# CHARACTERIZATION OF ESSENTIAL FISH HABITAT IN SAN DIEGO BAY

***PHASE II: Qualitative Habitat Characterization and Mapping Report***

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# CHARACTERIZATION OF ESSENTIAL FISH HABITAT IN SAN DIEGO BAY

## INTRODUCTION

### PURPOSE

Biological resources associated with various natural and man-made habitats in San Diego Bay are not well documented, nor is there currently a standardized system for classifying many of these habitats, particularly those that are man-made. In order to assess fish use of various habitats throughout San Diego Bay, the U.S. Navy Natural Resources Branch of the Southwest Division Naval Facilities Command (Navy) has contracted with Merkel & Associates (M&A) to develop a habitat classification system.

Amendments made in 1996 to the Magnuson-Stevens Fishery Management and Conservation Act (Federal Register 1997) require the delineation of essential fish habitat (EFH) for all managed species. Federal action agencies which fund, permit, or carry out activities that may adversely impact EFH are required to consult with the National Marine Fisheries Service (NMFS) regarding the potential effects of their actions. Of the approximately 87 species of fish previously identified in San Diego Bay (Bay) (Pondella 2006, Allen 2002, Merkel & Associates 2000, DoN and SDUPD 2000, Hoffman 1994,), seven are managed by the NMFS under two Fishery Management Plans (FMPs) - the Coastal Pelagics and Pacific Groundfish Management Plans (NMFS 2005, NMFS 1998a and b). Four are managed under the Coastal Pelagics FMP: northern anchovy, pacific sardine, pacific mackerel, and jack mackerel. The latter three are not found in abundance in San Diego Bay, and are covered under the Pacific Groundfish FMP: California scorpionfish, grass rockfish, and english sole.

A purpose of this study is to facilitate the valuation of habitats in the context of the EFH designation with special focus on the habitat types most likely to be impacted by Navy activities or to be used in the mitigation for Navy project impacts. This project will result in two products: 1) a broad-scale, qualitative assessment of the dominant habitat classifications within San Diego Bay with a map and description of those habitats, and 2) a detailed and quantitative description of a smaller set of habitats determined to be of greatest concern to the Navy. The habitat characterization is intended not only to provide information on the use of habitat by managed fish species, but also to provide information on ecosystem function and productivity generally within the dominant habitats present in the bay.

### ESTUARINE HABITAT CONTEXT

San Diego Bay is a naturally formed embayment and is the largest estuary between San Francisco Bay and Baja California. The bay is long and narrow with a crescent shape extending in a northwest to southeast direction. The northern region is connected to the Pacific Ocean through a mouth approximately 1 km wide. The southern region is closed and without substantial tributaries. The Otay River enters the bay at its southernmost extent and the Sweetwater River channel enters approximately 7 km to the north on the eastern shore. The absence of significant fresh water inflow for much of the year means that normal estuarine circulation in the bay is weak. Water residence times in the North Bay are typically short, except for areas within the enclosed side basins, where most commercial and marina activities are located (Largier 1995). However, residence times in the South Bay can be quite long (typically estimated at a month) and may be more extreme in the southernmost side basins such as the Coronado Cays or Chula Vista Marina. South San Diego Bay can exhibit moderately hypersaline conditions as a result of high water residence time and high evaporation rates. This is also exhibited in other southern California estuaries, such as Mission Bay.

Estuaries differ from open coastal habitats in that they generally are influenced by fresh water input and associated nutrients and sediment loading, they are relatively protected, and exhibit highly variable salinity, temperature, and dissolved oxygen regimes. The high variability in environmental characteristics within estuaries is challenging to many marine species, and many estuarine species are specifically adapted to these complex conditions (Zedler et al. 1992). Despite these challenges, estuaries are among the most productive areas on earth, are important to many valued fish species, and are commonly recognized as key nursery habitat for a variety of fish and invertebrates (Allen et al. 2006).

It is this nursery function that results in the importance of estuaries to commercially or recreationally valued fish, as many of these fish require estuarine habitats during one or more of their life history stages. During a 5-year study of fish assemblages in San Diego Bay, close to 70% of all collected fish were juveniles (Allen et al 2002). The catches of two managed pelagic species, the northern anchovy (*Engrualis mordax*) and Pacific sardine (*Sardinops sagax*), were 100% and 96% juveniles, respectively. Catches of other recreationally valued, though not managed species, kelp bass (*Paralabrax clathratus*), California halibut (*Paralichthys californicus*), barred sand bass (*Paralabrax nebulifer*), and spotted sand bass (*Paralabrax maculafasciatus*), were 100%, 99%, 97%, and 22% juveniles respectively.

Southern California estuaries can be considered distinct from the more classically defined estuaries of northern California. This is due to the relatively low rainfall and reduced influence of rivers in southern estuaries. Southern estuaries have been termed “intermittent estuaries” because they less frequently exhibit the salt-wedge hydrologic model (Allen et al., 2006). The fish species associated with southern California estuaries can be grouped based on their life histories and/or salinity tolerance as residents, seasonal, or visitors. Knowledge of the frequency and type of use by fish species is important for their targeted protection and habitat use by fish in San Diego Bay will be discussed in this context. The extremely high productivity of estuaries is of value to fisheries through transport of production by the transient visitors to outside communities, meeting the metabolic requirements of young for species using the estuary as a nursery, and allows high production within the populations of full-time residents. Differential habitat use within southern California estuaries characterizes their assemblages and an objective of this document is to describe how changes to the estuarine sub-habitats could affect species use.

Estuarine habitat is often discussed and analyzed as a unit, and compared in species composition and productivity to other large coastal systems (e.g., rocky shelf, canyons, neritic zone). A unique aspect of the present study is the distinction between sub-habitats within an estuarine system. These sub-habitats (e.g., sand, mud, eelgrass, rock) can all be compared to occurrences of the same substrates offshore, but are distinctly estuarine as they are subject to the physical and chemical conditions defining to an estuary.

# METHODS

## APPROACH

The initial, qualitative habitat classification is modeled after the Inventory and Evaluation of Habitats and Other Environmental Resources in the San Diego Region's Nearshore Coastal Zone, developed by the California State Coastal Conservancy and the San Diego Association of Governments (M&A & KTU+A 2004). The program was a cooperative, consensus-based effort involving state and federal resource and regulatory agencies including the NMFS, California Department of Fish and Game (CDFG), U.S. Fish and Wildlife Service (USFW), California Coastal Commission (CCC), and the U.S. Army Corps of Engineers (ACOE), among others. This system is a hierarchical system that combines abiotic variables with biotic communities. The system starts out with broad environmental and physical descriptors at the higher classification levels and becomes more specific at the lower levels, culminating in ecotype at the lowest level (See Figure 1 and Appendix A). Each habitat or ecotype represents the biological community or assemblage that is the product of the physical and biological variables defined at higher classification levels. This study did not include protected bays and estuaries; however, it provided a framework that could be expanded to characterize such systems.

Designation of habitats is based primarily on a series of physical characteristics, such as substrate type and tidal depth. Exceptions are made where a "habitat forming" organism, such as eelgrass (*Zostera marina*) dominates the environment. Following this format, habitats of interest within San Diego Bay were identified (Figure 1). Naturally occurring habitats include the substrates mud and sand, as well as, the habitat defined by eelgrass (Figure 2a). Man-made habitats are of particular interest for this study and include riprap shoreline, bulkhead wall, marinas, wharfs, launch ramps, moorings and markers, and artificial reefs (Figure 2b).

Preparation of qualitative habitat profiles (See Appendix B) provides information regarding the use by managed fishes, and other fish and invertebrate species on these habitats, and also information on the approximate productivity and diversity associated with each habitat type. This in combination with habitat maps (See Appendix C) allows the quantification of the amount of each habitat within San Diego Bay, will provide a basis for choosing a smaller number of habitats of greater interest to the Navy for more focused research. This study is not a quantitative study of fish use across habitat types, but rather a characterization of the potential community of fish and other marine organisms at each habitat. Each characterization is based on focused field visits at an example of each habitat in north and south San Diego Bay, as well as a review of the literature.

## DATA COLLECTION

### *Literature Research*

A literature search was performed in an effort to fill in gaps relating to seasonality and determine available data on species assemblages in San Diego Bay and similar habitats in other southern California bays and harbors. The resulting literature references are a mixture of published papers from scientific journals, as well as, technical reports. M&A also has a 16-year history of marine biological research in San Diego Bay. Therefore, much referenced data is the result of research into previous studies at M&A for applicable information never compiled for analysis in the present context.

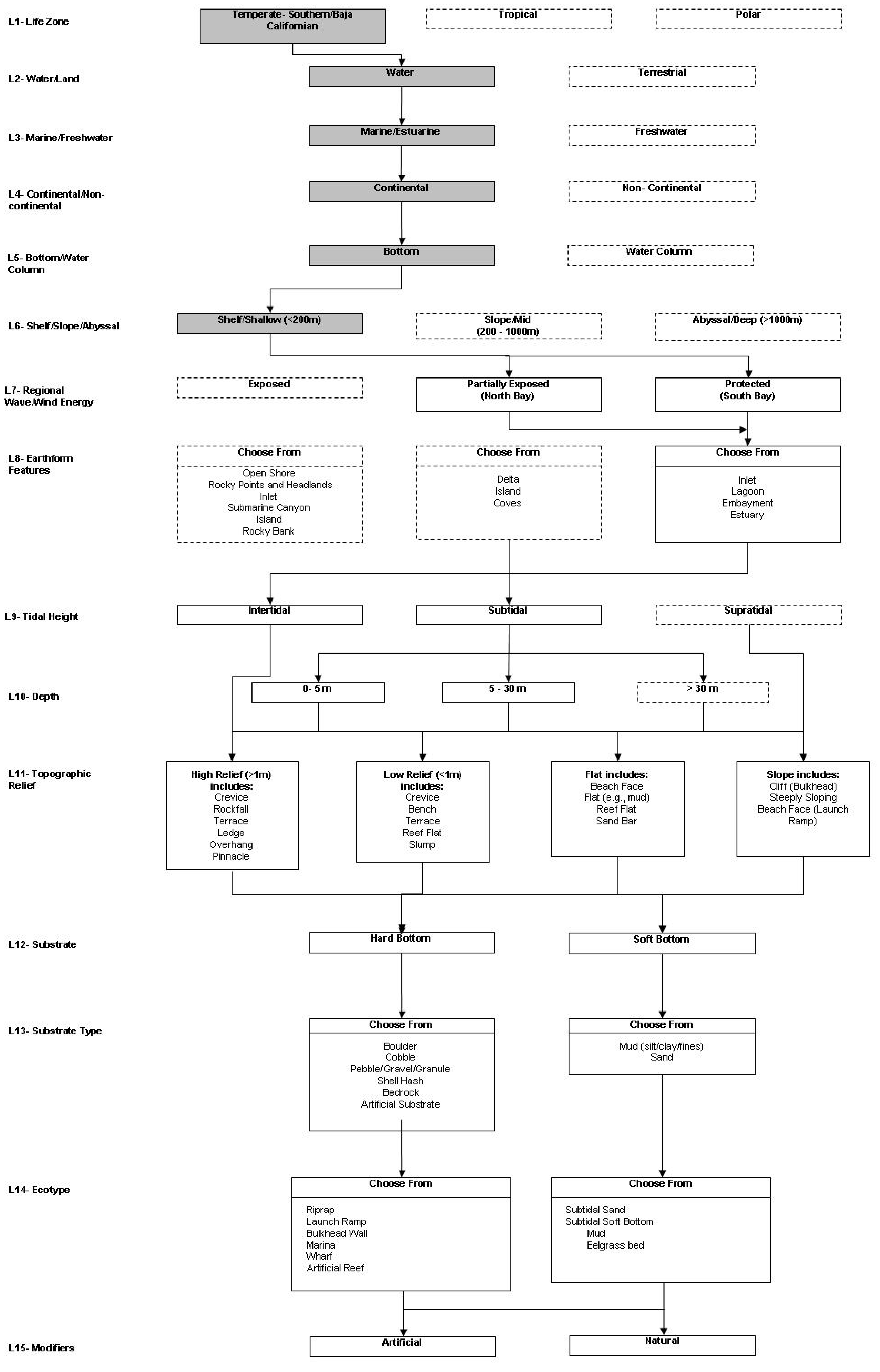


**Figure 1. Visual representation of Essential Fish Habitat Classification System exhibiting possible choices between levels. Dashed boxes represent those categories that are not applicable to the study area and filled boxes represent the only possible choices for that level. Vertical arrows between boxes restrict choices at subsequent levels, whereas horizontal lines connecting arrows represent multiple choices between levels.**

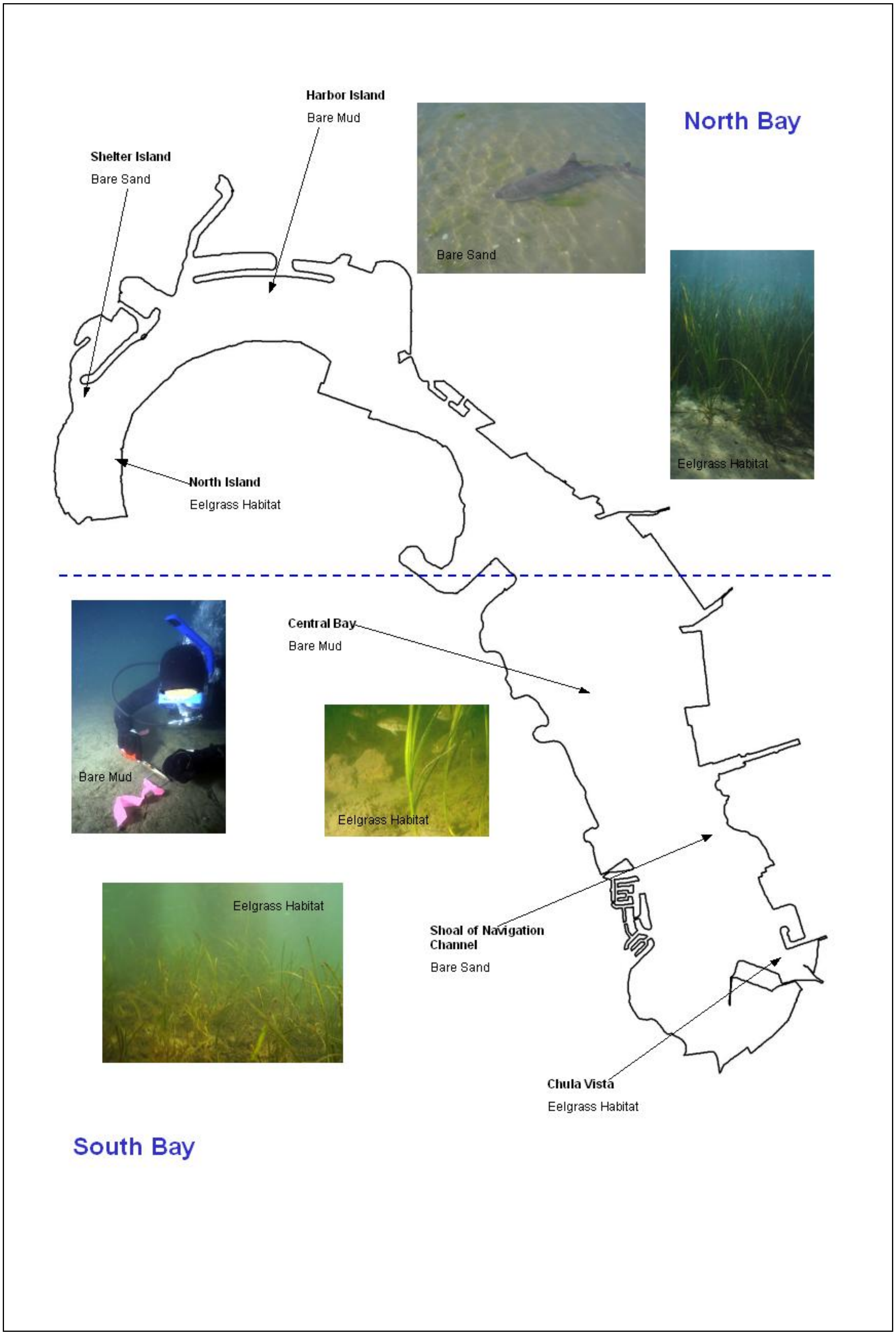


**Figure 2a. Natural habitats examined in North and South San Diego Bay.**

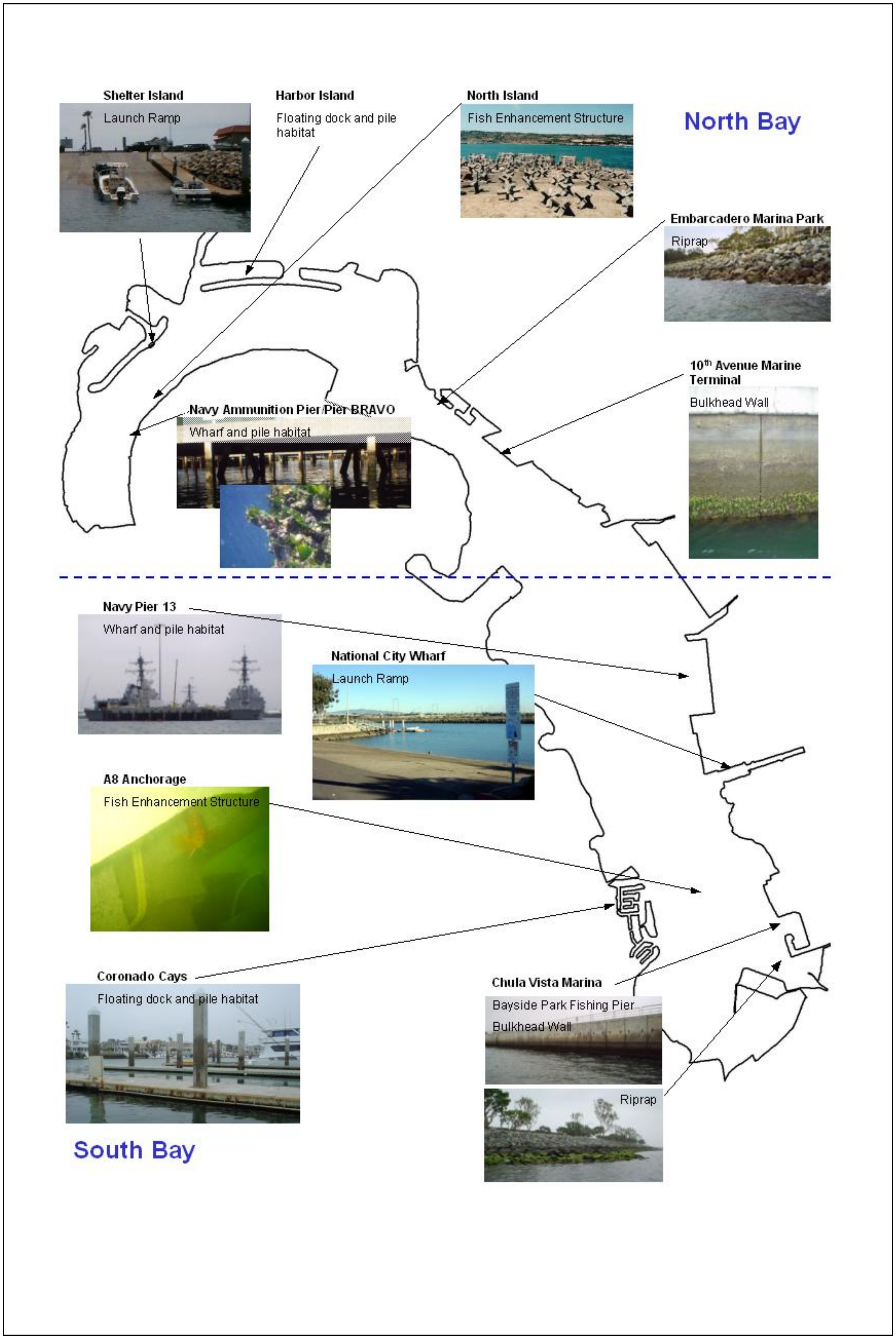


**Figure 2b. Man-made habitats examined in North and South San Diego Bay.**

### *Field Methods*

Field surveys for the present study were not intended to produce a definitive habitat-specific species list incorporating seasonal and annual variability. Rather, they provide a snap shot of each habitat, indicating obvious differences and triggering focus areas for further field efforts and literature research. The surveys resulted in a total species list of organisms observed at each habitat with an assessment of relative abundance among habitats. The methods described below were the procedures followed at all locations. Data were recorded on hand held slates and slates divided into sections for fish, benthic, and encrusting communities. Each community included a species list and a section for abundance or transect descriptions.

#### Fish Communities

Fish surveys resulted in a complete list of species observed within the habitat, separate from a count of fish observed along a defined transect. This allowed for a measure of relative fish abundance among sites. One continuous transect was intended to cover all areas of each site. The transect orientation and length was dependent on the site characteristics and included, in some cases, sections of the water column, as well as, bottom areas. Replicate transects were not conducted. A diver slowly swam the length of each transect recording fishes observed 3 meters to either side of the diver. All fishes were identified to the lowest taxon possible and counted or counted as "unidentifiable." Care was taken to not double count fish. When possible, all counted individuals were categorized by age class (adults [A], subadults [S], young-of-year [Y], juveniles [J] or recruits [R]). The diver also recorded the estimated horizontal visibility. The dive tender recorded coordinates, time of day, water temperature tidal stage (F-flood or E-ebb), depth (m) and weather (S-sunny, P-partly cloudy, C-cloudy).

#### Benthos

A diver recorded the presence of all flora and fauna on the surface of the substrate. Each species was ranked in abundance on the datasheet as rare (1-10 individuals observed), common (10-50), or abundant (>50). An approximate percent cover was recorded for any species noted to be abundant. Information such as evenness of occurrence or clustering of species was also noted.

A diver collected two sediment core samples at each site. A 10-cm diameter core was pushed approximately 15 cm into the substrate, although the actual depth and location of collections varied by habitat type. Each sample was sieved through a 1.0-mm mesh and organisms from each sample transferred to Nalgene containers, and preserved with a 10% formalin-seawater mixture.

#### Encrusting Communities

When surveying hard substrate or hard structure, encrusting communities were examined in a similar manner to the epibenthos. A diver recorded the presence of all flora and fauna on the surface of the substrate. Each species was ranked in abundance on the datasheet as rare (1-10 individuals observed), common (10-50), or abundant (>50). An approximate percent cover was recorded for any species noted to be abundant.

### MAPPING

The various habitats present within San Diego Bay have been delineated as part of the San Diego Bay Integrated Natural Resources Plan (DoN and SDUDP 2000), and results are presented in Appendix C.

## RESULTS

### FISH AND EPIFAUNAL INVERTEBRATES

The number of fish and epifaunal invertebrate species observed at each habitat in the North and South Bay are presented in Tables 1 and 2. The habitats are listed in descending order of the total number of species observed. For both fish and epifaunal invertebrates, artificial reefs ranked as the habitat with the highest number of species observed (Figures 3 and 4 respectively). Sand and eelgrass habitats also ranked high in number of fish species. It is not surprising that eelgrass ranked highly as it is known to be an important fish habitat. It is more interesting that the sand habitat ranked high. This may be partially due to improved visibility in this habitat. Sandy bottom is relatively rare in San Diego Bay. It generally occurs at the edges of channels where scouring from swift currents prevents the deposition of silt and where dredge depths are maintained. Characteristics of these areas, such as transitions between depths and current patterns may make the sandy areas more dynamic than simply the sediment type itself would produce. These results also suggest that habitats in North Bay are richer in fish species than habitats in South Bay, while species richness for epifaunal invertebrates appeared slightly greater in the South Bay compared to the North Bay. Rich in epifaunal invertebrates were piers, riprap, and marinas, which is to be expected as these habitats present a variety of attachment opportunities on hard substrate.

**Table 1. Number of fish species observed at habitats in North and South San Diego Bay.**

| Habitat | North Bay | South Bay | Total |
|---|---|---|---|
| **Artificial Reef** | 13 | 4 | 14 |
| **Sand** | 9 | 1 | 10 |
| **Eelgrass** | 9 | 2 | 9 |
| **Riprap** | 6 | 3 | 8 |
| **Pier** | 6 | 4 | 8 |
| **Bulkhead** | 5 | 1 | 6 |
| **Marina** | 1 | 3 | 3 |
| **Launch Ramp** | 1 | 1 | 2 |
| **Mud** | 1 | 0 | 1 |

**Table 2. Number of epifaunal invertebrate species observed at habitats in North and South San Diego Bay.**

| Habitat | North Bay | South Bay | Total |
|---|---|---|---|
| **Artificial Reef** | 13 | 14 | 23 |
| **Sand** | 11 | 15 | 23 |
| **Eelgrass** | 10 | 11 | 19 |
| **Riprap** | 11 | 14 | 17 |
| **Pier** | 7 | 12 | 17 |
| **Bulkhead** | 5 | 10 | 13 |
| **Marina** | 5 | 3 | 8 |
| **Launch Ramp** | 4 | 3 | 6 |
| **Mud** | 1 | 4 | 5 |

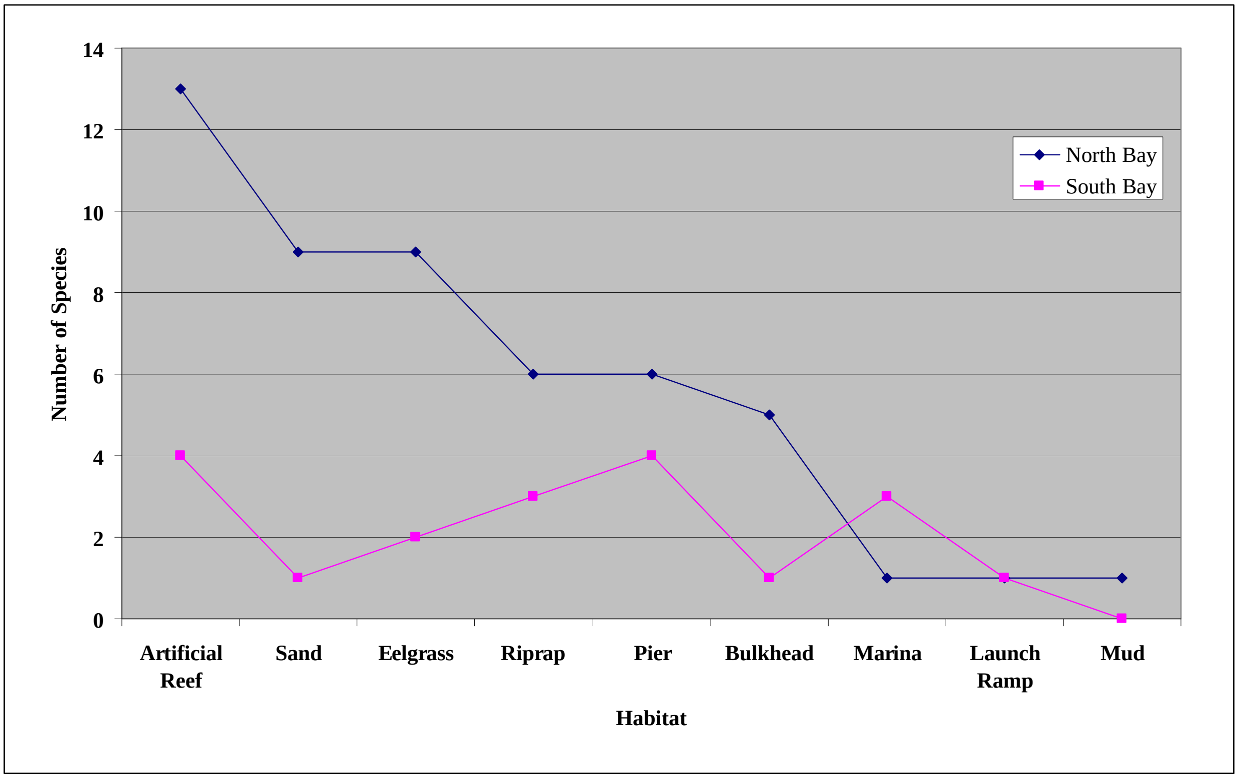


**Figure 3. Number of fish species observed in North and South San Diego Bay.**

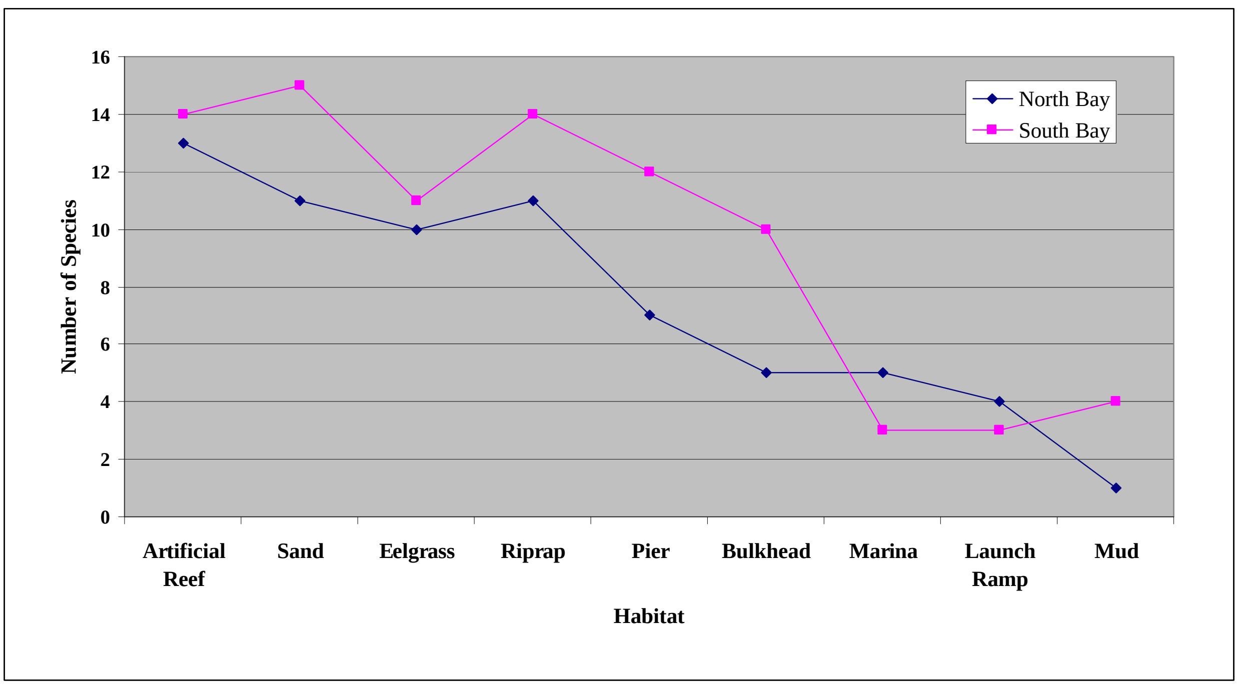


**Figure 4. Number of epifaunal species observed in North and South San Diego Bay.**

### BENTHIC INFAUNA

Cores taken at each habitat were analyzed for taxonomic group, abundance, and biomass. The number of taxa, counts, and their total weight at each habitat type in North and South Bay is presented in Table 3. Each of these metrics is generally higher in the northern habitats than in the southern habitats.

**Table 3. Number of taxa, total abundance, and weight of infaunal invertebrates by region and habitat type.**

| | North Bay | | | South Bay | | |
|---|---|---|---|---|---|---|
| **Habitat** | **# Taxa** | **Abund.** | **Weight (g)** | **# Taxa** | **Abund.** | **Weight (g)** |
| **Bulkhead** | 8 | 44 | 0.31 | 6 | 33 | 0.54 |
| **Pier** | 7 | 100 | 3.15 | 5 | 84 | 1.32 |
| **Marina** | 7 | 42 | 0.91 | 5 | 17 | 0.07 |
| **Eelgrass** | 9 | 19 | 1.49 | 8 | 108 | 20.36 |
| **Riprap** | 15 | 1240 | 3.81 | 5 | 106 | 1.71 |
| **Mud** | 7 | 53 | 0.75 | 4 | 75 | 5.97 |
| **Sand** | 14 | 150 | 5.41 | 7 | 57 | 0.43 |
| **Art Reef** | 13 | 410 | 2.11 | 6 | 37.5 | 2.39 |
| **Launch Ramp** | 17 | 343 | 54.20 | 8 | 31 | 0.85 |
| **Total** | | 2400 | 72.1 | | 549 | 33.64 |

Total abundance and weight of infauna were also examined by habitat type as an average of the northern and southern locations (Table 4). Infauna were most abundant at riprap sites, followed by artificial reefs and launch ramps (Figure 5). The highest biomass was observed at launch ramps, although this may be biased due to one sample with an unusually large amount of gastropod molluscs. Following launch ramps, eelgrass beds were high in infaunal biomass and were far higher than all other habitat types.

**Table 4. Mean abundance and weight of all infaunal invertebrates by habitat, which are listed in ranked order.**

| Habitat | Abundance | Habitat | Weight (g) |
|---|---|---|---|
| **Riprap** | 673.00 | **Launch Ramp** | 27.53 |
| **Artificial Reef** | 223.75 | **Eelgrass** | 10.93 |
| **Launch Ramp** | 187.00 | **Mud** | 3.36 |
| **Sand** | 103.50 | **Sand** | 2.92 |
| **Pier** | 92.00 | **Riprap** | 2.76 |
| **Mud** | 64.00 | **Artificial Reef** | 2.25 |
| **Eelgrass** | 63.25 | **Pier** | 2.23 |
| **Bulkhead** | 38.25 | **Marina** | 0.49 |
| **Marina** | 29.50 | **Bulkhead** | 0.42 |

The number of taxa observed at habitats in the north was greater than in the south, with averages of 10.8 and 6.0, respectively. Launch ramps ranked high in the number of infaunal species followed by sand and riprap. The number of species observed in ranked order decreases incrementally (Table 5), but appeared more constant in South Bay compared to North Bay (Figure 6).

**Table 5. Mean number of infaunal invertebrate taxa by region and habitat type.**

| Region | # Taxa |
|---|---|
| North Bay | 10.6 |
| South Bay | 6.0 |
| | |
| **Habitat Type** | **# Taxa** |
| Launch Ramp | 12.5 |
| Sand | 10.5 |
| Riprap | 10 |
| Artificial Reef | 9.5 |
| Eelgrass | 8.5 |
| Bulkhead | 7 |
| Pier | 6 |
| Marina | 6 |
| Mud | 5.5 |

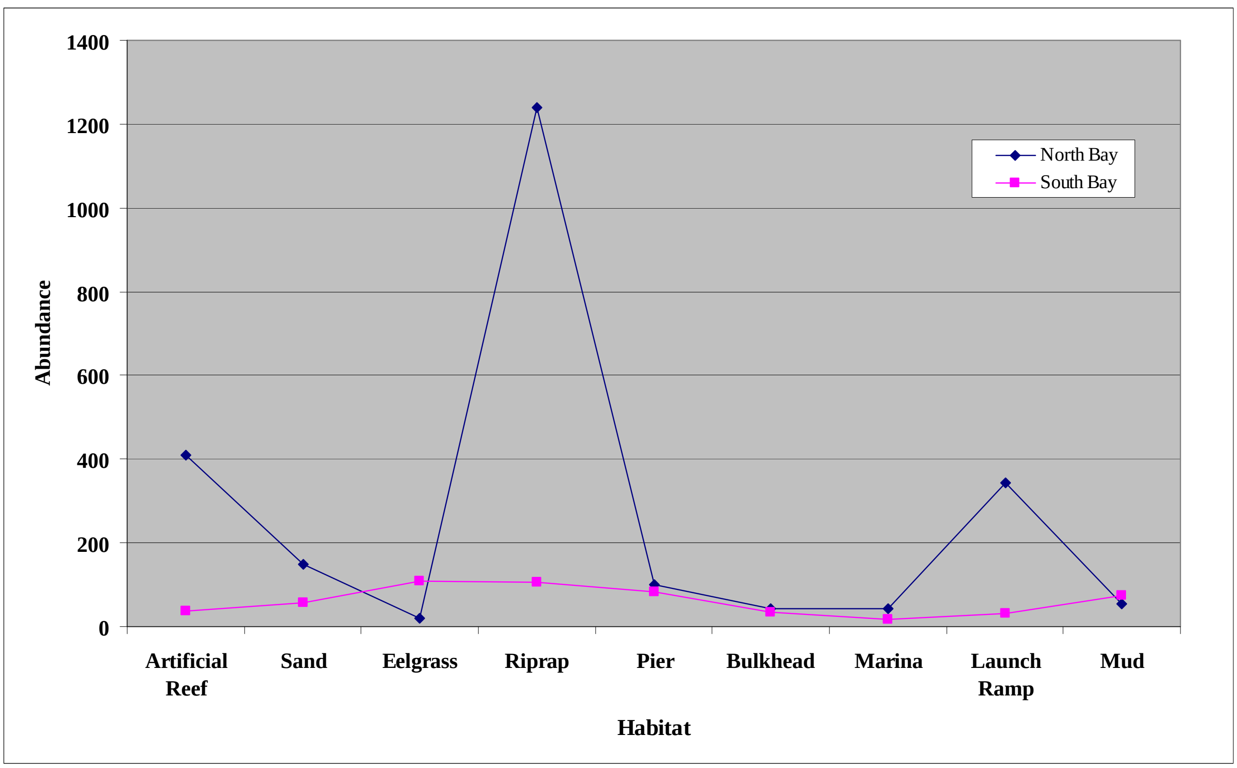


**Figure 5. Mean abundance of infaunal species collected in North and South San Diego Bay.**

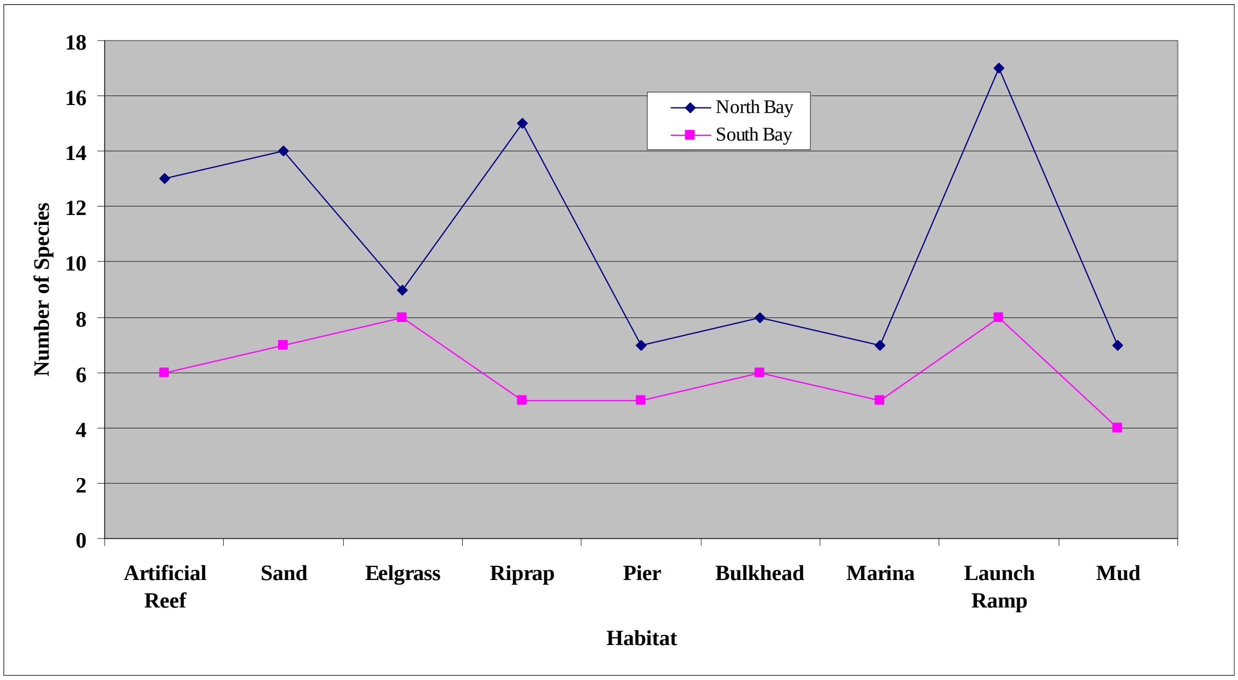


**Figure 6. Mean number of infaunal species collected in North and South San Diego Bay.**

## DISCUSSION

The objective of this study was to produce qualitative comparisons between estuarine habitat types and present a characterization of these habitats in San Diego Bay, with the intent to describe in-bay habitats in the context of fish use and characteristics relevant to fish, identify data gaps, and determine potentially interesting questions for further research. The following discussion presents a summary of findings from recent surveys, and observations of fish, and epifaunal and infaunal invertebrates by habitats and regions in the bay.

### BAY-WIDE DISTRIBUTION AND ABUNDANCE

Allen (1999) conducted a five-year survey from 1994 to 1999 that indicated the North Ecoregion was dominated numerically by northern anchovy, topsmelt, Pacific sardines, California grunion, slough anchovy, and shiner surfperch, while northern anchovy, topsmelt, round stingrays, bat rays, spotted sand bass, and California halibut constituted most of the biomass captured. Northern anchovy, topsmelt, and slough anchovy were the three most abundant species taken in the North-Central Ecoregion, while round stingrays, spotted sand bass, northern anchovy, and topsmelt completely dominated in terms of biomass. The South-Central Ecoregion was dominated numerically by the slough anchovy, topsmelt, northern anchovy, shiner surfperch, and bay pipefish. Round stingrays, spotted sand bass, slough anchovy, topsmelt, and California halibut dominated in terms of biomass. In the southern most ecoregion, slough anchovy, topsmelt, arrow goby, round stingray, northern anchovy, and shiner surfperch were the most abundant species, while round stingrays, spotted sand bass, barred sand bass, and bat rays dominated in biomass.

Species richness (number of species) was generally highest in the northern section of the bay nearest the bay mouth (Allen 1999). H’ diversity which incorporates evenness of relative species abundances was found to be highest in the southern portion of the bay peaking at about H’ = 1.5. The higher H’ values in the South Bay reflect the lower numerical dominance by a one or two species at these stations. Northern anchovy was the numerically dominant species overall in the North Bay, while slough anchovy dominated the South Bay.

Approximately 70% of all individual fish captured in San Diego Bay during Allen's study were juveniles. In fact, 28 of the 35 most abundant species were represented by over 50% juveniles. Of these, ten species were represented by more than 90% juveniles including the most abundant species, northern anchovy (100% juveniles). This high proportion of juveniles overall in the catch underscores the importance of the San Diego Bay system, particularly the intertidal habitat, as an important nursery area for a large number of fishes including open coastal pelagic species.

The results from this study generally support Allen's findings, as habitats in North Bay were richer in fish species than habitats in South Bay (Figure 3). The study also suggested that species richness for epifaunal invertebrates appeared slightly greater in the South Bay compared to the North Bay (Figure 4). Piers, riprap, and marinas supported rich epifaunal communities, which was to be expected as these habitats present a firm substrate for attachment. Infauna diversity was generally higher in the North Bay among all habitat types (Figure 6).

### HABITAT-ASSOCIATED DISTRIBUTION AND ABUNDANCE

Comparative fish community and abundance studies in San Diego Bay have previously focused on the relative differences between vegetated and non-vegetated soft bottom habitats (Allen 2002, Hoffman 2006). Vantuna Research Group (2006) suggested that eelgrass provides valuable habitat for several important species in San Diego Bay noting that kelp bass, giant kelp fish, barred sand bass, and California halibut utilize the eelgrass primarily as juveniles, while spotted sand bass and shiner perch are present in this habitat throughout their ontogeny.

As was observed from this examination of artificial habitats relative to natural habitats, man-made structures appear just as important on a scaled basis, if not more utilized by some fishes than natural, soft bottom habitats. While soft bottom communities will always be the principal component of the Bay environment, the structure and diversity of habitat provided by scattered hard structures provides elements that cannot be provided by soft bottom or shoreline alone. This includes persistent vertical structure and primary substrate across a broad vertical range of water column, high primary and secondary productivity, and complex and diverse sheltering sites.

Incorporating the differences associated in the fish communities between North and South Bay, Tables 6 and 7 provides a qualitative assessment of the fish species and their association with various habitats represented in the Bay.

Shoreline stabilization structures (e.g., pier pilings, bulkheads, riprap, floating docks, sea walls, mooring systems, and derelict ships/ship parts) form extensive artificial habitat in the northern and central portions of San Diego Bay, and to a lesser extent in the South Bay. Docks and marinas currently shade roughly 131 acres (53 ha) of bay habitat, and bridges about 11 acres (4.5 ha). There are 45.4 mi (73.1 km) or 74% of the bay's shoreline that are stabilized with rock or concrete. This includes about 20 mi (32 km) of shoreline armored with seawall (DoN and SDUPD 2000).

Artificial habitats, such as riprap seawalls in San Diego Bay provide habitat for open-coastal, rocky-intertidal species, as well as, non-open-coastal species. Pondella et al (2006) used the density of adult fishes to describe the relationship between the eelgrass habitats, enhancement reefs, soft bottom habitats, and Zuniga Jetty. The assemblages of these habitats clustered tightly by habitat type and relief. The fish assemblage at Zuniga Jetty was least similar to the remaining habitats. Zuniga Jetty was a mature high-relief submerged jetty located at the entrance of San Diego Bay; however, its

**Table 6. Summary of fishes observed in North San Diego Bay and associated habitat.**

| Species | Common Name | NORTH BAY HABITATS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bare Sand | Bare Mud | Eelgrass | Riprap | Marina | Wharf | Artificial Reef | Bulkhead Wall | Launch Ramp |
| *Acanthogobius flavimanus* | yellowfin goby | ■ | ■ | ■ | | | | | | |
| *Albula vulpes* | bonefish | ■ | ■ | ■ | | | | | | |
| *Anchoa compressa* | deepbody anchovy | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Anchoa delicatissima* | slough anchovy | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Anisotremus davidsoni* | sargo | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| *Atherinops affinis* | topsmelt | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Atherinopsis californiensis* | jacksmelt | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Cheilotrema saturnum* | black croaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Chromis punctipinnis* | blacksmith | | | ■ | ■ | | | ■ | | |
| *Citharichthys stigmaeus* | speckled sand dab | ■ | ■ | | | ■ | ■ | | | |
| *Clevelandia ios* | arrow goby | ■ | ■ | ■ | | | | | | |
| *Cymatogaster aggregata* | shiner surfperch | | | ■ | ■ | ■ | | ■ | | |
| *Cynoscion nobilis* | white seabass | ■ | ■ | ■ | | | | ■ | | |
| *Cynoscion parvipinnis* | shortfin corvina | ■ | ■ | ■ | | | | | | |
| *Embiotoca jacksoni* | black surfperch | | | ■ | ■ | ■ | | ■ | | |
| ***Engraulis mordax*** | **northern anchovy** | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Fundulus parvipinnis* | California killifish | ■ | ■ | ■ | | ■ | | | | ■ |
| *Genyonemus lineatus* | white croaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| *Gibbonsia elegans* | spotted kelpfish | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| *Gibbonsia metzi* | striped kelpfish | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| *Gillichthys mirabilis* | longjaw mudsucker | | ■ | | | | | | | |
| *Girella nigricans* | opaleye | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Gobiidae* | goby | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Gymnura marmorata* | California butterfly ray | ■ | ■ | ■ | | ■ | ■ | | | |
| *Halichoeres semicinctus* | rock wrasse | | | ■ | ■ | | | ■ | ■ | ■ |
| *Heterodontus francisci* | horn shark | | | ■ | ■ | | | ■ | | |
| *Heterostichus rostratus* | giant kelpfish | | | ■ | ■ | | ■ | ■ | ■ | |
| *Hippocampus ingens* | Pacific seahorse | | | | | | | | | |
| *Hippoglossina stomata* | bigmouth sole | ■ | ■ | ■ | | | | | | |
| *Hyporhamphus rosae* | California halfbeak | ■ | ■ | ■ | | | | | | |
| *Hypsoblennius gentilis* | bay blenny | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Ilypnus gilberti* | cheekspot goby | ■ | ■ | ■ | | | | | | |
| *Leptocottus armatus* | staghorn sculpin | ■ | | ■ | ■ | | ■ | ■ | | ■ |
| *Leuresthes tenuis* | California grunion | ■ | ■ | ■ | | | | | | |
| *Medialuna californica* | halfmoon | | | ■ | | | | | | |
| *Menticirrhus undulatus* | California corbina | ■ | ■ | | | | | | | |
| *Micrometrus minimus* | dwarf surfperch | | | ■ | ■ | ■ | ■ | ■ | | |
| *Mugil cephalus* | striped mullet | ■ | ■ | ■ | | | | | | |
| *Mustelus californicus* | gray smoothhound shark | ■ | ■ | ■ | | ■ | ■ | | | |
| *Mustelus henlei* | brown smoothhound shark | ■ | ■ | ■ | | ■ | ■ | | | |
| *Myliobatis californica* | bat ray | ■ | ■ | ■ | | ■ | ■ | | | |
| *Oxyjulis californica* | senorita | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| *Paraclinus integripinnis* | reef finspot | | | ■ | ■ | ■ | | ■ | | |
| *Paralabrax clathratus* | kelp bass | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Paralabrax maculatofasciatus* | spotted sand bass | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Paralabrax nebulifer* | barred sand bass | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Paralichthys californicus* | California halibut | ■ | ■ | ■ | | ■ | ■ | | | |
| ***Parophrys vetulus*** | **english sole** | ■ | ■ | | | | | | | |
| *Phanerodon furcatus* | white surfperch | ■ | ■ | ■ | | | | | | |
| *Playrhinoides triseriata* | thornback | ■ | | ■ | | | | | | |
| *Pleuronichthys coenosus* | CO turbot | ■ | ■ | | | | | | | |
| *Pleuronichthys decurrens* | curlfin turbot | ■ | ■ | | | | | | | |
| *Pleuronichthys guttulata* | diamond turbot | ■ | ■ | | | ■ | ■ | | ■ | |
| *Pleuronichthys ritteri* | spotted turbot | ■ | ■ | ■ | | ■ | ■ | | | |
| *Pleuronichthys verticalis* | hornyhead turbot | ■ | ■ | ■ | | ■ | ■ | | | |
| *Porichthys myriaster* | specklefin midshipman | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |
| *Porichthys notatus* | plainfin midshipman | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| *Pseudupeneus grandisquamous* | red goatfish | ■ | ■ | | | | | | | |
| *Quietula y-cauda* | shadow goby | | | ■ | | | | | | |
| *Rhinobatis productus* | shovelnose guitarfish | ■ | ■ | ■ | | ■ | ■ | | | |
| *Roncador stearnsii* | spotfin croaker | ■ | ■ | ■ | | ■ | ■ | ■ | | |
| *Sarda chiliensis* | Pacific bonito | ■ | ■ | ■ | | | | | | |
| ***Sardinops sagax*** | **Pacific sardine** | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| ***Scomber japonicus*** | **Pacific mackerel** | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |
| ***Scorpaena guttata*** | **California scorpionfish** | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| ***Sebastes rastrelliger*** | **grass rockfish** | | | ■ | | | | | | |
| *Seriphus politus* | queenfish | ■ | ■ | ■ | | | ■ | | | |
| *Sphyraena argentea* | California barracuda | ■ | ■ | ■ | ■ | | | | | |
| *Squatina californica* | Pacific angel shark | ■ | ■ | ■ | ■ | | | ■ | | |
| *Strongylura exilis* | California needlefish | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| *Sygnathus auliscus* | barred pipefish | | | ■ | ■ | | ■ | ■ | | ■ |
| *Symphurus atricauda* | California tonguefish | ■ | ■ | ■ | | ■ | ■ | | | |
| *Syngnathus arctus* | snubnose pipefish | | | ■ | ■ | | | ■ | | |
| *Syngnathus leptorhynchus* | bay pipefish | | | ■ | ■ | | | ■ | | |
| *Synodus lucioceps* | California lizardfish | ■ | ■ | | | | | | | |
| *Tridentiger trigonocephalus* | chameleon goby | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| ***Trachurus symmetricus*** | **jack mackerel** | ■ | ■ | | | ■ | ■ | | | |
| *Umbrina roncador* | yellowfin croaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| *Urolobatus halleri* | round stingray | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Xenistius californiensis* | salema | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Xystreurys liolepis* | fantail sole | ■ | ■ | ■ | | ■ | ■ | | | |
| *Zapteryx exasperata* | banded guitarfish | ■ | | ■ | | | | | | |

Species list compiled from Allen 1999 and Vantuna Research Group 2006 - sampling conducted via various trawls and seines

North and South Bay consolidated

Present/Common ■ (shaded)

Rare/Absent (blank)

FMP Managed Species **bold text**

**Table 7. Summary of fishes observed in South San Diego Bay and associated habitat.**

| Species | Common Name | SOUTH BAY HABITATS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bare Sand | Bare Mud | Eelgrass | Riprap | Marina | Wharf | Artificial Reef | Bulkhead Wall | Launch Ramp |
| *Acanthogobius flavimanus* | yellowfin goby | ■ | ■ | ■ | | | | | | |
| *Albula vulpes* | bonefish | ■ | ■ | ■ | | | | | | |
| *Anchoa compressa* | deepbody anchovy | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Anchoa delicatissima* | slough anchovy | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Anisotremus davidsoni* | sargo | | | ■ | ■ | | | ■ | | |
| *Atherinops affinis* | topsmelt | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Atherinopsis californiensis* | jacksmelt | | | | | | | | | |
| *Cheilotrema saturnum* | black croaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| *Chromis punctipinnis* | blacksmith | | | | | | | | | |
| *Citharichthys stigmaeus* | speckled sand dab | | | | | | | | | |
| *Clevelandia ios* | arrow goby | ■ | ■ | ■ | | | | | | |
| *Cymatogaster aggregata* | shiner surfperch | | | ■ | ■ | | | ■ | | |
| *Cynoscion nobilis* | white seabass | ■ | ■ | ■ | ■ | | | ■ | | |
| *Cynoscion parvipinnis* | shortfin corvina | ■ | ■ | ■ | | | | | | |
| *Embiotoca jacksoni* | black surfperch | | | | | | | | | |
| ***Engraulis mordax*** | **northern anchovy** | ■ | ■ | ■ | | | | | | |
| *Fundulus parvipinnis* | California killifish | ■ | ■ | ■ | | ■ | | | | ■ |
| *Genyonemus lineatus* | white croaker | | | | | | | | | |
| *Gibbonsia elegans* | spotted kelpfish | | | | | | | | | |
| *Gibbonsia metzi* | striped kelpfish | | | | | | | | | |
| *Gillichthys mirabilis* | longjaw mudsucker | ■ | ■ | ■ | | | | | | |
| *Girella nigricans* | opaleye | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Gobiidae* | goby | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Gymnura marmorata* | California butterfly ray | ■ | ■ | ■ | | ■ | ■ | | | |
| *Halichoeres semicinctus* | rock wrasse | | | ■ | ■ | | | ■ | | |
| *Heterodontus francisci* | horn shark | | | ■ | ■ | | | ■ | | |
| *Heterostichus rostratus* | giant kelpfish | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| *Hippocampus ingens* | Pacific seahorse | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Hippoglossina stomata* | bigmouth sole | | | | | | | | | |
| *Hyporhamphus rosae* | California halfbeak | ■ | ■ | ■ | | | | | | |
| *Hypsoblennius gentilis* | bay blenny | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Ilypnus gilberti* | cheekspot goby | ■ | ■ | ■ | | | | | | |
| *Leptocottus armatus* | staghorn sculpin | | | | ■ | | ■ | ■ | ■ | ■ |
| *Leuresthes tenuis* | California grunion | | | | | | | | | |
| *Medialuna californica* | halfmoon | | | | | | | | | |
| *Menticirrhus undulatus* | California corbina | | | | | | | | | |
| *Micrometrus minimus* | dwarf surfperch | | | ■ | | | | | | |
| *Mugil cephalus* | striped mullet | ■ | ■ | ■ | | | | | | |
| *Mustelus californicus* | gray smoothhound shark | ■ | ■ | ■ | | ■ | ■ | | ■ | |
| *Mustelus henlei* | brown smoothhound shark | | | | | | | | | |
| *Myliobatis californica* | bat ray | ■ | ■ | ■ | | ■ | ■ | | | |
| *Oxyjulis californica* | senorita | | | | | | | | | |
| *Paraclinus integripinnis* | reef finspot | | | | | | | | | |
| *Paralabrax clathratus* | kelp bass | | | ■ | ■ | | ■ | ■ | ■ | |
| *Paralabrax maculatofasciatus* | spotted sand bass | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| *Paralabrax nebulifer* | barred sand bass | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Paralichthys californicus* | California halibut | ■ | ■ | ■ | | | | | | |
| ***Parophrys vetulus*** | **english sole** | | | | | | | | | |
| *Phanerodon furcatus* | white surfperch | | | | | | | | | |
| *Playrhinoides triseriata* | thornback | | | | | | | | | |
| *Pleuronichthys coenosus* | CO turbot | | | | | | | | | |
| *Pleuronichthys decurrens* | curlfin turbot | | | | | | | | | |
| *Pleuronichthys guttulata* | diamond turbot | ■ | ■ | ■ | | ■ | ■ | | ■ | |
| *Pleuronichthys ritteri* | spotted turbot | | | | | | | | | |
| *Pleuronichthys verticalis* | hornyhead turbot | | | | | | | | | |
| *Porichthys myriaster* | specklefin midshipman | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Porichthys notatus* | plainfin midshipman | | | | | | | | | |
| *Pseudupeneus grandisquamous* | red goatfish | ■ | | | | | | | | |
| *Quietula y-cauda* | shadow goby | ■ | ■ | ■ | | | | | | |
| *Rhinobatis productus* | shovelnose guitarfish | ■ | ■ | ■ | | ■ | ■ | | | |
| *Roncador stearnsii* | spotfin croaker | ■ | ■ | | | ■ | ■ | ■ | | |
| *Sarda chiliensis* | Pacific bonito | ■ | ■ | | | | | | | |
| ***Sardinops sagax*** | **Pacific sardine** | ■ | ■ | ■ | ■ | ■ | | | | |
| ***Scomber japonicus*** | **Pacific mackerel** | | | | | | | | | |
| ***Scorpaena guttata*** | **California scorpionfish** | | | ■ | ■ | | | ■ | | |
| ***Sebastes rastrelliger*** | **grass rockfish** | | | | | | | | | |
| *Seriphus politus* | queenfish | | | | | | | | | |
| *Sphyraena argentea* | California barracuda | | | | | | | | | |
| *Squatina californica* | Pacific angel shark | | | | | | | | | |
| *Strongylura exilis* | California needlefish | ■ | | ■ | | | | | | |
| *Sygnathus auliscus* | barred pipefish | ■ | ■ | ■ | ■ | | | ■ | | |
| *Symphurus atricauda* | California tonguefish | | | | | | | | | |
| *Syngnathus arctus* | snubnose pipefish | | | | | | | | | |
| *Syngnathus leptorhynchus* | bay pipefish | | | ■ | ■ | | ■ | ■ | ■ | |
| *Synodus lucioceps* | California lizardfish | ■ | ■ | | | | | | | |
| *Tridentiger trigonocephalus* | chameleon goby | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| ***Trachurus symmetricus*** | **jack mackerel** | | | | | | | | | |
| *Umbrina roncador* | yellowfin croaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| *Urolobatus halleri* | round stingray | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ |
| *Xenistius californiensis* | salema | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ |
| *Xystreurys liolepis* | fantail sole | | | | | | | | | |
| *Zapteryx exasperata* | banded guitarfish | | | | | | | | | |

Species list compiled from Allen 1999, Vantuna Research Group 2006, Mekel & Associates 2000 - sampling conducted via various trawls and seines

North and South Bay consolidated

| | |
|---|---|
| Present/Common | ■ |
| Rare/Absent | |
| FMP Managed Species | **bold text** |

inclusion in the study helped illustrate the importance of three dimensional complexity or relief in the characterization of the fish assemblages. The study also determined that there were no significant differences in overall fish utilization of the enhancement reefs, as design and material type, either concrete or rock, performed similarly throughout the study.

While variation in enhancement reef type did not significantly affect fish utilization, overall reef performance with respect to fishery production of the three target species studied was also documented at various levels (Pondella et al. 2006). Both the density of young-of-the-year and adult fishes increased throughout the study period. This trend was expected as a response to reef community development and maturation. The most intriguing data were found in relation to the three fishery species. First, spotted bay bass, *Paralabrax maculatofasciatus*, were observed foraging over the entire enhancement area. Thus, while these reefs certainly "attract" spotted sand bass, the seasonal aspect of their utilization indicated that they are exploiting these habitats more substantially than other available habitats during portions of the year, specifically winter. In San Diego Bay (Allen et al., 2002) found that the lowest abundances of fishes, including spotted sand bass, occurred over soft bottom habitats in January (winter quarter sampling period). The general absence of spotted bay bass from the artificial reef area during the spring and summer period is concomitant with their reproductive period. They have been reported to spawn from June through August (Allen et al. 1995). The study supports the hypothesis that spotted bay bass move towards the mouth of the bay during the winter, which was consistent with the observed decreased density in the other portions of the bay. The enhancement reefs appeared to be acting as a winter foraging area for spotted sand bass. All age classes of kelp bass, *P. clathratus*, were abundant on the reefs at all times of the year during the study, indicating that the reefs were able to attract recruits and hold adults (Pondella et al. 2006).

Several sampling challenges should be considered when drawing comparisons from the data presented for this study. Diver surveys at one habitat type are more easily compared than at differing habitat types. For example, a diver survey for fish in open sand or mud environments would be expected to be more effective than a similar survey in structured habitats such as eelgrass or reefs. Structure provides shelter and therefore many fish present in those habitats could be concealed and thus fish are more easily under represented in structured environments than over open habitats. Similarly, diver surveys of epifaunal invertebrates should also be interpreted with caution for the same reason. Further, while divers tend to notice large, easily visible invertebrates and fish, other small organisms, such as amphipods can easily be over looked, but do significantly contribute to the biomass supported by that habitat.

Results of this study indicated that the number of fish species observed by diver surveys was greatest around structures in the South Bay. These structures are not native to the South Bay, and tend to attract or retain a more structured habitat guild to inhabit the South Bay. It may also be that some fish species inhabiting native South Bay environments, such as offshore and nearshore mud bottom and marshes are small and cryptic and not observed with survey methods used during this study. Although these species are not of direct importance to fishery management mandates or the recreational fishery, their value to the broader ecosystem should be considered. The number of fish species in the North Bay was also greatest at the artificial reefs, followed by the natural sand and eelgrass habitats. While diving surveys suggested a comparable richness of the open sandy bottom environments to that occurring in eelgrass, net fishing suggests that fish richness in eelgrass beds exceeds that of bare bottom environments (Hoffman 2006, Allen et al. 2002), supporting the point that structured habitats are more difficult to sample by visual inspection. Few fish were observed in marinas and on bare mud in both the north and south. In marinas, it was common to observe most fish detected near the edges of the marina with markedly lower abundance of fish within the core of the marinas. These trends in the number of species may also be mirrored by fish abundance at these habitats, and a more focused and quantitative study of abundance between habitats of interest would be valuable.

### HABITAT MANAGEMENT CONSIDERATIONS

Regarding future management of bay habitats, this study noted that not all artificial habitat, or even like habitat perform equally, and that other factors such as location, size, complexity, and adjacent habitats must be considered to truly understand the effects of structures on fish communities in San Diego Bay. In addition, specific goals or outcomes must be identified and considered prior to placement of artificial habitats, either for enhancement purposes or as a result of project-related design. For example, in order to maximize the potential benefit of riprap structures one needs to consider water depth, overall size of the structure (footprint, as well as, height or relief) and the potential species of interest, and for piers or wharves, one also needs to consider the effects of water movement and shading.

Figures 7 through 11 have been prepared for the purpose of presenting the conceptual effects of structures and natural habitats on fish community metrics of biomass, abundance, and species richness. As expected, higher metrics are associated with some structure (either natural or artificial) as these habitat elements provide a three dimensional structured environment, substrate for macroalgae and invertebrates, and forage and cover for fish species. However, there are limitations as some larger structures (e.g., large pier or wharf) do not provide consistent conditions as some areas beneath the piers experience reduced circulation and light levels affecting community composition.

As an example of the conceptual models presented in Figures 7 through 11, piers and wharves have been examined both as stand alone small piers, such as those extending to a small dock, or serving as a fishing pier, as well as larger piers and marginal wharves such as Naval finger piers and commercial terminal wharfs.

For small piers the structures typically result in limited effects on water movement and provide increased structure within the upper water column. These structures generally support macroalgae and drift kelp within the upper portions of the pier at elevations that would be low intertidal and shallow subtidal zones. Below the algal communities, encrusting growth of sponges, bryozoans, rock jingles, and tube-forming polychaetes often occur. These algal and encrusting invertebrate communities host a number of mobile invertebrates and small fish such as blennies, pipefish and kelpfish and can also attract perches, opaleye, and scorpionfish. Sand bass and kelp bass often occur in association with such piers. As encrusting organisms die or are broken free of the piles, they drop to the bayfloor and create a zone of enriched sediment and more diverse rubble that supports gobies, blennies, and scavenging demersal fish at higher concentrations than typically observed away from the structures. Within the water column around piers, schooling pelagic fish tend to aggregate for shelter or forage. This often attracts larger predatory fish as well. Around small piers, the biomass, abundance, and species richness of fish typically rises relative to that observed in open mud bottom habitats (Figure 7).

At more exposed portions of larger piers and marginal wharves, similar elevation of biomass, abundance, and richness of fish communities is seen as with smaller piers. However, larger piers tend to include areas beneath the piers that experience reduced circulation and light levels. These areas promote a gradient of cryptic community development beginning with jingles and bryozoans in the twilight zone, transitioning to sponges and ultimately very little growth in the darkest most quiescent waters beneath the piers. These piers provide refugia to principally nocturnal species such as black croaker, round stingray, smoothhound. As a result, large numbers of fish may be found beneath pier structures and biomass may exceed that of open waters due to fish size, however, species richness generally is depressed below that observed in open bay environments. In the deepest recesses of the piers, fish abundance and biomass also decline to low levels (Figure 7).

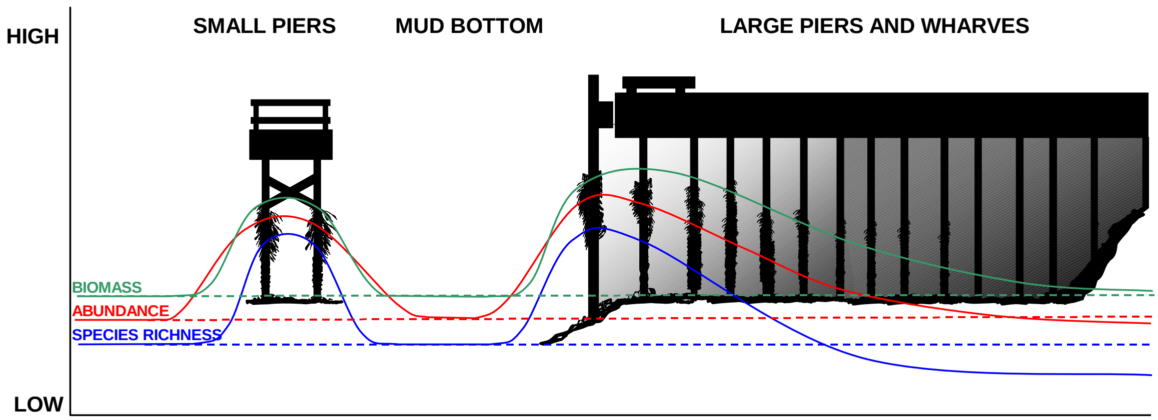


**Figure 7. Qualitative biological metrics for small and larger piers.**

Comparable effects of structures and their influence on fish community metrics can be seen with other natural and artificial habitat components as are represented in Figures 8 through 11. Docks and marinas tend to have similar influences as piers and wharves on fish metrics, however, lacking some of the characteristics that are derived by permanently darkened environments.

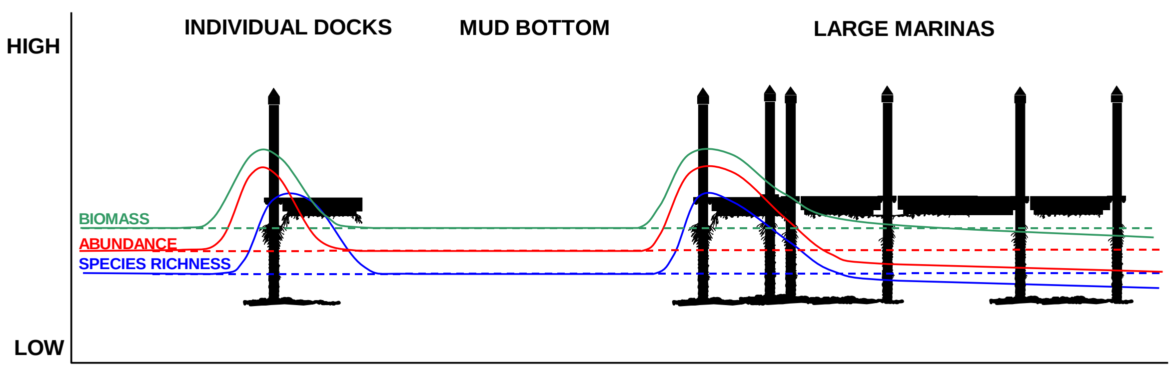


**Figure 8. Qualitative biological metrics for small and large dock structures.**

The complexity of intertidal rip rap in its support of macroalgal beds and provision of structure to both diurnal and nocturnal structure associated species has been documented by Pondella in San Diego Bay as well as this study. However, the benefits of the rock decline with both rising elevation to the intertidal zone and diminishing void space (Figure 9). Less complex features such as bulkhead walls would be expected to have lesser, but still measurable influence on fish community metrics. Regarding species that may be associated with these habitats, Tables 6 and 7 note the species/assemblages associated with the various habitat types in context to location in the bay (i.e., North vs. South Bay).

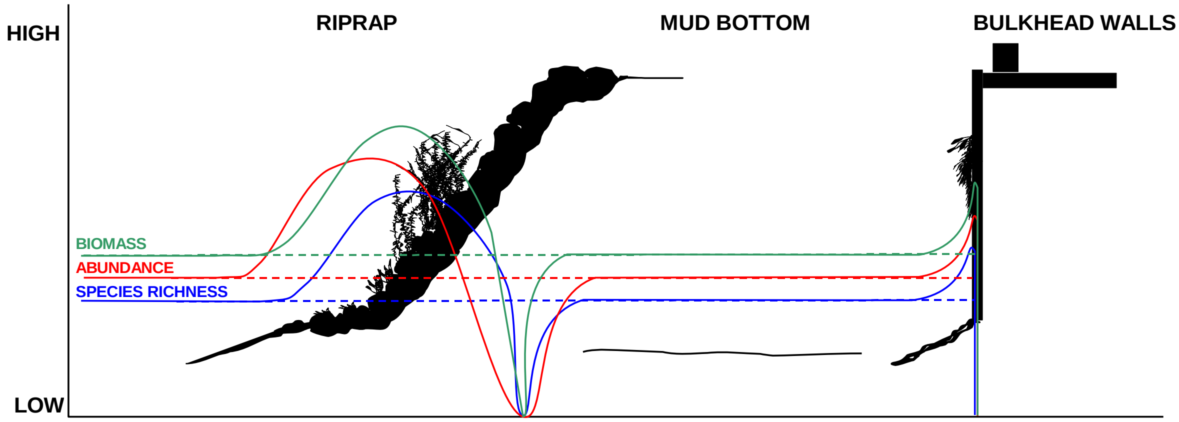


**Figure 9. Qualitative biological metrics for rip rap and bulkhead shoreline structures.**

Perhaps the least influential features on fish community metrics are individual moorings or markers associated with navigation channels or mooring fields (Figure 10). In the case of these small features, the structures may be too small to retain significant fish communities, but may support a limited number of individual fish that add to small increases in biomass, abundance, and richness in fish communities. This may include resident fish such as blennies and midshipman that occupy cracks and crevices in the structure, burrows below the structure, or even open links in chains and shackles. These features also serve to attract temporary use by transient larval, juvenile, and adult demersal and pelagic fish that may not be held by the small-scale feature. Schooling fish aggregate for brief periods around these small structures while they forage on concentrated food sources and roving predators would temporarily investigate structures such as these for potential prey.

On the opposite end of the spectrum are purpose-built artificial reefs (Figure 10). These reef structures are designed and scaled to serve as a supplemental fish habitat that adds diversity and structural complexity to the environment. There are several such reefs in San Diego Bay and depending upon the location in the Bay, scale of the reef, the materials used and design employed, the reefs support somewhat differing fish communities. While well-designed and constructed reefs may provide the greatest benefits to fish communities of all artificial structures in the Bay, it would not be unexpected for expansive reefs to begin to reveal depressed community metrics within their core areas. This is the result of a loss of beneficial interface effects between the reef and the adjacent open bottom.

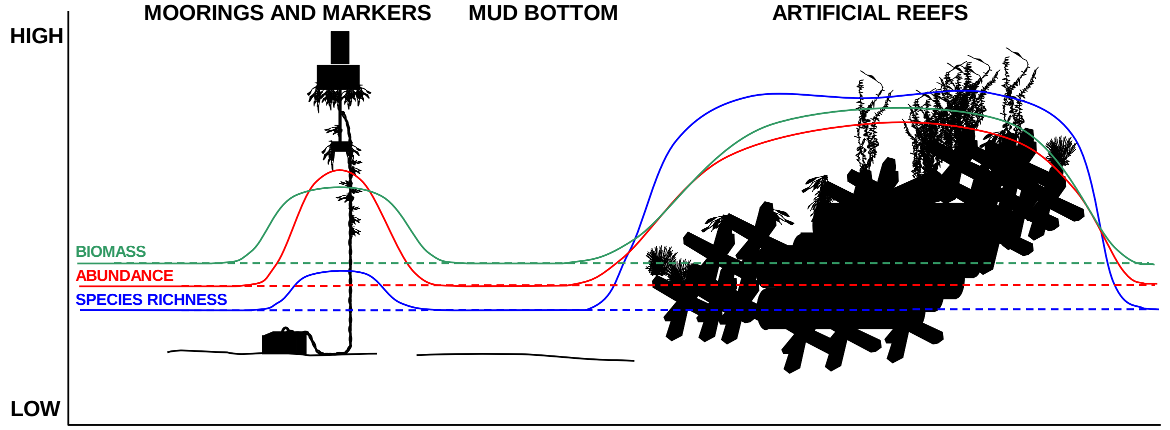


**Figure 10. Qualitative biological metrics for moorings and artificial reefs.**

While purpose-built reefs have demonstrable values to fish communities, opportunities to integrate reef design elements into other structures have not bee fully pursued. One such example is a Port mooring area where mooring anchor blocks were designed and constructed with voids to promote habitat values beyond those that would be normally found at simple mooring blocks. Other opportunities for such habitat integration are presently being pursued by the Navy for both in-bay and off-shore facilities.

When considering the three primary natural habitat features in San Diego Bay, the biomass, richness, and fish abundance generally increases along a gradient from mud bottom to sand bottom, to eelgrass beds (Figure 11). This graphic tends to contradict the diver sampling performed in the present investigation that suggested a moderate equivalency between sand bottom and eelgrass beds. However, the cryptic nature of fish in eelgrass makes it impossible to equivalently sample these environments by diver methods. Mud bottom is generally associated with more quiescent waters in which fewer open coastal species are typically found. As a result, the differences between mud and sand may be somewhat influenced by geography of the features as well as differing intrinsic characteristics.

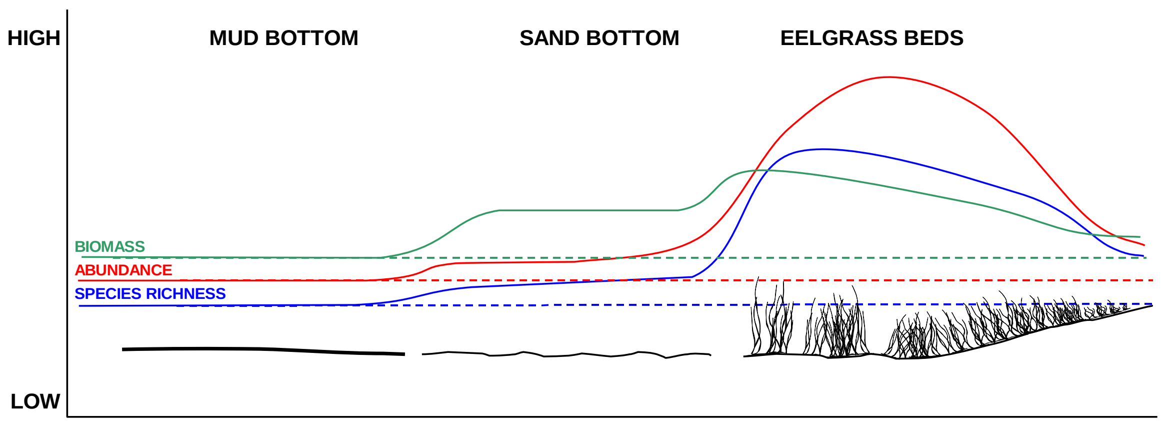


**Figure 11. Qualitative biological metrics for soft bottom and eelgrass habitat.**

Based on some of the curves presented, it is clear that there can be too much of a good thing. While habitat structuring features, both natural (e.g., eelgrass beds) and artificial (e.g., piers, docks, reefs), can provide for increases in multiple fish community metrics, they may also draw these metrics down below those found within open bay environments. While the general effects of structures on fish community metrics can be explained with some degree of confidence, the quantification of these effects is more difficult and would require considerable amount of further investigation. The importance of this issue is that structures can be beneficial in the proper extent, location, and scale. Beyond some tipping point, the structures become detrimental to the overall system. Understanding when structures are a benefit and when they are a detriment is a critical need for prudent management decision making within San Diego Bay as well as other coastal environments. While it may be years before such understanding is fully developed. There is no reason not to implement some of the principals identified regarding structure effects into decision-making or design as projects are advanced. Where demonstrable benefits can be identified from design enhancements, these should be sought to improve the benefits of artificial structures being placed in San Diego Bay. Further efforts should also be undertaken to identify more precisely where tipping points exist when community metrics change from positive to negative offsets from the ambient conditions of open bay environments.

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# Appendix A
# Habitat Classification System Definitions

**Level 1- Life Zone**
Polar- High latitude areas between 66°33' N and S and the poles (90°)
Temperate- Mid-latitude areas between the tropical and polar regions (23°27' N and S – 66°33' N and S)
Tropical- Low latitude areas between the equator and 23°27' N and S

**Level 2- Water/Land**
Terrestrial- Areas that are primarily of or relating to land
Water- Areas that are primarily of or relating to freshwater or marine systems

**Level 3- Marine/Freshwater**
Freshwater- Non-terrestrial areas not influenced by seawater
Marine/Estuarine- Non-terrestrial areas influenced by seawater

**Level 4- Continental/Non-continental**
Continental- Water and benthos that borders land masses, occupying the zone extending seaward from the low-tide line to a depth where the continental shelf meets the abyss or any attribute that is derived from the interaction with the continental landmass.

Non-continental- Water and benthos beyond the edge of the continental shelf, including those surrounding non-continental islands.

**Level 5- Bottom/Water Column**
Bottom/Benthic- The portion of the marine realm that is on, in, or close to the ocean floor regardless of depth

Water Column- The portion of the marine realm that is only water and not on, in, or close to the bottom of the ocean floor

**Level 6- Shelf/slope/abyssal**
Abyssal- Greater than 1000 m water depth

Shelf (continental)- Less than 200 m water depth, submerged border of continental landmasses that occupies the zone extending seaward from the low-tide line to a point where the ocean bottom abruptly slopes more steeply toward greater depth.

Slope (continental)- 200 – 1000 m water depth

**Level 7- Regional wave/wind energy**
Exposed- Open to full oceanic wave and wind energy

Partially Exposed- Receives intermittent energy or is moderately protected by features that reduce oceanic wave and wind energies

Protected- Enclosed water bodies sheltered from oceanic wave and wind energies on a consistent basis

**Level 8- Earthform features**
Cove- Small recess in the coast (e.g., La Jolla Cove and Children’s Pool)

**Embayment- Enclosed waterbody with a narrow inlet**

Estuary- Semi-enclosed body of water with mixture of seawater from open connection to ocean and freshwater from land drainage

Inlet- Entrance to an enclosed water body such as a bay or lagoon

Island- Small land-mass surrounded by water (e.g., Channel Islands)

Lagoon- Shallow body of seawater generally separated from the open sea by a shallow bar or bank

Open Shore- Exposed beaches and shores on the continental mainland

Rocky Bank- Submerged rocky shoal not directly connected to island or mainland shorelines (e.g., Cortes and Tanner Banks)

Rocky Points and Headlands- High, steep-faced promontories extending outward from the coastline into the sea

Submarine Canyon- V-shaped indentation incised into the continental shelf and slope, often terminating on the deep sea floor in a fan of sediment, resembling a terrestrial river-cut canyon.

**Level 9- Tidal height**
Intertidal- Shore zone between extreme high tide and extreme low tide water levels

Subtidal- Shore zone below the level of extreme low tide

Spray/splash zone (Supratidal)- From the highest reach of spray and storm waves to about the mean of all high tides.

**Level 10- Depth**
Depth range classes are defined as depth below mean lower-low water (MLLW). The three depth classes utilized for this classification system are 0 – 5 m, 5 – 30 m, and > 30 m.

**Level 11- Topographic relief**
Flat- A substrate with less than approximately 1:20 slope ratio (rise:run). Approximately 0% slope.

High relief- Hard bottom with vertical relief that protrudes greater than 1 m above the surrounding terrain

Low relief- Hard bottom with vertical relief that protrudes less than 1 m above the surrounding terrain

Slope- A sloping substrate with greater or equal to an approximately 1:20 slope ratio (rise:run). Slope is generally distinguished from flat based on characteristic changes of physical environment such as instability of sediment, slumping, slides, or chronic unidirectional transport of bed sediment loads.

**Level 12- Substrate**
Hard bottom- Substrates defined by large particle sizes or cemented substrates, generally with organisms that live attached on the surface (e.g. bedrock, boulder, cobble/pebble, gravel, shell hash, and artificial substrate)

Soft bottom- Substrate defined by small particle size and unstable bottom conditions, generally with organisms that live buried beneath the surface (e.g. sand and mud bottoms).

**Level 13- Substrate type**
Artificial Substrate- Man-made substrates or structures that are placed in the marine environment for the purpose of habitat enhancement or creation, or for human usage

Bedrock- Rock exposures typically consisting of sedimentary rock benches or platforms. Formations may also include other rock exposures such as metamorphic or igneous outcrops.

Boulder- Large rocks with minimum diameters of 256 mm that can form high relief habitat when piled up or when their diameter exceeds 1 m (Wentworth Scale)

Cobble- Small rocks with diameters from 64 - 256 mm generally occurring on flat or low slope areas forming low relief, hard substrate habitat (Wentworth Scale)

Pebble/Gravel/Granule– Small rocks with minimum diameters from 2 to 64 mm generally occurring on flat or low slope areas forming low relief, hard substrate habitat

Shell Hash **–** Bottom sediments principally comprised of molluscan or bivalve shell fragments

Sand- Coarse unconsolidated sediment with grain size diameters from 0.0625 to 2 mm (Wentworth Scale)

Mud (silt/clay/fines)- Fine unconsolidated sediment with grain size diameters of less than 0.0625 mm (Wentworth Scale)

**Level 14-Ecotype**
See ecotype descriptions

**Level 15- Modifiers**

*Degree of Human Impact*
High Impact- High impact areas are subject to a high degree of human disturbance and as a result exhibit measurable ecosystem functions below the level of nearby areas with the same physical characteristics.

Low Impact- Low impact areas are not subject to a high degree of human disturbance and as a result exhibit measurable ecosystem functions at or above the level of nearby areas with the same physical characteristics

*Stability*
Stable- Stable conditions describe the persistent, regular occurrence of an ecotype that exhibits normal seasonal cycles and levels of disturbance.

Unstable- Unstable conditions denote irregular or non-persistent and erratic changes of an ecotype that differ from normal seasonal cycles and levels of disturbance.

*Local Energy Regime*
High Energy- High energy environments describe areas where local wind/wave energy is enough to create substantial impacts on physical and biological features such as water movement, substrate stability, or population densities.

Low Energy- Low energy environments describe areas where local wind/wave energy does not create substantial impacts on physical and biological features such as water movement, substrate stability, or population densities.

# Appendix B
# Ecotype Descriptions

# Eelgrass Bed

**Kelp bass at edge of eelgrass bed**
**Shelter Island, North San Diego Bay**

***Overview***

Eelgrass (*Zostera marina*) is a subtidal marine angiosperm typically found in protected bays and estuaries throughout the temperate Northern Hemisphere. Eelgrass is a clonal plant that creates dense beds of vertical shoots and typically ranges from 0.5m to greater than 1.0m tall in sand and mud habitats. In the San Diego region, eelgrass growth is generally limited at its upper limit by desiccation stress, and at its deeper limit by light availability. Eelgrass does not grow on steep slopes and is typically found on loose sands and stable muds.

***Ecosystem Functions***

Seagrasses are among the most productive autotrophic communities in the world (Duarte and Chiscano 1999). The high biomass produced by seagrasses is transferred to other organisms in the ecosystem, and therefore this habitat has been considered one of the most valuable in the world due to the level of increased productivity provided (Costanza et al. 1997). Eelgrass beds provide numerous ecosystem functions that support diverse infaunal, epifaunal, and demersal assemblages of organisms. Eelgrass beds support these animal communities by providing a large amount of primary production, acting as a key nursery habitat for nearshore and offshore species, maintaining water quality in bays and estuaries, and reducing turbidity by dampening water motion near the sediment. These functions are provided mainly through the production of highly nutritional detritus, their multidimensional structure, by acting as biological filters of nutrients, and by stabilizing sediment through their root complexes, respectively. Because of the high primary production and habitat structure provided, many commercially and ecologically valuable fish and invertebrates, such as California halibut (*Paralichthys californicus*), sand bass (*Paralabrax* spp.), and spiny lobster (*Panulirus interruptus*) utilize eelgrass beds for adult and nursery habitat. Vantuna Research Group (2006) suggested that eelgrass provides valuable habitat for several important species in San Diego Bay; kelp bass, giant kelp fish, barred sand bass, and California halibut utilize the eelgrass primarily as juveniles, while spotted sand bass and shiner perch are present in this habitat throughout their ontogeny. Eelgrass is therefore key to the recruitment of these species. In San Diego Bay, eelgrass also serves as the main food source for green sea turtles (*Chelonia mydas*), living in the warmer South Bay.

***Status and Distribution***

Due to the ecological and economic importance and limited distribution of eelgrass beds, the State and Federal governments afford them special protection. Eelgrass beds are considered a special aquatic site under section 404(b)(1) of the federal Clean Water Act and an ecologically sensitive habitat area by the California Coastal Commission.

Invertebrate epibiota on eelgrass blades

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Partially exposed, Protected |
| **Earthform Features** | Estuary |
| **Salinity** | Seawater (Typically 33-34 ppt) |
| **Tidal Height** | Subtidal |
| **Depth** | 0 – 5 m |
| **Topographic Relief** | Flat |
| **Substrate** | Sand, Mud |

*****Regional characteristics for So. California

***Commonly Associated Species***

| **Common Name** | **Scientific Name** |
|---|---|
| Bent-nose clam | *Macoma nasuta* |
| Wavy chione | *Chione undatella* |
| Egg cockle | *Laevicardium substriatum* |
| Bubble snail | *Bulla gouldiana* |
| Navanax | *Navanax inermis* |
| Covered-lip nassa | *Nassarius tegula* |
| Spiny lobster | *Panulirus interruptus* |
| Sand basses | *Paralabrax spp.* |
| California halibut | *Paralichthys californicus* |
| Surfperch | Embiotocidae |
| Round stingray | *Urobatus halleri* |

***North vs. South San Diego Bay***

The amount, distribution, and physical characteristics of eelgrass beds vary between the different regions of San Diego Bay. In 2004, eelgrass coverage was estimated at approximately 147 acres in the North Bay, compared to approximately 1,240 acres in the South Bay. These characteristics can also vary seasonally and annually. The surface area of bottom covered with eelgrass, patchiness within an area and patch characteristics (shoot density and shoot length) are all thought to affect use of the habitat by fish and invertebrates in estuarine environments.

The structural complexity of eelgrass beds on varying scales relates to the ability for species to use the habitat for refuge and foraging. The effects of these habitat characteristics on epifauna and fish recruitment have been studied in San Diego Bay (Hovel & Anderson 2005). It was determined that fish settlement and recruitment in San Diego Bay was highly variable, but more dependent on location in the bay (relative to oceanic input) than characteristics of the eelgrass beds. Although larval selectivity in settlement location is known to occur, patterns driving larval abundance were more important to recruitment than post-settlement factors dictated by eelgrass bed quality. Therefore, eelgrass beds in South Bay may be of high quality, but will not support the abundance and diversity of juvenile fish due the limited water flow. Some fish species; however, such as giant kelpfish and arrow gobies did show recruitment variability with eelgrass bed characteristics. Similarly, epifaunal density and diversity was more related to location within the bay than to characteristics of the eelgrass beds with northern eelgrass beds exhibiting higher density and diversity of shrimp, amphipods and isopods than southern eelgrass beds.

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# Subtidal Sand

Sea pen and tube-dwelling anemone
North San Diego Bay

### *Overview*

Bare sand is relatively rare in San Diego Bay and occurs were sedimentation rates are low preventing the accumulation of silt, and where depths are too great for eelgrass growth. Sand also occurs on the edges of navigational channels where dredge cuts reveal buried sand. The relief of this habitat is flat and complexity is low.

### *Ecosystem Functions*

Sandy bottom habitats perform many of the same the general ecosystem functions as soft bottom subtidal habitats. Similar to mud bottom, invertebrate filter and deposit feeders dominate this habitat and serve as a food base for flat fishes and rays, many of which are commercially or recreationally important.

The distribution of organisms in the subtidal sand ecotype is spatially and temporally patchy. For example, sand dollars (*Dendraster excentricus*) occur in large clustered beds in areas where wave action and sediment type permit. Communities that persist for long periods of time and then disappear exemplify temporal fluctuations in the distribution of subtidal sand species. For example, research indicates that entire sand dollar beds, which appeared stable over a period of six years, could totally disappear over a period of 19 years (Davis and VanBlaricom 1978).

Typical animal assemblages of sand bottom habitats include a variety of invertebrates. Tube-building polychaete worm (*Diopatra ornata*) communities are commonly found in shallow, relatively sandy habitats. Other shallow sand bottom species include sea pens (e.g., *Stylatula elongata*), the bivalve *Tellina modesta*, tube dwelling anemones (*Pachycerianthus fimbriatus*) and the gastropod *Caecum crebricinctum*. Key predators in sandy subtidal habitats can include armored sea stars (*Astropecten* spp.), bat rays (*Myliobatis californica*), round stingrays (*Urobatus halleri*), leopard sharks (*Triakis semifasciata*), and flatfish (e.g., halibut and turbot). Ephemeral occurrences of floating algae are common, as are algae and invertebrates that require hard substrate that are attached to smaller pebbles or shells on the sand surface.

### *Status and Distribution*

The western shore of San Diego Bay is a sand spit separating the bay from the ocean extending from Imperial Beach nearly to Point Loma. These once shifting sands have been stabilized as have shifting sands in the outer bay area (Shelter and Harbor Islands) (Largier 1995). The relatively small occurrences of sand are found along the western shoreline and at the edges of navigational channels were dredging and higher current velocities maintain the exposure of sand. A large extent of submerged sand also occurs immediately outside the bay to the east of Point Loma.

Diamond turbot
North San Diego Bay

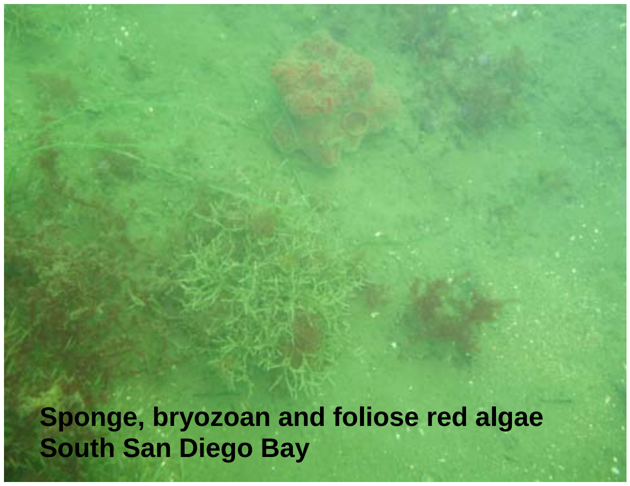
***Physical Environment****

| **Exposure Regime** | Exposed, partially exposed |
|---|---|
| **Earthform Features** | Estuary |
| **Tidal Height** | Subtidal |
| **Depth** | 0 - 5 m, 5 – 30 m |
| **Topographic Relief** | Flat |
| **Substrate** | Sand |

*Regional characteristics for So. California

***Commonly Associated Species***

| Common Name | Scientific Name |
|---|---|
| Tube-dwelling anemone | *Pachycerianthus fimbriatus* |
| Sea pen | *Stylatula elongata* |
| Sponges | *Aplysina fistularis, Tetilla mutabilis* |
| Bryozoans | *Thalamoporella californica* |
| California halibut | *Paralichthys californicus* |
| Diamond turbot | *Hypsopsetta guttulata* |
| Bat ray | *Myliobatis californica* |
| Round stingray | *Urobatus halleri* |


**Sponge, bryozoan and foliose red algae South San Diego Bay**

***North vs. South San Diego Bay***

Differences between sand habitats in north and south San Diego Bay were observed during the current study. The influence of tidal flushing was observed in the north bay with the sandy habitat being of a courser grain sand. More open coast species were observed in this habitat such as the red sea urchin (*Strongylocentrotus franciscanus*). Sandy habitat in the south bay was covered by a layer of fine silt and could be characterized as muddy sand. The decreased tidal action was evident with the presence of scattered floating algae and bryozoan colonies. Although a greater abundance of fish has been found in vegetated versus non-vegetated sites in San Diego Bay (Hoffman 2005, Allen et al. 2002), some fish species depend upon non-vegetated areas and may prefer sand. Allen et al. (2002) found that California halibut and diamond turbot both occurred in order of greatest abundance at deep non-vegetated sites, shallow non-vegetated sites, and vegetated sites. The managed species Pacific sardine and northern anchovy were both caught in greater abundance in non-vegetated sites than vegetated sites when in nearshore areas.

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# Marina

***Overview***

Marinas are complex habitats typically consisting of bare bottom, riprap, pile, and floating dock substrates. They differ from pier and wharf habitats in that they have lower concentrations of piles, more light availability, and are generally located in more protected side basins of the bay. They also are areas of a high concentration of boats, which may have impacts on water quality. Marinas offer a variety of substrate types, but focus here is provided to bottom subtrates and the effects that surrounding marina structures have on fish use and resources available to fish on and around that substrate.

**Coronado Cays**
**South San Diego Bay**

***Ecosystem Functions***

The fouling or encrusting community of invertebrates and algae dominate this habitat, occurring on floating docks, piles, and boat hulls. Fish assemblages associated with marinas are not well studied. This is likely due to the difficulty of sampling in this habitat as the use of seines and trawls is impractical. The fouling community attracts schooling fish, which feed on the attached invertebrates and algae. Fish common to marinas include silversides, perches, basses, opaleye, and croaker. The abundance of relatively well-lit floating docks is distinctive to marina habitats. Floating docks are not subject to tidal influence (are never exposed) and remain on the sea surface. This provides the dock substrate with constant light available for photosynthesis, and a distinct positioning relative to the currents. Surface versus other layers of the water column are subject to different currents, which may determine the species composition of larval settlers and levels of food resources. Connell (2001) performed a study comparing the epibiotic assemblages of floating structures, pilings, and natural reefs, and found that the abundance of most taxa was greatest on floating structures relative to pilings and reefs. In particular, mussels, tunicates, barnacles, bryozoans, and green algae were most abundant on floating structures. This may make marina habitats particularly good foraging resources for some fish species. Production from floating docks can be attributed directly from the biota attached to the dock, and also the material that falls from the dock, increasing production on the substrate below the dock.

**Fouling organisms on a floating dock**
**Shelter Island, North San Diego Bay**

The fouling community on marina substrates has been studied in San Diego Bay relative to boat concentration in the marinas (Lenihan et al. 1990). High concentrations of boats are associated with concentrations of several pollutants including oil and gas, organochlorides, and metals. Mussels, sponges, and bryozoans (total and encrusting) had significantly greater cover in marinas with few boats, while only tunicates and branching bryozoans showed no patterns between marinas with few or many boats. This pattern was observed on all available substrates. Overall fewer species, less biomass, and lower cover of sessile groups was observed in marinas with many boats. Crustaceans and invertebrates, termed “nestling fauna” showed no significant pattern with the number of boats. Although not directly tested, the observed patterns were hypothesized to result from concentrations of tributylin, a toxic additive to paint. Bioaccumulation of toxic chemicals in invertebrates and fish in the bay is a concern. McCain et al. (1992) found high concentrations of PCBs in the liver of white croaker (*Genyonemus saturnum*) in San Diego Bay and signs of fin erosion were observed in barred sand bass (*Paralabrax nebulifer*).

***Status and Distribution***

Several marinas occur in both the north and south bay areas. The largest marinas are at Shelter Island, Harbor Island, Glorietta Bay, and Chula Vista. The area of bay surface covered by recreational and commercial (not industrial) structures totaled 38 acres without boats and 189 acres when at capacity with boats (USDoN, SWDIV 2000).

**Burrow of unknown animal beneath docks**
**Chula Vista Marina, South San Diego Bay**

***Physical Environment****

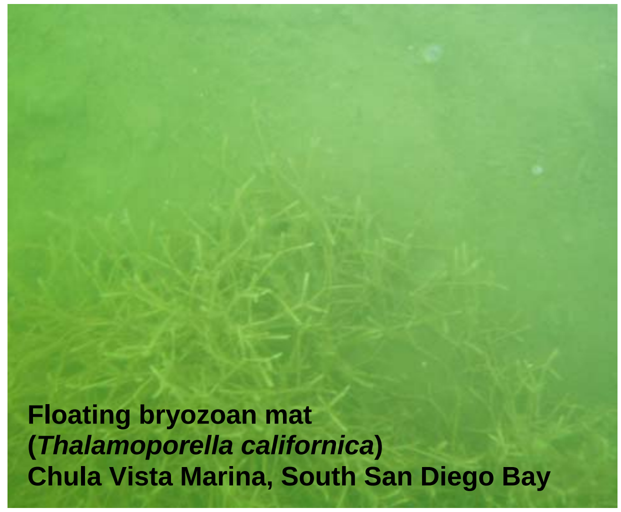
| **Exposure Regime** | Protected, partially exposed |
|---|---|
| **Earthform Features** | Estuarine |
| **Tidal Height** | Intertidal, Subtidal |
| **Depth** | 0-5 m, 5-15 m |
| **Topographic Relief** | Flat (bottom substrate) High (Piles) |
| **Substrate** | Artificial |

***Regional characteristics for So. California

***Commonly Associated Species***

| **Common Name** | **Scientific Name** |
|---|---|
| Sponges | *Haliclona* sp., *Leucetta losangelensis, Hymeniacidon* sp*., Cliona* sp. |
| Hydroids | *Agalophenia* sp. |
| Bryozoan | *Bugula neritina, Watersipora* sp., *Thalamoporella californicus* |
| Scaled worm snail | *Serpulorbis squamigerus* |
| Filamentous red algae | *Polysiphonia* sp. |
| Serpulid polychaete | *Hydroides* sp. |
| Filamentous red algae | *Polysiphonia* sp. |
| Mussels | *Mytilus* spp. |
| Barnacles | *Balanus spp. and Megabalanus californicus* |
| Tunicates | *Ciona intestinalis, Botryllus, Botrylloides,* and *Styela* spp*.* |
| Topsmelt | *Atherinops affinis* |
| Opaleye | *Girella nigricans* |
| Round stingray | *Urobatus halleri* |
| Barred sand bass | *Paralabrax nebulifer* |

### *North versus South San Diego Bay*



**Floating bryozoan mat (*Thalamoporella californica*) Chula Vista Marina, South San Diego Bay**

The encrusting invertebrate and algal communities present on marina structures are subject to the same gradient in availability of oceanic water as all habitats in the bay. In addition, marinas are typically located in protected side basins, further limiting water flushing, and are subject to water quality issues related to a high concentration of boats. Lenihan et al. (1990) found that the percent cover of sessile organisms in marinas at North Bay locations was similar to South Bay locations with few boats. This suggests that flushing is a major factor in determining community structure, as South Bay marinas with many boats would experience the least flushing and exhibit different biota. Additionally, organisms common in South Bay marinas with many boats were rare at North Bay locations. During the current study, several species of invertebrates and fish characteristic of open coastal communities were observed at the northern site but were not present at the southern site.

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# Launch Ramp


**Typical launch ramp structures**

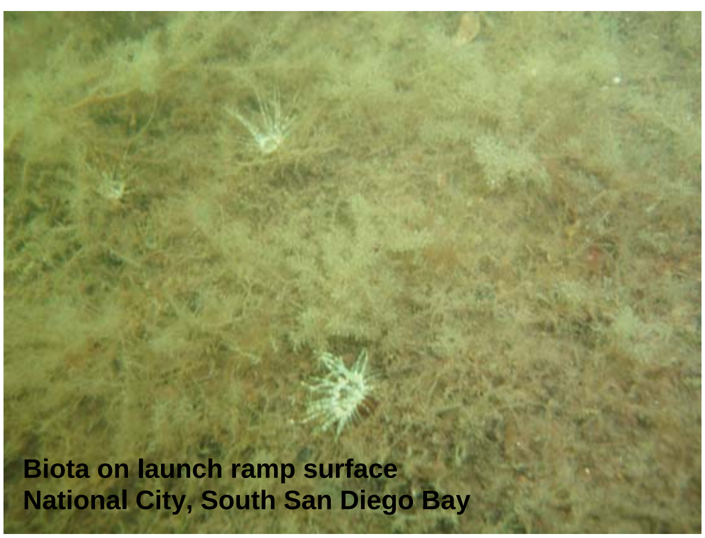
***Overview***

Launch ramps are areas paved with concrete for access to vessels on trailers. These ramps are typically edged with riprap or are an interruption in a riprap shoreline, and have one or more associated floating docks. The concrete ramps will be the focus of this discussion, as riprap and dock structures are described in their respective sections. The ramps extend from supratidal to subtidal levels, and are met by soft muddy bottom. The substrate relief is a low slope similar to a beach face and has low habitat complexity.

***Ecosystem Functions***

Launch ramps present a very gently sloping relief and low complexity substrate. The cement ramp surface is similar to dock piles as a substrate type, but several factors in positioning make these two substrates very different. The vertical versus nearly flat relief, light availability, and rates of disturbance separate these substrates. Frequent disturbance from trailers over the surface of the ramps, as well as, from propeller wash may limit the encrusting community to those species that rapidly colonize or are very hardy. The abundance and particularly diversity of algae and encrusting invertebrates on the surface of the ramps was observed to be very low in the current study. A low growth of red turf algae and a few anemones and tunicates were attached to the substrate. Fish assemblages associated with launch ramps are not well studied, and are likely limited in abundance and diversity as well.

Aspects of the physical environment around launch ramps is likely very similar to that in many marinas. The high concentration of boats, and particularly outboard motors, may impact fish and invertebrate communities similarly to the impacts observed by Lenihan et al. (1990). This study examined the fouling community on marina substrates in San Diego Bay relative to boat concentration in marinas and observed that fewer species, less biomass, and lower cover of sessile groups was observed in marinas with many boats.


**Biota on launch ramp surface**
**National City, South San Diego Bay**

Apart from the ramp structure itself, the environment of the ramp basin or ramp area is somewhat unique in that it presents a close arrangement of the ramp, pile, floating dock, and riprap structures. Riprap inside of launch ramp basins was observed to be particularly bare in the current study when compared to riprap exposed to the open bay water in both the north and south bay environments.

***Status and Distribution***

Several launch ramps occur in San Diego Bay with most being in the South Bay. Public launch ramps are located on Shelter Island in the North Bay and at Glorietta Bay, the Sweetwater

Channel and the Chula Vista Marina in the South Bay. In addition, there are several private ramps located on Navy property at the Submarine Base, North Island, and Coronado.

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Protected, partially exposed |
| **Earthform Features** | Estuarine |
| **Depth** | 0-5 m |
| **Topographic Relief** | Low slope |
| **Tidal Height** | Intertidal, Subtidal |
| **Substrate** | Artificial |

*****Regional characteristics for so. California

**Soft bottom habitat at launch ramp base National City, South San Diego Bay**

***Commonly Associated Species***

| Common Name | Scientific Name |
|---|---|
| Anenomes | Unknown species |
| Branching bryozoan | *Thalamoporella californica* |
| Filamentous red algae | *Ceramium* sp. |
| Invasive soft bryozoan | *Zoobotryon verticillatum* |
| Clear tunicates | *Ciona intestinalis* |
| Gobies | Gobiidae |
| Round stingray | *Urobatus halleri* |

***North versus South San Diego Bay***

The encrusting invertebrate and algal communities present on launch ramp substrate are subject to the same gradient in availability of oceanic water as all habitats in the bay. Launch ramps, like marinas, are typically located in protected side basins, further limiting water flushing and are subject to water quality issues related to a high concentration of boats. Lenihan et al. (1990) found that the percent cover of sessile organisms in marinas at North Bay locations was similar to South Bay locations with few boats. This suggests that flushing is a major factor in determining community structure, as South Bay marinas with many boats would experience the least flushing and exhibit different biota. Additionally, organisms common in South Bay marinas with many boats were rare at North Bay locations.

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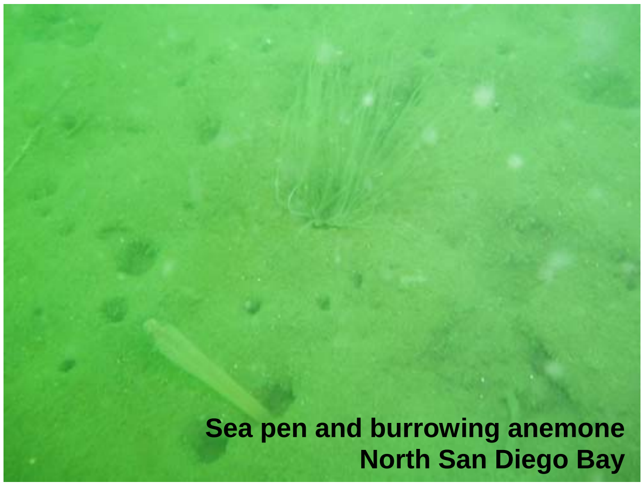
# Bare Mud/Silt

***Overview***

Bare mud is the most common of all substrate types found in San Diego Bay, as in most bays and harbors. Bare mud occurs where artificial substrates have not been introduced and where conditions are not suitable for eelgrass growth. The relatively reduced water circulation in estuaries allows the settlement of the fine particles that make up mud (relatively few areas of increased circulation or wave action in estuaries result in natural hard or sandy bottom). These fine particles of organic and inorganic matter enter estuaries through riverine and oceanic input, as well as, through deposition of plant detritus produced by salt marshes and seagrass beds.



**Sea pen and burrowing anemone**
**North San Diego Bay**

***Ecosystem Functions***

Estuarine sediments are the sites of key ecological functions such as decomposition, nutrient cycling, and nutrient production (Levin et al. 2001). Infaunal invertebrates in these sediments increase percolation of water and oxygen levels through bioturbation and suspension feeding. Shredders such as gastropod mollusks break up large pieces of organic matter, while deposit feeders both transform and bury or bring up organic matter. Dominant suspension feeders are often bivalve mollusks, but some polychaetes, crustaceans, and sponges also perform this function. These animals can increase water clarity and light levels, and reduce pollutants (Alpine & Cloern 1992). Infaunal and epifaunal invertebrates serve as the major food base for many species of fish and larger invertebrates including shrimp, crabs, lobster, halibut and croaker which transfer this production across habitats (Levin et al. 2001).

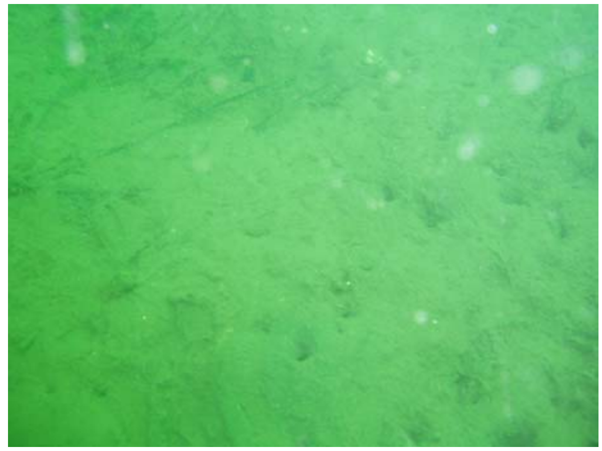
Many assessments of fisheries utilization of southern California bays and harbors focus on bare versus vegetated substrates (Allen et al. 2002, Hoffman 1994, Valle et al. 1999). Bare areas of any type (sand or mud) are lumped, although it is reasonable to suggest that bare areas are in most cases mud. Hoffman (1994) found that fish catches were generally twice as high in eelgrass beds compared to non-vegetated areas. Allen (2002) found significantly higher catches at vegetated sites when using five out of the ten gear types used during the study. Valle et al. (1999) found that California halibut were more abundant in unvegetated areas of Alamitos Bay and were more abundant near the bay entrance than inside. This indicated that California halibut settlement and juvenile site selection may be based on larval supply from outside the bay and less on physical characteristics of the substrate. Unvegetated habitat was also important for Pacific staghorn sculpin, cheekspot goby, and diamond turbot.

Mudflats are areas of periodically submerged mud bottom. When submerged these areas are habitat for a set of closely associated fish species including California killifish (*Fundulus parvipinnis*) and a variety of gobies. These forage fish provide a food source for aerially feeding birds, and wading birds feed in the mudflats when the tide is low. Periphytic diatoms, single celled plants, form a layer on the surface of bare sediments attached to individual grains (Ford 1994), and serve as a food source for small invertebrates and some fish, such as striped mullet, which ingests sediment.

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Protected |
| **Earthform Features** | Estuary |
| **Tidal Height** | Subtidal |
| **Depth** | 0 – 5 m, 5-30 m |
| **Topographic Relief** | Flat |
| **Substrate Type** | Mud (silts and clays) |

*Regional characteristics for So. California



***Status and Distribution***

Bare mud occurs in San Diego Bay throughout all spatial and depth ranges. Bare mud may be in shallow waters where conditions (shading, turbidity) are not suitable for eelgrass as well as in the deepest areas of the bay within the navigation channels. Bare mud as a habitat is typically not considered in evaluations of impacts of development, although alteration of this habitat through eutrophication, pollution and armorment should be considered. Intertidal flats, which includes mudflats, sand flats, and salt marsh represent approximately 918 acres of the shoreline habitat in San Diego Bay (USDoN and SDUPD 2000).

***Commonly Associated Species***

| **Common Name** | **Scientific Name** |
|---|---|
| CIQ goby | Gobiidae |
| Specklefin midshipman | *Porichthys myriaster* |
| California halibut | *Paralichthys californicus* |
| Round stingray | *Urobatus halleri* |
| Spotted turbot | *Pleuronichthys ritteri* |
| California killifish | *Fundulua parvippinnis* |
| Sea pen | *Stylatula elongata, Vigularia* spp. |
| Burrowing anenome | *Zaolutus actius* |
| Clam | *Macoma* spp. |
| Gastropod | Gem Murex |
| Speckled scallop | *Argopecten aequisulcatus* |
| Navanax | *Navanax inermis* |
| Green algae | *Ulva* spp., *Chaetomorpha* spp., *Cladophora* sp., *Enteromorpha* sp. |
| Red algae | *Gracilaria verrucosa* |

***North vs. South San Diego Bay***

Allen (2002) found that both the density and biomass of all fish species combined decreased with increasing distance from the bay mouth in the deeper bare bottom habitats. This pattern remained when examining fisheries species as well. This does not mean, though, that the conditions found in south San Diego Bay are undesirable for all species associated with bare bottom. The species exhibiting the northern reaches of their range are more abundant in the south bay which acts as a warm water refuge for these species. The species associated with south bay bare bottom habitats include the banded guitarfish and butterfly ray.

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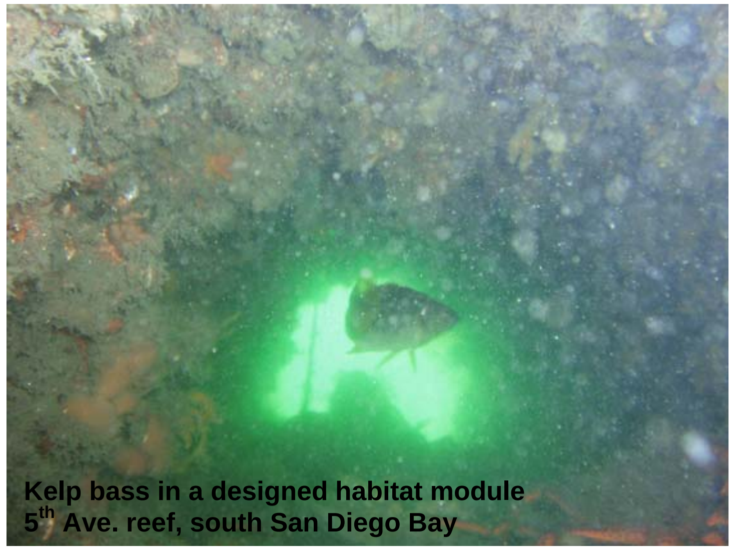
# Artificial Reef

***Overview***



**Kelp bass in a designed habitat module**
**5th Ave. reef, south San Diego Bay**

Artificial reef is distinguished in this study from other artificial substrates (riprap, bulkhead, launch ramp, piling) by not being attached to the shoreline as armorement or being a component of a dock structure. Dock and wharf structures have unique characteristics of depth, light, and placement in the Bay. Artificial reefs as defined here may be placed specifically for fish enhancement or may be unintentional. Examples of unintentional reefs include sunken debris and underwater dikes. Artificial reefs in the bay have been created either to mitigate the loss of another habitat or provide recreational fishing opportunities. Artificial reefs in the Bay are composed of quarry rock, concrete rubble, sunken ships, debris piles, or designed habitat modules. This provides both high-relief and substrate complexity.

***Ecosystem Functions***

Given that San Diego Bay species assemblages are a mixture of estuarine and open coastal species, it follows that artificial hard substrates will be islands of concentration of the more open coastal assemblages. This was observed to be the case by Davis et al. (2002) on shoreline riprap in San Diego Bay, which allows the extension of open coastal species range into the bay. Artificial reef habitat is more commonly used and studied in offshore areas and relatively little is known about their functioning inside protected embayments and estuaries.

The ecosystem functions of artificial reefs are a topic of debate among scientists, resource managers, and users. While it could be agreed that the replacement of damaged or lost hard-bottom habitat with functionally equivalent human-made habitat may be a critical mechanism for maintaining or restoring marine resources, creating functionally equivalent reefs remains a challenge. Conclusive evidence indicating the level of function of artificial reefs compared to natural reefs has yet to be attained because many studies have not compared artificial reefs with natural reefs of the same structural complexity, size, age, and isolation. And while some studies have shown that species richness and abundance is greater on natural reefs, other research does not support this conclusion. Fisheries managers also disagree over whether artificial reefs enhance productivity or simply attract animals from natural habitats and much research indicates that artificial reefs can have deleterious effects on reef fish populations by increasing fishing effort and catch rates. These fisheries parameters relating to artificial reefs will be reef-specific and relate to local patterns of larval supply (Carr & Hixon 1997) and substrate limitation (Grossman et al. 1997). For San Diego Bay, hard substrate limitation is experienced by reef species as the bay is naturally dominated by soft substrates. Larval supply is likely the dominating factor in reef species assemblages due to the relatively extreme gradient in water circulation.

Reef assemblages on artificial habitat in San Diego Bay include a variety of encrusting organisms, algae, and fish. No focused studies of invertebrate and algal assemblages have been performed on artificial reef habitats specifically in San Diego Bay. Information relevant to artificial reef invertebrates can be derived from one study of shoreline riprap (Davis et al. 2002) and one study of piling structures in the Bay (Ford et al. 1975). Results from these studies are described in their respective sections. Fish species associated with bay reefs include sand basses (*Paralabrax* spp.), surfperches (Embiotocidae), blacksmith (*Chromis punctipinnis*), opaleye (*Girella nigricans*), sargo (*Anisotremus davidsonii*), and others. These reefs also provide cover for large invertebrates such as lobster (*Panulirus interruptus*) and octopus (*Octopus bimaculoides*). Pondella et al. (2006) compared artificial reefs constructed of riprap to eelgrass and bare sand habitat in San Diego Bay, as well as, to the older, more exposed riprap on Zuniga Jetty at the bay mouth. Fish species assemblages and densities were different between the bay and the jetty. Species occurring on Zuniga Jetty such as garibaldi (*Hypsypops rubicundus*) and senorita (*Oxyjulis californica*) were absent from the bay reefs. In an analysis of Pearson's correlation coefficients with regard to fish density, bay reefs were more similar to soft bay habitats than they were to Zuniga Jetty. The issue of attraction versus production was examined with regard to the bay reefs. Spotted sand bass appeared to be attracted to the reefs and made use of them as winter forage habitat. Barred sand bass alternatively, appeared to exhibit attraction, as well as, increased production in the reef area. Presence of settling larvae, juveniles and later stages with apparent adult fidelity to the reefs were taken as indicators of production.

***Status and Distribution***

Many examples of intentional and unintentional artificial reefs occur in the bay (reference map). In the North Bay, intentional reefs of a variety of ages are located off North Island, Shelter Island, and Harbor Island. Intentional reefs in South Bay are located off Delta Beach and in central South Bay. Sunken boats and debris piles occur throughout the bay, but are particularly prevalent in the South Bay.

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Partially exposed, protected |
| **Earthform Features** | Estuary |
| **Tidal Height** | Subtidal |
| **Depth** | 0 – 5 m<br>5 – 30 m |
| **Topographic Relief** | High |
| **Substrate** | Artificial, variable |

***Regional characteristics for So. California

***Commonly Associated Species***

| **Common Name** | **Scientific Name** |
|---|---|
| Gorgonian | *Muricea californica* |
| Hydroids | *Agalophenia* sp. |
| Colonial ascidians | *Botryllus* spp. and *Bottryloides* spp. |
| Spiny lobster | *Panulirus interruptus* |
| Sponges | *Haliclona* sp., |
| Bryozoans | *Thalamoporella californicus* |
| Mussels | *Mytilus* spp. |
| Octopus | *Octopus* spp. |
| CA scorpionfish | *Scorpaena guttata* |
| Blacksmith | *Chromis punctipinnis* |
| Salema | *Zenistius californiensis* |
| Surfperch | *Embiotoca* spp. |
| Sand bass | *Paralabrax* spp. |

**Debris pile with bicycle tire**
**A8 Anchorage, south San Diego Bay**

**Octopus in a designed habitat module**
**5th Ave. reef, north San Diego Bay**

### *North versus South San Diego Bay*

Davis et al. (2002) and Pondella et al. (2006) provide the only known published reports of species assemblages on artificial hard substrates in San Diego Bay. Bay reefs studied by Pondella et al. (2006) were in the North Bay and found to be different from Zuniga Jetty. Based on information from Davis et al. (2002), one would expect that these differences would be amplified with increased distance from the Bay mouth, as this study found that bare space increased and species richness decreased with increasing distance from the mouth. This suggests that if the attraction and production of open coast species is desired, reefs in South Bay would do relatively little towards that goal. Although not demonstrated in a focused study, it can be anticipated that reefs in the southern portions of the bay are subject to higher rates of silt deposition and the encrusting community of filter and suspension feeders are negatively impacted. It was noted during the present study that a greater number of fish species were observed at the artificial reef in North Bay and included California scorpionfish (*Scorpaena guttata*), garibaldi (*Hypsypops rubicundus*), and giant kelpfish (*Heterostichus rostratus*), which were not observed at the South Bay location.

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# Wharf & Pier

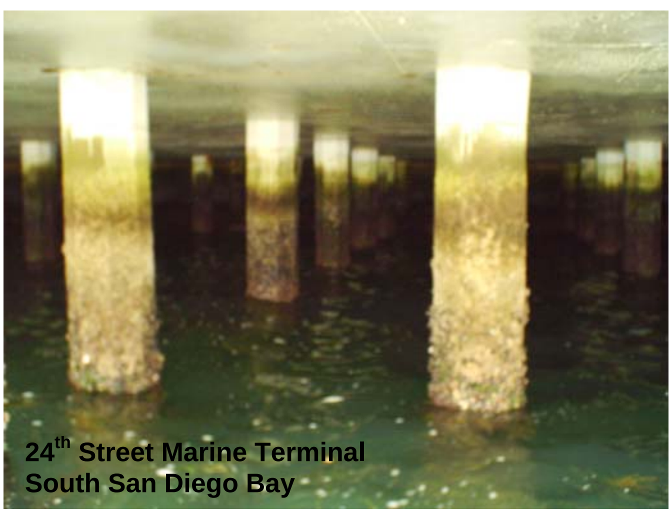
***Overview***

A wharf is a platform, generally supported by pilings and running parallel to shore. Similarly, a pier is a pile-supported platform but it runs perpendicular to shore. For the purposes of this study, discussion of this habitat is limited to large wharf and pier structures. These types of structures are similar in that they provide a high concentration of piles, and impose a high degree of shading on the water column. These structures are generally concrete decks with pre-stressed concrete piles. Associated fender systems are constructed from a variety of materials including foam filled or pneumatic rubber, recycled plastic piles, fiberglass piles filled with concrete, and untreated timber.

**Navy Pier**
**South San Diego Bay**

***Ecosystem Functions***

Pier and wharf pilings provide habitat for an assemblage of organisms known as the fouling community. This community appears to attract schooling fish, which feed on the attached invertebrates and algae. Only one detailed study including multi-season data has been conducted describing the invertebrate communities on concrete and wooden piles in San Diego Bay (Ford et al. 1975). This study was conducted on concrete and wooden piles at the B Street, Broadway, and Navy Piers during 1972-1973. The attached and free living invertebrates associated with the piles included polychaete worms, crustaceans, molluscs, cnidarians, tunicates, and sponges in order of abundance. Species composition and abundance was found to be highly seasonally variable.



**24th Street Marine Terminal**
**South San Diego Bay**

The habitat value of these structures is unclear and warrants further study. Typically environmental assessments for San Diego Bay projects have considered the addition of hard substrate an environmental benefit to fishes (although not to birds) because the attached fouling community serves as forage for fish (USDoN, SWDIV 2000). For example, pier demolition has involved sinking of pier components rather than removal as provision of an artificial reef. The benefit of these structures to fish is unconfirmed. Merkel & Associates (1999) performed a study of wharf shading impacts to associated encrusting communities and to fish. It was determined that encrusting pile communities were not as numerous or species rich on the inside shaded piles, but that a developed pile community existed throughout the habitat. Infaunal communities continued to be present in the shaded regions. Fish sightings were too limited to determine differences in abundance along a shade gradient.

The limited availability of light beneath piers and wharves separates these habitats from other artificial structures such as pontoons and floating docks, or artificial reefs. Connell (2001) performed a study comparing the epibiotic assemblages of floating structures, pilings, and natural reefs, and found that assemblages on pilings and reefs were more similar to each other than to floating structures. Pile communities were distinguished by having intertidal areas (periodically exposed to air) and limited light. Proximity to the sea surface is also likely to be a determinant of the availability of larval settlers and of food resources**.**

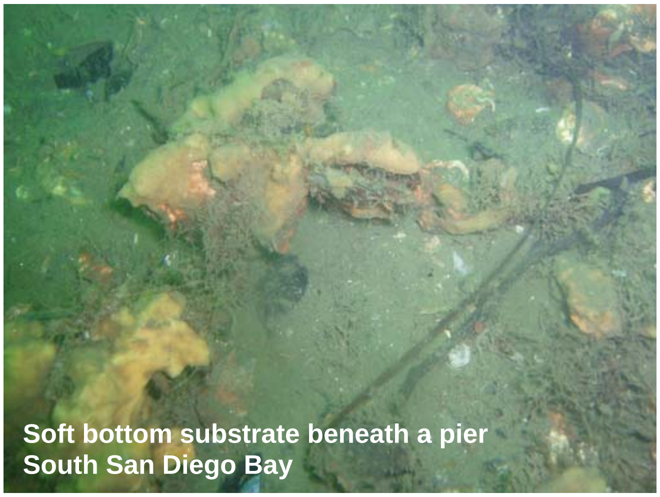
***Status and Distribution***

Wharves and piers of the size discussed here occur throughout San Diego Bay for primarily U.S. Navy and commercial purposes. The area of bay surface covered by industrial and Navy structures totaled 93 acres without ships and boats, and 307 acres when at capacity with ships and boats in 1995 (USDoN, SWDIV 1999). Navy structures occur predominantly on the eastern shoreline of Point Loma and the eastern shoreline of the south bay. Commercial/industrial structures occur mainly on the eastern shoreline of the central bay.

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Protected, partially exposed |
| **Earthform Features** | Estuarine |
| **Salinity** | Seawater (typically 33 – 34 ppt) |
| **Tidal Height** | Intertidal, Subtidal |
| **Substrate** | Artificial |

*****Regional characteristics for So. California



**Soft bottom substrate beneath a pier**
**South San Diego Bay**

***Commonly Associated Species***

| **Common Name** | **Scientific Name** |
|---|---|
| Sponges | *Haliclona* sp. and *Leucetta losangelensis* |
| Hydroids | *Obelia* and *Eudendrium* sp. |
| Bryozoan | *Bugula neritina* |
| Scaled worm snail | *Serpulorbis squamigerus* |
| Sea urchins | *Strongylocentrotus* spp. |
| Seastars | *Pisaster* spp. |
| Littorine snails | *Littorina* spp. |
| Mussels | *Mytilus* spp. |
| Barnacles | *Balanus* spp. and *Megabalanus californicus* |
| Tunicates | *Ciona intestinalis, Botryllus, Botrylloides*, and *Styela* spp. |
| Grapsid crabs | *Pachygrapsus crassipes* and *Hemigrapsus* spp. |
| Majid crabs | *Pugettia* and *Loxorhynchus* spp. |
| Black croaker | *Cheilotrema saturnum* |
| Blacksmith | *Chromis punctipinnis* |
| Barred sand bass | *Paralabrax nebulifer* |

**Epibiota on a pier piling**
**South San Diego Bay**

### ***North versus South San Diego Bay***

The encrusting invertebrate and algal communities present on pier and wharf pilings, while different from those on other hard substrates, are subject to the same gradient in availability of oceanic water in the bay. The availability of food with a moving current, the supply of larval recruits, and water quality all depend on the level of flushing. During the current study, several species of invertebrates and fish characteristic of open coastal communities were observed at the northern pier site and were not present at the southern location. These included the California scorpionfish (*Scorpaena guttata*), rock scallop (*Crassedoma giganteum*), California sea cucumber (*Parastichopus californicus*), giant spined star (*Pisaster giganteus*), and giant keyhole limpet (*Megathura crenulata*).

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# Riprap

***Overview***


**Chula Vista Marina**
**South San Diego Bay**

Riprap is defined as walls or mounds of stones for structural use. Riprap is generally used as "armor" for stabilization of naturally soft shorelines, but may also be used in dikes or jetties. Riprap generally consists of 0.5 to 1 m diameter granite quarry rock but may also be concrete rubble and debris. Despite the prevalence of riprap shorelines, the species compositions and use of this habitat is little studied. Only one published report of riprap shoreline biota exists for southern California and describes a study of the shorelines of San Diego Bay (Davis et al. 2002). Other studies of riprap habitat have been published, though these focus on riprap breakwaters and artificial reefs (Froeschke et al. 2005, Pondella et al. 2006).

***Ecosystem Functions***

As a hard substrate, riprap is comparable in habitat function to natural rock reefs. The crevices formed between boulders create a relatively high complexity, which is required by many species for shelter, and results in high surface area for algal and encrusting invertebrate species. The frequency of riprap use in urban estuaries has the effect of converting the natural soft substrate species assemblages to rocky reef assemblages more similar to higher energy habitats just outside the estuary (Davis et al. 2002). Differences from open coast reefs include rock type, a lack of tide pools, reduced flow speeds and exposure level, and different colonization histories. The large expanse of open space of new riprap allows colonization by species typically space-limited on natural substrates. Despite these differences, the presence of riprap allows the presence of open coast species in San Diego Bay that would otherwise be excluded.

Some level of success has been documented in efforts to use riprap as artificial reef for fish enhancement. Pondella et al. (2006) found that fish enhancement structures constructed of concrete and granite boulders near the mouth of San Diego Bay increased local fishery production. The enhancement structures were significantly different in fish assemblage from Zuniga jetty, a more exposed and mature riprap structure at the opening of San Diego Bay. The structures were used seasonally for foraging by spotted sand bass, attracted both adults and newly recruited kelp bass, and appeared to not only attract but also contribute to production of barred sand bass. Froeschke et al. (2005) analyzed fish use on the riprap breakwater of Los Angeles Harbor and found that the habitat supported a diverse and abundant reef fish assemblage that was above or comparable in richness and density to similar natural and other artificial reefs. Similar to Zuniga jetty, the breakwater was mature and fully exposed, likely enhancing its performance relative to the potential of estuarine riprap structures.

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Partially exposed, Protected |
| **Earthform Features** | Estuary |
| **Tidal Height** | Subtidal, Intertidal, Supratidal |
| **Depth** | 0 – 5 m |
| **Substrate** | Imported Boulder |

*****Regional characteristics for So. California

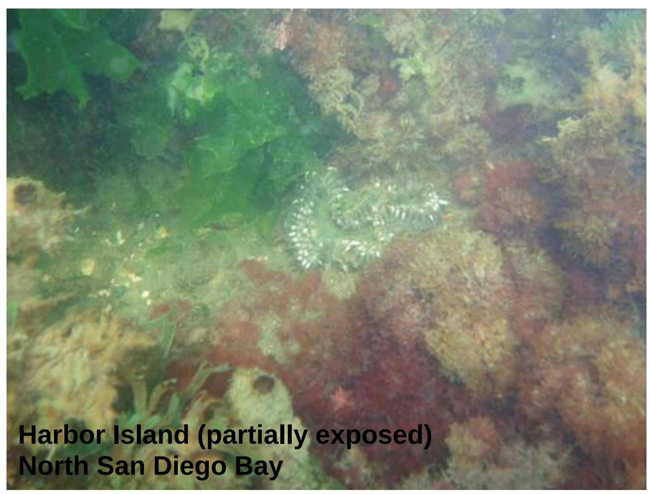
***Status and Distribution***

Shoreline armored with riprap is highly prevalent in San Diego Bay as in most southern California bays and harbors. The San Diego Bay shoreline is 74% armored (USDoN, SWDIV 2000). Riprap is also commonly used for stabilization in dikes or berms in completely subtidal uses or for limiting or changing water flow in jetties.

***Commonly Associated Species***

| Common Name | Scientific Name |
|---|---|
| Black surfperch | *Embiotoca jacksoni* |
| California clingfish | *Gobiesox rhessodon* |
| Dwarf surfperch | *Micrometrus minimus* |
| Garibaldi | *Hypsypops rubicundus* |
| Unidentified Goby | *Gobiidae* sp. |
| Opaleye | *Girella nigricans* |
| Topsmelt | *Atherinops affinis* |
| White surfperch | *Phanerodon furcatus* |
| Woolly sculpin | *Clinocottus analis* |
| Coralline Reds | *Corallina* spp. |
| Foliose Reds | *Laurencia* spp, *Plocamium* spp., *Gigartina, Prionitis, Gelidiaceae, Polysiphonia* |
| Invasive Brown Algae | *Sargassum muticum* |
| Sea Lettuce | *Ulva* spp. |
| Barnacle | *Balanus* spp. |
| Native Oyster | *Ostrea lurida* |
| Mussel | *Mytilus* spp. |
| Pacific Jewel Box | *Pseudochama exogyra* |
| Tunicate | *Styela* spp. |
| Yellow Sponge | *Aplysina fistularis* |
| Red Invasive Bryozoan | *Watersipora* spp. |

***North vs. South San Diego Bay***



**Harbor Island (partially exposed)**
**North San Diego Bay**

Riprap was examined in the current study in the North Bay at outer Harbor Island and in South Bay at the Chula Vista marina. The two sites were similar in being nearly fully covered in algae and invertebrates. The number of species observed at the two sites was also similar. Six reef fish species were observed at Harbor Island including kelp bass, black surfperch and opaleye. Only three species of fish were observed in Chula Vista and these were not reef-specific species (topsmelt, round stingray, and gobies). Although these sites are in the northern and southern regions of the bay, both are on the outside of marinas with full exposure to the bay. Riprap was observed in the more protected areas of launch ramps and appeared drastically different in these locations, being largely bare of algae with reduced encrusting animals (pictured left). Davis et al. (2002) performed a focused analysis on exposure levels and corresponding riprap assemblages, and found that exposed sites had less empty space than protected sites. This is opposite to the pattern seen on open coast reefs where a high degree of exposure results in bare areas. It appears that exposure within estuarine environments is not severe enough to remove growth and results in an overall benefit. This benefit may be due to

**National City Launch Ramp (fully protected)**
**North San Diego Bay**

better water quality and/or increased larval supply and food resources with increased water movement. Species richness decreased with increasing distance from the bay mouth at exposed riprap sites, suggesting that South Bay may be limited by larval recruits from open water.

***References***

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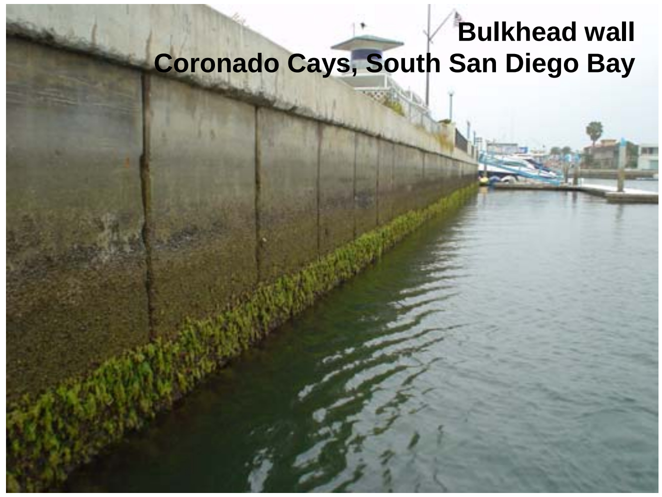
# Bulkhead Wall



Bulkhead wall
Coronado Cays, South San Diego Bay

***Overview***

Bulkhead walls are used extensively in the bay for shoreline stabilization, although less commonly than riprap. Bulkhead walls present a concrete surface with vertical relief and little complexity and therefore would be expected to have relatively little habitat value.

***Ecosystem Functions***

The fouling or encrusting community of invertebrates and algae present on bulkhead walls is similar to that found on piles. The attached and free-living invertebrates associated with the piles studied by Ford et al. (1975) in San Diego Bay are likely similar and of similar abundance on bulkhead walls. These include polychaete worms, crustaceans, molluscs, cnidarians, tunicates, and sponges in order of abundance. Species composition and abundance would also be highly seasonally variable. Intertidal biota of bulkhead walls consists of only a few species highly tolerant to desiccation such as barnacles. The biomass and species richness increases in subtidal regions.

Fish assemblages associated with bulkhead walls have not been studied. Bulkheads could be expected to provide foraging opportunities to fish because of the associated fouling organisms, although their relative value is likely low. The cover and habitat complexity provided by marina and pier or wharf habitat provides better hiding spaces and possibilities for escape from predators. Bulkheads are typically adjacent to a variety of deep-water marine uses and therefore present no intertidal area other than the periodically exposed vertical face of the wall. This abrupt land/sea interface allows none of the beneficial upland transition zones that can buffer marine systems from terrestrial uses and act as filters of pollutants and nutrients. For this reason, bulkhead walls probably present a negative influence on water quality, particularly when adjacent to industrial uses such as boat yards.

***Status and Distribution***

There are 45.4 mi or 74% of the Bay's shoreline that are stabilized with rock or concrete, which includes about 20 mi of shoreline armored with seawalls (USDoN 2000). Recommendation was made by the recent San Diego Bay Integrated Natural Resources Management Plan to "Discourage the construction of seawalls, revetments, breakwaters, or other artificial structure for coastal erosion control," unless several criteria for necessity and mitigation are met.

Low wall biota
Chula Vista, South San Diego Bay

***Physical Environment****

| | |
|---|---|
| **Exposure Regime** | Protected, partially exposed |
| **Earthform Features** | Estuarine |
| **Tidal Height** | Intertidal, Subtidal |
| **Depth** | 0-5 m, 5-15 m |
| **Topographic Relief** | Vertical |
| **Substrate** | Artificial |

***Regional characteristics for So. California**

***Commonly Associated Species***

| Common Name | Scientific Name |
|---|---|
| Sponges | *Haliclona* sp., *Leucetta losangelensis, Hymeniacidon* sp., *Cliona* sp. |
| Hydroids | *Agalophenia* sp. |
| Bryozoan | *Bugula neritina, Watersipora* sp., *Thalamoporella californicus* |
| Scaled worm snail | *Serpulorbis squamigerus* |
| Serpulid polychaete | *Hydroides* sp. |
| Barnacles | *Balanus* spp. and *Megabalanus californicus* |
| Tunicates | *Ciona intestinalis, Botryllus, Botrylloides*, and *Styela* spp. |
| Sea lettuce | *Ulva* sp. |
| Filamentous red algae | *Polysiphonia* sp., *Ceramium* sp. |
| Gobies | Gobiidae |

***North versus South San Diego Bay***

**Goby on vertical bulkhead wall**
**Chula Vista, South San Diego Bay**

The encrusting invertebrate and algal communities present on bulkhead walls are subject to the same gradient in availability of oceanic water as all habitats in the bay. In addition, bulkhead wall are common in marinas and industrial areas associated with additional water quality issues. The decreased species richness with increased distance from the bay mouth and increased bare space on riprap substrate in protected areas relative to exposed observed by Davis et al. (2002) are phenomena which likely also effect bulkhead walls. Additionally the importance of flushing in marinas to the percent cover and species richness of sessile organisms observed by Lenihan et al. (1990) on marina piles should show similar patterns on marina bulkhead walls. Therefore bulkhead wall habitat for encrusting communities is probably more productive and species rich in the north bay though this trend will be influenced and possibly reversed when comparing habitats adjacent to the bay and within commercial basins (i.e. biomass and richness are a function of flushing and protected sites in the north bay may be similar to exposed sites in the south bay).

***References***


Davis, J.L.D., L.A. Levin, and S.M. Walther. 2002. Artificial armored shorelines: sites for open-coast species in a southern California bay. Marine Biology 140:1249-1262.

Ford, R.F., R.W. Chambers, and R.L. Chambers. 1975. Thermal distribution and biological studies for the Station B Power Plant, vol. 5A&5B. Prepared for the San Diego Gas & Electric Co., Environmental Engineering Laboratory Technical Report. Contract P-25072.

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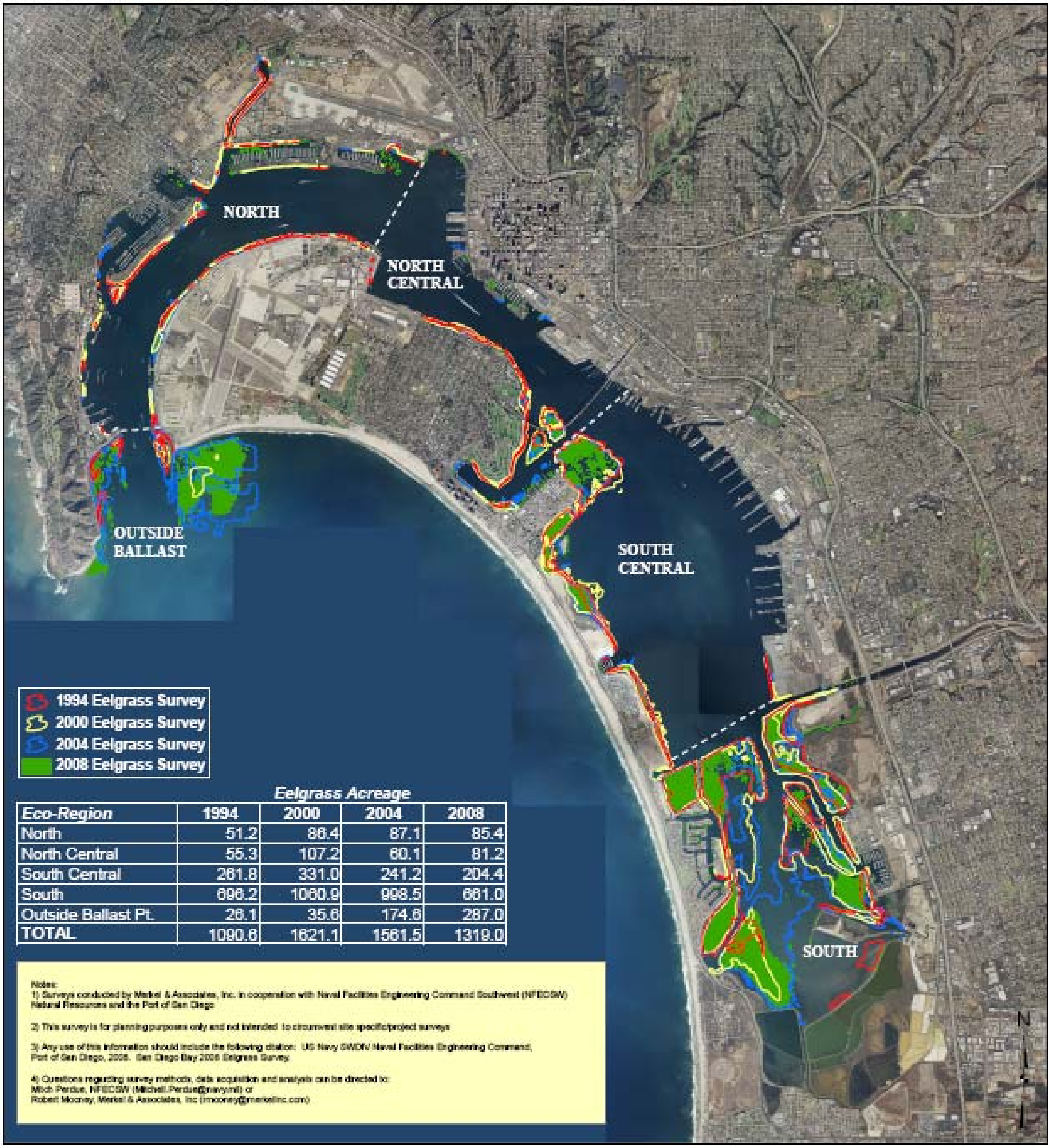
# Appendix C
# Maps of Habitat Types in San Diego Bay




*Eelgrass Acreage*

| *Eco-Region* | 1994 | 2000 | 2004 | 2008 |
|---|---|---|---|---|
| North | 51.2 | 86.4 | 87.1 | 85.4 |
| North Central | 55.3 | 107.2 | 60.1 | 81.2 |
| South Central | 261.8 | 331.0 | 241.2 | 204.4 |
| South | 696.2 | 1060.9 | 998.5 | 661.0 |
| Outside Ballast Pt. | 26.1 | 35.6 | 174.6 | 287.0 |
| **TOTAL** | 1090.6 | 1621.1 | 1561.5 | 1319.0 |

Notes:
1) Surveys conducted by Merkel & Associates, Inc. in cooperation with Naval Facilities Engineering Command Southwest (NFECSW) Natural Resources and the Port of San Diego

2) This survey is for planning purposes only and not intended to circumvent site specific/project surveys

3) Any use of this information should include the following citation: US Navy SWDIV Naval Facilities Engineering Command, Port of San Diego, 2008. San Diego Bay 2008 Eelgrass Survey.

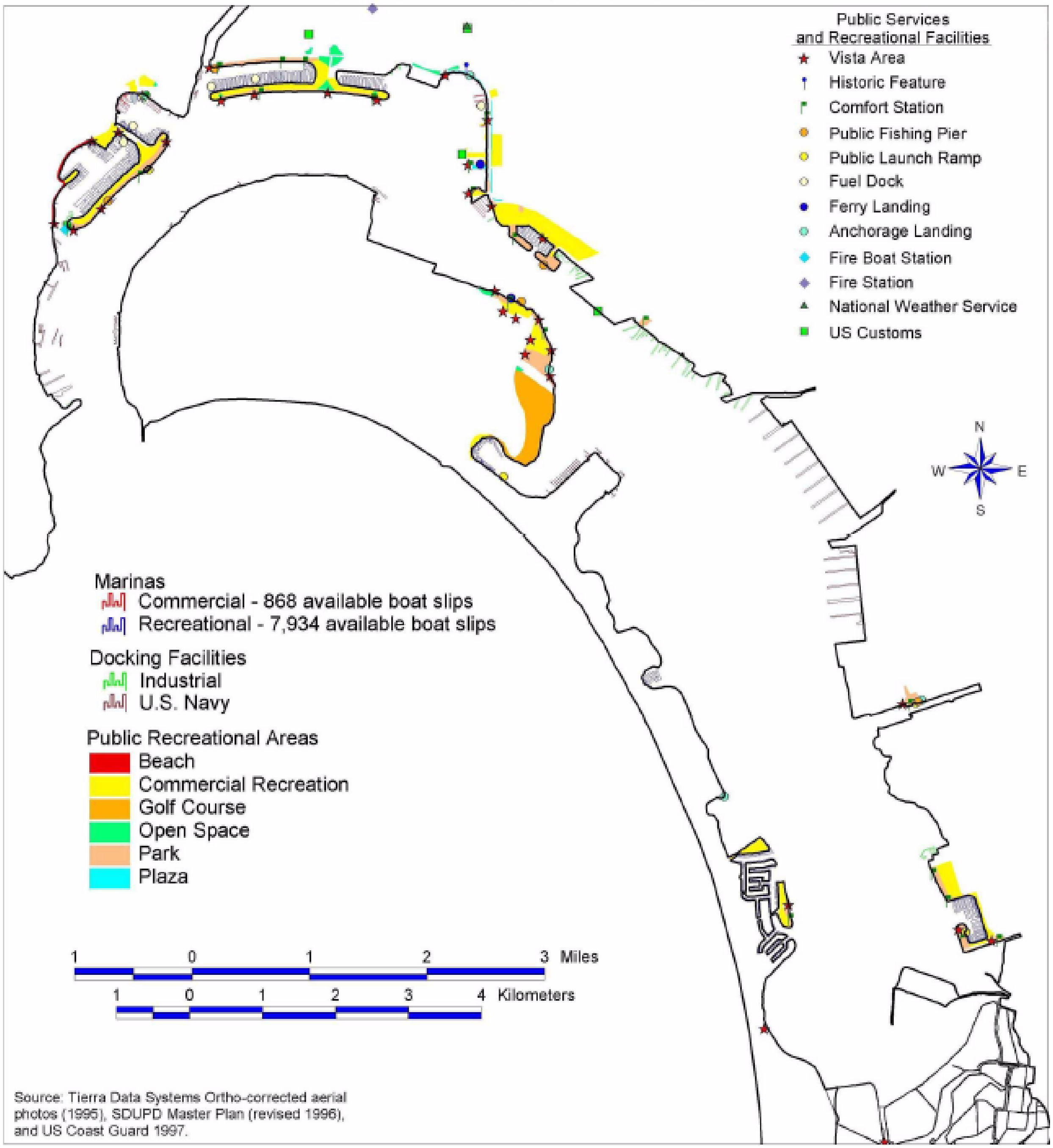
4) Questions regarding survey methods, data acquisition and analysis can be directed to:
Mitch Perdue, NFECSW (Mitchell.Perdue@navy.mil) or
Robert Mooney, Merkel & Associates, Inc (rmooney@merkelinc.com)

0 0.5 1 2 3 4 5 6 7 8 Kilometers

0 0.5 1 2 3 4 5 6 Miles

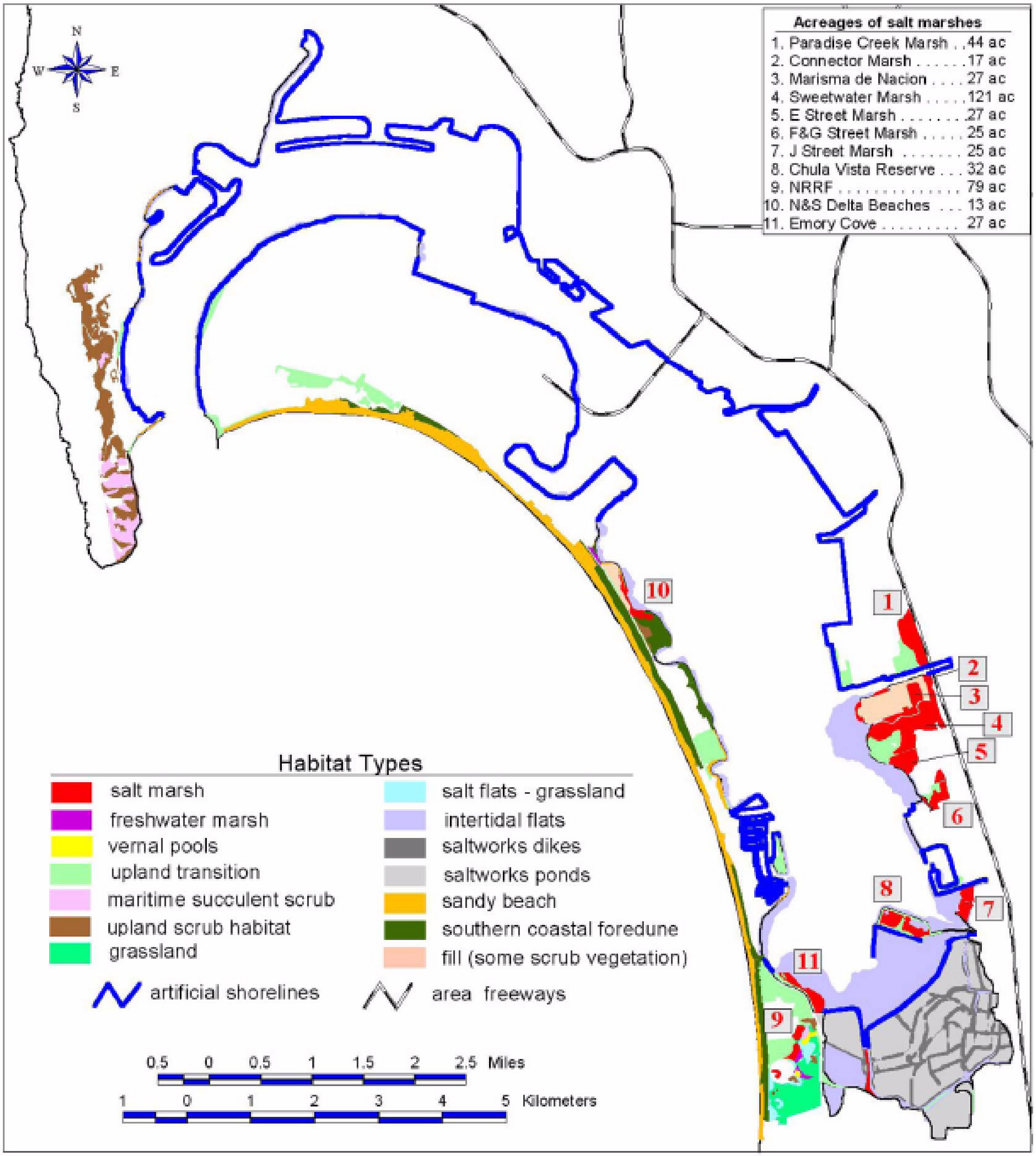
# San Diego Bay
# 2008 Eelgrass Survey

# San Diego Bay
# Marinas, Docks, and Public Recreational Areas

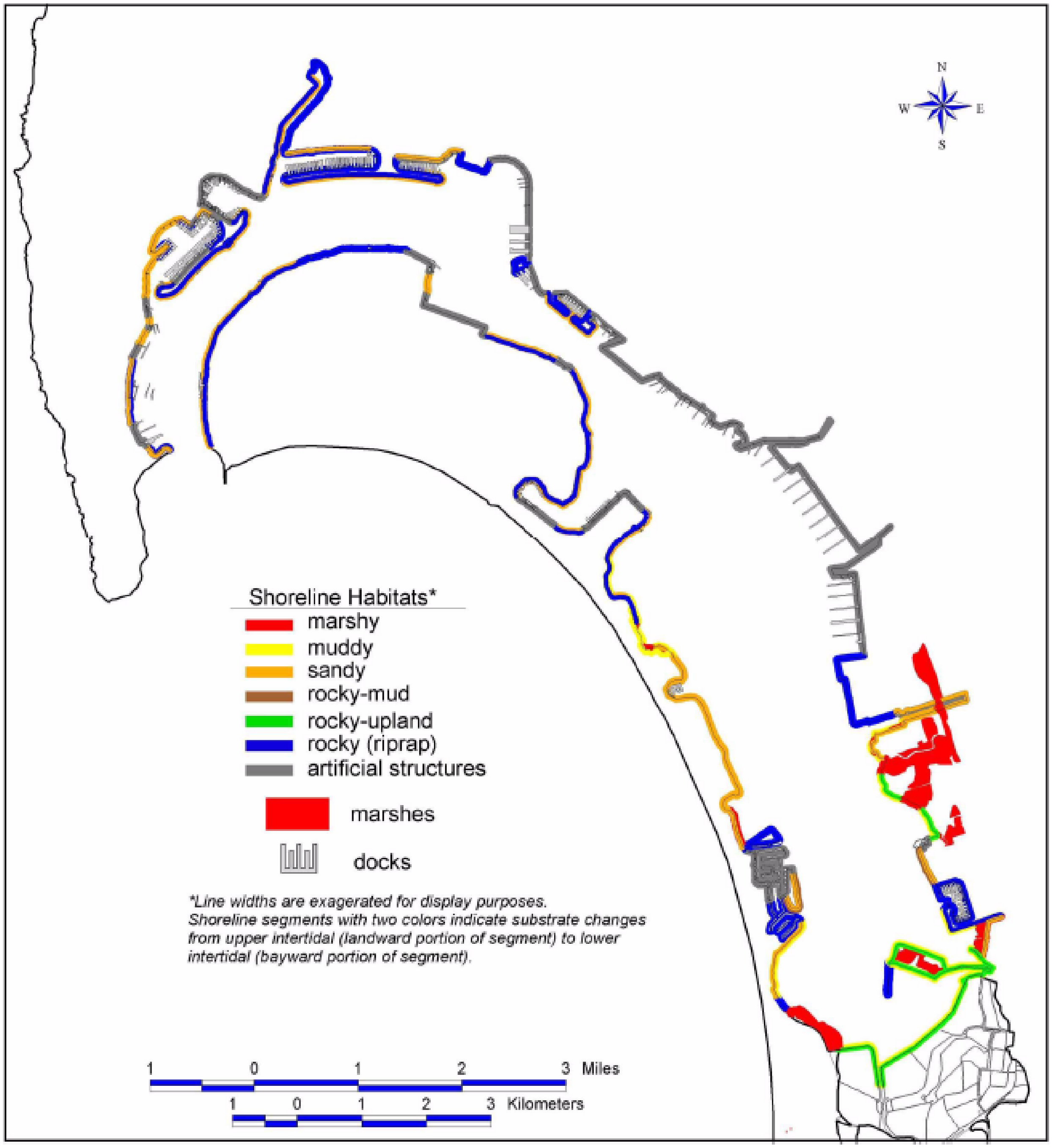



Source: Tierra Data Systems Ortho-corrected aerial photos (1995), SDUPD Master Plan (revised 1996), and US Coast Guard 1997.

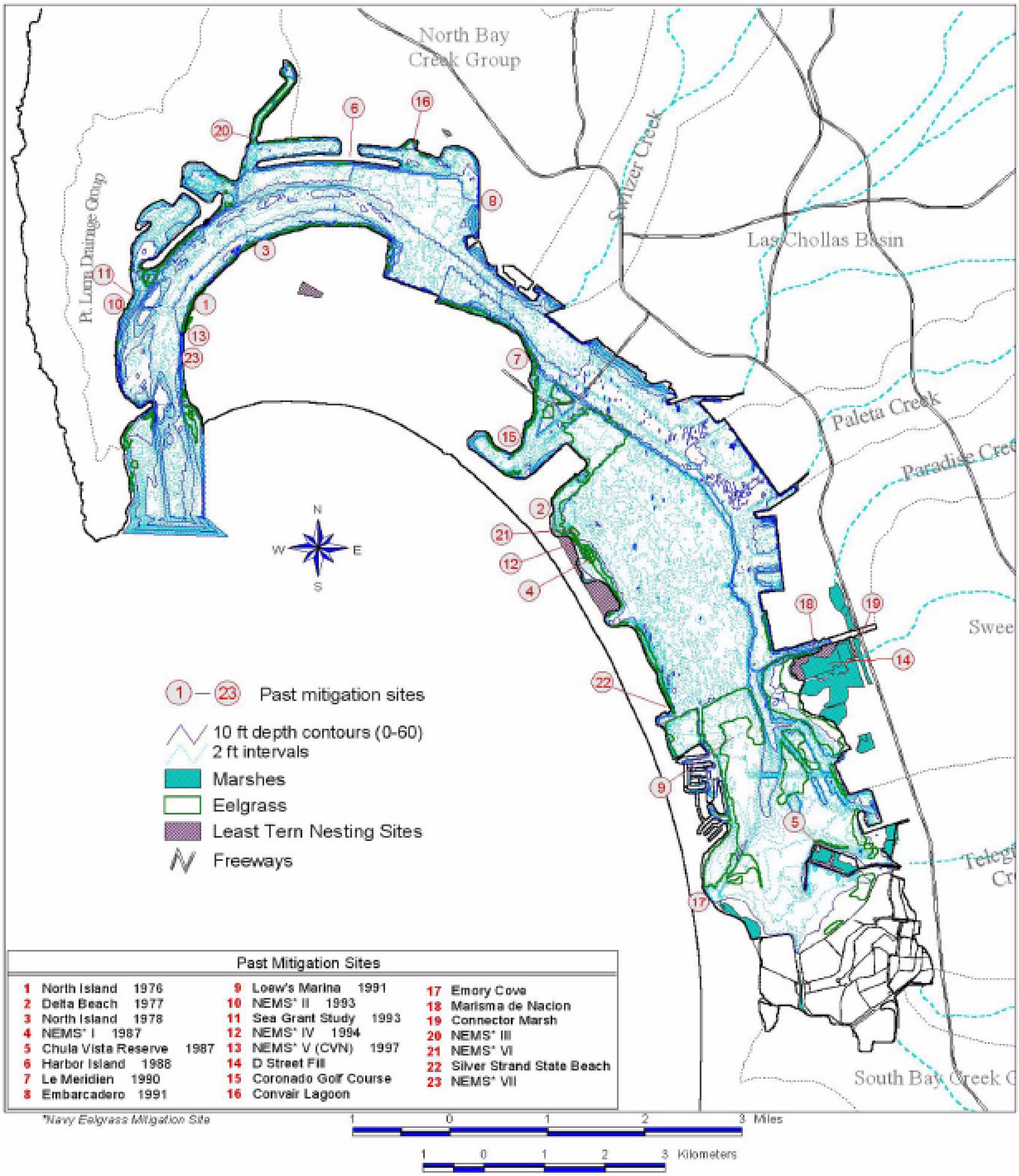
# Salt Marsh and Other Habitats Adjacent to San Diego Bay



# San Diego Bay Shoreline Habitat and Existing Docks



# Past Mitigation Sites in San Diego Bay



# Protected Marine and Coastal Habitat Areas in San Diego Bay