter than fork length. OT = Otter Trawl

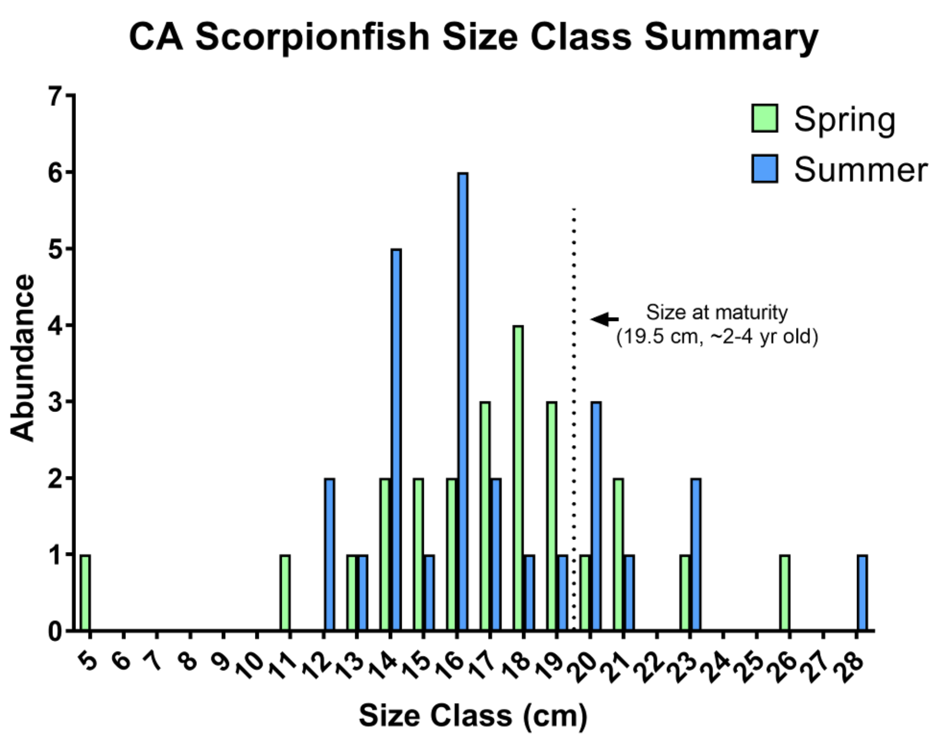


Figure 4-36. California Scorpionfish Size Class Summary.

Note: Length at maturity from Love 2011

4.6.2 Station Comparisons

Species Richness

Otter trawl sampling collected a total of 59 species over all sampling events; 44 species were captured during the day and 49 species were captured during the night (Appendix D). Spring sampling captured 46 species while summer sampling captured 50 species (Appendix D). When all sampling events were combined, Inner Harbor Station LA14 (Consolidated Slip) had the fewest species captured (n=7), while Outer Harbor Stations LA9 (Pier 400) and LB12 (Long Beach Main Channel – Police Station) had the most species captured (n=23; Table 4-17).

Diversity and Evenness Indices

Shannon-Wiener diversity index values ranged from 0.67 to 2.65, and Margalef index values ranged from 1.38 to 3.95 (Table 4-17). While generally similar patterns emerge from both indices, there are some notable differences. Both indices identified SWH Stations LA2 and LA3 as having the highest diversity, which is consistent with previous Biosurveys and the surveys targeting pelagic fish using the lampara net in 2018. However, differences between the indices were evident when factoring in the evenness of the community. While Shannon-Weiner and Pielou’s identified LB12 as having the lowest values due to white croaker and queenfish making up 93% of the total abundance, the Margalef’s index score of 2.79 for this station was in the middle of the observed range for all sites. The station with the most even distribution of fish based on Pielou’s index was LB16, which was the third ranked station according to the Shannon-Weiner index but was the eighth highest ranked station based on the Margalef index. Some stations were ranked similarly by all three indices, such as LB6, a deep Outer Harbor location that had the lowest Margalef score (1.38) and among the lowest according to Shannon-Weiner (0.81) and Pielou’s index (0.33).

In general, stations that were dominated by only a few species scored low across all indices, although this pattern was more apparent using the Shannon-Weiner or Pielou’s indices. The top five stations in terms of total abundance of fish captured ranked in the bottom five of at least one index, while two of the three stations with the lowest total abundance (less than 50 total fish across all sampling events) were ranked in the top three of at least one index.

Table 4-17. Demersal Fish Catch Summary by Station Captured using the Otter Trawl (All Seasons Combined)

Station	Station Descriptor	Habitat	Location	Depth Strata	Taxa Richness	Total Abundance per Station	Total Biomass per Station (kg)	Shannon-Wiener Diversity Index	Margalef Diversity Index	Pielou's Eveness Index
LA1	Outer Pier 400	Outer	Outer	Very Deep	20	9416	89.7	0.75	2.08	0.25
LA2	LA SWH East	SWH	SWH	Shallow	20	124	16.4	2.65	3.94	0.88
LA3	LA SWH West	SWH	SWH	Shallow	20	123	13.4	2.48	3.95	0.83
LA4	LA Main Channel	Outer	Channel	Deep	16	163	11.0	1.96	2.94	0.71
LA5	West Basin	Inner	Basin	Deep	12	174	13.3	1.76	2.13	0.71
LA6	LA East Basin	Inner	Basin	Deep	14	168	11.5	1.95	2.54	0.74
LA7	Seaplane Lagoon	SWH	SWH	Shallow	17	280	19.2	2.29	2.84	0.81
LA9	Pier 400	Outer	Channel	Deep	23	330	11.3	2.35	3.79	0.75
LA10	Fish Harbor	Inner	Basin	Deep	18	1240	28.0	1.12	2.39	0.39
LA11	LA Outer Channel	Outer	Outer	Very Deep	20	406	22.7	1.99	3.16	0.67
LA14	Consolidated Slip	Inner	Slip	Deep	7	15	1.32	1.73	2.22	0.89
LA15	LA Turning Basin	Outer	Basin	Deep	16	142	4.32	2.16	3.03	0.78
LA16	Bannings Landing	Inner	Slip	Deep	11	39	2.24	2.08	3.19	0.81
LB1	Outer Anchorages	Outer	Outer	Deep	15	368	12.7	1.21	2.37	0.45
LB2	LB SWH	SWH	SWH	Shallow	17	505	35.4	1.70	2.57	0.60
LB3	West Basin	Outer	Basin	Deep	17	2335	44.6	0.85	2.06	0.30
LB4	Channel 2	Inner	Slip	Deep	18	144	6.62	2.03	3.42	0.70
LB5	SE Basin East	Outer	Basin	Deep	16	217	5.61	2.18	2.79	0.79
LB6	Pier J	Outer	Slip	Deep	12	2954	41.9	0.81	1.38	0.33
LB7	Main Channel Pilot Station	Outer	Channel	Very Deep	17	3128	58.9	1.15	1.99	0.41
LB9	Outer Channel	Outer	Outer	Very Deep	18	1489	91.0	1.18	2.19	0.41
LB10	SE Basin West	Outer	Basin	Deep	12	1575	10.1	0.85	1.49	0.34
LB12	Main Channel Police Station	Outer	Channel	Very Deep	23	2645	68.0	0.67	2.79	0.21
LB13	LB Turning Basin	Outer	Basin	Very Deep	13	195	10.7	2.19	2.28	0.85
LB14	Cerritos Channel	Inner	Channel	Deep	19	262	16.6	2.21	3.23	0.75
LB16	Channel 3	Inner	Slip	Deep	12	49	2.28	2.35	3.07	0.92

4.6.3 Station Groups

As with other study elements, the sampling stations were grouped according to habitat (Inner, Outer, SWH), location (Outer, SWH, Channel, Basin, Slip), and depth (Shallow [0-7 m], Deep [7.1-18 m], Very Deep [18+ m]) and compared using the aforementioned metrics.

Grouping stations according to habitat reveals some patterns that have already been discussed, such as those for SWH stations (Figure 4-37), which had the highest average species richness but relatively low abundance and total biomass. However, on average stations located in SWH also had the highest mean values for the diversity and evenness. However, the single station with the greatest abundance and biomass, and near the top for species richness, was Station LA1 located in the Outer Harbor (Outer Pier 400). . Outer Harbor stations overall had the lowest diversity and evenness indices, in part due to the large catches of a few species (i.e. anchovies, white croaker and queenfish) which occurred at several stations in this group. Inner Harbor stations had the lowest mean values for species richness, abundance and total biomass, but they were between SWH and Outer Harbor stations for the diversity indices and were among the stations that scored highest on Pielou's evenness index.

Location and habitat groups share some patterns, but location groups also identify some unique patterns (Figure 4-38). Species richness was generally highest at channel, SWH, and Outer Harbor stations. Channels had two stations with the highest species richness (Station LA9 Pier 400 Channel and Station LB12 Main Channel Police Station) with 23 species per station, while the station with the lowest species richness (Station LA14 Consolidated Slip, with 7 species) was classified as a slip station. Outer Harbor stations had the highest mean abundance, although the variability among these stations was high and the mean abundance was highly influenced by one station at which 9,416 fish were caught (LA1), the highest of any station. Locations in the Outer Harbor and channels also had the greatest average total biomass, as these groups had stations which were dominated by large catches of a few species. While the SWH locations had the lowest average abundance and total biomass, this habitat had the highest average values for diversity and evenness. Outer Harbor stations on average had the lowest diversity scores among all indices, with the other four groups showing greater site-to-site variability in species present.

Field observations indicated that many of the largest catches were in the deepest areas, and the comparison for depth strata groups bear this out (Figure 4-39). Species richness was similar across all depth groups, but the Very Deep stations had much higher average total abundance and biomass. The large catches at Very Deep stations generally consisted of only a few dominant species, causing the very deep stations to score the lowest on all of the diversity and evenness indices. Shallow stations showed a consistent pattern of high species diversity, low total abundance and biomass, but among the highest overall diversity and evenness index scores.

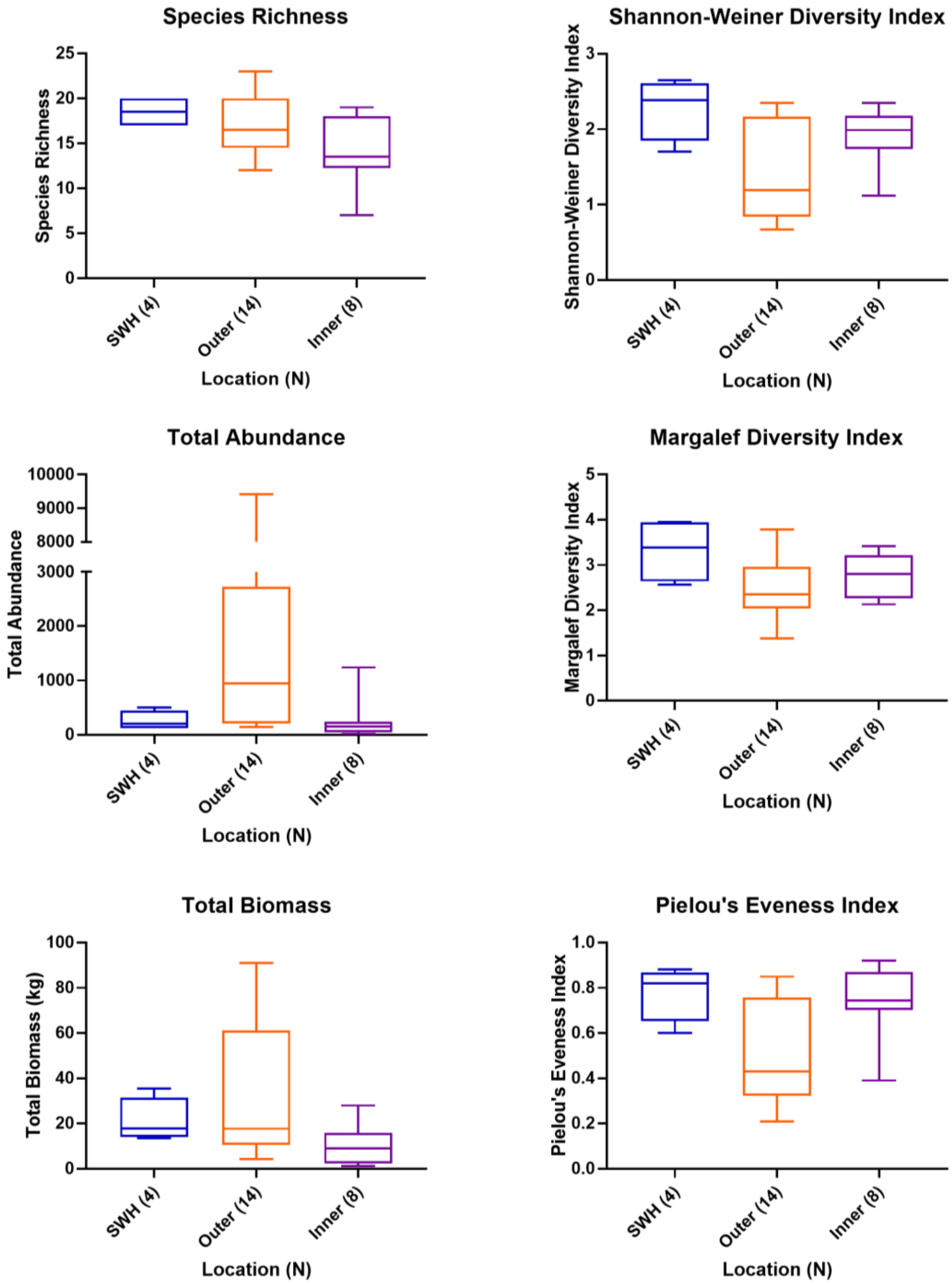


Figure 4-37. Station Habitat Group Summaries for Demersal Fish Captured Using the Otter Trawl (All Seasons Combined)

(Box plots showing the median, range, and quartiles for each dataset)

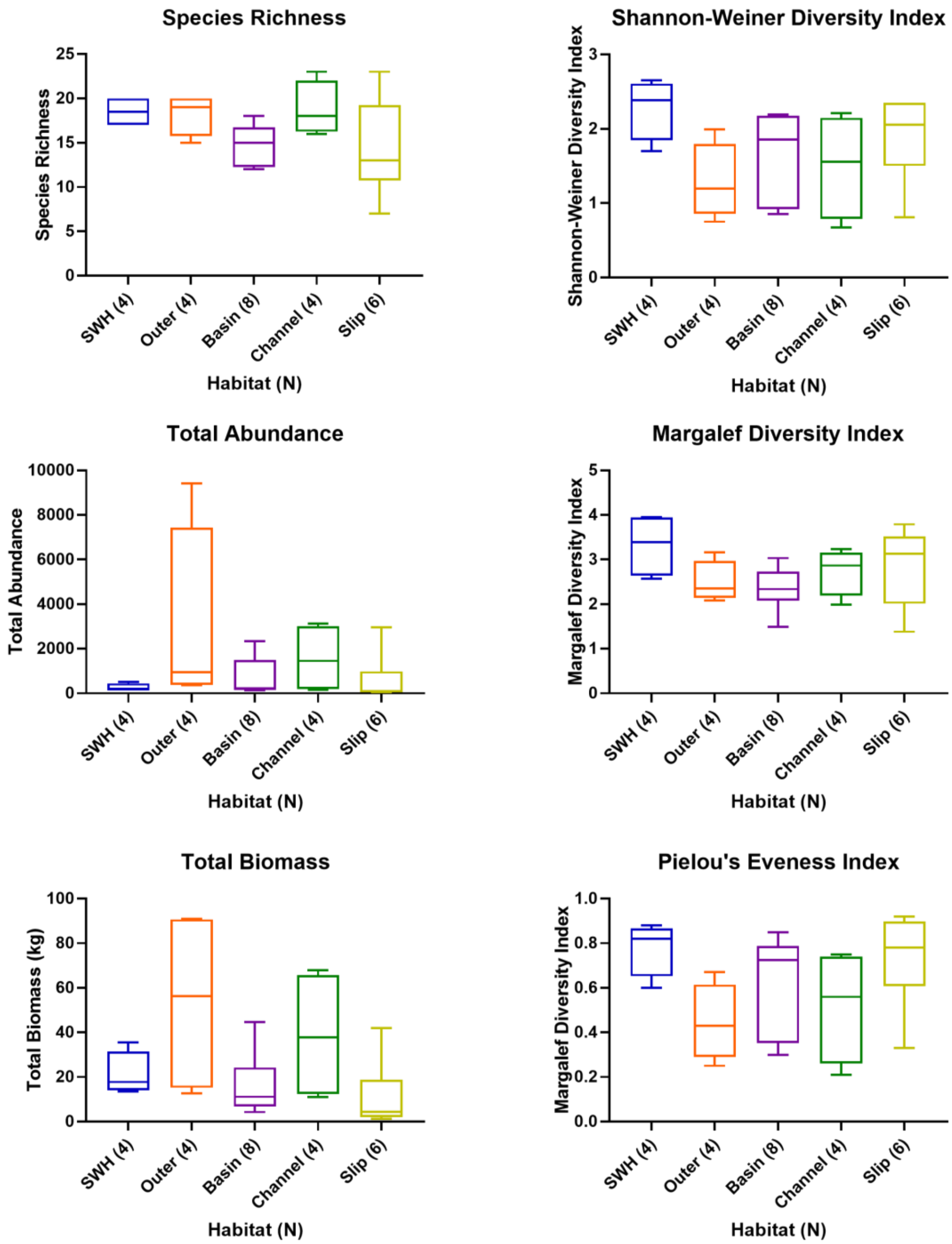


Figure 4-38. Station Location Group Summaries for Demersal Fish Captured Using the Otter Trawl (All Seasons Combined)

(Box plots showing the median, range, and quartiles for each dataset)

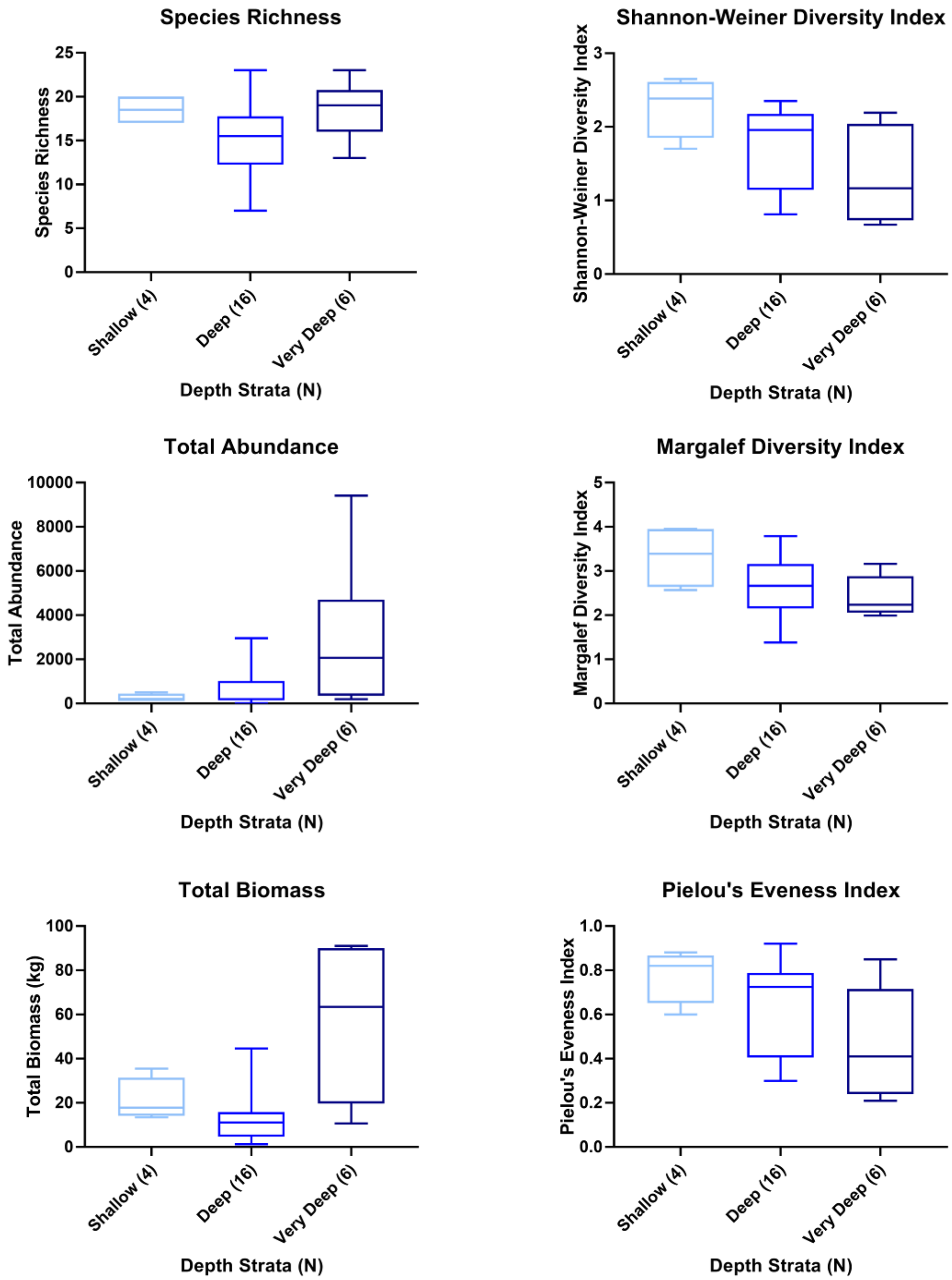


Figure 4-39. Station Depth Strata Group Summaries for Demersal Fish Captured Using the Otter Trawl (All Seasons Combined)

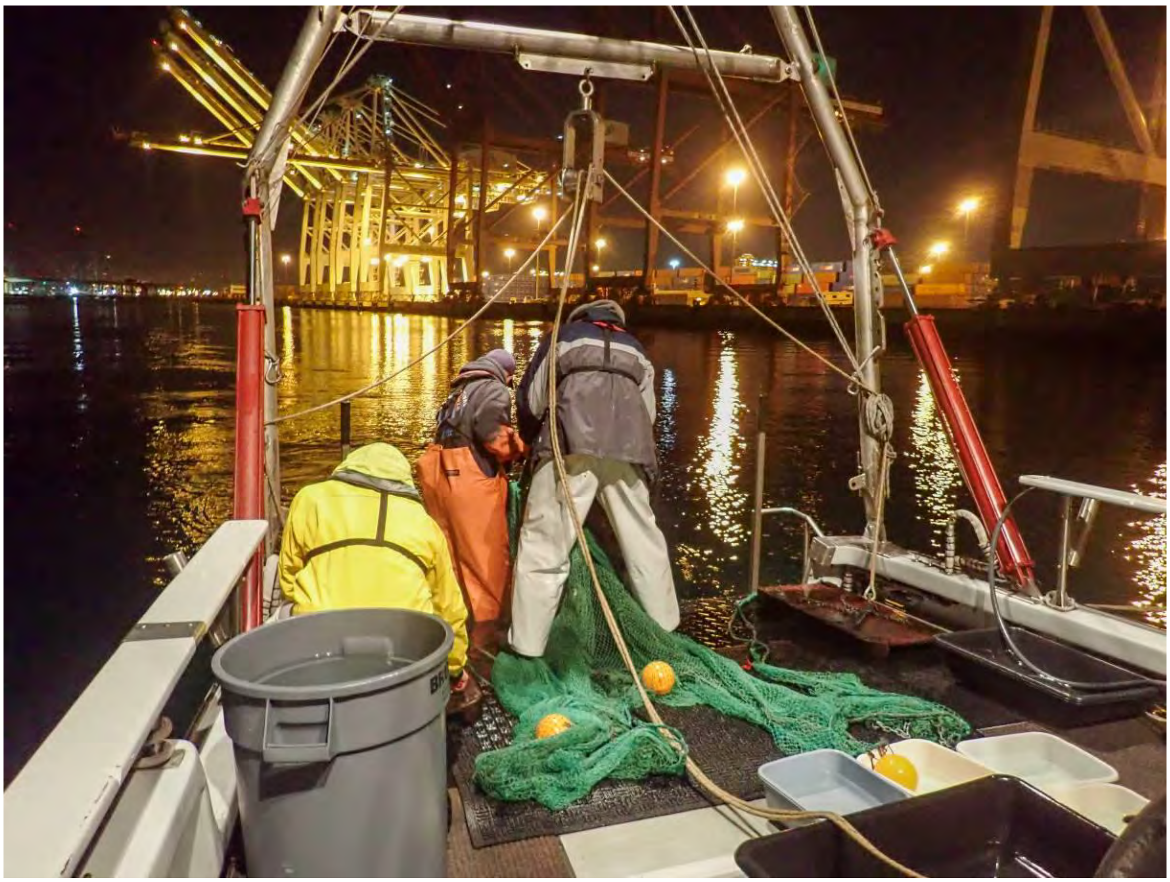
(Box plots showing the median, range, and quartiles for each dataset)
Note: Shallow 0-7 m, Deep 7.1-18 m, Very Deep 18.1+ m

Multivariate Analyses

Multivariate analysis of demersal fish abundance data combined across all sampling events was performed using the PRIMER statistical package (see Section 1.7). The resultant nMDS plots, shade plots, and SIMPER analysis figures and tables for location, habitat, and depth strata groups can be found in Appendix D. The analysis provided an in-depth evaluation of station groups and patterns of demersal fish communities across stations. Statistically significant differences for each station type (habitat, location, and depth strata) were observed using ANOSIM (see Section 1.7). Pairwise tests were able to show which pairs within each station type were the most distinct. Analysis of the different station habitat types showed that the largest distinction was between Outer Harbor and SWH stations (Figure 4-40). Pairwise comparisons based on location showed the largest differences between SWH and the Outer Harbor and basin stations (Figure 4-41). Outer Harbor, slip, and channel stations were the most alike. Depth strata analysis showed that Shallow and Very Deep stations were the most distinct from one another, while the difference between Deep and Very Deep stations was not statistically significant (Figure 4-42).

Cluster analysis with similarity profile (SIMPROF) analysis of trawl abundance data identified six groups of stations (A – F) that were significantly different from one another. The resulting nMDS plot (Figure 4-43) can be overlaid onto the station map (Figure 4-44) for easier interpretation. Stations in clusters A and D are found predominantly in the Inner Harbor areas within slips and basins, with station LB5 in Southeast Basin the only exception. Interestingly, all SWH stations are in cluster F, which confirms that these stations are unique compared to the rest of the Port Complex in terms of their community composition. Cluster E is one of the largest groups, encompassing almost all the outer POLB stations as well as LA1 outside Pier 400 and LA10 in Fish Harbor. Cluster C is made up of two outer stations in POLA that are relatively deep, including Pier 400 (LA9) and the outer POLA main channel (LA11). Cluster B is the only ‘group’ that includes only one station (LA4), in the POLA main channel.

From the cluster analysis groups, a shade plot was made to display the relative abundances of the top 35 species (as determined by their ability to discriminate stations) at each station (Figure 4-45). An additional similarity percentages (SIMPER) analysis was run to determine the species that characterized each group. This analysis was useful to compare station cluster groups that were located near each other on the nMDS but that may have encompassed different habitat types to determine the differences in community composition. Clusters A and D were located in the Inner Harbor basins and slips, but cluster A stations were dominated by barred sand bass and queenfish (25% and 21% of total abundance, respectively) with northern anchovy and white croaker as secondary species (22% combined). Cluster D was more evenly represented by barred sand bass, white croaker, queenfish, and specklefin midshipman, with each making up 12-15% of the total community composition. While the species composition was relatively similar between these two groups, the relative abundances were different. Cluster E was dominated by white croaker (21%) with northern anchovy (15%) and queenfish (14%) the other major contributors. Cluster C, near Pier 400 and the outer POLA main channel, was the most evenly distributed community: white croaker, queenfish, California lizardfish, California tonguefish, and speckled sanddab combined to make up 50% of the community composition and no single species contributed more than 13%. Cluster B was made up of only one Outer Harbor station (LA4) due to its unique community composition. This site was heavily dominated by barred sand bass (45%), with plainfin midshipman, speckled sanddab, and specklefin midshipman all contributing 10%. Notably, this was the only station where no queenfish were caught, and it had the second lowest catch of white croaker (3), which was markedly different from every other station group, in which white croaker made up at least 5% and queenfish made up at least 10% of the community. Midshipmen have been shown to be a preferred prey species of barred sand bass (Roberts et al. 1984), so the co-occurrence of these species here could suggest the selection of the habitat by the barred sand bass due to the presence of midshipmen. Cluster F, comprised of SWH stations exclusively, also had one of the most distinctive community assemblages, with 48% of the community being represented by queenfish (18%), round stingray (15%), and California halibut (15%). Round stingray and California halibut did not make up a high proportion of the community in any other station group.



Recovering the otter trawl during night sampling

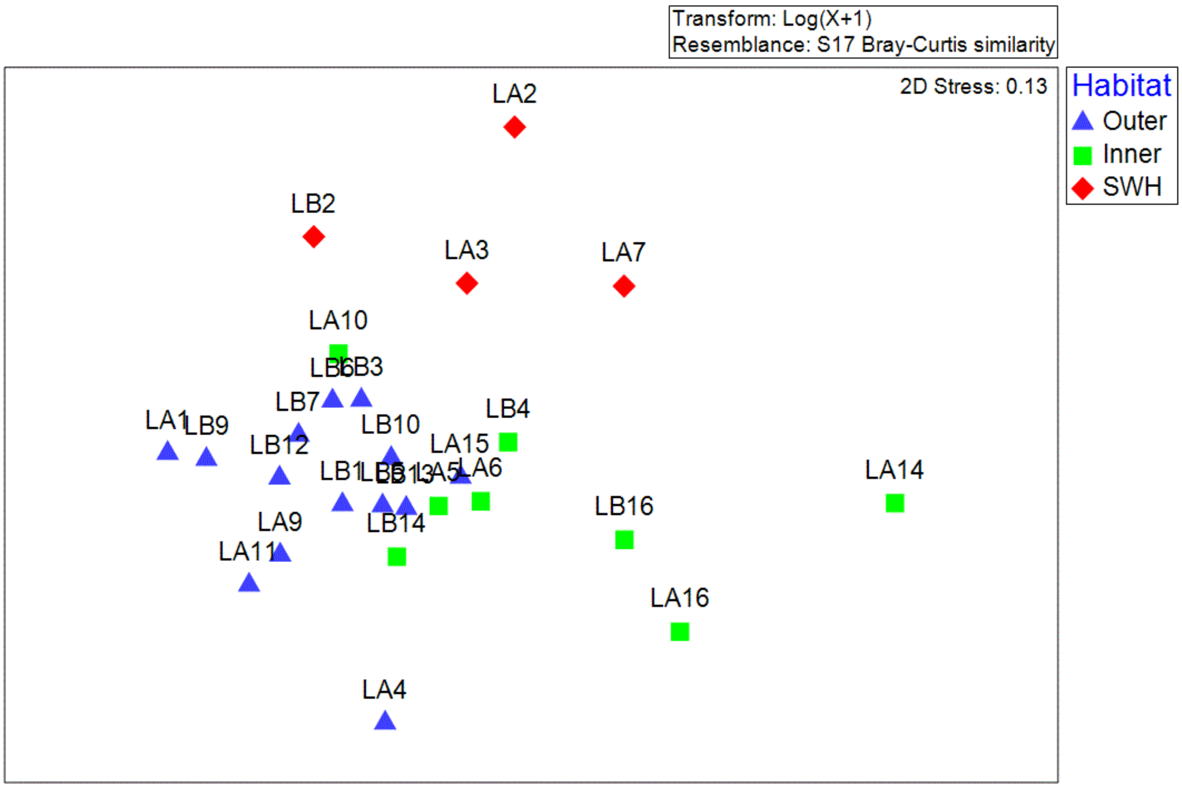


Figure 4-40. Habitat Groups nMDS Plot (All Seasons Combined)

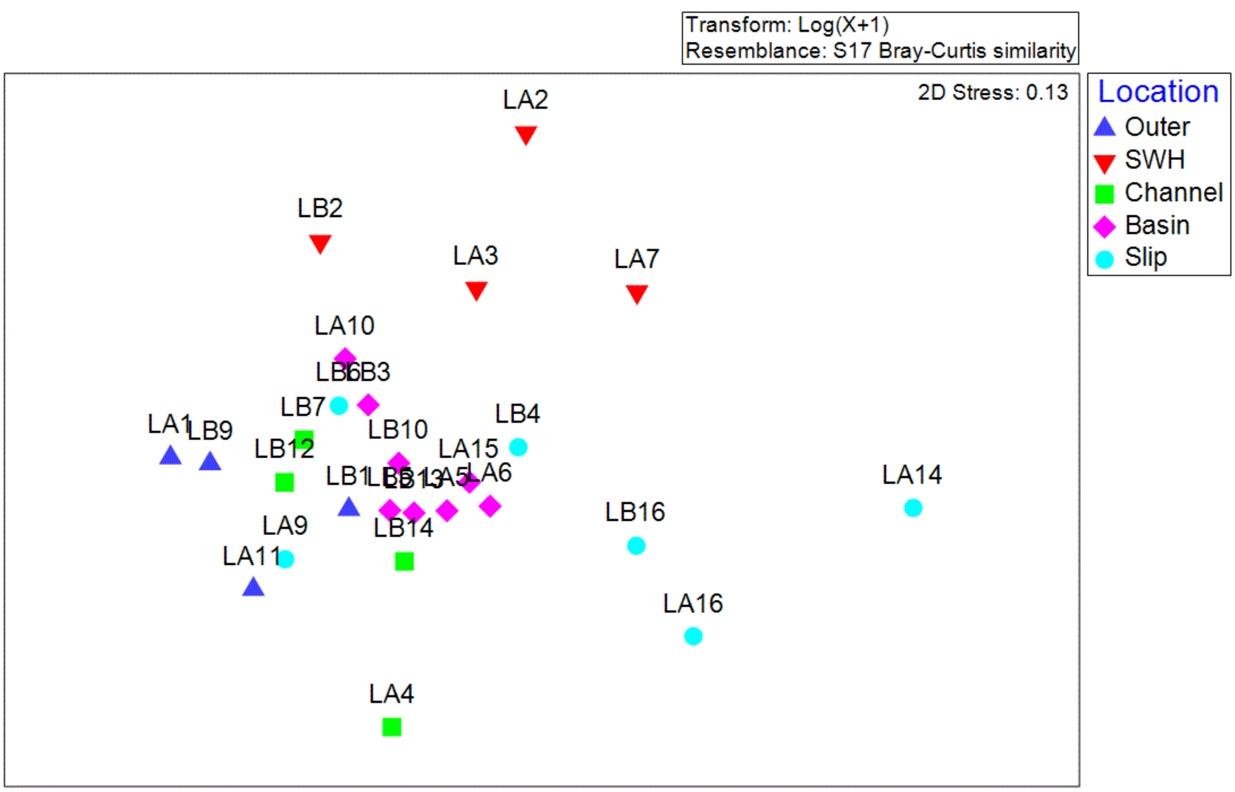


Figure 4-41. Location Groups nMDS Plot (All Seasons Combined)

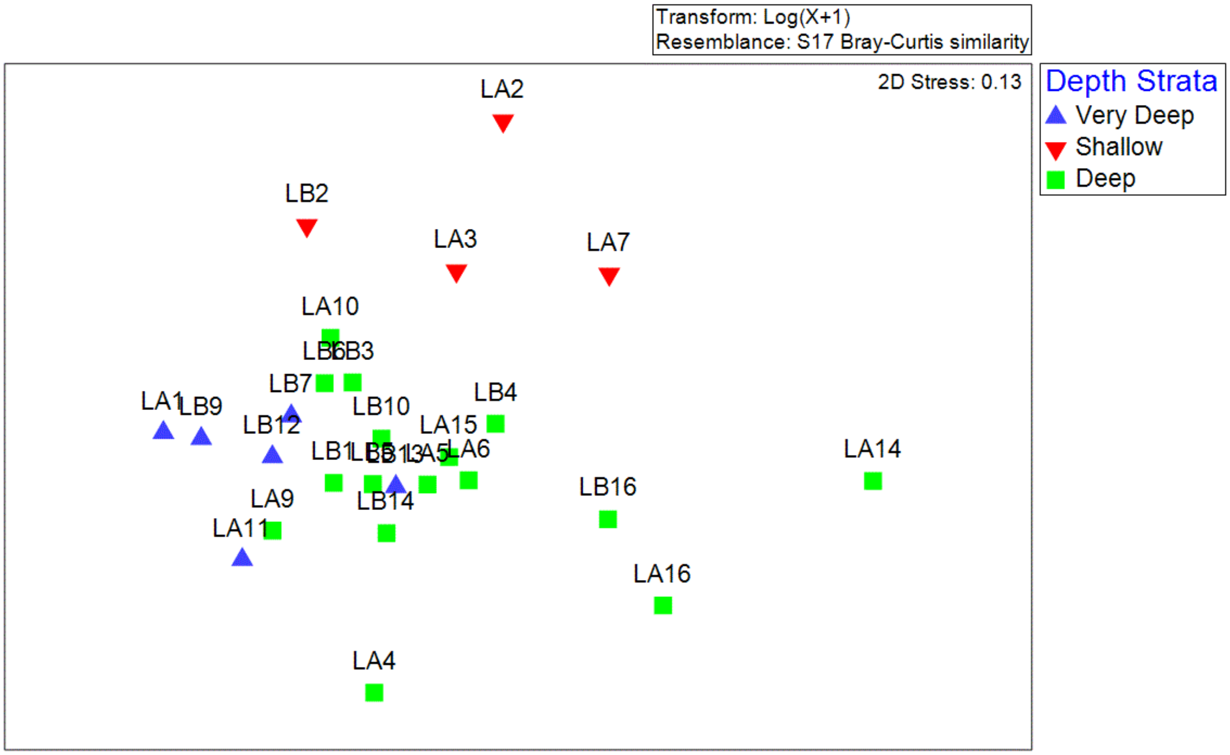


Figure 4-42. Depth Strata Groups nMDS Plot (All Seasons Combined)

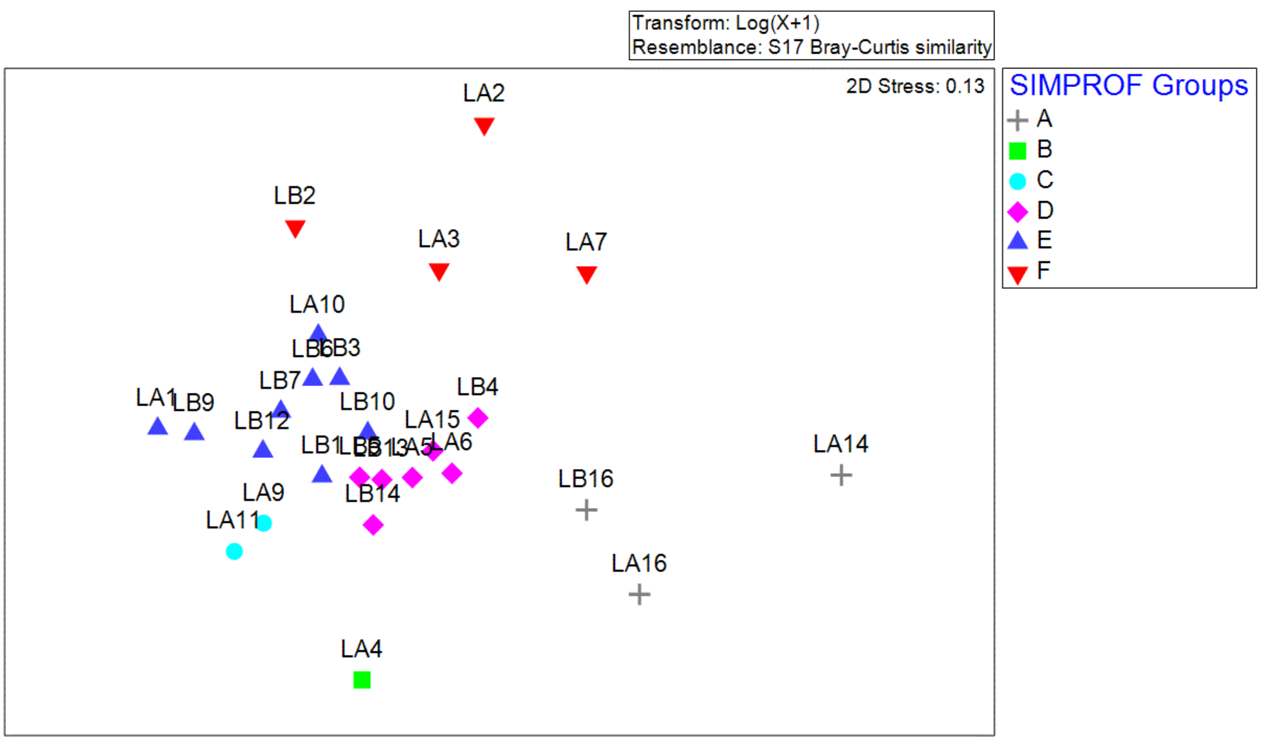


Figure 4-43. Similarity Profile Analysis Groups nMDS Plot (All Seasons Combined)

Demersal Fish Abundance By Trawl Station (Non-Metric Multidimensional Scaling Groups)
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 4-44. Similarity Profile Analysis Groups Station Map Overlay (All Seasons Combined)

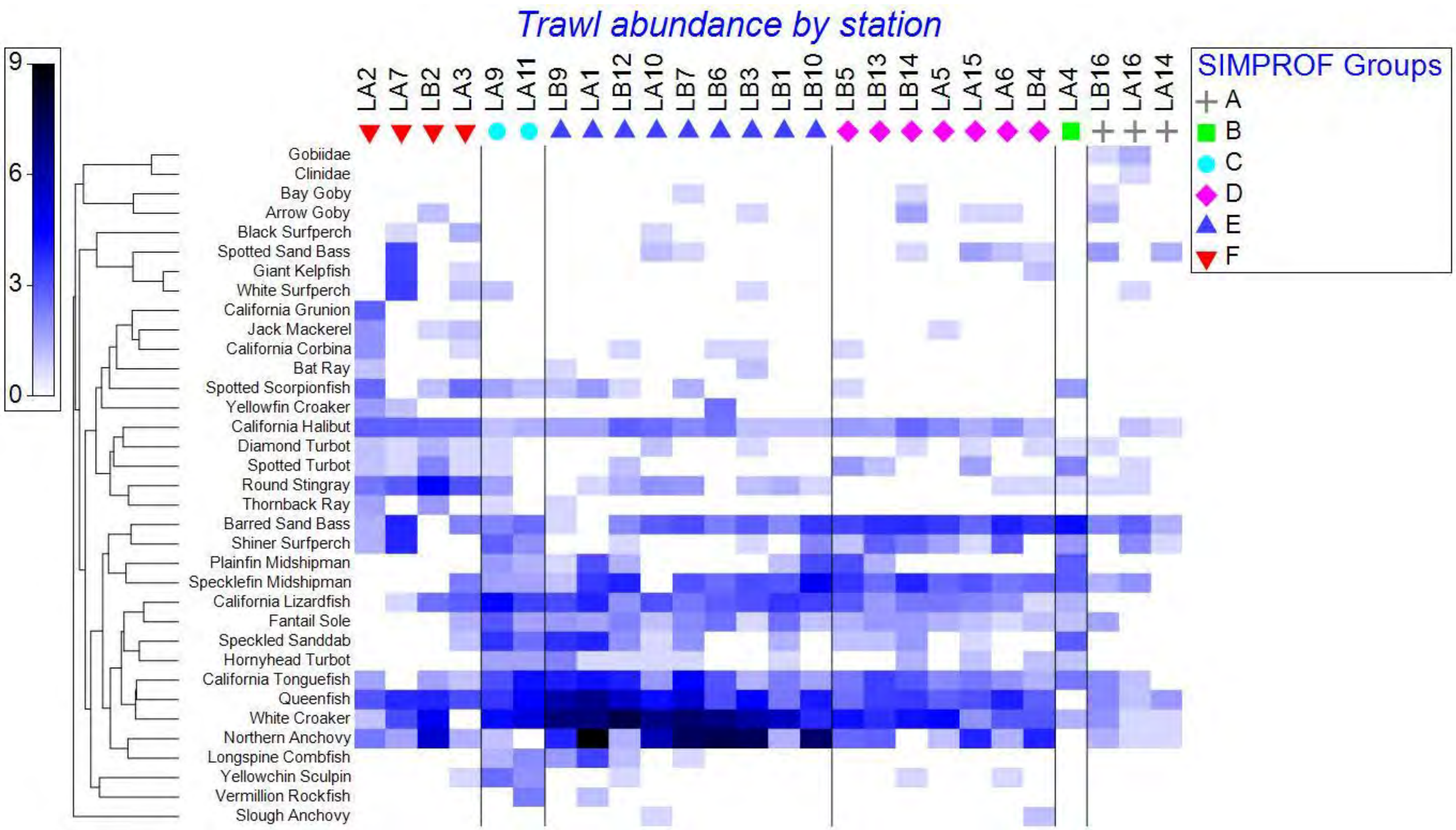


Figure 4-45. Species Heatmap Derived from Similarity Profile Group Analysis – Top 35 Species (All Seasons Combined)

4.6.4 Fish Health

Overall, the fish captured appeared healthy and most specimens had normal color and energy. External anomalies such as lesions, tumors, fin erosion and spinal deformities were very rare, observed for only one white croaker which showed a spinal deformity (Table 4-18 and Figure 4-46). Combined with the California grunion caught in otter trawls that had a spinal deformity, this represents an anomaly rate of 0.00004% out of the 48,179 total fish captured during the 2018 Biosurvey. Fish anomalies have not been mentioned in past Biosurvey years, but the anomaly rate in the Port Complex is lower than that observed during regional monitoring in 2018 (Wisenbaker et al. 2021) which found a Southern California Bight-wide rate of 0.0002% and a 0.00009% rate within San Diego Bay.

Table 4-18. Fish Anomalies Identified from Benthic Trawls

Station	Location	Sample Date	Species	Common Name	Size Class (cm)	Anomaly
LB7	POLB Main Channel – Pilot Station	9/22/18	Genyonemus lineatus	White Croaker	12	Spinal Deformity

Figure 4-46. Spinal Deformity in White Croaker

4.6.5 Historical Comparisons

Trawl sampling across the 2000, 2008, 2013, and 2018 studies has captured a total of 100 different fish species (Appendix D), although each year's species richness has remained similar -- 59 to 62 (Figure 4-47). Of the 100 fish species, 35 were captured in all four studies; many of them are abundant and commonly encountered during sampling and thus can be considered as characteristic of the Port Complex (Table 4-19). Each Biosurvey captured several unique species that did not appear in any of the other Biosurveys. For example, in 2018 species such as black croaker (*Cheilotrema saturnum*), ocean whitefish (*Caulolatilus princeps*) and rock wrasse (*Halichoeres semicinctus*) were captured for the first time. These were generally one individual and represent either occasional visitors to the Port Complex or very uncommon species that happen to be encountered. These less frequently caught species also might represent non-targeted fish species that are normally associated with hard substrate types such as black croaker and rock wrasse captured in 2018. These fish are common in the Port Complex but are not normally present over the soft bottom or within the open pelagic habitats currently targeted by this program.

Mean abundance per station in each Biosurvey ranged more widely, from 178 to 402 fish, largely as a result of occasional very large catches of one or two species in some years but not others. For example, in the 2000 Biosurvey, trawl sampling captured over 20,000 white croaker, far more than in any other year. Mean biomass per station in three of the four Biosurveys has been between 6 and 7 kg; the substantially higher mean biomass in 2013 (11.3 kg per station) was likely due in part to unusually large catches of California lizardfish (*Synodus lucioceps*) not seen in other Biosurveys.

The four Biosurveys performed to date were compared in terms of their demersal fish species composition by identifying the top 10 species (by abundance or biomass) in each Biosurvey, combining all other species in an "other" category, and calculating the percent composition of each of the eleven species categories (Figures 4-48 and 4-49). The top three species in terms of relative abundance were the same in 2018, 2008, and 2000: northern anchovy, white croaker, and queenfish. In 2013, however, California lizardfish replaced northern anchovy as one of the three most abundant species and was even more abundant than queenfish during that year. The large increase in lizardfish abundance was a trend observed across the Southern California Bight during regional monitoring in 2013. The reason for lizardfish population increase during this time is still uncertain but could be partially due to the cooler waters and strong upwelling that preceded the Biosurveys conducted during the summer of 2013 (Walther et al. 2017). A few other species such as specklefin midshipmen and California tonguefish were represented in the top 10 species across all four Biosurveys, while species such as barred sand bass, California halibut, and speckled sanddabs were represented in the top ten in three of the four Biosurveys. When considering the low relative contribution of all the other species not in the top 10 (ranging from 2.85% in 2018 to 6.07% in 2008 and 2013) it appears that the community has consistently been comprised of several dominant species while the secondary tier is more variable in terms of composition.

Relative biomass across the four Biosurveys consistently shows white croaker to be the largest contributor, ranging from 38% in 2008 to 52% of total biomass in 2013. The ranks for other species were more variable, but California halibut was in the top four across all Biosurveys while queenfish was in the top four during three of the four Biosurveys. Biomass was more easily influenced by catches of a few large individuals, as the top ten has previously included species such as Pacific electric rays (2018 and 2008), bat rays (2013, 2008 and 2000), and shovelnose guitarfish (2013 and 2000).

The EI was also chosen for the first time as a comparative tool to assess the structure of demersal fish communities over the last 20 years of biological monitoring in the Port Complex. The top 15 species captured using the otter trawl for each Biosurvey year ranked by EI scores are shown in Table 4-20, with species appearing across all four Biosurveys highlighted. White croaker was by far the highest ranked species across all years, while northern anchovy and queenfish were never lower than fourth. Overall, nine species were ranked in the top 15 species using the EI metric over the last four Biosurvey periods..

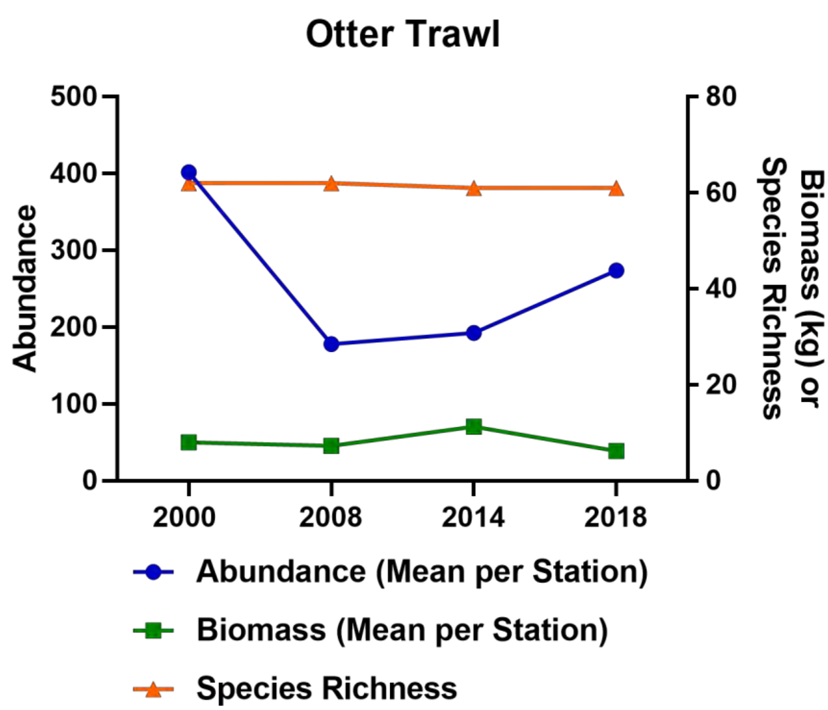


Figure 4-47. Historical Comparison of Species Richness, Mean Abundance and Mean Biomass Collected using the Benthic Otter Trawl

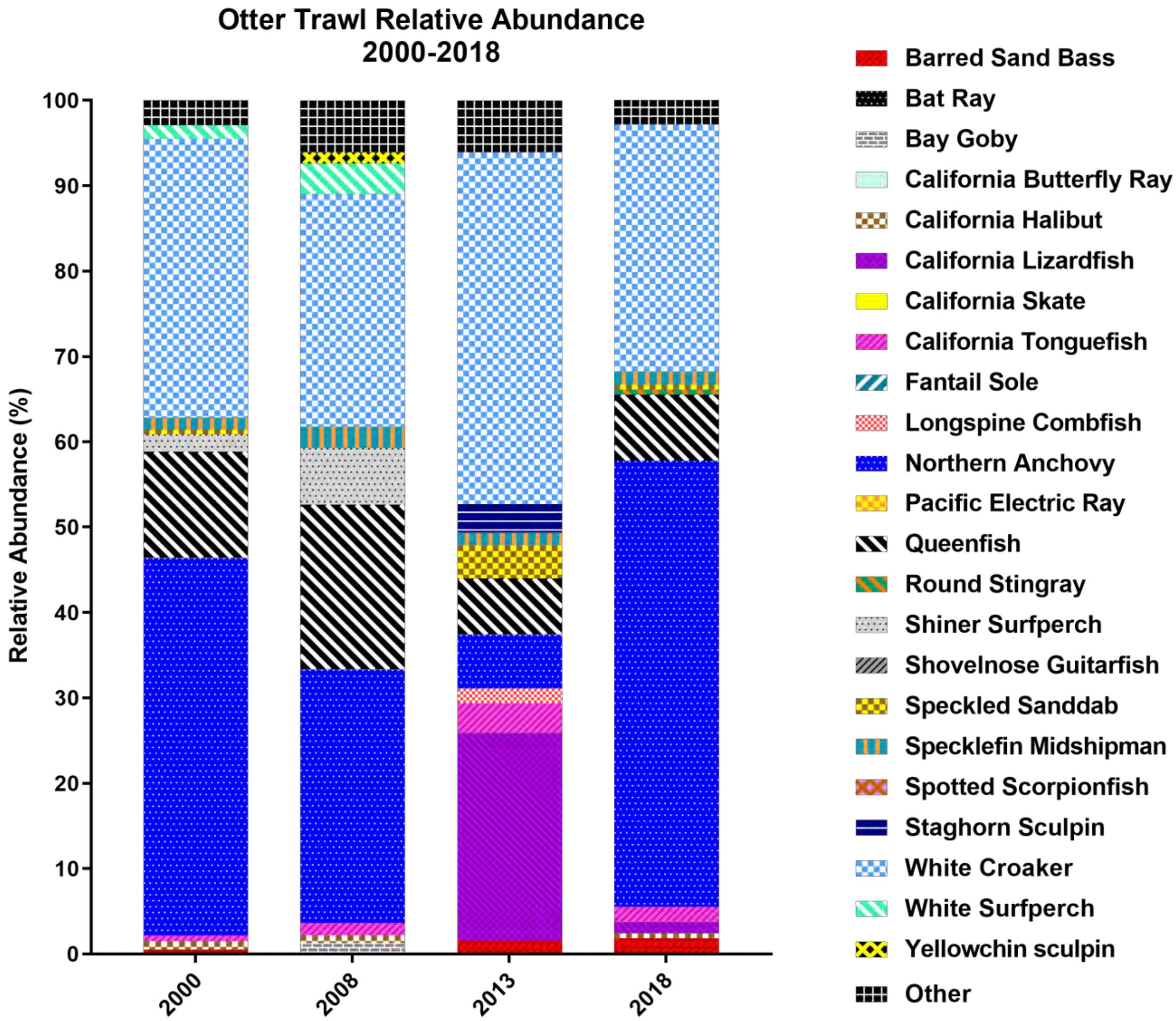


Figure 4-48. Historical Comparison of Relative Abundance of Fish Captured by Otter Trawls

Note: Top 10 species are shown for each specific time period. Species listed alphabetically to aid species comparison between abundance and biomass

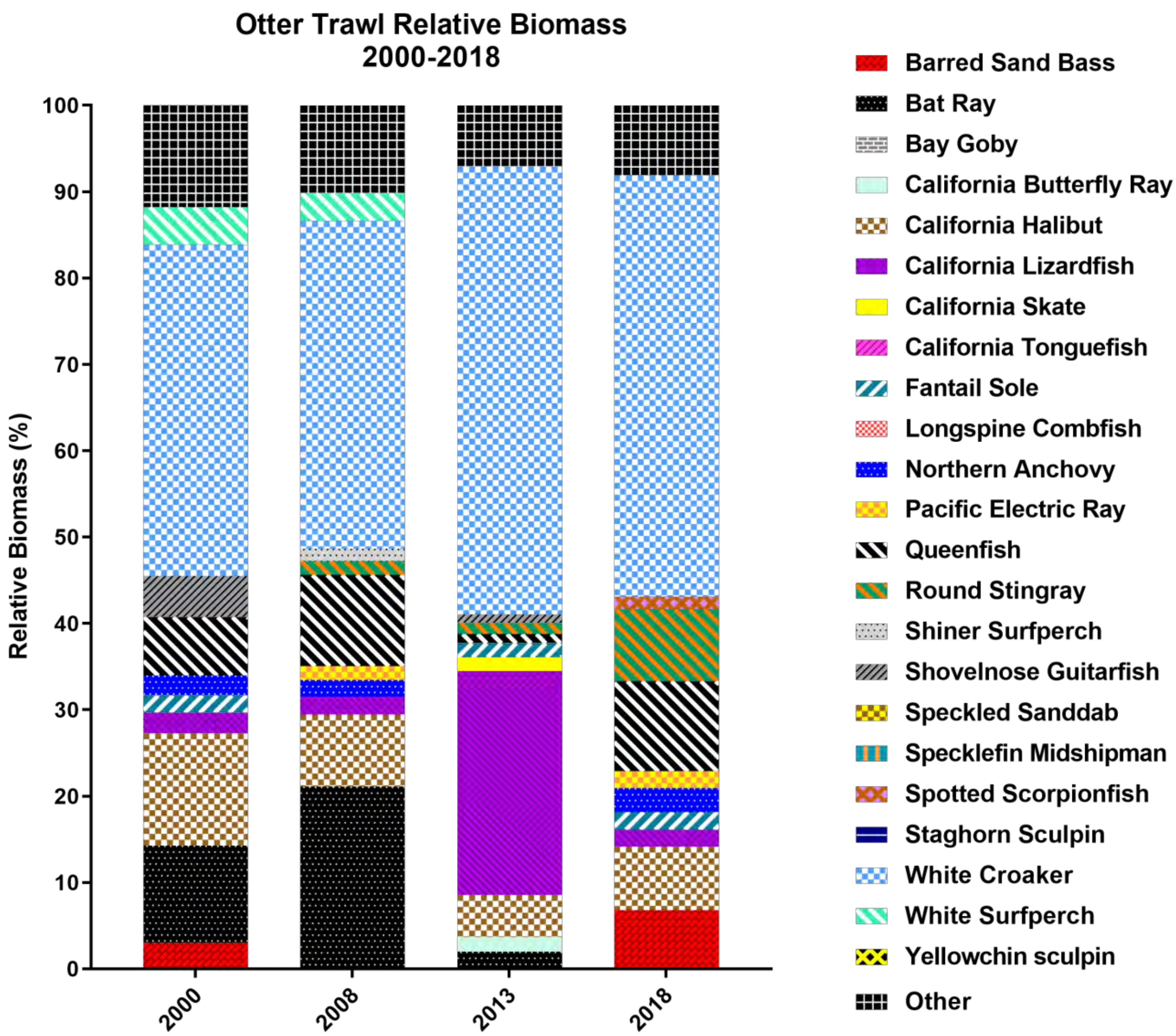


Figure 4-49. Historical Comparison of Relative Biomass of Fish Captured by Otter Trawls

Note: Top 10 species are shown for each specific time period. Species listed alphabetically to aid species comparison between abundance and biomass

Table 4-19. Historical Trawl Fish Abundance of Species Caught in All Biosurvey Years to Date

Common Name	Scientific Name	2018	2013	2008	2000
Barred Sand Bass	*Paralabrax nebulifer*	519	309	130	310
Basketweave Cusk-Eel	*Ophidion scrippsae*	10	46	5	50
Bat Ray	*Myliobatis californica*	5	8	37	54
Bay Goby	*Lepidogobius lepidus*	3	67	253	209
Black Surfperch	*Embiotoca jacksoni*	5	6	5	24
California Corbina	*Menticirrhus undulatus*	11	1	1	23
California Halibut	*Paralichthys californicus*	162	153	192	547
California Lizardfish	*Synodus lucioceps*	389	4780	116	121
California Scorpionfish	*Scorpaena guttata*	50	29	11	13
California Skate	*Raja inornata*	6	62	23	11
California Tonguefish	*Symphurus atricaudus*	509	685	291	372
Diamond Turbot	*Hypsopsetta guttulata*	16	7	11	44
English Sole	*Parophrys vetulus*	1	2	24	3
Fantail Sole	*Xystreurys liolepis*	103	152	46	94
Giant Kelpfish	*Heterostichus rostratus*	29	28	7	52
Goby spp	*Gobiidae*	5	4	1	1
Hornyhead Turbot	*Pleuronichthys verticalis*	30	110	93	130
Kelp Bass	*Paralabrax clathratus*	1	5	9	24
Northern Anchovy	*Engraulis mordax*	14883	1241	6037	22846
Pacific Butterfish	*Peprilus simillimus*	2	29	1	47
Pacific Staghorn Sculpin	*Leptocottus armatus*	1	662	7	8
Plainfin Midshipman	*Porichthys notatus*	98	90	6	135
Queenfish	*Seriphus politus*	2201	1298	3922	7705
Round Stingray	*Urobatis halleri*	166	28	26	35
Shiner Surfperch	*Cymatogaster aggregata*	138	17	1354	1321
Slough Anchovy	*Anchoa delicatissima*	3	2	1	16
Speckled Sanddab	*Citharichthys stigmaeus*	175	762	121	332
Specklefin Midshipman	*Porichthys myriaster*	444	282	517	1084
Spotted Turbot	*Pleuronichthys ritteri*	35	24	34	179
Thornback Ray	*Platyrhinoidis triseriata*	11	20	4	13
Vermillion Rockfish	*Sebastes miniatus*	11	45	20	4
White Croaker	*Genyonemus lineatus*	8231	8106	5527	20761.5
White Surfperch	*Phanerodon furcatus*	34	35	729	993
Yellowchin Sculpin	*Icelinus quadriseriatus*	22	43	262	72
Yellowfin Goby	*Acanthogobius flavimanus*	2	4	53	2

Table 4-20. Historical Summary of Fish Captured using the Otter Trawl (2000 – 2020) – Top 15 Species Ranked by EI

2018 Trawl Fish Ecological Index — 59 Species Total

Species		% of Total Abundance	% of Total Biomass	Frequency of Trawl Capture (%)	Ecological Index
Common Name	Scientific Name				
White Croaker	*Genyonemus lineatus*	28.9	48.8	96	7474
Northern Anchovy	*Engraulis mordax*	52.2	2.8	88	4866
Queenfish	*Seriphus politus*	7.73	10.5	96	1749
Barred Sand Bass	*Paralabrax nebulifer*	1.82	6.8	92	796
California Halibut	*Paralichthys californicus*	0.57	7.33	92	729
Round Stingray	*Urolophus halleri*	0.58	8.34	65	583
California Lizardfish	*Synodus lucioceps*	1.37	1.99	85	284
California Tonguefish	*Symphurus atricauda*	1.79	1.03	92	260
Fantail Sole	*Xystreurys liolepis*	0.36	2.04	81	194
Specklefin Midshipman	*Porichthys myriaster*	1.56	0.49	81	166
California Scorpionfish	*Scorpaena guttata*	0.18	1.42	42	67.4
Speckled Sanddab	*Citharichthys stigmaeus*	0.61	0.38	54	53.7
Shiner Surfperch	*Cymatogaster aggregata*	0.48	0.36	62	52.0
Diamond Turbot	*Hypsopsetta guttulata*	0.06	0.52	46	26.8
Spotted Sand Bass	*Paralabrax maculatofasciatus*	0.15	0.43	35	20.3

2013 Trawl Fish Ecological Index — 61 Species Total

Species		% of Total Abundance	% of Total Biomass	Frequency of Trawl Capture (%)	Ecological Index
Common Name	Scientific Name				
White Croaker	*Genyonemus lineatus*	41.2	51.9	100	9314
California Lizardfish	*Synodus lucioceps*	24.3	25.9	100	5026
Queenfish	*Seriphus politus*	6.60	1.06	88	766
Northern Anchovy	*Engraulis mordax*	6.31	0.26	81	658
California Halibut	*Paralichthys californicus*	0.78	4.88	96	566
Speckled Sanddab	*Citharichthys stigmaeus*	3.88	0.71	88	459
California Tonguefish	*Symphurus atricaudus*	3.49	0.43	88	392
Staghorn Sculpin	*Leptocottus armatus*	3.37	0.18	73	355
Longspine Combfish	*Zaniolepis latipinnis*	1.71	0.83	35	255
Barred Sand Bass	*Paralabrax nebulifer*	1.57	0.86	92	243
Fantail Sole	*Xystreurys liolepis*	0.77	1.62	81	239
Specklefin Midshipman	*Porichthys myriaster*	1.43	0.88	96	231
Bat Ray	*Myliobatis californica*	0.04	2.00	23	204
California Skate	*Raja inornata*	0.32	1.62	85	193
California Butterfly Ray	*Gymnura marmorata*	0.02	1.67	4	168

2008 Trawl Fish Ecological Index — 62 Species Total

Species		% of Total Abundance	% of Total Biomass	Frequency of Trawl Capture (%)	Ecological Index
Common Name	Scientific Name				
White Croaker	*Genyonemus lineatus*	27.2	41.1	100	34506
Queenfish	*Seriphus politus*	19.3	11.5	100	10782
Bat Ray	*Myliobatis californica*	0.18	22.9	37	6517
Northern Anchovy	*Engraulis mordax*	29.7	2.10	100	4590
White Surfperch	*Phanerodon furcatus*	3.59	3.49	100	3053
California Halibut	*Paralichthys californicus*	0.94	2.89	100	2326
California Lizardfish	*Synodus lucioceps*	0.57	2.23	100	1784
Fantail Sole	*Xystreurys liolepis*	0.23	1.31	84	873
Shiner Surfperch	*Cymatogaster aggregata*	6.66	0.56	63	694
California Skate	*Raja inornata*	0.11	1.50	58	676
Specklefin Midshipman	*Porichthys myriaster*	2.54	0.54	89	601
Barred Sand Bass	*Paralabrax nebulifer*	0.64	0.83	84	592
Round Stingray	*Urobatis halleri*	0.13	1.71	37	492
California Tonguefish	*Symphurus atricaudus*	1.43	0.42	100	468
Hornyhead Turbot	*Pleuronichthys verticalis*	0.46	0.44	89	348

2000 Trawl Fish Ecological Index — 62 Species Total

Species		% of Total Abundance	% of Total Biomass	Frequency of Trawl Capture (%)	Ecological Index
Common Name	Scientific Name				
White Croaker	*Genyonemus lineatus*	35.9	38.4	100	7424
Northern Anchovy	*Engraulis mordax*	39.5	2.3	100	4178
Queenfish	*Seriphus politus*	13.3	6.8	100	2007
California Halibut	*Paralichthys californicus*	0.95	13.0	100	1395
Bat Ray	*Myliobatis californica*	0.09	11.3	61	694
White Surfperch	*Phanerodon furcatus*	1.72	4.37	100	608
Barred Sand Bass	*Paralabrax nebulifer*	0.54	3.01	100	355
Shiner Surfperch	*Cymatogaster aggregata*	2.28	1.34	83	302
Specklefin Midshipman	*Porichthys myriaster*	1.87	0.70	94	243
Shovelnose Guitarfish	*Rhinobatos productus*	0.05	4.76	50	241
California Lizardfish	*Synodus lucioceps*	0.21	2.39	89	231
Fantail Sole	*Xystreurys liolepis*	0.16	2.00	94	204
Spotted Turbot	*Pleuronichthys ritteri*	0.31	1.19	89	134
CaliforniaTonguefish	*Symphurus atricauda*	0.64	0.59	78	95.8
Hornyhead Turbot	*Pleuronichthys verticalis*	0.22	0.62	83	70.4

Note: Species that appear in the top 15 across all Biosurvey years are highlighted.

4.6.6 Discussion

Fish communities in soft bottom habitats within the Port Complex are largely dominated by white croaker and queenfish that forage for small invertebrates such as worms and shrimps, as well as a few predatory species such as barred sand bass and California halibut. The diverse epibenthic and infaunal invertebrate community provides ample foraging opportunity for numerous other fish species. Eelgrass beds and the protected shallow soft-bottom habitats also provide critical nursery habitat for a number of species common to the Port Complex, including critically endangered species such as black sea bass and species with economic importance such as California halibut, barred sand bass, and rockfish. The abundant fish populations also make the Port complex important feeding grounds for large, solitary predatory species, including several observed in 2018 (and previous Biosurveys) such as bat rays and Pacific electric rays and other large predatory species observed in past Biosurveys such as thresher and leopard sharks.

Fish communities in shallow subtidal and soft bottom habitats have remained relatively similar across Biosurvey years. Climatic trends such as the 2014-2016 warm water event do not appear to have as marked an influence on the composition of demersal fish assemblages as on the pelagic species. The most notable change in fish populations during the 2013 Biosurvey was a large increase in the population of lizardfish, a trend observed in regional monitoring during 2013 that was widespread across bays, harbors, and the continental shelf and might be influenced by unusually strong upwelling (Walther et al. 2017). Fish surveys in San Diego Bay following the warm water event did not find a significant shift in community structure, although they did note the expansion of southern species and more regular capture of species previously only observed in Baja California (Williams et al. 2016).

As observed for the pelagic fish species, a distinct key observation noted for some of the more common fish species was the high proportion of juvenile fish captured indicating their use of the harbor complex as a critical and productive nursery habitat.

Gopher rockfish captured in otter trawls

Managed Species

Eight of the species managed under the PCG FMP were captured in otter trawls during the 2018 Biosurvey (Table 4-21). The most abundant managed species were the California scorpionfish, vermillion rockfish, California skate and gopher rockfish, while only single individuals of bocaccio (8 cm long juvenile), brown rockfish, English sole, and Pacific sanddab were captured. Past Biosurveys in total have documented 16 managed species, although their abundance has consistently been relatively low and varies from year to year.

Giant sea bass have been a protected species since 1982, when both commercial and sport fishing of the species was banned. The International Union for Conservation of Nature and Natural Resources (IUCN) classified the species as critically endangered in 2004, and efforts to better monitor their populations are underway in California. Giant sea bass were first recorded in the Port Complex in 2013 with two individuals captured during trawls, and one individual was captured during the 2018 trawl sampling.

Table 4-21. Pacific Coast Groundfish FMP Species Abundance in Port of Long Beach/Port of Los Angeles

Common Name	Scientific Name	Abundance			
		2018	2013	2008	2000
Big Skate	*Raja binoculata*	0	0	0	8
Black Rockfish	*Sebastes melanops*	0	0	0	32
Bocaccio	*Sebastes paucispinis*	1	1	0	0
Brown Rockfish	*Sebastes auriculatus*	1	4	1	0
Cabezon	*Scorpaenichthys marmoratus*	0	4	0	1
Calico Rockfish	*Sebastes dallii*	0	9	0	0
California Scorpionfish	*Scorpaena guttata*	50	31	11	19
California Skate	*Raja inornata*	6	63	23	11
English Sole	*Parophrys vetulus*	1	2	24	3
Gopher Rockfish	*Sebastes carnatus*	3	3	0	0
Grass Rockfish	*Sebastes rastrelliger*	0	0	0	3
Leopard Shark	*Triakis semifasciata*	0	2	0	3
Lingcod	*Ophiodon elongatus*	0	0	0	1
Pacific Sanddab	*Citharichthys sordidus*	1	0	171	52
Spiny Dogfish Shark	*Squalus acanthias*	0	0	1	0
Vermillion Rockfish	*Sebastes miniatus*	11	45	20	4

Note: Boccacio in 2018 was caught in lampara sampling.

4.7 Non-native Species

Species identified in each element of the 2018 Biosurvey and the historical Biosurveys (2000-2013) were cross referenced to determine their status with web-based databases and scientific literature including:

- Non-native status determined from National Exotic Marine and Estuarine Species Information System (NEMESIS) database (Fofonoff et al. 2020), which was compiled with information previously held in the California Aquatic Non-Native Organism Database (CANOD) and used in previous Biosurveys.
- Cryptogenic species, defined by Carlton (1996) as “a species that is not demonstrably native or introduced” and has insufficiently documented life history or native range to allow characterization as either native or introduced, were determined using the CDFW report “Introduced Aquatic Species in California Bays and Harbors 2011 Survey” (CDFW 2014).

When no information for a species was available, the species name was entered into other databases such as World Register of Marine Species (WoRMS) and/or Integrated Taxonomic Information System (ITIS) to verify taxonomic status and/or synonyms. A synonym is a scientific name that applies to a taxon that may go by a different scientific name. If a synonymized name was present, it was entered into the non-native species databases to determine if status information was available.

Infauna

Of the total 369 infaunal species identified in the 2018 Biosurvey, 19 were identified as non-native and 43 as cryptogenic (i.e., of uncertain status; Tables 4-22 and 4-23). By comparison, a total of 22 non-native species have been identified over the last four Biosurveys combined. In 2018, the 19 non-native species represented 5.2% of the total species identified. This percentage is greater than in past Biosurveys, which ranged from 2.2 to 3.5% of all species identified. While the number of such species increased in 2018, their relative abundance decreased: the 2,965 non-native individuals made up 18.0% of the 16,436 total infaunal organisms collected, whereas past Biosurveys were 30.6% in 2000, 15.8% in 2008, and 12.5% in 2013 (Figure 4-50).

The bivalve *Theora lubrica* was observed in all station groups in 2018 and is the most widespread non-native species, having been captured at 91% of stations. This wide distribution was nevertheless a decrease from previous Biosurveys, which found *T. lubrica* at 100% of stations in 2000, 93% in 2008 and 97% in 2013. Only *Philine auriformis* was as widely distributed (84% of stations) in 2018, with no other non-native species detected at more than 35% of stations. Nearly all of the *Pseudopolydora paucibranchiata* (87%) were captured at Cabrillo Marina (LA12), while 72% of *Grandidierella japonica* were captured in Consolidated Slip (LA14) and 26% captured at Cabrillo Marina (LA12). The prevalence of these two species at these stations was a driving factor in their statistical grouping as shown in Figure 4-18. It should be noted that *P. paucibranchiata* is designated as a non-native species in the NEMESIS database (Fofonoff et al. 2020), but the CDFW 2014 report classified it as cryptogenic. For the purposes of this report the species will be considered non-native.

In comparison to the 43 cryptogenic species identified in this Biosurvey, a total of 61 cryptogenic species have been captured over the last four Biosurveys combined, although the CDFW 2014 report classifies 12 of these species as likely native. The 43 cryptogenic species identified in 2018 represented 11.7% of the 369 species identified, which is within the range of 11.1 to 12.8% observed in past Biosurveys (Figure 4-50). The relative abundance of cryptogenic species in 2018 was 9.1%, which is also within the range of past Biosurveys (from a low in 2000 of 6.7% to the high in 2013 of 16.9%).

A study examining benthic infauna communities from regional monitoring in the summer of 1998 covered nine Southern California embayments, including 46 stations in the Port Complex (Ranasinghe et al. 2005). There were no significant differences in the relative abundance of non-native species between harbors. The Port Complex had the lowest percent non-native species (7.2%; range 7.2 to 12.4%) of all harbors where non-natives were detected (only one station, in Ventura Harbor, had no non-natives), and the third-lowest percent non-native abundance (26.2%; range 12.5 to 31.9%). There was a significant positive correlation between non-native species abundance and total abundance, the total number of species, and native species abundance. The authors theorize this could indicate that resources are not limiting and therefore there is little or no direct competition. However, two of the most abundant species were a tube-dwelling worm (*Pseudopolydora paucibranchiata*) and the Asian mussel

(*Musculista senhousia*), both of which modify the habitat with their tubes and byssal mats. This creates structure and habitat heterogeneity that can enhance the abundance of native species (Ranasinghe et al. 2005.)

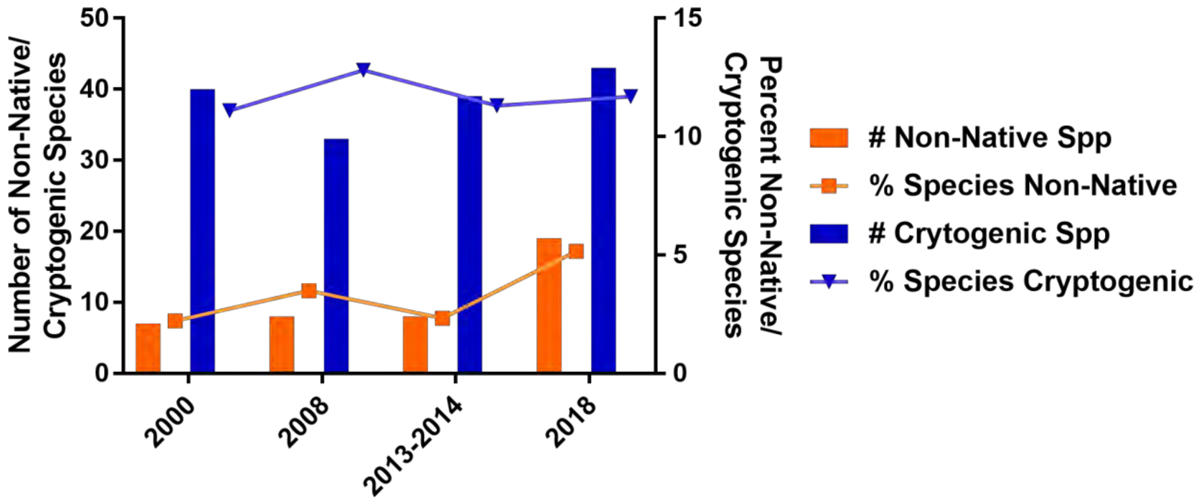


Figure 4-50. Benthic Infauna Non-Native and Cryptogenic Species and Percent of Total Species Richness

Table 4-22. Abundance of Non-Native Benthic Infauna from 2000-2018

Phylum	Species Name	2000	2008	2013	2018
Annelida	*Hydroides elegans*	0	0	1	0
	Megasyllis nipponica	0	0	0	2
	Polydora cornuta	2	0	0	0
	Pseudopolydora paucibranchiata [1]	7667	326	80	1451
Arthropoda	*Caprella simia*	0	7	0	15
	Corophium heteroceratum	395	286	377	276
	Deltamysis holmquistae	0	0	0	1
	Grandidierella japonica	149	66	8	332
	Monocorophium acherusicum	157	0	0	4
	Monocorophium insidiosum	0	5	0	1
	Paranthura japonica	0	0	0	4
Bryozoa	*Amathia verticillata*	0	0	P	P
Chordata	*Ciona savignyi*	0	0	0	1
	Molgula ficus	0	0	0	1
Cnidaria	*Laomedea calceolifera*	0	0	0	12
	Nematostella vectensis	0	0	0	1
Mollusca	*Crassostrea gigas*	0	2	0	0
	Musculista senhousia	0	0	1	97
	Mytilus galloprovincialis	1	4	0	2
	Philine auriformis	21	35	14	155
	Theora lubrica	1490	1007	494	609
	Venerupis philippinarum	0	0	0	1
# Non-Native Species		8	9	8	19
% of Infauna Species Non-Native		2.22	3.49	2.33	5.15
% of Infauna Abundance Non-Native		30.6	15.8	12.5	18.0

[1] *P. paucibranchiata* is also considered cryptogenic (CDFW 2014). Non-native designation as determined by NEMESIS database (Fofonoff et al. 2020). P = Present where no abundance is available.

Table 4-23. Abundance of Cryptogenic Benthic Infauna from 2000-2018

Phyla	Species Name	2000	2008	2013	2018	Likely Introduced or Native
Annelida	*Amaeana occidentalis*	1	8	5	4	Unknown
	Amphicteis scaphobranchiata	1	0	9	38	Unknown
	Aphelochaeta monilaris	147	51	216	15	Unknown
	Apoprionospio pygmaea	1	4	5	0	Unknown
	Aricidea (Acmira) catherinae	1	0	0	2	Unknown
	Boccardiella hamata	2	0	0	0	Introduced
	Cossura candida	2	92	95	58	Unknown
	Diopatra ornata	24	7	2	33	Unknown
	Dipolydora bidentata	336	7	0	0	Unknown
	Dipolydora socialis	1	16	36	10	Unknown
	Dorvillea (Schistomeringos) annulata	22	0	3	62	Unknown
	Drilonereis longa	0	0	5	0	Unknown
	Eteone fauchaldi	0	0	1	0	Unknown
	Euchone limnicola	3	213	102	381	Unknown
	Exogone lourei	4	8	1	73	Native
	Glycera americana	8	68	24	51	Native
	Glycera macrobranchia	0	0	0	3	Native
	Goniada littorea	4	7	9	4	Unknown
	Harmothoe hirsuta	1	0	7	0	Unknown
	Levinsenia gracilis	8	17	81	7	Unknown
	Lumbrineris cruzensis	10	2	0	1	Unknown
	Lumbrineris inflata	0	0	0	1	Unknown
	Lumbrineris japonica	2	24	67	41	Native
	Lumbrineris latreilli	245	0	0	0	Native
	Lumbrineris limicola	152	0	0	1	Unknown
	Marphysa disjuncta	23	15	313	89	Unknown
	Mediomastus californiensis	0	0	65	0	Unknown
	Megalomma pigmentum	7	19	3	0	Unknown
	Melinna oculata	2	16	9	26	Unknown
	Metasychis disparidentatus	2	2	5	12	Unknown
	Monticellina siblina	1	369	29	0	Unknown
	Nephtys ferruginea	6	12	3	2	Native
	Notomastus tenuis	2	0	0	11	Unknown
	Ophiodromus pugettensis	373	2	0	0	Unknown
	Paradialychone ecaudata	0	0	0	1	Unknown
	Paradialychone paramollis	0	0	0	4	Unknown
	Phyllodoce longipes	1	5	1	3	Unknown
	Pista brevibranchiata	0	0	27	127	Unknown
	Pista wui	0	218	75	36	Unknown
	Platynereis bicanaliculata	1	2	4	4	Unknown
	Praxillella pacifica	181	10	5	12	Unknown
	Prionospio heterobranchia	162	6	0	19	Introduced
	Scoletoma erecta	0	7	0	7	Unknown
	Sphaerosyllis californiensis	44	0	0	1	Unknown
	Spiophanes duplex	0	156	13	50	Unknown
	Spiophanes norrisi	0	0	1	107	Native

Table 4-23 (Continued). Abundance of Cryptogenic Benthic Infauna from 2000-2018

Phyla	Species Name	2000	2008	2013	2018	Likely Introduced or Native
Arthropoda	*Caprella californica*	1	0	6	0	Native
	Ericthonius brasiliensis	0	0	5	5	Unknown
	Ischyrocerus pelagops	0	0	3	0	Native
	Laticorophium baconi	1	0	0	0	Unknown
	Neotrypaea gigas	12	235	8	26	Native
	Podocerus brasiliensis	0	2	0	0	Native
	Podocerus cristatus	366	0	0	0	Unknown
	Zeuxo normani	0	47	7	0	Unknown
Cnidaria	*Rhizocaulus verticillatus*	2	0	0	0	Unknown
Echinodermata	*Amphipholis squamata*	4	28	5	16	Unknown
Nemertea	*Carinomella lactea*	0	0	0	13	Native
	Cerebratulus marginatus	0	0	0	2	Unknown
	Tetrastemma candidum	0	0	0	1	Unknown
	Tubulanus polymorphus	0	87	60	109	Unknown
Sipuncula	*Apionsoma misakianum*	0	0	2	23	Unknown
# Cryptogenic Species		40	33	39	43	
% of Infauna Species Cryptogenic		11.1	12.8	11.3	11.7	
% of Infauna Abundance Cryptogenic		6.70	16.0	16.9	9.07	

Note: Cryptogenic designation and status as likely introduced, native or unknown from CDFW 2014.

Epibenthic Invertebrates

Seven non-native species were collected by trawl sampling during 2018, while no non-native species were captured using beach seines. No cryptogenic or unresolved species were captured in trawls or in beach seines in 2018.

The most abundant non-native species was the spaghetti bryozoan (*Amathia verticillata*, formerly *Zoobotryon verticillatum*), which contributed nearly a quarter of the total biomass collected across all trawls (Table 4-24), compared to just 2.6 percent of biomass in the summer of 2013. Two chordates, three molluscs, and one arthropod made up the other six non-native species. The abundance of the six other non-native species was higher than in 2013 (Table 4-25). Although the two non-native tunicate species, the Pacific oyster, and Mediterranean mussel were not captured in trawls in the 2000 and 2008 Biosurveys, these species, which are generally associated with hard substrates, were noted during riprap sampling. The presence of these species in the epibenthos during the last two Biosurveys may have resulted from these animals becoming dislodged from hard substrate and scattering over the soft-bottom, or to the collection of debris and small rocks from the bottom that these animals attached to.

The white bubble snail (*P. auriformis*) has been one of the most abundant non-natives captured in the Port Complex, and the 308 individuals in 2018 made it the second most abundant behind the warty tunicate (*Styela clava*). The absence of the white bubble snail in 2008 is due to the taxonomic effort that only identified the white paperbubble (*Philine alba*) to species, and all other individuals in the genus were left at *Philine sp*. Even if all the individuals of *Philine sp*. in 2008 are assumed to be *P. auriformis*, only 29 individuals were collected and if accurate is the only Biosurvey where this non-native species was not among the most abundant.

The spaghetti bryozoan (*A. verticillata*) was observed by the California Department of Fish and Wildlife during a 2011 survey of introduced species in California's bays and harbors, noting its presence in the Port Complex as well as in Oceanside Harbor, Mission Bay, and San Diego Bay (CDFW 2014), and was recorded for the first time in the 2013 Biosurvey. This warm-water cosmopolitan fouling species has become more widely detected around the world in recent years (Humara-Gil and Cruz-Gomez 2019). It is thought that marinas and ports may facilitate the spread of this and other associated non-native species through hull fouling (Marchini et al 2015).

Table 4-24. Abundance, Biomass and Frequency of Trawl Capture for Non-Native Epibenthic Invertebrates in 2018

Species			Total Abundance per Taxa	Total Biomass per Taxa (kg)	% of Total Biomass	Frequency of Trawl Capture (%)
Phylum	Common Name	Scientific Name				
Arthropoda	Oriental shrimp	*Palaemon macrodactylus*	23	0.01	0.01	11.5
Bryozoa	Spaghetti bryozoan	*Amathia verticillata*	NA	38.1	22.80	42.3
Chordata	Warty tunicate	*Styela clava*	380	2.63	1.57	76.9
	Pleated tunicate	*Styela plicata*	77	1.23	0.73	46.2
Mollusca	Pacific oyster	*Crassostrea gigas*	149	2.40	1.44	57.7
	Mediterranean mussel	*Mytilus galloprovincialis*	200	0.76	0.46	46.2
	White bubble snail	*Philine auriformis*	308	0.14	0.09	50.0

Table 4-25. Abundance of Non-Native Epibenthic Invertebrates from 2000-2018

Phylum	Common name	Scientific Name	2000	2008	2013-2014	2018
Arthropoda	Oriental shrimp	*Palaemon macrodactylus*	0	2	15	23
Bryozoa	Spaghetti bryozoan	*Amathia verticillata*	0	0	NA	NA
Chordata	Warty tunicate	*Styela clava*	0	0	141	380
	Pleated tunicate	*Styela plicata*	0	0	49	77
Mollusca	Pacific oyster	*Crassostrea gigas*	0	0	22	149
	Mediterranean mussel	*Mytilus galloprovincialis*	0	0	51	200
	White bubble snail	*Philine auriformis*	409	0	200	308

Note: Abundance data is not applicable to the sponge *A. verticillata*

Demersal Fishes

Trawl sampling only detected one introduced fish species, the yellowfin goby (*Acanthogobius flavimanus*), which has been caught in every Biosurvey to date. Two individuals were caught across all sampling events, one in Fish Harbor (LA10) and one at Outer Pier 400 (LA1), an abundance similar to previous Biosurveys.

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5.0 HARD SUBSTRATE ASSOCIATED COMMUNITIES

Most of the shoreline of the Port Complex consists of rock dikes known as riprap; the remainder is formed by steel walls known as sheet piling, concrete or wooden bulkheads, and a limited amount of sandy beach. In addition, extensive breakwaters and jetties add several miles of riprap to the total. Tens of thousands of concrete, wood, and steel pilings support the wharfs and docks of the marine terminals, maritime service businesses, recreational boating marinas and other infrastructure throughout the Port Complex. The sheer amount of these structures means that riprap and pilings are a significant habitat type in the Port Complex, supporting a wide variety of marine flora and fauna. Riprap alone represents over 50 miles of rocky shoreline, and the pilings add a substantial amount of hard substrate for plants and animals to attach to or live near.

Past Biosurveys have demonstrated that much of the riprap within the Port Complex supports extensive stretches of canopy-forming algae such as giant kelp (*Macrocystis pyrifera*) and feather boa kelp (*Egregia menziesii*). In addition to the primary canopy-forming species, kelp communities are generally composed of a number of species of shorter stature (understory) and encrusting red, brown, and green algae, and support a diverse assemblage of invertebrates that live on the kelp and the understory algae and on the riprap itself, and a number of fish species that rely on the kelp community for shelter and food. Riprap that doesn't support kelp nevertheless supports a diverse assemblage of algae and invertebrate animals, the composition of which varies with depth, degree of exposure and wave energy, and other factors.

Pilings likewise have been shown by previous Biosurveys to support a diverse assemblage of algae and invertebrates, again varying with depth and water movement, as well as degree of shading and the composition of the piling material. Coralline algae and fleshy algae such as *Sargassum*, *Undaria*, and *Ulva*, and a variety of attached and motile invertebrates such as tunicates, bryozoans, sponges, tube worms, barnacles, mussels, and sea stars have been documented forming dense growths on pilings.

The 2018 study of hard substrate associated communities used essentially the same methods as the previous harbor-wide studies (MEC 2002, SAIC 2010, MBC 2016) but with modifications to include a more comprehensive survey of macroalgae and of riprap and piling associated invertebrates and fishes. The survey design, including the modifications from previous studies, is described in detail in Appendix A. Briefly, the extent of kelp and other canopy-forming macroalgae was assessed with aerial surveys, while canopy-forming algae, understory algae, encrusting algae, and the invertebrates associated with the riprap were assessed by divers using swath and uniform point contact (UPC) methodologies. Piling habitat was assessed using modified (for the vertical nature of the habitat) UPC techniques. The integration of these survey elements allows for a more complete picture of the habitat available on riprap and pilings and the associated communities that utilize them.

The results of these sampling efforts are presented in this section as follows:

- Kelp canopy area estimated from aerial imagery;
- Density of targeted canopy-forming algae, understory algae, and invertebrate species collected by swath surveys on riprap subtidal habitats;

- Percent cover of invertebrates and algae on 1) riprap subtidal and intertidal habitats and 2) pilings as a rapid assessment method to compare against quadrat scrapings;
- Detailed taxonomic composition of invertebrates and algae from quadrat scrapings on subtidal and intertidal riprap and piling habitats;
- Presence of fish observed by divers during summer surveys.

5.1 Habitat Characteristics

Visual surveys on riprap were conducted in spring and summer 2018, while quadrat scrapings and percent cover surveys on pier pilings were only conducted in summer 2018. Riprap and piling habitat data was analyzed by habitat (Inner Harbor and Outer Harbor), location (Breakwater, SWH, Outer, Channel, Basin, Slip) and by depth (Upper and Lower Intertidal, Subtidal). Station designations, and more detailed descriptions of survey methods for visual surveys and quadrat scrapings can be found in Table 5-1, Figure 5-1 and Appendix A. Additional multivariate analysis and data summary tables can be found in Appendix E.

Table 5-1. Riprap and Pier Piling Station Locations and Station Groups

Kelp Station	Riprap Station	Pier Piling Station	Port	Habitat	Location	Station Descriptor	# of Depth Strata
T1	--	--	POLB	Outer	Breakwater	Middle Breakwater	3
T2	LARR1	--	POLA	Outer	SWH	CSWH Phase 2 Breakwater	2
T3	--	--	POLA	Outer	SWH	N. Cabrillo Beach & Scout Camp	2
T4	--	--	POLA	Outer	Outer	Outer East Pier 400	2
T5	--	--	POLB	Outer	Breakwater	East Middle Breakwall	3
T6	LBRR4	LBPP1	POLB	Outer	Basin	SE Basin	2
T7	--	--	POLB	Outer	Basin	Inner Harbor Turning Basin	2
T8	--	--	POLB	Inner	Slip	Channel 3	2
T9	--	--	POLA	Outer	SWH	Seaplane Lagoon	1
T10	--	--	POLA	Inner	Basin	East Basin Channel Entrance	2
T11	--	--	POLB	Inner	Slip	Channel 2	2
T12	LBRR2	--	POLB	Inner	Channel	Cerritos Channel	2
T13	LARR2	--	POLA	Inner	Slip	South of Consolidated Slip	2
T14	LBRR1	--	POLB	Outer	Breakwater	Pier J Breakwater	3
T15	LBRR3	--	POLB	Outer	Basin	Navy Mole	2
T16	--	--	POLA	Outer	Outer	POLA Main Channel Entrance	2
T17	--	--	POLA	Inner	Basin	Fish Harbor Entrance	2
T18	--	--	POLA	Inner	Slip	Slip 1	2
T19	LARR3	LAPP3	POLA	Inner	Basin	POLA West Basin South	2
T20	LARR4	LAPP1	POLA	Outer	Slip	Berth 48	2
--	--	LAPP2	POLA	Outer	Channel	POLA Main Channel - USS Iowa	--
--	--	LAPP4	POLA	Inner	Channel	East Basin Channel	--
--	--	LBPP2	POLB	Outer	Basin	Pier T	--
--	--	LBPP3	POLB	Inner	Slip	Pier B	--
--	--	LBPP4	POLB	Inner	Channel	Pier A	--

Riprap, Pier Piling, Macroalgae, and Associated Benthic Invert. Community Stations
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 5-1. Riprap, Pier Piling, Macroalgae and Associated Benthic Invertebrate Community Stations

5.2 Kelp Canopy from Aerial Imagery

5.2.1 2018 Kelp Canopy

Aerial imagery from the Central Region Kelp Survey Consortium was used to estimate the coverage of canopy formed by giant kelp and feather boa kelp within the Port Complex. Images in the spring were taken on March 28th, 2018 at approximately a -0.133 m MLLW tidal elevation. Images in the summer were taken on July 2nd, 2018 at approximately a 1.032 m MLLW tidal elevation.

Kelp canopy covered 118 acres in spring 2018 and 114 acres in summer 2018. The extent of kelp canopy coverage can be seen in Figures 5-2 to 5-5 (the northern portions of the Port Complex are not pictured because no kelp was present there).

Kelp was present on the breakwaters protecting the harbor, on shoreline riprap along piers in the Outer Harbor, and on submerged rock dikes. The reduction in kelp canopy between seasons in 2018 appeared relatively consistent across all stations, with aerial imagery indicating the greatest reductions in the kelp canopy at the following locations:

- The east side of Pier J along the pier and the breakwater outside the Pacific Container Terminal
- The west side of Pier J near the pilot station
- Inside West Basin on the western and southern margins
- The southeast side of Pier 400
- The mouth of Fish Harbor
- The riprap groin protecting Cabrillo Marina

Figure 5-2. POLB Kelp Canopy – Spring 2018

Red shading indicates kelp canopy at the surface.

Figure 5-3. POLA Kelp Canopy – Spring 2018

Red shading indicates kelp canopy at the surface.

Figure 5-4. POLB Kelp Canopy – Summer 2018

Red shading indicates kelp canopy at the surface.

Figure 5-5. POLA Kelp Canopy – Summer 2018

Red shading indicates canopy cover at the surface

5.2.2 Historical Canopy Kelp Comparisons

Kelp canopy coverage during the spring of 2018 was similar to that observed in spring 2014 (132 acres), but substantially higher than in 2008 and 2004 (Figure 5-6). Coverage in the summer of 2018 was more than twice as high as that observed any other sampling year. Additionally, the kelp canopy only decreased 3.4% from spring to summer in 2018, while in previous years the spring-to-summer decrease was more marked, as high as 65% in 2014. The decrease in 2014 could be in part due to the warm water anomaly that was beginning to develop in the area during this time. Because kelp has an exceptionally rapid growth rate and responds quickly to transient changes in environmental conditions (Cavanaugh et al. 2011), the frequency of measuring kelp canopy every five years is prone to miss variability that occurs between years.

Another confounding factor that may influence the seasonal variability is that the Central Region Kelp Survey Consortium (CRKSC) aerial kelp canopy surveys have not historically controlled for tidal elevation during their flights to collect aerial imagery. Tidal elevation and tidal currents are known to influence how much canopy is available at the surface for detection by aerial or satellite sensors, with a study in British Columbia finding that a 2 m increase in tide resulted in a 40% decrease in detectable kelp canopy (Nijland et al. 2019). Based on flight logs, spring 2018 images were taken at a -0.133 m MLLW tidal elevation while summer 2018 images were taken at a 1.032 m MLLW tidal elevation. 2013 had similarly mismatched tidal elevations, with spring 2013 images taken at a 0.810 m MLLW tidal elevation while summer 2013 images were taken at a 1.525 m MMLW tidal elevation. The higher tidal elevations were likely a factor in the decrease in kelp canopy detected in the summer for these years, however the effect of tidal elevation in the Port Complex on kelp canopy has not been quantitatively assessed.

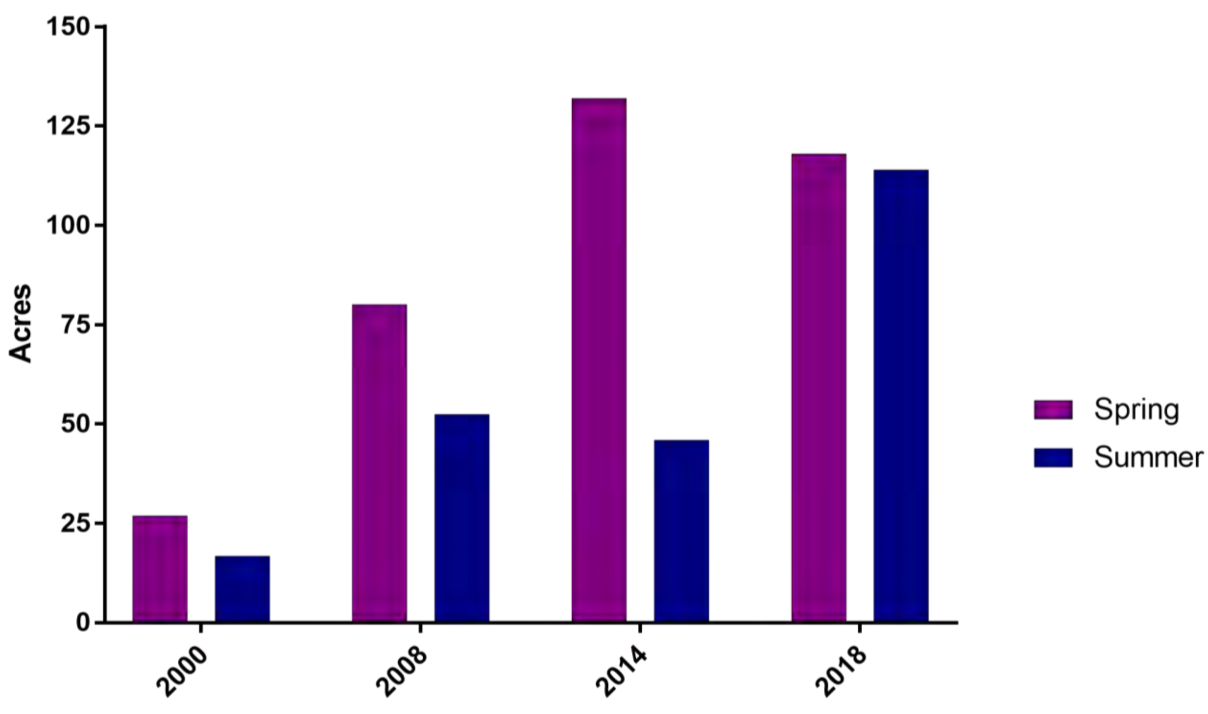


Figure 5-6. Kelp Canopy in the Port Complex by Year and Season

The CRKSC aerial kelp canopy surveys report the yearly maximum extent from four quarterly surveys at each kelp bed in Palos Verdes as well as the Port Complex (MBC 2019). The 2018 CRKSC report documented the largest kelp canopy area in the Port Complex and across all kelp beds in Palos Verdes since 2009 (Figure 5-7). It is evident that there was an effect of the marine heatwave in 2014, however the kelp beds quickly rebounded in 2015 and have shown continual improvement since. Resilience to climatic events and similar subsequent recovery have been demonstrated in Southern California kelp beds in response to the 1998 El Niño (Steneck et al. 2002) While CRKSC data provides useful context, it should be noted that from year to year the season in which the canopy maximum is obtained is not always consistent and can make interpreting drivers of these patterns difficult.

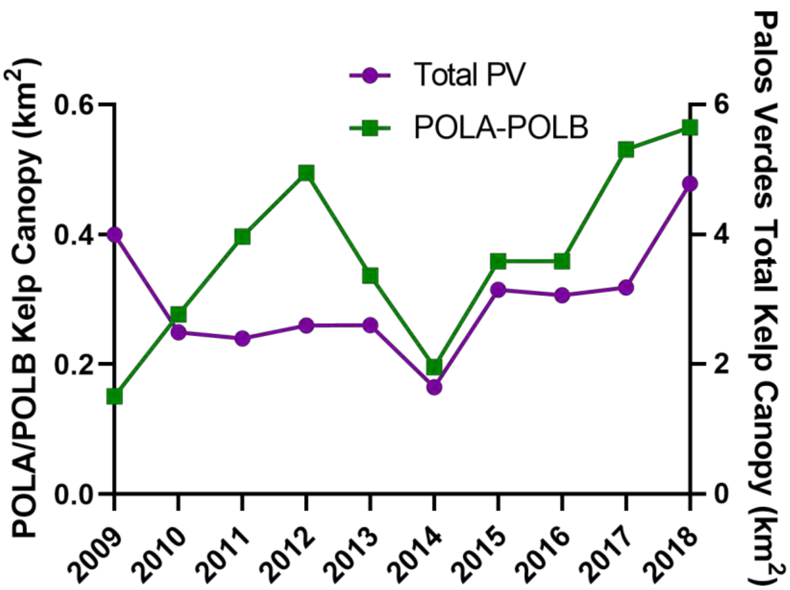


Figure 5-7. Yearly Maximum for Kelp Beds Within POLA/POLB and Palos Verdes from CRKSC Aerial Surveys

5.3 Macroalgae and Macroinvertebrates

In addition to the canopy-forming species (primarily *Macrocystis pyrifera*), kelp communities on riprap generally include other algal species that can be categorized into layers distinguished by morphoological adaptations (Dayton et al. 1984). These include 1) a tall understory canopy in which fronds are supported well above the substratum by erect stipes (characteristic species include *Pterygophora californica* and *Eisenia arborea*); 2) a low understory canopy in which fronds lie on or immediately above the substratum (e.g., *Laminaria farlowii* and *Stephanocystis osmundacea*); 3) densely packed algal turf made up of articulated coralline algae (*Corallina pinnatifolia* and *C. vancouveriensis*, *Lithothrix aspergillum*) and many species of foliose and siphonous red, brown, and green algae; and 4) encrusting coralline algae (e.g., *Lithophyllum sp*. and *Lithothamnion sp*). These complex habitats provide habitat for numerous sessile and mobile invertebrates which can be large and easily identified by visual diver surveys, while the majority of invertebrates are small and cryptic within the algal turfs and attached to the rocks.

Previous Biosurveys have only used quadrat scrapings to sample smaller cryptic invertebrates while divers qualitatively assessed the percent cover of macroalgae species. One of the most impactful changes to the 2018 Biosurvey design was the modification of the riprap and piling surveys to incorporate methods adapted in regional monitoring programs of coastal rocky reefs, primarily from the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). The result was a much more rigorous quantative assessment of algal, invertebrate and fish communities that still included quadrat scrapings for high resolution taxonomy of the epifaunal community on riprap and pilings. The methods are briefly described here, with more complete descriptions and details in the methods appendix (Appendix A).

The 2018 survey included 20 riprap sites (Figure 5-1) that were surveyed using 2-3 (dependent on station depth) subtidal transects laid perpendicular to the slope which were used for swath and uniform point contact (UPC) surveys (Figure 5-8). UPC surveys used the tape to evenly space out 50 random points which a diver would use to assess the substrate (reef, boulder, cobble, sand) and cover categories (Table 5-2 and Table 5-3) to come up with percent cover. As a rapid assessment tool, UPC categories are not all species specific and some generalize many species into a broader category, in some cases because speciation is difficult in the field (e.g. tube worms, bryozoans). Swath surveys are used to estimate density of target organisms, which include larger macroalgae and large, mobile invertebrates that are not well represented by quadrats or percent cover surveys (Table 5-4). The swath target species were selected based on representation of different functional community groups common in coastal reefs. This target list is a subset of the total species living in the habitats because taxonomic and time constraints prevented recording every animal encountered. Divers swam along the transect and counted individuals that were within 1-meter of either side of the tape. If a diver encountered an abalone, it was identified to species and a length (in cm) was measured along the longest axis of the shell. Divers who encountered non-native algae or endangered abalone species (black or white abalone) anywhere on the site recorded it’s presence (in addition to size for abalone).

Piling stations (Figure 5-1) were surveyed vertically using a transect tape deployed from the intertidal zone down to the sediment-piling interface (Figure 5-6). Using the same distance intervals as riprap (5 points per meter), divers assessed cover categories prior to quadrat collection.

Quadrat scrapings (in duplicate) within the upper intertidal, lower intertidal and subtidal (1 meter above the sediment interface) were collected at 8 riprap and piling stations spread throughout the Port Complex (Figure 5-1). At riprap stations where quadrats were taken, two additional intertidal transects for UPC were deployed in the upper and lower intertidal zone. Random distances along each transect were selected for each quadrat prior to divers entering the water, and photos of the quadrat were taken prior to scraping. At piling stations, a scraping was taken on either side of the transect tape at the target depth.

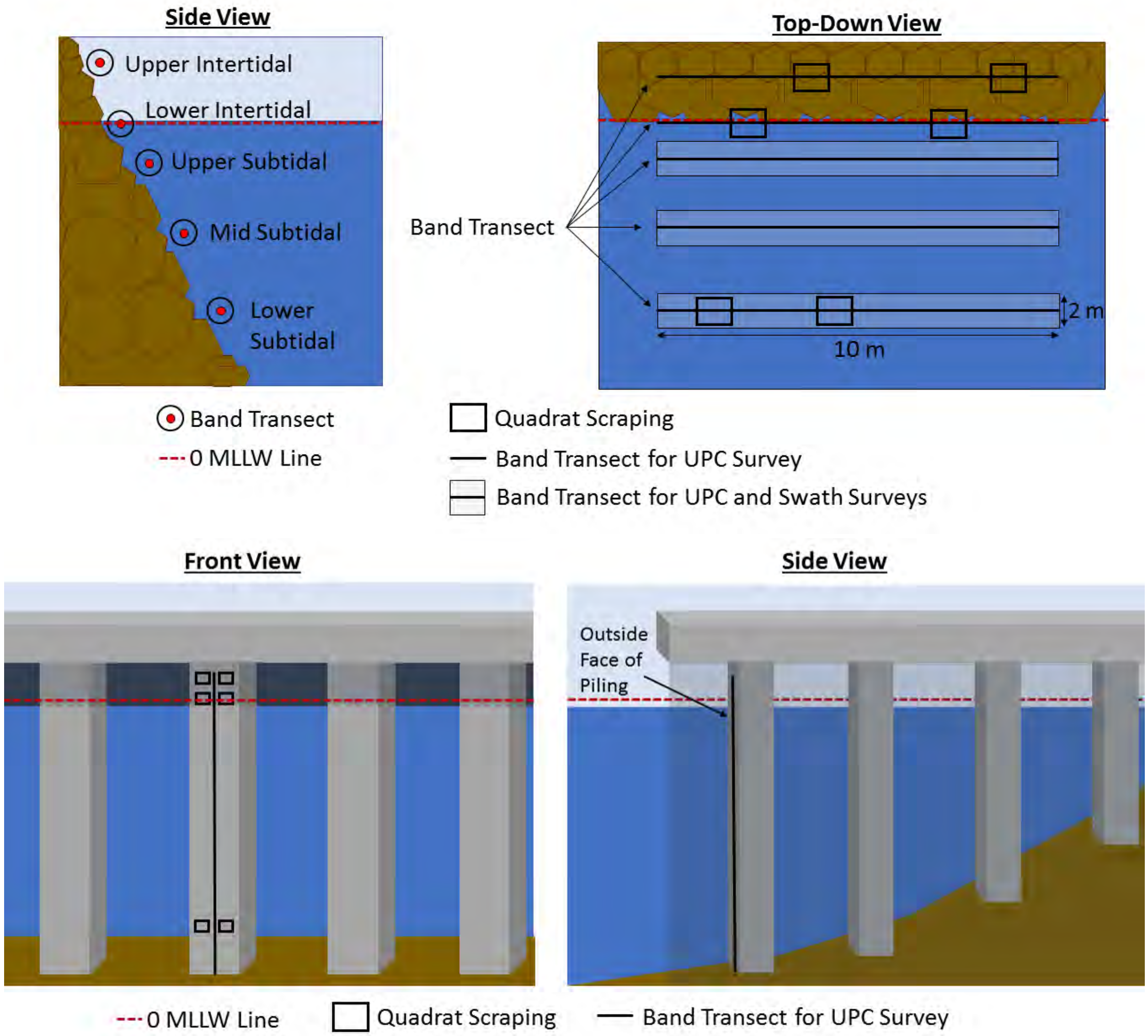


Figure 5-8. Riprap and Concrete Pier Piling Scraping Site Schematic

Table 5-2. Invertebrate Categories for UPC Surveys

Phylum	Class	Common Name	Species
Porifera	Demospongiae	Sponge	Many
	Calcarea		
Cnidaria	Hydrozoa	Ostrich-plume hydroid	*Aglaophenia struthionides*
		Hydroid	Many
	Anthozoa	Gorgonian	Many
		Anemone	Many
		Club-Tipped Anemone	*Corynactis californica*
		Cup Coral	Many
Bryozoa	Gymnolaemata	Bryozoans	Many
		Non-native Bryozoan	*Watersipora spp.*
		Southern Staghorn Bryozoan	*Diaperoecia californica*
Mollusca	Gastropoda	Scaled Worm Shell	*Serpulorbis squamiger*
		Snails	Many
	Polyplacophora	Chiton	Many
	Bivalvia	Clam	Many
		Rock Scallop	*Crassadoma gigantea*
		California Mussel	*Mytilus californianus*
		Mediterranean Mussel	*Mytilus galloprovincialis*
		Olympia Oyster	*Ostrea lurida*
		Pacific Oyster	*Crassostrea gigas*
Arthropoda	Crustacea	Barnacle	*Chthamalus sp.*
		Gooseneck Barnacle	*Pollicipes polymerus*
Echinodermata	Holothuroidea	Sea Cucumber	Many
	Asteroidea	Sea Star	Many
	Echinoidea	Urchin	Many
Annelida	Polychaeta	Tube Worms	Many
		Colonial Tube Worm	Many
Chordata	Urochordata	Solitary Tunicate	Many
		Colonial Tunicate	Many

Table 5-3. Algae and Seagrass Categories for UPC Surveys

Class	Common Name	Species
Phaeophyceae (Brown Algae)	Giant Kelp	*Macrocystis pyrifera*
	Understory Kelp	*E. arborea, P. californica, L. farlowii*
		Stephanocystis osmondacea
	Asian Kelp	*Undaria pinnatifida*
	Feather Boa Kelp	*Egregia menziesii*
		Desmarestia ligulata
	Dictyotales	*Dictyota binghamiae*
		Sargassum muticum
		Sargassum horneri
	Dead Holdfast of Kelps	
	Other Brown	Many
Rhodophyta (Red Algae)	Branching Red Algae	Many
	Bushy Red Algae	Many
	Leafy Red Algae	Many
	Lacy Red Algae	Many
	Turf Red Algae	Many
	Encrusting Red Algae	Many
	Articulate Coralline Algae	Many
	Crustose Coralline Algae	Many
Chlorophyta (Green Algae)	Sea Lettuce	*Ulva spp*
	Other Green Algae	Many
Tracheophyta (Flowering Plants)	Surfgrass	*Phyllospadix scouleri/torreyi*
	Common Eelgrass Pacific Eelgrass	*Zostera marina* *Zostera pacifica*

Table 5-4. Target Species for Swath Surveys

Functional Community Group	Common Name	Species
Canopy Forming Kelp	Giant Kelp	*Macrocystis pyrifera*
	Feather Boa Kelp	*Egregia* sp.
Understory Kelp	Laminaria	*Laminaria* sp.
	Bladder Chain Kelp	*Stephanocystis osmundacea*
	Southern Sea Palm	*Eisenia arborea*
	Pterygophora	*Pterygophora californica*
Non-native Algae	Sargassum	*Sargassum muticum*
	Sargassum	*Sargassum horneri*
	Wakame	*Undaria pinnatifida*
Herbivores	Green Abalone	*Haliotis fulgens*
	Pink Abalone	*Haliotis corrugate*
	Red Abalone	*Haliotis rufescens*
	Black Abalone	*Haliotis cracherodii*
	White Abalone	*Haliotis sorenseni*
	Purple Urchin	*Strongylocentrotus purpuratus*
	Red Urchin	*Mesocentrotus franciscanus*
	White Urchin	*Lytechinus pictus*
	Crowned Urchin	*Centrostephanus coronatus*
Filter Feeders	Rock Scallop	*Crassadoma gigantea*
	Brown/Golden Gorgonian	*Muricea* spp
	Red Gorgonian	*Leptogorgia chilensis*
	Large (<10 cm) Anemones	*Anenome* spp.
Carnivores	California Spiny Lobster	*Panulirus interruptus*
	Bat Star	*Asterina miniata*
	Ochre Star	*Pisaster ochraceus*
	Giant Spined Sea Star	*Pisaster giganteus*

5.3.1 Density of Targeted Macroalgae and Macroinvertebrates

Swath surveys on riprap habitats were used to gather abundance information on target species of canopy-forming algae, understory algae, and macroinvertebrates. The abundance of target species at a given station was divided by the area surveyed to obtain density.

Canopy Forming Algae

Giant kelp (*Macrocystis porifera*) and feather boa kelp (*Egregia menziesii*) are the only canopy-forming algae species that were targeted by the swath surveys. In addition to counting the giant kelp individuals encountered within the swath, divers counted the number of stipes greater than 1 meter in height as a way to assess recruitment and biomass of kelp, which has been shown to be complimentary to aerial or satellite canopy methods (Cavanaugh et al. 2011).

Canopy forming giant kelp and feather boat kelp at survey station in the Outer Harbor

Canopy-forming algae were observed at nine sites on the breakwaters and outer harbor. The mean number of stipes per giant kelp individual, an indication of kelp age and structural value, was greater in spring (6.63) than in summer (5.51), a statistically significant difference, although the median number of stipes in both seasons was 4 per individual (Figure 5-9). The largest giant kelp individuals encountered in spring and summer had 25 and 29 stipes, respectively. Giant kelp is known to recruit in the spring (Schiel and Foster 2015), suggesting that the sampling captured increased recruitment from spring to summer, thus accounting for the higher density and fewer stipes per individual. At one station (T2), canopy-forming algae were not present in the spring but were abundant in the summer (Figures 5-10 and 5-11). At the nine sites where canopy-forming algae were observed, fewer kelp individuals were observed in spring (155 giant kelp individuals and 8 feather boa individuals) than in summer (191 giant kelp individuals and no feather boa individuals). Surface-based visual surveys of the kelp canopy confirmed that feather boa was present only in the shallow margins of the kelp bed at some stations and did not account for more than 5% of the total canopy at any station. Station T14 (Pier J breakwater) had the highest density of canopy-forming algae in the spring (0.97/m^2), closely followed by T4 (Outer East Pier 400, 0.93/m^2). In the summer, density was highest at Station T4 (1.28/m^2) followed by T16 (POLA Main Channel Entrance, 0.80/m^2).

While aerial imagery provides extensive coverage of the entire Port Complex, in-water verification helps to identify areas where canopy-forming algae are present but may not reach the surface. At various times of the year the recruitment of giant kelp and feather boa juveniles may not be large enough to enable detection at the surface, or warm water events can cause senescence of fronds near the surface (Schiel and Foster 2015), causing them to change color and die off while leaving the rest of the individual intact below the thermocline. Conversely, aerial images, which are processed by computer-based color recognition calibrated to the color of canopy-forming algae, may at times overestimate kelp canopy in shallow areas where smaller macroalgae reach the surface or where shoreline features mimic the presence of kelp and increase the potential for misidentification.

Aerial imagery and diver surveys generally identified canopy-forming algae in the same areas, although there were a few discrepancies:

- The most notable was at station T20 (Berth 48). Aerial imagery suggests there was sparse canopy coverage in both seasons, but diver surveys found the area to be devoid of any macroalgae. Potentially, aerial imagery might have picked up drift kelp that was still alive in the area, however significant amounts of drift kelp were not observed by divers during either survey.
- No canopy-forming algae were observed in the survey swaths at Station T2 (CSWH Phase 2 Breakwater) during the spring survey, although sparse canopy was observed in the general area and aerial imagery supports the likely existence of canopy-forming algae in the area.
- No kelp canopy was evident near station T6 (SE Basin) from aerial imagery, but diver surveys found one giant kelp individual in each season.

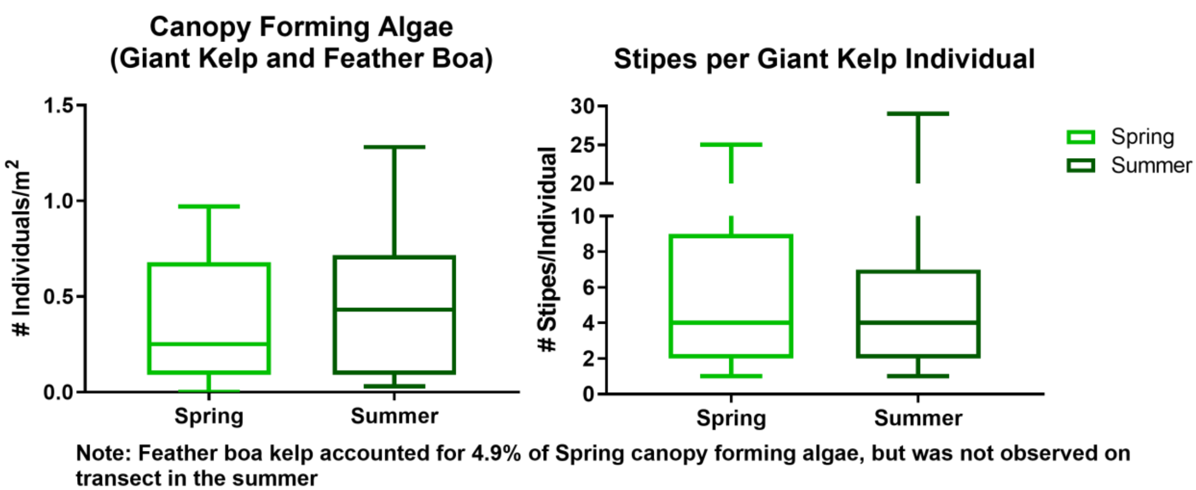


Figure 5-9. Canopy Forming Algae Density and Giant Kelp Stipes per Individual by Season

Note: Whiskers represent the range, the line represents the median, and the boxes represent the quartile range above and below the median

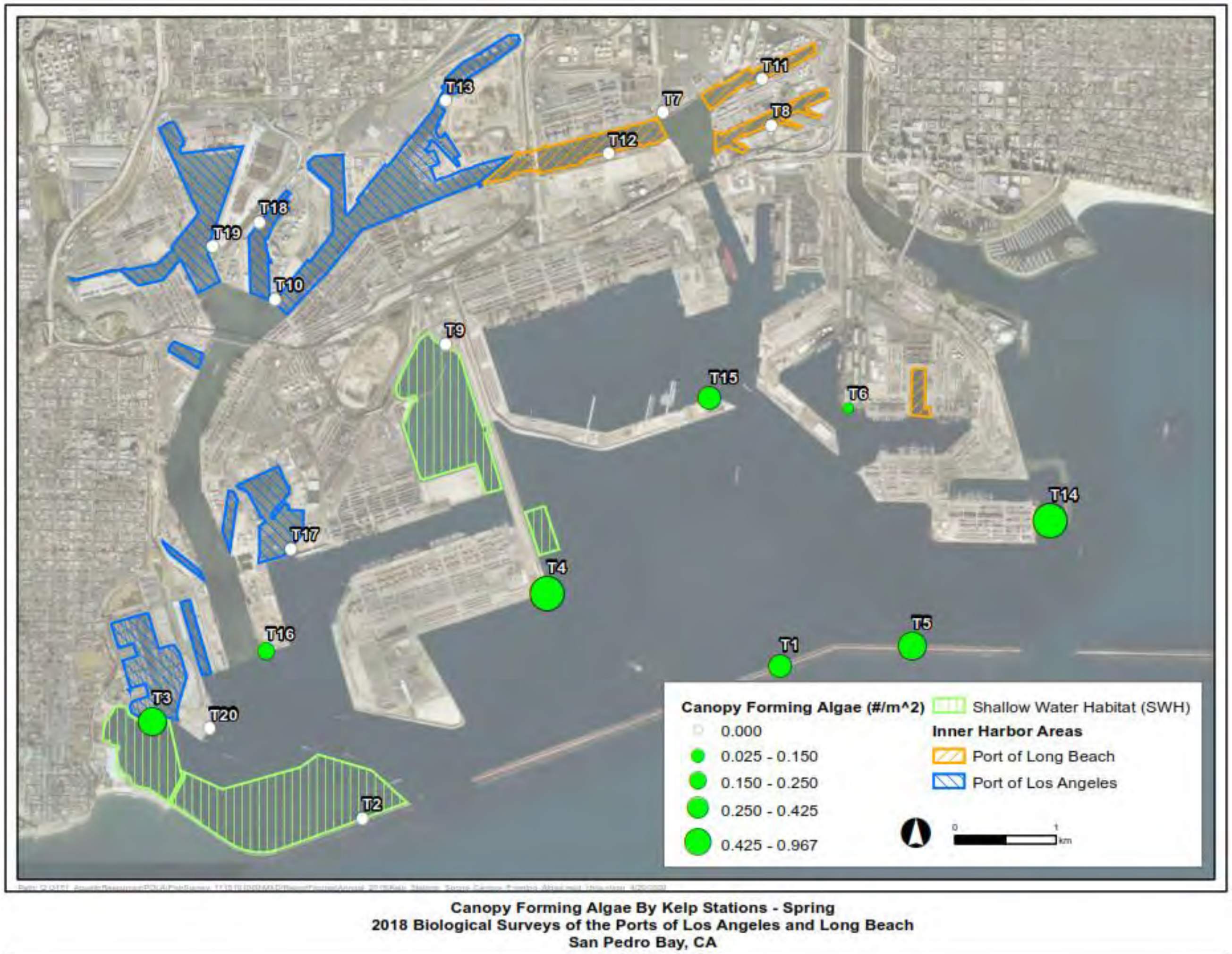


Figure 5-10. Canopy Forming Algae at Kelp Stations (Spring 2018)

Figure 5-11. Canopy Forming Algae at Kelp Stations (Summer 2018)

Understory Algae

In addition to assessing canopy-forming algae species, swath surveys also characterized understory kelp species, some of which are considered non-native (Table 5-4).

Common understory species in Southern California kelp forests include *Pterygophora californica, Eisenia arborea*, *Laminaria farlowii*, *Sargassum horneri, Sargassum muticum, Undaria pinnatifida*, and *Stephanocystis osmundacea*. Although none of the first three species was observed on any transect during the spring or summer swath surveys, they have been recorded in nearby surveys at coastal reefs in Palos Verdes and Orange County (Reef Check: http://data.reefcheck.us/), so their absence inside the Port Complex could be the result of limitation by physical conditions such as temperature and wave action. The relative density of each understory algae species observed in each season is shown in Figure 5-12.

S. osmundacea was the only targeted native understory alga that was observed across both seasons: it was observed at three stations in the spring (T4 – Outer East Pier 400, T5 – East Middle Breakwater and T16 – POLA Main Channel Entrance) and four stations in the summer (T4, T5, T14 – Pier J Breakwater, and T16). Spring density ranged from 0.08/m^2 at T5 to 1.11/m^2 at T16, while summer density ranged from 0.03/m^2 at T4 and T14 to 0.58/m^2 at T16.

The other three understory algae species observed in this Biosurvey are considered non-native: *Sargassum horneri, S.muticum*, and *U. pinnatifida*. *S. muticum* and *S. horneri* can at times become the dominant algal species, with high densities and heights of over 4 m, and they occasionally form a “canopy” that reaches the surface in shallow locations.

At least one of those species was found at every station except for T20 (Berth 48), which was devoid of any macroalgae, and all three species were observed during both seasons. There were noticable changes in density between seasons (Figure 5-13). Density of *S. horneri* was greatest at T11 (Channel 2) in both spring (8.11/m^2) and summer (20.0/m^2). Density of *S. muticum* in the spring was greatest at T6 (SE Basin, 18.75 /m^2), although T18 (Slip1, 16.7/m^2) and T3 (N. Cabrillo Beach & Scout Camp, 14.7/m^2) also had high densities. In summer, Station T11 had by far the highest density of *S. muticum* (17.7/m^2) of any station. Density of *Undaria* was greatest in spring at T17 (4.17/m^2, Fish Harbor Entrance) and T16 (1.11/m^2, POLA Main Channel Entrance), while no other station had a density above 1.0/m^2. Station T17 (Fish Harbor Entrance) was the only station at which *Undaria* was observed on a transect in the summer.

The density of all three species was higher at Inner Harbor stations than at Outer Harbor stations. Mean density of *Undaria* declined by 99% from spring to summer, while *S. muticum* experienced a 56% reduction. Both species are annuals that in their native ranges experience senescense and die off in summer months when water is warmer (Epstein and Smale 2017, Engelen et al. 2015), so this reduction is not unexpected. Conversely, the mean density of *S. horneri* increased 387% from spring to summer at all stations, despite also having an annual life cycle in its native range (Marks et al. 2015).

The *S. muticum* observed in the spring were generally larger, mature plants that created a sub-canopy, while most individuals in the summer were small juveniles that were usually no larger than 10 cm tall or wide. While *S. horneri* is known to create dense stands of larger adults of similar size, most of the *S. horneri* encountered in both seasons was relatively small. The current Biosurvey did not differentiate between the life stages, which would be useful to better understand the dynamics of these populations. The year-round presence of these species is likely attributable to cooler environmental conditions than in their native range. These cooler conditions partially inhibit dormancy of the reproductive adults, resulting in overlapping generations that are continuous through time even though individuals die within 12 months of recruitment (Marks et al. 2015, Epstein and Smale 2017, Engelen et al. 2015). While *Undaria* was less prevalent on riprap in the summer, divers noted its presence on pilings year-round, suggesting pilings as more favorable habitat.

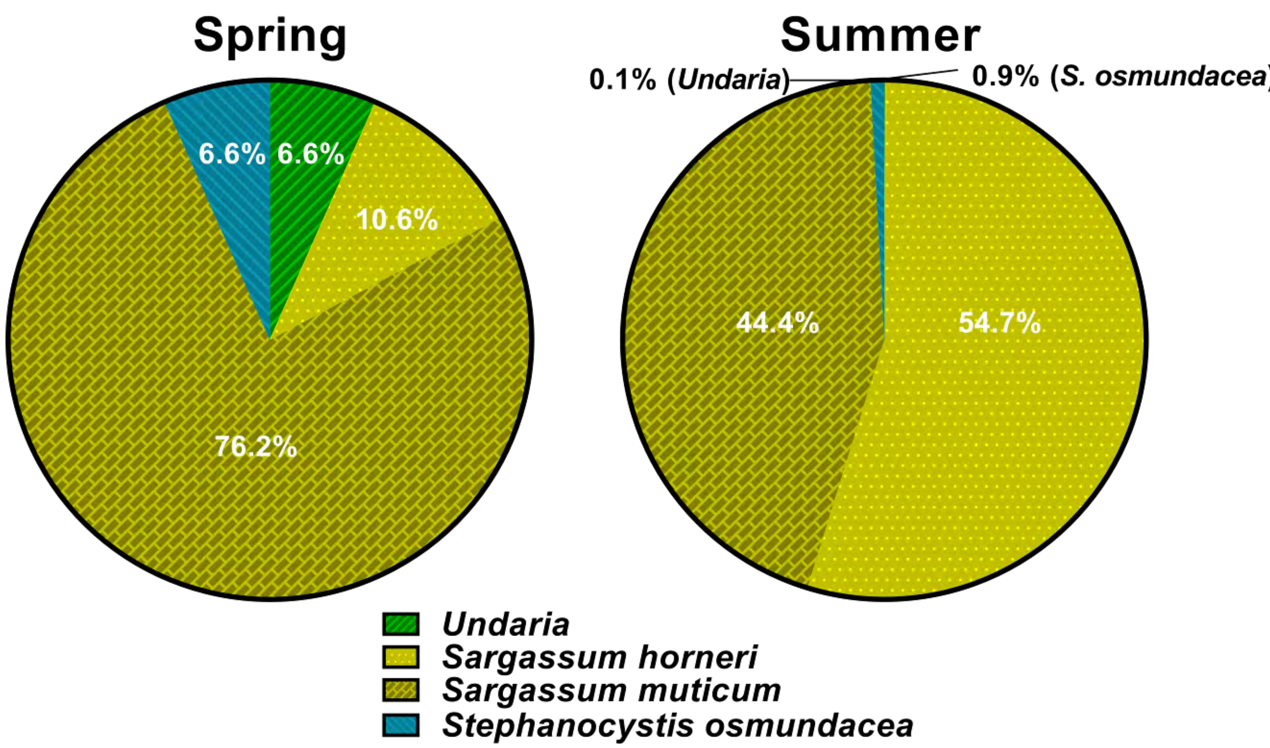


Figure 5-12. Proportions of Understory Algae Species Measured by Swath Surveys on Riprap in Spring and Summer 2018

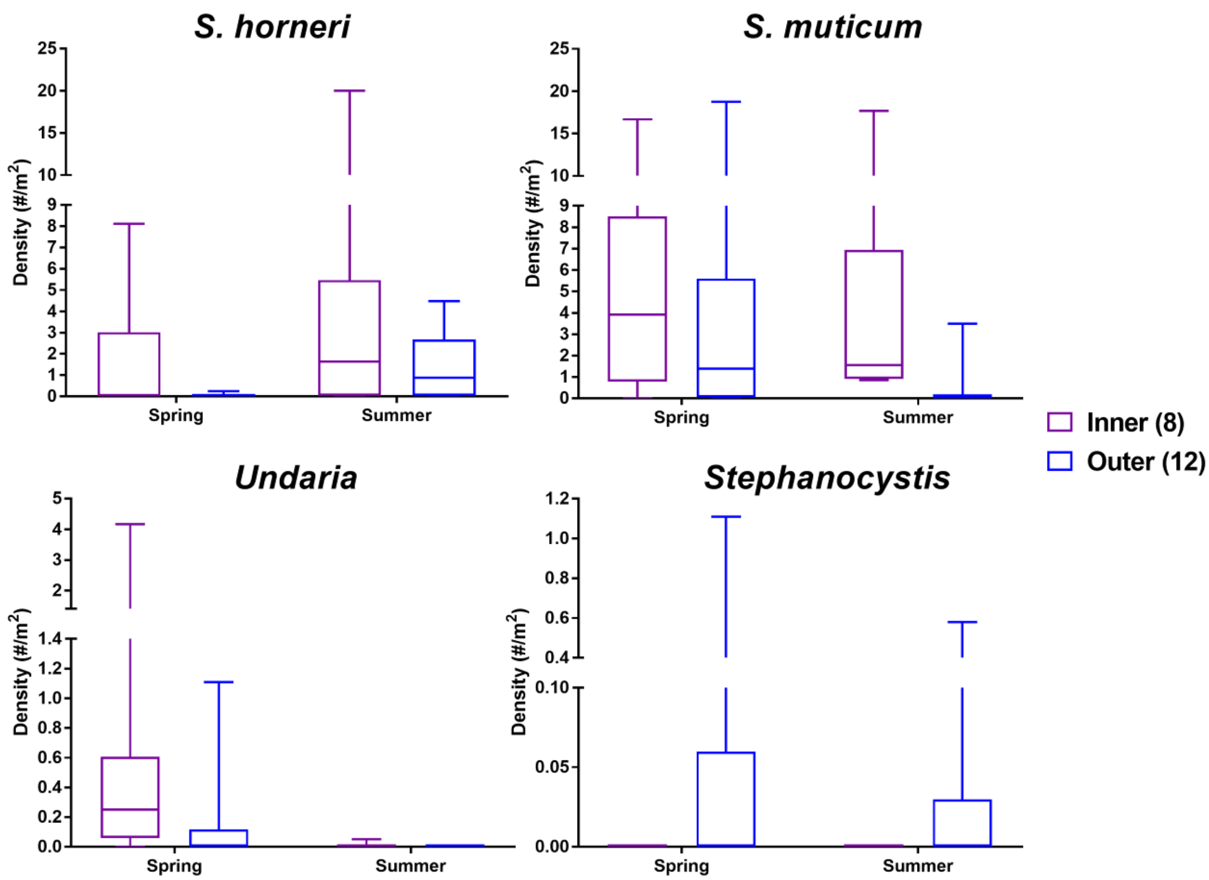
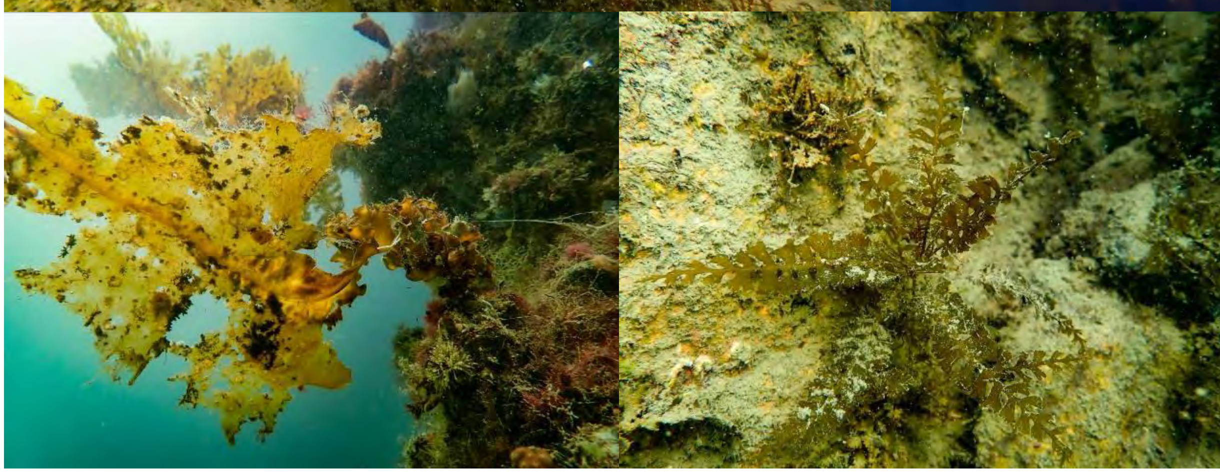


Figure 5-13. Density of Understory Algae Species Measured by Swath Surveys on Riprap in Inner and Outer Harbor Habitats During Spring and Summer 2018

Note: Whiskers represent the range, the line represents the median and the boxes represent the quartile range above and below the median.



Clockwise from top left: Mature *Sargassum muticum* spring 2018; *S. muticum* canopy at the surface with encrusting non-native bryozoan *Watersipora* in Seaplane Lagoon spring 2018; juvenile *Sargassum horneri* spring 2018; *Undaria pinnatifida* on piling summer 2018 with evidence of senescence.

Invertebrates

A target list of invertebrates that encompass different feeding guilds (predators, herbivores, and filter feeders) was the focus of the diver swath surveys (Table 5-4). Predators observed included California spiny lobster (*Panulirus interruptus*) and bat stars (*Patiria miniata*). Other target predator species, such as giant spine sea star (*Pisaster giganteus*) and ochre sea star (*P. ochraceus*), were seen at riprap and piling stations but not within the survey area, and therefore density data was not obtained. Filter feeders observed included anemones greater than 10 cm tall or wide (*Anthropleura spp*. and tube-dwelling species such as *Pachycerianthus fimbriatus*), brown and golden gorgonians (*Muricea fruticosa* and *M. californica*), red gorgonian (*Leptogorgia chilensis*), and rock scallop (*Crassadoma gigantea*). Herbivores primarily consisted of four species of urchins: red (*Mesocentrotus franciscanus*), purple (*Strongylocentrotus purpuratus*), white (*Lytechinus anamesus*, only in spring) and crowned (*Centrostephanus coronatus*). The herbivores also included three species of abalone: green (*Haliotis fulgens*), pink (*H. corrugata*) and white (*H. sorenseni*).

The relative contribution of each feeding guild to the total abundance did not vary significantly from the spring to the summer survey (Figure 5-14). However, there were distinct differences in the density of each guild between Inner and Outer Harbor habitats (Figure 5-15), although only the predators were significantly higher in Outer Harbor habitats for both seasons. Predator densities and species composition were markedly different between Inner and Outer Harbor habitats; predators at Outer Harbor stations were primarily spiny lobsters whereas at Inner Harbor stations the predators were primarily bat stars, although there were a few stations with both species present.

The filter feeders were predominately gorgonians in both seasons and were found primarily at breakwater and Outer Harbor pier stations. Across both seasons, these stations averaged 0.64/m^2 brown/golden gorgonians and 0.17/m^2 red gorgonians, whereas Inner Harbor basin, slip, and channel stations averaged only 0.02/m^2 for all gorgonians combined. Large anemones also only occurred at breakwater stations, although smaller anemones (i.e., just under the size requirement to be counted) were common throughout the Port Complex, especially at Station T7 (Inner Harbor Turning Basin), which had a high density of smaller tube-dwelling anemones. Rock scallops were common throughout the Port Complex with station T20 (Berth 48) having the highest density in both seasons (4.05/m^2 in the spring and 2.36/m^2 in the summer). Across both seasons, rock scallop density at all other stations where they were present averaged 0.16/m^2.

Red and purple urchins at survey station in Outer Harbor

Most herbivores in both seasons were purple urchins, which were found at the most stations, followed by red and crowned urchins. The white urchin was only found at Station T2 (CSWH Phase 2 Breakwater) in the summer. The abundance of urchins was greater at Outer Harbor stations than at Inner Harbor stations, although the difference was largely driven by one outlier and was not statistically significant in either season. Station T20 had by far the highest density of urchins (purple, red, and crowned) of any station in both seasons (spring = 17.7/m^2, summer = 13.8/m^2) with 94% consisting of purple urchins in both seasons.


Pink abalone (left) and green abalone (right) in the Outer Harbor

This is the first Biosurvey in which the three abalone species discussed were documented within the Port Complex. Abalone were found in Outer Harbor habitats on breakwaters and riprap. The spring survey found two green abalone and three pink abalone, and the summer surveys found three green, seven pink, and one white abalone. Green abalone ranged from 10-16 cm in size and were found in lower densities than pink abalone, with densities ranging from 0.02-0.03/m^2. Pink abalone ranged from 10-18 cm with densities ranging from 0.02-0.05/m^2, which is similar to the average density (0.041/m^2) of pink abalone found in Point Loma during a 2009 survey (Coates et al. 2014). Numerous small and large empty abalone shells were found at these sites as well. Rossetto et al. (2013) modeled the size at which 50% of individuals are sexually mature at Isla Natividad and found the threshold to be 136 +/- 7.8 mm for green abalone and 126.5 +/- 2.3 mm for pink abalone. If the same size threshold holds for the population in the Port Complex, approximately 50% of the green abalone and 66% of the pink abalone were mature adults. Abalone can live to be 30+ years of age, so while the 2018 is the first Biosurvey to document abalone using the new methodology, these species have likely existed in the Port Complex for decades. While the 1986-1987 Biological Baseline study (MEC 1988) did not include abalone in the results of their survey of invertebrates on riprap, the report included this note on the invetebrates on the breakwater: “Lobsters and black abalone (*Haliotis cracherodii*) are common”. Black abalone have suffered massive population declines in Southern California as a result of overharvesting and disease (withering syndrome), with the commercial and recreational fisheries closed in 1993, and were listed as endangered under the Endangered Species Act in 2009.

White abalone are an endangered species that are undergoing active, coordinated population restoration efforts led by NOAA and the CDFW. The 17-cm individual found in the Port Complex was reported to NOAA, who with the help of Wood divers conducted a follow-up survey in March 2019 to relocate the indvidual and search for other nearby white abalone. Finding no abalone within range for successful spawning, the team recovered the abalone to become part of the captive breeding program. In October 2019, the captive breeding program led by a team of scientists at NOAA Fisheries, CDFW, Aquarium of the Pacific, Paua Marine Research Group, and the Bay Foundation, successfully outplanted its first batch of 3,000 juvenile white abalone onto reefs off Palos Verdes in an attempt to restore wild populations (CDFW 2019).

White abalone following recovery by NOAA and Wood divers in March 2019

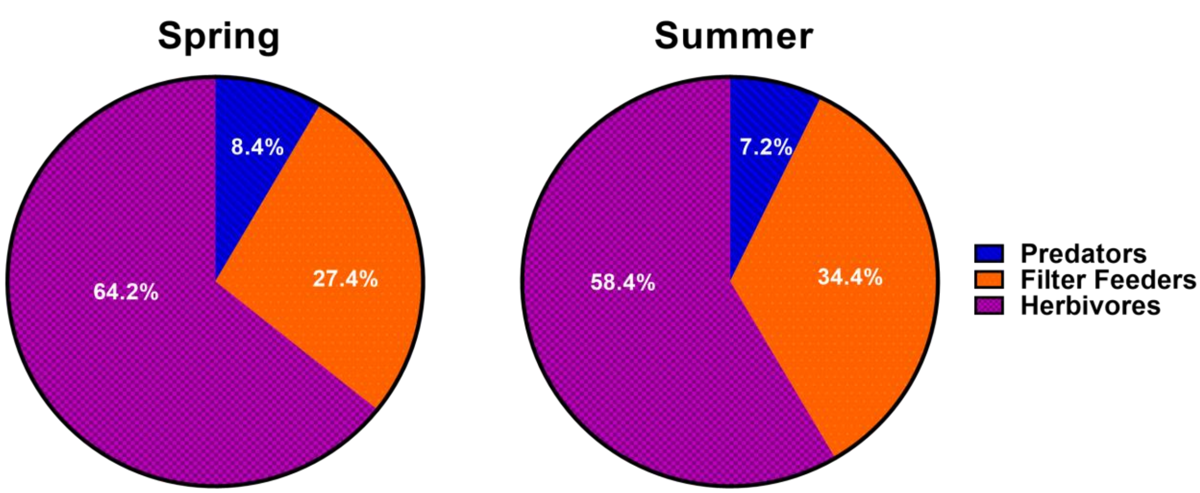


Figure 5-14. Proportion of Invertebrate Feeding Guilds Measured by Swath Surveys on Riprap in Spring and Summer 2018

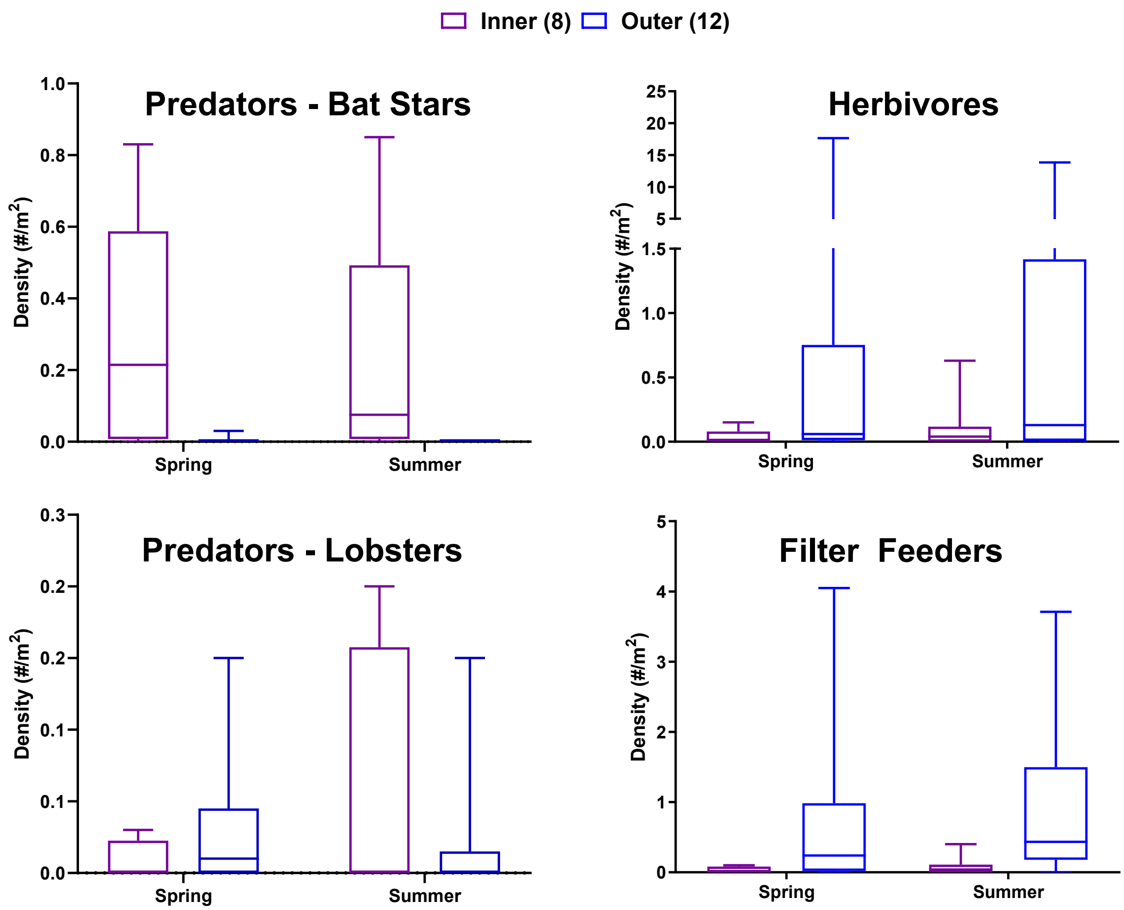


Figure 5-15. Density of Invertebrate Feeding Guilds Measured by Swath Surveys on Riprap in Inner and Outer Harbor Habitats During Spring and Summer 2018

Note: Whiskers represent the range, the line represents the median and the boxes represent the quartile range above and below the median.

Multivariate Analysis of Swath Data

Multivariate analysis of spring and summer density data on riprap was performed to assess potential differences in community composition patterns throughout the Port Complex (see Appendix A for a description of the analytical methodology). Additional shade plots, nMDS plots, and SIMPER analysis figures, as well as data tables for location, habitat, and depth strata groups, can be found in Appendix E. These analyses revealed the following noteworthy patterns:

- Both seasons showed statistical differences between Inner and Outer Harbor habitats, driven primarily by the presence of giant kelp, crowned urchins, and abalone in the Outer Harbor.
- Location groups for both seasons showed that Breakwater and Outer Harbor stations were similar, and both were statistically different from Basin and Slip stations, but not from Channel stations. Low replication in each group reduces statistical power for this analysis, but the results reflect the gradient in species composition and densities from Outer Harbor areas to Inner Harbor locations

Cluster analysis using similarity profile (SIMPROF) grouping (see Appendix A for a description of the methodology) was performed on spring and summer station densities. The resulting nMDS plots, overlaid on station maps in Figures 5-16 and 5-17, show that in both seasons stations largely separated out according to where kelp was present (Group B) and where kelp was not present (Group C), with station T20 constituting its own group (Group A). Two exceptions between spring and summer occurred at 1) station T6, which had kelp present (although at low density) but fell into group C potentially due to a higher density of lobsters and *S. muticum* that was more similar to Inner Harbor stations and 2) station T10, which formed its own group (Group D) in spring due to the low density of both *Sargassum* species compared to other Inner Harbor stations and the higher densities of bat stars and rock scallops.

Figure 5-16. Similarity Profile (SIMPROF) Analysis Results for Swath Surveys on Riprap (Spring 2018)

SIMPROF Groups By Kelp Stations - Summer
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 5-17. Similarity Profile (SIMPROF) Analysis Results for Swath Surveys on Riprap (Summer 2018)

5.3.2 Percent Cover of Macroalgae and Macroinvertebrates

The Uniform Point Contact (UPC) survey characterized the percent cover of invertebrate and algae species that grow close to the substrate surface. These surveys were performed at riprap stations to compliment swath surveys and at pier piling stations as a rapid-assessment method to compare against results of quadrat scrapings. All 20 riprap stations had UPC surveys conducted on the same subtidal transects on which swath data was taken. At the eight riprap stations where quadrats scrapings were taken at the intertidal and subtidal, UPC data was obtained for matching intertidal and subtidal depths. At the eight pier piling stations, UPC data was collected vertically along the face of the piling and encompassed intertidal and subtidal habitats where quadrats were scraped. Unlike swath surveys in which only targeted organisms were recorded, all invertebrates and algae encountered during the UPC surveys were assigned a taxonomic category and recorded.

Riprap

Riprap was sampled in the subtidal at all 20 stations in the spring and summer. UPC data were compiled into major taxonomic groups and compared across seasons and between Inner and Outer Harbor habitats, averaged across stations (Figure 5-18). Inner Harbor stations on average had more bare substrate (bare rock, sand, mud) than Outer Harbor stations. This difference was mostly due to Inner Harbor stations having more evident sedimentation near the riprap-soft bottom interface, presumably the result of nearby sources such as the Dominguez Channel and storm drains in addition to disturbance events such as vessel activity. Outer Harbor stations had a much higher proportion of gastropods, largely due to the high percentage of scaled worm snails (*Thylacodes squamigerus*), which added to the snails that were found in both the Inner Harbor and the Outer Harbor (*Kelletia kelleti, Conus sp., Tegula sp., Megastrea undosa*). Outer Harbor stations also had a higher percentage of coralline algae, which included crustose (*Lithophyllum sp*. and *Lithothamnion sp*.) and articulated species (*Corallina pinnatifolia* and *C. vancouveriensis, Lithothrix aspergillum*).

Multivariate analysis using an analysis of similarity (ANOSIM) showed significant differences in community composition between Inner and Outer Harbor habitats in both seasons (Appendix E). Similarity profile (SIMPROF) analysis revealed five groups in the spring (Figure 5-19) and four groups in the summer (Figure 5-20). Consistent with the results of the swath surveys, analysis of the UPC sampling showed station T20 as a stand-alone group in both seasons due to high percentages of scaled worm snails, bare rock, and urchins. Stations T10 (Seaplane Lagoon) and T9 (East Basin Channel Entrance) were also single-station groups, although only in spring, due to high green algae cover at T9 and high *S. muticum* and mud cover at T10. Inner Harbor stations were largely grouped together in both seasons (Group E in spring, Group A in summer) and were characterized by high percentages of mud, bare rock, and *S. muticum*. Outer Harbor stations in the spring were captured in Group B, characterized by gorgonians, giant kelp, articulated coralline algae, and crustose coralline algae. The summer survey sorted Outer Harbor stations into two groups, with more bryozoans, *S. muticum*, and red algae in Group D compared to more articulated and crustose coralline algae, bare rock, and shell hash (bare rock and shell presented as “bare substrate” below in Figure 5-18) in Group C.

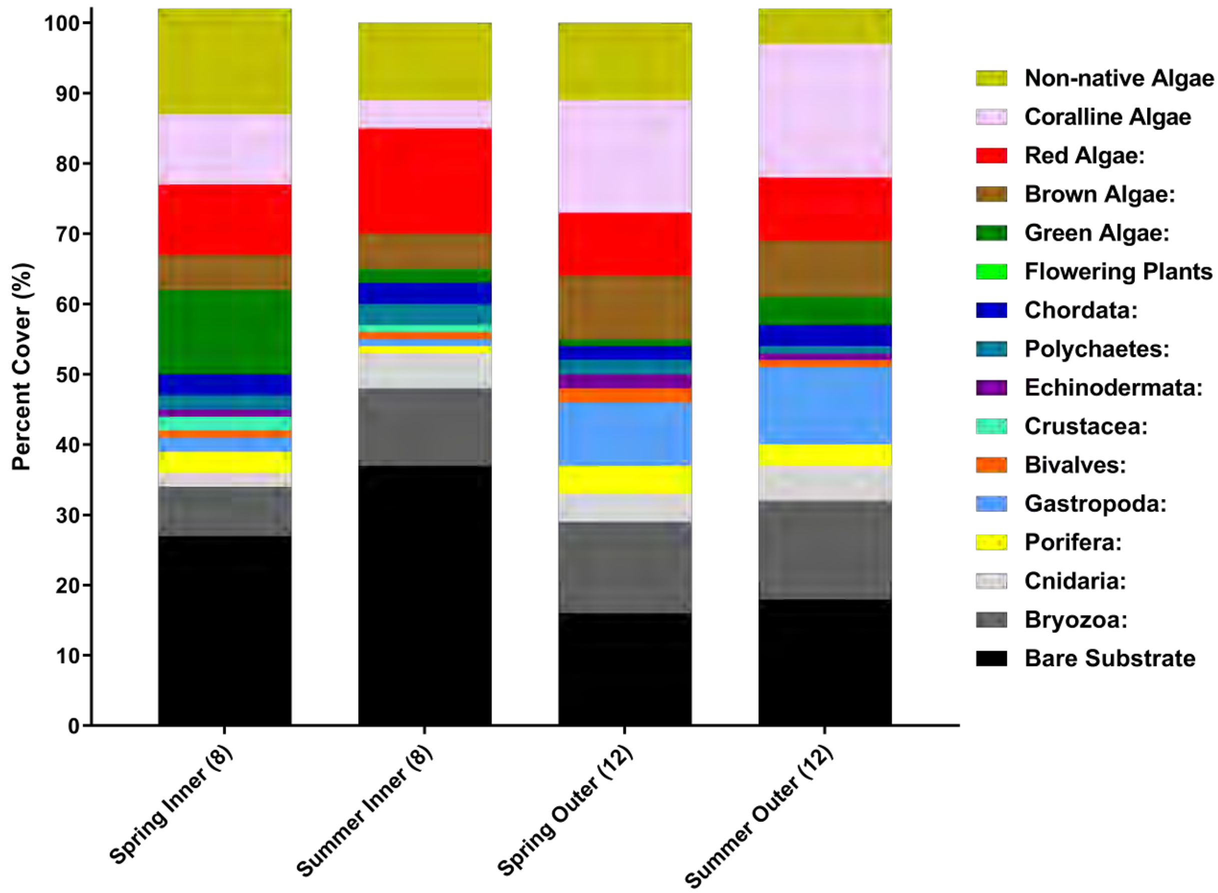


Figure 5-18. Average Percent Cover of Inner and Outer Harbor Riprap Stations By Season

Note: Averaging across stations results in totals not adding up to exactly 100%. Non-native algae encompasses Sargassum muticum, Sargassum horneri and Undaria.

Figure 5-19. Similarity Profile (SIMPROF) Analysis Results for UPC Surveys on Riprap (Spring 2018)

Figure 5-20. Similarity Profile (SIMPROF) Analysis Results for UPC Surveys on Riprap (Summer 2018)

Pilings

Percent cover data was collected by the UPC survey method across the intertidal and subtidal at those pier piling and riprap stations at which quadrat scrapings were also collected (see Figure 5-1). This UPC data was meant to serve as a "rapid assessment' method to compare against results found in the quadrat scrapings. The greatest proportion of cover across all pilings was chordates (primarily solitary tunicates), bryozoans, red algae and bivalves such as the Mediterranean mussel (*Mytilus galloprovincialis*) and rock scallops (*Crassadoma gigantea*). Differences between Inner and Outer Harbor piling stations were subtle, with higher coverage by chordates and red algae at Inner Harbor piling stations compared to higher coverage by bryozoans, cnidarians, bivalves and non-native algae at Outer Harbor piling stations.

Pilings in both Inner and Outer Harbor areas had higher percentages of cover by chordates, bivalves and cnidaria compared to riprap stations, while riprap had higher cover from coralline algae, gastropods and bare substrate (Figure 5-21). Riprap showed more pronounced differences between habitat areas compared to pilings, with patterns similar to those outlined above such as higher coverage of coralline algae and gastropods at Outer Harbor stations and nearly twice as much bare substrate at Inner Harbor stations.

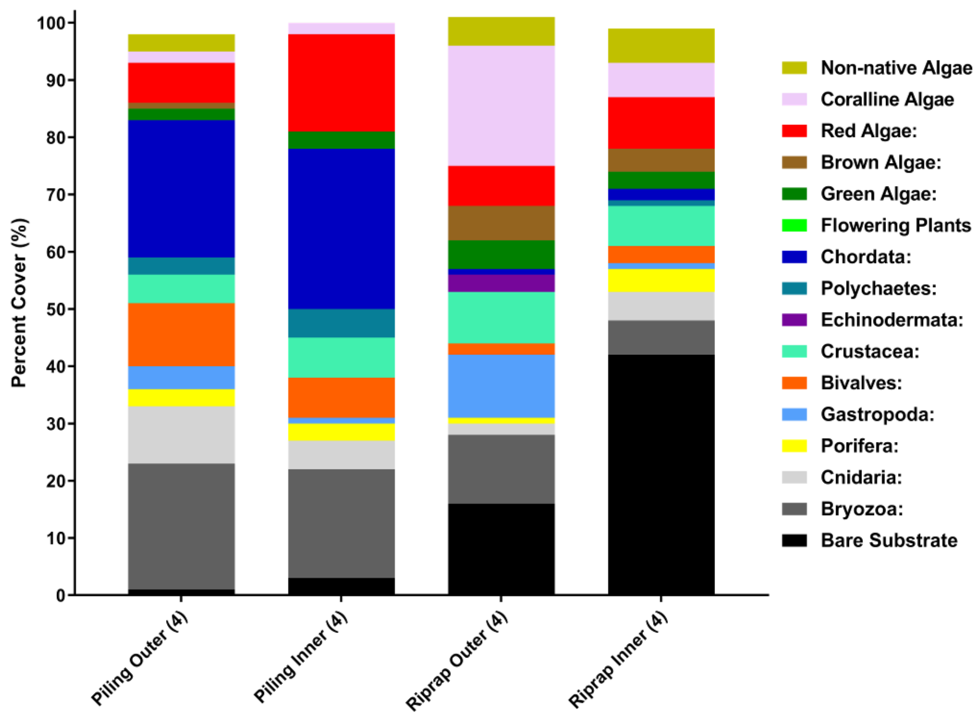


Figure 5-21. Average Percent Cover of Inner and Outer Harbor Riprap and Piling Stations By Substrate

Note: Averaging across stations results in totals not adding up to exactly 100%. Non-native algae encompasses Sargassum muticum, Sargassum horneri and Undaria.

Multivariate analysis of all cover categories using one-way ANOSIM showed significant differences in percent cover on riprap versus pilings, but no significant difference between Inner Harbor versus Outer Harbor stations when both substrates were considered. Using a two-way crossed ANOSIM for substrate and habitat showed significant differences for both substrate and habitat type. Cluster analysis with SIMPROF revealed five groups (Figure 5-22 and Figure 5-23), which separated all piling stations except for LAPP1 into Group C. This separation graphically illustrates the distinct difference between piling and riprap communities that is described above and in the next paragraph.

Using the shadeplot analysis with the top 25 cover categories that defined the SIMPROF groups revealed that LAPP1 separated from other piling stations into Group E (Figure 5-24); this was due to the higher density of Mediterranean mussels and the lack of red algae, green algae, crustose coralline algae, and gorgonians. LAPP1 was also physically distinct from other stations in that it is a circular support piling under a tall pier rather than a under a large wharf. This difference likely affects several physical characteristics at that station, including the amount of shading and water flow that the piling community is exposed to. LARR4 (Berth 48), as in the swath and subtidal UPC analysis, grouped out from all other stations into Group B due to the large percentage of bare rock, scaled worm snails, barnacles and crustose coralline algae. Group D only contained stations LBRR1 (Pier J Breakwater) and LARR1 (CSWH Phase 2 Breakwater). Group D had higher coverage of bryozoans, scaled worm snails, gorgonians compared to Group A, which had the remaining five riprap stations. Group A had higher coverage by bare rock, mud, solitary tunicates, solitary tube worms, sponges, and *Sargassum muticum*.

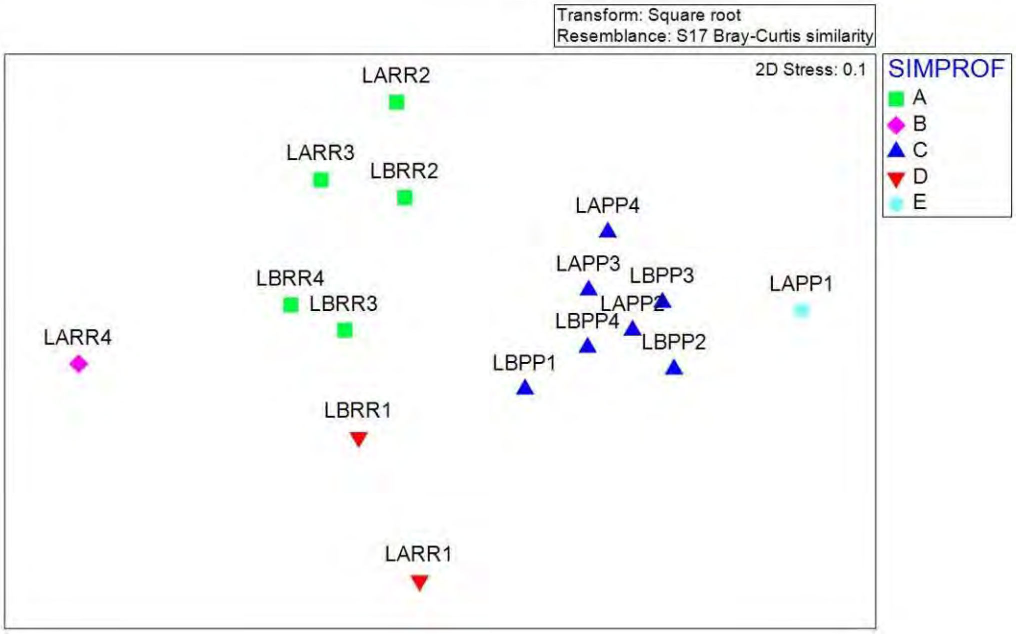


Figure 5-22. nMDS of Riprap and Piling Station Percent Cover (Summer 2018)

Figure 5-23. Similarity Profile (SIMPROF) Analysis Results for UPC Surveys on Riprap and Pilings (Summer 2018)

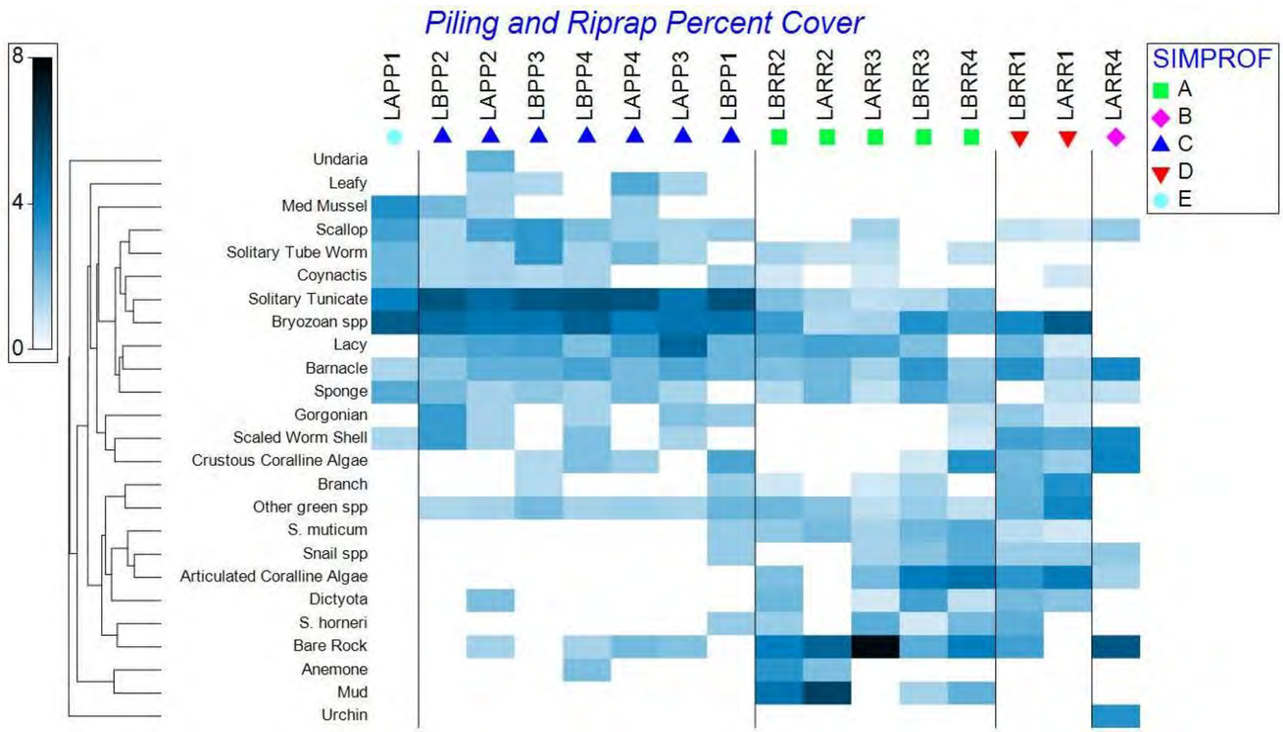


Figure 5-24. Shadeplot of Riprap and Piling Station Percent Cover by SIMPROF Group (Summer 2018)

5.3.3 Macroalgae and Macroinvertebrate Historical Comparisons

Changes to the survey methodology between the 2018 Biosurvey and past Biosurveys limits direct comparisons between Biosurvey years with respect to macroalgae and macroinvertebrates. The 2018 Biosurvey obtained more rigorous quantitative data for targeted invertebrates and macroalgae, while past Biosurveys obtained more qualitative presence/absence, and estimated percent cover only for macroalgae. Frequency of occurrence (as a percent of stations with species present across all seasons) of canopy algae (*Macrocystis* and *Egregia*) and understory algae (*Stephanocystis osmundacea*, *Undaria*, and *Sargassum* spp) is one of the few meaningful comparisons available across Biosurvey years (Table 5-5).

Occurrence of giant kelp has been relatively consistent across Biosurvey years, while feather boa was observed at more stations in past Biosurveys than in the 2018 Biosurvey due to the revised orientation of the diver transects (perpendicular to shoreline in 2018 Biosurvey versus parallel in previous Biosurveys). Feather boa is present primarily at the shallowest margins of the kelp beds where there is high wave energy, which the new methodology, using primarily sub-tidal transects for the swath survey, is not always capable of capturing at that tidal elevation. Future Biosurveys might consider an intertidal swath transect to capture feather boa more effectively. *S. osmundacea* has increased from 2000, when there was none observed, to the two most recent Biosurveys, where it was seen at 20-25% of stations. *Undaria* was not common in the 2000 Biosurvey, but the past three Biosurveys it has been observed at 65-75% of stations. In the 2000 and 2008 Biosurveys, there was no differentiation between the two non-native *Sargassum* species in part due to the absence of *S. horneri* in the Port complex until 2003 (Amec Foster Wheeler 2015). While *S. horneri* had become common by 2005 (Amec 2015), the 2008 Biosurvey did not differentiate between the species. Accordingly, the frequency of occurrence in 2008 is assumed to reflect primarily *S. muticum*, which has been commonly seen across all years at 80-90% of stations. *S. horneri* appears to be present at more stations in 2018 compared to 2013.

Table 5-5. Frequency of Occurrence (Percent of Sampling Stations) of Macroalgae Across Biosurvey Years

Species	2000	2008	2013	2018
Giant Kelp	50	55	60	45
Feather Boa	35	40	35	10
Stephanocystis osmundacea	0	10	25	20
Sargassum muticum	80*	85*	90	90
Sargassum horneri	NA	NA	50	75
Undaria	10	75	70	65

Note: * indicates that 2000 and 2008 study did not differentiate between S. muticum and S. horneri and thus is assumed to be S. muticum.

The other notable change that has occurred is station T20 (Berth 48) resembling deforested reefs (Schiel and Foster 2015), which have high urchin densities and a lack of macroalgae that can result from disease, herbivory, physiological stress (high temperatures, physical removal from storms) or interactions among these processes (Steneck et al 2002). Deforestation is often buffered by predators that feed on urchins such as sheephead and lobsters (which were commonly observed on riprap habitats within the Port Complex), although urchins from deforested areas have lower gonad production and therefore are lower quality prey which lobsters have been shown to preferentially avoid and if given the choice prefer kelp-bed urchin instead (Eurich et al. 2014). One of the most notable effects of deforestation is the loss of species that rely on kelp as the main source of primary production, which reduces food web complexity and shifts the community to rely on primary production from plankton, macroalgae and ephemeral microalgae (Graham 2004). Giant kelp was present at station T20 in the 2000-2013 Biosurveys, as well as 14 different algal species in 2013, but now the site is almost entirely devoid of algae aside from crustose corallines. While remnants of the former community are present (such as a pink abalone off-transect in the high subtidal zone), these species are likely relying on outside sources for food, such as drift algae that comes from nearby kelp beds. It is not possible based on past Biosurvey data to determine if urchin densities had been increasing at this station prior to 2018, and while deforestation events in Southern California are patchy and can be short in duration (Steneck et al 2002), the current 5-year cycle of the Biosurveys is unlikely to capture year to year variation that could determine which processes are causing the community shifts at station T20.

5.3.4 High Resolution Taxonomy of Riprap and Piling Invertebrates and Algae

Scrapings from duplicate 0.1 m^2 quadrats were collected at three depths (upper intertidal, lower intertidal, and subtidal) at the eight riprap and eight piling stations in summer 2018 throughout the Port Complex to obtain detailed taxonomic information on algae and invertebrates (including those too small to be observed by the UPC survey). The resulting data was averaged between replicates and analyzed between stations by substrate type as well as across tidal heights to examine spatial variability between habitats.

Spatial Comparisons

The data were summarized and broken out by substrate (riprap and piling) and habitat (Inner Harbor and Outer Harbor) (Table 5-6 and Figure 5-25) to look at patterns of species richness, abundance, and diversity. There were four piling stations in each habitat, while riprap had three Inner Harbor stations and five Outer Harbor stations.

In total, 507 species (476 invertebrate species and 31 algae species) were observed across all stations, with an average of 166 species per station. Total abundance of invertebrates across all stations was 31,686, with an average of 1,980 per station. Algal biomass totaled 130 g across all stations, with an average of 8.15 g per station. Total invertebrate biomass was 2,517 g, with an average of 157 g per station. Overall, pilings had greater mean species richness, abundance, and biomass than did riprap, although Shannon-Weiner diversity was slightly higher at riprap stations (Table 5-6).

Table 5-6. Species Richness, Abundance, and Diversity In Quadrat Scrapings for Riprap and Piling Stations

Metric	Substrate	Max	Mean	Median	Min
Species Richness	Riprap	237	160	159	98.0
	Pilings	231	172	155	132
Abundance	Riprap	2742	1427	1098	638
	Pilings	4551	2541	2155	1026
Biomass	Riprap	174	102	90.0	13.3
	Pilings	411	213	162	41.8
Shannon-Weiner Diversity	Riprap	4.11	3.43	3.55	2.13
	Pilings	4.00	3.29	3.42	2.11

The two habitat types also differed somewhat: for both riprap and pilings, mean species richness, abundance, and biomass were higher and diversity was lower at Outer Harbor stations than at Inner Harbor stations (Table 5-7), although unpaired t-tests on square-root-transformed data showed no significant differences.

Table 5-7. Algae and Invertebrate Species Richness, Abundance, and Diversity Index Values Derived from Quadrat Scrapings for Riprap and Piling Stations Between Inner and Outer Harbor Habits

Metric	Substrate	Habitat	Max	Mean	Median	Min
Species Richness	Riprap	Inner	151	124	114	108
		Outer	237	181	200	98
	Piling	Inner	192	158	155	132
		Outer	231	185	181	147
Abundance	Riprap	Inner	1776	1201	924	903
		Outer	2742	1562	1271	638
	Piling	Inner	2848	2197	2137	1665
		Outer	4551	2886	2983	1026
Biomass (g)	Riprap	Inner	120	60.7	48.7	13.3
		Outer	174	107	97.8	43.0
	Piling	Inner	397	168	99.0	78.1
		Outer	411	250	273	41.8
Shannon-Weiner Diversity	Riprap	Inner	3.21	4.11	3.68	4.00
		Outer	3.05	3.65	2.92	3.65
	Piling	Inner	3.02	4.04	2.94	3.80
		Outer	2.93	2.13	2.11	3.02

Relative invertebrate abundance by phylum at each riprap and piling station is summarized in Figure 5-26. The most notable difference between the two substrate types is the greater contribution by molluscs and smaller contribution by arthropods at Piling stations than at Riprap stations. With respect to habitat, the differences in relative abundance between Inner and Outer Harbor Riprap stations were subtle, with Inner Harbor stations generally having more annelids, echinoderms (such as brittle stars), and Other Taxa (e.g., bryozoans and cnidarians). Piling stations showed a somewhat clearer difference between Inner and Outer Harbor stations, primarily due to having relatively more molluscs and fewer arthropods at Inner Harbor stations (e.g., barnacles and mussels). With respect to substrate type, piling stations had fewer arthropods but more echinoderms, molluscs, and chordates than riprap stations.

Relative invertebrate biomass by phylum at each riprap and piling station is summarized in Figure 5-27. Outer Harbor riprap stations LARR1 and LARR2 were dominated by arthropods, while LBRR1 had the lowest total biomass of all riprap Outer Harbor riprap stations; sponges were the primary contributor to that biomass. All other riprap stations' biomass were predominantly made up of molluscs, although LBRR2 also had a large amount of bryozoans. Piling biomass generally was made up of a high proportion of molluscs, with arthropods (mostly barnacles) and chordates (tunicates) as large contributors to total biomass.

Relative algal biomass (Figure 5-28) differed dramatically between the two substrate types. Coralline algae were overwhelmingly dominant on riprap, whereas pilings supported a more diverse algal assemblage that was dominated by red and green algae.

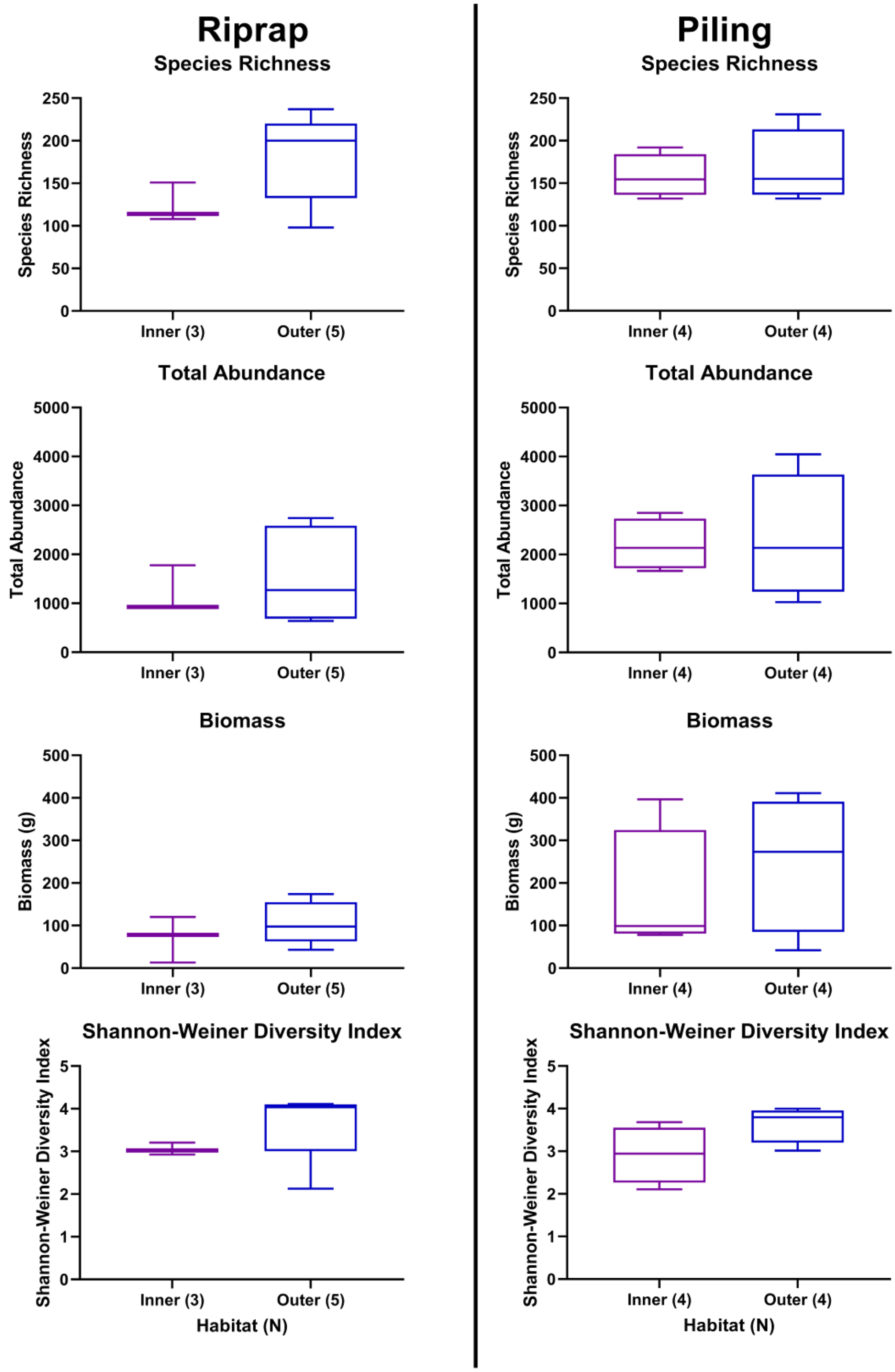


Figure 5-25. Algae and Invertebrate Species Richness, Abundance and Diversity Index Values for Riprap and Piling Quadrats Between Inner and Outer Harbor Habits

Note: Whiskers represent the range, the line represents the median and the boxes represent the quartile range above and below the median

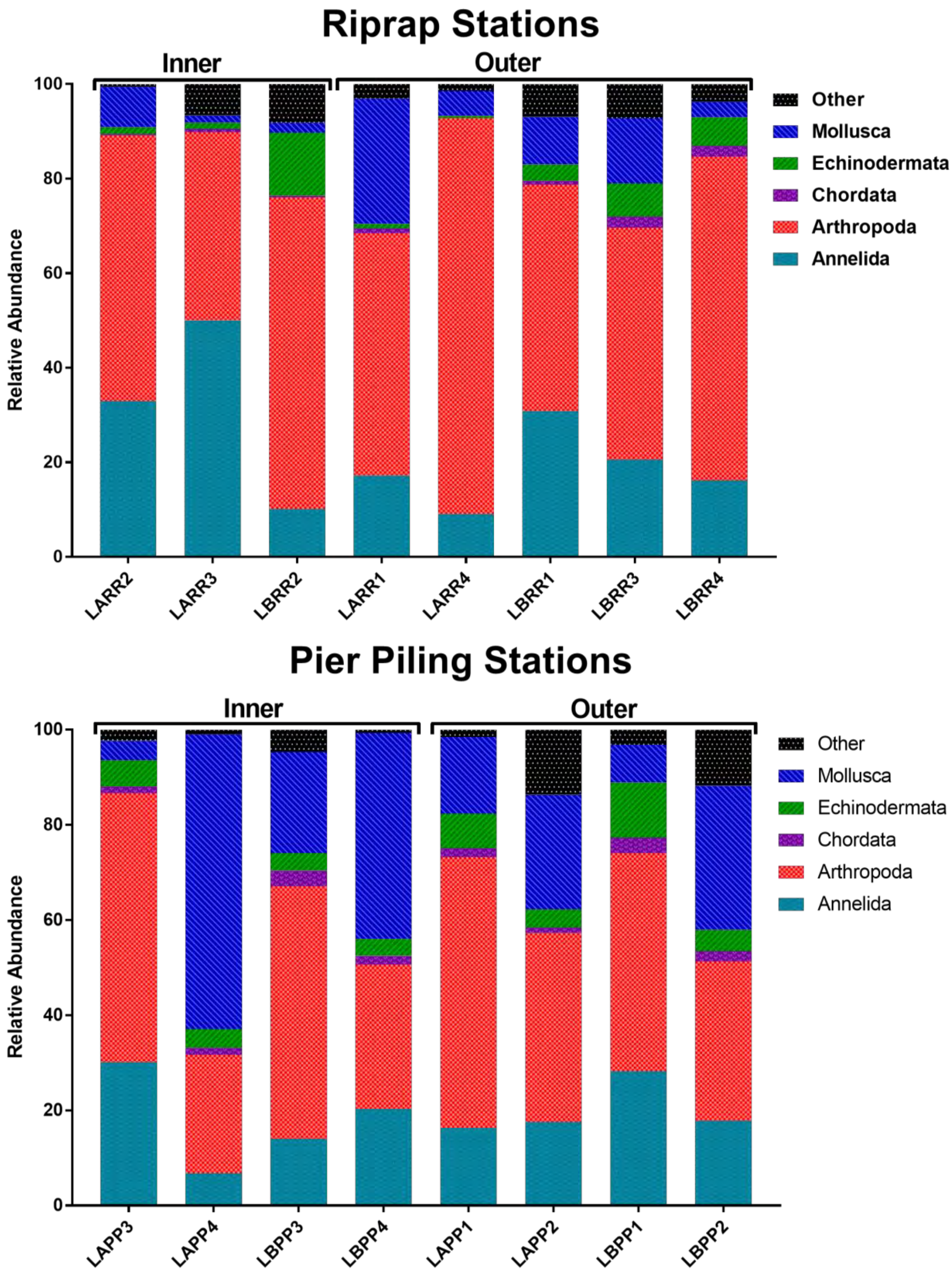


Figure 5-26. Relative Abundance of Invertebrate Phyla at Riprap and Piling Stations from Quadrat Scrapings

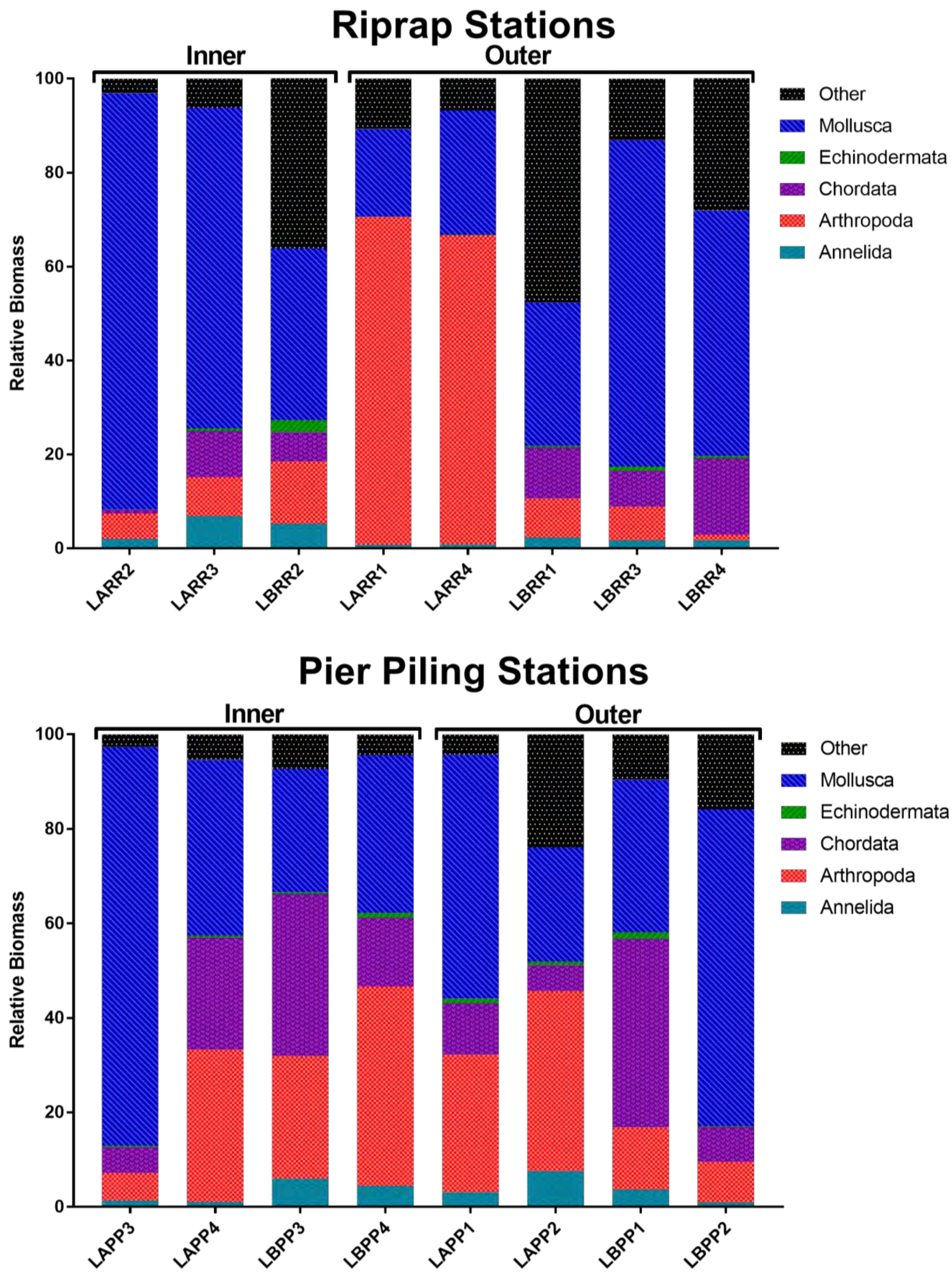


Figure 5-27. Relative Biomass Invertebrate Phyla at Riprap and Piling Stations from Quadrat Scrapings

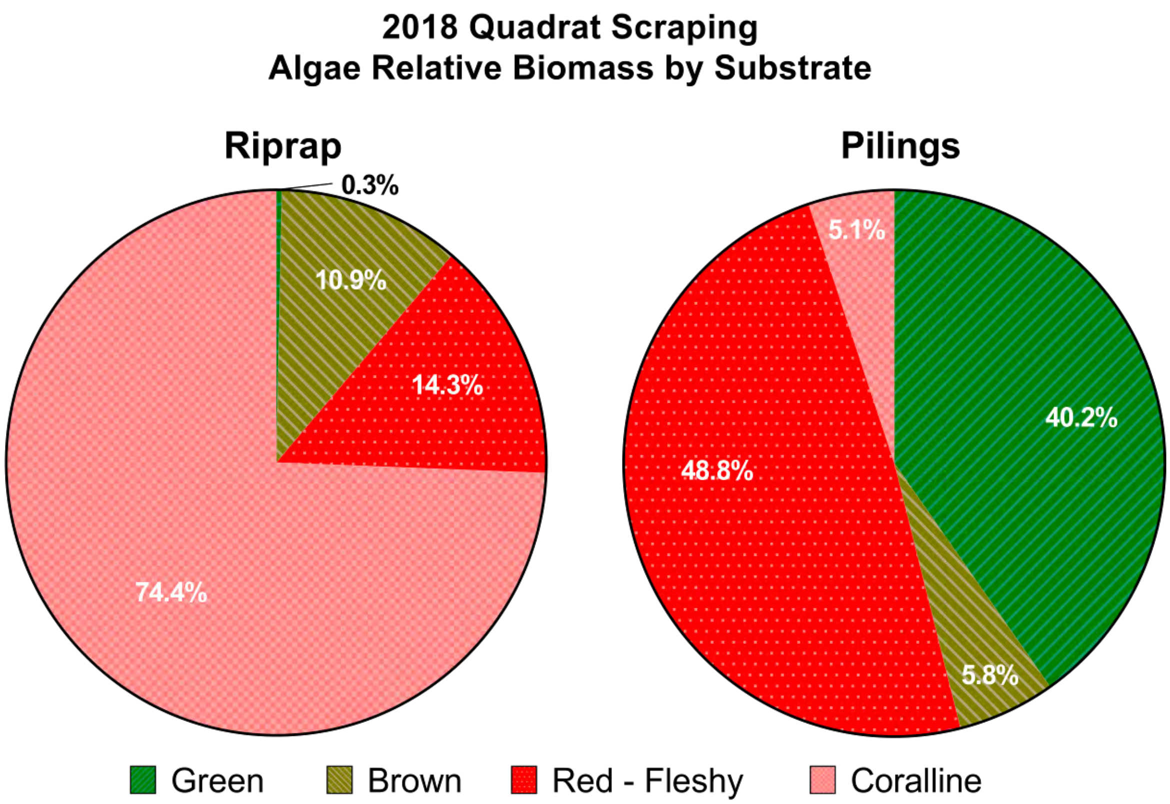


Figure 5-28. Relative Algae Biomass at Riprap and Piling Stations from Quadrat Scrapings

Influence of Tidal Height on Species Composition

The scraped quadrat data was also analyzed by substrate and tidal height (Table 5-8 and Figure 5-29) to examine species richness, abundance, and diversity as they varied with depth. The Kruskall-Wallis ANOVA with multiple comparisons showed that on riprap, species richness and diversity were both statistically significantly greater in the lower intertidal and subtidal than in the upper intertidal, while abundance was significantly higher in the lower intertidal than in the upper intertidal and subtidal. The same pattern was true for species richness and diversity at piling stations, but there was no statistical difference in abundance among the three depths for this substrate.

Table 5-8. Algae and Invertebrate Species Richness, Abundance and Diversity Index Values for Riprap and Piling Quadrats At Different Tidal Heights

Metric	Substrate	Height	Max	Mean	Median	Min
Species Richness	Riprap	Intertidal-Upper	50	18	13	1
		Intertidal-Lower	149	63	66	4
		Subtidal	106	64	66	27
	Piling	Intertidal-Upper	72	25	17	7
		Intertidal-Lower	119	73	64	43
		Subtidal	127	77	70	47
Abundance	Riprap	Intertidal-Upper	632	212	118	1
		Intertidal-Lower	2162	809	515	6
		Subtidal	1170	405	357	74
	Piling	Intertidal-Upper	1640	775	716	70
		Intertidal-Lower	1930	980	907	279
		Subtidal	1939	786	511	192
Shannon-Weiner Diversity	Riprap	Intertidal-Upper	3.03	1.59	1.32	0.00
		Intertidal-Lower	3.73	2.71	2.95	1.09
		Subtidal	3.68	3.27	3.33	2.65
	Piling	Intertidal-Upper	3.12	1.49	1.44	0.12
		Intertidal-Lower	3.67	2.95	2.91	2.28
		Subtidal	3.96	3.38	3.37	2.99

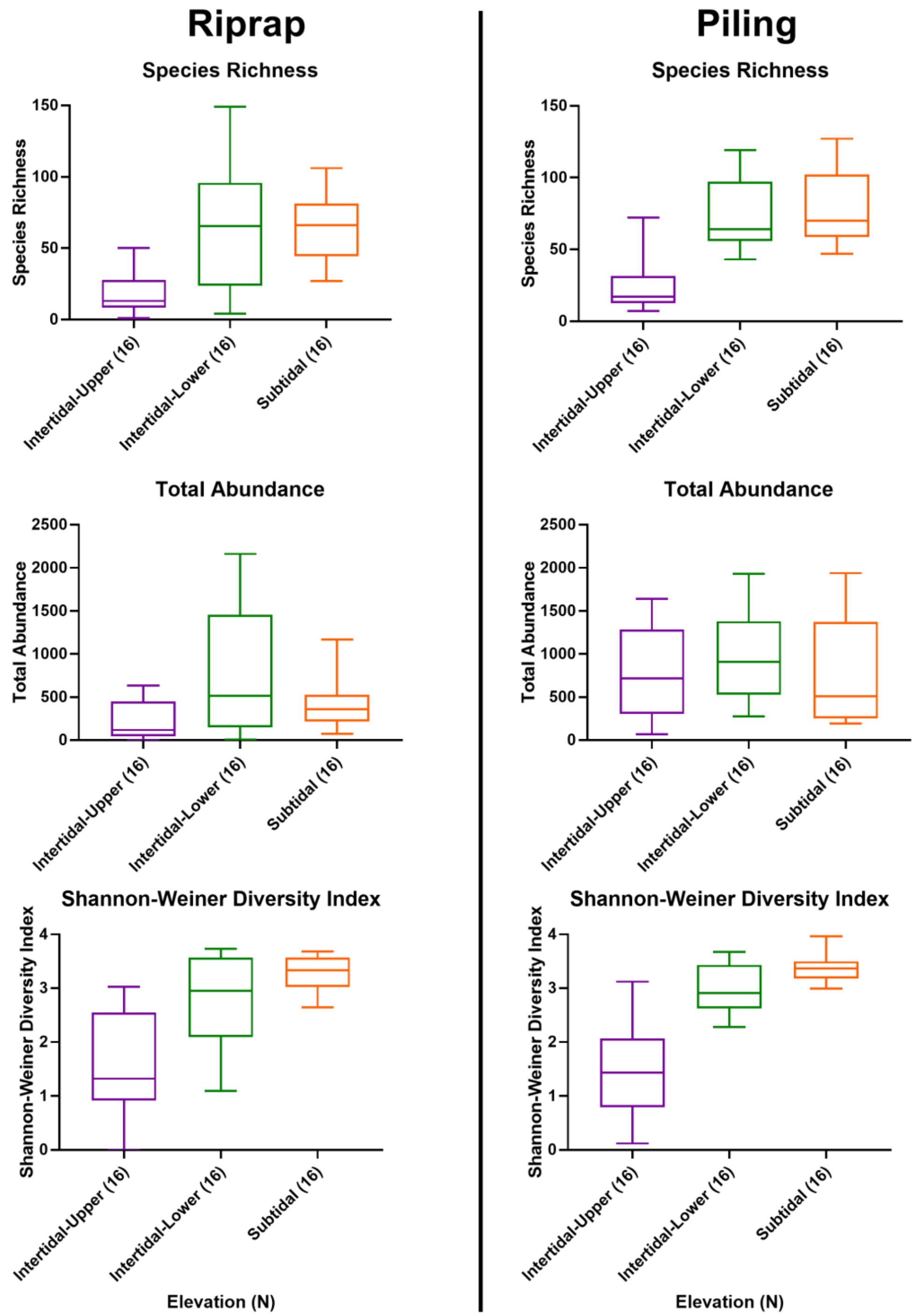


Figure 5-29. Algae and Invertebrate Species Richness, Abundance and Diversity Index Values for Riprap and Piling Stations Between Inner and Outer Harbor Habits from Quadrat Scrapings

Note: Whiskers represent the range, the line represents the median and the boxes represent the quartile range above and below the media

Multivariate Analysis of Station Groupings and Tidal Height

Multivariate analysis of quadrat scrapings data analyzed stations and tidal height to examine patterns across habitats and depths. Additional shade plots, nMDS plots, and SIMPER analysis figures, as well as data tables for location, habitat, and depth strata groups, can be found in Appendix E. One-way analysis of similarities (ANOSIM) confirmed that there were significant differences between substrates and between Inner and Outer Harbor habitats. Similarity profile (SIMPROF) analysis revealed that there were nine different groups, as shown in the nMDS plot (Figure 5-30) and overlaid on the station map (Figure 5-31). The shadeplot analysis (Figure 5-32) depicts patterns in species composition.

Station Group I was the largest group, consisting of all four Inner Harbor piling stations and Outer Harbor piling Station LAPP2 (POLA Main Channel), and was characterized by high abundance of the bivalve *Lasaea adansoni*, the amphipod *Zuexo normani complex*, and barnacles (*Chthamalus fissus* and *Balanus crenatus*). The three remaining Outer Harbor piling stations all sorted into three separate groups (E, G, H). LBPP2 (Pier T; Group H) was characterized by the abundance of Mediterranean mussels (*Mytilus galloprovinciallis*). LAPP1 (Berth 48; Group E) had high numbers of barnacles (*Chthamalus fissus* and *Balanus crenatus*) in addition to arthropods (*Diaulota sp., Caprella spp.*) and brittle stars (*Amphipholis squamata*). As mentioned in the percent cover analysis, LAPP1 was a tall, octagonal concrete piling under a narrow pier compared to other stations which were under large terminals. The different degree of shading and water flow around these different pilings may account for some of the differences in the observed community. LBPP1 (SE Basin; Group G) was the only piling station to be grouped with a riprap station (LBRR4), and in addition to some of the common arthropods found in other groups (e.g., *Caprella spp*.) had high numbers of some arthropod species that were less common in other piling groups (e.g., *Paramicrodeutopus schmitti* and *Chondrochella dubia complex*) and fewer barnacles than other piling groups.

Riprap stations were substantially more distinct from one another across locations than were the piling stations, with three of them forming single-station groups (A, B, and F). Group A consisted of Station LARR4 (Berth 48), that was unique in the abundance of barnacles and complete absence of a number of taxa that were present at most other stations (e.g., *A. squamata* and *L baconi*). Group B, consisting of Station LBRR2 (Cerritos Channel), was similar to other Inner Harbor riprap stations except for the high numbers of arthropods such as *Elasmopus bampo* and the non-native tube-building amphipod *Laticorophium baconi*, and of brittle stars (*Amphipholis squamata*). Group F, consisting of Station LBRR3 (Navy Mole), was similar to riprap communities in Groups G and D except for the high numbers of small snails (*Amphithalamus inclusus* and *Barleeia halloptiphilia*), which were not observed at many other stations. Group C consisted of two Inner Harbor stations, LARR3 (POLA West Basin – South) and LARR2 (South of Consolidated Slip), that were distinct from other stations in the presence of the disturbance-tolerant annelid *Psuedopolydora paucibranchiata*, high numbers of tube-dwelling polychaetes (Spirorbidae), and abundant ostracods (Podocopida). LARR1 (CSWH Phase 2 Breakwater) and LBRR1 (Pier J Breakwater) formed Group D, which had a fairly even distribution among species, with Mediterranean mussels, barnacles and arthropods being common, and was the only group with gooseneck barnacles (*Pollicipes polymerus*).

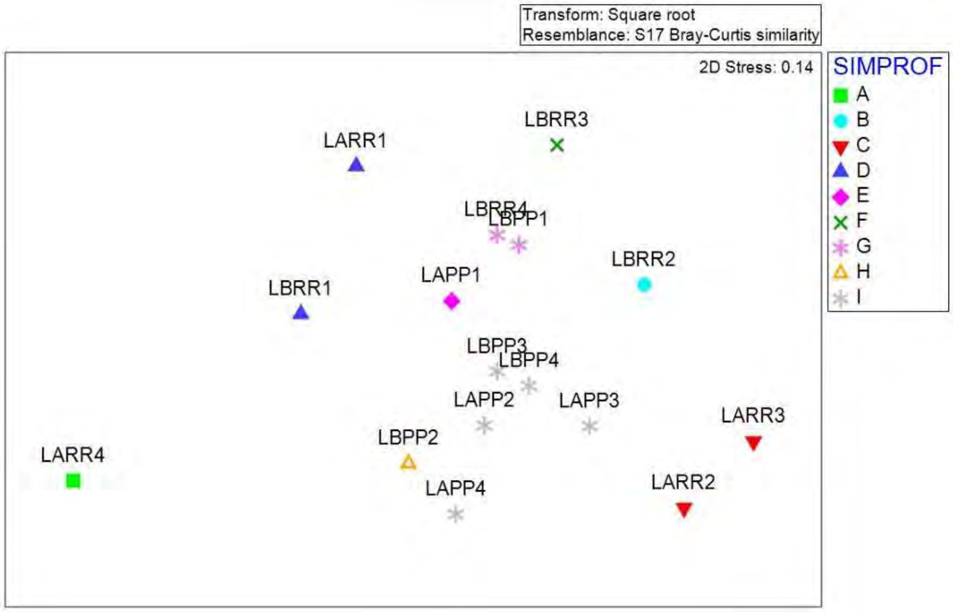


Figure 5-30. nMDS Plot of Riprap and Piling Stations by SIMPROF Group from Quadrat Scrapings

Figure 5-31. Riprap and Piling Community Groups by SIMPROF Group from Quadrat Scrapings

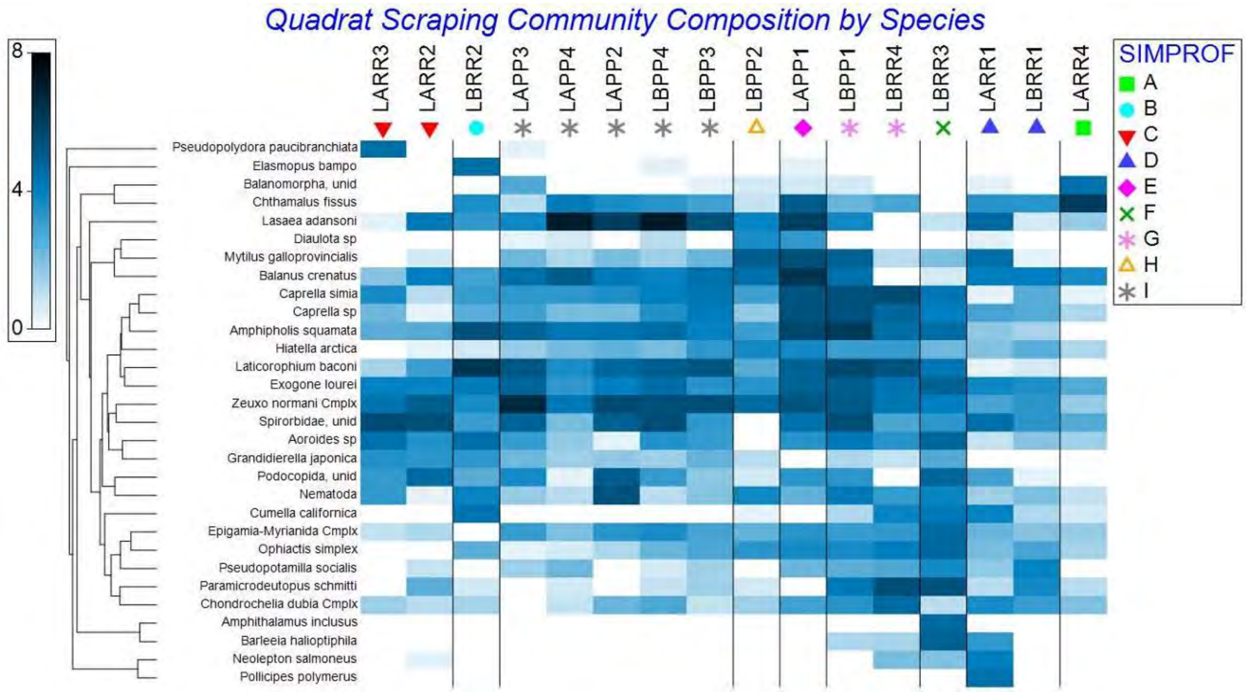


Figure 5-32. Riprap and Piling Community Composition (Top 30) Shadeplot Using SIMPROF Groups from Quadrat Scrapings

The results of the nMDS and one-way ANOSIM of quadrat scrapings by tidal height (Figure 5-33) confirmed that communities at the various depths are significantly different from one another. The shadeplot by tidal height (Figure 5-34) offers a visualization of the transition of the community through each tidal depth. Upper intertidal samples were characterized by a few species that are tolerant of the harsh physical conditions present, such as barnacles (*Balanus crenatus, Chthamalus fissus,* and *Pollicipes polymerus*), Mediterranean mussels, and bivalves such as *Lasaea adansoni* that thrive in crevices in rocks and between mussels. The lower intertidal and subtidal communities are less distinct from one another than they are from the upper intertidal communities. The lower intertidal samples had a diverse assemblage of species, including barnacles and mussels but also some amphipod crustaceans (e.g., *Zeuxo normani* and *Laticorophium baconi*) and annelids that cannot tolerate the long exposure to air and the resultant high temperatures and desiccation of the upper intertidal zone. The subtidal zone showed far fewer of the species that are found in the upper intertidal such as barnacles, although Mediterranean mussels were still present at many stations. Subtidal samples included many of the crustaceans that were found in the lower intertidal, but also had numerous species that were almost exclusively seen in the subtidal such as feather duster worms (Sabellidae), the polychaete *Pseudopolydora paucibranchiata*, and horseshoe worms (*Phoronis sp*).

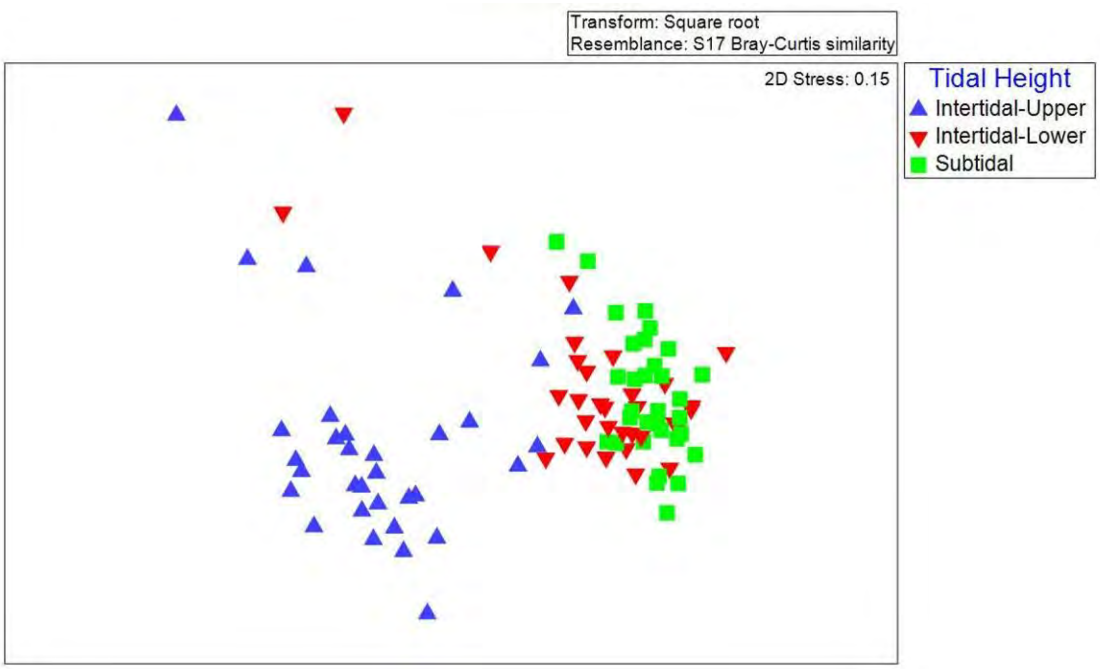


Figure 5-33. nMDS Plot of Riprap and Piling Community by Tidal Depth from Quadrat Scrapings

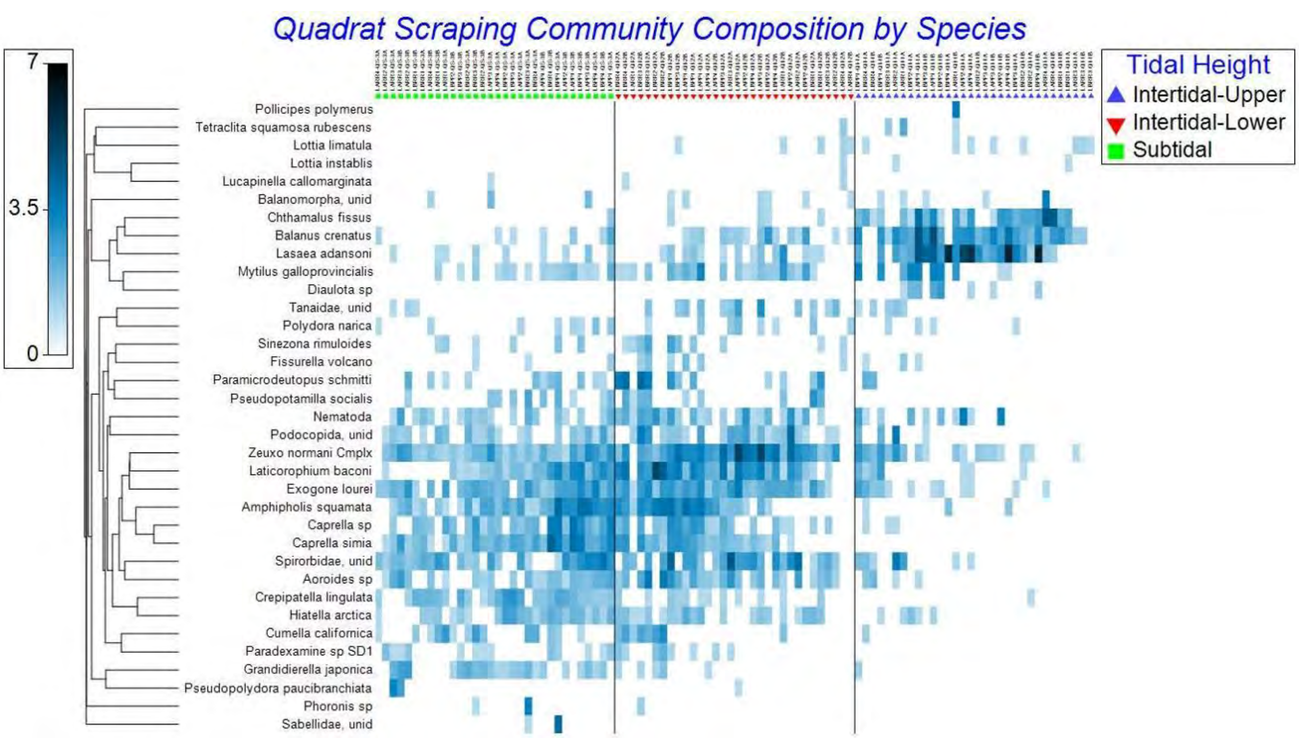


Figure 5-34. Riprap and Piling Community Composition Shadeplot (Top 30) by Tidal Depth from Quadrat Scrapings

5.3.5 Quadrat Scrapings Historical Comparisons

The comparisons of quadrat scraping data from previous Biosurveys can be accomplished with the caveat that the 2000, 2008, and 2013 studies surveyed only seven riprap stations and one piling station and sampled across multiple seasons. The 2018 study sampled more stations (8 riprap and 8 piling), but only in one season (summer, which has generally showed higher species richness, abundance and biomass; MBC 2016). In Figure 5-35 data for the 2000, 2008, and 2013 Biosurveys includes all seasons and all stations combined (riprap and piling), while for the 2018 study the piling stations have been separated from the riprap stations because the number of stations allowed calculations of mean values.

Total species richness and mean species richness per station have increased since 2000, with 2018 representing the highest mean (160 species per riprap station, 172 per piling station) and total (507 species across both substrates) observed in any of the Biosurveys to date. The increase in 2013 and 2018 may be due to improving habitat quality within the Port Complex; in 2018 the addition of piling stations also increased the spatial coverage of quadrat scrapings throughout the Port Complex and added more samples in a different substrate that is conducive to species that may not be present on riprap. In 2018 there were 133 species that were only observed on pilings, which nearly accounts for the difference in total species between 2013 (352) and 2018 (507).

Mean abundance on riprap was lower in 2018 (1,427) compared to 2013 (2,396) but markedly higher than in 2000 and 2008; the mean abundance on pilings (2,541) in 2018 was comparable to abundance at the combined riprap and piling stations in 2013. Mean biomass at riprap stations has shown considerable variability and no clear pattern over the years, likely due at least in part to the variable seasonality and station types across Biosurvey years. However, the mean biomass on pilings in 2018 (213 g) was higher than has been observed on riprap across previous all years (Figure 5-35).

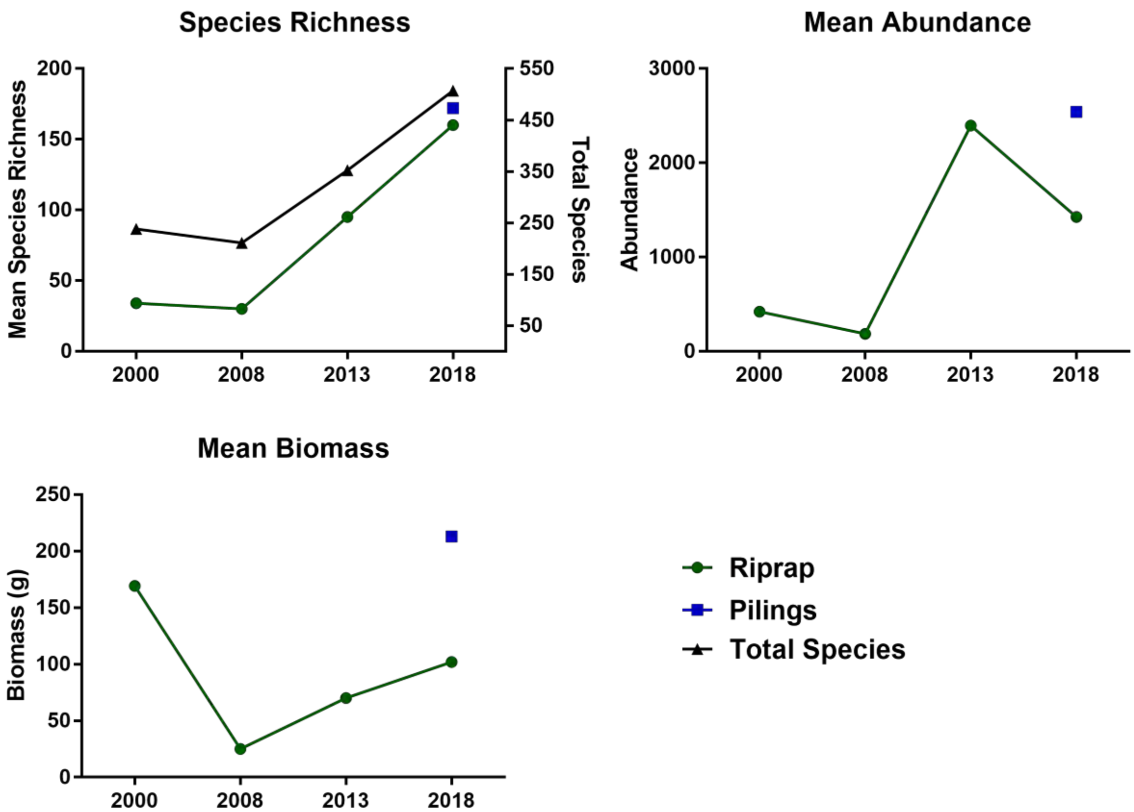


Figure 5-35. Mean Species Richness Per Station, Total Species Richness Per Biosurvey, Mean Abundance Per Station, And Biomass Per Station by Biosurvey

5.4 Fish Surveys of Riprap and Piling Habitats

A limitation of trawl and lampara sampling in characterizing the fish community of an area is that the equipment can only target pelagic or soft-bottom habitat, meaning that reef-associated species that may not inhabit these habitats are under-represented, or not present at all, in the resulting data. To fill this data gap, divers conducting swath, quadrat, and UPC sampling during the summer of 2018 also recorded the presence of fish species observed anywhere on site at the 20 riprap and 8 piling stations.

The divers observed a total of 29 species at riprap stations and 7 species at piling stations (Table 5-9). Unpaired t-tests found that species richness was significantly higher at riprap than at piling stations but was not significantly different between Inner and Outer Harbor habitats for either substrate (Figure 5-36). Many of the species observed during the riprap and piling surveys were not captured in trawl or lampara net sampling as they are typically associated with rocky reef or high-relief habitats; examples include garibaldi (*Hypsypops rubicundus*), opaleye (*Girella nigricans*), sheephead (*Pimelometopon pulchrum*; both male and females), horn shark (*Heterodontus francisci*), and moray eel (*Gymnothorax mordax*). Fish surveys on shallow (<17 m depth) oil platforms on the San Pedro Shelf in 2006-2008 identified 28 species, with 15 species in common with those observed during the 2018 Biosurvey (Martin and Lowe 2010), suggesting that many of these species may utilize shallow, structured habitats regardless of the substrate. The same study found that the top 25 meters of the structure contained 95% of total fish density and 77% of total fish biomass across shallow and deep oil platforms, which affirms the value of shallow, structured habitats on the San Pedro shelf.

The presence/absence data is presented as the frequency with which a species was observed at riprap, piling, or both habitats combined to look for trends in habitat usage (Table 5-8). Fish were not observed at one riprap station (T7 – POLB Turning Basin) and three piling stations (LAPP4 – East Basin Channel, LBPP1 – SE Basin, LBPP2 – Pier T). Kelp bass (*Paralabrax clathratus*) was the most commonly encountered species at both riprap and piling stations, followed by barred sand bass (*P. nebulifer*).

Multivariate analysis of the presence/absence data for riprap and piling stations that had fish present revealed the following patterns:

- One-way ANOSIM analysis indicate that riprap and piling fish assemblages were not significantly different ($p=0.051$), as the difference did not meet the statistical criterion of $p<0.05$. Similarity percentage analysis showed that black perch, kelp bass, opaleye, and barred sand bass were key members of the riprap community, while barred sand bass and kelp bass were most prevalent at pier pilings.
- Inner and Outer Harbor fish assemblages appear different, although statistically they were not ($p=0.058$).
- Stations grouped by location showed that only breakwater and channel stations were significantly different ($p=0.029$), although low replication within each group (between 3 and 7 stations) results in low statistical power to differentiate groups.

The nMDS plot of the fish assemblage by location group and the shadeplot of the 20 most abundant species that resolve the groups are presented in Figures 5-37 and 5-38. Note that stations LAPP2 and T9 group together as only fringehead sp. (Clinidae) was observed at those stations, while Station T3 separates near the bottom as only garibaldi was observed at that station. The shadeplot shows that four fish species (kelp bass, barred sand bass, opaleye, and black perch), were found in all five location groups while pile perch and garibaldi were found in all habitats except Channel.

Table 5-9. Frequency of Occurrence of Fish Species at Riprap and Pier Piling Habitat

Species		Frequency of Occurance (%)		
Common Name	**Scientific Name**	**Riprap Habitat**	**Pier Piling Habitat**	**Riprap and Pier Habitats**
Kelp Bass	*Paralabrax clathratus*	65	37.5	57.1
Barred Sand Bass	*Paralabrax nebulifer*	50	37.5	46.4
Black Surfperch	*Embiotoca jacksoni*	60	0	42.9
Opaleye	*Girella nigricans*	60	0	42.9
Garibaldi	*Hypsypops rubicundus*	40	0	28.6
Pile Surfperch	*Damalichthys*	20	12.5	17.9
Sheephead	*Pimelometopon pulchrum*	25	0	17.9
Goby spp	*Gobiidae*	15	12.5	14.3
Senorita	*Oxyjulis californica*	15	12.5	14.3
Fringehead sp.	*Clinidae*	10	12.5	11.3
Blacksmith	*Chromis punctipinnis*	10	12.5	10.7
Greenling spp	*Hexagrammidae*	15	0	10.7
Halfmoon	*Medialuna californiensis*	15	0	10.7
Horn Shark	*Heterodontus francisci*	15	0	10.7
Kelpfish spp	*Clinidae*	15	0	10.7
Sargo	*Anisotremus davidsonii*	15	0	10.7
Zebraperch	*Kyphosus vaigiensis*	10	0	7.14
Kelp Perch	*Brachyistius frenatus*	10	0	7.14
Spotted Scorpionfish	*Scorpaena guttata*	10	0	7.14
Anchovy spp	*Engraulididae*	5	0	3.57
Brown Rockfish	*Sebastes auriculatus*	5	0	3.57
California Halibut	*Paralichthys californicus*	5	0	3.57
Moray Eel	*Gymnothorax mordax*	5	0	3.57
Rock Wrasse	*Halichoeres semicinctus*	5	0	3.57
Round Stingray	*Urolophus halleri*	5	0	3.57
Sculpin spp	*Cottidae*	5	0	3.57
Shiner Surfperch	*Cymatogaster aggregata*	5	0	3.57
Smelt spp	*Atherinidae*	5	0	3.57
Spotted Sand Bass	*Paralabrax maculatofasciatus*	5	0	3.57
Total Species		**29**	**7**	**29**

Note: Dark green shading indicates species that have not been recorded in the Port Complex in past Biosurveys (2000-2013). Light yellow indicates species that were not observed in 2018 trawl or lampara samples but were observed in past Biosurveys.

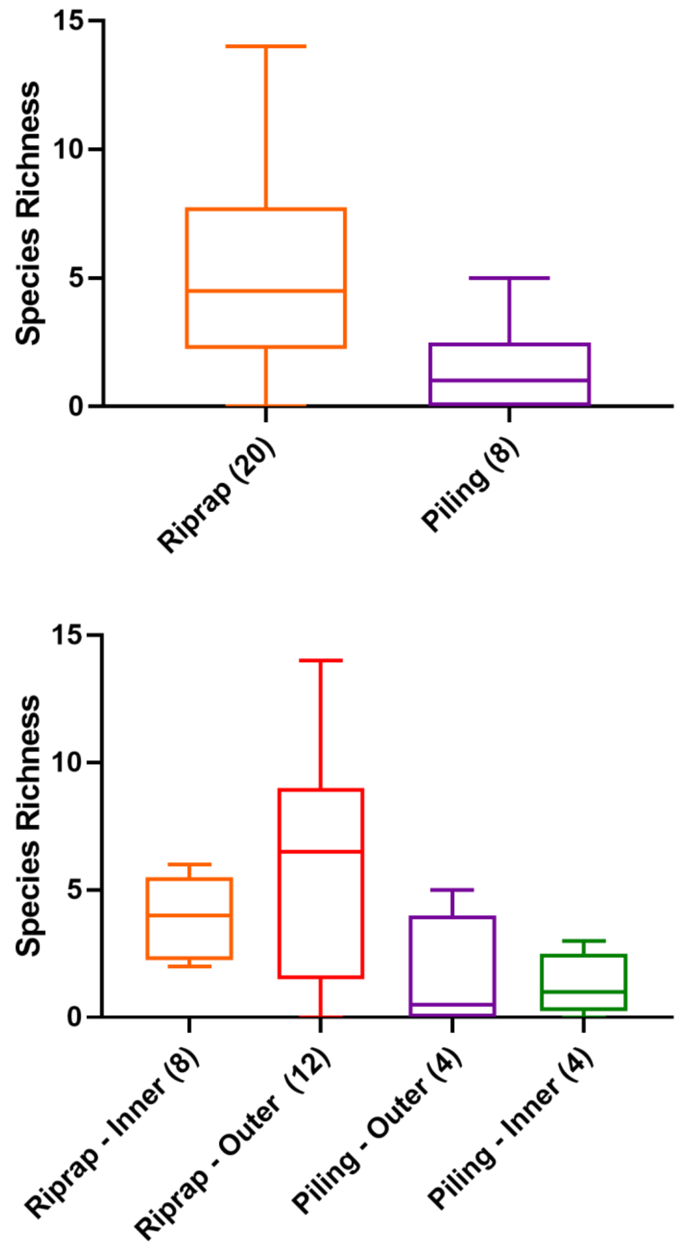


Figure 5-36. Species Richness of Fish at Riprap and Piling Habitats

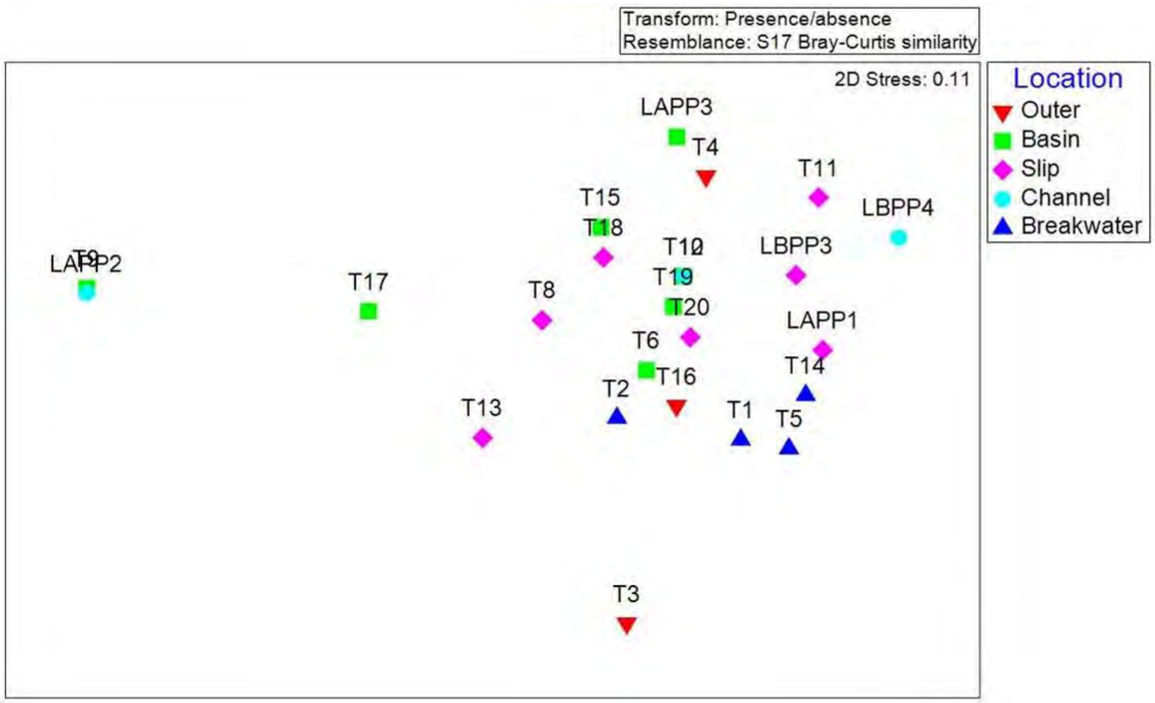


Figure 5-37. nMDS Plot of Fish at Riprap and Piling Habitats by Location Group

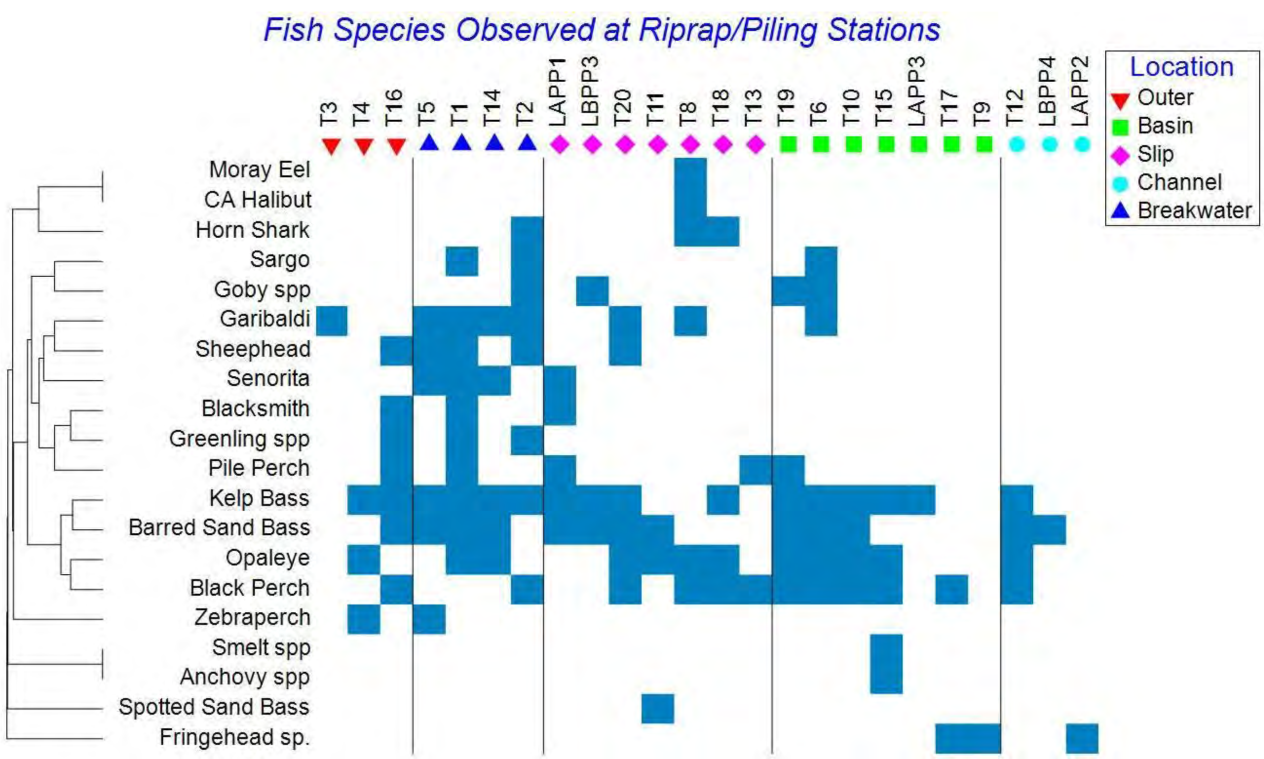


Figure 5-38. Shadeplot of Fish Presence/Absence (Top 20) at Riprap and Piling Habitats

5.5 Discussion

The 2018 Biosurvey utilized new survey methodologies to quantify the algal, invertebrate, and fish communities that are present on riprap and pilings within the Port Complex. The addition of piling stations in addition to riprap stations allowed for a more robust comparison between the two substrates. Fish present within these habitats have been inconsistently documented in past Biosurveys, but the results of the 2018 Biosurvey suggest that fish rely on these habitats for shelter and foraging opportunities. The changes made to the 2018 Biosurvey resulted in enhanced qualitative monitoring that integrates the whole community present. Continued implementation of these methods that include suggestions for future Biosurveys outlined below will allows for a better picture how the community changes over time and what may influence the patterns observed.

Hard Substrate Communities

One of the most readily apparent breaks in community structure is at riprap stations that have giant kelp present versus those that do not. This difference is likely driven primarily by physical factors such as available substrate, water movement from tidal and wave action, and temperature variability from Outer to Inner Harbor areas (see Chapter 2). The breakwaters and Outer Harbor riprap walls can be grouped together as those that support giant kelp, while channels, basins, slips, and Inner Harbor areas can be grouped together as areas that do not support giant kelp.

Wood diver counting kelp stipes in the Outer Harbor

The breakwaters and Outer Harbor riprap walls are a unique structural feature in the Port Complex, as they are constructed with large boulders (boulders >1 meter were defined as “reef” in this study) that provide both substantial surface area for algal and invertebrate recruitment and substantial interstitial space that helps capture drift algae, provides refuge from predators, and is habitat for invertebrates like brittle stars, urchins, juvenile abalone, and fishes (Schiel and Foster 2015). The presence of giant kelp that reach from the bottom to form a canopy at or near the surface also creates a vertical structure in the water column that can be utilized by fish and marine mammals. The diversity of habitats resulting from variation in rock type, topography, and the structural complexity of large benthic organisms (e.g., kelp holdfasts, gorgonians, etc.) within a forest has been shown to be arguably the most important contributor to local species diversity and abundance (Alexander et al. 2009). The interstitial space is also key on the breakwaters in helping promote wave-driven water movement, which provides high-energy environments that are favorable to algal recruitment, especially for canopy-forming species such as feather boa kelp, which is found almost exclusively on the breakwaters.

The high-relief boulder habitat in the Port Complex is more similar to the reefs found around the Channel Islands than to the shelf-like, low-relief rocky reefs found along the mainland coast (Pondella et al. 2015). The boulders are covered by high densities of fleshy red algae, crustose coralline algae, barnacles, mussels, bryozoans, and tubeworms. These habitats support diverse invertebrate communities including filter-feeding gorgonians, large predators such as lobsters, and grazers such as urchins and abalone, which rely primarily on detritus in the form of detached or dying algae that floats to the bottom as the base of the food chain.

Studies on kelp forests in central California have found that as much as 70% of kelp primary production becomes detritus that is consumed by numerous species that range from small crustaceans to larger herbivores within the forest, but some can drift into nearby soft-bottom habitats and provide particulate organic matter for epibenthic and infaunal invertebrates as well as nearby filter feeders (Schiel and Foster 2015), thereby increasing secondary production in those habitats (Krumhansl and Scheibling 2012). Drifting giant kelp was observed being consumed by various species at Inner Harbor stations throughout the Port Complex, suggesting that there is connectivity between Outer Harbor kelp forests and Inner Harbor benthic communities. Drift kelp may also be supporting organisms at stations such as T20 (Berth 48) where high densities of urchins and a pink abalone were observed despite the absence of all macroalgae.

The Outer Harbor and breakwater areas also support the highest diversity of fishes observed on riprap with species such as zebraperch, garibaldi, sheephead, senorita, and blacksmith that are commonly observed in nearby coastal kelp forests. These results are consistent with a study of a narrow kelp bed along the San Pedro Breakwater 30 years ago (MEC 1988). That study found the most abundant species to be blacksmith, three species of surfperches, senorita, and kelp bass, as well as sheephead, garibaldi and zebraperch. The MEC study also suggested that, on the basis of size distributions of fish on forested and unforested breakwater, the kelp bedserved as nursery habitat for a number of the abundant fish species by providing refuge and small-sized prey.

Channel, Basin, and Slip habitats generally grouped together in swath and UPC analyses as these stations had no canopy-forming algae present; instead, the algal community was dominated by non-native *Sargassum*, which seasonally grows in very high densities and forms a pseudo-canopy at shallow stations. The riprap substrate in these areas generally consists of smaller boulders and cobbles with higher percentages of gravel and sand compared to Outer Harbor stations. These habitats experience less wave energy, and some areas show sedimentation that blankets the rocky substrate, resulting in loss of available habitat for colonization by algae and sessile invertebrates. This higher level of sedimentation is likely the result of vessel activity, as the propellers of cargo ships and tugboats stir up the mud and silt of the harbor floor, in addition to inputs of suspended sediments such as storm drains and the Dominguez Channel.

Wood diver collecting UPC data in Inner Harbor

Areas with exposed rocky substrate are generally covered with articulated coralline algae, snails such as wavy top (*Megastrea undosa*) and Kellet's whelks (*Kelletia kelletii*), warty sea cucumbers (*Apostichopus parvimensis*), and bat stars (*Patiria miniata*). At stations with more structure due to larger boulders, refuge in the interstitial spaces supported predators such as spiny lobster (*Panulirus interruptus*) and horn sharks (*Heterodontus francisci*). Both swath and UPC surveys, which asses the larger invertebrate and algal species that are readily visible without a microscope, generally found little variation between the communities at channel, basin, and slip stations. Quadrat scrapings, which assess the smaller invertebrates, found a degree of variability among riprap stations that was similar to the high variability observed in the benthic infauna samples. The Inner Harbor riprap stations also had a less diverse fish community than Outer Harbor stations, comprised of species primarily associated with the soft bottom, such as barred sand bass, and also species associated with structure, such as black perch, kelp bass, and opaleye.

Biological communities on pilings in the Port Complex were analyzed in depth for the first time during this study, which found a diverse invertebrate and algal community on these structures. Both the UPC and quadrat surveys of pilings showed statistically significant differences between the community on pilings and that on riprap. While the resolution of the results varies based on the methods, the findings of both methods are complementary and suggest that both methods should be used in subsequent investigations of piling communities. One shortcoming of the piling survey was that large invertebrates (such as lobsters, bat stars and gorgonians) and large macroalgae (such as giant kelp and *Undaria*) were underrepresented in the data because only UPC surveys were conducted for percent cover and that method is prone to miss large, mobile invertebrates. Adaptation of the swath methodology to the pilings to capture this aspect of the community could provide for better comparison to riprap habitats.

The fish assemblage associated with pilings was not as diverse as that seen on riprap, however there were more than double the number of riprap stations and divers covered more area while surveying riprap habitat than pilings habitat. The prevalence of kelp bass utilizing mid-water areas with barred sand bass and surf perches primarily utilizing benthic habitats was also observed in shallow (<21 m) oil platforms on the San Pedro shelf (Marin and Lowe 2010). Studies of kelp bass tagged and tracked within a marine reserve at Catalina Island found that the largest kelp bass utilized under-pier habitats almost exclusively during the day while foraging out along riprap covered slopes at night (Lowe et al. 2003). These fish also had smaller home ranges compared to smaller kelp bass that used sparse kelp canopy for cover around sand/mud habitat, which is thought to be in part due to the refuge from predators and presence of schooling baitfish near the pier providing a high-quality habitat that the larger fish defended from other kelp bass. This suggests that the high occurrence of kelp bass, barred sand bass and surfperches (among others) within the Port Complex associated with pilings and riprap may be positive habitat selection due to refuge from predators and increased foraging opportunities.

Non-native Species

The 2018 Biosurvey observed 32 non-native invertebrate and algae species in quadrat scrapings and quantified the density of and percent cover of three non-native algae (*Sargassum horneri, S. muticum* and *Undaria pinnatifida*). Figures 5-39 and 5-40 show the density of the three non-native species at each station in the spring and summer from swath sampling. At least one of these species was observed at all stations except for T20 (the deforested station near Berth 48), although it is clear that Inner Harbor and Basin stations supported, on average, denser growths of these three species than did Outer Harbor stations.

Across all Biosurveys, a total of 40 non-native species have been catalogued on hard substrates using quadrat scrapings (Table 5-10). The 2018 Biosurvey observed 32 species on both riprap and pilings combined (6.31% of all species in quadrat scrapings), which was a marked increase in relative abundance of non-natives over previous Biosurveys (Table 5-10), as the next highest was 3.41% in 2013 although previous surveys only had one piling station. Of the 32 non-native species on both substrates, 22 were observed for the first time in 2018, driven primarily by 11 new chordate (tunicates) species with two *Ciona* species and *Molgula ficus* the most abundant. It is unlikely that these results reflect an actual dramatic increase in non-native species in the Port Complex. Instead, they are probably due to the increased effort in 2018 to sample more concrete pilings, which represent a very different habitat than riprap, with different physical characteristics (such as temperature, water flow, and light availability) that favor different communities from that of riprap. Eight of the species observed for the first time in 2018 on hard substrates were seen only on pier pilings, including two arthropods (*Caprella drepanochir, C. mutica*), a bryozoan (*Crytosula pallasiana*), four chordates (*Ascidia zara, Botrylloides violaceus, Molgula ficus* and *Polyandrocarpa zorritensis*), and a mollusc (*Philine auriformes*, which was also seen in the benthic infauna).

Two non-native algae species and 24 non-native invertebrate species were identified at riprap stations, while pilings had one non-native algae species and 27 non-native invertebrate species (Table 5-11). The biomass of the non-native algae *Sargassum muticum* and *S. horneri* was higher at riprap stations than at the piling stations, while the abundance of non-native invertebrates was higher at piling stations (1,799) than at riprap stations (924). The difference in invertebrate abundance was driven primarily by Mediterranean mussels (96 on riprap, 526 on pilings), tunicates (all species combined, 39 on riprap, 252 on pilings), and the amphipod *Caprella simia* (402 on riprap, 647 on pilings). The polychaete worms *Pseudopolydora paucibranchiata* and *Megasyllis nipponica* were among the few species that were notably more abundant at riprap stations than at piling stations. The addition of pilings to the 2018 Biosurvey highlights the importance of sampling different substrates, given that physical conditions, predation, and grazing pressure may influence the presence of different non-native species. The inclusion of pilings in future Biosurveys will allow for better detection of non-native species to the Port Complex.

Table 5-10. Non-Native Species Observed in Quadrat Scrapings Across Biosurvey Years

Phyla	Species Name	2000	2008	2013	2018
Annelida	*Branchiomma bairdi*				X
Annelida	*Hydroides elegans*			X	X
Annelida	*Megasyllis nipponica*				X
Annelida	*Polydora cornuta*	X			
Annelida	*Pseudopolydora paucibranchiata*	X		X	X
Arthropoda	*Amphibalanus amphitrite*		X		X
Arthropoda	*Amphibalanus improvisus*		X		
Arthropoda	*Caprella drepanochir*				X
Arthropoda	*Caprella mutica*				X
Arthropoda	*Caprella scaura*			X	
Arthropoda	*Caprella simia*		X		X
Arthropoda	*Grandidierella japonica*		X	X	X
Arthropoda	*Leucothoe nagatai*			X	X
Arthropoda	*Monocorophium acherusicum*		X	X	
Arthropoda	*Monocorophium insidiosum*	X			X
Arthropoda	*Paranthura japonica*				X
Bryozoa	*Anguinella palmata*				X
Bryozoa	*Cryptosula pallasiana*				X
Bryozoa	*Watersipora arcuata*			X	
Chordata	*Ascidia zara*				X
Chordata	*Botrylloides violaceus*				X
Chordata	*Botryllus schlosseri*				X
Chordata	*Ciona robusta*				X
Chordata	*Ciona savignyi*				X
Chordata	*Didemnum vexillum*				X
Chordata	*Microcosmus squamiger*				X
Chordata	*Molgula ficus*				X
Chordata	*Polyandrocarpa zorritensis*				X
Chordata	*Styela clava*			X	X
Chordata	*Styela plicata*				X
Chordata	*Symplegma reptans*				X
Mollusca	*Crassostrea gigas*	X		X	
Mollusca	*Crassostrea virginica*		X		
Mollusca	*Crepidula convexa*				X
Mollusca	*Mytilus galloprovincialis*	X	X	X	X
Mollusca	*Philine auriformis*				X
Mollusca	*Theora lubrica*			X	X
Mollusca	*Venerupis philippinarum*			X	
Ochrophyta	*Sargassum horneri*				X
Ochrophyta	*Sargassum muticum*				X
Total Non-Native Spp		**5**	**7**	**12**	**32**
Total Species		**238**	**211**	**352**	**507**
% Non-Native Species		**2.10**	**3.32**	**3.41**	**6.31**

Note: 2018 Biosurvey includes riprap and piling stations

Invasive Algae By Kelp Stations - Spring
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 5-39. Density of Non-native Algae Species (Spring 2018)

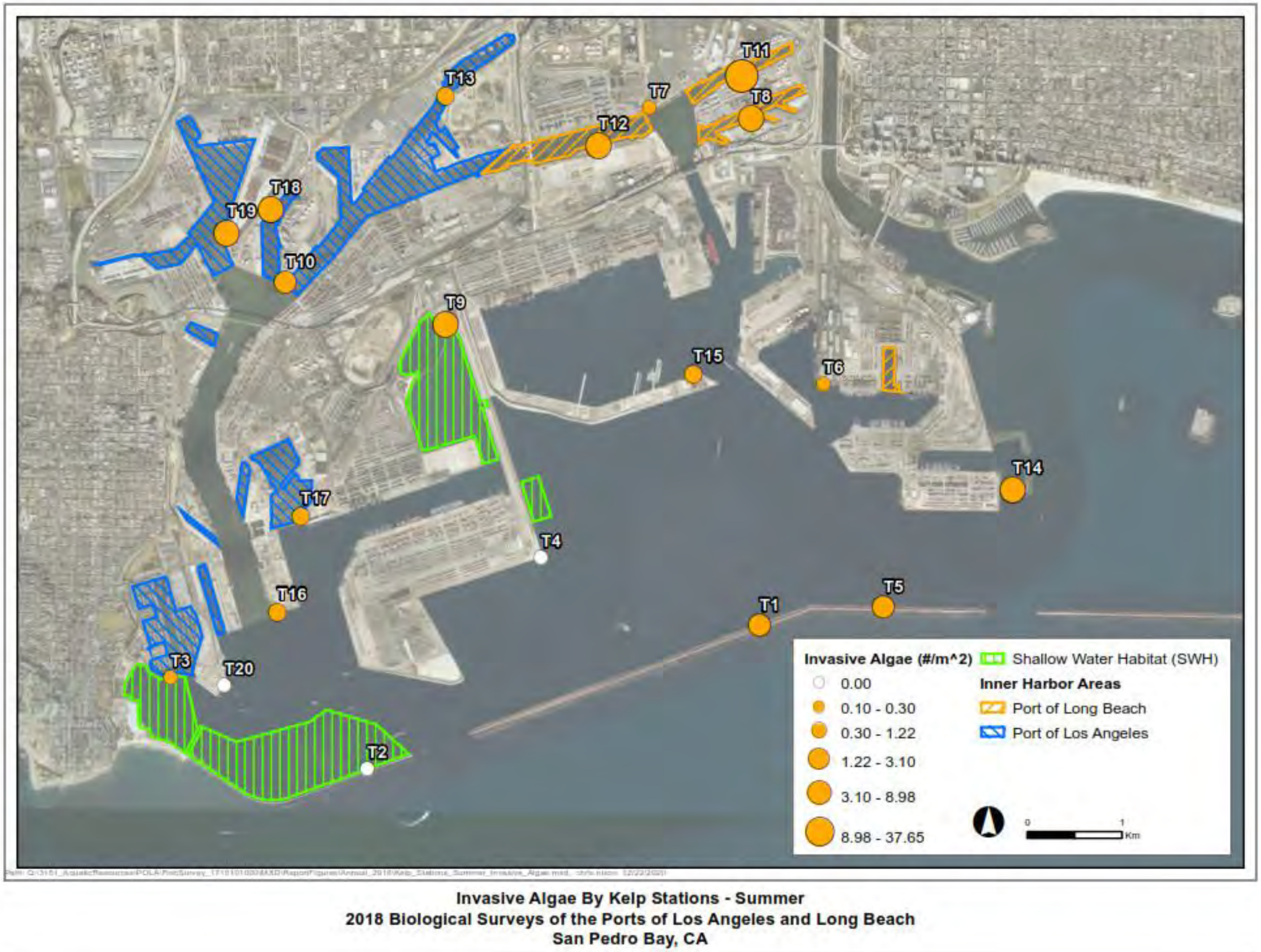


Figure 5-40. Density of Non-native Algae Species (Summer 2018)

Table 5-11. Non-native Species Abundance from Quadrat Sampling at Riprap and Piling Stations

Phylum	Species	LARR1	LARR2	LARR3	LARR4	LBRR1	LBRR2	LBRR3	LBRR4	LAPP1	LAPP2	LAPP3	LAPP4	LBPP1	LBPP2	LBPP3	LBPP4	All Stations	Riprap	Pilings
		Riprap								Pilings										
Ochrophyta	Sargassum horneri	0	0	0	0	0	0	0.035	0.065	0	0	0	0	0.01	0	0.015	0	0.125	0.1	0.025
Ochrophyta	Sargassum muticum	0	0	0	0	0	0	0	0.545	0	0	0	0	0	0	0	0	0.545	0.545	0
Annelida	Branchiomma bairdi	0	1	0	0	0	1	6	35	15	6	5	12	16	13	14	6	129	43	86
Annelida	Hydroides elegans	0	2	2	0	0	0	0	1	7	14	34	1	1	0	4	8	73	5	69
Annelida	Pseudopolydora paucibranchiata	0	0	87	0	0	0	0	0	0	0	1	0	0	0	0	0	87	87	1
Annelida	Megasyllis nipponica	0	1	0	0	3	2	64	26	2	0	1	0	26	0	0	1	124	96	29
Arthropoda	Amphibalanus amphitrite	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Arthropoda	Grandidierella japonica	0	26	30	0	0	25	14	2	0	5	9	4	3	2	10	4	130	95	35
Arthropoda	Caprella drepanochir	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1
Arthropoda	Caprella mutica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	0	3
Arthropoda	Caprella simia	1	2	37	1	13	22	69	260	211	32	25	25	217	19	70	50	1049	402	647
Arthropoda	Monocorophium insidiosum	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	2	1
Arthropoda	Leucothoe nagatai	1	1	0	0	2	0	1	5	4	1	2	16	20	23	26	9	107	8	100
Arthropoda	Paranthura japonica	1	11	6	0	0	5	19	8	1	4	13	5	16	1	8	4	99	49	51
Bryozoa	Cryptosula pallasiana	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	2	0	2
Bryozoa	Anguinella palmata	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	2	2	0
Chordata	Didemnum vexillum	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	1	1
Chordata	Ascidia zara	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	3	0	3
Chordata	Ciona robusta	6	1	3	0	0	0	0	4	39	0	1	5	39	2	7	6	111	13	98
Chordata	Ciona savignyi	0	1	2	0	0	1	0	10	5	2	10	6	12	2	8	6	62	12	50
Chordata	Molgula ficus	0	0	0	0	0	0	0	0	2	4	0	2	5	0	7	6	23	0	23
Chordata	Microcosmus squamiger	0	0	0	0	0	0	0	1	1	0	0	1	0	2	0	2	5	1	4
Chordata	Botrylloides violaceus	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	4	0	4
Chordata	Botryllus schlosseri	1	1	0	0	0	0	0	0	1	0	0	1	1	0	1	0	4	1	3
Chordata	Polyandrocarpa zorritensis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
Chordata	Styela clava	0	0	0	0	0	0	0	2	0	1	2	1	4	3	5	4	20	2	18
Chordata	Styela plicata	0	1	1	0	1	0	5	2	10	3	7	2	11	3	6	7	56	9	47
Chordata	Symplegma reptans	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	3	2	1
Mollusca	Mytilus galloprovincialis	86	1	0	0	1	0	7	2	221	7	9	3	128	147	9	4	622	96	526
Mollusca	Theora lubrica	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	2	0
Mollusca	Philine auriformis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
Mollusca	Crepidula convexa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Total		8	15	10	2	6	7	10	16	15	12	17	17	18	13	17	16	32	24	27

Note: *Sargassum* are presented as biomass (g) rather than abundance.

A total of 75 cryptogenic species (i.e., species whose origin is uncertain or unknown) have been observed on hard substrates over all Biosurvey years, with a total of 52 in 2018 (Table 5-12). This is an increase in total cyptogenic species over past Biosurveys, which ranged from 25 in 2000 to 35 in 2013. However, as shown in Table 5-10, the percentage of cryptogenic species relative to the total number of species has remained fairly consistent over the four Biosurveys.

While the number of non-native species has increased in the last five years, it appears that the increase is related to an overall increase in species richness. In the 2000 Biosurvey of riprap epifaunal communities, 5 non-native invertebrate species out of 238 total (2.1%) were observed, while the 2018 Biosurvey found 24 non-native invertebrate species out of 491 total species (4.9%), a modest relative increase despite an additional 22 non-native species. A major concern regarding the introduction of non-native species is that they will displace native species, eventually becoming dominant and altering the function of these habitats. Comparing the relative abundance of non-native species on riprap, the 2018 Biosurvey (8.1%) was relatively similar to 2000 (7.5%) and 2008 (6.1%), while not as high as 2013 (14.9%) which had high a high abundance (1,543) of the tube-building amphipod *Monocorophium acherusicum* compared to other years. While there is no available historical data for pilings, in 2018 they had similar relative abundance of non-native species (8.9%) as riprap. Therefore, it does not appear that non-native species are displacing native species, as overall diversity has been increasing without a subsequent increase in non-native species relative abundance.

This concept of correlation of non-native species richness with overall species richness has been observed previously in Southern California embayments. A 2011 study by CDFW (2014) targeting non-native species was designed using quadrat scrapings on artificial structures and paired Van Veen grabs to sample benthic infauna at 18 harbors throughout California, including eight stations in the Port Complex, using methods similar to those used to sample the same communities in the 2018 Biosurvey. The study found a total of 675 taxa within the Port Complex, of which 57 were non-native species (8.44% of all species) and 96 were cryptogenic species (14.2%); these were the highest numbers of non-natives and cryptogenic species observed in any harbor they surveyed. Mission Bay and San Diego Bay were both tied for second most non-native species with 53 each. However, because other harbors had far fewer total species present, as a percentage of total species, the Port Complex ranked 9th of the 13 Southern California harbors studied in terms of the proportion of non-native species and 6th for the proportion of cryptogenic species. San Diego Bay had the highest proportion of non-native species (12.0%) and Huntington Harbor had the highest proportion of cryptogenic species (17.1%), while Avalon Harbor had the lowest proportion of both non-native species (4.48%) and cryptogenic species (11.7%).

Table 5-12. Cryptogenic Species Observed Across Biosurvey Years

Phyla	Name	Likely Introduced or Native	2000	2008	2013	2018
Annelida	*Aphelochaeta monilaris*	Unknown			X	
Annelida	*Axiothella rubrocincta*	Unknown			X	
Annelida	*Boccardia proboscidea*	Native			X	X
Annelida	*Boccardia tricuspa*	Unknown			X	X
Annelida	*Boccardiella hamata*	Introduced	X	X	X	X
Annelida	*Chrysopetalum occidentale*	Unknown	X			
Annelida	*Ctenodrilus serratus*	Introduced	X			X
Annelida	*Dipolydora bidentata*	Unknown		X		
Annelida	*Dipolydora giardi*	Unknown	X			
Annelida	*Dipolydora socialis*	Unknown	X	X	X	X
Annelida	*Dodecaceria concharum*	Unknown	X	X		
Annelida	*Dodecaceria fewkesi*	Native	X		X	
Annelida	*Dorvillea (Schistomeringos) annulata*	Unknown			X	X
Annelida	*Euchone limnicola*	Unknown				X
Annelida	*Exogone lourei*	Native	X	X	X	X
Annelida	*Lepidonotus spiculus*	Unknown				X
Annelida	*Lumbrineris inflata*	Unknown		X		
Annelida	*Lumbrineris japonica*	Native			X	X
Annelida	*Mediomastus californiensis*	Unknown			X	
Annelida	*Neoamphitrite robusta*	Unknown		X		
Annelida	*Nereis grubei*	Unknown	X			
Annelida	*Ophiodromus pugettensis*	Unknown		X		
Annelida	*Paradialychone ecaudata*	Unknown			X	X
Annelida	*Phyllodoce longipes*	Unknown				X
Annelida	*Pista brevibranchiata*	Unknown				X
Annelida	*Platynereis bicanaliculata*	Unknown	X	X	X	X
Annelida	*Polydora cornuta*	Introduced	X			
Annelida	*Polydora websteri*	Unknown	X			
Annelida	*Prionospio heterobranchia*	Introduced				X
Annelida	*Pseudopolydora paucibranchiata*	Unknown	X		X	X
Annelida	*Scoletoma erecta*	Unknown				X
Annelida	*Sphaerosyllis californiensis*	Unknown	X	X	X	X
Annelida	*Spiophanes duplex*	Unknown			X	
Annelida	*Thelepus setosus*	Unknown			X	

Table 5-12. Cryptogenic Species Observed Across Biosurvey Years (Continued)

Phyla	Name	Likely Introduced or Native	2000	2008	2013	2018
Arthropoda	*Achelia echinata*	Unknown	X			X
Arthropoda	*Amathimysis trigibba*	Introduced		X		X
Arthropoda	*Ammothea hilgendorfi*	Unknown	X			X
Arthropoda	*Ammothella menziesi*	Unknown			X	
Arthropoda	*Aruga holmesi*	Native				X
Arthropoda	*Caprella californica*	Native	X	X	X	
Arthropoda	*Caprella equilibra*	Unknown		X		
Arthropoda	*Caprella laeviuscula*	Unknown				X
Arthropoda	*Caprella penantis*	Unknown		X	X	X
Arthropoda	*Ericthonius brasiliensis*	Unknown	X	X	X	X
Arthropoda	*Hemioniscus balani*	Unknown				X
Arthropoda	*Ianiropsis tridens*	Unknown			X	X
Arthropoda	*Jassa slatteryi*	Unknown	X			X
Arthropoda	*Laticorophium baconi*	Unknown	X		X	X
Arthropoda	*Leucothoe alata*	Unknown		X		X
Arthropoda	*Macrocyprina pacifica*	Native				X
Arthropoda	*Microjassa litotes*	Native		X	X	
Arthropoda	*Paradella dianae*	Native			X	X
Arthropoda	*Podocerus brasiliensis*	Native	X	X		X
Arthropoda	*Podocerus cristatus*	Unknown	X	X	X	X
Arthropoda	*Pseudotanais makrothrix*	Native				X
Arthropoda	*Zeuxo normani*	Unknown		X	X	
Cnidaria	*Euphysa ruthae*	Introduced				X
Cnidaria	*Plumularia setacea*	Unknown			X	X
Echinodermata	*Amphipholis squamata*	Unknown	X	X	X	X
Echinodermata	*Ophiactis simplex*	Native	X	X	X	X
Ectoprocta	*Amathia distans*	Unknown			X	X
Ectoprocta	*Buskia seriata*	Unknown			X	X
Ectoprocta	*Scruparia ambigua*	Unknown				X
Mollusca	*Sphenia fragilis*	Unknown				X
Nemertea	*Amphiporus imparispinosus*	Native				X
Nemertea	*Cerebratulus marginatus*	Unknown				X
Nemertea	*Emplectonema gracile*	Unknown				X
Nemertea	*Tetrastemma candidum*	Unknown				X
Nemertea	*Tetrastemma nigrifrons*	Native		X		
Nemertea	*Tubulanus polymorphus*	Unknown		X	X	X
Nemertea	*Zygonemertes virescens*	Unknown	X	X	X	X
Porifera	*Halichondria bowerbanki*	Unknown				X
Porifera	*Halichondria panicea*	Unknown			X	
Sipuncula	*Apionsoma misakianum*	Unknown				X
Sipuncula	*Phascolosoma agassizii*	Unknown		X		X
Total			**25**	**26**	**35**	**52**
Total Species			**238**	**211**	**352**	**507**
% Cryptogenic Species			**10.5**	**12.3**	**9.94**	**10.3**

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6.0 BIRDS

The Port Complex features an assortment of habitats that provide shelter, foraging, and nesting opportunities for a wide variety of avian species, including waterfowl, shorebirds, gulls, aerial fish foragers, upland birds, and raptors. This section presents the results of general avian surveys conducted in 2018 and 2019 within the Port Complex, which employed similar methodologies and survey intervals for assessing abundance, composition, and habitat usage of avifauna as those used in previous Biosurveys (MEC 2002; SAIC 2010; MBC 2016).

Surveys of birds in the Port Complex were conducted once per month from April 2018 to March 2019 (see Appendix A for survey dates and conditions). Each survey was conducted on two consecutive days, except when rain or high winds forced rescheduling to the next appropriate date. This ensured that survey counts, and species identifications were unimpeded by weather or water conditions. Each survey event commenced in the morning and continued until the survey was completed.

Consistent with previous Biosurveys, this study evaluates birds through a concept called "guilds." Birds that exploit the same set of resources in a similar manner are grouped into the same guild, regardless of their taxonomic relationship to each other. Grouping birds by guilds helps to illustrate patterns of habitat usage within the Port Complex and is used to simplify data management. Accordingly, all plunge diving birds such as terns and pelicans are grouped in the Aerial Fish Forager guild, ducks and similar swimming birds such as grebes, cormorants, and coots are in the Waterfowl guild, and birds that forage along the shoreline are in the Shorebird guilds (large and small). See Appendix F for lists of the species in each guild.

6.1 Survey Zones and Physical Features

The study area was divided into 31 survey zones (Table 6-1). With minor exceptions discussed below, the major zones and their boundaries were identical to those used during all studies from the year 2000 to the present survey effort (MEC 2002; SAIC 2010; MBC 2016).

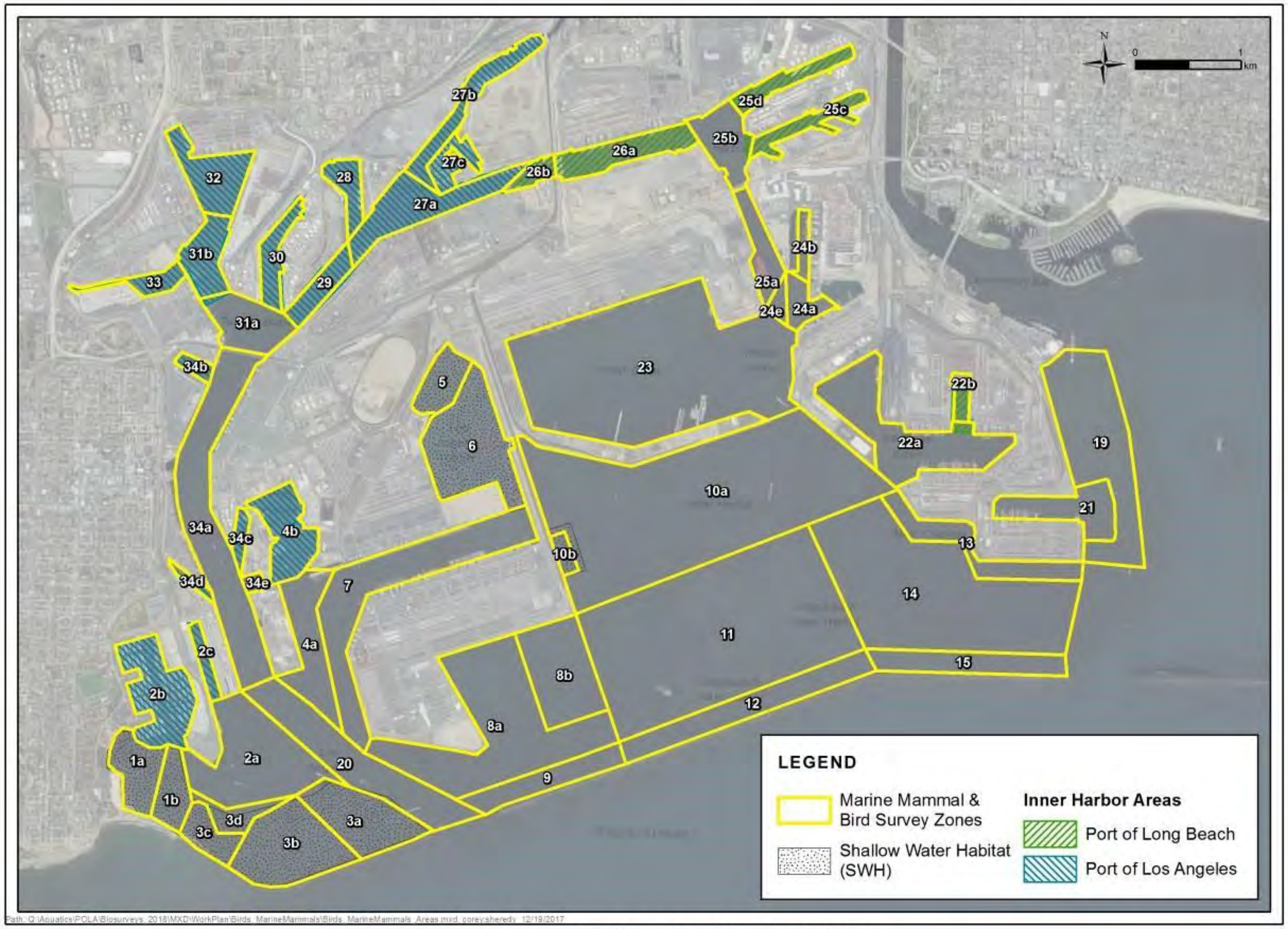
Like the previous Biosurveys, avian habitat usage in each zone was examined by recording the physical features on which birds were observed and the corresponding bird activities while using that feature. Birds use these features within each zone to fulfill a variety needs, from resting and nesting on port structures such as buildings, boats and docks/pilings to foraging in open water and shoreline (sandy beach and shallow water) areas. While the manmade structures within the Port complex are not traditional nesting habitat for most species, some birds have adapted to use similar features as a substitute. For example, in undeveloped areas rock pigeon (*Columba livia*), and cliff swallow (*Petrochelidon pyrrhonota*) are known to use rock outcrops, caves, and rock crevices for nesting (Brown and Brown 2020; Lowther and Johnston 2020), while in the Port Complex these species use buildings and dock pilings to fulfill a similar habitat niche. Similarly, double-crested cormorant (*Phalacrocorax auritus*) usually nests on cliffs, islands, and/or trees (Dorr et. al., 2020), while within the Port Complex they have adapted to nest in the structure of electrical transmission towers. Perches on tall structures such as bridges, lamp posts and buildings may also provide advantages for piscivorous birds to prey on fishes near the surface.

Within the context of this study, the physical feature designations included both natural and manmade elements and included the following: aerial, anchor line, barge/boat, spill boom, bridge, buoy, building/structure, dock/piling, dredge pipe, kelp, lamp post, open water (>1 foot deep), shallow water (<1 foot deep), riprap, sand beach/intertidal, and upland habitat (Appendix A).

Survey zones were numbered from 1-15 and from 19-34; the gap in the numbering sequence (16-18) reflects changes in harbor development, including the development of the Pier 400 landfill and Pier J expansion (MEC 2002). To better quantify bird usage, the 2013-2014 study implemented further divisions of some of the larger survey zones (zones 1, 2, 3, 4, 8, 10, 22, 24, 25, 26, 27, 31, and 34) into smaller subzones. For example, zone 1 and 3 were subdivided to obtain more detail in large shallow water habitats; several marinas and small slips were added to the survey as subzones; and several other zones were subdivided to allow for a separation of Inner and Outer Harbor areas. Since the 2013-2014 survey period, Zones 24c and 24d have been filled as part of POLB's the Middle Harbor Redevelopment Project, and the remaining zones 24a/24b and the base map may not be fully reflective of current conditions as the project progresses beyond 2018. These changes resulted in a total of 54 zones and sub-zones.

Table 6-1. Bird and Marine Mammal Survey Station Groups

Station	Port	Habitat	Location	Station Descriptor	Station	Port	Habitat	Location	Station Descriptor
1a	POLA	SWH	SWH	Cabrillo Beach North & Scout Camp	22a	POLB	Outer	Basin	SE Basin
1b	POLA	SWH	SWH	Cabrillo Beach South	22b	POLB	Inner	Slip	Pier G Slip
2a	POLA	Outer	Outer	Bait Barge Area	23	POLB	Outer	Basin	West Basin
2b	POLA	Inner	Basin	Cabrillo Marina	24a	POLB	Outer	Basin	East Basin Pier E-F
2c	POLA	Inner	Slip	East Channel	24b	POLB	Outer	Slip	East Basin Pier E-D
3a	POLA	SWH	SWH	Cabrillo SWH - Phase 2	24e	POLB	Outer	Channel	East Basin Pier D-T
3b	POLA	SWH	SWH	Cabrillo SWH - Phase 1	25a	POLB	Outer	Channel	POLB Back Channel
3c	POLA	SWH	SWH	Cabrillo SWH - Phase 3	25b	POLB	Outer	Basin	Inner Harbor Turning Basin
3d	POLA	SWH	SWH	Cabrillo SWH - Phase 4	25c	POLB	Inner	Slip	Channel 3
4a	POLA	Outer	Outer	Reservation Point East	25d	POLB	Inner	Slip	Channel 2
4b	POLA	Inner	Basin	Fish Harbor	26a	POLB	Inner	Channel	Cerritos Channel
5	POLA	SWH	SWH	Seaplane Lagoon SWH	26b	POLB	Inner	Channel	Cerritos Channel West
6	POLA	SWH	SWH	Pier 300 SWH	27a	POLA	Inner	Basin	East Basin
7	POLA	Outer	Channel	Pier 400 West & Pier 300 Channel	27b	POLA	Inner	Slip	Consolidated Slip
8a	POLA	Outer	Outer	Outer Pier 400 West	27c	POLA	Inner	Slip	East Basin Marinas
8b	POLA	Outer	Outer	Outer Pier 400 East Shallow Water	28	POLA	Inner	Slip	Slip 5
9	POLA	Outer	Breakwater	POLA Middle Breakwater	29	POLA	Inner	Channel	East Basin Channel
10a	POLB	Outer	Outer	Outer Navy Mole	30	POLA	Inner	Slip	Slip 1
10b	POLB	SWH	SWH	POLB SWH	31a	POLA	Outer	Basin	Turning Basin
11	POLB	Outer	Outer	Outer Harbor Anchorages	31b	POLA	Inner	Basin	West Basin South
12	POLB	Outer	Breakwater	POLB West Breakwater	32	POLA	Inner	Basin	West Basin
13	POLB	Outer	Outer	Outer Pier J South	33	POLA	Inner	Slip	Berths 118-120
14	POLB	Outer	Channel	POLB Outer Harbor Main Channel	34a	POLA	Outer	Channel	POLA Main Channel
15	POLB	Outer	Breakwater	POLB East Breakwater	34b	POLA	Inner	Slip	Cruise Center
19	POLB	Outer	Outer	Queensway Bay	34c	POLA	Inner	Slip	Berth 240
20	POLA	Outer	Channel	POLA Outer Main Channel	34d	POLA	Inner	Slip	S.P. Slip
21	POLB	Outer	Slip	Pier J Slip					



Proposed Marine Mammal and Bird Survey Zones
2018 Biological Surveys of the Ports of Los Angeles and Long Beach
San Pedro Bay, CA

Figure 6-1. Bird and Marine Mammal Survey Zones

6.2 Total Avian and Guild Abundance

A total of 48,754 individual bird sightings belonging to 87 species in 28 families were observed in the Port Complex during the 2018-2019 study period (Appendix F). Monthly survey totals ranged from a low of 35 species in May 2018 to a high of 54 species in February 2019 (Figure 6-2). Total numbers of individual birds ranged from 2,260 in May 2018 to 6,990 in August 2018, with an overall average of 4,063 individuals per survey. The abundance of each bird species in the eight ecological guilds and species counts by survey period are provided in Appendix F.

Avian abundance within the Port Complex was highly seasonal, with bird numbers peaking during migration and winter months and at their lows during the summer (Figure 6-2). Seasonal patterns in the species observed were primarily driven by changing abundances of species in the guilds Waterfowl (grebes, ducks, and cormorants), Aerial Fish Foragers (terns and pelicans), and to a lesser extent, Gulls (Figure 6-3). Of the 87 bird species observed during the 2018-2019 surveys, 26 species were observed during ten or more survey months, potentially indicating year-round occupancy within the Port Complex (Table 6-2). Two additional species were observed during nine of the 12 of the survey months, also suggesting a year-round presence. A total of 24 species were observed during only one or two survey months, indicating either rare species not typically observed within the survey area, such as American oystercatcher (*Haematopus palliates*) and black scoter (*Melanitta americana*), infrequent migratory visitors like red-breasted merganser (*Mergus serrator*), or common resident but upland species that are infrequently detected by the current survey method, such as finches, warblers, hummingbirds, etc.

The patterns of diversity and abundance of avian species in this survey were generally consistent with those observed during prior surveys within the Port Complex and with the results of regional avifauna studies. Nine of the ten most abundance avian species belonged to three guilds highly associated with water (Gulls, Aerial Fish Foragers, and Waterfowl); the remaining species, rock pigeon is a species known to be closely associated with humans and their structures; in this study and the previous surveys it was commonly observed throughout the Port Complex on buildings and pilings.

Table 6-2. Monthly Abundance of Birds Observed in at Least Ten Monthly Survey Events April 2018-March 2019 in All Zones

Common Name	April 2018	May 2018	June 2018	July 2018	August 2018	September 2018	October 2018	November 2018	December 2018	January 2019	February 2019	March 2019	Months in Port
Western Gull	1169	936	622	841	995	1874	2623	1815	1533	1634	1038	730	12
Western Grebe	1142	161	120	104	113	146	406	587	712	954	422	1082	12
Rock Pigeon	286	188	263	305	275	436	467	478	469	531	434	329	12
Brandt's Cormorant	186	8	165	393	1016	244	782	524	263	206	53	81	12
Brown Pelican	41	353	728	263	337	268	137	150	150	129	52	172	12
Double-crested Cormorant	146	182	232	186	205	206	146	107	130	127	116	111	12
Heerman's Gull	1	16	84	230	354	258	205	140	258	167	18	9	12
Great Blue Heron	32	49	73	58	74	70	73	72	51	70	42	40	12
Royal Tern	8	108	2	3	1	7	29	65	33	92	43	112	12
Black Oystercatcher	10	14	29	39	39	44	52	12	17	23	20	21	12
American Crow	12	5	12	11	6	7	15	12	7	16	25	19	12
Snowy Egret	6	8	18	18	17	9	6	13	7	16	22	5	12
House Finch	9	7	12	5	14	4	16	7	2	3	4	8	12
Osprey	3	1	3	1	1	5	7	6	4	5	4	3	12
Surf Scoter	53		1	3	4	1	12	196	312	311	275	322	11
Clark's Grebe	14		4	6	7	4	1	27	13	17	3	18	11
California Gull	18	3		1		3	22	6	101	20	78	9	10
European Starling	27	6	29		1	1		22	27	20	22	8	10
Black Turnstone	21		3	5	51	23	8	10		10	1	1	10
Common Raven	18	10	17	4	8		10	11	4		5	7	10
Surfbird	12	4		1	26	3		1	2	2	2	26	10
Spotted Sandpiper	8	1			3	5	6	8	6	6	7	3	10
Black-crowned Night Heron	1		8	3	6	5	1		1	1	3	8	10
Willet	4			3	4	2	2	4	5	4	4	3	10
Red-throated Loon	1		1	5	2	1		3	1	4	2	2	10
Muscovy duck	1		1	1	1	2	1		1	1	1	1	10

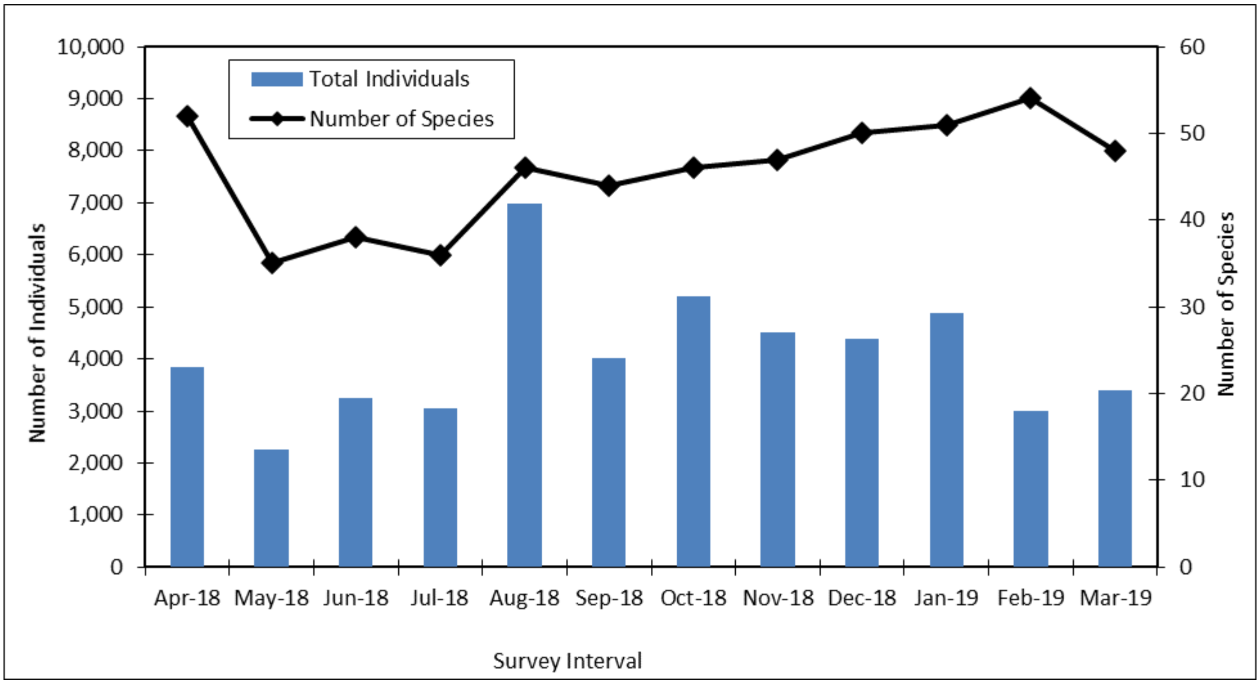


Figure 6-2. Total Avian Abundance and Species Counts by Survey

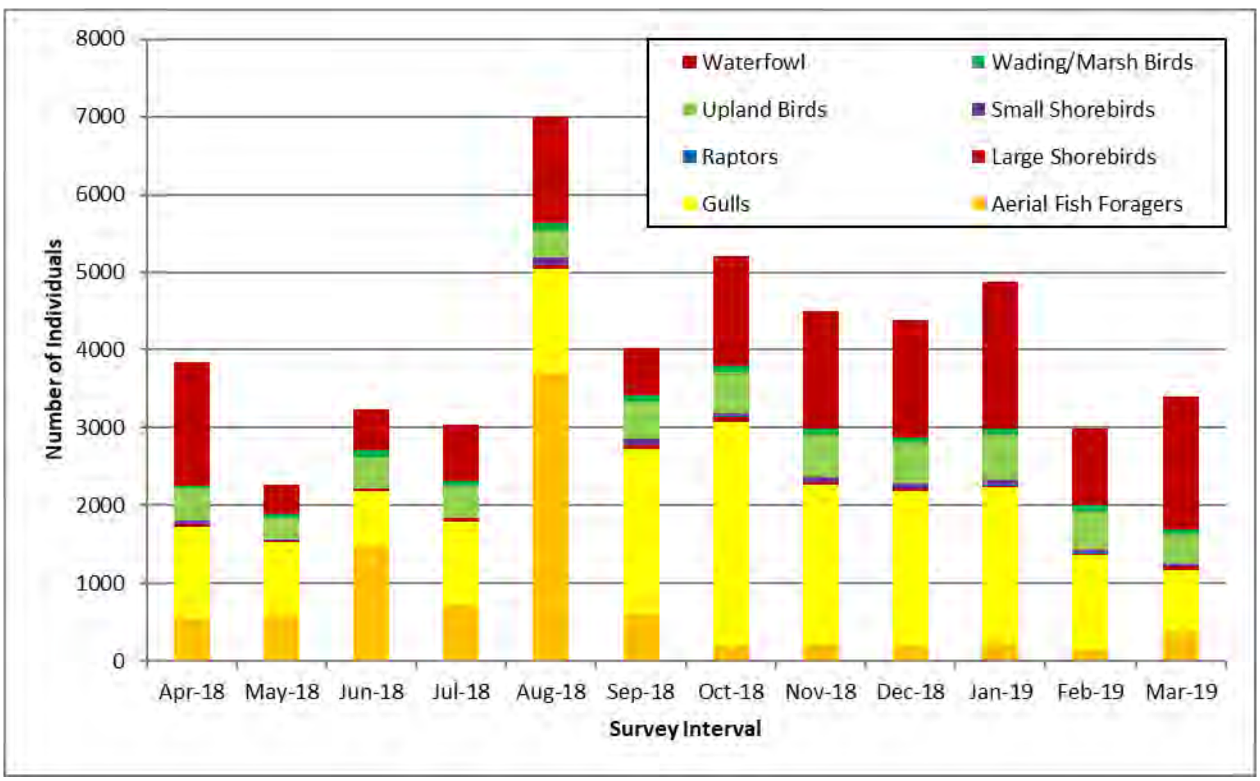


Figure 6-3. Avian Abundance by Guild and Survey Interval.

The most abundant guild was Gulls, which represented 37.6% of all birds observed during the survey period. Of the seven gull species observed, the western gull (*Larus occidentalis*) was by far the most abundant gull species (86% of all Gulls). Although populations of gulls are high throughout the year in the Port Complex, seasonal patterns were evident during the 2018-19 survey period (Figure 6-3). Overall, gull abundances peaked in October and remained high into January. The western gull was a dominant species during each survey event, but abundances increased notably from September to January. Heermann's gull (*Larus heermanni*) was also present year-around but was much less abundant from February to May. The seasonality of gull populations was driven by the convergence of migratory species (e.g., Heermann's gull, ring-billed gull [*Larus delawarensis*], and California gull [*Larus californicus*]) with the resident populations of adult and recently fledged western gull.

Raft of western grebes resting on the Open Water

A total of 22 species of the Waterfowl guild were observed, accounting for 29.1% of total avian abundance over the study period. Western grebe (*Aechmophorus occidentalis*) was the most observed Waterfowl species, accounting for 41.9% of total Waterfowl, with Brandt's cormorant (*Phalacrocorax penicillatus*) and double-crested cormorant the next most abundant. Many Waterfowl species were seasonal; as a result, the guild was most abundant from October to April, when many migrant species, especially western grebe, surf scoter (*Melanitta perspicillata*) and Brandt's cormorant, joined with the resident Waterfowl of the Port Complex. Small increases in migratory and post-breeding bird species such as American coot (*Fulica americana*), lesser scaup (*Aythya affinis*), bufflehead (*Bucephala albeola*), eared grebe (*Podiceps nigricollis*), and Clark's grebe (*Aechmophorus clarki*) also influenced the seasonal abundance of Waterfowl to some extent. While some migrant Waterfowl species remained in small numbers year-round, many species (mainly grebes and ducks) were completely absent for several months at a time.

The eight species of Aerial Fish Foragers represented 18.4% of total abundance. Elegant tern (*Thalasseus elegans*) and brown pelican (*Pelecanus occidentalis*) were the two most common species, accounting for 88.1% of the total abundance of the guild (57.1% and 31.0%, respectively). Patterns in the seasonal abundance of Aerial Fish Foragers showed an inverse relationship to those of Waterfowl. Populations peaked during the breeding period (May-August 2018) when migrant populations of elegant tern and California least tern (*Sternula antillarum brownii*) arrived at nesting colonies on Pier 400 (Zones 7 and 8a) and brown pelicans returned from their offshore nesting colonies on the Channel Islands.

The five remaining avian guilds (Large Shorebirds, Small Shorebirds, Wading/Marsh birds, Raptors, and Upland birds) comprised 14.9% of total abundance during the study period; over half of those were a single species in the Upland guild, rock pigeon which were present in steady numbers throughout the survey period. The abundance of Wading/Marsh birds remained relatively constant throughout the survey period, with only a small increase during the summer months due to the nesting success of the great blue heron (*Ardea herodias*). Likewise, Raptors and Upland Birds did not display strong seasonal patterns of abundance, as these species were mostly incidental sightings in upland habitats near harbor waters. Small Shorebirds showed a small peak in abundance during migration and winter months, when species such as black-bellied plover (*Pluvialis squatarola*), black turnstone (*Arenaria melanocephala*), and surfbird (*Calidris virgate*) used the Port Complex on the way to and from their breeding grounds. The abundances of Large Shorebirds did not display strong seasonal patterns of abundance, primarily due to the year-round presence of black oystercatcher (*Haematopus bachmani*), which are known to breed within the Port Complex (MEC 2002, SAIC 2010, MBC 2016).

6.3 Species Composition

Abundant Avian Species

The ten most abundant species accounted for 90.0% of all observations, and the top three species (western gull, western grebe, and elegant tern) accounted for over half of total bird abundance (Table 6-3). As a result, the overall abundance of each avian guild was largely driven by high numbers of only one or two species.

While western gulls were present in large numbers year-round, they were most abundant from September through January. Western gulls were observed breeding within the Port Complex; nests and/or chicks were observed on port structures; and young western gulls were later observed as fledglings foraging and mixing with both migrant and resident gulls. Western grebes were also present throughout the year. While this species is not known to nest within the Port Complex, between 100 and 150 non-breeding resident birds were observed during the summer months. Elegant terns are migratory in the Port Complex and were only observed during March to October; as many as 4,500 nesting elegant terns were documented by Langdon Biological Consulting (LBC) during the 2018-2019 survey period in the course of a separate study to assess population and reproduction status of California least tern in the Port Complex (LBC 2019).

Rock pigeon, Brandt's cormorant, brown pelican, and double-crested cormorant were observed in every survey event. With the exception of brown pelican, these species are known to nest within the Port Complex (MEC 2002; SAIC 2010; MBC 2016). The eighth through tenth most abundant species consisted of Heermann's gull, surf scoter, and great blue heron. All three of these species were present in the Port Complex year-round (surf scoter was not detected in May but was likely present as it was detected during every other survey month), but of these only the great blue heron is known to breed within the Port Complex.

Table 6-3. Ten Most Abundant Bird Species in the Port Complex, 2018-2019

Species	Total Abundance	Percent of Total	Guild
Western Gull	15810	32.4	Gulls
Western Grebe	5949	12.2	Waterfowl
Elegant Tern	5127	10.5	Aerial Fish Foragers
Rock Pigeon	4461	9.2	Upland Birds
Brandt's Cormorant	3921	8.0	Waterfowl
Brown Pelican	2780	5.7	Aerial Fish Foragers
Double-Crested Cormorant	1894	3.9	Waterfowl
Heermann's Gull	1740	3.6	Gulls
Surf Scoter	1490	3.1	Waterfowl
Great Blue Heron	704	1.4	Wading Birds
TOTAL	43876	90.0	

Rare and Uncommon Avian Species

Rare and uncommon sightings during the 2018-19 surveys included both species not typically observed in Southern California and species that occur regularly but in low numbers. These species increased overall diversity but contributed little in terms of abundance.

American oystercatcher on the outer breakwater.

Two species rarely seen in Southern California were observed during the 2018-19 survey period. One American oystercatcher was observed foraging and resting on riprap in eight of the twelve survey months, primarily in zone 15 (POLB Breakwater) zone and once in Zone 22a (POLB East Basin). Although this species occurs with some regularity in coastal northern Baja California, it is a rare visitor to the Los Angeles area. At the northern tip of its range the American oystercatcher is known to hybridize frequently with the black oystercatcher (Unitt 2004, Garrett et al. 2006), to the extent that only 43 of the 103 observations in California (from years 1862 to 2019) are accepted as true American oystercatcher, the others being considered hybrids (CBRC 2019). The bird observed during the 2018-19 survey period showed very little evidence of hybridization (for a Southern California bird; validated with photo documentation) and was proposed as a valid record of American oystercatcher in California (Kimball Garett, pers comm.).

A single black scoter was observed on March 22, 2019 in Zone 22a (POLB South East Basin) resting with a group of surf scoters. Black scoter is a rare, but regular, winter migrant to the coastal region of Los Angeles, where they can occur seasonally, although usually only as one or two individuals (Garrett et al. 2006).

Several of the rarely documented species were birds that are uncommon (American Birding Association definition used here: found in small numbers, and usually – but not always – found with some effort in appropriate habitat at right time of year) in the Port Complex but not considered to be rare in the region. These observations, in decreasing abundance, included: herring gull (*Larus argentatus*), western meadowlark (*Sturnella neglecta*), peregrine falcon (*Falco peregrinus*), Bonaparte's gulls (*Chroicocephalus philadelpia)*, common loon (*Gavia immer*), glaucous-winged gull (*Larus glaucescens*), red-necked phalarope (*Phalaropus lobatus*), horned grebes (*Podiceps auritus*), blue-winged teal (*Spatula discors*), brant (*Branta bernicla*), and red-breasted merganser.

6.4 Spatial Variation

As with previous surveys of the Port Complex, the 2018-2019 avian surveys found spatial variation among survey zones and habitat types. To be comparable with previous studies (MEC 2002, SAIC 2010, MBC 2016), abundance and density are presented by zone.

Abundance and Species Richness by Survey Zone

Certain survey zones supported consistently greater numbers of individual birds or bird species over the twelve surveys. The ten zones that supported the greatest total numbers of individuals accounted for 55.0% of the 48,754 total observations; seven of those zones include large areas in the Outer Harbor (breakwaters and harbors), two are located in shallow water habitat Zones 1a and 6, and one is located in the Inner Harbor (Zone 4b; Fish Harbor) (Figure 6-4). These ten zones alone comprise 64.1% of the total Port Complex water area. Zone 8a (Outer Pier 400 West) supported the highest abundance of birds, with 5,164 individual observations, whereas in Zone 10b (POLB SWH), one of the smallest survey zones (15 acres), only 25 birds were observed for the entire survey year.

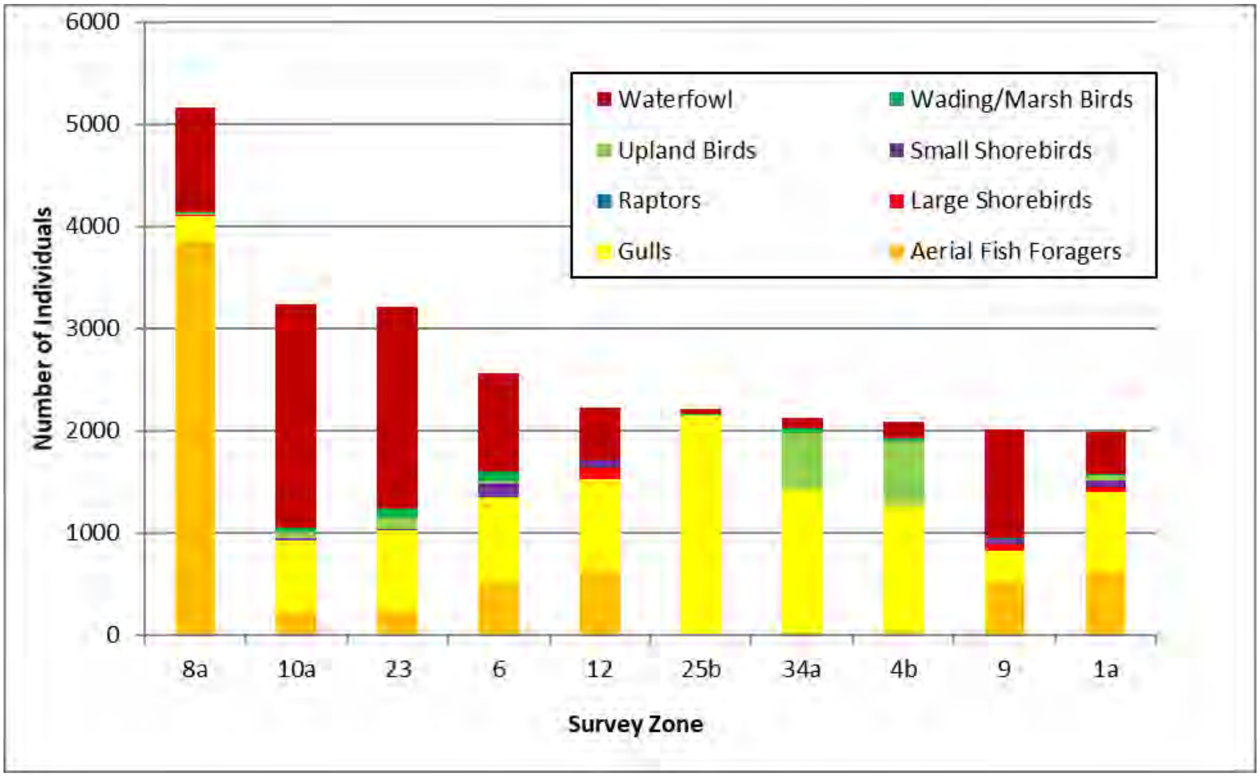


Figure 6-4. Total Abundance of Avian Guilds in the Ten Most Populous Zones During 2018-19

Density by Survey Zone

Western gull and chicks resting on a dock piling in Zone 25b (POLA)

Mean avian densities (birds in zone/acre/monthly survey event) for each survey zone are presented in Figure 6-5. Given the high variability in the size of the zones (the largest zone [10a] is 859.2 acres, while the smallest zone [34e] is 7.7 acres), mean density data provides a better illustration of avian usage over mean abundance alone. Presenting the data as mean densities and total counts of the three most abundant guilds (Gulls, Waterfowl, and Aerial Fish Foragers) within each survey zone (Figures 6-6 through 6-8) better illustrates areas of high avian usage within the Port Complex for these three guilds than mean abundance alone.

The greatest mean densities of birds occurred in Zones 34c (Berth 240) and 2c (East Channel) (4.1 and 2.9 birds/acre, respectively). These zones are both small inner slips off of the Los Angeles Main Channel that consist of narrow, open-water navigation channels with fully developed shorelines (riprap, docks, pilings, and upland areas) and anthropogenic structures (buildings, boats, buoys, etc.). Although small numbers of individuals were observed (an average of 66 to 70 per survey), the high densities in these zones are primarily attributed to the small size of these zones (16.2 and 22.0 acres for Zone 34c and 2c, respectively) relative to the abundance of structures that were heavily utilized by resting western gulls and rock pigeons. The location within the Port Complex, presence of fishing boats associated with the municipal fish market and a bait barge in this area also likely enhanced its appeal to these birds. Similar high mean bird densities were calculated for other small zones including Zones 34d, 25b, and 1a (Figure 6-5). Fifteen of the 54 survey zones had mean densities greater than one bird per acre. Zones 11 and 20, large zones containing only open water habitats, were the least dense survey zones (average monthly counts of less than 0.07 birds per acre).

Of the ten most populous zones (Figure 6-4), half (Zones 12, 25b, 4b, 9 and 1a) were also among the ten zones with greatest mean density (Figure 6-5). In these zones, avian density was mainly driven by high numbers of roosting birds. Zones 9 and 12 are outer harbor locations where large aggregation of gulls, cormorants, and brown pelicans roosted on the breakwaters. Similarly, hundreds of Gulls, Aerial Fish Foragers, and Waterfowl were observed using the sandy beach habitat in Zone 1a (Cabrillo Beach North). Large aggregations of gulls, rock pigeon, and cormorants used the inner harbor locations of Zone 4b (Fish Harbor) and 25b (Inner Harbor Turning Basin) for roosting and foraging.

Seven of the ten most densely populated zones were small zones in inner slips and basins that were surrounded and bordered by developed shorelines. These zones provide roosting (docks/pilings, buildings/structures) and foraging resources for opportunistic avian species often associated with urban structures such as rock pigeon, western gull, and to a lesser extent, barn swallow (*Hirundo rustica*), and European starling (*Sturnus vulgaris*) (Hensley et. al 2019; Brown and Brown 2020).

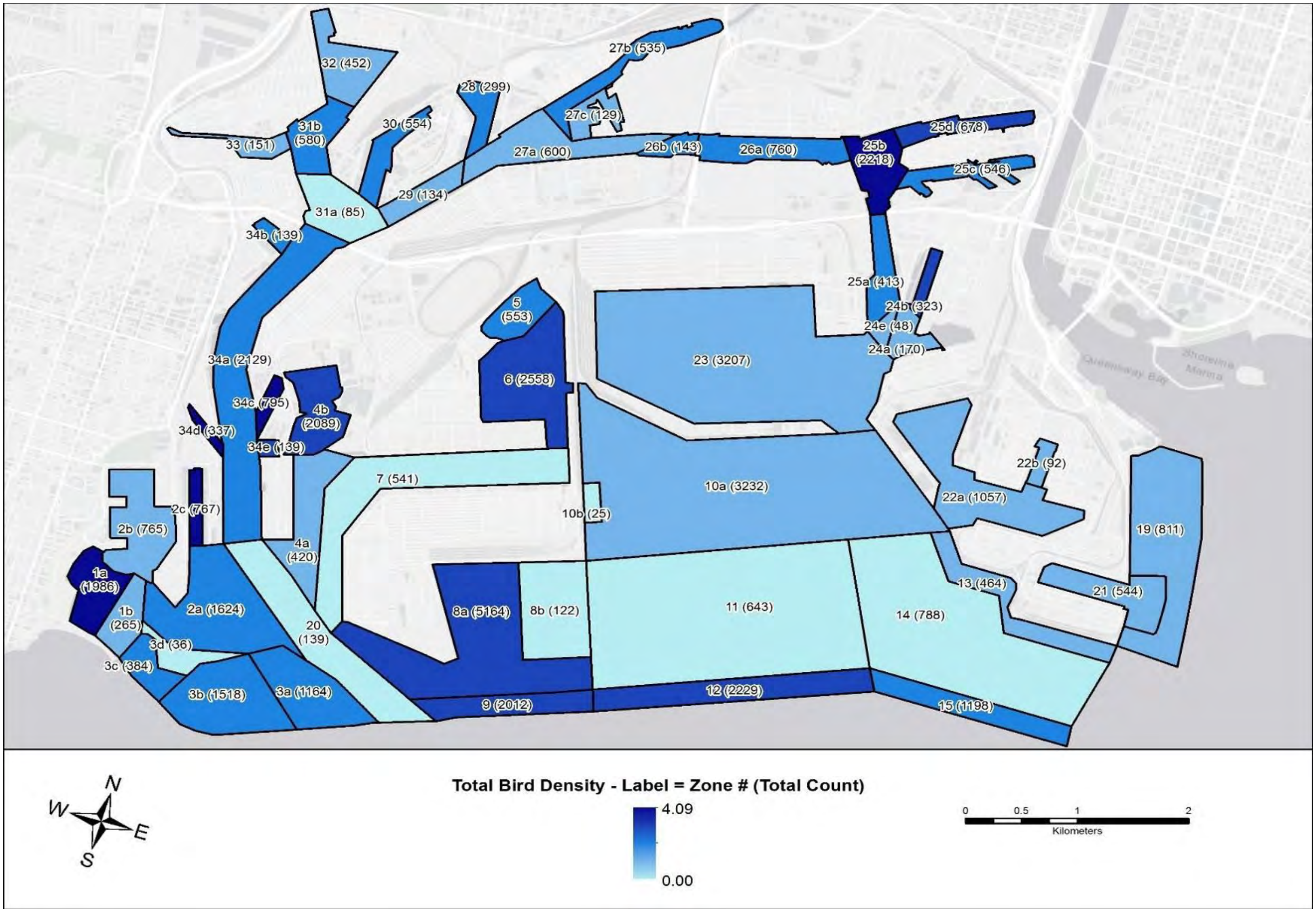


Figure 6-5. Total Mean Avian Density (#/Acre, Color Scale) and Abundance (In Parentheses) by Survey Zone

Patterns of Guilds

Gulls: Zone 25b (POLB Inner Harbor Turning Basin) had both the highest density and the highest abundance of Gulls (Figure 6-6), accounting for 12.1% of total Gulls observed. Other areas of high density and abundance of Gulls were Zones 2c, 4b, and 34a-34d (adjacent to the Municipal Fish Market, restaurants, and the commercial fishing fleet), the sandy beach areas adjacent to Cabrillo Beach (Zone 1a), along the Middle Breakwater (Zones 12 and 15), docks and open water in the West Basin (Zone 31b), and along the Inner Slips in POLB (Zones 25c and 25d).

Waterfowl: Mean densities of Waterfowl (Figure 6-7) were greatest in Zone 24b (East Basin Pier E-D) and Zone 9 (POLA Middle Breakwater). Zone 24b is a small, narrow slip where large groups of western grebe were observed roosting in the sheltered waters. Despite the high mean density, only 241 individual Waterfowl were counted in this zone, and 229 occurred on one day. These observations suggest that the high density in this zone is not entirely representative, but rather a one- day anomaly due to specific weather or water conditions. In contrast, Zone 9 (POLA Middle Breakwater) was both populous and dense with 1,066 total Waterfowl observations distributed over every survey period. The riprap in this zone provided communal roosting opportunities for groups of Brandt's cormorant.

Mean densities of Waterfowl were also high in Zones 5 (Seaplane Lagoon), and 1a and 3b (near Cabrillo Beach) due to large rafts of western grebe, surf scoter, lesser scaup, and, to a lesser extent, bufflehead and cormorants. High densities in Zone 26a (Cerritos Channel) were due to the colony of double-crested cormorants that nest in the transmission towers. The most Waterfowl observations occurred to the north and south of the Navy Mole in Zones 10a and 23 (2,185 and 1,971 total observations, respectively), however their size (859 and 738 acres, respectively) results in low densities of Waterfowl usage. These zones provide large expanses of sheltered waters that were more heavily utilized by resting and foraging birds than the Inner Harbor Slip zones of 24b and 30 which, despite high density figures, had far fewer birds (241 and 140 total observations, respectively).

Aerial Fish Foragers: Observations were concentrated around Piers 300 and 400 and in the SWH zones; Aerial Fish Foragers were scarce in the inner harbor survey zones and in the deep, open-water zones of POLB (Figure 6-8). Mean densities and abundances of Aerial Fish Foragers were greatest in Zone 8a, adjacent to the elegant tern and California least tern nesting colonies on Pier 400. Zones 1a (Cabrillo Beach North) and 6 (Pier 300 SWH) also had high densities of birds, as these zones provided a variety of physical features that were used by Aerial Fish Foragers. For example, in the sheltered waters of Zone 6, a variety of tern species roosted on the sandy beach and sections of floating dredge pipe, while the riprap provided roosting sites for brown pelicans. Zone 1a provided sandy beach habitat and buoys that were used by roosting black skimmer and tern species. Both of these areas contained shallow water Habitat (with eelgrass [*Zostera marina*]) that supported foraging opportunities for Waterfowl and Aerial Fish Foragers. Zones that contained large amounts of riprap (Zones 9, 12, 3a, and 3b) also supported high densities of Aerial Fish Foragers, as these zones were heavily used as roosting locations by brown pelican.

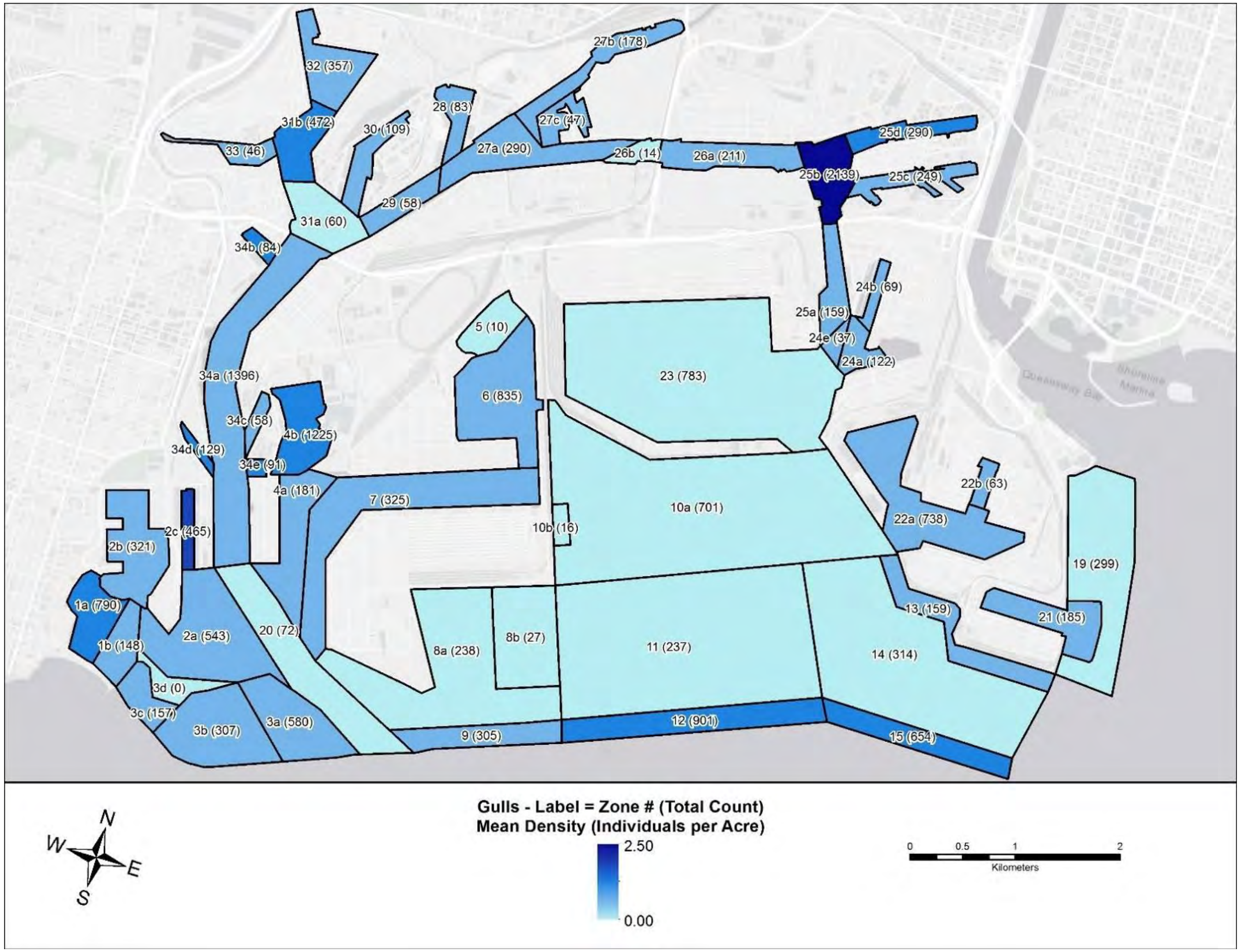


Figure 6-6. Mean Densities (Color Scale) and Abundance (In Parentheses) of Gulls by Survey Zone

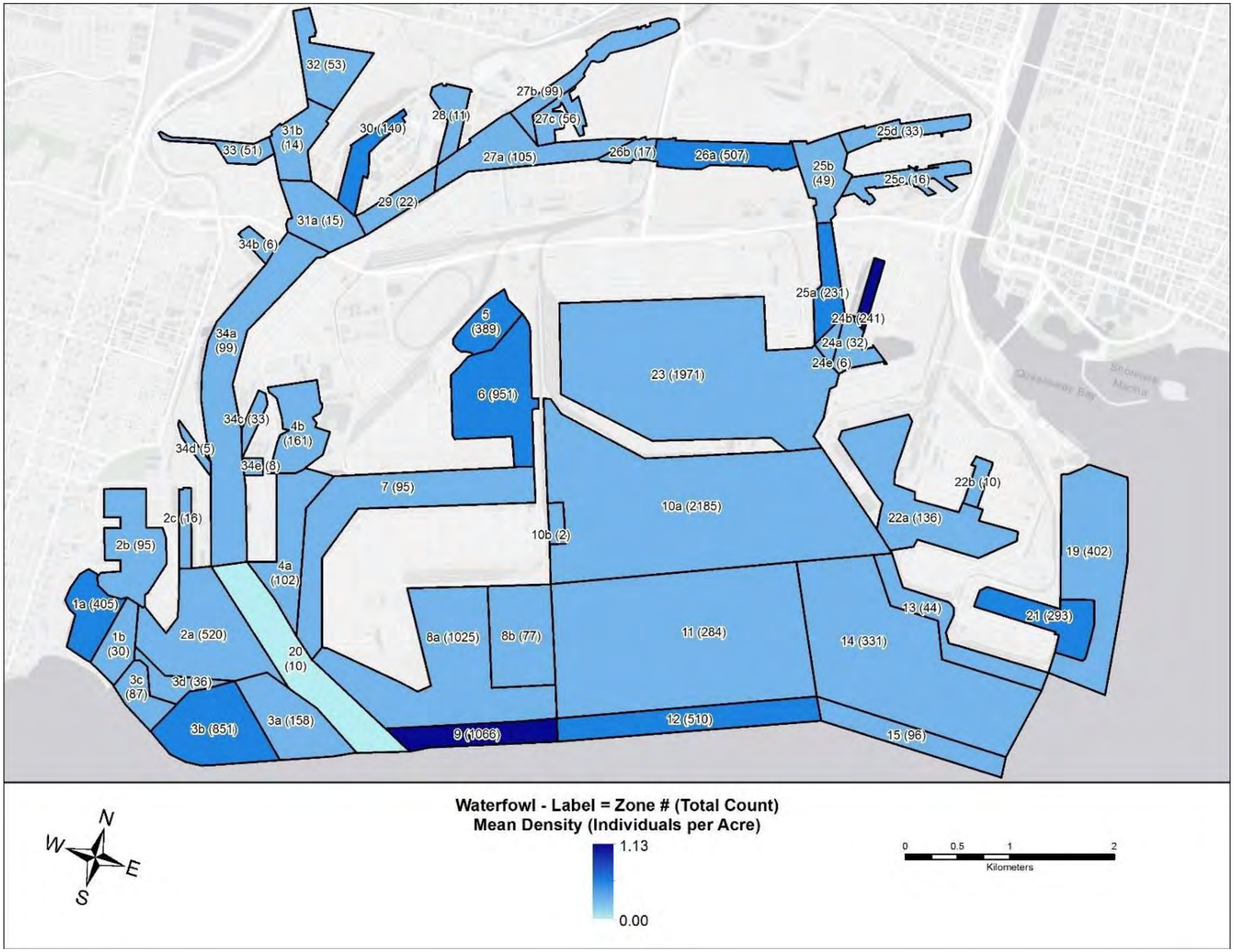


Figure 6-7. Mean Densities (Color Scale) and Abundance (In Parentheses) of Waterfowl by Survey Zone

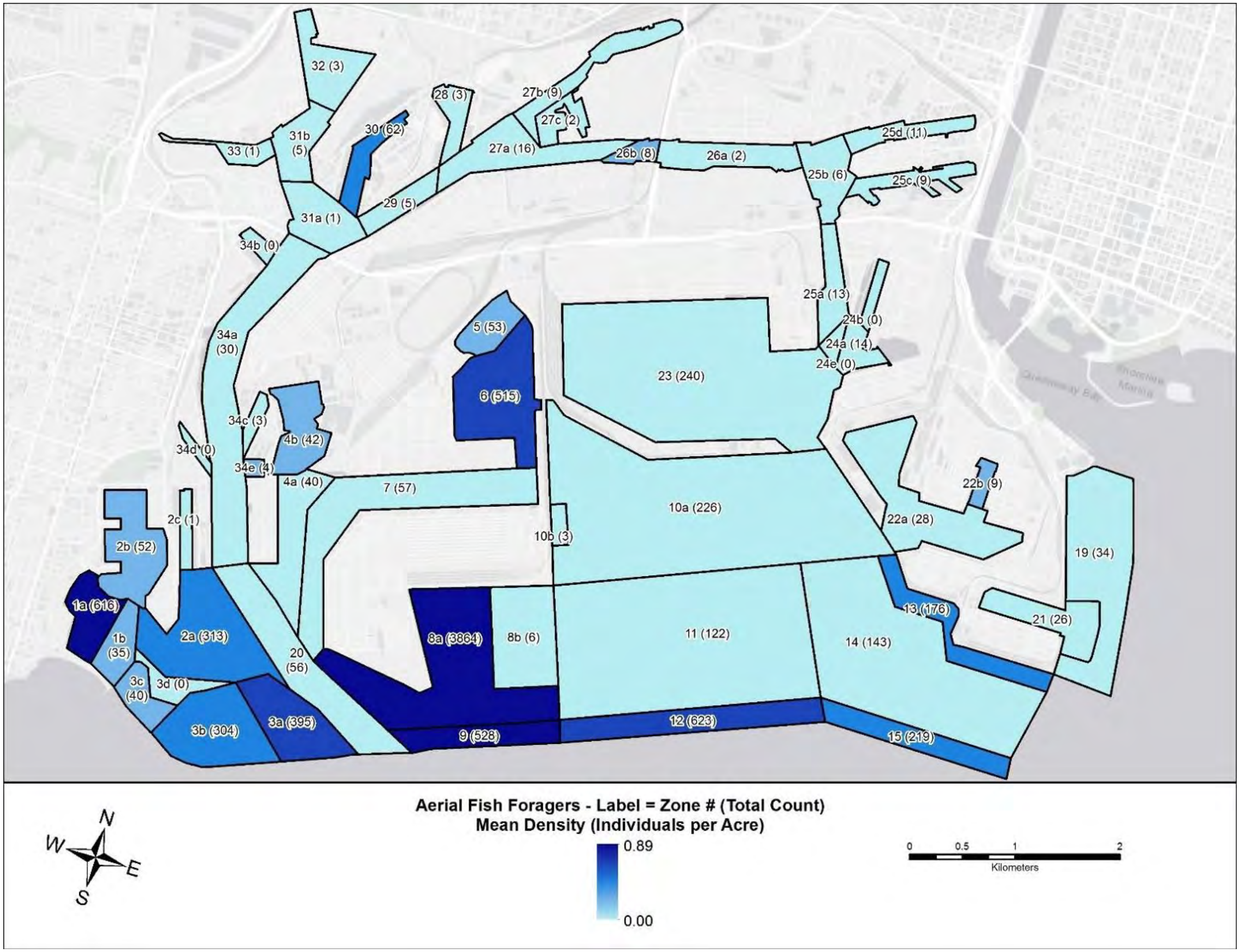


Figure 6-8. Mean Densities (Color Scale) and Abundance (In Parentheses) of Aerial Fish Foragers by Survey Zone

Other Guilds: The densities of less abundant avian guilds (Raptors, Small and Large Shorebirds) were not mapped because the low numbers of birds spread out over the entire Port Complex resulted in low densities in all survey zones. However, patterns of usage were observed for these less abundant avian guilds.

Survey zones 6, 15, 12, 1a, and 9 accounted for 69.2% of all Small Shorebird observations. Zone 6 (Pier 300 SWH) alone accounted for 23.9% of Small Shorebird observations, largely due to a flock of black-bellied plover repeatedly observed resting on riprap and dredge pipe during winter surveys. Similarly, four survey zones (Zones 1a, 9, 12, and 15) accounted for 89.1% of Large Shorebird observations. These zones encompass the Middle Breakwater, where black oystercatcher was the most abundant large shorebird species, and Cabrillo Beach, where whimbrel and willet (*Tringa semipalmata*) were the most abundant.

Unlike Small and Large Shorebirds, Wading/Marsh Birds were ubiquitous (although in small numbers) throughout the Port Complex, with observations occurring in 49 of the 54 survey zones. This guild was most abundant in Zones 6, 23, 34a, 2a, and 27b, which together accounted for 35.3% of total observations. Densities and abundances of great blue heron (the most abundant member of the guild) were highest in zones near known nesting locations (Zones 6 and 23 near the Navy Mole and Zone 34a, the POLA Main Channel). Zone 2a includes a bait barge that provides an opportunistic location for foraging and roosting, and Zone 27b (Consolidated Slip) contains long stretches of developed shoreline where great blue heron roosted.

The current survey method is not designed to provide comprehensive observations of Upland and Raptor species, being focused on water areas. Raptor observations were sporadic and irregular; only 67 total raptors were observed during the 2018-19 survey period, and they occurred in 34 of the 54 survey zones.

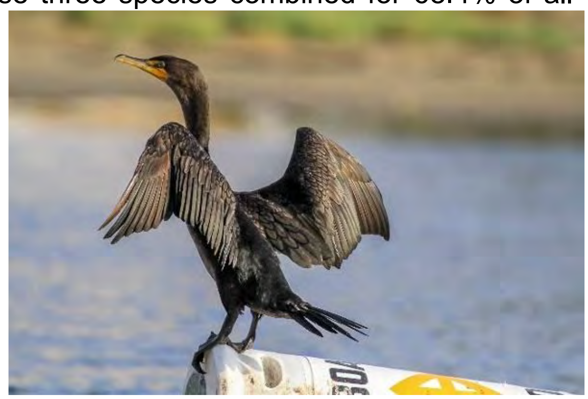
The occurrences and distributions of Upland species were overwhelmingly dominated by rock pigeon; excluding rock pigeon, Upland birds accounted for only 1.7% of all species observed, across all survey events. Given this and the incidental nature in which Upland birds were detected, it was not considered useful to produce figures depicting the densities of Upland species. Still, patterns of usage by Upland birds within the Port Complex were noted. After rock pigeon, the most numerous Upland species were barn swallow, European starling, and American crow (*Corvus brachyrhynchos*). Overall, Upland species were most abundant in Zones 34c (Berth 240), 4b (Fish Harbor), and 34a (POLA Main Channel). These zones contain large sections of shoreline that are completely developed with urban structures (large docks, buildings, piers, etc.), which these Upland species often use for roosting, nesting and foraging.

6.5 Avian Usage of Physical Features and Avian Activity

As discussed in Section 6.1, birds use physical features in their environment for a variety of activites. These features can support activities from merely resting to active foraging. As in previous harbor-wide studies, the data on avian abundances and distribution collected in this study were evaluated in terms of how birds used the various physical features present in the Port Complex.

Open water more than one foot deep is by far the most extensive natural physical feature in the Port Complex and is available in all survey zones. The 2018-2019 surveys observed 37.9% of all birds in this feature (Appendix F). A total of 71.5% of all Waterfowl (primarily western grebe, along with surf scoter and Brandt's cormorant), 28.1% of all Gulls (a combination of western gull, Heermann's gull, and ring-billed gull), and 27.9% of all Aerial Fish Foragers (primarily elegant tern) were observed utilizing Open water. Open water was broadly utilized during every month, but the heaviest usage occurred during the non-breeding months (October-April), when large rafts of western grebe and surf scoters used the sheltered waters within the Port Complex for roosting and foraging.

Riprap was the second most utilized feature within the Port Complex; 22.5% of all birds during the 2018-2019 surveys were observed on riprap. Riprap was available in 45 of 54 survey zones and was a popular roosting resource for many of the most abundant avian species including elegant tern, western gull, and brown pelican. These three species combined for 68.4% of all birds observed along the riprap. Riprap was also an important resting, foraging, and in some cases, nesting resource for other avian guilds. A total of 78.9% of Small Shorebirds, 87.0% of Large Shorebirds, and 26.1% of Wading/Marshbirds (primarily foraging great blue heron and snowy egret) were observed on riprap.



Double-crested cormorant resting on a buoy near Cabrillo Beach.

Docks/pilings were the third most utilized feature, accounting for 16.0% of total bird observations. This feature was present in 42 of 54 survey zones, sometimes making up large portions of the edges. Docks/pilings were most heavily utilized by gulls, which represented 65.0% of all observations on this feature. Collectively, Upland species (almost entirely rock pigeons) represented 23.1% of total birds observed on docks/pilings. Within the Port Complex, rock pigeon showed strong fidelity to the dock/piling feature and were most populous in zones in the slips and channels of the inner harbor. All other avian guilds combined accounted for 12.0% of observations in the dock/piling feature.

The remaining 16 types of physical features accounted for 24.2% of avian observations. Among these less utilized features, abundance was greatest in the building/structure feature. This feature type accounted for 8.0% of the observations, with western gull (43.8%), rock pigeon (36.2%), and double-crested cormorant (11.8%) being the prominent species. Barges/boats accounted for 4.1% of observations and provided roosting locations primarily for western gull, rock pigeon, and Brandt's cormorant.

Although only a small fraction of bird observations occurred on dredge pipe (3.7%) and sandy beach (2.8%), these features provided roosting locations for a diverse set of avian species (18 and 26 species, respectively). The area of sandy beach and dredge pipe is insignificant in terms of the size of the Port Complex as a whole. Nevertheless, 1,322 birds were observed along the sandy beaches and 1,835 birds were documented on dredge pipes. Together, these two physical features combined included 35 of the 46 documented species and 6.5% of all avian observations despite encompassing only 0.6% total acreage of the available habitat.

Figure 6-9 illustrates the use of habitat types in the Port Complex by the ten most abundant species of birds observed during the 2018-2019 surveys. As previously discussed, these ten species account for 90.0% of all birds observed and, therefore, are the dominant factors in that usage. Western gull, the most abundant avian species, was observed in all areas of the Port Complex, with their distribution spread between open water (28.5%), dock/pilings (27.8%), riprap (16.4%), and building/structures (10.7%). Similarly, the rock pigeon, double-crested cormorant, Heermann's gull, and great blue heron showed a relatively equal distribution in their preferred habitat types, with large numbers associated with many feature types.

In contrast, many of the other abundant avian species found within the Port Complex show preference to one or two specific types of physical features. For example, western grebe and surf scoter were only observed in open water, and brown pelican and Brandt's cormorant preferred riprap, where 72.6% and 39.5% of the observations were made, respectively. The majority of elegant terns were observed on riprap (56.5%) with another 34.7% over the open water.

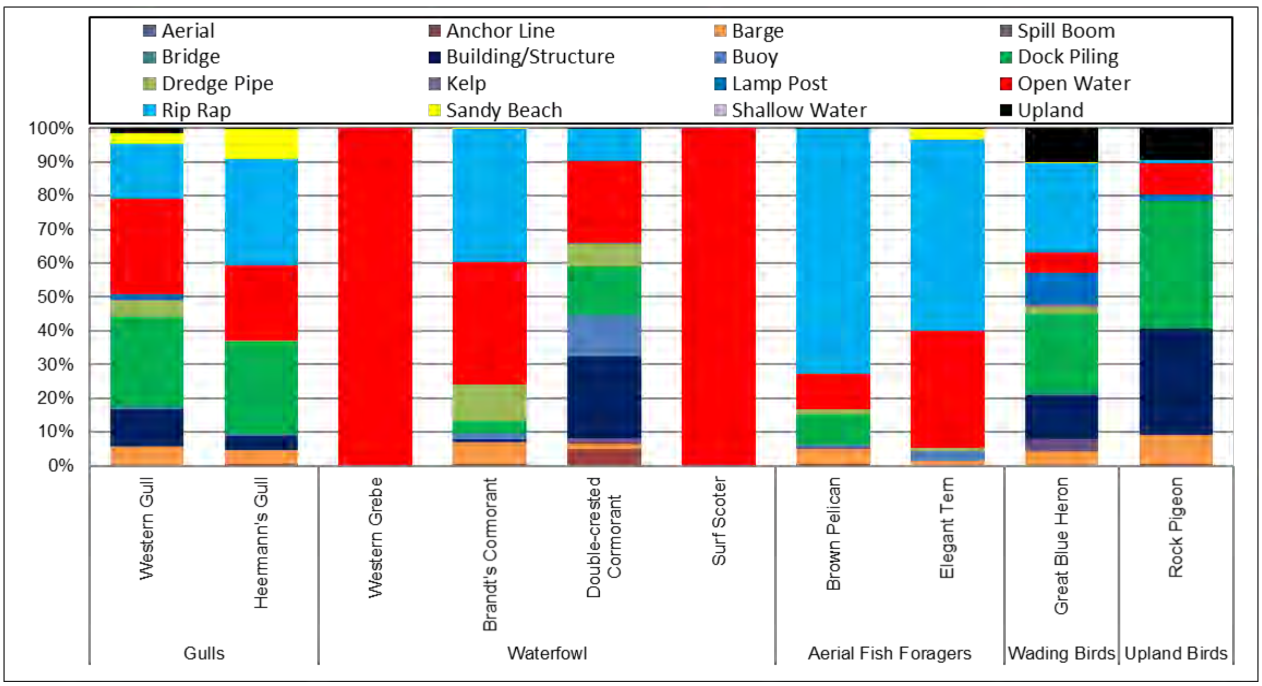


Figure 6-9. Total and Relative Abundance of the Ten Most Common Avian Species by Where They Were Observed

Avian Activity/Behavior

Bird activities were categorized into one of five categories: foraging, resting, courting, nesting, or flying. In the 2018-2019 surveys, most birds (37,914), accounting for 77.8% of total observations, were observed resting (Figure 6-10). Flying, foraging, and nesting accounted for 10.9%, 10.4%, and 0.7% of total observations, respectively. Flying birds included those traveling from one location to another. Only five species were observed courting: elegant terns performing courtship displays in Zone 1a, a single common raven (*Corvus brachyrhynchos*) presenting nesting material to its mate in Zone 23, one pair of western grebes performing their courtship dance in Zone 2b, western gull courtship activities in Zone 25c, and rock pigeon displays in multiple zones.

Nesting locations of many species are difficult to detect without a focused effort, given that they tend to be deliberately concealed from potential predators. The survey protocol of this study was not specifically designed to detect nesting, particularly given the vessel-based methodology. Nevertheless, many observations of nesting activities were noted during the 2018-2019 survey period.

Species from seven of the eight avian guilds were observed nesting within the Port Complex. Nesting activity was observed for three Upland bird species: American crow (nesting in upland habitat in Zone 23), house sparrow (*Passer domesticus*) (Zone 2b), and rock pigeon (Zones 3c and 4b). The only species of Large Shorebird observed nesting in the Port Complex was the black oystercatcher (Zone 12). No Small Shorebird nesting was documented during the survey. Western gulls were observed nesting on buildings and dock pilings in sheltered locations throughout the Port Complex (no other members of the Gull guild were observed nesting). The only nesting Waterfowl was double-crested cormorant (Zone 26a). Great blue heron was the only Wading/Marsh bird species observed nesting in the Port Complex (60 total observations in 10 different zones). A single osprey (in Zone 24b on a lamp post) was the lone Raptor species observed nesting during the 2018-2019 survey period.

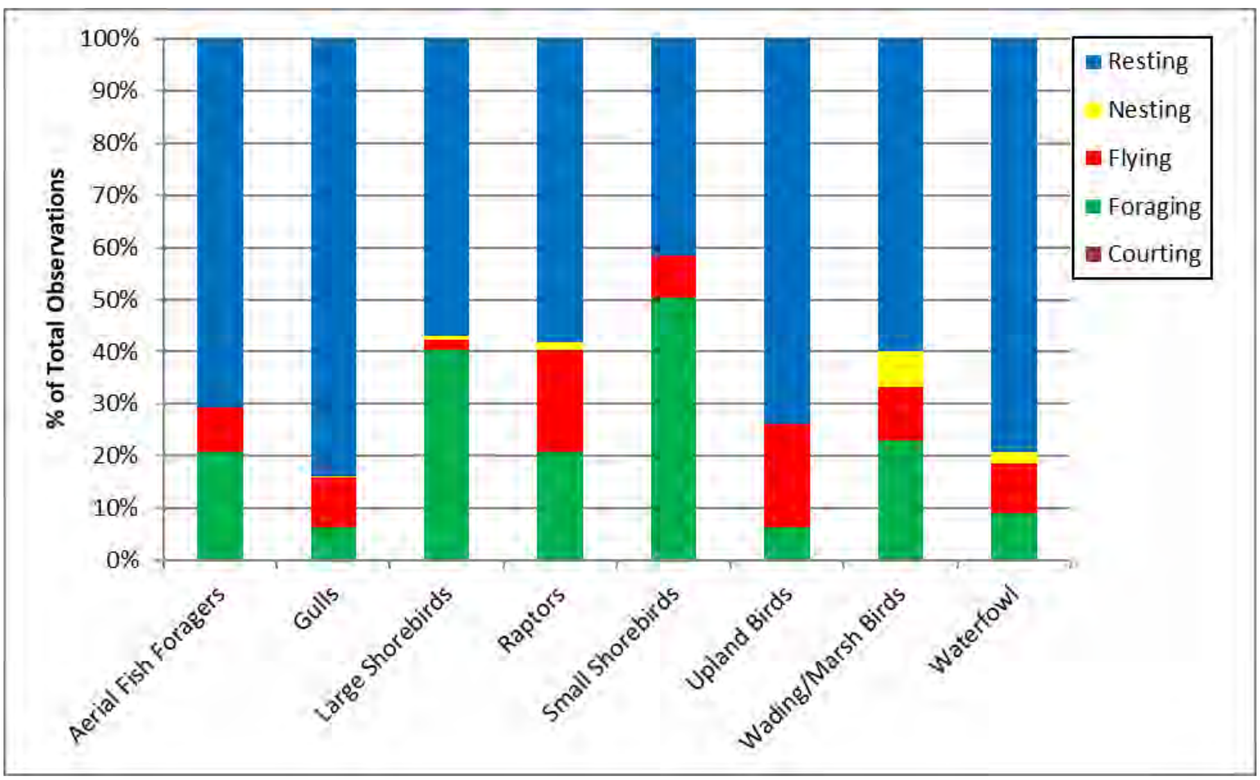


Figure 6-10. Percent of Total Abundance of Avian Guilds by Activity

6.6 Historical Comparisons

The Ports have supported a number of major avian studies over five decades dating back to at least 1973. However, many of these surveys have used different methodologies, durations and areas surveyed, and many physical changes to the Port Complex have occurred in the last 45 years. In contrast, essentially the same methodology has been used in all Biosurvey efforts (2000, 2008, 2013, and 2018), thus allowing for direct comparisons of species composition, abundance, and diversity. These four studies are the primary basis of the discussion and comparisons in the following text, as incorporating other studies with significantly different methodologies, protocols, and area covered would likely lead to inaccurate conclusions.

Abundance

Raft of foraging birds near the middle breakwater

The 2000, 2008, and 2013-2014 studies were fairly consistent in terms of species richness and abundance: 96 to 99 total species and between 47 and 50 species and 5,878 and 6,365 individuals per survey (Figure 6-11). The 2018-2019 survey effort observed a similar number of species, both total (87) and per survey (46) as in prior surveys, but total abundance (48,754) and the abundance per survey (4,063) were about one-third less than in the prior surveys, with the largest decrease being from the 2013-2014 survey (Table 6-4).

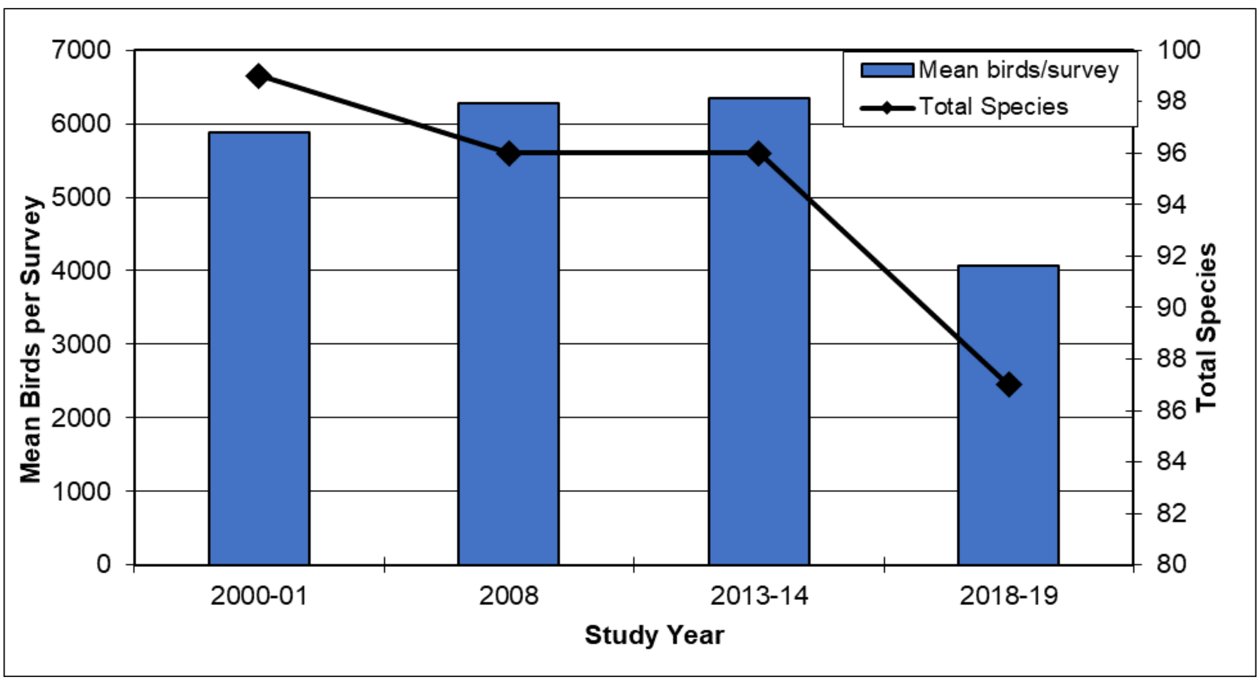


Figure 6-11. Historical Comparison of Mean Abundance and Total Number of Species Observed in the Ports of Long Beach and Los Angeles.

Table 6-4. Comparison in Avian Observations (by Guild) Between the 2013-2014 and 2018-2019 Survey Events

Avian Guild	Total Observations Survey Year		Change	
	2013-2014	2018-2019	Difference (#)	Difference (%)
Aerial Fish Foragers	16,168	8,973	-7,195	-44.5%
Gulls	29,137	18,327	-10,810	-37.1%
Large Shorebirds	389	414	25	6.4%
Raptors	34	67	33	97.1%
Small Shorebirds	651	552	-99	-15.2%
Upland Birds	5,052	5,334	282	5.6%
Wading/Marsh Birds	1,122	900	-222	-19.8%
Waterfowl	23,707	14,187	-9,520	-40.2%
Totals	76,260	48,754	-27,506	-36.1%*

*Total percentage difference of all avian observations.

The declines in abundance from the 2013-2014 study are particularly large in the three most abundant avian guilds (Gulls, Aerial Fish Foragers, and Waterfowl), averaging 41%. For the ten species that have declined the most, declines range from 12% to 94%, averaging 43% (Table 6-5). Similar population trends in these guilds have recently been documented along the western coast of North America. Unusual oceanographic conditions began to surface in late 2013 that included the beginning of a large and persistent marine heat wave (Bond et al. 2015). This feature evolved through the years from 2013 to the current survey period and has affected different parts of coastal California at different times. The marine heatwave has led to a cascade of events that saw increases (in some areas) in sea surface temperatures, declines and location shifts in forage prey base (e.g., plankton, baitfish), decreases in avian nesting success, mass avian die-offs, and increased mammal strandings and starvations (Bond et al. 2015, Peterson et al. 2017, Robinson et al. 2018, Cornwall 2019). Lastly, El Niño/Southern Oscillation phenomenon (ENSO) and marine heat waves are known to produce year-to-year variation in numbers of breeding Pacific seabirds, their productivity, their lifespan, and their behavior (Ainley et al. 1988, Hyrenbach and Veit 2003, Cavole et al. 2016, Ainley et al. 2018). Given that, a discussion of the top ten declining bird species is presented below with comparisons to regional trends.

Table 6-5. Comparison of the Ten Avian Species with the Largest Declines from 2013-2014 to 2018-2019

Species	Total Observations Survey Year		Change	
	2013-2014	2018-2019	Difference (#)	Difference (%)
California Gull	4,510	261	-4,249	-94.2%
Eared Grebe	1,454	129	-1325	-91.1%
Heermann's Gull	4,867	1,740	-3,127	-64.2%
Brown Pelican	7,320	2,780	-4,540	-62.0%
Ring-billed Gull	1,236	501	-735	-59.5%
Double-crested Cormorant	3,905	1,894	-2,011	-51.5%
Western Grebe	11,039	5,949	-5,090	-46.1%
Surf Scoter	2,535	1,490	-1,045	-41.2%
Elegant Tern	8,083	5,127	-2,956	-36.6%
Western Gull	17,961	15,810	-2,151	-12.0%
Totals	62,910	35,681	-27,229	-43.3%*

* Total percentage difference of the ten listed species.

A bay-wide avian survey in 2016-2017 in San Diego Bay noted that 14 species were at least 20% less abundant than in previous surveys and that three other species were at least 50% less abundant than in previous surveys (Tierra Data Inc. 2018).

The San Diego Bay survey saw a greater than 50% decline in the number of surf scoters counted in 2016-2017 compared to 2009-2010. That decline is comparable to the 41.2% documented for this survey event (Table 6-5) and similar to trends found throughout the Pacific Flyway that also show declines in Washington, Oregon, and California (Anderson et al., 2020). Although, a recent analysis of surf scoter numbers in San Francisco Bay (where 40-50% of the Pacific Flyway's surf scoter population occur) showed that 2018 surf scoter numbers were higher than the four previous survey years (2013-2016) combined (Strong 2019), which may indicate a shift in the wintering location from other places in Southern California, rather than a true increase in the regional population.

The brown pelican has consistently been one of the most abundant species within the Ports, never accounting for less than 9% of all birds from 2000-2014 (MEC 2002, SAIC 2010, MBC 2016), 14% during a 1986-1987 study (MEC 1988), and 15.1% during a 1983-1984 study of outer Long Beach Harbor (MBC 1984). In the current study, brown pelican accounted for just 5.7% of avian observations. Moreover, there was a 62.0% decline in brown pelican observations when compared to the previous survey in 2013-2014 (Table 6-5). The reason for that decline is unclear; however, recent collapses in nesting colonies have been documented in the Gulf of California (Anderson and Gress 2015, Anderson and Kerlin 2014) and along the California coast (Jaques 2016). Additionally, brown pelican populations are known to fluctuate when waters in the Northern Pacific become anomalous, with low productivity and near collapses in some nesting colonies and expansion and contraction of numbers in other locations (Jaques 2016).

Western grebe resting on the Open Water

In the past few decades, western grebes have declined throughout their entire range, with as much as a 50% decline in the past 20 years (LaPorte et al. 2013, Erikson et al. 2017). Despite these numbers, wintering observations along the southern coast of California have increased by 300%, which is thought to be a result of the shifting of the core population south (from the Pacific Northwest in the Salish Sea to coastal California) (Wilson et al. 2013). Authors of the study hypothesize that a shift in forage prey base from Pacific herring (*Clupea pallasii*) to Pacific sardine (*Sardinops sagax*) may be a driving factor, with birds traveling farther distances in search of more productive wintering waters. These studies indicate that declines in western grebe observations in a certain area are not necessarily indicative of a decline in the population, but rather could be due to a shift in its geographical distribution.

Populations of avian species such as Brandt's and double-crested cormorant are known to fluctuate greatly based on ocean temperature conditions, with nesting success declining during warm-water periods (Wallace and Wallace 1998, Capitolo et al. 2004, Ainley et al. 2018). Since the 2008-2009 survey period, the Brandt's cormorant nesting colony that existed in Zone 23 (West Basin) has disappeared. Nesting activity appears to have been declining since 2008-09, when as many as 215 nests were observed (SAIC 2010); the following survey (MBC 2016) yielded only six nesting birds, and the current survey saw no nesting birds. Double-crested cormorant observations in the 2018-2019 surveys were half that of the 2013-2014 study (Table 6-5). The exact reason for this decline is unclear, but the installation of bird deterrent measures where double-crested cormorants previously nested (in the transmission towers at Zone 26a) may be a contributing factor. During the 2018-2019 survey events, Southern California Edison's Transmission Tower Replacement Project installed approximately 100 large boat buoys in the transmission towers in order to discourage birds from roosting and nesting. Given that this was the only location used by double-crested cormorants for nesting within the Port Complex, as well as the birds' known nesting site fidelity, displaced birds are likely to travel outside the survey area to find alternative nesting sites. It is unknown if the birds will return to the new transmission towers to nest following the construction activities.

From the 2013-2014 study period, California, Heermann's, and western gulls saw declines of 94.2%, 64.2%, and 59.5%, respectively. Fluctuations in Gull observations are not uncommon, as numbers and concentrations are known to alter based on anthropogenic factors such as agricultural methods, pest management, and landfill practices (Burns et al. 2018). Furthermore, western gull and Heermann's gull populations are known to decline with warmer sea surface temperatures, conditions that have persisted off of coastal California since late 2013 (Pierotti and Annett 1995, Velarde and Ezcurra 2018). In recent years, California gull populations have been expanding from the main California breeding colony in Mono Lake west and south into San Francisco Bay where they are flourishing. As a result, current estimates for breeding western gull are higher than previous assessments (Doster and Shuford 2018).

The reason for the 94.2% decline observed in the Port Complex during the 2018-2019 study period is unknown, and a contrary trend was noted in San Diego Bay, where Tierra Data Inc. (2018) noted that California gull observations (16,876) in 2016-2017 more than doubled when compared to previous surveys in 2006-2007 and 2009-2010 (5,948 and 6,682, respectively).

Avian Guilds

Despite the reduced number of birds observed over the past two decades, the guild composition within the Port Complex has been relatively consistent for the past four studies (2000, 2008, 2013, and 2018), with Gulls, Waterfowl, and Aerial Fish Foragers comprising no less than 85% of total abundance across all survey years (Figure 6-13). In these four studies, Gulls have comprised a steady proportion of total abundance, ranging from 34.4% (in 2008) to 44.6% (in 2000). During this same time frame, Waterfowl accounted for between 21.4% and 38.5% of observations, and Aerial Fish Foragers accounted for between 17.5% and 22.4% of the observations. Shorebirds, Wading/Marsh Birds, and Upland species have never combined for more than 15% of total abundance, for any study period. Wading/Marsh bird observations have been consistent across survey years and have never comprised more than 1.8% of total abundance, with great-blue heron being the dominant species, across all survey years. Prior to this study, Upland birds have never accounted for more than 6.6% of total abundance. The 2018-19 survey period saw a 77.9% increase in observations of Upland species from prior surveys (from 6.24% to 11.1%, respectively), with rock pigeon and common raven observations increasing from previous studies.

Foraging shorebirds in the shallow water at Cabrillo Beach

Total abundance of Shorebirds (small and large) has been lower in every survey since 2000 (Figure 6-12). Authors of previous Port-wide assessments have hypothesized that the decrease over time may be due to tidal fluctuations at the time of surveys (SAIC 2010) or a lack of available mudflat habitat (MEC 2002), although there had been no change to mudflat habitats within the Port Complex in that time period. Numbers of Shorebirds have not declined noticeably in nearby wetland systems, such as the Bolsa Chica Wetlands, where shorebirds have consistently comprised more than 50% of total observations during annual surveys (M&A 2016). The largest area of tidal marsh/mudflat within the Port Complex (Salinas de San Pedro Wetlands) occurs near the Cabrillo Beach Launch Ramp, but that area is not included in the Port-wide biological studies. Anecdotal observations indicate that the area may harbor small populations (although sometimes in large flocks) of Shorebirds during migratory and wintering months (ebird 2019). Additionally, there are mudflat areas near the Port Complex, such as Golden Street Marine Reserve and the Los Angeles River at West Willow Street, that provide superior foraging opportunities for all Shorebirds compared to the areas currently surveyed within the Port Complex. It seems likely, therefore, that the variation between monitoring years is likely stochastic and influenced by observations of transient flocks of birds migrating or traveling to nearby foraging habitats. For example, more than 300 western sandpipers (*Calidris mauri*) were observed in 2000; however, only four individuals of this species were observed in 2008, 18 individuals were observed in 2013-2014, and only nine during the 2018-2019 surveys.

Wading/Marsh bird observations have been consistent across survey years and have never comprised more than 1.8% of total abundance, with great-blue heron being the dominant species, across all survey years.

Prior to this study, Upland birds have never accounted for more than 6.6% of total abundance. The 2018-19 survey period saw a 77.9% increase in observations of Upland species from prior surveys (from 6.24% to 11.1%, respectively).

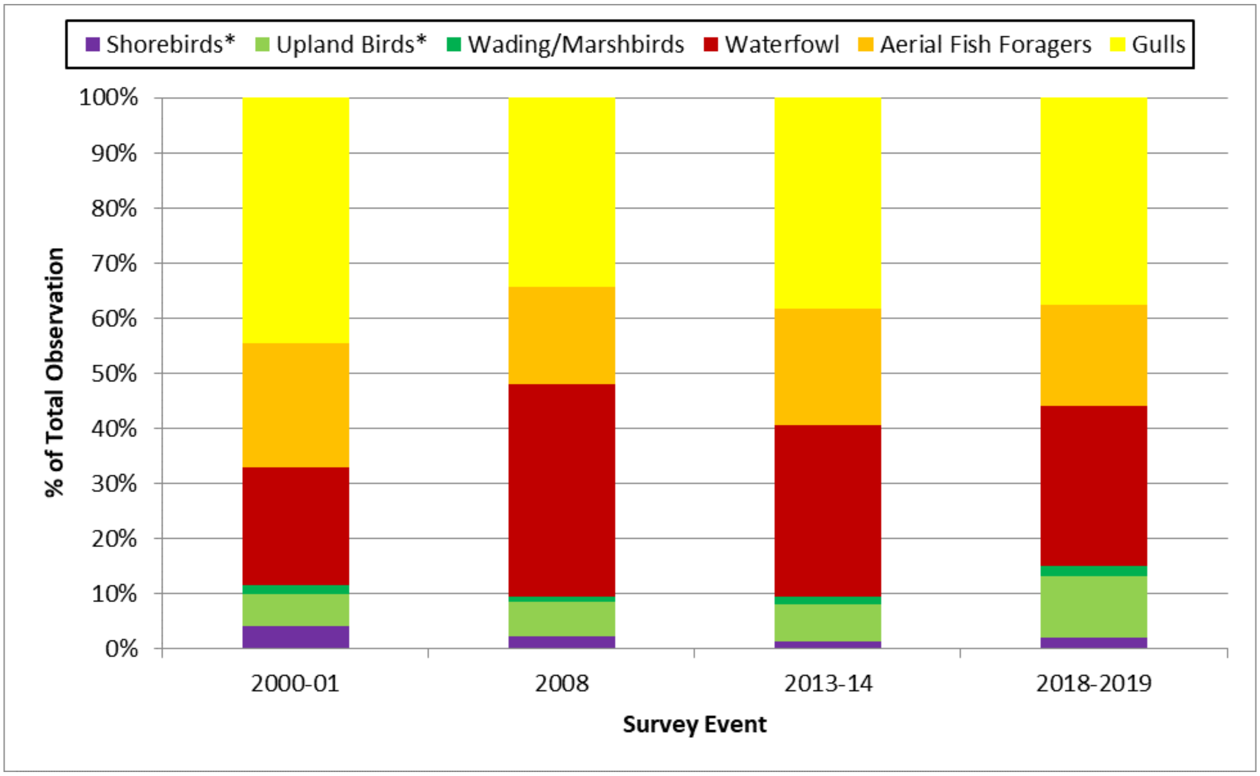


Figure 6-12. Historical Comparison of Avian Guilds in the Port Complex Based on the Percent of Observations

*small shorebirds and large shorebirds are combined to allow for inter-study comparisons. Raptors are included with upland birds.

Species Composition

Since the implementation of the current survey protocols in 2000, the assemblages of the 2018-2019 study's ten most abundant species have remained fairly consistent, and those ten species have accounted for approximately 90% of total observations during each study (Table 6-6). While the ten species have remained constant (except for the current survey, in which great blue heron replaced California gull as a top ten species), the percent composition of the ten most abundant species has been somewhat variable (Figure 6-13).

Overall, western gull has been the dominant species in recent survey years. Western grebes and elegant terns were the second and third most abundant bird species in 2013-2014 and in 2018-2019 but accounted for smaller percentages of total birds during the 2000 and 2008 studies (Table 6-6). Both Brandt's cormorant and surf scoter comprised much greater proportions of total abundance during the 2008 surveys than during the other three surveys, in which their contributions to abundance were fairly consistent.

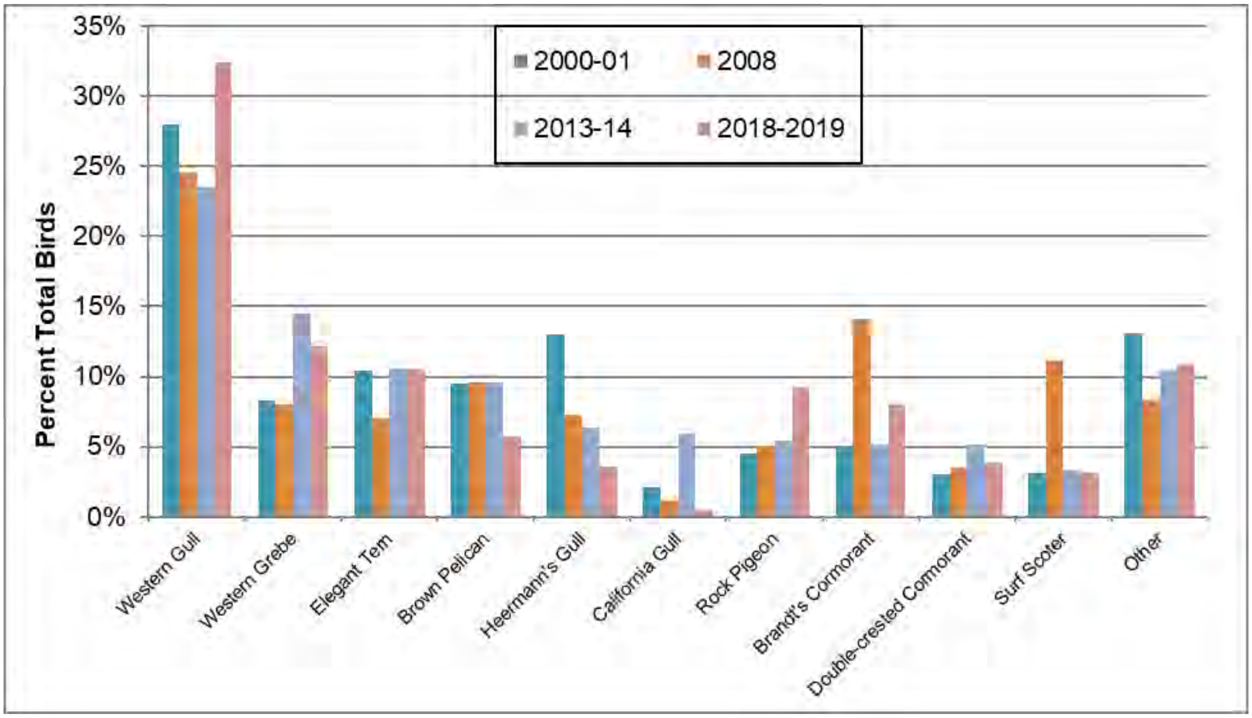


Figure 6-13. Historical Comparison of Composition of the Ten Most Abundant Avian Species in the Port Complex

Table 6-6. Historical Comparison of the Composition of the Ten Most Abundant Avian Species in the Port Complex

Species	Survey Event			
	2000-01	2008	2013-14	2018-19
Western Gull	28.0%	24.6%	23.6%	32.4%
Western Grebe	8.3%	8.0%	14.5%	12.2%
Elegant Tern	10.4%	7.0%	10.6%	10.5%
Brown Pelican	9.5%	9.6%	9.6%	5.7%
Heermann's Gull	13.0%	7.3%	6.4%	3.6%
California Gull	2.1%	1.2%	5.9%	0.5%
Rock Pigeon	4.5%	5.1%	5.4%	9.2%
Brandt's Cormorant	5.0%	14.1%	5.2%	8.0%
Double-crested Cormorant	3.0%	3.5%	5.1%	3.9%
Surf Scoter	3.1%	11.2%	3.3%	3.1%
Other	13.1%	8.4%	10.5%	10.9%

6.7 Discussion

The spatial variations documented during the 2018-2019 survey efforts were consistent with other recognized patterns from previous survey years. The zones with the most abundant bird populations have remained consistent over the past three surveys. The large, open-water zones of the Outer Harbor (Zones 10a, 22a, and 23) have historically supported, and continue to support, large rafts of foraging and resting Waterfowl dominated by western grebe, surf scoter, and several cormorant species. The zones along the Middle Breakwater (Zones 9, 12, and 15) support large flocks of roosting brown pelican, double-crested cormorant, Brandt's cormorant, and multiple gull species. Historically, these three breakwater zones have been among the most populous, and they accounted for the highest densities (birds/acre) during the 2000 study (MEC 2002); Zone 9 was the fourth most populated zone in the 2008 study (SAIC 2010) and the fifth most in 2013-2014 (MBC 2016). The POLA Main Channel (Zone 34a) and Fish Harbor (Zone 4) have historically supported large numbers of resting and foraging gulls, particularly western gull and Heermann's gull. Zone 34 was the second most populated zone in the 2008 study (SAIC 2010) and the fourth most populated zone in 2000 (MEC 2002) and 2013-2014 (MBC 2016). Finally, Zone 8a, adjacent to the tern nesting colony at Pier 400, has supported the largest number of birds for the past two survey events (MBC 2016 and current study).

For all years in which the current survey methods were employed, open water, riprap and dock/pilings have continually been the most heavily utilized physical features in the Port Complex. Across all surveys since 2000, no less than 70% of observations have occurred in these three types of features, with open water the most used feature in three of the four recent studies (it was third during the 2000 study). Riprap was the most used habitat during 2000 study, accounting for 25% of total observations (MEC 2002), and the second most used habitat in 2008, 2013-2014, and 2018-2019. These findings are not unexpected given that riprap and open water are the dominant physical features seen from the survey boats. Additionally, the majority of birds within the Port Complex were observed resting. The shoreline features (e.g., dock/piling, riprap) are extensively used by gulls, pelicans, and cormorants for resting, as well as by small and large shorebirds for resting and foraging.

Special-Status Species

Several special-status (i.e., listed by United States Fish and Wildlife Service [USFWS] or the California Department of Fish and Wildlife [CDFW]) avian species were observed within the Port Complex during the 2018-2019 surveys (Table 6-7; complete data are provided in Appendix F). Status was determined from the CDFW California Natural Diversity Database Special Animals List (CDFW 2018). Birds for which special status applies only to nesting colonies or communal roosting locations (rather than wintering or foraging areas) are included in Table 6-7 and discussed below.

Several other special-status avian species were observed within the Port Complex during the 2018-2019 surveys (Appendix F) that are protected at nesting sites but are not known to breed within the survey area. Accordingly, there is no sensitive habitat for these species in the Port Complex. They include California gull, long-billed curlew (*Numenius americanus*), whimbrel (*Numenius phaeopus*), marbled godwit (*Limosa fedoa*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), and common loon.

California least tern: The California least tern is listed as federally endangered and state endangered. This species is a spring and summer visitor to the Port Complex, where it has nested since at least 1976 (Keane Biological Consulting 1999); since 1997 the species has nested at a managed site on Pier 400 (SAIC 2010). California least terns usually arrive at the Pier 400 nesting site in early April and remain until all chicks have fledged, which can be as late as September. During the 2018-2019 survey period, California least terns were present only from April through July. Most of the birds were observed in either Zone 8a, adjacent to the Pier 400 colony, or in the shallow water habitats where they forage (Zones 2a, 3a-d, 6, and 10). During the 2018 nesting season, the nesting site monitoring effort recorded 133 nests and estimated that there were approximately 97 breeding pairs that produced 230 eggs and an estimated 69 fledglings (LBC 2019).

Peregrine falcon: Peregrine falcons were formerly listed as federally and state endangered or threatened but have since been federally de-listed, although it is still fully protected under California state law. Falcons have historically nested within the Port Complex on both the Schuyler F. Heim Bridge and the former Gerald Desmond Bridge (MEC 2002, SAIC 2010). Although no nesting was observed during the 2018-19 survey (or the 2013-2014 survey effort), one peregrine falcon was observed flying under the Gerald Desmond Bridge (Zone 25b) in April 2018. A search for a nesting location was unsuccessful, though it is known that peregrine falcons nest on the understory of the bridge. This may be related limitations of the current survey method that limit the detections of Upland and Raptor species. Additional observations of peregrine falcon were limited to a single individual flying over the tern colony at Pier 400 (Zone 8a) in May 2018 and two observations of birds resting on the riprap of the breakwaters in Zones 3a and 9 (January and February 2019, respectively).

Table 6-7. Occurrence of Special-Status Bird Species Nesting in Los Angeles-Long Beach Harbor 2018-2019

Species	Status	Zones Where Observed	Total Number Observed
California Least Tern (*Sterna antillarum browni*)	FE, SE CDFW:FP	6,7, 9, 12, 10a, 1a, 34a, 3b, 3c, 4a, 8a, 8b	90
Peregrine Falcon (*Falco peregrinus*)	Delisted CDFW:FP FWS:BCC	9, 25b, 3, 8a	4
Brown Pelican (*Pelecanus occidentalis*)	Delisted CDFW:FP	5, 6, 7, 9 11, 12, 13, 14, 15, 19, 20, 21, 23, 29, 30, 32, 33	2780
Elegant Tern (*Thalasseus elegans*)	CDFW:WL	25 of 54 Total Zones (see Appendix F)	5127
Caspian Tern (*Hydroprogne caspia*)	FWS:BCC	32 of 54 Total Zones (see Appendix F)	210
Black Skimmer (*Rhyncops niger*)	CDFW:SCC FWS:BCC	14, 19, 10a, 1a, 1b, 3b, 4a, 8a	184
Great Blue Heron (*Ardea herodias*)	CDFW:SA	All zones except 11, 14, 20,1b, 24e, and 13d	704
Black-crowned Night Heron (*Nycticorax nycticorax)*	CDFW:SA	9, 23, 30, 33, 1a, 1b, 22a, 25c, 27a, 2b, 2c, 34a, 34c, 34d, 4b	37
Double-crested Cormorant (*Phalacrocorax auritus*)	CDFW:WL	All zones except 22b and 3d	1894
Black Oystercatcher (*Haematopus palliates*)	FWS:BCC	9, 12, 15	320
Osprey (Pandion halieatus)	VDFW:WL	24 of 54 Total Zones (see Appendix F)	43

FE = Federally Endangered; SE = State of California Endangered
CDFW:FP = California Department of Fish and Wildlife - Fully Protected Species
CDFW:WL = California Department of Fish and Wildlife - Watch List
CDFW:SSC = California Department of Fish and Wildlife - Species of Special Concern
CDFW:SA = California Department of Fish and Wildlife - Special Animal, tracked by CDFW but not protected status
FWS:BCC = U.S. Department of Fish and Wildlife - Bird of Conservation Concern

Brown Pelican: The brown pelican was formerly listed as federally and state endangered or threatened, but has since been federally de-listed, although the species is still fully protected under California state law. Brown pelicans do not nest within the Port Complex; the only large nesting colonies in the western United States are located on the Channel Islands and the Los Coronados Islands (Unitt 2004); however, the Port Complex has historically provided important roosting and foraging habitat for this species, which rests on the breakwaters and forages in the protected waters of the harbor. Brown pelicans were observed in large numbers within the Port Complex during every one of 2018-19 survey days, and the species was the sixth most abundant species, accounting for 5.7% of total bird observations. Brown pelicans were least abundant in February, March, and April (52, 172, 41 individuals, respectively), when breeding birds are gathered at their nesting colonies. Abundances increased markedly after the breeding season as the birds returned from their nesting colonies and migrated northward, reaching a high of 728 individuals in July 2018. Brown pelicans were observed primarily in the Outer Harbor, with large concentrations of individuals roosting on the breakwater riprap in Zones 3a, 3b, 9, 12, and 15. Smaller numbers of birds were observed foraging and roosting in the shallow water habitats associated with Zones 2a and 6.

Elegant tern: Elegant terns have typically nested within the Port of Los Angeles on Pier 400. During the 2018-2019 surveys, elegant tern was the third most abundant avian species, accounting for 10.5% of total observations. This species was only observed from March through October, with the peak number of individuals (3,328) recorded in August. Elegant terns were most abundant in Zone 8a and other areas adjacent to Pier 300 and Pier 400 but were regularly observed foraging in the shallow water habitats at Cabrillo Beach and Seaplane Lagoon (Zones 1-3 and 5-6, respectively).

Caspian tern: Caspian terns routinely nest at the Pier 400 site. LBC (2019) estimated that 300 Caspian terns nested on Pier 400 during the 2018 nesting period. Similar to the other tern species, the Caspian tern were observed primarily from April to September (one bird was observed in November). Caspian terns were observed in 60% of the survey zones but were most abundant in Zones 6, 8a, and 1a, all of them zones associated with prior known nesting locations sites (Piers 300 and 400) and/or sandy beach roosting sites (Cabrillo Beach and Seaplane Lagoon). Abundances were highest in April (34 observations) and again in July (64 observations), which correspond to the breeding and post-breeding dispersal periods (Unitt 2004), respectively.

Black Skimmer: Black skimmers routinely nest at the Pier 400 site; LBC (2019) estimates that as many as 90 nested on Pier 400 (within the Tern Management Area West) during the 2018 season. The 2018 Biosurvey found that black skimmer populations were bimodal; observations peaked in June (40 observations), coinciding with the breeding season, and then again in September (50 observations), when birds are presumed to be migrating to their winter roosting locations. The most observations were recorded in Zone 1a (Cabrillo Beach North), accounting for 87% of total black skimmer observations. Black skimmer has historically nested at Piers 300 and 400 (MEC 2002, SAIC 2010).

Great blue heron nesting on a Port Complex structure

Great Blue Heron: Colonies of great blue heron nest in the Port Complex (MEC 2002, SAIC 2010). Great blue heron was the tenth most abundant species observed during the survey period, representing 1.4% of the total avian abundance. This resident species was observed during every survey event and was documented in 48 of the 54 survey zones. Observations of great blue heron ranged from a low of 32 in April 2018 to 74 in August 2018. During this survey period, great blue heron were observed nesting from January through August, with the greatest densities of nests near the POLA Main Channel (Zones 34a and 34e) and the Outer Navy Mole Piers area (Zones 10a and 23).

Black-crowned Night Heron: Black-crowned night heron have also historically nested at the Outer Navy Mole Pier (MEC 2002), but no nesting was observed within the Port Complex during the 2018-2019 survey period. Aside from one nest in 2002 (MBC 2007, SAIC 2010), no nesting activities have been observed in any of the subsequent survey efforts. However, black-crowned night heron have recently been observed nesting in nearby areas (not captured by current survey methods) within *Ficus* trees adjacent to the federal building on Ferry Street (SAIC 2010) and outside the official survey events in *Ficus* trees on Via Cabrillo-Marina (pers. obs. 2019). Non-nesting birds were documented in Zones 9, 23, 30, 33, 1a, 1b, 22a, 25c, 27a, 2b, 2c, 34a, 34c, 34d and 4b for a total of 37 observations.

Double-crested Cormorant: Overall, the double-crested cormorant was the seventh most abundant species observed during the 2018-2019 surveys, accounting for 3.9% of total observations. This species was regularly observed nesting in electrical transmission towers in Zone 26a from April to July. The highest number of nesting birds, 150 adults and chicks, occurred in May.

Black Oystercatcher: The black oystercatcher was the most abundant species in the Large Shorebird guild, with birds observed in every survey month, ranging from 12 individuals (November 2018) to 52 individuals (October 2018). The majority were observed in Zones 9, 12, and 15 along the Middle Breakwater, where they have been known to nest (MEC 2002, SAIC 2010). During the 2018-2019 survey period, black oystercatchers were observed nesting only in Zone 12 (POLB Middle Breakwater; two juvenile birds observed).

Osprey: Osprey was the most abundant raptor species, with birds observed during every survey event. One osprey was observed during the 2018-2019 survey nesting on a light fixture along the Pier E-D Slip (Zone 24). Since this bird was observed during the final survey (March 2019), the outcome of the nesting event is unknown.

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7.0 MARINE MAMMALS

Marine mammal surveys were conducted concurrently with the monthly avian surveys, using the same methodologies (Appendix A). Observational information recorded included species identification, location (avian survey zone), number of individuals, activity, and habitat (physical feature type). Surveys of marine mammals in the Port Complex were conducted once per month from April 2018 to March 2019 (see Appendix A for survey dates and conditions). Each survey was conducted on two consecutive days, except when rain or high winds forced rescheduling to the next appropriate date. This ensured that survey counts and species identifications were unimpeded by weather or water conditions. Each survey event commenced in the morning and continued until the survey was completed.

Survey zones were numbered from 1-15 and from 19-34; the gap in the numbering sequence (16-18) reflects changes in harbor development, including the development of the Pier 400 landfill and Pier J expansion (MEC 2002). To better quantify marine mammal usage, the 2013-2014 study implemented further divisions of some of the larger survey zones (zones 1, 2, 3, 4, 8, 10, 22, 24, 25, 26, 27, 31, and 34) into smaller subzones. For example, zone 1 and 3 were subdivided to obtain more detail in large shallow water habitats; several marinas and small slips were added to the survey as subzones; and several other zones were subdivided to allow for a separation of Inner and Outer Harbor areas. Since the 2013-2014 survey period, Zones 24c and 24d have been filled as part of POLB's the Middle Harbor Redevelopment Project, and the remaining zones 24a/24b and the base map may not be fully reflective of current conditions as the project progresses beyond 2018. These changes resulted in a total of 54 zones and sub-zones.

Pinnipeds that are commonly observed within the Port Complex include harbor seal (*Phoca vitulina*) and California sea lion (*Zalophus californianu*s). Cetaceans known to occur within the Port Complex include common bottlenose dolphin (*Tursiops truncatus)* and common dolphins (*Delphinus* spp.). The gray whale (*Eschrichtius robustus*) is a rare visitor to the Port Complex waters but is commonly observed nearshore along coastal California during migration periods. Gray whales sometimes enter harbors and embayments to forage for benthic organisms in the soft sediments.

Both pinnipeds and cetaceans primarily use the waters and structures within the Port Complex to rest and to forage. Many of these species acquire a great deal of opportunistic food at fish docks, fishing boats and the bait barge located within the sheltered waters of the Port Complex. Haul out and resting areas for pinnipeds include docks, boats/barges, and buoys. No species of pinniped or cetacean is known to breed within the Port Complex.

7.1 Results

A total of 1,015 marine mammals belonging to five species were recorded during the 12 harbor-wide surveys (Table 7-1 and Figure 7-1). Tables of species observed by survey month and survey zone are provided in Appendix A.

Harbor seals (Phoca vitulina) resting on the POLB Middle Breakwater

The most commonly observed marine mammal was the California sea lion, which accounted for 58.8% of total marine mammal observations. This species was present year-round and was typically seen resting on buoys, docks, riprap shoreline, and the bulbous bows of large container ships in the outer harbor. Sea lions were particularly abundant in the sheltered waters of Zone 23 (POLB West Basin), where 40.0% of observations occurred (Figure 7-2). California sea lions were also frequently observed foraging near bait barges and fish packing docks (located in Zones 34a and 2a), and in the wake of fishing boats entering and exiting the harbor.

Common bottlenose dolphin (Tursiops truncatus) in POLB Southeast Basin

Harbor seals accounted for 29.3% of total marine mammal observations. Harbor seals were most commonly observed resting or foraging along riprap shorelines, particularly the breakwaters of the outer harbor, with 61.7% of total observations occurring in Zone 8a (Figure 7-3).

Three species of cetaceans were observed during the current surveys. Common dolphin accounted for 7.4% of total marine mammal observations. However, this total consisted of a single observation of a pod of 75 individuals near the San Pedro Bait Barge (Zone 2a) in October 2018. In contrast, common bottlenose dolphins were observed in small groups of three to five individuals several times throughout the survey year. The species accounted for 4.2% of total marine mammal observations and occurred in both the inner and outer harbor, as well as the Shallow Water Habitats (Figure 7-4). One encounter of a gray whale occurred in April 2018 in the outer harbor of Zone 13 (Outer Pier J South).

Gray whale (Eschrichtius robustus) mother and calf near Cabrillo Beach boat launch in March 2019. Mother can be seen near the end of the riprap groin, while the calf's spout is visible behind the riprap.

Note: Observation made outside of formal marine mammal surveys and not included in observation data

Table 7-1. A Comparison of Marine Mammals Observed in the Port Complex in 2013-2014 and 2018-2019

Species	2013-2014	Percent of Total	2018-2019	Percent of Total
California Sea Lion (*Zalophus californianus*)	587	67.5%	598	58.8%
Harbor Seal (*Phoca vitulina*)	223	25.7%	298	29.3%
Common Dolphin (*Delphinus* spp.)	40	4.6%	75	7.4%
Common Bottlenose Dolphin (*Tursiops truncatus*)	18	2.1%	43	4.2%
Gray Whale (*Eschrichtius robustus*)	0	0%	1	0.1%
Unidentified Dolphin	1	0.1%	1	0.1%
Unidentified Marine Mammal*	0	0%	1	0.1%

*Only small spout was observed

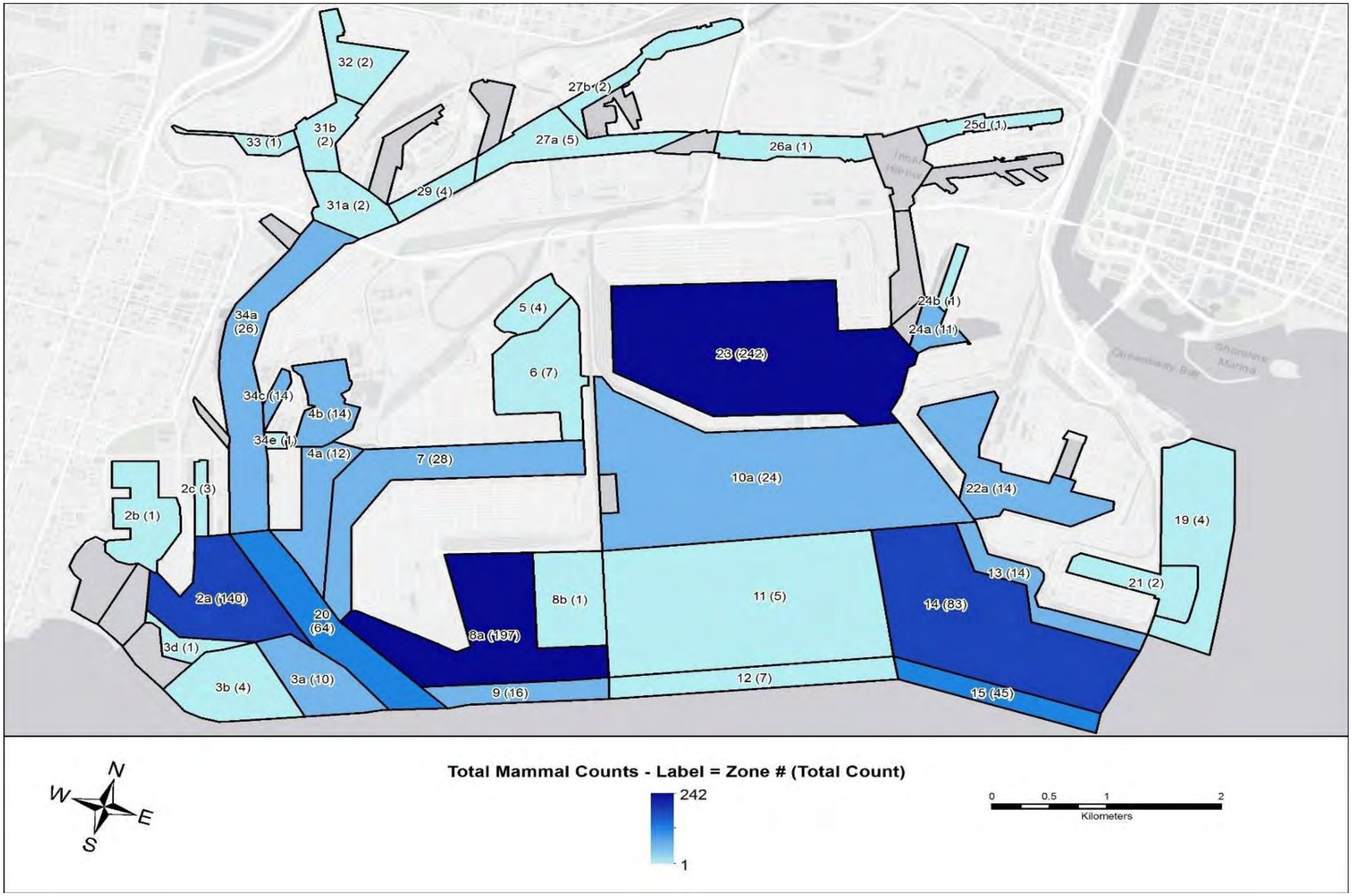

Figure 7-1. Total Abundance of Marine Mammals by Survey Zone

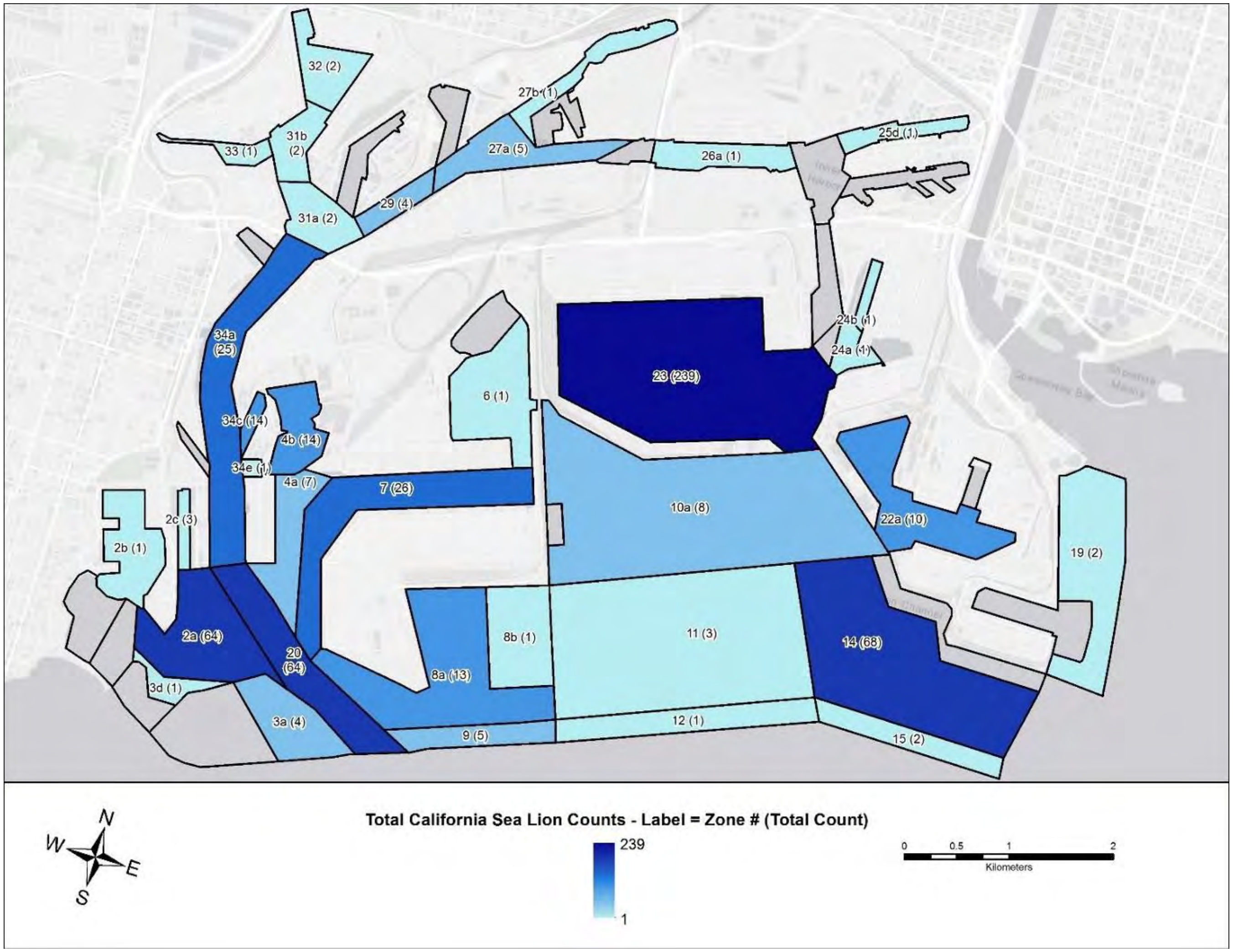

Figure 7-2. Total Counts in (Color Scale) and (Parentheses) of California Sea Lion by Survey Zone

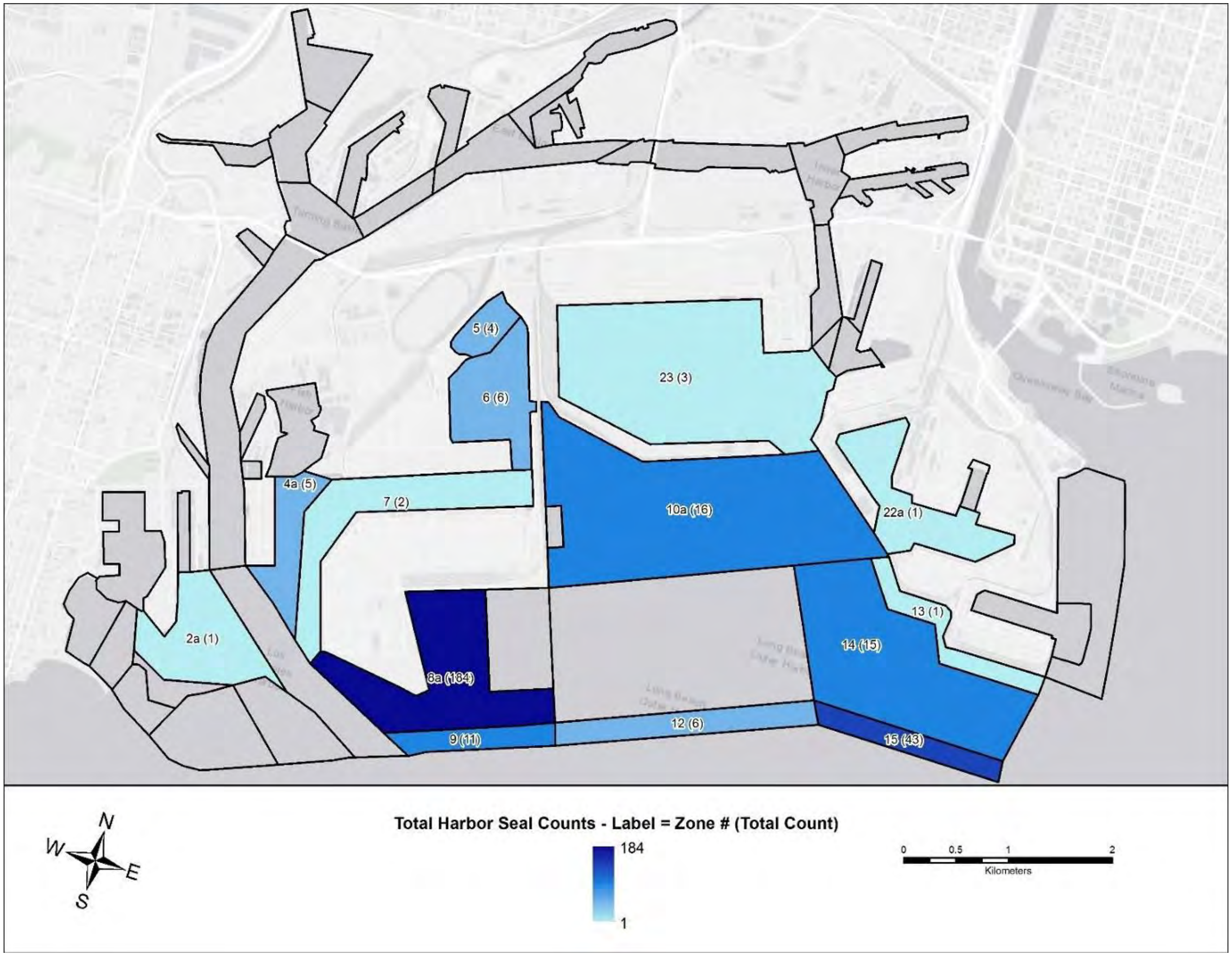

Figure 7-3. Total Counts in (Color Scale) and (Parentheses) of Harbor Seal by Survey Zone

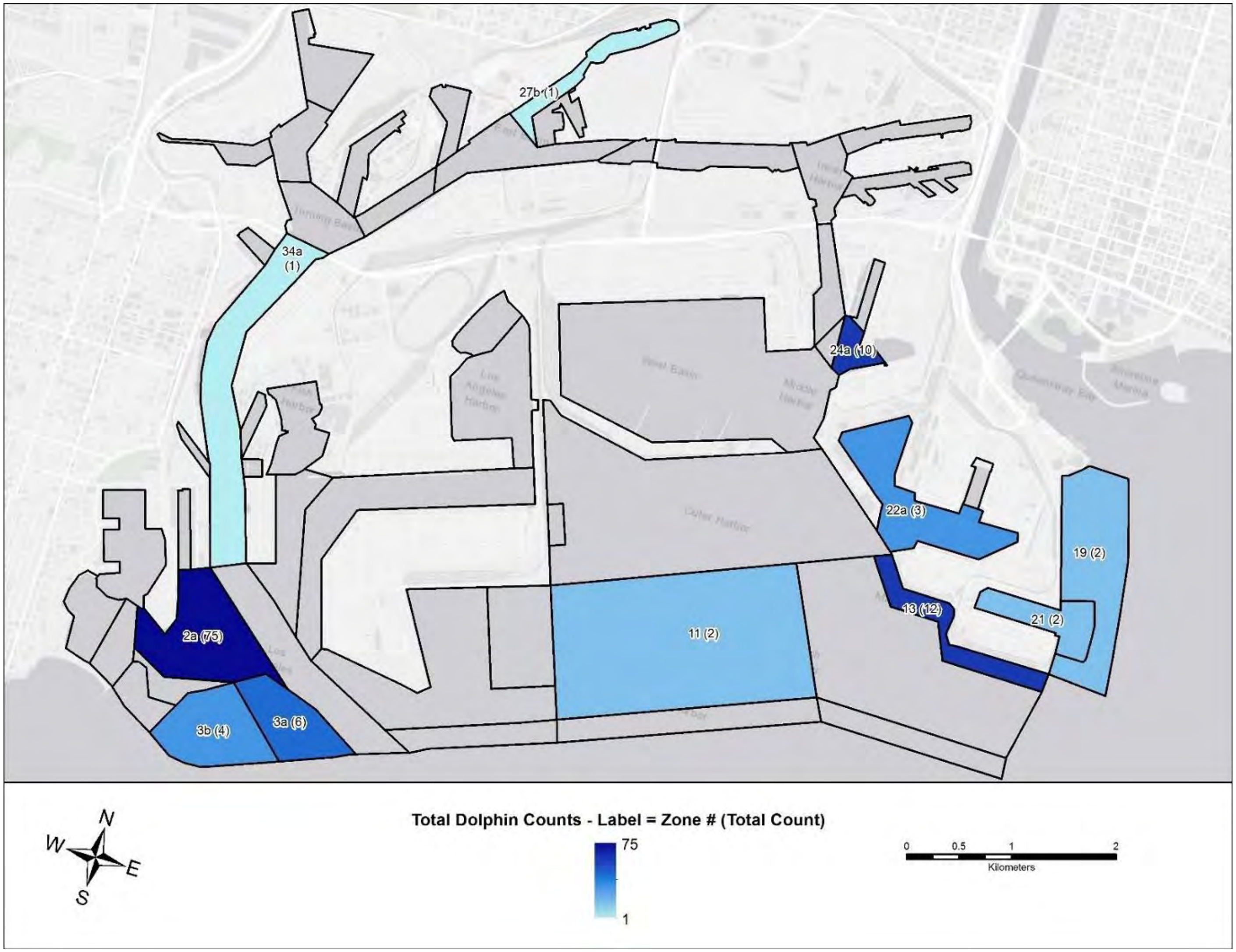

Figure 7-4. Total Counts in (Color Scale) and (Parentheses) of Common and Bottlenose Dolphin by Survey Zone

7.2 Historical Comparisons

Prior to the 2013-2014 study (MBC 2016), marine mammals were only documented as ancillary observations during avian and fish surveys, rather than as a quantitative task with an established protocol, making comparisons between the port-wide studies difficult. However, some general trends are apparent. All studies in which marine mammals were recorded have found California sea lion to be the most abundant marine mammal in the Port Complex. This species is distributed throughout the Port Complex, with higher numbers of individuals observed (1) resting on dock, buoys, boats, and barges throughout the Outer Harbor and (2) adjacent to bait barges, fishing vessels, and fish packing plants within the Port of Los Angeles. Harbor seals, in contrast, have only been observed on riprap and in waters adjacent to riprap, typically resting on the riprap or foraging in the kelp along the Outer Harbor breakwaters.

Previous studies observed small numbers of Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and gray whale within the Port Complex (USACE 1992, MEC 2002, SAIC 2010). Observations of Pacific white-sided dolphins in the Port Complex waters are rare, as these species prefer near shelf waters outside of harbors, but given the open nature of the survey area, this species could occur during any given survey, specifically from November to April when their numbers peak in coastal California. Gray whales were observed inside the breakwaters during both the present study and the 2000-2001 study (MEC 2002), but not during the 2008 or 2013-2014 studies.

7.3 Discussion

California sea lion and pup resting on a barge in POLB West Basin.

The 2013-2014 baseline study occurred during a period when sea lion strandings on the California coast were well above average (MBC 2016, NOAA 2019). From 2013 to 2017, NOAA declared an “Unusual Mortality Event” and determined that part of the cause was a change in availability and proximity of sea lion prey. A shift in the sardine spawning grounds to farther offshore in 2012 and 2013 caused sea lions to shift their forage prey base to other prey species such as squid and rockfish species that may not have provided adequate nourishment for adults and weening pups. The number of stranded sea lions during the first three months of 2015 was more than twice the number recorded during the first three months of 2013. Following the peak of stranding in 2015, stranding occurrences decreased in 2016, and in 2017, sea lion stranding returned to the pre-2013 average. Given the lack of real quantitative data from previous Port-wide studies, it is not possible to accurately determine whether sea lions in the Port Complex were more or less abundant than previous studies, or if the recent stranding events had any detrimental effects on the Port Complex sea lion population. However, the 2018-2019 study indicated a similar abundance of California sea lions compared to the 2013-2014 study.

7.4 References

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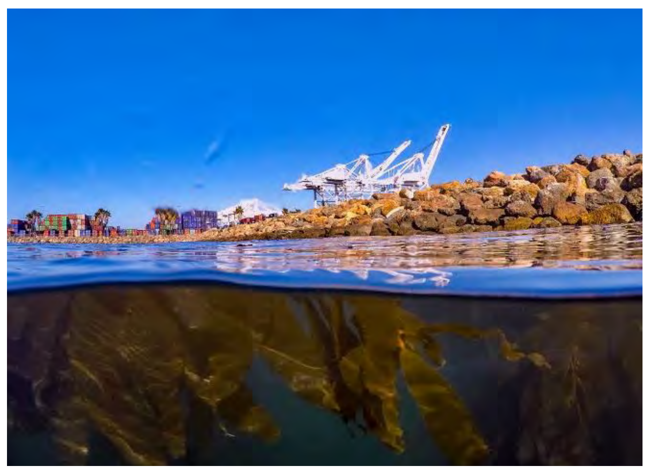
8.0 HABITAT COMPARISONS, NOTABLE TRENDS AND CONCLUSIONS

The ports of Los Angeles and Long Beach contain a wide variety of habitats supporting diverse biological communities that coexist with commercial and industrial operations in the nation's largest port complex. Biological monitoring of those habitats dates back to the 1950s with regularly-scheduled surveys of the entire Port Complex starting in 2000. The 2018 Biosurvey identified 104 species of fish (87 adult species and 17 larval taxa), 859 invertebrate taxa, 40 algae taxa, 87 species of birds (including several sensitive species), and 5 species of marine mammals totaling over 1,000 taxa living throughout the San Pedro Bay harbors, the highest diversity recorded in the four complex-wide Biosurveys conducted. Kelp survey efforts delineated more than 100 acres of kelp forest on the riprap and breakwaters in the Outer Harbor area and expanded survey methods on riprap and pilings documented species that had not been accounted for in previous surveys including garibaldi (*Hypsypops rubicundus*), horn sharks (*Heterodontus francisci*) and three species of abalone. Riprap, pier piling, and sandy bottom habitats support diverse invertebrate communities featuring burrowing species such as worms, crustaceans and clams, epifaunal species such as shrimp, crabs, and spiny lobsters (*Panulirus interruptus*). Fish populations remain abundant, with adults using the harbor area for shelter and to find food while juveniles use kelp and shallow eelgrass beds as nursery habitats.

The current Biosurvey had the same key objectives as past surveys: 1) describe how key biological community metrics vary among different habitats and sub-regions within the Port Complex, 2) how those metrics have changed over time, 3) how biological communities of the Port Complex compare to those throughout the Southern California region, and 4) how prevalent non-native species are throughout the Port Complex. The conclusions below summarize the findings of the 2018 Biosurvey in the context of the key objectives, with key summary points bulleted followed by supporting information.



Kelp near the surface at Pier J

8.1 Biological Communities Varied by Habitat Types and Depth

Observed spatial differences in biological communities were generally related to habitat type (Inner Harbor, Outer Harbor, and Shallow Water Habitat) and depth (Shallow [0-7 m], Deep [7.1-18 m], Very Deep [18+ m]) as the factors that most strongly influenced the distribution of species. Outer Harbor areas consist primarily of deeper, open water navigational areas, but also include enhanced Shallow Water Habitat areas that support eelgrass as well as kelp forest habitats along the breakwaters and riprap shorelines. Inner Harbor areas are relatively constrained and do not contain the same diversity of habitat types as seen in the Outer Harbor. This may affect the distribution of the many species that prefer habitats that rarely or never occur in the Inner Harbor areas (e.g., kelp, reef-sand interfaces, eelgrass). Soft bottom habitats and hard substrates such as riprap and pilings support diverse invertebrate communities that share some species but that, overall, have different species assemblages. Key differences in these sub-areas of the Port Complex are outlined below.

Inner vs. Outer Harbor and Habitat Types

- **Physical characteristics of the water column, such as temperature and wave energy, and of benthic habitats, such as grain size of sediments, differed between Inner and Outer Harbor habitats. Inner Harbor areas had higher average temperatures and more fine-grained sediments than the Outer Harbor.**

- **Pelagic larval and adult fish communities were more diverse in the Outer Harbor; however, there were no clear differences in abundance and biomass.**

- **Soft-bottom habitats showed significant differences between Inner and Outer Harbor Habitats for the benthic infauna, epibenthic invertebrate, and demersal fish communities. The Outer Harbor had higher species diversity, while the patterns of abundance and biomass varied by community type.**

- **Hard substrates (riprap and pilings) had consistently higher diversity, abundance, and biomass at Outer Harbor stations than at Inner Harbor stations.**

- **Kelp was only present in the Outer Harbor which likely contributed to increased diversity in those areas.**

The characteristics of the physical environment differ between Inner and Outer Harbor habitats. Water temperatures were generally higher in the Inner Harbor and sediments had higher percent fines and higher organic carbon content. These differences are consistent with the differing energy regimes of the two areas: the lower-energy environment of the Inner Harbor promotes sedimentation as opposed to Outer Harbor areas that are more affected by wave energy and wind-driven and tidal currents. The hard substrate of the riprap in the Outer Harbor usually contained more reef (>1 m in diameter) and boulders (15 cm - 1 m in diameter) than Inner Harbor areas, which had more cobble (5 - 15 cm) and more fine sediments on the surface of the rocky substrate.

In terms of species, the pelagic habitat showed little variability between the Inner and Outer Harbor areas. Larval fish species richness and diversity were greater in Outer Harbor areas, but larval fish abundance was higher in Inner Harbor areas. Adult pelagic fishes had greater species diversity in the Outer Harbor, especially the created Shallow Water Habitat areas, however abundance and biomass were highly variable and did not show clear differences between Inner and Outer Harbor areas.

Soft-bottom habitats, however, showed more distinctive differences between Inner and Outer Harbor areas. Benthic infauna species richness was higher at Outer Harbor stations, whereas Inner Harbor stations were more often dominated by only a few species in high abundance; this pattern led to higher abundance and biomass but lower diversity in these areas. Although epibenthic invertebrate species richness and diversity were higher at Inner Harbor stations and abundance and biomass were higher at Outer Harbor stations, the differences were not statistically significant. Demersal fishes had lower species richness, abundance, and biomass at Inner Harbor stations than at the Outer Harbor stations but were similar in terms of diversity

Giant kelp forming a canopy at a survey station in the Outer Harbor

index scores due to Outer Harbor stations generally being dominated by two species: white croaker and queenfish.

Hard substrates, especially riprap, differed definitively between Inner and Outer Harbor areas. Riprap in the Outer Harbor is exposed to more wave energy and was characterized by the presence of kelp and by high cover of coralline algae and abundant invertebrates such as gorgonians, snails, abalone, anemones, and lobsters. Inner Harbor riprap was more often covered with understory algae such as the non-native *Sargassum horneri* and *S. muticum*, which in the spring were present in high densities before dying back in the summer. Common invertebrates encountered on the riprap at Inner Harbor stations included bat stars (*Patiria miniata*), warty sea cucumbers (*Apostichopus parvimensis*), and a variety of snail species. There were more fish species observed on average at Outer Harbor riprap stations compared to Inner Harbor stations, which is likely in part due to the presence of kelp habitat in the Outer Harbor.

The epifauna on pilings was significantly different from that found on riprap, with pilings having higher average species richness, abundance, and biomass per unit of area. Piling communities had more molluscs, bryozoans, and chordates (tunicates), while riprap was dominated by arthropods and annelids. Differences between Inner and Outer Harbor piling stations were subtle with higher coverage by chordates and red algae at Inner Harbor piling stations and higher coverage by bryozoans, cnidarians, bivalves and invasive algae at Outer Harbor piling stations. On average, similar numbers of fish species were present at both Inner and Outer Harbor piling stations.

Benthic Infauna vs Epifaunal Invertebrate Communities

- **Invertebrate communities on riprap and pilings had higher diversity, abundance and biomass than those in soft-bottom habitats.**

- **Invertebrate communities on hard substrates differed in taxonomic composition compared to soft-bottom habitats, although there was some overlap, with nearly 10% of all species found in all three.**

Benthic infauna and epifaunal invertebrates on pilings and riprap were surveyed using similarly rigorous taxonomic methods, allowing for a detailed comparison of how similar the communities are for each type of substrate. Riprap stations sampled by quadrat scrapings catalogued a total of 459 invertebrate species, while piling stations had 412 invertebrate species. Benthic infauna sampling across spring and summer found a total of 369 invertebrate species, with a combined total of 809 taxa represented by all three habitats. Fairly distinct algal communities were observed on the riprap and pier pilings (Figure 8-1). Algal community on riprap stations (32 species) was predominantly coralline algae, while pilings (23 species) were composed predominantly of red and green algae.

As Table 8-1 and Figure 8-2 show, riprap and pier pilings had significantly higher species richness, abundance, and biomass than soft-bottom benthic habitats, although riprap and pier pilings did not differ from one another in those summary metrics. No difference was observed between any substrate type for diversity index scores.

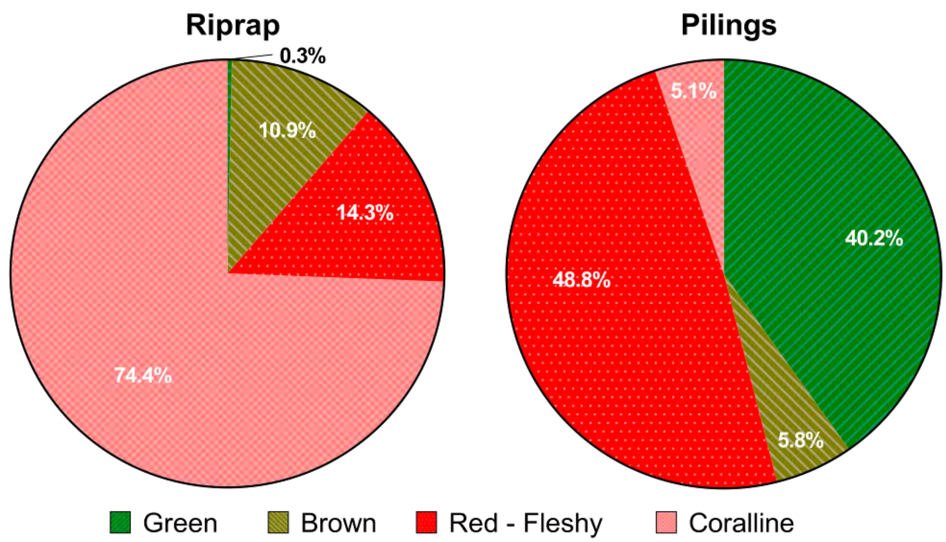


Figure 8-1. Relative Algae Biomass at Riprap and Piling Stations from Quadrat Scrapings

Table 8-1. Invertebrate Species Richness, Abundance, Biomass and Diversity in Quadrat Scrapings for Riprap, Piling and Soft-Bottom Infauna Habitat Stations

Metric	Substrate	Max	Mean	Median	Min
Species Richness	Riprap	237	160	159	98
	Pilings	231	163	155	132
	Infauna	139	80	73	43
Abundance (#/m2)	Riprap	81,244	42,274	32,519	18,904
	Pilings	119,881	67,152	63,304	30,400
	Infauna	20,870	5,136	3,205	1,590
Biomass (g/m2)	Riprap	5,154	2,758	2,666	395
	Pilings	12,184	6,191	4,804	1,238
	Infauna	326	104	72	18
Shannon-Wiener Diversity Index	Riprap	4.11	3.43	3.55	2.13
	Pilings	4.00	3.29	3.42	2.11
	Infauna	4.32	3.44	3.59	1.87

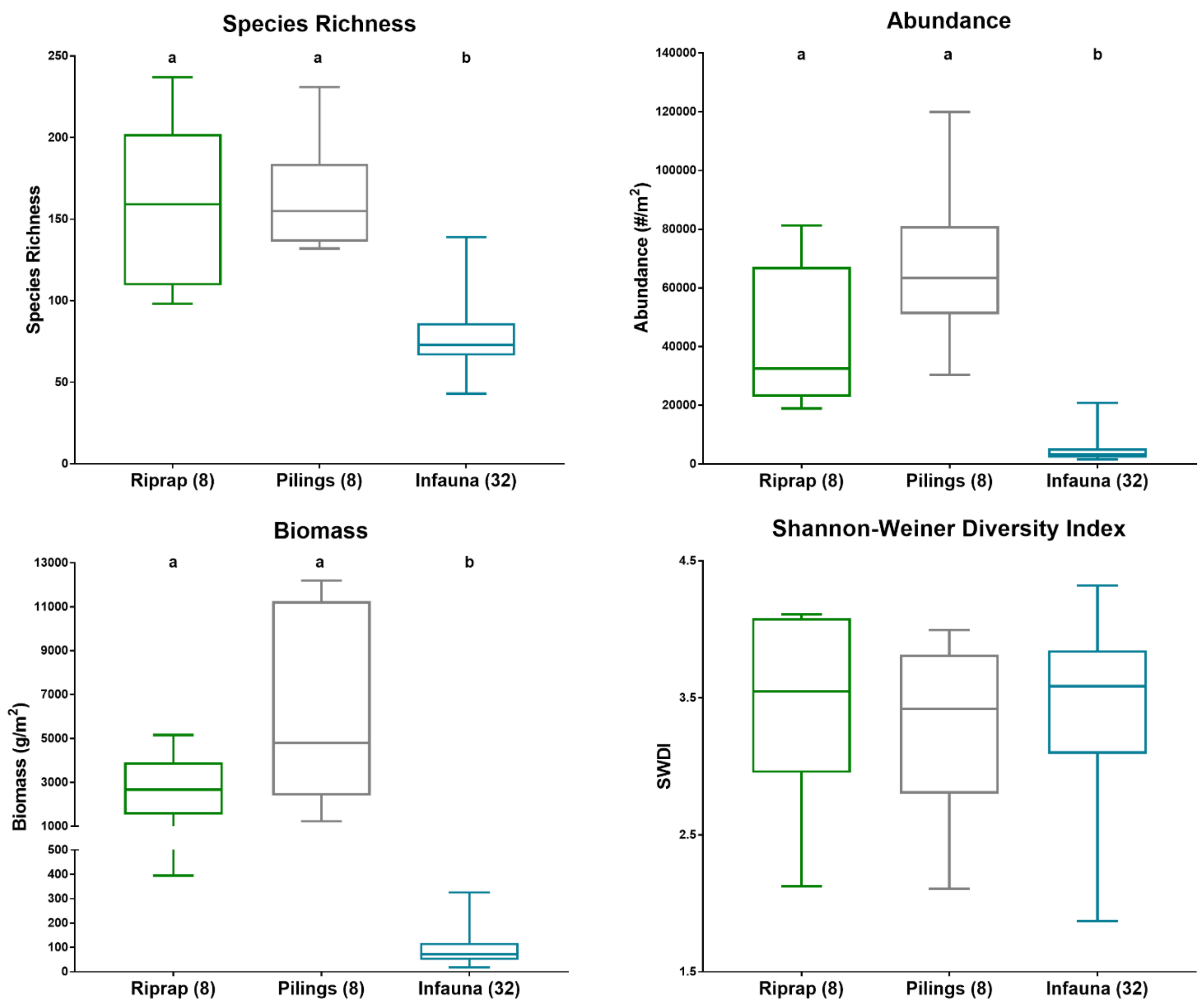


Figure 8-2. Species Richness, Abundance, Biomass and Diversity Index Values per Station for Riprap, Piling and Infauna Invertebrate Communities Sampled During 2018 Biosurvey

Note: Whiskers represent the range, the line represents the median, and the boxes represent the quartile range above and below the median. Letters above boxes indicate statistically significant differences based on Kruskall-Wallis ANOVA on square-root transformed data. Numbers in parentheses of x-axis labels represent number of stations.

Riprap and piling stations were relatively similar in terms of major phyla (Figure 8-3), both being dominated by arthropods, but soft-bottom habitats differed in that annelids were the dominant phylum. Relative biomass was similar for riprap and piling stations, with both dominated by molluscs (mostly mussels and scallops), which also happen to be exceptionally efficient at filtering large quantities of water and thrive on vertical habitats within the water column. High densities of these filter-feeding species may contribute to increased water clarity throughout the water column. Soft-bottom habitats were quite different, with biomass dominated by annelids.

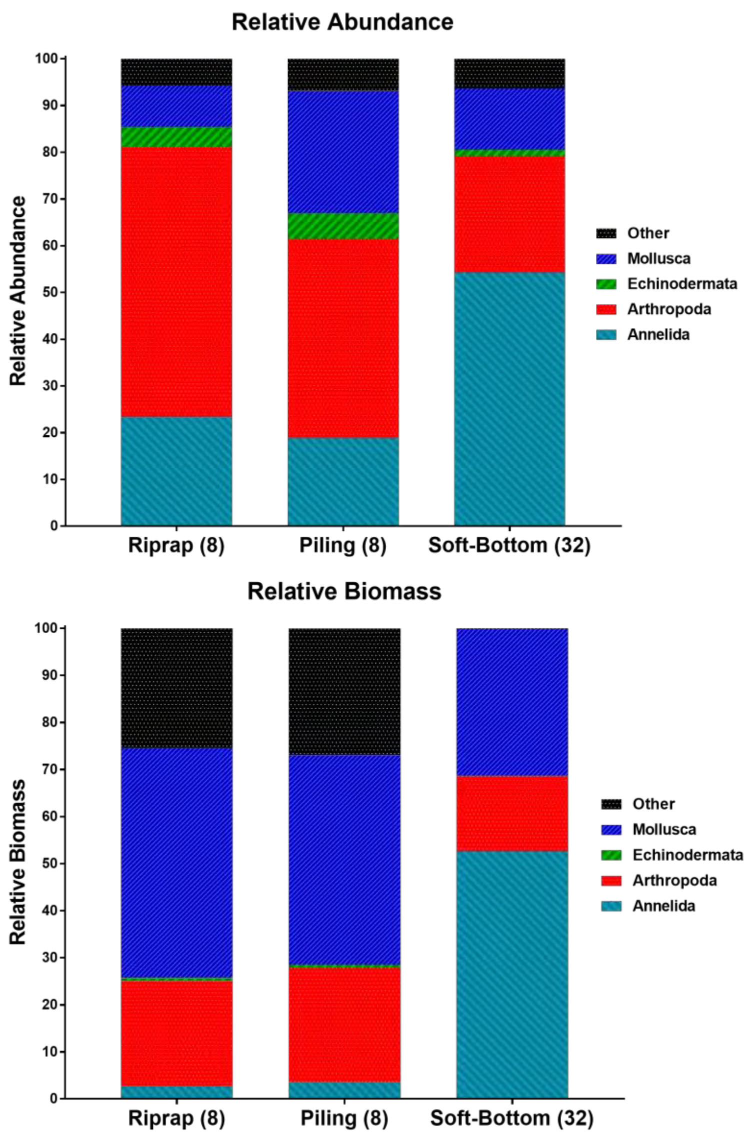


Figure 8-3. Relative Abundance and Biomass of Invertebrates by Phyla Averaged Across All Stations for Riprap, Pilings and Soft-bottom Habitats Sampled During the 2018 Biosurvey

Note: "Other" includes chordata, bryozoans, and other minor phyla. Numbers in parentheses of x-axis labels represent number of stations.

While the composition of the invertebrate community differs substantially between substrate type, there is a considerable amount of overlap in species between substrates. The combined list for riprap, pilings, and soft-bottom habitat, not including algae, contains 809 taxa (Table 8-2, Figure 8-4). The soft-bottom habitat (Infauna) had the highest proportion of species found only in that habitat type (297 species, 36.7%), while riprap and pilings shared the highest proportion of species (176 species, 21.8%). There were 78 species (9.64% of the total) that were found on all three substrate types, and an additional 50 species (6.18%) that overlapped with soft-bottom habitats and either riprap or pilings. Of the 40 algal species found on riprap and piling habitats, 15 species were found in both while riprap had more unique species (15) compared to pilings (5).

The observed invertebrate taxonomic differences between the riprap/pilings and soft-bottomed benthic substrate are not surprising given the obvious habitat differences and species preferences. The ecological functioning and value of one substrate type compared to others is not well understood and requires further study to understand impacts on an ecosystem level. However, this analysis suggests that there is some plasticity for some benthic invertebrates and the substrates they can inhabit.

Table 8-2. Invertebrate Taxa Found on Different Substrates from the 2018 Biosurvey

Substrate Type	# Taxa	% Total Taxa
Only Riprap	120	14.8
Only Pilings	88	10.9
Only Soft-Bottom	297	36.7
Pilings + Riprap	176	21.8
Riprap + Soft-Bottom	32	3.96
Pilings + Soft-Bottom	18	2.22
Pilings + Riprap + Soft-Bottom	78	9.64
Total	**809**	**100**

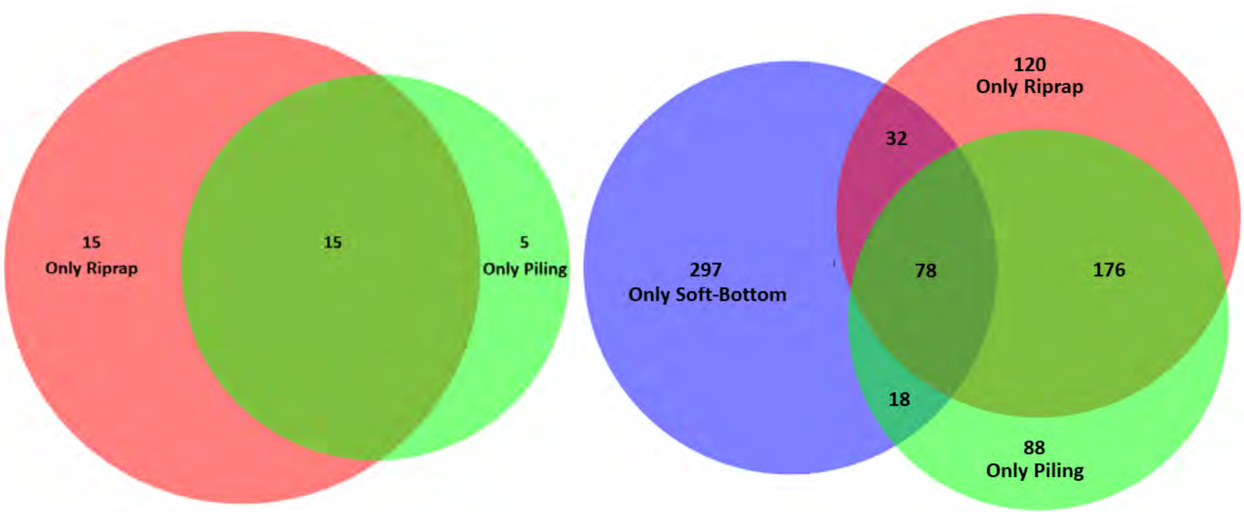


Figure 8-4. Venn Diagram of Number of Algae (left) and Invertebrate (right) Taxa Found in Soft-Bottom, Riprap and Piling Habitats

Influence of Depth on Biological Communities

- **Pelagic fishes and benthic infauna were more abundant in shallow habitats, but epibenthic invertebrates and demersal fishes had the highest abundances in very deep areas due to high densities of target shrimp, white croaker and queenfish.**

- **Northern anchovy showed a unique pattern of habitat usage during the day versus at night. During the day, anchovy shoal in dense schools in deep and very deep areas of the Port, possibly to avoid predation, while at night they return to shallow areas in loose schools, which may be in response to higher prey abundance near the surface at night.**

- **Hard substrate communities showed less diversity and abundance in the upper intertidal than in the lower intertidal and subtidal, consistent with the harsher habitat conditions in the upper intertidal.**

In addition to the variety of habitat types, Outer Harbor habitats also contain a wide range of depths. Pelagic communities such as larval and adult fishes did not show strong patterns related to depth as they are able to use the entirety of the water column and are known to migrate vertically in diurnal patterns following food. Both larval and adult fishes were more abundant at Shallow (0-7 m) stations compared to Deep (7.1-18 m) and Very Deep (18.1+ m) stations, while species richness and biomass were highly variable and had no clear pattern with depth.

Demersal invertebrate and fish communities did show patterns related to depth. Benthic infauna had higher average species richness and biomass at Very Deep stations, driven in part by a higher proportion of molluscs at these stations, but much higher average abundance at Shallow stations (driven by amphipods) than at Deep and Very Deep stations. Epibenthic invertebrate communities at Very Deep stations were commonly dominated by target shrimp in very high abundances, while Shallow stations were more diverse in their composition but lower in total abundance and biomass. Fish showed a similar pattern to epibenthic invertebrates, with Very Deep stations dominated by white croaker (*Umbrina roncador*) and queenfish (*Seriphus politus*) in high abundances with Shallow stations exhibiting a more diverse and evenly composed species assemblage with lower total abundance.

An interesting insight into diurnal habitat usage by northern anchovy (*Engraulis mordax*) in the Port Complex arose from the differences in their depth distribution and the gear type with which they were captured. Northern anchovies appear to shoal into dense schools in deeper channels in the Outer Harbor area during the day, which resulted in the largest catches of northern anchovy concentrated at a few Deep and Very Deep stations in the daytime trawls that targeted demersal fishes (75% of the 19,767 total anchovies captured across both seasons), whereas nighttime trawl catches were much smaller. Conversely, at night northern anchovy appear to migrate into shallow habitat in loose schools and were more commonly captured in nighttime lampara nets targeting pelagic fishes at numerous stations (24% of the total anchovy captured across both seasons), but especially in shallow areas with eelgrass such as Seaplane Lagoon. These patterns may reflect predator avoidance during the day by seeking deep refugia, and feeding at night by moving into shallow, plankton-rich water.

Epifaunal communities on riprap and pilings also showed significant differences in their depth distribution, with upper intertidal communities being less diverse and abundant compared to those found in lower intertidal and subtidal depths. This observation is consistent with observations of communities on rocky shores, where the upper intertidal experiences a large range of temperature and salinity conditions in addition to periodic exposure to air, which only a small subset of species such as mussels and barnacles are well adapted to manage. Subtidal areas experience more stable physical conditions and are less exposed to disturbance from weather and human activity, which allows for a more diverse community.

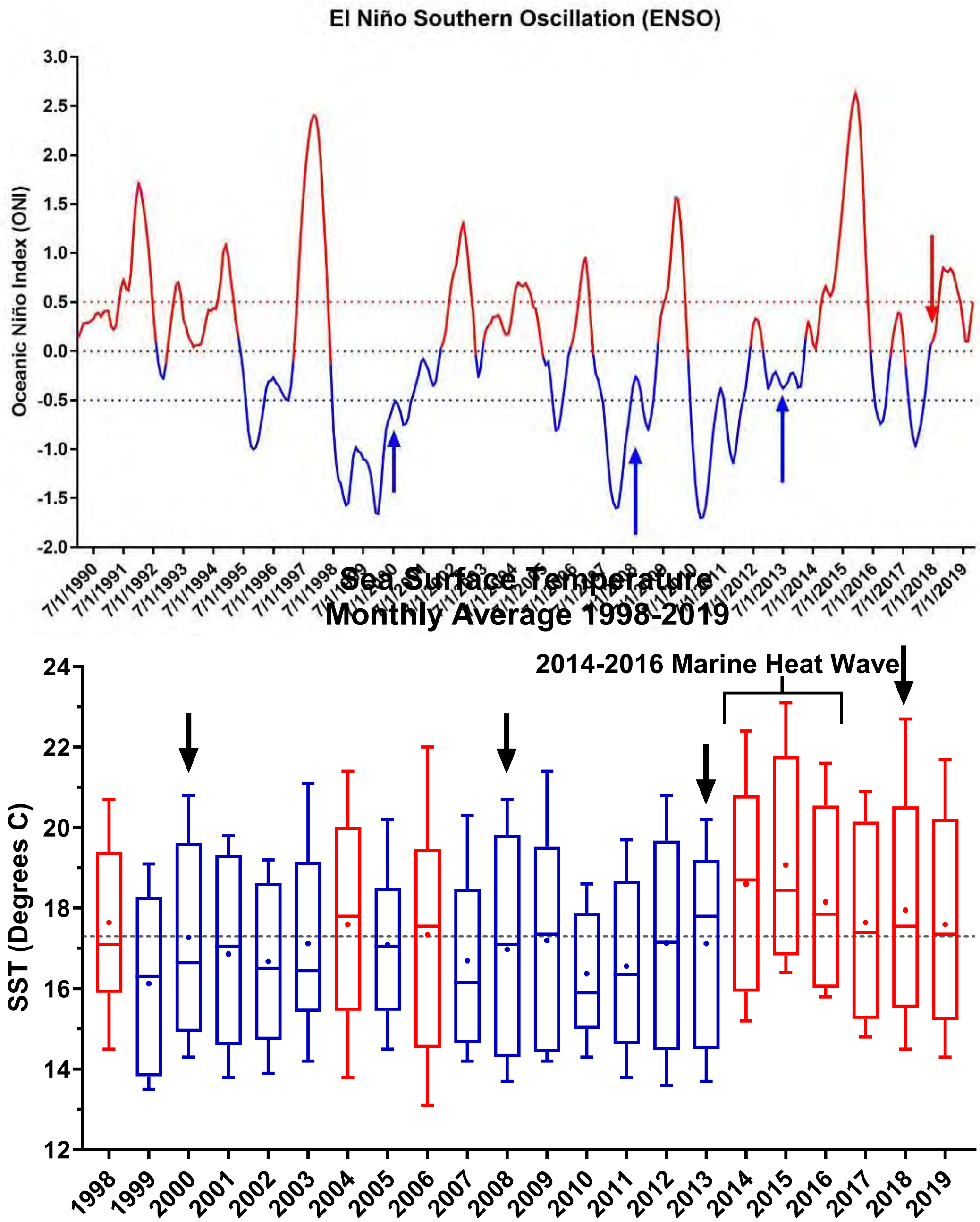
Results from this study and others highlight the importance of shallow water habitats for biological communities, providing a nursery ground for numerous fish species, as well as foraging areas for higher trophic level organisms including a variety of fish and bird species. Deep habitats are also areas that provide ample foraging opportunity and habitat for fishes and invertebrates, although these areas tend to be less diverse and dominated by only a few species.

8.2 Historical and Regional Context

Regional Climate Events

- **Unlike the previous three Biosurveys, the 2018 survey occurred when the average water temperature was above the 20-year average and followed a marine heatwave in 2014-2016.**

One of the most notable trends affecting biological communities within the Port Complex is long-term climate patterns, such as “El Niño” and “La Niña” measured by the Oceanic Niño Index (ONI), and the more recently recognized phenomenon of marine heatwaves that can evolve and persist in the Northeastern Pacific (Jacox et al. 2019). The first three Biosurveys occurred during cool periods of the ONI (Figure 8-5), while the 2018 Biosurvey was the first to occur during a warm period and followed the longest and most intense El Niño in the last 20 years. While ONI represents conditions that occur across the Pacific, local buoy data from the San Pedro Channel (Figure 8-5) show that the 2018 Biosurvey was the only one of the four Biosurveys to occur during a year in which the yearly mean exceeded the 21-year sea surface temperature (SST) average. The 2014-2016 marine heatwave can be clearly seen in the period between the 2013 and 2018 Biosurveys, with the three highest monthly mean SST in the past 20 years (22-23° C) recorded in 2014, 2015, and 2018. This heat wave is thought to have led to a cascade of events including increases (in some areas) in sea surface temperatures, declines and location shifts in forage prey base (e.g., plankton, copepods, baitfish), decreases in avian nesting success, mass avian die-offs, and increased mammal strandings and starvations (Bond et al. 2015, Peterson et al. 2017, Robinson et al. 2018, Cornwall 2019). While many species with longer life spans such as fishes and marine mammals may persist and adapt to higher temperatures, invertebrates and plankton that make up the base of the food chain are more susceptible to changing oceanographic conditions, and changes in populations of those organisms can affect higher trophic levels (Cavole et al. 2016, Jacox et al. 2019).



Data from Coastal Data Information Program, Integrative Oceanography Division, operated by the Scripps Institution of Oceanography Buoy 092 - San Pedro (Lat: 33.6179, Long: -118.317). Dotted line is average temperature from 1998 to 2019 (17.3 degrees C). Annual average temperatures below the 21-year average are denoted as blue, while annual average temperatures above the 21-year average are red. Black arrows represent the four historical Biosurvey years. Whiskers represent the min-max, the line represents the median and the dot represents the average.

Figure 8-5. Oceanic Niño Index (ODI) and Sea Surface Temperature Monthly Average 1998-2018

Warm periods are depicted by red lines and cold periods are depicted by blue lines. Historical Biosurvey sampling years are represented by arrows.

Eelgrass

- **In 2018, eelgrass occurred at somewhat greater depths, and was found in more areas of the Inner Harbor, than in previous Biosurveys. This is concurrent with a trend of improving water clarity observed during POLA's monthly WQ monitoring from 2009 to 2018.**

Over 95 percent of the eelgrass (*Zostera marina*) in the Port Complex occurs in two areas: the Pier 300 Basin and the Cabrillo Beach area. These core areas have supported the vast majority of all eelgrass throughout the last four Biosurveys. However, the 2013 and 2018 Biosurveys noted the establishment of eelgrass beds in Slip No. 1 and the expansion of beds in the East Basin yacht marinas. While changes in mapping methodologies over the past two decades limit the capacity to make robust numerical comparisons of eelgrass acreage over time, the changes in distribution throughout the Port Complex clearly point toward improving suitability of the Port Complex to support eelgrass.

An interesting observation in 2018 is that deeper margins of eelgrass were generally located in Inner Harbor areas, such as along Cerritos Channel and within marina basins, as opposed to Outer Harbor areas, which have more oceanic influence. This observation may indicate greater average water clarity in the Inner Harbor than within the Outer Harbor, which may be a factor in the recent expansion of eelgrass within the Inner Harbor areas since the 2008 Biosurvey. Similar observations of deep eelgrass beds have been made within the industrialized portions of San Diego Bay where it is believed that water clarity is enhanced by less wind-induced sediment suspension, relatively slow water turn-over (and thus continued settlement of suspended particulates), and trapping and removal of sediment particles by salps and other filter-feeders.

Benthic Infauna and Epibenthic Invertebrates

- **Species sensitive to pollution continue to become more abundant in the Port Complex, indicating the continued improvement of water and sediment quality.**

- **Continual refinement of sampling methods and inclusion of sampling in new habitats, such as concrete pilings and kelp beds, resulted in the highest diversity of invertebrates observed to date.**

The 2018 Biosurvey collected more species of benthic invertebrates, both infauna and larger epibenthic invertebrates such as shrimp and crabs than any previous Biosurvey. In recent Biosurveys, pollution intolerant (i.e., sensitive) species have become more common in the ten most abundant species in the Port Complex than in previous studies, and the pollution-sensitive amphipod *Amphideutopus oculatus* was the most abundant species in the past two Biosurveys. While some non-native species have also remained in the top ten species, they are no longer the most abundant species and not all are widespread, for example two of most abundant non-native species (the worm *Pseudopolydora paucibranchiata* and amphipod *Grandidierella japonica*) are only abundant in a few areas of the Port Complex like Cabrillo Marina, Fish Harbor and Consolidated Slip.

In 2018, epibenthic invertebrates had the highest diversity and second highest average abundance and biomass of all Biosurvey years. The target shrimp (*Sicyonia penicillata*) was first collected in the Port Complex during the 2008 Biosurvey and became the dominant epibenthic species in 2013 and 2018. This species is likely representative of long-term range shifts by species with typically southern distributions becoming more abundant at the northern end of their range, as *S. penicillata* was noted in coastal environments in the Southern California Bight for the first time in 1998 (Estrada-Ramirez and Calderon-Aguilera 2001, Montagne and Cadien 2001) and is now a dominant species in embayments and inner shelf habitats in the Southern California Bight (Wisenbaker et al. 2021).

Pelagic and Demersal Fish

- **The core community of pelagic and demersal fishes in the Port Complex has remained remarkably consistent over the past two decades, with anchovy, topsmelt, and California grunion the most common pelagic species and queenfish, white croaker, barred sand bass, and California halibut the most common demersal fish species.**
- **Regional monitoring in 2018 showed that San Pedro Bay (including the Port Complex) had roughly four times as many demersal fish species as Mission Bay and San Diego Bay**

Deploying the lampara net in POLA Main Channel

Pelagic communities have been highly variable across Biosurvey years due to occasional extremely large catches of schooling fishes such as northern anchovy. In 2018, larval and adult pelagic fish species richness was consistent with past surveys. In addition, the composition of the ten most abundant species has remained consistent across Biosurvey years, defining the core pelagic fish community consisting primarily of anchovy (Engraulidae), topsmelt (*Atherinops affinis*), and California grunion (*Leuresthes tenuis*).

Demersal fish species in soft-bottom habitats and shallow subtidal habitats have remained remarkably consistent throughout the years, including the 2018 Biosurvey, in terms of species richness and composition of the ten most abundant species. White croaker has remained the top species in terms of the Ecological Index, which balances the total abundance, total biomass, and frequency of occurrence of each species across all stations as a metric to assess how the community is structured. Queenfish (*Seriphus politus*), northern anchovy, barred sand bass (*Paralabrax nebulifer*), and California halibut (*Paralichthys californicus*) also make up the core demersal fish community across all surveys.

Regional monitoring in other Southern California embayments in 2018 using daytime benthic trawls (Wisenbaker et al. 2021) revealed that the Port Complex has the highest diversity of fishes (59 species in daytime benthic trawls only) compared with San Diego Bay (17 species) and Mission Bay (16 species). More intensive fish surveys in San Diego Bay in 2019 that sampled multiple habitat types (similar to the Biosurveys) for larval fishes and adult fishes using beach seines, fish traps, trawls, and purse seines captured a total of 45 fish species (Williams et al. 2019), which was roughly half of the 88 total fish species observed in all survey types in the Port Complex during the 2018 Biosurvey.

Riprap and Pilings

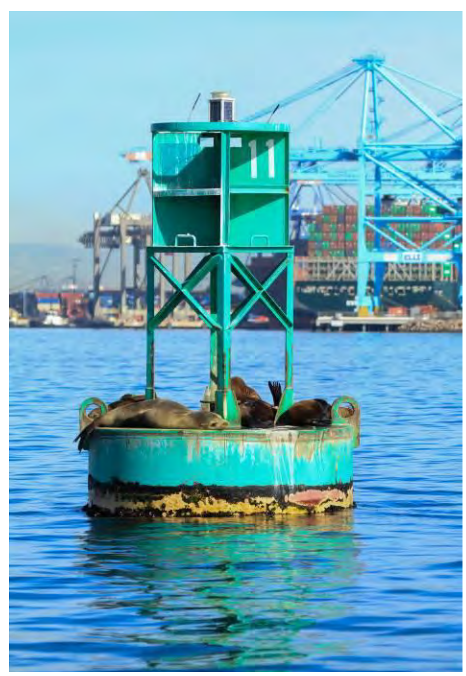
- **Survey methods were expanded in 2018 to include concrete pilings as well as riprap, and quadrat and visual surveys on these habitats resulted in the highest diversity recorded of any Biosurvey to date.**
- **Nine species of fish typically associated with hard substrates were catalogued for the first time as part of the Biosurveys, including garibaldi, sheephead, horn shark, and moray eel.**

Riprap habitats have continued to support canopy-forming kelps (*Macrocystis pyrifera* and to a lesser extent *Egregia menziesii*), with the second largest spring canopy (118 acres) and the largest summer canopy (114 acres) across the last four Biosurveys as measured by aerial imagery. The 2018 Biosurvey was the first to characterize large invertebrates in these habitats in addition to macroalgae, and the first to sample concrete pilings. Between riprap and piling habitats, over 500 species of invertebrates and 40 species of algae, the highest species richness on these habitats of any Biosurvey year to date, were identified through quadrat scrapings and visual surveys. Fish present at riprap and piling stations were recorded for the first time during the 2018 Biosurvey, and 9 reef-associated fish species were noted for the first time, including garibaldi, sheephead (*Semicossyphus pulcher*), horn shark, and moray eel (*Gymnothorax mordax*). Kelp bass (*Paralabrax clathratus*), barred sand bass, black surfperch (*Embiotoca jacksoni*), and opaleye (*Girella nigricans*) were the most commonly observed species within these habitats.

Birds and Marine Mammals

- **The ten most abundant bird species have remained consistent over all Biosurvey years and have typically accounted for approximately 90% of the total observations.**
- **Warmer waters along the West Coast may have contributed to a 10-12% decrease in the number of bird species (87) and about a one-third decrease in their abundance in 2018 compared to previous Biosurveys.**

Western gulls (*Larus occidentalis*) were the most abundant in 2018, followed by western grebes (*Aechmophorus occidentalis*) and elegant terns (*Thalasseus elegans*). However, the 2018 Biosurvey did see a decline in total species (87, down from 96-99 in previous surveys) and a roughly 33% decline in the average abundance of birds per monthly survey. The large and persistent marine described above may have contributed to these declines, as El Niño/Southern Oscillation phenomenon (ENSO) and marine heatwaves are known to produce year-to-year variation in numbers of breeding Pacific seabirds, their productivity, their lifespan, and their behavior (Hyrenbach and Veit 2003, Cavole et al. 2016, Ainley et al. 2018).



Sea lions in the Outer Harbor

Marine mammals have only been quantified since 2013, with previous surveys only recording them as ancillary observations during bird surveys. California sea lions

(*Zalophus californianus*) have consistently been the most abundant species within the Port Complex, followed by harbor seals (*Phoca vituline*), common dolphins (*Delphinus delphis*), and bottlenose dolphins (*Tursiops truncates*). While not year-round visitors, during their migratory period in the spring gray whales (*Eschrichtius robustus*) have occasionally been observed in Outer Harbor areas.

While regional climate patterns have resulted in shifts in some communities as noted above, the biological communities surveyed in the 2018 Biosurvey continue to thrive in conjunction with the operation of the nation's largest port complex. Long-term monitoring dating back to the 1950's documents the improvement over the last 40 years in response to federal and state regulatory programs and the environmental initiatives of the two ports.

8.3 Managed and Other Special-Status Species

Fish

- **Northern anchovy, Pacific sardine, jack mackerel, and Pacific mackerel use the Port Complex as nursery habitat before moving offshore as adults. These are the only species managed under the Coastal Pelagic Species Fishery Management Plan found in the Port Complex.**

- **Species managed under the Pacific Coast Groundfish Fishery Management Plan are not abundant in the Port Complex, and many are only observed in Outer Harbor areas near eelgrass and kelp beds.**

Thirteen managed species were captured during the 2018 Biosurvey, including four fish species under the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP), eight species under the Pacific Coast Groundfish (PCG) FMP, and one other protected species. Of the four CPS FMP species, only northern anchovy appear to use the Port Complex during both the day and night, as Pacific sardine (*Sardinops sagax*), jack mackerel (*Trachurus symmetricus*), and Pacific mackerel (*Scomber japonicus*) were captured almost exclusively at night. These pelagic species appear to use the Port Complex as a nursery habitat before larger individuals move offshore, as published length at maturity data indicate that the majority of fish captured for all four species were juveniles.

California scorpionfish in POLA Main Channel

The eight PCG FMP species were not abundant: only fifty individuals of the most abundant species, California scorpionfish (*Scorpaena guttata*), were captured over both seasons. No more than eleven individuals of any other species were captured, and four species were represented by only a single individual. Length at maturity information available that at least some of these species are utilizing the Port Complex as nursery habitat and based on their location of capture it appears they favor Outer Harbor areas near eelgrass and kelp beds.

Giant sea bass (*Stereolepis gigas*) have been protected since 1982, when both commercial and sport fishing of the species was banned. Giant sea bass were first recorded in the Port complex in 2013 with two individuals captured during trawls, and one small individual was captured during the 2018 trawl sampling.

Invertebrates

- **New survey methods on riprap documented the presence of pink, green and the endanged white abalone in the Port Complex for the first time. Approximately half were mature adults, suggesting that populations have likely been present for decades and actively recruit to these habitats.**

This is the first Biosurvey in which green (*Haliotis fulgens*), pink (*H. corrugata*) and white abalone (*H. sorenseni*, an endangered species) have been documented and quantified within the Port Complex. Pink abalone were present in densities similar to densities elsewhere in Southern California (Coates et al. 2014), but neither pink nor green abalone were present in densities meeting CDFW's targets for population recovery (CDFW 2005). However, the numerous small and large empty abalone shells that were noted suggest that there is active recruitment to, and predation upon, populations of green and pink abalone in the Port Complex. Size at maturity data suggest that approximately 50% of the green abalone and 66% of the pink abalone observed in the Port Complex were mature adults. As these species can live to be 30 years old, it is likely that abalone populations have existed in the Port Complex for decades, and the new survey methods employed during this survey allowed for the first detailed survey of their population.

White abalone (Haliotis sorenseni) in the Outer Harbor

Because only a single white abalone individual was found in the Port Complex, it is not possible to conclude that there is a breeding population in the Port Complex. However, as described in Chapter 5, the ongoing captive breeding program is attempting to restore wild populations in the San Pedro Bay region (CDFW 2019), which could lead to a breeding population in the Port Complex in the future.

Birds

- **Three of the ten most abundant bird species observed in the 2013 and 2018 Biosurveys are special-status, indicating the importance of the Port Complex to these protected species.**

Eleven special-status (i.e., listed by United States Fish and Wildlife Service (USFWS) or the CDFW) bird species were observed within the Port Complex during the 2018 Biosurvey. Three of the special-status species (brown pelican [*Pelecanus occidentalis*], elegant tern [*Thalasseus elegans*], double-crested cormorant [*Phalacrocorax auratus*]) were among the ten most abundant species in the 2013 and 2018 Biosurveys and have been consistently abundant in earlier surveys. The persistence of these species over time, and the numbers of special-status birds observed, indicates that the Port Complex provides important foraging and roosting opportunities for these species. Notably, the Pier 400 site provides an important nesting opportunity for all three special-status tern species (elegant tern, California least tern [*Sterna antillarum browni*] and Caspian tern [*Hydroprogne caspia*]), which have nested at the site every year since the Biosurveys began, and the breakwaters have consistently supported large numbers of foraging brown pelicans and black oystercatchers (*Haematopus palliates*).

8.4 Non-Native Species

- **Of the 1,003 invertebrate, algae and fish taxa observed in 2018, 46 (4.6%) were non-native species. This is an increase from 27 observed in 2013, although the increase may be in part due to the inclusion of new habitats in 2018.**

- **Riprap, piling and soft-bottom habitats were similar in their proportion of non-native species (4-6% of all species) .**

- **The relative abundance of non-native species was higher in soft-bottom habitats (18%) than in riprap and piling habitats (8-9%).**

- **It does not appear that non-native species are displacing native species within the Port Complex, given the high diversity and abundance of fish, invertebrates and algae across the habitats examined and the similar proportion of non-native species across survey years.**

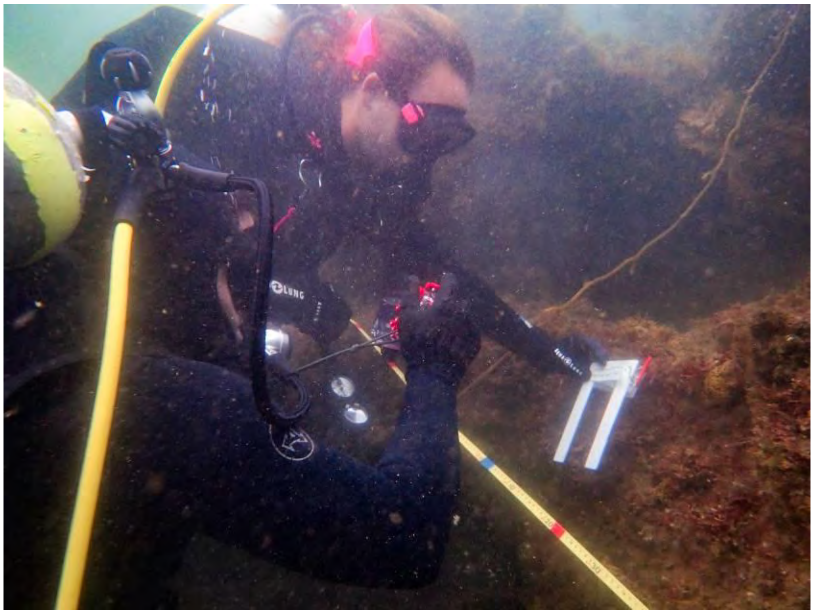
Epifaunal community on concrete piling

In total, 46 non-native species were identified in the current study (Table 8-3), which is an increase over the 27 species observed in 2013, 19 species in 2008 and 25 species in 2000. Accordingly, non-native species comprise 4.6% of the 1,003 invertebrate, algae, and fish taxa documented in the Port Complex in the 2018 Biosurvey. While the total non-native species in the 2018 survey appears to be a marked increase in the number of non-native species, the design of the Biosurveys is to sample biodiversity across a variety of representative habitats and is not a targeted survey for non-native species. The expanded methods and habitat types surveyed in 2018 may have contributed to the increase in non-native species detected, in addition to the possibility of climate-mediated change in invertebrate communities resulting in new species appearing in new locations as their range expands with increasing water temperatures and events like marine heatwaves (Weiskopf et al. 2020, Pinsky et al. 2020, Lonhart et al. 2019). Many of the non-native species observed for the first time in the 2018 Biosurvey were represented by only a few individuals, and while it is not clear if these are the result of range shifts or introductions through other notable vectors of non-native species introduction such as ballast water or recreational vessel activity (Lonhart et al. 2019), further monitoring will be required to determine their persistence and effect on native species.

The majority of non-native species, and all of the species not observed in previous Biosurveys, were invertebrates, as discussed below. The number of non-native fish species has remained consistent across the past four Biosurveys, with only two species (yellowfin goby [*Acanthogobius flavimanus*] captured in trawl sampling and a tripletooth goby species *Tridentiger* sp., most likely *T. trigonocephalus* [chameleon goby] captured in ichthyoplankton sampling) have been observed in all four Biosurveys captured in the ichthyoplankton and in benthic trawls and are the only non-native fish species captured to date. The non-native macroalgae, namely *Sargassum horneri*, *Sargassum muticum*, and *Undaria pinnatifida*, have been present on riprap and pilings throughout the Port Complex in all four Biosurveys, with highest densities at Inner Harbor areas.

Table 8-3. Number of Non-Native Species by Community Type in 2018

Phyla		# Non-Native Species	Ichthyo-plankton	Demersal Fishes	Epibenthic Invert-ebrates	Benthic Infauna	Riprap Epifauna	Piling Epifauna
Chordates	Fishes	2	2	1				
	Sea Squirts	12			2	2	8	12
Invertebrates	Annelids	4				2	4	4
	Arthropods	12			1	7	6	7
	Bryozoa	4			1	1	2	2
	Cnidaria	2				2		
	Mollusca	7			3	5	3	2
Macroalgae	Ochrophyta	3					3	2
Totals		46	2	1	7	19	25	28



Divers photographing a quadrat on riprap prior to collection

The Biosurveys have been monitoring infauna and riprap communities since 2000, and concrete pilings were surveyed for the first time in 2018. From these samples, the total number of taxa, number of non-native and cryptogenic species, and relative abundance of non-native and cryptogenic species can be compared against other studies in the Port Complex and in the region (Tables 8-4 and 8-5). The list of cryptogenic species from CDFW (2014) was used for this assessment because of its similarity of methodology with the Biosurveys. The percent of non-native benthic infauna species in the Port Complex has ranged from 2.2% to 5.2%, which is lower than Ranasinghe et al. (2005) observed in 1998 while the relative abundance of non-natives is within the range observed across all harbors in 1998. From 2000 to 2018, the proportion of non-native species in riprap communities ranged between 2% and 5%, while those on pier pilings had 6% non-native species, which put them in the low range for all areas in Southern California surveyed in 2011 (CDFW 2014). It should be noted that the 2011 survey combined both benthic infauna and epifauna growing on artificial substrates for their calculations. For the 2018 Biosurvey data, combining invertebrates and algae in benthic infauna with riprap and piling communities sampled with quadrats resulted in a total of 844 taxa and 39 non-native species (4.6%), which is similar to the percentage observed in Avalon Harbor (4.5%). Not all artificial habitats were sampled during the Biosurvey as was done in other studies (Cohen et al. 2005, CDFW 2014), meaning that the presence of some non-native species could have been underestimated if those species preferentially settle on one substrate type over another.

Of the habitats quantitatively surveyed with quadrat scrapings and benthic grabs during the 2018 Biosurvey, riprap had the lowest percent of non-native species (4.9%) while pilings had the highest (6.2%; Table 8-5 and 8-6). Note that a species observed by divers on pilings and riprap (the algae *Undaria pinnatifida*) was not included in this analysis as it was observed during visual diver surveys and not captured in quadrat scrapings. In terms of relative abundance, however, riprap and pilings were similar (8.1% and 8.8%, respectively) and less than half of the relative abundance of non-natives in soft-bottom habitats (18.0%). The Biosurveys have also identified a number of cryptogenic (i.e., of uncertain origin) species; these appear not to have changed substantially over the course of the Biosurveys. Benthic infauna had the highest percentage of cryptogenic species (11.7%) and relative abundance of cryptogenic species (9.1%), while pilings and riprap had a considerably lower number of cryptogenic species. However, piling and riprap had considerably higher abundance, meaning that although there are relatively fewer cryptogenic species on hard substrates than in soft-bottom habitats, they are present in greater abundances.

Table 8-4. Non-Native and Cryptogenic Species Richness and Dominance in Benthic Infauna Communities Sampled During Biological Surveys of the Ports of Los Angeles and Long Beach

Benthic Infauna	2000	2008	2013	2018
Species Richness	361	258	344	369
# Non-Native Species	8	9	8	19
% Species Non-Native	2.22	3.49	2.33	5.15
% Abundance Non-Native	30.6	15.8	12.5	18.0
# Cryptogenic Species	40	33	39	43
% Species Cryptogenic	11.1	12.8	11.3	11.7
% Abundance Cryptogenic	6.7	16.0	16.9	9.07

Table 8-5. Non-Native and Cryptogenic Species Richness and Dominance in Epifaunal Communities Sampled During Quadrat Scrapings Biological Surveys of the Ports of Los Angeles and Long Beach

Marine Growth Community	Riprap				Pilings
	2000	2008	2013	2018	2018
Species Richness	238	211	352	491	435
# Non-Native Species	5	7	12	24	27
% Species Non-Native	2.1	3.32	3.41	4.89	6.21
% Abundance Non-Native	7.45	6.07	14.9	8.12	8.85
# Cryptogenic Species	25	26	35	21	24
% Species Cryptogenic	10.5	12.3	9.94	4.28	5.52
% Abundance Cryptogenic	2.37	15.6	11.3	17.4	17.0

Note: the non-native algae *Undaria pinnatifida* not included here because not captured in quadrats

The 2018 Biosurvey soft-bottom, riprap, and piling community results suggest that these different habitats offer different opportunities to non-native species. Riprap and pilings are more heterogeneous and extend through the water column, exposing their communities to a range of abiotic conditions that are conducive to more total species, whereas the more homogenous soft-bottom habitat offers a narrower range of abiotic conditions. Soft-bottom habitats support greater relative abundances of non-native species, which could be a result of a few species that become very abundant and modify the substrate to be more conducive to larger populations of that particular species (Ranasinghe et al. 2015).

While non-native and cryptogenic species are present in most anthropogenically influenced coastal habitats in Southern California, it does not appear that they are outright displacing native species within the Port Complex, as the diversity and abundance of fish, invertebrates and algae has remained high across the habitats examined in this study.

8.5 References

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