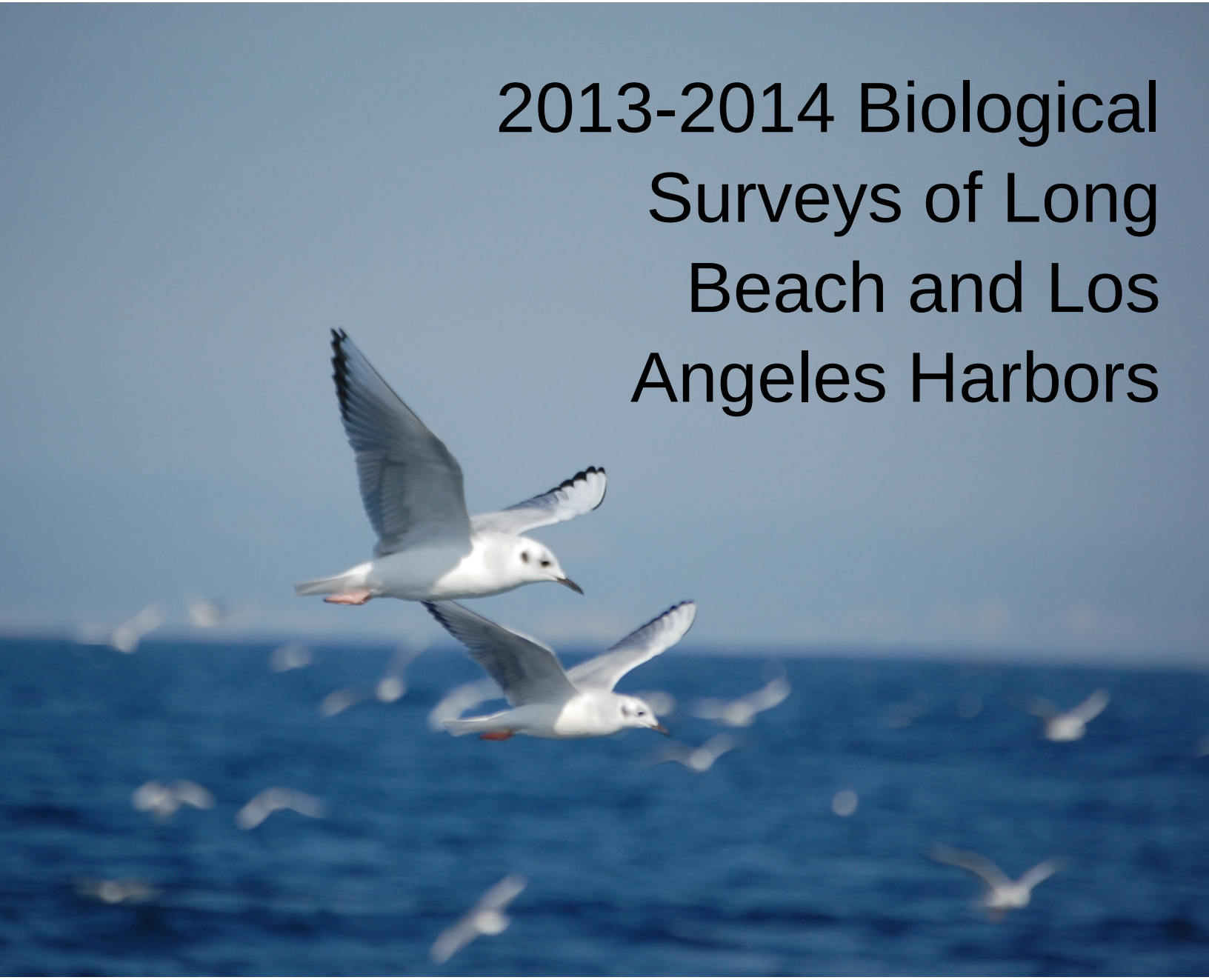
2013-2014 Biological Surveys of Long Beach and Los Angeles Harbors



June 1, 2016

Prepared for:

The Port of LONG BEACH

THE PORT OF LOS ANGELES

2013-2014 BIOLOGICAL SURVEYS OF LONG BEACH AND LOS ANGELES HARBORS

Prepared for:

Port of Long Beach
Long Beach, California

Port of Los Angeles
San Pedro, California

Prepared by:

MBC *Applied Environmental Sciences*
Costa Mesa, California

Merkel & Associates
San Diego, California

June 1, 2016

PROJECT STAFF

PORT OF LONG BEACH

Stacey Crouch

Justin Luedy

PORT OF LOS ANGELES

Kat Prickett

Rachel McPherson

MBC *Applied Environmental Sciences*

Project Manager – David G. Vilas

Marine Scientists

D.S. Beck
M.D. Curtis
E.F. Miller
R.H. Moore
C.L Paquette
D.G. Vilas

Technicians

S.M. Beck
W.H. Dossett
J.R. Nunez
L.C Nunez
J.L. Rankin
D.J. Schuessler
J.J. Sloan
J.N. Smith
B.L Smith
H.K. Vilas
M.S. Vilas

Project Coordinators

K.L. Mitchell
M.R. Pavlick

PROJECT STAFF

Merkel & Associates

Project Manager – Keith Merkel

Marine Scientists

A. Gonzales
A. Gutierrez
H. Henderson
L. Honma
B. Kelly
B. Peterson
B. Stidum
M. Tamburro
T. Valencia
K. Withy-Allen
R. Woodfield

Technicians

M. Jilka
R. Petruccelli
R. Storaasli
J. Volker

Thomas Johnson Consultant LLC

Editor – Thomas D. Johnson, PhD

TABLE OF CONTENTS

Appendices

LIST OF FIGURES

EXECUTIVE SUMMARY

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

LIST OF TABLES

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

CHAPTER 10

CHAPTER 11

EXECUTIVE SUMMARY

The ports of Long Beach and Los Angeles (Ports) are located in San Pedro Bay, which is bounded by the City of Los Angeles communities of San Pedro, on the west, and Wilmington, on the north, and by the City of Long Beach on the north and east (Figure ES-1). Both ports are departments within their respective city governments, and are therefore independent of each other, but because they are contiguous, sharing waterways and land, they are referred to in this report as the Port Complex. Both ports have assessed marine biological conditions throughout the San Pedro Bay Port Complex on multiple temporal and spatial levels since the 1970s, with thorough, harbor-wide assessments performed in 2000 and 2008. The present biological study is undertaken to provide a characterization of physical and marine biological conditions throughout the Ports in 2013–2014.

The Ports retained MBC Applied Environmental Sciences and its subcontractors to conduct physical and biological surveys in Long Beach and Los Angeles Harbors in 2013. The goal was to describe current biological conditions and compare them to the previous studies conducted in 2000 (MEC 2002) and 2008 (SAIC 2010). The objectives of the study were to evaluate the following:

- Physical characteristics (water quality and sediment grain size);
- Benthic infauna;
- Ichthyoplankton;
- Demersal fish and macroinvertebrates;
- Pelagic and shallow-water fishes;
- Riprap epifauna;
- Kelp and macroalgae;
- Eelgrass;
- Birds; and
- Marine mammals.

In addition, the study evaluated the presence of non-native species.

One of the uses of the present study will be to evaluate the quality of the various areas of the Port Complex as habitat for biological resources. This evaluation is important because it will guide the Ports and the natural resources agencies as they make decisions regarding mitigation for environmental impacts of port developments and operations.

The terms “Inner Harbor” and “Outer Harbor” are used in this report as the major distinction between areas of the Port Complex. This delineation is based on habitat quality as revealed by the periodic harbor-wide studies from the 1980s through 2008. Inner Harbor refers to areas of lower quality, and currently consists of a number of dead-end slips and basins in the inner areas of the two ports.

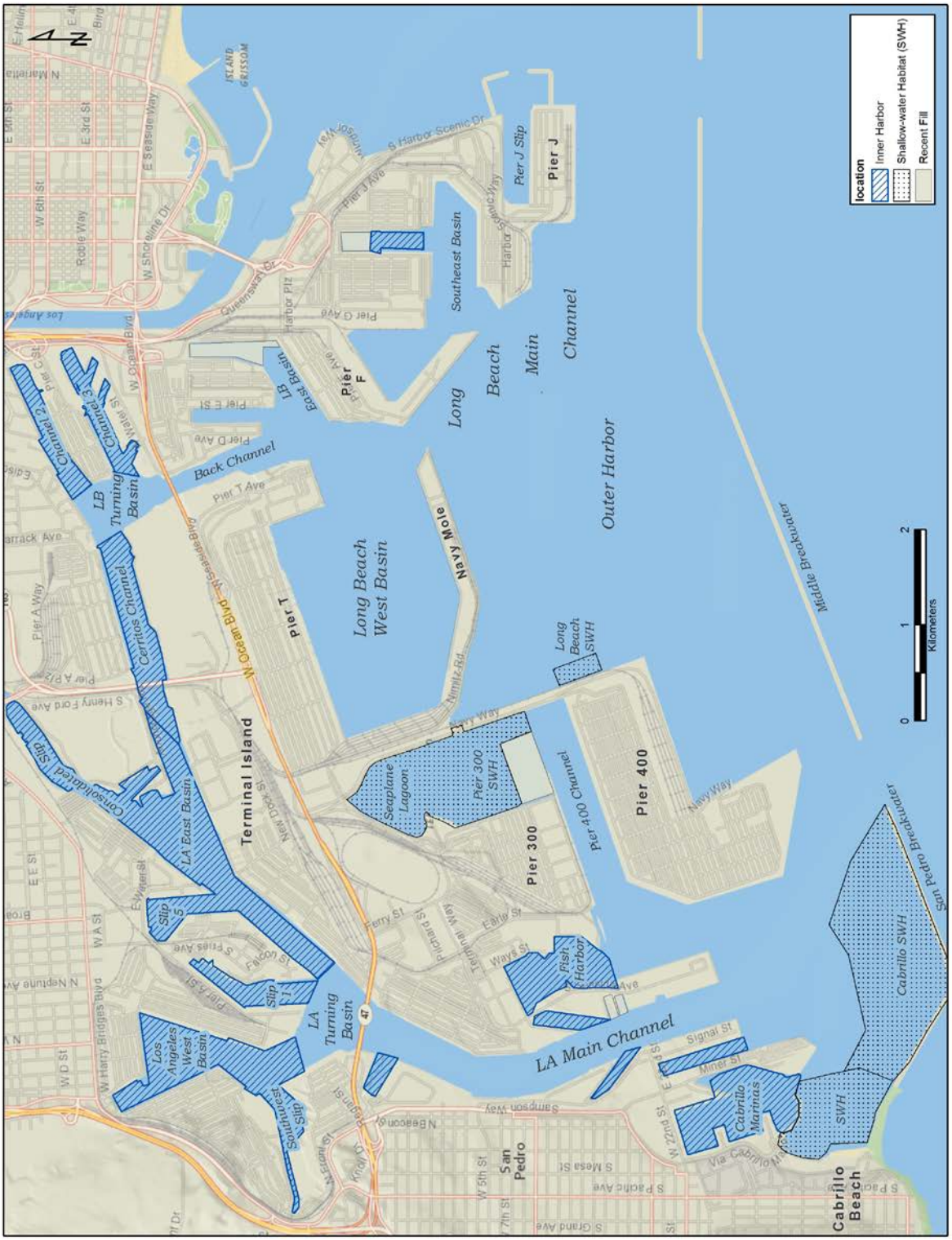


Figure ES-1. The Los Angeles – Long Beach Port Complex.

Outer Harbor includes the open waters immediately behind the breakwaters that protect the Port Complex, but also includes the main navigation channels and a number of basins in the middle and inner areas of the two ports. The boundaries between Inner Harbor and Outer Harbor are indicated on Figure ES-1.

The design and methods of the 2013–2014 study were similar to those used during the 2000 and 2008 studies. Sampling for water quality and sediment, fish, ichthyoplankton, and benthic infauna was conducted at up to 32 stations throughout the Port Complex. Sampling for the remaining elements was conducted at fewer stations or, in the case of birds, in zones that covered the entire water area of the Port Complex.

PHYSICAL CHARACTERISTICS	**Surveys:**
No. of Stations: 32 **Methods:** SBE CTD Profiler Van Veen Grab	Summer: August 2013 Winter: February 2014 Spring: May 2014

Water quality measurements (temperature, dissolved oxygen concentrations, salinity, chlorophyll, pH, and water clarity) were conducted in summer 2013 and in winter and spring 2014 at 32 stations in the Port Complex. The results were consistent with results measured previously in the Port Complex and other embayments in southern California. Surface water temperatures ranged from approximately 15.5°C (all three seasons) to 21.1°C (summer high temperature). Water temperatures at most stations decreased with depth, particularly at the deeper stations and in summer; this pattern is typical of coastal marine waters. Seasonal variability in surface temperatures was more pronounced in the Outer Harbors than in the Inner Harbors. Temperature profiles in this study showed seasonal trends typical of previous studies in the Port Complex and of waters in the Southern California Bight.

Dissolved oxygen (DO) at the surface exceeded 6 milligrams per liter (mg/l) during all three seasons (the regulatory threshold for water quality is 5 mg/L), reaching a high of 10.1 mg/L in the Outer Harbor during the summer survey. In spring, DO concentrations below 5 mg/l were measured near bottom at 11 stations on the Long Beach side of the Port Complex and at four stations on the Los Angeles side. The lowest value of 4.0 mg/L occurred in the Consolidated Slip of Los Angeles Harbor, but most of the other values below 5 mg/L occurred at the bottom of deep (more than 10 m) stations throughout the Port Complex. Patterns of DO concentration with depth in the current study were similar to those reported during the two previous biological

surveys except that the DO values of less than 5 mg/l in summer and at mid-depth in spring reported during the 2000 study were not found during the current study. This suggests continued improvement in water quality in the Port Complex since 2000.

Salinity throughout the Port Complex averaged 33.5 practical salinity units (psu), which is similar to the average salinity of open coastal water in southern California. Salinity tended to be similar at all depths, although near the surface salinity was slightly lower than average at a few locations (indicative of freshwater input). In winter, salinity throughout the water column was generally slightly lower than in spring and summer. Water clarity was variable with season and depth, but in general was higher in winter than in spring or summer and lower near the bottom than at mid-depth.

Hydrogen ion concentration (pH) is a measure of the acidity of water, and is important in marine ecology because many organisms have adapted to the narrow range within which ocean pH varies. Surface pH values were highest during the summer survey and lowest during the spring survey, but overall pH varied little around an average of approximately 7.95, which is typical of coastal southern California ocean waters.

Because of growing concerns over harmful algal blooms in coastal waters, data on chlorophyll-*a* concentrations (a primary indicator of plant biomass) was collected during the water quality sampling surveys. Since these data were collected for the first time in the harbor-wide surveys, they provide background information if needed in the future. Chlorophyll-*a* was generally low (less than 20 mg/m^3), with highest values usually reported at mid-depth or, less frequently, near bottom. Overall, chlorophyll-*a* levels were highest during the summer survey. No red tides (toxic phytoplankton blooms) were noted during any of the water quality surveys. The spatial and temporal patterns of temperature, salinity, and dissolved oxygen recorded during the current study were consistent with those measured in previous harbor-wide surveys and were indicative of conditions that would support healthy biological communities.

Sediment samples for grain size analysis were collected in summer and spring at each station. Sediment grain size is important for two reasons: first, sediments consisting of finer particles usually contain higher concentrations of contaminants (e.g., metals and pesticides) due to the greater available surface area; and second, because infaunal communities are strongly influenced by the characteristics of the sediments in which they live. Sediment grain size affects aspects such as ease of burrowing, availability of suitable particles for constructing burrows and tubes, and the amount of organic food material.

During both surveys, surface sediments were composed primarily of silt with smaller amounts of sand and clay. Sediments at the Long Beach Turning Basin, in the Los Angeles Main Channel, and at the shallow water habitats in the Outer Harbor constructed to mitigate past port developments were coarser than the harbor-wide average. Sediment grain-size distribution during this study was generally similar to that reported in 2000 (sediment sampling was not conducted as part of the 2008 survey). Over time, however, grain size changes in the Port Complex have been notable. In the late 1970s, prior to the construction of Piers 300 and 400, sediments in the Outer Harbor and channels were primarily sand, whereas more recent studies have found Port Complex sediments to be sandy silt and silt.

ADULT AND JUVENILE FISHES		
No. of Stations: 26 (+2 seines) **Methods:** Lampara (Pelagics) Otter Trawl (Demersal) Beach Seine (Nearshore)	**Surveys:** Summer: August 2013 (Seine) September–October 2013 (Trawl) August 2014 (Lampara) Spring: April–May 2014 (Trawl) May 2014 (Lampara/Seine)	

Several sampling approaches were utilized in order to comprehensively sample the diverse assemblages of fish species and individuals that occupy the different habitat types within the Port Complex. A lampara net was used to sample pelagic fish (fish living in the water column), an otter trawl was used to sample demersal fish (fish living on or near the bottom), and a beach seine was used to sample fish in shallow subtidal habitats at Cabrillo Beach and the Pier 300 Shallow Water Habitat (Figure ES-1).

Lampara sampling collected a total of 747,465 pelagic fish weighing 2,718 kilograms (kg) and comprised of 36 species. Northern Anchovy (*Engraulis mordax*) was the most abundant species collected, representing approximately 97% of the total lampara catch. Other species present in moderate abundances—each less than 1.7% of the total catch—included California Grunion (*Leuresthes tenuis*), Pacific Mackerel (*Scomber japonicus*), Topsmelt (*Atherinops affinis*), and Jacksmelt (*Atherinopsis californiensis*). All other species accounted for 0.1% or less of the total catch. The lampara catch was ten times as large as the largest catch in previous studies (Figure ES-2); this was due partly to one enormous catch of Northern Anchovy (over a half a million individuals were caught in a single net haul), but even omitting that catch, the average lampara catch in 2013-2014 was three times larger than in the 2000 study; the reason for this difference is not clear.

Northern Anchovy also contributed most to the biomass of pelagic fish (1,789.5 kg, or 66% of the total biomass). Other species with relatively high total biomass included Pacific Mackerel, Bat Ray (*Myliobatis californica*), California Grunion, and Topsmelt. Greater biomass was collected during day sampling than during night sampling. Most of the pelagic species in this study and in the previous studies seem to be distributed throughout the Port Complex, with no obvious preference for particular areas. Species richness, however, is typically higher at the shallow Outer Harbor stations. While there were some differences between results of the current study and previous harbor-wide studies, possibly due to sampling gear and sampling design differences and to atypical catches, the species composition of the pelagic assemblage

and its spatial and seasonal patterns of abundance in 2013–2014 generally resembled the patterns observed during previous studies.

Figure ES-2. Mean abundance, biomass, and number of pelagic species.

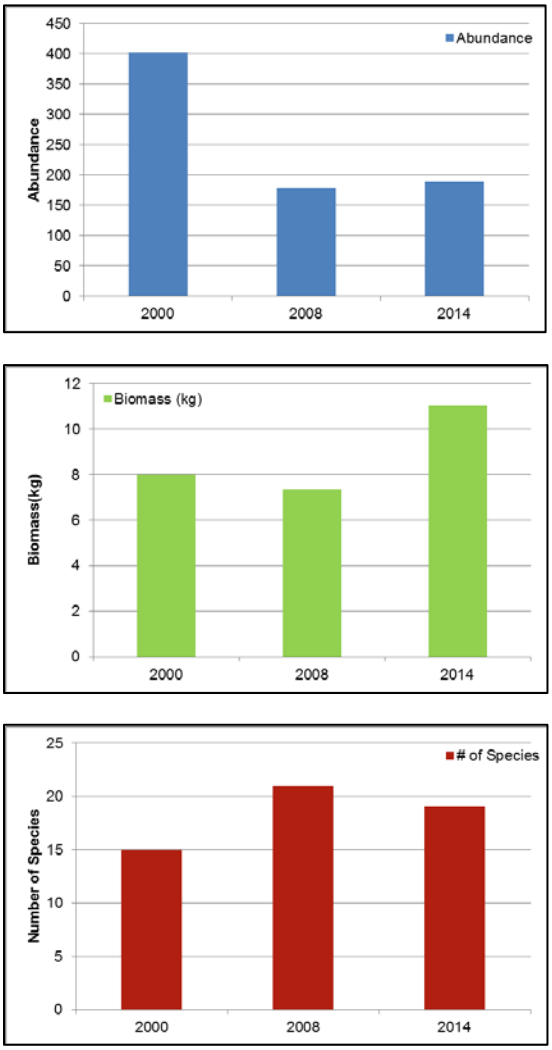


Figure ES-3. Mean abundance, biomass, and number of species collected by otter trawl sampling.

The trawl samples collected 61 demersal fish species represented by 19,655 individuals, with a combined weight of 1,149 kg. White Croaker (*Genyonemus lineatus*) was the most abundant species collected, representing approximately 41% of the total otter trawl catch, and California Lizardfish (*Synodus lucioceps*) was the second most abundant species, accounting for 24% of the total catch. The abundance of California Lizardfish in the current study is a noteworthy change from the two previous harbor-wide studies in which California Lizardfish accounted for less than 1% of the total catch. Other abundant species included Queenfish (*Seriphus politus*), Northern Anchovy (a pelagic fish caught in bottom trawls because its schools often extend from surface to bottom), Speckled Sanddab (*Citharichthys stigmaeus*), California Tonguefish (*Symphurus atricaudus*), Pacific Staghorn Sculpin (*Leptocottus armatus*), Longspine Combfish

(*Zaniolepis latipinnis*), Barred Sand Bass (*Paralabrax nebulifer*), and Specklefin Midshipman (*Porichthys myriaster*). All other species each accounted for 0.8% or less of the total catch.

With few exceptions (e.g., California Lizardfish), a consistent group of fish species has dominated the demersal fish community since the 1970s, and generally the most abundant species have included White Croaker, and Queenfish, although relative numbers of these species have varied with time. Several of these species, most notably White Croaker and Queenfish, are characteristic of bays and harbors rather than offshore waters of the continental shelf and slope. For those species, regional studies suggest that the Port Complex represents an important habitat. As in previous harbor-wide surveys, highest abundance and biomass were collected in summer (when White Croaker and California Lizardfish were most common). Differences among the fish communities appeared to be attributable to location (i.e., Inner Harbors vs. Outer Harbors) and depth (i.e., shallow vs. deep), and patterns of distribution were generally similar to those from previous surveys. On the other hand, the mean number of fish caught was markedly higher in 2000 (402) than in either the current study (189) or the 2008 study (178; Figure ES-3); the reasons for this pattern are not known.

The beach seine surveys collected a total of 2,693 fish belonging to 20 species and weighing a total of 26 kg. Topsmelt was the most abundant species and accounted for 52% of the total abundance. Queenfish comprised 27% of the total catch and Northern Anchovy ranked third in abundance with 17% of the catch. Biomass, however, was dominated by large individuals, including two Leopard Sharks (*Triakis semifasciata*) and four Round Stingrays (*Urobatis halleri*).

The shallow-water fish assemblage in the Port Complex is dominated by species that are common in protected bays in the presence of submerged aquatic vegetation. The species captured during these beach seine surveys were consistent with prior harbor-wide surveys: Topsmelt has consistently been the most abundant shallow-water fish species in the Harbor Complex. Topsmelt are planktivorous, and in turn are heavily preyed upon by a variety of predators that live both in and out of the water (i.e, nearly all fish-eating [piscivorous] species in nearshore waters and piscivorous birds such as the endangered California least tern [*Sternula antillarum browni*]).

ICHTHYOPLANKTON		
No. of Stations: 26 **Methods:** Manta (Surface) Bongo (Water Column) Wheeled Bongo (Epibenthos)	**Surveys:** Summer: August 2013 Winter: February 2014 Spring: May 2014	

As in prior studies, the ichthyoplankton (fish eggs and larvae) community in 2013-2014 was diverse and variable throughout the Port Complex in both space and time. In the present study, ichthyoplankton were sampled three times during the study (summer 2013, winter 2014, spring 2014) utilizing a stratified sampling design consistent with previous surveys in the Port Complex. The design ensured that ichthyoplankton were sampled at the surface (neuston), through the water column, and near the bottom (epibenthic).

The abundance of fish eggs provides some indication of reproductive activity in the Port Complex. The abundance and location of fish larvae is not as reliable an indication of local spawning activity, given the potential for transport by currents and the activity of the larvae, but can suggest the importance of an area as a potential nursery area for juvenile life stages.

In general, eggs were concentrated near the surface rather than in the midwater and epibenthos. Egg concentrations were highest in winter and lowest in spring. Most fish eggs taken during the study were indistinguishable and were recorded as “unidentified fish eggs”. Anchovy eggs accounted for 16% of all fish eggs reported during the winter survey, 3% of the spring count, and 1% of the summer count. *Pleuronichthys* (turbot and sole) eggs contributed 2% or less to the totals during all surveys.

Seventy-nine larval fish taxa were taken during the sampling (compared to 71 in 2008 and 44 in 2000), and ten of those numerically dominated the larval fish assemblage in the Port Complex. As in prior harbor-wide studies, CIQ gobies (which includes *Clevelandia ios*, *Ilypnus gilberti,* and *Quietula y-cauda*) were the most abundant larval fish taxon; the adults of all three species are present in the Port Complex. Unidentified anchovies were the second most abundant larva in the present study, but were ranked 35th in 2008 and were not reported at all in 2000. As in previous studies, Bay Goby (*Lepidogobius lepidus*), combtooth blennies (*Hypsoblennius* sp), White Croaker, and Yellowfin Goby (*Acanthogobius flavimanus*) were among the ten most common larval taxa. White Croaker, whose numbers have declined along the open coast of southern California, has nevertheless maintained a large population in the Port Complex. This abundance was reflected in the current study by high numbers of White Croaker larvae, suggesting local spawning and retention in the Port Complex.

During this study, larval fish concentrations were consistently highest near the seafloor and lowest at the surface, and more larval fish were collected in winter than in summer or spring. Highest densities (number per 100 m^2 of sea surface) occurred in the Outer Harbor and Los Angeles Main Channel Entrance. Seasonal patterns by species were generally similar to those documented since 2000: anchovies and Bay Goby were present throughout the year, but White Croaker larvae were most abundant in winter, and Queenfish larvae were most abundant in spring.

BENTHOS		
No. of Stations: 32 **Methods:** Van Veen Grab (Infauna) Otter Trawl (Epibenthic fauna)	**Surveys:** Summer: August 2013 (Grab) September–October 2013 (Trawl) Spring: April–May 2014 (Grab and Trawl)	

The benthic infauna are assemblages of invertebrates that live within the bottom sediments. They are an integral part of the marine ecosystem as an important food source for fish and larger invertebrates and a key link in nutrient recycling. Some species are highly sensitive to effects of human activities, while others thrive under altered conditions. The assessment of the benthic community is, therefore, a major component of many marine monitoring programs, including the previous harbor-wide studies. In the present study, the benthic infaunal communities were sampled at 32 stations throughout the Port Complex in summer 2013 and spring 2014. Benthic epifauna (the mobile organisms living on the sediment surface) were sampled as part of the otter trawl effort in the fish sampling.

Abundances of benthic infauna in the Port Complex were slightly higher in summer than in spring, at Outer Harbor stations than at Inner Harbor stations, and at shallow stations than at deep stations. Abundance appeared to be strongly influenced by depth: mean abundance at the seven shallow stations (4–7 m) was more than twice that at deep stations (9–24 m). Abundances at the five shallow water habitat stations in areas created for mitigation averaged 40% greater than at the two other shallow stations (Fish Harbor and the Consolidated Slip). In general, results were consistent with those from the 2000 and 2008 surveys, although the mean abundance of organisms (individuals/m^2) has declined since the 2000 study from about 4,100/m^2 to about 1860 m^2.

Two-hundred and sixty-four infaunal species were collected in the Port Complex. Species richness was greater in summer (261 species) than in winter (238 species), higher, on average,

in the Outer Harbors than in the Inner Harbors, and slightly higher at shallow stations than at deep stations. As in previous studies, the mean number of species was also considerably higher at the stations in shallow water habitats created for mitigation in the Outer Harbor (40 species in the present study) than at the two Inner Harbor shallow stations (28 species). These results were similar to those reported during previous harbor-wide surveys.

The biomass of infaunal organisms was similar between seasons and between shallow stations and deep stations. However, biomass in the Outer Harbors was about 40% greater than that in the Inner Harbors. In previous surveys, differences in biomass were apparent between seasons (biomass was greater in summer in the 1986–1987 and 2000 surveys) and among locations within the Port Complex. In general, biomass has reflected abundance; for instance, in the present study, low biomass coincided with low abundance.

The Benthic Response Index (BRI) is the abundance-weighted average pollution tolerance of the species occurring in a sample (the index was not available for use in previous studies). The index provides a scientifically valid criterion or threshold that can be used to distinguish “healthy” and “unhealthy” benthic communities. In 2013–2014, BRI values for communities at all but two locations in the Port Complex were in the “Reference” category for southern California marine bays and harbors, indicating that the communities were healthy. Values for two locations fell into the “Low Disturbance” category: Fish Harbor (summer and spring) and Consolidated Slip (spring). Mean BRI for the Inner Harbor stations was considerably greater than the mean for the Outer Harbor stations, likely indicating the generally more polluted nature of Inner Harbor sediments. At most of the stations, BRI values were similar between seasons. The BRI values determined in 2013–2014 reflect a general improvement in benthic conditions in the Port Complex compared to previous region-wide studies.

Overall, water circulation appeared to influence the composition of the infauna communities. Abundance, species richness, biomass, and diversity were lower, and BRI was higher, in the Inner Harbor, where most of the sampling stations were in dead-end slips and basins with reduced water circulation. At some of these locations, dissolved oxygen at the bottom was below 5 mg/L during the spring survey. Among the Inner Harbor stations, Fish Harbor and Consolidated Slip supported community types that tolerate contaminated sediments. The northern portion of the Pier 300 Shallow Water Habitat also supported a pollution-tolerant community.

The total of 16,607 individuals of epibenthic invertebrates taken in trawl samples in the present study was considerably higher than the totals reported from the 2000 study, when 9,185 individuals were caught, and the 2008 study, when 7,043 individuals were reported. The present study collected 110 species, which was considerably higher than the 61 species caught during both of the previous harbor-wide surveys. As in the previous studies, the epifauna was dominated by arthropods, particularly several shrimp and crab species. Mean abundance was about one-third lower in summer than in spring, and during both seasons abundance was higher during night trawls. Slightly more individuals were taken at Inner Harbor stations than at Outer Harbor stations and at non-mitigation shallow-water stations than at mitigation-area shallow-water stations.

Biomass of epibenthic fauna in 2013–2014 was dominated by two taxa: unidentified sponge (Porifera), which accounted for 55% of summer biomass, 33% of spring biomass, and 46% overall; and shrimp, which contributed 12% to the summer biomass, 38% to spring biomass, and 23% overall. Mean biomass per trawl was much higher in 2013–2014 than in the previous harbor-wide surveys: seven times that in 2008, and three and one-half times higher than in 2000 (Figure ES-4).

Improvements in environmental conditions have occurred in the Port Complex since the 1950s due to greater control of discharges and other changes in port activities. As a result, species richness and diversity have risen slightly, and the infaunal communities are less dominated by opportunistic, pollution-tolerant species, while species that are sensitive to pollution have become more common. In 1954, only one pollution-sensitive species was among the top ten species in a harbor survey. The number of pollution-sensitive species has gradually increased, and, in 2013–2014, a pollution-sensitive species, *Amphideutopus oculatus*, was the most abundant species for the first time. This species was one of the ten most abundant species for the first time in surveys in 1994 and 1996. Five other pollution-sensitive species were also among the top ten in 2013–2014.

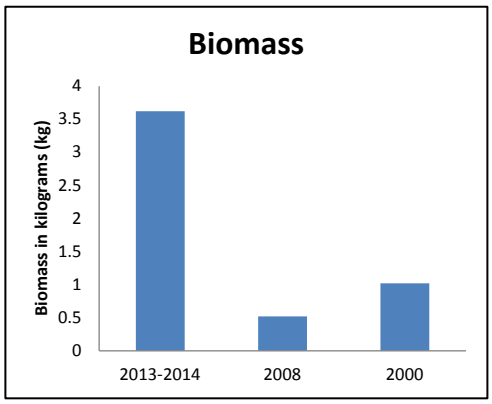


Figure ES-4. Mean epibenthic invertebrate biomass (kg) per trawl in recent studies of the Port Complex.

RIPRAP BIOTA		
No. of Stations: 8 **Methods:** Scraped Quadrats Photo/Video Quadrats and Transects	**Surveys:** Summer: September 2013 Spring: May 2014	

Riprap biota (invertebrates and algae attached to the rock dikes and concrete pilings in the Port Complex) was surveyed at eight stations in summer 2013 and spring 2014. Three depth zones were investigated, consistent with methods used in the 2008 study: upper intertidal, mid-lower intertidal, and subtidal. Two sampling methodologies were employed: scraped quadrats, consistent with previous harbor-wide surveys, and a rapid assessment protocol using photo

quadrats and video transects that was new to this study in an effort to develop a more efficient technique.

Five-hundred and fifty-eight species were observed or collected in the scraped quadrats: 429 were collected or observed in summer and 366 in spring, with a total abundance of 38,332 individuals, two-thirds of them in the summer survey. Abundance appeared to be influenced by depth, since mean abundance in the mid-lower intertidal zone was twice that in the upper intertidal and about 40% greater than in the subtidal. Historically, mean abundance has consistently been higher at Outer Harbor stations than at Inner Harbor stations. Outer Harbor riprap abundance was similar in 2000 and 2008, but in 2013-2014 the abundance of riprap biota in the Outer Harbor was about twice that reported in the two previous studies. Mean abundance at Inner Harbor stations in the present study was nearly three times higher than in 2008 and seven times greater than in 2000.

Although there have been some changes in the dominant species between the present study and previous studies, barnacles, caprellid shrimp, and encrusting organisms such as bryozoans, sponges, and coralline algae have consistently been among the most abundant organisms in the scraped quadrats. A notable change has been the decline of bay mussels (*Mytilus galloprovincialis*), which was a dominant species in the 2000 and 2008 studies but was a minor component of the riprap biota in the present study. The mean number of species in 2013–2014 (118) was notably higher than in 2008 (30) and 2000 (39). Overall, the number of riprap-associated species has doubled since 2000, despite the four seasonal samples collected in 2000 compared to only two in 2013–2014. In 2008, the total number of species was about 40% lower than in 2013–2014. It is clear, therefore, that there has been a steady increase in the species richness of attached fauna in the Port Complex in recent years.

While species richness and abundance in 2013–2014 were substantially higher than in previous harbor-wide studies, overall diversity was similar, and biomass was much lower than in 2000 and 2008. Since field and laboratory methods and station locations were comparable among the three studies, the reasons for these differences are unclear. Differences in the sizes of dominant riprap organisms may contribute to this variability The moderate number of relatively large individuals in earlier studies has been replaced by smaller but more numerous organisms (in terms of both species and abundance).

The rapid assessment method showed that the high intertidal zone at almost all sites was mostly bare rock, with barnacles (*Balanus* and *Chthamalus*), limpets (*Lottia* spp), the ephemeral green alga *Ulva*, encrusting red and brown algae, and red algal turfs the main biotic components; few differences were observed between the two seasons at most stations. Percent cover in the middle-lower zone was much more variable among sites than it was in the high intertidal. Macroalgae in the middle-lower intertidal zone consisted most commonly of *Ulva*, articulate corallines, and red algal turfs, but relative cover varied among locations and between surveys. At most sites, the subtidal zone contained a high percentage of articulated coralline algae (e.g. *Corallina* spp and *Bossiella* spp) and/or red algal turf, as well as a mixture of other macroalgae and invertebrates. Several fish (mostly gobies and sculpins) were observed in the mid-low intertidal zone. In the subtidal zone, poor resolution of video/photos or coverage by silt inhibited characterization of patterns of coverage at most sites. The biota at the pier piling site

(Los Angeles West Basin) was markedly different from that at the rocky or concrete slab substrate locations, with a high relative abundance of hydroids, oysters, mussels, and scallops, which were largely absent or rare at other sites. Overall, the rapid assessment methods suffered from an inability to identify organisms, caused by a combination of poor video resolution, poor visibility, and coverage by silt.

KELP AND MACROALGAE	**Surveys:** Summer: September 2013 (Dive) September 2014 (Overflight) Spring: May 2014 (Dive) June 2014 (Overflight)	
No. of Macroalgae Stations: 20 **Methods:** Diver Transects Aerial Overflights		

The Port Complex provides an enormous amount of hard substrate in the form of riprap, breakwaters, and jetties, but that substrate is present in steep, linear configurations, which limits kelp coverage to narrow bands. Furthermore, much of the rocky substrate is in protected locations that do not allow the water circulation that kelp depends upon. That same substrate, however, represents favorable habitat for a variety of other macroalgal species characteristic of southern California rocky shorelines. In particular, the breakwaters and south-facing Outer Harbor rock dikes are exposed to waves and currents typical of open coastal sites. The protected channels and basins are favorable habitat for algal species that cannot withstand vigorous wave and current action.

The distribution of kelp in the Port Complex was quantified using aerial infrared photographs taken during overflights conducted in spring and summer 2014 by the ongoing Central Region Kelp Survey Consortium. In addition, biologist-divers surveyed 20 fixed stations (the same stations surveyed in 2000 and 2008) throughout the Port Complex in summer 2013 and spring 2014 to establish the species composition and vertical distribution of kelp and macroalgae. The divers swam transects at each station.

Estimated canopy coverages in the Port Complex were 132 acres in spring and 46 acres in summer. Giant kelp (*Macrocystis pyrifera*) was the dominant kelp in 2014, with an unknown, but small, contribution to total canopy coverage by feather boa kelp (*Egregia menziesii*). Kelp grew along the inside and outside of the outer breakwaters, on riprap along the piers and wharves of the Outer Harbors, on riprap along some of the piers and wharves not directly exposed to the harbor entrances, and on submerged rock dikes. The thickest canopy coverage occurred in spring. Canopy coverage in spring 2014 was higher than in spring 2000 and 2008, but coverage in summer 2014, although much greater than in 2000, was 12% lower than in 2008 (Figure ES-5).

The ongoing regional kelp surveys found that in 2012, the canopy coverage at kelp beds within the Port Complex (treated as a single unit) ranked 2nd out of 26 beds between Ventura and Newport Beach, California, and in 2013, they ranked 7th and comprised 6% of the total canopy coverage. The substantial reductions in coverage experienced by the Port Complex kelp beds in 2014 may have been due to the unusually high water temperatures in summer/fall 2014.

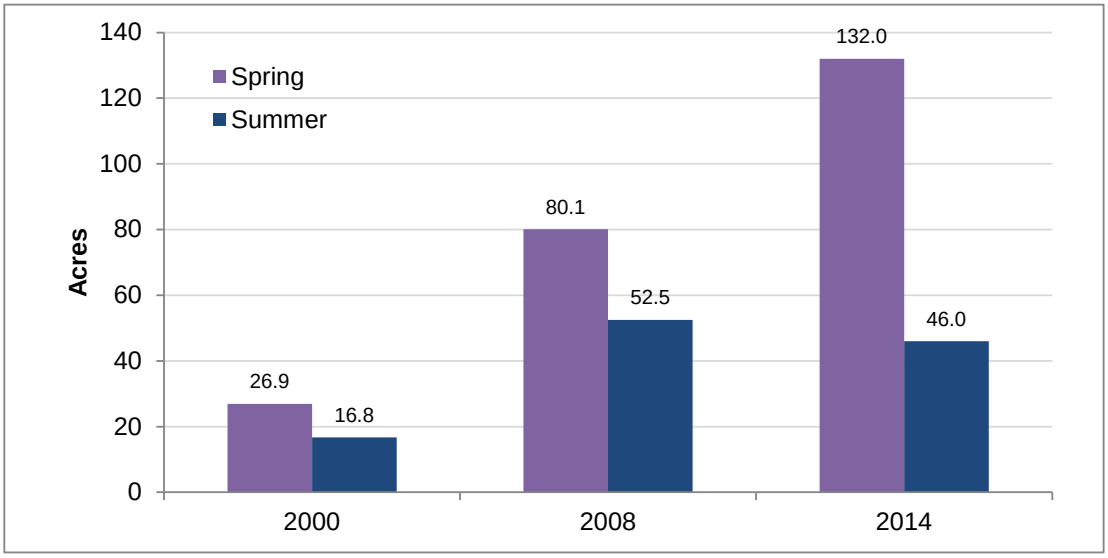


Figure ES-5. Estimated kelp coverage in the Port Complex by season in 2000, 2008, and 2014.

During the diver surveys, 30 algal taxa representing at least 28 distinct genera were observed during summer 2013 and 28 taxa representing at least 26 distinct genera were observed during spring 2014. In summer, the most frequently observed taxa overall were *Macrocystis*, *Ulva*, *Sargassum muticum*, *Colpomenia*, *Undaria*, and *Weeksia,* while *Macrocystis*, *Sargassum muticum*, *Undaria*, Corillanaceae, and *Prionitis* were common in spring. In general, species richness and density were higher in the Outer Harbors than in the Inner Harbors. Macroalgae coverage along each transect ranged from 2% to 34% in summer and from 2% to 70% in spring. During both seasons, coverage decreased with depth. Overall, the results of the 2013–2014 macroalgae diver surveys were consistent with those from 2000 and 2008.

The increasing coverage of giant kelp and the diversity of algae within the Port Complex suggest that factors affecting recruitment and growth have been favorable in recent years. Some of the most abundant macroalgae, however, are introduced/invasive species. In California, the Port Complex ranked second (out of seven harbors) in the number of introduced species. Three invasive macroalgal species were observed in 2013–2014: *Sargassum muticum*, *S. horneri*, and *Undaria pinnatifida*. All three are adapted to survive under a wide range of habitats and environmental conditions, and all three continue to thrive in the Port Complex.

EELGRASS		
Methods: Sidescan Sonar Remotely Operated Vehicle Diver Transects	**Surveys:** Summer: September 2013 (Sidescan) October 2013 (ROV/Diver) Spring: May–June 2014 (Sidescan) May 2014 (ROV/Diver)	

Eelgrass beds function as habitat and nursery areas for commercially and recreationally important marine fish and invertebrates, and provide critical structural environments for a variety of fish and invertebrate species. Eelgrass supports juvenile fish as well as mature, often predatory, fish that hunt along the margins of the bed's protective structure. Eelgrass is also considered to be an important resource supporting migratory birds during critical migration periods. In addition to its habitat and resource value, eelgrass traps and removes suspended particulates, improves water clarity, reduces erosion, facilitates nutrient cycling, and oxygenates the water column.

Eelgrass (*Zostera marina*) surveys used a combination of acoustic techniques (interferometric sidescan sonar), diver surveys, and Remotely Operated Vehicle (ROV) surveys. The acoustic surveys were conducted in two seasons—at the height of the summer growing season (summer 2013) and at the beginning of the growing season (spring 2014) in order to detect seasonal variability of eelgrass areal extent and density. Diver and ROV eelgrass bed density and ground-truthing surveys were conducted in October 2013 and May 2014.

Eelgrass within the Port Complex totaled 60.4 acres in September 2013 and 67. 6 acres in May 2014 (Figure ES-6). Approximately 99% of the eelgrass occurred on the Los Angeles side of the Port Complex in both spring and summer; very little shallow water area that could support eelgrass is present on the Long Beach side. More than 95% of all eelgrass occurred in the Seaplane Lagoon/Pier 300 Basin and adjacent to Cabrillo Beach. With the exception of one bed, eelgrass coverage increased between the summer and spring surveys. Nearly all of the increase was in the Seaplane Lagoon/Pier 300 Basin, an area that was stricken by eelgrass wasting disease in 2011.

The condition of eelgrass within the Port Complex was generally good. Turion (plant shoot) densities at nearly all sites were within ranges generally considered to be low to moderate for southern California eelgrass beds. The Seaplane Lagoon/Pier 300 Basin eelgrass beds recovered from the 2011-2012 wasting disease and were at pre-2011 conditions. Other beds in the Port Complex exhibited limited or no evidence of disease.

Some areas mapped in 2013–2014 were known to support eelgrass but were not included in previous eelgrass assessments (which focused on the larger beds at Seaplane Lagoon/Pier 300 and Cabrillo Beach). Eelgrass grew at depths between +0.5 ft and -15 ft Mean Lower Low Water in 2013–2014, and the deeper distribution was generally along Cerritos Channel and in basins/marinas. It is evident eelgrass has vastly expanded both in bottom coverage and geographic extent, with multiple occurrences (not previously mapped) of eelgrass colonizing suitable habitats within the Port Complex.

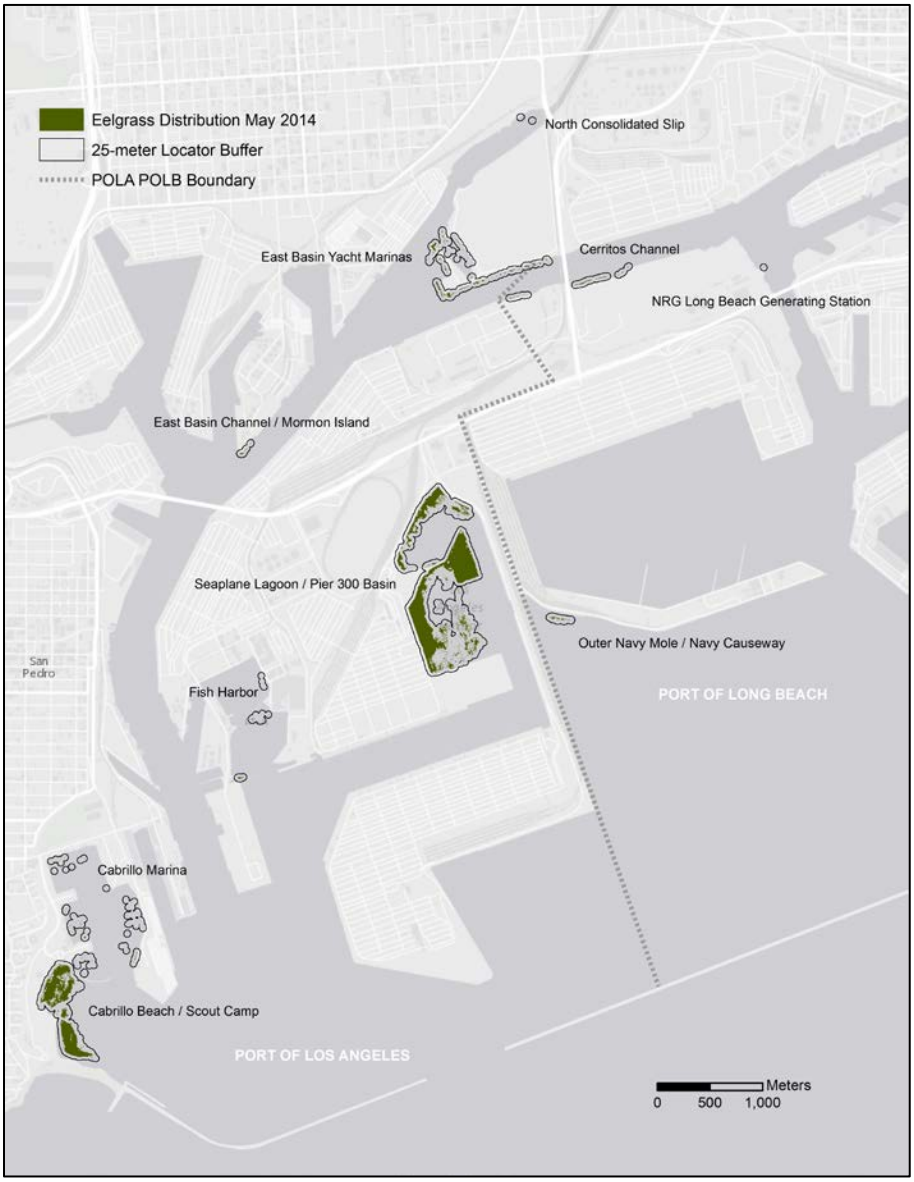


Figure ES-6. Eelgrass distribution within the Port Complex in spring.

BIRDS		
Methods: Visual Surveys in 31 Zones	**Surveys:** Monthly from September 2013 to August 2014	

Bird surveys were conducted monthly from September 2013 to August 2014 in 31 zones in the Port Complex. With some exceptions, zone boundaries were identical to those delineated and utilized during previous studies.

The surveys recorded a total of 76,260 individuals of 96 species representing 30 families. Numbers of birds observed per survey ranged from a low of 3,764 individuals in August 2014 to a high of 11,739 individuals in November 2013, with a mean of 6,355 individuals/survey. Numbers of species ranged from a low of 33 species in June 2014 to a high of 59 species in April 2014. Patterns of abundance within the Port Complex were highly seasonal. Of the 96 bird species observed during the 2013–2014 surveys, only 29 were observed during ten or more survey months, indicating year-round occupancy within the Port Complex. The results of the current study were similar to previous studies that used the same methodology: during the 2000 study a total of 99 species and 117,560 individuals were observed, with a mean of 50 species and 5,878 individuals per survey, and in the 2008 study a total of 96 species and 125,535 individuals were observed, with a mean of 49 species and 6,277 individuals per survey (Figure ES-7).

The guild composition within the Port Complex has been comparable for the past three harbor-wide studies, with gulls, waterfowl (ducks, geese, and grebes), and aerial fish foragers (terns and pelicans) accounting for over 80% of the birds. During the current study, the most abundant bird guild was gulls, which represented 38% of all birds, and included Western Gull (*Larus occidentalis*), the most abundant species overall. Western gull, abundant throughout the survey year, accounted for nearly 24% of all bird observations for the year. Waterfowl represented 31% of bird observations and were most abundant from November through January. Dominant waterfowl included both year-round resident species that peaked in abundance during winter months, such as Western Grebe (*Aechmophorus occidentalis*) and two species of cormorant (*Phalacrocorax* spp; included with waterfowl to be consistent with the two previous studies) and winter visitors, such as Bufflehead (*Bucephala albeola*) and Eared Grebe (*Podiceps nigricollis*).

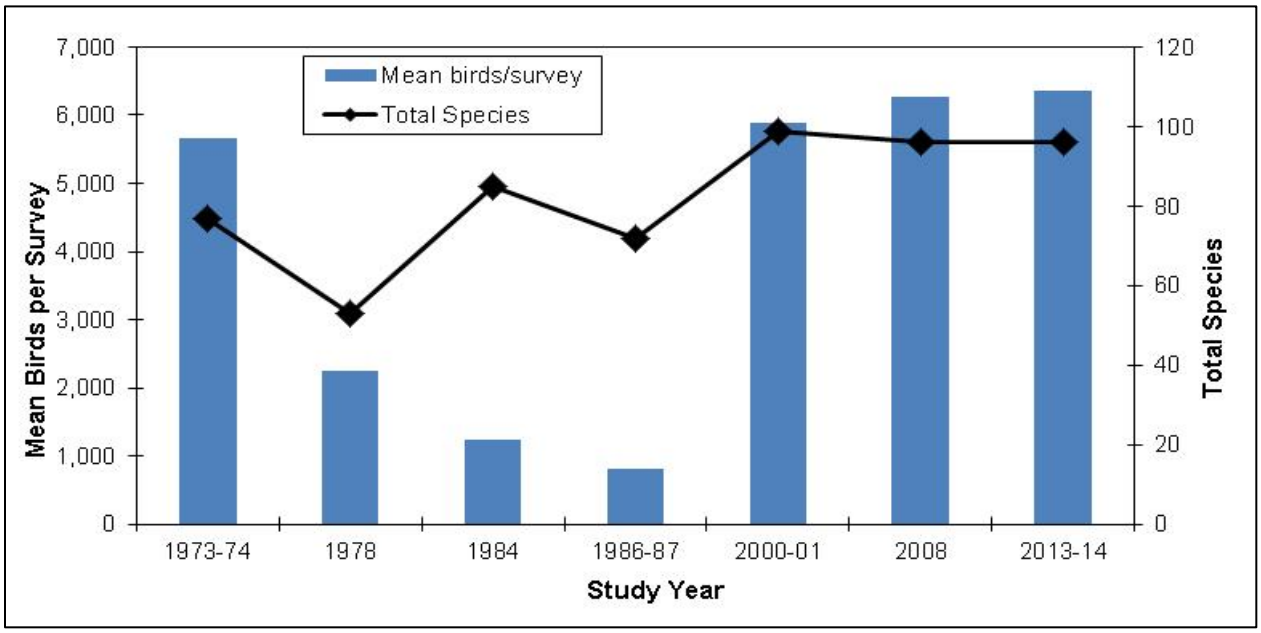
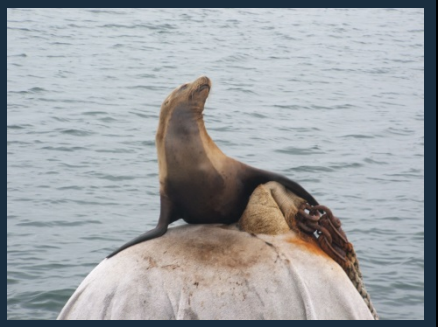


Figure ES-7. Historical comparison of mean abundance and total number of species observed in the Port Complex.

Aerial fish foragers represented another 21% of total observations; from May through July, during the nesting season of Elegant Tern (*Thalasseus elegans*), California Least Tern (*Sternula antillarum browni*), and Black Skimmer (*Rynchops niger*) in the Port Complex, this was the most abundant guild. The Port of Los Angeles maintains a protected California Least Tern nesting site on Pier 400 that is also used by other terns. The remaining avian guilds (large and small shorebirds, wading/marsh birds, raptors, and upland birds) together accounted for about 10% of total observations during the current study. These results are generally consistent with previous studies, except that, for reasons that are unclear, shorebirds continue to decline in abundance, a trend that has persisted since the 1970s.

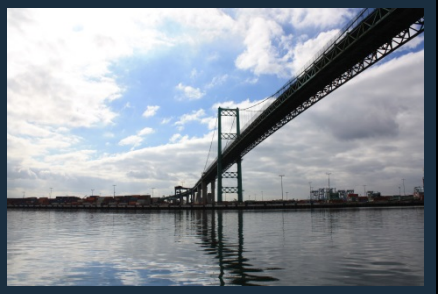
As with previous surveys of the Port Complex, there was spatial variation among survey zones and habitat types. The large, open-water zones in the Port Complex have historically supported, and continue to support, large rafts of foraging and resting waterfowl, dominated by Western Grebe, Surf Scoter (*Melanitta perspicillata*), and multiple cormorant species. The zones along the Middle Breakwater support large flocks of roosting Brown Pelican (*Pelecanus occidentalis*), Double-crested Cormorant (*Phalacrocorax auritus*), Brandt's Cormorant (*Phalacrocorax penicillatus*), and multiple gull species. The Los Angeles Main Channel and Fish Harbor have historically supported large numbers of resting and foraging gulls, particularly Western Gull and Heermann's Gull (*Larus heermanni*), which are attracted to the nearby fish markets and processing plants.

The two most utilized habitat types within the Port Complex during the 2013–2014 surveys, as in the previous surveys, were open water and riprap. The riprap is used by gulls, pelicans, and cormorants for resting, as well as by small and large shorebirds for resting and foraging.

MARINE MAMMALS		
Methods: Visual Surveys in 31 Zones	**Surveys:** Monthly from September 2013 to August 2014	

Marine mammal surveys were conducted concurrent with the monthly bird surveys. As in previous studies, California sea lion (*Zalophus californianus californianus*) was the most commonly observed marine mammal in the Port Complex; in the current study it accounted for 68% of total marine mammal observations. This species was observed year-round and was typically found resting on buoys, docks, riprap shoreline, and on the bulbous bows of container ships. Harbor seals (*Phoca vitulina*) were less common, accounting for 26% of total marine mammal observations. Harbor seals were usually observed resting or foraging along riprap shorelines, particularly adjacent to the breakwaters of the Outer Harbors.

Cetaceans were much less common during 2013–2014 than in previous harbor-wide surveys, with observations limited to occasional sightings of pods or small groups of individuals foraging in the Outer Harbors. The only cetacean taxa observed during the study were common dolphin (*Delphinus* spp) (a single observation of a pod of 40 individuals), and bottlenose dolphins (*Tursiops* spp) (groups of three to five individuals). Both dolphin species were observed only in the Outer Harbors of the Port Complex. Previous studies have observed occasional gray whales and Pacific white-sided dolphins, but neither species was observed in the current study.

NON-NATIVE SPECIES		
Methods: Data Analysis	**Surveys:** Results from all surveys.	

An introduced, exotic, non-indigenous, or non-native species is a species living outside its native distributional range, and has arrived there by human activity, either deliberate or accidental. Among the hundreds of species collected in the present study, 27 are classified as introduced (non-native or non-indigenous) species; another 107 are of undetermined status, but

cannot be classified as introduced. In 2008, 19 non-native species were taken among the various sampling methodologies, while 25 were reported in 2000.

Eight non-native species were taken in benthic infauna sampling during the present study. The most frequently occurring introduced infauna species were: the Asian clam, *Theora lubrica*, which occurred at 31 of the 32 stations; the amphipod *Sinocorophium heteroceratum*, which was taken at 12 stations; and the New Zealand snail (*Philine auriformis*), which was collected at eight stations. These results are very similar to the results of the 2000 and 2008 harbor-wide studies.

Eight non-native epibenthic invertebrate species were taken by otter trawl and beach seine sampling. The New Zealand snail was the most frequently encountered non-native species, occurring at 15 of the 26 trawl stations. The sea squirt *Styela plicata* was collected at eight stations, stalked sea squirt (*Styela clava*) at seven stations, bay mussels (*Mytilus galloprovincialis*) at six stations, and spaghetti bryozoan (*Zoobotryon verticillatum*) at four stations. The oriental shrimp (*Palaemon macrodactylus*) was the only introduced species taken in beach seine sampling. Epibenthic sampling in previous harbor-wide studies did not find as many introduced species, but in the present study the high number was the result of collecting riprap biota, probably sloughed off nearby hard substrate, in the trawls, which did not occur in previous studies.

Eighteen non-native species were collected at riprap stations during the present study, which is somewhat higher than in previous harbor-wide studies. The riprap community is particularly susceptible to the introduction of non-native species because it includes fouling organisms that are carried worldwide on the hulls of oceangoing vessels. Eight of the 18 introduced species, including a barnacle, two tunicates, and three bryozoans, are considered to have been introduced on vessel hulls. Three species of mollusks, including Pacific oyster, were introduced by the aquaculture industry. The highest number of non-native species was found in the Los Angeles West Basin (at the only pier piling surveyed). The amphipod *Aoroides secundus* was the most frequently encountered species, occurring at all eight riprap stations. The encrusting bryozoan *Watersipora arcuata* was found at seven stations. Overall, nine of the 18 non-native riprap species occurred at two or more of the stations.

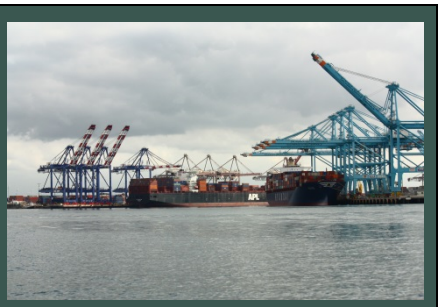
Three introduced algae species were observed among the 20 kelp and macroalgae stations during the 2013–2014 studies. *Sargassum muticum* was the most frequently encountered species, followed by *Undaria pinnatifida* and *Sargassum horneri*. At least one of these species was reported at every station during the survey, and all three occurred at six of the 20 stations. *S. horneri* was introduced to the Ports by ships, *S. muticum* was an unintentional introduction growing on imported Pacific oysters, and *U. pinnatifida* was introduced to California as a result of importation for cultivation, accidental transport with oysters, and ship hull fouling.

Two introduced fish species were taken during the fish surveys. Both Yellowfin Goby (*Acanthogobius flavimanus*) and Chameleon Goby (*Tridentiger trigonocephalus*) were taken in Fish Harbor, and Chameleon Goby was collected in Consolidated Slip. Yellowfin Goby larvae were also collected during ichthyoplankton sampling. Yellowfin Goby has consistently been collected in the harbor-wide studies, but the Chameleon Goby was previously collected only as

a single individual in the 2000 study, although it has been collected elsewhere in southern California since the 1960s.

A regional survey of southern California harbors conducted in 2011 found that although the Port Complex had the highest species richness (675 total species), it also had the highest number of introduced species (57). Other harbors with similar numbers of introduced species included Mission Bay and San Diego Bay, both with 53 species despite having less than half as many total species. The presence of non-native species may result in a range of environmental effects, with direct effects including preying on native species and outcompeting native species for food or other resources, with larger ecosystem effects including food web changes (by removing native food sources), decreased biodiversity (by changing the abundance or diversity of native organisms), and alteration of ecosystem conditions. However, the past three harbor-wide studies have not documented severe ecosystem disruption by introduced species; instead, the newcomers appear to have fit into the harbor biological communities, which now consist of a mixture of a few non-native and many native species.

CONCLUSION



Results of the 2013–2014 harbor-wide study suggest that the Port Complex continues to support healthy and robust biological communities. The establishment of eelgrass in Inner Harbor areas not previously colonized, and record canopy coverage of giant kelp, suggest that water clarity continues to improve in the Port Complex. For the first time, a pollution-sensitive infaunal species was the most abundant species collected in Port sediments, and community parameters suggest that benthic conditions continue to improve. Fish and invertebrate communities within the harbor are diverse and abundant, and region-wide changes in community composition and abundance were reflected within the Port Complex. Non-native species are established throughout the Ports, but do not appear to be proliferating more than in 2000 and 2008. Kelp, macroalgae, fish, and birds undergo wide seasonal changes in distribution and abundance, but results in 2013–2014 were similar to those of previous surveys, and reflect the improvements in water, sediment, and habitat quality in the Port Complex that began in the 1970s and continue to the present.

CHAPTER 1 INTRODUCTION

The ports of Long Beach and Los Angeles (the Ports) are located in San Pedro Bay, which is bounded by the communities of San Pedro, Wilmington, and Long Beach (Figure 1-1). San Pedro Bay is an embayment of the coast of the Southern California Bight, which is defined as the nearshore coastal region from Point Conception south into Baja California. The two ports are departments of their respective cities (Long Beach and Los Angeles), but because they are contiguous, sharing a harbor complex of waterways and land, they are referred to in this report as the Port Complex. Over the years since the 1970s, the Ports have assessed marine biological conditions throughout the Port Complex on multiple temporal and spatial scales, including harbor-wide assessments performed in 2000 and 2008. The present study was undertaken to provide a characterization of physical and marine biological conditions throughout the Port Complex in 2013–2014.

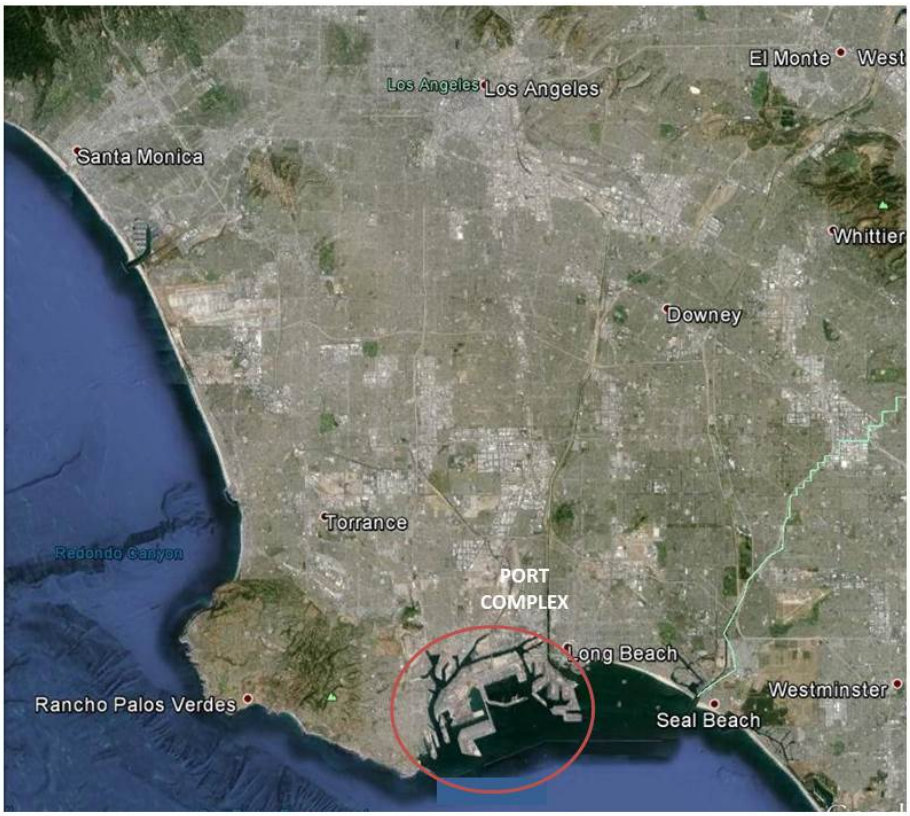


Figure 1-1.The San Pedro Bay project area.

OVERVIEW OF THE STUDY AREA

Until the 20th Century, the harbor complex was an estuary at the mouth of the San Gabriel and Los Angeles Rivers characterized by extensive mudflats and marsh areas. The estuary provided

habitat for birds, fish, and invertebrates, and the barrier beach of Rattlesnake Island (now Terminal Island) served as nesting habitat for terns and shorebirds.

Dredging, filling, channelization, and other construction over the past 100 years have created the present Port Complex (Figure 1-2). From the mid-1900s to the mid-1930s, three breakwaters (San Pedro, Middle, and Long Beach) were constructed to protect the harbors from damaging wave action. The three breakwaters total nine miles long and are separated by the entrances to Los Angeles Harbor (Angel's Gate) and Long Beach Harbor (Queen's Gate). With construction of the breakwaters, the development of the harbor continued with a series of dredge and fill operations to construct channels, basins, and berths, and to provide fill for additional land necessary for terminal development.

The habitats available for plants and animals have changed as a result of these modifications. The harbor area, including the lower Los Angeles River and the Dominguez Channel (a flood control channel emptying into the Consolidated Slip), is no longer a true estuary because it does not maintain significant year-round fresh water input, and the biota are not distributed along salinity gradients as in typical estuarine systems. Very little sandy beach and salt marsh habitat remain. Dredging to construct channels, turning basins, and berths has decreased the amount of soft-bottom, shallow-water habitat, and the placement of shoreline structures, such as bulkheads, riprap, and pier pilings, has greatly increased the hard substrate available for fouling organisms (e.g., mussels, barnacles, anemones, and seaweeds). The construction of the breakwaters altered circulation and water quality in the harbor.

Figure 1-2 names the features that are referred to in the present study; in particular, the figure shows the division of the Port Complex into Inner Harbor and Outer Harbor. This delineation, as used in this report, was originally established in 1997 by resource agency and port staff for use in determining biological mitigation required for port development projects. It was based entirely upon interpretations of the ecological data available at that time; subsequent adjustments to the boundaries were based upon the biological surveys conducted in 2000 (see the "Previous Studies section below) and documented in Exhibit C of the Bolsa Chica Memorandum of Agreement. Because the inner/outer distinction is based upon habitat quality rather than geographical or topological factors, many areas that may look as if they would be Inner Harbor are, in fact, considered Outer Harbor (e.g., Southeast Basin and the two turning basins). Throughout this report the various sampling stations and survey zones are termed Inner Harbor or Outer Harbor based on where they are located on Figure 1-2.

CLIMATE AND WEATHER

Southern California lies in a climatic regime defined as Mediterranean, characterized by mild winters and warm, dry summers. In the Port Complex, coolest temperatures generally occur from December through February, with warmest temperatures in August and September. Monthly average temperatures range from 57° F (14°C) in December and January to 75°F (24°C) in August. Monthly average precipitation ranges from 0.03 inches (1 millimeter [mm]) in July and August to 3.19 inches (83 mm) in February, with most precipitation occurring from November through March (TWC 2013).

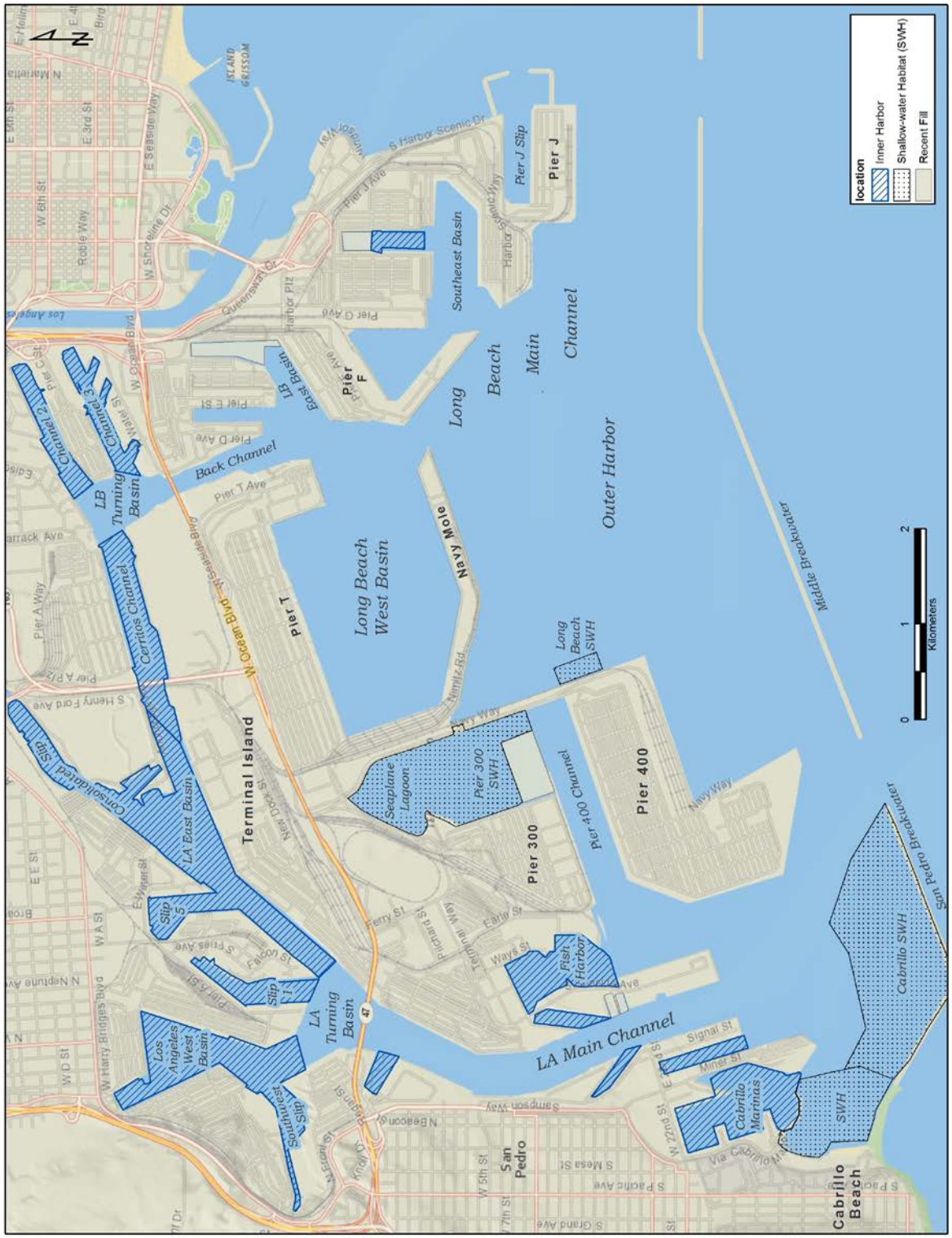


Figure 1-2. The Port Complex study area.

A subtropical high-pressure system offshore of the Southern California Bight produces a net weak southerly/onshore flow in the area (Dailey et al. 1993). Wind speeds are usually moderate, on the order of six miles (10 kilometers [km]) per hour. However, strong winds occasionally accompany the passage of a storm. A diurnal land breeze is typical, particularly during summer, when a thermal low forms over the deserts to the east of the Los Angeles area. Wind speeds diminish with proximity to the coast, averaging about one half the speeds offshore. On occasion, a high-pressure area develops over the Great Basin, reversing the surface pressure gradient and resulting in strong, dry, gusty 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 AND CURRENTS

Tides in 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 day. Since 2003, water levels in the Outer Harbor have ranged from -2.34 ft to + 7.92 ft (-0.71 m to +2.41 meters [m]) above Mean Lower Low Water (MLLW; NOAA 2013).

The Port Complex is protected from incoming waves by the three breakwaters described above. In addition to wave protection, the breakwaters reduce the exchange of water between the Port Complex and the rest of San Pedro Bay, hence creating unique tidal circulation patterns. Maximum flood and ebb current patterns in the Port Complex under typical tidal conditions, as predicted by the Water Resources Action Plan's (WRAP) hydrodynamic and sediment transport model (POLA and POLB 2009), are shown in Figure 1-3. On the Long Beach side, flood currents enter the harbor through the Queen's Gate, as well as the opening at the eastern tip of the Long Beach Breakwater (off the map in Figure 1-2, to the east). Flood currents coming through Angel's Gate flow principally up the Los Angeles Main Channel but also into the Outer Harbor east of Pier 400. During ebb tide, water is drawn from all parts of the Port Complex toward the openings in the breakwaters. Ebb currents leaving the Los Angeles side flow through the Angel's Gate, while ebb currents leaving the Long Beach side exit either through the Queen's Gate or the eastern opening.

Tidal current speeds in the Port Complex are generally weak, with a typical maximum of less than 0.5 ft/second (0.15 m/second). Currents through Angel's Gate and Queen's Gate are faster, but are still usually less than 0.8 ft/second (0.24 m/second). Significant flows from flood control channels (the Los Angeles River and Dominguez Channel) during winter storms can cause localized faster surface currents.

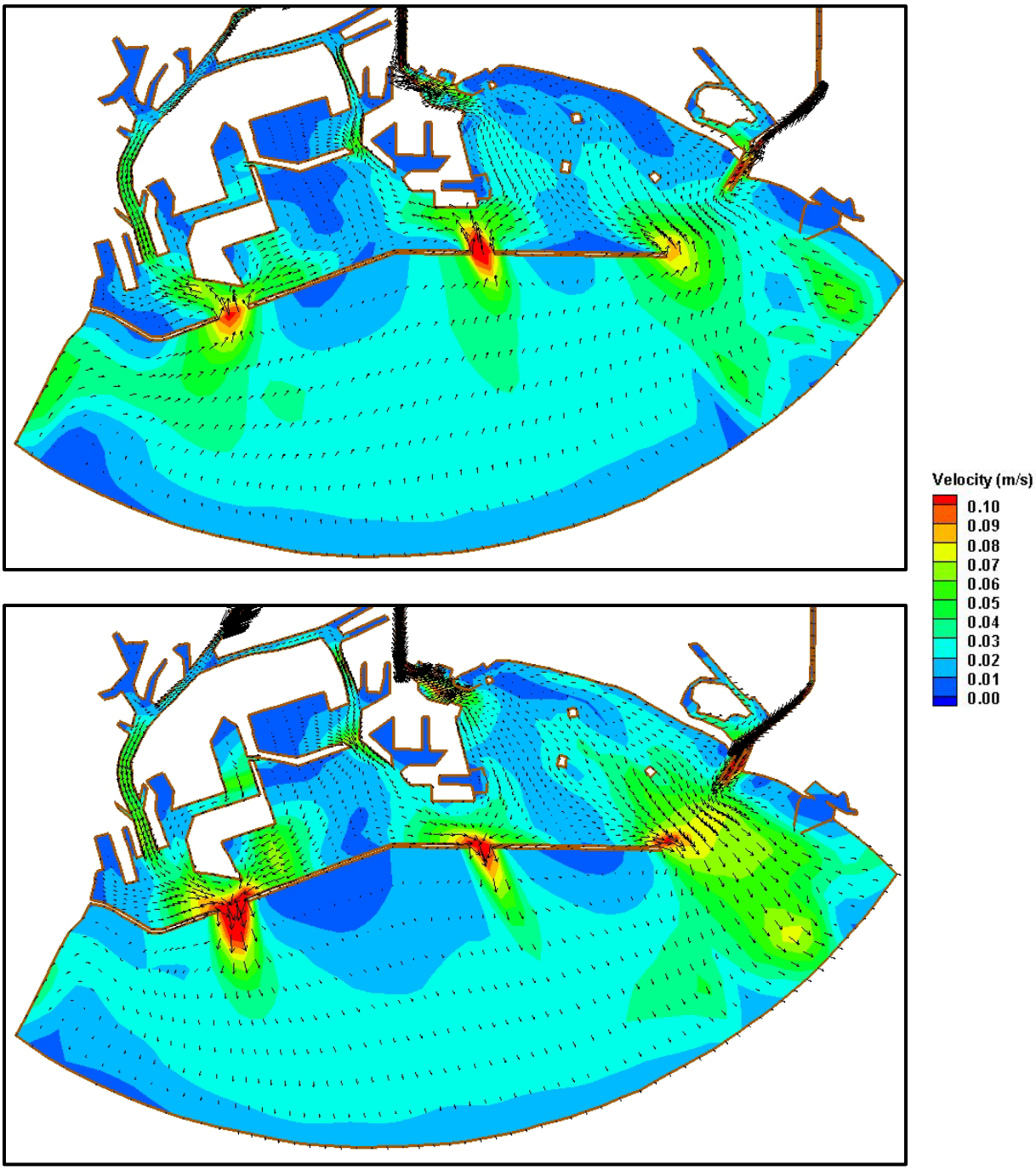


Figure 1-3. Current patterns in the Ports of Long Beach and Los Angeles predicted by the WRAP Model (POLA and POLB 2009). Top: Typical flood tide currents. Bottom: Typical ebb tide currents**.**

PORT DEVELOPMENTS SINCE 2008

Major projects or physical changes that have occurred since the last Port-wide biological survey (2008) include:

- Long Beach Main Channel deepening;
- Long Beach Middle Harbor Redevelopment dredge and fill project;
- Long Beach West Basin dredge and Pier G fill project;
- Completion of the Los Angeles Main Channel deepening dredge and fill project (including expansion of the Cabrillo Shallow Water Habitat and expansion of Pier 300);
- Los Angeles West Basin fill project;
- Maintenance dredging and pile driving in both ports.

In 2009, the Ports adopted the WRAP to support the attainment of beneficial uses and to prevent degradation of water and sediment quality within the Ports (POLA and POLB 2009). The WRAP identifies numerous current and potential control measures to minimize adverse effects of port operation and development on water and sediment quality. These include land use control measures, on-water source control measures, sediment control measures, and watershed control measures.

OVERVIEW OF PREVIOUS STUDIES

Marine habitat and associated biological communities within the Ports have been periodically studied since the 1950s. In 1951 and 1952, the State Department of Public Health (Bureau of Sanitary Engineering) and California Department of Fish and Game performed physical and biological sampling within the Ports. Harbor waters were subject to untreated discharges from storm drains, industrial sources, and domestic/sanitary sources (State Dept. of Public Health 1952), and as a result many areas exhibited high bacteria levels and low dissolved oxygen concentrations. Although some areas of the Port Complex had relatively high dissolved oxygen concentrations and supported moderately diverse invertebrate populations, some areas had such low dissolved oxygen that no animals lived in them (Reish 1959). The discharge of oil refinery wastes was prohibited in 1968, and by 1970 improvements to water quality and species diversity were already apparent (Reish 1972).

From 1971 through 1978, the Harbors Environmental Project of the University of Southern California conducted Port-wide marine environmental studies. These studies were performed to characterize the harbor environment, to evaluate impacts from dredging, and to evaluate impacts from proposed Port expansion projects (HEP 1980). Physical, chemical, and marine biological studies were also carried out in Long Beach Harbor in 1974–1978 before, during, and after modernization of the Long Beach Generating Station, which used harbor waters for condenser cooling (EQA and MBC 1978). The NPDES discharge permits for the Long Beach Generating Station (discharged to the Back Channel) and the Harbor Generating Station (discharged to Los Angeles West Basin) have required extensive physical and marine biological monitoring since the 1970s, and the NPDES permit for the Terminal Island Treatment Plant (TITP; Los Angeles Outer Harbor) has also required extensive physical and biological studies since 1993.

There have been numerous focused water quality, sediment quality, and biological studies in various portions of the Port Complex since the 1980s. Large-scale marine environmental surveys were performed in the Port of Los Angeles in 1986–1987 (MEC 1988), in the Port of Long Beach in 1983–1984 (MBC 1984) and 1990–1993 (MBC 1994), and throughout the entire Port Complex in 2000 (MEC 2002) and 2008 (SAIC 2010). In addition, physical and biological surveys in the Port Complex were conducted as part of regional (Southern California Bight) monitoring studies in 1998, 2003, 2008, and 2013.

STUDY OBJECTIVES

The primary objectives of the present study were to evaluate the current state of the marine biological resources of the Port Complex and to compare the results to previous harbor-wide surveys. To accomplish these objectives, the present study sampled and/or evaluated the following elements:

- Physical characteristics (water quality and sediment grain size);
- Benthic infauna;
- Ichthyoplankton;
- Demersal fish and macroinvertebrates;
- Pelagic and shallow-water fishes;
- Riprap epifauna;
- Kelp and macroalgae;
- Eelgrass;
- Birds;
- Marine mammals; and
- Non-native species.

Study findings for each of these resources are presented and summarized in the following chapters. Field data and data analyses utilized for data presented in the subject chapters are presented in Appendices A through K.

STUDY DESIGN

The design of the 2013–2014 study was similar to those used during the 2000 and 2008 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 2013–2014 included:

- The number of ichthyoplankton stations increased from 19 to 26;
- The benthic infauna and sediment grain size analysis surveys occurred in summer and spring;
- The number of water quality surveys increased from one to three;
- A rapid assessment study was added to the riprap study; and
- Photo quadrats were added to the kelp and macroalgae study.

With concurrence of the resource agencies, the Ports decided to decrease the number of seasons sampled and to allocate the resulting resources to an increased the number of sampling stations. Previous studies indicated that winter sampling did not provide data that provided much additional insight over spring and summer data. Therefore, winter sampling was sacrificed in order to add three new sampling stations (LB15, LB16, and LA16).

In addition, some stations were repositioned to account for Port development activities since 2008. To the extent possible, an equal or nearly-equal number of stations was sampled in each Port for each project element, arranged so as to sample as many habitat types as possible. The stations occupied for the water quality and sediment element, the fish and ichthyoplankton elements, and the benthos and epibenthos elements are listed in Table 1-1 (note that the fish, ichthyoplankton, and epibenthos elements sampled only 26 of the 32 stations). Five of the stations (LA2, LB2, LA3, LA7, LA8) are located in shallow water areas that were created by the two Ports to mitigate for impacts to marine biological resources caused by Port developments, specifically harbor fills to create land for marine cargo terminals. For elements that used different stations (riprap, kelp and macroalgae, eelgrass, and birds), station maps and lists are provided in the respective report sections. These maps, along with station coordinates, are also presented in Appendix L. Station location changes since the 2008 study include:

- Station LB12 was moved from Slip 1 in Long Beach East Basin because the area had been filled since the previous survey. Slip 3 in the East Basin was considered for the new location, but concerns about the ongoing and planned construction in the East Basin as part of the Middle Harbor Redevelopment Project prompted relocation to the Back Channel, outside of the construction zone. This change may affect comparisons with previous studies, as Slip 1 was a “dead-end” Inner Harbor slip and the Back Channel is an open, deep water Outer Harbor channel. Future studies should consider relocating Station LB12 to Slip 3 to better represent the habitat previously represented by Slip 1.
- New Station LB15 was located near the center of the Middle Breakwater in the Outer Harbor;
- New Station LB16 was located in Channel 3 in the Inner Harbor;
- Station LA6 was moved from the entrance to Slip 5 to the Los Angeles East Basin (but remained in the Inner Harbor);
- Station LA10 was moved from the entrance to Fish Harbor in the Outer Harbor, where it was located for the 2008 survey, to the center of Fish Harbor in the Inner Harbor (consistent with the 2000 survey);
- Station LA14 was located in Consolidated Slip midway between the locations of previous Stations LA14i and LA14o (but remained in the Inner Harbor);
- Station LA15 was moved from the border between the LA Turning Basin and the entrance to the Los Angeles West Basin to the middle of the LA Turning Basin in the Outer Harbor;
- New Station LA16 was located in Slip 5 in the Inner Harbor; and

Table 1-1. Station designations and harbor habitat types.

Station	Designation/Location	Harbor Type	Station	Designation/Location	Harbor Type
LB1	LB Outer Harbor (N)	Outer	LA1	LA Outer Harbor (E)	Outer
LB2*	Long Beach SWH	Outer	LA2*	Cabrillo SWH (E)	Outer
LB3	LB West Basin (W)	Outer	LA3*	Cabrillo SWH (W)*	Outer
LB4	Channel 2	Inner	LA4	LA Main Channel	Outer
LB5	Southeast Basin (S)	Outer	LA5	LA West Basin (N)	Inner
LB6	Pier J Slip	Outer	LA6	LA East Basin	Inner
LB7	LB Main Channel (N)	Outer	LA7*	Pier 300 SWH	Outer
LB8	Pier J Slip Breakwater	Outer	LA8*	Seaplane Lagoon	Outer
LB9	LB Main Channel (S)	Outer	LA9	Pier 400 Channel	Outer
LB10	Southeast Basin (N)	Outer	LA10	Fish Harbor	Inner
LB11	LB West Basin (E)	Outer	LA11	LA Outer Harbor (W)	Outer
LB12	Back Channel	Outer	LA12	Cabrillo Marinas	Inner
LB13	LB Turning Basin	Outer	LA13	Southwest Slip	Inner
LB14	Cerritos Channel	Inner	LA14	Consolidated Slip	Inner
LB15	LB Outer Harbor (S)	Outer	LA15	LA Turning Basin	Outer
LB16	Channel 3	Inner	LA16	Slip 5	Inner

Note: N, S, E, W differentiate stations that that are in the same basin or channel by orientation – north, south, east, or west.

* SWH indicates shallow-water habitat in the Outer Harbor

- Kelp and Macroalgae Station T3 was moved by the field crew to the outer breakwater of the Cabrillo Marina (still in the Outer Harbor) because the original location, the groin at Cabrillo Beach, was removed after 2008.

Most of the field methods in 2013–2014 were similar to those used during the 2008 study. However, the duration of ichthyoplankton tows was reduced from 10 minutes to three minutes. This change was determined on the basis of review of data from past ichthyoplankton studies (including MBC et al. 2007). SAIC (2010) recommended changing the stepped-oblique tow used in 2000 and 2008 to a standard oblique tow, which was implemented in 2013 and is consistent with other ichthyoplankton studies in the southern California region.

ENVIRONMENTAL CONDITIONS DURING THE STUDY PERIOD

Because the results of the 2013–2014 surveys will be compared with results of other studies within the Port Complex, it is important to describe the climatic and oceanographic conditions in which the study was undertaken. In September 2013, at the onset of the study, the Port Complex was part of a large area of southern California classified as an area of "severe drought" (USDM 2013). At that point, rainfall in the Ventura/Los Angeles area was only 47% of the historic average (CDEC 2013). By October 2014, when field sampling ended, precipitation was only 41% of the historic average (CDEC 2014). Sea surface temperatures were near average at the end of 2013, but well above average during the first three months of 2014 (Figure 1-4).

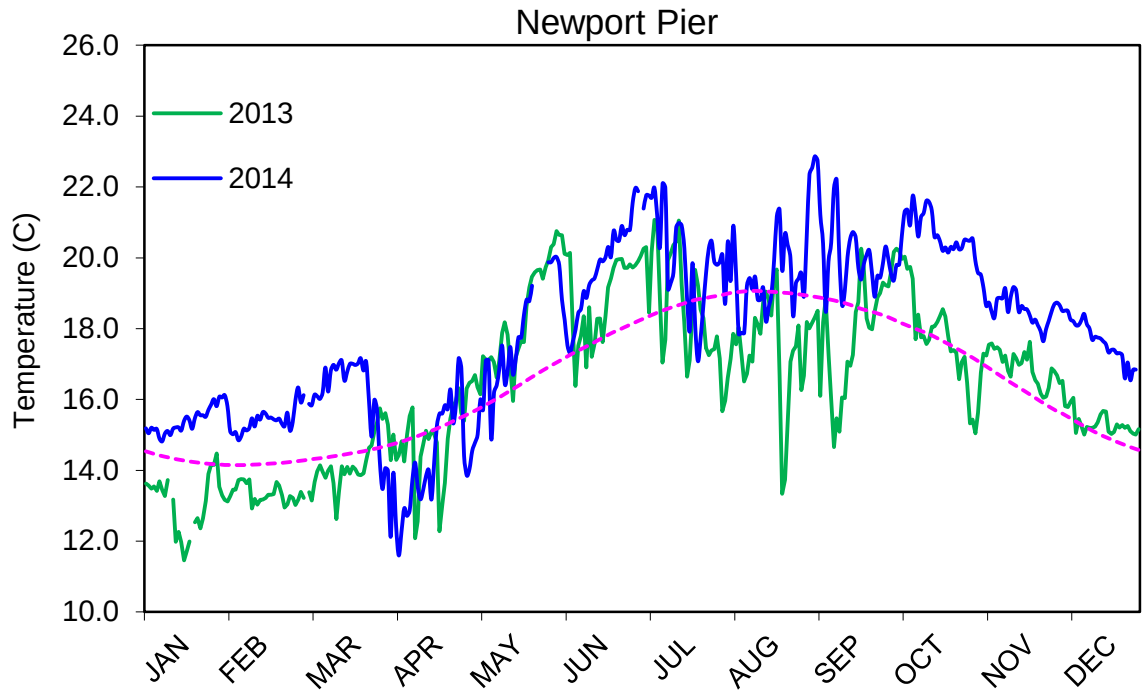


Figure 1-4. Sea surface temperatures at Newport Pier in 2013 and 2014. Also included is the harmonic mean (1925–2014, in pink) averaged at 60-day intervals.

El Niño-Southern Oscillation (ENSO)-neutral conditions persisted in the Northern Hemisphere during the study, but shifted to El Niño–positive, as determined by the Oceanic Niño Index, in spring 2015 (CPC 2015), not long after the study ended. These unusual conditions may have been at least partly responsible for a number of observed biological phenomena in 2013-2014, such as sea star wasting disease (USC 2014) and a very high incidence of sea lion strandings (NOAA 2015).

In the eastern Pacific Ocean, a mass of warmer-than-average water (termed “The “Blob”) persisted for at least 18 months starting in 2013 (Kintisch 2015), although the warmer temperatures did not appear to affect California waters until 2014. In August 2014, Hurricane Marie produced waves of up to 3.42 m (11.2 ft) in height (CDIP 2015) that damaged all three breakwaters and damaged pilings at Pier T (Gazzettes 2014; Press Telegram 2015).

REPORT ORGANIZATION

This report is organized in accordance with the list of elements set forth in the Objectives section, above. Each chapter includes:

- An introduction to the subject matter;
- A description of the materials and methods;
- Results of field and laboratory investigations; and
- A discussion of the results.

Tables, figures, and a list of references are included within each chapter, and additional analyses and raw data are included as appendices (by element).

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CHAPTER 2 PHYSICAL CHARACTERISTICS

This section presents the results of water quality and sediment grain size surveys conducted throughout the Port Complex during 2013–2014. Because marine biological communities exist in equilibrium with their physical environment, changes in seawater and sediment characteristics (e.g., temperature, salinity, dissolved oxygen concentrations, grain size composition) can affect these communities. For example, many organisms are sensitive to variations in dissolved oxygen and pH, and the activity levels of fish and marine invertebrates are governed by water temperature. Likewise, sediment characteristics are known to affect the ability of benthic infaunal organisms to burrow, build tubes, and feed (Gray 1981; Snelgrove and Butman 1994).

MATERIALS AND METHODS

WATER QUALITY

Water quality surveys were conducted during August 2013 (summer), February 2014 (winter), and May 2014 (spring) at 32 stations in the Port Complex (Figure 2-1; Table 2-1; Appendix L). Vertical profiles of the water column were measured using a Sea-Bird® Water Quality Monitoring System (SBE 25). The SBE 25 is a conductivity-temperature-depth (CTD) profiler equipped with additional sensors for hydrogen ion concentration (pH), dissolved oxygen (DO), fluorometry, and light transmission. Chlorophyll-a, an indication of the amount of phytoplankton in the water, was measured for the first time in harbor-wide surveys during the current study with a fluorometer.

Water quality sampling.

At each station the CTD was turned on, lowered to the water surface, allowed to equilibrate for 90 seconds, lowered slowly to the seafloor, raised to the surface, and turned off. All parameters were measured throughout the water column at each station during each survey; the CTD was programmed to collect eight readings per second. Data were reviewed in the field to identify any anomalies.

A 0.3-m diameter Secchi disk was also used to measure water clarity. At each station the Secchi disk was lowered from the water surface down through the water column. The depth at which it was no longer visible was recorded on formatted data sheets.

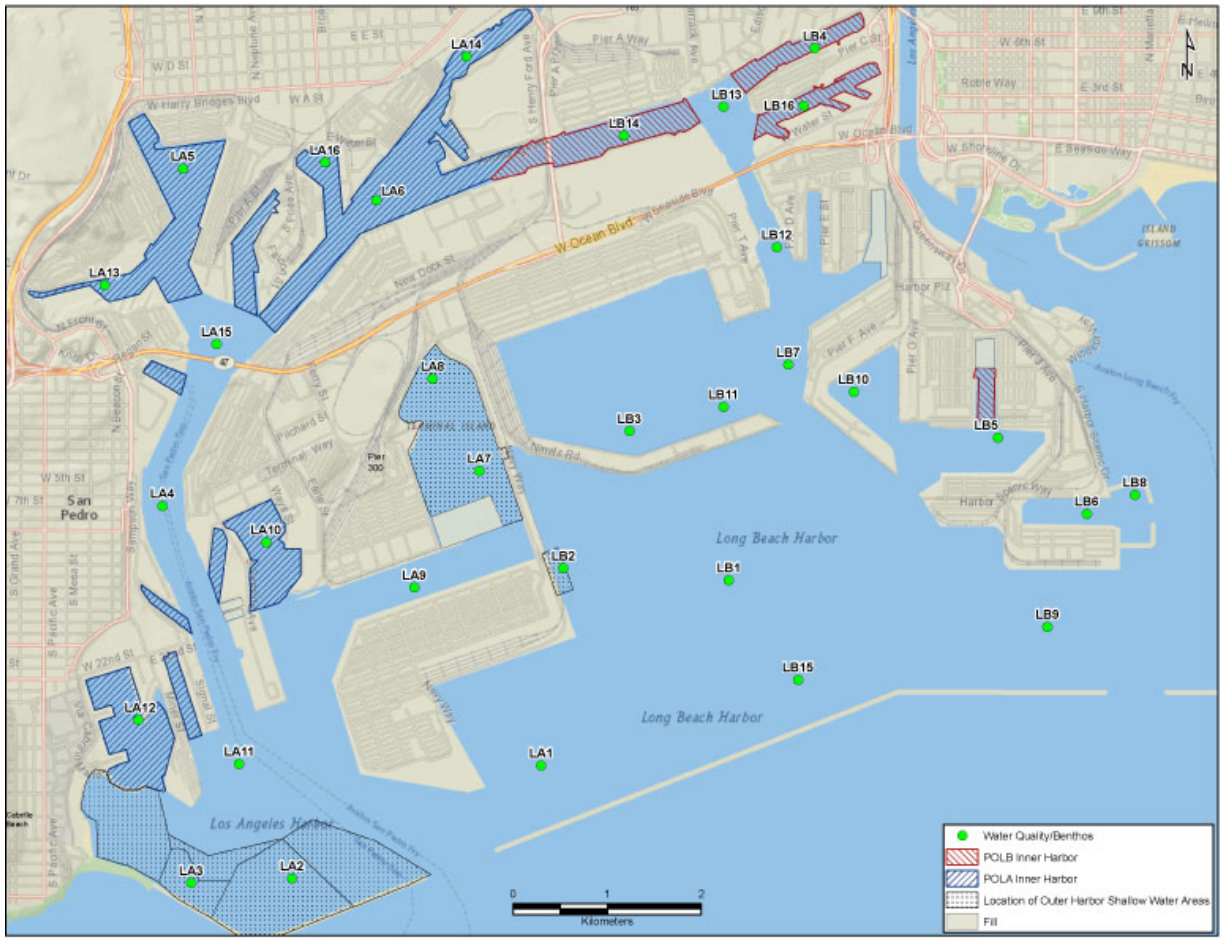

Figure 2-1. Location of water quality and sediment stations.

All of the CTD probes/sensors were calibrated by Sea-Bird Electronics at the factory in 2013 prior to the start of the study. The DO probe, pH probe, and transmissometer were also calibrated by MBC scientists according to factory standards prior to each survey. Water quality data was processed using the Sea-Bird proprietary software (SeaSoft). The resulting data were imported into Microsoft Office Excel spreadsheets for further reduction and analysis.

Water quality profiles were constructed using SigmaPlot version 11, and mapped images were constructed using ArcGIS version 10.3.1. For figures where continuous data is presented between the stations, the ArcMap Spline with Barriers tool (ArcMap 2015) was utilized to interpolate information between the station points.

Table 2-1. Stations used for water and sediment sampling.

Station	Designation/Location	Harbor Type	Station	Designation/Location	Harbor Type
LB1	LB Outer Harbor (N)	Outer	LA1	LA Outer Harbor (E)	Outer
LB2*	Long Beach SWH	Outer	LA2*	Cabrillo SWH (E)	Outer
LB3	LB West Basin (W)	Outer	LA3*	Cabrillo SWH (W)*	Outer
LB4	Channel 2	Inner	LA4	LA Main Channel	Outer
LB5	Southeast Basin (S)	Outer	LA5	LA West Basin (N)	Inner
LB6	Pier J Slip	Outer	LA6	LA East Basin	Inner
LB7	LB Main Channel (N)	Outer	LA7*	Pier 300 SWH	Outer
LB8	Pier J Slip Breakwater	Outer	LA8*	Seaplane Lagoon	Outer
LB9	LB Main Channel (S)	Outer	LA9	Pier 400 Channel	Outer
LB10	Southeast Basin (N)	Outer	LA10	Fish Harbor	Inner
LB11	LB West Basin (E)	Outer	LA11	LA Outer Harbor (W)	Outer
LB12	Back Channel	Outer	LA12	Cabrillo Marinas	Inner
LB13	LB Turning Basin	Outer	LA13	Southwest Slip	Inner
LB14	Cerritos Channel	Inner	LA14	Consolidated Slip	Inner
LB15	LB Outer Harbor (S)	Outer	LA15	LA Turning Basin	Outer
LB16	Channel 3	Inner	LA16	Slip 5	Inner

Note: N, S, E, W differentiate stations that that are in the same basin or channel by orientation – north, south, east, or west.

* SWH indicates shallow-water habitat in the Outer Harbor

SEDIMENT GRAIN SIZE

Sediment grain size surveys were conducted during summer and spring. Bottom samples for sediment grain size analysis were collected with a standard 0.1-m^2 van Veen grab at the same 32 stations sampled for water quality (Figure 2-1, Table 1-1). A sample of sediment for grain size analysis was collected from the upper two centimeters of each grab. Samples were transferred to labeled plastic bags, stored at 4°C, and transported to the analytical laboratory for analysis. Strict chain-of-custody procedures were followed during sample collection, transport, and analysis.

The size distributions of sediment particles were determined using two techniques: laser light diffraction to measure the amount and patterns of light scattered by a particle's surface for the sand, silt, and clay material; and by standard sieving for the gravel material (if present). Laboratory data from the two methods were combined and presented in tabular format and plotted as size distribution curves. Resulting analyses included mean grain size, sorting, skewness, and kurtosis.

WATER QUALITY RESULTS

In summer, water quality was sampled on 27 August 2013, in winter on 13 February 2014, and in spring on 1 May 2014. No oil, grease, or red tide was noted at any station on any survey date. Waters throughout the Port Complex were slightly turbid at most stations in summer and winter, but clear during the spring survey at all stations except LB16 (Channel 3), where slight turbidity was observed. Floating debris (e.g., wood, plastic, and/or drift kelp) was observed at 20 stations in summer, 13 stations in winter, and 15 stations in spring.

Temperature, DO, pH, salinity, and water clarity data are presented graphically by parameter, station, and depth in Figures 2-2 through 2-6. These data, as well as conductivity, density, and fluorescence, are also presented in tabular format by station and summarized by survey in Appendices A-1 through A-3.

TEMPERATURE

In marine waters more than a few meters deep a typical summer temperature profile consists of warmer water in the upper layer and cooler water below. The transition from warmer to cooler water is often abrupt: temperature can drop by more than 1°C per meter, a phenomenon called the "thermocline". Thermoclines typically develop in the spring, as solar warming heats up the surface water faster than wind and turbulence can mix surface and deep water, and disappear in fall as a result of reduced warming and increased wind mixing. Some of the stations in the Port Complex are too shallow for a thermocline to develop, and others are subject to too much mixing.

Surface water temperatures during the summer survey ranged from 15.48°C at Station LA3 to 21.16°C at Station LA8 (Figure 2-2; Appendix A-1). Distinct thermoclines were evident at a number of stations during the summer sampling (Figure 2-2). At some stations, particularly Inner Harbor stations such as LA5 and LA6, the difference between surface and bottom temperatures exceeded 5.5°C, but a more typical difference was on the order of 3°C.

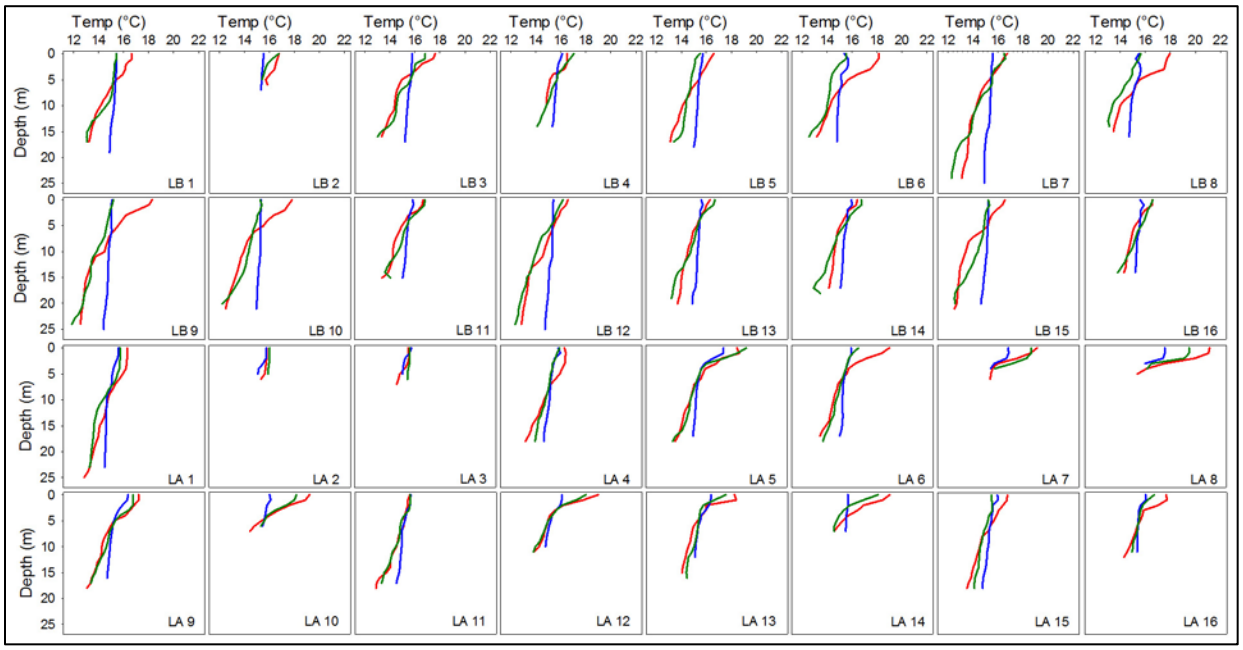

Figure 2-2. Seasonal water column temperature profiles for water quality stations. Note: Red indicates summer 2013, blue indicates winter 2014, and green indicates spring 2014.

In winter, surface water temperatures ranged from 15.23°C at Station LB9 to 17.58°C at Station LA8 (Figure 2-2; Appendix A-2). Temperatures decreased only slightly (1.5°C or less) with depth through the water column. However, there were indications of weak thermoclines at several stations (e.g., LA5, LA7, LA8, LA12), with surface-to-bottom differences of up to 2.5°C. These stations were mostly in basins with restricted circulation, which allowed solar warming of surface water to overcome wind mixing.

In spring, surface water temperatures ranged from 15.34°C at Station LB9 to 19.52°C at Station LA8 (Figure 2-2; Appendix A-3). As in the summer survey, temperature decreased with depth at most stations, and surface-to-bottom differences of up to 6°C were observed. Strong thermoclines were present at a few stations (e.g., LA5, LA8, and LA12), but in general, temperatures decreased fairly steadily with depth.

DISSOLVED OXYGEN

Because dissolved oxygen (DO) is critical to marine organisms, its concentration in a given water body is an important measure of habitat quality. Oxygen solubility is inversely related to water temperature, so that in the absence of other factors DO concentrations are higher in cold water (i.e., during winter) than in warm water. However, factors such as the production of oxygen through the photosynthetic activity of phytoplankton and seaweed, the consumption of oxygen by decay processes, chemical reactions, and animal respiration, and the mixing of waters with different DO concentrations can result in higher or lower DO concentrations than would be predicted on the basis of water temperature alone. In southern California, nearshore surface waters are nearly always saturated, with levels as high as 140% of saturation occurring on occasion (SCCWRP 1973). Dissolved oxygen typically fluctuates in the nearshore temperate

environment around 7 to 8 mg/l, with the threshold of biological concern being 5 mg/l (LARWQCB 1994).

During the summer survey, surface DO concentrations ranged from 6.39 mg/l at Station LA14 to 10.10 mg/l at Station LA1 (Figure 2-3; Appendix A-1). Surface DO concentrations exceeded 7 mg/l at all but two stations (LB4 and LA 14), and values greater than 9 mg/l were measured at eight stations. All but one of the surface concentrations above 9 mg/l occurred at Outer Harbor stations, including several in open basins (LB3 and LA7). The exception was Station LA13, where, despite being in an Inner Harbor basin, high surface and near-surface concentrations occurred.

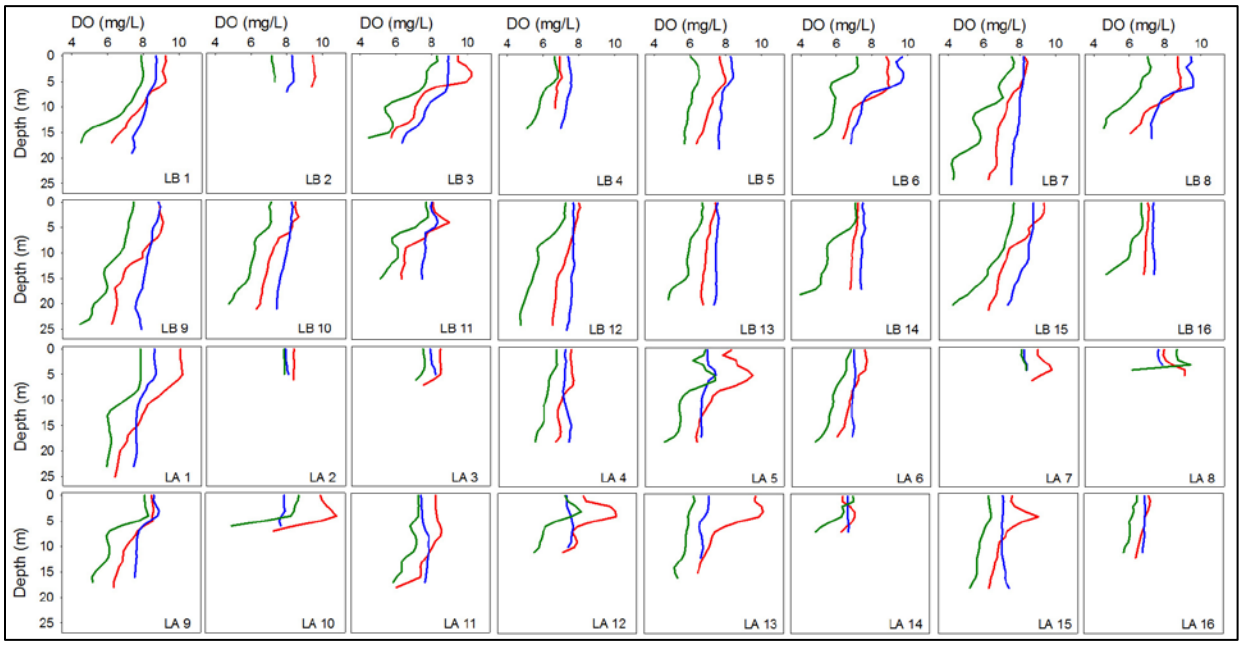

Figure 2-3. Seasonal water column dissolved oxygen profiles for water quality stations.
Note: Red indicates summer 2013, blue indicates winter 2014, and green indicates spring 2014.

At most stations, summertime DO concentrations increased with depth in the upper five meters of the water column, to produce subsurface maxima, and then decreased toward the bottom. Highest subsurface values were found at LA1, LB3, and LA10); the very high value at LA10 (10.81 mg/l) was likely due to intense photosynthetic activity in the shallow, calm-water basin. The greatest surface-to-bottom decreases in DO, of approximately 3.7 mg/l, occurred at Stations LB3 and LA1. The lowest value, 5.73 mg/l, was measured near bottom at Station LB3.

In winter, surface DO concentrations ranged from 6.68 mg/l at Station LA14 to 9.70 mg/l at Station LB6 (Figure 2-3; Appendix A-2). Subsurface maxima occurred in the upper five meters at some stations (e.g., LB8, LB11, and LA9), but in general, DO concentrations either changed little from surface to bottom or decreased steadily with depth. Overall, the greatest surface-to-bottom difference (a decrease of 2.9 mg/l) was recorded at Station LB6. The lowest value during the winter survey, 6.34 mg/l, was measured near bottom at Station LB3.

In the spring survey, surface DO values ranged from 6.04 mg/l at Station LB5 to 8.70 mg/l at Station LA10 (Figure 2-3; Appendix A-3). Subsurface DO concentrations were slightly higher than surface concentrations at a few stations, but in general, DO decreased with depth at all stations except at the shallow Stations LB2, LA2, and LA7. The pattern of highest DO concentrations near the surface likely reflected increased photosynthetic activity compared to winter. The greatest surface-to-bottom decreases, of about 3.8 mg/l, were recorded at Stations LB3 and LA10. Dissolved oxygen concentrations <5 mg/l were measured near bottom at 15 stations in spring. The lowest DO value of 4.00 mg/l was measured near bottom at Station LB14.

PH

Hydrogen ion concentration (pH) is a measure of the acidity of water. Because of the buffering capacity of seawater, the pH of ocean waters varies in a narrow range around an average of approximately 8.1 (Sverdrup et al. 1942), meaning that ocean water is slightly alkaline. Hydrogen ion concentration is important in marine ecology because many organisms have adapted to the narrow range within which ocean pH varies. Besides influencing the pH of body fluids, pH also affects the ability of organisms to form hard body parts such as snail shells and coral: more acidic conditions tend to dissolve the calcium carbonates that comprise most shells and coral reefs.

In nearshore areas, pH may be more variable than in the open ocean due to physical, chemical, and biological influences. For instance, in areas with large organic influx, such as bays, estuaries, and river mouths, increased microbial decomposition can lower pH levels. Lower pH values may also occur in areas of freshwater influx, since fresh water generally has a lower pH than salt water. In contrast, phytoplankton blooms, which are often associated with nearshore upwelling, can cause an increase in pH levels. High photosynthetic rates increase the removal of carbon dioxide from water, and thus reduce the carbonic acid concentration and increase the pH.

During the summer survey, surface pH ranged from 7.92 at Station LA14 to 8.19 at Station LA1 (Figure 2-4; Appendix A-1), and averaged 8.01 among all stations and depths. At 16 stations, pH increased with depth in the upper few meters of the water column, and then decreased with depth to the bottom. Near-bottom pH values were lower than surface concentrations at all stations except at Station LA14.

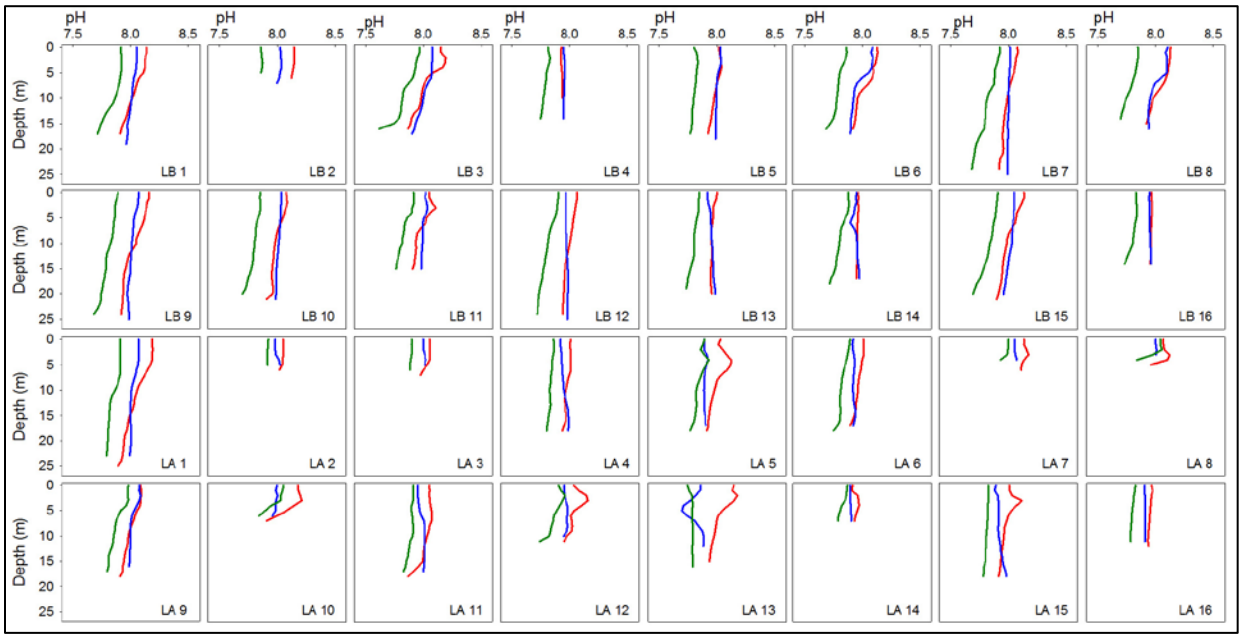

Figure 2-4. Seasonal water column pH profiles for water quality stations. Note: Red indicates summer 2013, blue indicates winter 2014, and green indicates spring 2014.

In winter, pH at the surface ranged from 7.86 at Station LA13 to 8.11 at Station LB8 (Figure 2-4; Appendix A-2), and averaged 8.00 among all stations and depths. At 19 stations, pH increased with depth in the upper few meters of the water column, and then decreased with depth to the bottom. Near-bottom pH values were up to 0.1 pH unit higher than surface concentrations at 14 stations.

During the spring survey, surface pH ranged from 7.74 at Station LA13 to 8.05 at Station LA10 (Figure 2-4; Appendix A-3), and averaged 7.85 among all stations and depths. At 14 stations, pH increased slightly with depth in the upper few meters of the water column, and then decreased with depth to the bottom. Near-bottom pH values were less than or equal to surface concentrations at all stations except at Station LA13.

WATER CLARITY

Water clarity is important in aquatic environments primarily as an indicator of light penetration, which affects the depth to which photosynthesis takes place. It also indicates the presence of suspended particulate matter such as plankton and sediments. Local variations in water clarity can be caused by resuspension of sediments by wind, currents, vessel passages, and dredging or other in-water construction, by stormwater or wastewater discharges, and by phytoplankton blooms.

During the summer survey, transmissivity (percent light transmittance) at the surface ranged from 50.4% at Station LA10 to 75.0% at Station LA12, with values at most stations between 60–70% (Figure 2-5; Appendix A-1). Secchi depths in the Port Complex ranged from 2.5 to 4.5 m and averaged 3.1 m. Transmissivity varied considerably with depth among stations.

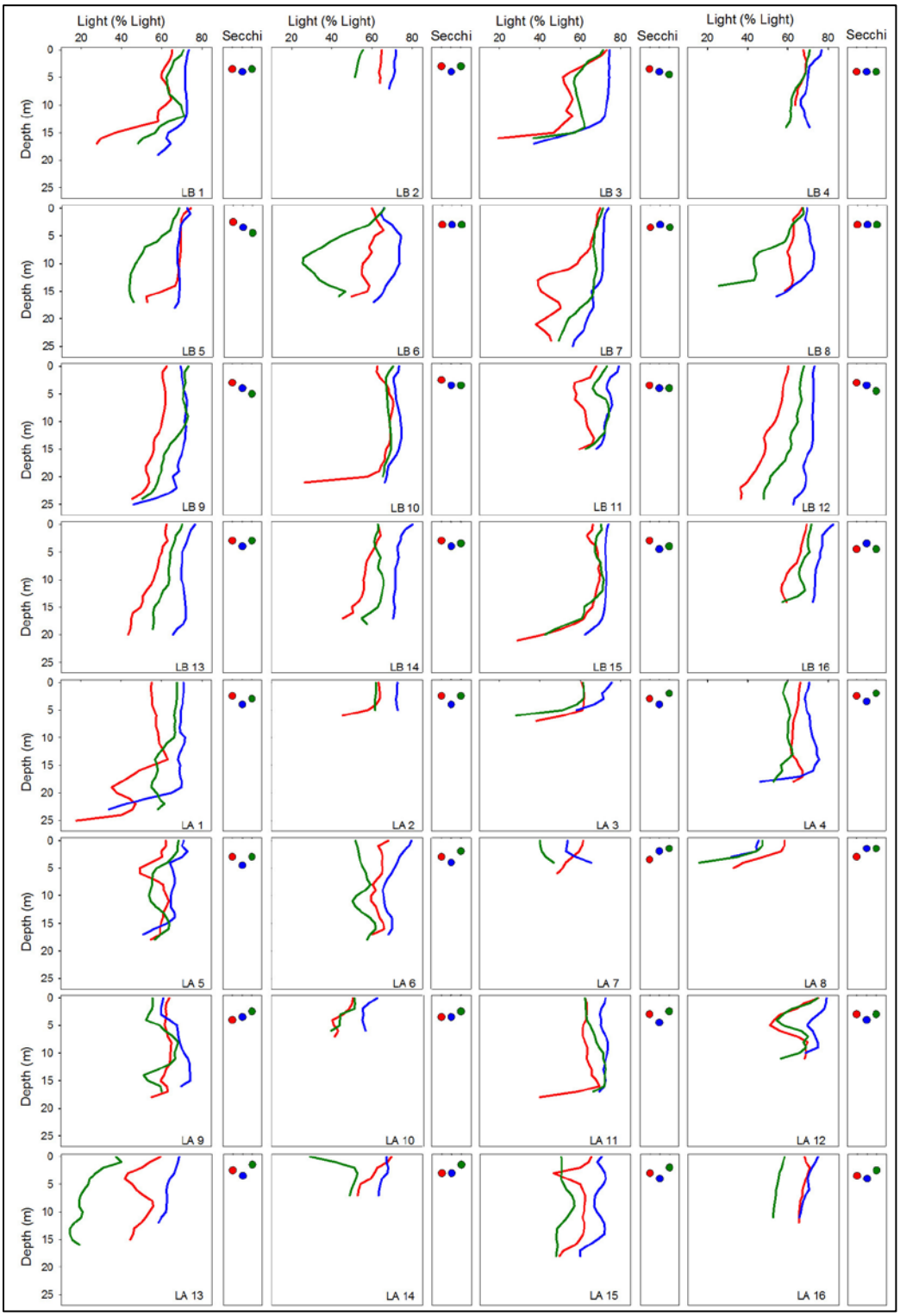

Figure 2-5. Seasonal water column percent transmissivity profiles for water quality stations. Note: Red indicates summer 2013, blue indicates winter 2014, and green indicates spring 2014.

Overall, transmissivity declined with depth during the summer survey, which is likely due to resuspension of bottom sediments. The greatest surface-to-bottom difference in light transmittance was a reduction of almost 54 percentage points at Station LB3.

During the winter survey, harbor waters were, on average, somewhat clearer than during summer. Transmissivity at the surface ranged from 45.3% at Station LA8 to 82.5% at Station LB16 (Figure 2-5; Appendix A-2), with values at most stations between 65–80%. Secchi depths ranged from 1.5 to 4.5 m and averaged 3.7 m. Transmissivity did not decrease steadily with depth at every station: mid-depth maxima were observed at 14 stations. However, near-bottom transmissivity was lower than at the surface at all stations except LA2, LA7, and LA9. Surface-to-bottom differences of more than 37 percentage points were measured at Stations LB3 and LA1.

In spring, transmissivity at the surface ranged from 28.8% at Station LA14 to 74.7% at Station LA12 (Figure 2-5; Appendix A-3). Surface transmissivity was markedly lower than in winter or summer at 14 stations, and was lower than in winter at another 14 stations. This pattern was likely due largely to increased phytoplankton activity. Secchi depths ranged from 1.5 to 5.0 m and averaged 3.0 m. At most stations, transmissivity did not decrease steadily with depth, and it actually increased with depth at LA6, LA7, LA9, LA11, and LA14. The greatest surface-to-bottom differences in light transmittance were reductions of over 40 percentage points at Stations LB3 and LB8.

SALINITY

The concentration of dissolved salts, salinity, in the open ocean is generally approximately 35 parts per thousand (ppt) (Sverdrup et al. 1942). In nearshore areas subjected to freshwater influx, salinity is usually slightly lower than in the open ocean. In southern California, salinity of nearshore waters is generally between 33 and 34 ppt (Hickey 1993). Reductions in nearshore salinity usually result from freshwater input, while slight increases are often associated with upwelling of colder, more saline waters or solar heating and evaporation in poorly-mixed surface waters during summer months.

Salinity in the Port Complex over all stations, depths, and seasons averaged approximately 33.5 practical salinity units (psu) (Appendices A-1 through A-3). Salinity values were similar throughout the Port Complex, mostly varying between 33.3 and 33.6 psu from surface to bottom. The only exceptions were at Station LA14 and at stations near the Los Angeles River mouth (LB6, LB8, and LB9), where surface lenses of slightly lower salinity, due to freshwater runoff from the land, were recorded in all three seasons: 32.8 psu at LA14 and 32.6 psu at LB9 in summer; 33.1 psu at LB14 and 31.9 psu at LB8 in winter; and 32.2 psu at LA14 and 33.2 psu at LB9 in spring.

CHLOROPHYLL

Chlorophyll-a, measured indirectly as fluorescence, is an indicator of phytoplankton productivity. Phytoplankton concentrations tend to be highest in the nearshore zone, where nutrients are more abundant than offshore, and in upper portions of the water column, where sunlight is available.

Chlorophyll-a was generally low (less than 20 milligrams per cubic meter [mg/m^3]) during the surveys, with highest values at each station reported at mid-depth or, less frequently, near bottom (Appendices A-1 through A-3). Overall, chlorophyll-a levels were highest during the summer survey; chlorophyll values were similar in winter and spring, and generally lower than in summer. Highest values (greater than 50 mg/m^3) occurred in mid-water at Station LA5 and near bottom at Station LA10. Lowest values (less than 2 mg/m^3) occurred near the surface at Station LA16 in winter and near-bottom at Stations LB14 and LA5 in spring.

SEDIMENT RESULTS

Sediments were collected on 28 and 29 August 2013 (summer), and 19 and 20 May 2014 (spring). Sediment distribution curves and parameters describing sediment grain size characteristics for each station are presented in Appendices B-1 and B-2 and summarized in Appendices B-3 and B-4.

GRAIN SIZE

Grain size is expressed in phi (Φ) units, which are inversely related to grain diameter. In summer, sediments at the 32 stations were composed primarily of silt (56%), with smaller amounts of sand (24%) and clay (19%) (Figure 2-6; Appendix B-3); gravel was not found at any of the stations. The mean grain size was 5.32 phi (25 µm effective diameter, medium silt). Sediments were finest at Station LB12, where mean grain size was 6.62 phi (10 µm, fine silt), and coarsest at Station LA2, where mean grain size was 2.66 phi (158 µm, fine sand).

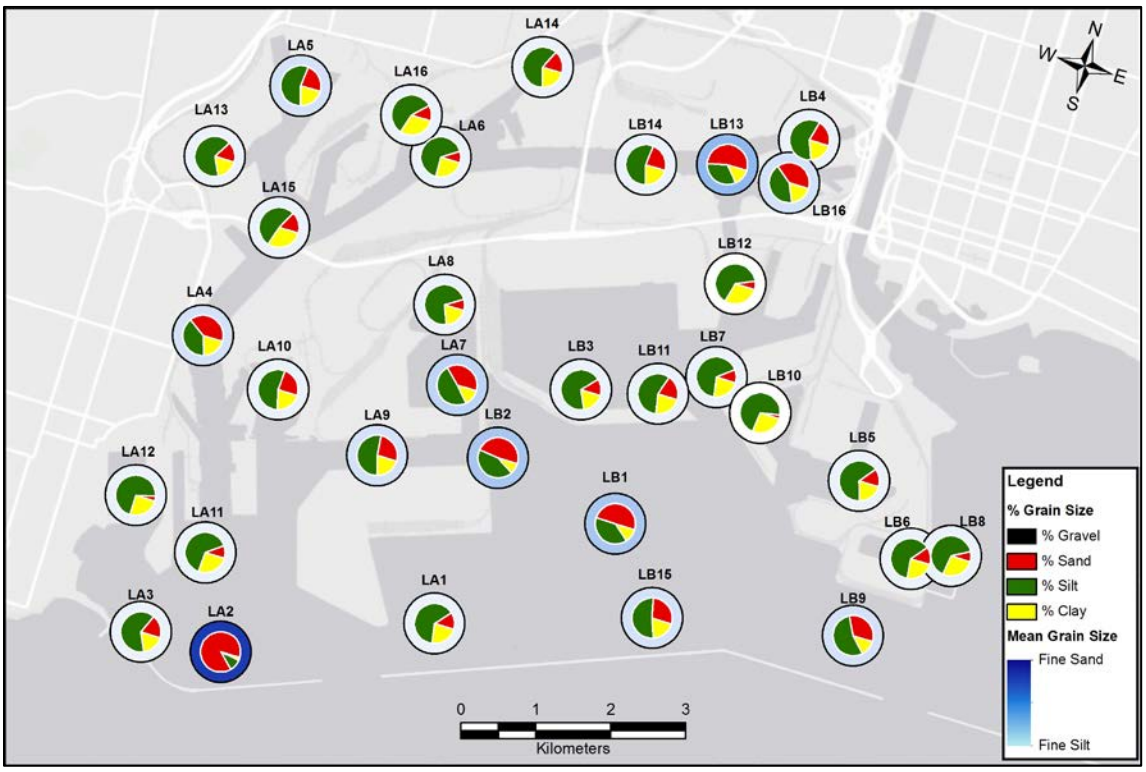

Figure 2-6. Percent contribution by grain size by station and distribution of mean grain size. Summer 2013.

In spring, sediments at the 32 stations were composed primarily of silt (56%), with smaller amounts of sand (23%) and clay (21%) (Figure 2-7; Appendix B-4). Gravel was found only at Station LA15, where it constituted less than 1% of the sediment. Sediments were finest at Station LB7 and LA8 (6.80-6.87 phi, 9 µm, fine silt) and coarsest at Station LA4, where mean grain size was 2.32 phi (200 µm, fine sand).

OTHER SEDIMENT MEASURES

Values for the remaining sediment measures (sorting, skewness, and kurtosis) are presented in Appendix B. Sorting is a measure of the spread of the particle distribution curve. ”Poorly-sorted” sediments are composed of a broad range of particle size classes, and poor sorting indicates that a variety of processes, which may include deposition, tidal currents, and propeller wash, are influencing local sediment characteristics. “Well-sorted” sediments are composed of fewer size classes, and indicate that processes affecting grain size are relatively consistent. Skewness is a measure of the symmetry of the particle distribution curve; a value near zero indicates a symmetrical distribution of fine and coarse materials around the median of the curve, a value greater than 0.1 indicates an excess of fine material, and a value less than -0.1 indicates an excess of coarse material. Kurtosis is a measure of the peakedness of the particle distribution curve. A kurtosis value near 1.0 represents a normal (mesokurtic) particle distribution curve, a value greater than 1.1 indicates a leptokurtic (peaked) distribution with better sorting in the central portion of the curve than in the tails, and a value less than 0.9 indicates a platykurtic (flattened) distribution and a lack of dominance by any one size category.

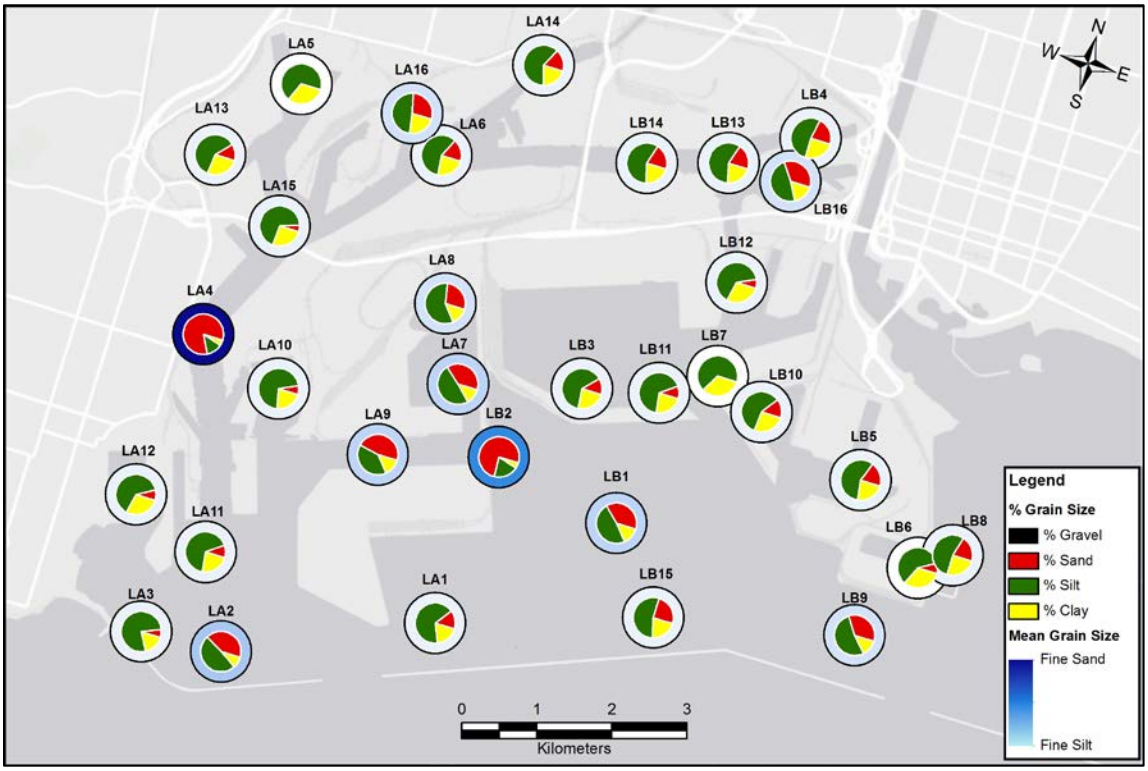

Figure 2-7. Percent contribution by grain size by station and distribution of mean grain. Spring 2014.

In summer, sorting averaged 2.10 phi overall, representing very poorly sorted sediments (Appendix B-3). Sediment distribution curves for most stations were either unimodal with a peak in the clay or silt/clay categories, or bimodal or multimodal with a primary peak in the clay or silt/clay categories and a smaller peak or two smaller peaks in the fine sand, very fine sand, or silt categories (Appendix B-1). In spring, sorting averaged 1.96 phi overall, representing poorly sorted sediments (Appendix B-4). As in summer, sediment distribution curves for most stations were either unimodal with a peak in the clay or silt/clay categories, or bimodal or slightly multimodal with a primary peak in the clay or silt/clay categories and smaller peaks in the fine sand, very fine sand, or silt categories (Appendix B-2).

Skewness values indicated that, in general, sediment distributions were symmetrical or fine-skewed. Kurtosis values indicated that sediments were mesokurtic at most stations in summer, but in spring about half of the stations were platykurtic.

DISCUSSION

WATER QUALITY

Temperature profiles in the Port Complex showed seasonal trends typical of the Southern California Bight (SCCWRP 1973; Soule and Oguri 1980; Hickey 1993; MEC 2002; SAIC 2010). Seasonal variability of surface temperatures was more pronounced in the Outer Harbor (Figure 2-2; Appendices A-1 through A-3). At shallow stations and stations farther into the Port Complex, however, seasonal variability was less pronounced. Warmest surface water temperatures were consistently measured at Stations LA7 and LA8 (Figure 2-8). These stations are among the shallowest, and experience reduced circulation (Everest 2009). The warmer surface water temperatures reported during all three seasons at Stations LA5 and LA 13, even in winter (Figure 2-8), may be related to the discharge of thermal effluent from the Harbor Generating Station. Discharges ranged between 86 and 96 million gallons of water per day at temperatures of 5 to 9°C above the mean during each sampling event (Krivak 2014 pers. comm.).

In the Port Complex, surface DO values exceeded 6.0 mg/l at all stations during all three seasons. In summer, surface values greater than 7 mg/l were measured at most stations, and values were greater than 9 mg/l at several stations (Figure 2-3; Appendices A-1 through A-3). This pattern was likely the result of high levels of photosynthesis enabled by long days and high sunlight. Lowest surface DO concentrations were reported in spring. The spatial trend of lower DO values at Inner Harbor stations observed during the 1970s (Soule and Oguri 1980) was apparent in 2013–2014 (Figure 2-9); however, surface values less than 5 mg/l, which were reported at some Inner Harbor stations during the 1970s, did not occur at any stations during the current study.

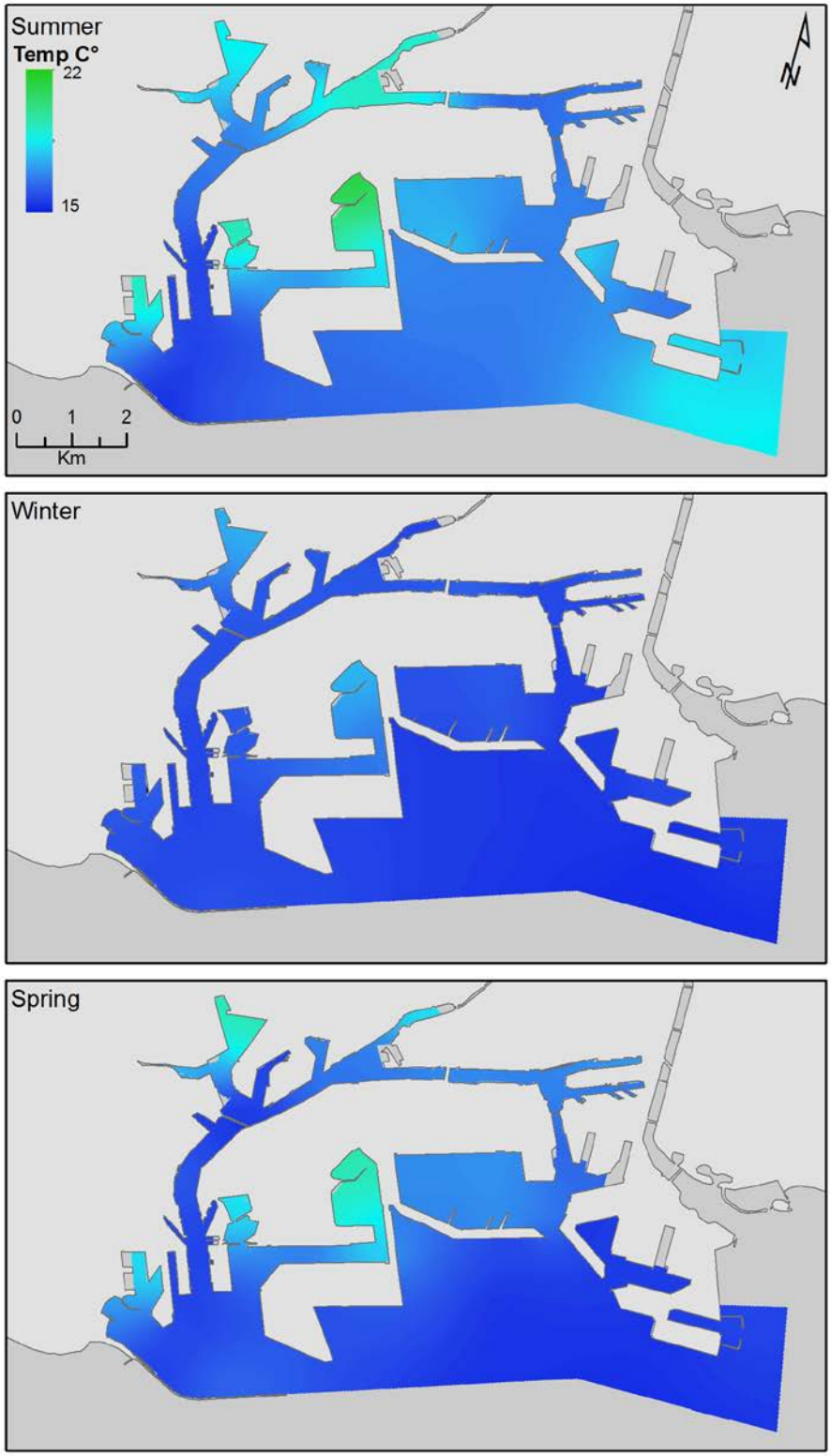

Figure 2-8. Spatial distribution of surface temperature in the Port Complex by season. Summer (top), winter (middle) and spring (bottom).

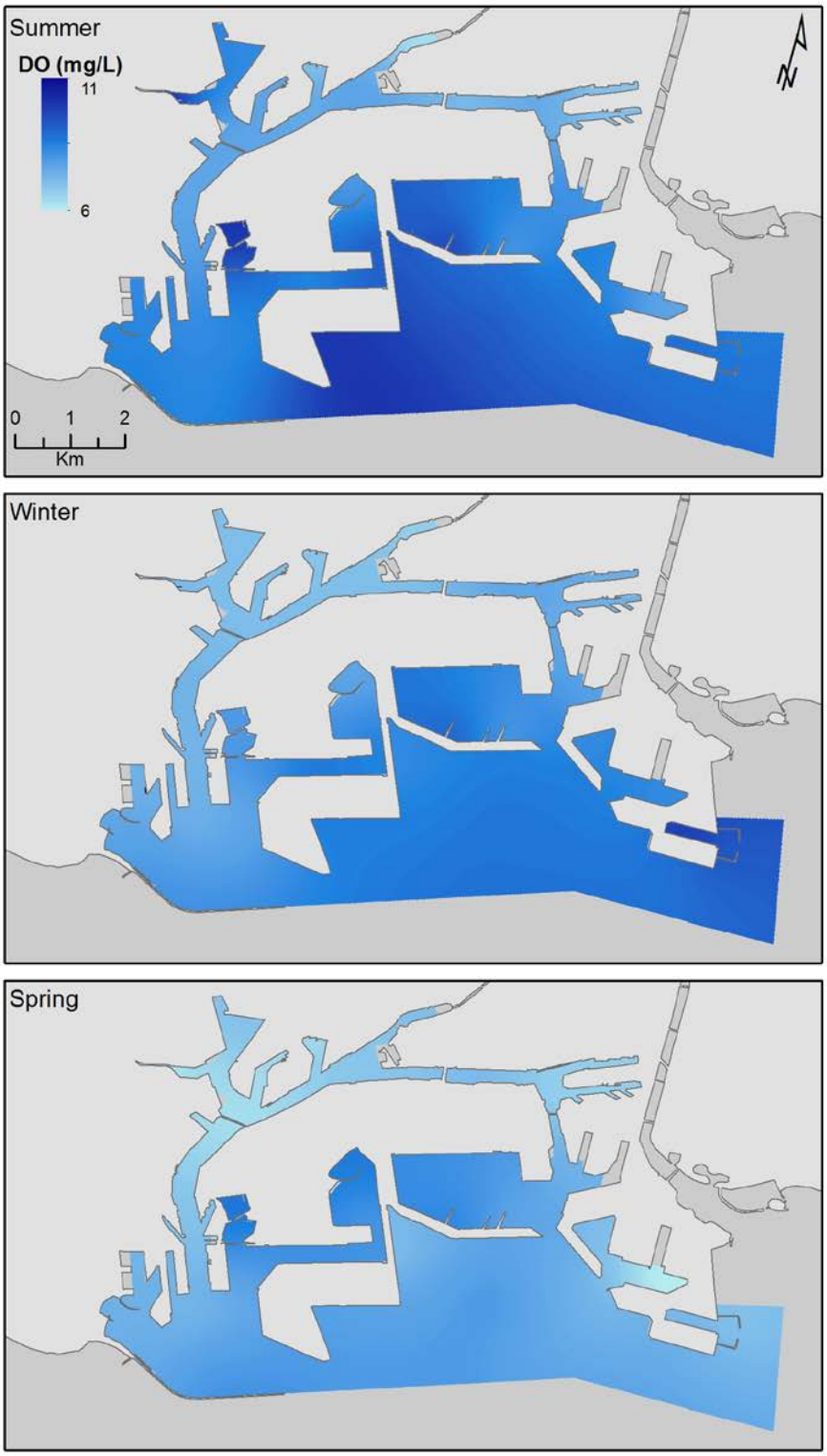

Figure 2-9. Spatial distribution of surface dissolved oxygen concentrations in the Port Complex by season. Summer (top), winter (middle) and spring (bottom).

During all seasons, highest DO values were measured in the upper few meters of the water column, particularly during the summer and winter surveys (Figure 2-3; Appendices A-1 through A-3). Below these maxima, DO concentrations decreased variably with increased depth to the bottom. The lowest near-bottom values were recorded at the deepest stations. During the summer and winter surveys, near-bottom DO values exceeded 5 mg/l at all stations. In spring, however, near-bottom DO concentrations of less than 5 mg/l were measured at 15 stations in the Port Complex, including the lowest DO value of 4.00 mg/l at Station LB14 (Cerritos Channel). Patterns of DO concentration with depth in the current survey were similar to those reported during the two previous biological surveys (MEC 2002; SAIC 2010), although the DO values of less than 5 mg/l in summer and at mid-depth in spring reported during the 2000 study were not found during the current study. This suggests continued improvement in water quality in the Port Complex since 2000.

In the Ports, surface pH values were highest during the summer survey and lowest during the spring survey (Figure 2-4; Appendices A-1 through A-3). Similar seasonal differences in pH have been observed in previous Port-wide surveys (Soule and Oguri 1980; MEC 2002), and likely reflect seasonal variability in salinity and photosynthetic activity. Other than the slight seasonal variability mentioned above, gradients or consistent spatial patterns in pH conditions were not apparent.

Water clarity varied among stations, depths, and seasons during the study, but in general, water clarity based on Secchi disk depth was highest during the winter survey and lowest during summer (Figures 2-5 and 2-10). Secchi depths were shallower (indicating reduced clarity) throughout the Port Complex during the summer survey than in winter and spring. In general, water clarity was highest in the Outer Harbor during winter and spring, and shallowest Secchi depths occurred in the Pier 300 Shallow Water Habitat and Seaplane Lagoon, likely due to water column mixing by wind. As in the 2000 surveys (MEC 2002) and the 2008 surveys (SAIC 2010), seasonal patterns in transmissivity were not evident during the 2013–2014 surveys, nor were temporal differences among the three most recent studies apparent.

In the Port Complex, surface salinity varies spatially, with lower surface salinities usually isolated to the vicinity of freshwater sources, and seasonally, especially in winter when storm runoff can influence salinity throughout the Port Complex (Soule and Oguri 1980; MEC 2002; SAIC 2010). Both of these patterns were observed during the current study. Consistent with the results from previous studies (e.g., MEC 2002 and SAIC 2010), lower surface salinities indicated freshwater input at a few locations. These locations included Consolidated Slip (and to a lesser extent East Basin and Slip 5) in Los Angeles Harbor in summer and spring, and two stations within and one adjacent to Pier J during all seasons (Figure 2-6). This pattern suggests the influence of freshwater input from the Dominquez Channel at Inner Harbor stations and from the Los Angeles River on the eastern side of the Port of Long Beach.

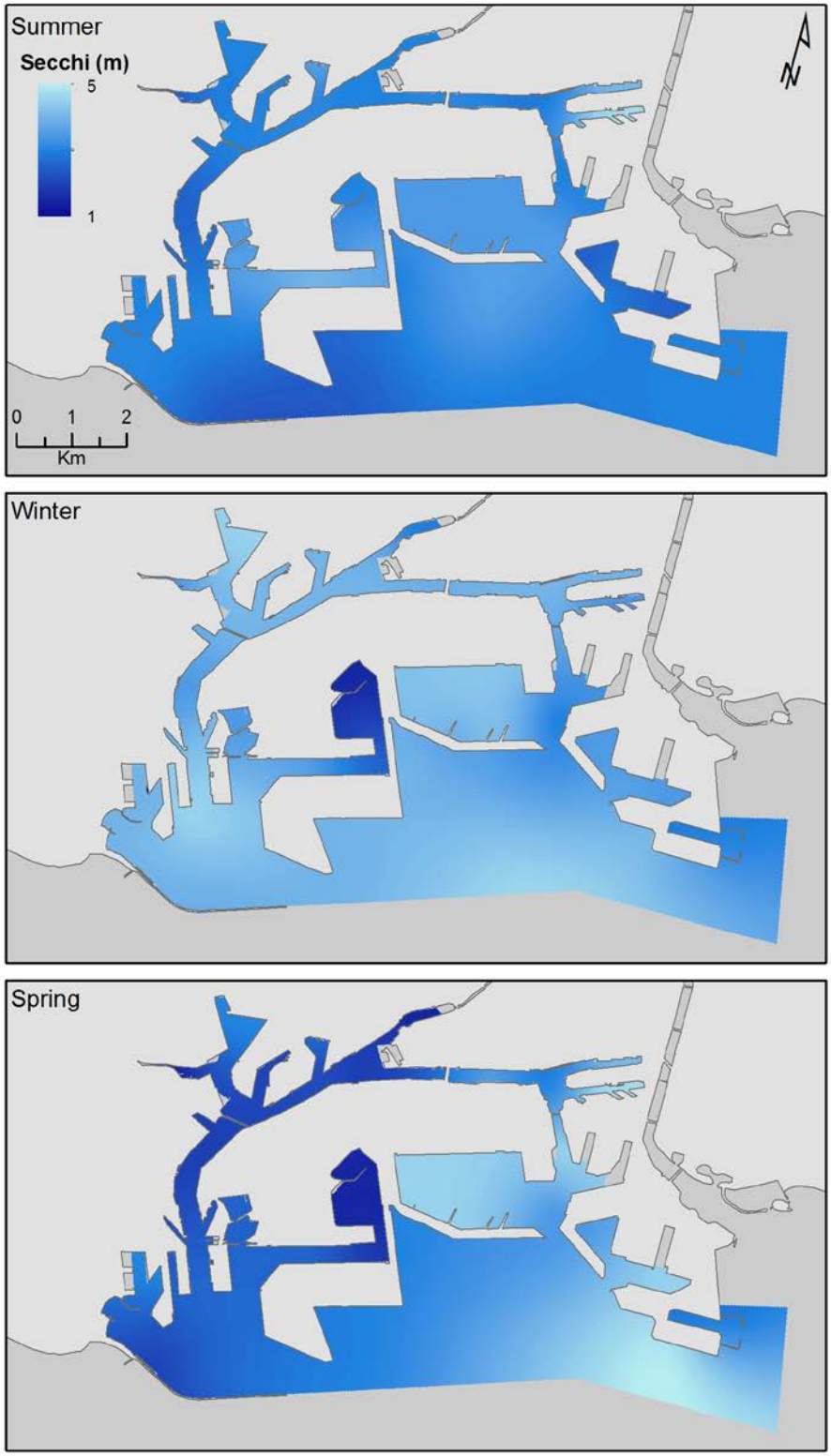

Figure 2-10. Spatial distribution of Secchi depth in the Port Complex by season. Summer (top), winter (middle) and spring (bottom).

Lower surface salinities were observed in summer and spring at Southwest Slip, and to a lesser extent in Los Angeles West Basin, suggesting consistent freshwater inputs at these locations. Urban runoff is a likely cause of the lower salinities: the Gaffey Street and John S. Gibson Boulevard storm drain channels and several underground drains feed surface runoff from San Pedro into the Southwest Slip, while the Bixby Slough culverts feed runoff from Machado Lake and parts of Wilmington into the West Basin (LACDPW 2015). Lower salinities at these locations were not noted in 2000 or 2008 (MEC 2002; SAIC 2010). In winter, salinity throughout the water column was slightly lower than during the other two surveys, indicating a seasonal reduction in salinity throughout the Port Complex during the rainy season. Despite no rain recorded in the Port Complex during the week prior to the winter survey, freshwater flow in the Los Angeles River on the day of the winter survey was nearly 50% higher than reported during the summer survey and more than twice that reported during the spring survey (CAAP 2014; USGS 2015).

Chlorophyll-a concentrations varied considerably in the Port Complex, ranging from a low of 1.5 mg/m^3 to a high of 60.7 mg/m^3. Both extremes occurred in Inner Harbor basins (Los Angeles West Basin and Slip 5). As this survey marked the first time chlorophyll-a was measured during harbor wide surveys, no comparison with previous surveys is possible. Chlorophyll-a values in the present study were similar to those reported in the Outer Harbor during recent studies (CLA-EMD 2014). On the basis of 10 years of fluorescence monitoring in the nearshore waters of southern California, Howard et al. (2012) suggest a chlorophyll-a threshold of 5 mg/m^3 to identify plankton blooms. The average chlorophyll-a values in the present study exceeded this threshold at most stations during all three surveys, suggesting high phytoplankton concentrations compared to coastal waters across the southern California shelf.

SEDIMENTS

Sediment grain sizes in the silt and clay categories, collectively referred to as “fines”, are typical of embayment habitats throughout southern California. In regional sampling, sediments from southern California Ports/Bays/Harbor collected in 2003 and from Ports in 2008 averaged 68% and 70% fines, respectively (Schiff et al. 2006; Schiff et al. 2011), which was somewhat lower than the average of 77% fines for both surveys during the current study. Despite the minor differences in results, the overall pattern indicates that sediments in the Port Complex are largely fines, with sand constituting a small fraction of the grain size composition. The dominance by fines during the current study was similar to the results of the 2000 study (MEC 2002); in fact, the differences in grain size distributions between the current study and the 2000 study were similar to the differences between the summer and spring surveys during the current study. Compared to historic data, however, grain size changes in the harbor have been notable: in the late 1970s, prior to the construction of Piers 300 and 400 and the Pier J Expansion, sediments in the sand category dominated Outer Harbor and channel stations (Soule and Oguri 1980).

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CHAPTER 3 ADULT AND JUVENILE FISHES

This section presents the results of surveys of the fish assemblages in the Port Complex conducted during 2013–2014. As in previous harbor-wide surveys (MEC 2002; SAIC 2010), multiple gear types were utilized in order to sample the diverse assemblages of species and individuals in the various habitat types within the Port Complex. A lampara net was used to sample pelagic fish (species associated with the water column), an otter trawl was used to sample demersal fish (fish living on or adjacent to the bottom), and a beach seine was used to sample fish found in shallow, nearshore habitats. Lampara and otter trawl sampling for this study took place in the spring and summer at 26 stations (Figure 3-1; Table 3-1; Appendix L), whereas in 2000, sampling occurred during four seasons at 14 stations and in 2008 sampling occurred in three seasons at 19 stations.

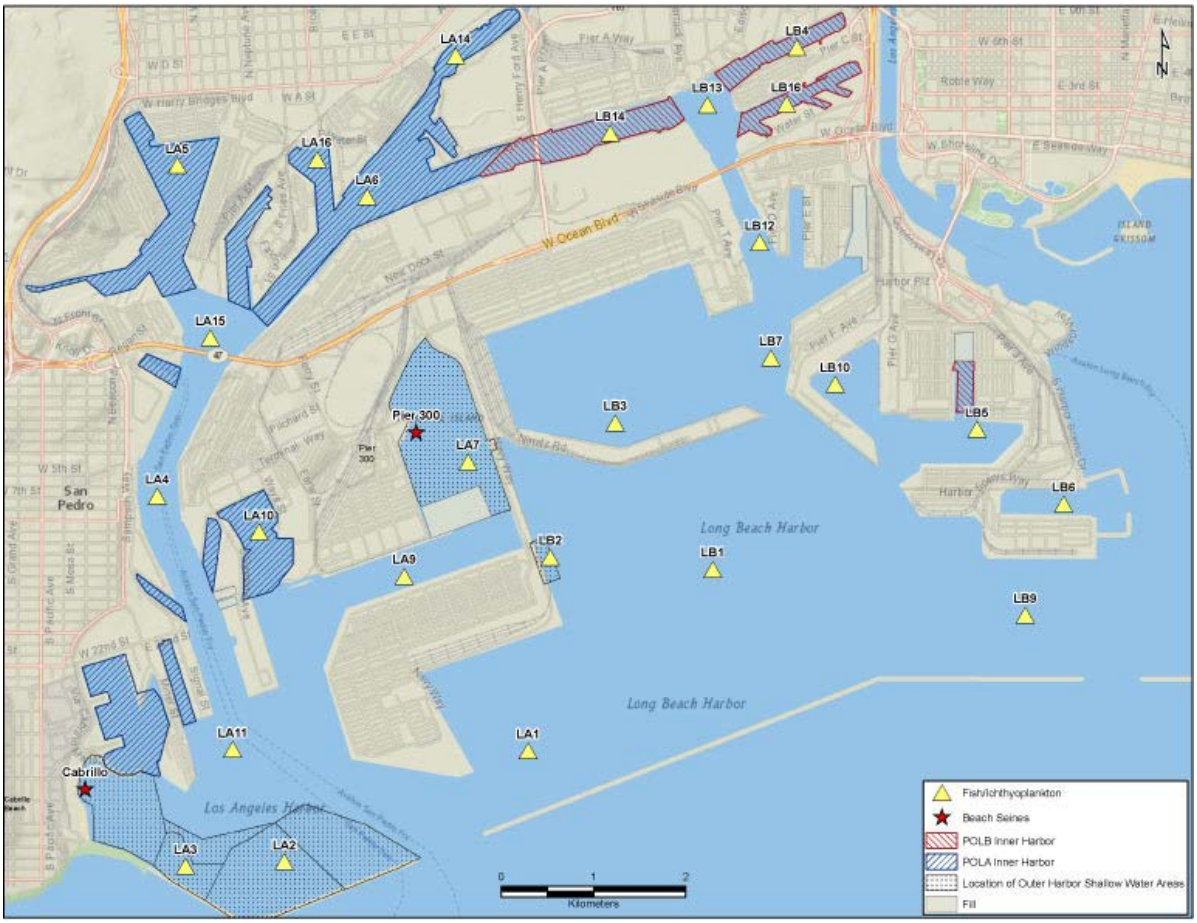

Figure 3-1. Location of fish sampling stations.

Table 3-1. Fish sampling station designations and harbor habitat types.

Station	Designation/Location	Harbor Type	Station	Designation/Location	Harbor Type
LB1	LB Outer Harbor (N)	Outer	LA1	LA Outer Harbor (E)	Outer
LB2*	Long Beach SWH	Outer	LA2*	Cabrillo SWH (E)	Outer
LB3	LB West Basin (W)	Outer	LA3*	Cabrillo SWH (W)	Outer
LB4	Channel 2	Inner	LA4	LA Main Channel (N)	Outer
LB5	Southeast Basin (S)	Outer	LA5	LA West Basin (N)	Inner
LB6	Pier J Slip	Outer	LA6	LA East Basin	Inner
LB7	LB Main Channel (N)	Outer	LA7*	Pier 300 SWH	Outer
LB9	LB Main Channel (S)	Outer	LA9	Pier 400 Channel	Outer
LB10	Southeast Basin (N)	Outer	LA10	Fish Harbor	Inner
LB12	Back Channel	Outer	LA11	LA Outer Harbor (W)	Outer
LB13	LB Turning Basin	Outer	LA14	Consolidated Slip	Inner
LB14	Cerritos Channel	Inner	LA15	LA Turning Basin	Outer
LB16	Channel 3	Inner	LA16	Slip 5	Inner
Cabrillo Beach Beach Seine*		Shore	Pier 300 SWH Beach Seine*		Shore

Note: N, S, E, W differentiate stations that that are in the same basin or channel by orientation – north, south, east, or west.

* SWH indicates shallow-water habitat in the Outer Harbor.

MATERIALS AND METHODS

PELAGIC FISH

Pelagic species were sampled using the same type of lampara net used in the previous harbor-wide studies. The net had a 22-m-deep,166-m-long corkline, two 67.7-m wings with 15-cm mesh, a throat with 1-cm mesh, and a bag with a 0.6-cm mesh. Lampara sampling typically

involves setting the net in a circle; however, in areas where boat movement was restricted, such as dead-end slips and narrow channels, the set was elliptical.

Surveys were conducted during the day and night in spring (May 2014) and summer (August 2014; Appendix C-2). Summer sampling was delayed by net manufacturing difficulties and therefore did not coincide with the otter trawls and beach seines. In addition, Station LA7 was not accessible during the summer survey and was not sampled.

All fish captured in each haul were transferred to tubs filled with seawater, processed on the deck of the survey vessel, and released. Data recorded for fish caught in each haul included species, counts, standard length (SL – to the nearest millimeter [mm])), and wet weight (to the nearest one gram [g]). Species that could not be identified in the field were transported to the laboratory and identified using field identification references and/or a dissecting microscope. All fish identifications were made using widely accepted field identification guides such as Miller and Lea (1972) and Eschmeyer et al. (1983). Fish nomenclature was standardized in conformance with Nelson et al. (2004) and Page et al. (2013).

If more than 30 individuals of a species were caught in a single replicate haul, a batch sampling procedure was utilized. First, the standard length (mm) and weight (g) was measured for each of 30 randomly selected individuals within the species. Second, the size class (to the nearest centimeter [cm]) was recorded for each of the next 70 randomly selected individuals, and an aggregate weight was measured for the group of 70 individuals. Third, an aggregate weight was measured for a total of 400 additional individuals. Finally, an aggregate weight was measured for any remaining individuals. Fish abnormalities, including fin erosion, lesions, pop-eye, tumors, and parasites were noted on pre-formatted data sheets set up for direct entry into the database. Macroinvertebrates collected in lampara hauls were not recorded.

A lampara net was used to sample pelagic fish species.

When hauls were sufficiently large, fish were scooped from the bag end of the net using a standard bait brailer (diameter = 40 cm, depth = 50 cm) and placed into buckets and bins where the catch was sorted by species. Small catches were transferred directly from the net into the sorting containers. A maximum of six brailed scoops was processed, consistent with the previous harbor-wide studies (MEC 2002; SAIC 2010). This approach helped avoid impractical processing time that would have been associated with extremely large hauls, and minimized incidental take from the sampling effort. Consequently, if a haul appeared to be greater than six scoops, the fishes to be processed (six scoops) were randomly withdrawn from the net. A count of the excess scoops returned to the water was recorded for later use in calculating the total catch for the sample. This procedure minimized the effects of

being captured and is assumed to have resulted in significantly increased survival of most fishes.

DEMERSAL FISH

Demersal (bottom-dwelling) fish and macroinvertebrates were collected using a 7.6-m, semi-balloon otter trawl net constructed with 2.5-cm side mesh and fitted with a 1.3-cm mesh cod end. The trawl was towed along the seafloor behind a survey vessel at approximately two knots (1 m/sec) for five minutes, corresponding to a sample distance of approximately 300 m. Trawls were conducted during the day and night in summer (September-October 2013) and spring (April-May 2014) at the 26 stations indicated in Figure 3-1. The location of each station was determined using differential Global Positioning System (dGPS).

Trawl catches were transferred to tubs of seawater and processed immediately on the survey vessel's deck to minimize fish mortality. Fish were identified to species, measured, and weighed using the methods described above for pelagic fishes. The same batch sampling procedure used for pelagic fish was used for catches with more than 30 individuals of any species.

Otter trawl sampling (top); Processing catch (middle); Beach seine sampling (bottom).

SHALLOW SUBTIDAL FISH

Shallow-water fishes were surveyed using a 15.2-m long by 1.8-m deep beach seine net with 0.6-cm-mesh wings and a 0.3-cm-mesh bag end. Two stations were sampled during each survey: Cabrillo Beach, north of the launch ramp, and the Pier 300 Shallow Water Habitat (Figure 3-1). Two hauls were performed at each station during each survey (summer, August 2013, and spring, May 2014), and fish were processed using the same methods described for pelagic and demersal fish. Fish that were observed but not captured at each station (including fish that escaped the seine) were recorded. After

field processing was completed, all live specimens were immediately returned to the water.

DATA ANALYSIS

All data were entered into a database that included species codes, counts, lengths, and weights. The database was subjected to standardized quality assurance routines. Consistent with previous Port-wide surveys, abundance and biomass values in this report are presented as catch per unit effort (CPUE); that is, catch in one set of the lampara net, otter trawl, or beach seine. In addition, abundance and biomass values are also presented as density (number of individuals per 100m^2) or biomass (kg per 100 m^2) using sample area conversions for lampara (catch area of 4,000 m^2 [MEC 2002]) and otter trawl (catch area of 1,512 m^2 [Miller and Schiff 2011]). Fish length data were standardized to one centimeter size classes. A summary of all species collected by gear type during the 2013–2014 study is provided in Appendix C-1.

Community measures of species richness and diversity were calculated using CPUE values, and included number of species, Shannon Wiener diversity, Margalef diversity, and Dominance. Diversity indices and Dominance were calculated using the following formulas:

- Number of species or unique taxa;
- Shannon Wiener diversity (H'): $-\Sigma pi \times \ln(pi)$, where pi is the count for species i;
- Margalef diversity: $(S-1)/\ln(n)$, where S is the number of taxa, and n is the number of individuals; and
- Dominance: number of top ranked (by abundance) species that together contribute 75% or more of total abundance.

Cluster analysis was also performed on the mean abundance data for each station, and clusters were grouped based on similarity between and among stations. The analysis also focused on those common species that better characterize the community, and the number of species used was based on frequency of occurrence. Data were subjected to log (x+1) transformations and analyzed using PC-ORD (McCune and Mefford 2011). Transformed data were classified using the Bray-Curtis dissimilarity measure, which presents results by species and station plotted in a two-way dendrogram. Dendrograms provide a graphic representation of the relative abundance and spatial occurrence of each species, and of relationships between species. The two-way analysis utilized in this study illustrates the relative abundance of species, as well as groupings (clusters) of both species and stations.

RESULTS

PELAGIC FISH

Pacific Butterfish, *Peprilus simillimus*.

ABUNDANCE

A total of 747,465 fish was collected by lampara sampling during day and night surveys at all 26 stations combined (Table 3-2, Appendix C-4; additional lampara abundance data, including survey data by station for each season, are presented in Appendices C-7 [spring] and C-8 [summer]). As described below, approximately two-thirds of the individuals were Northern Anchovy collected at one station (LA3) in one net haul. More fish were collected during day sampling (535,521) than at night (211,944) (Table 3-2, Appendix C-4). However, Northern Anchovy accounted for most of this difference; the numbers of other fish collected during the day and night were similar (13,264 during the day and 12,193 at night). Such day/night differences in catch as did occur for some species are likely due to a combination of fish behavior (decreased ability to detect and avoid sampling gear at night), increased dispersal of schooling species, and increased foraging activity at night (Horn and Allen 1981).

The highest mean abundance (day and night samples combined) occurred at Station LA3 (mean = 136,377), while the lowest mean abundance was reported at Station LA1 (mean = 80). With the exception of a few stations with markedly high or low mean abundances, most station means ranged between 500 and 2000 individuals. As with total abundances, mean abundance per station was higher during the day (10,304 individuals) than at night (4,166 individuals) (Appendix C-5).

The marked day/night differences in species composition (Figures 3-2 and 3-3) were driven by the dominance of Northern Anchovy in the night catches. Although the total day catch of Northern Anchovy was more than twice as large as the night catch, virtually all of those individuals were caught at Station LA3 during the spring survey. Excluding that one station, the night catch of Northern Anchovy was actually 30 times as large as the day catch. Northern Anchovy constituted nearly 95% of the total night catch, but only approximately one-third of the total day catch. Accordingly, as Figures 3-2 and 3-3 show, the species composition of the day catch was much more diverse than that of the night catch.

Seasonal differences in lampara catch (Figures 3-2 and 3-3) were also driven by the large number of Northern Anchovy collected in spring. Excluding Northern Anchovy, the most notable seasonal difference was the higher abundance of California Grunion in summer. In general, however, there were no clear seasonal patterns of species composition or abundance.

Table 3-2. Species and numbers of fish caught by lampara in 2013-2014.

Common Name	Scientific Name	Day Catch	Night Catch
Northern Anchovy	*Engraulis mordax*	522,257	199,751
California Grunion	*Leuresthes tenuis*	3,557	9,053
Pacific Mackerel	*Scomber japonicus*	4,956	148
Topsmelt	*Atherinops affinis*	2,435	1,614
Jacksmelt	*Atherinopsis californiensis*	1,895	141
Queenfish	*Seriphus politus*	22	607
White Croaker	*Genyonemus lineatus*	73	211
Pacific Butterfish	*Peprilus simillimus*	140	58
Pacific Sardine	*Sardinops sagax*	24	153
Jack Mackerel	*Trachurus symmetricus*	62	53
California Lizardfish	*Synodus lucioceps*	77	24
Shiner Surfperch	*Cymatogaster aggregata*	0	44
Bat Ray	*Myliobatis californica*	5	23
White Surfperch	*Phanerodon furcatus*	5	15
Barred Sand Bass	*Paralabrax nebulifer*	1	11
Slough Anchovy	*Anchoa delicatissima*	0	10
Specklefin Midshipman	*Porichthys myriaster*	0	5
California Halibut	*Paralichthys californicus*	2	2
Diamond Turbot	*Pleuronichthys guttulatus*	1	3
Pacific Barracuda	*Sphyraena argentea*	0	4
Kelp Pipefish	*Syngnathus californiensis*	2	1
Round Stingray	*Urobatis halleri*	1	2
California Scorpionfish	*Scorpaena guttata*	1	1
Cheekspot Goby	*Ilypnus gilberti*	2	0
Fantail Sole	*Xystreurys liolepis*	1	1
Giant Kelpfish	*Heterostichus rostratus*	1	1
California Skate	*Raja inornata*	0	1
Deepbody Anchovy	*Anchoa compressa*	0	1
Hornyhead Turbot	*Pleuronichthys verticalis*	1	0
Kelp Bass	*Paralabrax clathratus*	0	1
Pile Surfperch	*Damalichthys vacca*	0	1
Plainfin Midshipman	*Porichthys notatus*	0	1
Shadow Goby	*Quietula y-cauda*	0	1
Shovelnose Guitarfish	*Rhinobatos productus*	0	1
Spotted Turbot	*Pleuronichthys ritteri*	0	1
	Total	535,521	211,944

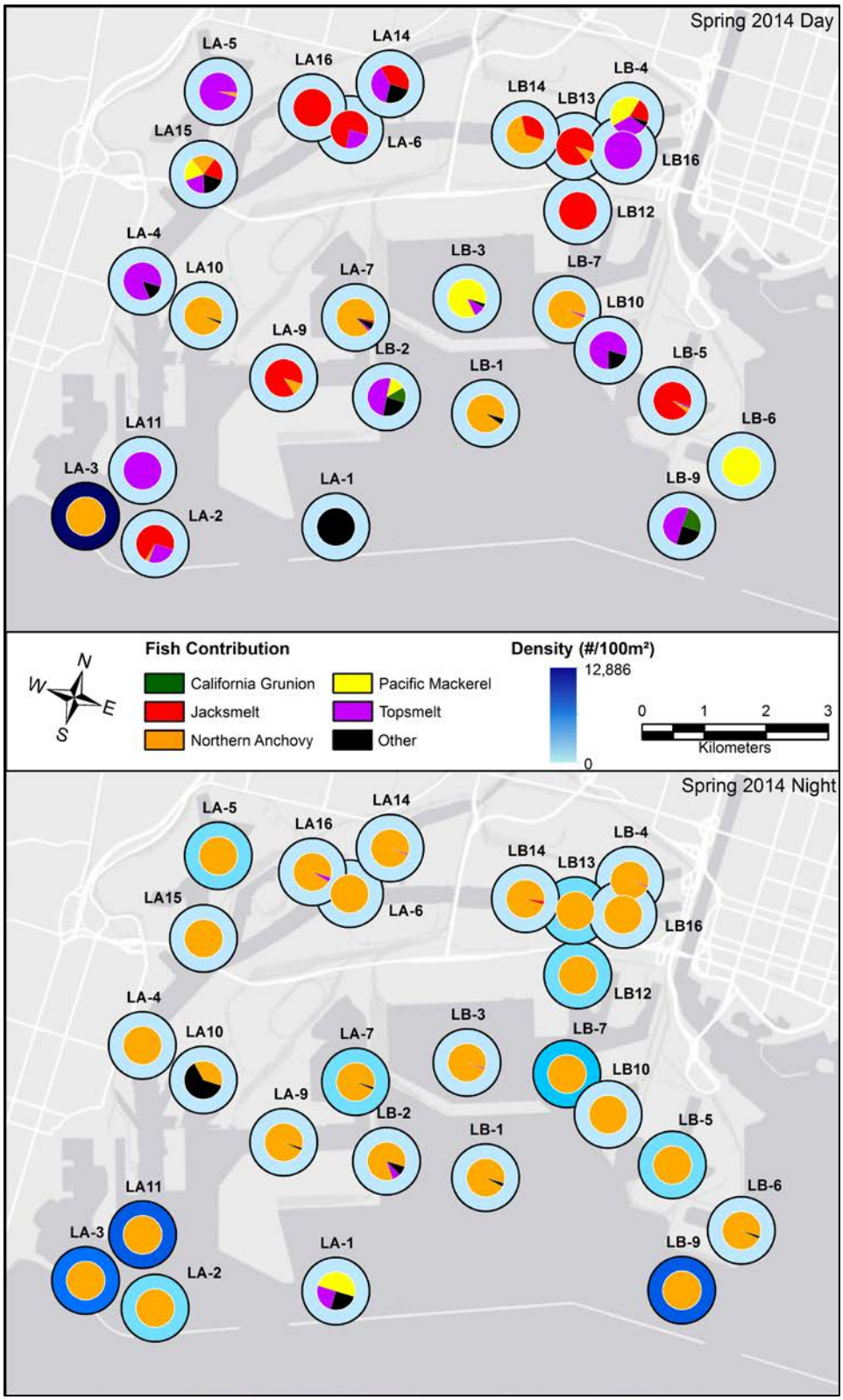

Figure 3-2. Species composition of the lampara catch in spring.

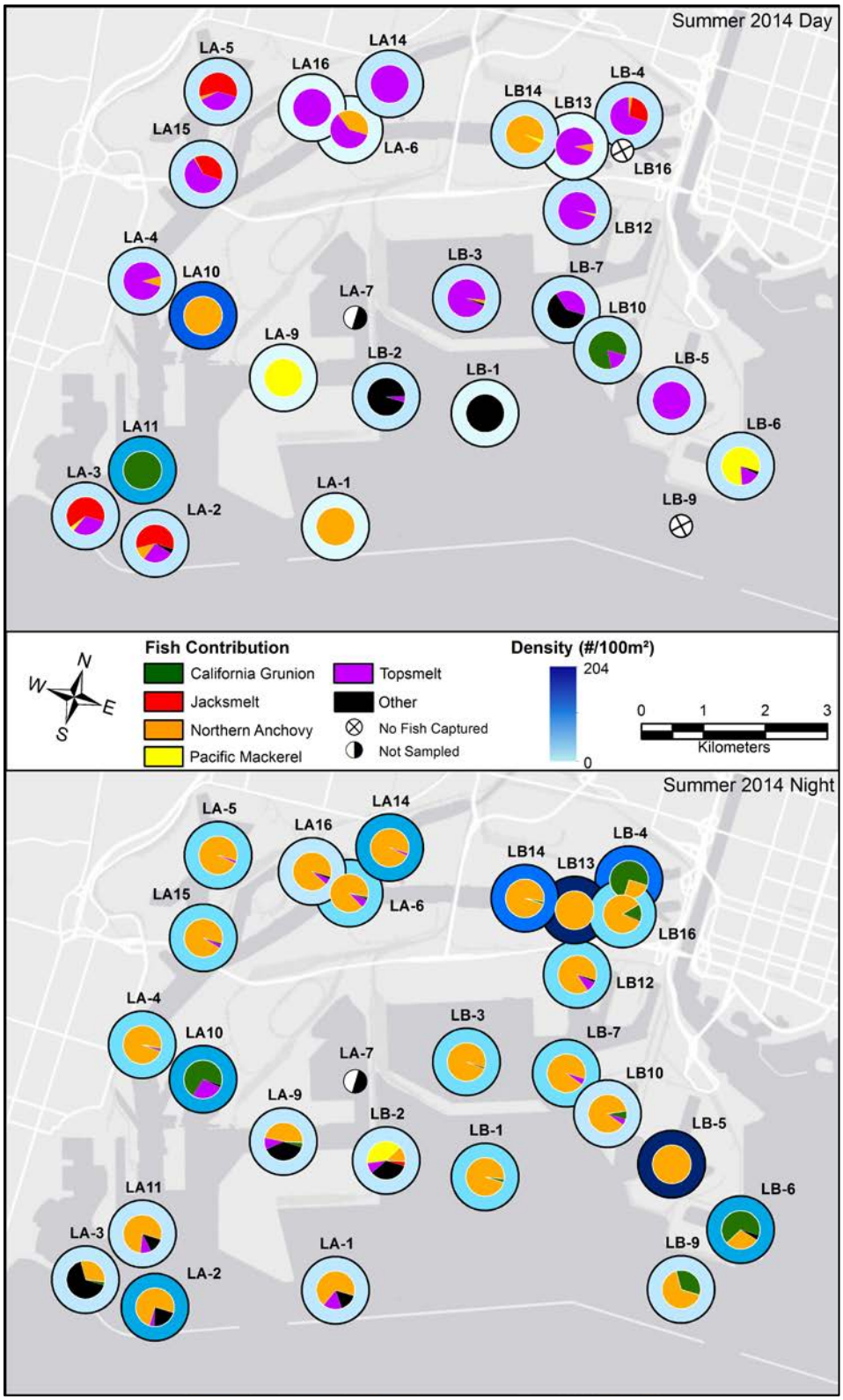

Figure 3-3. Species composition of the lampara catch in summer.

BIOMASS

A total of 2,717.5 kg of fish was collected by lampara during day and night surveys at all 26 stations combined (Appendix C-4; additional lampara biomass data, including survey data by station for each season, are presented in Appendices C-7 [spring] and C-8 [summer]). Northern Anchovy biomass (1,789.5 kg) represented approximately 66% of the total. Other species with high total biomass included Pacific Mackerel (24%), Bat Ray (3.8%), California Grunion (2%), and Topsmelt (1%); no other species accounted for more than 0.6% of the total biomass. Greater biomass was collected during day sampling (2,294.3 kg) than during night sampling (423.2 kg), primarily due to one very large catch each of Northern Anchovy (at Station LA3) and Pacific Mackerel (at Station LB6) in the spring survey; these two species accounted for approximately 90% of all fish biomass (Appendix C-4). The highest mean biomass (day and night samples combined) occurred at Station LA3 (mean = 395.3 kg), and the lowest at Station LA16 and Station LB10 (mean = 0.6 kg) (Appendix C-5).

NUMBER OF SPECIES

A total of 36 species was collected with the lampara net during all surveys and stations (night and day combined) (Table 3-2, Appendix C-4). Slightly more species (all surveys combined) were collected at night (34) than during the day (24), but at individual stations the mean number of species was generally twice as high at night as during the day (Appendix C-5). The total number of species collected varied from a low of none, at Station LB9, to a high of 18 species collected at Station LA2 at night (Appendix C-5). Seasonal differences in the number of species at each station are presented in Figures 3-4 and 3-5; in general, more species were collected during the summer.

DIVERSITY AND DOMINANCE

Diversity indices provide information about community composition by combining species richness (i.e., the number of species present) and relative abundances of different species (equitability) into one measure. There are several methods to calculate diversity, but two commonly used indices, Shannon Wiener (H') and Margalef, that were used in previous studies were employed again for the current study, as was the common measure Dominance. For Shannon Wiener indices, values vary from 0, for communities with only a single taxon, to high values, for communities with many taxa but each with few individuals. The Margalef index incorporates both the number of species and the total number of individuals. Note that variation of this index depends on the number of species, so the number of individuals is less important in the calculation, whereas the Shannon Wiener index considers both the number of species and the contribution of each species to total abundance (Alam et al. 2013). Dominance is expressed as the number of top ranked (by abundance) species that together contribute 75% or more to total abundance.

Shannon Wiener values ranged from a low of 0.00 at several stations during the day (Stations LA11 and LB16, where only one species was caught) to a high of 1.32 during the day at Station LB2. These low values indicate that, in general, a very few species constituted most of the abundance. Values varied greatly among stations and between day and night, but in general were higher during the day than at night, and at Outer Harbor stations than at Inner Harbor stations (Figures 3-4 and 3-5, Appendix C-6).

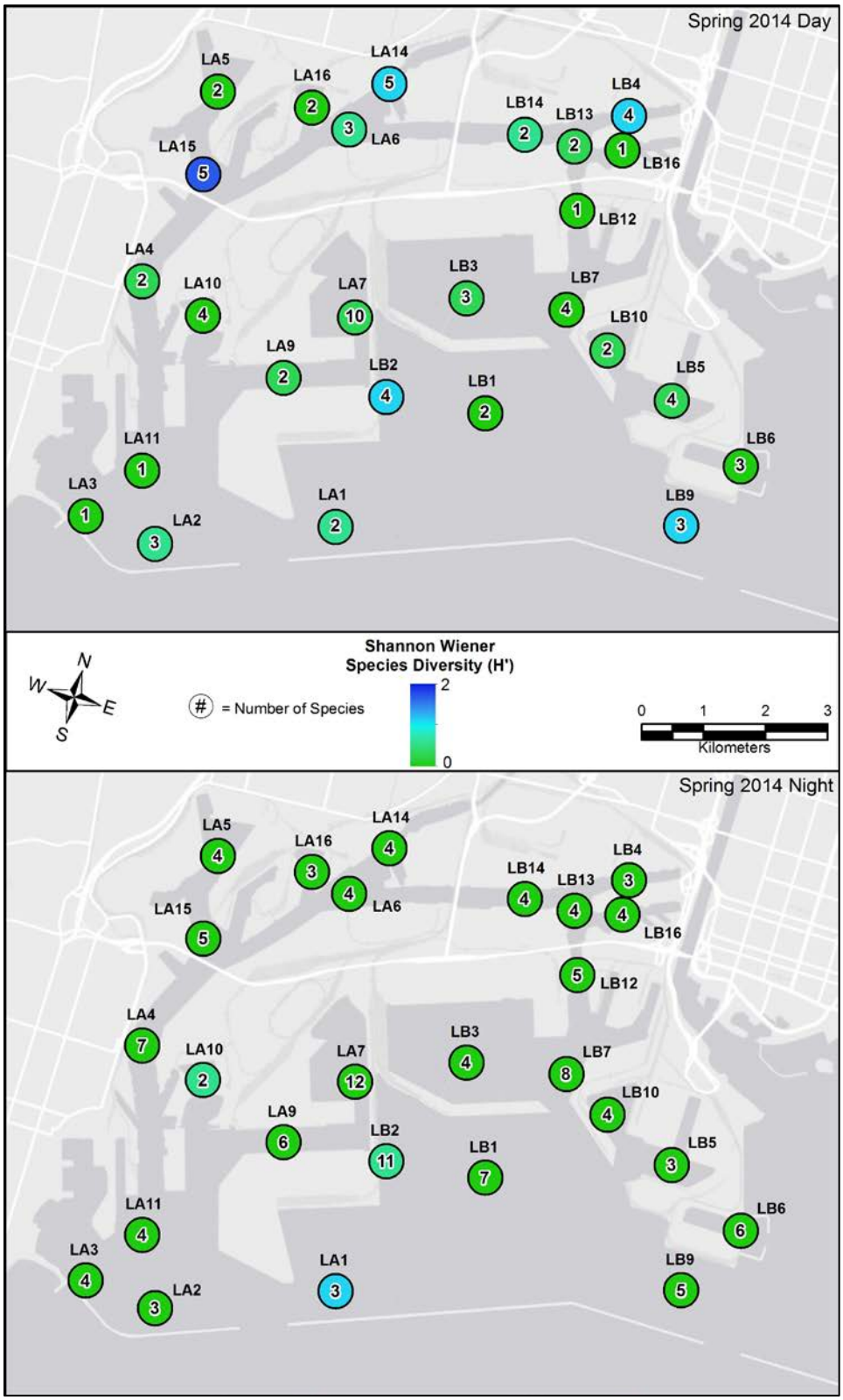

Figure 3-4. Diversity (H') and number of species caught by lampara sampling in spring.

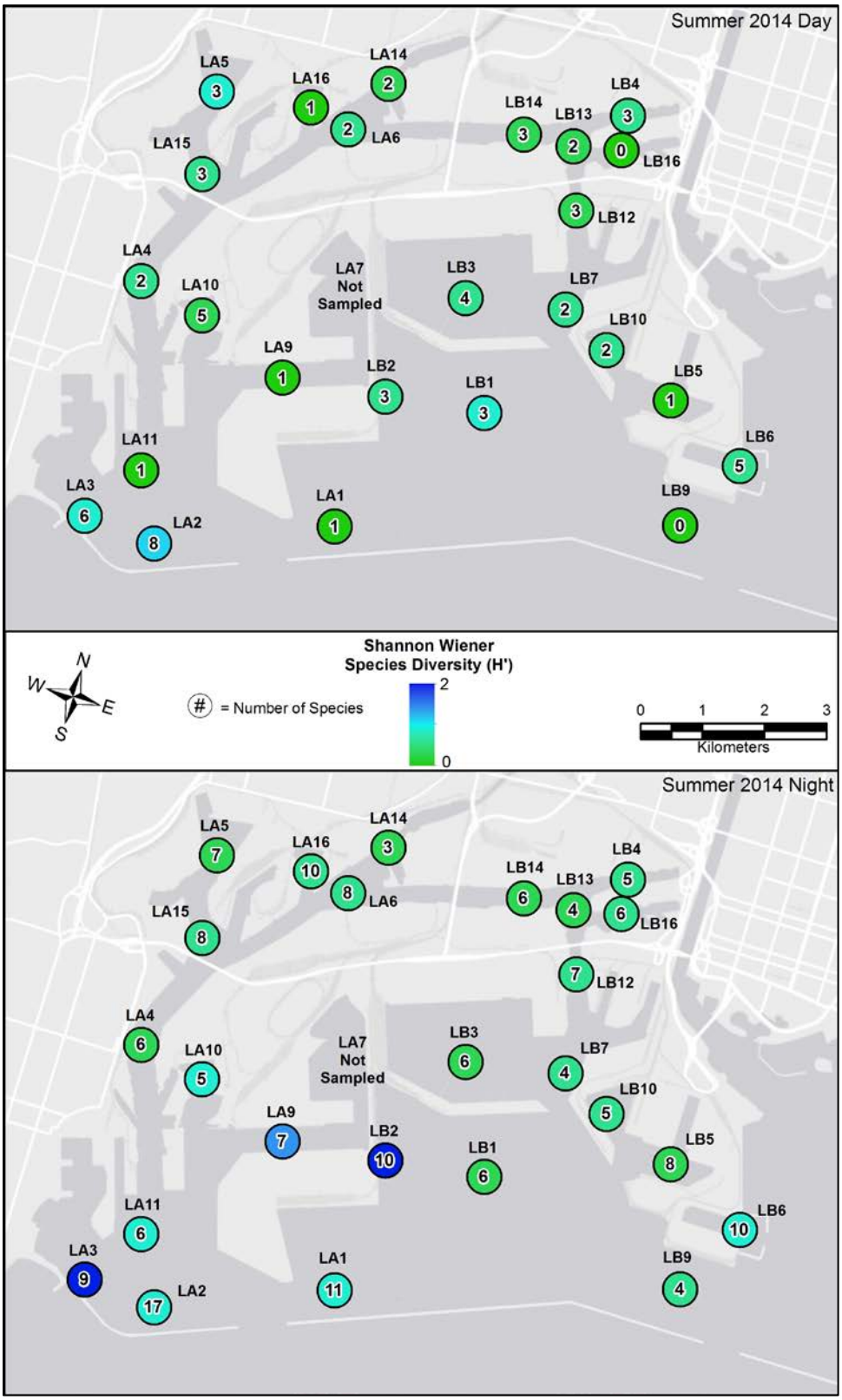

Figure 3-5. Diversity (H') and number of species caught by lampara sampling in summer.

Margalef values (Appendix C-6) ranged from a low of 0.25 at Station LA11 (day) to a high of 2.26 at Station LA1 (night). Values followed the opposite pattern from the Shannon Wiener index, with night values being higher than day values at 20 of the 26 stations. Dominance was very low (1 or 2) at all stations

MOST ABUNDANT SPECIES

Four of the 36 species collected over all surveys and stations comprised over 99.5% of the total catch: Northern Anchovy, California Grunion, Pacific Mackerel, and Topsmelt (Appendix C-4). All of these species are schooling fishes that spend most of their lives in the harbor environment.

As described above, Northern Anchovy was the most abundant species collected, representing 96.6% of the total lampara catch and approximately 66% of the total biomass (Appendix C-4). Individual lengths ranged between 3 and 12 cm SL, with most individuals between 4 and 8 cm SL (Figure 3-6). No clear difference between spring and summer in the size distribution of the population was evident.

California Grunion was the second most abundant fish species collected during lampara surveys, representing approximately 1.7% of the total catch and 2.0% of the total biomass (Appendix C-4). Sizes ranged between 4 and 18 cm SL, with most individuals between 6 and 9 cm SL (Figure 3-6). Higher numbers of smaller individuals occurred in the summer, while fewer larger individuals were collected in spring.

Pacific Mackerel and Topsmelt represented approximately 0.7 and 0.5% of the total lampara catch and 24.0% and 1.1% of the total biomass, respectively (Appendix C-4). Pacific Mackerel had a clear bimodal size distribution, with smaller individuals in spring (peak at 22 cm SL) and larger individuals (peak at 24 cm SL) in summer (Figure 3-6). The size distribution of Topsmelt was more complex: the spring population had a unimodal size distribution, with a peak at 12 cm SL, and the summer population had a bimodal distribution, with peaks at 8 cm and 14 cm SL (Figure 3-6). Topsmelt reach approximately 10 cm in their first year, and 15 cm in their second and third years (Love 2011). This suggests there was a relatively high proportion of Age-1 and greater fish in spring, and Age-0 fish in summer.

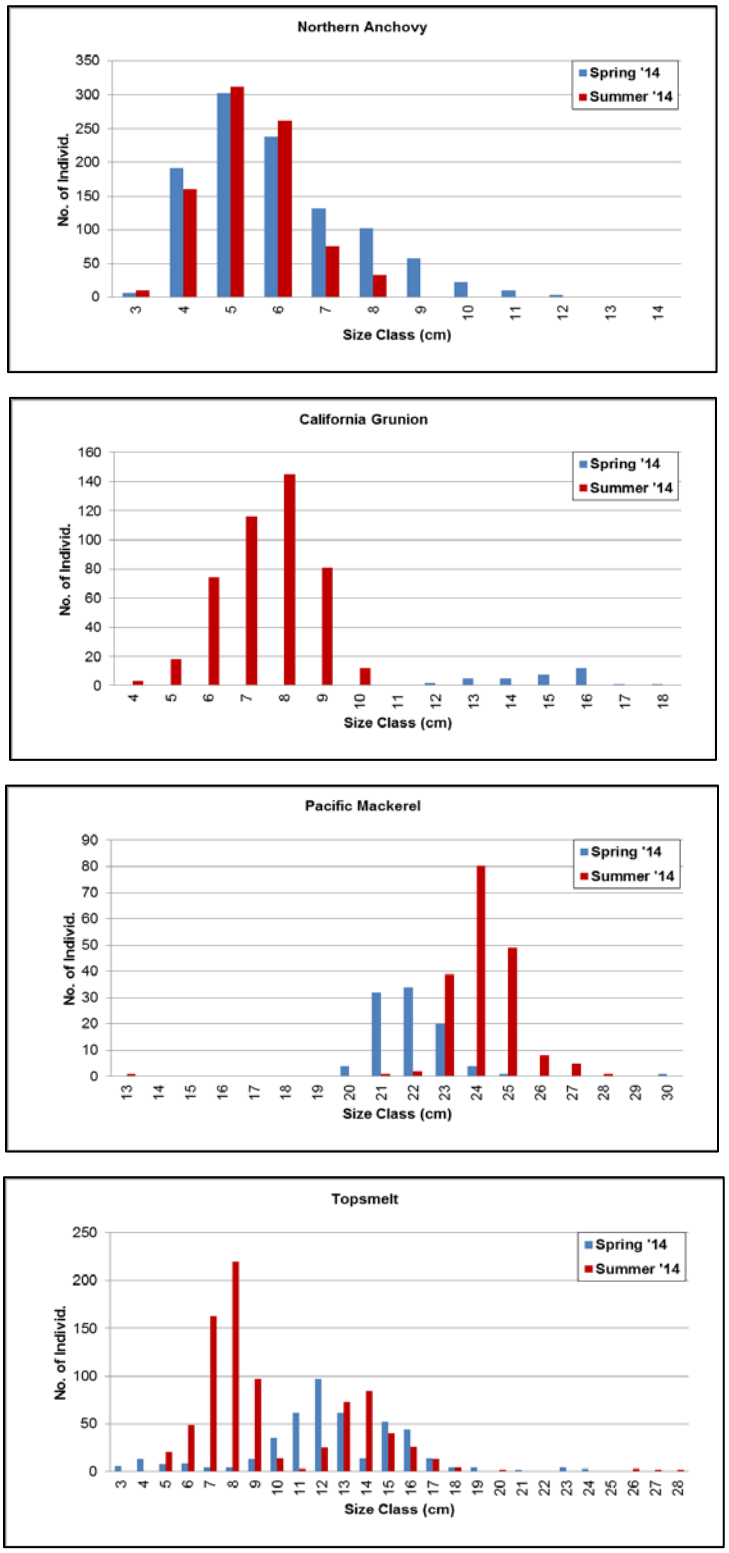

Figure 3-6. Size-frequency distribution of selected fish caught by lampara in the Port Complex.

SPATIAL VARIATION

Mean abundance, biomass, number of species, and diversity varied with location and water depth throughout the Port Complex (Figure 3-7). An analysis of station groups based on Inner versus Outer Harbor (Table 3-1) and of shallow Outer Harbor (LB2, LA2, LA3, and LA7) versus deep Outer Harbor stations showed that abundances were substantially higher at deep Outer Harbor stations than at shallow Outer Harbor stations and Inner Harbor stations. Species richness, on the other hand, was highest at the shallow Outer Harbor stations. Biomass was somewhat lower at Inner Harbor stations than at Outer Harbor stations, but there was no clear spatial pattern in Shannon Wiener diversity.

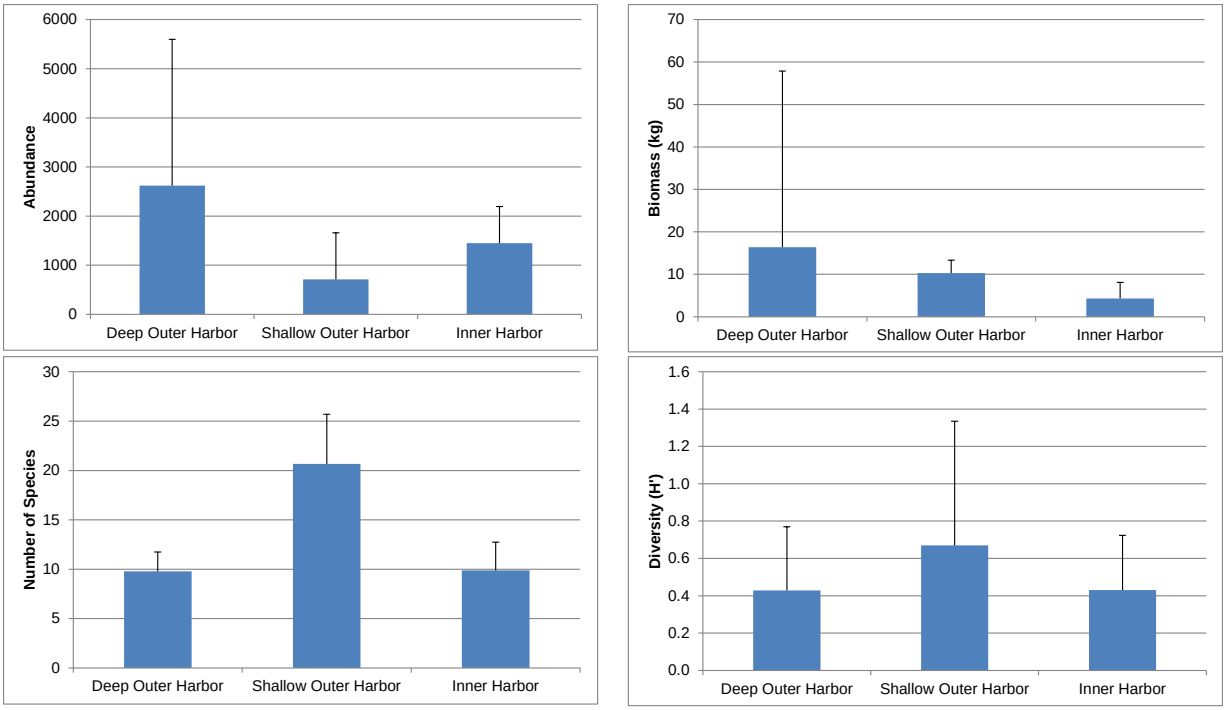

Figure 3-7. Mean (+standard deviation) abundance, biomass, number of species, and diversity (H') collected by lampara for different areas within the Port Complex.

Classification analysis based on the similarity of species composition and mean abundance at each station resulted in five station groups (clusters) and three different species clusters (Figure 3-8). Station Group I consisted of 13 stations where Northern Anchovy and Topsmelt were abundant; the stations included both Inner Harbor and Outer Harbor stations, but all are deep stations. Station Group II consisted of Stations LB2 and LB7: both are Outer Harbor locations, but LB2 is a created shallow water habitat station while LB7 is a deep-water station.

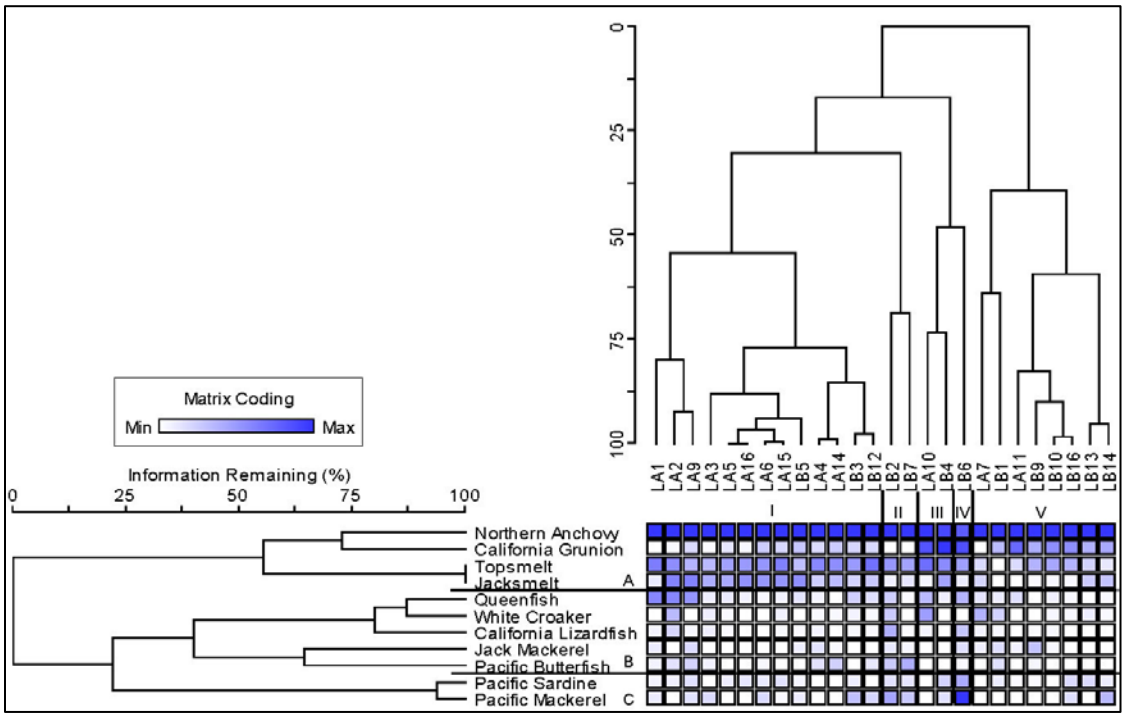

Figure 3-8. Two-way dendrogram based on mean abundance at each station for lampara sampling.

Station Group III also consisted of two stations (Stations LA10 and LB4), both deep Inner Harbor locations where Northern Anchovy and Grunion were abundant. Group IV consisted of a single location (Station LB6) that is a deep Outer Harbor location where more Pacific Mackerel were captured than elsewhere. Group V consisted of eight deep Outer Harbor stations where Northern Anchovy, Grunion, and Topsmelt were common.

DEMERSAL FISH

ABUNDANCE

Otter trawl sampling collected a total of 19,655 fish, comprising 61 taxa, during day and night surveys at 26 stations (Table 3-3, Appendix C-9; additional otter trawl data, including survey data by station for each season are presented in Appendices C-12 [summer] and C-13 [spring]). More fish were collected at night (12,194) than during the day (7,461) (Appendix C-9). White Croaker (*Genyonemus lineatus*) was the most abundant species collected, representing approximately 41% of the total otter trawl catch. Other abundant species included California Lizardfish (*Synodus lucioceps*), Queenfish (*Seriphus politus*), Northern Anchovy, Speckled Sanddab (*Citharichthys stigmaeus*), California Tonguefish (*Symphurus atricaudus*), Pacific Staghorn Sculpin (*Leptocottus armatus*), Longspine Combfish (*Zaniolepis latipinnis*), Barred Sand Bass (*Paralabrax nebulifer*), and Specklefin Midshipman (*Porichthys myriaster*). The other 51 species each accounted for 0.8% or less of the total catch.

California Lizardfish, *Synodus lucioceps* (top); White Croaker, *Genyonemus lineatus* (bottom).

Mean abundance by station is presented in Appendix C-10, and the proportion of the total contributed by the most abundant species is presented in Figures 3-9 and 3-10. Mean abundance (day and night samples combined) was highest at Outer Harbor Station LB3 (mean = 470) and lowest at Inner Harbor Station LA16 (mean = 46). Mean abundance per station was higher at night (235 individuals) than during the day (143 individuals).

As in the 2000 survey (MEC 2002), abundance varied by season, with highest abundances in summer; high numbers of White Croaker and California Lizardfish collected during the summer contributed to this seasonal pattern (Figure 3-9).

Table 3-3. Species and numbers of demersal fish captured by otter trawl, 2013 – 2014.

Common Name	Scientific Name	No.	Common Name	Scientific Name	No.
White Croaker	*Genyonemus lineatus*	8,106	Calico Rockfish	*Sebastes dallii*	9
California Lizardfish	*Synodus lucioceps*	4,780	Bat Ray	*Myliobatis californica*	8
Queenfish	*Seriphus politus*	1,298	Diamond Turbot	*Pleuronichthys guttulatus*	7
Northern Anchovy	*Engraulis mordax*	1,241	Arrow Goby	*Clevelandia ios*	6
Speckled Sanddab	*Citharichthys stigmaeus*	762	Black Surfperch	*Embiotoca jacksoni*	6
California Tonguefish	*Symphurus atricaudus*	685	Kelp Bass	*Paralabrax clathratus*	5
Staghorn Sculpin	*Leptocottus armatus*	662	Onespot Fringehead	*Neoclinus uninotatus*	5
Longspine Combfish	*Zaniolepis latipinnis*	337	Brown Rockfish	*Sebastes auriculatus*	4
Barred Sand Bass	*Paralabrax nebulifer*	309	Cabezon	*Scorpaenichthys marmoratus*	4
Specklefin Midshipman	*Porichthys myriaster*	282	Goby, juvenile	*Gobidae*	4
California Halibut	*Paralichthys californicus*	153	Southern Spearnose Poacher	*Agonopsis sterletus*	4
Fantail Sole	*Xystreurys liolepis*	152	Yellowfin Goby	*Acanthogobius flavimanus*	4
Hornyhead Turbot	*Pleuronichthys verticalis*	110	California Butterfly Ray	*Gymnura marmorata*	3
Plainfin Midshipman	*Porichthys notatus*	90	Gopher Rockfish	*Sebastes carnatus*	3
Spotted Sand Bass	*Paralabrax maculatofasciatus*	71	Shovelnose Guitarfish	*Rhinobatos productus*	3
Bay Goby	*Lepidogobius lepidus*	67	Spotted Cusk-Eel	*Chilara taylori*	3
California Skate	*Raja inornata*	62	Barred Pipefish	*Syngnathus auliscus*	2
Basketweave Cusk-Eel	*Ophidion scrippsae*	46	Chameleon Goby	*Tridentiger trigonocephalus*	2
Vermillion Rockfish	*Sebastes miniatus*	45	English Sole	*Parophrys vetulus*	2
Yellowchin Sculpin	*Icelinus quadriseriatus*	43	Giant Sea Bass	*Stereolepis gigas*	2
White Surfperch	*Phanerodon furcatus*	35	Leopard Shark	*Triakis semifasciata*	2
California Scorpionfish	*Scorpaena guttata*	29	Slough Anchovy	*Anchoa delicatissima*	2
Pacific Butterfish	*Peprilus simillimus*	29	Bay Blenny	*Hypsoblennius gentilis*	1
Giant Kelpfish	*Heterostichus rostratus*	28	Blackeye Goby	*Rhinogobiops nicholsii*	1
Round Stingray	*Urobatis halleri*	28	Bocaccio	*Sebastes paucispinis*	1
Spotted Turbot	*Pleuronichthys ritteri*	24	California Corbina	*Menticirrhus undulatus*	1
Kelp Pipefish	*Syngnathus californiensis*	22	Pile Surfperch	*Damalichthys vacca*	1
Thornback Ray	*Platyrhinoidis triseriata*	20	Rockfish, juvenile	*Scorpaenidae*	1
Shiner Surfperch	*Cymatogaster aggregata*	17	Sculpin, juvenile	*Cottidae*	1
Cheekspot Goby	*Ilypnus gilberti*	14	Stripefin Ronquil	*Rathbunella alleni*	1
Striped Kelpfish	*Gibbonsia elegans*	10			

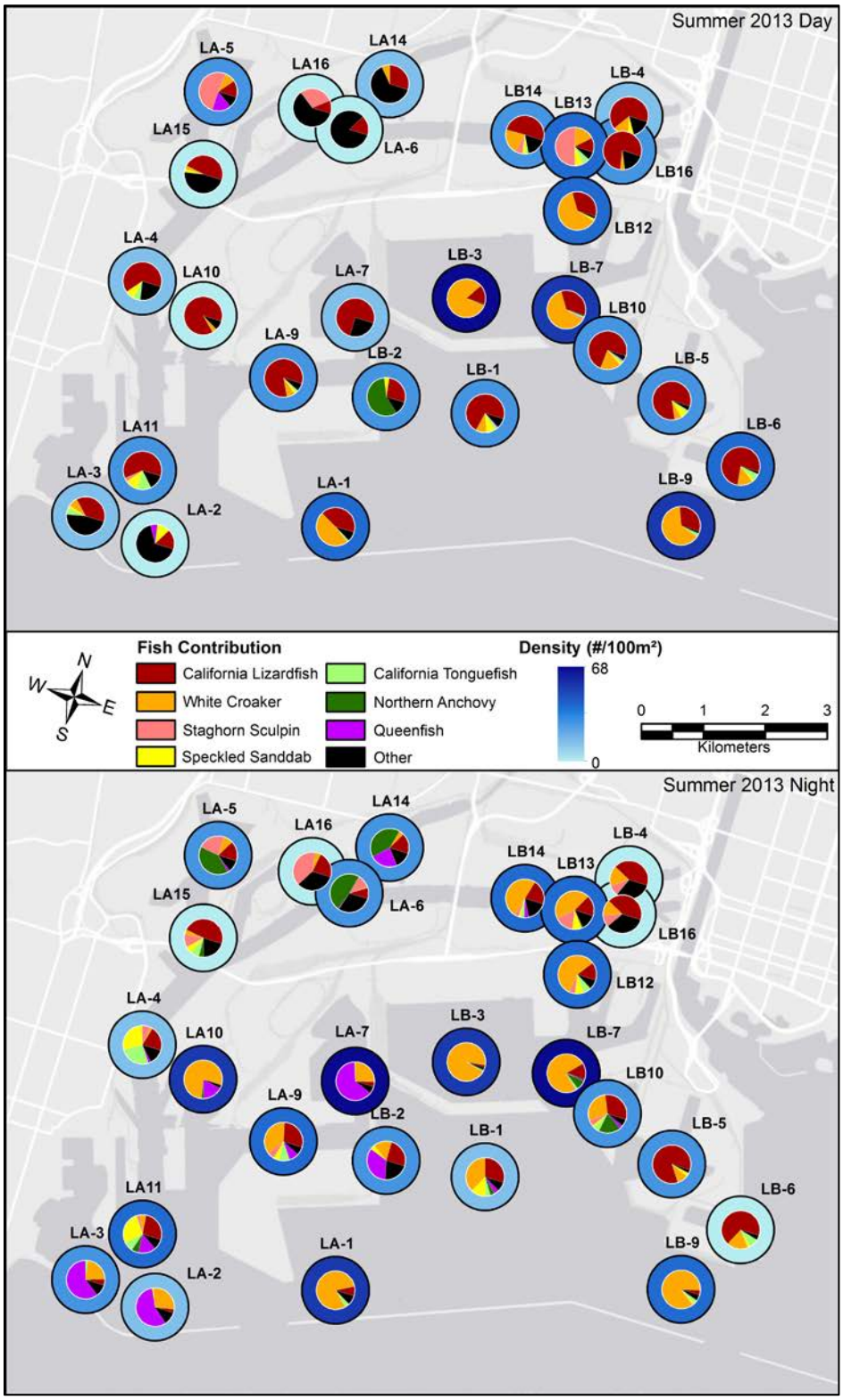

Figure 3-9. Species composition of the otter trawl catch in summer.

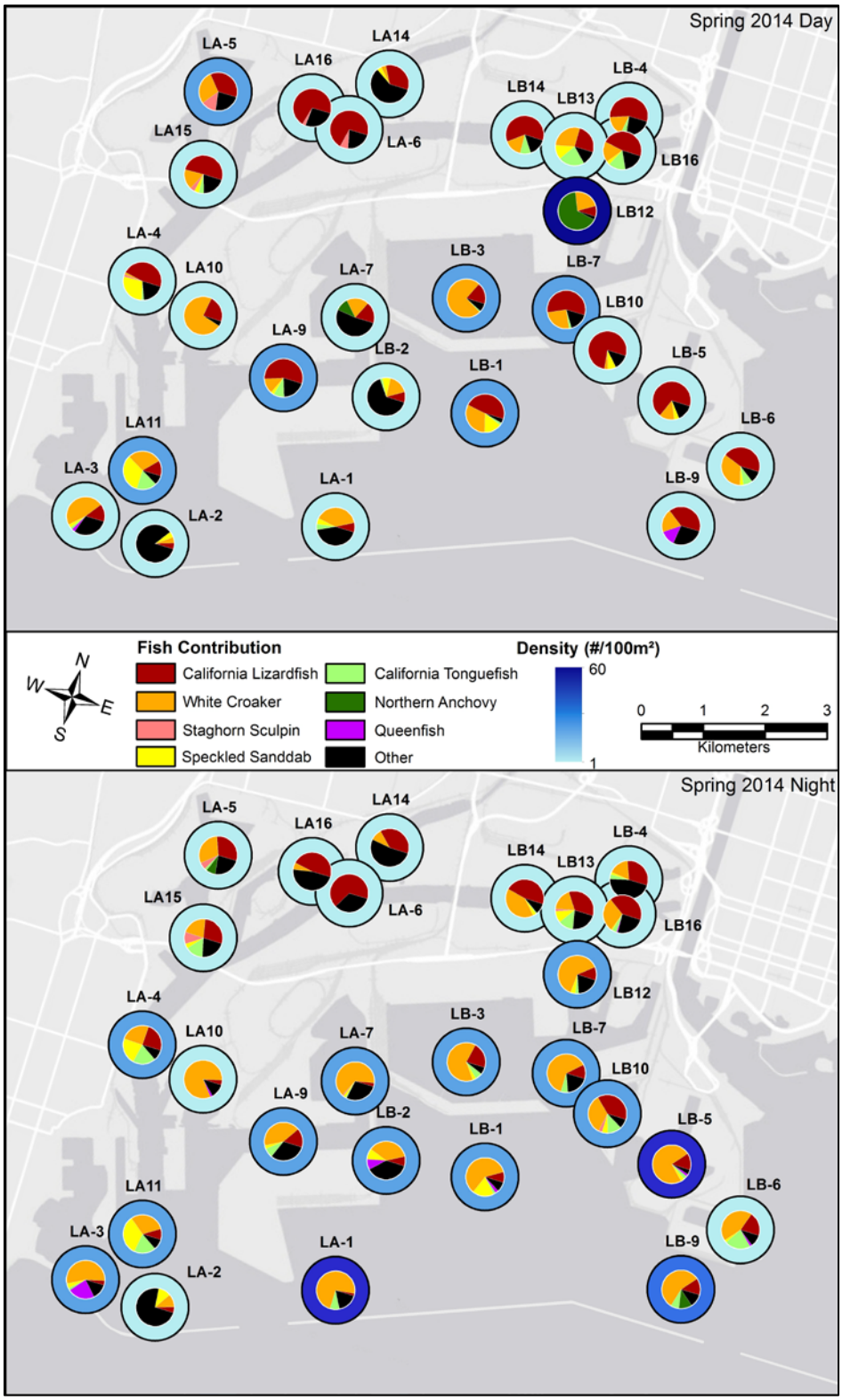

Figure 3-10. Species composition of the otter trawl catch in spring.

BIOMASS

Otter trawl sampling collected a total of 1,148.6 kg of fish during the 2013-2014 surveys (Appendix C-9). In general, White Croaker and California Lizardfish were the largest components of the biomass caught in trawl samples (Figures 3-11 and 3-12). White Croaker, with a total biomass of 596 kg, represented approximately 52% of the total biomass, and California Lizardfish accounted for 26%. Other species with high biomass included California Halibut (*Paralichthys californicus*, 4.9%), Bat Ray (2%), California Butterfly Ray (*Gymnura marmorata*, 1.7%), California Skate (*Raja inornata*, 1.6%), Fantail Sole (*Xystreurys liolepis*, 1.6%), Round Stingray (*Urobatis halleri*, 1.3%), and Queenfish (1.1%).

Greater biomass was collected during night sampling (722.0 kg) than during day sampling (426.6 kg), primarily due to large catches of White Croaker and California Lizardfish at night (Appendix C-9).

The highest mean biomass (day and night samples combined, 30.4 kg) occurred at Station LB7, while the lowest mean abundance (1.9 kg) occurred at Station LA6. Mean biomass at most stations was variable but averaged 11.0 kg, (Appendix C-10), as well as greater biomass collected in summer compared to spring (Figures 3-11 and 3-12). Additional otter trawl data, including survey data by station for each season are presented in Appendices C-12 (summer) and C-13 (spring).

NUMBER OF SPECIES

A total of 61 species was collected by otter trawl; 50 species were collected during day surveys and 51 species during night surveys (Appendix C-9). The number of species collected at each station during a single survey (Figures 3-13 and 3-14) ranged from a low of 2 (Station LA6 in the spring night trawl) to a high of 22 at Station LA11 at night in summer; in general more species were collected during summer surveys. Some stations were more species-rich than others: combining all trawls, the most species (26) were collected at Stations LB2 and LA7, and the fewest (11) were collected at LA16 (Appendix C-10).

DIVERSITY AND DOMINANCE

Values of Shannon Wiener diversity varied greatly among stations and between day and night surveys, ranging from a low of 0.54 at Station LB3 during the night to a high of 2.42 during the day at Station LA2 (Figures 3-13 and 3-14, Appendix C-11). There was little evidence of spatial or temporal patterns, except that diversity was consistently high at the created shallow water habitat stations (LA2, LA3, LB2), and generally higher during the night surveys.

Margalef values followed a similar pattern, with night values being slightly higher than day values. Margalef values ranged from a low of 1.00 at Station LA10 (day) to a high of 3.98 at Station LA3 (day). As in the case of Shannon Wiener diversity, the highest Margalef values occurred at Stations LB2, LA2, and LA3, located in the created shallow water habitats. Dominance in otter trawl samples was much higher than in the lampara samples, ranging from one (Station LB3, LB West Basin West) to seven (Station LA3), but there were no clear spatial or temporal patterns to dominance values.

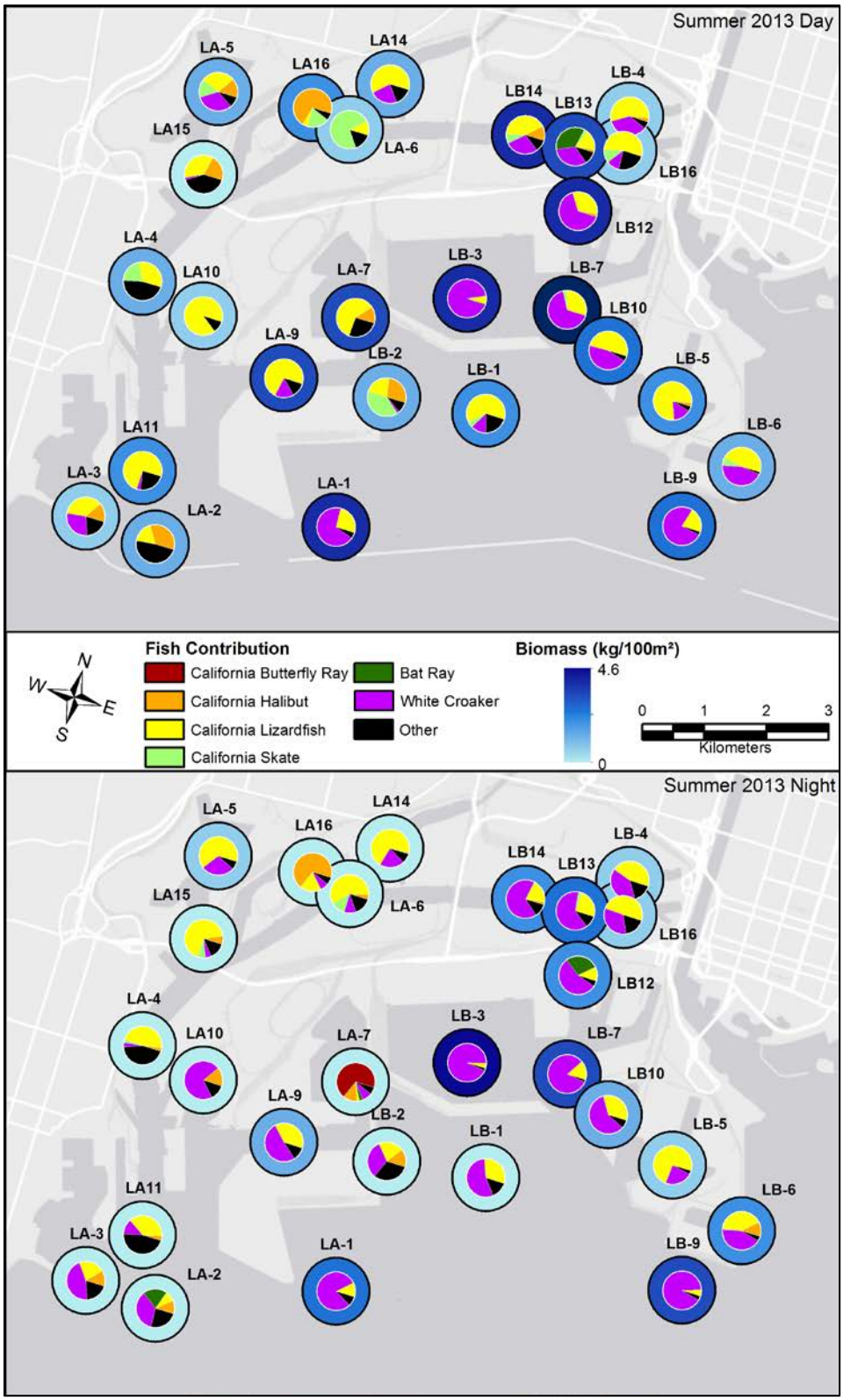

Figure 3-11. Biomass of the otter trawl catch in summer.

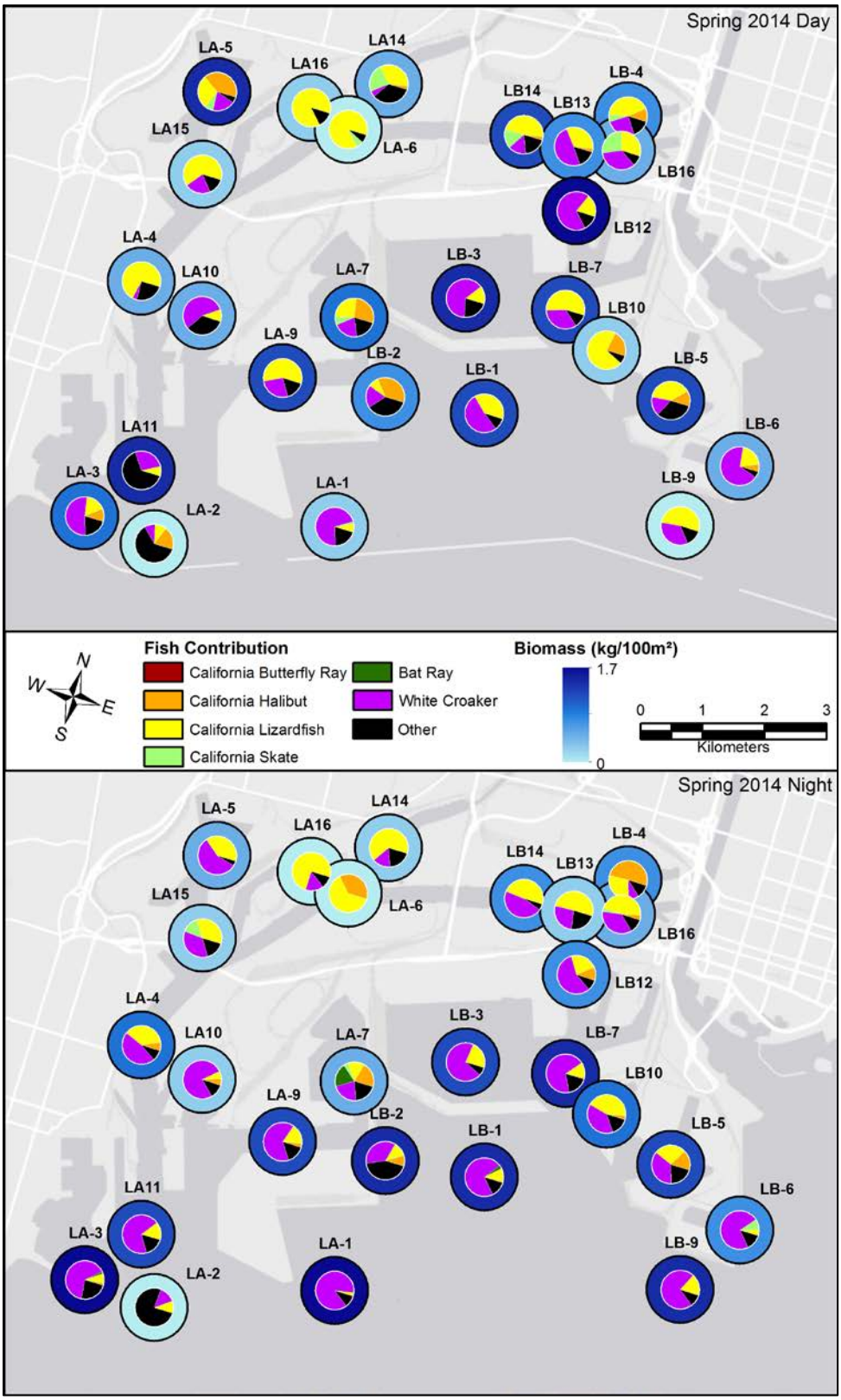

Figure 3-12. Biomass of the otter trawl catch in spring.

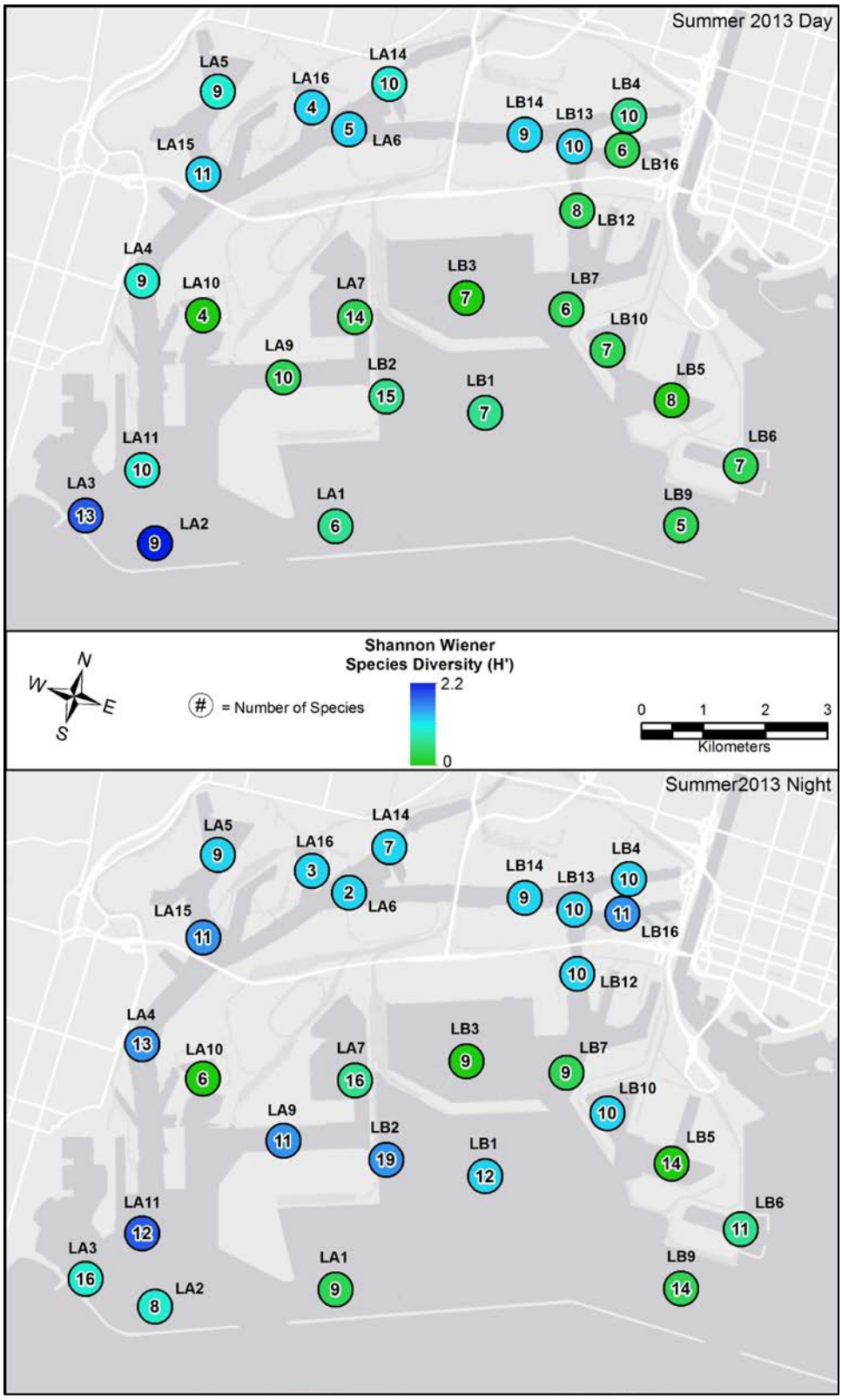

Figure 3-13. Diversity (H') and number of fish species caught by otter trawl in summer.

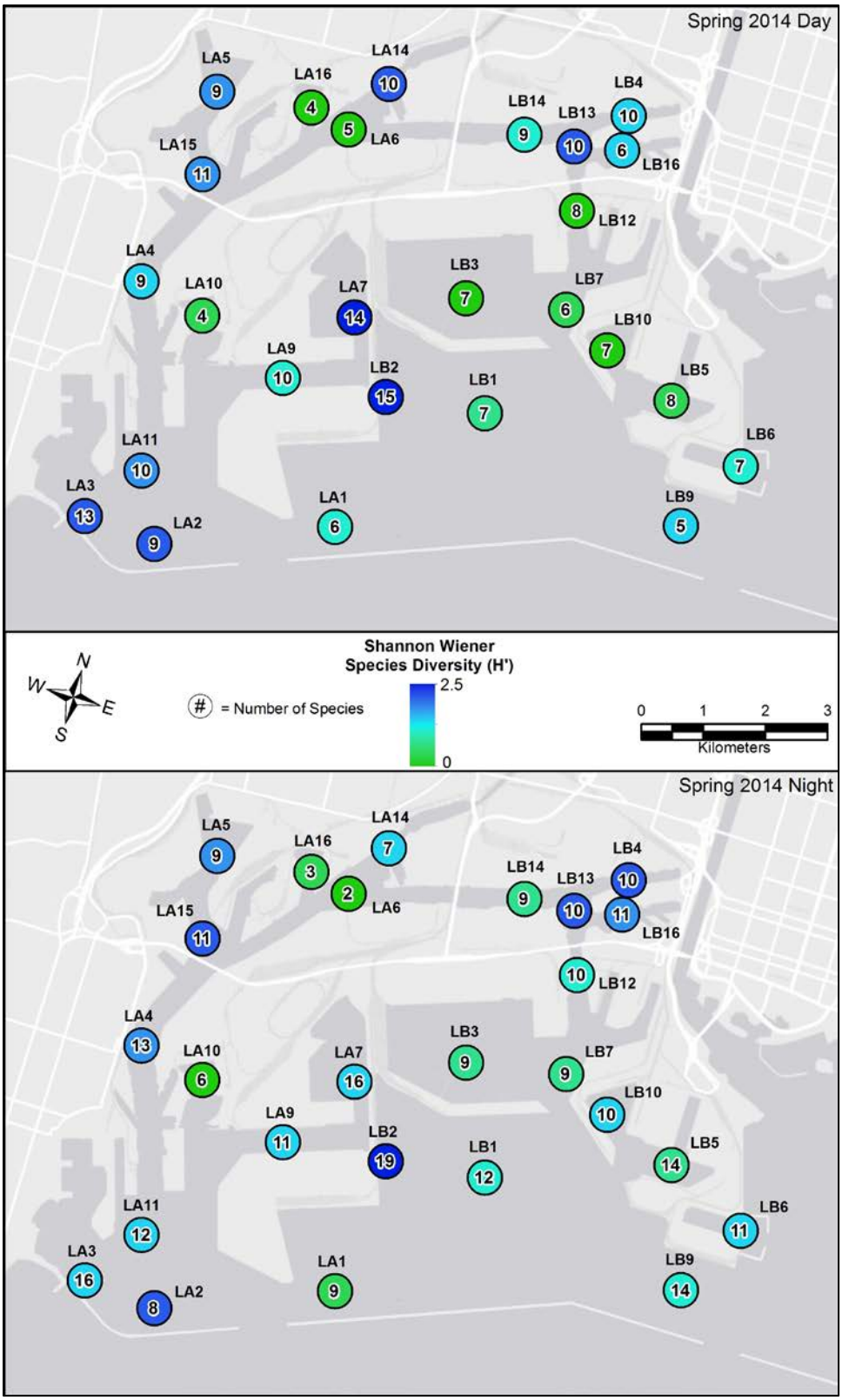

Figure 3-14. Diversity (H') and number of fish species caught by otter trawl sampling in spring.

SELECTED SPECIES

Ten of the 61 species collected over all surveys and stations comprised approximately 94% of the total catch (Table 3-3, Appendix C-9). White Croaker, the most abundant species collected, represented 41.2% of the total otter trawl catch and approximately 52% of the total biomass (Appendix C-9). Size of all measured White Croaker ranged between 2 and 27 cm SL, with most individuals between 14 and 20 cm SL (Figure 3-15). In both summer and spring, the catch showed a bimodal distribution of sizes. In summer, the smaller size class was centered on 3-4 cm SL and the larger class was centered on the 15-18-cm SL size range. In spring, the size distribution was larger, with the smaller class centered on the 8-9 cm SL range and the larger class centered on the 17-19-cm SL size range.



Onespot Fringehead (*Neoclinus uninotatus*), Thornback Ray (*Platyrhinoidis triseriata*), and Longspine Combfish (*Zaniolepis latipinnis*) were among the species captured by otter trawl.

California Lizardfish was the second most abundant fish species collected during otter trawl surveys, and represented approximately 24.3% of the total catch and 25.9% of the total biomass (Table 3-3, Appendix C-9). The size distributions of measured fish (Figure 3-15) were bimodal in both seasons. The smaller size class in summer was centered on the 12-15 cm SL range and the larger class was centered on 23 cm SL. In spring, a number of very small fish (3-4 cm SL) were caught, but most individuals were between 16 and 26 cm SL. The smallest fish in the spring samples may represent juveniles newly recruited from larval forms.

Queenfish was the third most abundant fish species collected during otter trawl surveys, representing approximately 7% of the total catch and 1.1% of the total biomass (Table 3-3, Appendix C-10). Most individuals in summer were small, 4 to 8 cm SL, but a few individuals were in a larger size class that ranged between 15 and 20 cm SL (Figure 3-15). In spring, however, most of the few fish that were collected were in the larger size class; these fish may represent grown individuals of the smaller size class seen the previous summer.

Although it is considered a pelagic species, Northern Anchovy represented 6.3% of the total otter trawl catch and 0.3% of the total biomass (Table 3-3, Appendix C-10). Sizes ranged between 3 and 10 cm SL, with most individuals between 4 and 7 cm SL (Figure 3-15). Higher numbers of smaller individuals occurred in the summer, with fewer individuals collected in spring.

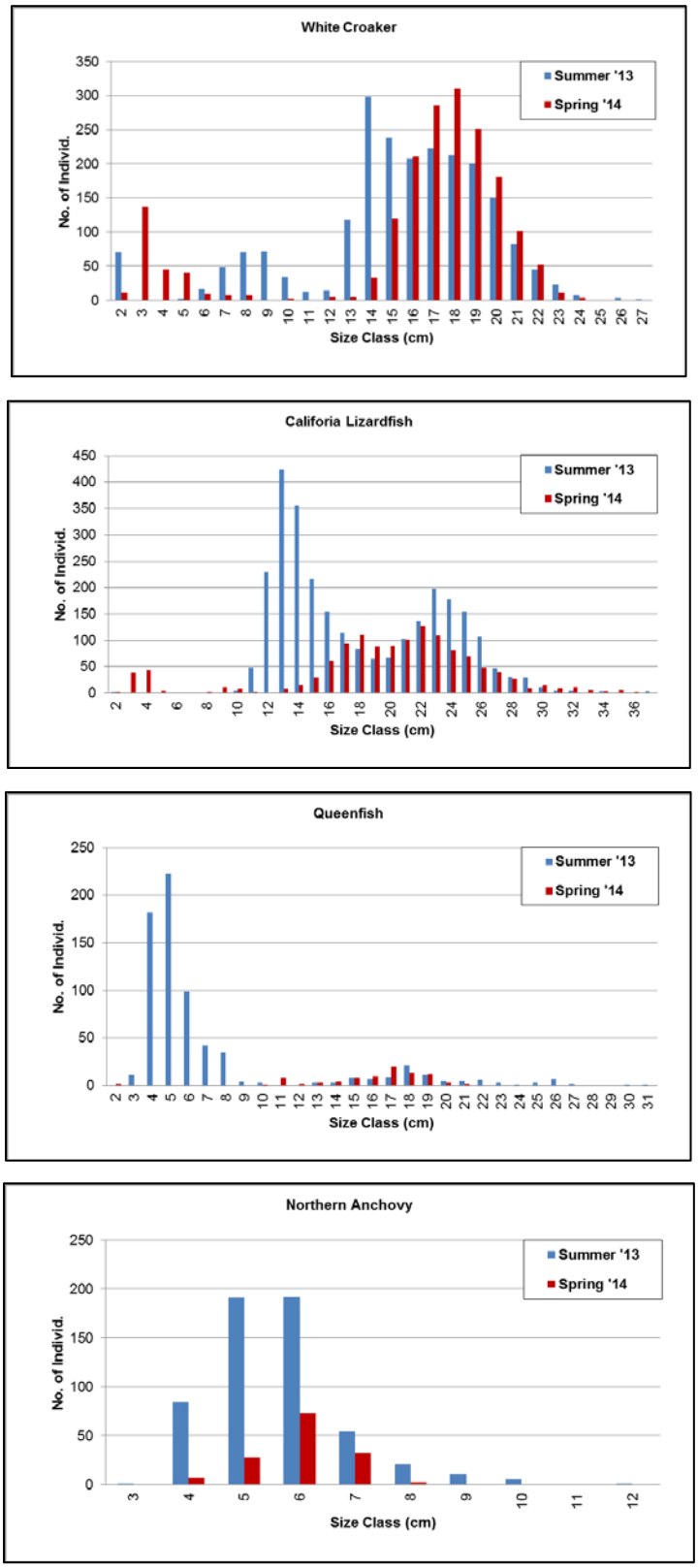

Figure 3-15. Size-frequency distribution of selected fish caught by otter trawl.

SPATIAL VARIATION

Otter trawl sampling revealed differences in mean abundance, biomass, number of species, and diversity that could be attributed to location (i.e., Inner Harbor vs. Outer Harbor) and depth (i.e., shallow vs. deep). An analysis of station groups based on Inner versus Outer Harbor (Table 3-1) and of shallow Outer Harbor (LB2, LA2, LA3, and LA7) versus deep Outer Harbor stations (Figure 3-16) showed that abundances were substantially higher at deep Outer Harbor stations than at shallow Outer Harbor stations and Inner Harbor stations. Species richness, on the other hand, was highest at the shallow Outer Harbor stations. Biomass was somewhat lower at shallow Outer Harbor and Inner Harbor stations than at Outer Harbor stations, and Shannon Wiener diversity was slightly higher at the shallow Outer Harbor stations than elsewhere.

Classification analysis resulted in six station groups (clusters) and six different species clusters based on the similarity of species composition and mean abundance at each station (Figure 3-17). Station Group I consisted of seven stations that were generally deep Outer Harbor stations on the Long Beach side, including some basins and channels, where Lizardfish, White Croaker, and Longspine Combfish were abundant. Station Group II also consisted of seven stations, six being deep Outer Harbor stations and one (Station LB14) a deep Inner Harbor station, and could be characterized as supporting higher diversity than Group I. Station Group III consisted of the four stations in shallow-water habitats, and included species generally not collected at deep water stations, including California Halibut. Group IV consisted of a single Inner Harbor location (Station LA10) where Queenfish were abundant. Groups V and VI consisted of seven deep Inner Harbor stations characterized by high catches of Northern Anchovy, Staghorn Sculpin, and Spotted and Barred Sand Bass.

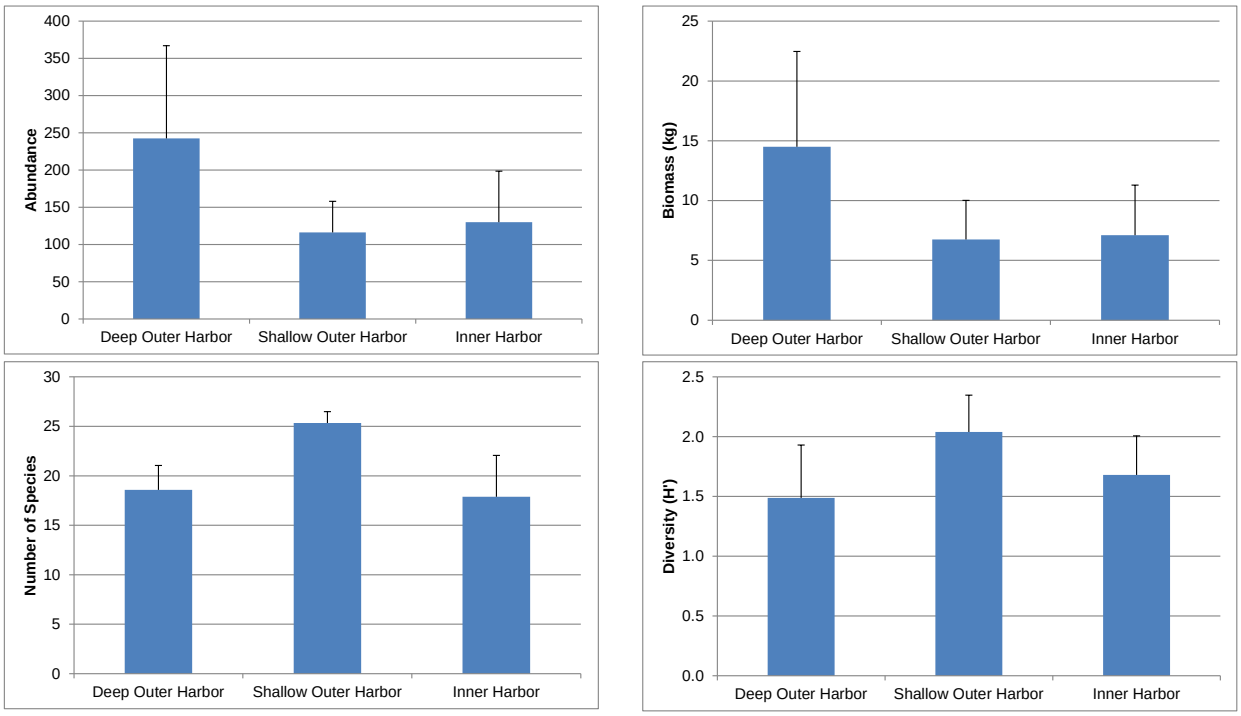

Figure 3-16. Mean abundance, biomass, number of species, and diversity (H') collected by otter trawl.

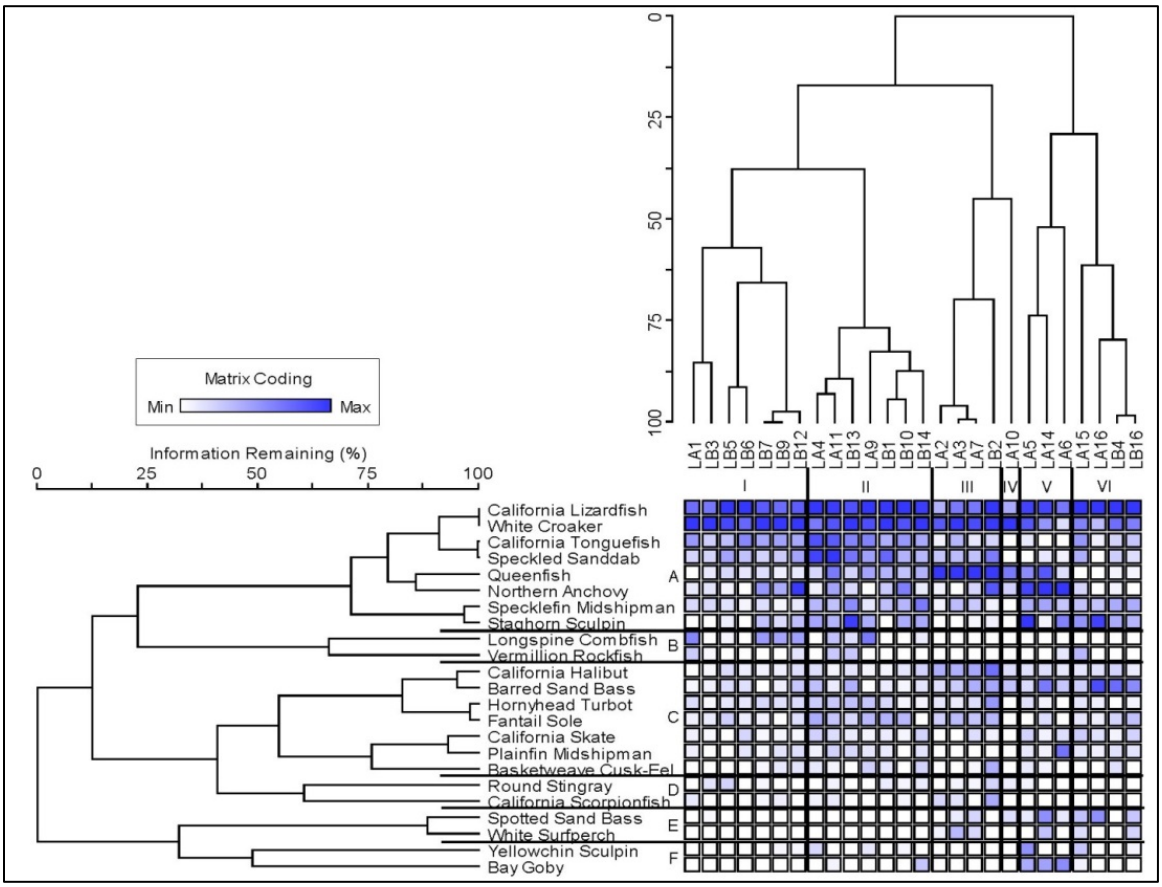

Figure 3-17. Two-way dendrogram based on mean abundance at each station for otter trawl sampling.

SHALLOW SUBTIDAL FISH

Data from the beach seine surveys to sample the shallow subtidal fish community at Cabrillo Beach and Pier 300 are provided in Appendices C-14 and C-15.

ABUNDANCE

A total of 2,693 fish were caught during the beach seine sampling events (Table 3-4 and Figure 3-18). Seventy-seven percent of the catch (2,067 fish) occurred at Cabrillo Beach, and 71% of the total was caught during the summer survey (Figure 3-18). Sampling at Cabrillo Beach caught 517 fish/ net haul versus the 157 fish/ net haul taken at Pier 300.

At both sites, the summer catch exceeded that of spring. Topsmelt, Queenfish, and Northern Anchovy dominated the catch and accounted for a cumulative 96% of the total abundance. Topsmelt accounted for 52% of the catch. Of the Topsmelt, 51% were taken at Cabrillo Beach during the summer survey. Queenfish ranked second at 27% of the total catch, but all were taken at Cabrillo Beach and most were taken in summer. Likewise, Northern Anchovy was caught only during the summer survey at Cabrillo Beach, but still ranked third overall with 17% of the catch.

Table 3-4. Beach seine fish catch statistics including abundance (No.), biomass (Kg), sampling effort (number of hauls), number of species, Shannon Wiener diversity index (H´), and Margalef diversity (d) by survey and station.

	Cabrillo Beach						Pier 300							
	Summer		Spring		Total		Summer		Spring		Total		Annual Total	
Species	No.	Kg	No.	Kg	No.	Kg	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Topsmelt	718	0.52	101	0.01	819	0.53	423	1.60	166	0.21	589	1.81	1,408	2.34
Queenfish	736	0.23	3	0.00	739	0.23	-	-	-	-	-	-	739	0.23
Northern Anchovy	447	0.35	-	-	447	0.35	-	-	-	-	-	-	447	0.35
California Halibut	-	-	18	0.34	18	0.34	-	-	4	0.06	4	0.06	22	0.40
California Grunion	-	-	-	-	-	-	19	0.01	-	-	19	0.01	19	0.01
Kelp Pipefish	2	0.00	16	0.02	18	0.03	-	-	1	0.00	1	0.00	19	0.03
Dwarf Perch	7	0.04	8	0.04	15	0.08	-	-	-	-	-	-	15	0.08
Round Stingray	-	-	4	2.36	4	2.36	-	-	3	1.41	3	1.41	7	3.77
Diamond Turbot	-	-	-	-	-	-	-	-	4	0.16	4	0.16	4	0.16
Leopard Shark	-	-	1	0.40	1	0.40	-	-	2	17.00	2	17.00	3	17.40
Barred Sand Bass	1	0.01	-	-	1	0.01	-	-	-	-	-	-	1	0.01
P. Staghorn Sculpin	-	-	-	-	-	-	1	0.01	-	-	1	0.01	1	0.01
Giant Kelpfish	1	0.00	-	-	1	0.00	-	-	-	-	-	-	1	0.00
Bay Goby	-	-	1	0.00	1	0.00	-	-	-	-	-	-	1	0.00
Gray Smoothhound	-	-	1	0.35	1	0.35	-	-	-	-	-	-	1	0.35
Spotted Sand Bass	-	-	-	-	-	-	-	-	1	0.03	1	0.03	1	0.03
Thornback	-	-	1	0.09	1	0.09	-	-	-	-	-	-	1	0.09
Turbot, unid.	-	-	-	-	-	-	-	-	1	0.00	1	0.00	1	0.00
Shov. Guitarfish	-	-	1	0.65	1	0.65	-	-	-	-	-	-	1	0.65
Snubnose Pipefish	-	-	-	-	-	-	-	-	1	0.00	1	0.00	1	0.00
Total Abundance	1,912	1.15	155	4.26	2,067	5.41	443	1.62	183	18.86	626	20.48	2,693	25.89
Number of Hauls	2		2		4		2		2		4		8	
Number of Species	7		11		14		3		9		11		20	
Diversity (H')	1.11		1.25		1.22		0.19		0.49		0.32		1.19	
Margalef Diversity	0.79		1.98		1.70		0.33		1.54		1.55		2.41	

Note: "-" = absent, “0.00” = <0.005

BIOMASS

Beach seine surveys caught 26 kg of fish (Table 3-4). Unlike the case with abundance, sampling at Pier 300 resulted in the heaviest catch and accounted for 79% of the total biomass. Sampling at Cabrillo Beach caught 1 kg/net haul versus the 5 kg net haul taken at Pier 300.

Very little biomass was caught during the summer survey at Pier 300. Eighty-three percent of the biomass at Pier 300 was due to two Leopard Sharks (*Triakis semifasciata*) taken during the spring survey, when 92% of the station's total biomass was caught. At Cabrillo Beach, a similar pattern occurred, but not to the same extent. The spring survey at Cabrillo Beach caught 79% of the station's total biomass, most as a result of the capture of four Round Stingrays weighing a total of 2 kg.

NUMBER OF SPECIES

Twenty species were caught during the two beach seine surveys (Table 3-4). Although total abundance differed between the two sampling sites, the total number of species was similar, with 14 at Cabrillo Beach and 11 at Pier 300. At each site, the spring survey caught more species than the summer survey.

DIVERSITY AND DOMINANCE

Shannon Wiener diversity (H´) across all surveys was 1.19, and ranged between 0.19 and 1.25 for each survey (Table 3-4). The overall Margalef diversity (d) was 2.41, and ranged from 0.33 to 1.98 per survey. Despite differences in index values and calculation, both indices exhibited the same general pattern: the Pier 300 catch was consistently less diverse than the Cabrillo Beach catch, and the spring catches were more diverse than the summer catches.

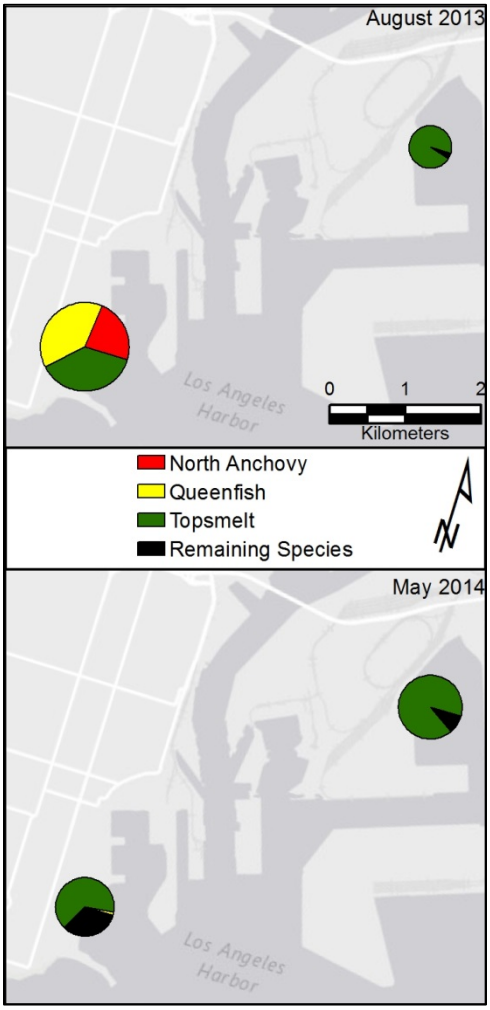

Figure 3-18. Abundance of fishes caught by beach seine sampling in summer and spring at Cabrillo Beach and Pier 300. Note: The size of each pie indicates the percent of the total abundance during each survey.

DISCUSSION

PELAGIC FISH

While results of the current study are generally consistent with those of past harbor-wide studies, some differences were apparent (Figure 3-19). Mean abundance was highest in the present study (7,234 individuals per lampara sample) and lowest in 2008 (295 individuals per sample). The 2014 figure was skewed by a single enormous catch of Northern Anchovy at Station LA3, but even omitting that sample, the average catch in 2014 (2,005 per sample) was substantially larger than in previous studies. Mean biomass per sample was similar in 2000 and 2014 (20.3 and 26.4 kg, respectively), but in 2008 the figure was dramatically lower (2.4 kg per sample).

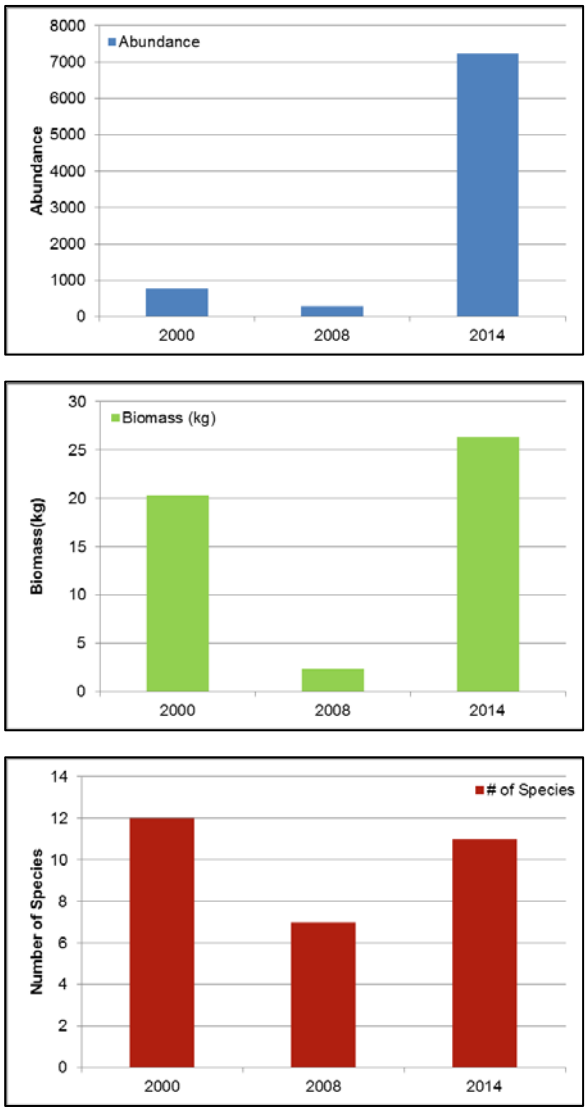

Figure 3-19. Mean abundance, biomass, and number of species collected by lampara sampling.

Similarly, the total number of species was similar in 2000 and 2014 (50 and 36, respectively), as was the number of species per sample (12 and 11 species, respectively), whereas only 20 species total and 7 species per sample were recorded in 2008. The reasons for the dramatic differences in abundance, biomass, and species richness between 2008 and the other two studies are unclear, but could be related to natural regional cycles or climatic patterns.

Seasonal patterns of pelagic fish abundance and biomass in the Port Complex from previous studies suggest a high degree of variability: summer was the peak of abundance in 2000 (MEC 2002) whereas winter was the peak of abundance in 2008 (SAIC 2010) and there was no seasonal peak in the present study, if the one disproportionately large collection of Northern Anchovy is excluded. This lack of a consistent seasonal pattern is likely due partly to highly variable catches of the most dominant pelagic species during each survey and partly to slightly different study designs (two seasons of sampling in the present study compared to three or four seasons in previous surveys).

With a few exceptions, mean abundance, biomass, number of species, and diversity of pelagic fish in the present study showed no clear patterns related to location in the Port Complex. On the other hand, the 2008 study documented differences between Inner Harbor and Outer Harbor in species composition (SAIC 2010), and the 2000 study found that Outer Harbor assemblages generally had relatively higher abundances that were distributed among more species (higher diversity) than those in the Inner Harbors (MEC 2002). Results of the present study suggest similar habitat associations or distributions of pelagic species, with higher abundances and diversity at Outer Harbor areas, although the higher diversity could be attributed to the created shallow-water habitat stations (Figure 3-7). Most of the pelagic fish species in this study and previous studies (summarized in SAIC 2010) appear to be distributed harbor-wide, with no clear preference for particular areas.

Some of the differences between the present study and previous studies may be due to differences in sampling gear, sampling design, and atypical catches (Figure 3-19). For example, because the 2000 study (MEC 2002) used a slightly longer and deeper net it also collected demersal fishes, which could have influenced the fish habitat association analyses. This study, as well as the 2008 study, used a net that was slightly shorter and less deep, so that fewer incidental demersal species were collected. In addition, unlike previous surveys, sampling for the present study took place only in the spring and summer, compared to four times per year in 2000 (at 14 stations) and three times per year in 2008 (at 19 stations). This temporal and spatial variation in sampling could affect the mean values presented in the various reports.

DEMERSAL FISH

The Port Complex is one of the most intensively studied marine areas in southern California. Otter trawl sampling for various port projects and regional studies (e.g., Southern California Coastal Water Research Project Regional Surveys) began in the 1970s and has continued to the present day. Demersal fish assemblages in the Southern California Bight (SCB), exhibit clear differences in species composition between bays and harbors and offshore areas. Regional surveys conducted in 2008 suggested that many demersal species common in bays and harbors were absent or nearly so at offshore sampling sites (i.e., the outer continental shelf or upper slope) (Miller and Schiff 2011). For example, White Croaker and Queenfish were dominant species captured in the Port Complex in 2000, 2008, and the present study, but were caught in only 4% of the remaining areas of the SCB, whereas sanddabs were dominant in continental shelf areas but were a minor component of the Port Complex assemblage.

A consistent group of species has, with few exceptions, dominated the demersal fish community of the Port Complex since the 1970s. Generally, the most abundant species have been White Croaker and Queenfish (not counting Northern Anchovy, which is a pelagic species). Relative abundances of these species have varied with time, but these two species have always been among the most abundant in study after study. The dominance of White Croaker relative to other species has ranged from moderate levels in the 1970s and early 1980s (35 to 61% of total catch) to high levels in the mid-1980s to mid-1990s (63 to 90% of total catch), but has returned to moderate levels since 1998 (36 to 47% of total catch; MEC 2002, SAIC 2010, this study).

The relative abundance of Queenfish has exhibited considerable interannual variation, ranging from 4 to 38%. Miller & Schiff (2011) document a region-wide decline in Queenfish abundance

that is associated with a decline in their zooplankton food source, but Queenfish have been the second or third most abundant demersal species in the Port Complex through all three harbor-wide studies, indicating that the Port Complex remains a favorable habitat for the species and, presumably, their food source.

In this study, California Lizardfish was the second most abundant species captured, accounting for 24.3% of the total catch. In previous harbor-wide surveys, California Lizardfish accounted for less the 1% of the total catch. The species appears to not be a deep-water fish: Miller and Schiff (2011) documented its peak abundance along the inner continental shelf of southern California (5 m to 30 m) and did not find it in outer shelf areas. The reason for this change from previous studies is not clear.

As in previous harbor-wide surveys, seasonal differences in trawl catch were observed in this study, with the highest abundances and biomass occurring in summer; White Croaker and California Lizardfish collected during the summer contributed to this seasonal variation. However, it should be noted that sampling for this study only occurred in the spring and summer, which complicates comparisons with previous studies.

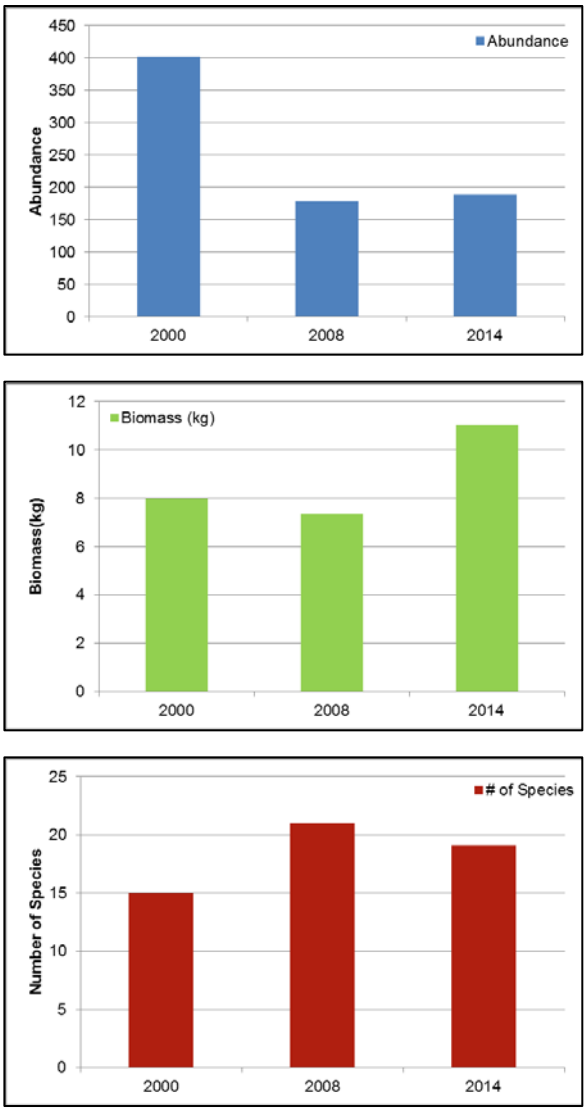

Figure 3-20. Mean abundance, biomass, and number of species collected by otter trawl sampling.

Some differences between the present study and previous studies are evident in Figure 3-20. Mean abundance was highest in 2000 (402 individuals per station), but values were similar in 2008 and 2014 (178 and 189 individuals per station, respectively). Mean biomass values ranged from a low of 7.3 kg per station in 2008 to a high of 11 kg per station in 2014. The mean number of species was similar in 2008 and 2014 (21 and 19 species, respectively), with the lowest number of species per station in 2000 (15 species). Note that otter trawl sampling for this study took place only in the spring and summer at 26 stations compared to four times per year at 14 stations in 2000 and three times per year at 19 stations in 2008. Therefore, comparisons with historical data need to take into consideration potential variation associated with seasonality and the number of deep water stations (the number of shallow water stations has remained the same since 2000).

SHALLOW SUBTIDAL FISH

The fishes captured during the beach seine surveys at Cabrillo Beach and Pier 300 were similar to those taken in previous surveys of the Port Complex (MEC 2002; SAIC 2010), and would be considered common in protected bays in the presence of submerged aquatic vegetation (Allen et al. 2002). While the stations and methods have remained consistent among the three surveys, more seasons were sampled in each of the previous surveys (2000 and 2008). The 2000 and 2008 surveys caught more fish at Pier 300, whereas the present survey caught more fish at Cabrillo Beach.

Despite the differences in sampling frequency, the mean catches per seine haul at Pier 300 in 2000 and in the present study were very similar (155 and 157 fish, respectively). Both studies caught far fewer fish per seine haul than did the 2008 study. At Cabrillo Beach, the two previous studies reported similar average numbers of fish per seine haul, which were approximately one-tenth the number caught in the present study. These results indicate how variable shallow-water fish abundance is, at least when sampled at the frequency of these studies.

Species richness varied among the surveys as the least abundant species, or those represented by fewer than five individuals, were not consistently taken in all years. However, in each of the three surveys, Topsmelt was by far the most abundant species, accounting for at least 67% of the total beach seine catch. The catch in the present study reflected a common pattern in community ecology wherein one or a few species dominate an assemblage (McGill et al. 2007).

The proportional abundance of Topsmelt in the present study (more than 67% of the catch) was consistent with the findings of previous studies (2008: 67%, 2000: 90%), but was greater than the overall proportional abundance in nearshore waters (41%) reported by Allen and Pondella (2006). Topsmelt are planktivorous, and in turn are heavily preyed upon by a variety of predators that live both in and out of the water (Love 2011). Nearly all fish-eating (piscivorous) fish common to nearshore waters prey opportunistically upon Topsmelt. Living near the water's surface also subjects Topsmelt to extensive predation by birds, including the endangered California least tern (*Sternula antillarum browni*).

OTHER OBSERVATIONS

Two of the 70 fish species collected during lampara, otter trawl, and beach seine sampling during the 2013–2014 study have been classified as introduced (non-native or non-indigenous). Both were taken only during otter trawl sampling, and will be discussed in the Non-native Species section (Chapter 11). No cryptogenic (native range or region unknown) or unresolved species (species complexes, including more than one species, or questionable identification) were taken.

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CHAPTER 4 ICHTHYOPLANKTON

The Port Complex supports a diverse assemblage of ichthyoplankton (fish eggs and larvae) that has been periodically studied for over 40 years (HEP 1976, 1979; Brewer 1983; MBC 1984; MEC 1988; MEC 2002; MBC et al. 2007a; SAIC 2010). For the present study, ichthyoplankton sampling was conducted in 2013–2014 to characterize the species composition, relative abundance, and spatial patterns of larval fishes within the Port Complex.

Sampling fish eggs during multiple seasons provides some indication of reproductive activity because viable fish eggs for most species in the Port Complex often hatch within five days after spawning. The actual hatching time varies by species and is a function of environmental parameters (such as water temperature, dissolved oxygen, etc.). Unlike larval fish (described below), unattached fish eggs are essentially passive particles in the water column and are entirely subject to ambient water motion (currents, waves, eddies, etc.). Information on fish egg distribution can be used as general indicator of spawning activity in various areas.

For most fish species, pelagic larval durations -- the time larvae spend in the water column -- range from days to a few weeks. Unlike eggs, larval fish develop the ability to maintain and adjust their position in the water column early in development (Fuiman 2002). While able to maintain their position in the water column better than fish eggs, larval fish are still generally distributed by water motion. Therefore, their presence may not always be indicative of spawning or potential settlement into the local habitat. Both spawning and settlement can be inferred to some extent based on the size of each larva in relation to its species-specific growth potential (i.e., a small larva with a yolk sac is likely just hatched from an egg, and therefore could be locally sourced, while a very large and well-developed larva could be the product of an egg laid outside the Port Complex).

Larval fish, like all predators, are most common near their prey (zooplankton and fish eggs in this case) (Werner 2002). Zooplankton are patchily distributed, and commonly aggregate along subtle, but distinct, environmental features in nearshore waters. Changes in seawater density, turbulence, and prevailing current patterns all contribute to the formation and dissolution of zooplankton aggregations, which in turn affect larval fish distribution (Werner 2002). The leading causes of death in larval fish are the inability to find sufficient, high-quality prey, and being preyed upon by other organisms (Miller and Kendall 2009). The dynamic interaction of these biological and environmental factors leads to the large-scale variability often observed in larval fish assemblages over space and time. Because of this inherent spatial variability, the present study used a spatially comprehensive sampling plan to describe the ichthyoplankton community of the Port Complex.

MATERIALS AND METHODS

FIELD COLLECTION

To take advantage of day/night differences in ichthyoplankton activity rates and reduced net avoidance at night, all sampling occurred at night. This strategy typically results in higher catch rates, greater species diversity, and a larger size range of larval fish (Horn and Hagner 1982; Stephens 1986). Sampling was conducted at the same 26 stations used for the juvenile and

adult fish sampling (Figure 4-1, Table 4-1; Appendix L). Surveys were conducted in summer (September 2013), winter (February 2014), and spring (May 2014), and each lasted two or three nights. The depth-stratified sampling design used in the present study was consistent with previous surveys in the Port Complex (MEC 2002; SAIC 2010) and included: a manta net sampling the air-water interface (neuston); an oblique tow with a bongo net that sampled the midwater (beginning near the bottom and progressing to the surface); and an epibenthic tow with a wheeled bongo that sampled the waters just above the seafloor. All nets were towed for approximately three minutes during each deployment. The mouth of each net was fitted with a calibrated flowmeter. Flowmeter data were used to calculate the volume of water filtered by each net; the targeted volume for all nets was 30 m^3 of seawater filtered.

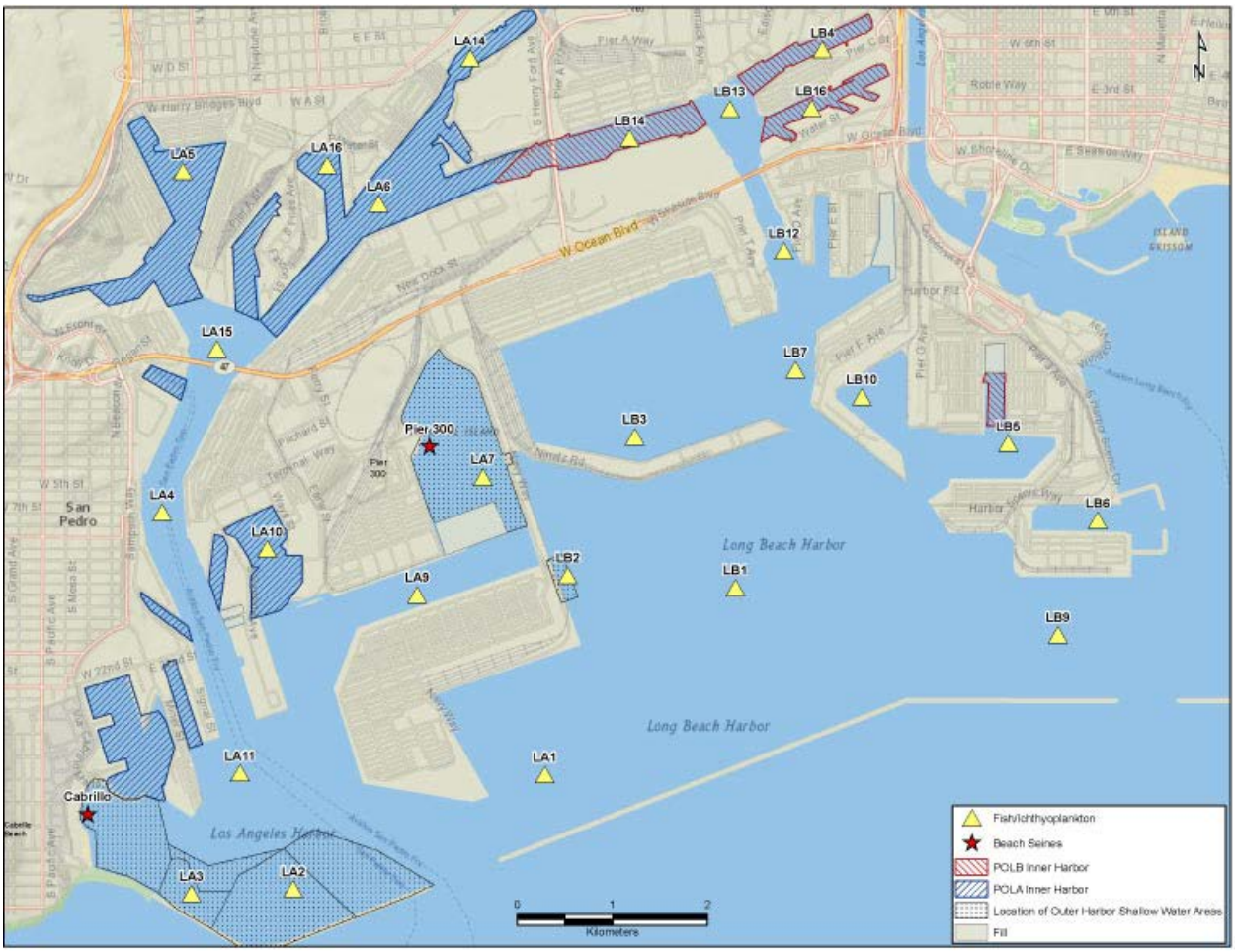


Figure 4-1. Location of ichthyoplankton sampling stations.

Both the manta net and the bongo net are standard sampling nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program to sample fish eggs and larvae offshore California (McClatchie 2013). The bongo net (with or without wheels) consists of two 60-cm-diameter aluminum rings, each ring fitted with a conical, 335-micron (µm) Nitex mesh net. The wheeled bongo effectively samples the near-seafloor water mass in areas with inconsistent bathymetry and substrate, or with debris on the seafloor. The manta net was towed

Table 4-1. Ichthyoplankton sampling station designations and harbor habitat types.

Station	Designation/Location	Harbor Type	Station	Designation/Location	Harbor Type
LB1	LB Outer Harbor (N)	Outer	LA1	LA Outer Harbor (E)	Outer
LB2*	Long Beach SWH	Outer	LA2*	Cabrillo SWH (E)	Outer
LB3	LB West Basin (W)	Outer	LA3*	Cabrillo SWH (W)	Outer
LB4	Channel 2	Inner	LA4	LA Main Channel (N)	Outer
LB5	Southeast Basin (S)	Outer	LA5	LA West Basin (N)	Inner
LB6	Pier J Slip	Outer	LA6	LA East Basin	Inner
LB7	LB Main Channel (N)	Outer	LA7*	Pier 300 SWH (S)	Outer
LB9	LB Main Channel (S)	Outer	LA9	Pier 400 Channel	Outer
LB10	Southeast Basin (N)	Outer	LA10	Fish Harbor	Inner
LB12	Back Channel	Outer	LA11	LA Outer Harbor (W)	Outer
LB13	LB Turning Basin	Outer	LA14	Consolidated Slip	Inner
LB14	Cerritos Channel	Inner	LA15	LA Turning Basin	Outer
LB16	Channel 3	Inner	LA16	Slip 5	Inner

Note: N, S, E, W differentiate stations that that are in the same basin or channel by orientation – north, south, east, or west.

* SWH indicates shallow-water habitat in the Outer Harbor.

outside the boat's wake, and both midwater and epibenthic bongo tows were made off the stern of the vessel. During the midwater tow, the bongo was lowered to the seafloor with the boat's engines disengaged, and then winched aboard at a consistent rate while the boat was moving forward. Epibenthic sampling was similar to the midwater sampling except that the winch was not engaged until after the three-minute tow was completed, and then the boat's engines were stopped and the net retrieved. If additional water needed to be filtered for any sampling type, the net was lowered and retrieved again as just described. Station designation, water depth, date, time, net type, net-specific flow meter readings, net-specific calculated flow, and general observations were recorded on preformatted data sheets for each tow.

Wheeled bongo nets.

On retrieval, the samples were condensed into the cod end by washing down the nets from the outside in order to avoid introducing any ichthyoplankton from the seawater wash-down hose. Samples from each net were placed in separate plastic jars with external and internal labels indicating the sample number, station, date, net type, and bongo net number.

All samples were fixed in a mixture of 5% buffered formalin in filtered seawater in the field, and then transferred to 70% isopropyl alcohol after approximately 72 hours.

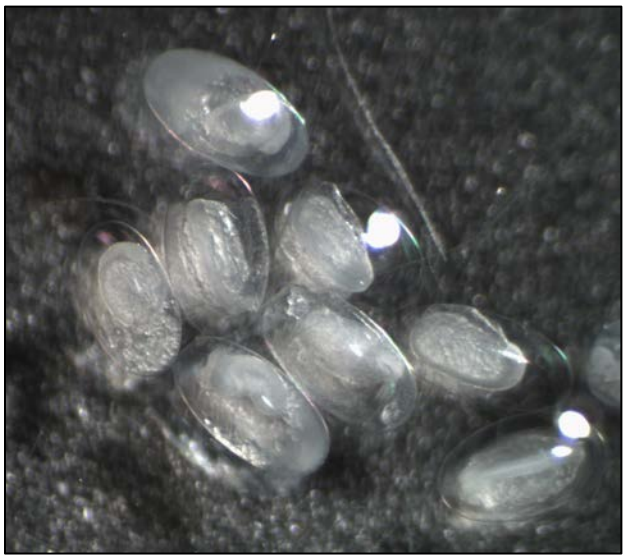
LABORATORY PROCESSING

After transfer to alcohol, all samples were processed in the MBC sorting and taxonomy laboratory. Fish eggs and larvae were sorted from the samples under dissecting microscopes. Larval fish taxonomy was completed in accordance with Moser (1996), and species-specific counts were recorded for each net sample. Except for anchovy (Engraulidae) and turbot (*Pleuronichthys* spp) eggs, the eggs of local fish species are indistinguishable from one another; accordingly, eggs were classified in the laboratory as "anchovy", "turbot", or "unidentified eggs".

Multiple stages of lefteye flounders (Paralichthyidae) caught during the 2013–2014 ichthyoplankton surveys.

DATA ANALYSIS

All catch data (fish eggs and larvae) were standardized to number of fish eggs or larvae as a concentration per 100 m^3 using the flowmeter data. Area-normalized concentrations (the number of eggs or fish per 100 m^2 of sea surface), termed densities in this analysis, were estimated by multiplying the number of each taxon per 100 m^3 by the depth of water that the net sampled. The surface tow sampled the upper 0.16 meters of the water column, the epibenthic tow sampled the lower 0.70 meters of the water column, and the midwater tow sampled the rest of the water column (station water depth – [0.16 + 0.70]). Concentrations (eggs/larvae per 100 m^3) by tow type across all seasons and stations were compared using a Kruskal-Wallis one-way analysis of variance on ranks. All comparisons among stations used the weighted densities. These same data were compared with the mean water temperatures and dissolved oxygen concentrations in the water column reported in the Physical Characteristics chapter using linear regression as an exploratory analysis. Water quality and larval fish data were matched based on station and season sampled. Larval fish population indices included the number of taxa, Shannon Wiener (SW) diversity (H'), Margalef diversity (d), and dominance.



Anchovy (Engraulidae) eggs caught during the 2013–2014 ichthyoplankton surveys. The oval shape is unique to anchovy eggs.

Larval densities at each station, combined across all three sampling seasons, were compared by non-metric multivariate multidimensional scaling (nMDS) using PRIMER v.6 (Clarke and Gorley 2006). An nMDS is similar to a cluster diagram in that it graphically represents the similarities between stations. However, a cluster diagram exhibits similarities or dissimilarities by the length of each arm branch of the cluster. In an nMDS plot, similarity is displayed by the proximity of each data point to each other data point in (in this case) two-dimensional space. Prior to the nMDS analysis, data were fourth-root transformed to minimize variability and the influence of large catches. A Bray-Curtis dissimilarity matrix was calculated from the transformed data. Cluster analysis with a similarity profile (SIMPROF) test was used to identify related stations based on their respective community compositions. A SIMPROF test compares each branch point (node) in the cluster to determine if any significant differences exist at the subsequent nodes. The results of the SIMPROF tests were used to aggregate stations into groups during each season. Additional data analysis methods and explanations are included in the Results section to facilitate ready interpretation of the data presentation.

RESULTS

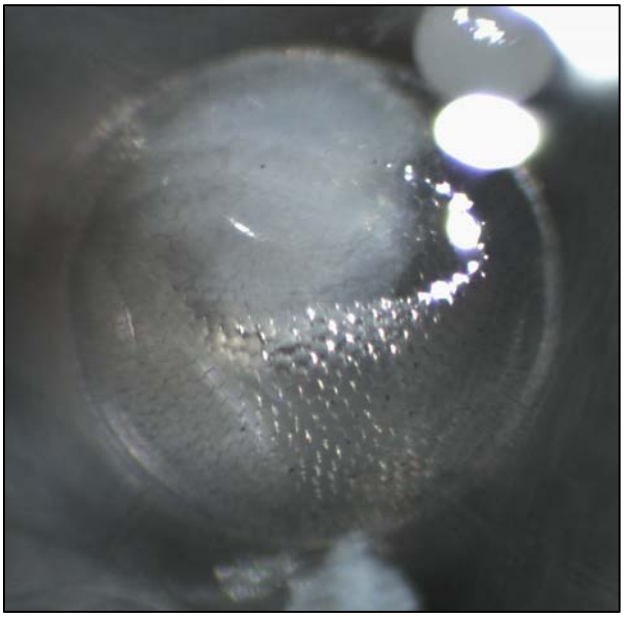
All metadata and raw abundance data for each survey are tabulated in Appendix D.

FISH EGGS

Fish eggs were taken at every station throughout the Port Complex during all three seasons. The density of eggs was highest at most stations in winter, and tended to be higher in the Outer Harbor (especially at Station LB9) than in the Inner Harbor (Figure 4-2).

Concentrations of eggs were highest in winter, with an overall mean (mean of station means) of 2,156 eggs/100 m^3 (± 1,477), intermediate in summer (519 eggs/100 m^3, ± 301), and lowest in spring (311 eggs/100 m^3, ± 128). In general, egg concentrations at the surface were higher than in the midwater and near-bottom layers combined, particularly during the summer and winter surveys (Table 4-2).

Egg concentrations at the various stations ranged from 10 to 37,991 eggs/100 m^3 for surface tows, from 6 to 2,812 eggs/100 m^3 for midwater tows, and from 0 to 9,301 eggs/100 m^3 for epibenthic tows. Surface sampling caught an average of 2,265 eggs/100 m^3 per station over the course of the study. This number far exceeded both the midwater and the epibenthic samples: 340 eggs/100 m^3 and 382 eggs/100 m^3, respectively. Exceptions to the pattern of highest egg concentrations at the surface occurred at Stations LB3 and LB9, where average egg concentrations over the three seasons were highest in the epibenthic samples.



Turbot (*Pleuronichthys* spp) egg caught during the 2013–2014 ichthyoplankton surveys. The “honeycomb” sculpturing is unique to turbot eggs.

Anchovy eggs accounted for 16% of all fish eggs reported during the winter survey, 3% of the spring count, and 1% of the summer count. Turbot eggs constituted 2% of the spring count and 1% of the totals during the other two surveys.

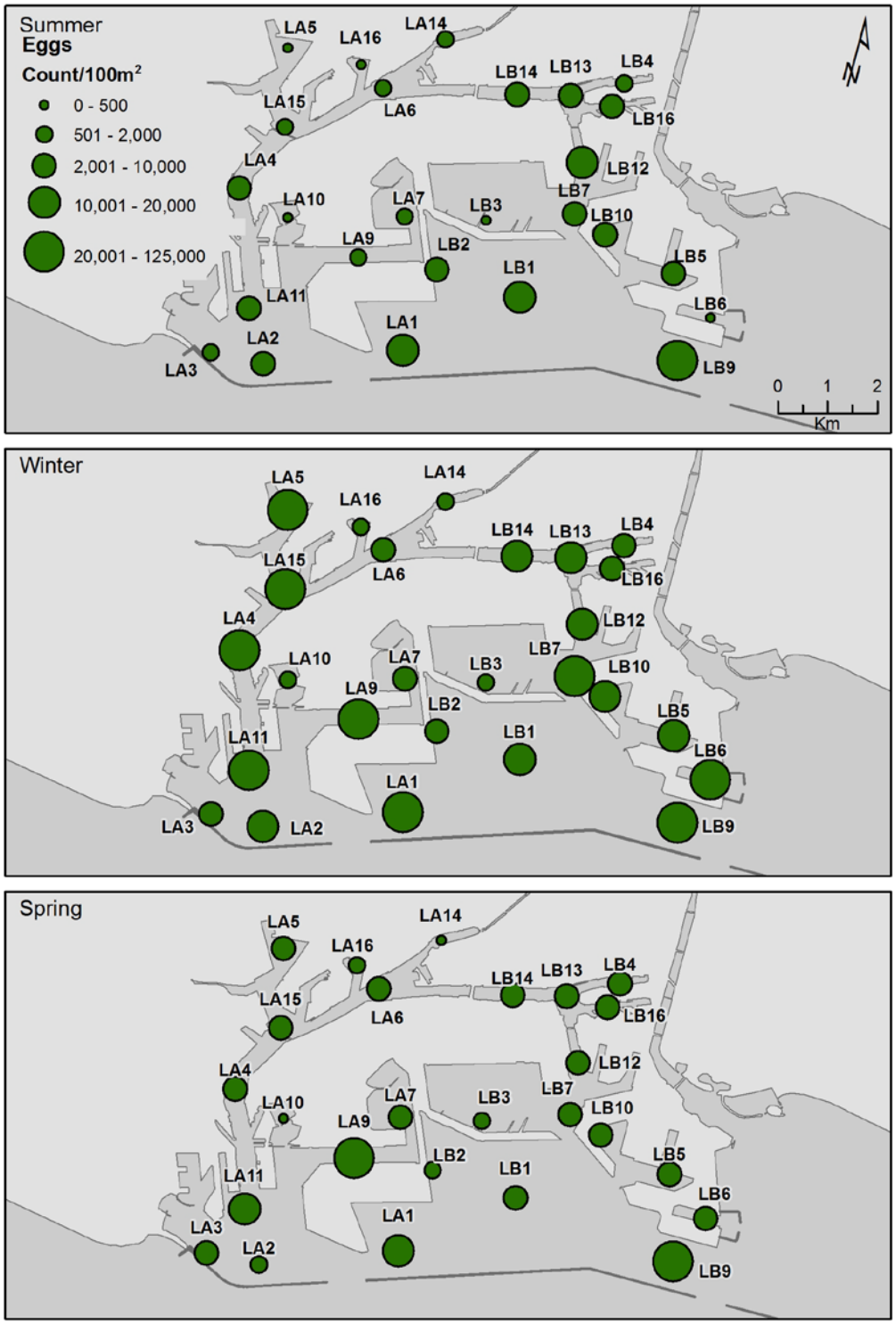


Figure 4-2. Densities of fish eggs in the Port Complex in summer, winter, and spring.

Table 4-2. Mean concentration (number per 100 m^3) of fish eggs by strata and season.

Taxon	Stratum	Summer	Winter	Spring
	Surface	24	361	14
Anchovy (Engraulidae)	Midwater	4	62	4
	Epibenthos	1	63	2
	Surface	23	178	12
Turbot (*Pleuronichthys*)	Midwater	2	4	2
	Epibenthos	5	25	2
	Surface	1073	4563	541
Unidentified eggs	Midwater	126	352	123
	Epibenthos	151	402	111

LARVAL FISH

Seventy-nine taxa of larval fish were collected during the sampling, but only ten of those numerically dominated the larval fish assemblage in the Port Complex (Table 4-3, Appendix D). Highest densities of larval fish (Figure 4-3) occurred in the Outer Harbor during the winter survey. The CIQ goby complex (which includes the practically indistinguishable larvae of Arrow Goby [*Clevelandia ios*], Cheekspot Goby [*Ilypnus gilberti*], and Shadow Goby [*Quietula y-cauda*]) was abundant during all surveys, but densities varied spatially. Larvae of Northern Anchovy (*Engraulis mordax*) and combtooth blennies (*Hypsoblennius* spp) were also common during all three surveys.

While some degree of seasonal variability was observed for larvae of all ten of the most abundant species, abundance of several of those was highly seasonal. For example, Bay Goby (*Lepidogobius lepidus*) larvae were collected almost exclusively in summer; White Croaker (*Genyonemus lineatus*), unidentified anchovies (Engraulidae), and unidentified yolk sac larvae were most abundant in winter; and Queenfish (*Seriphus politus*) and Jacksmelt (*Atherinopsis californiensis*) were most common in spring.

CONCENTRATIONS BY STRATA

Larval fish concentrations were consistently higher near the seafloor (i.e., in the epibenthic tows) than in the water column or at the sea surface during all three surveys (Table 4-3); the exceptions were Jacksmelt, most of which were caught in the surface layer, and Combtooth blenny larvae and yolk sac larvae, which were more abundant in the water column than near the bottom. This pattern demonstrates that fish larvae congregate near the bottom, because although the volume of water sampled by the epibenthic tows was much smaller than the volume sampled by the midwater tows, the numbers of larvae captured were much greater.

Table 4-3. Mean concentration (number per 100 m^3) of the ten most abundant fish larva taxa by strata and season.

Taxon	Stratum	Summer	Winter	Spring
CIQ Goby (Gobiidae)	Surface	6	1	3
	Midwater	39	24	16
	Epibenthos	89	45	35
Unid. anchovies (Engraulidae)	Surface	-	2	<0.5
	Midwater	<0.5	38	10
	Epibenthos	1	86	35
Combtooth blennies (*Hypsoblennius* spp)	Surface	10	4	34
	Midwater	13	4	27
	Epibenthos	5	2	10
White Croaker (*G. lineatus*)	Surface	-	4	-
	Midwater	1	31	3
	Epibenthos	1	46	19
Northern Anchovy (*E. mordax*)	Surface	-	-	1
	Midwater	5	13	9
	Epibenthos	10	20	26
Bay Goby (*L. lepidus*)	Surface	2	<0.5	<0.5
	Midwater	21	2	1
	Epibenthos	83	5	2
Unid. Yolk Sac	Surface	1	35	1
	Midwater	1	23	<0.5
	Epibenthos	1	6	<0.5
Yellowfin Goby (*A. flavimanus*)	Surface	-	<0.5	2
	Midwater	-	3	12
	Epibenthos	-	13	28
Queenfish (*S. politus*)	Surface	-	-	<0.5
	Midwater	1	<0.5	3
	Epibenthos	3	<0.5	5
Jacksmelt (*A. californiensis*)	Surface	-	44	186
	Midwater	-	1	1
	Epibenthos	-	1	1

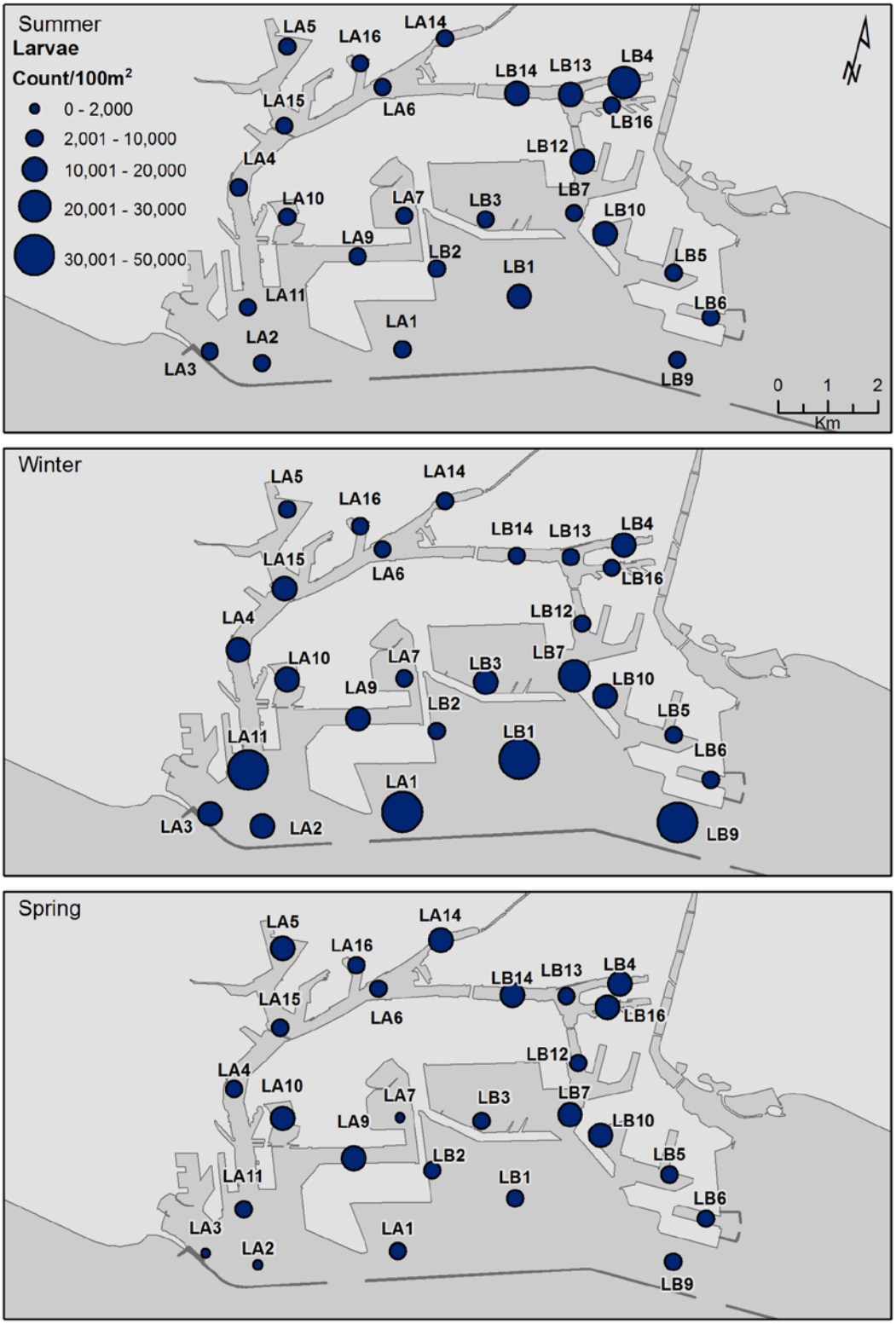


Figure 4-3. Larval fish density by station in the Port Complex in summer, winter and spring. See Appendices D-2-A, D-3-A, and D-4-A for counts.

The median concentration was highest in epibenthic tows in winter (Figure 4-4). Larval concentrations in the midwater stratum were higher in winter than in the other two seasons, while surface concentrations peaked in spring. Lowest concentrations at the surface and in the water column were reported during the summer survey, and lowest epibenthic concentrations occurred in spring. No significant relationships between larval fish abundances and water quality parameters were detected; less than 5% of the variation was explained by the regression models by season and cumulatively across all seasons (data not presented).

To detect patterns of larval distribution within the Port Complex, the mean, harbor-wide concentration of fish larvae (i.e., all 26 stations combined) was calculated for a given season and stratum, then each station was compared to that mean value. The analysis did not reveal any consistent patterns in station-specific concentrations by depth stratum either within seasons or across seasons: high abundance at a given station and stratum in one season was no predictor of a similar pattern at that station in another season.

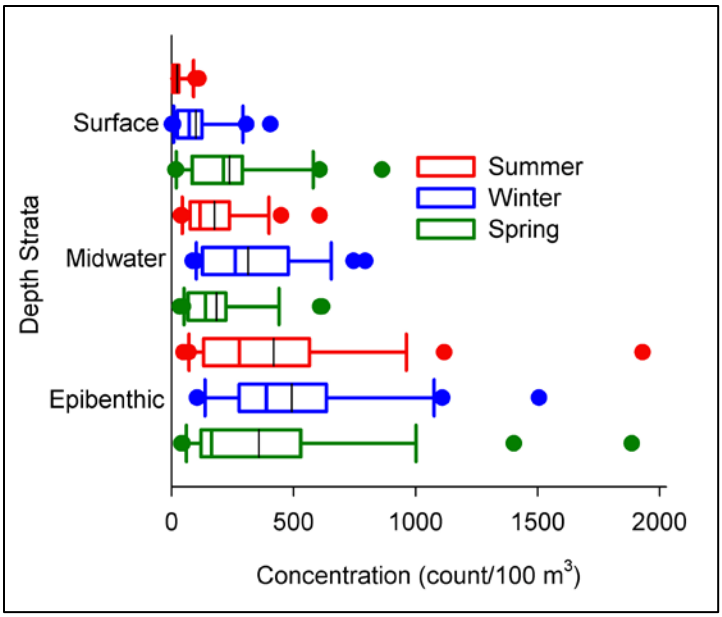


Figure 4-4. Larval fish concentration (count/100 m^3) by depth strata for each of the three sampling periods. The thin vertical black line within each box is the mean of the data set; the vertical colored line is the median. Each box encompasses the 75th and 25th quartiles, the error bars are the 95% confidence intervals (the non-outlier minimum and maximum values), and dots are outliers.

DOMINANT LARVAL TAXA

The CIQ goby complex was the most commonly caught larval taxon during the 2013–2014 study (Table 4-3). CIQ goby densities were generally highest in summer and lowest in spring (Figure 4-5). The highest CIQ goby density (8,362/100 m^2) was recorded in spring at Station LA10, where CIQ gobies were consistently abundant, but densities at Stations LB1, LA14, and LA2 in summer were also high, ranging from 6,294–7,447/100 m^2. While CIQ goby larvae were found throughout the Port Complex during all surveys, the only consistent pattern of abundance by location among the surveys was the high abundances at Station LA10. Goby larvae were most abundant in the epibenthos during all three surveys (Table 4-3).

Unidentified anchovies were the second most abundant larval fish taxon, and they were far more abundant in winter than in summer or spring (Figure 4-5). Highest densities were reported at Outer Harbor stations and at Station LB4. As with gobies, anchovy larvae were most abundant in the epibenthos during all three surveys (Tables 4-2 and 4-3).

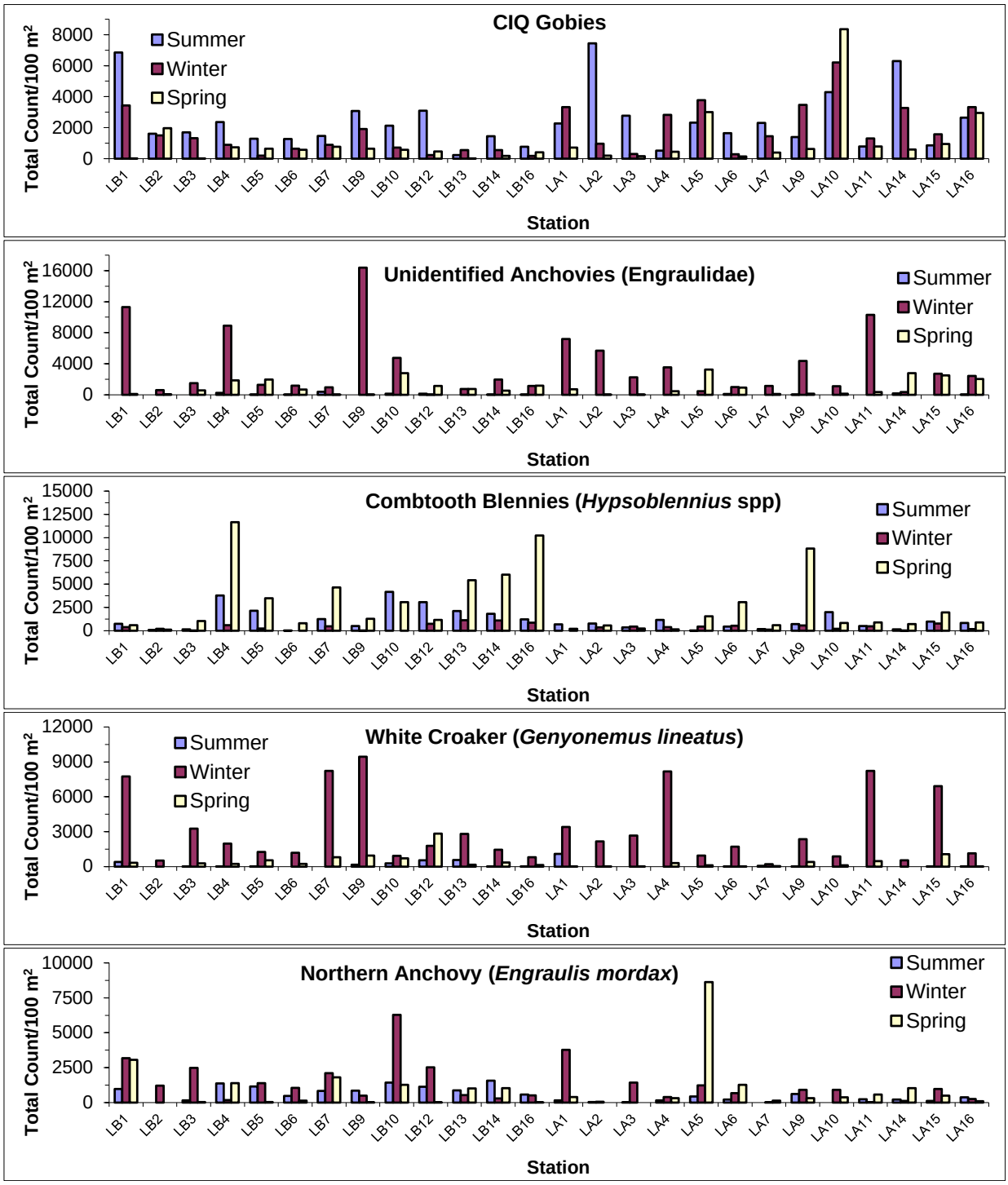


Figure 4-5. Larval fish density (number/100 m^2 of sea surface) of the ten most common fish taxa taken in summer, winter, and spring. Note: Change in y-axis scales.

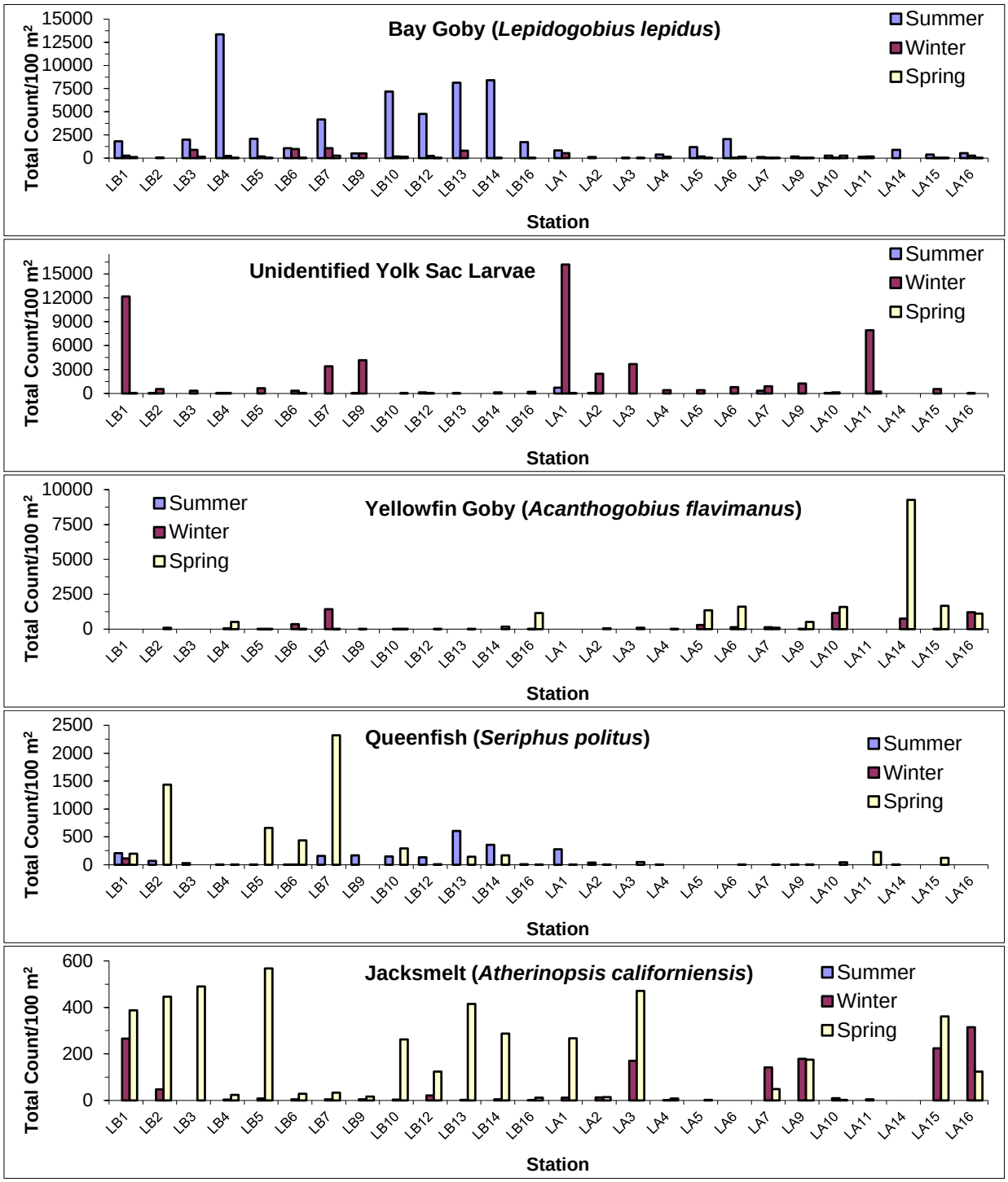


Figure 4-5 (cont.). Larval fish density (number/100 m^2 of sea surface) of the ten most common fish taxa taken in summer, winter, and spring. Note: Change in y-axis scales.

The spatial distribution of combtooth blennies was nearly opposite that of the CIQ goby complex (Figure 4-5). In general, combtooth blenny larvae were most abundant in spring and summer, and were more abundant at Inner Harbor and channel stations, particularly stations on the Long Beach side, than at open Outer Harbor stations. Combtooth blenny larvae tended to be most abundant in the neuston and midwater during all three surveys (Table 4-3).

Bay Goby (*Lepidogobius lepidus*) larva caught during the 2013–2014 ichthyoplankton surveys.

White Croaker larval densities were highest in winter throughout the Port Complex, but comparatively few were caught in summer or spring (Figure 4-5). Densities were substantially higher in the main shipping channels, right up to the turning basins, of the two ports than elsewhere. White Croaker larvae were most abundant in the epibenthos and midwater during winter, and were nearly absent in summer (Table 4-3). Northern Anchovy larvae occurred throughout the Port Complex in generally consistent densities during all surveys (Figure 4-5). The exceptions were particularly large catches at Station LB10 and Station LA1 in winter and at Station LA5 in spring. Northern Anchovy larvae were most abundant in the epibenthos during all three surveys, and were rarely captured at the surface (Table 4-3).

Bay Goby distribution was similar to that of combtooth blennies, but Bay Goby was most common in basins and channels on the Long Beach side of the Port Complex (Figure 4-5). By far the highest densities occurred in summer; few Bay Goby larvae were captured in winter or spring. Bay Goby larvae were most abundant in the epibenthos (Table 4-3). Unidentified yolk sac larvae (recently hatched and minimally developed) were rarely collected except during the winter survey (Figure 4-5). As with unidentified anchovies, highest densities occurred at Outer Harbor stations, especially the main shipping channels (Figure 4-5), and at the surface and in midwater (Table 4-2).

Yellowfin Goby larvae were markedly less abundant than CIQ goby and Bay Goby (Table 4-2, Figure 4-5). No Yellowfin Goby larvae were caught during the summer survey, and highest densities occurred in spring. While larvae were taken at most stations in the Port Complex in at least one survey, by far the highest density was recorded at Station LA14 in spring. Larvae of Yellowfin Goby were most abundant near bottom (Table 4-2). Queenfish larvae were most abundant in spring, and common in summer, but were taken at only two stations (LB1 and LB12) in winter (Figure 4-5). Queenfish larvae were much more abundant on the Long Beach side of the Port Complex (Figure 4-5), and were more abundant in the epibenthos and midwater than near the surface (Table 4-2).

When present, Jacksmelt was the most abundant larval taxon collected in surface samples (Table 4-2). Jacksmelt were taken in high numbers throughout the Port Complex in spring and

in lower densities in winter (Figure 4-5). No Jacksmelt were collected in summer (four unidentified silversides [Family Atherinopsidae, which includes Jacksmelt] were caught in summer, but they could not be distinguished between Jacksmelt, Topsmelt, or California Grunion). Almost all Jacksmelt larvae were collected in the surface layer.

SEASONALITY

Summer

During the summer survey, larval densities ranged from about 2,200/100 m^2 to 23,000/100 m^2 among all stations, and were highest on the Long Beach side, especially at Inner Harbor and basin stations (Figure 4-6, Appendix D-2-A). Densities in summer were lower than in winter and higher than in spring. Bay Goby was the dominant taxon at the stations where densities were highest, Combtooth blennies dominated the larval catch at three stations (LB5, LA4, and LA15), and CIQ gobies were the dominant taxon at most other stations. Shannon Wiener diversity in summer (Figure 4-7) ranged from 0.86 to 2.10 with a median of 1.35. Diversity tended to be higher in deep Outer Harbor areas, but the pattern was not pronounced.

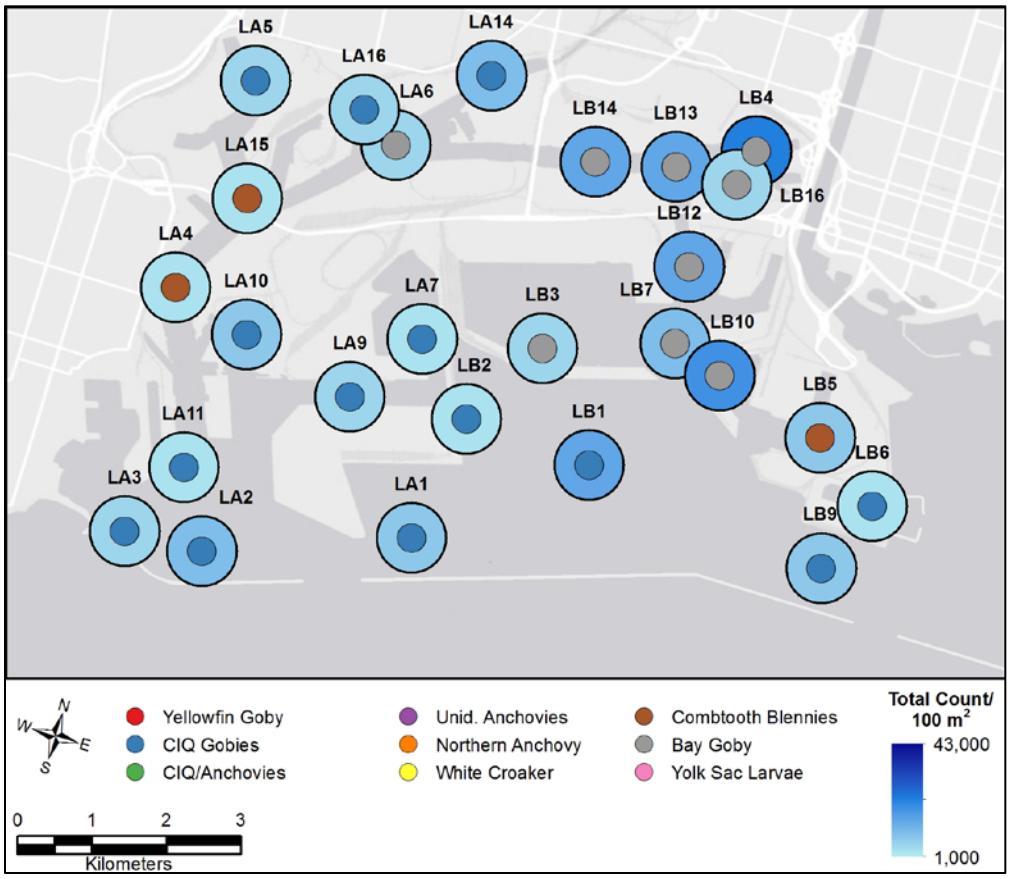


Figure 4-6. Most abundant species and density (number/100 m^2) of larvae at each station in summer.

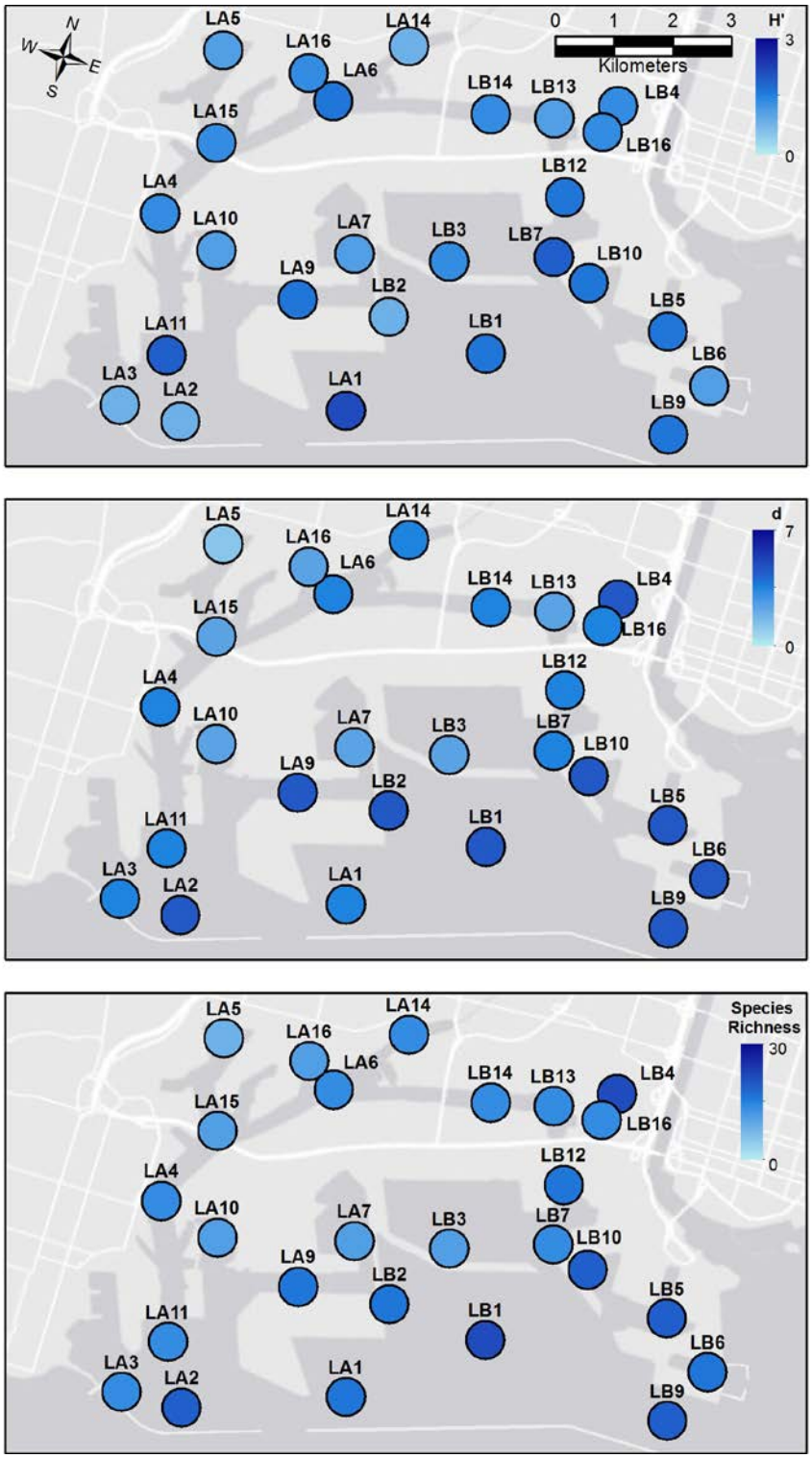


Figure 4-7. (Top) Shannon Wiener species diversity (H´), (middle) Margalef diversity (d), and (bottom) species richness of the larval fish community by station in summer. The scales on these maps are also used in Figures 4-10 and 4-12.

The patterns of Margalef diversity and species richness (Figure 4-7) were similar to that of Shannon Wiener diversity, but the pattern of higher values in the Outer Harbor was more pronounced. The number of larval fish taxa taken at each station in summer ranged from 8 to 20 (Figure 4-7). The median species richness of 13 taxa was the lowest of the three seasons (Appendix D).

Winter

Highest larval densities in the Port Complex occurred in winter, and ranged from 4,043/100 m^2 to nearly 43,500/100 m^2 (Figure 4-8, Appendix D-3). Densities were highest in the Outer Harbor and lowest at Stations LA7, LB2, and LB16. The larval fish assemblage was more diverse in winter than in summer. CIQ gobies were the dominant taxon at most of the stations on the Los Angeles side, but only at LB2 on the Long Beach side. White Croaker was the most abundant species at Inner Harbor channel stations and at Stations LB3 and LB6. Anchovies (Engraulidae and Northern Anchovy) were the dominant catch at 10 of the 26 stations, but did not exhibit any clear distributional pattern. Yolk sac larvae were the most abundant taxon at three Outer Harbor stations on the Los Angeles side. Shannon Wiener diversity values in winter (Figure 4-9) were generally the highest of the three seasons, and the range of values among stations was narrower than in summer or spring.

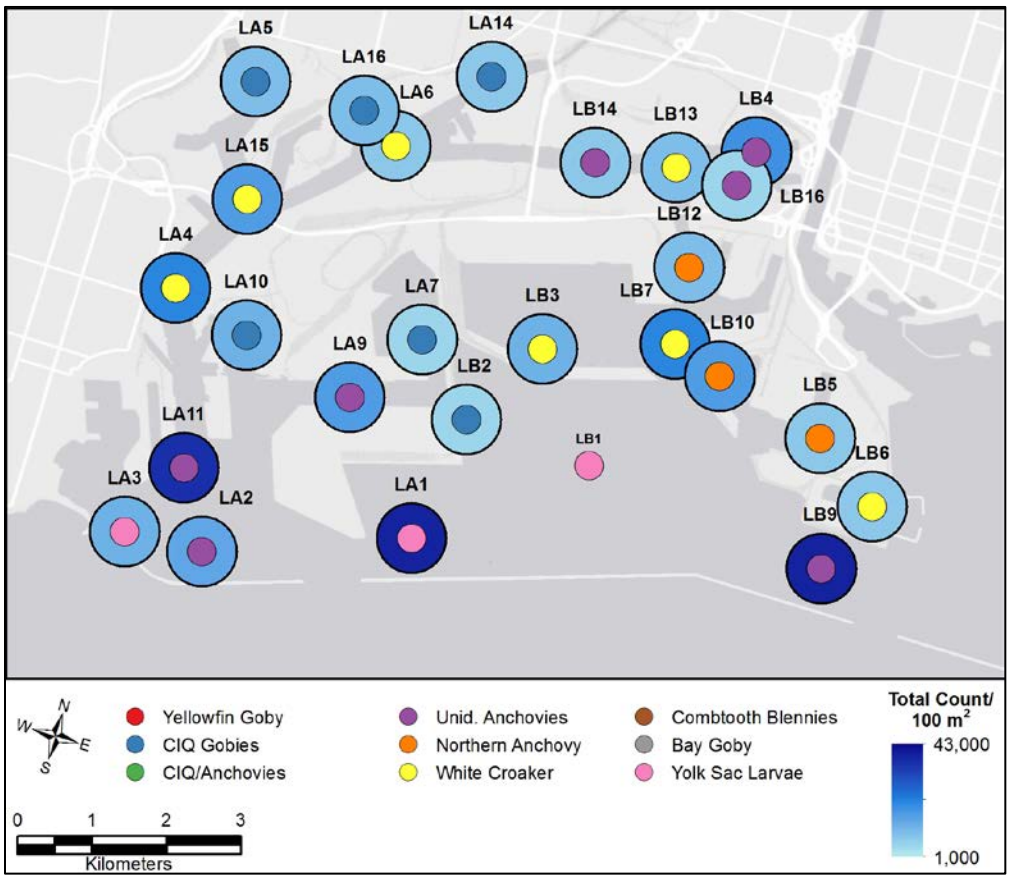


Figure 4-8. Most abundant species and density (number/100 m^2) of larvae at each station in winter.

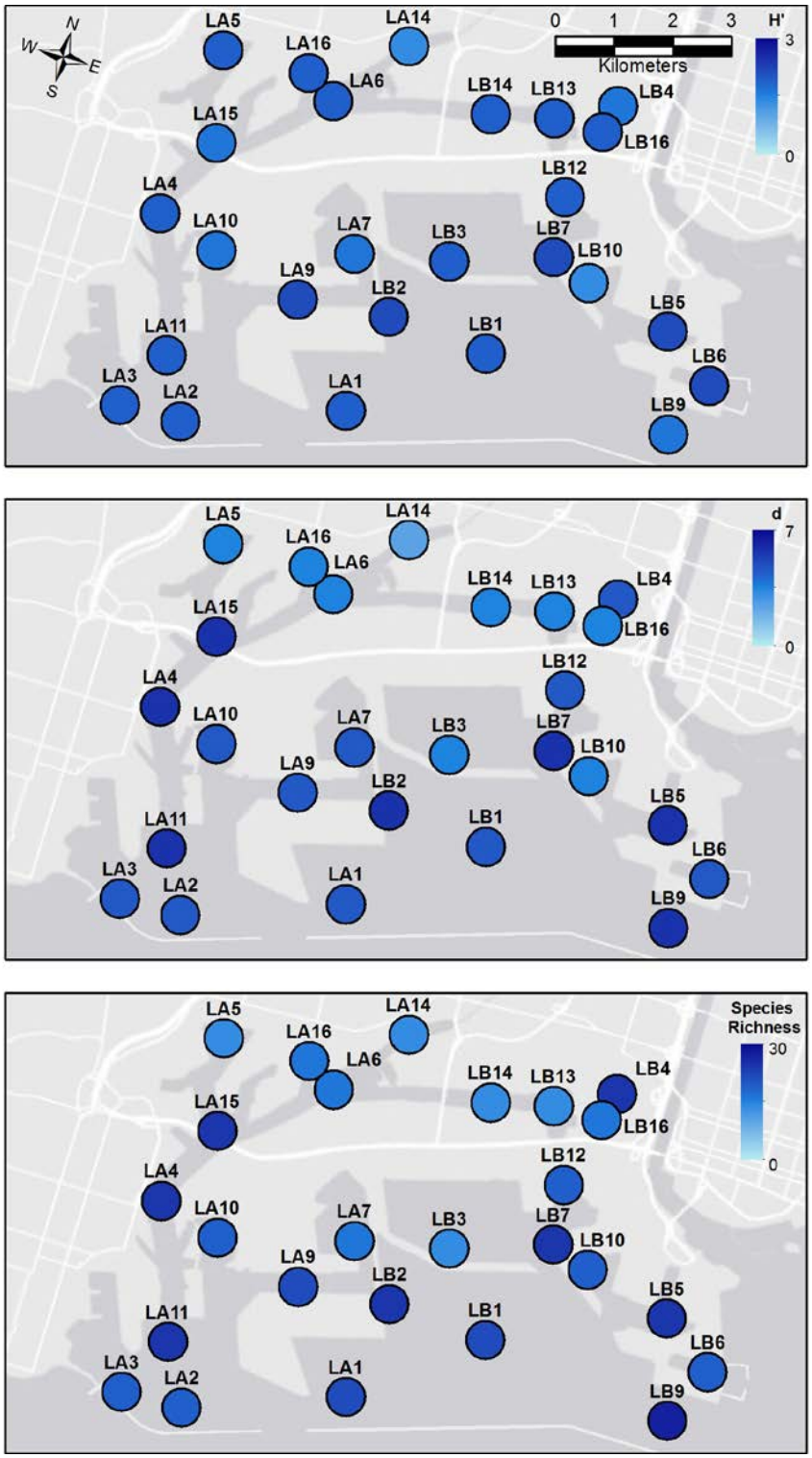


Figure 4-9. (Top) Shannon Wiener species diversity (H´), (middle) Margalef diversity (d), and (bottom) species richness of the larval fish community by station in winter.

Margalef diversity values (d) were generally higher in winter than in summer, but similar to those in spring. Highest values occurred at Stations LB2 and LB5 and at stations in the main shipping channels. Species richness in winter ranged from 12 to 26 taxa per station, with a spatial pattern of species richness similar to that of Margalef diversity. Overall, the winter survey was more species-rich than the summer and spring surveys.

Spring

Larval fish densities in the spring survey ranged from 1,149/100 m^2 to 18,329/100 m^2 (Figure 4-10, Appendix D-4). The median density was higher than in summer but lower than in winter. Highest densities were recorded at Inner Harbor stations in both Ports. Combtooth blennies were the most common taxon and were ranked first at 16 of the 26 stations. These 16 stations included channel and basin stations in the Inner Harbor, several Outer Harbor basin and channel stations, and the Cabrillo and Pier 300 created shallow water habitats. The other species in Table 4-3 were each dominant at only a few stations.

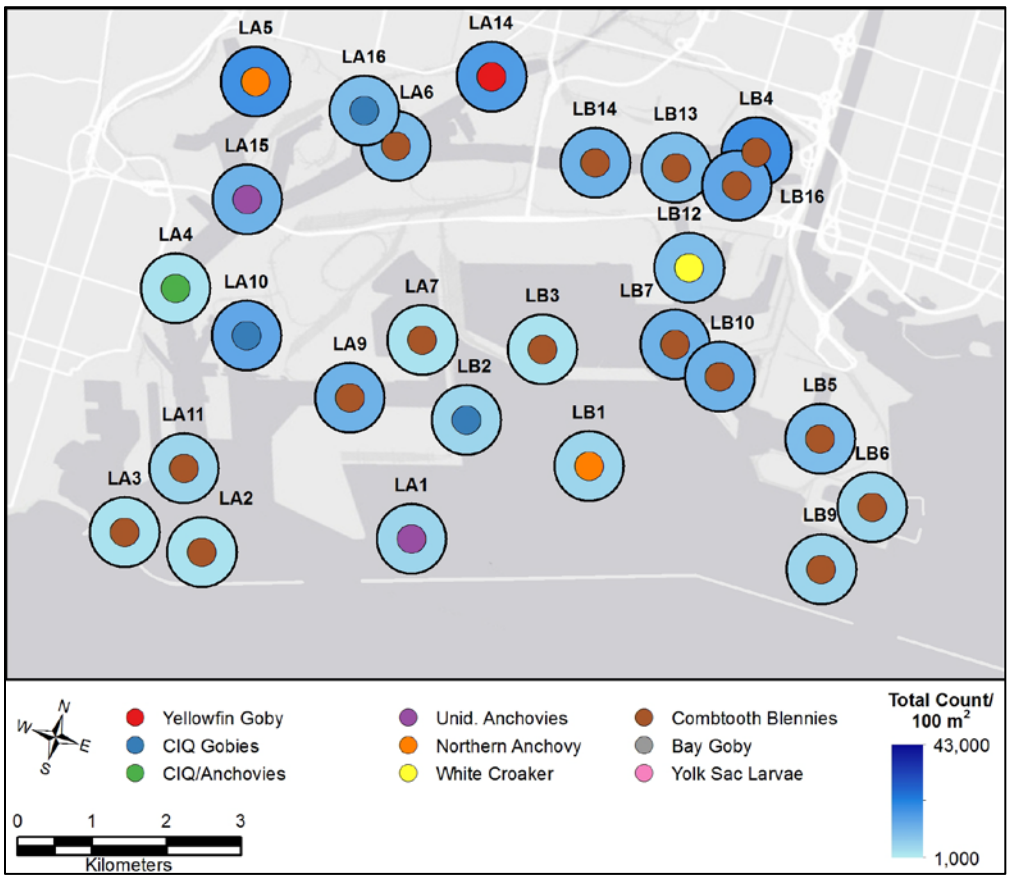


Figure 4-10. Most abundant species and density (number/100 m^2) of larvae at each station in spring.

Shannon Wiener diversity (Figure 4-11) was higher in spring than in summer, but lower than in winter. In general, diversity was higher in the Outer Harbor than in the Inner Harbor, but there was no clear spatial pattern. Margalef diversity (Figure 4-11) showed a similar pattern but, as in

summer, the pattern was more pronounced. Species richness (Figure 4-11) ranged from 11 to 25 taxa per station, and was generally similar to the pattern for Margalef diversity.

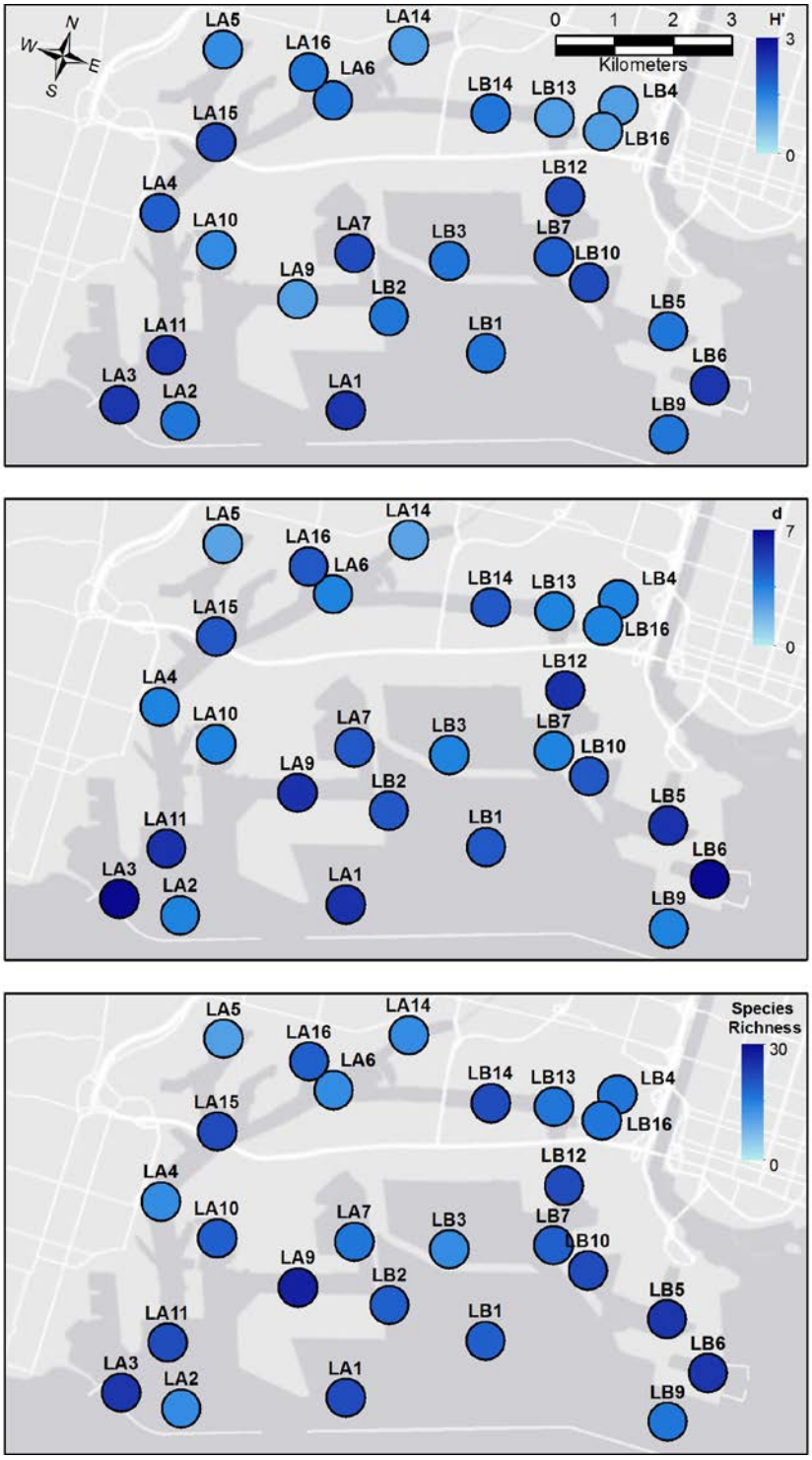


Figure 4-11. (Top) Shannon Wiener species diversity (H´), (middle) Margalef diversity (d), and (bottom) species richness of the larval fish community by station in spring.

COMMUNITY ANALYSIS

Multivariate analysis identified five station groups based on the species-specific total densities (number/100 m^2) across all sampling periods and collection types (Figure 4-12). Group 1 was comprised of 12 stations in the main shipping channels, turning basins, and two slips throughout the Port Complex. Group 2 was comprised of four deep stations in the Outer Harbor. Group 3 included both stations at the Cabrillo Beach Shallow Water Habitat (LA2 and LA3) and Station LA9. Group 4 was the most distinct of the station groups in the nMDS plot, and was composed of two stations (LB2 and LB7) in created shallow water habitats. Finally, four stations in dead-end slips in the Inner Harbor clustered into Group 5.

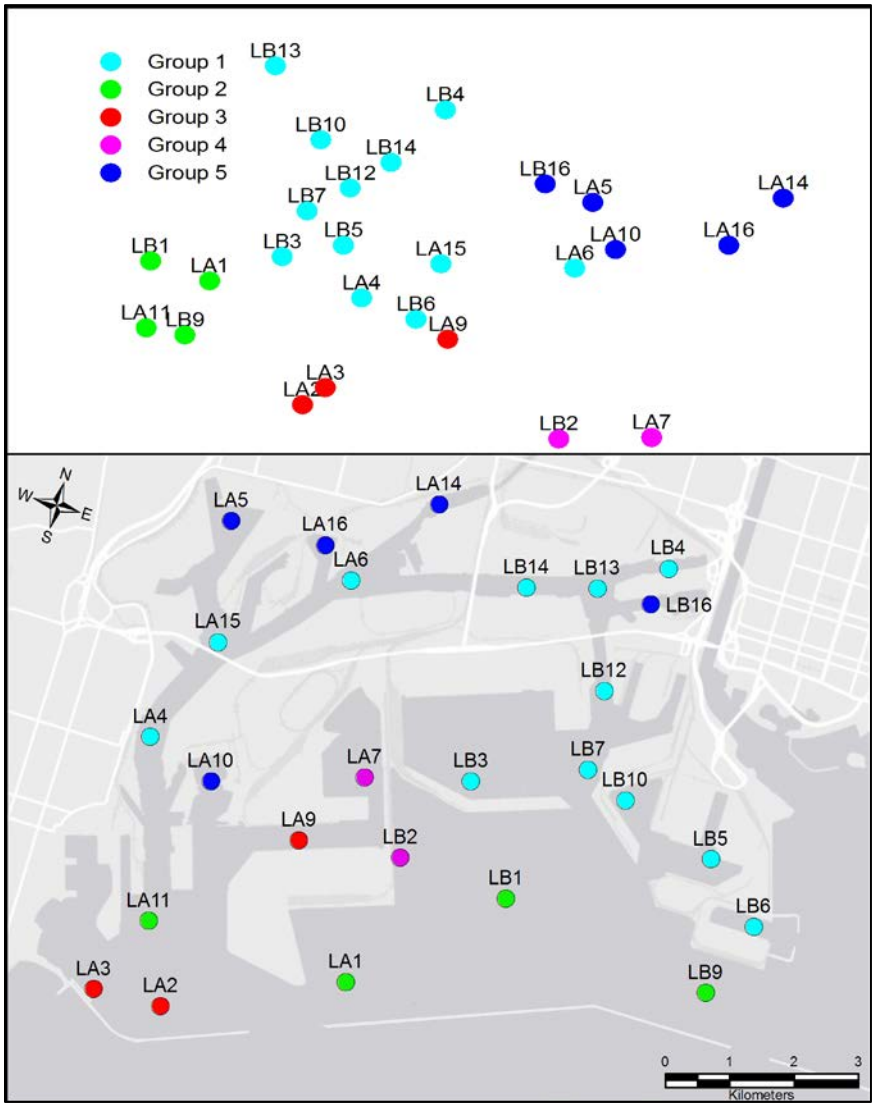


Figure 4-12. (Top) Station similarities as a function of their two-dimensional distance from each other using the SIMPROF test. (Bottom) Group membership of stations.

Unidentified anchovies, White Croaker, and yolk sac larvae were the most substantial contributors (>18% each) to total density in Group 1 (Figure 4-13). The Group 2 community was largely comprised of CIQ gobies (26%), unidentified anchovies (19%), and Combtooth Blennies (19%). Nearly 50% of Group 3 consisted of CIQ gobies, but this group included a number of other taxa. CIQ gobies also constituted a substantial portion of Group 4 (37%), along with Combtooth blennies (15%) and Yellowfin Goby (14%). Bay Goby and Combtooth Blennies were the largest components of Group 5, with 18% and 21% of the total density, respectively, but this group is notable for the similar proportion contributed by six taxa, whereas dominance in the other groups was concentrated in fewer taxa.

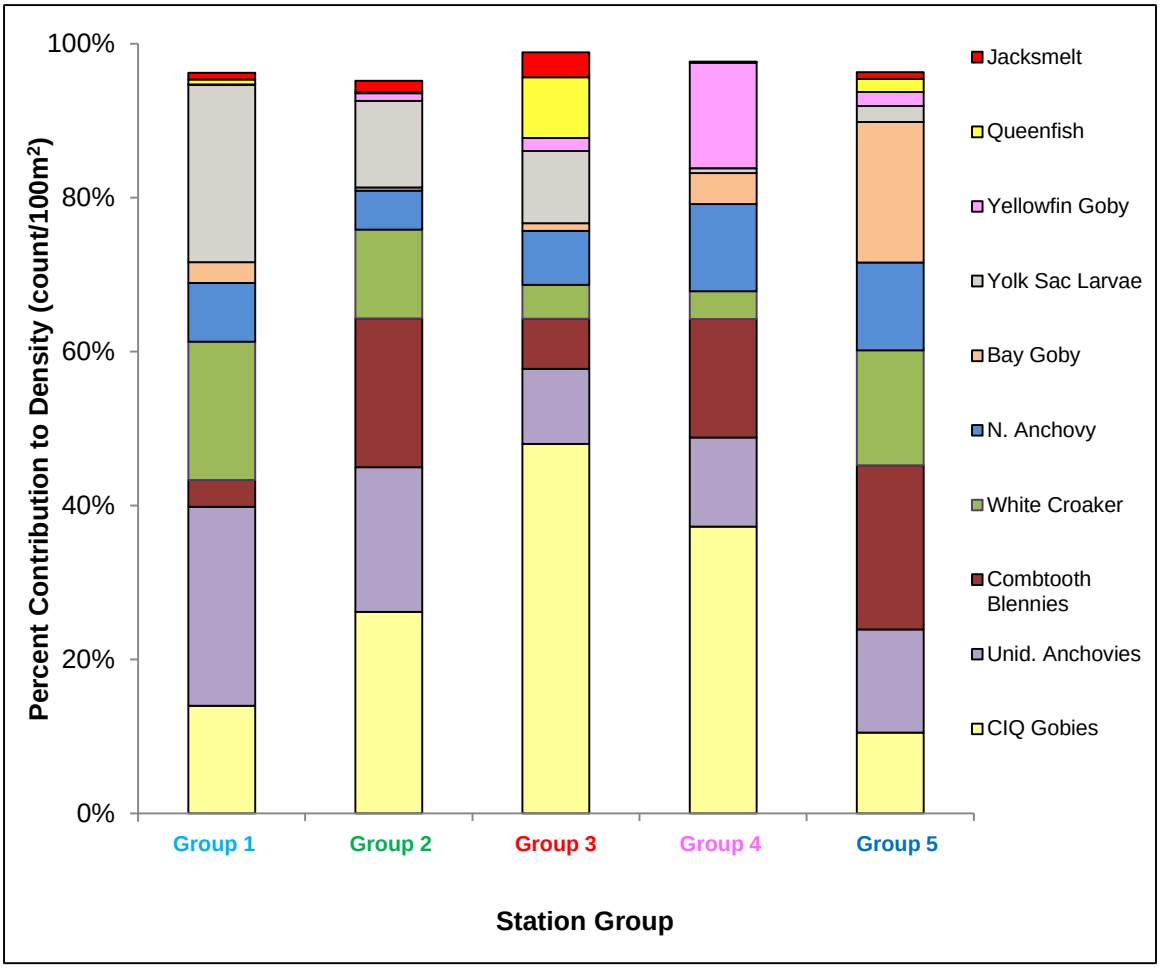


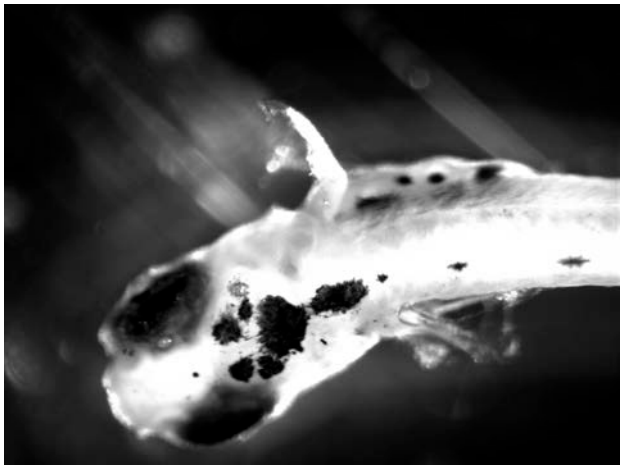
Figure 4-13. Contribution of the 10 most common taxa (all sampling methods) to the station groups designated in Figure 4-12.

DISCUSSION

In 2013–2014, as in prior studies (MEC 2002; MBC et al. 2007a; SAIC 2010), the ichthyoplankton community was diverse and variable throughout the Port Complex in both space and time. Direct comparisons between prior studies and the 2013–2014 study are complicated by differences among the three harbor-wide studies (2000, 2008, 2013-2014). While the sampling equipment was consistent in all three studies and the 2008 and 2013–2014 studies used a similar subsampling protocol for fish eggs, the 2013–2014 study sampled at 26 stations in three seasons and processed all fish larvae.

The prior studies sampled fewer stations, and the 2000 study sampled more seasons and utilized a different subsampling protocol. While most stations sampled in 2008 were resampled in 2013–2014, in several cases station locations were shifted slightly. Such subtle shifts can have profound effects on characterizations of the ichthyoplankton community because of differences in water movement and substrate composition. Differences in subsampling approach can further affect the resulting data.

In 2000, there were 44 taxa reported, while the 2008 and 2013–2014 studies collected 71 and 79 taxa, respectively (MEC 2002; SAIC 2010). No significant advances in ichthyoplankton taxonomy have occurred over this period to cause this change in species richness, and all three studies relied on Moser (1996) as the main identification reference. Although the methodologies among the three studies were different, generalized comparisons between the three studies can be made.



New World silverside (Atherinopsidae) larva caught during the 2013–2014 study.

The presence of fish eggs in plankton samples typically indicates the presence of spawning populations within the time and geographic range the eggs could have been transported from the spawning site to the collection site. Planktonic fish eggs, as compared to demersal fish eggs attached to substrate, provide food for predators and function as a key step in dispersal to maintain gene flow between subpopulations (Miller and Kendall 2009). Demersal eggs provide forage, but not genetic flow. (Gobies and blennies, which were dominant larval fish taxa in 2013–2014, have demersal eggs.) The translation of egg densities to juvenile and adult populations often fails to achieve acceptable resolution due to the high mortality rates (>99%) of marine fish larvae, although mortality declines as size increases (McGurk 1986).

Concentrations of eggs at each station during the present study were generally similar to those found during 2008 (SAIC 2010). In both studies, highest concentrations occurred at the surface (the neuston tows), although the average concentration in 2013–2014 was more than twice that reported in 2008 (Figure 4-14).

Higher average concentrations of eggs in both midwater and near-bottom tows were reported in 2008 than in 2013–2014, although the differences are small. In 2000, slightly higher egg concentrations were collected in midwater tows than near bottom, while in the present study more eggs were taken in the epibenthic tows than in midwater tows.

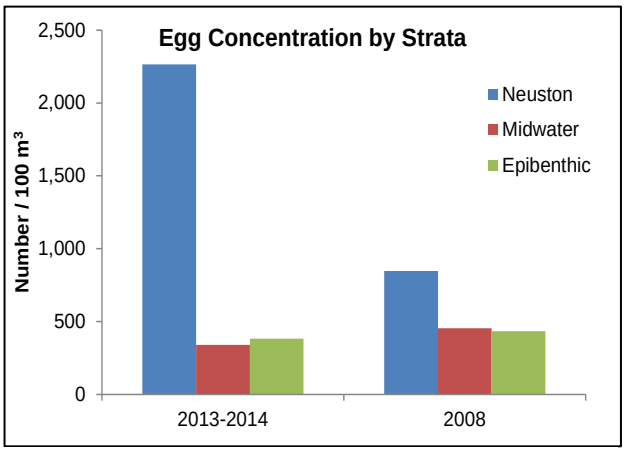


Figure 4-14. Concentration of fish eggs by strata, all seasons combined.

In the present study, as in both prior harbor-wide studies, CIQ gobies (analogous to goby type A in 2000), Bay Goby, combtooth blennies, White Croaker, and Yellowfin Goby were among the ten most common larval fish taxa (Table 4-4). Northern Anchovy was among the top ten in 2000 and 2013–2014, but was ranked 12th during the 2008 study. Unidentified anchovies were the second most abundant larva in the present study, but were ranked 35th in 2008 and were not reported at all in 2000. Queenfish ranked among the top ten species in 2000 and during the present study, but was not reported in the 2008 study. Jacksmelt, the tenth most abundant species in the present study, was 13th in 2000 and 32nd in 2008. These results highlight the dynamic nature of the ichthyoplankton assemblage in the Port Complex as it changes over time in response to regional and local trends in climate, oceanography, food resources, and predation.

In 2008 and 2013–2014, larval concentrations were substantially higher in the epibenthos than in the neuston (Figure 4-15). The midwater sampling caught more larval fish on average in 2008, while the epibenthic sampling caught significantly more larval fish in 2013–2014. SAIC (2010) assessed the need to maintain the depth-stratified sampling method versus utilizing the oblique tows of the CalCOFI methods. They ultimately concluded that the depth-stratified method best served the study's purpose, a conclusion supported by the results of the present study. Fish eggs and some larval fish, such as Jacksmelt, were primarily taken at the surface, but for most species, concentrations of larvae were highest near the seafloor. Therefore, elimination of the surface and bottom strata could limit the resolution of community characterizations.

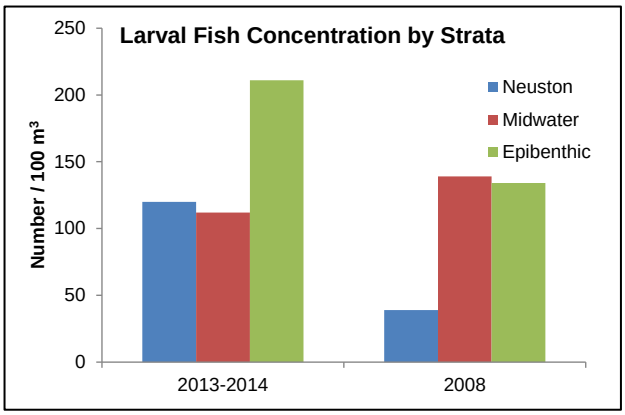


Figure 4-15. Concentration of larval fish by strata, all seasons combined.

Table 4-4. Ranked larval fish abundance (based on the ten most abundant groups in the present study) in harbor-wide ichthyoplankton studies. Taxa not reported in a given study marked as "-".

Common Name	Taxa	Ranking		
		2013 – 2014	2008	2000
Gobies	CIQ Gobies[1]	1	1	1
Unidentified Anchovies	Engraulidae	2	35	–
Combtooth Blennies	*Hypsoblennius* spp	3	2	6
White Croaker	*Genyonemus lineatus*	4	7	7
Northern Anchovy	*Engraulis mordax*	5	12	3
Bay Goby	*Lepidogobius lepidus*	6	3	2
Unidentified Larval Fish	Unidentified Larval Fish (includes yolk sac larvae)	7	5	12[2]
Yellowfin Goby	*Acanthogobius flavimanus*	8	6	8
Queenfish	*Seriphus politus*	9	–	5
Jacksmelt	*Atherinopsis californiensis*	10	32	13

[1] Includes Goby Type A identified in MEC (2002). [2] Ranking based on sum of all identified yolk sac larvae in MEC (2000).

Of the ten most abundant larval taxa collected, Jacksmelt was the only species with highest larval concentrations in the neuston. This is consistent with the known life history of this species in the Port Complex (IRC 1981; MEC 2002; MBC et al. 2007a; SAIC 2010). Combtooth blennies were more abundant in the midwater and surface strata than in the epibenthos, and the remaining seven identifiable larval taxa were most abundant in the epibenthos. This is also consistent with known life history strategies in the Port Complex (MEC 2002; MBC et al. 2007; SAIC 2010).

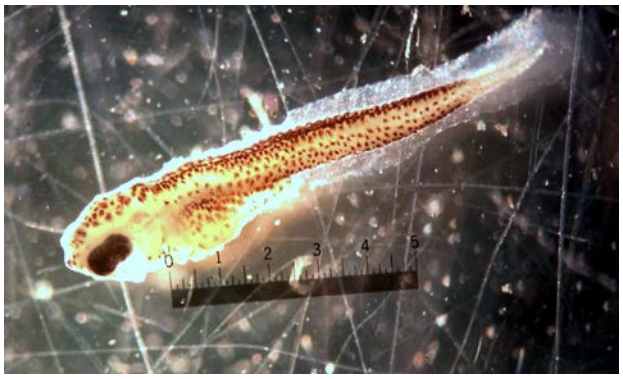
More larval fish were collected in the present study in winter than in summer or spring. The winter survey collected a substantial number of recently hatched yolk sac larvae and species known to spawn in the winter, such as Northern Anchovy and White Croaker (Baxter 1966; Love et al. 1984; Gadomski and Caddell 1996). These taxa were prevalent at half of the stations in winter, but they were less abundant in the summer and spring surveys. Although during the present study, highest total larval densities occurred during the winter survey, gobies were most abundant during summer and blennies were most abundant in spring. This pattern repeats the results of previous studies: in 2000 and 2008, gobies and blennies were most abundant in summer (SAIC 2010, MEC 2002). In a 2006 study that sampled Slip 5 (i.e., near Station LA16) on a biweekly basis and six other stations throughout the Port Complex on a monthly basis

(MBC et al. 2007a), highest larval concentrations occurred in spring, largely due to high concentrations of Yellowfin Goby and other gobies, White Croaker, and combtooth blennies.

Seasonal patterns of abundance of the top ten species were generally similar to those documented since 2000. Anchovies and Bay Goby were present throughout the year, but White Croaker larvae were most abundant in winter and Queenfish were most abundant in spring. White Croaker were most abundant in winter in 2008 (SAIC 2010), but most abundant in spring in 2000 and 2006 (MEC 2002; MBC et al. 2007). Queenfish were most abundant in spring 2000, but not collected (or identified to species) in 2008.

California clingfish (*Gobiesox rhessodon*) larva caught during the 2013–2014 ichthyoplankton surveys.

Anchovies found in southern California waters include Slough Anchovy (*Anchoa delicatissima*), Deepbody Anchovy (*A. compressa)*, and Northern Anchovy (Love 2011). Northern Anchovy ranges along the west coast of North America from Baja California into southern Canadian waters. Anchovies, especially Northern Anchovy, commonly occur offshore in southern California, and often in high numbers (McGowen 1993; MBC and Tenera 2007; MBC et al. 2007a, b; Pondella et al. 2012; Suntsov et al. 2012). There are differences in habitat preferences among the three anchovy species that bear consideration in evaluating the results.



Cabezon (*Scorpaenichthys marmoratus*) larva caught during the 2013–2014 ichthyoplankton surveys. Scale in millimeters.

Northern Anchovy is the most abundant fish in the Port Complex. Its pelagic ecology includes dense schooling behavior in the water column, and individuals range from near the seafloor up to the surface as the school follows/hunts zooplankton (Love 2011). Both Slough and Deepbody Anchovy occur most frequently in protected bays and harbors, but can occasionally be taken along the open coast. However, both species are very uncommon in the Port Complex. Northern Anchovy spawning peaks in the winter, but Slough and Deepbody Anchovy spawn primarily in spring and summer months. Therefore, based on spawning periodicity and the overwhelming abundance of Northern Anchovy in the Port Complex, most of the anchovy larvae caught in winter in the present and previous studies were likely Northern Anchovy.

White Croaker was previously among the most common fish collected in southern California scientific surveys, but their numbers have declined along the open coast (Miller et al. 2011;

Miller and Schiff 2012; Miller and McGowan 2013). This has translated to reductions in their larval densities as well (Pondella et al. 2012). However, White Croaker populations have persisted in the Port Complex (MEC 2002; SAIC 2010; Miller and Schiff 2011). The stations on the Long Beach side where White Croaker larvae were taken in high numbers also supported large numbers of juvenile and adult White Croaker (see Chapter 3). Whether or not the White Croaker larvae were spawned in the Port Complex is unknown. Given the population's distribution, however, local production and retention is likely.

Pipefish (Syngnathidae) larva, likely Kelp Pipefish (*Syngnathus californiensis*), caught during the 2013–2014 ichthyoplankton surveys.

The present study and prior studies have shown that goby and blenny larvae are the dominant components of the larval fish assemblage in the Port Complex, and that they are consistently most abundant in spring and summer. In the three harbor-wide studies, the dominant larval taxon at many stations within the Port Complex, especially those in the shallow areas, has been CIQ gobies (Table 4-4). Accurately differentiating the larvae of each CIQ goby species is a difficult task due to the extensive overlap in key physical characteristics such as pigment patterns and the number of vertebrae. However, CIQ goby larvae can be readily separated from other taxa by the same physical features. The complex name has not been standardized, and has appeared as "goby a/c", "goby type a", and "CIQ". Previous studies in the Port Complex used two of these names: goby type a (MEC 2002) and CIQ goby (MBC et al. 2007a; SAIC 2010). This goby complex is common in nearshore and bay habitats in the greater Los Angeles area (McGowen 1993; MBC 2005; MBC and Tenera 2007; MBC et al. 2007a, b, c; Pondella et al. 2012; Suntsov et al. 2012). All three species are common in shallow, quiet waters within bays and estuaries in Southern California. However, there are differences among their preferred habitats within that broad category: Arrow Goby and Shadow Goby are often found in eelgrass beds (*Zostera marina*) and soft sediments (Love 2011), but Cheekspot Goby is common on soft sediments and is rarely found among vegetation (Love 2011).

In the present study, Stations LB2, LA16, and LA10 were dominated by CIQ goby larvae in all three seasons. CIQ gobies were also the most abundant taxon at other stations in summer and winter. Eelgrass was not prevalent at any of the three sampling stations, but it was found elsewhere in Fish Harbor near Station LA10 and in some areas of the LA East Basin near Station LA16. The presence of suitable habitat and the distribution of CIQ goby larvae among those habitats suggest that at least two of the three CIQ goby species were represented in the Port Complex. A fourth goby species, Bay Goby, typically occupies habitat similar to that of Arrow Goby and Shadow Goby, thus complicating attempts to understand the distribution

pattern of CIQ gobies. Both taxa occurred in otter trawl sampling in the Port Complex, but the net mesh used was too large to effectively sample the goby community.

Combtooth blennies have been among the five most abundant fish larval taxa since harbor-wide studies began in the 1970s (MEC 2002). Combtooth blennies were the dominant larval taxon at most stations in spring during the present study, they were the dominant taxon in summer during the 2008 study, and they were the sixth most abundant taxon in summer during the 2000 study (SAIC 2010, MEC 2002). Like CIQ gobies, combtooth blennies commonly occur in nearshore waters of southern California, including in bays and harbors (McGowen 1993; MBC 2005; MBC and Tenera 2007; MBC et al. 2007a,b,c; Pondella et al. 2012; Suntsov et al. 2012). Combtooth blennies did not appear to favor any particular habitat type in any of the recent harbor-wide studies: they were abundant, and often dominant, at stations in the deep-water channels, dead-end slips, and created shallow water habitats. Vegetation, water temperature, dissolved oxygen concentration, and other physical parameters did not appear to influence their distribution.

In the present study, the larval fishes of the Port Complex segregated into five discrete groups that, with some exceptions, could be defined by habitat types. For instance, Group 1 included the deep-water channels, turning basins, and the southeastern area of the Long Beach side. The taxa in the open-water habitat of the Outer Harbors also showed a close affinity for each other and formed Group 2. This pattern is similar to that reported by SAIC (2010), although station grouping in 2008 was not as distinct as in the present study. The greater number of stations sampled in 2013–2014 likely contributed to a clearer differentiation based on location and habitat type.

Of the 79 taxa collected in the present study, one species—Yellowfin Goby—is an introduced (non-native or non-indigenous) species. No cryptogenic (native range or region unknown) or unresolved (species complexes, including more than one species, or questionable identification) species were identified. Non-native species are discussed in Chapter 11.

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CHAPTER 5 BENTHOS

This section presents the results of benthic (seafloor) sampling surveys conducted throughout the Port Complex during 2013–2014. The benthic infauna and epifauna are communities comprised of invertebrates that live, respectively, within and on top of the bottom sediments. Benthic infaunal organisms tend to be small, and require microscopes to remove and identify the animals. Epifauna species tend to be larger, and are also referred to as macroinvertebrates. Both communities are an integral part of the marine ecosystem; they are an important food source for fish and larger invertebrates, and contribute to nutrient recycling. Some species are highly sensitive to effects of human activities, while others thrive under altered conditions. The assessment of the benthic community is, therefore, a major component of many marine monitoring programs.

MATERIALS AND METHODS

BENTHIC INFAUNA

Benthic surveys were conducted in summer (28 and 29 August 2013) and spring (19 and 20 May 2014). Sediment samples were collected using two chain-rigged, tandem-mounted 0.1-m^2 van Veen grabs at 32 stations within the Port Complex (16 stations in Long Beach Harbor and 16 in Los Angeles Harbor) (Figure 5-1; Table 5-1; Appendix L). The van Veen grabs were lowered rapidly through the water column until near the bottom, and then slowly lowered until contact was made. The grabs were then carefully raised until clear of the bottom. One grab was used for benthic infauna analysis, and the other for sediment grain size analysis. Once on board, the grab for benthic infauna was drained of water and initial qualitative observations of color, odor, consistency, etc. were recorded. Sample acceptance was based on criteria specified in the Southern California Bight 2013 Regional Marine Monitoring Survey (Bight'13) Field Operations Manual (SCCWRP 2013). Grab samples were sieved through a 1.0-millimeter screen in the field. Retained organisms and larger sediment fragments were washed into labeled storage containers in an isotonic magnesium sulfate ($MgSO_4$) solution to relax the organisms. After 30 minutes the samples and labels were transferred to storage bags and preserved with 10% buffered formalin. Samples were returned to the laboratory and allowed to soak for four to seven days to fix the organisms.

Benthic infauna sampling using double van Veen grabs.

In the laboratory, samples were rewashed through a 0.25-mm screen, transferred to 70% isopropyl alcohol, sorted to major taxonomic groups, identified to the lowest practical taxonomic level, and counted. Identifications and nomenclature followed

the usage accepted by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT 2014).

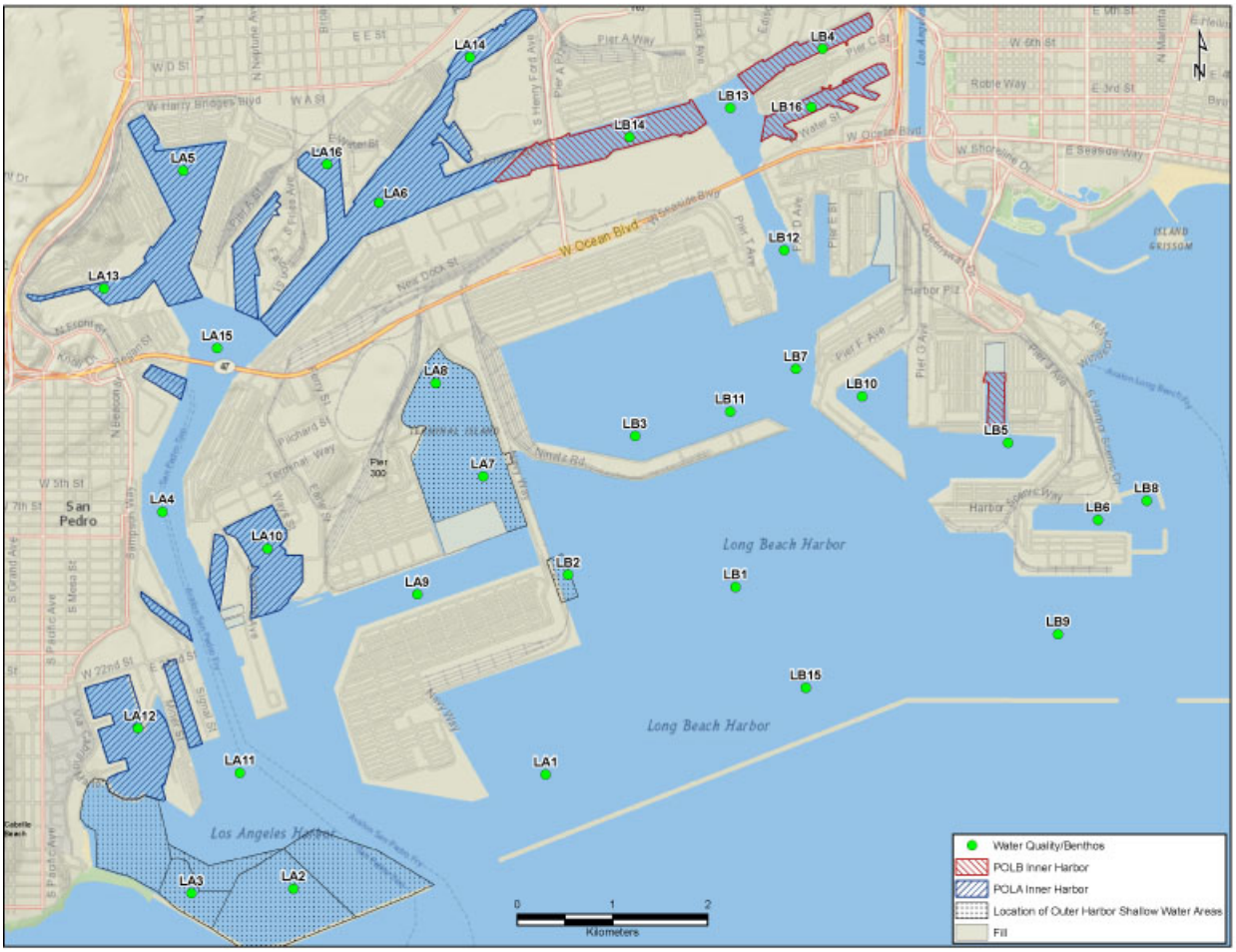


Figure 5-1. Location of benthic infauna stations.

Following identification, the weight of organisms in each major taxonomic group was obtained for each replicate. Small, pre-weighed mesh screens were immersed in 70% isopropyl alcohol, blotted on a paper towel, and air-dried for five minutes. Then the organisms were placed on the screens and the process repeated. Total wet weight minus screen tare weight provided the wet weight of the organisms. Large organisms, if present, were weighed separately.

All data were entered into a database which included species count and phylum weight per station. In addition, the database was subjected to standardized quality assurance routines. Consistent with the previous baseline survey analyses, abundance and biomass values were converted to densities (number or biomass) per one meter square (m^2). Community measures calculated included: abundance, species richness (number of species or unique taxa), biomass, Shannon Wiener species diversity (H'): -Σpi X ln(pi), where pi is the count for species I, and Southern California Benthic Response Index (BRI) (Smith et al. 1999, 2001, 2003; Ranasinghe et al. 2007).

Table 5-1. Benthic stations and harbor habitat types.

Station	Designation/Location	Harbor Type	Station	Designation/Location	Harbor Type
LB1	LB Outer Harbor (N)	Outer	LA1	LA Outer Harbor (E)	Outer
LB2*	Long Beach SWH	Outer	LA2*	Cabrillo SWH (E)	Outer
LB3	LB West Basin (W)	Outer	LA3*	Cabrillo SWH (W)	Outer
LB4	Channel 2	Inner	LA4	LA Main Channel (N)	Outer
LB5	Southeast Basin (S)	Outer	LA5	LA West Basin (N)	Inner
LB6	Pier J Slip	Outer	LA6	LA East Basin	Inner
LB7	LB Main Channel (N)	Outer	LA7*	Pier 300 SWH	Outer
LB8	Pier J Slip Breakwater	Outer	LA8*	Seaplane Lagoon	Outer
LB9	LB Main Channel (S)	Outer	LA9	Pier 400 Channel	Outer
LB10	Southeast Basin (N)	Outer	LA10	Fish Harbor	Inner
LB11	LB West Basin (E)	Outer	LA11	LA Outer Harbor (W)	Outer
LB12	Back Channel	Outer	LA12	Cabrillo Marinas	Inner
LB13	LB Turning Basin	Outer	LA13	Southwest Slip	Inner
LB14	Cerritos Channel	Inner	LA14	Consolidated Slip	Inner
LB15	LB Outer Harbor (S)	Outer	LA15	LA Turning Basin	Outer
LB16	Channel 3	Inner	LA16	Slip 5	Inner

Note: N, S, E, W differentiate stations that that are in the same basin or channel by orientation – north, south, east, or west.

* SWH indicates shallow-water habitat in the Outer Harbor.

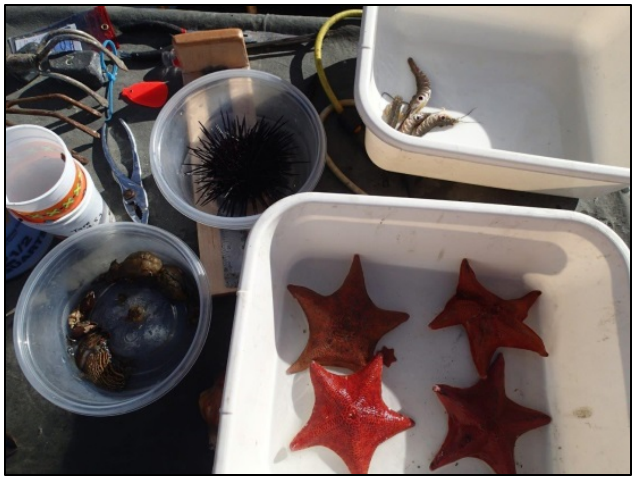
In addition, the composition of the benthic community was characterized by cluster analysis. Infauna data were subjected to log (x+1) transformations and analyzed using PCORD (McCune and Mefford 2011).Transformed data were classified using the Bray-Curtis dissimilarity measure

(Clifford and Stephenson 1975). Bray-Curtis dissimilarity results by species and station were plotted in a two-way dendrogram to visualize the community structure. Clusters or groups were identified using best professional judgment after reviewing the resulting two-way dendrogram to provide a graphic representation of the relative abundance and spatial occurrence of each species, and relationships between species. Because physical conditions are not identical at all stations, the biological community varies with location. Cluster analysis helps describe the differences in the biological community that arise from variable physical conditions. The two-way analysis utilized in this study illustrates the relative abundance of species, as well as groupings (clusters) of both species and stations.

EPIBENTHIC INVERTEBRATES

Epibenthic invertebrates were collected during demersal (bottom) fish sampling using otter trawls and beach seines. Trawls were conducted during the day and night in summer (September–October 2013) and spring (April–May 2014) at the same 26 stations occupied by the demersal fish surveys (Table 3-1; Figure 5-2; Appendix L). Beach seine samples were collected at two shallow-water locations (Cabrillo Beach and the Pier 300 SWH; Figure 5-2) during daylight hours in summer (August 2013) and spring (May 2014). Shallow-water epibenthic samples were collected by beach seine, at the same time as shallow subtidal fish, as described in Chapter 3, Adult and Juvenile Fishes.

Otter trawl samples were collected using the same gear and methods as described for demersal fish (Chapter 3), as macroinvertebrates were simply collected from the demersal fish samples. Macroinvertebrates collected from trawl surveys were identified to the lowest practicable taxon, counted, and an aggregate weight (to the nearest gram [g]) was determined for each species. Identification of invertebrates was aided by a combination of photography and collection of voucher specimens for taxa that could not be identified in the field. Macroinvertebrate identifications were made using field identification guides including Morris et al. (1980), Coan et al. (2000), Fitch (1952), Morris (1966), Jensen (1995) and Behrens and Hermosillo (2005). Invertebrate nomenclature was standardized in conformance with SCAMIT (2014).



Epibenthic sample separated for processing. Clockwise from far left: tunicates (*Styela* spp), purple sea urchin (*Strongylocentrotus purpuratus*), target shrimp (*Sicyonia penicillata*) and bat stars (*Pateria miniata*).

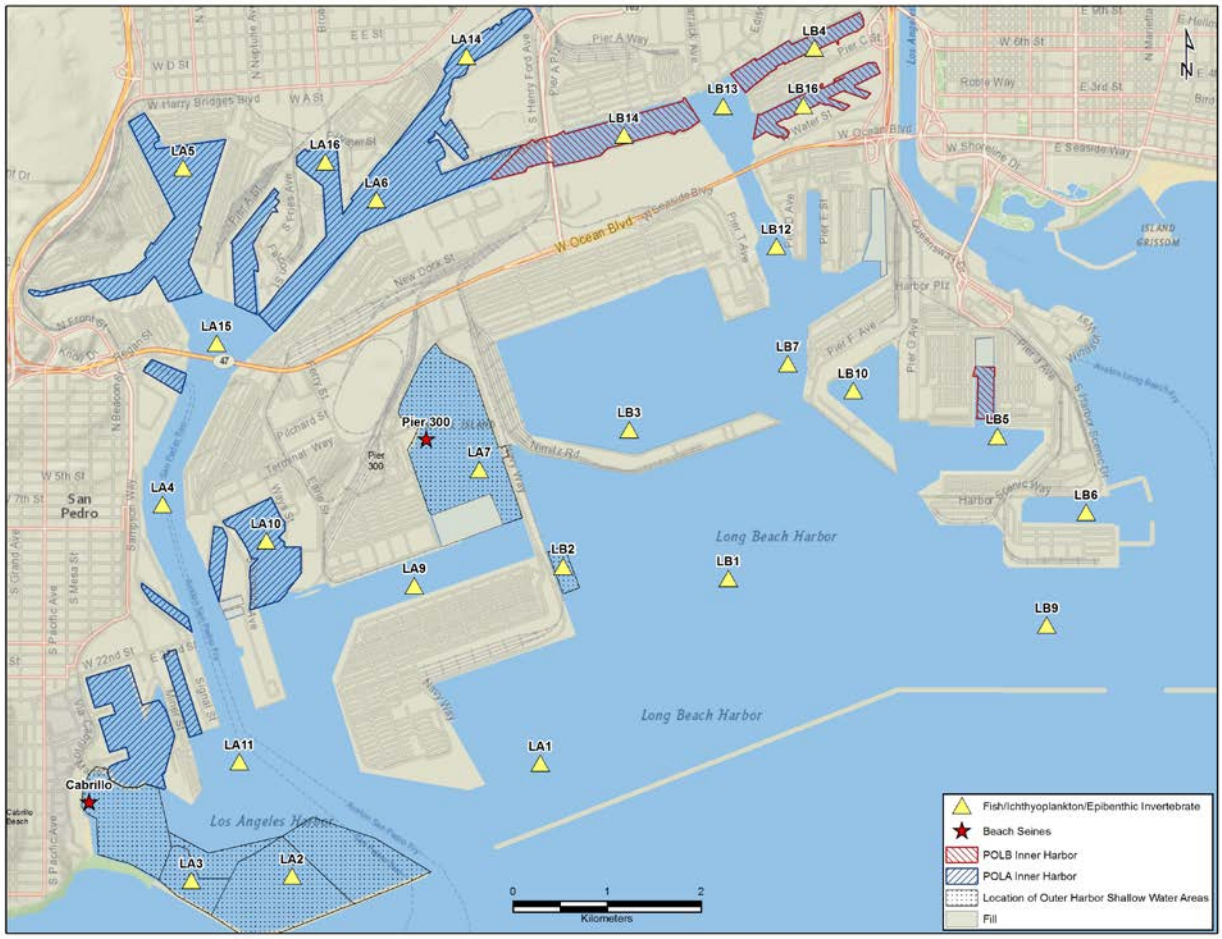


Figure 5-2. Location of epibenthic invertebrate stations.

The catch in each haul was transferred to buckets of seawater and processed in the field. Every invertebrate specimen was identified and weighed to the nearest gram. Individual organisms were counted and colonial organisms such as tunicates (Chordata) and sponges (Silicea and Calcarea) were noted. Sponge identification is not practical in the field as it requires microscopic examination of spicules; for this reason sponges were identified to the inclusive taxon of Porifera used in previous surveys. Following field processing, all specimens were immediately returned to the water to reduce potential mortality.

Beach seine sampling.

All data were entered into a database which included species count and weight per station. Identifications and nomenclature followed the usage accepted by SCAMIT (2014). In addition, the database was subjected to standardized quality assurance routines. Due to relatively low numbers of epibenthic invertebrates, community measures utilized actual catch numbers instead of values calculated to a standardized area. Because colonial organisms are difficult to enumerate and were common at some stations during trawl sampling, trawl community parameters were based on biomass. Beach seine results are presented as a sum of both replicates at each site for each season. Community measures calculated included: abundance, species richness (number of species or unique taxa), biomass, Shannon Wiener species diversity (H') based on biomass for trawl-caught organisms and abundance for seine-caught organisms, and community composition for trawl-caught epibenthic invertebrates (based on biomass).

RESULTS

BENTHIC INFAUNA

Community measure data and benthic response indices by survey and sampling station are presented in appendices E-2, E-3, and E-5; biomass data are presented in Appendix E-4. Benthic sampling collected 264 infaunal species in the summer and spring surveys (Appendix E-1). In the summer survey, 4,206 individuals and 261 species were collected, and in the spring survey, 3,570 individuals and 238 species were collected (Table 5-2). The species making up at least 1% of the total abundance in each survey are presented in Table 5-3 (summer) and Table 5-4 (spring).

Table 5-2. Infaunal community parameters. Totals are for all stations combined per season. Mean is per station and range is for all stations during the season.

Parameter	Summer	Spring
Abundance		
Total	4,206	3,570
Mean	131	112
Range	24-484	24-395
Species Richness		
Total	261	238
Mean	37	33
Range	11-63	10-61
Biomass (g)		
Total	115.42	119.88
Mean	3.61	3.75
Range	0.55-15.37	0.06-12.99
Diversity (H')		
Mean	3.01	2.89
Range	1.83-3.57	1.95-3.77
Benthic Response Index (BRI)		
Mean	15.99	17.15
Range	2.37-42.91	2.65-44.76

ABUNDANCE

In summer, abundance averaged 131 individuals per sample (1,310 individuals/m^2) at the 32 stations in the Port Complex (Table 5-2). Abundance was highest at Station LA2, with 484 individuals (Figure 5-3). Abundance was also high at Station LA7 (447 individuals). Lowest abundance was found at Station LA11, and abundance was also low at Station LA8. In spring, abundance averaged 112 individuals per sample (1,120 individuals/m^2) (Table 5-2). Abundance was highest (395 individuals) at Station LB2 and moderately high at Stations LA7 (260 individuals), LA2 (200 individuals), and at several Inner Harbor stations on the Los Angeles side (Figure 5-3). Lowest abundance occurred at Station LA15, where only 24 individuals were collected.

Table 5-3. The most abundant infaunal species, summer.

Phylum	Species	Overall Abundance	Percent of Total	Cumulative Percentage
AR	*Amphideutopus oculatus*	378	9.0	9
MO	*Theora lubrica*	344	8.2	17
AN	*Cossura* sp A Phillips 1987	273	6.5	24
AR	*Sinocorophium heteroceratum*	242	5.8	29
AN	*Euchone limnicola*	149	3.5	33
AN	*Aphelochaeta monilaris*	116	2.8	36
AR	*Neotrypaea* sp	113	2.7	38
AN	*Pista wui*	102	2.4	41
AN	*Cossura candida*	100	2.4	43
MO	*Tellina modesta*	92	2.2	45
AR	*Scleroplax granulata*	68	1.6	47
AN	*Leitoscoloplos pugettensis*	61	1.5	48
AN	*Sigambra setosa*	56	1.3	50
AN	*Mediomastus ambiseta*	55	1.3	51
AN	*Mediomastus californiensis*	51	1.2	52
AN	*Streblosoma* sp B SCAMIT 1985	48	1.1	53
MO	*Rictaxis punctocaelatus*	46	1.1	55
AN	*Streblosoma crassibranchia*	44	1.0	56
MO	*Philine* sp A SCAMIT 1988	43	1.0	57
AN	*Monticellina cryptica*	42	1.0	58
AN	*Marphysa disjuncta*	41	1.0	59
AR	*Heterophoxus ellisi*	41	1.0	60
MO	*Volvulella panamica*	41	1.0	61
NE	*Tubulanus polymorphus*	41	1.0	62

Key: AN = Annelida, AR = Arthropoda, MO = Mollusca, NE = Nemertea; "most abundant" means those species that each constituted at least 1% of the total abundance

Annelids were the most abundant infauna phylum in the Port Complex, comprising 47% of the individuals in summer and 54% in spring (Figure 5-3; Appendix E-3). Arthropods and mollusks were next most abundant in both surveys, followed by nemerteans and echinoderms.

SPECIES RICHNESS AND COMPOSITION

In the summer survey, samples averaged 37 species per station (Table 5-2). Species richness was highest at two locations: Station LB2 and Station LA16, with 63 species each (Appendices E-2 and E-3). Species richness was also high at Stations LB9 (61 species), Station LA15 (55 species), and Station LB1 (54 species). Lowest species richness occurred at Station LA8 (11 species). Values were also low at two other stations on the Los Angeles side: LA11 (18 species) and LA10 (19 species).

Table 5-4. The most abundant infaunal species, spring.

Phylum	Species	Overall Abundance	Percent of Total	Cumulative Percentage
AN	*Paramage scutata*	275	7.7	8
AN	*Cossura* sp A Phillips 1987	226	6.3	14
AN	*Euchone limnicola*	214	6.0	20
MO	*Theora lubrica*	150	4.2	24
AR	*Scleroplax granulata*	148	4.1	28
AR	*Sinocorophium heteroceratum*	135	3.8	32
AR	*Amphideutopus oculatus*	128	3.6	36
AN	*Aphelochaeta monilaris*	115	3.2	39
AR	*Neotrypaea sp*	90	2.5	41
AR	*Leptochelia dubia* Cmplx	78	2.2	44
AN	*Pista wui*	73	2.0	46
AN	*Laonice cirrata*	64	1.8	48
AN	*Cossura candida*	61	1.7	49
AR	*Pinnixa* sp	52	1.5	51
AR	*Nebalia daytoni*	51	1.4	52
AR	*Euphilomedes carcharodonta*	50	1.4	54
AR	*Photis brevipes*	50	1.4	55
AN	*Aphelochaeta glandaria Cmplx*	49	1.4	56
AR	*Pinnixa franciscana*	49	1.4	58
AN	*Pseudopolydora paucibranchiata*	45	1.3	59
AN	*Streblosoma crassibranchia*	43	1.2	60
AN	*Mediomastus ambiseta*	40	1.1	61
AR	*Eochelidium* sp A SCAMIT 1996	40	1.1	62
AN	*Streblosoma* sp B SCAMIT 1985	35	1.0	63
AN	*Glycera americana*	34	1.0	64

Key: AN = Annelida, AR = Arthropoda, MO = Mollusca, NE = Nemertea; "most abundant" means those species that each constituted at least 1% of the total abundance

In spring, species richness averaged 33 species per station overall (Table 5-2). Species richness was highest at Station LB2 (61 species), and moderately high at Stations LB15 (57 species), LA2 (52 species), and LB5 (50 species) (Figure 5-4). Only 10 species were found at Station LA15, but other stations with low numbers of species included Station LB16, LA10, LA11, and LA12, with 17 species each. More species of annelids occurred in the samples than any other group, and they comprised 44% of the species in summer and 42% in spring. In summer, mollusks, arthropods, and echinoderms were next in order of numbers of species, and in spring, arthropods, mollusks, and nemerteans were next after annelids (Figure 5-4; Appendix E-2). There were no clear differences in species composition related to location in the Port Complex, although arthropods appeared to constitute a somewhat larger proportion of the species at Inner Harbor stations than at Outer Harbor stations.

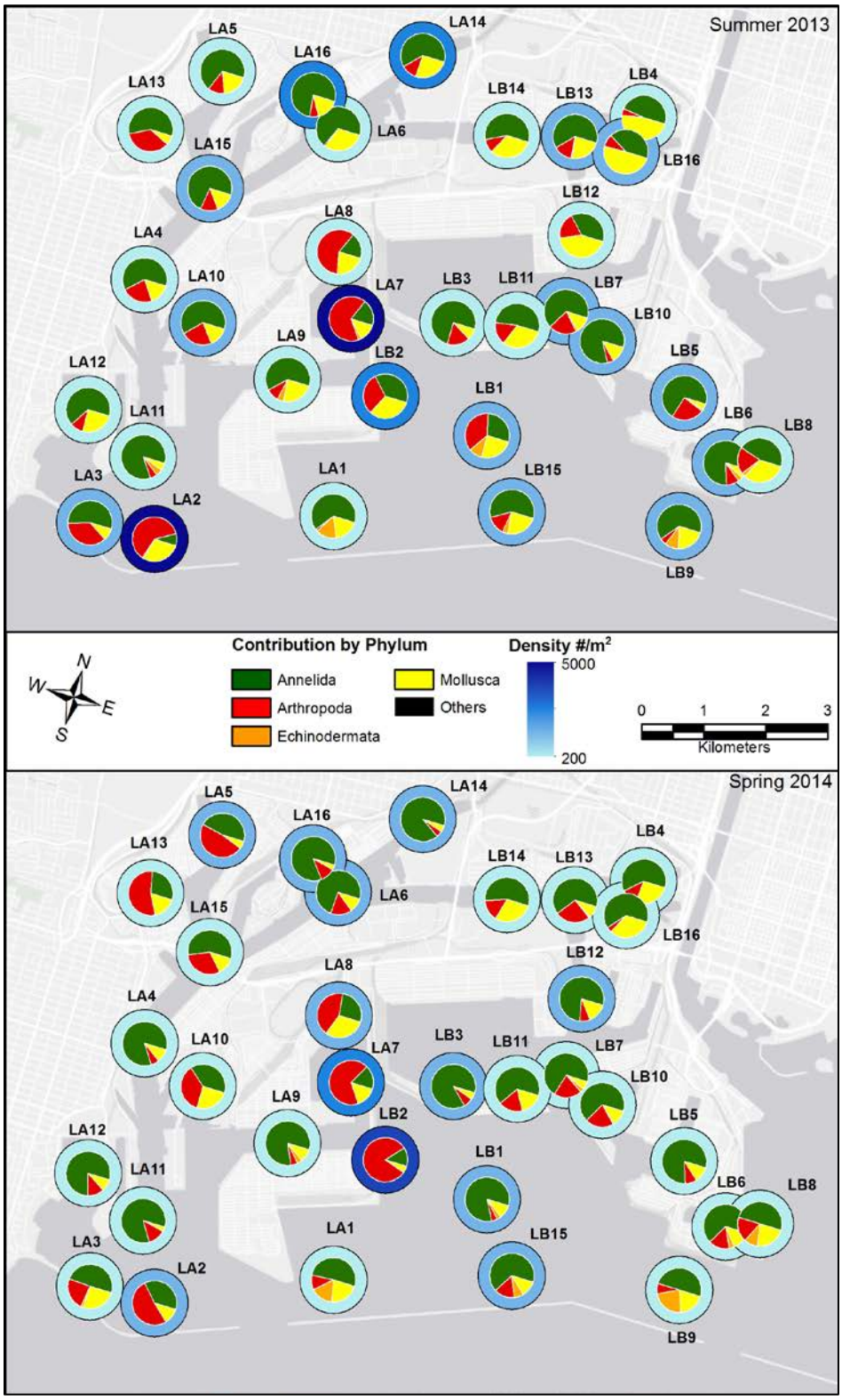


Figure 5-3. Density of benthic infaunal individuals and relative abundance of each phylum at each station in summer (top) and spring (bottom).

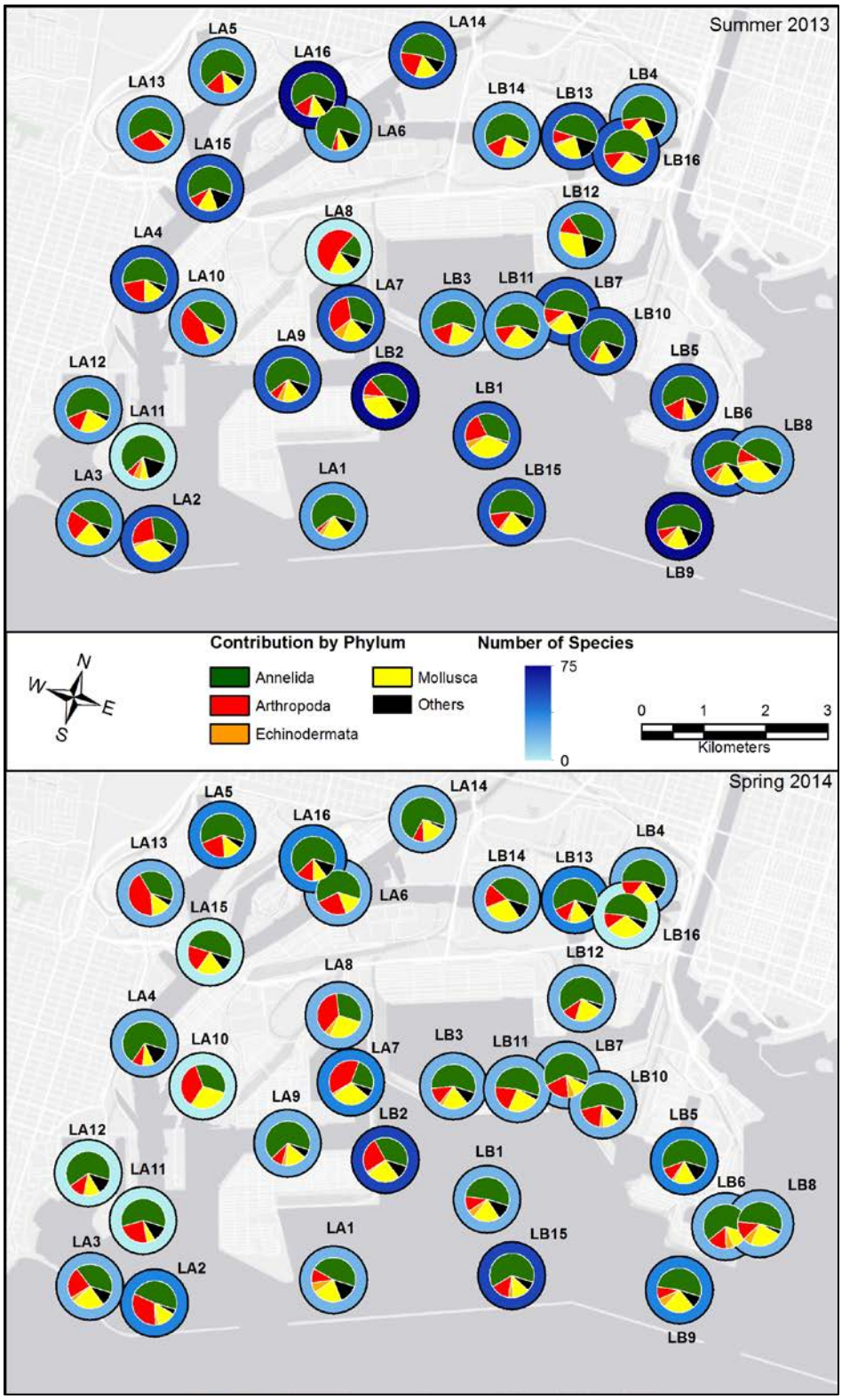


Figure 5-4. Species richness of benthic infauna and relative number of species in each phylum at each station, summer (top) and spring (bottom).

BIOMASS

In the summer survey, the biomass of infauna in the Port Complex averaged 3.61 g per station (36 g/m^2) (Table 5-2). Values ranged from 0.55 g (6 g/m^2) at Station LA3 to 15.37 g (154 g/m^2) at Station LA11 (Figure 5-5; Appendix E-4). At some stations, high biomass values were attributable in part or entirely to the presence of one large individual; for example, the very high biomass at Station LA11 in summer was due almost entirely to the presence of a single large sea cucumber, *Pentamera pseudopopulifera* and a large spoonworm, *Listriolobus pelodes*.

In the spring survey, biomass was similar to that in summer, with a harbor-wide mean of 3.75 g per station (38 g/m^2) (Table 5-2). Values ranged from 0.06 g (0.6 g/m^2) at Station LA15 to 12.99 g (130 g/m^2) at Station LB9 (Figure 5-5; Appendix E-4). The high biomass at Station LB9 was due to presence of two large *L. pelodes.*

In both surveys, annelids comprised nearly half of the total infauna biomass, due primarily to their greater abundance (Figure 5-5; Appendix E-4). Highest annelid biomass (6.3 g) occurred at Station LB13 in spring; other stations with high annelid biomass included LB3 and LB8 in spring and LB10 in summer. The lowest annelid biomass (0.01 g) occurred at Station LB16 in spring.

In both seasons, mollusks constituted the next highest proportion of the biomass. Particularly high mollusk biomass occurred at four locations in summer: Station LB2, where mollusks were very abundant, Station LB5, where one individual clam, a milky venus (*Compsomyax subdiaphana*), comprised 82% of the biomass, Station LA4, where several medium-sized *Cryptomya californica* were collected, Station LA7, where several medium-sized lesser jackknife clams (*Tagelus subteres*) were collected, and Station LA2. Biomass was also high at Stations LB7 and LB15 due to large individuals of the mollusk *Periploma discus*. In spring, mollusk biomass was high at Stations LA2, where a large California cone snail, *Conus californicus*, was collected, LA3, with a large *P. discus*, LA8, where several medium-sized *C. californica* occurred, LB5, with a large *C. subdiaphana*, and LB7, where two *P. discus* dominated the biomass.

Overall, arthropods constituted the third highest proportion of the biomass in the Port Complex, although at most stations arthropods actually were a very small proportion of the biomass. On the summer survey, arthropod biomass was higher than mollusk or annelid biomass at only three stations: Station LA4, where a giant ghost shrimp (*Neotrypaea gigas*) was collected and at Stations LA8 and LA10 where blue mud shrimp (*Upogebia pugettensis*) constituted most of the biomass. In spring, arthropod biomass was highest at Stations LA7 and LA10, and also moderately high at Station LA8, all due to the presence of ghost shrimp (*Neotrypaea* sp).

Biomass of the other two taxonomic groups (echinoderms and miscellaneous phyla) tended to be a minor component of the total at each station, except in a few cases when one or two large individuals contributed substantial biomass. Station LA11 in summer, described above, is an example, as are Station LB9 in summer and spring and Station LB12 in summer (Appendix E-4).

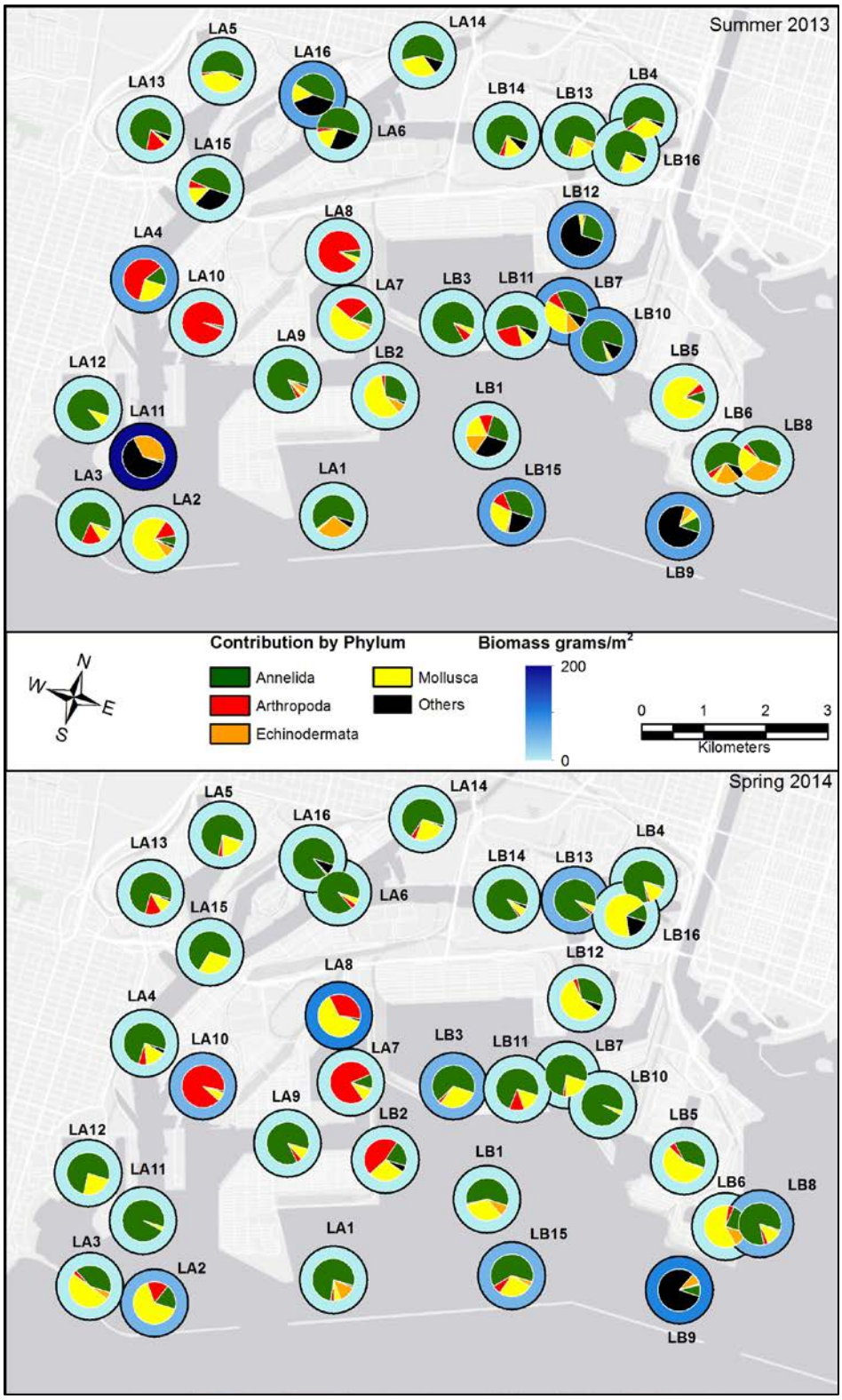


Figure 5-5. Biomass of benthic infaunal organisms and relative biomass of each phylum at each station, summer (top) and spring (bottom).

Over both seasons, annelid biomass was substantially greater on the Long Beach side of the Port Complex whereas arthropod biomass was substantially greater on the Los Angeles side, and mollusk biomass was similar on both sides (Appendix E-4).

SHANNON WIENER SPECIES DIVERSITY (H')

Mean species diversity was slightly higher in summer than in spring (Table 5-1). In summer, highest diversities were reported at Station LB9 and Station LA16 (Appendix E-5). In spring, highest species diversity occurred at Stations LB15, LB5, and LA4 (Appendix E-5). As Figure 5-6 shows, there were no obvious spatial or seasonal patterns of diversity in the Port Complex.

SOUTHERN CALIFORNIA BENTHIC RESPONSE INDEX (BRI)

A number of indices have been developed to allow the use of benthic infauna data to assess sediment conditions in bays and estuaries (Ranasinghe et al. 2007; SCCWRP 2008). Indices that include measures of community composition, with relative dominance of pollution-tolerant and pollution-sensitive species show the best relationship to pollution gradients. The initial benthic response to low levels of stress is a shift in species composition and loss of species richness. One of these indices is the Benthic Response Index, or BRI (Smith et al. 1999, 2001, 2003), which is the abundance-weighted average pollution tolerance of species occurring in a sample, using a scale of 0 to 100, with higher values indicating greater disturbance. With the BRI, the abundance of pollution-tolerant species in a community is used to calculate a value indicating disturbance of the marine environment by contaminants accumulated in the sediments, and low concentrations of dissolved oxygen in near-bottom waters (Smith et al 1999).

The BRI was developed to provide a scientifically valid criterion or threshold that can be used to distinguish "healthy" and "unhealthy" benthic communities (SCCWRP 2009). For southern California marine bays and harbors, BRI scores greater than 39.96 but less than 49.15 (Low Disturbance) indicate that the community has been subject to anthropogenic disturbance (e.g., pollution) sufficient to modify the composition of the community, such as loss of species that otherwise would be found in a similar but unpolluted habitat. BRI scores greater than 49.15 but less than 73.27 indicate Moderate Disturbance, where communities exhibit clear evidence of physical, chemical, other anthropogenic, or natural stress, while scores above 73.27 indicate High Disturbance.

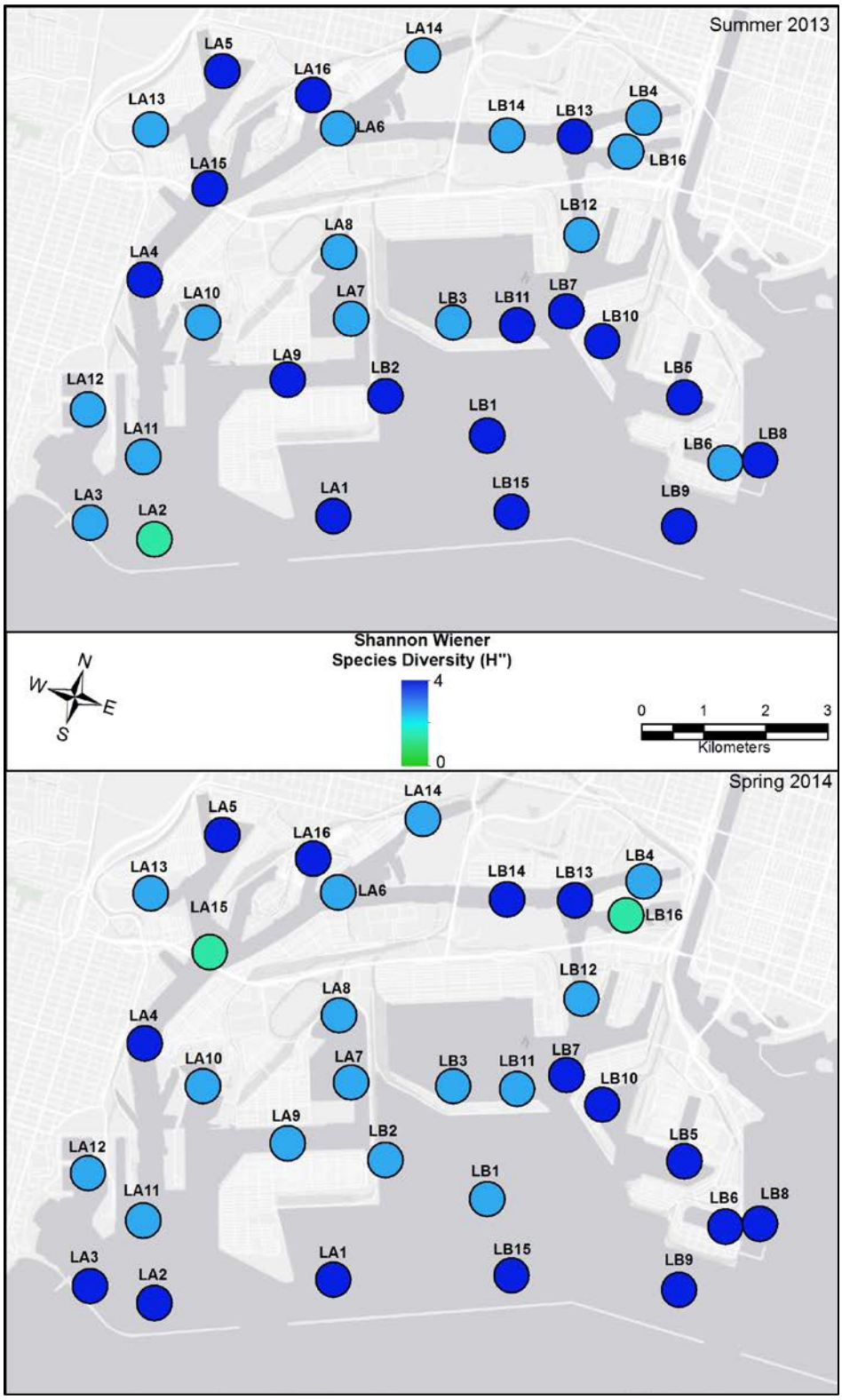


Figure 5-6. Shannon Wiener Species Diversity (H') for the benthic infauna at each station, summer (top) and spring (bottom).

Mean BRI was very similar in the summer (16.0) and spring (17.2) surveys (Table 5-1; Figure 5-7). In summer, BRI values ranged from 2.4 for the community at Station LB12 to 42.9 for the community at Station LA10 (Appendix E-5). In spring, BRI values ranged from 2.7 for the community at Station LA9 and 2.8 for the community at Station LB7 to 44.8 for the community at Station LA10 (Appendix E-5). The BRI was also high, 41.2, for the community at Station LA14. Most BRI values were in the Reference category (below 39.96), indicating that the communities were healthy. However, values at two locations exceeded that threshold, putting them in the category of Low Disturbance: Station LA10 in spring and summer and Station LA14 in spring (Figure 5-7). The field observations on both surveys indicated that the sediment samples from Station LA14 were black, with an odor of hydrogen sulfide (Appendix E-9-B; all other samples in the Port Complex were described as gray or brown, and without odor).

COMMUNITY COMPOSITION

The benthic infauna communities found in the Port Complex were similar in the spring and summer surveys. The 24 most abundant species in the summer survey, each of which represented 1% or more of the abundance, together represented 62% of the abundance even though they were only 9% of the total number of species (Table 5-3). The amphipod *Amphideutopus oculatus* was the most abundant species, even though it was found at only 12 stations and was abundant at only four of those. It was most abundant at Station LA2 but also very abundant at Station LB2 (both stations are created shallow-water habitats).

The amphipod *Sinocorophium heteroceratum* and the annelid *Euchone limnicola* were other abundant but unevenly distributed species. *S. heteroceratum* occurred at nine stations but was abundant only at Station LA7 (another created shallow-water habitat), while *E. limnicola* was most abundant at Station LA14. The Asian clam *Theora lubrica* and the annelid *Cossura* sp A Phillips 1987 were among the abundant species that were more evenly distributed.

In the spring survey, 25 species constituted 1% or more of the abundance (Table 5-4). Together they represented 11% of the species and 64% of the total abundance. The annelid *Paramage scutata* was most abundant, comprising 8% of the total abundance, followed by *Cossura* sp A and *E. limnicola*, each accounting for about 6% of the abundance. *P. scutata* and *Cossura* sp A were fairly evenly distributed among the stations, although *P. scutata* was much more abundant at Station LA6 than at any other station. *E. limnicola* was rather unevenly distributed, being very abundant at only two stations: Station LB3 and Station LA14. *Theora lubrica* and the burrow pea crab *Scleroplax granulata* were also abundant. *T. lubrica* was fairly evenly distributed, while *S. granulata* was less so, with highest abundance at Station LA5. As in summer, *S. heteroceratum* was most abundant at Station LA7 and *A. oculatus* was most abundant at Station LB2.

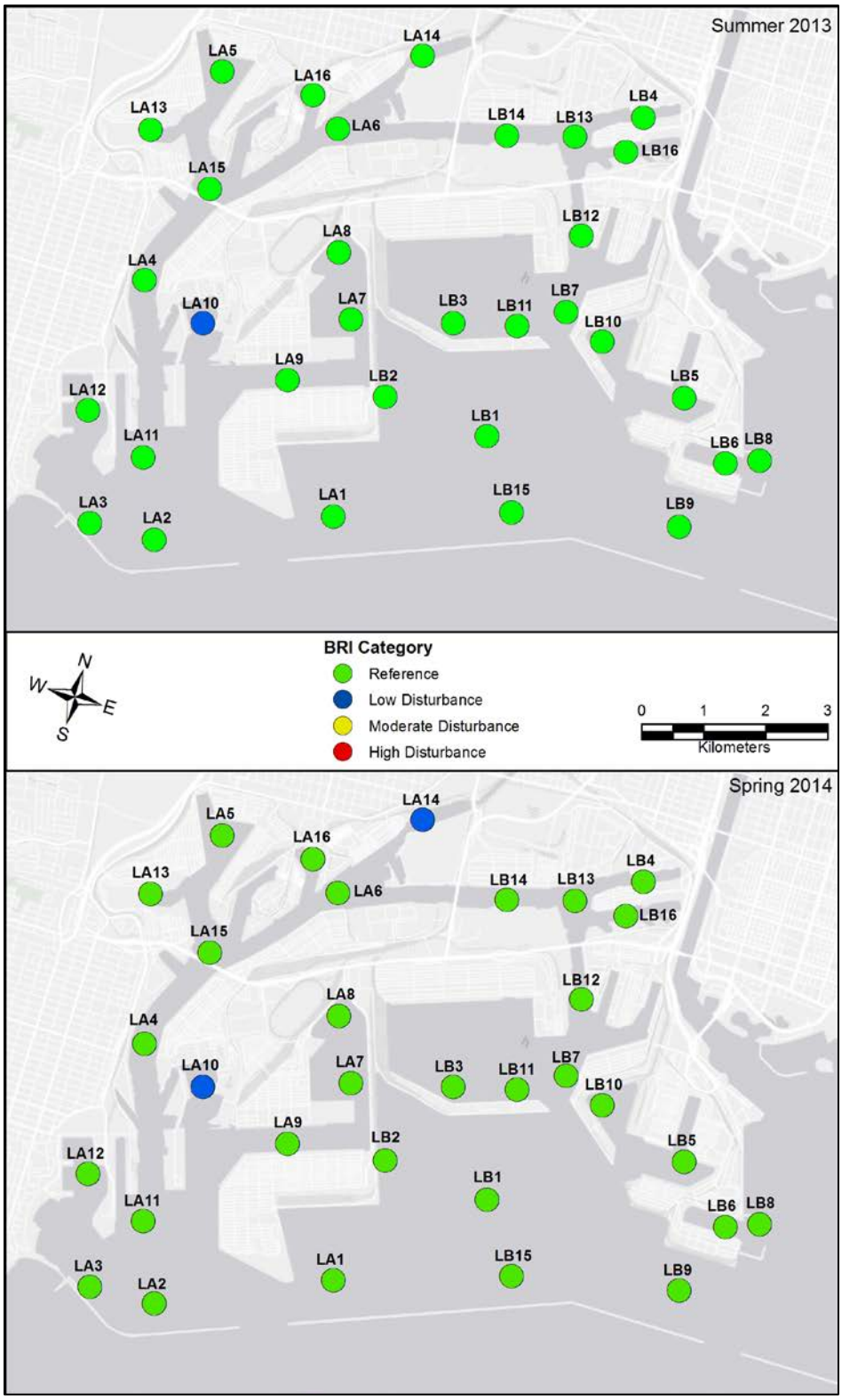


Figure 5-7. Southern California Benthic Response Index values for the benthic infauna at each station in summer (top) and spring (bottom).

Cluster analysis of the 32 stations sampled in summer, based on the 24 most abundant species (Table 5-3), resulted in eight station groups, which were combined into five major groups (the two-way coincidence table forms Appendix E-7). These major groups were plotted in Figure 5-8; the sampling stations in that group are depicted in the group's assigned color. The major difference among the groups was between the first two groups (I and II), which were closer to each other than to the other groups, and the remaining groups (III through VIII). This means that the stations in Groups I and II were distinctly different from the other stations. Group I (red in Figure 5-8) consisted of four stations in the Outer Harbor: three in created shallow-water habitats of both ports and one deep-water station (LB1). *Amphideutopus oculatus* was the dominant species at Group I stations, and was also dominant in Group II (orange in Figure 5-8), which consisted of a single Outer Harbor station (LA11). Abundance and species richness were low in Group II, and the most abundant species were not among the 24 most abundant species in the summer survey.

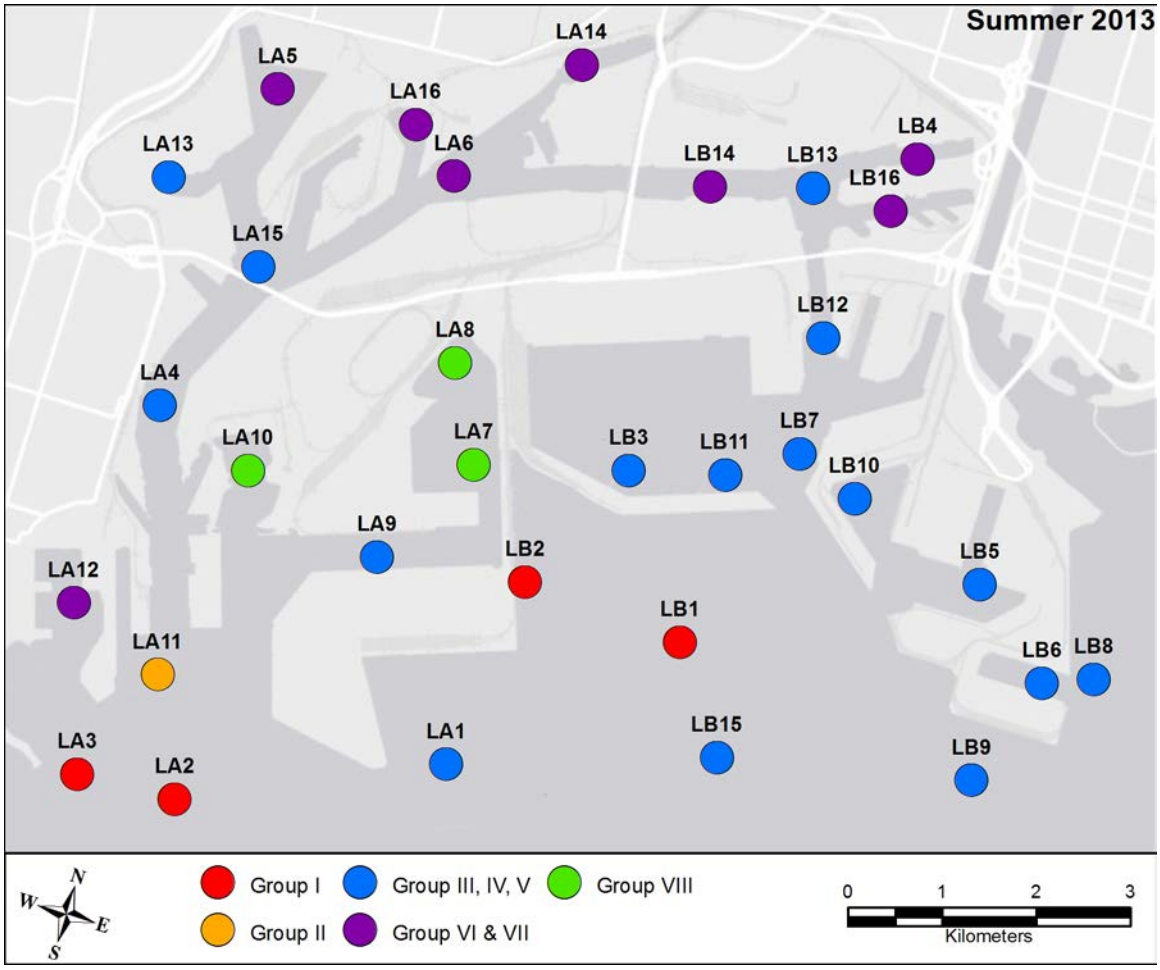


Figure 5-8. Major categories of community groups identified by cluster analysis of the 24 most abundant infauna species in summer.

Among the remaining stations, the ones that clustered most closely were those in Groups III, IV, and V (blue on Figure 5-8), most of which are in Outer Harbor and channel areas on the Long Beach side, but also including five stations on the Los Angeles side (four in the Outer Harbor and channels and one in the Inner Harbor). Generally*, Cossura* sp A*, Aphelochaeta monilaris,* and *Neotrypaea* sp were the community dominants at those stations. Another distinctive grouping was the stations in Groups VI and VII (purple on Figure 5-8), which are all in the Inner Harbor of the Port Complex; *Theora lubrica* was the dominant species at these stations. Group VIII (green in Figure 5-8) was not closely related to the other groups. It consisted of only three stations, including one in the created Pier 300 Shallow Water Habitat, one in Seaplane Lagoon, and one in Fish Harbor; *Sinocorophium heteroceratum*, *Euchone limnicola*, and *Theora lubrica* were most abundant at these three stations.

In spring, cluster analysis based on the 25 most abundant species (Table 5-4) also resulted in eight station groups in five major categories (Figure 5-9; Appendix E-7). The major difference was between Groups I through III and Groups IV through VIII. Stations that clustered in Groups I and II (blue in Figure 5-9) are primarily in the deeper areas of the Port Complex, and all but one are in the Outer Harbor. Most stations in Groups I and II are on the Long Beach side. *Paramage scutata*, *Cossura* sp A, *Aphelochaeta monilaris*, *Theora lubrica*, and *Laonice cirrata* were most abundant at the majority of these stations. The two Outer Harbor stations in Group III (orange in Figure 5-9) clustered with the previous two groups, but at a level that indicated low similarity. *P. scutata* was the dominant species at Stations LA11 and LA15, but the communities had low species richness, lacking most of the species seen at the other stations.

Greater variability in community composition was seen among the remaining stations. At stations in Groups V and VI (purple in Figure 5-9), the communities were dominated by *Cossura* sp A and *E. limnicola*. Group V included two stations in the Long Beach West Basin and three Los Angeles Inner Harbor stations. Group VI included the three stations at the Los Angeles created shallow-water habitats. *T. lubrica*, *S. heteroceratum*, and *Amphideutopus oculatus* were abundant there, in addition to *Cossura*. sp A and *E. limnicola*. Station Groups VII and VIII (green in Figure 5-9) clustered distantly with Groups V and VI, and included six stations with no obvious physical similarities except that all but one is in a dead-end slip or basin, and only two (LA8 and LB8) are in the Outer Harbor. Finally, Group (IV, red in Figure 5-9) consisted of a single station, LB2, that clustered distantly with Groups V through VIII. The community at Station LB2 included several species that occurred only there (*Nebalia daytoni* and *Photis brevipes*) or were much more abundant there than elsewhere (*Amphideutopus oculatus* and *Leptochelia dubia* Complex [Cmplx]). In addition, species that were abundant at most of the other stations were absent or uncommon at Station LB2.

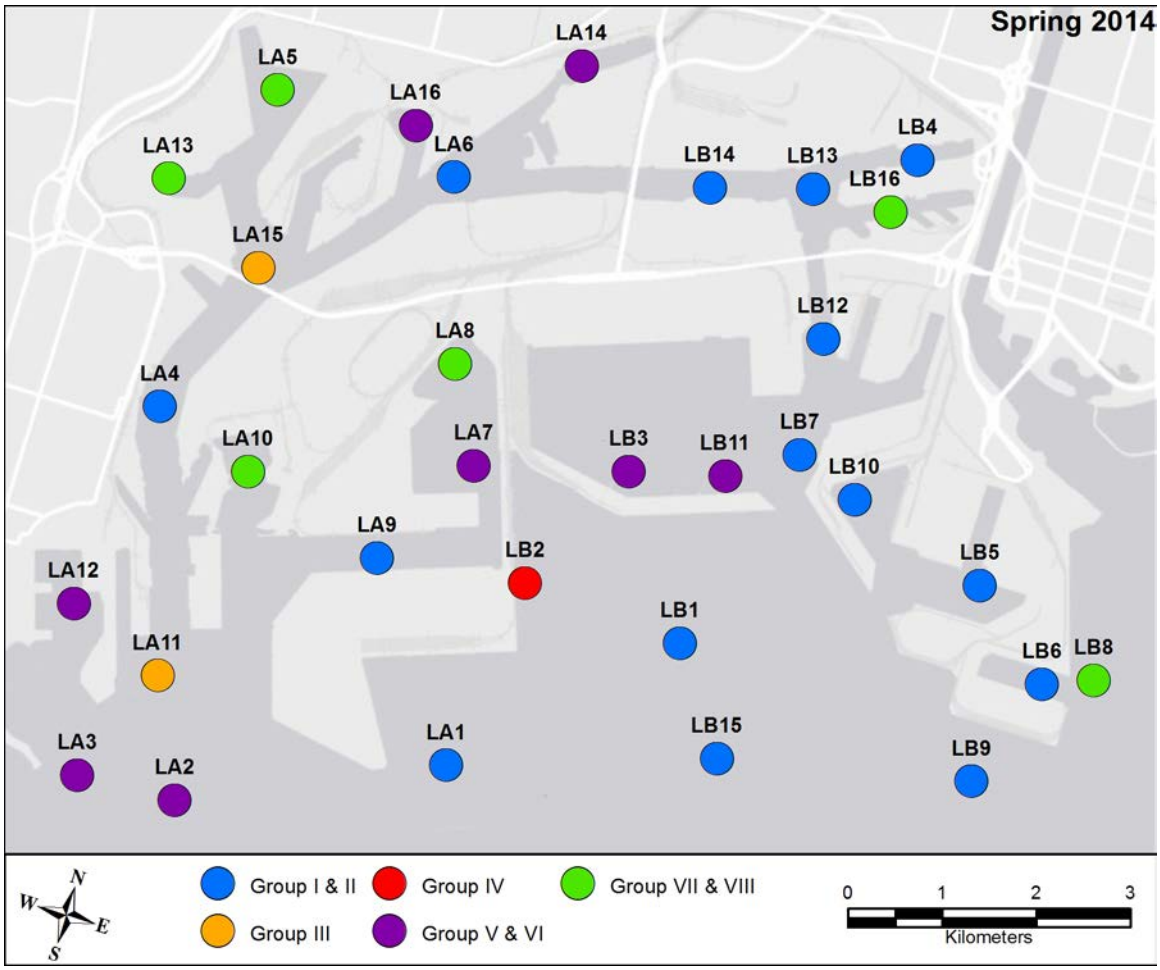


Figure 5-9. Major categories of community groups identified by cluster analysis of the 25 most abundant infauna species in spring

EPIBENTHIC INVERTEBRATES

One hundred and ten epibenthic invertebrate species were caught in day and night trawl surveys in the Port Complex in summer 2013 and spring 2014 (Table 5-5; Appendix E-11; species abundances by station are presented in Appendix E-12). Summaries of epibenthic catches by major taxonomic group are presented in Appendix E-14. Seventy-six individuals of seven invertebrate species were caught during beach seine sampling in summer 2013 and spring 2014 (Table 5-6; Appendices E-16 and E-17).

ABUNDANCE

In summer, the abundance of trawl-caught invertebrates averaged 126 individuals per trawl at the 26 stations in the Port Complex (Table 5-5; Appendix E-12). Mean abundance was higher at night throughout the Port Complex. Abundance was greatest at Stations LA6 and LA5 during night sampling, when 677 and 675 individuals were collected, respectively (Appendix E-12).

Table 5-5. Community parameters for trawl-caught epibenthic organisms. Totals are for all stations combined for each survey. Means are per station and include all stations for the survey.

	Summer			Spring			
Parameter	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Grand Total**
Abundance							
Total	1,909	4,632	6,541	3,441	6,625	10,066	16,607
Mean	73	178	126	132	255	194	320
Species Richness							
Total	66	53	77	60	59	77	110
Mean	8	9	9	10	10	10	9
Biomass (kg)							
Total	100.0	118.3	218.3	84.5	74.2	158.7	377.0
Mean	3.85	4.55	4.20	3.25	2.86	3.05	3.62
Diversity (H')							
Total	1.74	1.95	1.92	1.51	1.69	1.76	1.96
Mean	0.93	1.09	1.01	0.84	0.96	0.90	0.96

Highest daytime abundance of 234 individuals occurred at Station LA16. Abundance was higher at night than during the day, but there was no clear spatial pattern to abundance. In spring, the abundance of trawl-caught invertebrates averaged 194 individuals per trawl (Table 5-5; Appendix E-12). Mean abundance was higher at night than during the day throughout the Port Complex. Abundance was greatest at Station LB7 during both day and night sampling, when 809 and 1,282 individuals were collected, respectively (Appendix E-12). As in summer, there was no clear spatial pattern of abundance.

Thirty-one individuals were taken in beach seine sampling in summer 2013 (Table 5-6; Appendices E-16 and E-17). All 31 individuals were caught at Cabrillo Beach. Forty-five individuals were taken in the spring 2014 beach seine sampling (Table 5-5; Appendices E-16 and E-17), 43 at Cabrillo Beach and two at Pier 300.

SPECIES COMPOSITION AND RICHNESS

Arthropods, which include shrimps, crabs, and spiny lobsters, were taken in every trawl sample and were by far the most abundant epibenthic invertebrate phylum in the Port Complex. In summer, arthropods comprised 80% of the individuals during the day and 94% at night, and in spring they comprised 90% of the individuals during the day and 95% at night in spring

(Appendix E-14). Arthropods were the second most speciose group in summer and the most speciose group in spring. All but two of the 76 animals collected during beach seine sampling were arthropods.

Table 5-6. Combined abundance and catch parameters for seine-caught macroinvertebrate species.

Ph*	Common Name / Species Name	Cabrillo Beach Summer	Cabrillo Beach Spring	Cabrillo Beach Total	Pier 300 Summer	Pier 300 Spring	Pier 300 Total	Grand Total
AR	blackspotted bay shrimp *Crangon nigromaculata*	-	29	29	-	-	-	29
AR	yellow crab *Metacarcinus anthonyi*	10	6	16	-	-	-	16
AR	oriental shrimp *Palaemon macrodactylus*	11	4	15	-	-	-	15
AR	Pacific sand crab *Emerita analoga*	10	-	10	-	-	-	10
AR	California green shrimp *Hippolyte californiensis*	-	3	3	-	-	-	3
MO	fat western nassa *Caesia perpinguis*	-	-	-	-	2	2	2
AR	graceful rock crab *Metacarcinus gracilis*	-	1	1	-	-	-	1
	Total Abundance	31	43	74	-	2	2	76
	Number of Species	3	5	6	-	1	1	7
	Diversity (H')	1.10	1.03	1.48	0.00	0.00	0.00	1.56
	Biomass (g)	24	53	77	-	2	2	79

*Ph = Phylum; AR = Arthropoda, MO = Mollusca, "-" = absent

Mollusks (sea slugs, sea hares, octopi, oysters, mussels, and scallops) were the second most abundant phylum in spring and the third most abundant in summer. Mollusks were the most species-rich taxonomic group of epibenthic invertebrates: more mollusk species occurred in summer trawls than any other phylum, and they comprised 40% of the species caught during the day and 36% of the species at night (Figures 5-10 and 5-11; Appendix E-14).

Echinoderms (sea cucumbers, brittle stars, and sea stars) were the third most abundant group in spring and fourth in summer, after “Other” phyla. Chordates (tunicates, or sea squirts, included in the group “Other” in the figures) were the second most abundant group during the day in summer, with most individuals taken at Station LA14 in day sampling. Several species of echinoderms (sea cucumbers, brittle stars, and sea stars) were fairly abundant in the summer survey at a number of stations on the Long Beach side, but were rare in the spring survey in both harbors. More echinoderm species were taken at night than during the day.

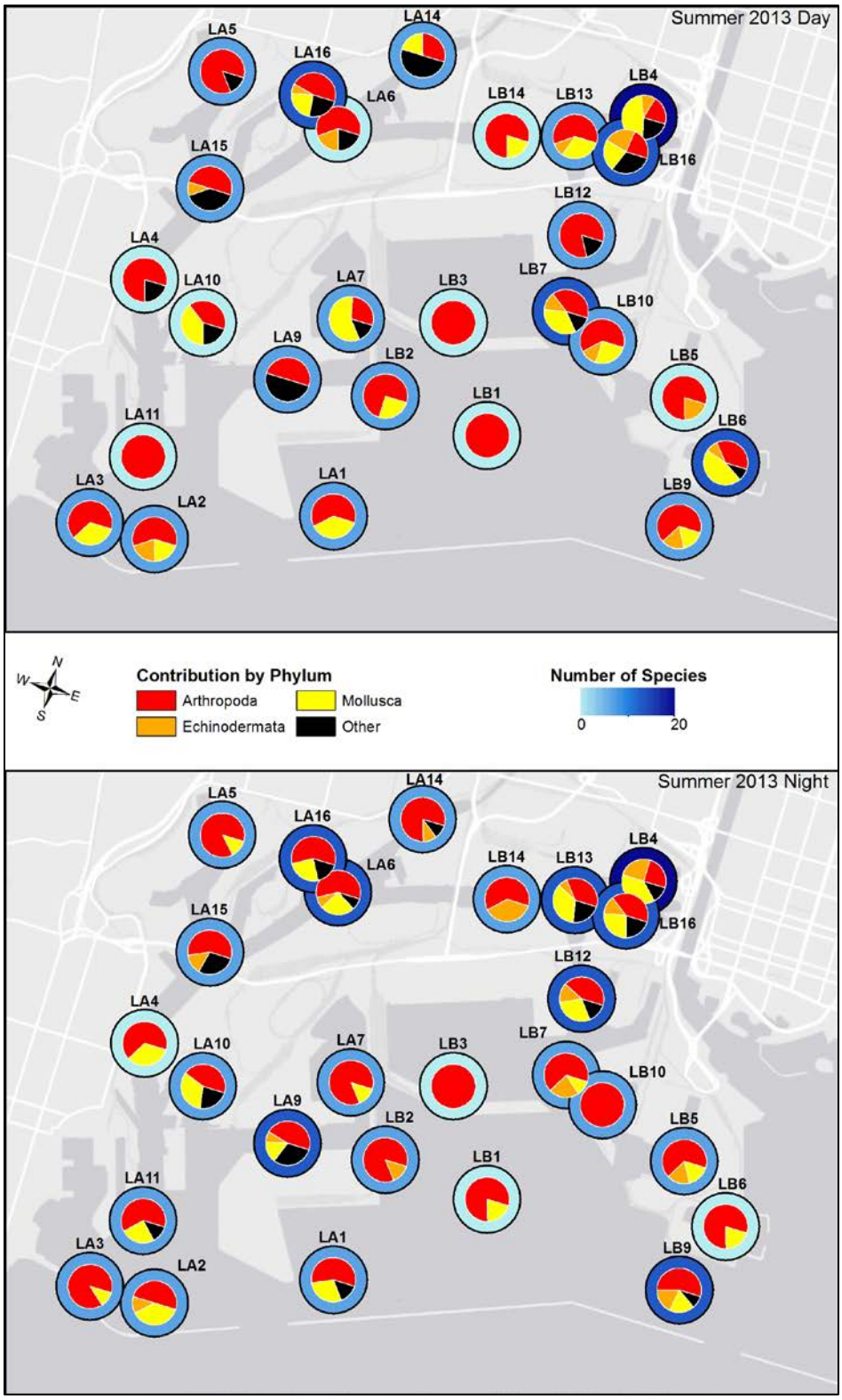


Figure 5-10. Species richness of trawl-caught epibenthic invertebrates and relative proportion of each phylum at each station, day and night in summer.

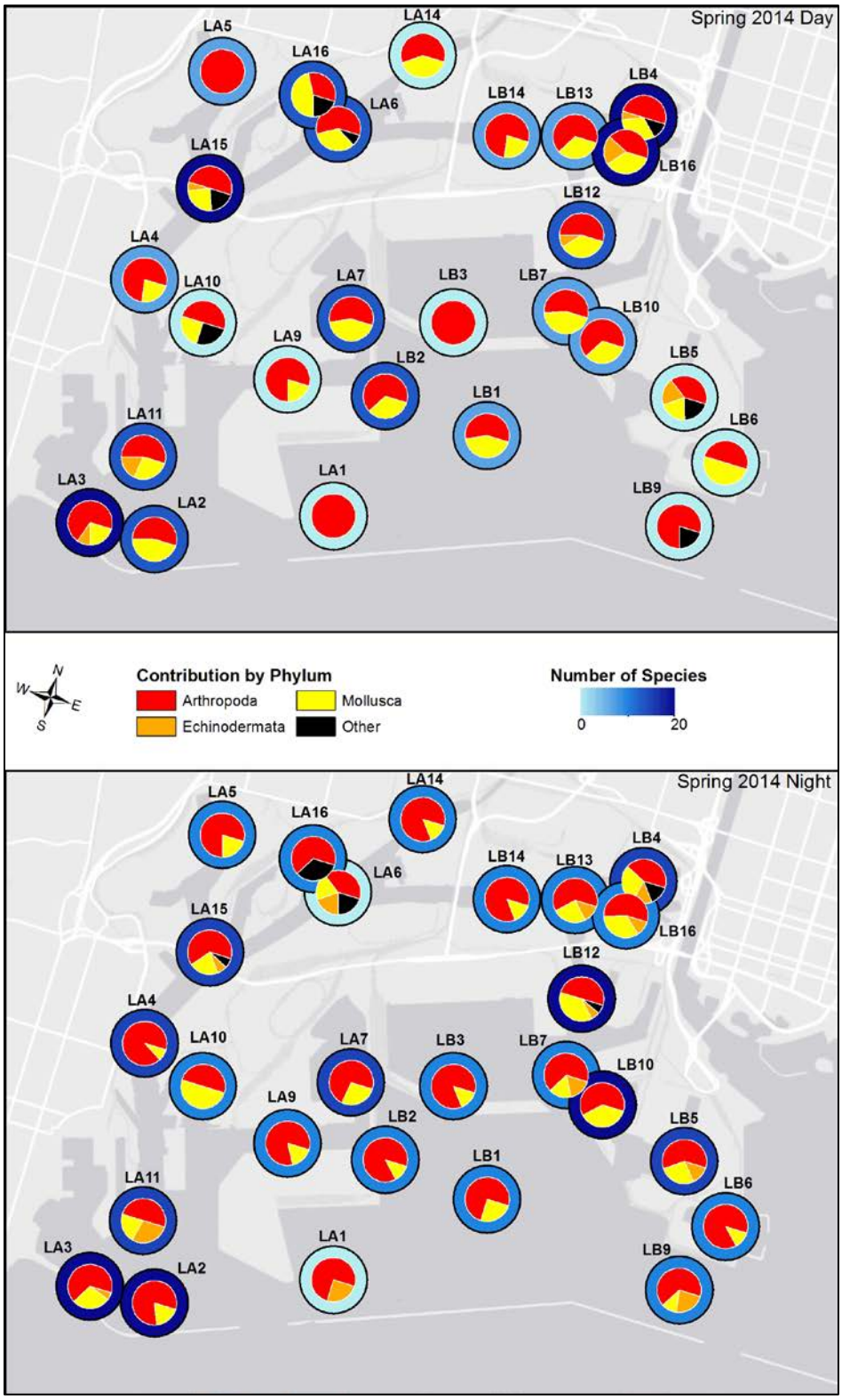


Figure 5-11. Species richness of trawl-caught epibenthic invertebrates and relative proportion of each phylum at each station, day and night in spring.

In summer, trawls collected an average of nine species per station (Table 5-5; Appendix E-14). Species richness was highest at Station LB4, with 19 species taken during the day and 16 at night (Figures 5-10 and 5-11). High species richness was also reported at Station LB7, with 15 species collected at night, Stations LB12 (Back Channel) and LB13 (LB Turning Basin), with 14 species each during night, Station LA16 (Slip 5), with 13 species taken during the day, and Station LA9 (Pier 400 Channel), with 13 species taken at night. In general, species richness in summer was higher in back channels and slips than in the open Outer Harbor area (Figure 5-10).

In spring, trawl samples collected an average of ten species per station (Table 5-5; Appendix E-14). Species richness was highest at Station LA3, with 20 species taken during the day and 18 at night (Figure 5-11). Sixteen species were reported at Stations LB4, LB16, and LA15 during the day and at Stations LB10, LB12, and LA2 at night. There was no clear spatial pattern to species richness in the spring survey.

Three species were taken in beach seine sampling in summer, all three at Cabrillo Beach (Table 5-5; Appendix E-17). Six species were taken in beach seine sampling in spring, five at Cabrillo Beach and one at Pier 300 (Table 5-5; Appendix E-17).

BIOMASS

In summer, biomass averaged 4.20 kg per trawl (Table 5-5; Appendix E-14). Biomass was highest in the Los Angeles Inner Harbor: at Station LA6, with 46.52 kg taken during the day, and at Stations LA6 and LA16 with 28.67 kg and 30.45 kg, respectively, at night (Figure 5-12; Appendix E-14); these high values of biomass were the result of large catches of sponges.

In spring, biomass averaged 3.05 kg per trawl (Table 5-5; Appendix E-14). Highest daytime biomass occurred at Station LA16 (33.03 kg) and highest nighttime biomass occurred at Station LB7 (13.36 kg) (Figure 5-13). High biomass also occurred at Station LA15 during day surveys. With the exception of Stations LA15 and LA16, where large catches of sponges occurred, biomass in spring was fairly evenly distributed among stations in the Port Complex.

Unidentified sponges (Porifera) contributed 60% of the biomass during the day and 51% of the biomass during the summer night trawls (Appendix E-14). Sponges also dominated the biomass during the day in spring, contributing 55% of the biomass, but arthropods constituted 81% of the trawl biomass at night. Biomass contributed by sponges was second highest, and mollusk biomass was third highest, during night sampling in spring. Arthropods were second in biomass, followed by echinoderms, during both day and night in summer and during the day sampling in spring.

The biomass of epibenthic invertebrates taken in beach seines in summer was 0.02 kg, all from organisms caught at Cabrillo Beach (Table 5-6; Appendix E-17). Biomass in spring was 0.055 kg, all but 0.002 kg of which was caught at Cabrillo Beach. In the beach seine samples, 97% of the biomass was contributed by arthropods.

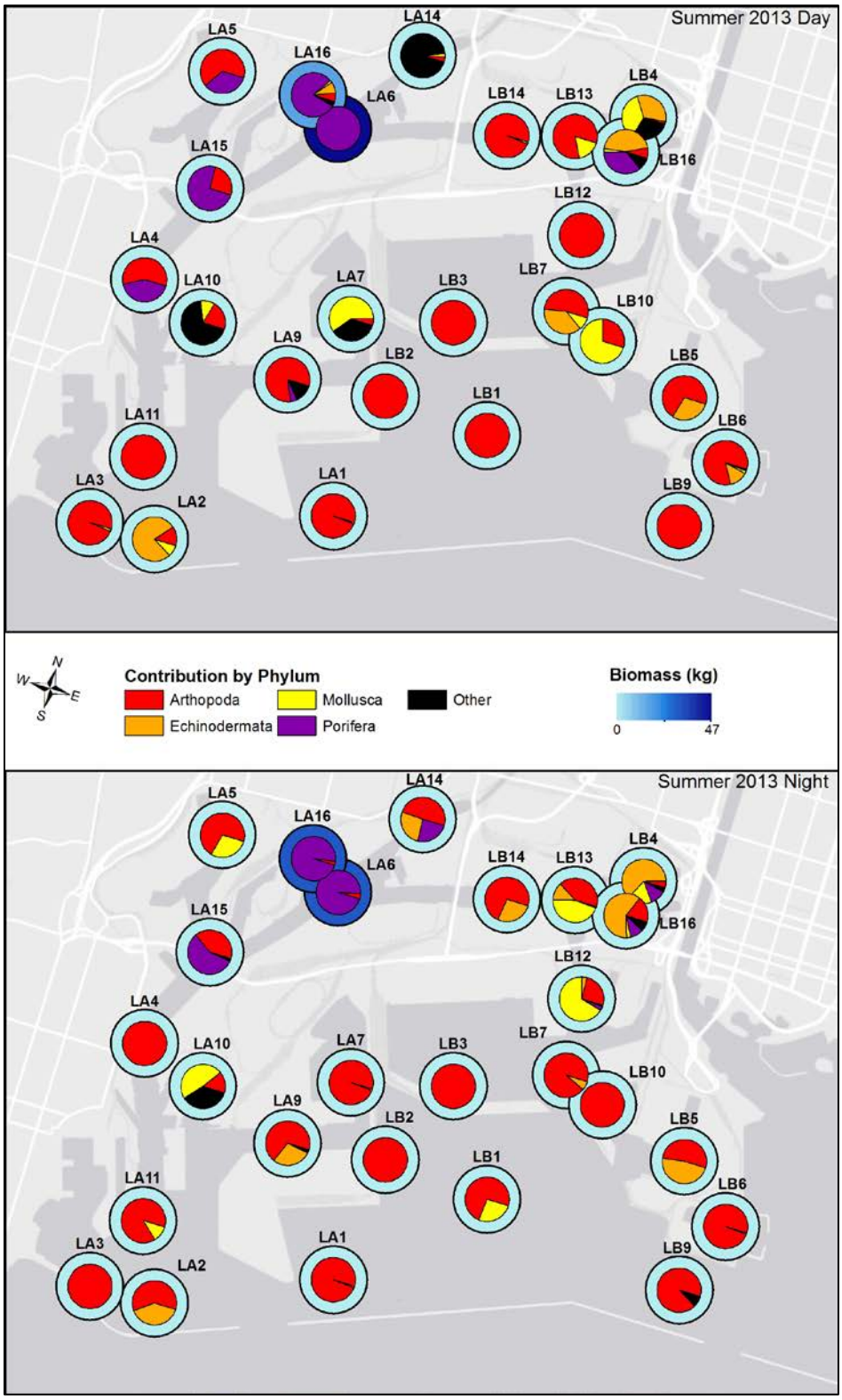


Figure 5-12. Biomass in kilograms (kg) of trawl-caught epibenthic invertebrates and relative proportion of each phylum at each station, day and night in summer.

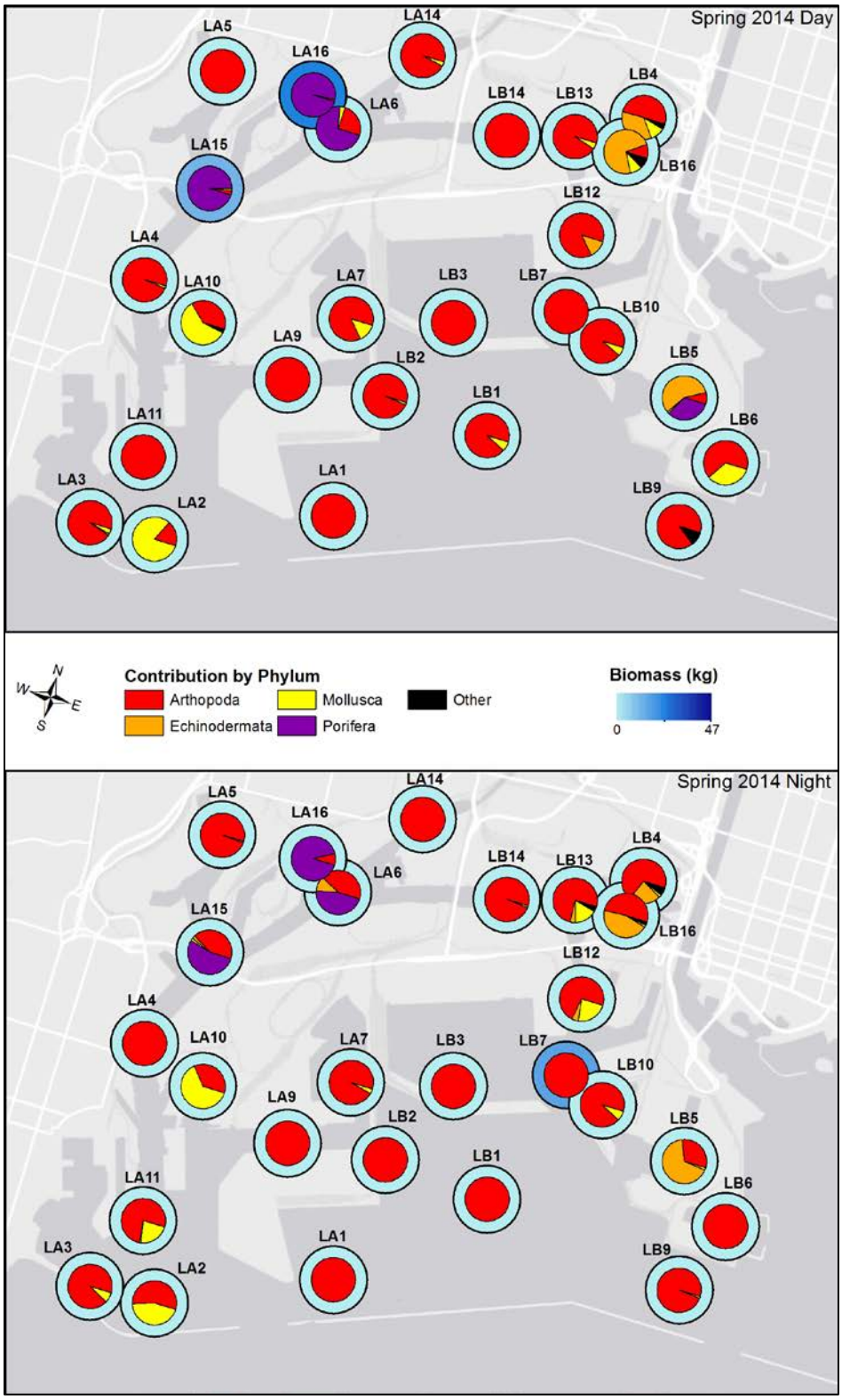


Figure 5-13. Biomass in kilograms (kg) of trawl-caught epibenthic invertebrates and relative proportion of each phylum at each station, day and night in spring.

SHANNON WIENER SPECIES DIVERSITY (H')

Mean species diversity of trawl-caught invertebrates was slightly higher in summer than in spring (Table 5-5). Diversity was generally somewhat higher in night trawls than in day trawls. In summer, highest diversities were 1.92 at Station LB13 at night, 1.88 at Station LB4 during the day, and 1.78 at Station LA5 at night (Figure 5-14; Appendix E-13). Lowest diversities were reported at Station LA6 (0.08) during the day and Station LA16 (0.16) at night, both due to very high biomass by a single taxon (unidentified sponges). In beach seine samples, diversity of replicate samples at Cabrillo Beach in August was 1.10 (Table 5-6). No epibenthic invertebrates were taken at Pier 300 in summer.

In spring, highest diversities occurred at Station LA5 (1.86 and 1.52 during night and day), Station LB4 during the day (1.76), and Station LB10 at night (1.74) (Table 5-5; Figure 5-15). Lowest diversities occurred at Station LB7 (0.07 at night and 0.23 during the day), Station LA16 (0.10), and Station LA14 (0.25), both during the day. The low diversity values at these stations were due to very high biomass contribution by a single taxon. In beach seine samples, diversity at Cabrillo Beach in May was 1.03 (Table 5-6). Only one epibenthic species was taken at Pier 300, so diversity was 0.

COMMUNITY COMPOSITION

As stated above, comparisons of the trawl-caught epibenthic invertebrates were based on biomass of the dominant species, rather than abundance. To account for two sampling periods at each station and to facilitate comparisons between stations, results from the day and night trawls were averaged. Epibenthic invertebrates caught by beach seine were not included in this analysis.

The composition of the epibenthic community was generally similar between the summer and spring surveys, with seven species in common among those that contributed the most to biomass during both seasons. In summer, the 22 species that each contributed 0.5% or more to the biomass represented 98% of the biomass even though they accounted for only 29% of the species (Table 5-7; Appendix E-13). Unidentified sponges (Porifera) contributed most to biomass in summer, even though they were found at only 12 stations and were abundant at only two of those. Sponge biomass was highest at Stations LA6 and LA16, which together accounted for 95% of all sponge biomass in summer. Target shrimp (*Sicyonia penicillata*) accounted for the second highest biomass in summer. Although biomass of target shrimp was only about one-fifth of that of sponges, they were taken at all but three stations. California spiny lobsters (*Panulirus interruptus*) were taken only occasionally and only at seven stations in summer, but being large animals, they accounted for the third highest biomass of epibenthic species. Xantus swimming crab (*Portunus xantusii*) was evenly distributed in the Port Complex, being taken at 23 of the 26 trawl stations. Highest biomass for the species occurred at Stations LA4, LA15, LA16, and LB2.

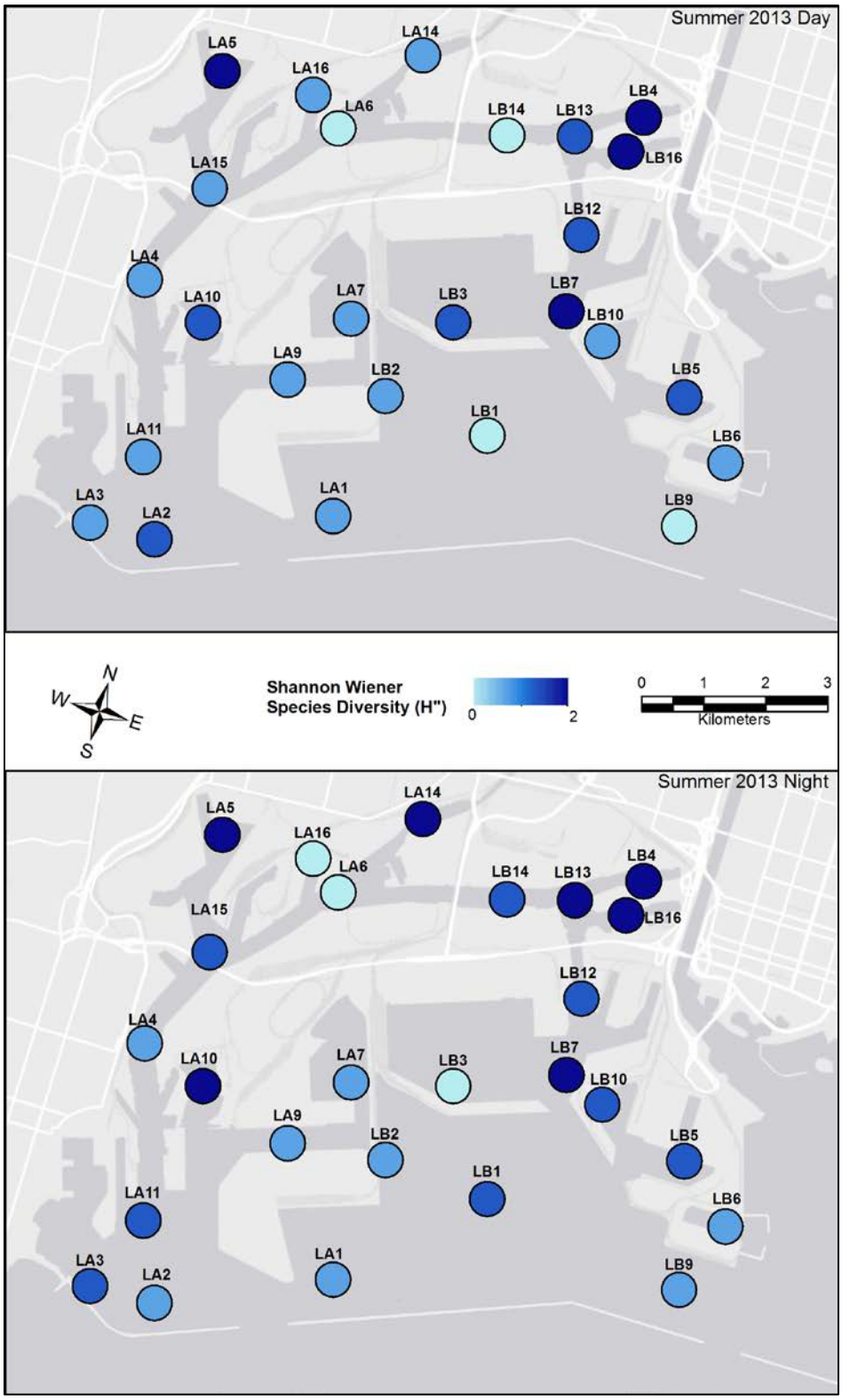


Figure 5-14. Shannon Wiener Species Diversity (H') of trawl-caught epibenthic invertebrates at each station in summer.

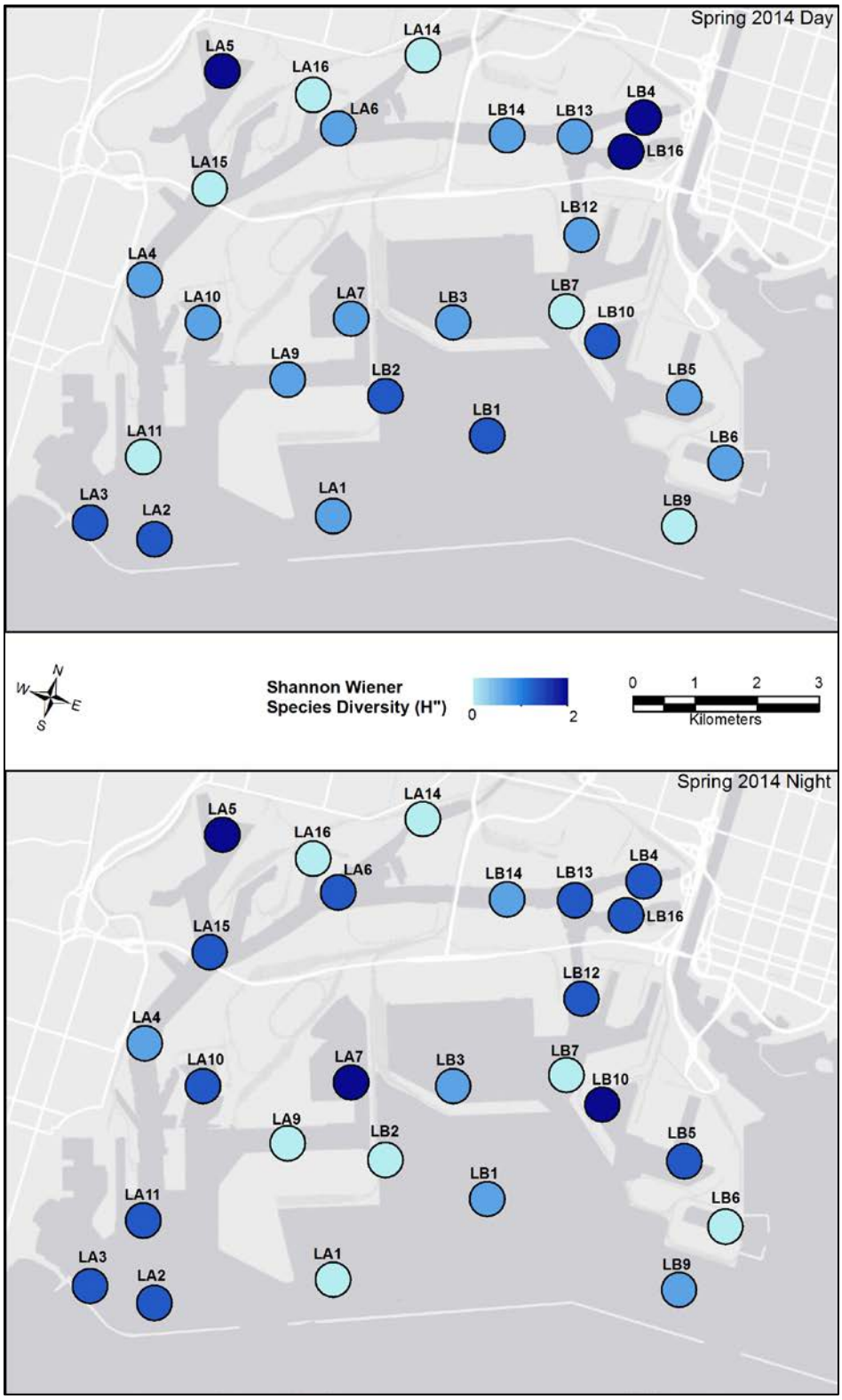


Figure 5-15. Shannon Wiener Species Diversity (H') of trawl-caught epibenthic invertebrates at each station in spring.

Table 5-7. Biomass (kg) of the 22 trawl-caught epibenthic species that contributed 0.5% or more to total biomass in summer.

Phylum	Common Name	Species Name	Total Biomass (kg)	Percent of Total	Cumulative Percentage
PO	unidentified sponge	Porifera, unid.	120.56	55.2	55
AR	target shrimp	*Sicyonia penicillata*	26.13	12.0	67
AR	California spiny lobster	*Panulirus interruptus*	10.65	4.9	72
AR	Xantus swimming crab	*Portunus xantusii*	9.68	4.4	77
MO	California seahare	*Aplysia californica*	5.93	2.7	79
EC	short-spined sea star	*Pisaster brevispinus*	5.92	2.7	82
EP	spaghetti bryozoan	*Zoobotryon verticillatum*	5.63	2.6	85
EC	California sea cucumber	*Parastichopus californicus*	5.11	2.3	87
EC	warty sea cucumber	*Parastichopus parvimensis*	4.58	2.1	89
EC	bat star	*Patiria miniata*	2.48	1.1	90
MO	giant rock scallop	*Crassadoma gigantea*	1.68	0.8	91
MO	California two-spot octopus	*Octopus bimaculoides*	1.66	0.8	92
EC	giant-spined sea star	*Pisaster giganteus*	1.65	0.8	92
AR	yellow crab	*Metacarcinus anthonyi*	1.45	0.7	93
EC	sunflower star	*Pycnopodia helianthoides*	1.43	0.7	94
CO	stalked sea squirt	*Styela clava*	1.38	0.6	94
EP	Bryozoan	*Thalamoporella californica*	1.28	0.6	95
AR	sheep crab	*Loxorhynchus grandis*	1.19	0.5	95
AR	yellowleg shrimp	*Farfantepenaeus californiensis*	1.18	0.5	96
AR	blackspotted bay shrimp	*Crangon nigromaculata*	1.16	0.5	97
MO	giant keyhole limpet	*Megathura crenulata*	1.14	0.5	97
AR	Pacific rock crab	*Romaleon antennarium*	1.09	0.5	98

Key: AR = Arthropoda, CO = Chrodata, EC = Echinodermata, EP = Ectoprocta, MO = Mollusca, PO = Porifera

In spring, the 12 species that each contributed 0.5% or more of the total survey biomass (Table 5-8; Appendix E-13) represented 96% of the total biomass, although they constituted only 16% of the species. Target shrimp were the largest component of biomass in spring, accounting for 38% of the survey total. The species was caught at every station except Station LA10. Unidentified sponges contributed the second highest biomass, although they were taken at only five stations. Highest sponge biomass occurred at Station LA16, where 67% of the total sponge biomass in the spring survey was taken. Xantus swimming crab was the only species that occurred at every station in spring, and the highest biomass of this species was taken at Stations LB2 and LA4. Among the remaining top species, ridgeback rock shrimp (*Sicyonia ingentis*) and giant-frond-aeolis (*Dendronotus iris*) were fairly evenly distributed, each being found at 16 stations throughout the Port Complex.

Table 5-8. Biomass (kg) of the 12 trawl-caught epibenthic species that contributed 0.5% or more to total biomass in spring.

Phylum	Common Name	Species Name	Overall Biomass	Percent of Total	Cumulative Percentage
AR	target shrimp	*Sicyonia penicillata*	60.51	38.1	38
PO	unidentified sponge	Porifera unid.	52.38	33.0	71
AR	Xantus swimming crab	*Portunus xantusii*	17.71	11.2	82
EC	California sea cucumber	*Parastichopus californicus*	6.49	4.1	86
AR	California spiny lobster	*Panulirus interruptus*	6.15	3.9	90
AR	ridgeback rock shrimp	*Sicyonia ingentis*	2.60	1.6	92
MO	California seahare	*Aplysia californica*	2.15	1.4	93
MO	giant-frond-aeolis	*Dendronotus iris*	1.19	0.7	94
AR	Pacific rock crab	*Romaleon antennarium*	0.97	0.6	95
MO	bay mussel	*Mytilus galloprovincialis*	0.95	0.6	95
AR	graceful crab	*Metacarcinus gracilis*	0.76	0.5	96

Key: AR = Arthropoda, EC = Echinodermata, MO = Mollusca, PO = Porifera

Cluster analysis of the 26 stations sampled in summer 2013, based on the 22 species that contributed most to the survey biomass (Table 5-7), resulted in seven station groups (Figure 5-16; Appendix E-15-A). Groups I-III were more closely related to one another than they were to Groups IV – VII. Group I (purple in Figure 5-16) included five Inner Harbor stations and one Outer Harbor station (LB1). Sponge was reported at all of these stations except LB1, which clustered with the others because of similar occurrences of other species such as target shrimp, Xantus swimming crab, California two-spot octopus (*Octopus bimaculoides*), and blackspotted bay shrimp. Group II (green in Figure 5-16), which included three stations in channels, clustered fairly closely with Group I, although California two-spot octopus did not occur at these stations. Group III (red in Figure 5-16) included Station LB12 and Station LA3, based on similar occurrences of the dominant species, particularly yellow crab (*Metacarcinus anthonyi*) and sheep crab (*Loxorhynchus grandis*).

The largest cluster of stations, Group IV (blue in Figure 5-16), was composed primarily of stations in the Outer Harbor, plus one Inner Harbor station (LB14). Generally, target shrimp and Xantus swimming crab were common at these stations and sponge was absent. Group V (orange in Figure 5-16) included only the stations in Channels 2 and 3, where the contribution by the top species was more diverse than elsewhere in the Port Complex.

Groups VI (yellow in Figure 5-16) and VII (brown in Figure 5-16) clustered most distantly from the previous groups, based on the lower contribution to these communities by otherwise common species. Group VI included three stations in created shallow-water habitats where sponge was absent, target shrimp and Xantus swimming crab were not abundant, but California spiny lobster was common. Group VII clustered farthest from any other group and included a single station (LB10) from which sponge, target shrimp, and Xantus swimming crab were all absent.

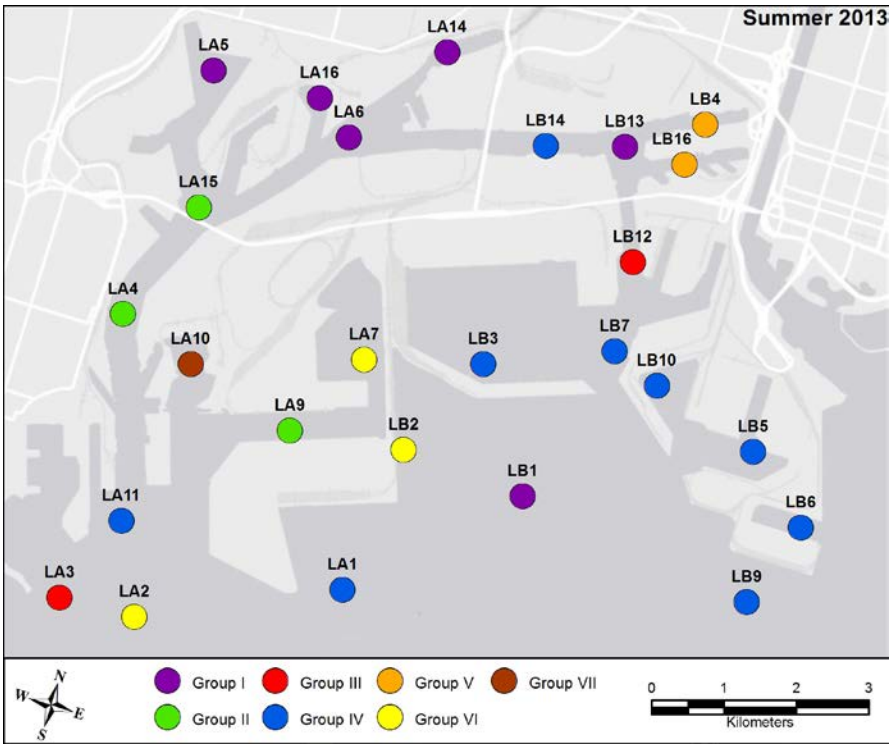


Figure 5-16. Major community groups identified by cluster analysis of the 22 epibenthic species that contributed most to seasonal biomass in summer.

Cluster analysis of the 26 stations sampled in spring 2014, based on the 12 species that contributed most to the survey biomass (Table 5-8), resulted in six station groups (Figure 5-17; Appendix E-15-B). Groups V and VI clustered most closely together and most distant from Groups I through IV. Group I (purple in Figure 5-17) included three Outer Harbor stations and three Inner Harbor stations. Clustering of the stations was based on similar occurrences of target shrimp, Xantus swimming crab, and giant-frond-aeolis. Group II (green in Figure 5-17) included three stations on the Los Angeles side where sponge was common. Group III (yellow in Figure 5-17) included the three stations at created shallow-water habitats on the Los Angeles side. Group IV (brown in Figure 5-17) clustered farthest from Groups I through III, and included only Fish Harbor, where target shrimp was absent and graceful crab was most abundant.

As in summer, the largest group in spring (Group V, blue in Figure 5-17) was composed of stations in the Outer Harbor. Generally, target shrimp, Xantus swimming crab, and ridgeback rock shrimp were common at these stations, and contributions by the remaining nine species were low or they were absent. As in summer, Group VI (orange in Figure 5-17) was characterized by the presence of more of the top species than elsewhere in the Harbor Complex and, as in summer, included the stations in Channels 2 and 3.

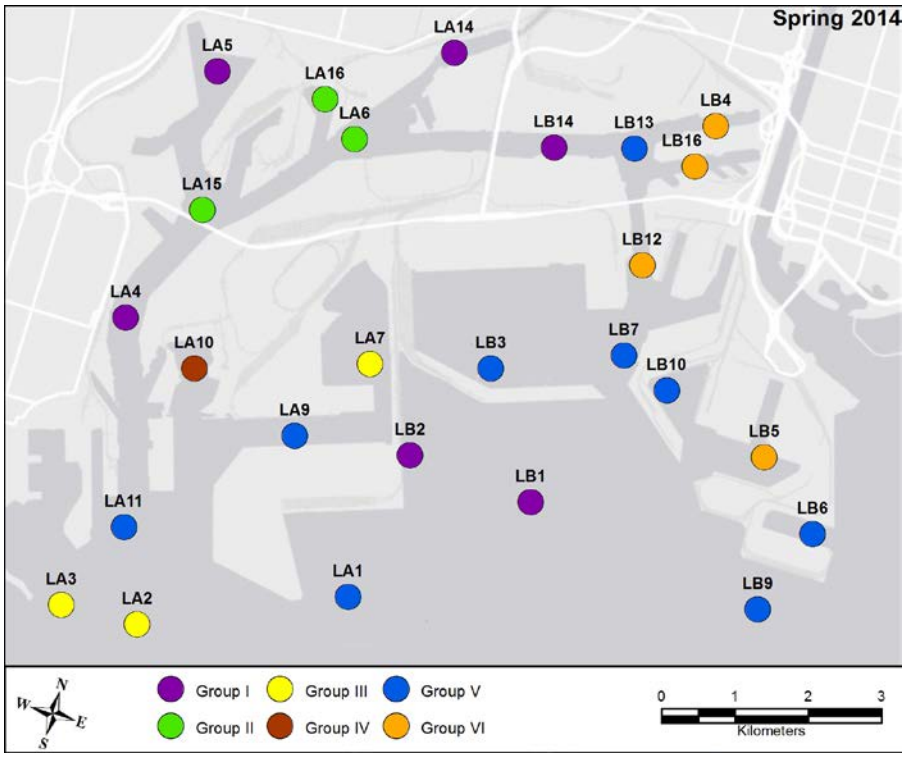


Figure 5-17. Major community groups identified by cluster analysis of the 12 epibenthic species that contributed most to seasonal biomass in spring.

DISCUSSION

BENTHIC INFAUNA

Abundances of benthic infauna in the Port Complex were slightly higher in summer than in spring, at Outer Harbor stations than at Inner Harbor stations, and at shallow stations than at deep stations (Figure 5-18). Abundance appeared to be strongly influenced by depth: mean abundance at the seven shallow stations (4–7 m) was more than twice that at deep stations (9–24 m). Substantial differences in abundance were also found between the five shallow-water habitat stations in areas created for mitigation (Stations LB2, LA2, LA3, LA7, and LA8) and the two other shallow stations in the Port Complex (Stations LA10 and LA14): mean abundance at the shallow-water habitat stations was about 40% greater than the mean for the two other shallow stations. The relatively poor sediment quality at one of the non-mitigation stations (Station LA14; Appendix E-9) may account for much of the difference. In addition, the five created shallow-water habitats are located in the Outer Harbor whereas Stations LA10 and LA14 are located in the Inner Harbor. For purposes of mitigation, resource agencies have not considered depth a factor affecting habitat quality in the Inner Harbor.

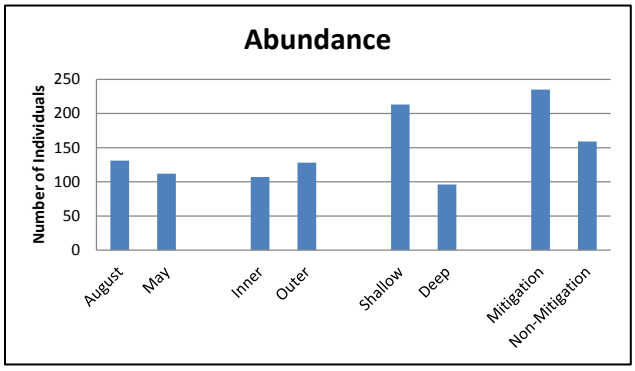


Figure 5-18. Mean infaunal abundance by season and location in the Port Complex.

Abundance was consistently low at three stations on the Long Beach side of the Port Complex (LB14, LB3, and LB6) and three stations on the Los Angeles (LA11, LA12, and LA1). Large differences in abundances between summer and spring were seen at a few stations, such as LB16 and LA15 (high in summer, low in spring) and LA16 (very high in summer, average in spring). These differences may be due to the inherent patchiness of infaunal communities: in 2000, mean abundances for samples taken at adjacent stations in the shallow-water habitats differed by up to 45%.

These results are generally consistent with those of recent surveys conducted in the Port Complex. In two previous studies (MEC 1988, SAIC 2010), abundance was highest in summer, and higher in the Inner Harbor than in the Outer Harbor (in the 1986-1987 study [MEC 1988] only the Los Angeles side of the Port Complex was sampled). In the 2000 study, however (MEC 2002), abundance was higher in winter and higher in the Outer Harbor (MEC 2002). Abundance was substantially higher at shallow stations than at deep stations in all surveys except 1986–1987 (MEC 1988), when it was slightly higher at deep stations. Although abundances at all stations have varied through time, a few stations (LA2, LA7, LA14, LA16, and LB9) have consistently had high abundances in most surveys. Consistently low abundances have been seen at Stations LA1, LA11, LA12, LB6, and LB14.

Abundance has declined over time from a mean of 4,100 individuals/m^2 in 2000 to about 1,860 individuals/m^2 in 2008 and 1,215 individuals/m^2 during the 2013–2014 study. Reduction in infaunal organism abundance, along with an increase in diversity, is indicative of a successional shift in the community over time following stress or disturbance (Wilber and Clark 2007). As environmental stress is reduced, opportunistic species that initially occur in high numbers are replaced by larger and longer-lived organisms, resulting in a benthic community characterized by lower abundance but higher diversity compared to previous communities. Long-term abundance trends suggest that environmental conditions of the benthic habitat have improved throughout the Port Complex since the 2000 survey, continuing the improvement in benthic habitat conditions throughout the Port Complex from the earliest harbor-wide monitoring surveys.

In the present study, species richness was greater in summer (a total of 261 species and a mean of 37 species per station) than in spring (a total of 238 species and a mean 33 species per station) (Figure 5-19), higher in the Outer Harbor (40 species per station) than in the Inner Harbor (30 species), and slightly higher at shallow stations (36 species per station) than at deep stations (35 species). The number of species was also considerably higher at the stations in the shallow-water habitats created for mitigation in the Outer Harbor (a mean of 40 species per station) than at the two shallow stations in the Inner Harbor, which had a mean of 28 species per station (as noted above, however, water depth in the Inner Harbor has not been a factor in habitat quality considerations).

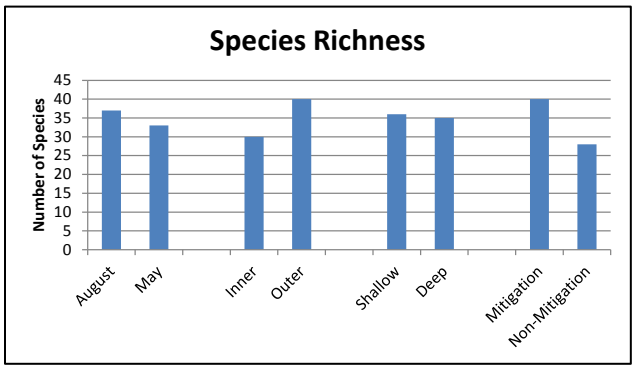


Figure 5-19. Mean infaunal species richness by season and location in the Port Complex.

Species richness in this study was quite similar to that reported in previous studies, ranging from 31 species in 2008 to 36 species in 2013–2014. Except in 2000, species richness was higher in summer than winter, and higher in the Outer Harbor than in the Inner Harbor (MEC 1988, 2002; SAIC 2010). In all surveys, species richness was higher at the shallow-water habitats created in the Outer Harbor than at shallow stations in the Inner Harbor.

Biomass has differed substantially among surveys, ranging from a mean of 37 g/m^2 in 2013–2014 to 121 g/m^2 in 2008. The present study found few spatial or seasonal patterns in biomass (Figure 5-20). The greatest difference was between Inner and Outer Harbor stations: biomass was about 40% greater in the Outer Harbor than in the Inner Harbor.

Previous studies also reported differences in biomass between shallow and deep stations: biomass was somewhat greater at shallow stations in 1986–1987 and 2000, but greater at deep stations in 2008; it was also slightly greater at the shallow-water habitats created in the Outer Harbor than at the Inner Harbor shallow stations in 2000 and 2008.

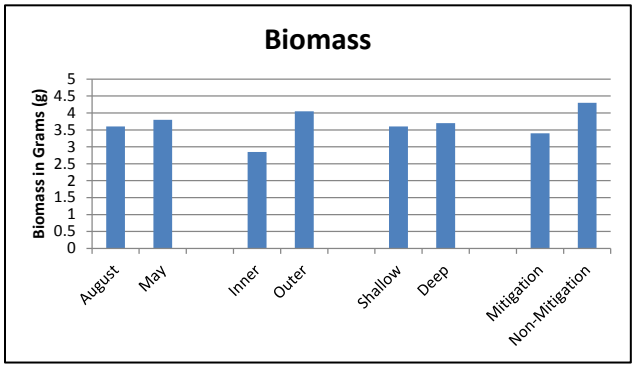


Figure 5-20. Mean infaunal biomass by season and location in the Port Complex.

As in the present study, little difference in diversity was seen between seasons or locations in previous studies (MEC 1988, 2002; SAIC 2010). The general pattern in previous studies was similar to that of the present study: higher diversity in the Outer Harbor, at deep stations, and in the created shallow-water habitats. Overall mean species diversity was lowest in 2008 and highest in 2013–2014.

As described above, harbor-wide mean Benthic Response Index (BRI) values were similar between summer and spring, but they differed considerably by location (Figure 5-21). Mean BRI at the shallow stations was almost twice that of deep stations, which was the result of the very high values at the two Inner Harbor shallow stations (LA10 and LA14). For the same reason, the mean for the two stations that were not in the shallow-water habitats created for mitigation was almost twice that of the mitigation-site stations in the Outer Harbor.

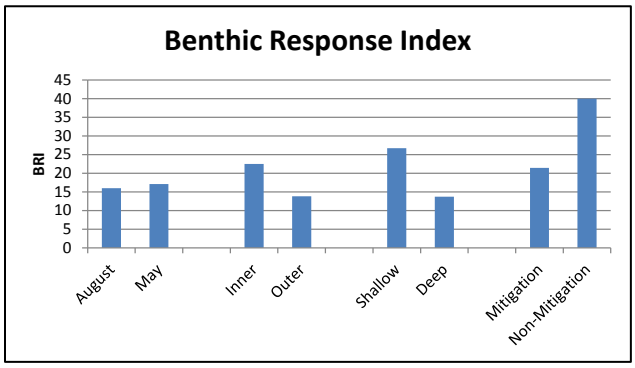


Figure 5-21. Mean BRI by season and location in the Port Complex.

Generally, higher BRI values (indicating greater disturbance) coincided with the presence of certain species that were moderately to very abundant, such as the polychaete annelids *Capitella capitata* Cmplx, *Euchone limnicola*, *Pseudopolydora paucibranchiata*, *Aphelochaeta glandaria* Cmplx, and *A. petersenae*, and oligochaete annelids (Appendix E-2). Low values, indicating little disturbance, coincided with numerical dominance by the amphipod *Amphideutopus oculatus*, the polychaetes *Paramage scutata* and *Aphelochaeta monilaris*, and the brittle-star *Amphiodia urtica*. BRI values for each survey were plotted on a relative scale against depth and grain size (Appendix E-8). The plots show that BRI was higher at shallow stations than at deep stations and that at deep stations BRI values were greater at stations where sediments were finer.

Target shrimp (*Sicyonia penicillata*) caught during epibenthic sampling.

BRI was not evaluated in previous Port-wide studies. MEC (2002) included a list of benthic species reported to be representative of background, organically enriched, and polluted habitats, but the comparison of locations with respect to habitat quality relied on the cluster analysis rather than a pollution-specific index. That analysis indicated that in both that study and the 1986-1987 study (MEC 1988), Station LA14 in the Consolidated Slip formed a separate cluster group, characterized by a suite of pollution-tolerant organisms. It also showed that that the station in the Consolidated Slip sampled by the HEP studies (HEP 1979) clustered only with the stations in and around Fish Harbor. These results suggest that the degree of sediment contamination in the Consolidated Slip was sufficient to set that area apart from the rest of the Port Complex. In the 2008 study, however, as in the present study, Station LA14 clustered with other stations, primarily Inner Harbor stations. Similarly, Station LA10 in Fish Harbor has clustered with a few other, mostly Inner Harbor, stations in dead-end slips and basins in all studies through 2008. Only in the present study has Station LA10 formed its own cluster group. In every case, however, the species assemblage at Station LA10 included pollution-tolerant species as either dominant or very abundant.

While BRI was not determined in previous harbor-wide studies, BRI was evaluated in samples collected in the Port Complex during regional studies conducted in summer 2003 and summer 2008. During the 2003 study, BRI was evaluated at 13 stations within the footprint of the current study: 31% of the stations, all within the Outer Harbor, were in the Reference category, indicating that the communities were healthy; 61% of the stations, including Inner Harbor and deep and shallow Outer Harbor stations, indicated Low Disturbance; and one station (8% of the total) in the East Basin of the Port of Los Angeles indicated moderate disturbance (Ranasinghe et al. 2007). In 2008, 25% of the 24 stations sampled in the Port Complex, again mostly Outer Harbor stations, were in the Reference category, 67% of the stations, including inner, and deep and shallow outer harbor stations, indicated Low Disturbance, and two stations (8%) in the Los Angeles West Basin and East Basin indicated Moderate Disturbance (Ranasinghe et al. 2012). No Moderate or High Disturbance stations were indicated during the present study and only one station in summer (3% of all stations) in Fish Harbor and two stations (6%) in spring in Fish Harbor and Consolidated Slip fell into the Low Disturbance category. These results, similar to those found for abundance, suggest an improvement in benthic conditions throughout the Port Complex since the earlier regional monitoring surveys.

Cluster analysis in the present study showed patterns similar to those of abundance, species richness, and BRI (habitat types and ranges of physical characteristics and infaunal parameters for the cluster groups are shown in Appendix E-9). The communities were different between the Inner Harbor and Outer Harbor, between shallow and deep stations, and between shallow open water (including some of the shallow-water habitat sites) and shallow basins. Water circulation appears to be the largest influence on benthic communities. Abundance, species richness, biomass, and diversity were lower, and BRI was higher, in the Inner Harbor, where most of the sampling stations were in dead-end slips and basins with reduced water circulation. At some of these locations, dissolved oxygen at the bottom was below 5 mg/L during the summer survey. Among the Inner Harbor stations, Fish Harbor and Consolidated Slip support community types that tolerate contaminated sediments. Seaplane Lagoon, where modeling has shown water circulation to be restricted (e.g., Figure 1-3), also supports a pollution-tolerant community. The created shallow-water habitats in the Outer Harbor had communities with high abundance and moderate to high diversity, but BRI was higher than at the other open-water areas of the Outer Harbor. Station LA11 in the Outer Harbor consistently differed from all other Outer Harbor stations, with low abundance and species richness; in spring the community at that location resembled that at the Los Angeles Turning Basin. Another unusual grouping was Station LB8. In summer, its community resembled other Outer Harbor communities, but in spring the community was more like some of those in the Inner Harbor.

Similar cluster groups were seen in previous surveys (HEP 1976; MEC 1988, 2002; SAIC 2010). In all of these studies, the most consistent differences in the Port Complex were between communities in the Inner Harbor and those in the Outer Harbor, and, in the Outer Harbor, between shallow water and deep water. However, improvements in environmental conditions have occurred in the Port Complex since the 1950s due to greater control of discharges throughout the watershed, as well as changes in port activities. As a result, species richness and diversity have risen, the communities are less dominated by opportunistic, pollution-tolerant species, and species that are sensitive to pollution have become more common. In 1954, only one pollution-sensitive species was among the top ten species in a harbor survey (Appendix E-10). The number of pollution-sensitive species has gradually increased, and in the present study, a pollution-sensitive species, *Amphideutopus oculatus*, was the most abundant species for the first time. This species was one of the ten most abundant species for the first time in surveys in 1994 and 1996 (SAIC/MEC 1997). Five other pollution-sensitive species were also among the ten most abundant in the present study.

Of the 344 infauna species found in the present study, eight have been classified as introduced (non-native or non-indigenous), 55 are considered cryptogenic (native range or region unknown), and six are unresolved (species complexes, including more than one species, or questionable identification). These species will be discussed in the Non-native Species section, Chapter 11.

EPIBENTHIC INVERTEBRATES

In the present study, the abundance of trawl-caught epibenthic invertebrates in the Port Complex varied with season, time of day, and location (Figure 5-22). Mean abundance was about one-third lower in summer than in spring, and during both seasons abundance was substantially lower in day trawls than in night trawls. Slightly more individuals were taken at Inner Harbor stations than at Outer Harbor Stations and at shallow-water stations in the Inner Harbor than at the shallow-water stations created in the Outer Harbor for mitigation. Abundance appeared to be somewhat influenced by depth: mean abundance at the six shallow stations (4–7 m) was about 25% lower than at deep stations (9–24 m).

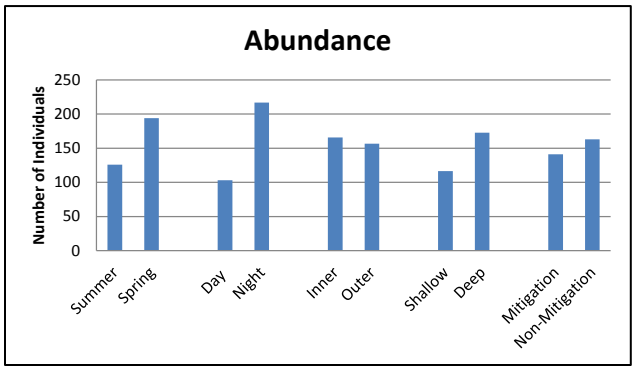


Figure 5-22. Mean epibenthic invertebrate abundance in the Port Complex.

During both seasons, abundance was dominated by arthropods, particularly target shrimp, blackspotted bay shrimp, blacktail shrimp (*Crangon nigricauda*), ridgeback rock shrimp, Xantus swimming crab and tuberculate pear crab (*Pyromaia tuberculata*). Except for the tuberculate pear crab, these species are highly mobile and often found in large aggregations. They likely move though the Port Complex in response to variations in prey and predator abundances, water quality conditions, tides and currents, and diel rhythms. Small species such as *Crangon* shrimp and tuberculate pear crab likely reduce activity during the day to avoid visual predators. Increased activity at night by those species probably contributed most to the observed day/night differences.

While high abundance was not associated consistently with any station during these surveys, low abundance was. Mean abundance at Station LA10 was only 22% of the mean abundance for the Port Complex in summer, and only 4% in spring (Appendix E-12). Despite historically low abundances in Fish Harbor, generally attributed to pollution (Reish 2002), the 2008 study found that abundances of epibenthic invertebrates in Fish Harbor were not notably different from those in other areas of the Port Complex (SAIC 2010). Because the station was not sampled for epibenthos during the 2000 survey (MEC 2002) or the 1986-1987 survey (MEC 1988), no other comparisons are possible. The reason for reduced numbers of epibenthic invertebrates in Fish Harbor in the present study compared to other areas in the Port Complex is unknown.

The 16,607 individuals of epibenthic invertebrates taken in trawl samples in the present study was considerably higher than the totals reported from the 2000 study, when 9,185 individuals were caught, and the 2008 study, when 7,043 individuals were reported (MEC 2002; SAIC 2010). This is despite the fact that although all three studies used the same sampling methods, the present study actually conducted somewhat fewer trawls than the previous studies. Sampling for this study took place in two seasons at 26 stations (52 trawls), whereas the 2000 study conducted trawling during four seasons at 14 stations (56 trawls) and the 2008 study

conducted trawling three times per year at 19 stations (57 trawls). While differences in numbers of stations and seasons sampled make direct comparisons difficult, some trends between the surveys are apparent. The mean catch per trawl in the present study (160 individuals) was more than two and a half times higher than in either of the previous two harbor-wide surveys. As in the present study, the 2000 and 2008 studies collected greater numbers of epibenthic invertebrates at deep stations than at shallow stations, and greater numbers at night than in the daytime (Figure 5-23). As in the present study, abundance in the 2000 and 2008 studies was dominated by arthropods (MEC 2002; SAIC 2010). Because epibenthic invertebrates were not reported from beach seine sampling in surveys conducted in 2000 or 2008 (MEC 2002; SAIC 2010), no comparisons with the present study are possible.

One-hundred and ten epibenthic invertebrate species were reported in trawl sampling in the Port Complex (Table 5-4). Mean species richness per station showed little variation between seasons, day and night trawls, Inner and Outer Harbor, and shallow and deep locations (Figure 5-24). Slightly more species (11) were taken on average at stations in the created shallow-water mitigation areas in the Outer Harbor than at the non-mitigation shallow-water stations in the Inner Harbor (nine).

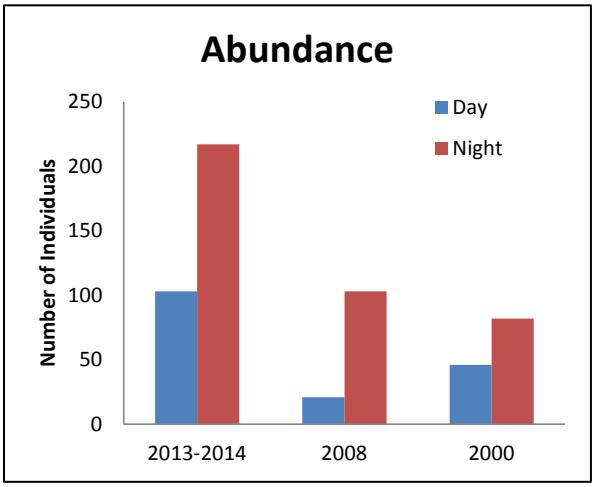


Figure 5-23. Epibenthic invertebrate abundance in day and night trawl in recent studies of the Port Complex.

The 110 epibenthic invertebrate species reported in trawl samples in 2013–2014 was considerably higher than the 61 species caught during both of the previous harbor-wide studies (MEC 2002; SAIC 2010). The overall mean number of species per station for this survey was higher than in 2000 (six species) and was the same as the mean number of species reported in 2008 (MEC 2002, SAIC 2010).

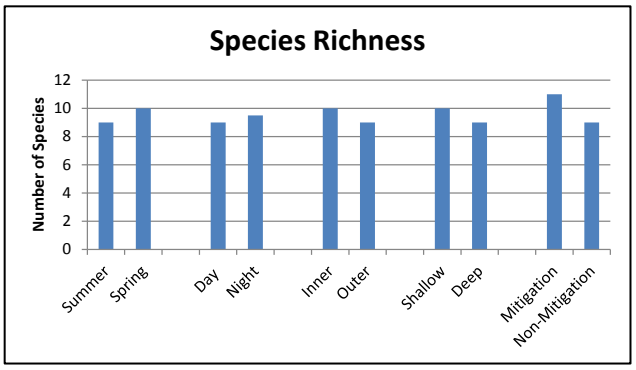


Figure 5-24. Epibenthic species richness by season and location in the Port Complex.

Mean biomass of trawl-caught epibenthic invertebrates was about 25% lower in spring than in summer, although no marked difference between day and night trawls was apparent (Figure 5-25). Mean biomass was more than twice as high at Inner Harbor than at Outer Harbor stations and twice as high at deep stations as at shallow stations. Biomass was also higher at the Inner Harbor shallow stations than at the Outer Harbor shallow stations created for mitigation. These

patterns generally reflect the patterns or abundance, although, as discussed in the results section, they tended to be skewed by occasional occurrences of large individuals.

Mean biomass per trawl varied considerably between this and the previous harbor-wide studies (Figure 5-26). Biomass in the current study was seven times that reported in 2008, and three and one-half times higher than in 2000 (MEC 2002; SAIC 2010). These differences are likely attributable to the high biomass of sponge taken in the present study. Sponge was not reported in trawl samples from the 2000 study, and was only a minor contributor to the epibenthic community in 2008.

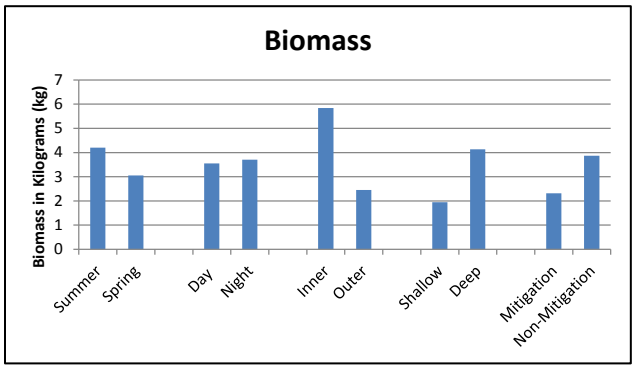


Figure 5-25. Biomass (kg) of epibenthic invertebrates by season and location in the Port Complex.

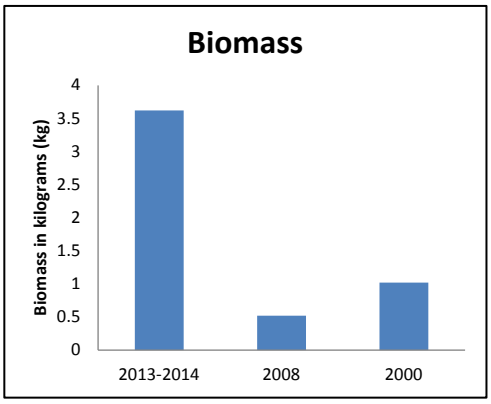


Figure 5-26. Mean epibenthic invertebrate biomass (kg) per trawl in recent studies of the Port Complex.

Another factor in the increase in biomass may be a change in the size of the most abundant organisms. While arthropods were numerically dominant in all three surveys, the most common species in 2000 were blackspotted bay shrimp and tuberculate pear crab, which together accounted for nearly 80% of the total abundance. These are both relatively small species, averaging less than one gram per individual (based on data from the current survey), compared to target shrimp, the most abundant species in the present study, which averaged 14 grams per individual. The combined abundance of blackspotted bay shrimp and tuberculate pear crab in 2000 was higher than that of target shrimp in 2013–2014, but this difference in abundance was more than offset by the larger size of the target shrimp. Similarly, in 2008, four species together accounted for 80% of the biomass: blackspotted bay shrimp, ridgeback rock shrimp, blacktail shrimp, and Xantus swimming crab. Ridgeback rock shrimp and Xantus swimming crab may be of comparable weight to target shrimp, but because the combined abundance of the four top species in 2008 was lower than the abundance of target shrimp alone in 2013–2014, their biomass was substantially lower than the biomass of target shrimp.

In the present study, diversity was slightly higher in summer than in spring, at night than during the day, at Inner Harbor than Outer Harbor, at shallow than at deep, and at stations in mitigation sites than at stations at non-mitigation shallow sites (Figure 5-27). None of these differences

were substantial, however, with mean station diversity differing by only about 0.1 units in any comparison.

Despite the determination of diversity based on biomass in this study, instead of abundance as was used in previous studies, mean diversity per trawl was similar among the studies (Figure 5-28). Lowest diversity was found during the 2008 study and highest during the present study (MEC 2002; SAIC 2010).

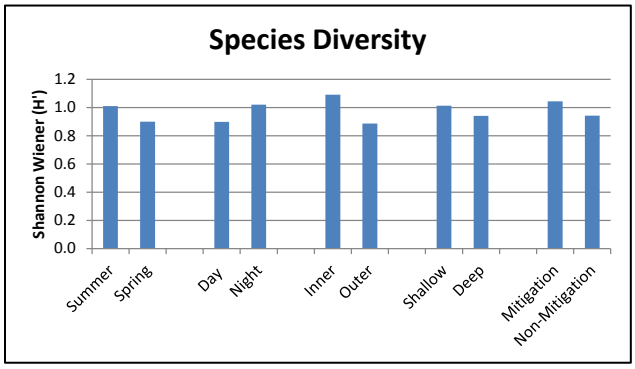


Figure 5-27. Mean epibenthic invertebrate diversity by season and location in the Port Complex per station by season and location in the Port Complex.

The ability to compare trawl-caught epibenthic invertebrate community clustering in the present study to that of previous studies is limited. Dendograms for the epibenthic assemblage were not provided for the 2008 survey (SAIC 2010), and while MEC (1988) provided community information for their study of Los Angeles Harbor, the area surveyed was much more limited than that of the present study. MEC (2002) conducted a cluster analysis of stations based on similarities of the epibenthic assemblages, but differences in the numbers of stations between that study and the present study limits comparability. As in the present study, the 2000 study found that stations in the Outer Harbor on the Long Beach side of the Port Complex grouped together, as did Outer Harbor basin stations. Shallow stations throughout the Port Complex also generally grouped together in 2000.

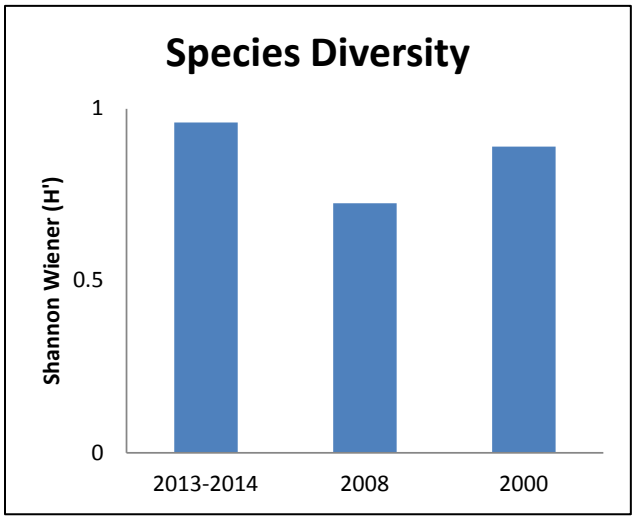


Figure 5-28. Epibenthic invertebrate diversity in recent studies of the Port Complex.

The greatest difference between the two studies was related to Inner Harbor stations. In 2000, an area from the Los Angeles Turning Basin to Long Beach Channel 3, including both East and West Basin and the Consolidated Slip on the Los Angeles side, the Cerritos Channel, and the Long Beach Turning Basin, grouped together into a single community type, which was essentially the Inner Harbor. In 2013–2014, several of those stations clustered, either in summer or in spring, into station groups that included Outer Harbor stations. This was particularly true of Station LA5 (LA West Basin), Station LA14 (Consolidated Slip), and Station LB13 (LB Turning Basin) in spring, and Station LB14 (Cerritos Channel) and Station LA15 (LA

Turning Basin) in summer. Based on recurring dominant species, the community in Channels 2 and 3 in 2013–2014 appears to be the most similar to that found throughout the Inner Harbor in 2000. The clustering of formerly Inner Harbor stations in the turning basins and Cerritos Channel with Outer Harbor stations in 2013-2014 suggests an improvement in habitat quality in the navigational channels since the 2000 study.

Xantus swimming crab (*Portunus xantusii*) caught during epibenthic sampling.

Of the 110 trawl-caught epibenthic invertebrate species found in the present study, eight have been classified as introduced (non-native or non-indigenous). No cryptogenic (native range or region unknown) or unresolved species (species complexes, including more than one species, or questionable identification) were taken. Of the seven invertebrate species caught in beach seine sampling, one species was introduced. These species will be discussed the Non-native Species section, Chapter 11.

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CHAPTER 6 RIPRAP BIOTA

This section presents the results of surveys of riprap communities conducted throughout the Port Complex during 2013-2014. In the Port Complex, riprap habitat includes the boulders of the outer breakwaters, armor rock and concrete rubble that lines much of the shoreline within the Ports, and pier and wharf pilings. Riprap provides hard-substrate habitat similar to that found on rocky coasts and reefs. The habitat extends from the splash zone, which may only occasionally be submerged on the highest tides, through the intertidal zone, where the community is submerged and exposed twice per day, to the subtidal zone, where the biota is always submerged. Depending on location in the Port Complex, riprap communities may be exposed to seasonal storm surge and high waves, ship and boat wakes, and muted tidal changes year round. Riprap supports a unique biotic community adapted to, and, in many cases, attached to, the substrate.

MATERIALS AND METHODS

Riprap biota (invertebrates and algae) was surveyed in summer, between 17 and 19 September 2013, and in spring, between 15 and 30 May 2014. Surveys occurred in three depth zones at each of eight stations (four in each harbor; Figure 6-1; Table 6-1): upper intertidal, middle-lower (mid-low) intertidal, and subtidal, consistent with methods used by SAIC (2010). Station descriptions, including approximate subtidal sampling depth, are presented in Appendix F-23, and surface photos of each station are provided in Appendix F-24. Seven of the stations were located on the boulders of riprap and the Middle Breakwater, but Station LARR3 was located on a flat-sided piling supporting a wharf. Depth zones for the survey were delineated based on a combination of biological and tidal factors: the upper intertidal was located in the equivalent of the barnacle zone, the mid-low intertidal was sampled at a depth equivalent to the mussel zone, and the subtidal was sampled near the deepest extent of the riprap, but about 1 to 2 meters (m) above the soft-substrate bottom in order to avoid the ecotone/highest sedimentation zone. This approach resulted in different sampling depths at each station, since no two stations had the same water depth (Appendix F-23). Two sampling methodologies were employed at each station: scraped quadrats consistent with methods used in previous harbor-wide surveys, and a rapid assessment protocol developed for this survey. The two methods were performed side-by-side in order to compare their effectiveness and determine whether to use only the rapid assessment method in future surveys, given its potential to save considerable resources.

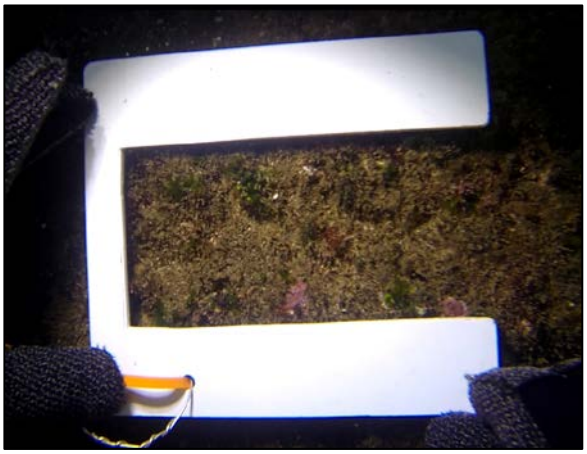


Photo of 112.5 cm^2 quadrat before scraping.

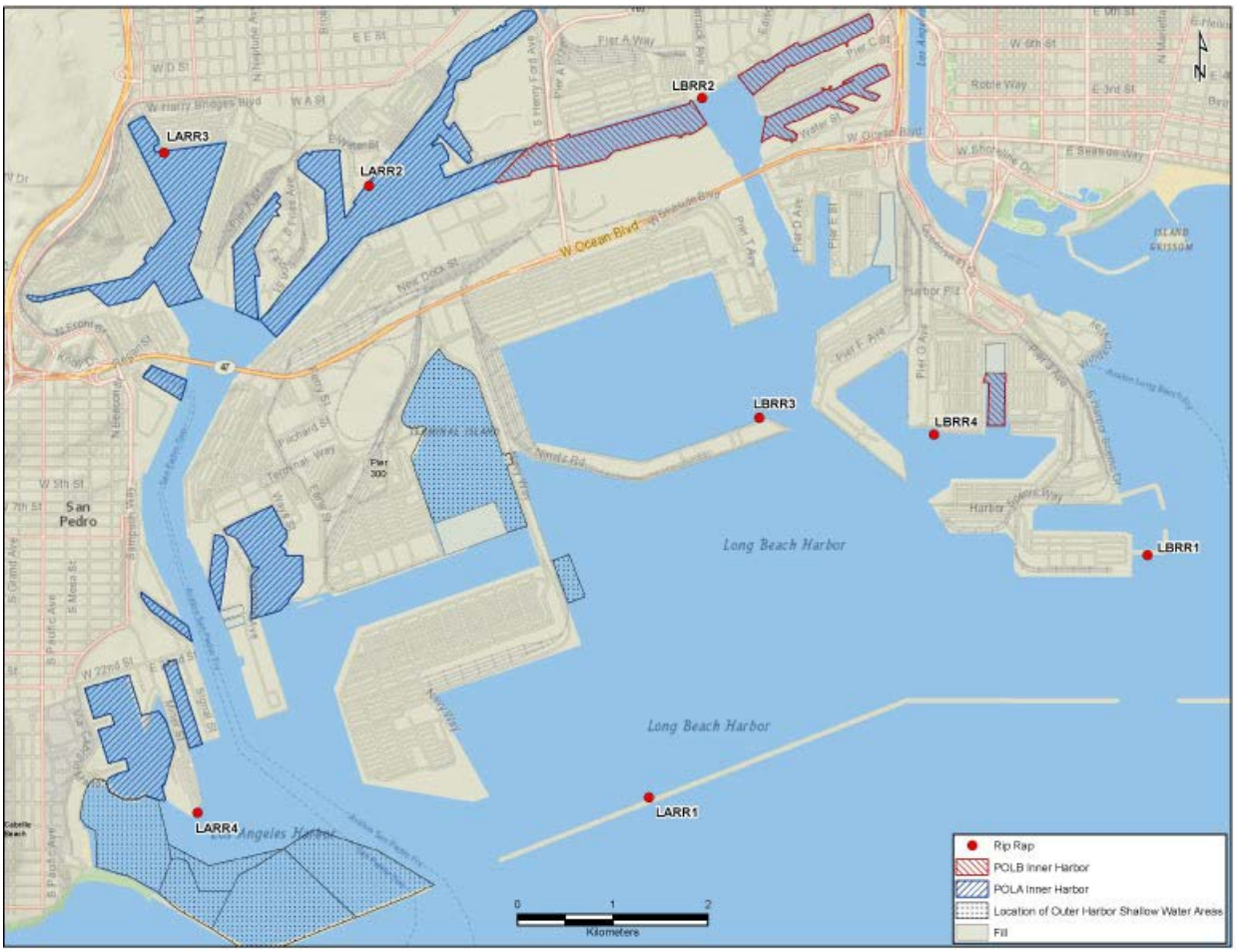


Figure 6-1. Locations of riprap stations.

SCRAPED QUADRATS

At each station and depth zone, all of the organisms in each of two quadrats were scraped off the substratum with a chisel and transferred to 333-µm mesh bags. The quadrats were 7.5 centimeter (cm) x 15 cm, for a sample area of 112.5 cm^2 each. Photos of each quadrat were taken before sampling. The organisms collected from each scraped quadrat were removed from the 333-µm mesh bags, transferred to pre-labeled jars, and preserved in 10% formalin-seawater solution. In the laboratory, the samples were transferred using 250-µm mesh screens to 70% isopropyl alcohol and sorted into major phyla using a microscope. Individuals were then identified to the lowest practical taxonomic level, usually species, and enumerated by taxon. Colonial organisms and algae were recorded in relative terms (e.g., present, common, abundant, and very abundant).

Table 6-1. Stations used for riprap sampling.

Station	Designation/Location	Harbor Type	Station	Designation/Location	Harbor Type
LARR1	Middle Breakwater	Outer	LBRR1	Pier J Breakwater	Outer
LARR2	LA East Basin	Inner	LBRR2	LB Turning Basin	Outer
LARR3	LA West Basin	Inner	LBRR3	West Basin Navy Mole	Outer
LARR4	Berth 48	Outer	LBRR4	Southeast Basin	Outer

Note: Station LARR3 was the only station on a concrete wharf piling; all other stations were on boulder riprap.

After identification, organisms were batch-weighed by phylum. Community measures reviewed included:

- Abundance of enumerated organisms and relative abundance of non-counted organisms;
- Species richness (number of species or unique taxa);
- Biomass by phylum;
- Shannon Wiener species diversity (H') ($-\Sigma pi \times \ln(pi)$, where pi is the count for species i) based on enumerated taxa;
- Community composition analysis based on enumerated taxa.

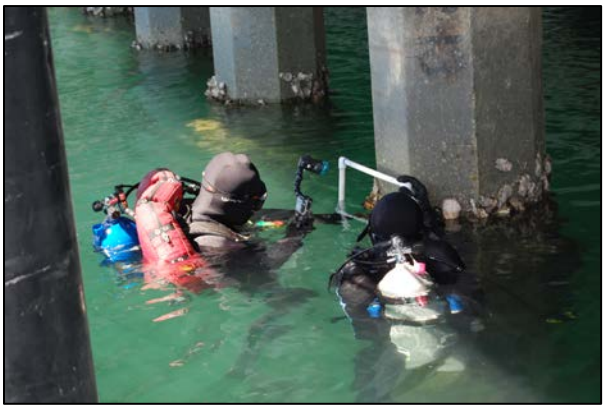
RAPID ASSESSMENT

The rapid assessment methodology was developed for this study to provide tiered sampling frames working from a smaller scale (photo quadrats and short transects at each end of the station) to a larger scale (longer transects in the middle of the station). Four stations were sampled in the Port of Long Beach and four in the Port of Los Angeles (Figure 6-1). Under this sampling approach, each station (including the upper intertidal, lower intertidal, and subtidal zones) was documented in the field using video, followed by post-collection video analyses. All video was collected using a GoPro® submersible video camera. Still photos were captured from the video file. Survey plots and transects progressed along a constant isobath within each depth zone as follows:

(1) Eight 0.28-m x 0.45-m (1/8-m^2) macro quadrat video/still photos were taken with stationary video using a plot frame to allow animal movement to be seen (one minute per plot). In the laboratory, video was scanned to determine the best still footage that included the entire plot and at an angle nearing 90 degrees directly above the plot. The image was then copied and pasted into Adobe Photoshop, and a 100-point grid was overlaid on the photograph to fit within the plot boundary. Using a point-contact method, the organism at each of the 100 points was recorded and percent cover was calculated based on 100 possible points. For example, if 20 of 100 points fell on urchins, the plot consisted of 20% urchins. Biota was identified to the lowest possible taxonomic level, but

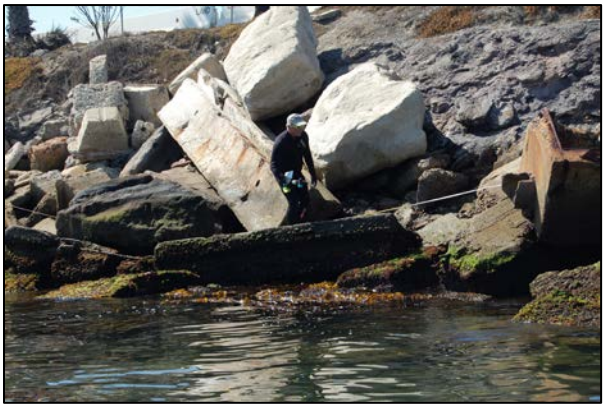
in many cases, low resolution or visibility resulted in grouping of similar taxa. When organisms were layered, only the top layer was identified and recorded. Points were scored as “unidentifiable” or “silt covered unknown” when the resolution of the photograph or coverage by silt prohibited identification. Points were scored as zero when they fell on non-biotic substrate, such as bare rock or sand. When a plot did not fit completely on a rock or when the view was obstructed by water drops on the lens or by parts of the camera equipment, the point was “unscorable” and percent cover was calculated based on the total number of scorable points.

(2) Four 1-m x 1-m quadrat (1-m^2) close video searches of the riprap were undertaken, including a distant and a macro search of the plot. Footage was scanned, and non-biotic substrata and biotic cover were visually ranked from the most abundant to least abundant within the plot. Each taxon or substrate type was assigned a relative percent cover based on the following categories: 7 = 90–100%, 6 = 75–90%, 5 = 50–75%, 4 = 25–50%, 3 = 10–25%, 2 = 2–10%, and 1= <2%. In many cases, resolution of the video or coverage of biota by silt prohibited identification, which were then scored “unidentifiable or “silt covered unknown”. When layering of organisms occurred, only the top layer was identified.



Divers video surveying 1-m^2 quadrat.

(3) Video footage was taken along two 10-m transects and one 50-meter transect in each depth zone at each station using an underwater video camera. Videographers swam along each transect, but the distance above the transect was highly variable, so the total area observed in the video was unknown. Conspicuous organisms were ranked based on estimated relative abundance on the following scale: 4 = abundant, 3 = common, 2 = uncommon, and 1 = rare. Organisms were identified to the lowest taxonomic level possible. The relative abundance of silt, sand, or mud was also estimated. Organisms that were unidentifiable to any taxonomic level, such as “silt covered unknowns”, were not included in the analyses.



Video survey of 50-m transect.

These three methodologies were conducted at each of the eight sites and three zones in summer 2013. Once sampling and data processing were completed, the methods were modified to address difficulties assessing community information from small plots using video, quadrat placement, view scaling, and excessive field sampling effort. A summary of sampling methods utilized during the spring 2014 survey, along with modifications and justifications for the changes, are provided in Appendix F-25. The changes included:

(1) Still photos were reduced to 1/8 m^2 plots using a plot frame.

(2) The 1-m^2 quadrats were located to the extent possible on the top of horizontal surfaces, except at piling stations.

(3) For the video transects, a two-meter-long rod marked at quarter-meter increments was added to the center of the field of view of the transect tape to specify the distance away from transects that were sampled. The 50-m transect sampling was removed from the methodology and replaced with a third 10-m transect (accordingly, the summer survey had two 10-m transects and one 50-m transect while the spring survey had three 10-m transects). In spring, the transects were separated by at least five meters.

Data from both the summer and spring surveys were analyzed for a variety of biotic measures:

(1) The mean percent cover was calculated for eight 1/8-m^2 plots (but in a few cases six or seven plots) for each depth zone (upper intertidal [or high zone], mid-low [or low zone], and subtidal zone) for all eight sampled locations. Due to a high percentage of “silt covered unknown” and “unidentifiable”, other measures, such as community composition and diversity, could not be calculated accurately. The relative abundance of non-native species was also examined separately.

(2) In the 1-m^2 plots, the mean relative percent cover was calculated for four plots in each depth zone for the eight sampled locations. Because the contribution to percent cover by “silt covered unknown” and “unidentifiable” was notably lower than in the 1/8-m^2 plots, species diversity and community composition were calculated. For species diversity, the mean number of species (including higher level taxa) was calculated for each zone, station, and survey (or year). Community structure data were analyzed using PRIMER to produce both an MDS plot and a cluster analysis to compare similarities among zones, locations, and years. Plots with greater than 25% cover of unidentifiable biota were removed from the analyses; in some cases, this omitted sites, seasons, locations, and/or depth zones. The relative abundance of non-native species was also examined separately.

(3) In the video transects, the mean relative abundance ranking of conspicuous species/taxa and sand/silt was calculated from three transects in each depth zone at the eight sampled locations during both sampling seasons. Community structure data were analyzed using PRIMER to produce both a multi-dimensional scaling plot and a cluster analysis to examine similarities among zones, locations, and years. The relative abundance of non-native species was also examined separately.

RESULTS

SCRAPED QUADRATS

Five-hundred and fifty-eight species were found in the riprap biota in the Port Complex surveys in summer 2013 and spring 2014 (Appendix F-1). In summer, 25,183 individuals of 341 species was enumerated and another 88 colonial or algae species were identified, for a total of 429 species (Table 6-2; Appendices F-2 through F-5). In spring, 13,149 individuals of 288 species were enumerated and another 78 colonial or algae species were reported for a total of 366 species (Table 6-2; Appendices F-2 through F-5). Densities by station and by tidal level are presented in Appendices F-13 and F-14, respectively.

ABUNDANCE

In summer, the scraped quadrats at the eight stations in the Port Complex yielded an average of 3,148 individuals per station (46,637 individuals/m^2) (Table 6-2). Abundance was highest at Station LBRR2 with 6,696 individuals; more than half of the total belonged to a single amphipod species (*Monocorophium acherusicum*). Abundance was also high at Station LARR1 (4,111 individuals), and nearly one-half of the total was contributed by the reddish lepton clam (*Lasaea adansoni*). Lowest abundance was found at Station LARR2. In the summer survey, abundance averaged 551 individuals per quadrat (24,489 individuals/m^2) per station in the upper intertidal zone, 1,356 individuals (60,267 individuals/m^2) in the mid-low intertidal, and 1,241 individuals (55,155 individuals/m^2) in the subtidal (Table 6-3). Lowest abundance (18 individuals) in the summer survey occurred in the upper intertidal at Station LARR2 while the highest abundance (5,688 individuals) occurred in the subtidal at Station LBRR2 (Figure 6-2).

Algae dominated the non-enumerated species at stations in summer. The sea bubble (*Colpomenia sinuosa*) was ranked highest, particularly at Stations LBRR2 and LBRR4 (Appendix F-2). Sea lettuce *(Ulva* sp) and creephorn (*Chondracanthus* sp) were the second and third highest ranked species, respectively, and were most common at Stations LARR1, LBRR1, and LBRR3; these are all open-water stations in the Outer Harbor. Sea bubble was collected almost exclusively in samples collected at mid-low levels, while sea lettuce and creephorn occurred in relatively similar numbers in the mid-low and subtidal zones. Three species of bryozoans (ectoprocts) were particularly abundant: *Crisia occidentalis* was most common at Station LARR4, *Celleporaria brunnea* occurred primarily at Station LARR3 (the only pier piling station) and Station LARR4, and *Filicrisia* sp was most common at Stations LARR1 and LARR4. All of these species were reported primarily at the mid-low and subtidal levels, and of these only sea lettuce occurred in the upper intertidal.

In the spring survey, the abundance of enumerated species averaged 1,644 individuals per quadrat (24,355 individuals/m^2) for the eight stations in the Port Complex (Table 6-2). Abundance was highest at Station LARR3 with 3,561 individuals (nearly 60% was contributed by the caprellid amphipod *Caprella californica*) and at Station LBRR1 on the outer breakwater of Pier J, with 3,094 individuals (about one-third of which were brown acorn barnacles, *Chthamalus fissus*). Lowest numbers of individuals in spring were found at Station LBRR2 (where the highest abundance of enumerated species occurred in summer) and at Station LARR2.

Table 6-2. Riprap biota community parameters by station and survey. Totals are for all quadrats and levels combined by station.

Summer 2013	LBRR1	LBRR2	LBRR3	LBRR4	LARR1	LARR2	LARR3	LARR4	Survey Total	Survey Mean
Number of Individuals	3,123	6,696	3,393	2,183	4,111	483	2,215	2,979	25,183	3,148
Density (Number per m^2)	46,267	99,200	50,267	32,341	60,904	7,156	32,815	44,133	–	46,637
Total Number of Enumerated Species	112	100	114	103	127	25	105	149	341	104
Diversity (H')*	2.64	2.30	2.47	2.75	2.46	1.75	3.42	3.20	–	2.62
Number Colonial/Algae Species	19	14	32	28	25	8	26	38	88	24
Total Number of Species	131	114	146	1313,0	152	33	131	187	429	128
Biomass (g)	54	39	42	25	181	4	330	50	726	91
Density (g/m^2)	800	578	622	370	2,681	59	4,889	741	–	1,348
Spring 2014	**LBRR1**	**LBRR2**	**LBRR3**	**LBRR4**	**LARR1**	**LARR2**	**LARR3**	**LARR4**	**Survey Total**	**Survey Mean**
Number of Individuals	3,094	244	2,170	729	1,148	436	3,561	1,767	13,149	1,644
Density (Number per m^2)	45,837	3,318	32,148	10,800	17,007	6,459	52,756	26,178	–	24,356
Number of Enumerated Species	134	25	106	52	98	77	103	88	288	85
Diversity (H')*	2.82	2.15	3.21	1.58	2.92	3.23	1.80	2.69	–	2.55
Number Colonial/Algae Species	33	2	35	14	31	23	17	27	78	23
Total Number of Species	167	27	141	66	129	100	120	115	366	108
Biomass (g)	74	23	84	29	34	36	102	16	399	50
Density (g/m^2)	1,096	341	1,244	430	504	533	1,511	237	–	741

*Diversity based on enumerated species only.

Abundance of enumerated individuals by depth zone at the eight stations in the Port Complex in spring averaged 531 (23,600 individuals/m^2) per quadrat in the upper intertidal, 817 individuals (36,311 individuals/m^2) in the mid-low intertidal, and 295 individuals (13,111 individuals/m^2) in the subtidal zone (Table 6-3). Highest abundance by depth zone was found in the mid-low intertidal zone. Lowest abundance (12 individuals) was reported in the upper intertidal at Station LARR2, while highest abundance (2,145) occurred in the mid-low intertidal at Station LARR3 (Figure 6-2).

Byrozoans, algae, and a sponge dominated the non-enumerated species in spring. The bryozoan *Thalamoporella californica* was particularly abundant at Station LBRR3, while the bryozoan *Celleporaria brunnea* was most common on the pier pilings at Station LARR3 (Appendix F-3). Maiden's hair (*Cladophora* sp) was common at Stations LBRR1, LBRR2 and LBRR4, while the coralline alga *Corallina vancouveriensis* was common at Stations LBRR1 LARR1, LARR2 and LARR4, but was rare at Station LBRR3 and absent from Station LARR3. Other common species included the calcareous sponge *Leucosolenia nautilia*, sea lettuce, and the bryozoans *Crisulipora occidentalis* and *Diaperoforma californica and Filicrisia* sp. Of these common species, only the sponge and sea lettuce were reported in the upper intertidal at any station; otherwise, distribution was relatively similar between the mid-low and subtidal levels.

Table 6-3. Riprap biota community parameters by level and survey. Totals are for all scraped quadrats by level. Means are per station.

Summer 2013	Upper	Mid-Low	Subtidal
Total Number of Individuals*	4,407	10,845	9,931
Mean Number of Individuals*	551	1,356	1,241
Density (Number per m^2)*	24,489	60,267	55,156
Diversity (H')*	0.96	2.13	3.01
Average Number of Species	12	66	86
Average Biomass (g)	47	22	21
Density (g/m^2)	2,089	978	933
Spring 2014	**Upper**	**Mid-Low**	**Subtidal**
Total Number of Individuals*	4,251	6,537	2,361
Mean Number of Individuals*	531	817	295
Density (Number per m^2)*	23,600	36,311	13,111
Diversity (H')*	0.61	2.20	2.71
Average Number of Species	10	63	65
Average Biomass (g)	23	18	9
Density (g/m^2)	1,022	800	400

* Based on enumerated species only.

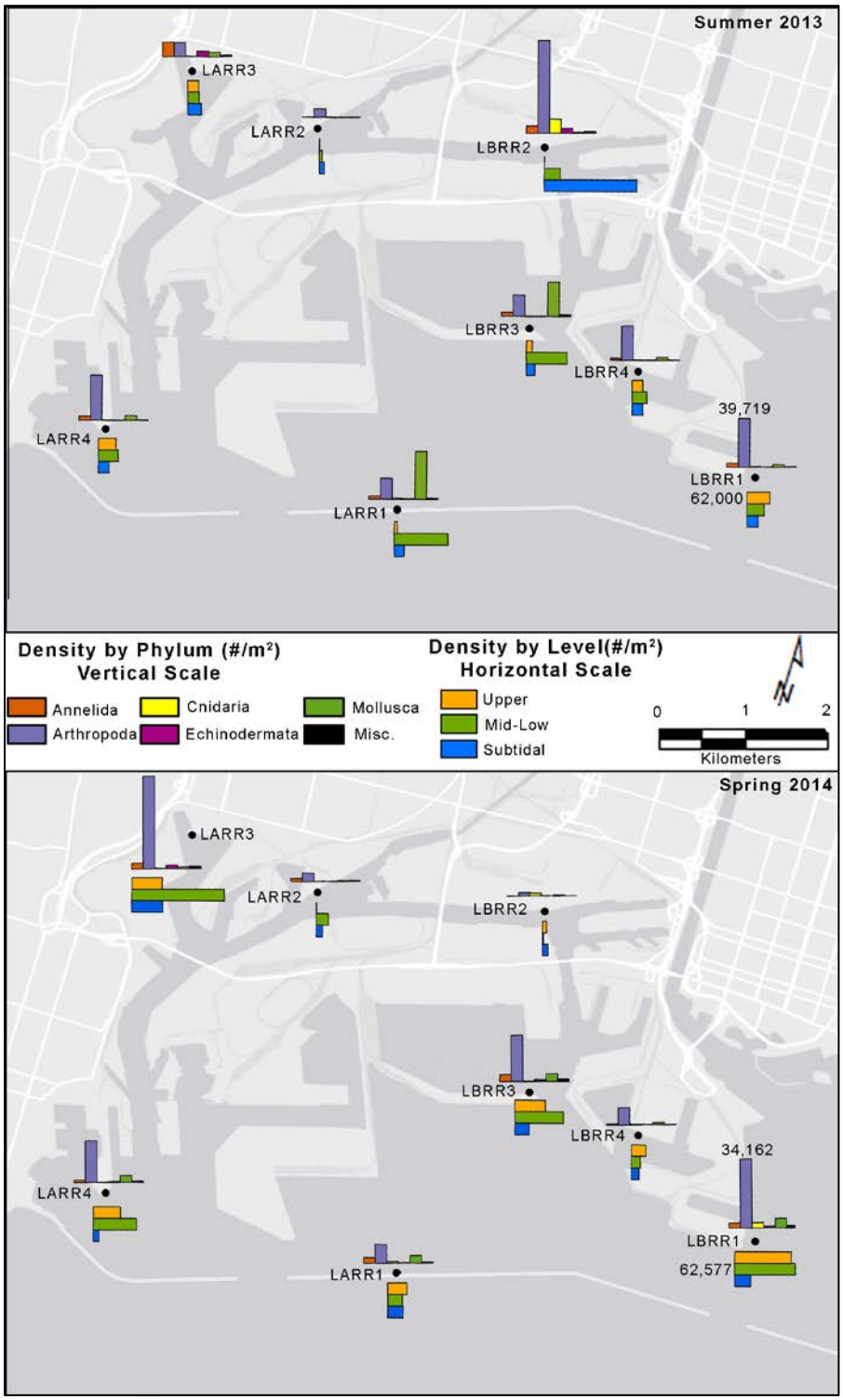


Figure 6-2. Relative density of enumerated species in each phylum by station (all quadrats at all levels combined), and density by level at each station (both quadrats combined). Note: Because plots are relative comparisons by season, the highest values for both the horizontal and vertical bars for Station LBRR1 are provided for scale.

Arthropods were the most abundant phylum in riprap sampling in the Port Complex, comprising 62% of the enumerated individuals in summer and 76% in spring (Figure 6-3). Mollusks and annelids were next most abundant in both surveys, followed by cnidarians and echinoderms during both seasons.

SPECIES RICHNESS

Species richness (number of species) includes all identified species, both those with discrete individuals and colonial/algal species. For simplicity, each unique designation for any organism, even if identified at a higher taxonomic level than species, was included in the species count.

In summer, species richness averaged 128 species (104 enumerated, 24 colonial) per station for the Port Complex (Table 6-2; Appendix F-2). Species richness was highest at Station LARR4 with 187 species, and lowest at Station LARR2 with 33 species (Figure 6-3). There were an average of 12 species per station in the upper intertidal, 66 species in the mid-low intertidal, and 86 species in the subtidal zone (Table 6-2). Highest species richness (137 species) occurred in the subtidal zone at Station LARR4. Lowest species richness (three species) occurred in the upper intertidal at Station LBRR2 (Figure 6-3).

In spring, species richness averaged 108 species per station (Table 6-2; Appendix F-3). Species richness was highest at Station LBRR1 (167 species) and lowest at Station LBRR2 (27 species). Species richness by depth zone in averaged 10 species per station in the upper intertidal, 63 species in the mid-low intertidal, and 65 species in the subtidal zone (Table 6-3). Highest species richness (122 species) occurred in the mid-low intertidal at Station LBRR3, while lowest species richness (four species) occurred in the mid-low intertidal at Stations LBRR2 and LBRR4 and in the upper intertidal zone at Station LARR2 (Figure 6-3).

Annelids comprised 26% of all species reported during the summer survey and 24% of the species reported in spring, whereas arthropods comprised 25% of species in summer and 27% of species in spring (Figure 6-3). The next most speciose groups were mollusks (18% in summer and 16% in spring, bryozoans (7% and 8%), and red algae (5% and 6%).

BIOMASS

In summer, biomass in scraped quadrats averaged 91 grams (g) per station (1,348 g/m^2) (Table 6-2). Biomass was greatest at the pier piling station (LARR3) with 72% of the weight contributed by mollusks, including several large Pacific oysters (*Crassostrea gigas*) collected in the upper intertidal zone (Figure 6-4). Lowest biomass occurred at Station LARR2. Biomass by depth zone averaged 47 g per station (2,110 g/m^2) in the upper intertidal, 22 g (992 g/m^2) at in the mid-low intertidal, and 21 g (932 g/m^2) in subtidal (Table 6-2). Highest biomass (256 g) by station and zone was reported in the upper intertidal at Station LARR3 (as noted above). Lowest biomass (0.1 g) occurred in the subtidal zone at Station LARR2, where 89% of the biomass was due to a few barnacles in the upper tidal zone.

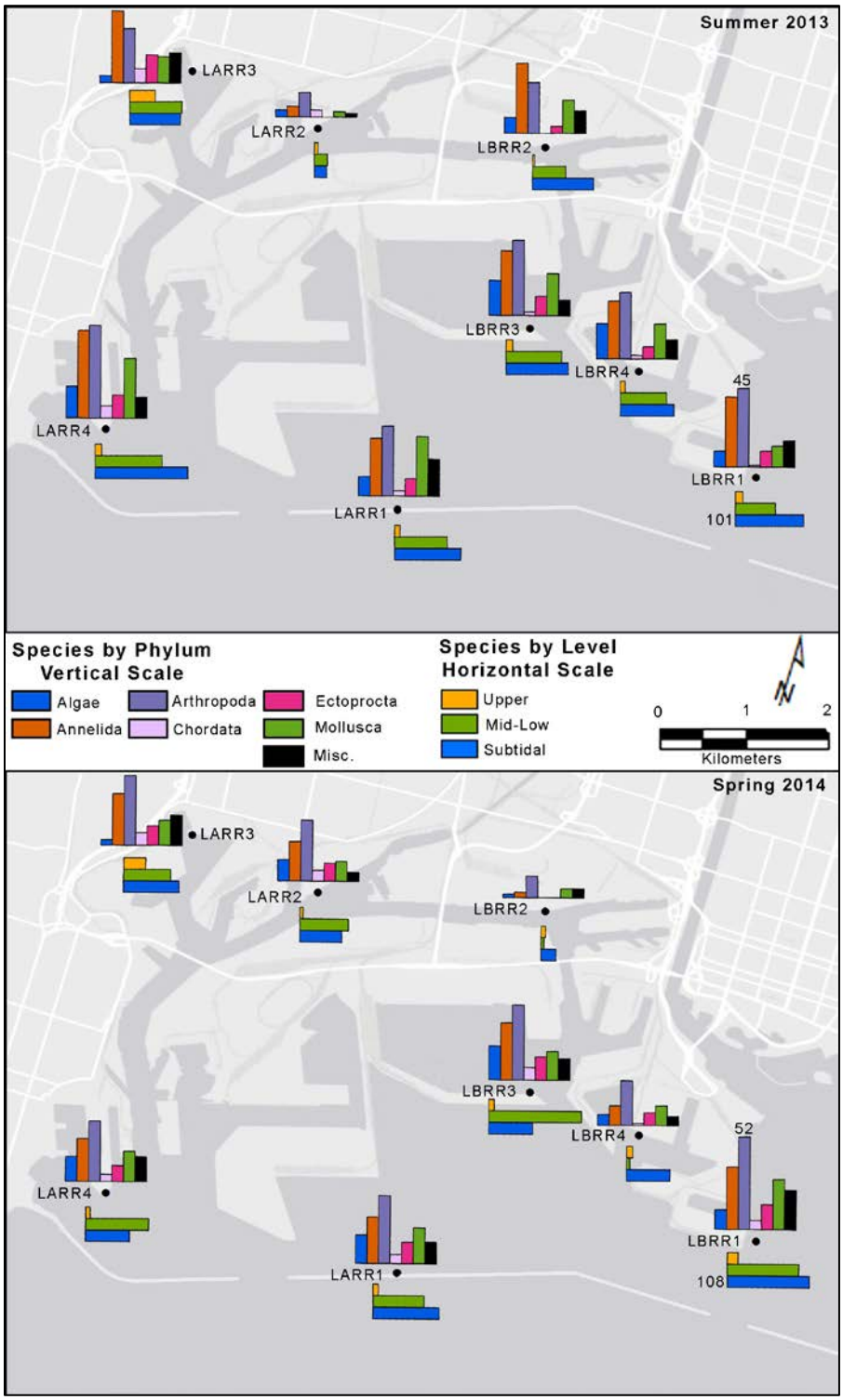


Figure 6-3. Number of species in each phylum by station (all quadrats at all depth zones combined) and number of species by depth zone (both quadrats combined). Note: Because plots are relative comparisons by season, the highest values for both the horizontal and vertical bars for Station LBRR1 are provided for scale.

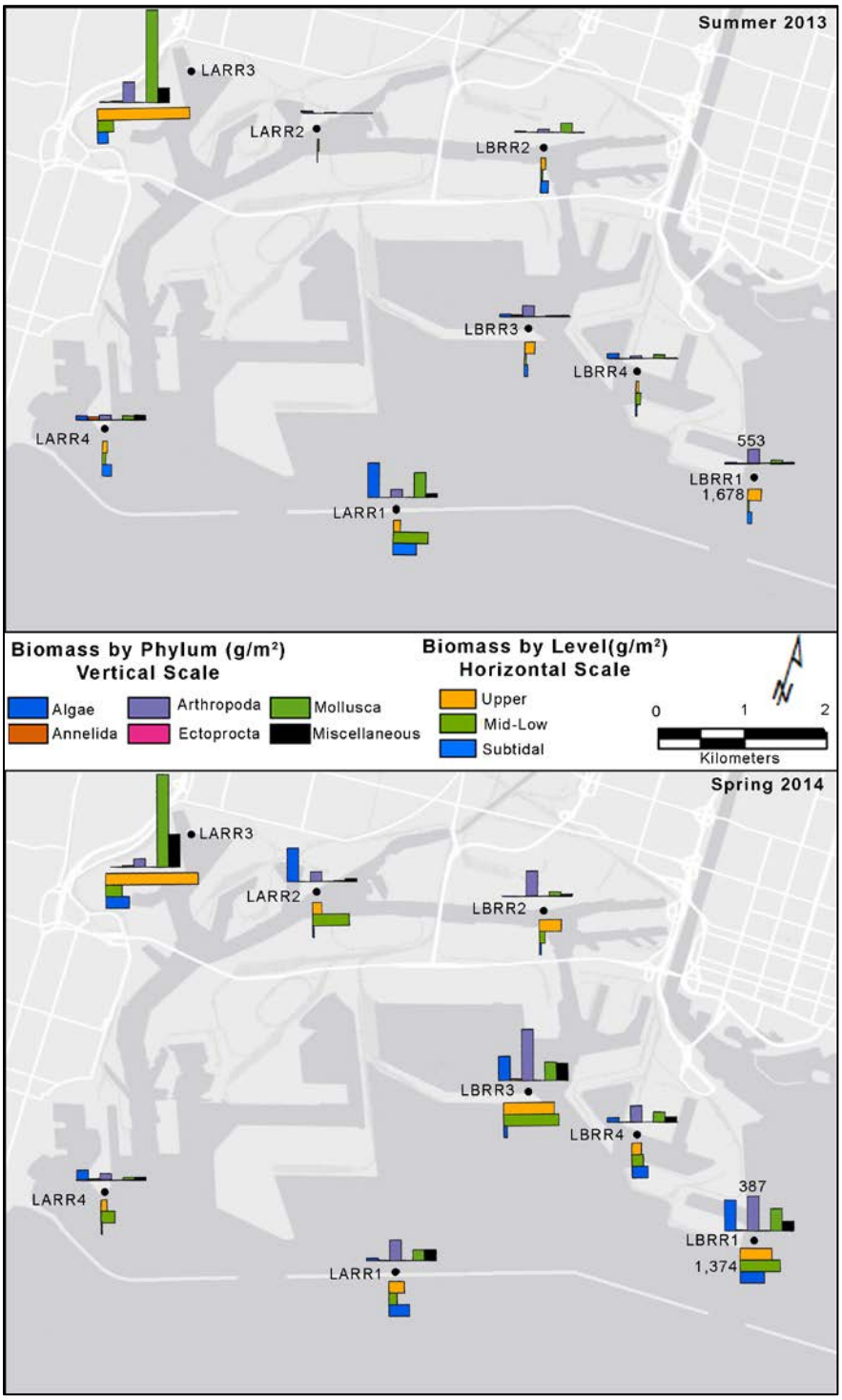


Figure 6-4. Proportional contribution to biomass, by phylum, of all species by station (all quadrats at all levels combined) and biomass by depth zone at each station (all organisms in both quadrats combined). Note: Because plots are relative comparisons by season, the highest values for both the horizontal and vertical bars for Station LBRR1 are provided for scale.

In spring, biomass in the scraped quadrats averaged 50 g per station (741 g/m^2) (Table 6-2). Biomass was again greatest at Station LARR3, with 68% of the biomass contributed by mollusks, mostly due to large Pacific oysters collected in the upper intertidal (Figure 6-4). Lowest biomass occurred at Station LARR4. Biomass by depth zone averaged 23 g per station (1018 g/m$^{2)}$) in the upper intertidal, 18 g (804 g/m^2) in the mid-low intertidal, and 9 g (395 g/m^2) in the subtidal zone (Table 6-3). Highest biomass (71 g) by station and depth zone was reported in the upper intertidal at Station LARR3, and lowest biomass (0.8 g) occurred in the subtidal at Station LARR4.

In summer, mollusks contributed the highest proportion to the biomass, with most of the weight contributed by Pacific oysters on the pier pilings at Station LARR3 (Figure 6-4). Biomass of arthropods was the second highest overall, and was primarily due to high abundance of acorn barnacles (*Chthamalus fissus* and *Balanus glandula*) at some stations. Algal biomass was the third highest in summer, and was highest at the mid-low intertidal at Station LARR1. Biomass by depth zone was highest in the upper intertidal at half of the stations in summer. High biomass at these stations resulted from a few large Pacific oysters or mussels (*Mytilus* sp), or by many individuals of acorn barnacle. In general, algae contributed most to weight at stations where biomass was highest in the mid-low intertidal or subtidal.

In spring, arthropods (mostly barnacles) contributed the highest proportion to biomass at the stations on the Long Beach side, but algae and mollusks (mostly oysters) dominated biomass on the Los Angeles side (Appendix F-9). Biomass of miscellaneous phyla, predominantly bryozoans, was generally higher in spring than in summer.

SHANNON WIENER SPECIES DIVERSITY (H')

Overall mean diversity of enumerated species per station ("station diversity") was slightly higher in the summer survey than in spring (Table 6-2). In summer, the highest diversity value was at Station LARR3 and lowest diversity was at Station LARR2, where both the lowest abundance and least number of species was reported for the entire summer survey. In spring, high diversity values were reported at Stations LBRR3 and LARR2. The lowest diversity occurred at Station LBRR4, and diversity was also low at Station LARR3 (Table 6-2).

Diversity of enumerated species by depth zone was similar between seasons (Table 6-3). Lowest diversities (H' between 0.4 and 1.3) occurred in the upper intertidal. Diversities were slightly higher at mid-low intertidal stations, with mean H' values between 1.9 and 2.5. Highest diversities, with an H' range from 2.6 to 3.1, occurred in the subtidal zone.

COMMUNITY COMPOSITION

The riprap communities, based on enumerated species at each station in the Port Complex, were fairly similar in the summer and spring surveys. Eighteen species each contributed 1% or more to total abundance in summer, and 17 species contributed 1% or more in spring. Eleven of these top species were common to both seasons. The contribution of those species differed between seasons, however, so each survey was evaluated separately. All enumerated species in all depth zones were included in this analysis to facilitate comparisons of the communities between stations.

In summer, the 18 most abundant species represented 74% of the overall abundance even though they accounted for only about 5% of the total number of enumerated species (Appendix F-10). The reddish lepton clam (*Lasaea adansoni*) was the most abundant species in summer due to high abundance at Stations LBRR3 and LARR1. The amphipod *Monocorophium acherusicum* was the second most abundant species in summer; however, more than 99% of the individuals were collected at Station LBRR2. Brown acorn barnacle (*Chthamalus fissus*) was slightly less abundant than *M. acherusicum*, and it was found at all stations; it was most abundant at Stations LBRR1, LARR4, and LBRR4. Two other taxa—unidentified harpacticoids (the fourth most abundant species) and unidentified podocopid ostracods—were also reported at all eight stations during the summer survey.

Cluster analysis of the eight stations sampled in summer resulted in three station groups (Figure 6-5; Appendix F-10). The largest cluster of stations, Group III (blue in Figure 6-5), included both Inner and Outer Harbor stations in both ports. The three stations that clustered most closely in this group were those where reddish lepton clam and the white acorn barnacle (*Balanus glandula*) were most common, while all four stations in Group III included similar numbers of podocopids, harpacticoids, and the tanaid *Zeuxo normani*. Group I (green in Figure 6-5) included three stations which can be generally characterized as protected Outer Harbor locations. Stations in this group were characterized by high abundances of brown acorn barnacles, harpacticoids, *Z. normani*, two species of caprellid amphipod (*Caprella* sp and *C. scaura*), and a cumacean (*Cumella californica*). Group II (purple in Figure 6-5) consisted of a single station, LARR2, where unidentified harpacticoid copepods dominated the community, but where numbers of most of the other top species were low.

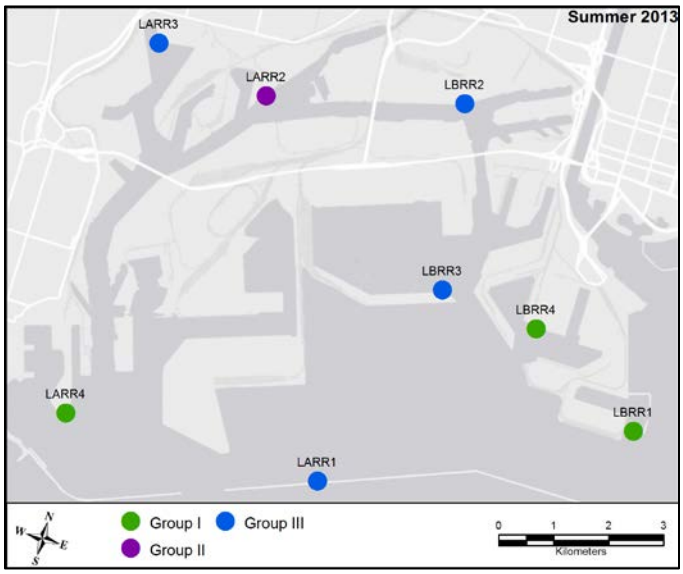


Figure 6-5. Major community group for each station identified by cluster analysis of the 18 most abundant infauna species in summer.

In spring, the 17 species that each contributed 1% or more to the total abundance together represented 75% of the overall abundance even though they accounted for only about 6% of the total number of enumerated species (Appendix F-11). Brown acorn barnacle and a caprellid amphipod (*Caprella californica*) were the most abundant species in the spring survey, and each accounted for 20% or more of the total abundance for the season. Both species were reported at seven stations, though abundances were highly variable among the stations. White acorn barnacle was also found at seven of the eight stations in variable abundances. The Pacific half-slippersnail (*Crepipatella lingulata*) was the only top species found at all eight stations in the spring survey.

Cluster analysis of the eight stations sampled in spring resulted in three station groups (Figure 6-6; Appendix F-11). The largest cluster of stations, Group III (blue in Figure 6-6), included two Inner and two Outer Harbor stations. Within this group the Inner Harbor stations on the Los Angeles side were distinct from the Outer Harbor stations on the Long Beach side, but the separation was at a low level of difference. All four stations were characterized by high numbers of *Caprella californica*, *Caprella* sp., *Zeuxo normanni*, and white acorn barnacle. Group I (green in Figure 6-6) included three Outer Harbor stations, two of them the same stations as in Group I in summer. Stations in this group were characterized by high numbers of brown acorn barnacles, but generally low abundances of the other species that were abundant in summer, such as *Z normanni*, *Caprella* sp., and harpacticoids. Group II (purple in Figure 6-6) included only Station LBRR2, where abundances of species other than barnacles were generally low.

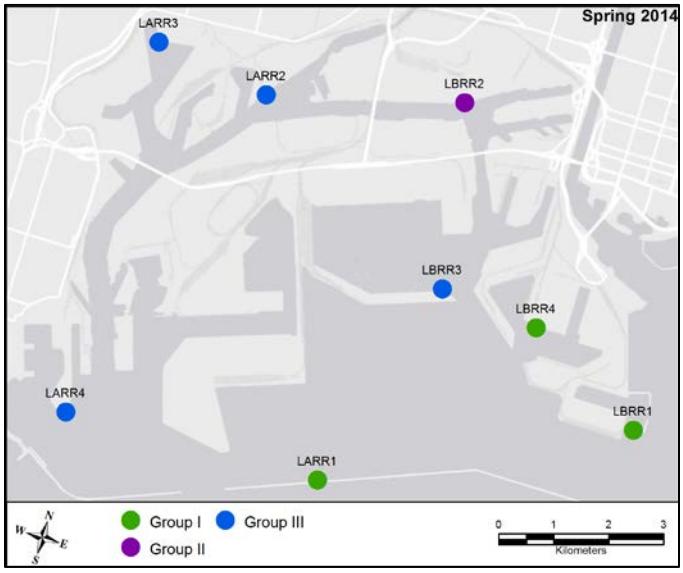


Figure 6-6. Major community group for each station identified by cluster analysis of the 17 most abundant infauna species in spring.

Numbers of the most abundant species were also utilized to facilitate comparisons of the communities among depth zones at all stations. In the summer survey, stations and zones clustered into five groups based on abundances of the top species by level (Figure 6-7). Communities in the upper intertidal zone were clearly different from those in lower zones. Upper intertidal zones clustered into only two groups: the first group (green) included only the stations where brown acorn barnacle was abundant (identified as Group I [green] in Figure 6-5), while the second group (pink) included all of the remaining upper intertidal zones. The remaining zones clustered into three groups. Most distant were the mid-low intertidal zones at Stations LBRR3 and LARR1 (dark blue) where reddish lepton clam was abundant (Appendix F-2). The largest group includes four mid-low zones and six subtidal zones at five stations (red): mid-low intertidal and subtidal at all three Group I stations and the mid-low and subtidal zones at the outer-most Group III stations in Figure 6-5. Harpacticoids were common at all of these levels (Appendix F-2). The remaining group (light blue) included mid-low and subtidal zones in the LB Turning Basin and in the LA West Basin, and the subtidal zone at the breakwater station.

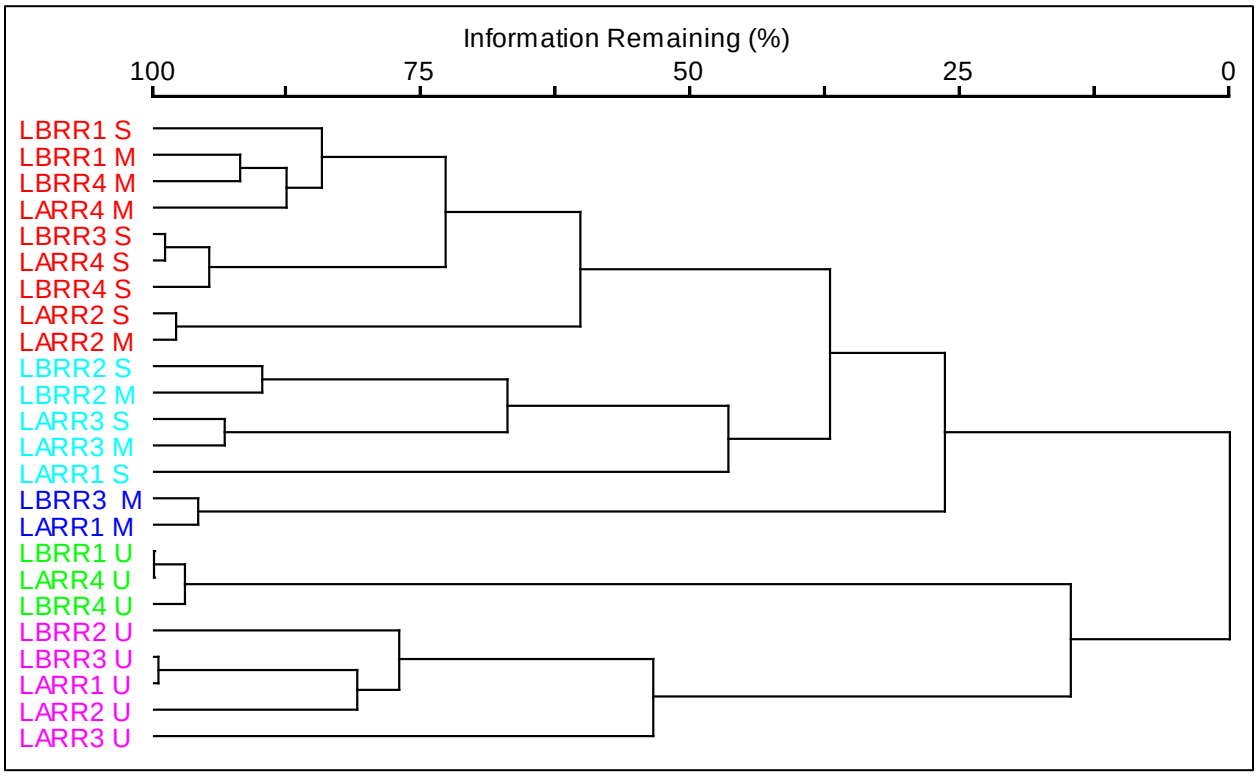


Figure 6-7. Dendrogram based on abundances of top enumerated species (those that contributed 1% or more to the survey total) by station and depth zone in summer. Note: U = upper intertidal, M = mid-low intertidal, and S = subtidal.

In the spring survey, stations and zones again clustered into five groups (Figure 6-8). Communities at four upper intertidal zones (dark blue) at the four stations farthest inside the Port Complex were very different from the other groups and were less similar to each other than those that clustered together in the other groups (Appendices F-3 and F-11). The remaining four upper intertidal stations and two mid-low intertidal stations clustered together (light blue) at a slightly lower level. These stations were generally characterized by high abundances of brown acorn barnacle (Appendix F-11). The next group (red) included twelve sample locations: five in the mid-low intertidal and seven in the subtidal zone. The communities at these stations were generally characterized by high species numbers and high relative abundance of *Caprella californica*. The last two groups were single-sample clusters: the mid-low intertidal at Station LBRR1 (green), where several species with low occurrence elsewhere in the Port Complex were abundant, and the subtidal zone at Station LBRR2 (pink), which was dominated by sea anemones (Actiniaria) and few other individuals among the top species (Appendix F-11).

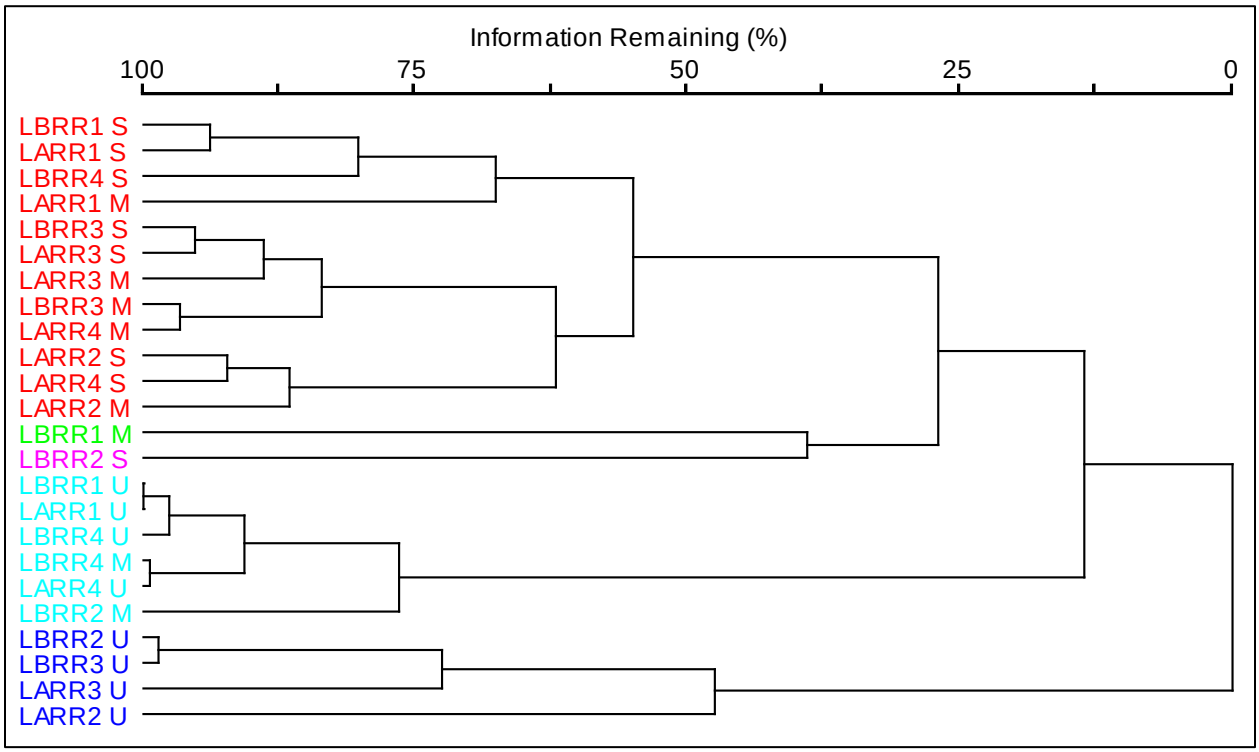


Figure 6-8. Dendrogram based on abundances of top enumerated species (those that contributed 1% or more to the survey total) by station and depth zone in spring. Note: U = upper intertidal, M = mid-low intertidal, and S = subtidal.

RAPID ASSESSMENT

One-hundred and one taxa were reported in the riprap biota rapid assessment photo and video surveys in the Port Complex in summer 2013 and spring 2014 (Appendix F-12).

1/8-M^2 PHOTOPLOTS

Sixty-seven taxa were identified in the 1/8-m^2 photoplots: 56 in summer and 49 in spring (Appendix F-15). Numbers of taxa in the 1/8-m^2 photoplots in summer ranged from 3 to 8 in the upper intertidal zone, from 8 to 17 in the mid-low intertidal, and from 6 to 14 in the subtidal. Percent cover of biota in the 1/8-m^2 photoplots was variable in the summer survey. Mean coverage in the upper intertidal ranged from 7.6% at Stations LARR2 and LBRR2 to 64.7% at Station LARR4, and averaged 40.0% for the depth zone as a whole (Appendix F-15-A). In the mid-low intertidal zone, percent cover ranged from 12.3% at Station LARR2 to 78.4% at Station LARR1, and averaged 53.8%. In the subtidal, percent cover ranged from 7.8% at Station LBRR4 to 46.8% at Station LARR2, and averaged 30.1%.

In spring 2014, the number of taxa ranged from 2 to 8 in the upper intertidal, from 4 to 16 in the mid-low intertidal, and from 2 to 12 in the subtidal. Percent cover of biota in photoplots was variable in the spring survey. Mean coverage of biota in the upper intertidal ranged from 0.5% (the lowest for either survey) at Station LARR2 to 52.4% at Station LBRR1, and averaged 30.8% (Appendix F-15). In the mid-low intertidal zone, percent cover ranged from 12.9% at Station LBRR2 to 81.9% (the highest mean percent cover value for either survey) at Station

LBRR3, and averaged 59.3%. In the subtidal, percent cover ranged from 1.4% at Station LBRR3 to 45.1% at Station LARR1, and averaged 20.2%.

Because the video/photos in the mid-low and subtidal zones were taken underwater, many points in those quadrats were unidentified, usually due to poor resolution because of low visibility or the coverage of biota/substrate by silt. In spring, the amount of coverage by silt (making identification impossible) increased compared to summer at Stations LARR2 and LARR3, but decreased at Stations LBRR2 and LBRR3. At Station LARR3, the increase in silt-covered unknowns coincided with decreases in tunicates and tube-dwelling worms/gastropods, although it is unknown whether these taxa declined or were just covered by silt and not identified. At Station LBRR2, the decrease in silt-covered unknowns from summer to spring coincided with an increase in bare rock and encrusting brown algae that may have been covered by silt in the previous season. At Station LBRR3, similar declines in silt coincided with an increase in *Ulva*.

1-M² PLOTS

Mean species richness (macroalgae and invertebrates) among zones and stations, and between seasons, ranged from 2.8 species in the upper zone at Station LARR2 in the summer survey to 15.0 species in the mid-low zone of Station LBRR4 in spring (Table 6-4).

UPPER INTERTIDAL

Bare rock accounted for more than 75% of the area in the upper intertidal zone at Stations LBRR2 and LARR2 in summer and more than 90% of the area at the same stations in spring (Appendix F-16). The lowest percent of bare rock in the upper intertidal was at Station LARR4 in spring. Macroalgae were uncommon in the upper intertidal zones (Appendix F-17). Coverage was generally limited to small amounts of red algal turfs or occasional leafy green or encrusting algae. Highest percent cover and highest number of algal taxa (four) occurred at Station LARR4 in summer.

Barnacles (*Balanus*, *Chthamalus*, and sometimes *Tetraclita*) were abundant in the upper intertidal zone (Appendix F-18), followed by various limpets (*Lottia* spp). At the piling station (Station LARR3), the macroinvertebrate community was vastly different from that at other locations, with the dominant taxa consisting of oysters, mussels, and scallops. The highest number of macroinvertebrate taxa (eight) occurred at Station LARR3 during both seasons and at Station LBRR4 in summer. No fish were reported in the upper intertidal 1-m² plots during either season (Appendix F-19).

MID-LOWER INTERTIDAL

In the mid-low intertidal zone, bare rock was visible at most sites, and was common at Stations LBRR1 and LARR2 in summer and at Stations LBRR2 and LBRR4 in spring (Appendix F-16). In addition, cover by unidentifiable, silt-covered organisms exceeded 50% of the quadrat area at several stations. The number of macroalgae taxa ranged from two at Stations LBRR2 and LARR3 in spring to 14 at Station LBRR3 in spring (Appendix F-17).

The number of macroinvertebrate taxa in the 1-m^2 plots varied from two at Station LARR2 in spring to 16 at Station LBRR4 in summer (Appendix F-18). Commonly observed taxa included sponges, tube snails *(Serpulorbis squamigerus*), limpets (*Lottia* spp), and barnacles *(Balanus*, *Chthamalus*, and *Tetraclita)*. At Station LARR3 (the piling station), sponges, tunicates, hydroids, and tube-forming worms/gastropods were more abundant than at the other mid-low intertidal stations. Percent cover of invertebrates was somewhat variable among stations and between seasons. Fish (Opaleye, *Girella nigricans*, and unidentified sculpins in both seasons) were reported only in the mid-low intertidal at Station LBRR4 (Appendix F-19).

Table 6-4. Mean species/taxa richness in 1-m^2 plots.

Station	Tidal Level	Summer	Spring
LBRR1	Upper	4.5	5.0
	Mid-low	6.0	13.0
	Subtidal	9.5	11.8
LBRR2	Upper	4.3	1.5
	Mid-low	10.8	7.0
	Subtidal	5.5	2.8
LBRR3	Upper	4.5	4.8
	Mid-low	8.8	10.5
	Subtidal	11.0	10.0
LBRR4	Upper	5.5	5.0
	Mid-low	14.3	15.0
	Subtidal	8.3	7.8
LARR1	Upper	4.0	5.5
	Mid-low	5.8	10.0
	Subtidal	5.8	10.8
LARR2	Upper	2.8	3.3
	Mid-low	3.3	4.3
	Subtidal	3.0	4.5
LARR3	Upper	5.5	7.5
	Mid-low	7.8	5.5
	Subtidal	6.5	7.3
LARR4	Upper	5.3	5.0
	Mid-low	12.3	11.0
	Subtidal	8.5	9.5

SUBTIDAL

Cover by unidentified, silt-covered organisms exceeded 10% of the quadrat area at six of the eight stations in summer, and at all eight stations in spring (Appendix F-16). Silt-covered organisms accounted for at least 60% of the area at Station LBRR4 during both seasons and at Station LARR2 in spring. The number of macroalgae taxa ranged from zero at Stations LBRR2 and LARR3 in spring to 13 at Station LBRR3 in summer (Appendix F-17). *Ulva* and other leafy green algae, *Colpomenia*, *Dictyopterus undulata*, *Dictyota flabellata*, giant kelp, *Sargassum* spp, *Rhodymenia* spp, articulated and crustose corallines, and unidentified algal turfs were commonly encountered in the subtidal zone. The percent cover of these taxa, however, was generally low, with no single algal taxon contributing more than 25% of the percent cover at any station.

The number of macroinvertebrate taxa in the subtidal, ranged from none at Station LARR2 in summer to 13 at Station LBRR1 in spring (Appendix F-18). Sponges, cup corals, gorgonians, tube snails, sea cucumbers, and sea urchins were frequently encountered in the subtidal. Gobies (unidentified and Blackeye Goby, *Rhinogobiops nicholsi*) were observed at Stations LBRR3 and LBRR4 in summer (Appendix F-19).

MULTIVARIATE ANALYSIS

Community composition analysis of the 1-m^2 plots was used to compare similarities between sampling sites in relative abundances of all species together. The multi-dimensional scaling (MDS) analysis did not reveal pronounced patterns of differences among the stations. The cluster diagram (Figure 6-9), however, illustrates several patterns, with all of the upper intertidal samples clustering together, most of the mid-lower samples clustering together, and with the Station LARR3 (mid-low and subtidal zone) group and Station LARR4 (subtidal) group in summer clearly different from the other samples. The Station LARR3 group is different due to high abundances of sponges, tunicates, and tube-forming worms/gastropods, while Station LARR4 consisted of a suite of macroalgal species not common at other locations (Appendix F-17), particularly fleshy reds (*Rhodymenia* and *Prionitis* types) and fleshy brown species (*Desmerestia* and *Undaria*).

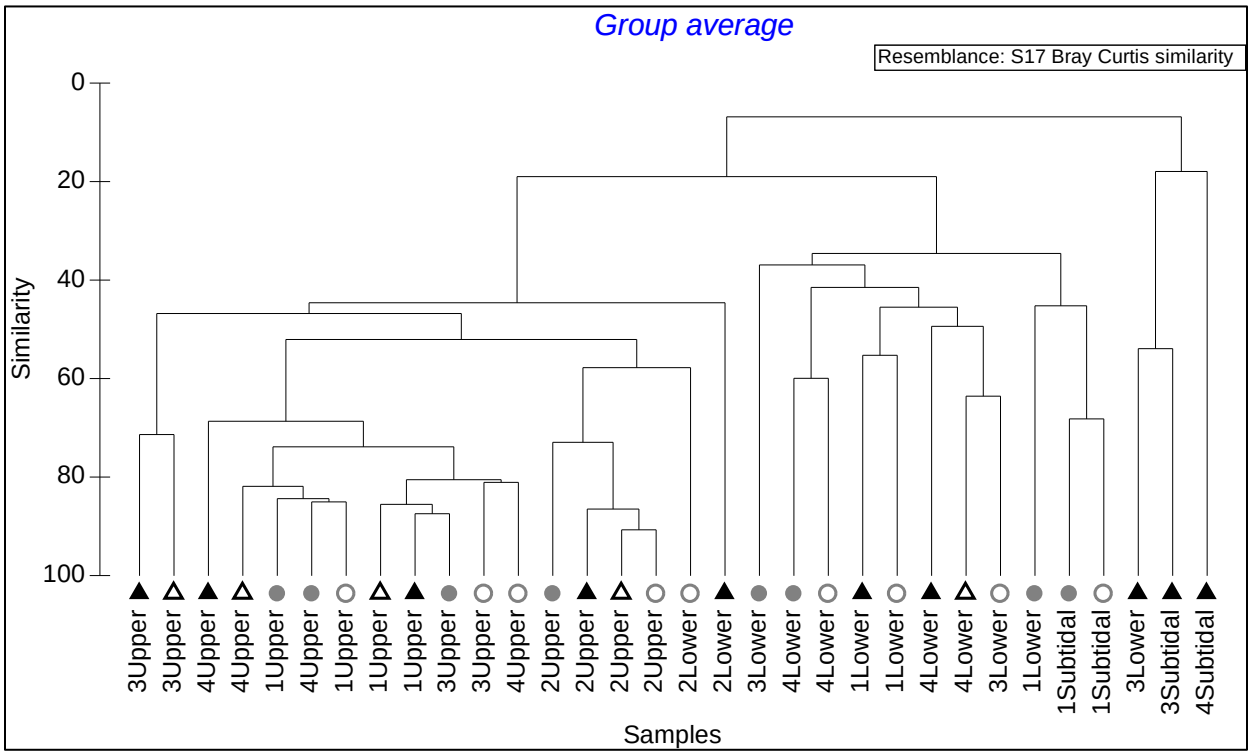


Figure 6-9. Cluster analysis of community structure in 1-m^2 plots, based on assessments of mean relative abundances. Note: The circles indicate stations on the Long Beach side, triangles those on the Los Angeles side. Filled symbols indicate summer data, open symbols indicate spring data. Each symbol is labelled by station and tidal zone. Plots with greater than 25% cover of unidentified biota covered by silt were removed from the analyses, which omitted some sites, years, locations, and/or tidal heights.

VIDEO TRANSECTS

In the video transects, more algal taxa were observed in summer (18 taxa) than in spring (13 taxa) (Appendix F-20). Similarly, the abundance of algal species in summer was considerably higher than in spring.

UPPER INTERTIDAL

The most frequently observed seaweed taxa in the upper intertidal zone were *Ulva*, red algal turfs, and encrusting algae (Appendix F-20). The number of taxa ranged from zero at Station LBRR2 in spring to seven at Station LARR4 in summer.

Slightly more invertebrate taxa were observed in summer (43 taxa) than in spring (41 taxa) (Appendix F-21). The abundance of invertebrates was also higher in summer than in spring. Invertebrates were dominated by barnacles (*Balanus*, *Chthamalus,* and *Tetraclita*) and various limpets (*Lottia* spp) (Appendix F-21) except at Station LARR3, where sponges, erect tube-forming worms, oysters, mussels, and tunicates were abundant. The number of invertebrate taxa ranged from three at Stations LARR4 (summer) and LBRR2 (spring) to 16 at Station LARR3 in spring.

MID-LOWER INTERTIDAL

Common seaweeds in the mid-low intertidal included *Ulva*, red algal turfs, encrusting algae, and articulated corallines (Appendix F-20). Fleshy red algae were also present at many of the sampling locations, and giant kelp was noted at several stations during both seasons. The remaining seaweed taxa were highly variable among sites and between surveys. The number of algal taxa in the mid-low intertidal ranged from one at Station LARR3 in spring to 13 at Station LBRR4 in summer.

The number of invertebrate taxa in the mid-low intertidal ranged from one at Station LARR2 in spring to 20 at Station LBRR4 in summer (Appendix F-21). At Station LARR3 (the piling habitat), sponges, hydroids, erect tube-forming worms, oysters, mussels, and tunicates were abundant. These taxa were not as common at the remaining stations; instead, anemones, cup corals, tube snails, limpets, barnacles, and echinoderms were common, especially in summer.

SUBTIDAL

In the subtidal zone, *Ulva*, red algal turfs, encrusting algae, and articulated corallines were common, and giant kelp occurred at several stations during both seasons (Appendix F-20). The number of algal taxa in the subtidal ranged from none at Station LBRR2 in spring 2014 to 11 at Station LBRR4 in summer.

Invertebrate taxa included many that were also common in the mid-low intertidal such as sponges, anemones, cup corals, tube snails, limpets, and echinoderms, as well as gorgonians and hydroids, although barnacles were less frequently encountered (Appendix F-21). Again, the community at Station LARR3 was different from those at the other sites. The number of invertebrate taxa at the subtidal level ranged from one at Stations LARR2 and LARR4 in spring to 18 at Station LBRR4, also in spring.

At least nine species of fish were observed in video transect surveys during the study (Appendix F-22). No fish were observed in the upper intertidal, and fish were uncommon in the mid-low intertidal and subtidal zones. Fish were encountered in only 18 of the 48 video transects, and no more than four taxa were observed in a single transect.

MULTIVARIATE ANALYSIS

Community structure analyses (Figure 6-10) show patterns of similarity among zones, but few patterns among sites or between surveys; the exception is Station LARR3, the piling station, which clearly differed. The subtidal zones at Stations LBRR1, LBRR2, and LBRR4 in spring were somewhat similar to the mid-low intertidal and subtidal zones at Station LARR3, and the high intertidal zone samples of most sites clustered together.

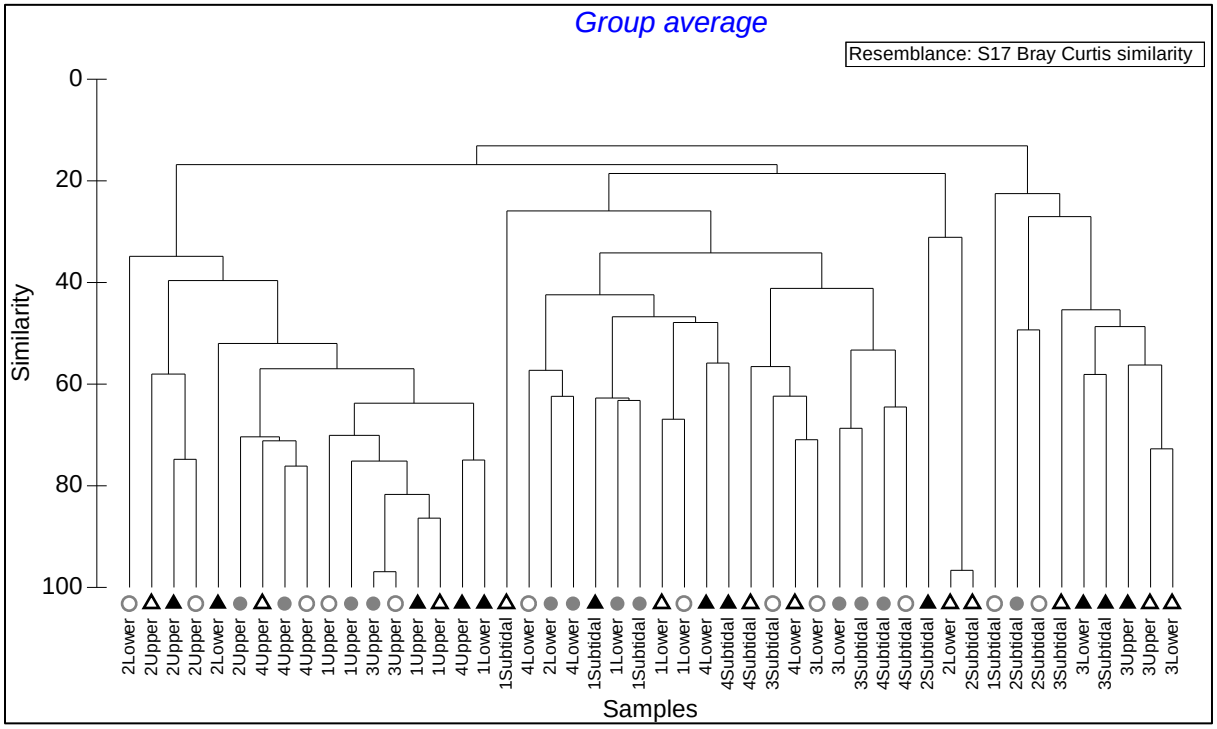


Figure 6-10. Cluster analysis of community structure in videos along transects, based on assessments of mean abundances. Note: Circles indicate samples from the Long Beach side, triangles those from the Los Angeles side. Filled symbols indicate summer data, open symbols indicate spring data. Each symbol is labelled by station and tidal zone.

DISCUSSION

SCRAPED QUADRATS

Abundance of enumerated riprap species in the Port Complex was nearly twice as high in summer as in spring (Figure 6-11). Abundance was also about 8% greater at stations in the Outer Harbor than at those in the Inner Harbor (for this and subsequent comparisons Station LBRR2 is included among the Inner Harbor Stations). Abundance appeared to be strongly influenced by depth: mean abundance in the mid-low intertidal zone was twice that in the upper intertidal and about 40% greater than in the subtidal scrapings.

Riprap station locations and tidal zones sampled in 2013-2014 were consistent with those in previous harbor-wide surveys conducted in 2000 and 2008. While there were some differences among the surveys (winter and summer surveys in 2008, and sampling in four seasons in 2000), direct comparisons are possible.

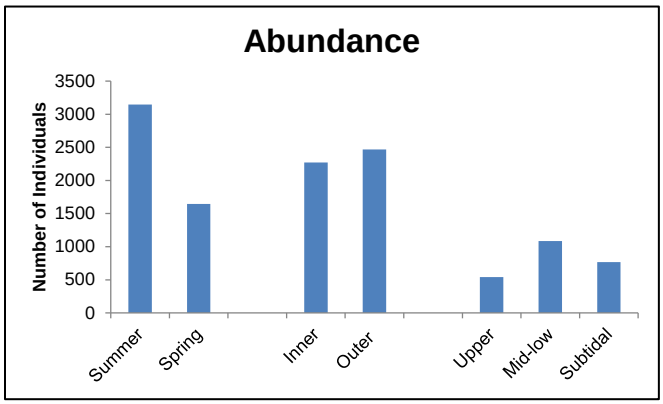


Figure 6-11. Mean abundance of enumerated species per station, all quadrats and depth zones combined, by season and location, and mean number of individuals by depth zone, all quadrats, stations and seasons combined.

Abundance data presented in Figure 6-12 are based on the mean values for both replicates at each depth zone for all stations, standardized to a 112.5-cm^2 quadrat (2013–2014 data presented above is based on totals for both replicates). In addition, data presented here for 2000 includes only values reported for the spring and summer surveys (MEC 2002). Based on this, the total of 19,162 individuals taken in both seasons in the present study was considerably higher than both the 8,264 individuals reported for summer and winter together in 2008 and the 7,411 individuals reported for the spring and summer 2000 surveys (MEC 2002; SAIC 2010). The reason for the great difference in abundance between this study and the previous two studies is unclear, although, as discussed below, improvements in habitat quality may well be a factor. In all of the studies, abundance was greater in summer than in winter or spring.

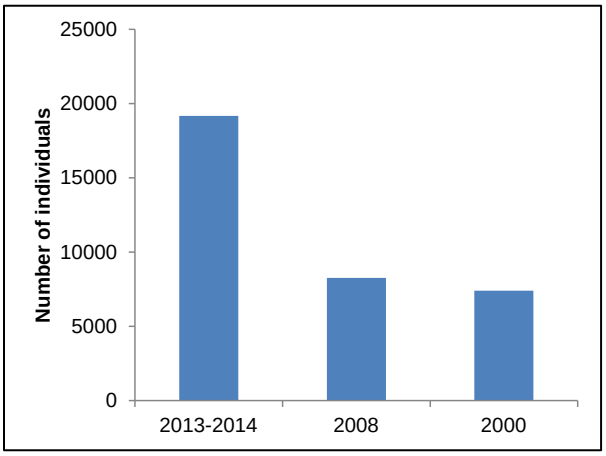


Figure 6-12. Total abundance of enumerated species all stations and depth zones combined standardized to 112.5-cm^2 quadrat by survey.

In comparing locations (Inner versus Outer Harbor) over the three harbor-wide surveys (Figure 6-13), mean abundance was consistently higher at Outer Harbor stations than at Inner Harbor stations. Outer Harbor abundance in 2013-2014 was about twice that in the two previous surveys.

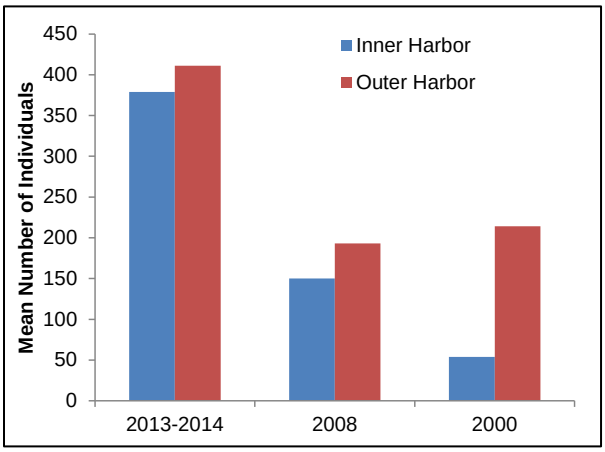


Figure 6-13. Mean abundance of enumerated species per 112.5 cm^2 by location and survey.

Mean abundance at Inner Harbor stations in 2013–2014 was nearly three times higher than in 2008 and seven times greater than in 2000. While mean abundance at Inner Harbor stations has consistently been lower than at Outer Harbor Stations, the difference has declined over time; in 2000, abundance at Inner Harbor Stations in summer and spring was only 25% of that at Outer Harbor stations, while in 2008 Inner Harbor abundance was 78% that of the Outer Harbor. In the current study, Inner Harbor abundance was 92% of that in the Outer Harbor. The declining differences between the two habitats, along with increased abundance in the Outer Harbor, suggest that there has been a continued improvement in riprap habitat conditions at Inner Harbor stations over the period of the three surveys.

Another trend that has been consistent among the recent Port Complex surveys is the difference in abundance by depth zone. In all three surveys, highest abundance of enumerated individuals was found in the mid-low intertidal, and lowest abundance occurred in the upper intertidal (Figure 6-14). This is consistent with expected zonation patterns, especially in the upper intertidal, where the community consists of organisms that can tolerate periodic desiccation and where bare substrate is common (Ricketts and Calvin 1968). Abundance by depth zone was similar between the 2000 and 2008 surveys, especially in the upper intertidal. In a trend noted previously, mean abundances in all three zones in the present study were approximately double those reported in both of the previous studies.

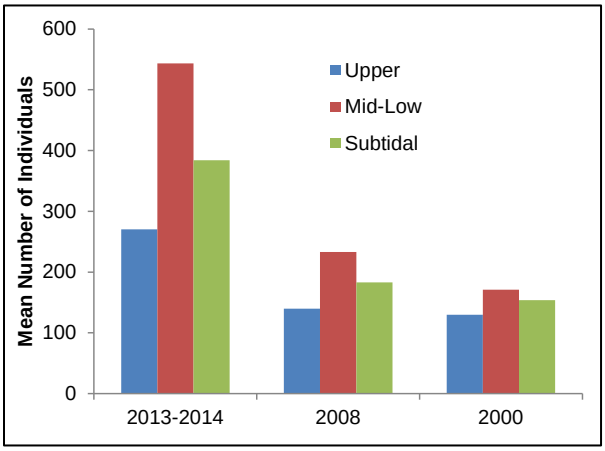


Figure 6-14. Mean abundance of enumerated species per 112.5 cm^2 by level and survey.

In the present study, species richness was greater in summer than in spring (a total of 435 species and a mean of 128 species per station compared with a total of 365 species and a mean of 108 species, respectively) (Table 6-2; Figure 6-15). Species richness was also about

50% higher in the Outer Harbor (136 species) than in the Inner Harbor (88 species). Species richness appeared to be strongly influenced by depth; the mean number at upper intertidal quadrats (11 species) was one-sixth that found in the mid-low intertidal (65 species) and one-seventh that found in the subtidal (76 species) (Table 6-3; Figure 6-15).

Despite some differences in data presentation among the three recent harbor-wide surveys, some trends in the number of species reported were apparent. The overall number of species has increased since the 2000 survey, which, despite including four seasonal surveys compared to the two surveys of the present study, collected less than one-half of the species collected in the current survey (Figure 6-16). In 2008, the total number of species was greater than in 2000, but was still about 40% lower than in 2013–2014. While algal species were not included in the 2008 species counts (as they were in 2000 and 2013–2014), this is unlikely to affect this comparison greatly given that algal species form a small part of the total species list. The mean numbers of species per station were similar in 2000 (39 species) and 2008 (30 species). In this case, the lower number of species in 2008 may have been a result of excluding algal taxa.

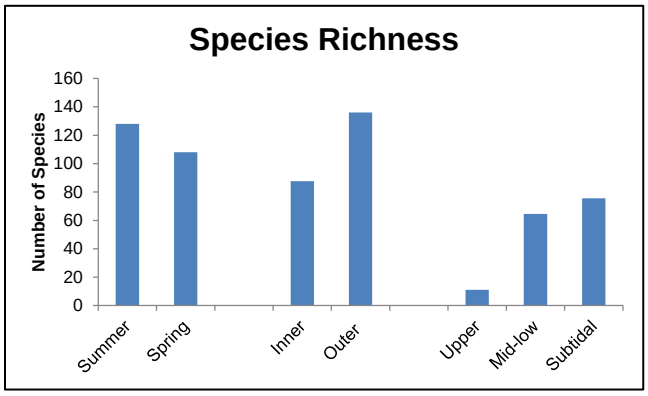


Figure 6-15. Mean species richness per station, all quadrats and depth zones combined, by season and location, and mean number of species by depth zone, all quadrats, stations, and seasons combined.

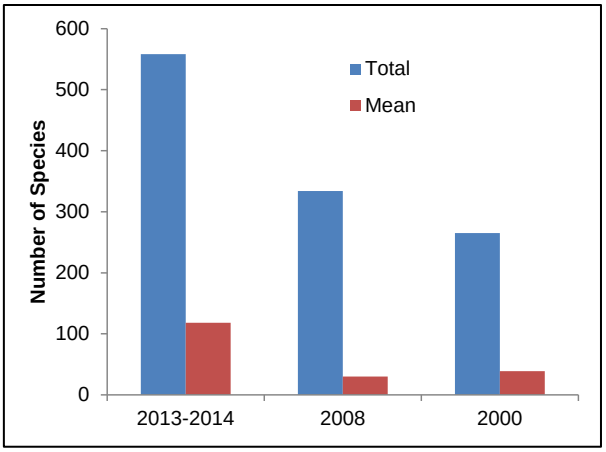


Figure 6-16. Total number of species, all stations and levels combined, and mean number of species by stations, all depth zones combined, by study. Note: 2008 data does not include algae species, 2000 data total over four seasons.

Mean number of species reported in the present study (118) was notably higher than in the previous surveys. As with abundance, reasons for the differences in number of species reported are not clear.

In 2008, as in 2013–2014, more species were reported in summer, while in 2000, more species occurred in spring than in summer (MEC 2002; SAIC 2010). Another pattern found during all three surveys was a greater number of species at Outer Harbor stations than at Inner Harbor stations. Similar to the results of the current survey, Outer Harbor species richness in 2000 was about 60% higher than that at Inner Harbor stations (MEC 2002). In 2008, species richness was also higher at Outer Harbor than at Inner Harbor stations, but only by less than 10% (SAIC 2010).

Another trend that has been consistent among the three recent harbor-wide surveys is that species richness has been highest in the subtidal and lowest in the upper intertidal (Figure 6-17). Mean number of species reported from the upper zone has remained fairly consistent among the three surveys, ranging from seven species in 2000 to 12 species in 2008. The number of species reported from the mid-low and subtidal zones, however, has increased over the period of the three studies.

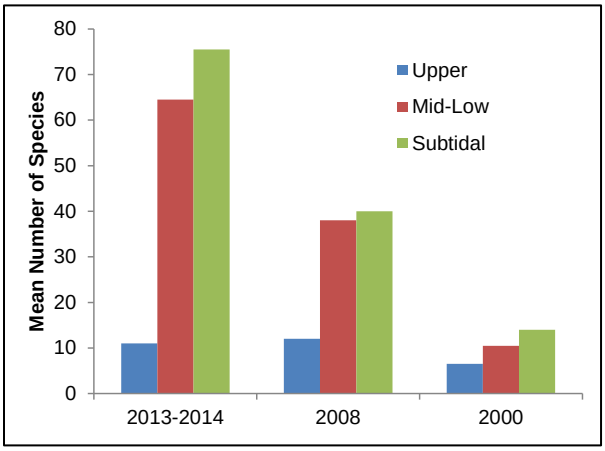


Figure 6-17. Mean number of species by depth zone and study.

In the present study, there were clear differences in biomass by season, location, and depth zone (Figure 6-18). However, because biomass was influenced by a relatively few large individuals, it was generally not reflective of abundance. Furthermore, the influence of a few large individuals means that comparisons based on biomass may not be straightforward. Despite the higher abundance and species richness reported during the 2013–2014 surveys, total biomass was less than one-half that reported in 2008, and less than one quarter of the biomass reported for spring and summer in 2000 (Figure 6-19). As in the current study, where biomass was dominated by a few large Pacific oysters, biomass in 2000 and 2008 was dominated by mollusks, particularly by bay mussel (*Mytilus galloprovincialis*), which was very common at several stations in both surveys (MEC 2002; SAIC 2010). While bay mussels were still relatively common in the present study, they were less abundant, and the individuals were likely smaller than those collected in scraping samples in the previous surveys.

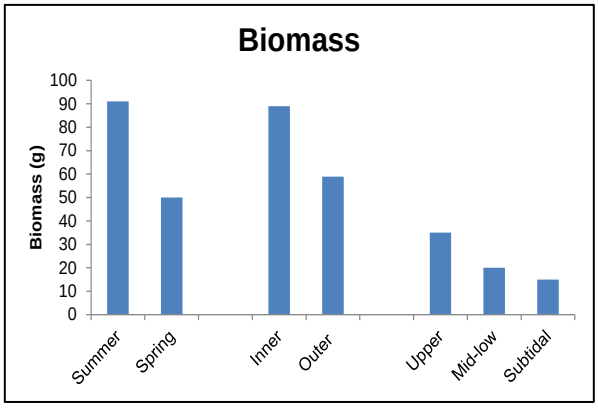


Figure 6-18. Mean biomass of all species per station, all quadrats and levels combined, by season and location in the Port Complex and mean biomass by level, all quadrats, stations and seasons combined.

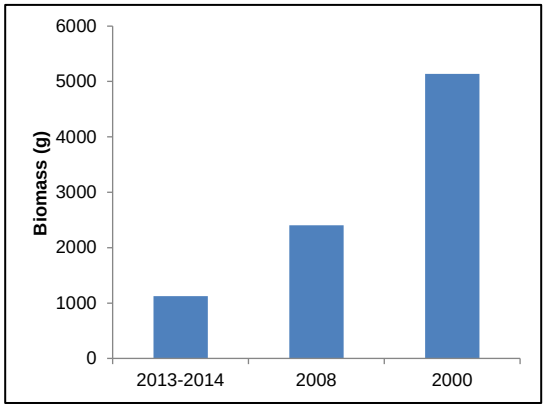


Figure 6-19. Total biomass, all stations and levels combined by survey in the Port Complex. Note: Algae not included in 2008 biomass total.

Patterns in biomass by location have also changed since the 2000 survey (Figure 6-20). In 2013–2014, as in 2008, biomass was higher at Inner Harbor stations than at Outer Harbor stations; the difference was more pronounced in 2008. In 2000, however, mean biomass was higher at Outer Harbor locations than in the Inner Harbor, likely because in that study highest mollusk weight occurred at Outer Harbor stations.

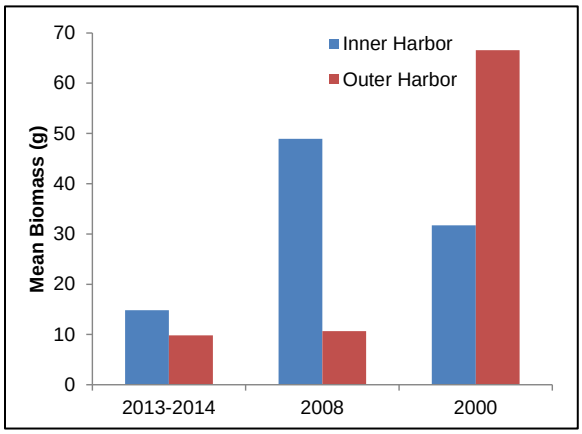


Figure 6-20. Mean biomass per 112.5 cm^2 by location and survey in the Port Complex. Note: Algae not included in 2008 biomass total.

Patterns of biomass by depth also appeared to be primarily influenced by differences in the distribution of mollusks among surveys. The dominance by Pacific oyster in 2013–2014 was apparent in the higher mean biomass in the upper intertidal compared to the other two zones (Figure 6-21). In 2008, biomass was distributed relatively evenly among the three zones; mollusk biomass was highest in the upper intertidal at Station LARR3, but was also high in both the mid-low intertidal and the subtidal at Stations LARR3 and LBRR2. In spring 2000, mollusk biomass was highest in the subtidal at Station LBRR3, resulting in higher biomass for that zone (Figure 6-21; MEC 2000).

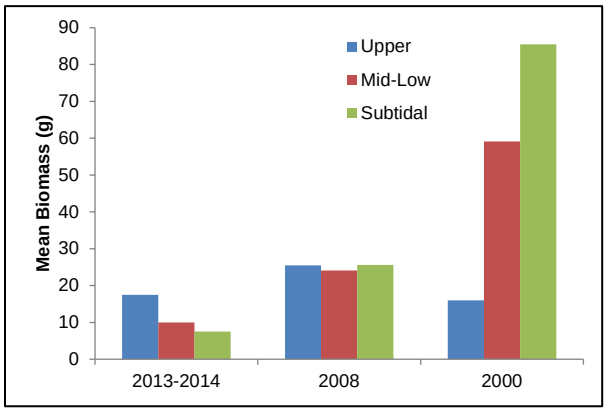


Figure 6-21. Mean biomass per 112.5 cm^2 by depth zone and survey in the Port Complex. Note: Algae not included in 2008 biomass total.

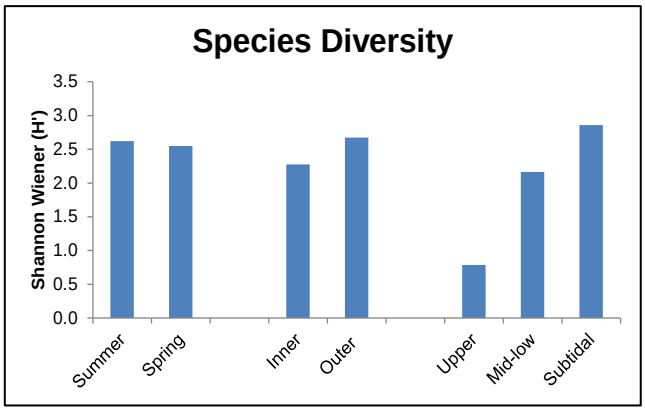


Figure 6-22. Mean diversity of enumerated species per station, all quadrats and levels combined, by season and location, and by depth zone, all quadrats, stations and seasons combined.

In 2013–2014, species diversity generally reflected species richness. Diversity was slightly higher in summer than in spring and higher in the Outer Harbor than in the Inner Harbor (Figure 6-22). Diversity values for riprap communities in 2013–2014 were comparable to those in both previous harbor-wide studies (MEC 2002; SAIC 2010; Figure 6-23). Diversity appeared to be

influenced more by depth zone than by location or season. Lowest values by far in all three studies were for the upper intertidal, and highest values were for the subtidal (except in 2008; Figure 6-23). Overall, mean diversity was highest in 2008 and lowest in 2000.

Even though species richness was highest in 2013–2014, relatively few species (or taxa) occurred commonly (i.e. contributed 1% or more to the total survey abundance of enumerated species) in the riprap biota scraping samples. In summer, this list included 18 of 341 species, and in spring, 17 of 288 species (Table 6-1; Appendices F-10 and F-11). Twenty-four species occurred among the top species in both seasons.

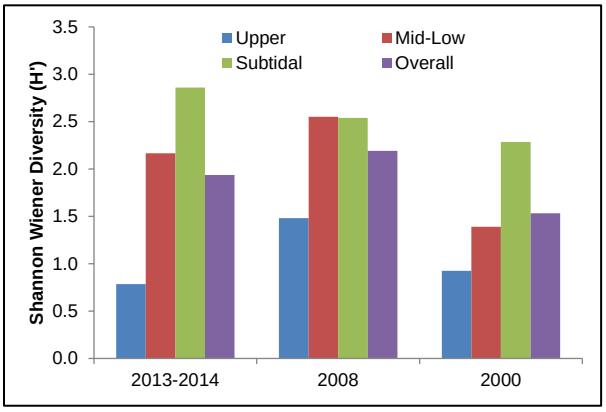


Figure 6-23. Mean species diversity by depth zone and survey in the Port Complex.

Community dominants found during the 2013-2014 survey were generally similar to those found during previous riprap surveys in the Ports. All three studies found that brown acorn barnacle dominated the upper intertidal community overall and white acorn barnacle was very common. In 2008, two additional species of barnacle, rough limpet (*Lottia scabra*), and reddish lepton clam were abundant in the upper-intertidal; rough limpet was also common in 2000 (MEC 2002; SAIC 2010). All of these species were reported in 2013–2014, but one of the two common barnacle species from 2008 was present only in moderate abundance at a few stations and the other was a single occurrence. Rough limpet was evenly distributed among stations in 2013–2014, but did not occur in high numbers, and reddish lepton clam was abundant at only two of the upper-intertidal sites.

In 2000, brown acorn barnacle and white acorn barnacle were dominant species in the mid-low intertidal, and rough limpet remained dominant in the mid-low intertidal. None of these was among the dominants in the mid-low intertidal in 2008 or 2013–2014. In 2000, Pacific lepton clam (*Lasaea subviridis*) and bay mussel were among the dominant species in the mid-low intertidal (MEC 2002), but in 2013–2014, reddish lepton clam was very abundant at a few mid-low sites, particularly in summer, and bay mussel, which was among the top species in May, was also most common in the mid-low intertidal. In 2008, the mid-low intertidal was dominated by small arthropods, dwarf brittle star, tube worms, and unidentified ascidians (SAIC 2010). In 2013–2014, small arthropods and dwarf brittle stars were also among the top species at the mid-low intertidal.

In the subtidal, brown and white acorn barnacles, bay mussel and three species of small arthropods were listed as abundant in the subtidal in 2000 (MEC 2002). In 2008, several species of small arthropods and annelids, tube worms, brittle stars, unidentified ascidians, bay mussels, and two species of slippersnails were among the abundant species in the subtidal

(SAIC 2010). In 2013–2014, several species of small arthropods, unidentified sea anemones, Pacific half-slippersnail, and dwarf brittle star were among the dominant species in the subtidal.

The rocky intertidal community in Back Channel (Long Beach Harbor) and at the Long Beach Pilot House was studied from the early 1970s through 2009 (Appendix F-26; MBC 2009). Transects at the +1 ft and +3 ft MLLW levels were sampled using a random point contact method. Mussels (*Mytilus* spp) were abundant during most years between 1991 and 2001. Mussels disappeared at the Pilot House station in 2002, but were still common in Back Channel. In 2008 and 2009, however, they declined precipitously in the Back Channel as well. Barnacle coverage persisted at these stations during the demise of the mussels; coverage of *Ulva* increased in the absence of mussels at the Pilot House, and coverage of the ectoproct *Watersipora* increased in the Back Channel. Region-wide, mussel cover and biomass along the southern California coast decreased markedly between the mid-1970s and 2002: cover by 40% and biomass by 51% (Smith et al. 2006). However, mussel cover and biomass remained unchanged or increased in central and northern California over the same time period. Reasons for the decrease in southern California are unknown. Abundance and occurrence of mussels in the Port Complex is known to be variable (Loi 1981; MBC 2009). The difference in mussel abundance between 2000 and 2008 could be related to improvements in local water quality over that period. Why Pacific oyster has become the dominant mollusk on the pilings in West Basin, apparently out-competing bay mussels, is unclear, although the disappearance of mussels was noted over a two-year period previous to the current survey (Sloan 2015, pers. comm.).

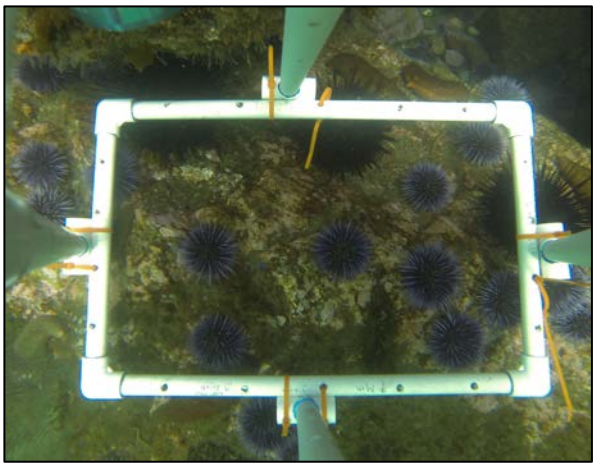
While numbers of species and individuals found during this study were overwhelmingly higher than reported in previous surveys, overall diversity was similar, and biomass was notably lower than in 2000 and 2008 (MEC 2002; SAIC 2010). Since field and laboratory methods and stations utilized were comparable among the three studies, reasons for these differences are unclear. Differences in sizes of community dominants contributed to this variability. The moderate number of relatively large individuals in earlier studies has been replaced by smaller but more numerous organisms (in terms of both species and abundance).

Of the 558 riprap biota taxa found in scraped quadrats in this study, 18 have been classified as introduced (non-native or non-indigenous), 58 are considered cryptogenic (native range or region unknown), and six species are unresolved (species complexes, including more than one species, or questionable identification). These species will be discussed in Chapter 11, Non-native Species.

RAPID ASSESSMENT

The three Rapid Assessment methods – 1/8 m^2 plots, 1 m^2 plots, and video transects – gave very similar results in terms of the character of the riprap communities at the various depth zones among the stations. They differed primarily in the scope of the assessment each allowed. The 1/8 m photoplots, for example, never saw fish, whereas several fish were observed in the video transects.

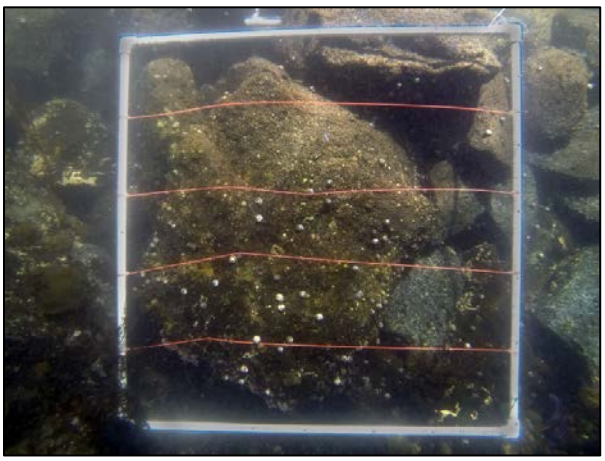
The percent cover of the various measured components -- unidentifiable points, silt-covered points, bare rock, and species/taxa -- was highly variable among zones and locations, but varied little by season (Appendix F-15). All three methods found that the upper intertidal zone at most sites was dominated by bare rock, barnacles (*Balanus, Chthamalus,* and occasionally *Tetraclitus*), limpets (*Lottia* spp.), encrusting algae (browns and reds), and red algal turfs. Overall, as typically found in intertidal studies, the upper intertidal had the lowest species diversity of any tidal zone. The biota in the upper intertidal at Station LARR3, the piling station, was vastly different from that at the other locations, being dominated by oysters, mussels, and scallops.



Purple sea urchins (*Strongylocentrotus purpuratus*) in a 1/8-m^2 photo plot.

Percent cover in the mid-low zone was much more variable among sites and seasons than it was in the high intertidal (Appendix F-15). At most sites, the mid-low zone contained at least some bare rock, a high percentage of articulated coralline algae (e.g. *Corallina* spp, *Bossiella* sp) and/or red algal turf and invertebrates. Giant kelp was present at five sites in summer and at six sites in spring. Station LARR3 was, again, dramatically different from the other sites, with relatively high coverage by sponges, tunicates, hydroids, and tube-dwelling worms or tube-forming gastropods. Species diversity was the highest in the mid-low intertidal.

At most stations in the subtidal zone many species were unidentifiable due to poor resolution of video/photos or coverage by silt. Therefore, patterns in the subtidal zone are hard to characterize. It is clear that these communities were heavily affected by silt, with many plots nearing 100% silt coverage. Ecologically, the presence of silt is important because fine sediments in the intertidal can clog feeding mechanisms in filter-feeding organisms, cover surface films fed on by intertidal grazers, block light availability for algae, and reduce settlement opportunities.



Overview of 1-m^2 video plot. (Video screen grab).

The rapid assessment methodologies used in this study were less successful than hoped in that they yielded much less information on the invertebrate component of the riprap community than did the scraped quadrats. However the rapid assessment surveys did yield information on coverage by algae that was not provided by the scraped quadrats. The most common problem encountered when evaluating rapid

assessment videos, photos, plots, and/or transects was the difficulty in identifying species or taxa. This was due to several issues: a) poor visibility because of sediment in the water column or insufficient lighting in the mid-low intertidal and subtidal zones; b) poor resolution by cameras both in and out of water; and c) silt covering large portions of the plots. The rapid assessment sampling program found no clear and consistent differences among stations and zones or between seasons during the study, suggesting that sampling could be reduced to one survey per study, which would allow an emphasis on field collection of data with minimal laboratory work required.

Of the 101 riprap biota taxa found in the rapid assessment survey in summer 2013 and spring 2014, six have been classified as introduced (non-native or non-indigenous), two are considered cryptogenic (native range or region unknown), and three species are unresolved (species complexes, including more than one species, or questionable identification). These species will be discussed in Chapter 11, Non-native Species.

Overview of a video transect. (Video screen grab).

SEA STAR WASTING SYNDROME

Pisaster ochraceus (and other *Pisaster* species) were present at four of the eight stations, and within several zones at one station in summer, but in spring they were absent from all but one station, where they were rare. This large decline in sea stars was likely driven by Sea Star Wasting Syndrome (SSWS), which has severely affected sea star populations along the West Coast of the United States. SSWS was first detected in summer 2013 in Washington State and rapidly spread to northern and central California. In early 2014, sea stars in southern California began to show signs of the disease, with a large proportion of sea stars dying shortly thereafter. At most of the monitoring sites in southern California, sea star abundances were reduced to zero. The disease is believed to be linked to a densovirus infection that results in the sea star melting in less than one day. While similar outbreaks have occurred in the past, they were typically localized and brief, whereas the 2013–2015 outbreak was widespread and has lasted for well over a year and a half. During the current study, the bat star, *Asterina miniata*, although somewhat more abundant in summer than the following spring, did not appear to be affected by SSWS, but the species has been shown to be susceptible to the disease elsewhere.

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CHAPTER 7 KELP AND MACROALGAE

This section presents the results of surveys of kelp and other macroalgae conducted throughout the Port Complex during 2013–2014. Kelp refers to brown algae that form surface canopies, and in the Port Complex the major species are giant kelp (*Macrocystis pyrifera*) and feather boa kelp (*Egregia menziesii*). Macroalgae are algae larger than planktonic species, and are known generally as "seaweed". Giant kelp is an important component of coastal and island communities in southern California, providing food and habitat for numerous animals (North 1971; Patton and Harmon 1983; Dayton 1985; Foster and Schiel 1985). Approximately 500 species of macroalgae occur in southern California, including 59 species of green algae (Chlorophyta), 86 species of brown algae (Ochrophyta), and 347 species of red algae (Rhodophyta) (Murray and Bray 1993).

Giant kelp is a brown alga that occurs along the entire coast of California where there is suitable habitat (i.e., hard substrate such as reefs, cobble, and riprap). It generally grows at depths of 6–18 m (20–60 ft), although in a few locations it as been found to 30 m (98 ft) (MBC 2014). *Macrocystis* is comprised of a holdfast that attaches to hard substrate, stipes (stalks), and blades emerging from floatation bladders. When individual plants reach sufficient size, the fronds (stipes and blades) spread out on the sea surface to form canopies. The plants can grow up to 35 cm per day (Dawson and Foster 1982).

Giant kelp (*Macrocystis pyrifera*) "forest"

Feather boa kelp is usually found from the lower intertidal zone to about 6 m (20 ft) (Dawson and Foster 1982). Like giant kelp, it occurs along the entire California coast on hard substrate, and is sometimes found on the inner edge of *Macrocystis* beds. It prefers moderately wave-swept habitats, and can grow to 15 m (49 ft) long (Blanchette et al. 2002).

Kelp and other macroalgae have a wide range of tolerances to environmental conditions, with various species having various preferences related to temperature, salinity, and light availability. Biotic interactions such as competition between plants for space and light, competition for space between plants and sessile animals such as barnacles and mussels, and grazing by herbivores such as snails and sea urchins influence the macroalgae community structure (Murray and Bray 1993).

MATERIALS AND METHODS

KELP OVERFLIGHTS

Kelp canopies within the Port Complex were surveyed using aerial mapping. The kelp survey used aerial infrared photographs from the ongoing Central Region Kelp Survey Consortium (MBC 2014). Overflights conducted in spring 2014 (June 27) and summer 2014 (September 10) were used for this project. Direct downward-looking photographs of the kelp were taken from an aircraft modified to facilitate aerial photography. The pilot targeted the following operating conditions:

- Weather: at least a 15,000' ceiling throughout the entire survey range and wind less than 10 knots,
- Ocean: sea/swell less than five feet and tide less than +1.0' Mean Lower Low Water (MLLW), and,
- Sun: sun angle greater than 30 degrees nadir.

The photographs from each survey were digitally assembled into a composite photo-mosaic that provided a regional view of the entire Port Complex. The mosaics were then transferred to GIS (ArcGIS 10.3) to geo-reference the images to match at least three prominent features on the map and to place them into specific Fish and Wildlife geo-spatial shape files. Each mosaic was converted to Universal Transverse Mercator (UTM), and ultimately converted to a geo-referenced JPEG file.

Surface canopy areas were calculated using the image classification function, an extension to the GIS program (SpatialEcology.com). Drift algae was not quantified. The resultant canopy areas were then layered onto standard base maps to facilitate seasonal comparisons. Differentiation between *Macrocystis* and *Egregia* was performed by ground-truthing in the field.

MACROALGAE DIVER SURVEYS

Macroalgal communities were surveyed and documented by biologist divers who surveyed 20 fixed stations (transects) throughout the Port Complex to establish the species composition and vertical distribution of kelp and macroalgae (Figure 7-1; Table 7-1; Appendix L). Surveys were performed in September 2013 (summer; note that the summer diver survey occurred in 2013 whereas the summer aerial survey occurred in 2014, both in September) and May 2014 (spring). Methods followed those from the 2008 Biological Survey (SAIC 2010) with a few exceptions:

- Transect T3 was relocated approximately 350 m northeast from its 2008 location (a groin at Cabrillo Beach that was subsequently removed) to a nearby breakwater at Cabrillo Marina;
- Biologists video-taped each transect so that field identifications could be verified in the laboratory;
- The coverage of each algal taxon was estimated within 5-meter increments along each transect (i.e., from 0 to 5 m, from 5 to 10 m, etc.); and
- Photographs of 0.125-m^2 quadrats were taken at 9 of the 20 stations to document sessile invertebrates.

Divers used a modified belt transect methodology. At each station, two divers swam from the waterline to the harbor floor following a fiberglass measuring tape. Transect endpoints were recorded with a handheld GPS unit. Each transect was divided into five-meter distance increments so the vertical distribution of algae could be analyzed. The divers recorded dominant macroalgal species (presence/absence data) that occurred within one meter on either side of the measuring tape. Thus, total species noted along each transect represented the total number of dominant species, not an exhaustive list of all species present. Each transect terminated at the point where algae were no longer found and the probability of encountering further algae was low, which typically was at the riprap/mud interface.

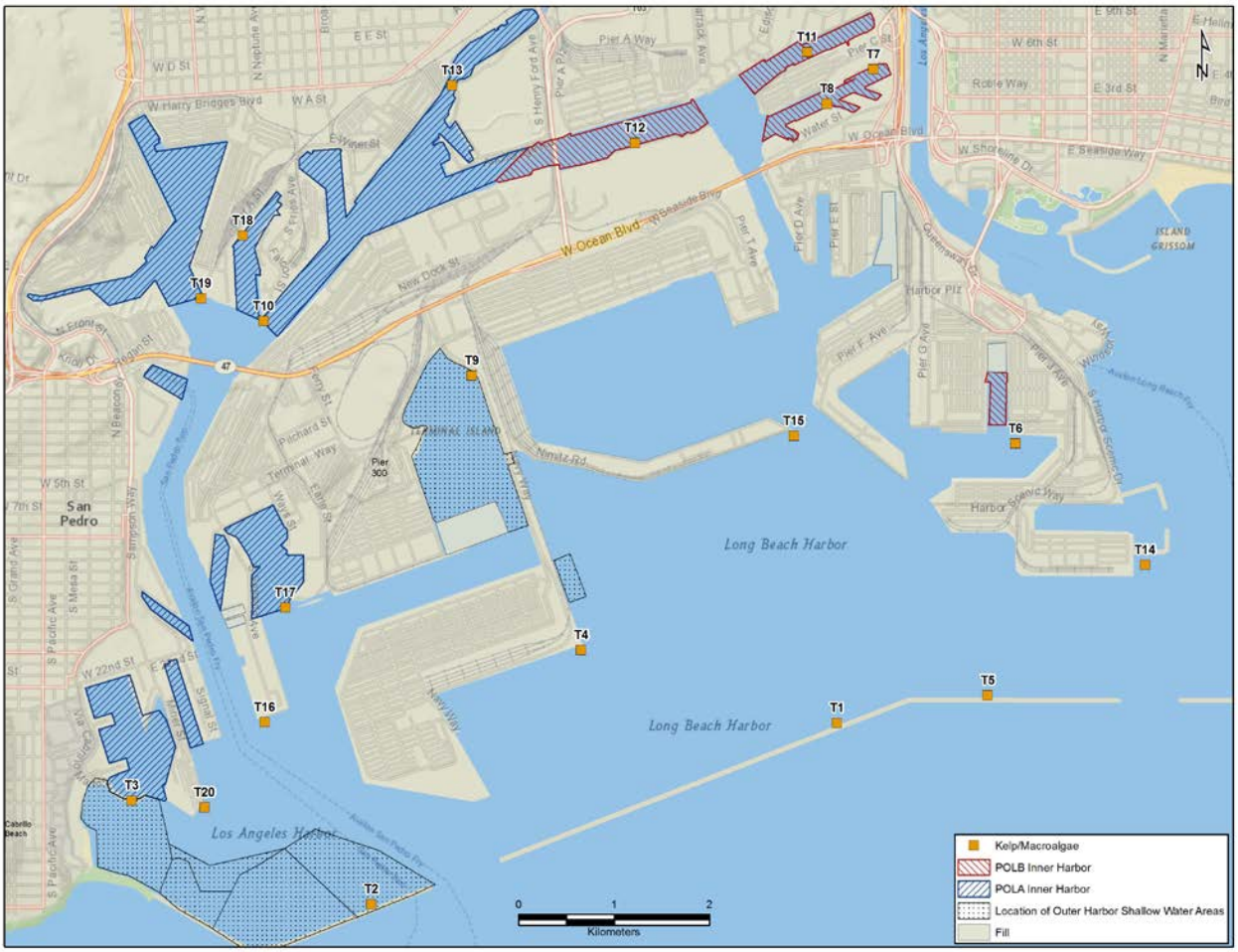


Figure 7-1. Location of kelp/macroalgae transects.

At nine transect stations, photographs of a single 0.125-m^2 quadrat were taken at three different depths. The nine stations and three depths were chosen prior to each survey using a random number generator. In the laboratory, photographs were reviewed and all organisms were identified to the lowest practicable taxonomic level. Coverage of macroalgae and encrusting organisms was recorded as the percentage of the photo-quadrat covered. Individual invertebrates (sessile and non-sessile) and fishes were enumerated.

Observed algae were usually recorded by genus because either multiple species within a genus can be encountered, or because identification to species level was not possible during the surveys for some specimens. For example, *Prionitis* and *Petalonia* sometimes occurred in mixed mats that were difficult to discern, in which case the coverage was designated "*Petalonia/Prionitis* complex". When possible, macroalgae were classified as native, introduced, or unknown/unresolved, based on known origins of the algae and on several literature sources (e.g., CDFW-OSPR [2009]). In the laboratory, the video footage from each transect and the photographs of the quadrats were reviewed by biologists. Data analyses included community composition, spatial occurrence, and density or occurrence by depth. Cluster analysis was performed on the mean percent cover of each macroalgal species at each transect, and station clusters were grouped by color based on similarity between and among stations. Data generated by the macroalgae surveys are presented in Appendix G.

Table 7-1. Transects used for the macroalgae diver surveys.

Transect	Designation/Location	Harbor Type	Transect	Designation/Location	Harbor Type
T-1	Middle Breakwater	Outer	T-11	Channel 2	Inner
T-2*	San Pedro Breakwater	Outer	T-12	Cerritos Channel	Inner
T-3*	Cabrillo Marina Jetty	Outer	T-13	Consolidated Slip	Inner
T-4	Pier 400	Outer	T-14	Pier J	Outer
T-5	Middle Breakwater	Outer	T-15	Navy Mole	Outer
T-6	Southeast Basin	Outer	T-16	LA Main Channel	Outer
T-7	Channel 3	Inner	T-17	Fish Harbor	Outer
T-8	Channel 3	Inner	T-18	Slip 1	Inner
T-9*	Seaplane Lagoon	Outer	T-19	LA West Basin	Inner
T-10	LA Turning Basin	Inner	T-20	LA Berth 44-50	Outer

* indicates shallow-water habitat in the Outer Harbor.

RESULTS

KELP CANOPY

The extent and location of the kelp canopies (*Macrocystis* and *Egregia*) in the Port Complex during the spring and summer of 2014 are depicted in Figures 7-2 through 7-5; no kelp was visible in the northern portions of the Ports that are not included in the figures. *Macrocystis* was apparently the dominant kelp in 2014 because, as explained in the Discussion section, below, the contribution of *Egregia* to total canopy coverage could not be reliably estimated based on visual surveys at the surface.

SPATIAL DISTRIBUTION

Within the Port Complex, kelp grew on the breakwaters protecting the harbors, riprap along the piers and wharves facing the open waters of the Outer Harbor, riprap along some piers and wharves not directly exposed to the Outer Harbor, and submerged rock dikes.

Specifically, during the spring survey, when kelp was at its maximum extent, kelp canopies were visible (from east to west) at:

- Both faces of the Long Beach and Middle breakwaters;
- Both faces of Pier F and the Navy Mole;
- The west-, south-, and east-facing outer faces of Pier J and both faces of the breakwaters protecting the Pier J slip;
- The west, south, and east faces of Pier 400;
- The submerged dike of the Pier 400 Submerged Storage Site;
- The eastern segment of the submerged dike of the Cabrillo Shallow Water Habitat;
- Both faces of the San Pedro Breakwater;
- The south and east faces of Reservation Point (Station T-16 on the east side of the Los Angeles Main Channel), including the jetty protecting Fish Harbor;
- The south and east faces of LA Berths 44-50 and the adjacent pier on the west side of the Los Angeles Main Channel; and
- The Cabrillo Marina jetty.

Feather boa kelp (*Egregia*).

TEMPORAL VARIABILITY

Kelp covered an estimated 132 acres in spring and 46 acres in summer. In spring, the thickest beds were on the breakwaters and at locations nearest the harbor entrances (i.e., Pier 400 and Pier J). Kelp persisted at most of the Outer Harbor locations in summer, although the densities of the beds were much lower than they were in spring. In summer, the thickest beds were along Pier J, Pier 400, and the San Pedro Breakwater; the beds along the Middle and Long Beach Breakwaters and the Navy Mole were not as lush as they were in spring, and no canopy was observed on the submerged dikes at the Cabrillo Shallow Water Habitat and Pier 400.

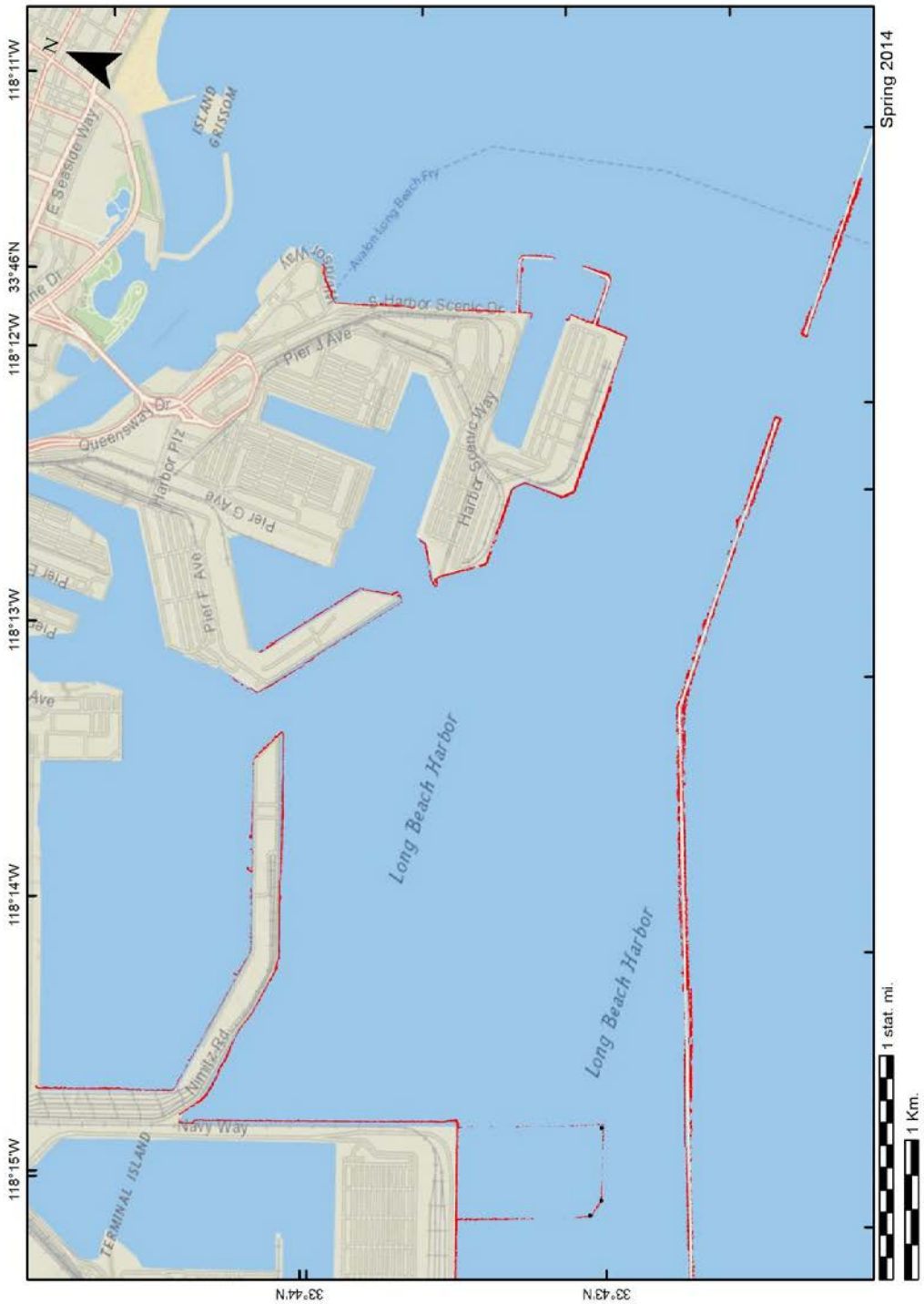


Figure 7-2. Kelp coverage (red) in Long Beach Harbor in spring.

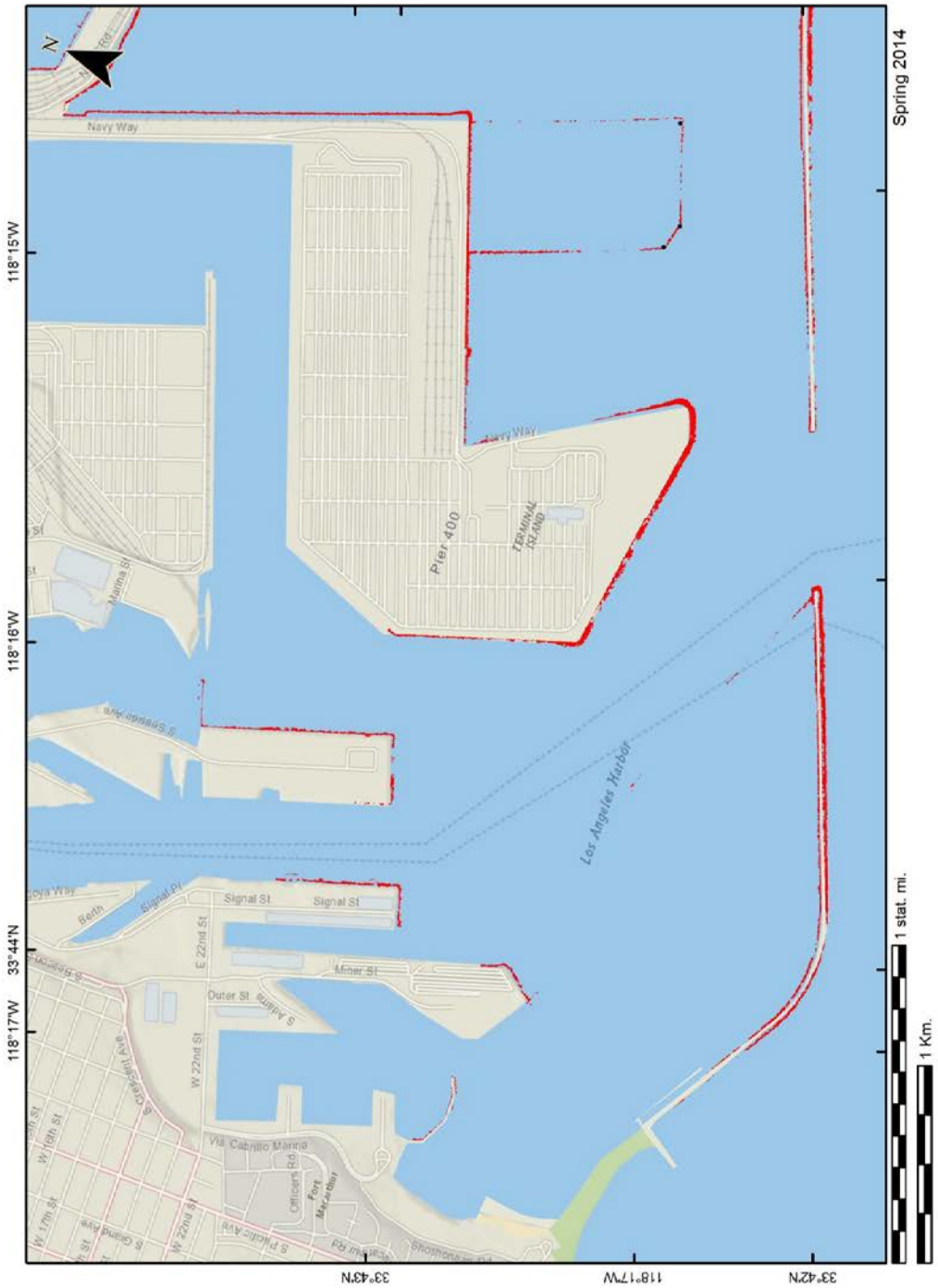


Figure 7-3. Kelp coverage (red) in Los Angeles Harbor in spring.

Figure 7-4. Kelp coverage (red) in Long Beach Harbor in summer.

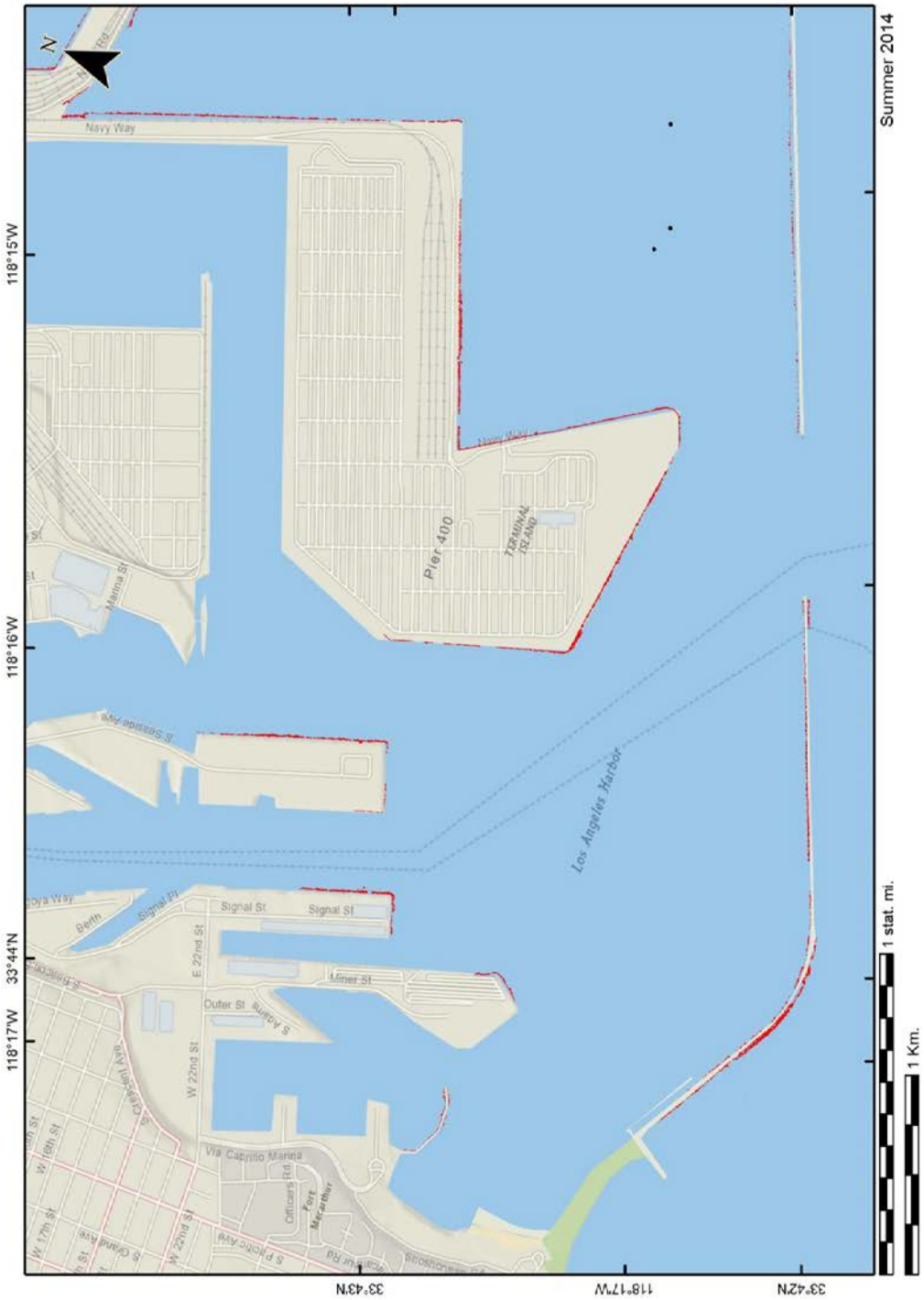


Figure 7-5. Kelp coverage (red) in Los Angeles Harbor in summer.

MACROALGAE SURVEYS

SPECIES COMPOSITION

A total of 34 taxa representing at least 29 distinct genera was observed during the macroalgae surveys (Appendix G-1). The summer survey identified 30 taxa representing at least 28 genera (Table 7-2, Appendix G-2). The most frequently observed taxa were *Macrocystis*, *Ulva* sp., *Sargassum muticum*, *Colpomenia* sp., *Undaria* spp., and *Weeksia* sp. On average, 10 genera were recorded along each transect. The lowest species richness (i.e., the fewest algal taxa) was recorded at Transect T-7 (Channel Three) and Transect T-9 (Seaplane Lagoon), each of which had only four taxa (Figure 7-6). The highest species richness (17 genera) was recorded at Transect T-16 (at the southwest corner of Reservation Point). Brown (Ochrophyta) and red (Rhodophyta) algae were observed at all transects, but green algae (Chlorophyta) were absent from five transects: T-4, T-6, T-7, T-11, and T-16.

A total of 28 taxa representing at least 26 distinct genera was observed during spring (Table 7-2, Appendix G-4). The most frequently observed taxa were *Macrocystis*, *Sargassum muticum*, *Undaria*, Corallinaceae (calcareous red algae), and *Prionitis* (Table 7-2). On average, nine genera were recorded along each transect. The lowest species richness was recorded at Transect T-9, where there were only two taxa (Figure 7-7). The highest species richness (17 genera) was recorded at Transect T-16. As in spring, brown and red algae were observed at all transects, but green algae were absent from eight transects: T-4, T-6, T-7, T-9, T-11, T-12, T-15, and T-16.

Macroalgae survey team.

DISTRIBUTION

Summer

Coverage of macroalgae along each transect in summer (Figure 7-8) ranged from 2% at Transect T-11 to 34% at Transect T-15, and averaged 17%. Overall, brown algae averaged 8% cover, red algae 7%, and green algae 2%. *Macrocystis* was observed at all of the Outer Harbor transects except T-5 and T-6.

Table 7-2. Macroalgal percent cover by distance along each transect during summer 2013. Green = higher percent cover, blue = lower percent cover; an increase in distance along transects is generally associated with an increase in water depth.

	Distance Along Transects (m)					
Taxon	0-5	5-10	10-15	15-20	20-25	>25
Macrocystis pyrifera	6.9%	2.5%	2.0%	1.7%	2.6%	0.8%
Ulva	3.5%	3.4%	1.0%	0.4%	-	-
Sargassum muticum	1.0%	1.4%	0.9%	0.3%	-	-
Colpomenia	1.4%	1.1%	0.2%	0.5%	-	-
Undaria pinnatifida	0.7%	0.8%	1.4%	0.5%	0.7%	-
Weeksia	0.3%	0.9%	0.7%	0.8%	0.6%	0.3%
Corallinaceae	3.0%	1.1%	1.0%	0.5%	-	-
Rhodymenia	2.2%	2.0%	1.0%	-	0.3%	-
Sargassum horneri	0.5%	2.3%	0.3%	0.4%	0.1%	-
Dictyopterus	0.3%	0.7%	0.3%	0.2%	0.6%	0.3%
Prionitis	0.2%	0.2%	0.4%	0.4%	0.3%	-
Gymnogongrus	0.2%	0.2%	0.3%	0.2%	0.4%	-
Chondria	0.3%	0.3%	1.3%	0.3%	0.1%	0.5%
Taonia	0.1%	0.1%	0.3%	0.3%	-	-
Acrosorium	0.2%	0.2%	0.2%	0.6%	0.7%	0.8%
Egregia	3.1%	-	-	-	-	-
Cystoseria	0.2%	0.8%	0.1%	0.5%	-	-
Plocamium	0.1%	0.5%	1.0%	0.2%	-	-
Dictyota	-	0.2%	0.1%	-	-	-
Gracilaria	0.5%	0.5%	-	0.2%	-	-
Bryopsis	0.3%	-	-	-	-	-
Chondracanthus	0.5%	-	0.1%	-	-	-
Cryptonemia	-	-	-	0.2%	-	-
Ectocarpus	0.7%	-	-	-	-	-
Petalonia / Prionotis	-	-	-	1.3%	0.7%	-
Ochrophyta, unid.	0.1%	0.3%	-	-	-	-
Botryglossum	-	-	0.1%	-	-	-
Codium fragile	0.1%	-	-	-	-	-
Desmarestia	-	-	0.1%	-	-	-
Rhodophyta, unid.	-	-	-	0.3%	-	-
Sum	25.8%	19.1%	12.1%	9.5%	7.1%	2.8%
No. Taxa	24	20	21	20	11	5
Chlorophyta	3.9%	3.4%	1.0%	0.4%	0.0%	0.0%
Ochrophyta	14.7%	10.0%	5.4%	5.7%	4.7%	1.2%
Rhodophyta	7.2%	5.7%	5.8%	3.4%	2.4%	1.7%

Macroalgal coverage was generally higher in the Outer Harbor than in the Inner Harbor (Figure 7-8). Coverage was highest at Transects T-15, T-2, and T-17, and lowest at Transects T-11, T-10, and T-7. Eelgrass (*Zostera* spp.) was growing at Transect T-10 between about -3 and -6 m, preventing the growth of macroalgae. Macroalgal coverage was higher at transects on the Los Angeles side of the Port Complex than on the Long Beach side due in part to depth differences: transects on the Long Beach side were on average deeper and included depths where light is limited and macroalgae are less likely to grow.

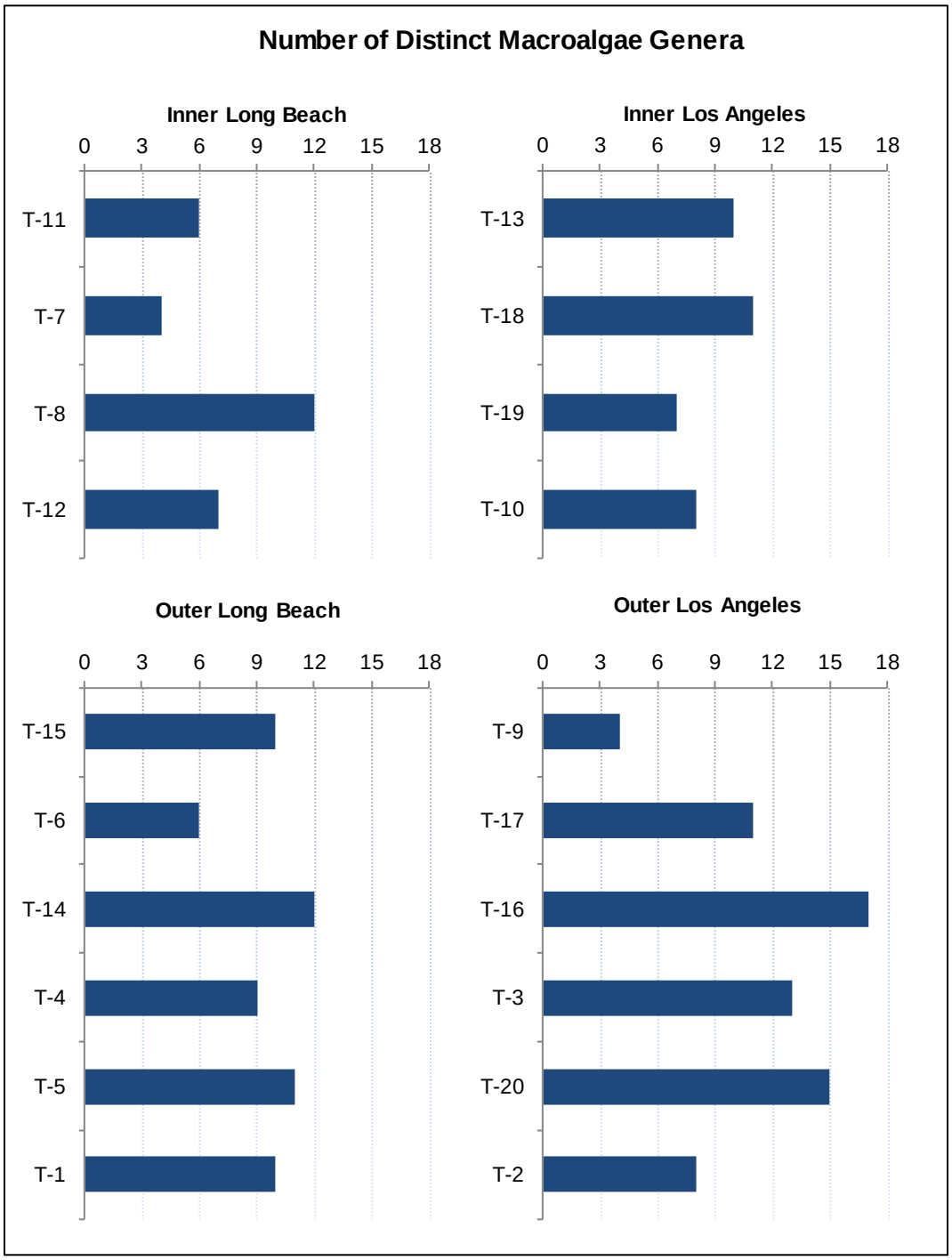


Figure 7-6. Number of macroalgal genera recorded along each transect during summer 2013. Transects are arranged from north (top) to south (bottom) in each graph.

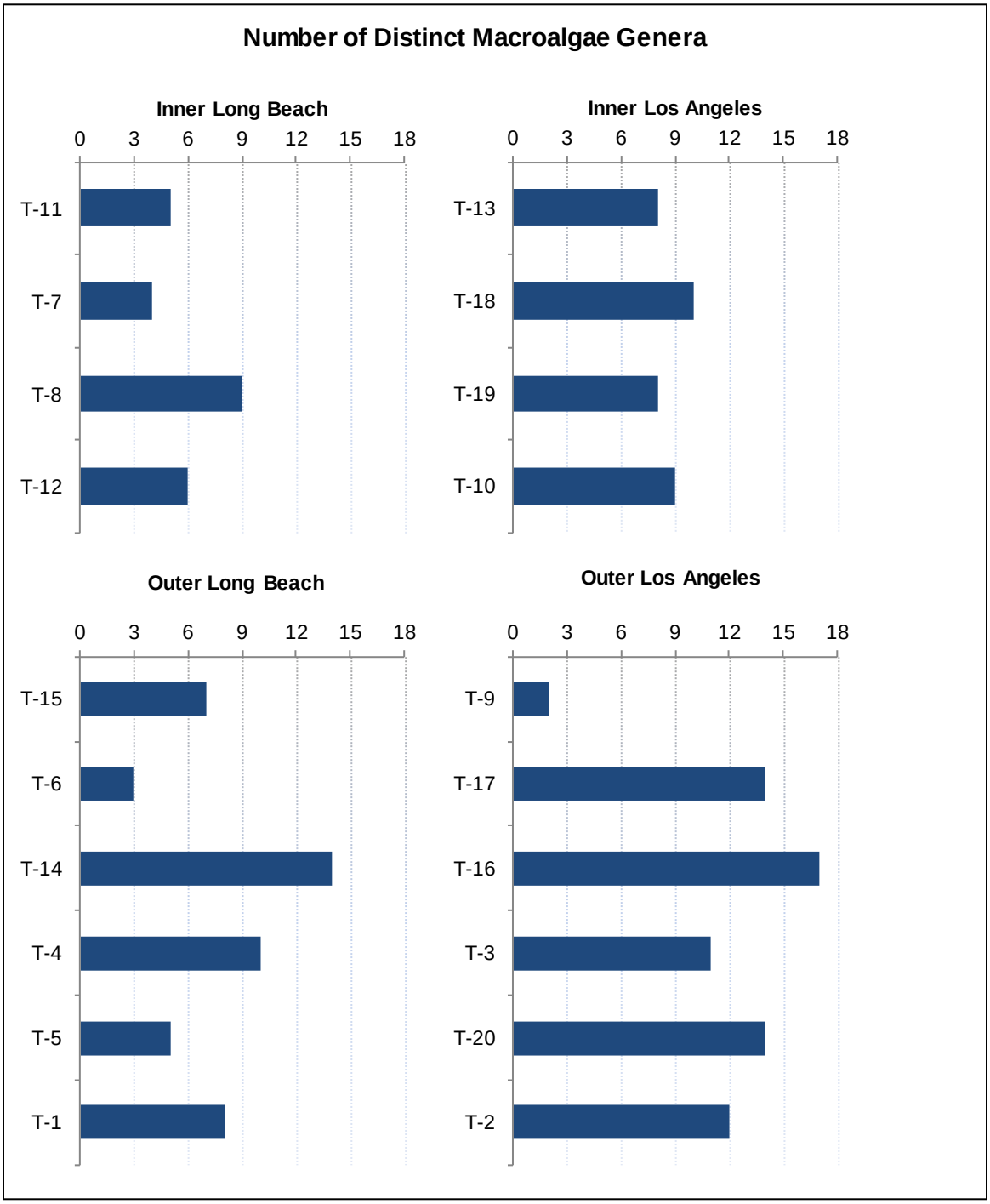


Figure 7-7. Number of macroalgal genera recorded along each transect during spring. Transects are arranged from north (top) to south (bottom) in each graph.

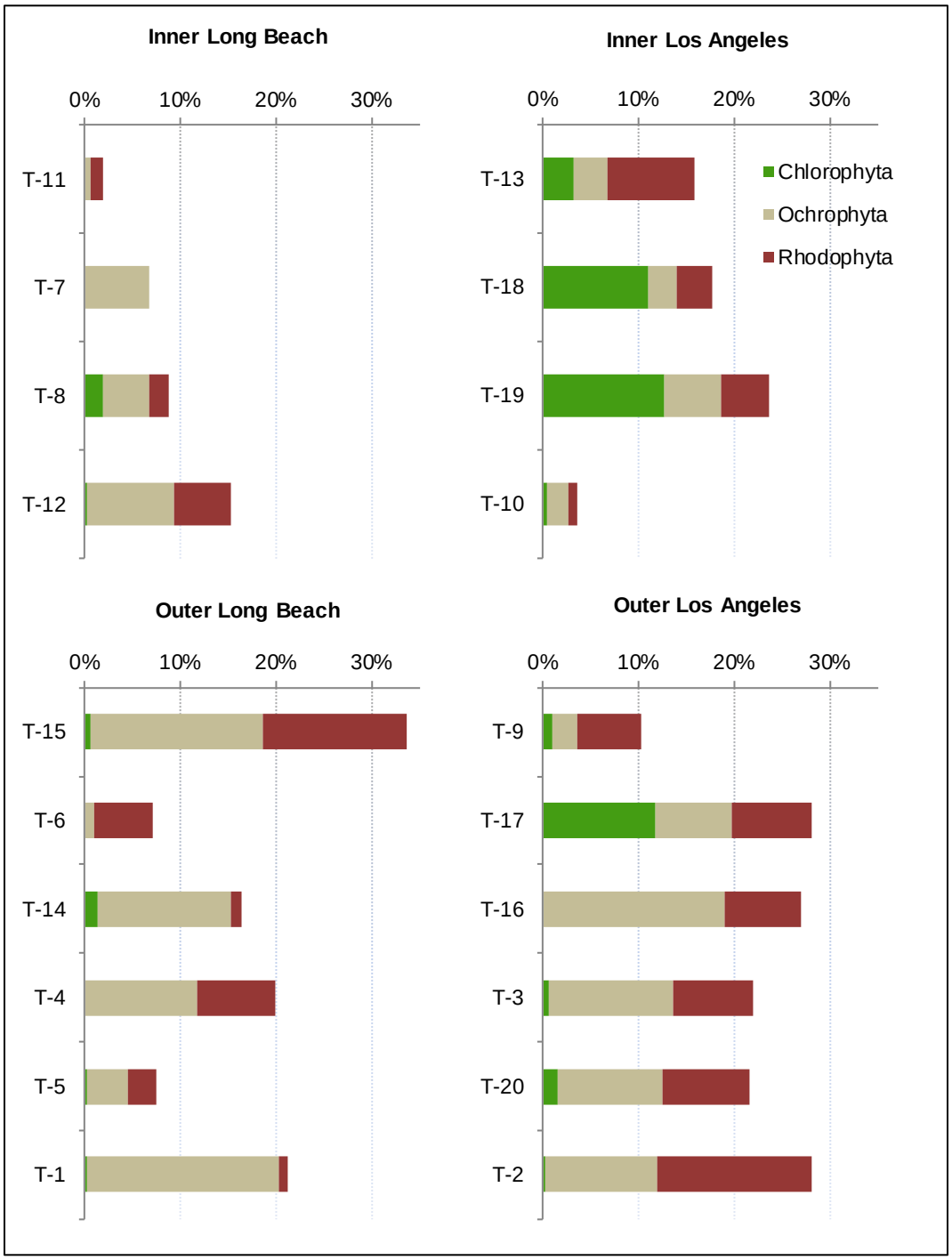


Figure 7-8. Macroalgal percent cover along each transect during summer 2013. Transects are arranged from north (top) to south (bottom) in each graph.

Coverage of macroalgae was substantially higher along the first 10 m of the transects (i.e., in shallower water) than farther from shore (Table 7-2). *Macrocystis* was especially abundant in the shallowest portions of the transects (6.9% coverage from 0 to 5 m), although it was one of only five taxa that was observed at distances >25 m from the shoreline. Coverage of *Macrocystis* was consistent at approximately 2-3% between 5 and 25 m along the transects. The kelp *Egregia* was only observed between 0 and 5 m from the shoreline. The next most abundant taxa, *Ulva*, *Sargassum muticum*, and *Colpomenia*, were most abundant between 0 and 10 m from the shoreline, and were absent beyond 20 m. The invasive alga *Undaria* was most abundant between 15 and 20 m (indicating that it thrives at lower light levels), and *Weeksia* was most abundant between 5 and 25 m.

Classification analysis resulted in five station groups (clusters) based on the similarity of species composition and mean percent cover at each station (Figure 7-9). Station Group A consisted of 10 Outer Harbor transects. Within that group, Transects T-2 and T-4 were the most similar overall; these two transects had similar depths (6.7 m and 6.1 m) and slopes (1.9:1 and 2.0:1, measured as run:rise), and the macroalgal communities at both were dominated by *Macrocystis* and *Rhodymenia*. Station Group B was comprised solely of Transect T-6. This transect was the deepest (14.9 m); coverage was low (7%) and comprised almost entirely of algae in the family Corallinaceae. Station Group C was comprised of four Inner Harbor transects, all on the Long Beach side of the Port Complex, Station Group D consisted of Transects T-9 and T-10, and Station Group E consisted of three Inner Harbor transects (T-13, T-18, and T-19) on the Los Angeles side.

These results show a clear spatial pattern: transects in or exposed to the open waters of the Outer Harbor formed Group A, characterized by generally higher percent cover and species richness, and the presence of *Macrocystis* and *Egregia*. Stations in the Inner Harbor slips and basins clustered together in Groups B, C, and E, characterized by generally lower percent cover and species richness.

Spring

In spring, coverage of macroalgae ranged from 2% at Transects T-11 and T-5 to 70% at Transect T-9. Macroalgae covered an average of 21% of each transect: 10% brown algae, 10% red algae, and 1% green algae. *Macrocystis* was observed at all of the Outer Harbor transects. As in summer, macroalgal coverage was generally higher at the Outer Harbor transects than at the Inner Harbor ones (Figure 7-10).

As in summer, coverage was substantially higher along the first 10 m of the transects than beyond 10 m (Table 7-3). Corallinaceae was the most abundant macroalga in the shallowest portion of the transects (9.9% coverage from 0–5 m), followed by *Macrocystis* (5.6%) and *Sargassum muticum* (5.2%). Eleven taxa occurred more than 25 m from the shoreline, *Macrocystis* being by far the most abundant. Seven of the eight occurrences of *Egregia* were within 5 m of the shoreline, illustrating how *Egregia* tends to occur at the shoreward edge of kelp beds. The eight most abundant taxa were concentrated between 0 and 15 m from shore.

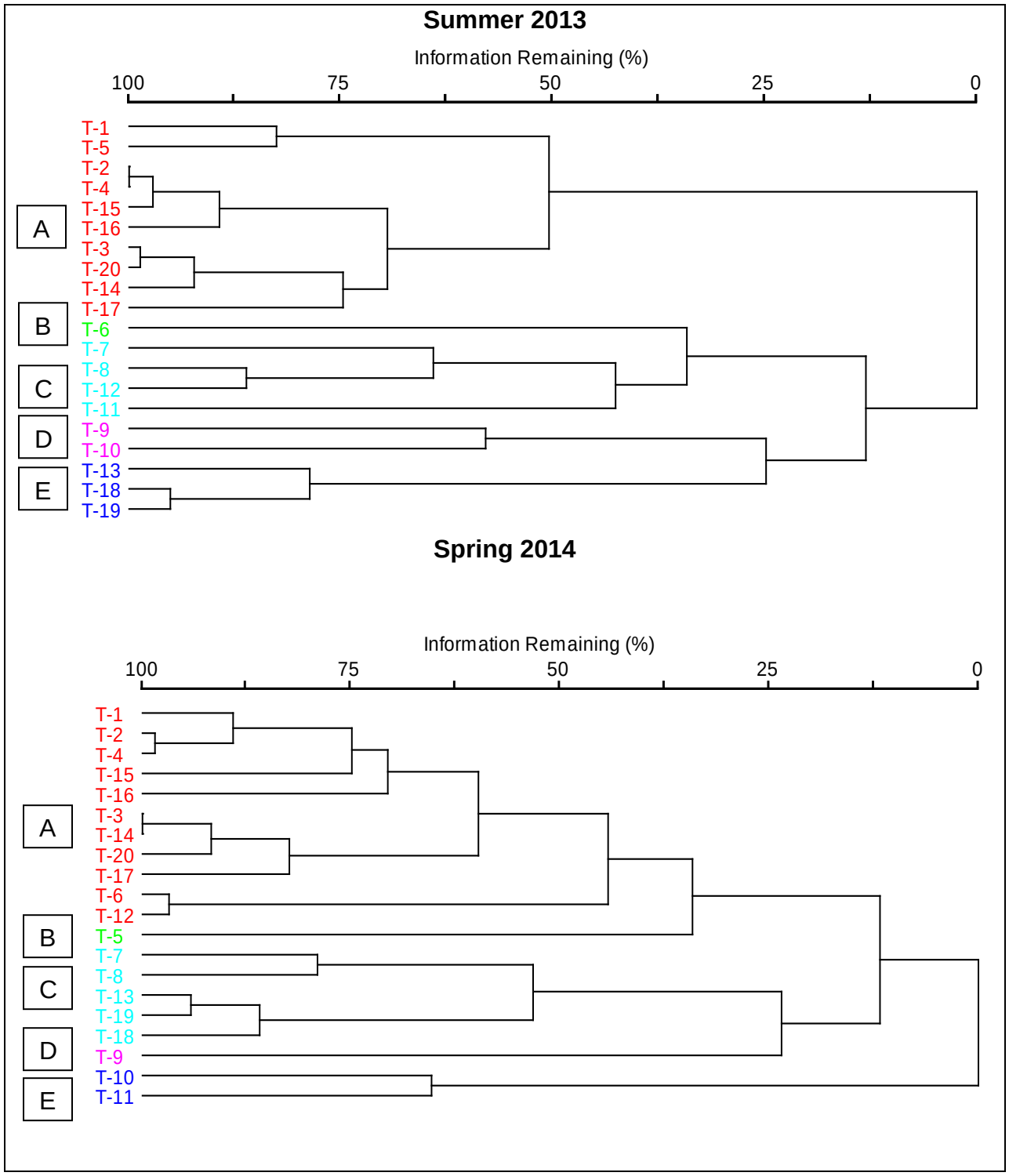


Figure 7-9. Macroalgal classification dendrograms based on mean percent cover at each transect. Summer (top) and spring (bottom).

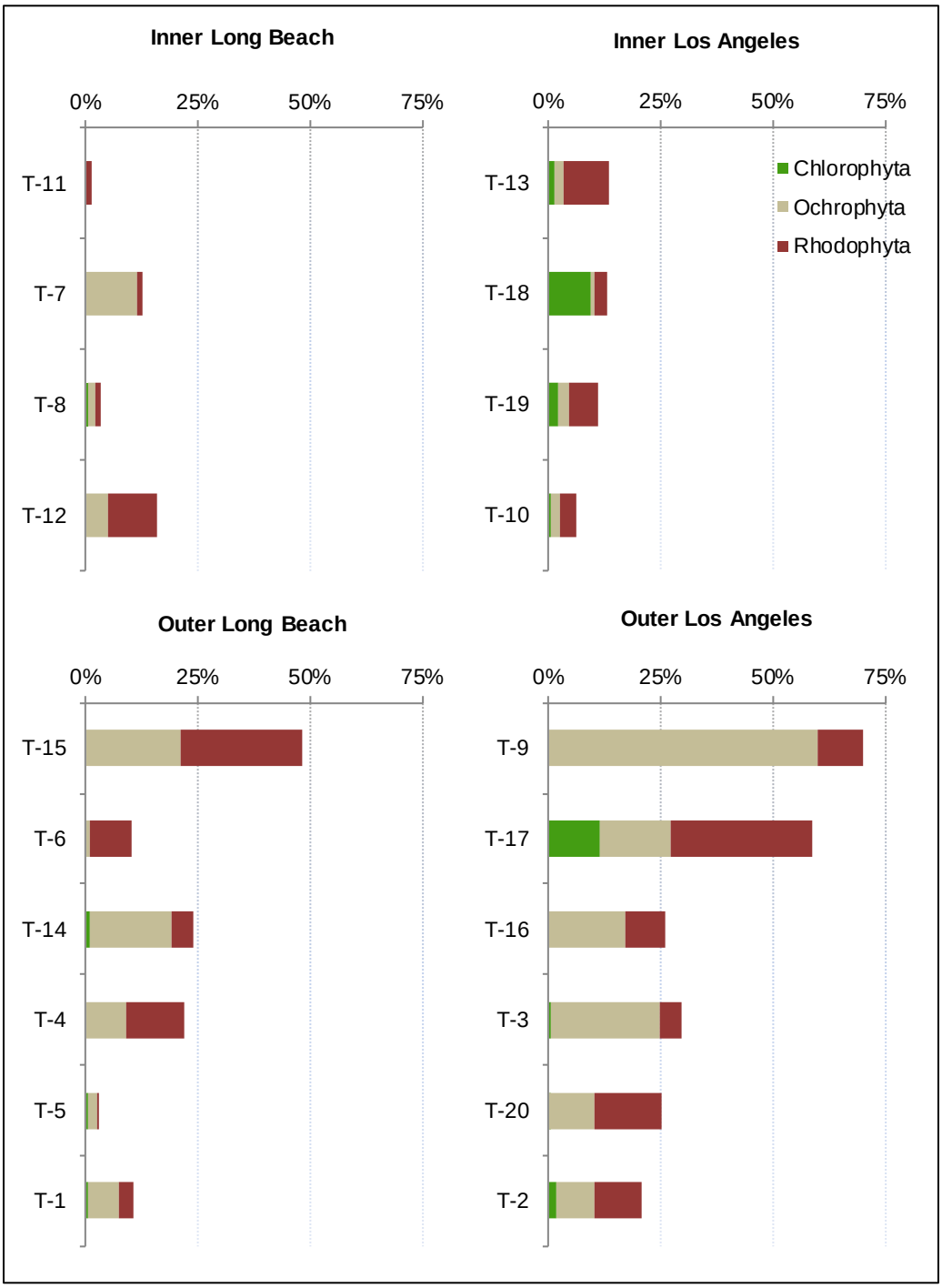


Figure 7-10. Macroalgal percent cover along each transect during spring 2014. Transects are arranged from north (top) to south (bottom) in each graph.

Table 7-3. Macroalgal percent cover by distance along each transect during spring 2014. Green = higher percent cover, blue = lower percent cover; an increase in distance along transects is generally associated with an increase in water depth.

	Distance Along Transects (m)					
Taxon	0-5	5-10	10-15	15-20	20-25	>25
Macrocystis pyrifera	5.6%	3.5%	2.2%	0.8%	1.0%	1.6%
Sargassum muticum	5.2%	6.4%	0.8%	0.1%	0.3%	0.2%
Undaria pinnatifida	0.5%	1.0%	1.1%	1.0%	0.3%	0.4%
Corallinaceae	9.9%	3.5%	0.7%	0.3%	-	-
Prionitis	0.4%	0.7%	0.9%	0.2%	0.3%	0.4%
Rhodymenia	1.3%	2.9%	1.5%	0.5%	0.3%	0.4%
Colpomenia	1.0%	0.7%	0.2%	-	-	-
Ulva	2.5%	1.5%	0.7%	-	-	-
Weeksia	0.1%	1.0%	0.8%	0.7%	0.2%	0.2%
Dictyopterus	0.1%	0.6%	0.4%	0.3%	0.7%	0.4%
Chondria	0.2%	0.3%	0.3%	0.4%	-	0.6%
Gymnogongrus	0.3%	0.2%	0.2%	0.1%	0.2%	-
Plocamium	0.1%	0.6%	1.1%	-	-	-
Cystoseira asmundacea	1.7%	0.4%	0.1%	0.8%	0.3%	-
Egregia	1.8%	-	0.5%	-	-	-
Taonia	-	0.1%	0.2%	0.2%	0.2%	-
Acrosorium	0.2%	0.2%	0.2%	0.1%	0.2%	0.2%
Chondracanthus	1.6%	0.1%	0.6%	-	-	0.2%
Desmarestia	-	0.1%	0.1%	0.3%	-	0.2%
Petalonia / Prionotis	0.1%	0.1%	0.1%	1.3%	0.2%	-
Sargassum horneri	-	0.1%	0.1%	0.1%	0.2%	-
Gracilaria	1.1%	2.1%	0.1%	-	-	-
Dictyota	0.1%	0.1%	0.1%	0.1%	-	-
Cryptonemia ovobata	-	-	0.1%	0.1%	-	-
Rhodophyta, unid.	0.1%	-	-	0.1%	-	-
Bryopsis	0.5%	-	-	-	-	-
Codium fragile	0.1%	-	-	-	-	-
Dictyoacea	-	-	-	0.1%	-	-
Sum	33.9%	25.4%	13.1%	7.3%	4.3%	4.8%
Taxa	23	22	24	20	13	11
Chlorophyta	3.0%	1.5%	0.7%	0.0%	0.0%	0.0%
Phaeophyta	16.0%	12.7%	5.9%	4.9%	3.2%	2.8%
Rhodophyta	15.0%	11.2%	6.5%	2.3%	1.2%	2.0%

Classification analysis resulted in five station groups (clusters) based on the similarity of species composition and mean percent cover at each station (Figure 7-9). Station Group A consisted of 11 transects, 10 in the Outer Harbor and one (T-12) in the Inner Harbor. These transects were characterized by moderate species richness, higher coverage (typically more than 15%) than at other transects, and dominance by *Macrocystis* (except at T-6 and T-12, which were dominated by coralline red algae [Corallinaceae]). Station Group B was comprised solely of Transect T-5,

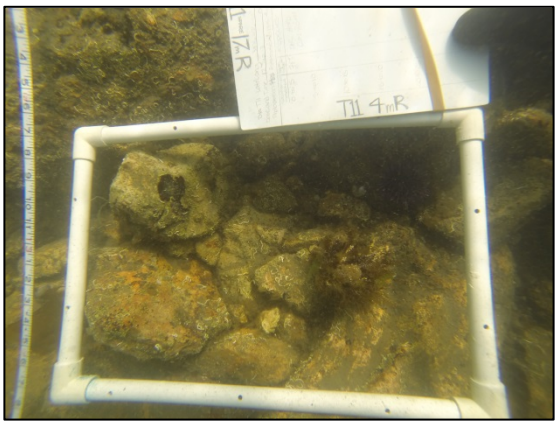
located on the Middle Breakwater, which exhibited the lowest coverage (2%) of any transect. Station Group C was comprised of five Inner Harbor transects. Coverage at these transects was low, but except at T-7 species richness was moderate; none of these stations supported kelp. Station Group D consisted only of one Transect T-9, which was a very short transect largely covered (70%, the highest of any transect) by *Sargassum muticum*. Station Group E consisted of two Inner Harbor transects (T-10 and T-11) characterized by low species richness and coverage.

PHOTO QUADRATS

Algal coverage in the photo quadrats is presented in Appendices G-3 (summer) and G-5 (spring).

SUMMER

A total of 18 macroalgal genera were identified at the nine photo quadrat transects examined in the summer survey. Coverage ranged from 0% (Transects T-10 and T-11) to 61% (Transect T-4). Nineteen distinct invertebrate taxa were identified in the photo quadrats (Appendix G-3). Ten of those taxa, represented by 36 individuals, are considered non-encrusting organisms: purple urchin (*Strongylocentrotus purpuratus*) and red urchin (*S. franciscanus*); limpet (*Acmaea* spp); tunicates (*Styela clava* and *Pyura haustor*); snail (*Tegula eiseni*); oyster (*Ostraea* sp.); rock scallop (*Crassadoma* spp); and strawberry anemone (*Corynactis californica*). Abundance of these organisms totaled 36 individuals (an average of about one per quadrat). In addition, one fish (Gobiidae) was also photographed. Encrusting organisms (or those whose individual abundance could not be quantified) included, in decreasing abundance: bryozoans (*Diaporoecia* and *Thalamoporella*); a snail (*Serpulorbis*); sea fan (*Muricea californica*); polychaetes (*Salmacina* and Spirorbidae); and diatom film (Bacillariophycae).



0.125-m^2 photo quadrat at Transect T-11.

SPRING

A total of 19 macroalgal genera were identified at the nine photo quadrat transects examined in the spring survey. Coverage ranged from 0% (several depths at six transects) to 89% (Transect T-17) (Appendix G-5). Twelve distinct invertebrate taxa were identified in the photo quadrats. Seven of those, represented by 59 individuals, are considered non-encrusting organisms: purple urchin; Christmas tree worm (*Spirobranchus* spp); limpet; burrowing anemone (*Pachycerianthus* spp); giant sea cucumber (*Parastichopus californicus*); nudibranch (*Hermissenda crassicornis*); rock scallop; snail *Lithopoma undosum*; and strawberry anemone. The only encrusting organism was diatom film.

DISCUSSION

In southern California, including in the Port Complex, the distribution of kelp is limited by available habitat, as well as by climatic and oceanographic processes on multiple scales. There is a negative correlation between temperature and kelp growth. This is thought to be because giant kelp depends on dissolved nutrients that usually occur in higher concentrations in cooler waters. Severe warm-water (El Niño) events can result in substantially smaller kelp canopies and can eliminate smaller beds altogether (MBC 2014). On a finer scale, differences in local circulation and oceanographic conditions can cause adjacent beds to follow different trajectories in a given year. For example, between 2012 and 2013 the canopy area of the southernmost kelp bed off Palos Verdes increased 75% at the same time an adjacent bed decreased by 6% (MBC 2014). Finally, kelp is limited by the availability of hard substrate (e.g., cobbles, boulders, and bedrock outcrops) large enough to provide a secure anchor point for the plants, which can be very long and heavy. The Port Complex provides an enormous amount of hard substrate in the form of riprap, breakwaters, and jetties, but that substrate is present in steep, linear configurations, which limits kelp coverage to narrow bands. Furthermore, much of the rocky substrate is in protected locations that do not allow the water circulation that kelp depends upon.

That same substrate, however, represents favorable habitat for a variety of other macroalgal species characteristic of southern California rocky shorelines. In particular, the breakwaters and south-facing Outer Harbor rock dikes are exposed to waves and currents typical of open coastal sites. The protected channels and basins are favorable habitat for algal species that cannot withstand vigorous wave and current action.

KELP

The amount of kelp growing in the Port Complex in spring 2014 was much higher than in spring 2000 or 2008 (Figure 7-11). Kelp coverage in summer 2014 was lower than in 2008 but higher than in 2000. The Central Region Kelp Survey Consortium (CRKSC) has photographed all of the kelp beds off the mainland between Ventura and Newport Beach, California, including those within the Port Complex, on a quarterly basis since 2003. The CRKSC's coverage assigns the Port Complex to the "POLA/POLB Bed", which includes areas outside the Port Complex (e.g., the oil islands and Long Beach Breakwater east of the current study area). However, beginning in 2005, kelp coverage within the Port Complex was calculated separately as part of the CRKSC's monitoring. The maximum canopy area in the Port Complex occurred in 2006 and 2012 (120 acres), and the lowest coverage was in 2007 (29 acres) (MBC 2014).

The trend in kelp coverage within the Port Complex has generally not coincided with trends in the other 25 beds in the region (Figure 7-12). For example, even though the second highest canopy coverage within the Port Complex occurred in 2006, the region-wide coverage ranked eighth out of the nine survey years, meaning that although region-wide 2006 was a low kelp year, inside the Port Complex it was a high kelp year. In 2013, the kelp within the Port Complex, considered as a single bed, ranked seventh in size out of the 26 beds monitored by the CRKSC, and comprised 6% of the total canopy coverage (MBC 2014). In 2012, the beds were much larger, ranking second in size and comprising 9% of the region's kelp canopy.

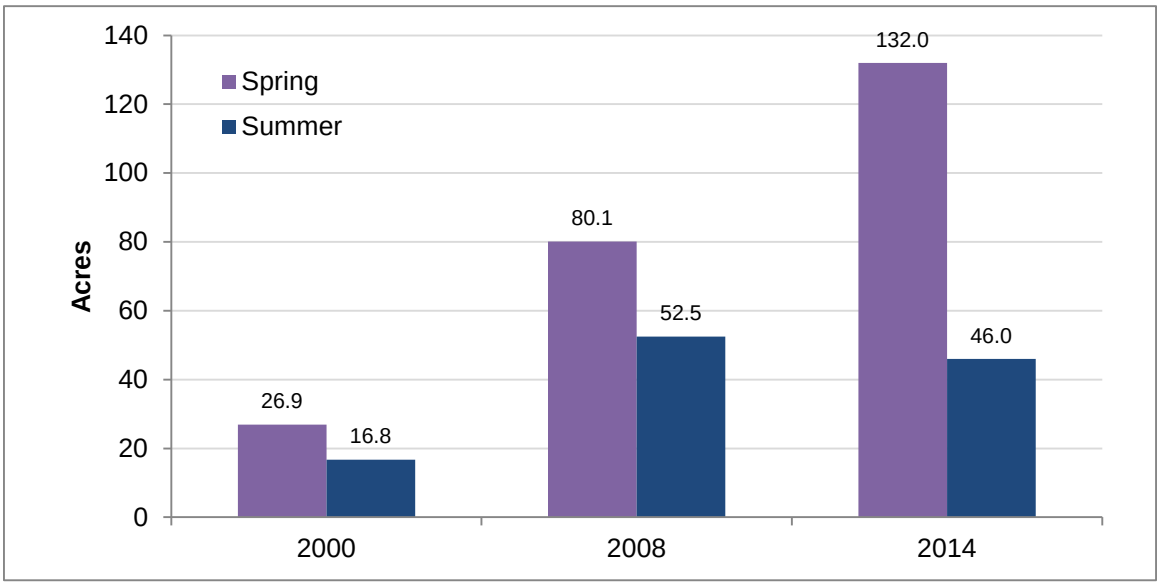


Figure 7-11. Estimated kelp coverage in the Port Complex by season in 2000, 2008, and 2014.

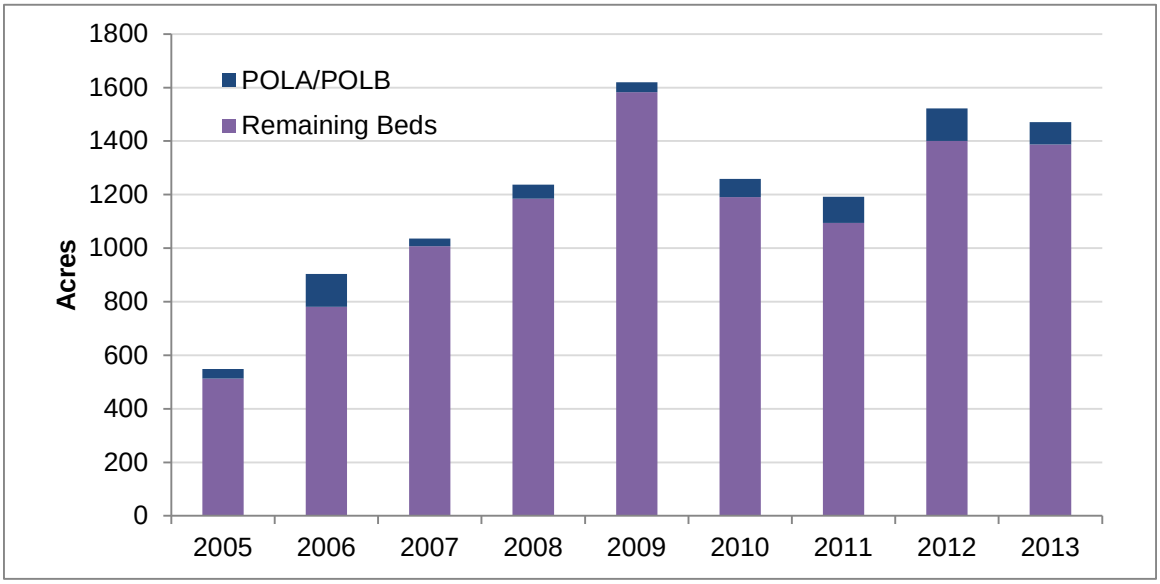


Figure 7-12. Estimated kelp coverage in the Port Complex and all other beds in the Central Region Kelp Survey Consortium, 2005–2013 (MBC 2014).

Previous harbor-wide kelp canopy estimates have separated the estimates for *Macrocystis* and *Egregia* (MEC 2002; SAIC 2010). Those studies and the current study have provided evidence that *Egregia*, like *Macrocystis*, has increased its coverage in recent years. In 2000 its distribution was limited to the Middle Breakwater (MEC 2002), but in 2008 it also grew on the

San Pedro Breakwater (SAIC 2010). In 2014, it grew along both breakwaters, as well as on Pier 400. However, it was not the dominant kelp, likely constituting less than 5% of the total kelp canopy, and it was limited to the inner (shallower) margin of the kelp beds. The current study attempted to consider *Egregia* separately, but for various reasons, aerial photography-based estimates of *Egregia*'s percent contribution to canopy cover would likely be inaccurate. Accordingly, the current study's estimates of kelp canopy coverage include both species combined.

In 2014, kelp beds within the Port Complex underwent typical seasonal reductions between spring and summer. It appeared that kelp beds were present at most locations both seasons but that they were substantially smaller in summer than in spring, and some of the beds disappeared entirely. Water temperatures in summer/fall 2014 were much higher than average: mean monthly temperatures at the San Pedro data buoy (5.5 nautical miles south of the Port Complex) in June, July, and September 2014 were the highest in at least the last 17 years (CDIP 2014). Since kelp coverage is known to be negatively correlated with water temperatures, it is likely that at least one factor in the reduced kelp canopy in summer 2014 was the unusually high water temperatures.

MACROALGAE

The diver surveys found that both species richness and percent cover varied substantially among stations, but that both measures were similar, on average, over seasons (10 species in summer, 9 in spring, 17% cover in summer, 21% in spring). The clear pattern that emerged from the analysis was the difference between Outer Harbor and Inner Harbor stations. In the multivariate analysis the Outer Harbors stations clustered fairly closely in both summer and spring (Figure 7-9), suggesting similarity in their algal assemblages. The key similarity appears to be the presence of *Macrocystis*. In summer, *Macrocystis* was the dominant genus at 8 of the 12 Outer Harbor transects and occurred at 12 of the 20 total transects, and in spring it was the dominant taxon at four Outer Harbor transects and occurred at ten of the total transects. Another similarity among Outer Harbor stations is the presence of *Egregia*, which occurred only in the Outer Harbor in both summer and spring.

Dominant taxa at the Outer Harbor transects not dominated by *Macrocystis* were Corallinaceae, *Gracilaria*, *Ulva*, *Rhodymenia*, *Sargassum muticum*, and *Cystoseira*. Some of these transects are somewhat protected from wave action, which could favor the growth of those species and inhibit the growth of *Macrocystis*. Despite the larger kelp canopies in spring than in summer, environmental conditions at the Outer Harbor transects in spring were favorable for the establishment of algal taxa other than *Macrocystis*. Even though kelp canopies can shade habitat and preclude establishment of other species, other factors (e.g., water temperature, nutrient concentrations, available light, grazing, and recruitment) enabled other macroalgae to grow and become dominant at some Outer Harbor transects.

Inner Harbor stations were more dissimilar from one another than Outer Harbor stations, and typically had fewer species and lower percent coverage than Outer Harbor stations. At the eight Inner Harbor transects the dominant taxa were similar in both seasons, and included *Ulva*, *Plocamium*, *Colpomenia*, *S. muticum*, *Weeksia*, and Corallinaceae.

Results of the 2013–2014 macroalgae surveys were consistent with those from 2000 and 2008 in terms of species composition, percent cover, and the distinction between Outer Harbor and Inner Harbor stations. The diversity of algae in the present study was similar to that recorded in 2000 and 2008, although somewhat more genera were recorded in the present study (26) than in the 2000 study (18). Furthermore, the invasive taxa *Undaria, S. muticum*, and *S. horneri* were among the top ten most abundant species in summer in the present study, which was not the case in the earlier studies.

A few interesting observations regarding past surveys emerged from this study. The green alga *Enteromorpha* was not recorded from the Port Complex in 2000 but was present at T-13 in 2008 (MEC 2002; SAIC 2010). However, in 2003 it was discovered that *Ulva* and *Enteromorpha* were not distinct genera, and *Enteromorpha* was synonymized with *Ulva* (Hayden et al. 2003). Therefore, it seems likely that the organism has been continuously present in the Port Complex. In addition, both the present study and the 2000 study noted that kelp coverage was lowest during both seasons at Transect T-5, while the density of red and purple sea urchins was highest at that transect during both seasons. The fact that sea urchins are a principal consumer of *Macrocystis* suggests that at least some level of grazing pressure was preventing kelp from flourishing at an otherwise favorable location. Overall, however, the increasing coverage of giant kelp and diversity of algae within the Port Complex over the past 15 years suggest that factors affecting recruitment and growth have been favorable.

The intertidal and subtidal biological communities in Long Beach Harbor were studied regularly from 1986 through 2008 as part of NPDES monitoring requirements for the Long Beach Generating Station on Terminal Island (MBC 2009). During the 23 years of study, the coverage of algae at +1 ft MLLW increased almost three-fold in the Outer Harbor, although there was substantial year-to-year variation. The increase was much smaller at +3 ft MLLW, and the coverage of algae at stations in the Back Channel and Inner Harbor was little changed over time. The increase in algae in the Outer Harbor coincided with a disappearance of mussels, which may reflect competition for attachment space.

As is discussed in more detail in Chapter 11 (Non-Native Species), the Port Complex ranked second among the seven California ports studied in the number of introduced species (OSPR 2002). Three invasive macroalgal species were observed in 2013–2014: *Sargassum muticum*, *S. horneri*, and *Undaria pinnatifida*. All three are adapted to survive under a wide range of habitats and environmental conditions, and all three continue to thrive in the Port Complex. No cryptogenic (native range or region unknown) species were observed, but six unresolved species (species complexes, including more than one species, or questionable identification) were observed during the two surveys. These species are discussed in Chapter 11.

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CHAPTER 8 EELGRASS

This section presents the results of eelgrass surveys conducted throughout the Port Complex during 2013–2014.

Eelgrass (*Zostera marina*) is a community structuring, vascular plant that forms expansive meadows or smaller beds in both subtidal and intertidal habitats in shallow coastal bays and estuaries, as well as within semi-protected, shallow, soft-bottom environments of the open coast.

Eelgrass (*Zostera marina*) beds function as habitat and nursery areas for commercially and recreationally important marine fish and invertebrates, providing cover, forage opportunities, habitat complexity, and enhanced productivity.

Eelgrass grows in soft-bottom environments ranging from silts to fine gravels, however the optimal growth medium is considered to be silty sands. Eelgrass in California is typically limited to low intertidal elevations along its upper margin by desiccation stress while the lower margin of growth is generally set by limitations on available photosynthetically active light. The elevation range of eelgrass is highly variable depending upon a number of factors including available habitat, wave energy, summer temperatures, and water clarity. Within San Pedro Bay, over 99% of the eelgrass occurs between +0.5 and -15 feet Mean Lower Low Water (MLLW).

Another species of eelgrass, *Z. pacifica*, is a broad-leaved plant found in sandy open coastal and semi-protected environments. To date, beds of *Z. pacifica* have not been discovered within the Port Complex; however, fresh detached leaves of *Z. pacifica* were observed floating in the Port of Long Beach in 2000 and again in 2013. *Z. pacifica* is known to occur in waters off the Long Beach marina immediately to the east of the Port Complex, which is likely the source of the floating detrital leaves. Presently, however, *Z. marina* is the only eelgrass species known to occur within the Port Complex.

Habitats vegetated with eelgrass are recognized as important ecological communities because of their multiple biological and physical values (e.g., major food source in nearshore marine systems, important structural environment for resident bay and estuarine species, etc.). As a result, eelgrass is considered a “foundation”, or habitat-forming species. Eelgrass is a major

source of primary production in nearshore marine systems, underpinning detrital-based food webs. In addition, several organisms directly graze upon eelgrass or consume algae and other plants that grow on eelgrass leaves ("epiphytes") and animals ("epifauna") supported by eelgrass plant structures, thus contributing to the system at multiple trophic levels. Eelgrass beds are, therefore, also a source of secondary production.

Eelgrass beds function as habitat and nursery areas for commercially and recreationally important marine fish and invertebrates, and provide critical structural environments for resident bay and estuarine species, including abundant fish and invertebrates. Eelgrass supports juvenile fish as well as mature, often predatory, fish that hunt along the margins of the bed's protective structure. Besides providing important habitat for fish, eelgrass is considered to be an important resource supporting migratory birds during critical migration periods. Eelgrass is particularly important to waterfowl such as black brant (*Branta bernicla nigricans*), which feed nearly exclusively on the plants, and to a number of other species that make a diet of both eelgrass and the epiphytic growth that occurs on the leaves.

In addition to its habitat and resource value, eelgrass traps and removes suspended particulates, improves water clarity, and reduces erosion by stabilizing the sediment. Eelgrass facilitates nutrient cycling and oxygenates the water column during daylight hours. Eelgrass also has the potential for considerable carbon sequestering.

Besides the critical resource values and ecosystem functions of eelgrass, it is uniquely suited to serve as a sentinel indicator of overall ecosystem condition. Eelgrass is an easily (and repeatedly) monitored, widely distributed integrator of environmental conditions that responds to natural and anthropogenic stressors that are chronic in nature. Eelgrass is robust with respect to short-term environmental fluctuations within normal or near-normal environmental ranges. However, eelgrass does respond to physical damage or short-term presence of high-toxicity discharge events. It also responds to disease that may be mediated by stress in the plants that weakens natural immunity.

Statewide, eelgrass coverage is believed to be limited to less than 15,000 acres, with the area of open-coastal eelgrass and Channel Islands eelgrass distribution and abundance being largely unknown, although several beds have been identified (Merkel 2013, Engle and Miller 2003, Coyer et al. 2008). Documented eelgrass within the Southern California Bight totals slightly over 5,000 acres (Bernstein et al. 2011). Throughout southern California, eelgrass is generally distributed sporadically in bays and estuaries. Dredging and filling of coastal wetlands, degradation of water quality, and loss of suitable habitat by other means has resulted in a fragmented distribution of this habitat. Today, eelgrass in the Southern California Bight remains well represented in San Diego Bay, Mission Bay, the restored Batiquitos Lagoon, the Bolsa Chica Wetlands, where it was introduced following restoration activities, and Agua Hedionda Lagoon. It is more limited in its distribution in other areas such as Oceanside Harbor, Dana Point Harbor, Newport Bay, Huntington Harbour, Alamitos Bay, and Anaheim Bay. Within the Port Complex, eelgrass has been regularly documented at Cabrillo Beach and the shallows adjacent to the Seaplane Lagoon and Pier 300 since at least the mid-1980s.

Due to the substantial function eelgrass and other seagrasses provide, they have special status designations under federal and state environmental laws and regulation. The U.S. Environmental Protection Agency (USEPA) has designated vegetated shallows, including

eelgrass beds, as special aquatic sites under the Clean Water Act. Special aquatic sites are given a higher level of protection under federal regulation and policy. Under the Clean Water Act (CFR 40 Part 230) Guidelines for Specification of Disposal Sites for Dredged or Fill Materials Subpart E, Potential Impacts on Special Aquatic Sites, there is a presumption of alternatives to discharges into special aquatic sites. 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 or have greater restrictions placed upon activities within them, 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 Environmentally Sensitive Habitat Area (ESHA).

MATERIALS AND METHODS

Eelgrass surveys were conducted over two seasons using a combination of acoustic techniques (interferometric sidescan sonar), diver surveys, and Remotely Operated Vehicle (ROV) surveys. The surveys were conducted at the height of the summer growing season and at the end of the winter season, during spring months, in order to detect seasonal variability of eelgrass aerial extent and density. Acoustic surveys of all shorelines and waters shallower than -30 feet MLLW within the Port Complex were conducted on September 9–11 and 26, 2013 (summer). The same areas were again surveyed on May 19–22 and June 10, 2014 (spring). Acoustic records of eelgrass were ground-truthed by diver and ROV surveys on October 21, 22, and 28, 2013 and May 19–20, 2014. These surveys also determined eelgrass bed density and characterized eelgrass health and vigor. Subsequent inspections to verify mapping of a few areas were also conducted on July 17, 2014 in conjunction with the July avian survey.

Survey vessel used to map eelgrass and provide bathymetric and sidescan waterfall data.

INTERFEROMETRIC SIDESCAN SURVEYS

Acoustic survey techniques generally followed those that have been developed and continually advanced since the mid-1980s. These methods provide for saturation coverage of all areas of potentially suitable bathymetric ranges to support eelgrass. Eelgrass is subsequently mapped by interpretation of acoustic signatures from rectified

swath records. The methods employed have been used extensively for system-wide mapping in such systems as Mission Bay and San Diego Bay (Merkel & Associates 2013, 2014). The methods in this study represent an evolution of the methods used in the prior two surveys of the Port Complex (MEC 2002; SAIC 2010).

Sonographic surveys were undertaken in navigable waters of the Port Complex using an interferometric sidescan sonar system. The interferometric sidescan system is a dual-channel, hull- mounted sonar operating at 468 kHz that integrates: a motion sensor to correct for vessel pitch, heave, and roll; a sound velocity sensor that corrects for speed of sound in water related to density differences resulting from changes in temperature and salinity; and a dual-antenna differential global positioning system (GPS) that provides sub-meter vessel positioning and correction for vessel yaw. Because the position of the interferometric sidescan sonar head is rigidly fixed to the vessel, the positional error is dramatically reduced from that associated with other mapping methodologies, such as towed sidescan sonar. With the survey system utilized in this effort, absolute positional error for eelgrass mapping is approximately ±1–2 meters (m). The relative positional error is estimated at ±0.5–1 m as the GPS error is substantially nullified across short distances.

Sidescan sonar mosaic of Cabrillo Beach and Cabrillo Marina basin, Port of Los Angeles

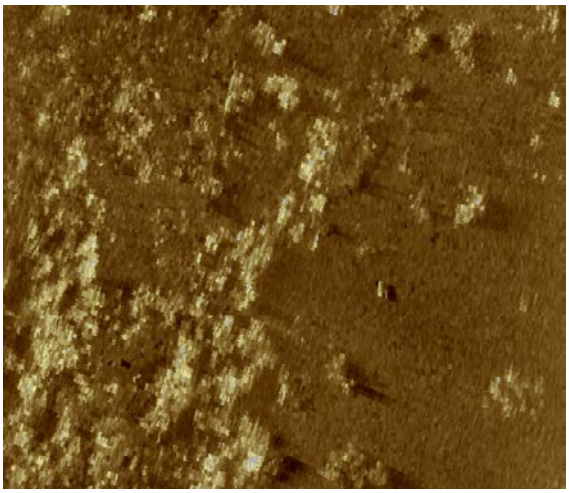
The interferometric sidescan was set to survey 31 m on the port and starboard channels so that the full swath width was nominally 62 m. Surveys were conducted by navigating parallel track lines such that with each pass of the sonar swath, the nadir gap that occurs directly below the survey vessel from the prior pass was covered with the subsequent pass. Transect surveys were performed until the entirety of the survey area was covered by sonar swaths.

Shallow areas were surveyed at high tide to provide sonar coverage to the shoreline beyond any eelgrass beds. Within tight marinas, multiple passes were made at differing angles, and the

survey vessel's thruster was used to pivot the vessel slowly at the ends of dock fingers in order to obtain full and precise sonar coverage of the marina bottom.

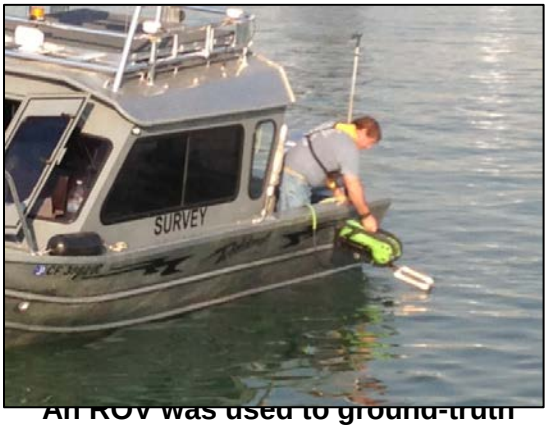
GROUND-TRUTHING AND DENSITY SURVEYS

Divers and an ROV were used to ground-truth acoustic records of eelgrass, characterize the health and vigor of the eelgrass, and collect eelgrass shoot densities data within identified patches of eelgrass.



Sidescan sonar swath showing eelgrass (bright reflections with shadows) on unvegetated soft bottom.

Ground-truthing was conducted in a non-random manner and was used to verify acoustic signature interpretations and to evaluate features for which classification was not possible from the acoustic records. Ground-truthing was performed after acoustic record processing was completed and was directed by targeting specific sites where the identification of a sonar contact during the mapping process was questionable. Between the initial mapping efforts and ground-truthing, a new field navigation map was prepared and loaded into the vessel's navigation system. The ground-truthing team then visited all of the questionable targets and verified their identity. The one-month gap between the September survey and the October ground-truthing would not be expected to compromise the validity of the ground-truthing since eelgrass bed condition is typically fairly stable during the later portion of the growing season, with relatively unchanged densities and spatial distribution until the winter low-growth period. Final adjustments to the mapping were made following this ground-truthing effort. Ground-truthing was again conducted in a similar manner following spring surveys.



An ROV was used to ground-truth acoustic records and collect eelgrass shoot density data.

Concurrent with the ground-truthing, eelgrass was examined at the eleven locations where eelgrass beds were present within the Port Complex (Table 8-1). These sites were investigated to characterize the condition of eelgrass beds, including plant vigor, silt and epiphyte loading, disease blemishes, and turion (shoot) density. These observations are presented in Appendix H-3. Turion density was determined by counting all of the shoots within a 1/16 m^2 quadrat. The eelgrass sites were examined during October 2013 and May 2014. It is important to note that turion density is a characteristic of plants, while gaps in the bed between plants are addressed as bottom coverage and not density. As a result, turion density cannot be measured as a zero count, but random sampling must include at least a portion of the above-ground plant and thus would include at least one turion in any sample.

DATA ANALYSIS

Following completion of the sidescan surveys, the digital sonar traces (backscatter data) were joined together into a single mosaic and geographically registered using the recorded navigational data. The registered sonar mosaic was then overlain on a geographically corrected aerial image of the project site and reviewed for accuracy. Eelgrass was then digitized by a geographic information systems (GIS) specialist, who inspected the sonar mosaic and delineated the eelgrass boundary.

Because of abundant linear air vacuoles (called “lacunae”) within eelgrass leaves, plants are highly reflective to sound generated by sonar. As a result, plants have a bright acoustic signature with many characteristics that are readily detectible in high-frequency, interferometric sidescan sonar. In some instances, eelgrass signature was masked by other highly reflective surfaces, such as rock or air vacuoles within the introduced alga *Sargassum muticum*. In such cases, characters such as growth form, shadow density, feature height and form, and bathymetric elevation and variance were used to separate eelgrass from other acoustic targets. Where there remained question in mapping, the features were marked for subsequent ground-truthing visual inspections as described above.

Eelgrass was mapped as spatially discrete patches defined by plant margins, rather than aggregations of plants, to define beds of differing extent of bottom coverage. Under this methodology, each patch of eelgrass was mapped by digitizing the boundary of the beds. Gaps within eelgrass beds that exceeded one meter across were cut out of the mapped bed to create a spatially accurate representation of both the bottom coverage of eelgrass and the total area of vegetated bottom present. This mapping methodology differs from that applied during the 2000 study, where eelgrass patches were aggregated into bottom cover classes of 5%–20% (sparse eelgrass), 20%–40% (moderate eelgrass), and greater than 40% (dense eelgrass) cover (MEC 2002). In that study, a minimum coverage of 5% was used for polygon mapping purposes and to define aggregations of eelgrass plants that constituted a bed. Individual plants were considered to be the boundaries of the bed in instances where individual plants were too far apart to constitute 5% plant cover. In the 2008 study, eelgrass was mapped more generically as high-density and low-density eelgrass beds (SAIC 2010). Very sparse eelgrass appears to have been either absent in 2008 or omitted from the mapping.

Mapping by cover class is typically used for regional eelgrass inventories and has been applied to prior baseline surveys. However, with improvements in positional control and the desire to conduct greater analyses into vertical distribution patterns, discrete mapping was selected for the present investigation over the use of the multiple cover-class mapping technique used in 2000 (MEC 2002) and in 2008 (SAIC 2010). This enhances information value from the mapping, but should be considered before making comparisons to data from prior survey years. However, the change in cover classes from four classes to two classes between the 2000 and the 2008 surveys already affected some of the capacity to evaluate temporal trends in a numeric manner.

Data on eelgrass depth distribution and bathymetry within the Port Complex were used to explore the depth range of eelgrass in Ports; the depth distribution relative to available depths within the bay; and factors that limit the vertical distribution of eelgrass within the Ports. The bathymetry of the Port Complex was obtained from the hydrodynamic model input data for the Dominguez Channel Estuary Model Study (Port of Los Angeles and Everest International

Consultants 2007) and histograms of the depth distribution were plotted as percentage of the total water area. The bathymetric data for eelgrass beds was developed from the interferometric sidescan data collection completed for the eelgrass mapping as it was essential to have a much more refined data set than available from the coarser grid used in the Harbor-wide hydrodynamic model.

RESULTS

Eelgrass within the Port Complex totaled 60.37 acres in summer and 67.56 acres in spring (Table 8-1). Approximately 99% of the eelgrass occurred on the Los Angeles side in both spring and summer (Figures 8-1 and 8-2). Note that all occurrences of eelgrass other than the Cabrillo Beach, East Basin Yacht Marinas, and Seaplane Lagoon/Pier 300 Basin (which includes the constructed Pier 300 Shallow Water Habitat) beds were very limited in extent (less than 0.5 acres). To aid in detection of these small patches on the report figures, eelgrass is plotted with a 25-m locator buffer around all beds. This locator buffer results in a visual suggestion of greater eelgrass than actually exists within small patches. The precise locations and extent of eelgrass are presented as enlargement maps in Appendix H-1 (Eelgrass Distribution Maps).

With one exception (Consolidated Slip), eelgrass coverage increased between the summer and spring surveys (Table 8-1). Nearly all of that increase (99.7%) was due to increased eelgrass coverage within the Seaplane Lagoon/Pier 300 Basin, an area that was stricken by wasting disease in 2011 but recovered in subsequent years (Merkel & Associates 2012).

Table 8-1. Distribution of eelgrass within Port Complex by survey season.

Location of Eelgrass Beds	Summer		Spring	
	acres	% of total	acres	% of total
Port of Long Beach	**0.605**	**1.00%**	**0.777**	**1.15%**
Navy Mole	0.158	0.26%	0.268	0.40%
Cerritos Channel	0.444	0.73%	0.505	0.75%
Back Channel	0.003	0.01%	0.003	0.00%
Port of Los Angeles	**59.765**	**99.00%**	**66.783**	**98.85%**
Seaplane Lagoon/Pier 300 Basin*	38.741	64.17%	45.909	67.95%
North Cabrillo Beach	9.924	16.44%	10.608	15.70%
South Cabrillo Beach	8.886	14.72%	8.121	12.02%
East Basin Yacht Marinas	1.805	2.99%	1.635	2.42%
Cabrillo Marina	0.182	0.30%	0.274	0.41%
Fish Harbor	0.123	0.20%	0.134	0.20%
Consolidated Slip	0.035	0.06%	0.012	0.02%
LA Turning Basin	0.068	0.11%	0.090	0.13%
Total Port Complex	**60.370**	**100.00%**	**67.560**	**100.00%**

* includes the constructed Pier 300 Shallow Water Habitat.

Figure 8-1. Eelgrass distribution within the Port Complex in summer.

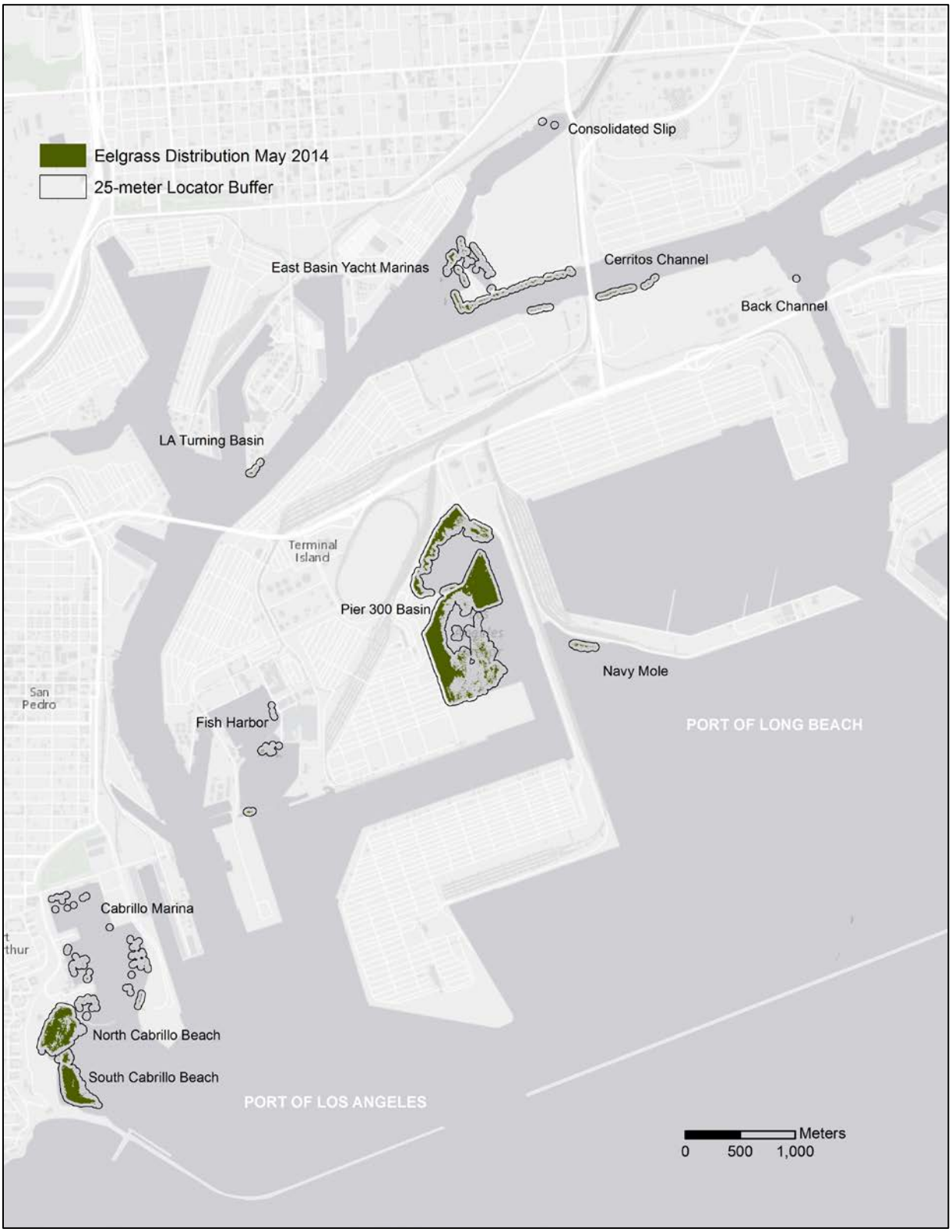


Figure 8-2. Eelgrass distribution within the Port Complex in spring.

Figure 8-3 presents the results of the turion density sampling, which are mapped in Figure 8-4; the raw density sampling data are presented in Appendix H-2. Turion densities at nearly all sites were relatively stable during both the October and May sampling periods, showing no obvious seasonal pattern (Figure 8-3). All densities were within ranges that are generally considered to be low to moderate density for southern California eelgrass beds, which typically range between approximately 100 to 400 turions/m^2. In the largest beds (Cabrillo Beach and Seaplane Lagoon/Pier 300), however, turion density was higher in spring than in summer. The greatest difference in turion density between seasons was observed at Cabrillo Beach, where the spring mean density (280 shoots/m^2) was nearly 2.7 times higher than during the summer (104 shoots/m^2); however, as depicted in Figure 8-3, the variability in the spring density values was very high (standard deviation = 166 shoots/m^2). Figure 8-4 shows that lower turion densities were primarily found along the East Basin Yacht Marinas, the Cerritos Channel, the Navy Mole, Fish Harbor, and Cabrillo Marina during either month. These sites share a commonality of being on the deeper margin of eelgrass growth within the Port Complex.

The observations made during the diver surveys (Appendix H-3) indicated that in summer the canopy height of many of the beds reached 1.5 m, but that in spring the maximum height was 1 m and most beds did not exceed 0.8 m in height. Epiphytic growth and sediment loading on the eelgrass blades were substantially greater in summer than in spring: epiphytic loading in spring only exceeded 5% in five beds, but in summer loading always exceeded 5% and reached 70% in the Cabrillo Marina. During both the summer and spring sampling periods, a considerable amount of macroalgae (*Chaetomorpha* sp., *Hypnea* sp., and *Gracilaria* sp.) was present within the shallow shoreline (beach edge) margins of the eelgrass. Very few signs of disease were observed in either season: only three beds in summer and two in spring showed disease.

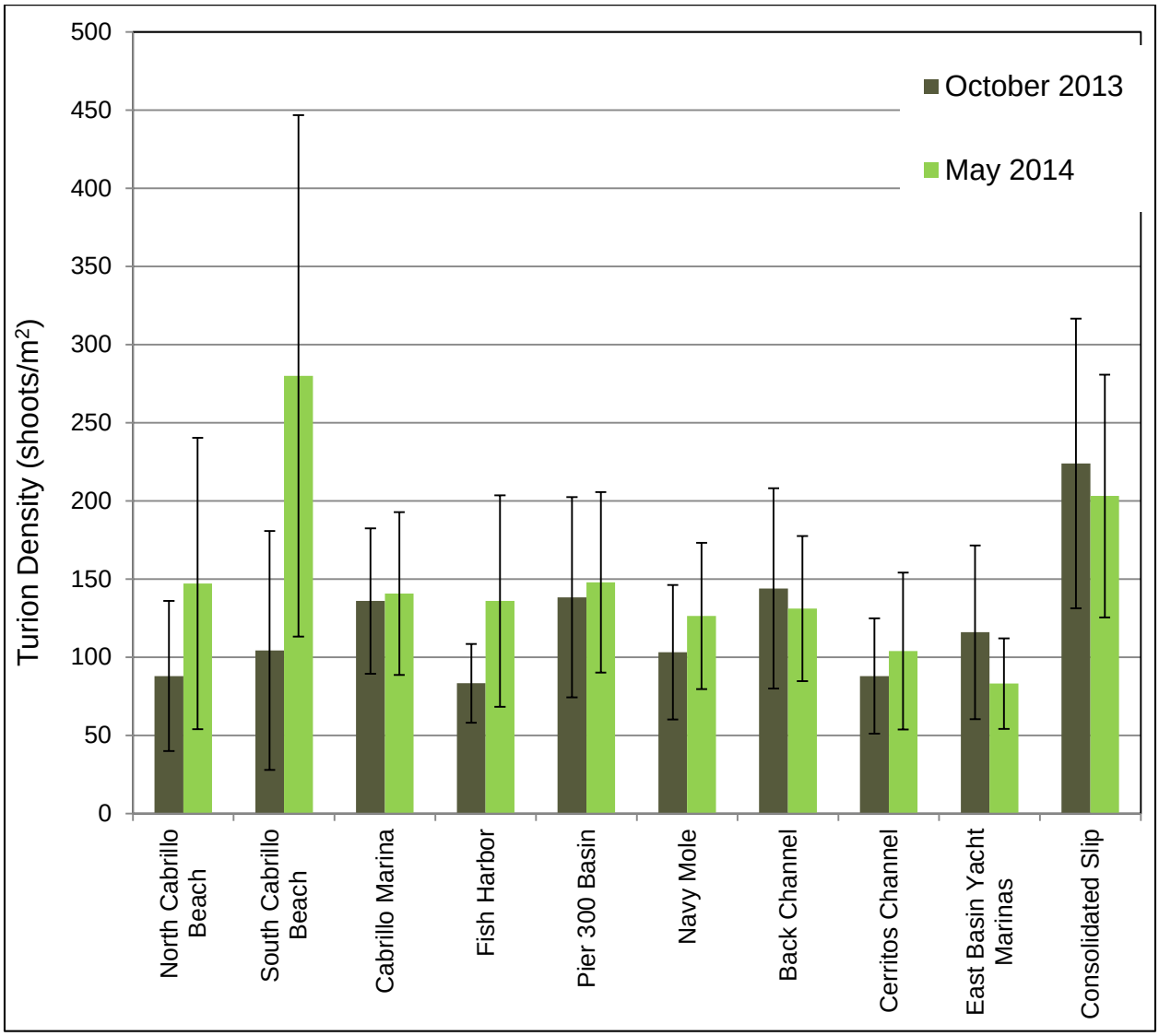


Figure 8-3. Mean turion density of eelgrass in summer and spring (±1 Standard Deviation).

Figure 8-4. Eelgrass distribution with color gradient depicting local turion density, summer (top) and spring (bottom).

DISCUSSION

Over 95% of the eelgrass in the Port Complex occurs in two areas: Seaplane Lagoon/Pier 300 Basin, and Cabrillo Beach. These two core areas have supported eelgrass throughout the last three harbor-wide surveys. Recent expansion of eelgrass has occurred in areas that previously lacked eelgrass. This expanded presence is evidenced by a number of small, scattered patches in marina basins and along channel margins.

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 covered eelgrass at Cabrillo Beach, while the 1999 survey looked at both Cabrillo Beach and the Seaplane Lagoon/Pier 300 Basin (Gregorio 1999). Survey methodology involved visual observations, fathometer readings, and diver transects. These methods provide less detailed and comprehensive data than the sidescan sonar methodology that has been employed in the subsequent surveys conducted in 2000, 2008, and the present study. While eelgrass was previously detected only in the Cabrillo Beach and Seaplane Lagoon/Pier 300 Basin areas, a total of six comprehensive surveys have now been completed within the Port Complex and it is possible to examine the recent history of the occurrence of eelgrass. As indicated previously, the prior use of aggregated density classes rather than discrete bed mapping limits the overall precision of the comparison; nonetheless, by digitally overlaying the spatial data layers from each survey and determining how often eelgrass was reported for an area, the long-term stability of eelgrass beds within an area may be explored (Figure 8-4). Because of a lack of comparability, the 1996 and 1999 survey data were omitted from the frequency analyses presented in Figure 8-5.

This analysis illustrates the persistent presence of eelgrass beds in the shallows of Cabrillo Beach and the Seaplane Lagoon/Pier 300 Basin during all surveys commencing in 2000. It also shows that the deeper margins of these areas exhibit much more dynamic conditions, with the frequency of occurrence ranging from 16 to 33 percent over much of the overall bed area. The persistence of eelgrass at the Seaplane Lagoon/Pier 300 Basin is no more than 66% because eelgrass was planted at the site after the surveys in 2000. 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, beds that were present during September 2013 were also present in May 2014, and are not random sporadic occurrences, but rather reflective of the increasing abundance of eelgrass in the Ports.

As indicated previously, the current system-wide survey noted substantial expansion of eelgrass into areas where it was not previously mapped in a comprehensive manner. However, eelgrass occurrence in small patches throughout the Port Complex has been noted for several years by Merkel & Associates and MBC staff while conducting biological investigations for the Ports. The first substantial expansion was noted in the mid-2000s, when eelgrass was documented in the Cabrillo Marina Basin and the Consolidated Slip. In the late-2000s, eelgrass was noted in the East Basin Yacht marinas, and in 2011 along the Cerritos Channel east of the Heim Lift Bridge (MBC 2011).

Figure 8-5. Frequency of eelgrass occurrence during six system-wide surveys conducted in 2000, 2008, and 2013–2014.

During the 2000 eelgrass survey, a single blade of recently detached Pacific eelgrass was found floating in the Back Channel. Additional *Z. pacifica* leaves were observed free floating in 2013. No Pacific eelgrass is known to occur, nor was it observed, within the Port Complex in 2013–2014. However, beds of Pacific eelgrass are present near the Long Beach Downtown Marina to the east of the study area. This species requires well-flushed, sandy environments, and could potentially occur offshore of Outer Cabrillo Beach, outside of the breakwater. It could also ultimately colonize some of the Cabrillo Shallow Water Habitat areas, but it has not yet done so.

While the frequency of eelgrass occurrence map (Figure 8-5) 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. This is because the evolving mapping methodologies—from a four-class bottom coverage (2000), to a two-class bottom coverage (2008) mapping classification, to the present discrete boundary-mapping method—do not allow for meaningful areal extent interpretation. By simple review of the mapping results, it would be assumed that eelgrass coverage in the Port Complex has declined. However, the opposite is true. Eelgrass coverage has vastly expanded both in bottom coverage and geographic extent, with multiple new occurrences beginning to colonize suitable habitat within the Ports.

EELGRASS DEPTH DISTRIBUTION

The depth distribution of eelgrass within shallow bays and estuaries is most often limited by physical stress of desiccation at its shallowest extent and by physiologic limits on photosynthesis at its deepest extent. Tidal range, water clarity, and seasonality all influence these growth margins, resulting in seasonal shifts in eelgrass beds to higher and lower elevations along the shore. This is manifested as horizontal changes in the bed. Typically during the winter, eelgrass is released from high summer temperatures and high solar radiation and the upper margin of the bed moves to shallower elevations. In the spring and summer months, eelgrass is pushed down from the intertidal margin but receives greater insolation at depth, so that the lower margin of the bed expands downward. In addition, during the spring months 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 of spring seed germination, early growing season surveys often identify expanded deeper bed margins of plants that do not typically survive through the entire growing season.

The Port Complex is a generally deep-water environment, partially naturally and partially the result of dredge and fill activities to construct navigation channels and berths. Most of the shoreline of the Port Complex is armored by riprap revetment and bulkheads, or lined by wharves whose steep slopes, lack of soft sediments, and shading restrict the presence of suitable shallow habitat. Because of the natural configuration of San Pedro Bay, the Long Beach side includes a greater amount of deep water than the Los Angeles side, which is adjacent to the east side of the Palos Verdes Peninsula and includes the historic shallows associated with the former barrier beach island. The Long Beach side retains no natural shallow-water environments, while on the Los Angeles side a small amount of native shallows

remain at Cabrillo Beach and in various basins that were never excavated to the depths needed to serve oceangoing vessels.

The plot of eelgrass depth distribution (Figure 8-6) shows the substantial lack of shallow water on the Long Beach side. Because only 0.8 percent of the 7,248 acres of water within the study area supported eelgrass during the present study, depicting eelgrass depth distribution curves as a function of total area of the Port Complex would make it impossible to detect the eelgrass. Therefore, Figure 8-6 presents eelgrass depth distribution as a percentage of the total area of eelgrass. The distribution reflects the percentage of the total eelgrass occurring within 1 foot depth bins within each of the Ports.

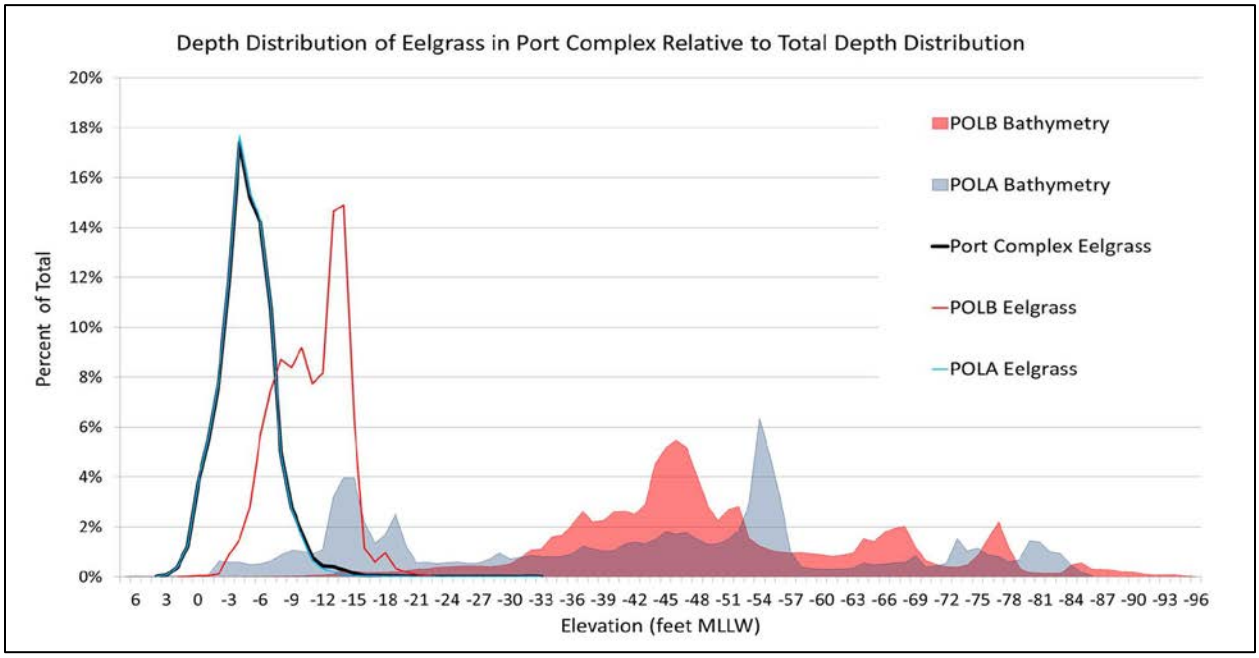


Figure 8-6. Depth distribution of eelgrass in the Port Complex relative to the total depth distribution.

While difficult to detect in Figure 8-6, the Los Angeles-side eelgrass depth distribution curve overlays the cumulative Port Complex eelgrass depth distribution curve almost exactly for all but the deepest portion of the curve. This coincidence of curves is due to the fact that approximately 99 percent of the total eelgrass is on the Los Angeles side.

Over 99% of the eelgrass in the Port Complex is limited to a depth range between approximately +0.5 and -15 feet MLLW. The small amount of eelgrass on the Long Beach side extends somewhat lower, and the highest percentage of the beds occurs at the lowest limits of eelgrass in the Ports. While this difference between the two ports in the depth distribution of eelgrass beds might on its face suggest differing depth range selectivity, it in fact reflects a lack of suitable shallow water habitat on the Long Beach side to support eelgrass and thus a greater proportional occurrence of eelgrass at lower depths than on the Los Angeles side. Not revealed in Figure 8-6 is that deeper margins of eelgrass are not located in the seaward portions of the Port Complex as one might expect, but rather are generally located along Cerritos Channel and within marina basins farther back into the Ports.

EELGRASS BED DENSITY AND CONDITION

Turion density in any given bed depends upon many factors, principally seasonality, water depth, energy environment, and degree of bed development over the available bottom. Factors such as high energy, shallow water, mid-late growing season timing, and closed canopy beds with little available primary space tend to favor higher turion densities, while low energy, deeper water, and short growing season lead to low to moderate densities. Densities of the existing beds are likely driven by most of the factors identified.

Overall, eelgrass density within the Port Complex was low to moderate when considering the range of densities that are typically encountered in southern California eelgrass beds. In the Port Complex most of the beds occur at depths below the shallower margin of most eelgrass elsewhere in southern California. As a result, the higher-density eelgrass that is typically common in shallow waters, is generally very limited in the Port Complex. However, at both the north and south Cabrillo Beach sites, eelgrass occurred over a broad depth range, and although the higher-density portions of the bed are located at the shallow margin of the bed, these areas were not dense enough and large enough to materially increase mean density of the bed as a whole. The seasonal difference in turion density at Cabrillo Beach was influenced by high seedling recruitment in spring into otherwise sparse beds along the lower margin of the site. This high seedling recruitment was not observed elsewhere.

Eelgrass condition was generally good. Overall, plants reflect the condition of the environments within which they persist. Deeper and more quiescent sites generally support taller eelgrass. Fouling of eelgrass in these areas is by non-photosynthetic epiphytes, or low-light epiphytes such as diatoms, as well as mucous strings that are produced by a host of zooplankton organisms and which snag on the eelgrass leaves and collect silt from the water column. In shallower sites, red and green algae are commonly the dominant epiphytes loading eelgrass, both attached to leaves and trapped within the leaf matrix. However on older leaves, spirorbid worms, bryozoans, and cnidarians can be common. Heavy epiphytic loading within the Ports is typically seasonal, with winter periods generally supporting lower degrees of loading and warmer summer periods fostering greater fouling levels. Heavy fouling can have substantial adverse effects on eelgrass as a result of reducing plant photosynthesis and weighing down and sinking leaves. Grazers on epiphytes, predominantly including mollusks and crustaceans, as well as some birds, can also result in damage to the eelgrass leaves.

The Seaplane Lagoon/Pier 300 Basin eelgrass beds were infected with wasting disease in 2011–2012 and suffered significant declines during that period. These beds have been returning and are nearly completely recovered from pre-2011 conditions. Evidence of wasting disease, naturally occurring in most eelgrass habitats at low levels, continues to be prevalent within the Seaplane Lagoon/Pier 300 Basin beds, with as many as 5-10% of the plants exhibiting some evidence of disease. However, the extent of disease is not presently threatening the viability of the bed as a whole. Other beds in the Port Complex exhibited limited (1-2%) to no evidence of disease (Appendix H-3). Elsewhere along the Pacific coast of North America, wasting disease continues to be a significant threat to eelgrass in some areas and is of concern in others. By 2014 in Morro Bay, eelgrass had been reduced to approximately three percent of its 2007 extent. In San Diego Bay, Mission Bay, Batiquitos Lagoon, and Agua Hedionda Lagoon, wasting

disease resulted in substantial declines of eelgrass during the mid- to late-2000s but much of this loss has subsequently been recovered. From 2011 through present, wasting disease has begun to result in eelgrass loss in more northerly bays and estuaries, including San Francisco Bay and Humboldt Bay, with reports of eelgrass decline also coming from as far north as Puget Sound. While the triggers for wasting disease to become virulent are not all fully known, the present period of outbreak is believed to be related to sea and atmospheric warming and drought conditions. The warmer conditions exacerbate increase stress on the plants, making eelgrass them more susceptible to disease, and the slight increase in salinity as a result of drought favors the growth and reproduction of *Labyrinthula zosterae* (the pathogenic eukaryotic organism that causes wasting disease).

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CHAPTER 9 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 2013 and 2014. These surveys employed similar methodologies and survey intervals as those used in previous studies within the Port Complex.

MATERIALS AND METHODS

The avian surveys were conducted once per month for a period of one year, from September 2013 to August 2014 (Appendix I-2). Each monthly survey was conducted on two consecutive days. In the event of adverse conditions (e.g. rain or high winds), surveys were suspended and rescheduled to the next appropriate date. This ensured that survey counts and species identification were accurate and unimpeded by weather or water conditions. Each survey commenced at dawn and continued until the survey was complete.

For the avian surveys the Port Complex was divided into 31 major survey zones (Figure 9-1; Table 9-1). With some exceptions, zone boundaries were identical to those delineated and utilized during previous studies (MBC [1984]; MEC [1988] and [2002]; SAIC [2010]).

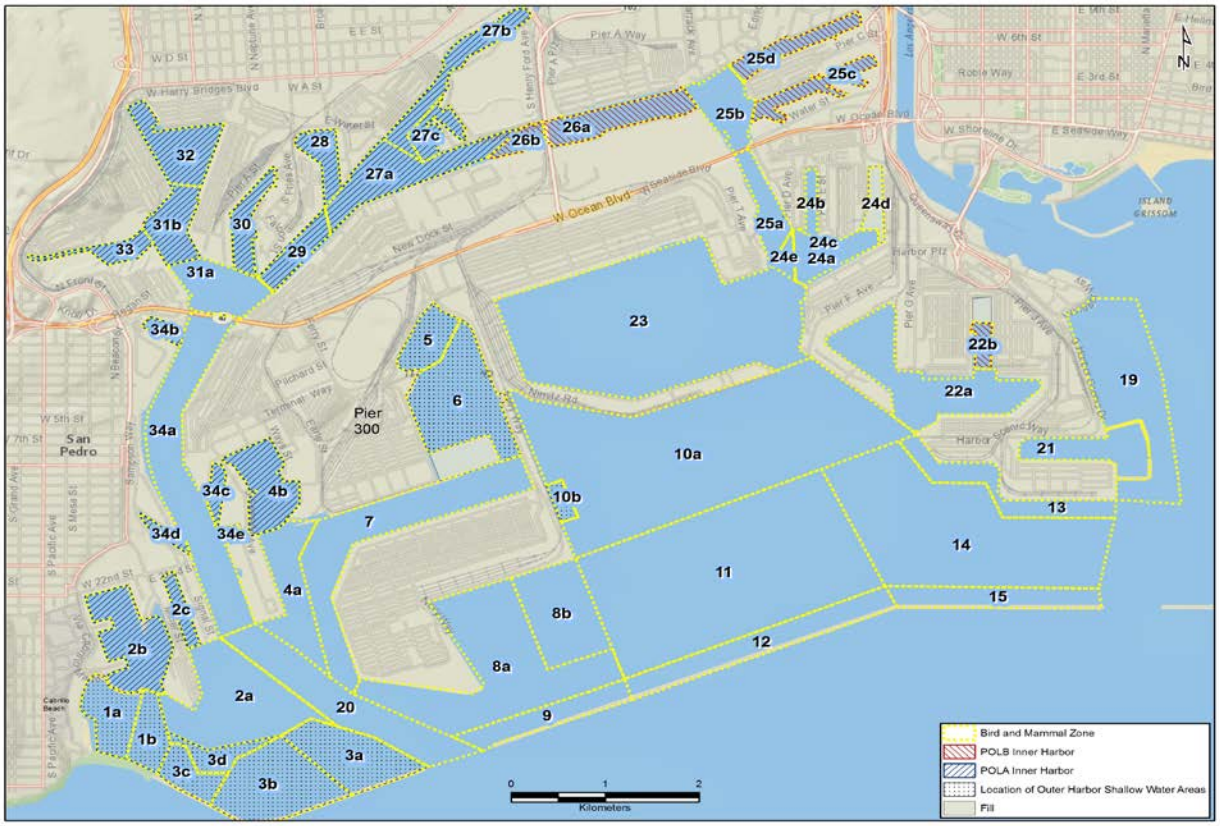

Figure 9-1. Location of avian survey zones.

Table 9-1. Zones used for avian surveys.

Zone(s)	Designation/Location	Harbor Type	Zone(s)	Designation/Location	Harbor Type
1a,b	Cabrillo Beach	Outer	22b	Pier G Slip	Inner
2a	Berth 48	Outer	23	LB West Basin	Outer
2b	Cabrillo Marina	Inner	24a,c,e	LB East Basin	Outer
2c	East Channel	Inner	24b	Slip 3	Inner
3a,b,c	Cabrillo SWH*	Outer	25a	Back Channel	Outer
4a	Reservation Point	Outer	25b	LB Turning Basin	Outer
4b	Fish Harbor	Inner	25c	Channel 3	Inner
5	Seaplane Lagoon	Outer	25d	Channel 2	Inner
6	Pier 300 SWH*	Outer	26a,b	Cerritos Channel	Inner
7	Pier 400 Channel	Outer	27a	LA East Basin	Inner
8a, b	LA Outer Harbor	Outer	27b	Consolidated Slip	Inner
9	Breakwater West	Outer	27c	East Basin Marinas	Inner
10a	Navy Mole	Outer	28	Slip 5	Inner
10b	LB SWH*	Outer	29	LA Main Channel North	Inner
11	LB Outer Harbor	Outer	30	Slip 1	Inner
12	Breakwater Center	Outer	31a	LA Turning Basin	Inner
13	Pier J South	Outer	31b	LA Turning/West Basin	Inner
14	LB Main Channel	Outer	32	LA West Basin	Inner
15	Breakwater East	Outer	33	Southwest Slip	Inner
19	Pier G East	Outer	34a	LA Main Channel	Outer
20	LA Main Channel South	Outer	34b	Berth 93 Slip	Inner
21	Pier J Slip	Outer	34c	Berth 240 Slip	Inner
22a	Southeast Basin	Outer	34d	SP Slip	Inner
			34e	Berth 243 Slip	Inner

Note: Zone 24d not surveyed because it has been filled since 2008.
* SWH indicates shallow-water habitat in the Outer Harbor.

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). Additionally, during the current study, several survey zones were broken into smaller subzones (e.g. Zone 3 was broken into 3a, 3b, 3c, and 3d). This change was made to better quantify bird usage in Outer Harbor shallow water habitats. Several marinas and small slips were added to the current surveys. These areas have not been previously surveyed and were added as subzones (e.g. Zone 34 (LA Main Channel) became Zone 34a and the slips off of the Main Channel were surveyed as Zones 34b, 34c, and 34d). Finally, several zones were broken into subzones to allow for a separation of Inner and Outer Harbor areas. Zones broken into additional subzones for any of the reasons listed above include Zones 1, 2, 3, 4, 8, 10, 22, 24, 25, 26, 27, 31, and 34. It should be noted that in the majority of zones, data from subzones may be summed to allow comparisons to previous study results.

Saturation surveys were completed by boat in all zones. Boat travel within survey zones was conducted in a manner that minimized the flushing of birds, in order to avoid double counts or observer-induced changes in bird behavior or habitat use. The survey team consisted of a boat captain, an observer, and a recorder. The observer was a trained ornithologist responsible for species identification and counts. The recorder was also a trained ornithologist and was responsible for assisting with bird counts and for completing and managing data sheets. Binoculars were used to aid in the identification of birds. The captain assisted with both avian and marine mammal survey observations, which were performed concurrently.

Biologists conducting bird surveys along the Outer Harbor breakwater.

All survey data were initially recorded in the field on hard copy data sheets and then transferred in the office to digital database files and checked for accuracy. Each observed bird species was assigned to one of eight ecological guilds: aerial fish foragers, gulls, large shorebirds, raptors, small shorebirds, upland birds, wading/marsh birds, and waterfowl (as presented in Table 9-2 and Appendix I-3). Cormorants were assigned to the waterfowl guild to be consistent with previous studies. The database was then queried to extract summary information for tables and figures. Data were analyzed to identify spatial and temporal trends in total avian abundance and density, numbers of species, and patterns of habitat usage, activity, and seasonal variation of species and guilds.

Table 9-2. Ecological guilds of birds in the Port Complex.

Guild	Common Name
Aerial Fish Foragers	
	Belted Kingfisher
	Black Skimmer
	Brown Booby
	Brown Pelican
	California Least Tern
	Caspian Tern
	Elegant Tern
	Forster's Tern
	Pomarine Jaeger
	Royal Tern
Gulls	
	Bonaparte's Gull
	California Gull
	Glaucous Gull
	Glaucous-winged Gull
	Hermann's Gull
	Herring Gull
	Mew Gull
	Ring-billed Gull
	Western Gull
Small Shorebirds	
	Black Turnstone
	Black-bellied Plover
	Dunlin
	Killdeer
	Least Sandpiper
	Rudy Turnstone
	Sanderling
	Semipalmated Plover
	Spotted Sandpiper
	Surfbird
	Wandering Tattler
	Western Sandpiper

Guild	Common Name
Large Shorebirds	
	Black Oystercatcher
	Long-billed Curlew
	Dowitchers
	Marbled Godwit
	Phalaropes
	Red Knot
	Whimbrel
	Willet
Waterfowl	
	American Coot
	American Wigeon
	Brandt's Cormorant
	Brant
	Bufflehead
	Clark's Grebe
	Common Loon
	Common Merganser
	Double-crested Cormorant
	Eared Grebe
	Greater Scaup
	Hooded Merganser
	Lesser Scaup
	Red-breasted Merganser
	Pacific Loon
	Pelagic Cormorant
	Pied-billed Grebe
	Mallard
	Red-throated Loon
	Ruddy Duck
	Surf Scoter
	Western Grebe
	Scripps's Murrelet

Guild	Common Name
Wading/Marsh Birds	
	Black-crowned Night Heron
	Cattle Egret
	Great Blue Heron
	Great Egret
	Green Heron
	Snowy Egret
Upland Birds	
	American Crow
	Anna's Hummingbird
	Barn Swallow
	Black Phoebe
	Brewer's Blackbird
	Cassin's Kingbird
	Cliff Swallow
	Common Raven
	European Starling
	Great-tailed Grackle
	House Finch
	House Sparrow
	Mourning Dove
	Northern Mockingbird
	N. Rough-winged Swallow
	Rock Dove
	Say's Phoebe
	Song Sparrow
	Western Meadowlark
	Yellow-rumped Warbler

At the start of each survey, date, survey time, team members, and weather conditions (air temperature, water temperature, wind speed, wind direction, cloud cover, precipitation, and tide height) were recorded. Data recorded for each observation included location (survey zone), time of observation, species identity, numbers of individuals, the environmental feature where the birds were observed, and bird activity. Other relevant information (e.g. injured or dead birds, banded birds, harbor activity that affected bird behavior, presence of nests or chicks, etc.) was recorded on the data sheets. The environmental feature designations included both natural and manmade elements: anchor line, barge/boat, spill boom, bridge, buoy, building/structure, dock/piling, dredge pipe, lamp post, open water (>1 foot deep), shallow wading depth water (<1 foot deep), riprap, sand beach/intertidal, and upland vegetation. Bird activities included: foraging, resting, flying, courting, and nesting.

RESULTS

ABUNDANCE AND DIVERSITY

A total of 96 bird species representing 30 families was observed in the Port Complex during the 2013–2014 surveys (Appendix I-1). Individual survey totals ranged from a low of 33 species observed in June 2014 to a high of 59 species observed in April 2014 (Appendix I-4, Figure 9-2). Total numbers of birds observed per survey ranged from 3,764 individuals in August 2014 to 11,739 individuals in November 2013. A total of 76,260 individuals was observed over the entire survey year, resulting in a mean of 6,355 individuals/survey.

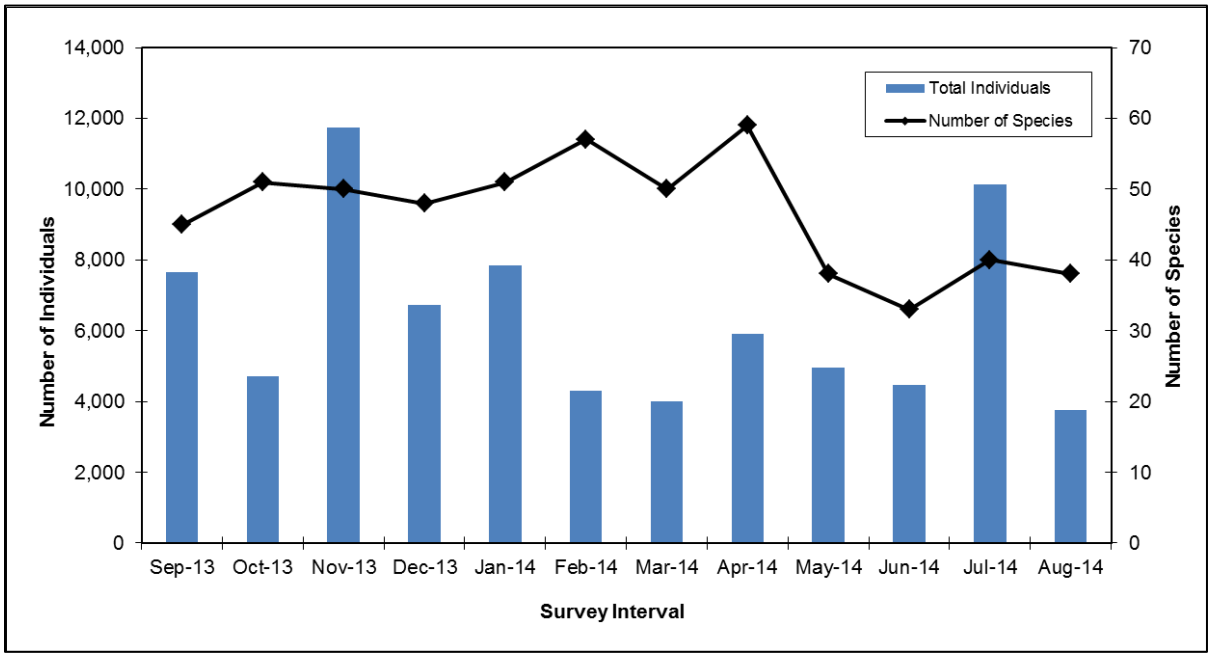

Figure 9-2. Total avian abundance and species counts by survey interval.

Patterns of abundance within the Port Complex were highly seasonal. Of the 96 bird species observed during the 2013–2014 surveys, only 29 occurred during ten or more survey months,

indicating year-round occupancy within the Port Complex. These included eight of the ten most abundant species, as described below. Thirty species were observed during only one or two survey months, indicating rare species not typically observed within the study area, migrating visitors, or resident but uncommon species. Most of the remaining species showed distinct seasonal patterns, being absent from the Port Complex for several months at a time.

As would be expected in a harbor environment, nine of the ten most abundant species belonged to three guilds associated with water: gulls, aerial fish foragers, and waterfowl. The most abundant guild was gulls, which represented 38.2% of all birds observed during the study. Gulls were abundant throughout the monitoring year, with the greatest numbers observed in September and November (Figure 9-3). The most abundant gulls during winter months included both year-round resident species such as Western Gull (*Larus occidentalis*) and Heermann's Gull (*Larus heermanni*), and species observed only in winter months, including California Gull (*Larus californicus*), Ring-billed Gull (*Larus delawarensis*), and Mew Gull (*Larus canus*).

Birds resting on the Middle Breakwater.

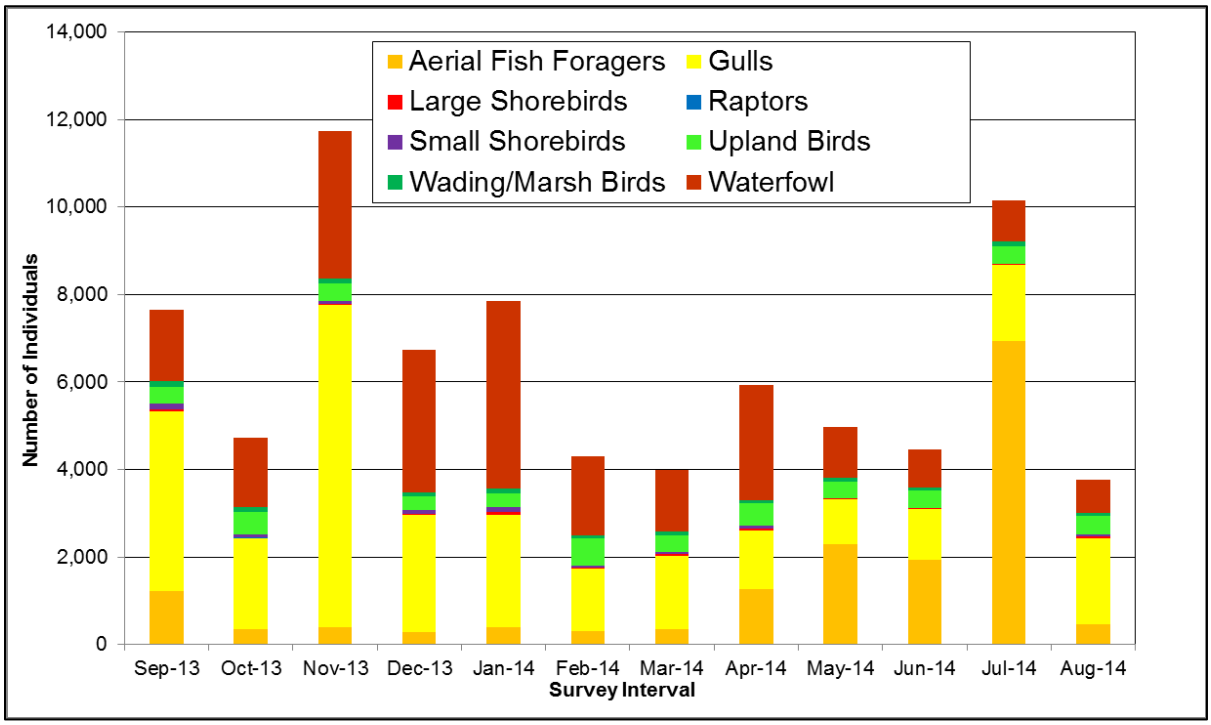

Figure 9-3. Avian abundance by guild and survey interval.

Waterfowl represented 31.1% of total observations and were most abundant during November, December, and January. Dominant species included both year-round resident species that peaked in abundance during winter months, such as Western Grebe (*Aechmophorus occidentalis*), Brandt's Cormorant (*Phalacrocorax penicillatus*), Double-crested Cormorant (*Phalacrocorax auritus*), and Surf Scoter (*Melanitta perspicillata*), and winter visitors, such as Bufflehead (*Bucephala albeola*) and Eared Grebe (*Podiceps nigricollis*).

Aerial fish foragers represented 21.2% of total observations. During May, June, and July 2014, the aerial fish foragers were the most abundant guild. The high overall abundance, observed in July 2014, was due primarily to Elegant Tern (*Thalasseus elegans*), as well as smaller numbers of California Least Tern (*Sternula antillarum browni*) and Black Skimmer (*Rynchops niger*), which nest in the Port of Los Angeles during spring and summer.

The remaining avian guilds (large and small shorebirds, wading/marsh birds, raptors, and upland birds) together accounted for only 9.5% of total observations during 2013–2014; over half of those were a single upland species, Rock Dove (*Columba livia*). Wading/marsh birds did not display strong seasonal patterns of abundance. Numbers of small shorebirds were greatest during winter months when species such as Black-bellied Plover (*Pluvialis squatarola*), Spotted Sandpiper (*Actitis macularius*), and Sanderling (*Calidris alba*) were present in the greatest numbers. 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 is known to breed within the Port Complex (MEC 2002; SAIC 2010). Likewise, raptors and upland birds did not display strong seasonal patterns of abundance.

SPECIES COMPOSITION

ABUNDANT SPECIES

The ten most abundant species observed during the 2013–2014 surveys accounted for 89.9% of total observations (Appendix I-5). As a result, the overall abundance of each avian guild was frequently driven by large numbers of only one or two species. Western Gull was the most abundant avian species observed within the Port Complex, accounting for 61.6% of all gulls observed, and 23.6% of total birds observed over the monitoring year (Appendix I-5). Western Grebe, the second-most abundant species, accounted for 46.5% of all waterfowl observed, and 14.5% of total birds observed. These two species accounted for more than a third of the total number of birds tallied during 2013–2014. While Western Gulls were present in large numbers year-round, the greatest numbers were observed from November through January. Many Western Gulls were observed breeding within the Port Complex, and nests and/or chicks were observed on the tops of buildings and on dock pilings during the summer nesting season. Western Grebes were also present throughout the year. While this species is not known to nest within the Port Complex, large rafts of adults (between 200 and 400 birds) were observed during summer months.

Other abundant species included Elegant Tern, Brown Pelican (*Pelecanus occidentalis*), Heermann's Gull, and California Gull, which accounted for 10.6%, 9.6%, 6.4%, and 5.9% of total observations, respectively. While Brown Pelican and Heermann's Gull occurred in large numbers throughout the year, Elegant Terns were only present in the Port Complex from March

through September, coinciding with the nesting season. California Gulls were only observed in large numbers between November and April, leaving coastal California to breed inland during the summer months. The seventh through tenth most abundant species consisted of one upland species, Rock Dove/Pigeon 5.4% of total observations), and three waterfowl species: Brandt's Cormorant (5.2% of total observations), Double-crested Cormorant (5.1% of total observations), and Surf Scoter (3.3% of total observations). All four of these species were present in the Port Complex year-round. Rock Dove and both cormorant species were observed nesting within the Port Complex. Surf Scoter does not nest within the study area, and its numbers peaked between November and January, outside the nesting season.

RARE SIGHTINGS

Rare sightings during the 2013–2014 surveys included species not typically observed within the study area, as well as resident but less abundant species. These species increased overall diversity but contributed little to patterns of abundance.

Scripps's Murrelet (*Synthliboramphus scrippsi).*

Rare species not typically observed within the Port Complex or within Los Angeles County included a single Scripps's Murrelet (*Synthliboramphus scrippsi*) observed in April in Zone 4b and a single Brown Booby (*Sula leucogaste*) observed in July in Zone 9. The Scripps's Murrelet (formerly known as Xantus's Murrelet) breeds on the Channel Islands, but is only rarely observed along the mainland. The Brown Booby is a subtropical species whose northern range is the Gulf of California and western Mexico. Rare observations of Brown Booby have been made within the Port of Los Angeles (International Bird Rescue 2012), and individuals of this species may wander north of the typical range in pursuit of schools of anchovy.

Cattle Egret (*Bubulcus ibis*), observed as a single individual in Zone 10a in September, is a winter migrant to the region and has been observed only rarely within the Port Complex (SAIC 2010). A single Pomarine Jaeger (*Stercorarius pomarinus*) was observed in Zone 9 in December 2013. This species breeds in the Arctic tundra and spends winters over open ocean. Two Glaucous Gulls (*Larus hyperboreus*) were observed in March 2014 in Zones 12 and 15 along the Middle Breakwater. This species is typically found in Alaska and is considered rare south of the Pacific Northwest.

Several of the rare sightings involved species that are uncommon within the Port Complex but that are not considered to be rare species in Los Angeles County. These include: a single unidentified Phalarope (*Phalaropus* sp) and two Semipalmated Plover (*Charadrius semipalmatus*) observed in October; a Red-breasted Merganser (*Mergus serrator*) observed in November; Bonaparte's Gull (*Chroicocephalus philadelpia*) observed in November (a total of 10 individuals) and again in April (as a single individual); two American Wigeon (*Anas americana*)

observed in December; a single American Kestrel (*Falco sparverius*) observed in January and March; a single Common Merganser (*Mergus merganser*) observed in January and April; a Hooded Merganser (*Lophodytes cucullatus*) and two Dunlin (*Calidris alpina*) observed in February; a single Red Knot (*Calidris canutus*), two Cooper's Hawk (*Accipiter cooperii*), and two Brants (*Branta bernicla*) observed in April; and a Red-throated Loon (*Gavia stellata*) observed in July.

SPECIAL-STATUS SPECIES

A number of special-status avian species were observed within the Port Complex during 2013–2014 surveys (Appendix I-6). Species for which special status applies only to nesting colonies or communal roosting locations (rather than wintering or foraging areas) were included in Appendix I-6 only if they are known to nest within the Port Complex. All species listed as threatened or endangered by United States Fish and Wildlife Service (USFWS) or the California Department of Fish and Wildlife (DFW) were included. Appendix I-6 only includes species observed during the 2013–2014 survey effort; species known to occur within the Port Complex, but not observed during the current surveys, are described briefly in the following text. Additionally, species with special status for nesting colonies, but that do not nest within the Port Complex, are described in the following text. Status was determined from the DFW California Natural Diversity Database Special Animals List (DFW 2015), and acronyms for special status designations are presented in Appendix I-6.

Two avian species observed during the 2013–2014 surveys are currently listed as threatened or endangered: California Least Tern and Scripps's Murrelet. The California Least Tern is listed as federally endangered and state endangered. This species is a spring and summer visitor to the Port Complex and has nested within the Port Complex since at least 1976 (Keane Biological Consulting 1999) and at the Pier 400 site since 1997 (SAIC 2010). California Least Terns usually arrive at the Pier 400 nesting site in early April and remain until September, or until all chicks have fledged. In the present study, California Least Tern was observed from April through July but was not thereafter. Most of the birds were observed in Zone 8a immediately adjacent to the Pier 400 nesting colony or flying over the colony. During the 2014 nesting season, California Least Tern monitors recorded 126 nests and estimated that there were 93 breeding pairs (eGIS 2015). The Pier 400 nesting site produced 64 fledglings during the 2014 nesting season (eGIS 2015).

Scripps's Murrelet is a small seabird that nests in the Channel Islands. The species is listed as state endangered and is currently a candidate for federal listing. It is threatened by the potential for oil spills that result from the heavy shipping traffic near the Channel Islands and by predation at nesting colonies by introduced species such as rats and feral cats (National Park Service 2011). A single Scripps's Murrelet was observed in the April survey in the open water habitat of Zone 4b.

Two additional species that were formerly listed as federally and state endangered or threatened but have since been federally de-listed (both are still fully protected under California state law) are Peregrine Falcon (*Falco peregrinus anatum*) and Brown Pelican. During the present study, a Peregrine Falcon was observed on three survey dates. One individual was flying over Zone 34d in October, a single individual was perched on a loading crane in Zone 21

in November, and a single individual was perched on a crane tower in Zone 31a in January. Peregrine Falcons have historically nested within the Port Complex on both the Schuyler F. Heim Bridge and the Gerald Desmond Bridge (MEC 2002; SAIC 2010). However, no evidence of nesting was observed during the present study. This may be related, in part, to the ongoing re-construction of both bridges, which is expected to continue through 2017.

Brown Pelicans do not nest within the Port Complex, and the only breeding colonies in the western United States are located on the Channel Islands. 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 all twelve of the 2013–2014 surveys, and was the fourth most abundant species, accounting for 9.6% of total bird observations during the survey period. Total abundance of Brown Pelicans ranged from a low of 212 individuals in February (coinciding with peak breeding season) to a high of 2,011 individuals in July. Brown Pelicans were observed primarily in the Outer Harbor, with large concentrations of individuals roosting on the San Pedro and Middle Breakwaters (Zones 3, 9, 12, and 15).

Other special-status avian species that are known to nest within the Port Complex include Double-crested Cormorant, Great Blue Heron (*Ardea herodias*), Black-crowned Night Heron (*Nycticorax nycticorax*), Black Oystercatcher, Black Skimmer, and several species of tern. The Double-crested Cormorant was the ninth most abundant species observed during 2013–2014 surveys, accounting for 5.1% of total observations. This species was regularly observed nesting in transmission towers in Zones 26a and 26b from February to July. The highest numbers of nesting birds (adults and chicks) occurred in April and May (150 and 160 individuals, respectively). Great Blue Heron are year-round residents of the Port Complex. A colony of Great Blue Heron occurs in a stand of Eucalyptus trees in Gull Park on the Navy Mole, and individuals were also observed nesting on light posts in Zones 10a and 25a. Black-crowned Night Herons have also historically nested at the Gull Park site (MEC 2002), but no nesting was observed within the Port Complex during the 2013–2014 surveys. Black Oystercatchers typically nest just above the high tide line on isolated rocky shorelines along the open coast (Tessler et al. 2007). This species has historically nested along the San Pedro and Middle Breakwaters (SAIC 2010). While no nesting was observed during 2013–2014 surveys, Black Oystercatchers were observed in every survey month, ranging from three individuals observed in July to 48 individuals in January. The majority were observed in Zones 9, 12, and 15 along the Middle Breakwater. Black Skimmers were observed from January through August, with the greatest number of individuals (28) counted in May. The largest number of occurred at Cabrillo Beach in Zone 1a. Black Skimmer has nested at the Pier 300 and Pier 400 sites, but has not been observed nesting within the Port Complex since 2000 (SAIC 2010).

Elegant Tern and Caspian Tern (*Hydroprogne caspia*) have historically nested within the Port of Los Angeles, formerly on Pier 300 and more recently on Pier 400. The Port of Los Angeles is one of only four breeding areas in southern California for the Elegant Tern (Burness et. al. 1999). During the 2013–2014 surveys, Elegant Tern was the third most abundant species, accounting for 10.6% of total observations. This species was only observed from March through September, with the peak number of individuals recorded in July (4,900 birds, located primarily in Zones 6 and 8a adjacent to Pier 300 and Pier 400). Elegant Terns were also regularly

observed resting on Cabrillo Beach (Zone 1a). Caspian Terns were also only observed in spring and summer months, but in much smaller numbers than Elegant Tern. The greatest number of individuals (24) was observed in April 2014, primarily in Zone 8a adjacent to Pier 400.

Several other special-status avian species were observed within the Port Complex during the 2013–2014 surveys (Appendix I-6). These species are typically protected at nesting sites, but do not breed within the Port Complex. They include: Forster's Tern (*Sterna forsteri*), California Gull, Long-billed Curlew (*Numenius americanus*), Osprey (*Pandion haliaetus*), Cooper's Hawk, Northern Harrier (*Circus cyaneus*), Great Egret (*Ardea alba*), Snowy Egret (*Egretta thula*), and Common Loon (*Gavia immer*).

Five special-status avian species were observed in the Port Complex during the 2000 and/or the 2008 studies that were not observed during the 2013–2014 surveys: Burrowing Owl (*Athene cunicularia*), Loggerhead Shrike (*Lanius ludovicianus*), Western Snowy Plover (*Charadrius nivosus nivosus*), White-faced Ibis (*Plegadis chihi*), and Tufted Puffin (*Fratercula cirrhata*).

SPATIAL VARIATION

ABUNDANCE BY SURVEY ZONE

As in previous studies of the Port Complex, the 2013–2014 avian surveys found spatial variation among survey zones and habitat types. To be comparable with previous studies (MEC 2002, SAIC 2010), abundance and density are presented by zone.

Appendix I-7 provides the total number of individuals and total species observed within each survey zone over the twelve surveys, and provides the mean density (individuals/acre, averaged over twelve survey intervals) for each survey zone. Certain zones supported consistently higher numbers of birds over the twelve survey intervals. The ten zones that supported the greatest total numbers of individuals (Figure 9-4) accounted for 57.8% of total observations; nine of those zones are large areas in the Outer Harbor. Zone 8a supported the greatest total abundance of individuals, accounting for 8.8% of total birds observed. In this zone, 32 species were observed over the twelve survey intervals, and 82% of total bird numbers were aerial fish foragers (Figure 9-4), dominated by Elegant Terns that nest adjacent to the zone during summer months.

Zones 10a and 23 supported the second and third greatest total abundance of birds, accounting for 8.0% and 7.0% of total observations, respectively (Figure 9-4). These two zones also supported large numbers of species (42 and 40 species, respectively). Waterfowl was the most abundant avian guild in each of these zones, due primarily to large rafts of resting and foraging Western Grebe, which accounted for 38.8% of total observations in Zone 10a and 54.2% in Zone 23. Other abundant waterfowl in these zones included Brandt's Cormorant, Double-crested Cormorant, Eared Grebe, and Surf Scoter.

Zone 34a supported the fourth highest abundance of birds, accounting for 7.0% of total observations. Gulls, especially Western Gull, were the most abundant guild in this zone, accounting for 86.7% of total individuals. Zone 34a is near the fish markets and restaurants along the Main Channel, which tend to attract gulls. The dominance of a single species resulted in lower species richness than in other populous zones: only 24 species were observed in Zone

34A. Large numbers of gulls were also observed in Zone 4b (Fish Harbor), where the commercial fishing fleet is located. Zone 4b supported the eighth greatest total abundance of birds, and gulls accounted for 75.0% of total observations in this survey zone.

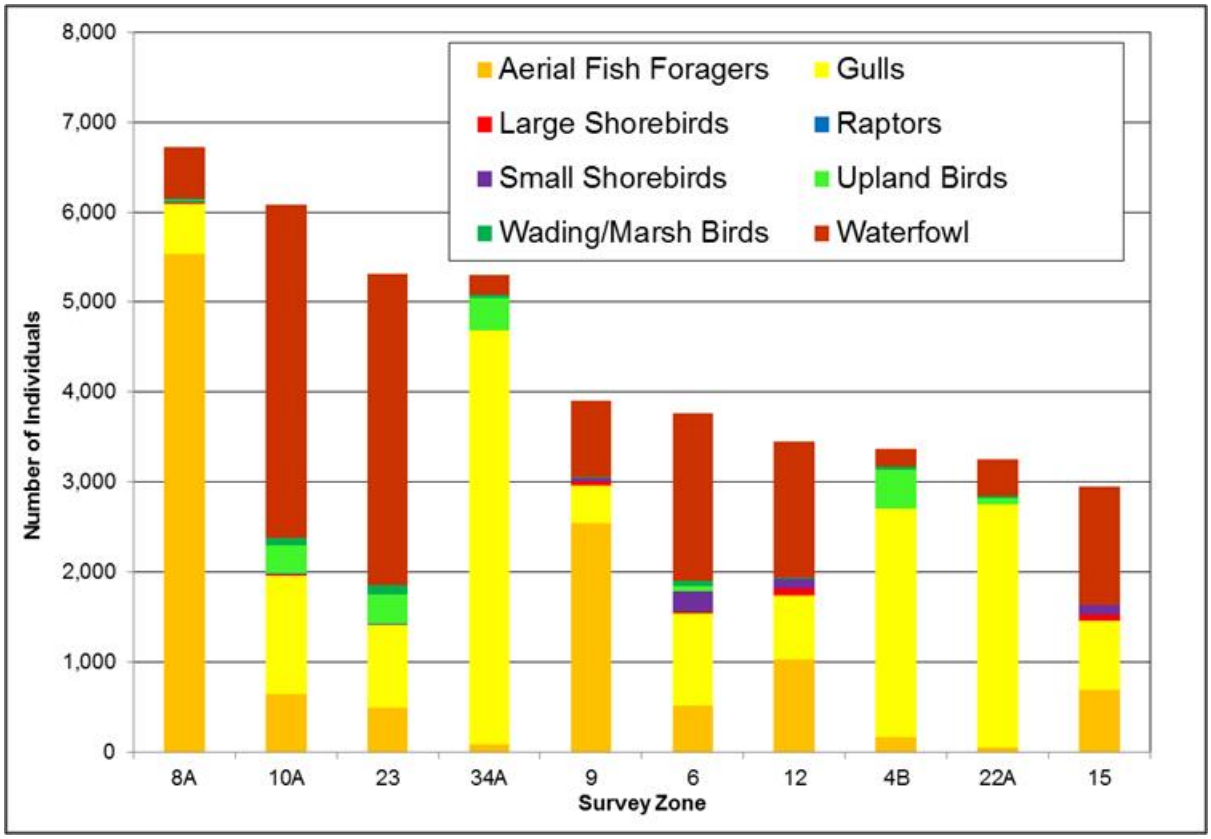

Figure 9-4. Total abundance of avian guilds in ten most populous zones during 2013–2014 surveys.

Zone 22a (Long Beach Southeast Basin) supported the ninth greatest abundance of birds, with 77.4% of the total accounted for by only three species of gulls (California Gull, Heermann's Gull, and Western Gull), which were resting on docks and anchor lines. Here, too, the dominance of a single guild and a small number of species resulted in a lower species richness in Zones 4b and 22a, which had 18 and 27 species, respectively.

Three of the most populous zones (9, 12, and 15) were located along the Middle Breakwater (Figure 9-1), which provides roosting habitat for aerial fish foragers, gulls, and waterfowl. These three zones accounted for 5.1%, 4.5%, and 3.9%, respectively, of total individuals observed. Large numbers of roosting Brown Pelicans accounted for 62.9% of the observations in Zone 9, and 33.5% of the Brown Pelicans observed in the Port Complex were found in Zone 9, indicating that this portion of the breakwater, adjacent to the Angel's Gate entrance to the Port of Los Angeles, is an important communal roosting area for this species. Zones 9, 12, and 15 also supported large numbers of roosting Brandt's Cormorant and Double-crested Cormorant, along with Heermann's Gull and Western Gull. While present in much lower numbers, large shorebirds and small shorebirds were also abundant in the breakwater zones, primarily due to

Black Oystercatcher (large shorebird) and Black Turnstone (*Arenaria melanocephala*) (small shorebird). Zones 9, 12, and 15 supported 24, 32, and 24 species, respectively.

Zone 6 was the sixth most populous zone during the 2013–2014 surveys. Waterfowl (accounting for 49.6% of total observations in this zone) was the most abundant guild in Zone 6, but all guilds were well represented. Zone 6 supported the greatest number of species (45) of any of the 31 survey zones. The large number of species represented in Zone 6 resulted from the diversity of features available to birds, along with its proximity to the Pier 400 nesting site.

Royal and Elegant Terns (*Thalasseus maximus*, T*. elegans*) resting on dock.

The lowest numbers of individuals were observed in Zones 24c, 24d, and 24e in the Long Beach Inner Harbor. Bird observations in these zones were limited to very small numbers of flying or resting gulls, Great Blue Heron foraging along the shoreline, and individual Western Grebe resting in the Main Channel.

DENSITY BY SURVEY ZONE

Mean avian densities (birds/acre) for each survey zone, as well as the proportional representation of the guilds, are presented in Figure 9-5. The survey zones within the Port Complex have been utilized during multiple prior surveys, allowing for interannual comparisons. However, the areas of the 31 zones delineated for the avian surveys are highly variable (the largest zone [10a] is 859.2 acres, while the smallest zone [24c] is 1.8 acres). For smaller zones, resultant high densities of birds are not an indication of avian “hot spots”, habitat quality, or an increased likelihood that an individual bird will utilize features within that zone. Rather, higher densities are a result of lower total acreage, i.e. each individual bird observed results in a higher density value when observed in a small zone compared to a large zone. The following discussion takes this into consideration and describes each avian zone and where birds were observed for specific areas within the Port Complex.

The greatest mean densities occurred in Zones 34d and 34e (9.1 and 7.3 birds/acre, respectively). These zones are small slips off of the Los Angeles Main Channel that consist of small, open-water navigation channels with fully developed shorelines (riprap, docks, and pilings). Avian usage within these zones was limited to small numbers of individuals (an average of 69 to 71individuals/survey), most of which were Western Gull and Rock Dove resting on piers, docks, and pilings. The high densities are attributable primarily to the small size of these zones (7.7 and 9.7 acres for Zone 34d and 34e, respectively) and the availability of developed shoreline, which are utilized by resting gulls. Similar high mean densities were calculated for other small zones including 24c, 24a, 34c, and 2C (Figure 9-5). Several large zones (4b, 9, 12, 15, and 22a) also had moderately high densities, indicating very abundant birds. Of the ten most

populous zones (Figure 9-4), only three (Zones 4b, 9, and 12) were also among the ten zones with greatest mean density (Figure 9-5).

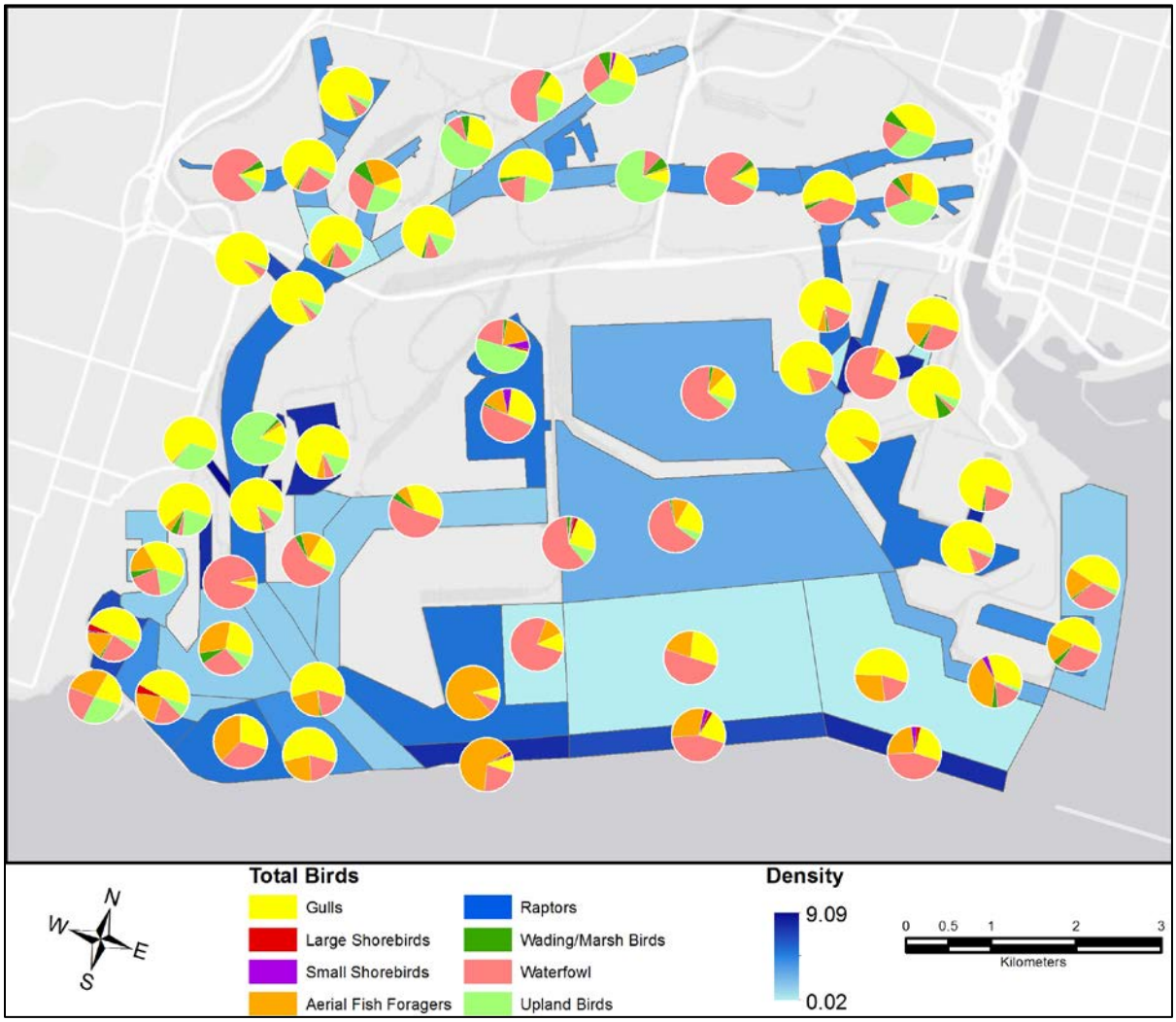

Figure 9-5. Density (individuals/acre) and relative abundance of avian guilds by survey zone.

Mean densities of the three most abundant guilds (Gulls, Waterfowl, and Aerial Fish Forgers) within each survey zone are presented in Figures 9-6, 9-7, and 9-8. These figures illustrate “hot spots” of usage within the Port Complex for these three guilds that are not as apparent when total avian density is considered. In addition to the large numbers (and high densities) of gulls found in Zones 34a and 4b adjacent to the commercial fishing fleet and fish markets, high densities of gulls were also found along the Middle Breakwater (Zones 9, 12, and 15), resting on docks and anchor lines in the Southeast Basin (Zones 22a and 22b), along the Back Channel (Zone 25a), and along the breakwater and sandy areas adjacent to Cabrillo Beach (Zone 1a) (Figure 9-6).

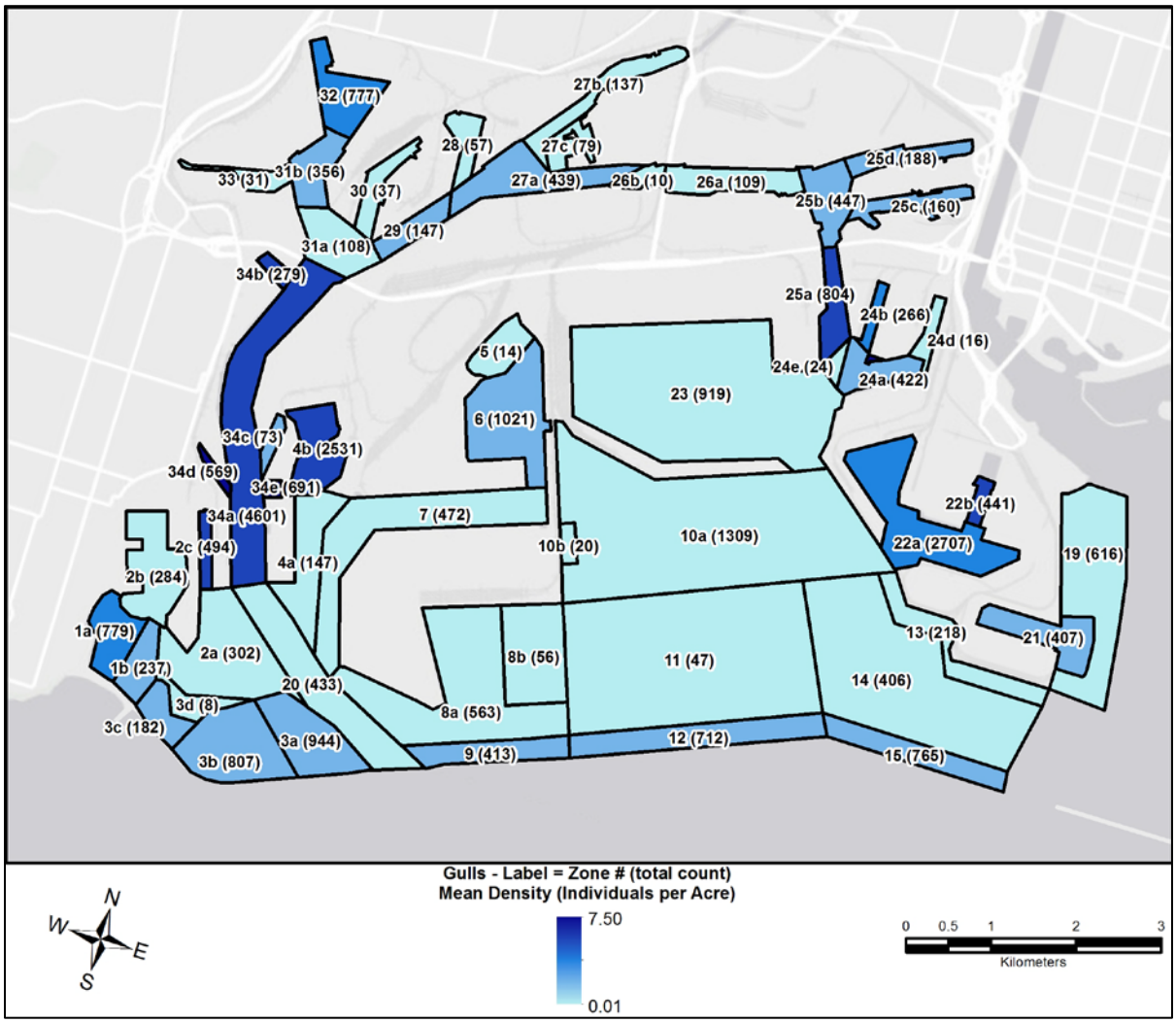

Figure 9-6. Mean density (color scale) and abundance (in parentheses) of gulls by survey zone.

Mean densities of waterfowl were greatest along the Middle Breakwater (Zones 9, 12, and 15) due to large numbers of cormorants, as well as in Zones 23, 24a, and 10a due to large rafts of Western Grebe, cormorants, and Surf Scoter (Figure 9-7). The high density of waterfowl in Zone 26a was a result of nesting cormorants. High densities of waterfowl in Zones 5 and 6 were due to rafts of foraging and resting Double-crested Cormorant and Eared Grebe.

Aerial fish foragers were largely absent from Inner Harbor zones. Individuals concentrated near known nesting areas and the Middle Breakwater. As a result, mean densities of aerial fish foragers were greatest in Zone 8a due to large numbers of Elegant Terns and California Least Terns nesting at Pier 400 (Figure 9-8). High densities of aerial fish foragers were observed in the vicinity of the Middle Breakwater (Zones 9, 12, and 15), due largely to resting Brown Pelican, and multiple species of terns were observed foraging in shallow water adjacent to Cabrillo Beach (Zone 1a) and the Cabrillo Shallow Water Habitat (Zone 3).

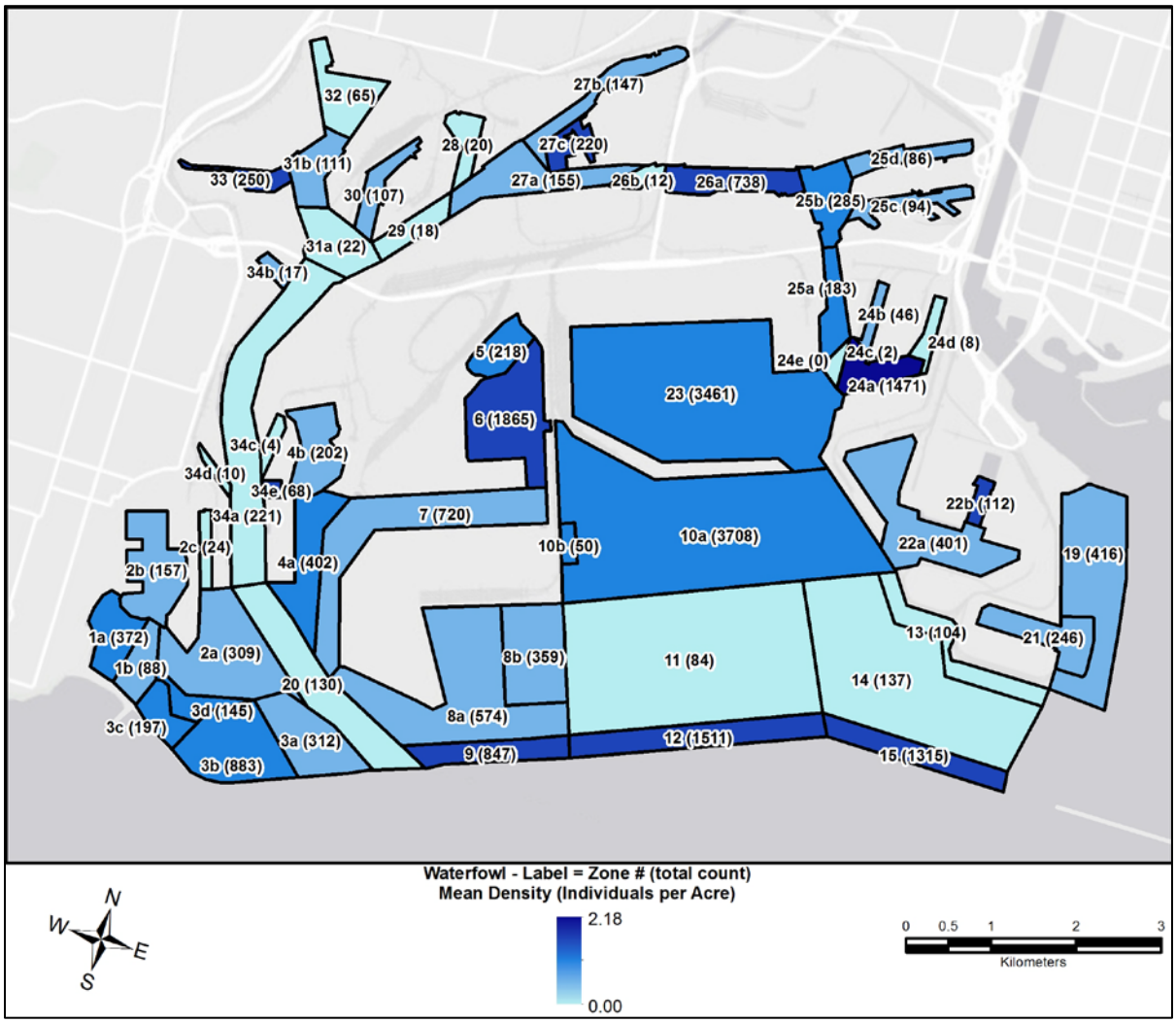

Figure 9-7. Mean density (color scale) and abundance (in parentheses) of waterfowl by survey zone.

The density of less abundant avian guilds was not mapped because the small numbers of birds resulted in low densities in all survey zones. However, patterns of usage were observed for the less abundant avian guilds. Four survey zones (5, 6, 12, and 15) accounted for 71.9% of all small shorebird observations (Figure 9-5). Zone 6 alone accounted for 32.5% of small shorebird observations, largely due to a flock of Black- bellied Plover observed repeatedly resting along the riprap during winter surveys. Similarly, four survey zones (1a, 9, 12, and 15) accounted for 68.6% of large shorebird observations. These zones encompass the San Pedro and Middle Breakwaters, where Black Oystercatcher was the most abundant large shorebird species, and Cabrillo Beach, where Willet (*Tringa semipalmata*) was the most abundant large shorebird.

In contrast to small and large shorebirds, wading/marshbirds were more evenly distributed throughout the survey zones. This guild was most abundant in Zones 23, 10a, 2a, and 7, which together accounted for 27.5% of total observations (Figure 9-5).

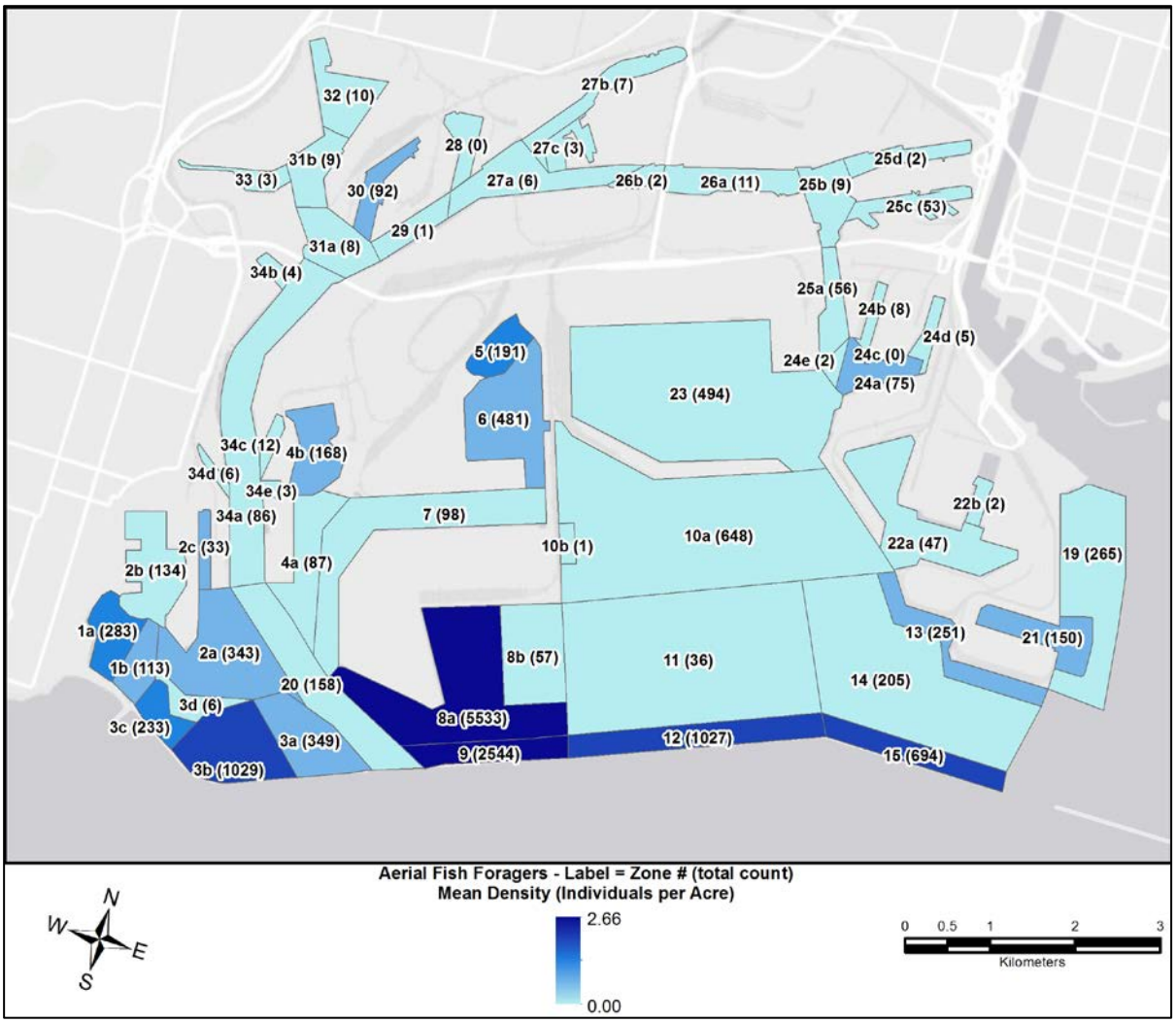

Figure 9-8. Mean density (color scale) and abundance (in parentheses) of aerial fish foragers by survey zone.

Densities in Zones 23 and 10a were driven by large numbers of Great Blue Heron in Gull Park on the Navy Mole. Densities in Zones 2a and 7 were driven by Great Blue Heron, Snowy Egret, and Black-crowned Night Heron foraging along docks and riprap. Only 34 total raptors were observed during the 2013–2014 surveys, and no patterns of abundance or density emerged from the data. Density of Upland Birds was greatest in Zones 5, 34c, 4b, and 34a, and was driven almost entirely by large numbers of Rock Dove.

AVIAN USAGE OF PHYSICAL FEATURES AND AVIAN ACTIVITY

Open water more than 1 foot deep is by far the most extensive type of natural feature in the Port Complex, and is available in all survey zones. The 2013-204 surveys observed 37.9% of all birds in this feature (Appendix I-8). A total of 69.2% of all waterfowl (primarily Western Grebe, along with Double-crested Cormorant and Brandt's Cormorant), 32.1% of all gulls (a combination of Western Gull, Heermann's Gull, and California Gull), and 17.5% of all aerial fish

foragers (primarily Brown Pelican) were observed in open water. Open water was heavily utilized during the winter months of November, December, and January by large rafts of gulls, Western Grebe, and Surf Scoter.

Riprap was the second most utilized feature within the Port Complex: 21.7% of all birds during the 2013–2014 surveys were observed on riprap. As previously discussed, riprap, particularly along the breakwaters, is a valuable roosting resource for Brown Pelican, and, in fact, 43.4% of all aerial fish foragers were observed along riprap. Riprap was also an important resting, foraging, and in some cases, nesting habitat for small shorebirds, large shorebirds, and wading/marshbirds. A total of 91.2% of small shorebirds, 67.9% of large shorebirds, and 35.0% of wading/marshbirds (primarily foraging Great Blue Heron and Snowy Egret) were observed on riprap.

Docks/pilings were the third most utilized feature, accounting for 14.2% of total bird observations. This feature was heavily utilized by resting gulls (accounting for 24.9% of all gull observations), wading/marshbirds (accounting for 20.1% of all wading/marshbird observations), and nesting Rock Dove (accounting for 37.7% of all upland bird observations). The remaining features each accounted for less than 3% of total observations.

Figure 9-9 summarizes the utilization of physical features in the Port Complex by the ten most abundant species of birds observed during the 2013–2014 surveys. As previously discussed, these ten species account for nearly 90% of all birds observed and, therefore, contribute largely to that usage. Western Gull, the most abundant avian species, was observed in all areas of the Port Complex, but nearly one third (31.2%) of them were on docks and pilings and nearly half (50%) of the individuals were split between open water, riprap, and flying.

In contrast, many of the other abundant avian species found within the Port Complex were observed on only a few types of features. For example, nearly all Western Grebes (99.8%), Surf Scoters (96.8%), and California Gulls (86.3%) were observed in open water. The majority of Brown Pelicans (67.8%) and Brandt's Cormorants (70.3%) were observed resting on riprap, particularly along the breakwaters. The majority of Elegant Terns (38.7%) were observed flying, with another 27.1% on open water and 25.4% resting on riprap.

Most birds in the Port Complex are resting: in the 2013-2014 surveys, 57,172 birds, accounting for 75.0% of total observations, were observed resting (Figure 9-10). Flying, foraging, and nesting accounted for 13.5%, 10.1%, and 1.4% of total observations, respectively. Flying birds included those traveling from one location to another, as well as aerial fish foragers that were actively searching for prey or diving. Flying birds accounted for 13.7% of total bird observations. Aerial fish foragers, raptors, and upland birds were all observed flying in large numbers.

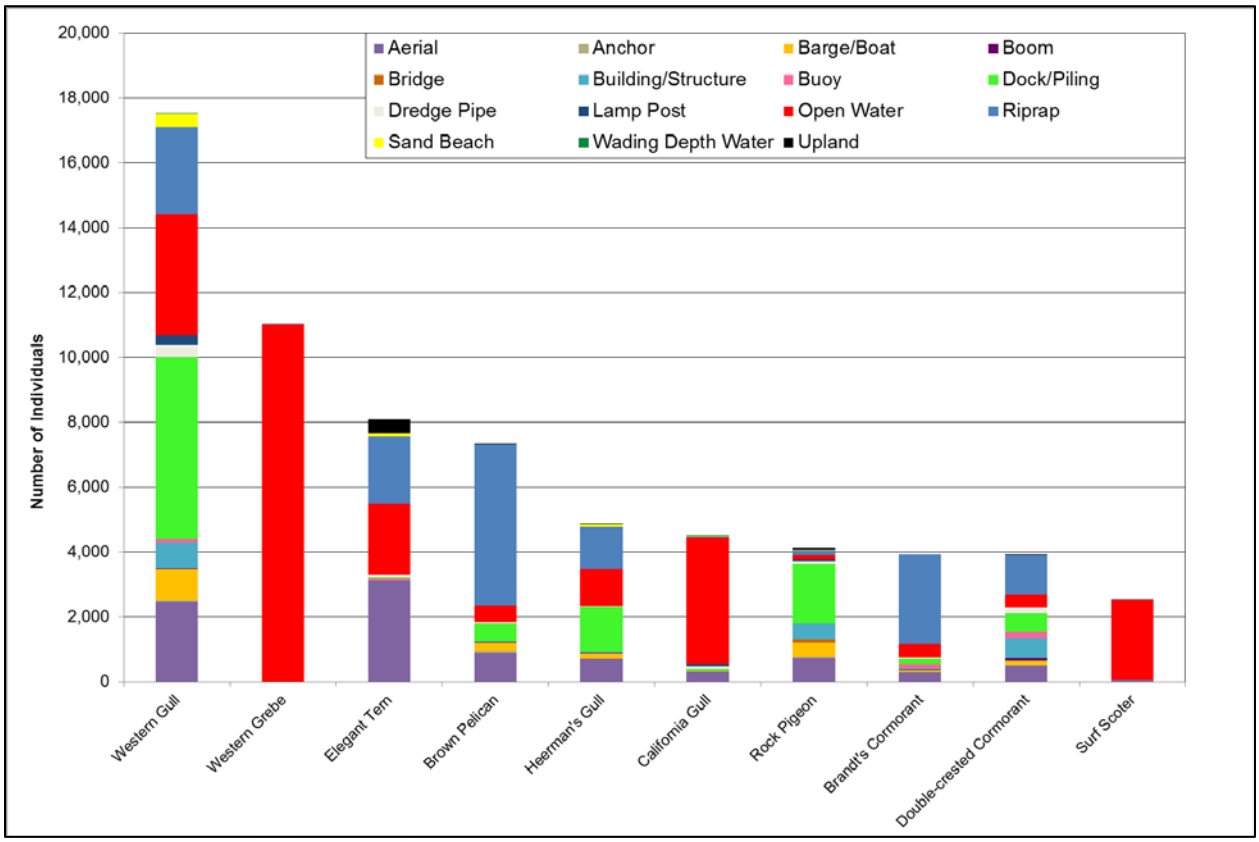

Figure 9-9. Total abundance of ten most common avian species by where they were observed.

Only upland birds, primarily Rock Doves, were observed courting, and that activity accounted for only 0.1% of total observations. Species from five of the eight avian guilds were observed nesting within the Port Complex: nesting aerial fish foragers included California Least Tern and Elegant Tern; nesting waterfowl were limited to Brandt's and Double-crested Cormorant; nesting wading/marshbirds were comprised solely of Great Blue Heron; and the only nesting gull species observed was Western Gull. Four upland species were observed nesting; Rock Dove, American Crow (*Corvus brachyrhynchos*), Cliff Swallow (*Petrochelidon pyrrhonota*), and Barn Swallow (*Hirundo rustica*). No large or small shorebirds or raptors were observed nesting within the Port Complex. As discussed previously, Black Oystercatcher and Peregrine Falcon are both known to nest within the Port Complex, but that activity was not observed by these species during the 2013–2014 surveys.

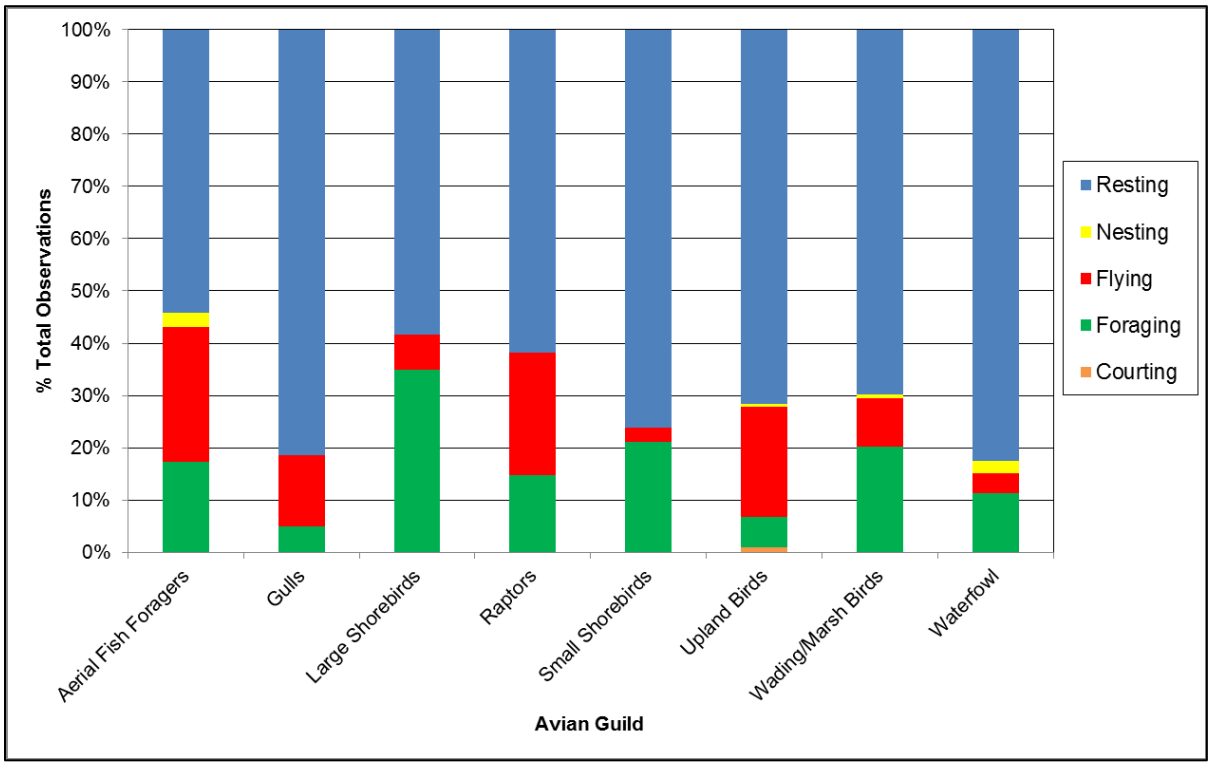

Figure 9-10. Percent of total abundance of avian guilds by activity.

DISCUSSION

Avian surveys have been conducted within the Port Complex periodically for more than forty years. Many of these surveys have differed in methodology, duration, and area covered. However, the same methodology was used in the three most recent survey efforts in 2000, 2008 (MEC 2002; SAIC 2010; the present study), thus allowing for direct comparisons of species composition, abundance, and diversity. During the 2000 study, a total of 99 species and 117,560 individuals were observed over 20 survey events, with a mean of 50 species and 5,878 individuals per survey. In 2008, a total of 96 species and 125,535 individuals were observed over 20 survey events, with a mean of 49 species and 6,277 individuals per survey. Those figures are similar to the 96 total species and means of 47 species and 6,365 individuals per survey counted during the 12 surveys in 2013–2014 (Figure 9-11).

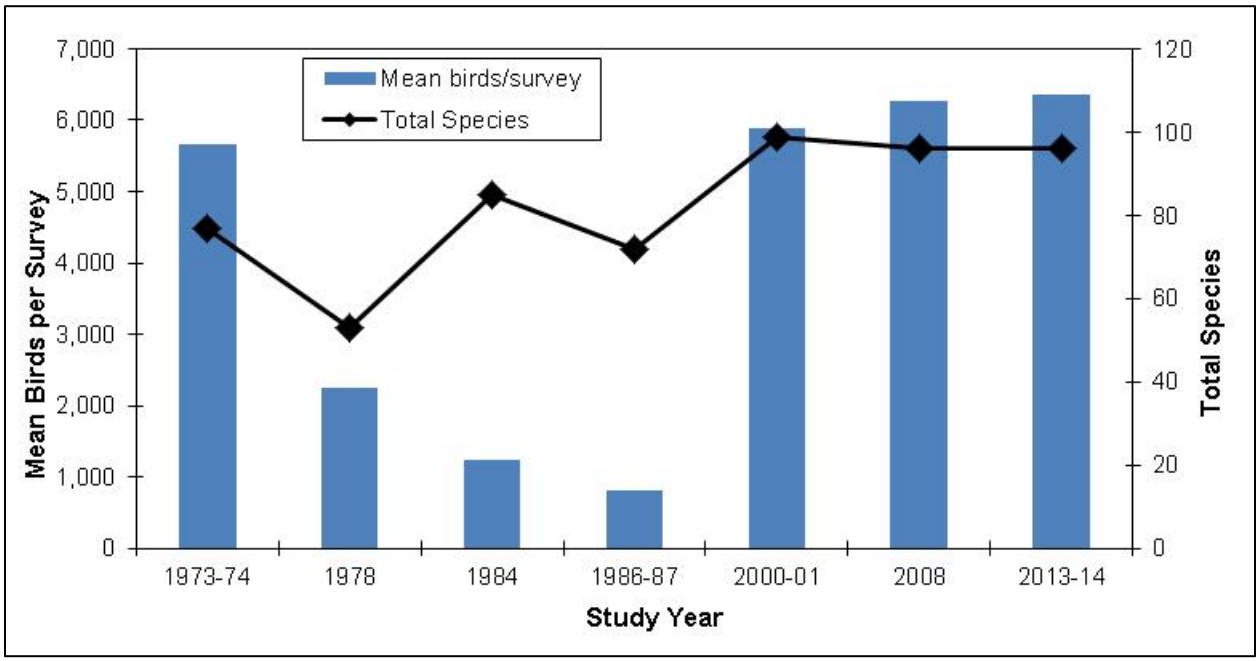

Figure 9-11. Historical comparison of mean abundance and total number of species observed in the Port Complex.

The guild composition within the Port Complex has also been comparable for the past three studies, with gulls, waterfowl, and aerial fish foragers accounting for the largest percentage of individuals observed. Gulls accounted for 44.1%, 34.4%, and 38.2% of observations in 2000, 2008, and 2013–2014, respectively (Figure 9-12). Waterfowl accounted for 21.4%, 38.5%, and 31.1% of observations and aerial fish foragers accounted for 22.4%, 17.5%, and 21.1% of observations during the same survey years.

Prior to 2000, gulls were the dominant avian guild, accounting for 30% to 70% of total observations (HEP 1976, 1979; MEC 1988). The Harbors Environmental Projects (HEP) surveys in the 1970's found that waterfowl accounted for 13% to 21% of observations and aerial fish foragers accounted for 8% to 19% of observations. The percentage of large and small shorebirds (presented together in Figure 9-12) has declined over each survey event since the 1970's.

The shifts in observed abundance of avian guilds are likely due to a number of factors, including area surveyed, changes in topography and shoreline configuration, and differences in general survey methodology including survey intervals. Surveys in the 1970's (HEP 1976, 1979) did not include open water habitat, where a majority of waterfowl occur.

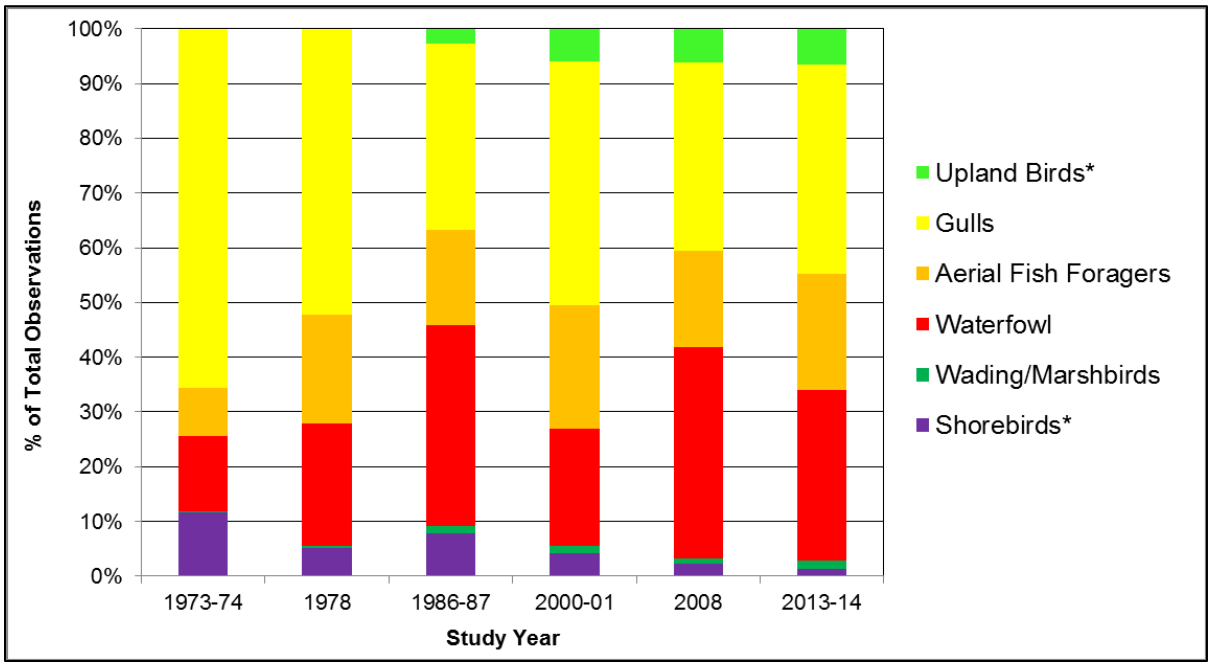

Figure 9-12. Historical comparison of percent composition of avian guilds in the Port Complex. Note: * small shorebirds and large shorebirds are combined to allow for inter-study comparisons. Raptors are included with upland birds.

Later surveys (MBC 1984; MEC 1988) focused on Outer Harbor habitats, resulting in an increased percentage of waterfowl observed but a lower percentage of upland birds. Numbers of gulls declined following surveys in 1978, perhaps due to implementation of secondary sewage treatment and waste management protocols at fish canneries, as suggested in the HEP study (1979). However, numbers of gulls increased by the 2000–2001 surveys and have remained relatively consistent since the 2008 survey. This is likely due to the current survey methodology, which includes both Inner and Outer Harbor habitats, and incorporates docks and pilings along developed shorelines that are frequently utilized by gulls.

It is not clear why large and small shorebirds have declined consistently since the 1970's. Authors of previous Port-wide survey reports have hypothesized that the decrease is due to a lack of available mudflat habitat (MEC 2002), or tidal fluctuations at the time of surveys (SAIC 2010). Numbers of shorebirds have not declined noticeably in adjacent wetland systems, such as Bolsa Chica, where shorebirds have consistently comprised greater than 50% of total observations during annual surveys (M&A 2013). Due to the lack of mudflat habitat and the small overall numbers of shorebirds observed within the Port Complex, variation in monitoring years may be driven by single observations of transient flocks of birds. For example, more than 300 Western Sandpipers (*Calidris mauri*) were observed in 2000; however, only four individuals of this species were observed in 2008 and 18 individuals were observed in 2013–2014.

Since implementation of the current survey protocols in 2000–2001, the ten most abundant species have remained consistent and have accounted for 87% to 92% of total observations during each study. Western Gull was the most abundant species during the 2000 and 2008

studies, accounting for 28% and 24.6% of total birds, respectively (Figure 9-13). Western Grebe, in contrast, accounted for a much lower percentage of total birds during the 2000 (8.3%) and 2008 (8.0%) studies. Both Brandt's Cormorant and Surf Scoter were more abundant during the 2008 surveys, accounting for 14.1% and 11.2% of total birds, respectively. Brown Pelican abundance has remained consistent over the past three studies.

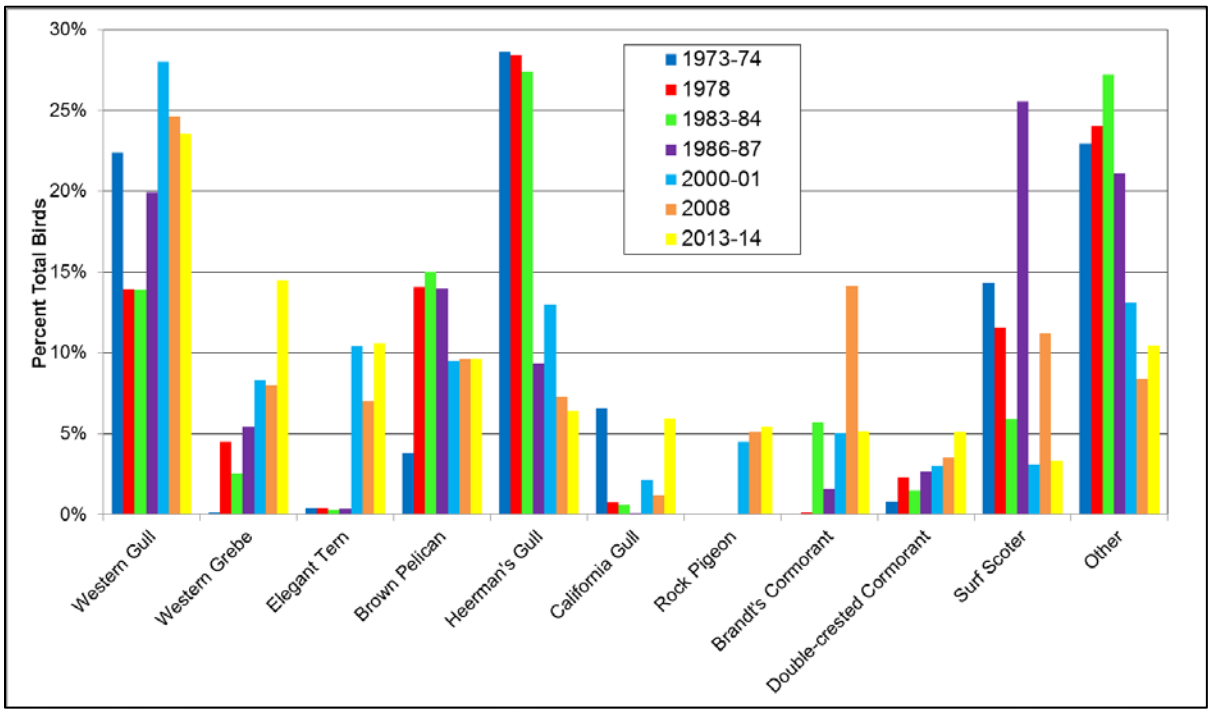

Figure 9-13. Historical comparison of percent composition of ten most abundant avian species in in the Port Complex.

As with previous surveys of the Port Complex, there was spatial variation among survey zones and habitat types in 2013–2014. The zones with the most abundant bird populations have remained consistent over the past three surveys. The large, open water zones Outer Harbor (Zones 10, 22, and 23) have historically supported, and continue to support, large rafts of foraging and resting waterfowl dominated by Western Grebe, Surf Scoter, and multiple cormorant species. The zones along the Middle Breakwater within the Port Complex (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, accounting 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). The Los Angeles Main Channel (Zone 34) 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 the 2000 study (MEC 2002). Finally, the zones adjacent to the nesting sites (particularly Zone 8 near Pier 300) support large numbers of aerial fish foragers, and are dominated by Elegant Terns.

The two most utilized habitat types within the Port Complex during the 2013–2014 surveys were open water, with 37.9% of all observations, followed by riprap with 21.7% of all observations; these are also the most common habitat types in the Port Complex. Open water was also the most utilized habitat during the 2008 study (30.1% of total observations), and the third most utilized habitat during the 2000 study (21% of total observations) (MEC 2002; SAIC 2010). Similar to the current surveys, riprap habitat has historically supported large numbers of birds. Riprap was the most utilized habitat during 2000 study, accounting for 25% of total observations (MEC 2002), and the second most utilized habitat during 2008 study, accounting for 24.1% of total observations (SAIC 2010). The Port Complex contains only a small amount of mudflat and sand beach habitat for foraging and resting, but has extensive riprap-lined shorelines. Additionally, the majority of birds within the Port Complex were observed resting. The riprap is used by gulls, pelicans, and cormorants for resting, as well as by small and large shorebirds for resting and foraging.

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CHAPTER 10 MARINE MAMMALS

This section presents the results of marine mammal surveys conducted during 2013–2014. All marine mammals in the Port Complex are protected by the Marine Mammal Protection Act of 1972 (MMPA) which prohibits their take. The United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) administer the MMPA.

Pinnipeds that are commonly observed within the Port Complex include harbor seal (*Phoca vitulina*) and California sea lion (*Zalophus californianus californianus*). Cetaceans known to occur within the Port Complex include bottlenose dolphin *(Tursiops* spp*)* and common dolphin (*Delphinus* spp).

Both pinnipeds and cetaceans utilize the waters of the Port Complex primarily to rest and forage. Many of these species acquire a great deal of opportunistic food at fish docks and the bait barges located within the Port Complex. Haul out and resting areas for pinnipeds include docks, boats, and buoys. No species of pinniped or cetacean is known to breed within the Port Complex.

MATERIALS AND METHODS

Marine mammal surveys were conducted concurrent with the monthly avian surveys (Figure 9-1, Table 9-1). Observational information recorded included species identification, location (avian survey zone), number of individuals, activity, habitat, and any other relevant information (e.g. injury, gender if feasible, etc.).

California sea lions (*Zalophus californianus californianus*) resting on buoy.

RESULTS

A total of 869 marine mammals belonging to four species were recorded during the 12 harbor-wide surveys (Table 10-1). Figure 10-1 illustrates the total abundance by survey zone of the marine mammals observed within the Port Complex. Tables of species observed by survey month and survey zone are provided in Appendix J.

The species most commonly observed was California sea lion, which accounted for 67.5% of total marine mammal observations. This species was observed year-round throughout the Port Complex, and was typically found resting on buoys, docks, riprap shoreline, and on the bulbous bows of docked cargo ships. California sea lions were also frequently observed foraging near bait barges and fish markets (located in avian survey zones 34a and 2a), and in the wakes of fishing boats entering and exiting the Port Complex.

Table 10-1. Marine mammals observed in the Port Complex, 2013–2014.

Species	Total Observations	Percent of Total
California Sea Lion (*Zalophus c. californianus*)	587	67.5
Harbor Seal (*Phoca vitulina*)	223	25.7
Bottlenose Dolphin (*Tursiops* spp.)	18	2.1
Common Dolphin (*Delphinus* spp.)	40	4.6
unidentified dolphin	1	0.1

Figure 10-1. Relative abundance of marine mammals by survey zone.

Harbor seals were less common than California sea lions, and accounted for 26% of total marine mammal observations. Harbor seals were most commonly observed resting or foraging along riprap shorelines, particularly the breakwaters of the Outer Harbor, and 83% of total observations of this species were made in the Outer Harbor (Figure 10-1).

Two species of cetaceans were observed during the current surveys. Common dolphin accounted for 4% of total marine mammal observations. However, this total consisted of a single observation of a pod of 40 individuals along the Los Angeles Main Channel in February. In contrast, bottlenose dolphins were observed in small groups of three to five individuals, several times throughout the survey year. The bottlenose dolphin accounted for 2% of total observations. Individuals of both dolphin species were only observed in the Outer Harbor (Figure 10-1).

Harbor seal (*Phoca vitulina*) resting on riprap.

DISCUSSION

For the past several Port-wide biological studies, marine mammals have been documented as ancillary observations during avian and fish surveys, making comparisons between survey events difficult. However, general trends are apparent. Similar to surveys in 2000 and 2008, California sea lion was the most abundant marine mammal observed during the 2013–2014 surveys. This species is abundant throughout the Port Complex, with higher numbers of individuals observed (1) adjacent to bait barges, fishing vessels, and fish packing plants within the Port of Los Angeles, and (2) resting on buoys and barges throughout the Outer Harbor. Harbor seals, in contrast, were only found in the Outer Harbor, typically resting on riprap or foraging in the kelp that lines the breakwaters of the Port Complex.

Cetaceans were much less common during 2013–2014 than in previous Port-wide surveys, with observations limited to occasional sightings of pods or small groups of individuals foraging in the Outer Harbor. Previous studies observed small numbers of Pacific white-sided dolphin *(Lagenorhynchus obliquidens*) and gray whale (*Eschrichtius robustus*) within the Port Complex (USACE 1992; MEC 2002; SAIC 2010), but neither species was observed in the current study.

The present study occurred during a period when sea lion strandings on the California coast were well above average (NOAA 2015). In 2013, NOAA declared an Unusual Mortality Event, and determined that part of the cause was a change in availability of sea lion prey. Prey is particularly important for sea lion mothers to support nursing, and for pups as they begin to wean and start foraging on their own. 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. Given the lack of quantitative data from previous harbor-wide studies it is not possible to determine whether sea lions in the Port Complex were more or less abundant than previously. Accordingly, no conclusions concerning the effects of the Unusual Mortality Event on sea lions in the Port Complex can be drawn.

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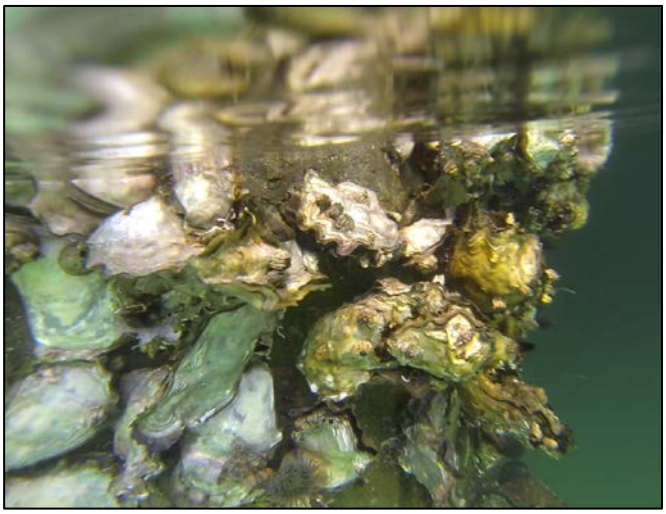
CHAPTER 11 NON-NATIVE SPECIES

An introduced, exotic, non-indigenous, or non-native species is a species living outside its native distributional range, and has arrived there by human activity, either deliberate or accidental. Numerous studies have been undertaken to understand the invasion histories of non-native species and to predict sustainable invasions (Carlton 1996). California's 2003 Marine Invasive Species Act requires resource agencies to conduct appropriate studies necessary to develop a baseline of non-native species occurring in the coastal marine waters of the state, and then to monitor those areas for any new introductions.

In the marine environment, the introduction of organisms has generally occurred in ports and harbors due in part to the primary vectors (ballast water and ship hull fouling) that are concentrated in those areas (Ruiz et al. 2011). Other vectors include aquaculture and the transport and sale of live bait, seafood, and organisms for research, education, and ornamental purposes. The intent of this section of the report is not to document the history of introductions or potential vector pathways, but to catalog those species identified during the present survey that have documented introduction status and to provide current knowledge regarding the introductions.

METHODS

Species identified for each element of the 2013–2014 study, as well as previous harbor-wide surveys (2008 and 2000), were entered into a web-based database or cross-referenced with database records from various sources including:



Introduced Pacific oysters (*Crassostrea gigas*) in spring.

- National Exotic Marine and Estuarine Species Information System (NEMESIS) which is a database of non-native species records for marine and tidal waters of the continental United States;
- California Aquatic Non-Native Organism Database (CANOD) which includes records of non-native species for similar habitats in California; and
- U.S. Geological Survey Nonindigenous Aquatic Species (USGS-NAS) program which provides scientific reports, online/real-time queries, spatial data sets, regional contact lists, and general information.

Several of the databases provide introduction status (e.g., introduced, cryptogenic, unresolved, or native, see below) and a synthesis of occurrence records of species compiled from literature-

based records and independent field surveys. Some databases also include information about invasion history, biogeography, and vectors associated with the species.

The databases provide definitions for introduction status:

- An “introduced” species refers to both innocuous and invasive introductions without specifying which. In order to address the stipulations of the Marine Invasive Species Act, any species that is not native to California waters and whose native range is known to be outside of the California borders is considered an introduced species. This includes species whose native range is elsewhere along the northeast Pacific coastline (not including California). This term is synonymous with the term “Non-native” used in the remainder of the chapter.

- A “cryptogenic” species as defined by Carlton (1996) is “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. Also, in cases where there were discrepancies in status between or among sources, the species was labeled as cryptogenic until the discrepancy was resolved. Cryptogenic species are numerous and likely underestimated to such an extent as to misshape our understanding of the true effects that invasions have on the ecosystem” (Carlton 1996).

- ”Unresolved” species are those that could not be identified beyond the family, class, order, or genus level and could not be confidently classified as introduced, cryptogenic or native. Also, specimens that have been given provisional names are assigned an introduction status of unresolved.

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.

If a species was determined to be introduced, cryptogenic, or unresolved, the species, status, and status information was entered into a comprehensive table (Appendix K-1). In addition, historical data were tabulated for each of the biological sampling elements during harbor-wide biological surveys in 2000, 2008, and 2013–2014. Species reported from all surveys reviewed were evaluated utilizing current knowledge of introduction status to make comparisons consistent among surveys conducted over a nearly 15-year period.

RESULTS

Table 11-1 provides a summary of the introduction status for species recorded during harbor-wide biological surveys, separated by survey type (e.g., infauna, epifauna, macroalgae, riprap, kelp, and fish). Note that some species may have been observed in multiple survey types, so summing the number of non-native species among sampling types would not provide an accurate record of the total number of non-native species recorded (Appendix K-2).

Table 11-1. Number of taxa per status category, and (percent of total) from studies in the Port Complex.

Survey Type	Study	Total Taxa	Status		
			Introduced	Cryptogenic	Unresolved
Infauna	2013–2014 Study	343	8 (2.3)	55 (16.0)	6 (1.7)
	2008 Study	258	9 (3.5)	32 (12.4)	-
	2000 Study	361	24 (6.6)	35 (9.7)	-
Epifauna	2013–2014 Study	110	8 (7.3)	-	-
	2008 Study	61	1 (1.6)	-	5 (8.2)
	2000 Study	61	1 (1.6)	-	1 (1.6)
Riprap	2013–2014 Study[A]	558	18 (3.2)	59 (10.6)	6 (1.1)
	2008 Study	334	12 (3.6)	31(9.3)	-
	2000 Study	265	16 (6.0)	13 (4.9)	-
Macroalgae/Kelp	2013–2014 Study	34	3 (8.8)	-	6 (17.6)
	2008 Study	22	2 (9.1)	-	5 (22.7)
	2000 Study	18	2 (11.1)	-	6 (33.3)
Fish	2013–2014 Study	70	2 (2.9)	-	-
	2008 Study	70	1 (1.4)	-	-
	2000 Study	76	2 (2.6)	-	-

Notes: 2013–2014 Study is present study; 2008 Study (SAIC 2010); 2000 Study (MEC 2002).
Some species may have been observed during multiple survey types.
[A] - Includes species identified during Rapid Assessment Surveys.

The present study collected 27 non-native (i.e., “introduced”) species, 95 cryptogenic species, and 12 unresolved species among the various sampling methodologies. In general, the number of introduced species documented for the last three harbor-wide studies within each sampling element has remained relatively constant, with the exception of infauna sampling in 2000, which recorded 24 non-native species compared to nine in 2008 and eight during the present study,

and epifauna sampling, in which the present study found eight introduced species compared to only one in the two previous studies (Table 11-1).

During benthic infauna sampling in 2013-2014, eight of the 343 taxa collected were non-native species (Table 11-1). Introduced species were collected at every one of the 32 stations, but no more than three non-native species were reported at any one station (Figure 11-1; Appendix K-2). The most frequently occurring introduced benthic infauna species was the Asian clam, *Theora lubrica*, which occurred at 31 of the 32 stations during summer and/or spring (Appendix K-2). In addition to being the most frequently encountered introduced benthic infauna species, *T. lubrica* was one of the most abundant benthic species overall; it ranked second in abundance (all stations combined) in summer (344 individuals collected) and fourth in spring (150 individuals). The amphipod *Sinocorophium heteroceratum* was collected at 12 stations and the New Zealand snail (*Philine auriformis*) at eight stations. The remaining five non-native benthic infauna species were found at one or two stations during the surveys.

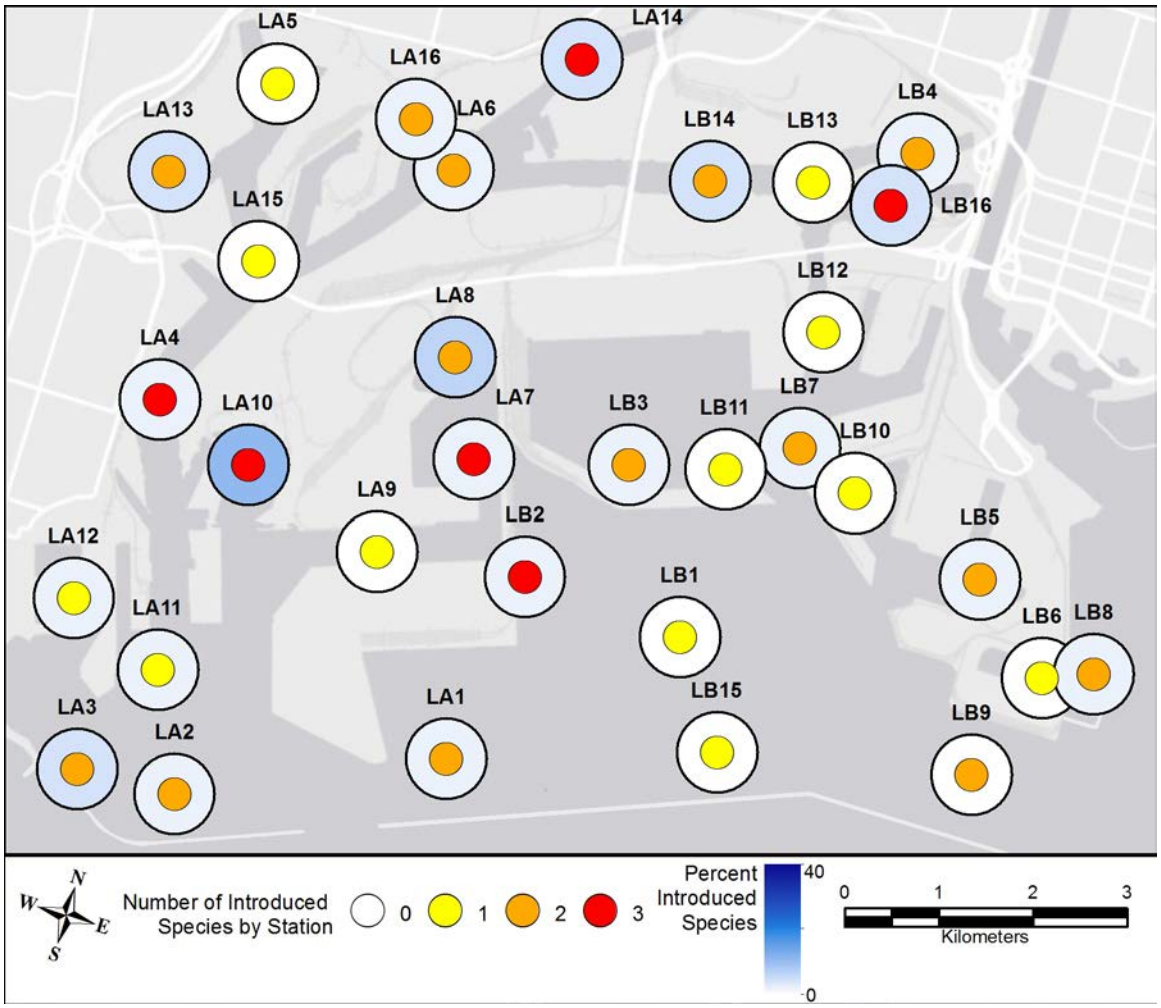


Figure 11-1. Numbers of introduced species identified at each benthic infauna station.

During epibenthic sampling, eight of the 110 invertebrate taxa collected by otter trawl or in beach seine sampling were non-native species (Table 11-1). Occurrence of non-native species was variable among the stations (Figure 11-2; Appendix K-2). The greatest numbers were recorded at Station LB12 (Back Channel, four species) and at Station LB4 (Channel 2, five species). The New Zealand snail was the most frequently encountered non-native epibenthic invertebrate species (200 individuals were collected), and it occurred at 15 of the 26 otter trawl stations. Nearly 70% of all individuals, however, were taken at three stations in spring, including 65 taken during a single trawl at Station LB1. The sea squirt *Styela plicata* was collected at eight of the stations, stalked sea squirt (*Styela clava*) was collected at seven of the stations, bay mussel (*Mytilus galloprovincialis*) was collected at six stations, and spaghetti bryozoan (*Zoobotryon verticillatum*) occurred at four of the stations. The remaining three non-native species occurred at one or two stations during the surveys. One introduced epibenthic invertebrate species, the oriental shrimp (*Palaemon macrodactylus*), was taken in beach seine sampling, and it was only collected at Cabrillo Beach.

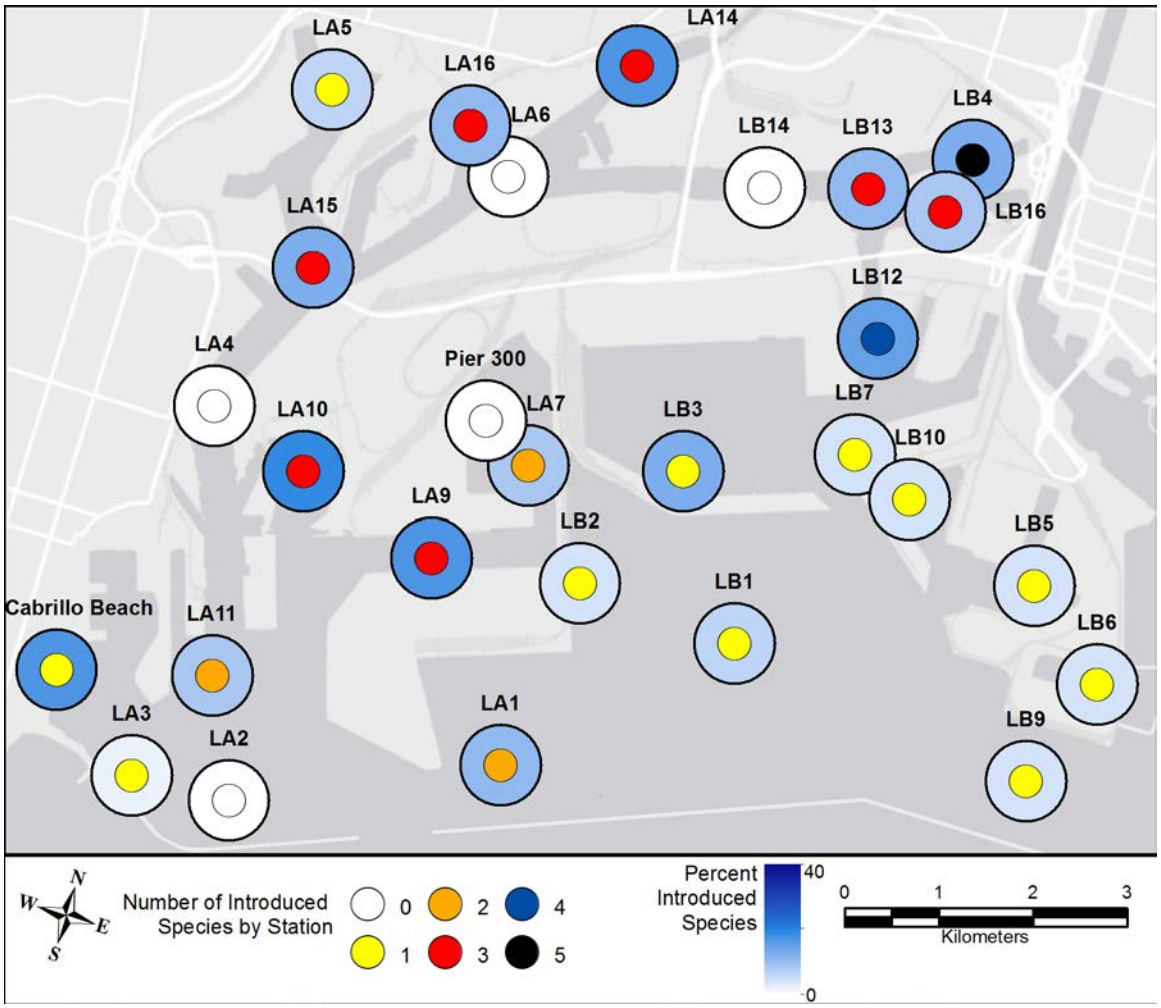


Figure 11-2. Numbers of introduced species identified at each epibenthic station.

During riprap sampling, 18 of the 558 taxa collected were non-native species (Table 11-1). Between six and 14 introduced species were reported at each of the eight stations (all depths, both seasons, and both survey methods combined) (Figure 11-3; Appendix K-2). The highest number of non-native riprap species was found at Station LARR3 (LA West Basin). Of the 18 introduced species, the amphipod *Aoroides secundus* was the most frequently encountered, and it occurred at all eight riprap stations. The encrusting bryozoan *Watersipora arcuata* was also common, being found at seven riprap stations. Overall, nine of the 18 non-native species found during riprap sampling occurred at four or more of the riprap stations.

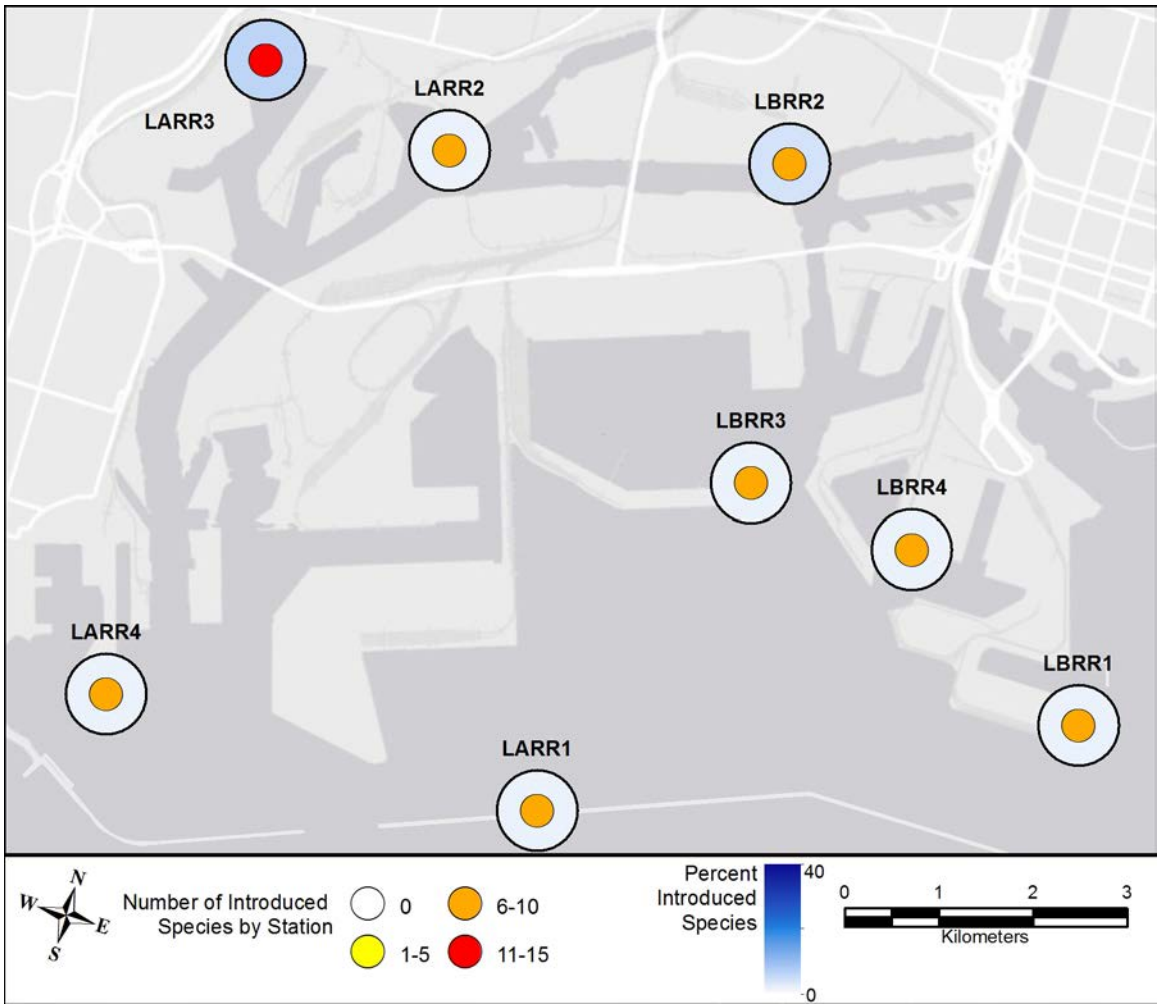


Figure 11-3. Numbers of introduced species at the riprap stations.

Three introduced species out of 34 total algae species were observed among the 20 stations sampled for kelp and macroalgae (Table 11-1): *Sargassum horneri*, *Sargassum muticum*, and *Undaria pinnatifida*. At least one of these species was reported at every station during the surveys, and all three occurred at six of the 20 stations (Figure 11-4; Appendix K-2). *Sargassum muticum* was the most frequently encountered introduced algal species, occurring at 18 stations. *Undaria pinnatifida* was observed at 14 stations and *Sargassum horneri* was observed at 10 stations.

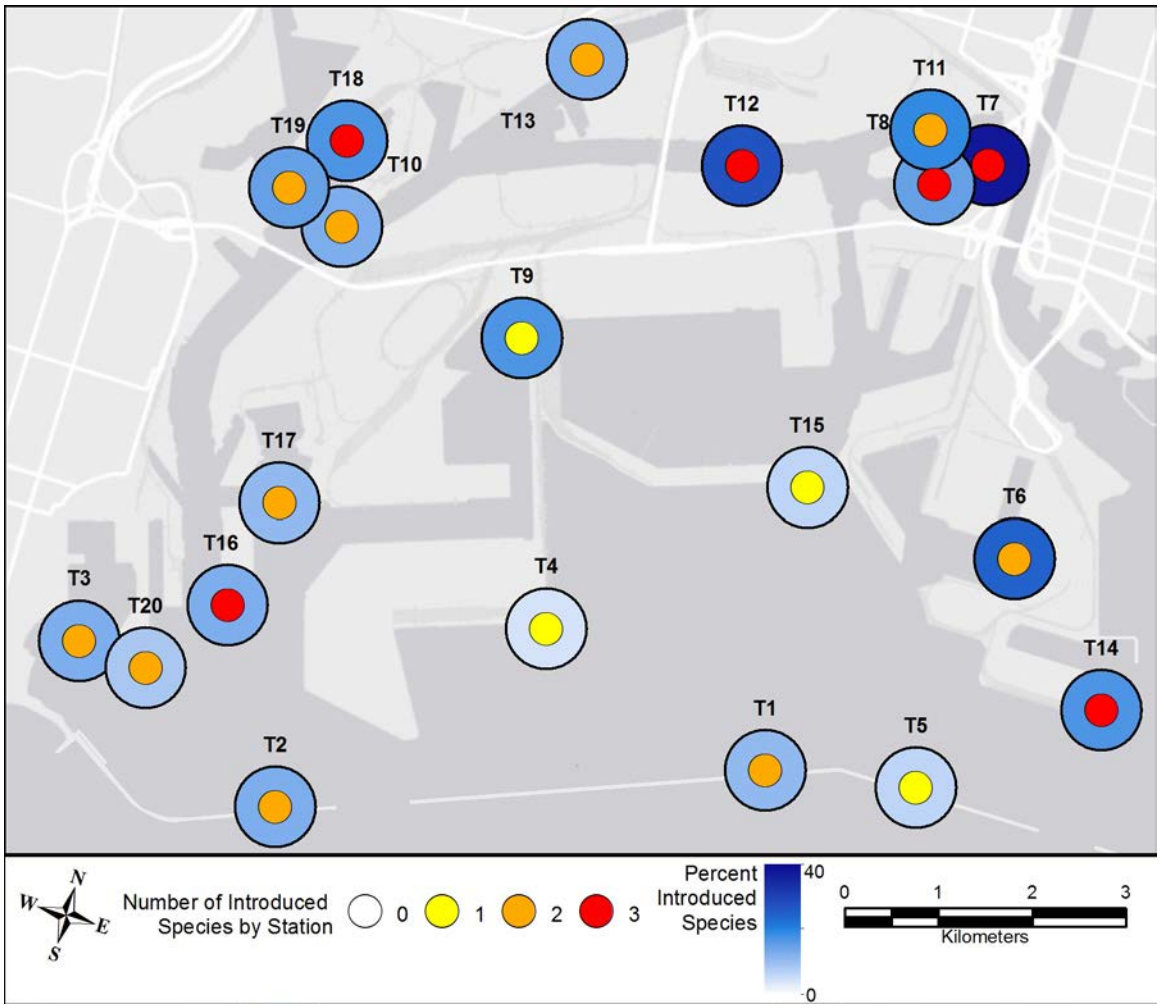


Figure 11-4. Numbers of introduced species at the kelp and macroalgae transects.

Two of the 70 total fish species taken during otter trawl sampling are introduced (Table 11-1; Appendix K-2). Both Yellowfin Goby (*Acanthogobius flavimanus*) and Chameleon Goby (*Tridentiger trigonocephalus*) were taken at Station LA10 (Fish Harbor), and Chameleon Goby was collected at Station LA14 (Consolidated Slip). Yellowfin Goby larvae were also collected during ichthyoplankton sampling (Appendix D). No introduced fish species were collected during lampara net sampling of the pelagic fish community or beach seine sampling of the shallow-water fish community.

DISCUSSION

Results of the California Department of Fish and Wildlife's most recent survey (2011) of southern California harbors are summarized in Table 11-2 (CDFW 2014). The objective of that study was to update the extent of invasions and subsequent spread of coastal aquatic organisms, and not to discuss potential areas of concern or introduction pathways. Among the eleven bays and harbors along the mainland coast of southern California (i.e., omitting Avalon Harbor on Catalina Island as a special case), from 8% to 12% of species are classified as

introduced. In the Port Complex, although the absolute numbers of introduced species was higher than in any other harbor, the percent of total species they represented (8.4) was lower than in all but two of the mainland bays and harbors (Santa Barbara and Port Hueneme; Table 11-2). Avalon Harbor is a special case because its isolation makes it much less prone to the coastwise spread of introduced species than mainland harbors.

Table 11-2. Number of taxa (and percent of total species) per classification in southern California harbors from 2011 CDFW study (CDFW 2014).

Waterbody	Total Taxa	Introduced	Cryptogenic	Unresolved
Santa Barbara Harbor	345	28 (8.1)	48 (13.9)	139 (40.3)
Channel Islands Harbor	401	42 (10.5)	56 (14.0)	156 (38.9)
Port Hueneme	407	32 (7.9)	54 (13.3)	144 (35.4)
Marina del Rey Harbor	313	32 (10.2)	38 (12.1)	132 (42.2)
LA/Long Beach Harbor	675	57 (8.4)	96 (14.2)	263 (39.0)
Huntington Harbor	287	33 (11.5)	49 (17.0)	101 (35.2)
Newport Bay	360	39 (10.8)	53 (14.7)	140 (38.9)
Dana Point Harbor	336	35 (10.4)	46 (13.7)	134 (39.9)
Avalon Harbor	513	23 (4.5)	6 (1.2)	185 (36.1)
Oceanside Harbor	364	38 (10.4)	57 (15.6)	146 (40.1)
Mission Bay	476	53 (11.1)	70 (14.7)	184 (38.6)
San Diego Bay	441	53 (12.0)	63 (14.3)	169 (38.3)

In the present study, the Asian clam occurred at all but one of the 32 benthic infauna stations, and it was one of the most abundant benthic species overall. The species was also widespread and abundant during the previous two harbor-wide surveys. In 2008 it was taken at 25 of 29 infauna stations, was the most abundant species overall, and contributed 10% to total infaunal abundance (SAIC 2010). In 2000, Asian clam occurred at all 32 infauna stations and was the fourth most abundant infauna species (MEC 2002). Asian clam was introduced from the western Pacific, was first observed in southern California in the late 1960s, and was found in high abundances in the Port Complex by 1973 (Appendix K-1). The introduced amphipod *Sinocorophium heteroceratum* was also widespread and abundant in previous harbor-wide studies (MEC 2002; SAIC 2010). Despite occurring at eight stations during the present survey, New Zealand snail was not abundant, which is consistent with the results from the 2008 study (35 New Zealand snails were found at 13 stations over two seasons) and the 2000 study (21 New Zealand snails were reported at eleven benthic infauna stations during four seasonal surveys).

In the epibenthos, however, the New Zealand snail was the most frequently encountered non-native epibenthic invertebrate species in the present study, occurring at 15 of the 26 otter trawl stations. During the 2008 study, only the white paperbubble (*Philine alba)* was identified to the species level in trawl samples, and all other individuals in the same genus were identified only as *Philine* spp. Assuming (per SAIC [2010]) that all *Philine* spp were *P. auriformis*, only 29 individuals were collected during trawls at 19 stations during three seasons in 2008 (SAIC 2010). In 2000, 409 New Zealand snails were collected in four-season trawls at 18 stations (MEC 2002). As in the present study, although New Zealand snail was frequently encountered, it was usually collected in low numbers. This suggests that while the species is well-established in the Port Complex, it is not increasing its population to any great extent.

Non-native yellowfin goby (*Acanthogobius flavimanus*) caught in summer.

The greatest difference in percent contribution by non-native species among the previous and current studies was found during the epifauna sampling. In both 2000 and 2008, non-native species accounted for 1.6% of the epibenthic species reported (MEC 2002; SAIC 2010). In the current study, 7.3% of the species reported (8 species) were non-native. Six of those species (bay mussel, Pacific oyster [*Crassostrea gigas*], three tunicates (including two *Styela* species), and a bryozoan [*Zoobotryon*]) are hard-substrate associated species that are not typically collected during epibenthic otter-trawl surveys. Although these species were not reported as part of the epibenthic community during the 2008 or 2000 harbor-wide studies, these are not new introductions, but were the result of collecting debris that supported these species. With the exception of one of the tunicates and the bryozoan, both of which are common in southern California harbors, all were recorded in previous baseline studies.

The riprap sampling effort in the present study reported 18 non-native species, 3.2% of the total number of species. The amphipod *Aoroides secundus*, which was reported at all eight riprap stations, was reported at one station during the 2000 harbor-wide study and at two stations during the 2008 survey (MEC 2002; SAIC 2010). The encrusting bryozoan *Watersipora arcuata*, reported at seven riprap stations during the present study, was not reported (or not identified to at least the generic level) in the two previous harbor-wide studies. While the total number of introduced species reported in the present study exceeds those reported in the riprap surveys conducted in 2000 and 2008 (16 and 12, respectively), the percent contribution by non-native species declined from 6.0% in 2000 to 3.6% in 2008 to 3.2% in 2013–2014 (MEC 2002; SAIC 2010).

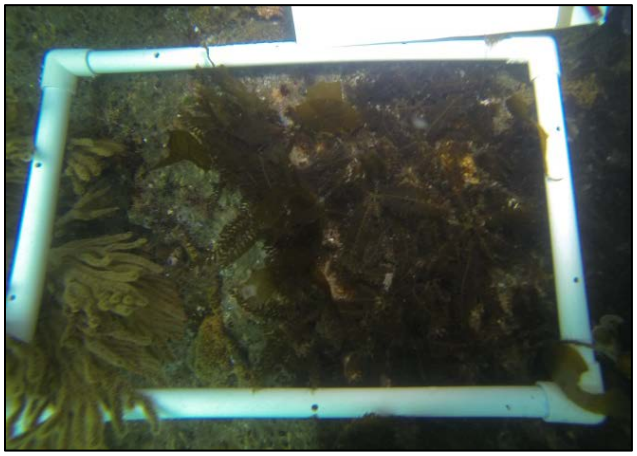
The riprap community is particularly susceptible to the unintentional introduction of non-native species since transport of fouling organisms living on ship hulls and anchors is considered a primary vector for the introduction of non-native species (Ruiz et al. 2011). While points of origin or method of introduction of all 18 introduced species are unknown, eight of them—a barnacle, two amphipods, two tunicates, and three bryozoans—are considered to be introduced by shipping or known to live on ship hulls (Appendix K-1). Three species—Pacific oyster, Asian mussel *(Musculista senhousei*), and Japanese littleneck clam (*Venerupis philippinarum*)—were transported to California by the aquaculture industry, with the latter two considered unintentional introductions linked to the importation of Pacific oyster (Appendix K-1).

It is interesting to note that during the 2013–2014 survey the station with the most introduced species, Station LARR3, is the only riprap station that is also an active shipping terminal. Some of the other seven stations are adjacent to terminals, but none have ships berthing immediately adjacent. Whether the high number of non-native species at Station LARR3 can be associated with the proximity and duration of ship calls at that location or with its character as vertical concrete pilings instead of sloped armor rock or concrete debris (see Appendix F-26) is not known. Station LARR3 was also the only riprap station where Pacific oyster, a community dominant at the station, was reported. Although not found at any of the sloped riprap stations, Pacific oyster was found in the epibenthic community of the Back Channel and Fish Harbor, where it presumably sloughed off nearby pilings (both areas have extensive piling habitat).

Kelp and macroalgae are also part of the riprap communities in the Port Complex and also subject to the introduction of foreign species. Of the three introduced algae species found during the present study, *Sargassum horneri* was introduced to the Ports by ships, *Sargassum muticum* was an unintentional introduction growing on imported Pacific oysters, and *Undaria pinnatifida* was introduced to California as a result of importation for cultivation, accidental transport with oysters, and ship hull fouling (Appendix K-1). All three of these species were reported at 10 or more of the 20 kelp and macroalgae stations during the present study and *b*oth *Sargassum muticum* and *Undaria pinnatifida* were reported in the two previous harbor-wide studies (MEC 2002; SAIC 2010). *Sargassum horneri* was first observed in the Port Complex in 2003.

Two introduced fish species were taken during otter trawl sampling in the Ports. Four Yellowfin Goby (*Acanthogobius flavimanus*) were collected in a single otter trawl in Fish Harbor during the present study. In 2008, 53 individuals were taken at ten stations, and in 2000 two individuals were taken at two otter trawl stations and 19 individuals were collected in beach seine sampling at the Pier 300 Shallow Water Habitat (MEC 2002; SAIC 2010). Yellowfin Goby, a native of Asia, was first reported in California in 1960 and was likely transported in a ship's bilge water or as eggs attached to the fouling community of a ship's hull (Appendix K-1). Chameleon Goby (*Tridentiger trigonocephalus*) was reported at Fish Harbor and Consolidated Slip during the present study, with one individual taken at each station. One individual was taken in trawl sampling at the Pier 300 Shallow Water Habitat in 2000, but Chameleon Goby was not reported during the 2008 harbor-wide survey (MEC 2002; SAIC 2010). Chameleon Goby was first reported in California in 1960, and was likely introduced from ballast water or eggs laid on the fouling community on a ship's hull (Appendix K-1).

The presence of non-native species may result in a range of environmental effects, with direct effects including preying on native species and outcompeting native species for food or other resources, and larger, ecosystem-level indirect effects including food web changes (by removing native food sources), decreased biodiversity (by changing the abundance or diversity of native organisms), and alteration of ecosystem conditions. However, the past three harbor-wide studies have not documented severe ecosystem disruption by introduced species; instead, the newcomers appear to have fit into the harbor biological communities, which now consist of a mixture of a few non-native and many native species.



Invasive alga *Sargassum horneri* (right) on the outer breakwater in summer. The native golden gorgonian (*Muricea californica*) is on the left of the quadrat.
Note: image is a video screen grab.

An example of a potential ecosystem impact is the first known Western Hemisphere infestation of the invasive strain of the tropical marine alga, *Caulerpa taxifolia*, which was discovered in summer 2000 in Agua Hedionda Lagoon (Carlsbad, California) and in Huntington Harbour (Huntington Beach, California). *Caulerpa* is commonly used in saltwater aquarium systems, and earlier releases of *C. taxifolia* into coastal European and Australian waters resulted in the establishment of extensive dense carpets of the seaweed. These dense mats smothered diverse natural communities and dramatically reduced biodiversity by displacing native seaweeds and animals. Based on the aggressive nature of this species and the displacement of native marine resources observed upon its discovery in California, it was recognized that the infestations posed a major threat to coastal ecosystems and to recreational and commercial uses dependent upon coastal resources. Eradication efforts were implemented, and in 2006, it was determined that *C. taxifolia* was successfully eradicated from southern California (M&A 2006).

While species such as *Caulerpa* may have large-scale impacts, the majority of non-native species have more subdued or less obvious effects. Mikel et al. (2002) found that embayments in southern California are highly invaded by non-native macrofauna, with non-native species encountered at 121 of 123 sites they sampled and more than a quarter of the animals classified as non-native. They suggested that intermediate levels of disturbance allow persistence of diverse native and non-native species within the same benthic community. Sampling the same southern California embayments, Cohen et al. (2002) found much greater diversity of non-native species on hard substrates than in the soft-bottom benthos; however, they did not note any ecosystem-level effects. They collected 65 non-native species from floating structures at 21 sites and only 13 non-native species from 13 benthic sampling sites. The present study

collected 27 non-native species among the various sampling methodologies, compared to 19 taken in 2008 and 25 in 2000 (MEC 2002; SAIC 2010).

While the purpose of the Cohen et al. (2002) and Mikel et al. (2002) studies, in addition to the 2011 CDFW study (CDFW 2014), was to document the presence of non-native species, the purpose of the present study was to characterize marine communities over a range of representative habitats throughout the Port Complex, and as part of that, to record the presence and location of non-native species. Despite differences in sampling methodologies between the last three harbor-wide studies, their results suggest little change in the proportion of non-native species (Table 11-3).

Table 11-3. Number of taxa by study in the Port Complex. Note: Percent of total number of species in ( ).

Survey Type	Study	Total Taxa	Introduced	Cryptogenic	Unresolved
Infauna/Epifauna	2011 CDFW Survey	675	57 (8.4)	96 (14.2)	266 (39.4)
	2013–2014 Study	362	14 (3.9)	54 (14.9)	6 (1.7)
	2008 Study	313	10 (3.2)	32 (10.2)	-
	2000 Study	409	25 (6.1)	35 (8.6)	-

Notes: 2013–2014 Study is present study; 2008 Study (SAIC 2010); 2000 Study (MEC 2002); 2011 CDFW survey (CDFW 2014).

However, the results also indicate that the methods used in these studies are inadequate to document non-native communities fully: the number of taxa (total and non-native) documented by the non-native-specific studies is considerably higher than those recorded during the harbor-wide studies (Table 11-3). The highest number of introduced species (57) in the Port Complex was documented in the 2011 CDFW survey (CDFW 2014). Note that while methods were generally similar, there were differences in study objectives (e.g., the CDFW 2011 study was specifically designed to document non-indigenous species), study design, sampling gear, sampling methodology that may account for the variability between studies. However, the harbor-wide studies may still detect new introductions, as well as possible changes in community structure, since habitats within the Port Complex are studied and mapped on a more frequent basis.

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