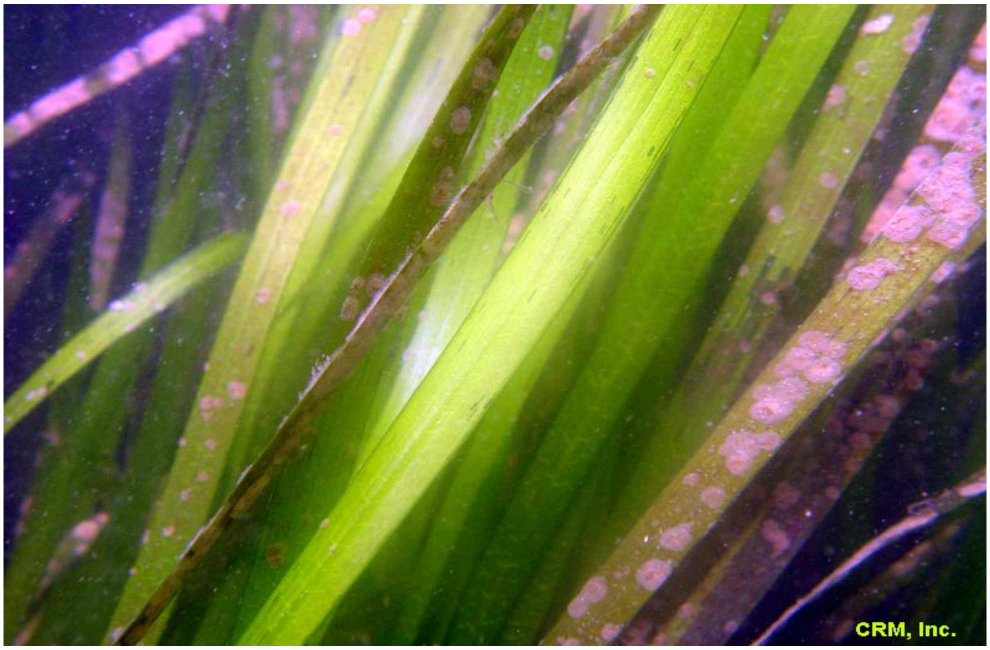
RESULTS OF THE SECOND NEWPORT BAY EELGRASS (ZOSTERA MARINA) BAY-WIDE HABITAT MAPPING SURVEY: STATUS AND DISTRIBUTION BETWEEN 2006 AND 2008
AND
OCEANOGRAPHIC CONDITIONS IN NEWPORT BAY BETWEEN 2008 AND 2009



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1. INTRODUCTION

1.1. BACKGROUND

The genus *Zostera* (eelgrass) is a marine angiosperm (flowering plant) and one of 12 genera of marine seagrasses world-wide (Hartog and Kuo, 2006; Phillips and Menez, 1988). It grows at depths between the mid-to-low intertidal zone and offshore subtidal depths of 30 meters in Southern California (Phillips and Menez, 1988; Phillips and Echeverria, 1990; Mason, 1957; Coyer et. al, 2007). Both *Z. pacifica* (previously described as *Z. asiatica* by Phillips and Echeverria, 1990) and *Z. marina* are found offshore in the Channel Islands and along the coast of Santa Barbara County (Coyer et. al, 2007), although recently, the results of the Coyer et al. study regarding *Zostera* speciation may be in question (Bryant Chesney, National Marine Fisheries Service, pers. com. with R. Ware, 6 June, 2010). In mainland bays, estuaries, and harbors, *Zostera marina* is more commonly found between the low-to-mid intertidal zone and depths of eight meters. A third species found along the west coast (*Zostera japonica*, "dwarf eelgrass") is an invasive from Asia (Posey, 1998). While its presence in the Pacific Northwest has been known since the early 1900s (Harrison and Bigley, 1982, Phillips, 1984) its presence in California has only recently been established (Humboldt Bay, Foss et al., 2007). However, *Z. japonica* is not known to occur in Newport Bay.

Zostera marina has historically grown in both Lower Newport Bay and Upper Newport Bay, although its distribution and abundance has varied greatly over time (Coastal Resources Management, Inc., 2009). Eelgrass beds are extremely valuable as a fishery habitat and nursery area for marine organisms. The importance of this fishery habitat periodically conflicts with the need for the City of Newport Beach to maintain and sustain a viable commercial and recreational harbor and for residents to maintain the integrity of their boat docks and piers. Consequently, there is a need for the City to document the distribution and abundance of eelgrass- spatially and temporarily-in order to (1) identify harbor project impacts on eelgrass, (2) to mitigate eelgrass habitat losses according to local, state, and federal environmental policy, and (3) to make informed harbor area management policy decisions.

Photograph 1. Eelgrass, *Zostera marina*. *Source Photo: CRM*

In 2003, Coastal Resources Management, Inc. (CRM) was retained by the City of Newport Beach to conduct the first bay-wide eelgrass habitat survey in Newport Bay (Coastal Resources Management, 2005). A total of 30.4 acres of eelgrass were mapped between 2003 and 2004. The study also documented eelgrass turion density at 14 sites throughout Newport Bay. Concurrently, the CRM study was augmented by a National Marine Fisheries Service (NMFS) survey of eelgrass that mapped 93 acres of eelgrass in the deeper navigational channels between Corona del Mar and Balboa Island (NMFS, 2003).

1.2 PROJECT PURPOSE

This present investigation reports on the second set of bay-wide eelgrass surveys conducted by CRM for the City of Newport Beach between September 2006 and August 2008, and research in Newport Harbor that focused on water column oceanographic and sediment conditions in Newport Bay between July 2008 and May 2009. In addition to monitoring temperature, pH, salinity, and dissolved oxygen, the study included the first-ever detailed monitoring of underwater light illuminance and light energy measurements throughout the bay. The purpose of this investigation was to provide the City of Newport Beach with detailed information on the distribution and abundance of eelgrass within Newport Harbor and Upper Newport Bay, and physical and chemical abiotic factors that may influence the distribution of eelgrass. This data base of information will assist the City in managing the bay's eelgrass resources. The public will benefit from the data base by being able to determine what environmental constraints dealing with eelgrass may be associated with infrastructure improvement projects such as bulkhead repair/maintenance, beach nourishment, harbor dredging, and dock and pier construction and maintenance.

1.3 PROJECT SETTING

Newport Bay is located within the city limits of Newport Beach, California (Figure 1). The City is bordered by the coastal cities of Huntington Beach to the northwest and Laguna Beach to the southeast.

Newport Bay is a combination of two geologically distinct bodies of water- Newport Harbor (Lower Newport Bay) and Upper Newport Bay. In recent history, Newport Harbor was a coastal lagoon. It was initially formed between 1824 and 1862 as a consequence of down current sand deposition from the Santa Ana River that formed a sand spit across the mouth of Upper Bay. This sand spit eventually developed into the present-day Balboa Peninsula (Stevenson and Emery 1958), Lower Newport Bay is four miles long and oriented in a northwest-to-southeast direction (Figure 1) parallel to the coastline. Today, the Harbor is a multi-user system. It is: a wildlife habitat this is transitional in nature between the tidal channel and marsh ecosystem of Upper Newport Bay and the open coastal marine environment; a major navigational harbor and anchorage for 9,000 small boats and larger vessels; and a center of business for marine-related activities and tourism (http://www.newportbeach.com/california). The federal navigational channel in Newport Bay is maintained by the U.S. Army Corps of Engineers (USACOE). A June 2008 survey of the channel conducted by the USACOE shows approximately 1 million cubic meters of sediment has accumulated above the authorized Operations and Maintenance (O&M) depths within actively maintained portions of the bay and therefore needs to be dredged (Anchor QEA, 2009). Some areas that need to be dredged however consist of sediments contaminated by historical releases from industrial sources and storm drains adjacent to the bay as well as ongoing runoff from the surrounding watershed. Consequently, studies are being conducted to determine where and how contaminated sediments within the bay should be dealt with (Anchor QEA 2009a, 2009b).

Upper Newport Bay is a drowned river valley and geologically much older than the Lower Bay. It extends in a north-to-northeasterly direction from the Pacific Coast Highway Bridge for a distance of about 3.5 miles and is bounded by the bluffs of the Newport Mesa on the west and the San Joaquin Terrace on the east. The Bay veers east at the "Dike" and extends to the Jamboree Road bridge, where the San Diego Creek empties into the Bay. The Central Orange County Water Management Area encompasses an area of approximately 154 square miles with overland flows draining toward the Pacific Coast into Newport Bay http://www.ocwatersheds.com/wma_CentralOC.aspx. This watershed is the major contributor of suspended sediments, nutrients, and other pollutants to the Newport Bay ecosystem.

Upper Newport Bay is characterized by mudflat, salt marsh, freshwater marsh, riparian, and upland habitats, and sediment control basins that are protected within the 752-acre State of California Upper Newport Bay Ecological Reserve (UNBER). Part of the Upper Bay (140 acres) is under the control of the County of Orange, and is designated as

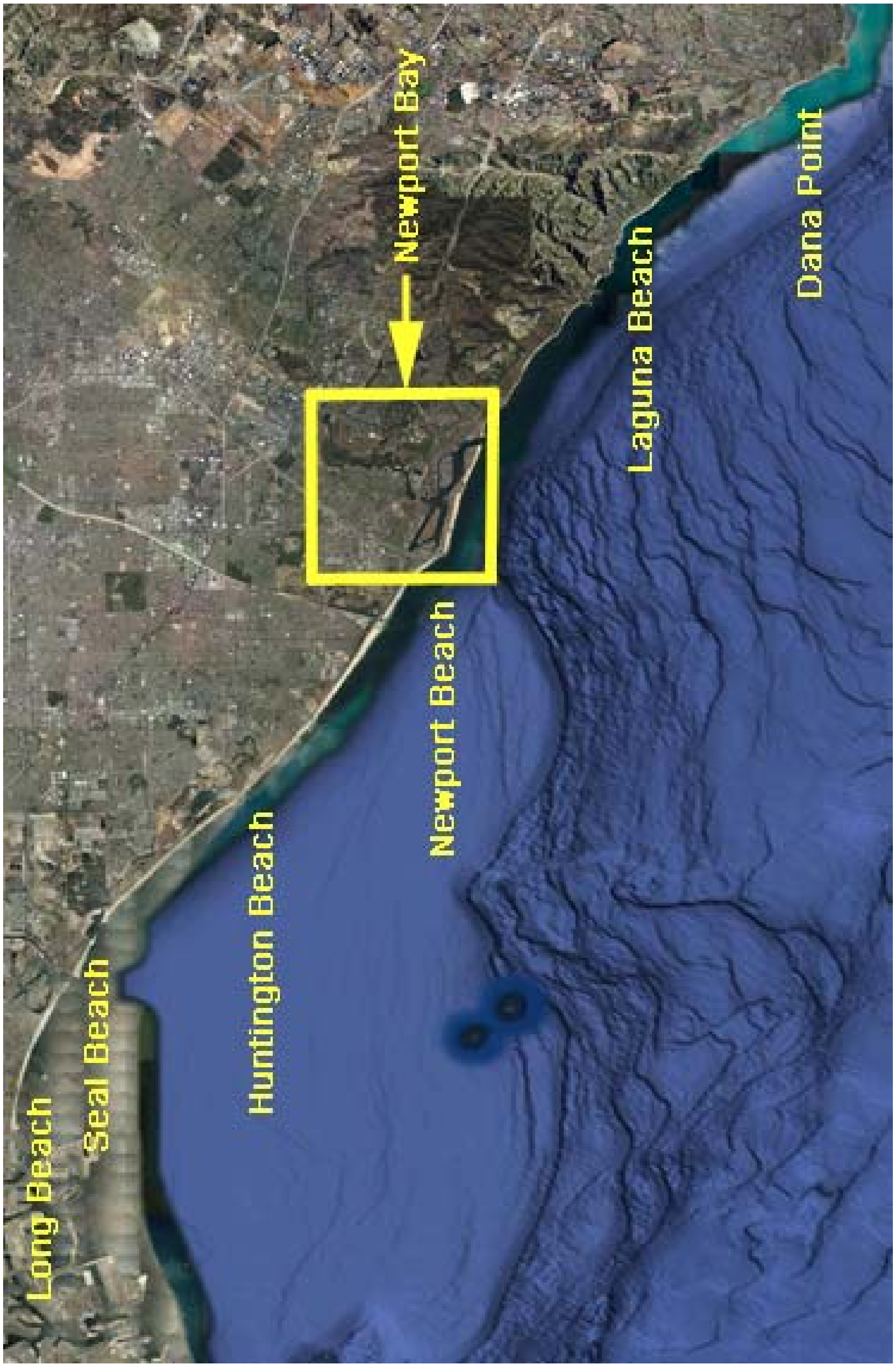


Figure 1. Regional Setting

Orange County Regional Park. While the majority of Upper Newport Bay is primarily a salt marsh system with freshwater influence, the lower one-third below Shellmaker Island and the UNBER has been dredged and filled since the early 1900's for housing development, recreational swimming, marinas, and a boat launch ramp.

Upper Bay sediment basins and channels are currently being dredged as part of the U.S. Army Corps of Engineers Ecological Restoration Project led by the US Army Corps of Engineers. The project involves extensive dredging of sediment, especially to maintain two major in-Bay sediment retention basins (near Jamboree Road and near the Salt Dike). A primary objective of this project is to effect management of sediments deposited within the bay, with the objective of reducing the frequency of dredging projects while also enhancing habitat values within the upper bay and slowing the detrimental impacts of sediment accumulation on the fish and wildlife habitats. These basins keep some sediment from reaching the remainder of the Upper Bay and from the Lower Bay. The dredging will also expand exiting channels that surround various islands in the Upper Bay, including Middle Island. New marsh islands and wetland channel habitat are also being constructed. A large portion of the dredge material is being barged from Upper Newport Bay to the EPA approved offshore disposal site, LA-3, located 6 miles offshore of Newport Beach. Scows and tugs are moored in Lower Newport Bay west of Harbor Island. While planning for the project began in 1993, actual in-bay work was started in 2006. The expected completion date is late 2010. With the restoration of better tidal flow in Upper Newport Bay and the creation of new wetland channels, there is some expectation that eelgrass may be able to recolonize areas of the Upper Newport Bay where it once grew more prolifically.

1.4 EELGRASS REGULATORY SETTING

While eelgrass does not have a formal listing as a state-or-federal endangered, rare, or sensitive species, the California Department of Fish and Game, U.S. Fish and Wildlife Service, and the National Marine Fisheries Service recognize its important as a protected resource and have defined measures to mitigate potential eelgrass habitat losses in the Southern California Eelgrass Mitigation Policy (National Marine Fisheries Service 1991 as amended).

As vegetated shallow water habitat, eelgrass is protected under the Clean Water Act, 1972 (as amended), section 404(b)(1), "Guidelines for Specification of Disposal Sites for Dredged or Fill Material", subpart E, "Potential Impacts on Special Aquatic Sites". This area includes sanctuaries and refuges, wetlands, mudflats, vegetated shallows, coral reefs, riffle, and pool complexes. Environmental legislation under the National Environmental Policy Act (NEPA) and State of California Environmental Quality Act (CEQA) dictates that project designs for coastal projects (1) make all possible attempts to avoid impacts to eelgrass, (2) minimize the degree or magnitude of impacts, (3) rectify, or compensate for unavoidable eelgrass habitat losses by restoring soft bottom habitat with eelgrass using transplant techniques, and (4) reduce or eliminate impacts to eelgrass over time by preservation and maintaining eelgrass over the life of the project.

The fishery value of Newport Harbor and Upper Newport Bay's eelgrass habitat and the need for its protection are also defined in the Essential Fish Habitat (EFH) provisions of the 1996 amendments to the Magnuson-Stevens Fishery Management and Conservation Act (FR 62, 244, December 19, 1997. Eelgrass habitats are considered habitat areas of particular concern (HAPC) for various federally-managed fish species within the Pacific Groundfish Fisheries Management Plan (FMP), (i.e., rockfishes). Designated HAPC, including eelgrass, are not afforded any additional regulatory protection under the Magnuson-Stevens Fishery Management and Conservation Act. However, federally permitted projects with potential adverse impacts to HAPC are more carefully scrutinized during the consultation process (National Marine Fisheries Service, 2008a).

The City of Newport Beach, within its adopted Land Use Plan (City of Newport Beach, 2009) acknowledges the importance of eelgrass in Newport Harbor as well as the "need to maintain and develop coastal-dependent uses in Newport Harbor that may result in impacts to eelgrass" and "Avoid impacts to eelgrass (*Zostera marina*) to the greatest extent possible. Mitigate losses of eelgrass at 1.2 to 1 mitigation ratio and in accordance with the Southern California Eelgrass Mitigation Policy. Encourage the restoration of eelgrass throughout Newport Harbor where feasible" (LUP Policy 4.2.5-1).

1.5 PHYSICAL AND CHEMICAL PROCESSES AFFECTING EELGRASS DISTRIBUTION AND ABUNDANCE

1.5.1 Winds

Daytime wind speeds normal occur from the west or southwest due to onshore flow from the Pacific Ocean. Average daytime maximum speeds are about 4 miles per hour (mph) in the summer and decrease to about 2 mph during winter (USACOE, 2000). Nighttime predominant wind patterns generally find an easterly to northeasterly flow set up from the general offshore flow enhanced by the local thermal drainage. Average night-time wind speeds in the winter reach 2 mph and fall to 1.5 mph during summer.

Strong offshore winds generate wind waves of about 0.5 ft from spring to summer in Upper Newport Bay. Funneling of winds within Upper Newport Bay can create frequent periods when winds exceed 15 mph. Santa Ana winds can achieve speeds in excess of 40 mph and are capable of creating waves in UNB of one to two feet. These waves can erode the shoreline (Stevenson and Emery, 1958).

1.5.2 Tides and Currents

Tides in Newport Bay are semi-diurnal, mixed tides with two high tides and two low tides each day. The heights of the two high and the two low tides are unequal, due to the phases of the moon and sun during the 28-day lunar cycle. Tides in Upper Bay are slightly higher than those at the harbor entrance and the time of the high tide in the Upper Bay is later than at the entrance channel by about 25 minutes (USACOE, 1992). Large storm events and El Nino Oscillation Events can affect tidal ranges. During a storm on 6 December, 1997, observed tides were 0.6 to 1.4 feet higher than the NOAA tide charts that year to the effects of El Nino (USACOE, 2000).

Some water motion is needed to supply nutrients to the plants, cool the flats, and prevent the buildup of floating organic matter that can smother eelgrass (Thom et al., 2003). Strong waves and currents will erode the sediment in an eelgrass bed (Phillips, 1984). Eelgrass will develop growth patterns based upon current velocities. In Newport Bay, the rate at tidal flushing occurs is dependent upon distance from the source of tidal change, the ocean entrance channel (Everest International Consultants, Inc., 2009). Tidal flushing rates for the bay range between less than one day near the ocean entrance channel to over 30 days in the channels of West Newport and above the “dike” in Upper Newport Bay (Figure 2). The distribution of eelgrass appears to be heavily influenced by the amount of time it takes to fully flush the bay based upon these tidal flushing rates (Coastal Resources Management Inc., 2009). Longer periods between complete tidal flushing reduces water quality by increasing water temperatures, lowering dissolved oxygen, and increasing the length of time that suspended sediments prevent light from illuminating the seafloor.

Currents in the Bay are driven by tides, seasonal fresh water inputs from major stream flows, and to a certain degree, winds. Generally current speeds range from about 0.5 to 1.8 feet/second (ft/sec) (0.3 to 1.1 knots) although maximum ebb currents may reach 4 ft/sec (2.5 knots) during extremely high flows (USACOE, 2000). Circulation in the Upper Bay is limited in smaller channels; typical current speeds in the main channel areas of the bay during non-storm periods are not considered erosive, but they are capable of transporting fine sediments resuspended by waves.

Generally, currents are strongest at the more constricted points in the bay between the Upper Bay Sediment Control Basins and PCH Bridge. Current magnitudes in the shallowest portions of sediment basins, side channels, and mudflats are considerably less than those found in the main channel; algae tends to proliferate in these areas. Low current areas in Upper Newport Bay include side channels around Middle Island and Shellmaker Island, the channel and mudflats immediately south of Middle Island, Newport Dunes, and Dover Shores.

The County of Orange (2010) measured tidal currents in Lower and Upper Newport Bay on an ebb tide during a storm event on 15 December 2008. Current velocities were 1.9 ft/sec at the UNB Unit 1 Basin; 2.13 ft/sec at the UNB Unit 2 Sediment Basin; 2.43 ft/sec at North Star Beach; 1.21 ft/sec at the PCH Bridge; and 1.42 ft/sec near Bay Island (Harbor Island Reach).

Current velocities were measured by Coastal Frontiers Corporation in Upper Newport Bay during non-storm event conditions on 11-12 June, 1992 during the USACOE Upper Newport Bay Reconnaissance Studies (ACOE, 1992). Current velocities at the Dike (i.e., Unit 2 Basin) ranged from approximately 0.5 ft/sec (ebb tide) to 0.25 ft/sec (flood tide). At North Star Beach, current velocities ranged between 1.1 ft/sec (ebb tide) to 0.8 ft/sec (flood tide). At the PCH Bridge, current velocities varied between 1.5 ft/sec (ebb tide) and 1.2 ft/sec (flood tide).

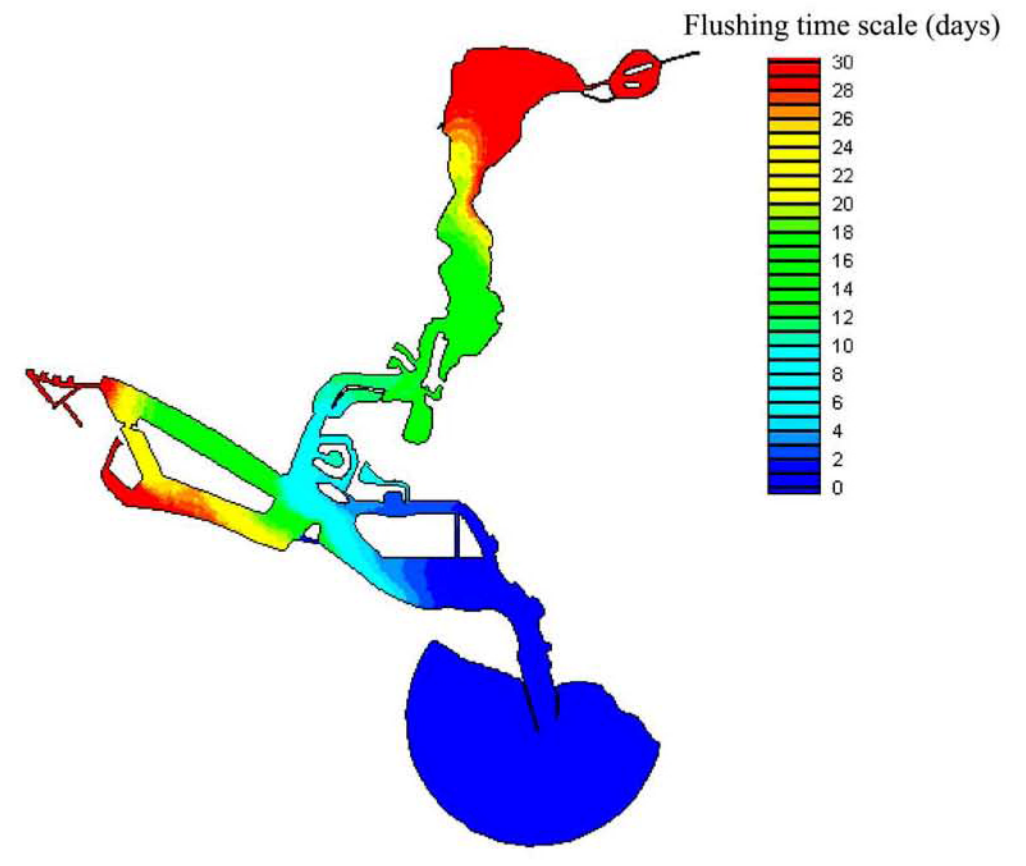


Figure 2. Tidal Flushing Rates in Newport Bay.
Source: Ying Poon, Everest International Consultants

1.5.3 Sediments

Eelgrass colonizes a range of sediments varying from firm sand with moderate wave action to soft muds in quiet bays (Phillips, 1984). Healthy beds are found in sediments with high sand proportions, although this is highly variable depending on the system. For example, in the San Juan Islands, eelgrass was healthiest in the northeastern portion of Padilla Bay (Takesue et al., 2005) which was dominated by fine sands (80%) by weight. It was absent from sites in south Padilla Bay which were dominated by fine silts (67% by weight). Eelgrass grows in predominantly fine sand sediments between the Entrance Channel to Harbor Island, while in most other areas of the Bay, eelgrass colonizes siltier, less compacted sediments. Except in higher current velocity channels, sediment particle size generally decreases with increasing depth in Newport Bay (Ware, 1993; Chambers Group Inc. and Coastal Resources Management 1998, 1999).

1.5.4 Depth

The upper elevational range limit of eelgrass on naturally sloped shorelines is primarily regulated by several factors including desiccation, sediment stability, and wave shock (Phillips, 1984, Boese et al., 2005). In Newport Bay this limit appears to be approximately at the Mean Lower Low Water mark (0.0 ft) although it can occur as high as +1 ft (MLLW). However, in many areas of Newport Bay and other modified southern

California embayments, its upper range limit is also affected by dredging and bulkheading activity that eliminates natural intertidal slopes and eelgrass meadows (Ware, 1993). Its lower depth limit is a function of light attenuation (Duarte, 1991) and irradiance (Backman and Barilotti, 1976; Zimmerman et al., 1991).

In Newport Bay, eelgrass is found at depths as great as -28 ft MLLW (-8.5 meters) in the Harbor Entrance Channel, although it more typically occurs at depths from 0.0 ft and -8.0 ft (0 to 2.4 meters) in other areas of Newport Bay (Ware, 1993; NMFS, 2003; CRM, Inc., 2005, Chambers Consultants Inc. and Coastal Resources Management, 1998 and 1999).

1.5.5 Light

Light is a primary factor that controls the distribution, density, growth and productivity of seagrasses (Ochieng et al. 2010; Simenstad et. al, 1997, Thayer et al., 1984; Backman and Barilotti, 1976; Zimmerman et al., 1991). In Newport Bay, as other shallow-water embayments, light penetration is affected by parameters such as time of day and year, tidal condition, suspended organics and sediment input into the bay from dry-season runoff, winter storms, plankton blooms, shading from docks and boats, and in-bay activities such as dredging and boating activity (Merkel and Associates 1996, MBC Applied Environmental Sciences and SCCWRP, 1980; CRM, Inc., 2009). Light penetrates deeper during the incoming tides compared to outgoing tides which carry higher levels of suspended organics and sediments out of Newport Bay. Zimmerman et al. (1991) estimated that eelgrass in San Francisco Bay required between three and five hours a day of irradiance to maintain carbon balance and growth, and suggested that eelgrass is adapted to extremely low light availability.

Water column turbidity was identified as a major factor determining eelgrass distribution in Dumas Bay, Washington (Norman et al., 1995), and in San Francisco Bay (Zimmerman et al., 1991 and 1995). Turbidity also appears to influence the distribution of eelgrass in Newport Bay. Eelgrass exhibits a greater depth range nearer the harbor entrance compared eelgrass beds located near Harbor Island, Balboa Island, Linda Isle, and Upper Newport Bay where water clarity is poorer and sediments are much finer (Coastal Resources Management, Inc., 2005).

Generally, the compensation depth (the depth of water where there is sufficient light so that photosynthesis equals respiration) for all seagrasses is about 11% of the available surface irradiance (Duarte, 1991). Dennison (1987) and Gallegos (1994) both have suggested eelgrass, in particular, is generally limited to depths where light is at least 15-25 % of surface irradiance. Seagrass growth and distribution are also affected by a decrease in solar radiation resulting from seafloor shading from docks, piers, and vessels (Beal and Schmidt, 2000). Studies indicate that shoot densities of seagrasses decrease near docks and pilings and that the construction of docks and piers can lead to a permanent loss of seagrass vegetation (Beal and Schmit, 2000). Pier and gangway height will affect how much light can penetrate beneath the piers. In locations in Newport Bay such as Corona del Mar, where piers are elevated 10-12 feet above the eelgrass, eelgrass will grow underneath these structures although their densities can be significantly reduced. In 2004, eelgrass turion densities were 65% less in shaded areas underneath a pier in Carnation Cove, Newport Bay compared to nearby open intertidal habitat (Coastal Resources Management, Inc., 2004).

1.5.6 Temperature

Eelgrass is a eurythermal species (Phillips, 1984). Its optimal temperature distribution is between 10° Celsius and 20 ° C (50 ° F to 68 ° F). Its extreme temperature ranges may vary from -6 ° C in Alaska to 40.5 °C (21.2 ° F to 104.9 ° F). Although there are a number of factors to consider, it is widely considered that a sustained temperature approaching 25 °C is the upper tolerance limit for eelgrass (Zimmerman et al., 1989; Bintz et al., 2003). In most areas of Lower Newport Bay, temperatures are generally not a limiting factor for eelgrass growth and distribution. During late summer, water temperatures in Newport Bay can exceed 24 ° C for sustained periods of time that promote seasonal biofouling of the blades (Coastal Resources Management, this report). The heavy blades then bend and come in contact with the sediments that lead to eventual burial and loss of eelgrass above-ground biomass. Seasonal water temperature increases will also result in increased competition for space between eelgrass and macroalgae, as well as between eelgrass and masses of the soft bryozoan, *Zoobotryon verticillatum* that attach to eelgrass and bottom debris. Both conditions can lead to reduced levels of light available for eelgrass.

1.5.7 Oxygen

Oxygen necessary to drive aerobic metabolism in seagrasses is derived from internal oxygen produced by photosynthesis and from passive diffusion of oxygen from water the water column or sediments under conditions when external oxygen partial pressures in the system exceed internal tissue oxygen partial pressures (Borum, et al., 2006). Oxygen is not a limiting factor or constitutes a stress on eelgrass systems (Phillips, 1984). As a primary producer, eelgrass fixes carbon at rates that are equivalent to or exceed the rates of the most intensively farmed agricultural crops (Thayer et al., 1984). However, during periods of high turbidity that reduces light levels, there is a decrease in photosynthesis and oxygen production and eelgrass root and rhizome tissue may experience periods of hypoxia and anoxia. While eelgrass tissue apparently can withstand 24 hour anoxic periods, (Smith, 1989), the long-term cumulative effects of prolonged anoxia are not known, but it is possible that eelgrass distribution, particularly at its deeper limit, may be negatively affected (Zimmerman et al., 1991).

1.5.8 Salinity

Eelgrass is a eurysaline species, tolerating a wide range of water salinities including the ranges that Newport Harbor waters experience. It has been documented to grow at stream mouths when the water is fresh at low tide (Phillips, 1984) but does not grow in persistent fresh water. At the other extreme, eelgrass can grow in hyper saline waters, of up to 42 parts per thousand (ppt). In Puget Sound, eelgrass grows best in a salinity of 20 to 32 ppt. Phillips (1972) found that most (70%) eelgrass seed germination occurred at 5 to 10 ppt at all temperatures, although at 10 ppt, seed germination often doubled from 10 C to 15C but did not do so in full strength seawater (30 ppt). Newport Bay salinity, on the average ranges between about 30 to 34 ppt, although during wet periods, surface salinity may decrease to below 25 ppt for short periods of time (County of Orange, 2005). Salinity is typically lower in the Upper Bay due to year-around runoff from the Newport Bay watershed (County of Orange, 2004; 1978).

1.5.9 Nutrients

Eutrophication is one of the main causes for decreased light availability that can lead to a decline of eelgrass populations. As excess nutrients stimulate phytoplankton growth, light penetration to the plants growing at depth is reduced. Increased epiphytic (and benthic) macroalgae growth from excessive nutrient loading can shade and suffocate eelgrass plants. As light diminishes, the plants develop thinner blades, leading to lower rates of productivity and a decrease in biomass and lower shoot densities (Denison, 1987). Decaying vegetation creates an anaerobic layer in the sediments that is necessary for the sulfur bacteria and the sulfur cycle to occur, which re-mineralize nutrients from the entrapped litter (Phillips, 1984). This process then leads to the recycling of nutrients (i.e., carbon, nitrogen, phosphorous) up through the root and rhizome system within the eelgrass meadow (Phillips, 1984).

1.5.10 Synergistic effects

Submarine light levels, turbidity, and temperature variations affect seagrass populations (Dixon, 2000). Within Newport Bay, these variables have not been investigated relative to the health of eelgrass beds. These data are required to understand the observed differences in eelgrass cover and density among the various regions of the bay, and to identify areas that may or may not be suitable for future eelgrass transplants. Consequently, the present studies are currently being conducted to address these issues and how abiotic parameters influence eelgrass distribution in the Bay.

1.6 EELGRASS BIOLOGY AND ECOLOGY

1.6.1 Distribution and Structure

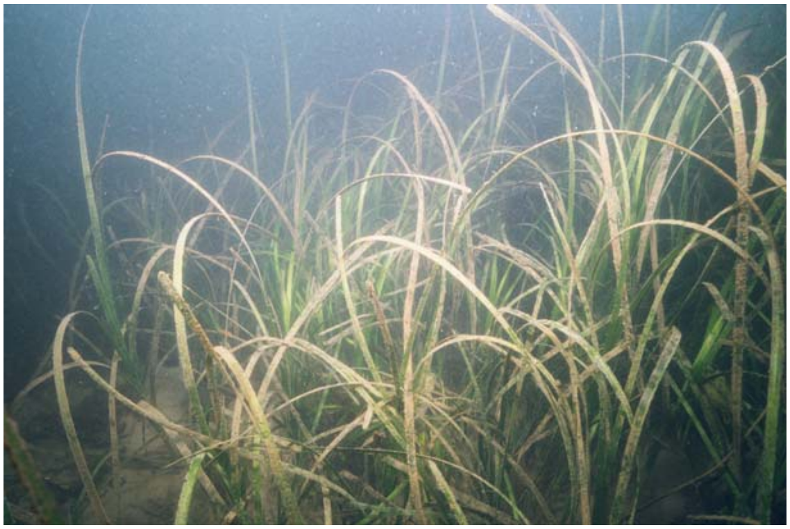
As mentioned, *Z. marina*'s elevational range limit is regulated by a combination of factors, although desiccation is a primary factor. Other influences on the upper elevation limit of eelgrass include sediment stability and wave shock. Its lower depth limit is a function of irradiance, sediment type, and current speed (Thayer et al. 1975; Phillips, 1984). Tamaki et al. (2002) noted that large amounts of sediment deposition on leaves related to water pollution and/or eutrophication seemed to be a factor to inhibit the survival of eelgrass at the outside edge eelgrass meadows. In many cases, the outer edge of a bed may also be deeper, so that natural light limitations and increased sediment deposition on leaves may act synergistically to limit eelgrass growth, particularly in low-current flow environments. Harbor and marina construction, and maintenance dredging projects that widen and deepen channels or replace natural shoreline slopes with vertical bulkheads eliminate the intertidal and shallow subtidal softscape often vegetated with eelgrass and artificially restricts the upper and lower range limits.

Zostera marina displays perennial growth along the Pacific Coast (Phillips, 1984) and exhibits seasonal growth and dieback that is correlated to water temperature and irradiance (Backman and Barilotti, 1976). *Z. japonica* however, displays annual growth. The typical growing season for *Z. marina* shoots and leaves (above ground growth) is between spring and summer; dieback occurs following periods of thermal stress. Above-ground growth declines between late fall and winter, although root and rhizome growth and vegetative spreading still is active. Increases in meadow size occur by the vegetative spreading of below ground root/rhizome mass.

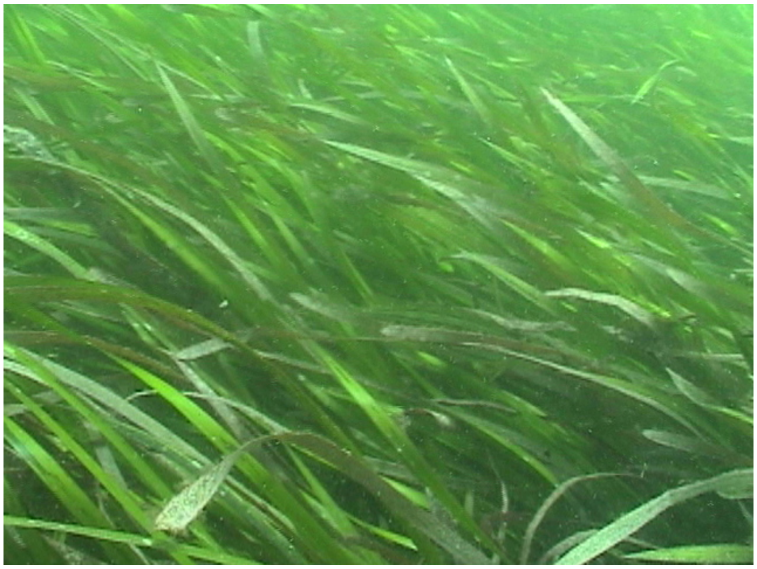
Shoots and leaves which can vary in length between several centimeters to over one meter long protrude above the sediment and vegetatively sprout from the root-rhizome mass below the sediment surface. Oxygen is shunted from the leaves to the roots and rhizomes which is driven by the gradient between high oxygen partial pressures in leaves or water and low partial pressure in roots and sediments (Borum et al., 2006). The root-rhizome mass functions as the plant's anchoring system as well as the primary site of nutrient uptake from the sediments. The roots penetrate deep into softer muds, but take on a mat-like form to adapt to sandy and swifter current habitats. The accumulation of senescent blades, shoots, and roots increases the sediment nutrient pool and creates anaerobic conditions within a few centimeters below the sediment surface. Nutrients are primarily absorbed from the sediments, translocated to the above ground biomass (shoots and leaves) and released to the water column (Phillips, 1984).

A seagrass meadow is defined by a visible boundary grading from an unvegetated to vegetated substrate (Thayer et. al, 1984) and can vary in size from discontinuous, isolated "patches" to large continuous coverage over many acres. Eelgrass "beds" and "patches" are terms associated with localized subsets of an eelgrass meadow separated by unvegetated bottom (Ware, 1993). Within a meadow, eelgrass blade length and shoot density can be highly variable as a result of water temperature, water currents, sediment characteristics, and water depth.

Eelgrass may display some genetic and/or environmental-associated variations in response to water temperature and/or light requirements. In Newport Bay, two forms are known- a narrow bladed form and a wide-bladed form. The wide-bladed eelgrass is found in the Newport Harbor Entrance Channel and Corona del Mar eelgrass beds while the narrow bladed variant occurs throughout most of the bay. It is not known if the wide-bladed form is a variant of *Z. marina*, or if it is separate species (i.e., *Zostera pacifica?)* that may occur along the outer coast of Santa Barbara County and the Channel Islands (Coyer et al., 2007). Genetic studies are required to determine its speciation. Until this issue is clarified, this wide-bladed form in Newport Bay is considered a variant of *Z. marina*.



Photograph 2. Narrow-bladed eelgrass form in Newport Bay. Source Photo: CRM



Photograph 3. Wide-bladed eelgrass form in Newport Harbor Entrance Channel. Source Photo: CRM

Epiphytes such as diatoms and green algae that attach to eelgrass blades add to the high productivity of eelgrass beds (Thayer et al. 1984; Phillips and Menez, 1988). The organic matter in the form of shoots, blades, and roots is transferred to both invertebrate and vertebrate secondary consumers that feed on the particulate matter through the detrital feeding pathway. In addition invertebrate and fish predators forage upon the diverse types of detrital feeding invertebrates which congregate within eelgrass habitat.

A significant proportion of the organics produced within eelgrass meadows is retained within the eelgrass system and recycled through the detrital food web (Zieman and Wetzel, 1974) but some carbon is exported by tidal currents to the offshore environment in the form of senescent blades, particulates, and dissolved organics. This exported detrital material can contribute to nearshore secondary production and can in some areas, contribute to detrital food chains of deep sea systems (Wolff, 1980). The exported leaves and shoots (and in many cases whole plants) are often abundant in the beach litter that is deposited at the high-tide line along the Huntington Beach, Newport Beach, Corona del Mar and Crystal Cove shorelines (R. Ware, pers. observations).

1.6.2 Biological Interactions

Eelgrass meadows (and subunits referred to as "beds" and "patches") are an important habitat for invertebrates as a source of food and attachment and biological cover, and for marine fishes that seek the shelter of the beds for protection and forage on the invertebrates that colonize the eelgrass blades and sediments in and around eelgrass vegetation (Ware, 1993).

The physical structure provided by eelgrass allows a multitude of epiphytes (diatoms and algae) and epifauna (worms, snails and crustaceans) to live on the shoots and blades; by infauna (worms, clams, and crustaceans) that live in the sediment among the roots and rhizomes; and by various demersal and water column fish which find protection and forage within the meadow. Invertebrates and fishes may be found in eelgrass meadows seeking shelter and food at different stages of their life history (Thayer et. al 1984, Phillips and Menez, 1988). Some are residents in eelgrass meadows (i.e., benthic invertebrates, epifauna, pipefish and kelpfish). Others utilize eelgrass during their juvenile life stages (lobster, barred sand bass, spotted sand bass, and California halibut) or seek food in the meadow on a daily or opportunistic basis (predatory snails, topsmelt, anchovy, perch, round sting rays, and kelp bass). Transient species use eelgrass meadows opportunistically as they happen upon shelter or food in the meadow (crabs, sea stars, urchins, topsmelt, surfperch and seaperch).

A combination of low and high density canopy, and open patches of unvegetated sediment may contribute to a greater diversity of organisms and a more complex ecological system. For example-open, unvegetated areas in eelgrass beds are frequented by demersal (bottom) fishes such as sand bass, staghorn sculpin, turbot, California halibut, and round stingray). Some disrupt the bottom sediments (bioturbation) and create their own open habitat in eelgrass beds as they forage in the muds (Merkel 1990). Dense, long-bladed canopy will provide a greater degree of protection and shelter for cryptic, resident species (canopy-associated pipefish and kelpfish), and shelter or foraging habitat for transients (surfperch and topsmelt).

Directed research in other southern California embayments concerning the value of eelgrass beds as a nursery or wildlife habitat has not received high priority although several studies (MBC, 1986; Hoffman, 1986, 1990, 1991) suggest the marine life of eelgrass meadows is enhanced in numbers, species, and standing crop compared to unvegetated soft bottom habitat. Infaunal and epifaunal invertebrate studies conducted in Mission Bay, Sunset Bay and Huntington Harbour eelgrass meadows suggest vegetated bay sediments support a higher diversity of invertebrates compared to unvegetated bay sediments because of the added structure and habitat (MBC Applied Environmental Sciences, 1986). Ninety-seven species of epifauna (plants and invertebrates living on the blades and shoots of eelgrass) were collected from in Mission Bay, Sunset Bay, and Huntington Harbour. Community composition and abundances were dominated by crustaceans (39 species), polychaete worms (23 species) and mollusks (13 species). Other common epifaunal invertebrates included nemertean worms, ectoprocts, hydrozoans, nematodes, and ascidians. The benthic community living amongst the root-rhizome mass included 216 species of invertebrates, dominated in richness and abundance by 87 species of polychaete worms, 63 species of crustaceans, 28 species of clams and 17 species of snails. Dominant organisms in both the epifauna and infaunal communities were species that occur commonly throughout embayments of Southern California. Eelgrass in Newport Bay, and other southern California bays also support unusual or rare species, including Pacific seahorse (*Hippocampus ingens*) that became established as a result of warm water intrusions into Southern California produced by El Nino conditions and the juvenile broad-eared pecten (*Leptopecten latiauratus*) which attaches to eelgrass shoots and blades.

Eelgrass meadows are also foraging centers for endangered seabirds such as the California least tern (*Sterna albifrons browni*) and California brown pelican (*Pelecanus occidentalis*) that feed on topsmelt and anchovy that congregate within eelgrass meadows.

1.6.3 Macroalgae and Macronutrients

Eelgrass competes with macroalgae for space and sunlight, and seasonal blooms of green algae can blanket eelgrass beds (R. Ware, pers. observation. Coastal Resources Management, Inc., 2005). Such events can contribute to year-to-year variations in eelgrass abundance throughout Newport Bay. Eelgrass meadows in Newport Bay often co-occur in the low intertidal or shallow subtidal zone with green algae (*Chaetomorpha* cf. *linum and Enteromorpha spp.)*, and in deeper parts of the meadow, with brown algae (*Ectocarpus sp.,*) and red algae (*Acrosorium* and *Gracilaria).* In areas of poor water circulation where tidal flushing rates are low, green algae is more abundant. In other areas (particularly in mid Newport Harbor and along Mariners Mile) the red algae *Acrosorium* competes with eelgrass for space and light (Coastal Resources Management, Inc., 2005). The combination of poor water circulation, warm water temperatures and high algal productivity in areas such as Newport Shores and West Newport Bay may affect the ability of eelgrass to colonize these areas. However, water quality improvements in the Newport Bay watershed (County of Orange, 2003, 2004) over the long-term, will benefit eelgrass by reducing turbidity, macroalgae competition, and shading.

Relationships between nutrients and macroalgae abundances and species compositions have been examined in Upper Newport Bay (SCCWRP, 2003; County of Orange, 2003, 2004, 2005). Findings of these studies indicate that nitrate, rather than organic nitrogen is the most common and the most bioavailable nitrogen source. Between 1996 and 2003, the incidence of nuisance algal blooms in the Upper Bay diminished (County of Orange, 2003). In addition, algal biomass decreased along a gradient between San Diego Creek and the Pacific Coast Highway Bridge. The decline in nuisance seaweeds in Upper Newport Bay was similar to those found for all kinds of algae when the limiting nutrient(s) are reduced. The most obvious explanation for the reductions in seaweeds in Newport Bay was the reduction in nitrate entering from San Diego Creek. Nezlin et al.,

2009) documented a combination of high macro algal biomass and vertical stratification that significantly contributed to hypoxic (low oxygen levels) in Upper Newport Bay.

1.6.4 Invasive Species

Caulerpa taxifolia (also known as noxious algae, see Photograph 4) has a potential to cause ecosystem-level impacts in Newport Bay and nearshore systems due to its extreme ability to out-compete other algae and seagrasses. grows as a dense smothering blanket, covering and killing all native aquatic vegetation in its path when introduced in a non-native marine habitat. Fish, invertebrates, marine mammals, and sea birds that are dependent on native marine vegetation are displaced or die off from the areas where they once thrived. It is a tropical-subtropical species that is used in aquariums. It was introduced into southern California in 2000 (Agua Hedionda Lagoon) and (Huntington Harbour) by way of individuals likely dumping their aquaria waters into storm drains, or directly into the lagoons. While outbreaks have been contained, the Water Resources Board, through the National Marine Fisheries Service and the California Department of Fish and Game require that pre-construction invasive algae surveys must be conducted to determine if this species is presence using standard agency-approved protocols and by National Marine Fisheries Service/California Department of Fish and Game Certified Field Surveyors for projects which have a potential to spread this species through dredging and other bottom-disturbing activities (National Marine Fisheries Service, 2008b).

Photograph 4. Noxious Algae, *Caulerpa taxifolia.* An invasive algae from the Mediterranean Sea. Source Photo: National Marine Fisheries Service

1.6.5 Recreational Fisheries

From a recreational standpoint, eelgrass meadows in Newport Bay provide fishing opportunities for boat and kayak fishermen; this translates into a consistent economic base for businesses within Newport Beach including the recreational fishing industry, boat and kayak rental/retail stores, and food concessions (Coastal Resources Management, Inc., 2009). Detailed bay fishing charts of Newport Harbor are available that include the CRM 2003-2004 eelgrass habitat maps produced for the Harbor Resources Division (http;//www.bajadirections.com).

1.6.6 Habitat Alterations

Seagrasses and associated invertebrates and fishes living within or dependent on seagrass beds as a source of protection or food are sensitive to environmental changes that result in shading, water motion changes, and habitat alteration. In many cases, these changes accompany the development of bays and harbors on international and local scales (Waycott et al., 2010, Ware, 1993). Globally, seagrass bed losses have accelerated from a median of 0.9% per year before 1940 to 7 % per year since 1990 and they have been disappearing at a rate of 110 km^2 per year (42 $miles^2$ per year) since 1980. The rate of seagrass habitat loss places it among the most threatened ecosystems on earth.

From a resource management perspective, seagrass distribution often conflicts with development and uses in the coastal zone (Coastal Resources Management, Inc. 2009, Waycott et al., 2010). Dredging, filling, and bulkheading in bays and harbors can directly impact seagrasses growing on soft bottom through burial or removal of vegetation (Phillips, 1984; Moore and Short, 2006; Waycott et al, 2010). Numerous other activities (i.e., boat propeller and anchor damage) or natural events (i.e., heavy seasonal run-off) may also directly impact or indirectly affect the distribution and abundance of seagrasses. Dredging and wastewater discharges may increase water turbidity and decrease the amount of underwater irradiance that reaches the bottom (Short and Wyllie- Echeverria, 1996; Short and Burdick, 1996; Zimmerman, 2006). Boat dock and pier construction can permanently shade or reduce the amount of light beneath structures (Beal and Schmit, 2000, Landry et al., 2008, Thom, 2006)). Climate change is expected to have deleterious effects on seagrasses (Waycott et al., 2010) although Zimmerman (2006) noted that the potential impact of increased atmospheric [CO_2] concentrations on eelgrass in Elkhorn Slough (as estimated by biophysical modeling) would be a 35% increase in eelgrass acreage due to a doubling of [CO_2]. Petrochemical spills from vessels, storage facilities, and waste-water sources and associated clean-up techniques using dispersants may pose a threat to coastal seagrass systems through direct smothering or the toxic effects of the water soluble fraction (WSF) of oil (Ralph et al, 2006), especially for intertidal seagrass meadows where oil is stranded. While short-term effects of oiling can include reduced growth rates, blackened leaves, and mortality (Ralph et a., 2006), seagrass meadows that were oiled in the Gulf War and by the Exxon Valdez spill showed little effects after one year of oiling. Recovery of deeper-occurring seagrasses exposed to water soluble fractions of oil (PAHs) alone is generally much more successful than recovery of smothered intertidal seagrasses (Ralph et al., 2006).

2.0 PROJECT FIELD METHODS AND MATERIALS

2.1 PROJECT STAFF

The primary eelgrass and oceanographic survey team included CRM marine biologists Rick Ware (Principal Investigator, M.S Biology), Stephen Whitaker (Field team leader, M.S., Biology), and Tom Gerlinger (M.S., Biology). Other staff participating in the surveys included Laurie Allen Requa (M.S., Marine Biology), Lein Jenkins (B.S., Marine Biology), Robin Cadiz (B.S., Marine Biology) and Robin Kohler (marine technician). Rick Hollar (Senior Oceanographer, Nearshore and Wetland Surveys) was the principal investigator for sidescan sonar surveys. Mr. Ryan Stadlman (City of Newport Beach GIS Department) assisted CRM in GIS presentations, calculated final eelgrass habitat acreages for sections of the harbor, and made the GIS data available to the public by uploading the maps to the City's website. Chris Miller and Tom Rossmiller (Harbor Resources Department) managed the project for the City of Newport Beach and provided logistical support.

2.2 PROJECT LOCATION

Studies were conducted in Newport Bay, Orange County, California (Figures 1 and 2). The project area included the intertidal and subtidal soft bottom habitats between Lower Newport Bay (Newport Harbor) and the southern reach of Upper Newport Bay between the Coast Highway Bridge and Dover Shores (Figure 2). Sediment and water quality sampling stations are shown in Figure 3 and listed in Table 1. Two regions within Upper Newport Bay were not surveyed for eelgrass during this study because they are managed by different agencies (California Department of Fish and Game and the County of Orange). However, these regions were surveyed during the period of study by MBC Applied Environmental Sciences for the Army Corps of Engineers in 2004 and 2006; Chambers Group, Inc. for the County of Orange Dunes Marina Dredge Project (2006); and Coastal Resources Management, Inc. for the Dunes Marina Dredge Project (2007) and the Dover Shores Community Association Dredge Project (2008b). The surveys excluded the Rhine Channel and channel west of Newport Blvd. However, site-specific surveys have been conducted in these areas in the past and the results of these surveys have been integrated into the discussion section of this report.

2.3 SURVEY DATES

Eelgrass surveys were conducted between September 2006 and August 2008. During this period, diver-biologist mapping occurred between September 2006 and October 2007, and eelgrass shoot density counts and length/width measurements were made between June and August 2008. Navigational channel sidescan sonar surveys were conducted in July 2008. Sediment grain size samples were collected in August 2008 and oceanographic and underwater light intensity studies were conducted during three sets of surveys-July/August 2008, November/December 2008, and March to May 2009.

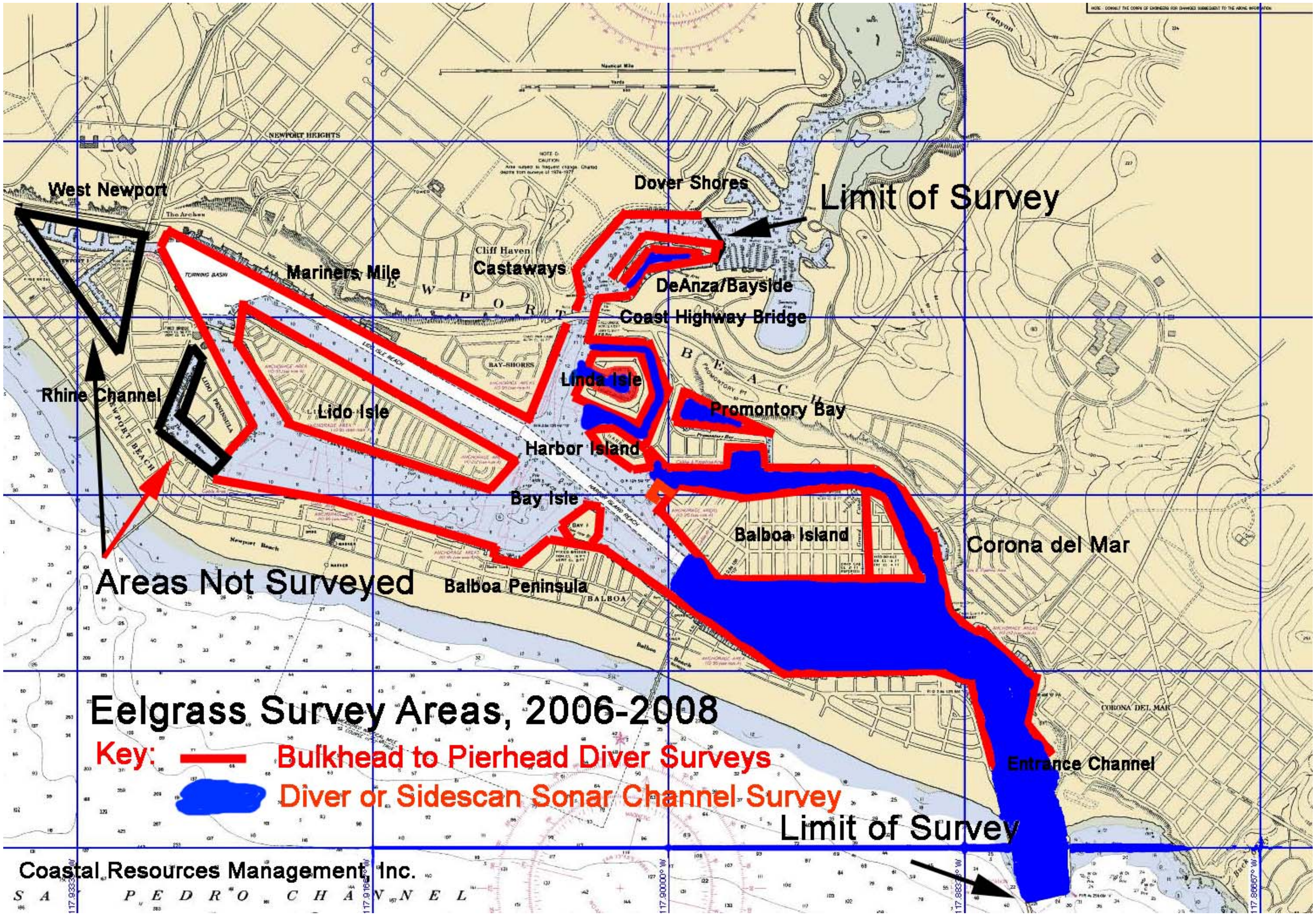


Figure 3 Location and Boundaries of Eelgrass Habitat Surveys, 2006-2008. Refer to Figure 2 for locations of water quality and sediment quality sampling stations.

Figure 4. Water Quality and Sediment Sampling Locations

Table 1 Description of Water and Sediment Quality Sampling Stations (See Figure 4)	
Station	**Description**
1	West Jetty
2	China Cove
3	Juncture East/South Balboa Island
4	Grand Canal
5	“I” Street, Balboa Peninsula
6	North Balboa Island
7	Harbor Island (South)
8	Bay Isle
9	Bayshores/Coast Highway Bridge
10	Upper Newport Bay (Dover Shores)
11	10th Street Beach, Balboa Peninsula
12	Rhine Channel 18th Street
13	Lido Reach Turning Basin
14	East Balboa Island
15	North Harbor Island
16	Inner Linda Isle
17	Balboa Channel (East)
19	Mooring Area B, Main Channel

2.4 SURVEY METHODS

2.4.1 Water and Sediment Sampling

Oceanographic Data. Oceanographic data were collected at 17 stations throughout Newport Bay weekly between July 20th and August 28th, 2008; November 18th and December 11th, 2008; and March 9th-May 2nd, 2009. A YSI 556 Multiprobe System (MPS) water quality meter was used to measure water temperature, hydrogen ion concentration (pH), dissolved oxygen, and salinity at three depths- 1 foot (ft) [0.3 meter] below the surface, mid-depth, and 1 ft (0.3 meter) above the seafloor. Water transparency was measured with a secchi disk. YSI-collected data were averaged over two, twenty-second sampling replicates at each depth. All data were digitally stored within the YSI 556 MPS unit for later data reduction.

Light-Temperature Data Loggers. In concert with the July 2008-May 2009 water quality monitoring surveys, CRM deployed a series of Onset Company Temperature and Light HOBO Pendant Data Loggers (Model UA-002-64; Photograph 5) at 17 stations in Lower and Upper Newport Bay between July 22nd and August 28, 2008; November 18th and December 11th, 2008; and March 9th-May 2nd, 2009 within eelgrass vegetated areas and unvegetated areas. The purpose was to assess variations in water temperature and illuminance on the bayfloor during maximum daily photoperiods (10 am to 3 pm) in areas where eelgrass is present and absent.

Two data loggers were deployed at each station. One data logger was deployed at a depth of 1 ft (0.3 m) below the surface (the "surface logger") and suspended from a horizontally-positioned section of PVC pipe that was attached to a mooring buoy or speed can anchor chain. A second data logger (the "bottom logger") was buoyed to a cement block or the bottom of the mooring buoy anchor chain and suspended at a calibrated depth of -4 to -5 ft Mean Lower Low Water at each station. This depth approximates the lower depth limit of eelgrass in many parts of Newport Harbor and Upper Newport Bay. In the absence of eelgrass vegetation, this depth simulates depths where eelgrass grows in other parts of the harbor. A surface depth data logger was not deployed in the Entrance Channel (S1) due to heavy navigational traffic; therefore data for the surface depth data logger for the nearest site (S2) was used as the surface data logger for S1.

In addition, an out-of-water light intensity "reference" data logger was positioned mid-bay at S9 in the main channel approximately 700 ft south of the Coast Highway Bridge on a permanent channel marker buoy (#9). This logger measured light intensity 3 feet above the water surface and served as the basis of comparison for underwater light loss one foot below the surface and immediately above the seafloor.

Data were logged at five-minute intervals continuously over the course of the surveys. Each data logger can hold up to 28,000 measurements. The data logger's operating temperature range is 0 to 50 degrees C. The unit is designed to measure total luminance

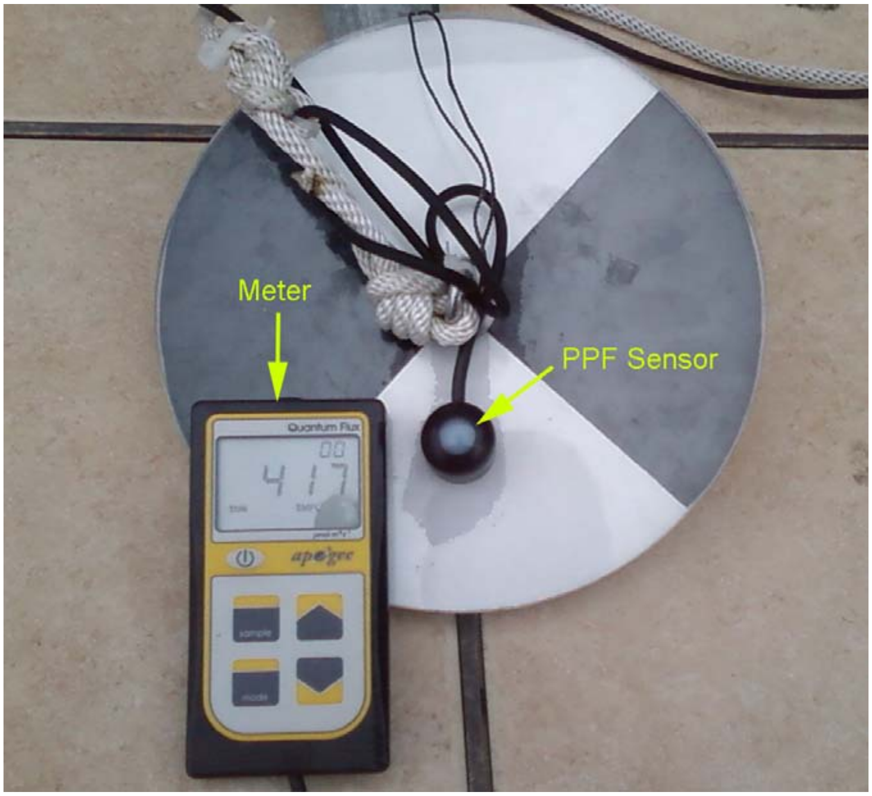
Photograph 5 . A HOBO Temperature and Light Pendant Data Logger That Measures Light Intensity (lumens per foot^2)

in the range of 0-30,000 lumens/square foot (foot candles). This measures illuminance over a broad spectrum of light wavelengths that is visible to the human eye that extends into the ultra violet and infrared wavelengths. Illuminance (i.e., brightness) does not directly correspond to measurements of light energy. The sensor is most useful for determining relative changes in illuminance rather than absolute values of intensity. However, a general conversion between illuminance and light energy (photosynthetic photon flux (PPF) is 1 PPF= 5.1 lumens per square foot (full sunlight, solar noon, and a summer day)[1].

Once deployed, the data loggers were serviced twice a week (Tues and Friday) by divers using a fine brush to clean off silt and fouling epiphytes and epifauna during the July-August and November-December surveys. During the March-May 2009 surveys, the data loggers were serviced once a week which increased the amount of biofouling compared to the previous surveys. Logger data collected after the third or fourth day of deployment during the March-May 2009 surveys were filtered out of the data base to reduce the potential for error caused by increased biofouling.

Photosynthetic Photon Flux Measurements (light energy). To measure the amount of light energy (irradiance) we quantified Photosynthetic Photon Flux (PPF) with a Apogee Quantum Meter Model MQ200 that was attached to a 20 centimeter radius Secchi Disk (Photograph 6) during weekly or biweekly oceanographic surveys. A “quantum” refers

[1] Source: http://www.apogeeinstruments.com/conv_fc.htm



Photograph 6. Apogee Quantum Meter that Measures Light Energy (photons) in µmol m^{-2} s^{-1}. The sensor is attached to a Secchi Disk.

to the amount of energy carried by a photon. The quantum meter measures the number of photons between 400 and 700 nannometer wavelength within violet to red wavelengths. This accounts for about 42 – 50% of the total light spectrum. Photosynthesis is largely driven by the number of photons within these wavelengths, so this radiation is referred to as the PPF and measured in µmol m^{-2} s^{-1}.

Instantaneous PPF readings were made during water quality surveys. Measurements were recorded at depths of 1 foot (0.3 meter) below the surface, at the Secchi extinction depth, mid depth, and 1 foot (0.3 meter) above the bayfloor. Light energy readings were recorded after a 10 second waiting period in order to stabilize light readings and to account for lateral movement of the weighted-secchi disk at depth.

Sediment Grain Size. Sediment samples were collected at 17 stations throughout Newport Harbor on 6 August 2008 (Figure 1). These samples were collected to determine sediment grain size characteristics within areas vegetated by eelgrass as well as unvegetated regions where previous pilot eelgrass transplants had failed (Chambers Group and Coastal Resources Management, Inc., 2004). Diver-biologists used a 0.01 square meter, one-liter volume box core sample to collect samples to a sediment depth of 11 cm. Samples were bagged, stored on ice, and transported to Associated Laboratories, Orange California for sediment analysis. All samples were collected at a depth of -5 ft Mean Lower Low Water (MLLW).

2.4.2 Eelgrass Mapping Surveys

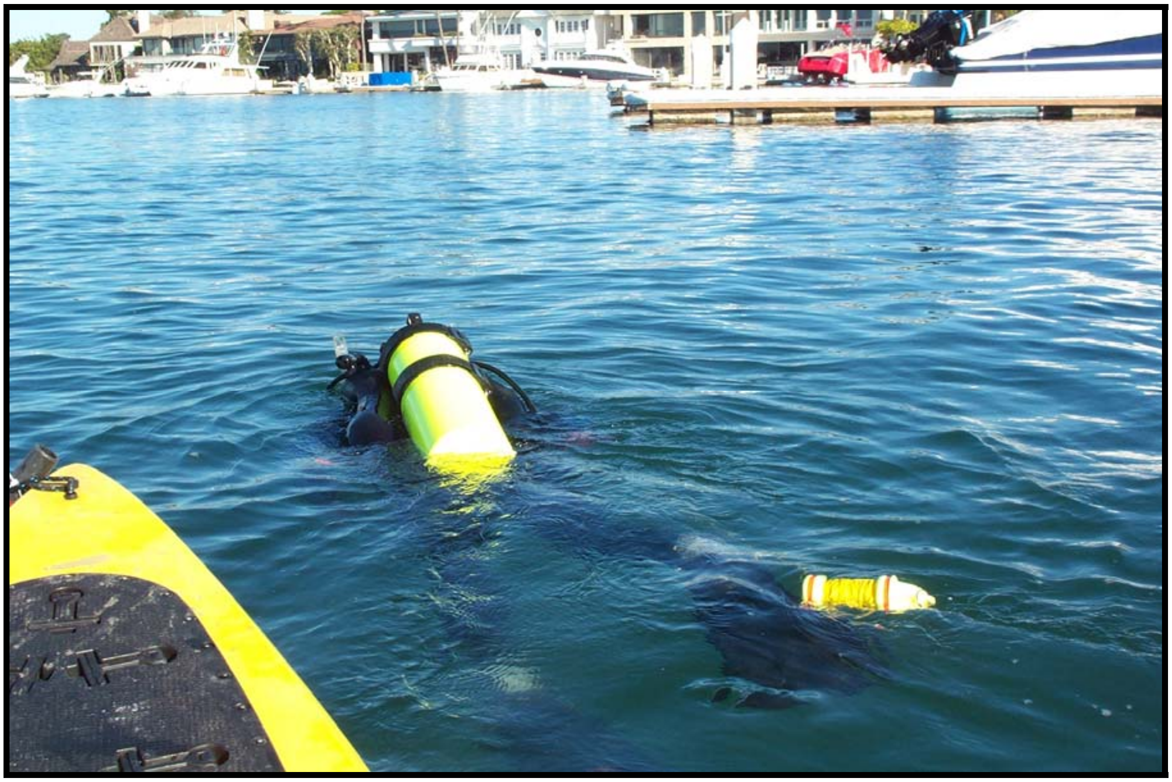
Two methods were used to map eelgrass. In shallow water areas (generally defined as between the bulkhead to the end of docks or pier structures) eelgrass mapping surveys were conducted using divers at depths between the low intertidal (on higher tides) and approximately -10 ft MLLW. In most cases, diver surveys included the bayfloor 30 feet past the end of docks and piers. Divers also surveyed shallow water side channels between and around Linda Isle and Harbor Island, all marina basins, inlets (Inner Linda Isle and Promontory Cove), and in Upper Newport Bay from the Coast Highway Bridge to Dover Shores (west side) and around the perimeter of DeAnza Marsh Peninsula.

In the main Newport Harbor deeper-water navigational channel, remote-sensing methods (sidescan sonar and remote video) were employed to survey the bottom habitat for eelgrass. These surveys were conducted between the harbor entrance west to the Balboa Ferry and north and west around Balboa Island and Harbor Island (Figure 2).

Diver-GPS Mapping Surveys. Eelgrass vegetation was mapped using a Global Position System (GPS) and a team of Coastal Resources Management biologists consisting of a diver and a surface support biologist in a kayak. To assist in the mapping process, an Ocean Technology Systems (OTS) surface-to-diver communications system was employed. Eelgrass depth ranges and characteristic marine flora and fauna were recorded during this phase of the field operations. A Thales Mobile Mapper Wide-Area Augmentation System (WAAS) GPS/GIS Unit was employed to map eelgrass beds and small eelgrass patches. The estimated GPS error of the Thales Mobile Mapper unit, with post-processing differential correction is less than 1 meter with clear open skies; however, in some instances, the error was higher because the team was working near bulkheads, underneath piers, and between docks where a clear view of the sky was not always possible. In these instances, the error was estimated to be 1 to 3 meters.

The biologist-diver first located the beginning of an eelgrass bed and marked it with a yellow buoy. The surface support biologist working from a kayak then initiated tracking of the biologist diver with the GPS as the diver swam the perimeter of the individual eelgrass bed (See Photographs 7 to 9). Once the diver returned to the beginning point, the GPS polygon area mapping was terminated. Eelgrass patches that were too small to survey or located in difficult areas to obtain a GPS signal (i.e., behind docks/under piers) were referenced as a GPS "point" and a size of the eelgrass patch was estimated by the diver.

Eelgrass Turion Density. Turions are eelgrass units consisting of the above-sediment portion of the eelgrass consisting of a single shoot and "blades" (leaves) that sprout from each shoot (Photograph 10). In order to assess eelgrass habitat vegetation cover, thirty (30) eelgrass turion counts were made at each of 14 stations throughout the study area by SCUBA-diving biologists that counted the number of live, green shoots at the



Photograph 7. GPS surveying methods using a kayak and diver

Photograph 8. Biologist in kayak follows the diver's buoy, tank, and bubbles

Photograph 9. View of GPS unit and diver below the surface. Source: CRM 2005

Photograph 10. Above-sediment morphological features of an eelgrass plant. Source: CRM 2005

sediment/shoot interface within replicated 0.07 square meter (sq m) quadrats. These counts were conducted along an underwater transect between the shallow-and-deep edges of eelgrass at each sampling site. Prior to conducting the survey, the team standardized their counting methods to ensure the accuracy of counts between different team members.

Eelgrass Blade Length and Width Analysis. Eelgrass blades (leaves) were collected by biologists at 17 sites throughout Newport Bay in June 2009 to determine average blade lengths and widths, since variation within these morphological characteristics are dependent on temperature and light (Ochieng al., 2010). The purpose of this analysis was to identify areas in Newport Bay with similar meristemic characteristics. Representative eelgrass shoots and blades were collected at each of the 17 sampling stations, kept on ice, and returned to the laboratory for analysis. Ten replicate measurements of blade lengths and widths were made at each station.

Extralimital Observations. Other background information collected during eelgrass habitat mapping surveys included water visibility, water depth, and plants and animals observed in the eelgrass beds during the survey.

Sidescan Sonar and Remote Video Mapping Surveys. Coastal Resources Management, Inc. and Nearshore and Wetlands Surveys (NWS) conducted sidescan sonar/remote video surveys in deeper channels of Newport Harbor and where diving was considered too hazardous and where previous surveys conducted by the National Marine Fisheries Service in Autumn 2003 indicated the presence of large eelgrass meadows The techniques developed by CRM and NWS overcome the limitations of using sidescan sonar in shallow water areas and in areas where maneuverability is restricted in Newport Harbor. The method is based on the use of an Imagenex 881 Sportscan sidescan sonar “fish” (Photograph 11). It is light weight and deployed and operated from a small vessel. The electronics are housed in the compact towfish, which is towed with a Kevlar signal cable. The system is powered from a 12-VDC power source. All of the functions of the sidescan system are controlled from a computer.

The equipment was installed on the research vessel *Wetland Surveyor*. A Leica 12-channel marine Professional DGPS receiver and sidescan sonar were connected to the data acquisition computer, which ran the Hypack Data Acquisition software. The Hypack 6.2b Hydrographic Data Acquisition and Processing Software is an integrated marine survey package. It allows for the collection and processing of data from a wide variety of instrumentation including GPS and sidescan sonar. All input data are accurately time-tagged to provide precise correlation between the various instruments. The output signal from the GPS receiver was also output to the remote-video camera system so that the video was annotated with coordinates. The sidescan sonar towfish was flown from the port bow of the survey vessel to avoid contamination of the signal with noise from the propeller wash.

The sidescan sonar information was linked to Coastal Resources Management, Inc.’s high-resolution underwater color video camera (Ocean Systems, Inc Deep Blue Professional Grade Color Underwater Video Camera) that integrates GPS data and time on the underwater video (Photograph 12). After the equipment had been installed,

Photograph 11. Imagenex 881 Sportscan Sidescan Sonar Towfish

Photograph 12. CRM's Ocean Systems Deep Blue High-resolution Underwater Video Camera

integrated, and tested, the data collection began. Position, sidescan, and video data were collected simultaneously while steering the survey vessel down Newport Harbor's main channel. The video camera was lowered from a point immediately astern of the towfish.

Field personnel viewed the bayfloor in real- time as the sidescan sonar produced bottom-profile information. The real-time information was simultaneously recorded on a Digital Video Recorder (DVR) that was used in the office/laboratory to verify the sidescan sonar locations of eelgrass, and additional information of the types of fish and marine life present.

Many targets were positively identified by plotting video targets on the geo-referenced photo-mosaics. However, many areas of interest-apparent on the post-processed mosaics- were not visible in the video record because of the expanded coverage afforded by the sidescan sonar system. Therefore, an additional field day was used to locate and identify the sidescan sonar targets by CRM diver-biologists, and an additional day was used to re-survey targets using the GPS and video camera system and the geo-referenced photo-mosaics. Using the Hypack map display, the survey vessel was navigated to a target of interest visible on a mosaic. The video camera was lowered and the area was examined until the target was identified. Each target was located and identified in turn as an eelgrass or non-eelgrass record.

2.5 DATA PROCESSING

2.5.1 Water Quality and Sediment Grain Size

YSI Water Quality Data. Data collected with the YSI 556 multiprobe meter (temperature, oxygen, pH, salinity, and oxidation/reduction potential) were processed using YSI *EcoWatch for Windows* data analysis program. Data were then transferred into *Windows Excel 2003*, and processed by replicate, station and depth. Graphics and statistics were prepared with Excel 2003, and SAS JMP 8 Statistical Discovery Graphics and Statistics Package software.

Data Loggers. Data loggers were returned to the laboratory for computer downloading using a HOBO Waterproof Shuttle and Coupler and HOBOware Pro Software Version 2.60. Data files were converted to Excel common-delineated files (csv) and exported into Excel file spreadsheets for each station. For each logger, the data were sorted by day and time, and then all data between 1000 and 1500 hours were exported into a separate data file. This time frame represents the period of maximum solar exposure and photosynthetic activity. These data were then used to calculate mean illuminance values for the “in air” reference site, at one-foot depth below the surface (“surface”), and at eelgrass depths (“bottom”). Data were averaged over the course of the logging period (July-August 2008, November-December 2008, March-May 2009) and summarized by survey, station, and sampling level. Percent light intensity was calculated for (1) standardized “bottom” values (approximately -5 ft MLLW) and “in air” reference levels and (3) standardized “bottom” values and in-water “surface” values one foot below the surface. These data were then tabularized, and graphically presented.

Quantum Meter PPF Data. Light energy information was transferred from field data sheets into an Excel spreadsheet program that integrated the data by station, sampling level, and survey. These data were then combined with the water quality data for each station, along with secchi depth data.

Sediment Grain Size. Sediment samples were processed by AP Engineering and Testing, Inc. ASTM Method D 422 to obtain grain size distributional curves (by weight, grams) for gravel, sand (coarse, medium, fine), silt, and clay fractions. Interpolation of median grain size values and Wentworth Size Class (Folk, 1980) were based upon sediment grain size distributional curves provided by AP Engineering and Testing, Inc.

2.5.2 Eelgrass Habitat Maps

Diver-collected field and sidescan sonar data were downloaded into a laptop computer and using Geographic Information Systems Software (Thales Mobile Mapping Software, GPS PRO Tracker, and ArcView 9.3) eelgrass bed polygons and eelgrass patch point data were produced and projected on City of Newport Beach geo-referenced aerial photograph files provided by the City of Newport Beach GIS Department. All survey data were standardized to City GIS formats, and presented in California State Plane Coordinate System Zone VI FIPS 0406 (feet). The results of the shallow water GPS mapping surveys and deeper channel sidescan sonar surveys were integrated into the City of Newport Beach GIS data base and the City of Newport Beach Harbor Resources Department public accessible website. For presentation and area calculation purposes, 18 eelgrass "regions" (Figure 5) were developed. The areas surveyed within these regions were between the shoreline and 10 meters past the end of dock structures. In addition, eelgrass beds that were continuous across channel bottoms separating two islands (i.e., Linda Isle and Harbor Island) were artificially divided down the center to allow for a calculation of eelgrass habitat areas within each region. An additional deeper navigational channel eelgrass region was also included. Eelgrass areal cover, by region, was calculated with the assistance of the City of Newport Beach GIS department staff based upon the combined areas of eelgrass polygons and eelgrass patches within each region.

Eelgrass Turion Density. Field-collected turion density counts (per 0.07 square meter) were entered into an Excel spreadsheet by station and depth, and converted to density per square meter. Summary statistics were then calculated (mean, standard deviation, and 95% confidence intervals) for each station and depth, and summarized in tabular and graphic format.

Eelgrass Blade Length and Widths. Blade and width measurements were taken between the base of the growing blade and the blade tip. Only individuals with clean, visibility leaf tips were used in the analysis. Summary statistics were then calculated (mean, standard deviation, and 95% confidence intervals) for blade widths and length at each station and summarized in tabular and graphic format.

Remote Video and Sidescan Sonar Data. Video tapes taken during the sidescan sonar survey were reviewed by observing the recorded data on a laptop computer at 1/3 the speed at which the data were collected. This information was used to ground-truth the sidescan sonar data, observe the health of eelgrass, and obtain targets of interest along with the latitude and longitude positions obtained from the GPS annotation on the video. The video surveys were also used to determine if invasive algae (*Caulerpa taxifolia*) was present within each of the survey areas. Once the video and diver survey targets were verified as either eelgrass or non-eelgrass, sidescan sonar data were processing using the Hyscan Processing module of the Hypack software. Geo-referenced photo-mosaic TIFF files were created by digitally overlaying data from overlapping sonar passes. These photomosaics were then imported into ArcView 9.3. Eelgrass polygons were developed based upon the identifiable eelgrass locations observed within the photomosaics.

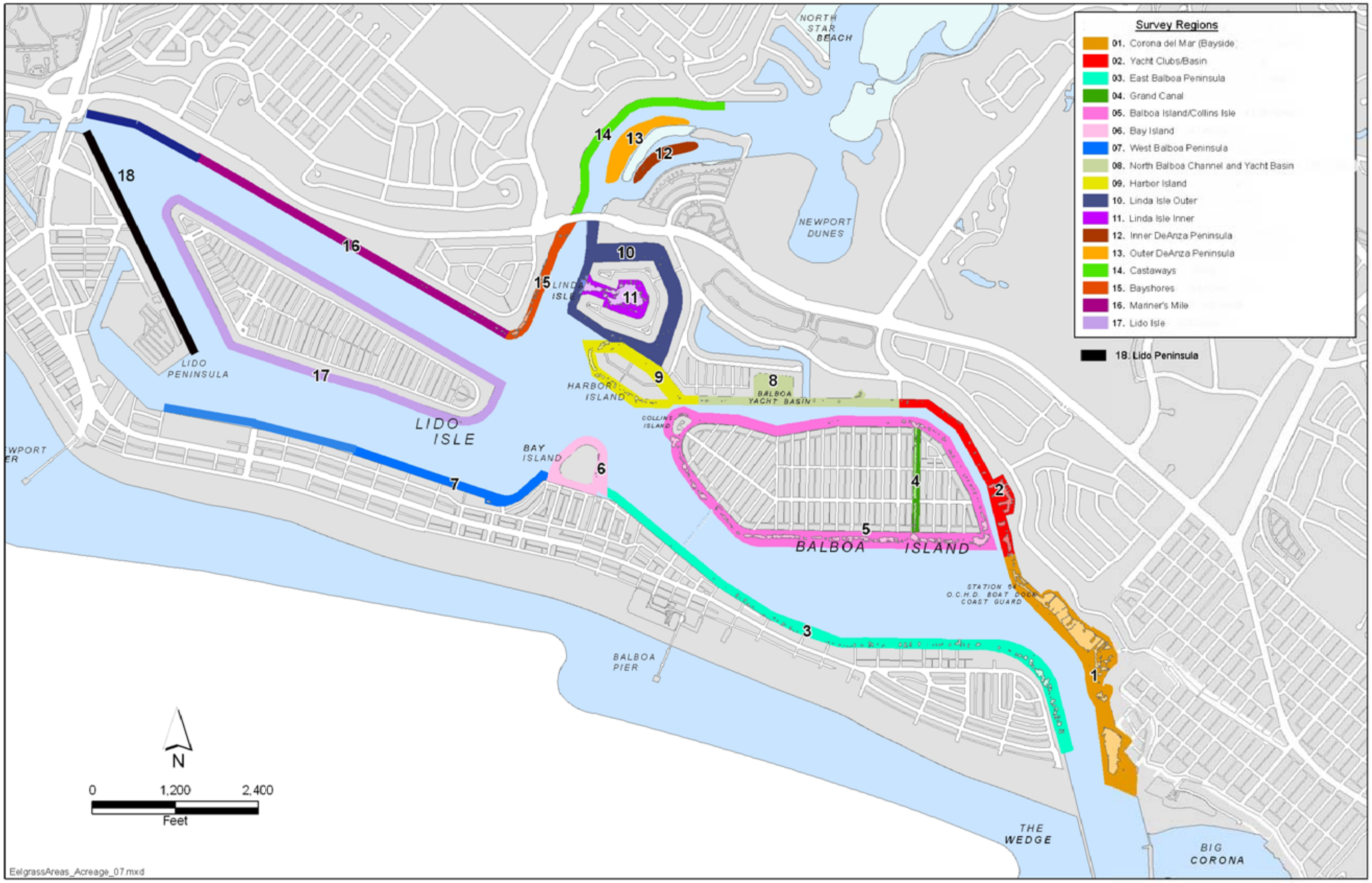


Figure 5. Eelgrass Survey Regions

3.0 OCEANOGRAPHIC SURVEY RESULTS

3.1 OCEANOGRAPHIC DATA

3.1.1 Regional Summary of Conditions, 2003-2009

Figure 6a summarizes air temperature and rainfall data for rainfall years 2003-2004 to 2008-2009. Average yearly air temperatures varied between 64 and 65 degrees ^{0} F (17.8-19.3 Celsius [^{0}C]). Rainfall totals were highest between 2004 and 2005 when 25 inches of rainfall were recorded. Rainfall in years 2006 through 2009 were below-average. Sea surface temperatures and salinity data for rainfall years 2003-2008 are shown in Figure 6b. Average sea surface temperatures (Figure 6b) varied between 59.9-62.2 ^{0} F (2005 and 2006), while mean salinity ranged from 32.9 (2004-2005) to 33.7 (2007-2008).

The 2006-2008 eelgrass surveys were conducted during periods of below-average rainfall, runoff volumes, sediment discharges (County of Orange, 2010), higher salinity, and higher sea surface temperatures compared to the 2003-2004 survey. However, the eelgrass surveys in 2008-2008 followed a significant rainfall year in 2004-2005 during which the annual discharge volume into the Upper Bay (75,860 acre feet) was the second highest recorded since 983 and the amount of sediment discharged into Upper Newport Bay (165,810 tons) was the 6th highest amount since 1983 (County of Orange, 2010).

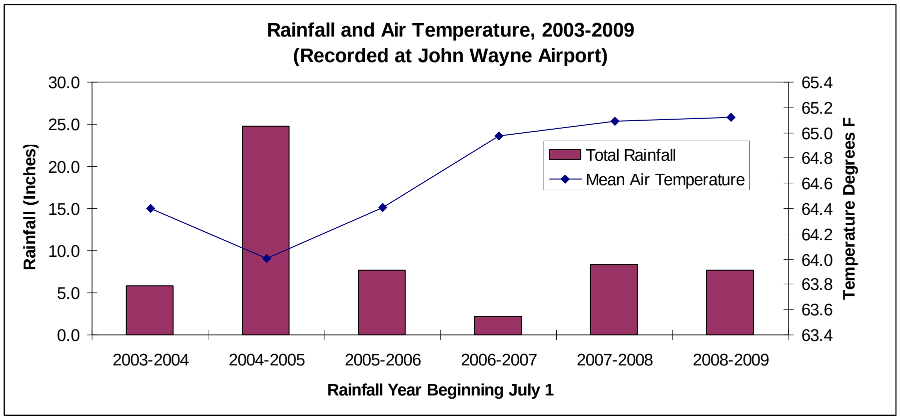


Figure 6a. Source: Accuweather.com

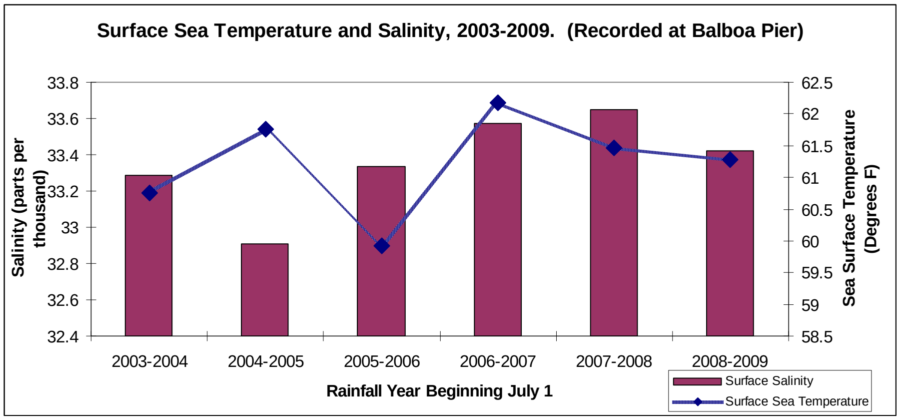


Figure 6b. Source: Southern California Coastal Ocean Observation System.com
Note: Data not available for SST after March 1, 2009, and for salinity after 1 Jan 2009)

Oceanographic data collected at 17 stations located throughout Lower Newport Harbor and in the main channel of Upper Newport Bay during July-August 2008 (summer) and November-December 2008 (late fall), and March-May 2009 (spring) are summarized in Table 2 (all stations, survey means). These data represent the average values of replicate data collected at the surface, mid-depth, and bottom depth at each station. Water transparency readings were collected at a single depth.

Table 2. Mean Values for Oceanographic Parameters. July 2008-May 2009

	Water Temp	**Water Temp**	**Dissolved Oxygen**	**Hydrogen Ion Concentration (pH)**	**Salinity**	**Water Transparency**	**Mean Water Column PPF***	**% In-Air Surface Irradiance PPF ****
Survey Period and Number of Surveys	**^{0}Farenheit**	**^{0}Celsius**	**mg/l**	**(unit-less)**	**Parts Per Thousand $^0/_{00}$**	**Secchi Depth (ft)**	**µmol m^{-2} s^{-1}**	
July-Aug 08 n=9 surveys	**72.45**	**22.47**	**7.41**	**8.01**	**32.41**	**6.2**	**433.8**	**6.9**
Nov-Dec 08 n=5 surveys	**61.18**	**16.21**	**7.56**	**8.02**	**29.30**	**4.5**	**159.0**	**3.9**
Mar-May 09 n=8 surveys	**62.08**	**16.71**	**8.10**	**8.08**	**32.51**	**4.4**	**426.0**	**5.6**

Notes: Data represents mean of values collected 1 ft below the surface, mid-depth, and 1 ft above the bottom at 17 stations during 22 surveys. *Photosynthetic Photon Flux **% relative to in air "reference" light values

3.1.2 Water Temperature

Water temperature in shallow coastal water and embayments vary daily and on seasonal basis. Thermal stratification (i.e., differences in the surface and bottom water temperatures)-form when the surface waters are heated, but there is an absence of heating of the bottom waters and an absence of mixing due to density differences in the water column. This thermal gradient will form a thermocline.

During upwelling periods, thermoclines will breakdown. In well-mixed embayments, thermoclines may not develop however, due to shallow depths, and wind/wave mixing.

On the average, water temperatures during the July-August 2008 surveys were approximately 11 ^{0} F warmer than during November-December 2008 or March-May 2009 surveys (Table 2). Mean water temperatures by survey ranged between 62.08 (March-May 2009) to 72.45 ^{0} F (July-August 2008). Spatially, water temperatures increased along a gradient between the Entrance Channel (S1) to Upper Newport Bay (S10), and between the Entrance Channel and West Newport (S10, S11, and S13, Figure 7). Comparative data, by survey are presented in Appendix 1.

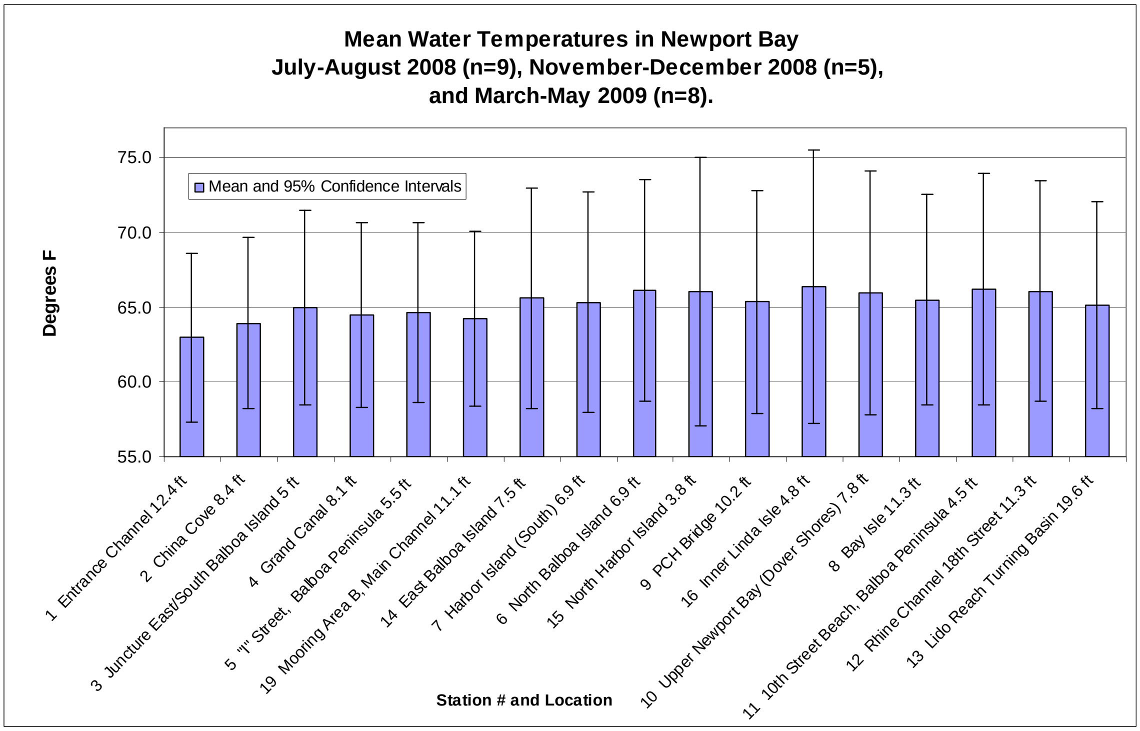


Figure 7

Water temperature increases were greater along the Entrance Channel-to-Upper Newport Bay gradient than between the Entrance Channel and West Newport (Figure 7). Water temperature varied between 62.96 ^{0} F (Entrance Channel) and 66.35 ^{0} F (Inner Linda Isle). The highest within-station variations were observed between Harbor Island and Upper Newport Bay. Minimum and maximum temperatures recorded were 59.17 ^{0} F (Entrance Channel, March-May 2009) and 75.65 ^{0} F (Inner Linda Isle, July-August 2008), respectively. The extremely warm temperatures in the Inner Linda Isle Inlet and the back channels surrounding Linda Isle during the summer survey (Appendix 1) approached the maximum, sustained temperature limit for eelgrass (Fonseca, 2009). However, survey temperature means for all three surveys are within the tolerant limits for eelgrass.

3.1.3 Diver Survey Water Temperature Measurements During Eelgrass Surveys

Bottom water temperatures recorded during the eelgrass mapping surveys conducted between September 2006 and August 2007 varied from 55 ^{o} to 78^o F. Mean bottom water temperature was 65^o F (n=53 measurements). Lowest water temperatures were recorded in Newport Harbor during March 2007 at the Entrance Channel while extremely warm bottom water temperatures were recorded at Linda Isle in July and August 2007 (77.6 ^{0} F) Water temperatures were not systematically recorded during the 2003-2004 surveys, and therefore are not included.

3.1.4 Dissolved Oxygen (DO)

Dissolved oxygen refers to the amount of oxygen dissolved in water. The concentration of DO is affected by several factors, including water temperature, sunlight, salinity, tidal flushing and exchange, and biological activity either in the water column or in the sediments. DO concentrations ranging between about 7 to 10 mg/l are considered "normal". Water can become "supersaturated" with oxygen (greater than 14 mg/l) during periods of high photosynthetic activity-blooms of macroalgae and phytoplankton. Hypoxic[1] conditions-low concentrations of oxygen less than 2 mg/l- are caused by the decay of organic matter, and eutrophic conditions. Levels above 4.6 mg/l would be expected to maintain the populations for most species except the most sensitive. This oxygen level could thus be considered as a precautionary limit to avoid catastrophic mortality events, except for the most sensitive crab species, and effectively conserve marine biodiversity (Vaquer-Sunyer and Duarte, 2008).

Generally, DO decreases with depth due to a reduction in photosynthesis, an increase in respiration, an increase in organic matter, and reduced light levels.

Mean DO survey values varied between 7.41 mg/l (July-August 2008) to 8.10 mg/l (March-May 2009). By station, DO concentration varied between 6.74 mg/l (S10, Upper Newport Bay) and 8.69 mg/l (S1, Entrance Channel and S2, China Cove). Spatially, DO concentrations decreased between the Entrance Channel (S1) to Upper Newport Bay (S10), and along a secondary gradient between the Entrance Channel and West Newport Bay (Figure 8 and Appendix 1). DO concentrations were higher during the March-May 2009 surveys than during July-August and November-December 2008, due in part to spring upwelling periods and plankton blooms, high water temperatures in summer that (Appendix 1).

Mean station values at all stations were above a minimal level of 5.0 mg/l to sustain marine life, although several individual reading at bottom and mid-depths particularly in West Newport (Rhine Channel (S12) and Lido Turning Basin (S13) were between 4 mg/l and 5 mg/l during both during July-August 2008 and November-December 2008 surveys.

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[1] Hypoxia is the condition in which dissolved oxygen is below the level necessary to sustain most animal life- generally defined by dissolved oxygen levels below 2mg/l [milligrams/liter] (or ppm [parts per million])." - Committee on Environment and Natural Resources (2000).

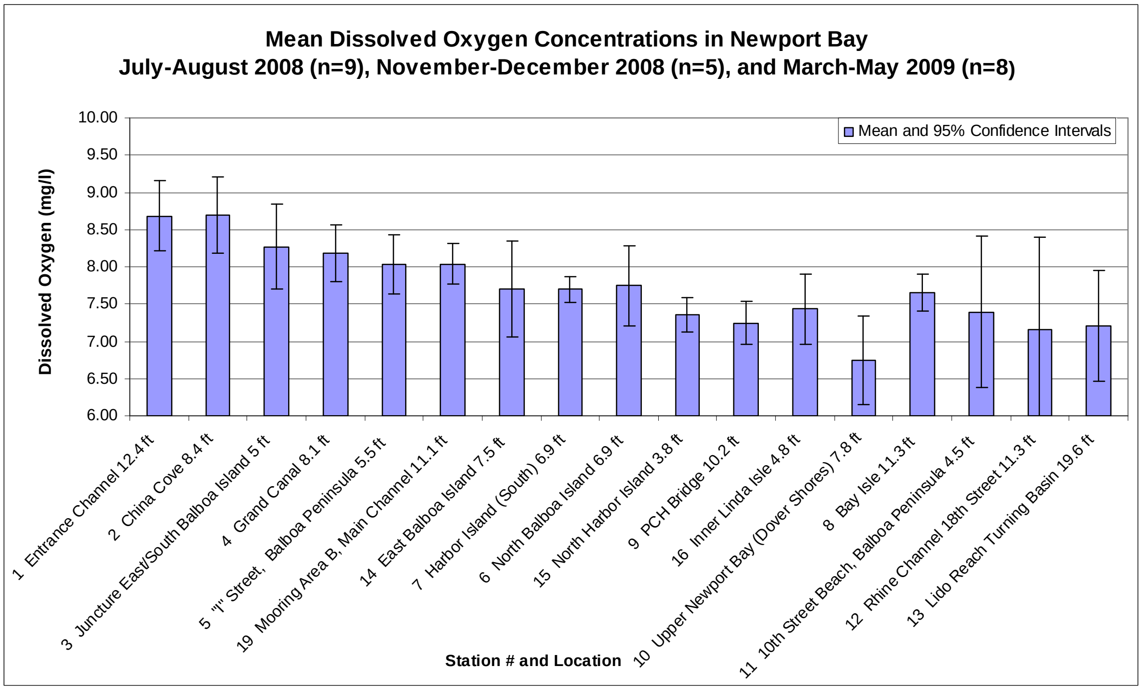


Figure 8

3.1.5 Hydrogen Ion Concentration (pH)

pH is the negative logarithm of the hydrogen ion concentration and is a measure of the acidity or alkalinity of a solution. A pH of 7.0 is neutral; values below 7.0 are acidic and those above 7.0 are basic. Seawater in southern California is slightly basic, ranging between about 7.5 and 8.6, although values in shallow open ocean water are usually between 8.0 and 8.2 (State Water Quality Control Board, 1965). Freshwater inputs tend to lower pH, and biological activity (i.e., photosynthesis) will raise the pH. Anoxic or low oxygen conditions will also decrease the pH due to the presence of hydrogen sulfide.

Survey values varied between 8.01 (July-August 2008) to 8.08 (March-May 2009). By station, pH values ranged between 7.92 (S10, Upper Newport Bay) and 8.11 (S1, Entrance Channel and S2, China Cove). Overall, pH decreased between the Entrance Channel (S1) and Upper Newport Bay (S10) due to a greater influence of freshwater and higher organics. It also decreased between the Entrance Channel and West Newport Bay stations 11-13 (Figure 9, Appendix 1). These trends occurred during both the July-August 2008 and November-December 2008 surveys. During the March-May 2009 surveys, however, pH was elevated between Linda Isle and Upper Newport Bay than the earlier periods, likely reflecting an increase in spring plankton bloom activity within the mid-to-upper bay areas.

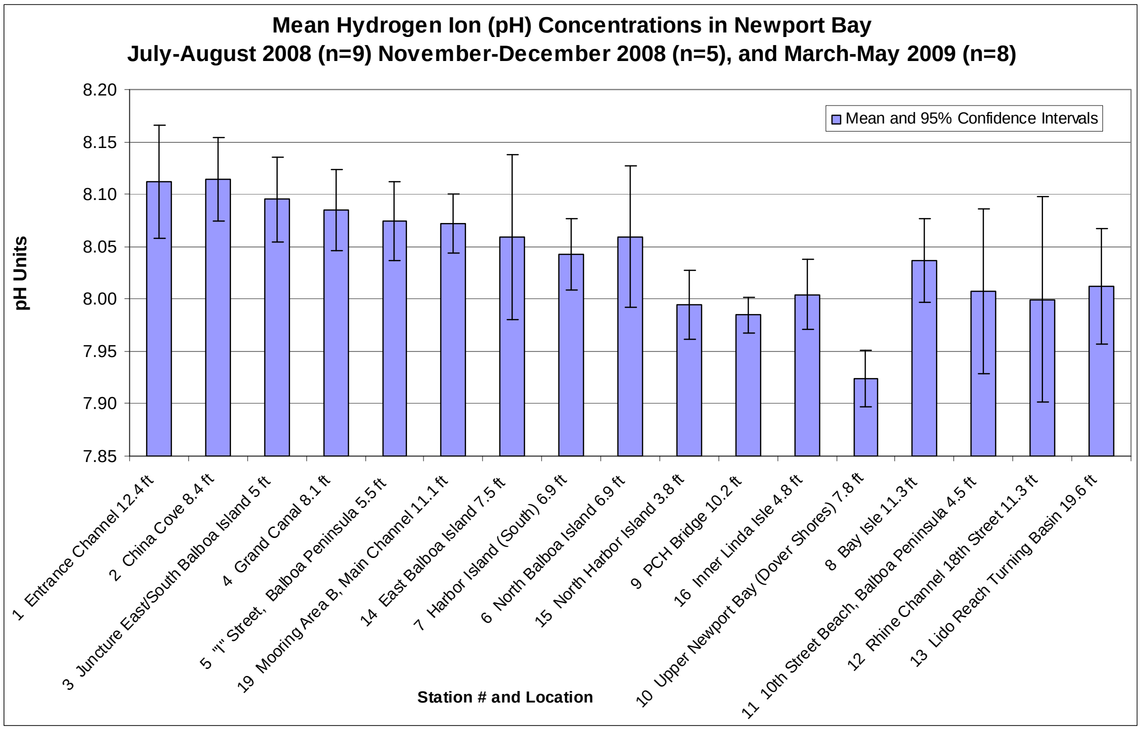


Figure 9

3.1.6 Salinity

Salinity is a measure of the concentration of salts in seawater and vary with the amount of freshwater input from rivers, creeks and flood control channels (i.e., San Diego Creek and Santa Ana Delhi-Channel in Upper Newport Bay), and storm drains that intermittently discharge throughout Upper and Lower Newport Bay. Typically, salinity will vary from about 25-34 parts per thousand ($^{0}/_{00}$) within coastal embayments and nearshore waters. It is less variable in oceanic waters, where salinity is about 34-35$^{0}/_{00}$. Salinity will increase with depth due to the presence of denser and cooler waters.

Mean salinity for all stations and surveys ranged from 29.30 $^{0}/_{00}$ (November-December 2008) to 32.51 $^{0}/_{00}$ (March-May 2009). By station, mean salinity was lowest in the Upper Bay at S10 (30.48$^{0}/_{00}$) and highest within the Entrance Channel at S1 (32.16$^{0}/_{00}$). Salinity was lowest at North Harbor Island (S15), within Inner Linda Isle (S16) and Upper Newport Bay (S10) during the November-December 2008 survey (27.48$^{0}/_{00}$, 24,47$^{0}/_{00}$, and 27.78$^{0}/_{00}$, respectively), and highest within the Entrance Channel in March-May 2009 (32.92 $^{0}/_{00}$). The influence of seasonal freshwater input from Upper Newport Bay was evident when comparing survey trends that illustrated reduced salinities in Newport Bay among all stations during the November-December 2008 survey when salinity varied between 27$^{0}/_{00}$ and 31 $^{0}/_{00}$ (Appendix 1). As illustrated in Figure 10, salinity variation was highest between Harbor Island and Upper Newport Bay due to seasonal increases in freshwater discharges from the Newport Bay watershed.

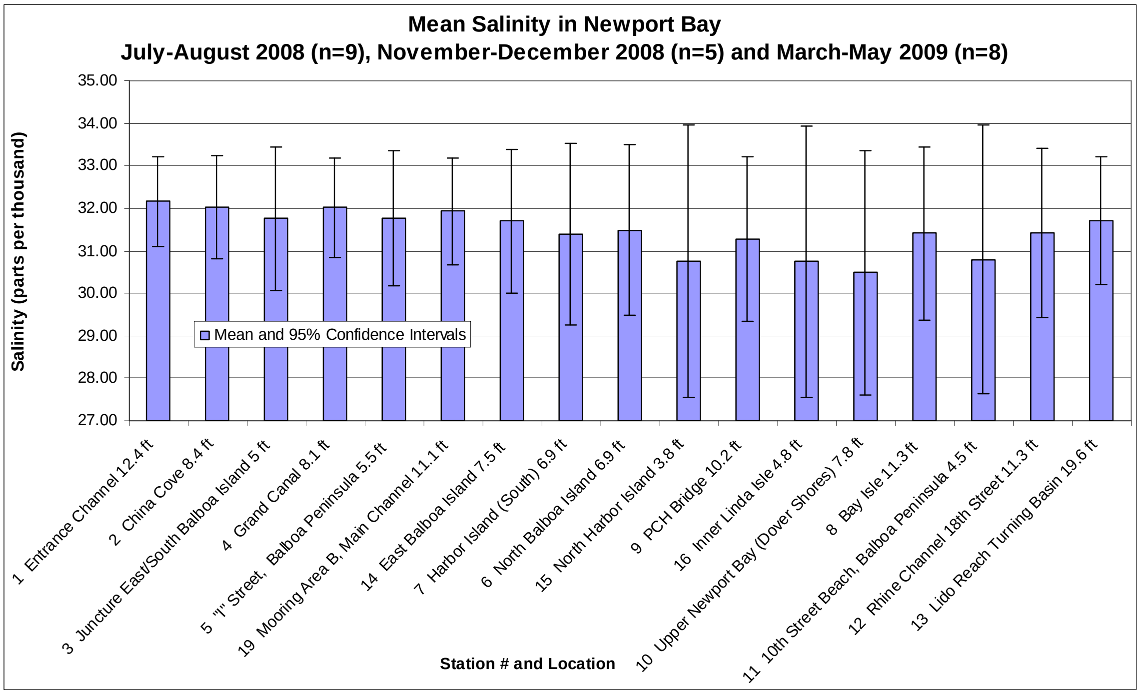


Figure 10

3.1.7 Secchi Depth (Water Clarity/Water Transparency)

A simple, but commonly and scientifically accepted method to measure water clarity (transparency) is to lower a Secchi Disk (Photograph 6) on a measured line into the water column until it disappears from view. The depth at which it disappears is the Secchi depth, which provides a measure of water transparency. Conversely, the secchi disk also describes how turbid the water is.

Mean water transparency varied from 4.4 ft (1.3 m) during March-May 2009 to 6.2 ft (1.9 m) during July-August 2008 (Table 2). By station, mean transparency varied from 3.7 ft at the PCH Bridge and Upper Newport Bay to 8.8 ft within the Entrance Channel. The decrease in water transparency (an increase in turbidity) with distance from the ocean entrance channel is illustrated in Figure 11. Water transparency decreased approximately 33% between the Entrance Channel (S1) to Balboa Island (S3). This trend continued along the gradient into Upper Newport Bay. Water transparency in West Newport (18th Street/Rhine Channel and Lido Reach Turning Basin) was greater than at all stations except those near Corona del Mar (5.9 and 6.2 ft, respectively). Of particular note was that transparency at the harbor mouth exhibited the most variation among all stations (Figure 11).

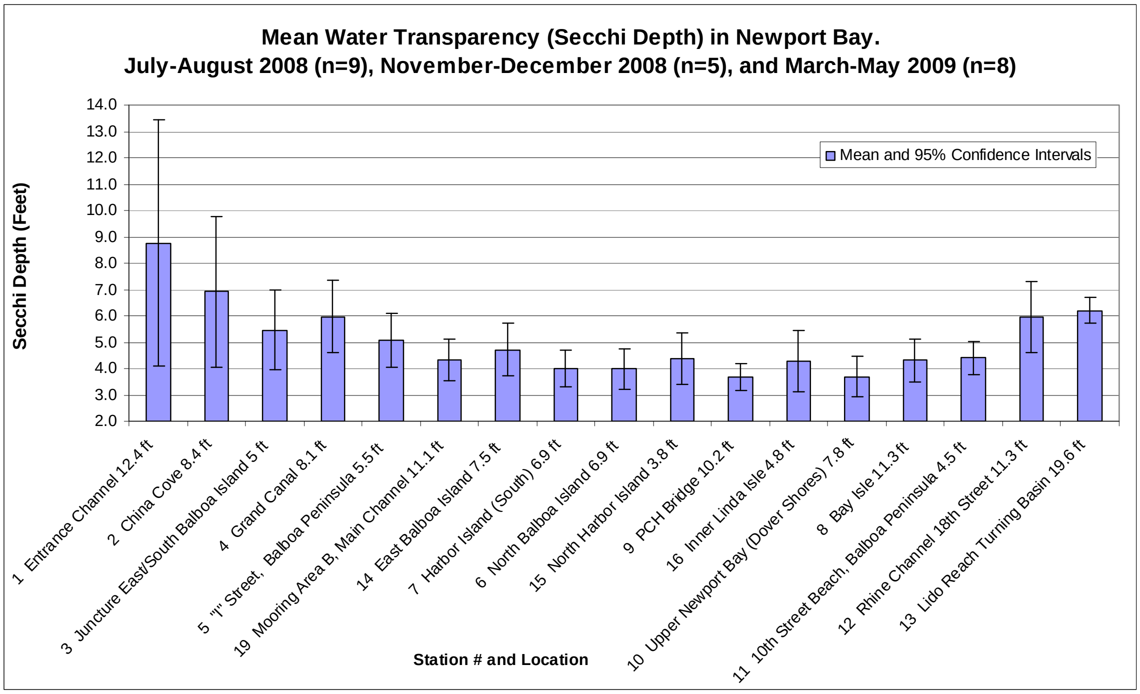


Figure 11

3.1.8 Photosynthetic Photon Flux (Light Energy)

Plants, including algae and seagrasses utilize light energy within the visible light spectrum between 400-700 nannometer wavelengths for photosynthesis. The light energy within these wavelengths required for photosynthesis was measured to compare available light energy within eelgrass beds and unvegetated bottom habitats at stations throughout Newport Bay. A lack of, or decreases in changes in light energy in the water column due to turbidity, plankton booms, shading, or other factors that reduce the amount of energy for photosynthesis will affect eelgrass production (Ochieng et al., 2010). While data were collected for surface, mid, secchi depths, and bottom depths at each station (along with "in air" reference data), we are reporting (1) light energy (PPF) and depth relationships (2) mean surface PPF irradiance (composited over surface, mid, and bottom depths 1 foot above the bayfloor; (3) the ratio of PPF light energy one foot above the bottom to light energy prior to being absorbed by water ("in air"); and (4) the ratio of PPF one foot above the bottom and one foot below the water surface. Both items 3 and 4 are measures of % surface irradiance (% SI).

Light Energy and Depth Relationships. Figures 12A-12C illustrate the relationship of light energy (a) within eelgrass beds (b) outside of eelgrass beds (c) for both eelgrass vegetated and unvegetated areas of Newport Bay obtained between July 2008 and May 2009. There was a strong correlative relationship between decreasing light energy and depth within eelgrass beds (r^2=0.63); decreasing light energy with depth within non-vegetated eelgrass areas (r^2=0.786); and within both vegetated and unvegetated eelgrass habitats (r^2=0.697) with depth. The mean light energy PPF value within the water column above eelgrass beds (354.5 μmol m^{-2} s^{-1}) was significantly greater than the mean light energy PPF value above barren substrate (294.7 μmol m^{-2} s^{-1}) (Student's T test,

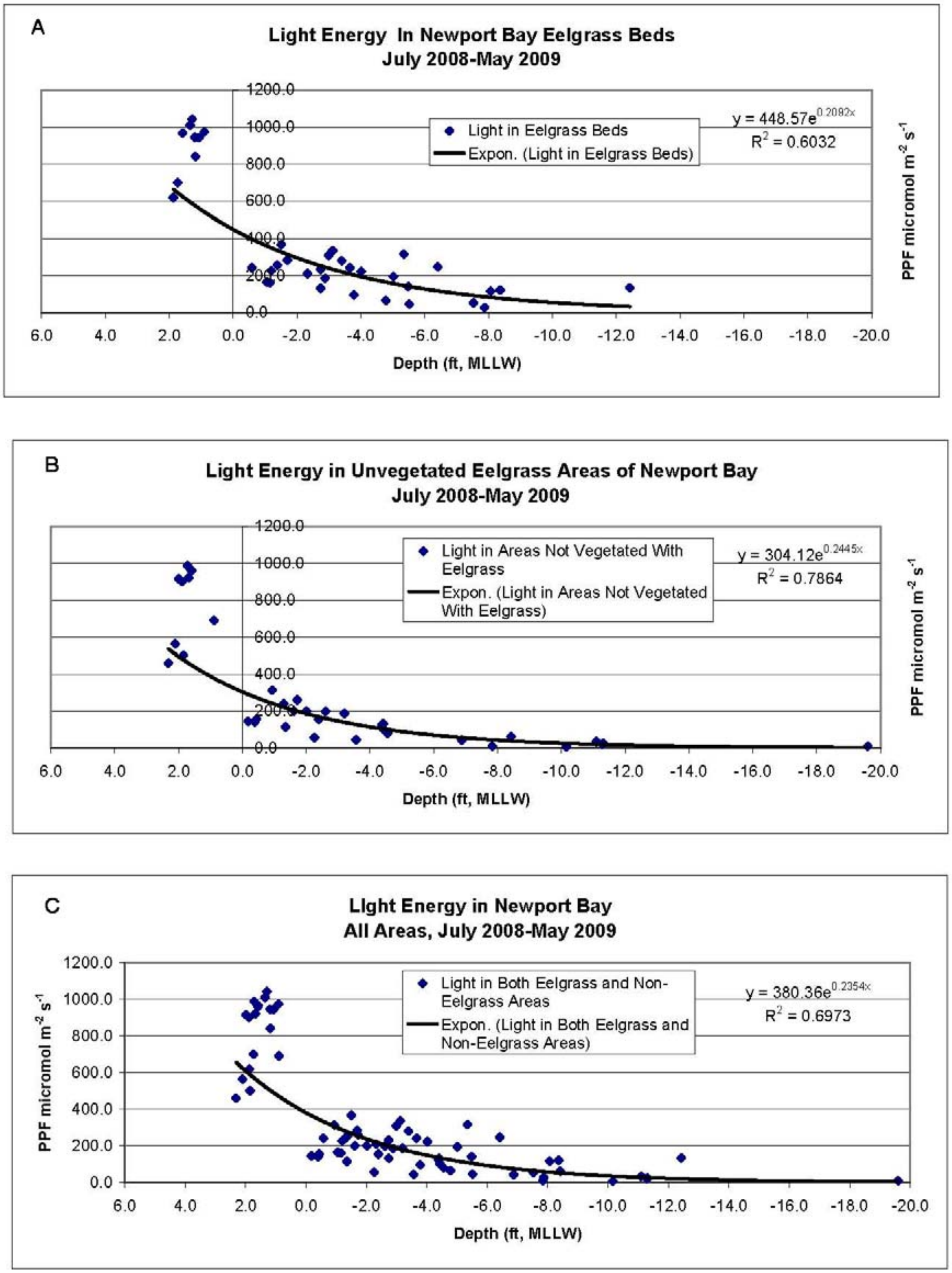


Figure 12A, Figure 12B, and Figure 12C

t=2.67 > 1.69 critical value of t, one-tail, square root transformed, 34 df). While all three relationships exhibited an expected decrease in light energy with depth, light energy within eelgrass beds between 0.0 ft and -8 ft MLLW was higher by approximately 100-200 µmol m^{-2} s^{-1} compared to locations that did not support eelgrass at equivalent depths (Figure 12 a and b).

Light Energy Relationships. Observed PPF (µmol m^{-2} s^{-1}) values within Newport Bay by station and survey are graphically presented in Appendix 1. For all surveys (22) and stations (18), the mean reference "in air" value was 1,200; the value one ft below the sea surface was 988.5; the value at the mean secchi depth (5.0 ft) was 229; mid-depth PPF was 205.3; and the PPF value one ft above the bottom was 78.8 (n=282 replicates per sampling level). The average proportion of light energy reaching the bottom (compared to ambient reference readings in air) over all surveys was 6.5% (n=18 stations, 18 surveys, depth range of -3.8 to -20 ft MLLW), while amount of light energy reaching the bottom compared to the light level one ft below the water's surface was 8.2% (n=18 stations, 18 surveys, and 282 replicates).

Mean light energy levels (PPF) ranged from 159 (November-December 2008, to 433.8 during the July-August 2008 period. Light energy in March-May 2009 exhibited a greater similarity to the July-August 2008 survey than during the November-December 2008 survey. Light levels in November-December were two-to-three times lower at all stations compared to the July-August 2008 or the March-May 2009 surveys (Appendix 1).

The distribution of light energy among all Newport Bay stations is illustrated in Figure 13. PPF values varied from 184.6 (Upper Newport Bay, S10) to 487.4 (10th Street Beach on the Balboa Peninsula, S11). Highest PPF was recorded in the Entrance Channel (S1), China Cove (S2), East Balboa Peninsula (S5), and South Balboa Island (S3, S4), and secondarily, at stations along the West Balboa Peninsula.

PPF values decreased between the Entrance Channel and Upper Newport Bay and (with the exception of S11 at 10th Street) PPF values in West Newport were lower than PPF values near the Entrance Channel. However, PPF values at West Newport stations were greater than for sites near Coast Highway Bridge and in Upper Newport Bay. Higher variation in PPF values near the entrance channel and at S11 was also reflected in the variability in secchi disk (water transparency) readings at these stations (Figure 13). Consistently poor transparency (high turbidity) and low light levels at bottom depths accounted for the lower PPF variation near the Coast Highway Bridge and in Upper Newport Bay compared to areas near the Entrance Channel.

Surface Irradiance Ratios. Bottom-to-ambient "in air" light SI energy ratios ranged from 3.9% during November-December 2008 to 6.9% during July-August 2008; bottom-to-subsurface light ratios were slightly greater and varied between 7.3% during November-December 2008 to 8.5% during July-August 2008 (Table 3). On the average, there was decrease of 2.3% in light energy once sunlight penetrated the water surface, with ranges between 1.6% and 3.4%. These data illustrate the seasonal decrease in solar energy that reaches the bayfloor. Late-fall survey (November-December) light energy

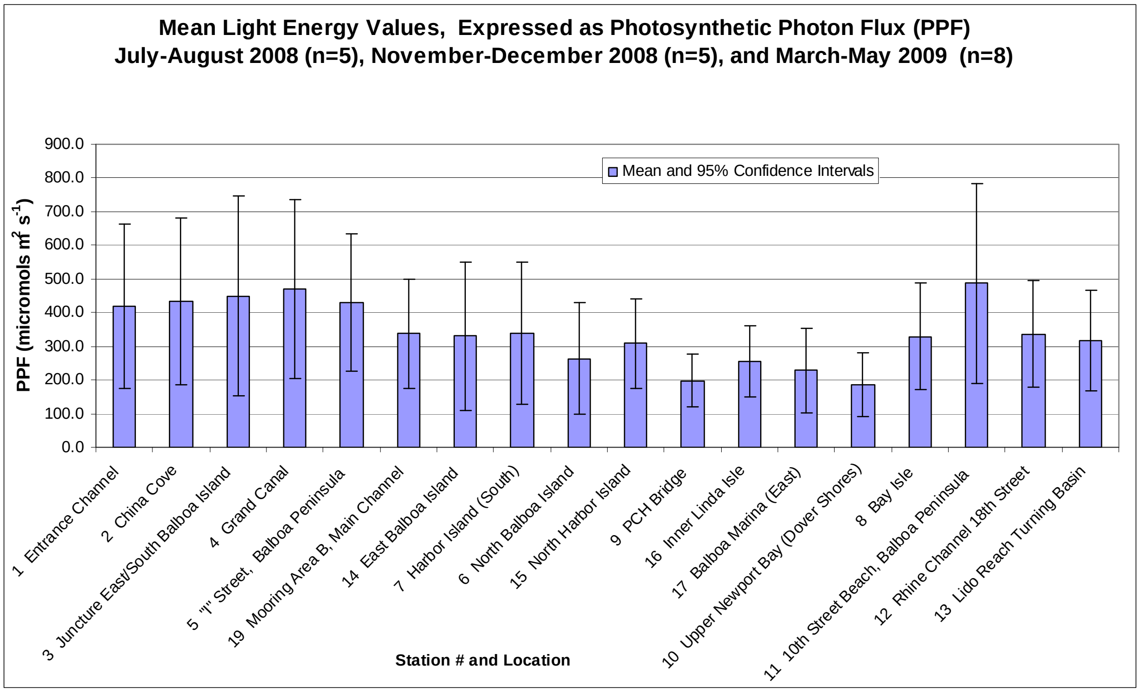


Figure 13

Table 3. Light Irradiance Ratios in Newport Bay Based On Photosynthetic Photon Flux (PPF) Values. July 2008-May 2009. All Stations and All Surveys Combined

Period	Bottom to In-Air "Ambient % SI	Bottom to 1 Foot Below the Water % SI
July-Aug 2008 n=5 surveys	6.9	8.5
Nov-Dec 2008 n=4 surveys	3.9	7.3
Mar-May 2008 n=8 surveys	5.6	7.7

levels were consistently lower than either the spring or summer levels growth periods, by survey and station (Appendix 1).

The relative percentages of light energy reaching the bayfloor compared to ambient light values, by station, are shown in Figure 14a and 14b. Spatially, SI ratios among stations for both "in air" and 1 ft below the water surface were similar within the harbor. The highest SI ratios were recorded in the Entrance channel, the eastern half of Balboa Island, and the Balboa Peninsula (S1 to S5); the north side of Harbor Island (S15); in the Linda Isle Inlet (S16); the eastern end of the Balboa Marina Channel (S17); and at 10th Street Beach on the West Balboa Peninsula (S11). The SI ratios of bottom-to-in air PPF for

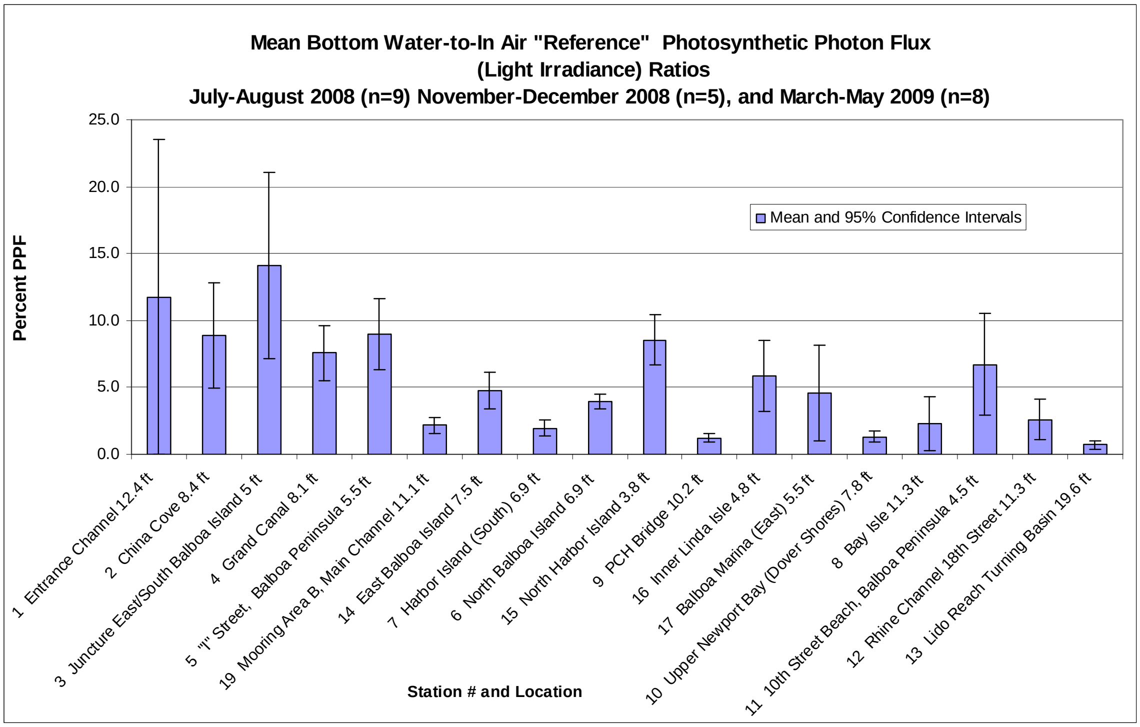


Figure 14a

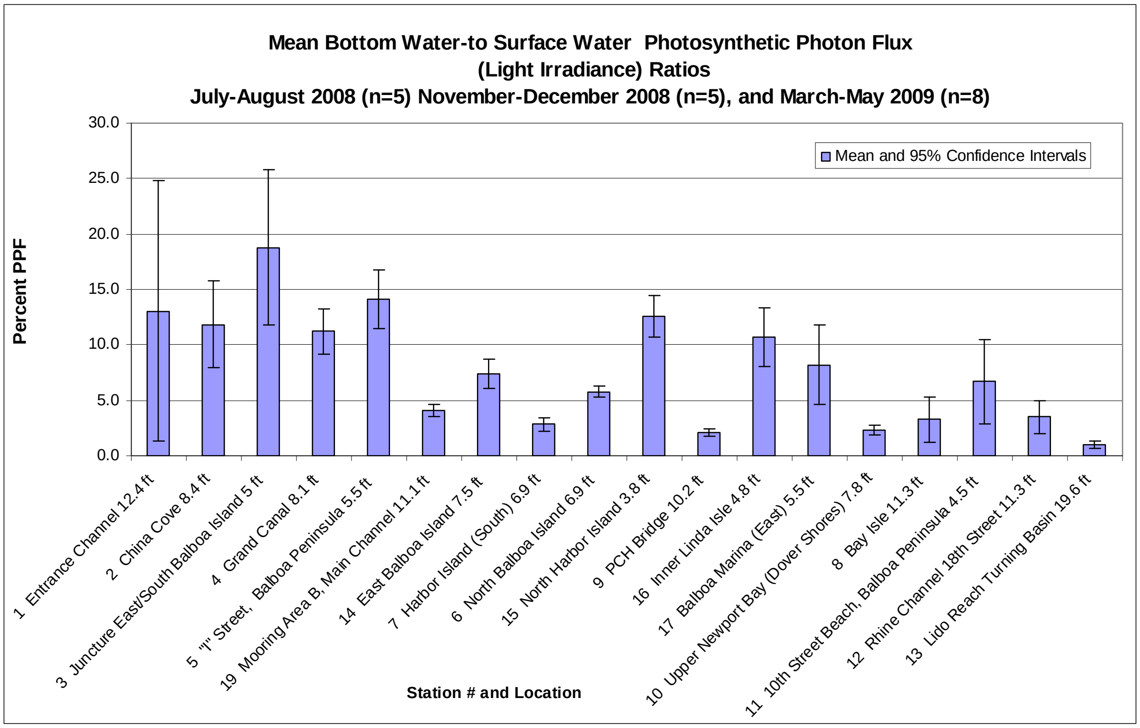


Figure 14b

these stations were greater than 5%; SI (subsurface) values that were greater than 10% occurred in the Entrance Channel (S1) at the southeast corner of Balboa Island (S3).

The percentage of light energy between surface water (1 ft below the surface) and the bayfloor by sampling location are shown in Figure 14b. Eleven of 18 stations exhibited SI light ratios that were greater than 5% (S1, S2, S3, S4, S5, S14, S6, S15, S16, S17, and S11); seven stations exhibited ratios greater than 10% (S1, S2, S3, S4, S5, S15, and S17).

Although there was a strong negative correlation between absolute PPF values and increasing depth, depth itself was not necessarily the only factor accounting for the relative amount of light energy reaching the bayfloor as indicated by weak correlative relationships between the PPF SI bottom-to- air ratio (r^2=0.21), as well the PPF bottom to surface water SI ratio (r^2=0.33) and depth. For example, the Entrance Channel station S1 (bottom depth 12.4 ft) had a higher ratio of surface light (13% SI) than stations that were shallower-S10 (7.8 ft depth) located in Upper Newport Bay (2.3% SI) and Station 8 (11.1 ft) located near Bay Isle (3.3% SI). In these cases, we suspect higher suspended sediments (higher turbidity, as recorded by lower secchi depth values) along the gradient between Upper Bay and mid-Newport Harbor contributed to low light percentages at depth.

3.1.9 Underwater Data Logger Temperature and Underwater Light Study

The results of underwater HOBO data logger deployment in Newport Bay between July 2008 and May 2010 are presented for periods of maximum daily sun exposure (10 am to 3 pm). These data were continuously collected whereas the PPF data collected during the CRM oceanographic surveys were instantaneous measurements collected between 9 am to 3 pm during days of sampling. HOBO logger data were recorded every five minutes over several weeks for each survey, representing a database of between 1,000 to 2,000 measurements per survey within the 9 am to 3 pm time period at most stations. Three stations in the mid-bay region (B15, B16, and B17) were deployed one day each week and retrieved at the end of the water quality survey field sampling day. Data for Stations S2, S7, and S10 included partial data due to logger loss and subsequent redeployments; the number of samples for these stations ranged between 197 and 547 per survey. The bottom loggers at S8 (Bay Isle) could not be re-located during the December and May surveys. Large masses of nylon fishing line were wrapped around the anchor chains and logger arrays; therefore, the loggers were likely lost due to fishing interactions.

Water Temperature. Survey data are provided in Appendix 2. Figure 15 illustrates increasing surface and bottom water temperatures from the Entrance Channel to Upper Newport Bay, and secondarily, between the Entrance Channel and West Newport during the five-hour period of maximum daily sun exposure. Mean bottom water temperatures ranged between 61.3^0 F (S1, Entrance Channel) and 68.3^0 F (S16, Inner Linda Isle). Mean surface water temperatures varied between 65.9^0 (S2, China Cove) and 69.7^0 F (S16, Inner Linda Isle and S17, Balboa Marina Channel). Two sections of the bay-Harbor Island to Upper Newport Bay, and Rhine Channel Reach/Lido Reach Turning Basin in West Newport Bay-exhibited elevated thermal regimes compared to regions near the Entrance Channel. The mean surface water temperature differential among all stations

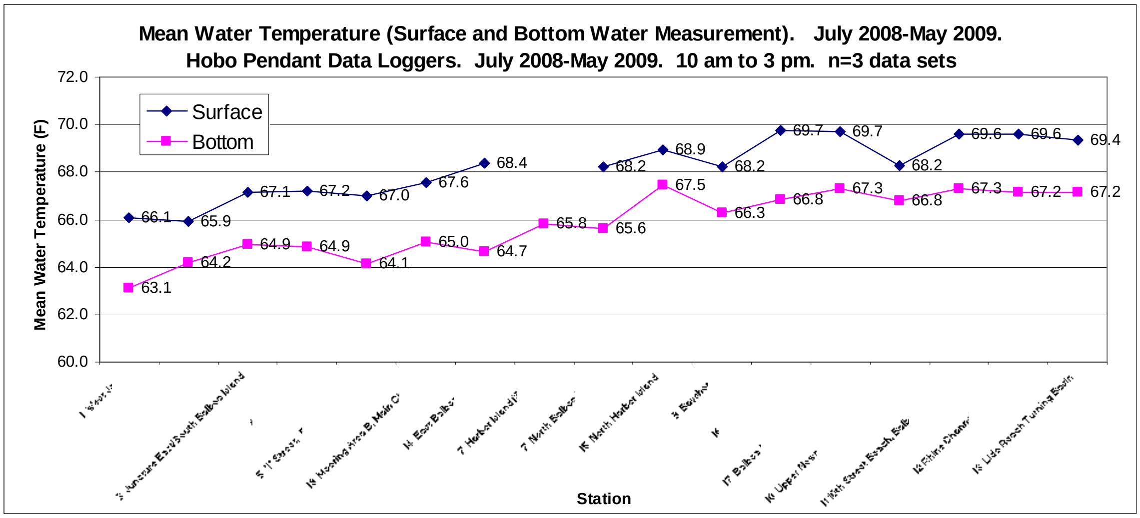


Figure 15

was 12.5° F at the surface and 8.9° F at the bottom between the warmest and coolest survey periods (July-August 2008 and November/December 2008).

The warmest bay temperatures were recorded during July-August 2008 (Table 4, Appendix 2). Surface water temperatures varied between 72.8° F (S1 and S2) and 78.3° F (18th Street, West Newport), with similar thermal maxima at 10th Street Beach (78.2° F), and Inner Linda Isle (78.2° F). Bottom water temperatures varied from 67.8° F (S5, Balboa Peninsula) to 74° F at both S10 (Upper Newport Bay) and S15 (North Harbor Island).

Table 4. Temperature Minima and Maxima. July 2008 though May 2009.
HOBO Pendant Data Loggers. 10 am to 3 pm. Temperature in Degrees Fahrenheit

	Survey Period, Temperature and Station		
Logger Position	**July-August 2008**	**November-December 2008**	**March-May 2008**
Surface Water (1 ft below the surface)	72.8 (S1) to 78.3 (S12)	62.2 (S2) to 64.1 (S17)	62.4 (S1) to 67.3 (S15)
Bottom Water	67.9 (S1) to 74.0 (S15)	62.0 (S2) to 63.4 (S11 and 12)	59.4 (S1) to 65.8 (S17)

Water temperatures were lowest during the late November-December 2008 sampling period. Surface water temperatures ranged from 62.2 ° F (S2, China Cove) to 64.1° F (S19, Main Channel), while mean bottom water temperatures varied between 62.2 ° F (S2, China Cove) to 63.4 ° F (S12 and 13, West Newport Bay). Temperature differences between the November/December 2008 and the March/May 2009 survey were minimal. Thermal minima were recorded during the March-May 2009 survey at in the Entrance Channel (S1), when the bottom water temperature averaged 59.4 ° F during seasonal upwelling conditions.

Thermal differentials (Figure 16) between surface and bottom waters averaged 4.3^{0}F in July-August 2008, 0.7^{0}F during November-December 2008, and 2.1^{0}F during March-May 2009. Within-station variation in surface and bottom water temperatures was highest in Upper Bay (S10, 14.8 ^{0} F at the surface; 12.0^{0} F at the bottom).

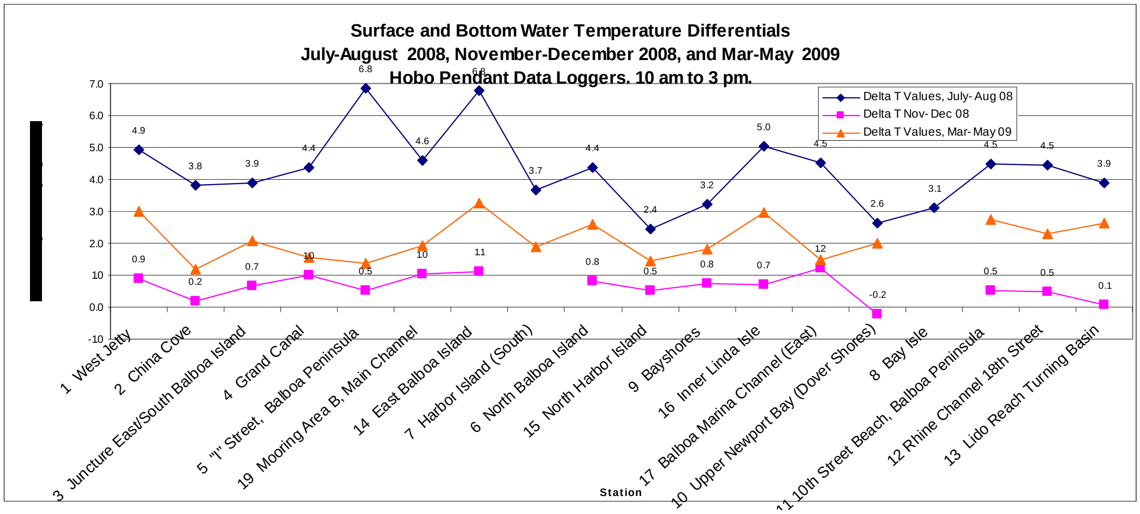


Figure 16

Underwater Illuminance. Data loggers were used along with the quantum energy meter to provide a second, relative index of light intensity within stations, and among various parts of Newport Bay. As discussed in Section 2, the HOBO Pendant data logger measures underwater "brightness" in a broad spectrum of light wavelengths visible to the human eye that extends that also extends into the ultra violet and infrared wavelengths. Since the human eye is particularly sensitive to yellow light, more weight is given to the yellow region of the spectrum and the contributions from blue and red light are largely discounted These data are recorded in the unit of lumens per foot squared (lumens/foot^2), which is the equivalent of one foot candle. These loggers are smaller than quantum meters, less expensive, and can be deployed in greater numbers for monitoring purposes. The brightness measurements taken by the HOBO data logger do not directly correspond to measurements made with a device having a different spectral sensitivity such as the Photosynthetic Photon Flux Quantum meter (PPF), that measures light energy (quantum units) rather than how bright the light is.

HOBO data logger placement depths were more consistent than sampling with the PPF Meter. Bottom sampling depths were at a standard depth near -5 feet MLLW, with the exception of the logger in the Entrance Channel where eelgrass grows deeper. At this location, the loggers were deployed at a depth of -9.3 ft MLLW.

Table 5 summarizes the survey's surface and bottom data logger information. Light intensity averaged 1597.1 lumens/ft^2, ranging between 572.1 (November-December 2008) to 2,483.5 lumens/ft^2 (July-August 2008). While the highest mean bottom light intensity occurred between March-May 2009 (696.8 lumens/ft^2), the highest surface values occurred during July-August 2008 (4,506.6 lumens/ft^2). Mean bottom light intensity was 493.6 lumens/ft^2 and mean surface light intensity was 2,700.6 lumens/ft^2.

Table 5. Summary of HOBO Pendant Data Logger Light Intensity Data. July 2008-May 2009

		Bottom Light Value (lumens/ft^2)	Surface Light Value (lumens/ft^2)	Reference "In Air" Light Values (lumens/ft^2)
July-Aug 08	**Mean**	**460.5**	**4506.6**	**16011.9**
Nov-Dec 08	**Mean**	**323.6**	**820.5**	**7465.9**
Mar-May 08	**Mean**	**696.8**	**2774.8**	**9998.7**
	Grand Mean	**493.6**	**2700.6**	**11158.8**
		Ratio of Bottom to 1 ft Below the Surface Value At Each Station	**Ratio of Bottom Values to "In Air" Values**	**Ratio of Bottom Values to Average Surface Values (All Stations)**
July-Aug 08	**Mean**	**11.5**	**2.9**	**9.5**
Nov-Dec 08	**Mean**	**45.5**	**4.3**	**40.9**
Mar-May 08	**Mean**	**29.4**	**7.1**	**31.6**
	Grand Mean	**28.8**	**4.8**	**27.3**

By comparison, the mean in-air light "reference" value was 11,158.8 lumens/ft^2. Percent light intensity (SI) between bottom-to-in air reference data ranged between 2.9% (July-August 2008) and 7.1% (March-May 2009), while bottom-to-surface water SI ranged between 11.5% (July-August 2008) and a high of 45.5 % (November-December 2008). Station comparisons, by survey are provided in Appendix 2. In addition, we calculated the bottom-to-average surface water SI. This value was used to minimize bias of higher-than-expected surface values due to some data loggers floating shallower than 1 ft below the surface as a consequence of mooring buoy anchor chain movement during low tides. This test did not result in any consistent trends.

Mean surface and bottom light intensity values between July 2008 and May 2009 are summarized in Figure 17 that illustrates a spatial trend of moderate-to-high light intensity between the Entrance Channel and the Pacific Coast Highway Bridge; the lowest light intensity in the Upper Bay, and moderate-to-high light intensity at stations in West Newport Bay. These trends may in part, be biased, in part by very high surface water light intensity values at stations S11, S12, and S13, during March and July, that we suspect may be a result of the loggers floating less than a foot below the surface based on field observations. These trends are illustrated in Figure 18 for surface light intensity values. Mean surface values generally varied between 1,100 and 2,100 lumens per ft^2, with S10 (Upper Newport Bay) exhibiting the lowest overall surface light intensity (833 lumens per ft^2). At the high end of the range, S11, S12, and S13 (West Newport) exhibited mean light intensity values greater than 2,000 lumens per ft^2. Bottom light intensity however, was lower at West Newport Bay stations than between the Entrance Channel and Harbor Island but higher than light levels in Upper Newport Bay (Figure 19). Light levels were also higher in Linda Isle Inlet (S16) and east Balboa Marina

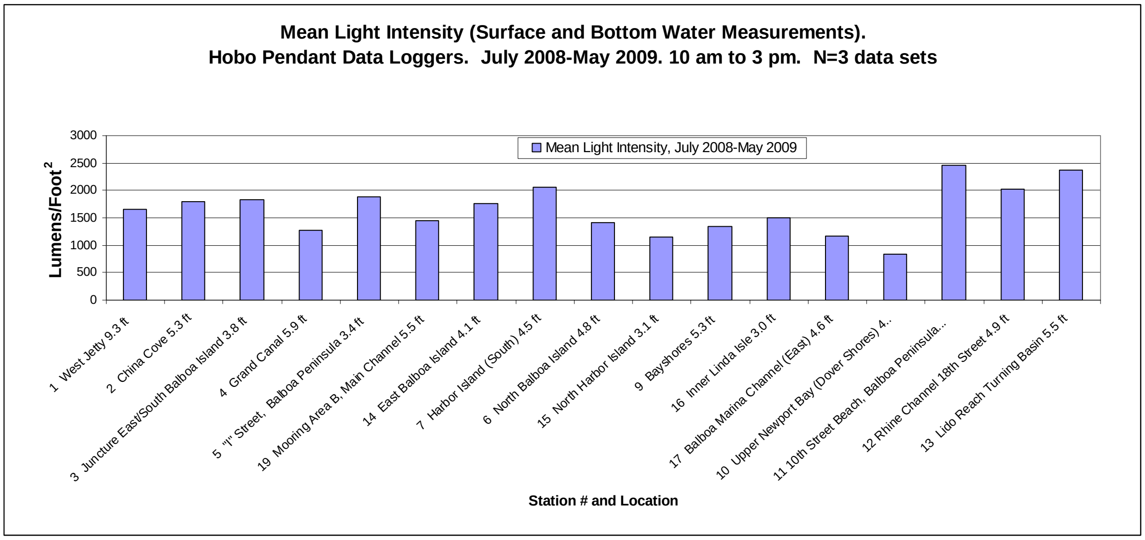


Figure 17

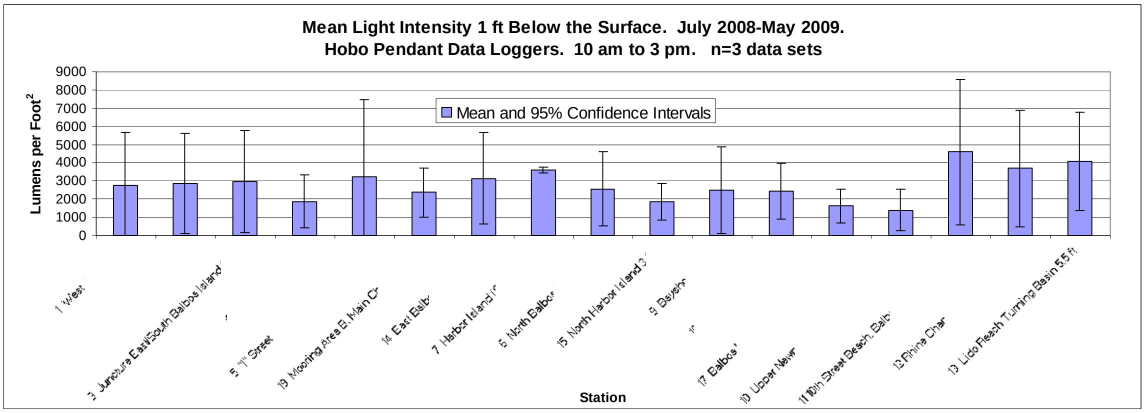


Figure 18

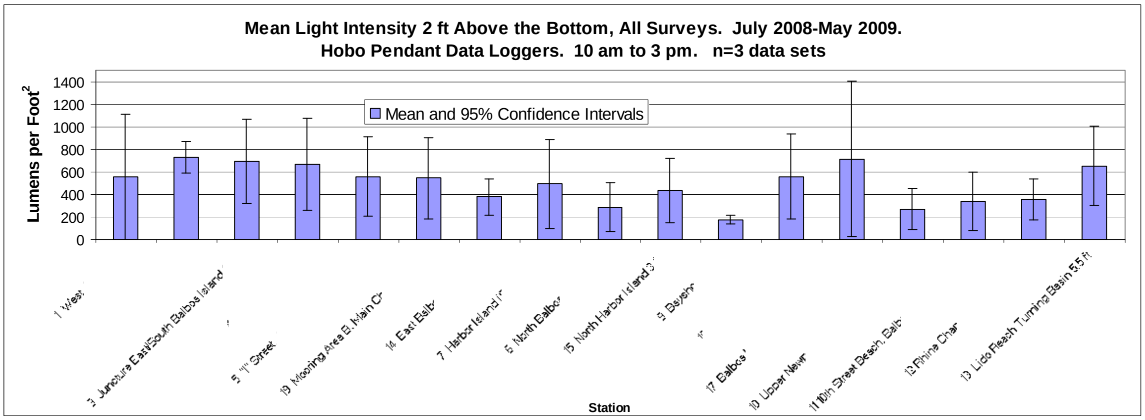


Figure 19

Channel (S17) than the Upper Bay. Variation was high among the three surveys for surface and bottom light levels, indicative of seasonal solar intensity differences.

Light Intensity Ratios. Light intensity ratios are presented in Figures 20a for bottom depths to in-air reference values and in Figure 20b for bottom depths to surface water values. Twelve of the 17 stations had ratios above 4%, and were scattered throughout the bay. Of these, six (S2, S3, S4, S16, S17, and S13) had ratios 6% or greater. Five sites (S6, S9, S10, S11, and S12) had ratios less than 4%. These sites were situated in the vicinity of North Balboa Island, Upper Newport Bay, and West Newport Bay.

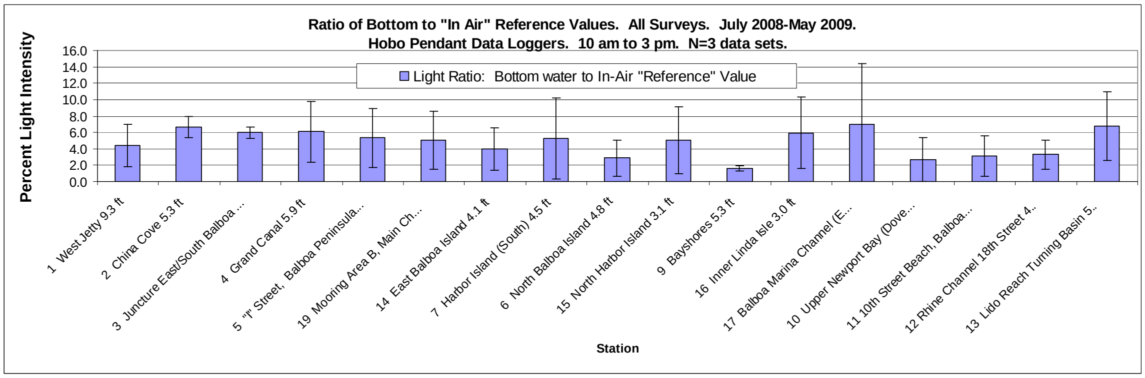


Figure 20a

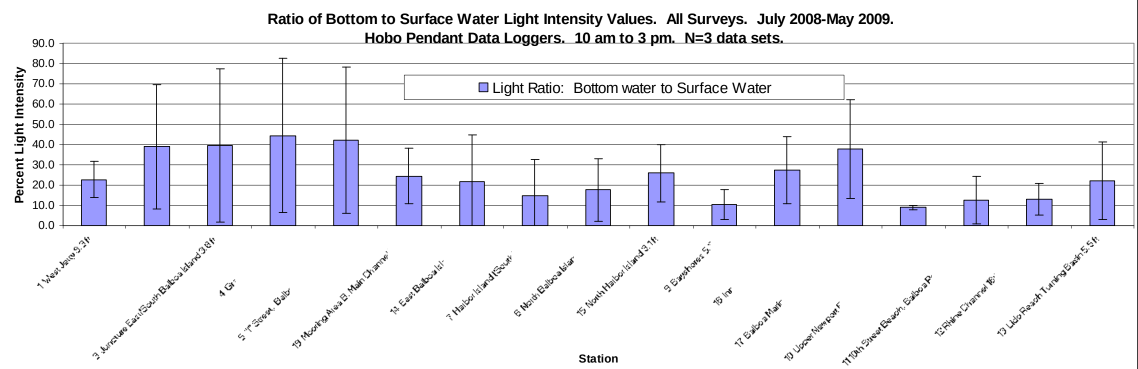


Figure 20b

Relative to bottom-to-surface water SI values, 11 of 17 stations had ratios greater than 20%. Of these, four sites (S2, S3, S4, and S5) located along Balboa Island and eastern Balboa Peninsula had SI values greater than 40%. The remaining six sites were less than 20% SI with Stations B9 (Coast Highway Bridge/Bayshores) and B10 (Upper Newport Bay) exhibiting the lowest SI ratios (10.6 and 9.0%, respectively).

3.2 SEDIMENT GRAIN SIZE

Eelgrass grows in a range of sedimentary environments ranging from coarse gravels to silts and clays (Phillips, 1984) and absorb nutrients (i.e., carbon, nitrogen, and phosphorous) from the sediments which stimulates leaf formation. Metals (i.e., zinc, manganese, copper, iron and cadmium) can also be absorbed and accumulated from the sediments (Phillips, 1984). As eelgrass material becomes senescent, nutrients can build up in the sediments around the accumulating detrital material. Because eelgrass blades can baffle bottom currents, eelgrass can also influence the rate of sedimentation and the sediment particle size distribution. Since this the feed-back loop involving eelgrass and sediments is important, we sampled the sediments in eelgrass beds, areas that were not vegetated with eelgrass, and areas in Newport Bay where eelgrass transplants had been attempted but had failed (Chambers Group, Inc., 2005b) to determine sediment characteristics.

Sediment particle size information for 18 stations is presented in Figures 21a and 21b. The percentage of sands (by weight) in eelgrass beds varied from 3.5% (Linda Isle Inlet) to 97.2 % sand in China Cove near the Entrance Channel. The gradation in the grain size fraction between the Entrance Channel to mid-bay (Harbor Island North, Linda Isle, and Balboa Marina Channel) reflected decreasing percentages of sands and increases in silt/clays. Stations sampled in West Newport (10th Street, 17th Street, and North Lido Isle Bridge) all exhibited high amount of sand because these sites have been nourished with beach sands. Pilot eelgrass transplants conducted at these sites (and in Upper Newport Bay) failed. On the average however, sediments tended to consist of more sand (10%) in eelgrass beds than in unvegetated sediments, although the relationship was not statistically significant (T test, ≤ critical value of t, two-tail, square root transformed, 11 df). The proportions of sand and silt/clay within a site can be highly variable.

Overall, this analysis indicated that eelgrass in Newport Bay lives in a wide-range of sediment types. Intertidal sediments and subtidal sediments in swifter-moving currents near the Entrance Channel are coarsest, whereas subtidal sediments decrease in particle size with depth, lower-moving current areas, and depositional areas in mid-bay and Upper Bay. Eelgrass will influence its own sedimentary environment by interrupting current flow, creating eddies, and promoting the settlement of silts and clays (Phillips, 1984, Lopez and Garcia, 1998). Koch et al (2006a), however, noted that sediment resuspension of fine sediments with high organics can occur under high wave exposure and current flow, and in highly wave exposed areas, sediment characteristics within and outside seagrass beds may not differ at all, or at least minimally. While sediments tend to be deposited in seagrass beds under calm conditions some of these particles may be resuspended by waves during storm events (Koch et al, 2006b). Seagrasses have acclimated to such relatively short (hours) pulsed high turbidity events. Turbidity events that last weeks or months (e.g., shoreline erosion, excessive river runoff, phytoplankton blooms) are the ones that lead to the loss of seagrasses (Moore et al. 1997).

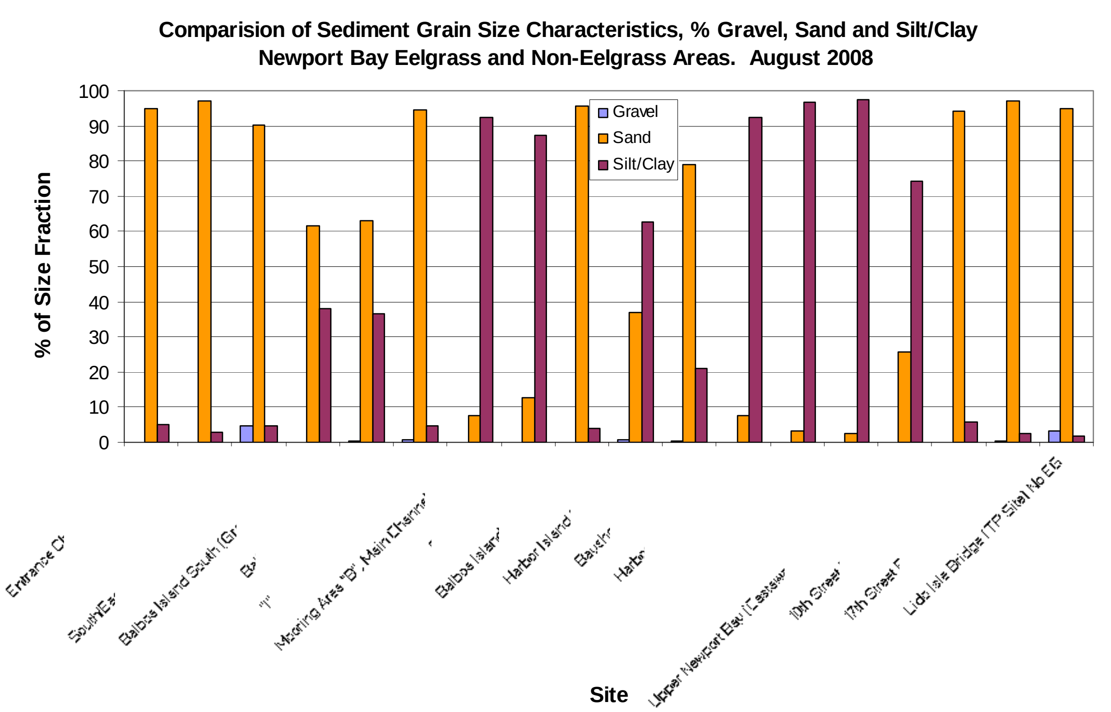


Figure 21a

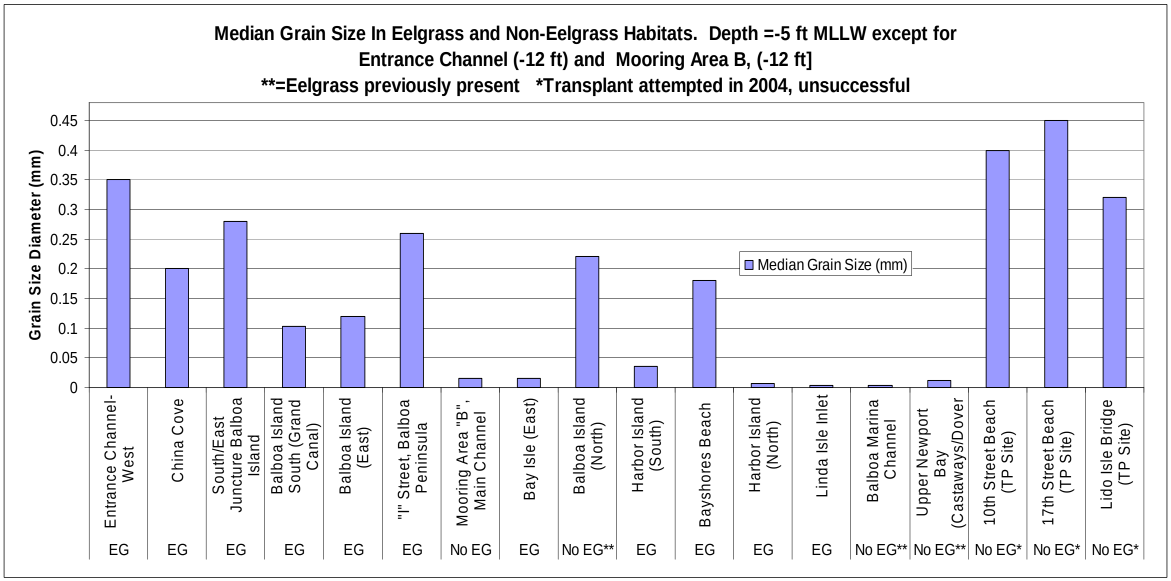


Figure 21b

Median grain sizes varied between medium sands near the Entrance Channel and West Newport (S1, S5, S11, S12, and S13) to clays in the Balboa Marina Channel (S17). It should be noted that the Balboa Marina Channel was dredged in late 2008 for the Balboa Marina Renovation Project, after the June 2008 grain size sample collection (Coastal Resources Management, Inc. 2009). Therefore, sediment characteristics in the channel may have coarsened as depths increased and depositional sediments have been removed from the channel. Very fine sediments were typical of deeper channel sediments sampled beneath Mooring Area "B" south of Balboa Island and along the depositional gradient between Upper Newport Bay and North Harbor Island.

The results of hierarchical cluster analysis (Figure 22) grouped stations with similar grain size characteristics into three stations groups (A-C). Group A stations were characterized by the highest percentages of medium to fine sands (Sediment Group 1), and the least percentages of fine material (Sediment Group 3). Stations in the grouping included eelgrass beds between the Entrance Channel to and including China Cove, Balboa Island, and East Balboa Peninsula (S1, S3, S4, S5), as well as Bayshores Beach located mid-bay (S9). Station S11 (10th Street Beach) was also included in this site group, which was where a pilot eelgrass transplant had failed in 2004.

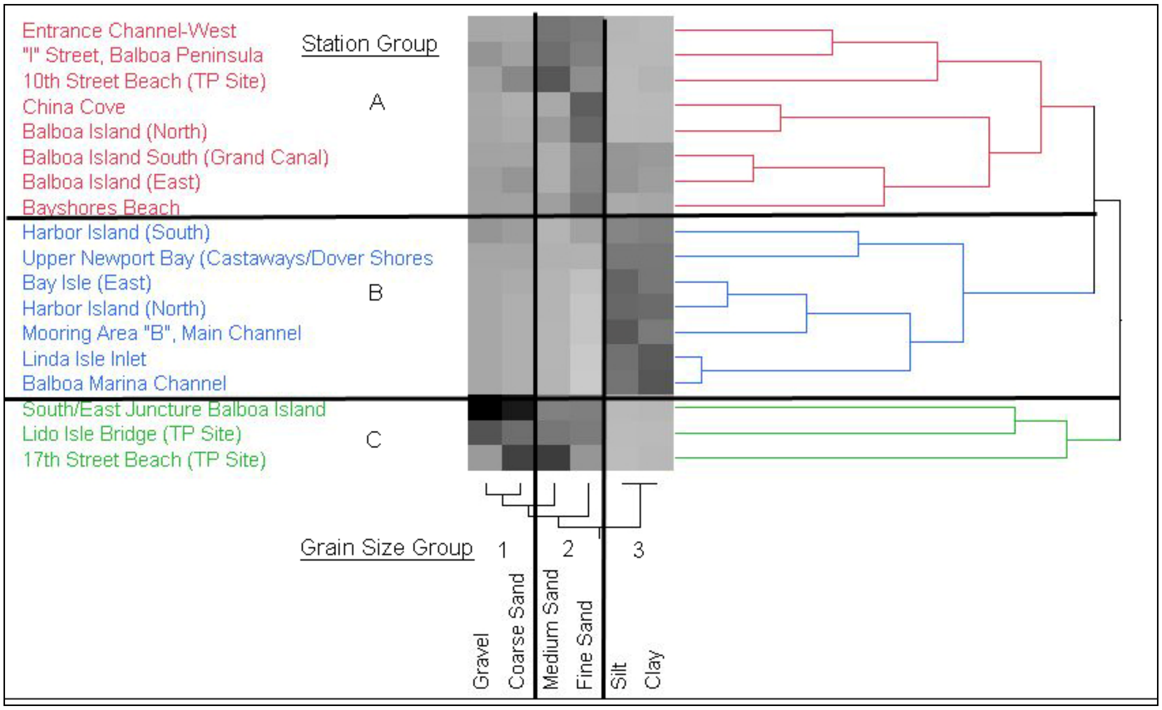


Figure 22. Two-Way Hierarchical Clustering of Sediment Types Based Upon Sediment Particle Size.

Coarsest Material: ● Finest Material: ○

Group B stations included mid-bay stations between Harbor Island and Upper Newport Bay (S6, S7, S8, S10, S15, S16, and S17) that were dominated by moderate-to-high amounts of silts and clays (Sediment Group 3) and less percentage of sands and coarser materials. Sediments in the main channel beneath Mooring Area "B" east of the Balboa Ferry (S19) were also included in this grouping. Most stations (with the exception of S19) were colonized by eelgrass during the 2006-2007 survey (Coastal Resources Management, Inc., this report), or had historically been vegetated with eelgrass (Coastal Resources Management, 2005) but not at the time of the sediment grain size survey. The S10 site in Upper Newport Bay was also a failed eelgrass transplant area.

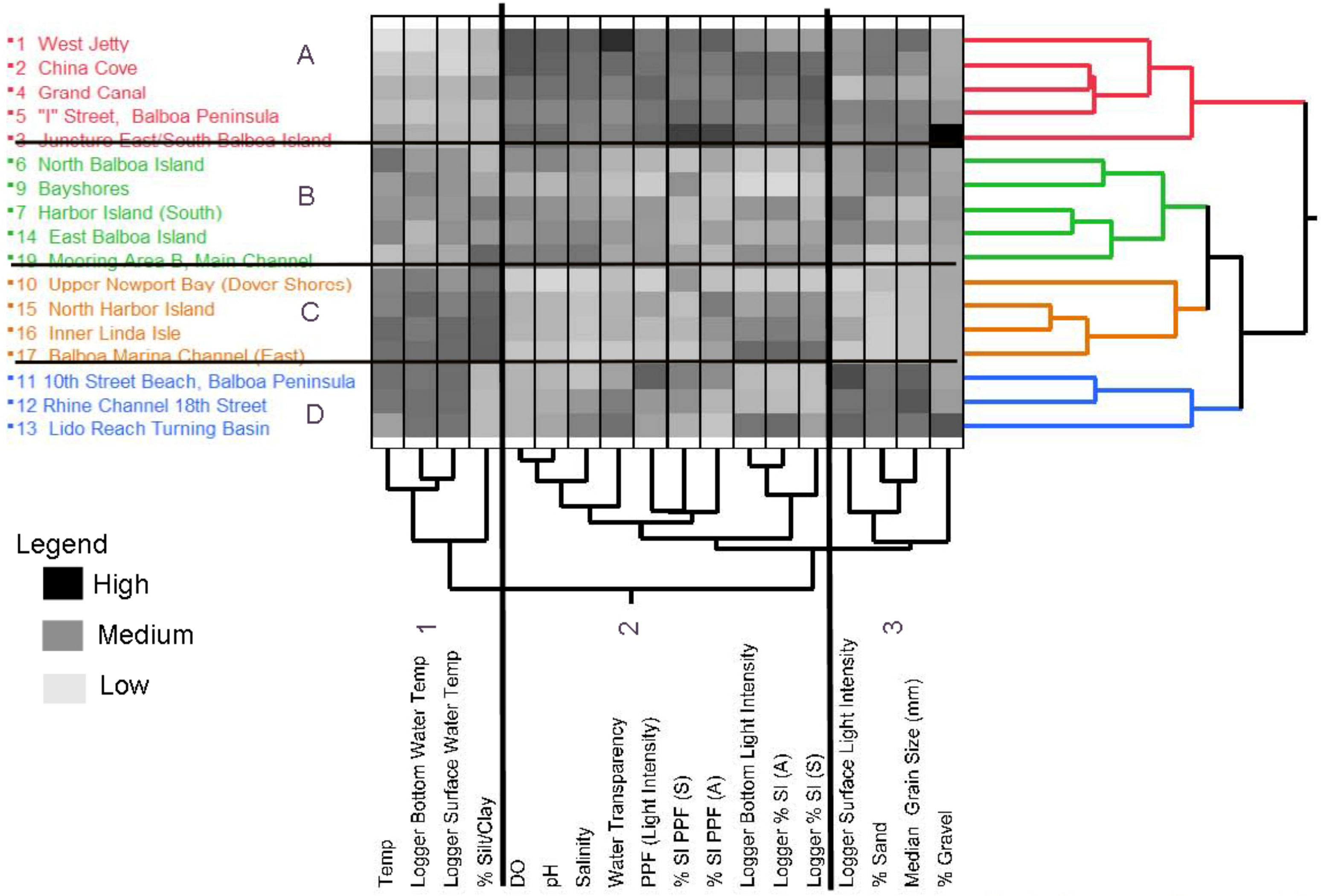
Group C stations included one eelgrass bed at the southeast corner of Balboa Island (S3) and two unvegetated areas bayward of beaches in West Newport-Marina Park (S12) and S13 (Lido Isle Bridge). Eelgrass transplants were attempted at these two West Newport Bay sites in 2004 under the Army Corps of Engineers Section 206 Water Resources Development Act of 1996, but failed. These sites were characterized by high percentages of gravel and coarse sands, moderate percentages of medium and fine sands, and being highly compacted (Sediment Group 2). Limited amounts of silts and clays were present at these stations. Based on the sediment type, these materials are typical of material used in beach nourishment projects used to either construct or maintain these public beaches.

3.3 SUMMARY OF OCEANOGRAPHIC INVESTIGATION RESULTS

Newport Bay is a dynamic system governed by semi-diurnal, mixed tides that bring coastal waters into the bay and then flush it on the out-going tides. The rate of tidal exchange varies with location in the harbor (Everest International Consultants, 2009), ranging from less than one day at the Entrance Channel to over 30 days at the extreme north region (Upper Newport Bay) and the extreme west end (West Newport). This tidal flushing gradient has pronounced effects on water quality; as clearly illustrated using hierarchical clustering techniques (Figure 23). Four station groups (A-D) and three oceanographic variable groups (1-3) were identified. Station Group A is located near the Entrance Channel and the eastern one-third of the harbor (Newport Harbor fore bay), and showed the greatest dissimilarity to Other Station Groups B, C, and D. Group A stations was defined by the low water temperatures, lowest percentages of silt clay (Group 1 variables), highest levels of dissolved oxygen, pH, salinity; the greatest water transparency and lowest turbidity (Group 2 variables); and the highest levels of illuminance and underwater light energy (Group 2 variables).

Groups B, C, and D stations were more similar to each other than to Group A stations. Group B stations were located in the vicinity of Balboa and Harbor Islands (fore-bay and mid-bay); Group C included mid-bay stations (Harbor to Linda Isle) and Upper Newport Bay station S10. Group D stations were limited to the West Newport Bay region.

Group B stations were characterized by moderate scores of all parameters in Group 1, 2, and 3, with none being extreme. Group C stations exhibited high water temperatures, highest percentages of silt/clay (Group 1 variables) lower levels of dissolved oxygen, salinity, pH, water transparency, illuminance, and light energy (Group 2 and 3 variables)



Coastal Resources Management, Inc.

Figure 23. Two-Way Hierarchical Classification of Newport Bay Abiotic Parameters, July 2008-May 2009

than Group B sites. Of the 4 stations within this group, Upper Newport Bay was the least similar to the mid-bay station group.

Lastly, Group D stations in West Newport Bay were characterized by (1) the coarsest sediments and the most sand and gravel where previous eelgrass transplants had failed compared to eelgrass sites in the bay; (2) the highest data logger surface water temperatures (Group 3 variables); and (3) higher salinity, illuminance, light energy, and percentages of light at the bottom (% SI) as quantified by both data loggers (lumens/ft^2) and the Quantum Meter (Photosynthetic Photon Flux, μmol m^{-2} s^{-1}) compared to Station C Group stations (mid-bay to Upper Newport Bay).

While the measured oceanographic parameters varied spatially and between sampling periods, mean dissolved oxygen values by station, survey, and season were above critical levels necessary to sustain marine life (5 mg/l), although some individual measurements (particularly in West Newport Bay) approached 5 mg/l at the deepest sampling depths (22 ft). There were no incidences of fish mortality, severe degraded water quality, or hypoxia at any of the stations sampled between July 2008 and March 2009.

The water column was also influenced by year-around watershed discharges into San Diego Creek and Upper Newport Bay punctuated by episodic high volume runoff input during storm events. These storm events reduced salinity, illuminance, irradiance, and increased water turbidity. Annual flow rates and fluvial sediment discharge volumes into Upper Newport Bay (measured in the San Diego Creek at Campus Drive) between 1983 and 2009 are presented in Appendix 3 to illustrate the variability in flow rates and sediment discharges. The annual water flow rate during 2004-2005 (75,860 acre feet) was the second highest recorded since 1983. Despite being the 2nd highest runoff year since 1983, the amount of sediment input into Newport Bay was not correspondingly as high. In 2004-2005 165,810 tons of was the 6th highest amount since 1983 (City of Newport Beach, 2008, County of Orange, 2010), with several years of lower watershed discharges generating higher sediment flow rates.

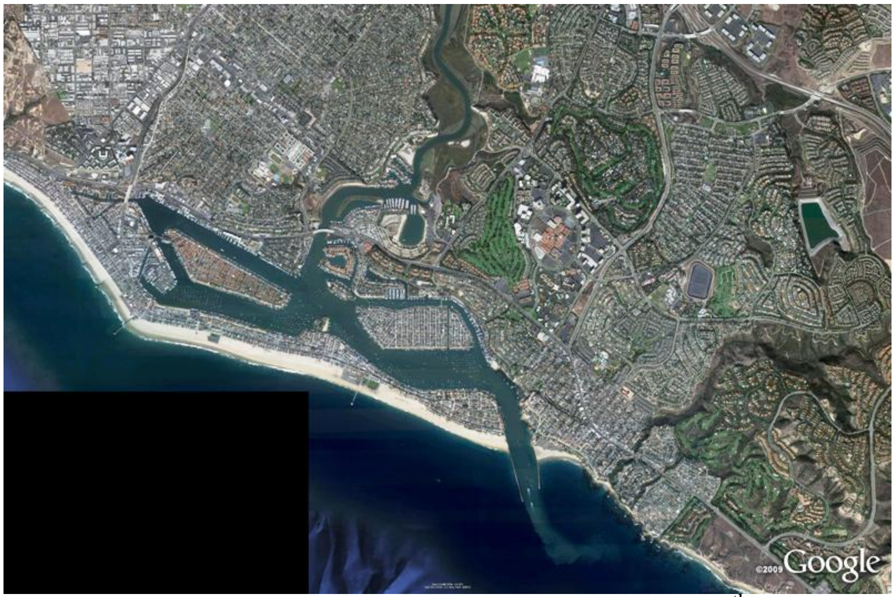
The typical pathway of runoff and sediment flow in Newport Bay is illustrated in Photograph 13a that shows an extensive turbidity plume between Upper Newport Bay and the Entrance Channel during a winter 1983 storm event. A similar plume is visible in a Google Earth aerial photograph of Newport Bay in November 2009 during which there was an ebbing spring tide, and no dredging activity in the Upper Bay (Photograph 13b). The pathway of the turbidity plume extends from Upper Bay to the Entrance Channel. Some areas may be sheltered from the main turbidity plume-the Dunes, Inner DeAnza/Bayside Peninsula, Linda Isle Inlet, South Balboa Island, and West Newport Bay. Fluvial sediment sampling and flow monitoring were conducted by the County of Orange at five locations in the Bay during a significant storm that occurred on December 15, 2008 to study the distribution and transport of sediment entering into Upper and Lower Newport Bay from San Diego Creek (County of Orange, 2010). Samples taken during the December 15, 2008 storm indicated that the highest fluvial sediment concentrations experienced were in the Upper Bay Unit I Sediment Basin (550 mg/L).

The concentration then dropped sharply to 102 mg/L in the Unit II Basin. Concentrations of samples taken at the next two stations (North Star Beach and PCH Bridge slightly rose (209 and 198 mg/L, respectively) and then diminished at Harbor Island Reach in Lower Bay (136 mg/L). Particle size distribution analysis indicated the Unit I Basin sample was 84 percent finer than 63 microns in diameter, and primarily silts and clays. At Harbor Island Reach, the sample was 93 percent finer than 63 microns in diameter (silts and clays).

Despite a reduction in fluvial sediment loads to the Upper Bay, "superfine" particles remain in suspension and are transported into Lower Newport Bay. These superfine particles reduce the levels of available light needed for eelgrass growth particularly in the Mid-Bay as indicated by the results of the light illuminance and irradiance studies. A comparative analysis of underwater horizontal visibility (collected by divers, see Section 4.1) between the 2003-2004 and 2006-2008 eelgrass mapping surveys indicate water clarity was much lower in 2006-2008 than during 2003-2004. The reduction in water clarity occurred despite rainfall years 2006-2007 and 2007-2008 being lower-than-average years of rainfall, runoff, and sediment deposition. Consequently superfine, sediment input from other factors than just heavy rainfall events are also contributing to reduced light levels in Lower Newport Bay. These factors could include site-specific projects in Upper or Lower Newport Bay or an increase in the discharge of super-fine sediments on a year-around basis that bypass any sediment controls in the watershed or Upper Newport Bay.

While successive ebb and flood tides dilute and re-distribute turbidity plumes, West Newport Bay in particular appeared to be less affected by watershed-generated turbidity because tidal currents transported turbidity plumes to the east out of the harbor rather than to the west towards Mariners Mile and the Rhine Channel. Oceanographic data collected in 2008-2009 support this hypothesis and indicate that water clarity, illuminance, and light energy levels were higher in West Newport than in either Upper Newport Bay or at mid-Newport Harbor sites (around Linda and Harbor Island). These parameters however, exhibited lower values compared to sites between Balboa Island and the Harbor Entrance Channel.

Photograph 13a. Turbidity Plume in Newport Bay During Winter 1983. Likely Taken on an Ebbing Tide. Source Photo: RBF.



Photograph 13b. Turbidity Plume in Newport Bay, November 19th, 2009. Photo taken on an outgoing, spring tide, and 0.02 inches of rain had fallen 6 days prior to the photograph. Source Photo: Google Aerials.

4.0 EELGRASS HABITAT MAPPING SURVEY RESULTS

Eelgrass habitat mapping surveys were conducted during 45 field days between September 4, 2006 and August 26th, 2008 and included diver/gps and remote sidescan sonar surveys. Nearly 16 linear miles of bay shoreline were surveyed, and the actual length covered by divers and the kayak exceeded 33 linear miles of shoreline.

4.1 DIVER SURVEY UNDERWATER VISIBILITY MEASUREMENTS DURING EELGRASS SURVEYS

Under water visibility (horizontal measurements) were recorded by CRM diver-biologists between 2003 and 2007 (Figure 24). On the average, underwater visibility was 1.7 feet greater prior to the initiation of the 2006-2007 eelgrass habitat mapping surveys than during the period in which the 2006-2008 eelgrass surveys were conducted. Average bottom water visibility during the 2003-2004 survey was 5.5+/2.9 ft (n=46 measurements), with a range of bottom visibility between 1 and 12 ft. During the 2006-2008 time period, average underwater visibility was 3.3 +/- 3.0 ft with an overall range between 0.5 and 20 ft (n=84 measurements).

Underwater visibility was greater in the vicinity of the Entrance channel and Balboa Island between 2006 and 2007 than during 2004-2006. Conversely, underwater visibility was substantially lower in 2006 and 2007 in back channels between Balboa Island, Harbor Island, Mariner's Mile, and Linda Isle and Balboa Marina than during the surveys conducted between 2003 and 2004.

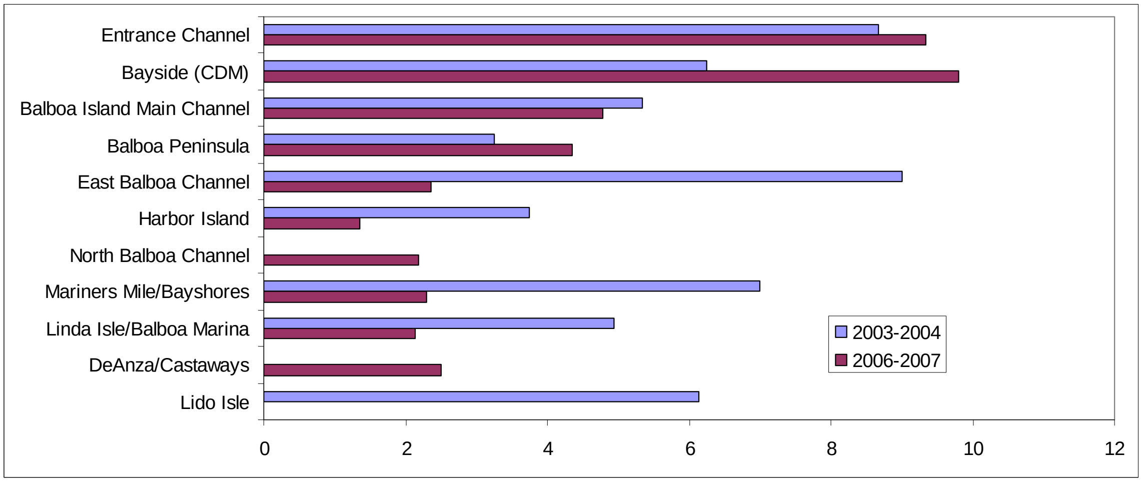


Figure 24.
Comparison of Underwater Visibility For Various Survey Regions of Newport Bay.
2003-2004 and 2006-2007

4.2 EELGRASS DISTRIBUTION AND ABUNDANCE

A total of 68.77 acres (28.6 hectares) of shallow and deep water eelgrass was mapped bay-wide between 2006 and 2008 (Table 6), representing 7.8% of the 884.9 acres (358.1 hectares) of soft bottom habitat within the Lower Newport Bay and Upper Newport Bay survey area. During the 2006-2008 surveys, 23.1 acres (9.3 hectares) of shallow water eelgrass was mapped by divers and 45.86 acres (19.3 hectares) of eelgrass was mapped using sidescan sonar methods. Eelgrass was mapped at depths between +0.8 and -27.8 feet Mean Lower Low Water (MLLW). A comparative review of the results obtained during the previous eelgrass habitat survey conducted in 2003-2004 is presented in Table 7. An overview of eelgrass distribution is presented in Figure 25, and high-resolution eelgrass habitat maps are shown in Figures 26 to 33 that super impose the 2003-2004 and 2006-2008 habitat maps on aerial photographs of the bay. Public-accessible habitat survey maps for the first and second eelgrass habitat mapping surveys are available online at the City of Newport Beach's website at:

http://www6.city.newport-beach.ca.us/website/InteractiveMap/map.asp

Comparatively, eelgrass vegetation accounted for 13.6% of the soft amount of bottom habitat in the survey area during the 2003-2004 survey, when a total of 30.4 acres of eelgrass were mapped within the shallow water habitat and 90 acres were mapped by the National Marine Fisheries Service in deep water habitat. The amount of eelgrass present in 2006-2008 represents a decline of 7.4 acres of shallow water eelgrass, a decline of 44 acres of deeper-occurring eelgrass in the navigational channels, and a decline of 5.8% in the amount of eelgrass compared to available soft-bottom habitat. Since the deepwater surveys were conducted by NMFS and by CRM using different methodologies, the differences in deeper-water acreages should be interpreted with some degree of caution.

During the 2006-2008 survey, shallow water eelgrass was common-to-abundant in the "forebay" between Corona del Mar and Balboa Island (within the Entrance Channel, Corona del Mar Reach and Balboa Reach) extending to Bay Isle at depths between 0.0 and -8 ft MLLW. Eelgrass was also abundant "midbay" within Linda Isle Inlet. These regions accounted for 91% of all of the shallow water eelgrass in Newport Bay (Table 5). Eelgrass acreages were low in other "midbay" areas (North Balboa Channel, the side channels around Harbor and Linda Isle, and Lido Reach/Mariners Mile, and Upper Newport Bay), and eelgrass was absent in "West Newport Bay" west of the Newport Harbor Yacht Club and along the Lido Peninsula (Figures 26 to 34; Table 5).

Table 6. Results of 2006-2008 Eelgrass Habitat Mapping Surveys Shallow and Deep Water Eelgrass Habitat.

Region #	Survey Region	2006-2008 (acres)	% Total, All Mapped Eelgrass	% of Shallow Water Eelgrass	Sediment* Classification
A	**Deep water Navigation Channel Between Harbor Entrance and Balboa Island**	**45.7**		**-**	**Coarse Silt to Medium Sand**
1	**Corona del Mar/Bayside Drive to OCHD**	**9.075**	**13.2**	**39.3**	**Fine Sand**
5	**Balboa and Collins Islands**	**4.554**	**6.6**	**19.7**	**Fine-Very Fine Sand**
11	**Linda Isle (Inner basin)**	**3.218**	**4.7**	**14**	**Very Fine Silt**
3	**Balboa Peninsula-East of Bay Island**	**1.557**	**2.2**	**6.8**	**Fine Sand to Medium Sand**
2	**Balboa Channel Yacht Basins**	**1.539**	**2.2**	**6.7**	**Silt to Fine Sand**
4	**Grand Canal**	**1.143**	**1.7**	**5.0**	**Fine Sand**
9	**Harbor Island**	**0.712**	**1.0**	**3.2**	**Fine to Coarse Silt**
15	**Bayshores**	**0.664**	**1.0**	**2.9**	**Very Fine Sand**
10	**Linda Isle (outer channels)**	**0.328**	**0.5**	**1.4**	**Fine to Coarse Silt**
8	**North Balboa Channel and Yacht Basins**	**0.115**	**0.2**	**0.5**	**Coarse Silt to Fine Sand**
16	**Mariners Mile**	**0.066**	**0.1**	**0.3**	**Coarse Silt to Fine Sand**
6	**Bay Island**	**0.051**	**0.1**	**0.2**	**Coarse Silt to Fine Sand**
7	**Balboa Peninsula-West of Bay Island**	**0.030**	**0.04**	**0.1**	**Fine Silt to Medium Sand**
12	**DeAnza/Bayside Peninsula (inner side)**	**0.009**	**0.01**	**0.04**	**Medium Silt**
17	**Lido Isle**	**0.004**	**0.01**	**0.02**	**Coarse Silt to Medium Sand**
13	**DeAnza/Bayside Peninsula (Outer)**	**0**	**0.00**	**0.00**	**Medium Silt**
14	**Castaways to Dover Shores**	**0**	**0.00**	**0.00**	**Medium Silt**
18	**Lido Peninsula**	**0**	**0.00**	**0.00**	**Fine to Coarse Silt**
	All Regions	**68.77**	**100.0**	**100.0**	

1 acre= 43,560 square feet
*Based on Wentworth Sediment Size Classification

Table 7. Results of Eelgrass Habitat Mapping Surveys, 2003-2004. Shallow Water Eelgrass Only

Region #	Survey Region	Area (acres)	% Total	Major Sediment Type
1*	Corona del Mar to OCHD	9.521	31.3	sand to silt
5	Balboa and Collins Islands	6.686	22.0	sand to silt
10	Linda Isle (outer channels)	2.916	9.6	silt
9	Harbor Island	2.721	8.9	silt
2	Balboa Channel Marinas/Yacht Basins	2.469	8.1	silt
3	Balboa Peninsula-East of Bay Island	1.672	5.5	silt
15	Bayshores	0.991	3.3	silt
4	Grand Canal	0.898	3.0	silt
13	DeAnza/Bayside Peninsula (Outer)	0.792	2.6	silt
8	N. Balboa Channel/Yacht Basins	0.698	2.3	silt
11**	Linda Isle (Inner basin)	0.281	0.9	silt
16	Mariner's Mile	0.234	0.8	silt
12	DeAnza/Bayside Peninsula (inner side)	0.209	0.7	silt
6	Bay Island	0.132	0.4	silt
14	Castaways to Dover Shores	0.132	0.4	silt
7	Balboa Peninsula-West of Bay Island	0.034	0.1	silt
17	Lido Isle	0.025	0.1	silt
	All Regions	**30.411**	**100.00**	

*data updated for Region 1 to include eelgrass polygon not included in original 2003-2004 report (CRM, 2005).
** Does not include 0.21 acre mapped by CRM during previous 2002 survey (Coastal Resources Management, Inc. (2002).

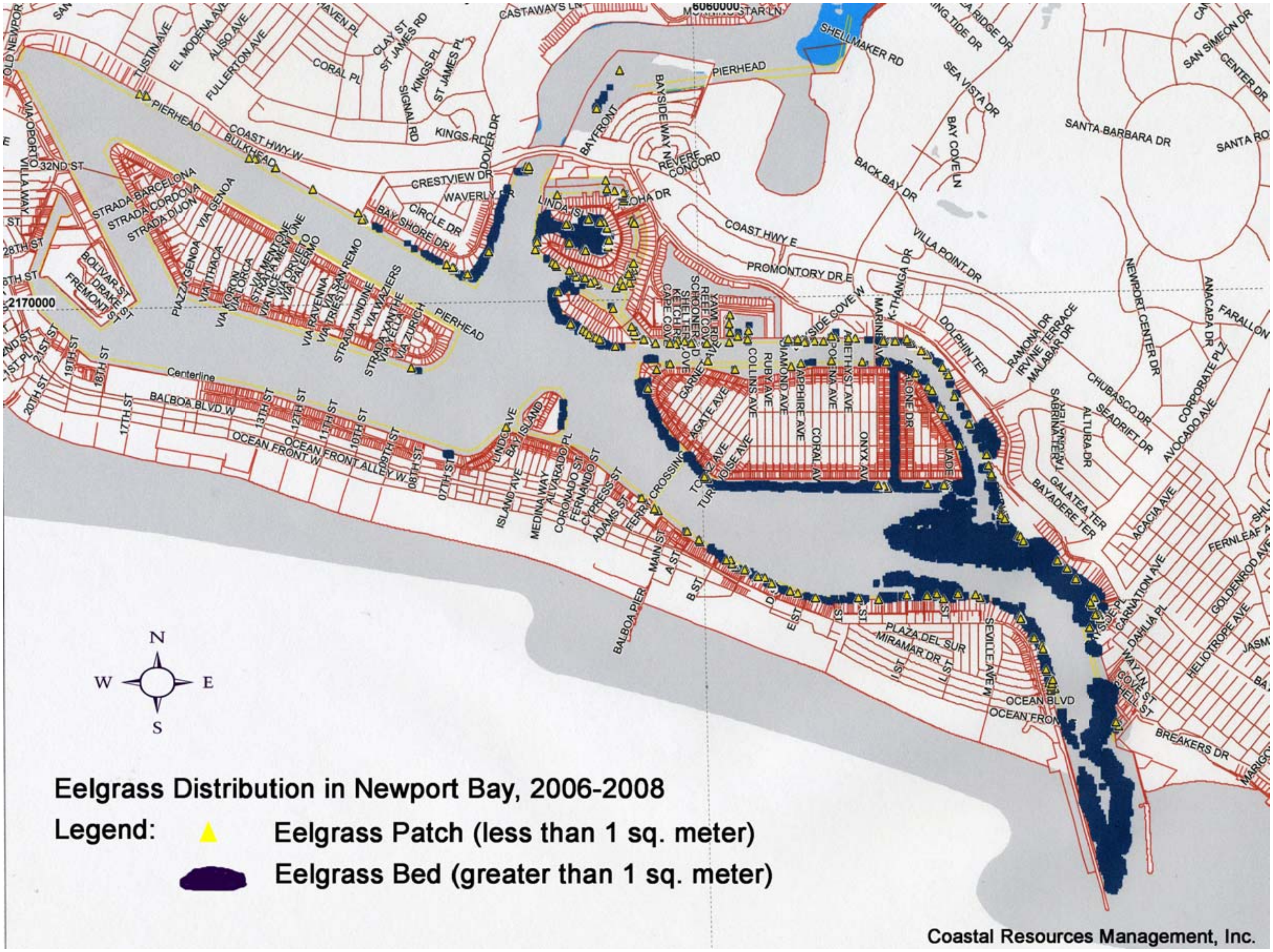


Figure 25. Overview of Eelgrass Distribution in Newport Bay, 2006-2008

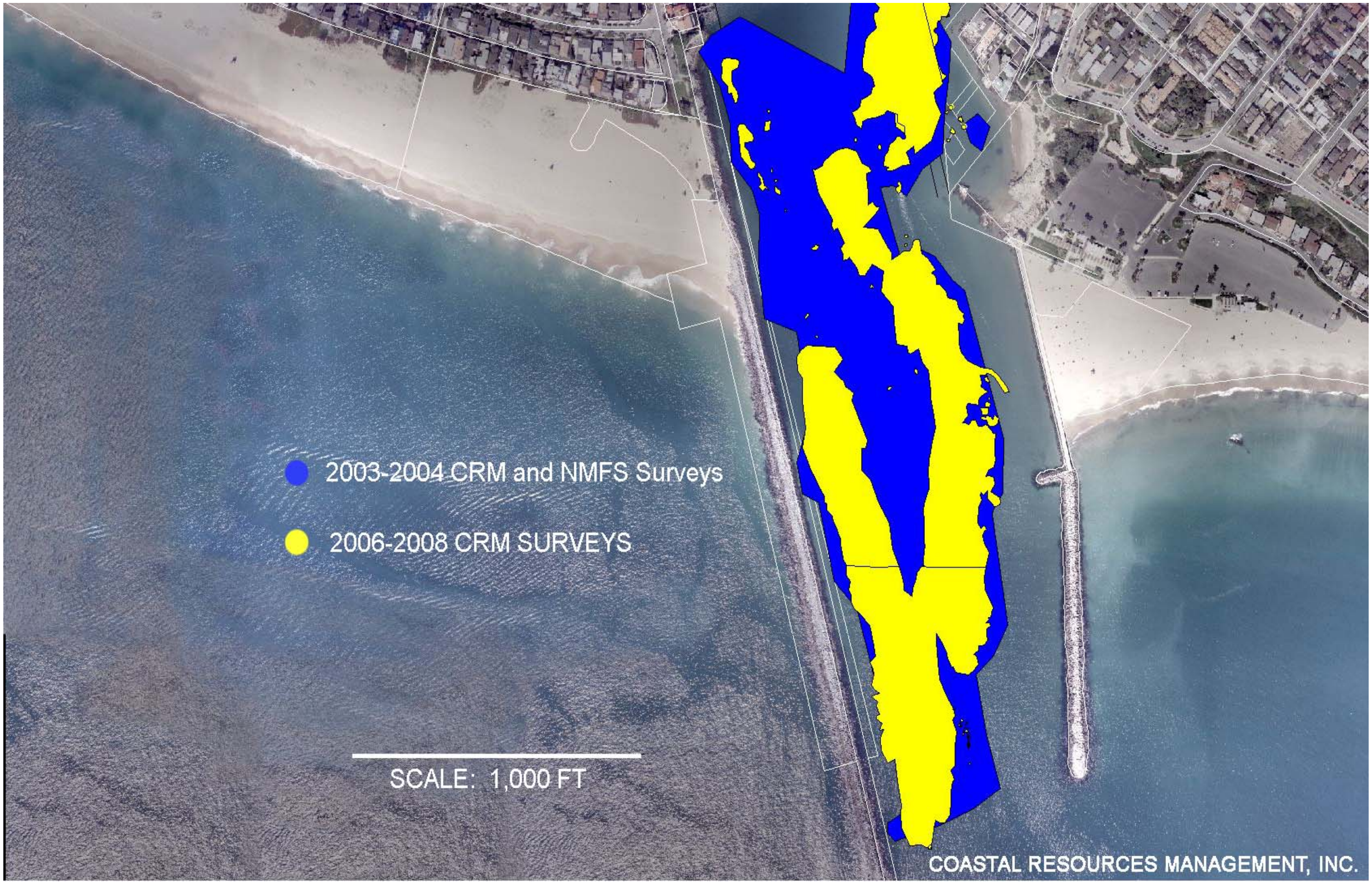


Figure 26. 2003-2004 and 200l6-2008 Eelgrass Habitat Maps. Harbor Entrance Channel

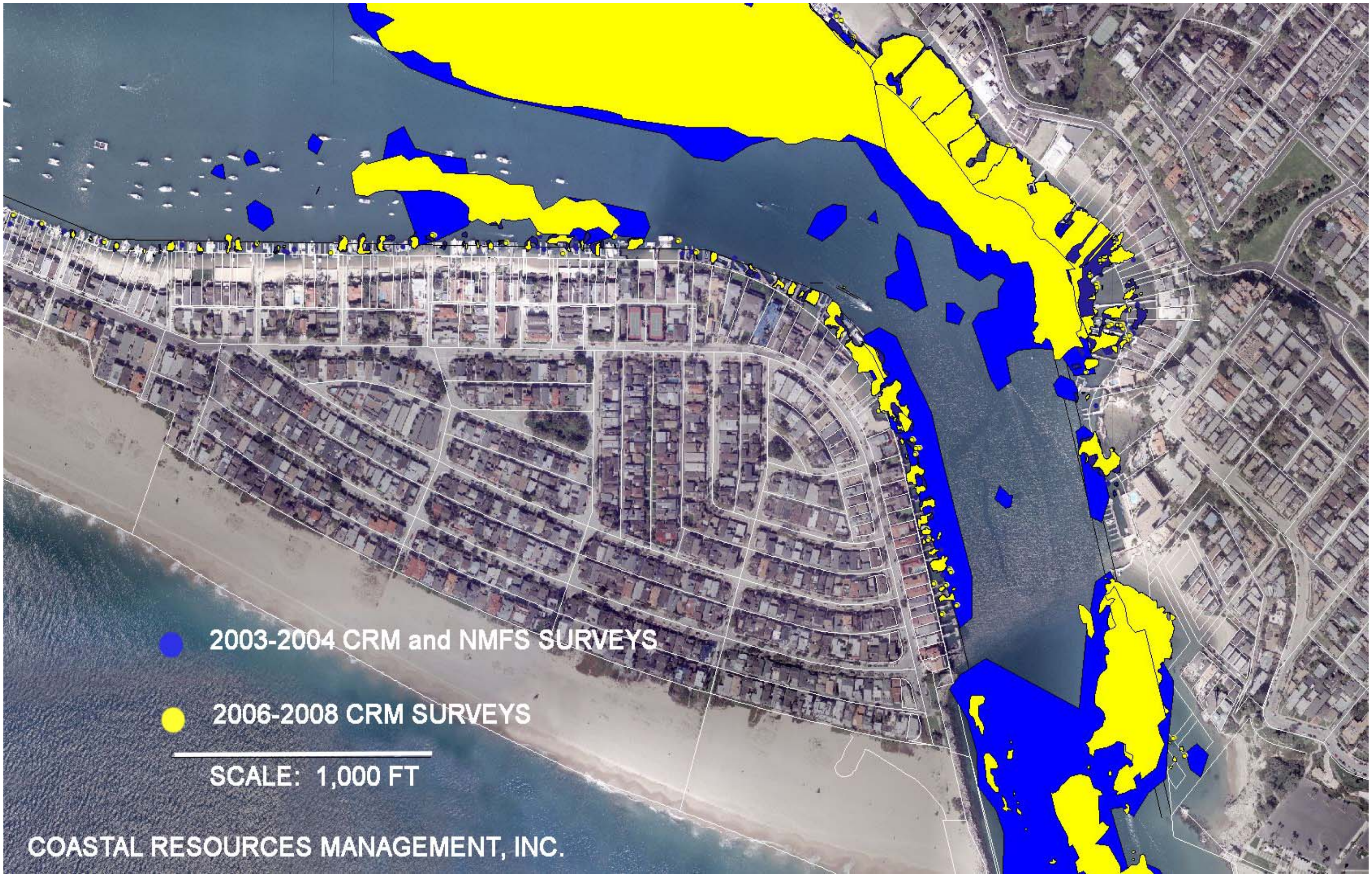


Figure 27. 2003-2004 and 2006-2008 Eelgrass Habitat Maps. Corona del Mar Bend and Balboa Reach

Figure 28. 2003-2004 and 2006-2008 Eelgrass Habitat Maps. Balboa Reach and Harbor Island Reach

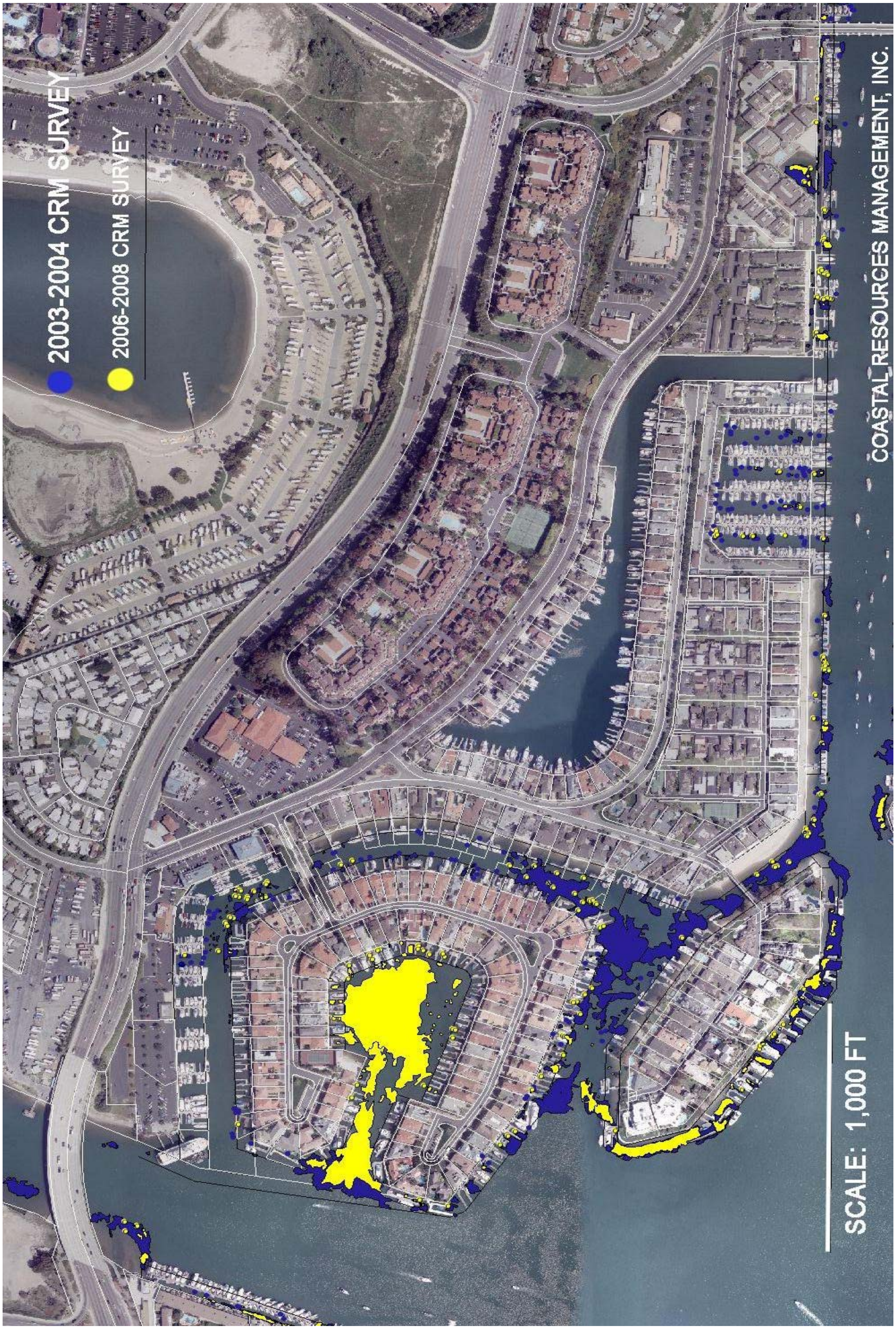


Figure 29. 2003-2004 and 2006-2008 Eelgrass Habitat Maps. Harbor Island Reach, Linda Isle, Balboa North Channel

Figure 30. 2003-2004 and 2006-2008 Eelgrass Habitat Maps. West Balboa Peninsula and South Lido Isle

Figure 31. 2003-2004 and 2006-2008 Eelgrass Habitat Maps. Lido Isle Reach, Bayshores (Mariner's Mile and Lido Isle

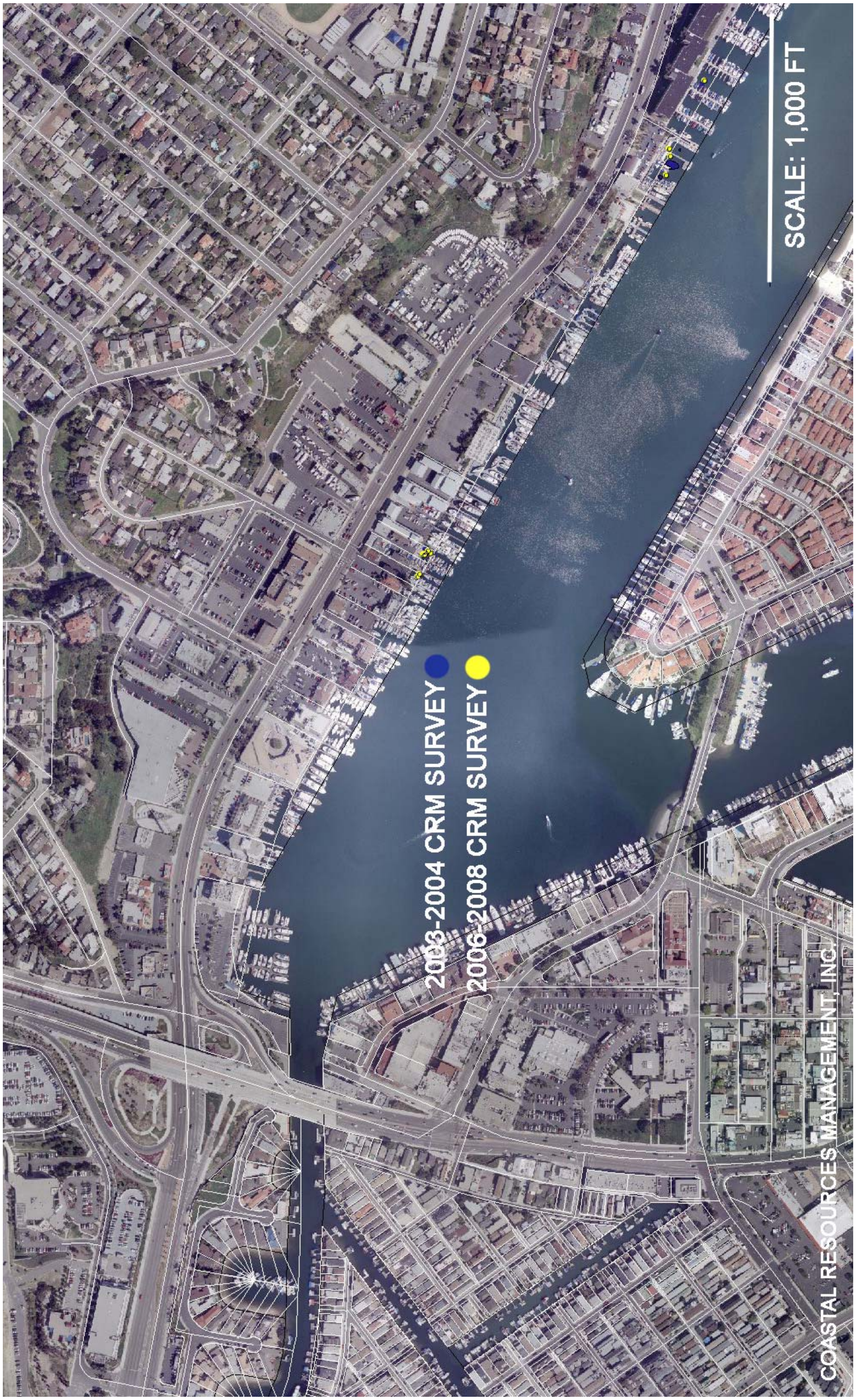


Figure 32. 2003-2004 and 2006-2008 Eelgrass Habitat Maps. Lido Peninsula and West Lido Isle Reach

Figure 33. 2003-2004 and 2006-2007 Eelgrass Habitat Maps. Balboa Marina Channel, PCH Bridge, and Upper Newport Bay

4.3 EELGRASS DISTRIBUTION BY REGION

Table 8 summarizes eelgrass distribution and abundance within the 18 shallow water regions and the one deepwater navigational channel eelgrass region for both the 2003-2004 and the 2006-2008 surveys.

Table 8. Summary of Distribution and Acreage in 2006-2008 and Comparison of Habitat Acreage to 2003-2004

Region	Description	2003-2004 (acres)	2006-2007 (acres)	Mean (acres)	Difference (acres)	% Difference
A*	Newport Harbor Deepwater Navigational Channels*	90.3	45.86	68.08	-44.44	-49.2
	Shallow Water Habitat					
1	Corona del Mar/Bayside Drive to OCHD	9.521	9.075	9.298	-0.446	-4.7
2	Balboa Channel Yacht Basins	2.469	1.539	2.004	-0.93	-37.7
3	Balboa Peninsula-East of Bay Island	1.672	1.557	1.615	-0.115	-6.9
4	Grand Canal	0.898	1.143	1.021	0.245	27.3
5	Balboa and Collins Islands	6.686	4.554	5.620	-2.132	-31.9
6	Bay Island	0.132	0.051	0.092	-0.081	-61.4
7	Balboa Peninsula-West of Bay Island	0.034	0.03	0.032	-0.004	-11.8
8	North Balboa Channel and Yacht Basins	0.698	0.115	0.407	-0.583	-83.5
9	Harbor Island	2.721	0.712	1.717	-2.009	-73.8
10	Linda Isle (outer channels)	2.916	0.328	1.622	-2.588	-88.8
11	Linda Isle (Inner basin)	0.281**	3.218	1.750	2.937	1045.2
12	DeAnza/Bayside Peninsula (inner side)	0.209	0.009	0.109	-0.2	-95.7
13	DeAnza/Bayside Peninsula (Outer)	0.792	0	0.396	-0.792	-100.0
14	Castaways to Dover Shores	0.132	0	0.066	-0.132	-100.0
15	Bayshores	0.991	0.664	0.828	-0.327	-33.0
16	Mariner's Mile	0.234	0.066	0.150	-0.168	-71.8
17	Lido Isle	0.025	0.004	0.015	-0.021	-84.0
18	Lido Peninsula	not surveyed	0	0.000	-	-
	*Deepwater and Shallow Water Regions	120.711	68.925	94.818	-51.786	-42.9
	Shallow Water Regions Only	30.411	23.065	26.738	-7.346	-24.2

Remote surveys conducted by National Marine Fisheries Service in 2003; CRM in 2008. Caution should be used when comparing results from 2003-2004 to

** Does not include 0.21 acre mapped by different methods in 2002 (Coastal Resources Management, Inc. (2002).

4.3.1 Deeper Navigational Channel Eelgrass, Entrance Channel to Corona del Mar and Balboa Reach (45.7 Acres)

This region was mapped using sidescan sonar techniques in June and July 2008. Eelgrass formed luxuriant meadows between the Entrance Channel and Balboa Island at depths between -7 and -27.8 ft MLLW. The amount of deepwater eelgrass habitat in the bay encompassed 45.7 acres (66.5% of all eelgrass in the bay), the bulk of which was mapped between the entrance channel and the southeast tip of Balboa Island (Figures 26 to 27).

Grain sizes in the deeper water channels in the entrance channel were characterized as medium sands. In Corona del Mar Reach, sediment grain sizes were finer (medium silt). A wide-blade variant of eelgrass occurs in the Entrance Channel and coexists with the more common narrow-bladed form. Eelgrass blade length extended to over 2 meters (6.6 ft) in length. Photographs 14 and 15 illustrate this wide-bladed form in the entrance channel.

4.3.2 Region 1-Corona del Mar-Bayside Drive including Coast Guard/O.C. Harbor Patrol Facilities (9.075 acres)

Eelgrass was dense and extensive between Bayside Drive and the County of Orange Sheriff Harbor Patrol Facilities, accounting for 13.2% of all eelgrass vegetation and 39.3% of the vegetated shallow water eelgrass habitat (Table 5, Figure 26-28). The depth range of eelgrass extended between the intertidal and -16 ft MLLW. Unlike many areas in Newport Bay, a substantial portion of the eelgrass meadow was intertidal (Photographs 16 and 17) due to a lack of dredging and channelization in this region of the bay. The greatest diversity of marine organisms occurs within the eelgrass meadows of this area and the harbor entrance channel (Chambers Group and Coastal Resources Management, 1998). Both narrow and wide blade forms of eelgrass occurred within the region. Sediments were coarser at shallow depths (fine sands) that graded into finer silts with increasing depth. Large concentrations of the speckled scallop (*Argopecten aequisulcatus*) were associated with eelgrass in this region in 2003-2004 (CRM, 2005), but not present in 2006-2007 in as high concentrations. While generally stable compared to 2003-2004, some loss of eelgrass was observed during the 2006-2007 survey in Carnation Cove proximal to the Carnation Cove storm drain. In 2003-2004, eelgrass encompassed 9.52 acres. Overall, there was a 4.5% decline in eelgrass vegetation compared to the 2003-2004 survey.

4.3.3 Region 2-Yacht Club Basins and Marinas Between the Orange County Harbor Department and the Balboa Bridge along Bayside Drive (1.539 acres)

The yacht club and marina basins in this region were colonized by moderate eelgrass cover. Most eelgrass was located in the Bahia Corinthian and Balboa Yacht Club basins (Figure 28). Depths in these basins were less than -10 ft MLLW and sediments tended to be fine sands and silts. This region accounted for 2.2% of all eelgrass and 6.7% of shallow water eelgrass. In 2003-2004, 2.469 acres of eelgrass was mapped (Table 5). Overall, there was a 37.7% decline in eelgrass vegetation compared to the 2003-2004 survey, primarily in the Balboa Corinthian and Bayside Marina basins.

Photograph 14. Entrance channel eelgrass meadows at depths of -15 ft MLLW

Photograph 15. Entrance channel eelgrass meadows

Photograph 16. Intertidal eelgrass meadows in Carnation Cove, Corona del Mar

Photograph 17. Close up of intertidal eelgrass vegetation in Carnation Cove

4.3.4 Region 3-East Balboa Peninsula (1.557 acres)

The East Balboa Peninsula region includes the shallow water zone between the bulkhead and the seaward ends of docks between the Entrance Channel to, but not inclusive of Bay Island (Figure 2). Primarily lined with docks, this shoreline was characterized by many small eelgrass beds and patches that were located between docks, within boat slips, and shoreward and seaward of docks at depths between -1 and -9 ft MLLW (Photograph 18). This region accounted for 2.3% of all eelgrass vegetation and 6.8% of the vegetated shallow water eelgrass habitat (Table 5, Figure 27). Eelgrass beds were smaller and patches more numerous in 2006-2008 compared to 2003-2004, when eelgrass cover accounted for 1.672 acres. Between 2003 and 2007, this region exhibited a 6.9% decline in eelgrass vegetation.

Photograph 18. Typical eelgrass bed located around the perimeter of a dock along the East Balboa Peninsula and Balboa Island

4.3.5 Region 4-Grand Canal (1.143 acres)

The Grand Canal separating “Little Balboa” and “Balboa Island” was vegetated with eelgrass along its entire length at depths between 0.0 and -6 ft MLLW, and at both the north and south entrance channels. Eelgrass accounted for 1.7% of all eelgrass in the bay and 5% of the vegetated shallow water eelgrass (Table 5, Figure 28). Portions of the Grand Canal were dredged in winter 1999 which resulted in loss of eelgrass habitat (Coastal Resources Management, Inc., 1999) However, regrowth through mitigation-mandated transplanting efforts conducted by MBC Applied Environmental Sciences and subsequent natural spreading occurred. Sediments range from fine sand to silt. Large concentrations of the speckled scallop (*Argopecten circularis*) were found in the canal eelgrass beds in 2003-2004 but they were less abundant in 2006-2007. During the previous eelgrass survey, the amount of eelgrass in the Grand Canal was 0.898 acre. Unlike most other areas, the Grand Canal exhibited a 27.3% increase in eelgrass acreage in 2006-2007 compared to the earlier 2003-2004 survey.

4.3.6 Region 5-Balboa and Collins Islands (4.554 acres)

While Balboa Island is rimmed with City-nourished sand beaches, Collins Island is bulkheaded and dredged. Eelgrass meadows lined the south-to-west and eastern perimeter of Balboa Island along Bayfront South and East, and the south side of Collins Island between docks and mooring systems (Photograph 19). Region 5 accounted for 9.1% of all eelgrass vegetation in the bay, and 6.6% of the shallow water eelgrass habitat. Sediments were fine to median sands in the low intertidal and shallow subtidal in areas of beach nourishment and fine sands to silt in the shallow to deeper waters surrounding the island. The narrow-bladed variant was most common although in deeper areas, the wide-bladed variant was occasionally observed, primarily along the southeastern tip of Balboa Island.

Photograph 19. Shallow water eelgrass habitat shoreward of a dock typical of Balboa Island and Balboa Peninsula eelgrass beds

On the south side of Balboa Island, eelgrass extended seaward of Bay Front South into the main channel and was growing at depths between 0.0 ft MLLW along the shoreline to approximately -10 to -12 ft MLLW within the Anchorage “B” mooring area (Figure 28). Like the Balboa Peninsula eelgrass beds, vegetation along Bay Front South occurred shoreward of docks, beneath many piers, within unused boat slips, between adjacent docks, and along open stretches of the shoreline in around boats on mooring lines. The deeper beds in the navigational channel coalesced with the meadows that extended into the harbor entrance channel (Figures 26 and 28).

Less eelgrass was present along East Bay Front in the East Balboa Channel than during the 2004-2006 survey. Eelgrass was virtually absent along the entire length of North Bay Front between Emerald and Marine Avenue with the exception of several patches and small beds located mostly between Sapphire and Apolena Avenues. Collins Island eelgrass habitat was present along its south and north perimeter.

In 2003-2004, the acreage of eelgrass around Balboa Island and Collins Island was 6.686 acres. The amount present during the 2004-2006 survey was 31% less than in the previous survey. Losses were highest along Bay Front North and Bay Front East.

4.3.7 Region 6-Bay Island (0.051 acre)

Bay Island accounted for 0.1% of all eelgrass in the bay and 0.2% of the shallow water eelgrass habitat. All of the eelgrass in 2006-2007 grew along the east-facing sandy beach and between the boat docks (Table 5, Figure 30). Sediments in this bed were medium-to-coarse silts. Eelgrass in this region was the narrow-bladed variant. In 2003-2004, the acreage of eelgrass around Bay Isle was 0.132 acres. During that survey, eelgrass was also present in the channel on the south side and southwest corner of the island but these beds were missing during the 2006-2007 survey. This vegetation was first observed between 1999 and 2002 (Coastal Resources Management, 2002). Eelgrass abundance around Bay Island was 61.4% less in 2006-2007 than during the 2003-2004 survey.

4.3.8 Region 7-West Balboa Peninsula (0.030 acre)

Region 7's eelgrass habitat was found exclusively in the Newport Harbor Yacht Club Basin at depths between 0.0 and -3 ft MLLW. It accounted for less than 1% of the total amount of eelgrass in the bay, and 0.1% of the shallow water eelgrass habitat (Table 5, Figures 30). Eelgrass in this region was the narrow-bladed variant. Eelgrass was absent farther west from the Newport Harbor Yacht Club to 19th Street near the Rhine Channel. Sediments were fine silts to fine sands along most of the Peninsula, except bayward of city-maintained beaches. Subtidal sediments in these areas were coarser (See Section 3). In 2003-2004, the acreage of eelgrass along the West Balboa Peninsula was 0.034 acres. The amount during 2006-2007 was 11.8% less than the previous survey.

4.3.9 Region 8-North Balboa Channel (North Side) from the Balboa Bridge to Beacon Bay (0.115 acres)

Eelgrass on the north side of the North Balboa Channel accounted for 0.2% of all eelgrass in the bay and 0.5% of the shallow water eelgrass (Table 5, Figure 29). Small eelgrass beds and patches were found behind and among dock structures similar to the location of eelgrass in East Balboa Reach (Region 2). A small eelgrass bed was present in the shallows of Bayside Cove behind the Belcourt Marina and several small eelgrass patches were found in the Fairways A, B, and C within the Balboa Yacht Basin. West of the

Balboa Yacht Basin, additional small eelgrass beds and patches were present along the Beacon Bay shoreline between Reef Cove and Cutter Road. Except for Beacon Bay where the beach-nourished shoreline and shallow subtidal sediments were fine sands, shallow water sediments were uniformly fine silts along other stretches of Region 8. Substantial losses of eelgrass occurred along Beacon Bay and in the Balboa Yacht Basin. Eelgrass abundance was 83.5% less in 2006-2007 than during the 2003-2004 survey, when 0.698 acres of eelgrass were mapped.

4.3.10 Region 9-Harbor Island (0.712 acres)

Eelgrass accounted for 1% of all eelgrass in the bay and 3.2% of the shallow water eelgrass. A large eelgrass bed continues to dominant the dock-free, west-face of the island. Eelgrass along the southwest-and north side of the island grew among and between docks and slips, and in the channel separating Harbor Island and Linda Isle (Figure 29). The depth range of eelgrass varied between 0.0 and -8 ft MLLW. Contrary to the results obtained during the 2003-2004 survey, very little eelgrass was present in the shallow water channel, east of the bridge connecting Harbor Island and Beacon Bay (Figure 29).

Eelgrass was light-limited between the bulkhead and the seaward end of the docks along most of the north side of Harbor Island due to shading effects of the large trees, homes, and docks. Sediments were sandier close to the bulkhead and graded into silts in the vicinity of the docks. Eelgrass abundance was 73.8% less in 2006-2007 than during the 2003-2004 survey, when 2.721 acres of eelgrass were mapped.

4.3.11 Region 10-Outer Linda Isle Channels (0.328 acres)

Eelgrass habitat accounted for 0.5% of all eelgrass in the bay, and 1.4% of the shallow water eelgrass habitat (Table 5, Figure 29). Sediments were fine to coarse silts. Depth ranges of eelgrass in this region varied between -2 and -8 ft MLLW.

Tetra Tech, Inc. (2003) mapped 0.18 acres on shoals in the center of the north Linda Isle channel between Linda Isle and the Balboa Marina and in the fairways of the marina in 2003, some of which did not overlap with CRM 2003-2004 data. Both surveys are shown in Figure 30. Eelgrass in this area was reduced to small patches and small beds primarily in the eastern section of the Balboa Marina Channel between 2006 and 2008. These were later eliminated during channel dredging in early 2009 for the renovation of the Balboa Marina (Coastal Resources Management, 2009). An eelgrass transplant program was implemented at the marina in July 2009 to mitigate for these losses (Coastal Resources Management, Inc. 2009).

Although this region was colonized by moderate cover of eelgrass during the 2003-2004 survey (2.961 acres), eelgrass cover declined to 0.328 acres (-88.5%) in the 2006-2008 survey. Eelgrass habitat decreases were observed throughout this region, with most losses occurring in the channel between Harbor Island and Linda Isle.

4.3.12 Region 11-Linda Isle Inner Basin (3.281 acres)

This region was mapped in 2007 by CRM and Nearshore and Wetland Surveys using sidescan sonar techniques and the results were verified by diver and remote-video surveys. Eelgrass was abundant in the entrance and back basin of Linda Isle, constituting 4.6% of all eelgrass in the bay and 19.7% of shallow water eelgrass habitat at depths between -3 and -6 ft MLLW (Table 5, Figure 29). Patches and small beds were also mapped around the basin's perimeter between docks and within unoccupied boat slips.

Since 2002, the acreage of eelgrass in Linda Isle basin has increased substantially. During a survey conducted for the Linda Isle Homeowners Association in 2002, the inner basin eelgrass beds totaled 0.21 acres (Coastal Resources Management 2002). The entrance to the basin supported 0.281 acres of eelgrass during the 2003-2004 survey, but the inner basin was not mapped.

Based on data extending back to 2002, at least 0.5 acres of eelgrass was likely present in the Inner Linda Isle basin in 2003-2004. Increases in eelgrass habitat between 2002 and 2004 and the 2006-2008 survey were 531% and 1,025%, depending on if the data includes or excludes the 2002 survey information, respectively.

4.3.13 Region 12-DeAnza/Bayside Peninsula, Inner Area (0.009 acre)

The amount of eelgrass in Region 12 constituted less than 1% of all eelgrass in the bay and 0.04% of shallow water eelgrass mapped by divers. Twelve small patches and beds were mapped at depths between -2 and –3 ft MLLW adjacent to the DeAnza/Bayside marsh peninsula during the 2006-2008 survey (Figure 33). Sediments in this region were fine silts except at the swimming beach which contained a greater percentage of sand.

During the 2003-2004 survey, 0.209 acres of eelgrass was mapped and two distinct concentrations of eelgrass were found. Nearly all of this vegetation (95.7%) was absent during the 2006-2008 survey. Eelgrass was initially observed in this section of Upper Newport Bay in a survey conducted in 1999 by Chambers Group and Coastal Resources Management (1999).

4.3.14 Region 13-DeAnza/Bayside Peninsula, Outer Area, Main Channel of Upper Newport Bay (0.00 acres)

No eelgrass was found during the 2006-2007 survey (Figure 33), although it was abundantly present during the 2003-2004 survey. The prior bay-wide survey identified 0.792 acres of eelgrass along the shoreline in Region 13, which consisted of small-to large patches and beds that extended along the southern one-half of the peninsula. Eelgrass in this region was the narrow-bladed variant.

Eelgrass was present in this section of Upper Newport Bay in the late 1960s and early 1970s. In 1999, only low density patches were observed (Chambers Group, Inc. and Coastal Resources Management 1999). Efforts to transplant eelgrass to this area were unsuccessful in 1985 (MBC Applied Environmental Sciences, 1987), and again in 2006

(Mike Curtis MBC Applied Environmental Sciences, Inc. personal communication with R. Ware).

4.3.15 Region 14-Castaways to Dover Shores, Upper Newport Bay (0.00 acres)

No eelgrass was found along the Castaways and Dover Shores shoreline on the west side of Upper Newport Bay (Figure 33). During the 2003-2004 survey, 0.132 acres were mapped along the shoreline. Most of this was present immediately north of the Coast Highway Bridge in front of the old Castaways Marina bulkhead at depths between -1 and -5 ft MLLW. Currently, this area is a staging area for Upper Newport Bay dredging and a debris containment boom is located in the vicinity of the previously-present eelgrass bed. The bed was present in the early 1990s (R. Ware, pers. observation), but disappeared following the 1998 El Nino (R. Ware, pers. observation). It was found again in 2002, (Coastal Resources Management and Chambers Group, 2002) and then during the 2003-2004 CRM mapping survey.

4.3.16 Region 15-Bayshores (0.664 acres)

Region 15 extends from the Coast Highway Bridge to the junction of the Lido Reach. The amount of eelgrass in Region 15 constituted less than 1% of all eelgrass in the bay and 2.9% of shallow water eelgrass habitat (Table 5, Figure 31). Sediments were generally fine to coarse silts along much of the bulkhead, although coarser sediments (fine sands) were present in front of the community's swimming beach.

During the 2003-2004 survey, 0.991 acre of eelgrass was present. Most of the eelgrass previously located on a shoal in front of the Anchorage Marina near the Coast Highway Bridge was missing during the 2006-2007 survey but eelgrass located along the bulkhead south to the Lido Reach persisted. Eelgrass grew between the bulkhead and the docks, between adjacent docks, and in wider, open areas adjacent to the community's swimming beach near the juncture of the Lido Reach. Eelgrass abundance was 33% less in 2006-2007 than during the 2003-2004 survey, when 0.991 acres were mapped.

4.3.17 Region 16-Mariners Mile (0.066 acre)

The Mariners Mile region within Lido Reach constituted 0.1% of all eelgrass in the bay and 0.3% of the shallow water eelgrass vegetation (Table 5, Figure 31 and 32). This region's eelgrass vegetation totaled 0.234 acres of eelgrass during the 2003-2004 survey. Compared to 2003-2004, there has been a 71.8% loss of eelgrass in this region. .

Eelgrass was located at depths between -2 and -7 ft MLLW in fine sand to silt sediments. Beds were concentrated between the bulkhead and the headwalks of the residential marina at Bayshores. Farther west, previous eelgrass beds located in the vicinity of the Balboa Bay Club, the Orange Coast College School of Sailing and Seamanship, and Southshore Yacht Club Basin were reduced to small patches. In addition to eelgrass, a small patch of another species of seagrass, ditchgrass (*Ruppia maritima*) was observed between dock slips immediately west of South Shore Yacht Club.

4.3.18 Region 17-Lido Island (0.004 acres)

Lido Island eelgrass coverage encompassed 0.004 acres, which constituted <0.1% of all eelgrass and <0.1% of shallow water eelgrass vegetation (Table 5, Figure 31). One small bed and one small patch were located on the far southeastern tip of the island representing the western-most extent of eelgrass in this channel leading back to the Lido Peninsula. Eelgrass abundance was 84% less in 2006-2007 than during the 2003-2004 survey, when 0.025 acres were mapped.

Losses were observed within the Lido Isle Yacht Club Basin, and small patches and a small bed around the northeast tip of the island. Sediments tend to be sandier around Lido Isle because the community beaches consist of beach-nourishment sands that tend to be sandy. Subtidally, the sediments varied between fine sands in the low intertidal to silts at deeper depths.

4.3.19 Region 18-Lido Peninsula (0.000 acres)

Eelgrass was not observed along the bulkhead of the Lido Peninsula extending between the Rhine Channel to the Newport Blvd Bridge (Figure 32). This region was not surveyed during the 2003-2004 survey.

4.3.20 Additional Eelgrass Habitat Mapping Surveys Not Associated with the CRM City of Newport Beach Surveys (Dunes Marina, Newport Dunes Aquatic Park, Upper Newport Bay North of Dover Shores, and West Newport Bay.

No eelgrass was observed in Upper Bay during extensive surveys conducted prior to Upper Newport Bay dredging in 1999 (Coastal Resources Management, 1999), prior to the Upper Newport Bay Restoration Dredging Project (MBC Applied Environmental Sciences, 2004). Chambers Group, Inc., (2005b) surveyed the Dunes Marina and the Dunes Aquatic Park in 2004 prior to dredging. A total of 53.8 sq ft of eelgrass was mapped in the marina at depths between -4 and -8 ft MLLW (Figure 34). No eelgrass was present during later, pre-dredging surveys of the area in 2007 (Chambers Group, 2007, CRM, Inc., 2007). Eelgrass was not observed west of the Newport Blvd Bridge in Balboa Coves (CRM, Inc. 2005, 2006) or along the north bulkhead in the Rhine Channel (CRM, Inc. 2007).

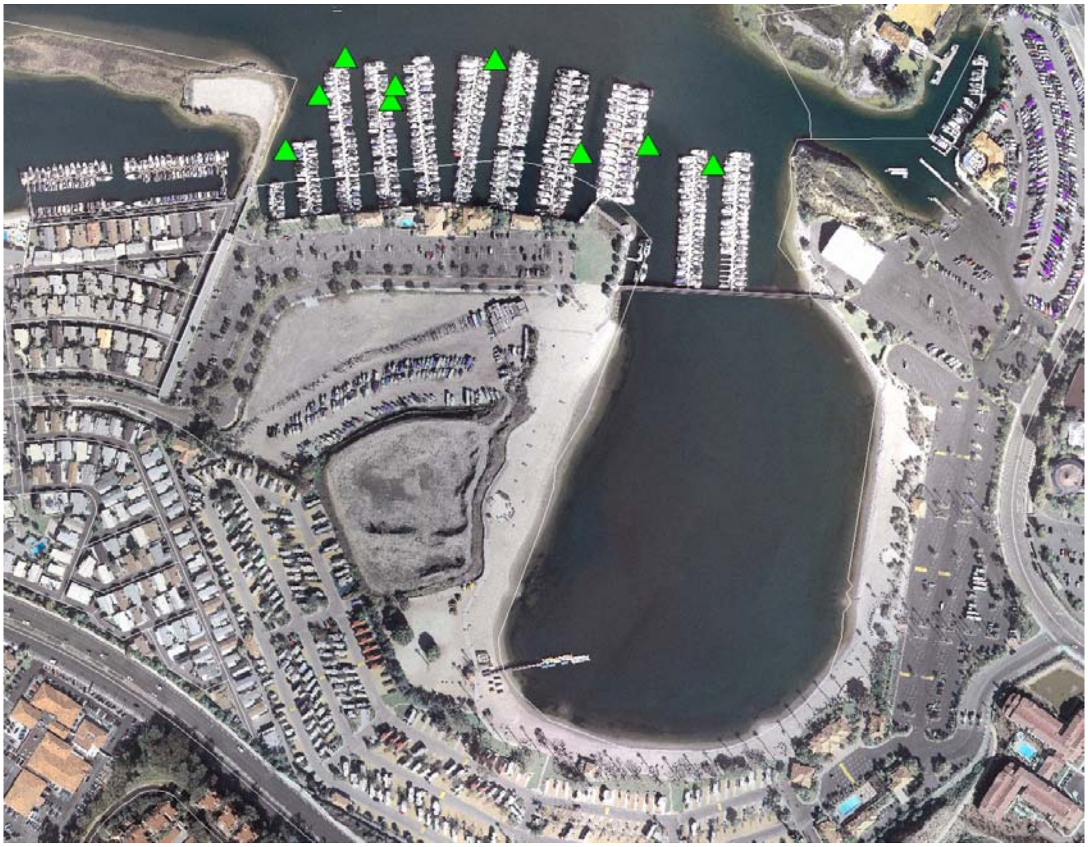


Figure 34. Location of eelgrass patches in the Dunes Marina. 2004. Source: Chambers Group, Inc. 2005.

4.3.21 Analysis of Mid-Bay and Upper Bay Eelgrass Bed Losses

While losses were observed throughout Newport Bay, most reductions in acreage in Newport Harbor occurred located in the mid-bay region (Figure 35). These regions included portions of Balboa Island, Harbor Island, and Linda Isle. Outlying, small eelgrass beds and patches in Lido Reach (Mariner's Mile) and the south side of Lido Island were also affected. In Upper Bay, large eelgrass beds previously located between Coast Highway Bridge and Shellmaker Island in Upper Newport Bay all but disappeared. Data losses, by area of the bay are presented in Appendix 5 summarize eelgrass habitat losses throughout the bay.

Figure 36a and 36b illustrate the distribution of eelgrass losses in the mid-bay region based upon how beds were oriented; i.e., on the north and east sides of the island or south and east sides of the island. Losses (by island orientation) are presented by acreage and percent loss for each locality. For both Balboa and Harbor islands, 94.4% and 62.1% of the eelgrass located in the channels on the north and east sides of the islands was not present during the 2006-2006 resurvey. These channels include North Balboa Channel extending between the Balboa Island Bridge to the end of Beacon Bay (the bridge to Harbor Island) and the north side Of Harbor Island separating Harbor Island and Linda Isle.

Figure 35. Mid-Bay and Upper Bay zones of extensive shallow water eelgrass losses between 2004 and 2007.

Losses surrounding Linda Isle were substantial on the south side between Linda Isle and Harbor Island, as well as on the north and west sides (97.7% and 88.5%, respectively. Of note is that the eelgrass habitat within Linda Isle Inlet exhibited a substantial increase in size while waters surrounding the Isle were nearly decimated.

Eelgrass in Upper Newport Bay experienced a near-total loss between 2003-2004 and 2006-2007. Of a total of 1.001 acre present in 2003-2004, only 9% remained in 2006-2007. All of the eelgrass located in the main channel west of the De Anza/Bayside Peninsula disappeared, while 0.09 acre on the east side of the peninsula survived.

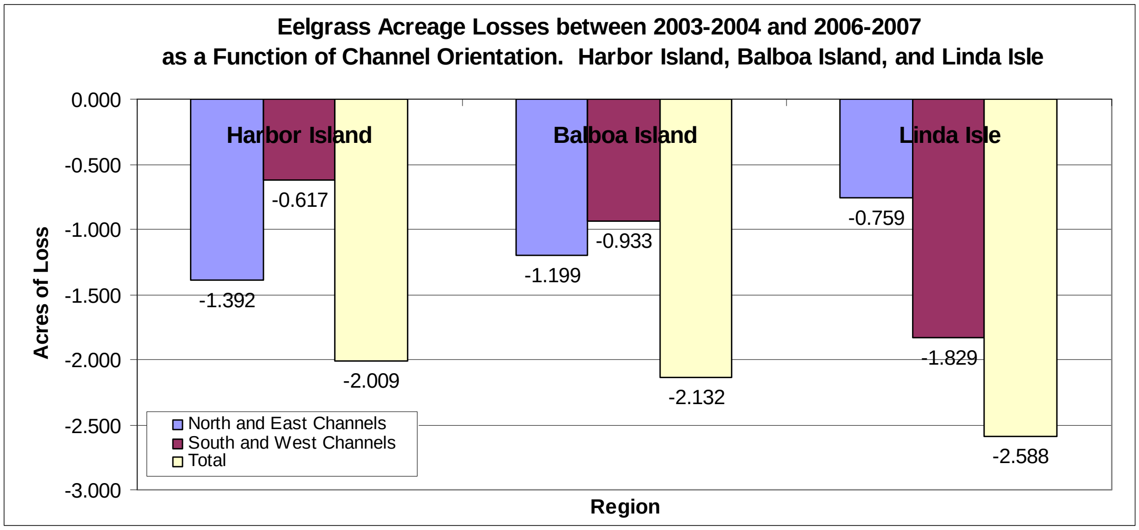


Figure 36a

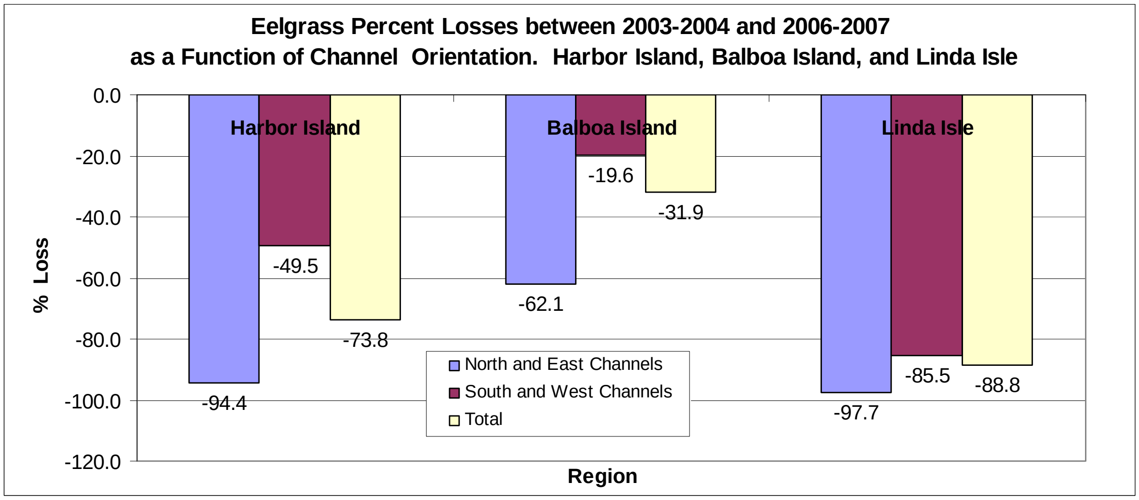


Figure 36b

4.4 EELGRASS HABITAT ANALYSIS BASED UPON STANDARDIZED SHORELINE LENGTHS

A comparison of eelgrass habitat changes between 2003 and 2007 for all regions based on unit area (linear-mile) section of shoreline is presented in Table 9. This analysis allows an assessment of bay-wide changes giving equal weight to shoreline lengths for each region investigated. For all areas, the change in eelgrass acreage was a loss of 7.10 acres per linear mile of shoreline, which represented an average loss of 0.66 acres per/mile per region (n=17 regions). Regions that increased their percent dominance in the bay included Linda Isle Inner Basin (21.6%), Corona del Mar/Bayside (5.82%), Grand Canal (5.82%), East Balboa Peninsula (2.39%), and West Balboa Peninsula (0.1%). Because of the extensive reduction of eelgrass in many areas of the Bay, eelgrass has been concentrated in fewer regions.

Table 9. Assessment of Change Based Upon Standardized Shoreline Lengths From Most Abundant to Least Abundant Eelgrass in 2006-2007

Rank	Region #	Survey Region	Acres/Linear Mile	% Total	Acres/Linear Mile	% Total	Change in Acres/Linear Mile	Change in % Total (Percent Dominance)
			2003-2004		2006-2007		2003-2007	2003-2007
1	11	Linda Isle (Inner basin)*	0.585	1.63	6.703	23.22	6.117	21.60
2	1	Corona del Mar/Bayside Drive to OCHD	11.164	31.05	10.641	36.87	-0.523	5.82
3	4	Grand Canal	1.469	4.08	1.870	6.48	0.401	2.39
4	3	Balboa Peninsula-East of Bay Island (Newport Yacht Club)	1.058	2.94	0.985	3.41	-0.073	0.47
5	7	Balboa Peninsula-West of Bay Island	0.031	0.09	0.028	0.10	-0.004	0.01
6	17	Lido Isle	0.011	0.03	0.002	0.01	-0.009	-0.02
7	16	Mariner's Mile	0.279	0.78	0.079	0.27	-0.200	-0.50
8	6	Bay Island	0.389	1.08	0.150	0.52	-0.239	-0.56
9	14	Castaways to Dover Shores	2.973	8.27	1.992	6.90	-0.981	-1.37
0	15	Bayshores	3.294	9.16	2.243	7.77	-1.050	-1.39
11	5	Balboa and Collins Islands	0.572	1.59	0.025	0.09	-0.548	-1.51
12	12	DeAnza/Bayside Peninsula (inner side)	1.014	2.82	0.167	0.58	-0.847	-2.24
13	8	North Balboa Channel and Yacht Basins	4.224	11.75	2.633	9.12	-1.591	-2.62
14	2	Balboa Channel Yacht Basins	2.429	6.76	0.273	0.95	-2.156	-5.81
15	10	Linda Isle (outer channels)	2.140	5.95	0.000	0.00	-2.140	-5.95
17	13	DeAnza/Bayside Peninsula (Outer)	4.088	11.37	1.070	3.71	-3.019	-7.66
17	9	Harbor Island	0.236	0.66	0.000	0.00	-0.236	-0.66
	18	Lido Peninsula	-	-	0.00	0.0		
		All Regions	**35.96**	**100.0**	**28.86**	**100.0**	**-7.10**	**-0.66**

* 0.21 acres surveyed within the basin in 2002 by CRM for another project not included in the total. Inner Basin partially surveyed in 2003-2004.

4.5 EELGRASS TURION DENSITY

A turion is an above ground unit of eelgrass growth that consists of an eelgrass shoot and associated eelgrass blades. Eelgrass density refers to the number of turion units per area of bayfloor. Turion density can be highly variable as a result of water temperature, water currents and tidal exchange rates, sediment characteristics, light availability, and water depth. A combination of low and high density canopy, and open patches of unvegetated sediment may contribute to a greater diversity of organisms and a more complex ecological system.

4.5.1 Depth, Light, and Sediment Relationships

Eelgrass turion density exhibited a significant correlation to sampling depth (r^2 = 0.58, Figure 37), but the relationship was not as strong as during 2004 (r^2 = 0.72) because of the substantial decrease in eelgrass density at shallower depths at mid-bay stations. This correlation is primarily dependent upon a decrease in submarine light levels with increasing depth (Zimmerman, 1991) but other factors appear to be affecting turion density-for example, possible higher levels of suspended sediments that limit submarine light values even at shallow depths, as shown by lower luminance and light energy levels in the mid-bay section of the Harbor in 2008-2009. This relationship is shown in Figure 38 that illustrates a significant correlation between turion density and percent surface irradiance (%SI), expressed as the ratio of bottom irradiance to ambient "in air" irradiance throughout Newport Bay (r^2=0.407, Anova, F ratio = 10.3095, p=0.0058, 16 df). Lowest % SI and turion density occurred at mid-bay stations and in Upper Newport Bay. Highest density and %SI occurred between the Entrance Channel and Balboa Island.

The distribution of eelgrass turion density as a function of median sediment grain size is illustrated in Figure 39 for samples taken in 2008. The data indicates that turion density is (1) highest where sediments are very fine-to-fine sand (0.1 to 0.25 mm); (2) low-to-moderate in medium-to-coarse silts (.004 to .035 mm); and (3) and low-to-moderate in medium-to-coarse sands. Densities are slightly skewed towards the smaller size fractions compared to the coarser sands, likely related to higher levels micro-and macro-nutrients associated with finer sediments.

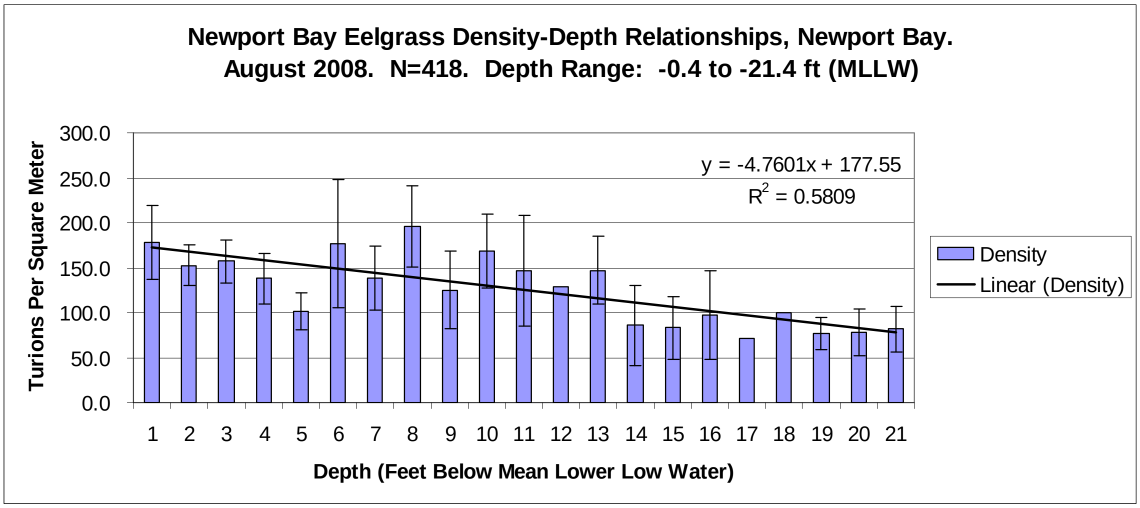


Figure 37

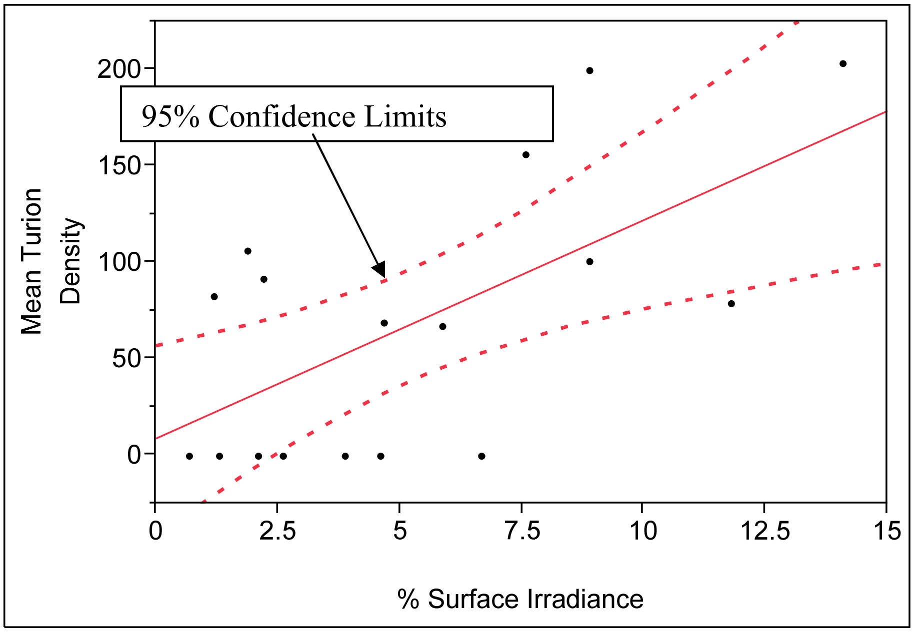


Figure 38.
Mean Turion Density By % Mean Surface Irradiance. August 2008 Turion Density (n=18 sites); Mean Surface Irradiance (July-August, November-December 2008, and March-May 2009. r^2=0.407

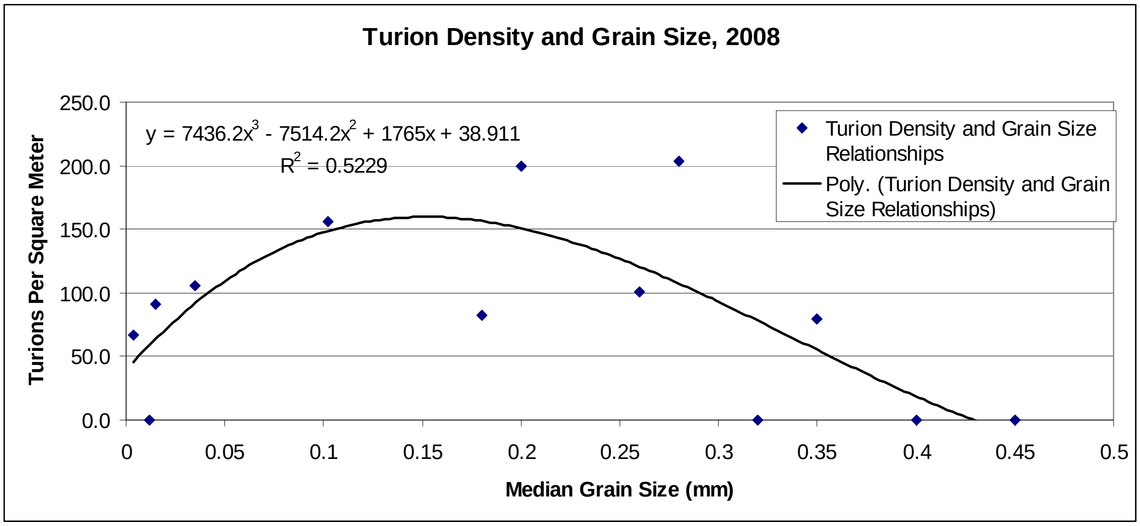


Figure 39

4.5.2 Eelgrass Density Spatial Trends

In 2008, Newport Bay eelgrass turion density was 136.1 turions per sq m (n=415 replicates (at stations of occurrence) which was 60% of the average density observed in Newport Bay in 2004 (231.2 turions per square meter; n=600 replicates). Individual density counts in 2008 varied between 41 and 400 per square meter. Mean station turion density was 94.1 +/- 82 per square meter (n=19 stations), taking into account "0" counts at five stations lacking eelgrass in 2008 that previously had eelgrass in 2004. Wide-bladed eelgrass in the Entrance Channel was sampled at depths between -8.6 and -21.4 ft MLLW. Density of this form of eelgrass ranged from 79 to 188.6 turions per square meter (n=30 replicates per area). Within the harbor, turion counts were taken at depths from -0.4 to -16.6 ft. The density of narrow-bladed eelgrass ranged between 67.1 per square meter in the Linda Isle Inlet and 234.8 per square meter in Carnation Cove along Bayside Drive in Corona del Mar (n=30 replicates per area).

Figure 40 compares the results of the 2004 and 2008 turion density surveys by station. Decreases in turion density were particularly severe at mid-bay sites between the Grand Canal and Bay Island; West Newport Bay (Lido Isle and OCC Boat Basin), and Upper Newport Bay. From "C" Street (East Balboa Peninsula) to Harbor Island, densities were less than 50% that observed during 2004. Five sites previously sampled areas in 2004 lacked eelgrass in 2008. Density decreases were also observed in the deeper eelgrass bed in the Entrance Channel. The least changes in density were observed between along the shallow water Corona del Mar eelgrass beds (China Cove and Carnation Cove), and at the southeast tip of Balboa Island.

Eelgrass density was significantly different between years ($F=24.45 \geq 4.60$ critical value of F, 1 df) but not significantly different between stations ($F=1.65 \leq 2.48$ critical value of F, 14 df; 2 Way ANOVA without replication, square root +1 transformed means).

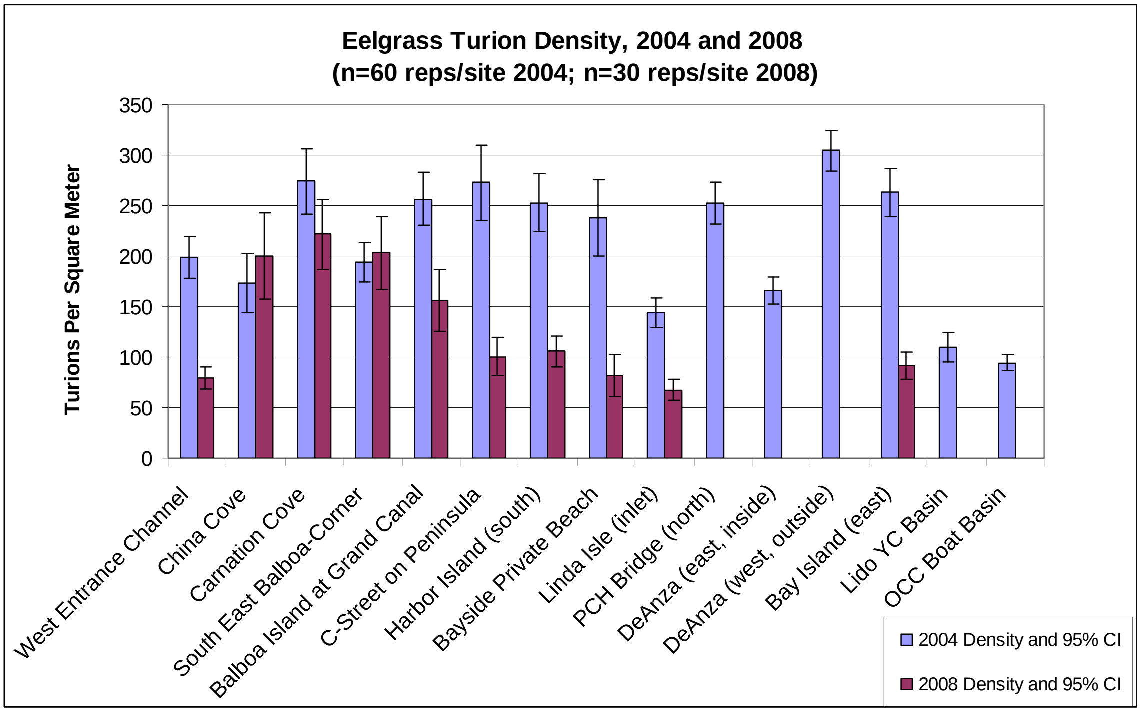


Figure 40.

4.6 EELGRASS LENGTH AND WIDTH ANALYSIS

Two growth forms of eelgrass occur in Newport Bay; narrow and wide bladed. The wide-bladed form typically occurs in the vicinity of the Entrance Channel, while the narrow-bladed form is known from both the Entrance Channel and the rest of Lower and Upper Newport Bay. The differentiation is important because if the two are considered separate species (*Zostera pacifica*, wide bladed; *Z. marina*, narrow bladed) as has been determined in the Channel Islands (Coyer et. al, 2001), then it has an effect on how these two species are managed relative to the Southern California Eelgrass Mitigation Policy (National Marine Fisheries Service, 1991 as amended). To date, the Policy does not differentiate between the two forms. Without DNA analysis, these co-variants are considered a single species.

Length and width data were collected at 14 locations throughout the bay in August 2008. Mean blade length was 92.1 +/- 26.7 cm and mean blade width was 0.6 +/ -0.2 cm (n=280 replicates). Data, by station are presented in Table 10. Summary graphics are contained in Appendix 6.

Table 10. Eelgrass Blade Length and Width Data. August 2008

Station Location	Mean Blade Length Data (cm)				Mean Blade Width Data (cm)		
	Mean	Std Dev	N		Mean	Std Dev	N
Entrance Channel (deep)	95.0	11.5	10		0.9	0.1	10
Entrance Channel (shallow)	86.5	19.9	10		1.0	0.1	10
China Cove (deep)	126.0	26.8	10		0.8	0.2	10
China Cove (shallow)	117.0	29.0	10		0.5	0.1	10
Carnation Cove-North	92.6	16.9	10		0.6	0.1	10
Balboa Island Southeast Corner	90.5	13.7	10		0.6	0.0	10
Grand Canal	88.6	12.9	10		0.6	0.1	10
C Street	69.1	13.7	10		0.6	0.1	10
Harbor Island South	82.0	22.6	10		0.6	0.1	10
Bay Isle	99.3	34.6	10		0.5	0.1	10
Bayshores Community Beach	57.8	3.7	10		0.5	0.1	10
East Balboa Channel	79.8	10.1	10		0.6	0.1	10
Harbor Island North	88.7	13.8	10		0.5	0.1	10
Linda Isle Inlet	115.9	34.0	10		0.6	0.1	10
Station Means	**92.1**	**18.8**	**10.0**		**0.6**	**0.1**	**10.0**

Eelgrass blade length means varied between 69.1 at C Street (Balboa Peninsula, 3.2 ft MLLW mean depth) and 126.0 cm in China Cove (7.6 ft MLLW mean depth). Three sites had mean blade lengths that were 15 to 20 cm longer than other stations; two of which were in Corona del Mar near the harbor mouth (China and Carnation Coves). The other long-bladed form was confined to the Linda Isle Inlet (4.5 ft MLLW depth), where the longest blade length (185 cm) was recorded. Eelgrass blade lengths at the remaining sites varied between 69.1 and 99.3 cm.

Mean blade widths ranged between 0.5 and 1.0 cm (Table 10). Eelgrass blade widths were 33% wider in the Harbor Entrance Channel and China Cove (0.8 to 1.0 mean width) compared to 11 other sites, that had mean blade widths of 0.6 cm or less.

Figure 41 compares the relationship of eelgrass blade lengths and widths at 14 stations throughout Newport Bay. This analysis suggests that the blade length and width in the Harbor Entrance Channel and nearby in Corona del Mar (and a lesser degree at the southeastern end of Balboa Island) are substantially different than those in other parts of the bay. Shallower beds along the Corona del Mar (3.5 ft depth station) exhibit wide, but narrower blades than the deeper-occurring vegetation (-7.9 to -19.3 ft) (Figure 38). This indicates that eelgrass in the Entrance Channel is not monotypic. In these areas, both the narrow-and-wide bladed forms co-exist and there is a gradation between forms. With distance into the harbor, narrow-bladed eelgrass becomes the dominant form. Interestingly, eelgrass in Linda Isle Inlet exhibited extremely long, but very narrow blades compared to other eelgrass in mid-bay regions.

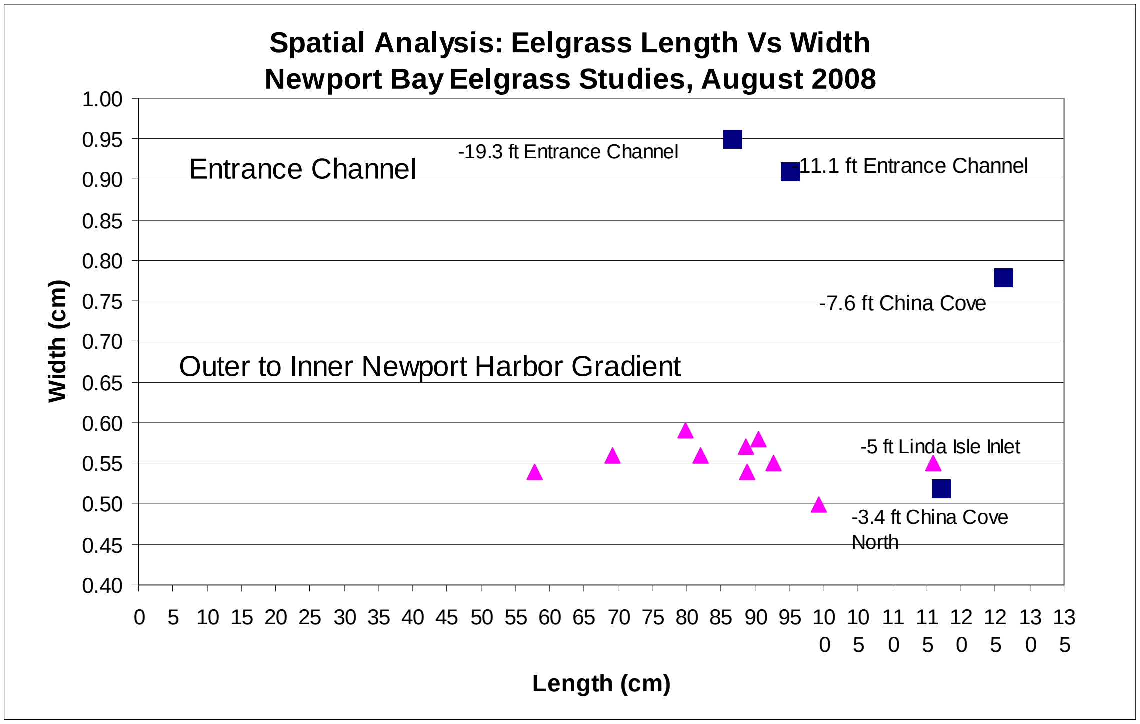


Figure 41.

4.7 MARINE ORGANISMS OBSERVED DURING THE SURVEYS

Appendix 7 lists the plants and animals observed during eelgrass bed surveys between 2003 and 2008. A total of 120 types of plants and animals were documented; of these 81 (67.5%) were sighted within or immediately adjacent to eelgrass beds. One was a sulfur bacterium, 18 were algae, two were seagrasses, 64 were macro-invertebrates, and 34 were fish (Table 10).

The greatest diversity of marine life was found in the Harbor Entrance Channel at depths between 10 and 28 ft and along the Corona del Mar shoreline between Pirate's Cove and Carnation Cove on the sand-flats to depths of -16 ft. Higher diversity in this zone was the result of better water quality and habitat heterogeneity; i.e., a mixture of deep sandy channel eelgrass, silty to sandy shallow water eelgrass, rocky reef, piling/and pier, and intertidal sand flats. The second most diverse zone was along the main channel along the south side of Balboa Island and the east end of the Balboa Peninsula extending west to The Pavilion. With increasing distance into the Bay, fewer types of fish and invertebrates were observed. Diver visibility also decreased which limited the ability of the biologists to document motile species outside their field of vision particularly during the 2006-2008 survey.

Table 11.
Taxonomic Composition of Plants and Animals Observed during Eelgrass Habitat Mapping Surveys. 2003-2008

Taxonomic Group	Number of Taxa	% Total
Bacteria	**1**	**0.8**
Algae	**19**	**15.8**
Sea grasses	**2**	**1.7**
Sponges	**1**	**0.8**
Cnidarians	**10**	**8.3**
Flatworms	**1**	**0.8**
Annelid worms	**2**	**1.7**
Mollusks	**28**	**23.3**
Arthropods	**8**	**6.7**
Echinoderms	**8**	**6.7**
Bryozoans	**3**	**2.5**
Tunicates	**3**	**2.5**
Fish	**34**	**28.3**
Total	**120**	**100.0**
In Eelgrass Beds	**81**	**67.5**

The most common epibenthic macro-invertebrates (animals that live on or protrude from the sediment surface) observed in or in the vicinity of eelgrass beds were burrowing anemones (*Pachycerianthus fimbriatus)* snails, (*Bulla gouldiana, Nassarius fossatus)* and predatory sea slugs *(Navanax inermis*). Concentrations of speckled scallops (*Argopecten circularis*), were found in the Grand Canal, along South Bay Front (Balboa Island), and in the Corona del Mar eelgrass beds. Biologists did note what seemed to be a dramatic decrease in scallop densities in and adjacent to eelgrass beds located in the Corona del Mar eelgrass beds, along South Bay Front (Balboa Island), and in the Grand Canal (See Photograph 20) between the 2003-2004 survey and the 2006-2007 survey. Speckled scallop population studies conducted by California Department of Fish and Game in Agua Hedionda Lagoon (1988) noted that the large population of speckled scallops is near its northern range extent in Southern California and that the population is ephemeral. Density is highest during periods of warmer-than-average temperatures, i.e., El Nino events). As water temperatures cool down, the population of scallops decline.

Epifauna found on the blades of eelgrass included the snail *Alia carinata* along with anemones, encrusting bryozoans and occasional red algal epiphytes. Sea pens (*Acanthoptilum gracile*) were common-to-abundant along the deeper fringes of eelgrass beds at depths below 8 ft MLLW between the Entrance Channel and Corona del Mar. Sea pens are elongated feather-like animals anemones and corals (Photograph 21). They anchor themselves into the sand and suspension feed in the water column. *A. gracile* formed such dense beds near the southeast end of Balboa Island that sea pen colonies initially were identified as eelgrass vegetation during the 2008 CRM sidescan sonar surveys due to similar sidescan sonar returns that both species generate.

Photograph 20. Speckled scallops in Grand Canal, Newport Bay within and nearby eelgrass beds. 2004.

Photograph 21. Sea Pens, *Acanthoptilum gracile* at the deep margin of eelgrass beds offshore Carnation Cove

However, CRM remote video and diver verification of the region's bayfloor confirmed that some of the deeper channel habitat (10- 18 ft MLLW) was colonized by sea pens in high densities particularly between Mooring Area B and the Orange County Sheriff's Harbor Patrol docks.

During warmer months, the ctenostome bryozoan *Zoobotryon verticillatum* was a common invasive in many parts of Newport Harbor, particularly in back-channels (Rhine Channel, West Newport, Harbor-to-Linda Isle, and the Linda Isle Inlet). *Z. verticillatum* is a suspension-feeding, spaghetti-like mass that attaches to boat docks, anchor chains, moorings, and other hard substrate, but can also be fouled in eelgrass beds. *Zoobotryon* can have ecological and economical impacts due to its capacity to expand in an aggressive way (http://www.elkhornslough.org/research/aquaticinvaders). It has been reported to cause the collapse of eelgrass cover when proliferating in summer (Williams, 2007).

Benthic macro-algae (*Enteromorpha*, *Colpomenia*, *Acrosorium*, and *Chondracanthus*) was more abundant mid bay, in Upper Bay and along Mariner's Mile in West Newport Bay than nearer the Entrance Channel (Photograph 22).

Photograph 22. Macro-algae mixed with eelgrass. Black surfperch

Intertidal sand dollars (*Dendraster excentricus*) beds were located on the sand flats within the cove adjacent to Channel Reef near the Entrance Channel during both the 2003-2004 and 2006-2007 surveys. Sand dollar density varied between approximately 10 and 100 per square meter in 2005, and between 115 to 325 per square meter in 2007 (Coastal Resources Management, Inc. 2009). Sand dollars were found around in and around the fringes of the eelgrass bed (Photograph 23). The channel nassa snail (N*assarius fossatus)* and the purple olive snail (*Olivella biplicata),* typical of nearshore shallow sand bottom epifaunal communities were also found in the cove's sandy sediments and seaward of the cove. While

Photograph 23. Intertidal eelgrass (on bottom left) and sand dollar beds (center and right) in Carnation Cove. 2008.

the occurrence of sand dollars is not unusual for nearshore southern California sandy subtidal habitats at depths between -10 and -25 ft MLLW, the occurrence of intertidal populations of sand dollar beds within Newport Bay and in association with eelgrass is unique and rare for Newport Bay. The population survives because wave motion/wave energy is moderate, sediments are clean sand to silty sand, and tidal exchange is excellent. The population represents a condition that was once likely much more common on Newport Bay tidal sand flats.

Plankton feeders (topsmelt, blacksmith, and señorita), and black surfperch ("pickers") were often seen schooling above eelgrass vegetation throughout the Bay. Ambush predators such as spotted sand bass (*Paralabrax maculatofasciatus*), barred sand bass (*P. nebulifer*) were associated with the deeper fringes lining the navigational channels. Benthic foraging round string rays (*Urolophus halleri*), turbot, (P*leuronichthys* spp) and juvenile California halibut (*Paralichthys californicus*) were observed in barren patches within beds or along the fringes.

Many of the type of fishes observed in the Entrance Channel and Corona del Mar eelgrass beds are nearshore reef and kelp bed associates (i.e., kelp bass *(P. clathratus*). blacksmith (*Chromis punctipinnis*), giant kelp fish (*Heterostichus rostratus*), garibaldi (*Hypsypops rubicundus*), senorita (*Oxyjulis semicinctus),* and halfmoon (*Medialuna californiensis*) that are attracted to the eelgrass beds for similar ecological functions as reefs- i.e., foraging, protection, and cover. Numerous juveniles of many species were observed in association with eelgrass throughout the Bay.

4.8 EELGRASS HABITAT STUDY SUMMARY AND CONCLUSIONS

4.8.1 Eelgrass Acreage and Density

Distribution and Abundance. CRM conducted eelgrass habitat studies between 2006 and 2008 and mapped a total of 23.1 acres of eelgrass in shallow water habitat at depths less than 10 feet (MLLW) and 45.7 acres of eelgrass at depths between 10 and 28 ft MLLW. Eelgrass was found in a wide range of sediment types, between fine-to-medium sands near the Entrance Channel and to very fine silt in the mid-bay (Harbor and Linda Island), along Mariner's Mile, and in Upper Newport Bay. The acreage of eelgrass in Newport Bay was inversely correlated to tidal residence time with the highest acreages present in the fore-bay between the Entrance Channel and Balboa Island (Figure 42 a-c) where: (1) tidal residence times are less than six days, circulation is good, and the resulting water temperatures, pH, salinity, dissolved oxygen, light luminance, and light energy levels reflect short tidal residence times and good water circulation.

The least amount of eelgrass (with one exception, below) occurred in regions of the Bay that had extended tidal residence times (7 to 14 days, Figure 42a-c), high water temperatures, variable water quality, and low illuminance and light energy levels. Bottom light levels and ratios of bottom-to-surface light values (% SI) in these regions were lower than regions nearer to the Entrance Channel. These areas included the mid-bay region (Harbor and Linda Isle), Upper Newport Bay, and West Newport Bay (West Balboa Peninsula, Mariner's Mile and Lido Isle).

Eelgrass was not found in regions where the tidal residence time exceeded 15 days and where sediments were extremely coarse. While these areas had extended tidal residence periods and some of the warmest water temperatures-other variables, such as salinity, dissolved oxygen, water clarity, light luminance and light energy levels were intermediate between fore-bay conditions near the Entrance Channel and those occurring in mid-bay or Upper Newport Bay. Consequently environmental gradients within the Bay are extremely important when analyzing the distribution of eelgrass.

Eelgrass Turion Density. Eelgrass turion density was inversely correlated with depth and the percentage of light immediately above the bottom compared to the surface; highest turion density was associated with sediments that displayed median grain sizes in the very fine-to-fine sand range. Eelgrass density also decreased with increasing distance away from the Entrance Channel along the tidal residence time gradient.

4.8.2 Blade Length and Width Analysis

The results of blade length and width analysis confirm qualitative observations and anecdotal information over the years that the Bay is colonized by two forms of eelgrass (1) a long, wide-bladed form that occurs in both shallow water and deep water eelgrass beds in the Channel Entrance Channel and the easterly section of Balboa Island and the Balboa Peninsula, and (2) a short-to-long, narrow-bladed form that is found mixed with the wide blade variant near the Entrance Channel, but is monotypic throughout most of the bay. The wide-bladed form grows to depths of -28 ft in the navigation channels, and exhibits blade lengths of up to 2 meters to compensate for less light at deeper depths.

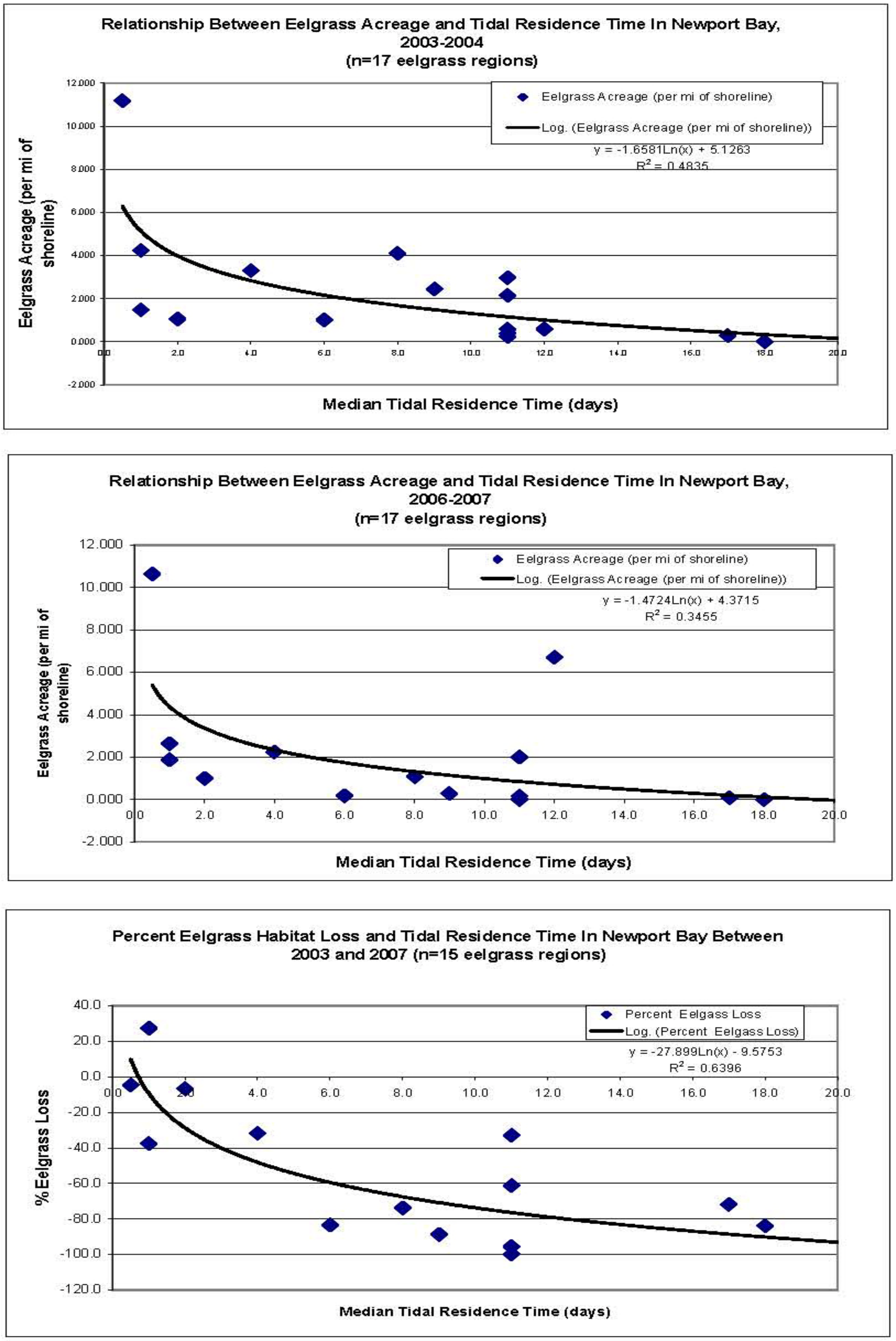


Figure 42 a, b, and c

Based on this analysis, we recommend that a study be initiated, in association with the National Marine Fisheries Service to identify the genetic relationships between the two growth forms since this has implications as to how the bay's eelgrass resources are to be managed and mitigated. In the short-term we highly recommend that the wide-bladed form of eelgrass not be used as donor material for any projects except in the immediate vicinity of where it occurs, since the probability of it growing in warmer, shallower areas of the bay is low.

4.8.3 Comparison of the Results of the First and Second Bay-Wide Surveys

The results of the 2006-2008 studies indicate that the Bay experienced a decline of 7.4 acres of shallow water eelgrass vegetation compared to the results of the 2003-2004 eelgrass mapping survey (CRM, Inc., 2005) when 30.4 acres of shallow water eelgrass were mapped. Although 45.6 acres of deep water eelgrass was mapped in 2008 by CRM and 90.3 acres of deep water eelgrass was mapped by the National Marine Fisheries Service in 2003, different sonar technologies were used to conduct the mapping project. Consequently, any loss estimate in deeper channel eelgrass vegetation may reflect in part, the different methods used by CRM and NOAA. We are confident however, that the methods employed during the 2008 CRM and Nearshore and Wetlands Surveys sidescan surveys, combined with ground-truthing by remote video and diver surveys provide a realistic estimate of eelgrass abundance within the deep water navigational channels in 2008 and a sound baseline for future assessments.

Significant losses of shallow water eelgrass occurred in Upper Newport Bay, in the mid-bay region surrounding Linda Isle and Harbor Island, and in the North Balboa Channel. While the overall loss throughout Newport Harbor was 24% compared to 2003-2004, losses in these particular regions ranged from 31% and 100%. Exceptions to the eelgrass loss patterns included both the inlet of Linda Isle and the Grand Canal, both of which exhibited increases rather than losses. Both of these areas are shallow, with relatively narrow openings.

The one exception where eelgrass flourished in the mid-bay region was Inner Linda Isle (Linda Isle Inlet) where eelgrass acreage significantly increased since the first survey. While initially it was thought that this area may have been excluded from effects of sedimentation (Coastal Resources Management, Inc. 2009), the basin has in-filled since its initial dredging in the 1960s from depths of about -9 ft MLLW (as shown on NOAA Navigational Chart 18754**)** to about -4 to -5 ft MLLW (this survey). The source of the sediment is inflow from the watershed via Upper Newport Bay. These depths are now typical eelgrass growing depths for this region of the Bay. As depths have decreased, eelgrass became established and flourished. It is atypical compared to other areas of high eelgrass abundance because (1) the tidal residence time in Linda Isle basin is comparable to areas that do not support extensive eelgrass beds or areas nearby that have had a significant reduction in eelgrass area since the 2003-2004 survey, and (2) sediments are extremely high in silt (96%) compared to other areas that support eelgrass. It does appear however, to have adapted by taking a modified growth form to counteract lower light levels in this section of the Bay. Eelgrass blade length/width data indicate it is extremely long, but narrow bladed type of eelgrass compared to other areas in the mid-bay (Figure 41).

Because of eelgrass losses in many areas of the Bay, the amount of eelgrass has been concentrated in fewer regions. Regions that increased their percent dominance in the bay included Linda Isle Inner Basin (21.6%), Corona del Mar/Bayside (5.82%), Grand Canal (5.82%), and East Balboa Peninsula (2.39%). These regions' eelgrass beds take on more ecological significance in the long-term management of Newport Bay's eelgrass resources as the other eelgrass beds diminish, should they not fully recover.

In addition to a reduction in eelgrass acreage, there was a significant decrease in eelgrass turion density between the two surveys, particularly at mid-bay and Upper Bay stations. Several stations lacked eelgrass where it had been present during the 2003-2004 turion density survey.

4.8.4 Management Implications

Based upon the knowledge obtained during the first and second bay-wide eelgrass surveys conducted between 2003 and 2008, the known tidal residence time periods in the bay, and the 2008-2009 oceanographic survey results, eelgrass distribution in Newport Harbor can be divided into three zones, as shown in Figure 43.

A Stable Eelgrass Zone. Eelgrass within this zone has shown longer-term stability, the highest ecological diversity, and provides longer-term critical habitat for organisms. It is associated primarily with the regions near the Channel Entrance, Corona del Mar, the southern side of Balboa Island, and the eastern section of the Balboa Peninsula. Tidal flushing is less than six days. Water quality is good, and light levels are the highest in the Bay. The amount of shallow water habitat in this zone is 20 acres (based on the average of the two bay-wide surveys) and the amount of deep water eelgrass habitat is 47 acres (based on the amount of the 2008 survey). The potential for successful eelgrass mitigation in this zone is the highest in the Bay due to stable environmental conditions, as documented in Section 3 of this report.

A Transitional Eelgrass Zone. Eelgrass in the transition zone is highly susceptible to year-to-year variation in acreage and density and the effects of large-scale storm events. Eelgrass is ephemeral and natural recovery from losses may be long-term. This zone is largely found in the central, mid-bay region (i.e., northern side of Harbor Island, the channels around Linda Isle, the northern and western portions of Balboa Island, and the northern side of the Lido Channel) and the lower one-third of Upper Newport Bay to Castaways Park and DeAnza/Bayside Peninsula. This zone is characterized by a tidal flushing time of 7 to 14 days, moderate but highly variable water quality, and lower and highly variable levels compared to the Stable Eelgrass Zone. Shallow water eelgrass in this zone accounts for 10 acres of eelgrass (based on the average of the two bay-wide surveys) and no deeper channel eelgrass habitat exists. Eelgrass mitigation in this zone has a low-to-moderate chance of success in the long-term due to highly variable and short-term and long-term environmental conditions, and its success cannot be predicted with any certainty.

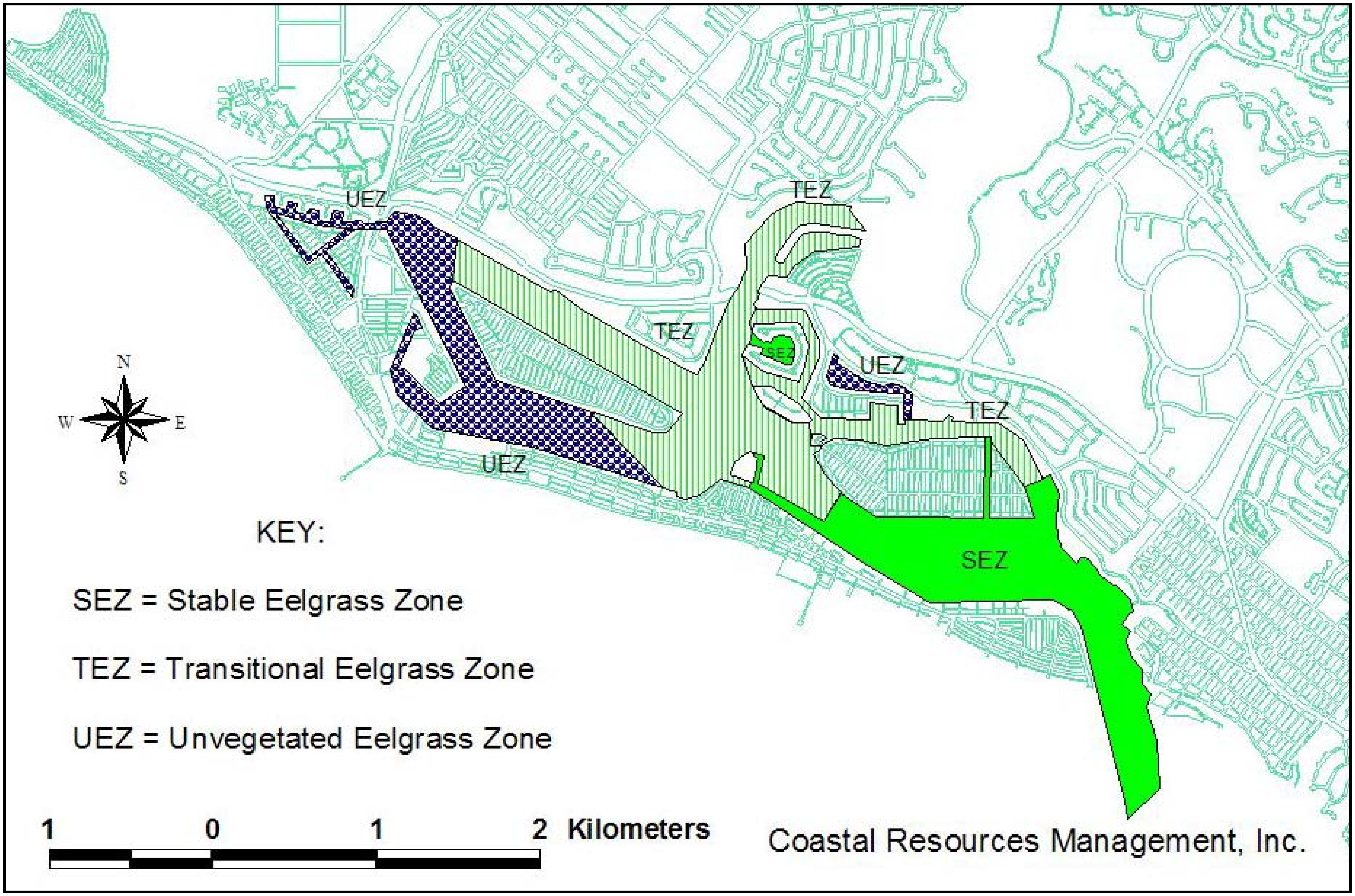


Figure 43. Eelgrass Habitat Zones in Newport Bay. 2003-2008

An Unvegetated Zone. Eelgrass is rarely found or it is absent. This zone is typical of West Newport Bay and the northern two-thirds of Upper Newport Bay past Castaways Park and the DeAnza/Bayside Peninsula. Tidal residence time is greater than 14 days, water quality can be highly variable, all of which may reduce the chances of eelgrass seeds transported to this region through tidal action to germinate. Because eelgrass has been lacking here historically, or occurs in very small amounts, mitigation and restoration of eelgrass in this zone is not recommended.

The limits of each of the three zones may expand or contract, depending on long-term water quality and oceanographic conditions in the bay. For example, should the Upper Newport Bay Restoration Project create better growing conditions (i.e., higher underwater light levels and less turbidity) then the transitional zone of eelgrass may extend farther up into Upper Newport Bay.

4.8.5 Short-and-Long Term Eelgrass Abundance Trends

Eelgrass habitat mapping surveys conducted between 2003 and 2008 have thoroughly documented eelgrass distribution in Newport Bay. While the period of time covered over the course of these surveys is considered "short term", the analysis of the data indicate a definite reduction in eelgrass vegetation in Newport Bay. Additional mapping in progress will provide a data base covering eight years, and a better indication of longer-term eelgrass distribution cycles in the bay. To date however, the oceanographic and eelgrass distributional data suggest that eelgrass in Newport Bay is primarily light-limited and correlated to gradients in turbidity, illuminance, and irradiance.

The events or sources of bay turbidity over the short-term that are correlated to a reduction in eelgrass cover and turion density are speculative. These may include:

- Intensive rainfall and the discharge of high volumes of runoff and sediments into Upper Newport Bay and Lower Newport Bay from the San Diego Creek Watershed during the 2004-2005 rainfall year;

- Additional dry-weather flows from the Newport Bay watershed that transport "superfine" sediments into Newport Bay which inhibit or limit light penetration at depths where eelgrass should be growing during the eelgrass growth period between spring and summer;

- secondary effects of the Upper Newport Bay Restoration Project from the movement of the dredge-scow and tugs in-and-out of Upper Newport Bay. These vessel movements create observable turbidity plumes and redistribute bottom sediments particularly in Upper Newport Bay and around Linda and Harbor Island where significant declines of eelgrass have been observed; and

- intense late-spring and summer plankton blooms following the winter and spring storms (i.e., 2005-2006 spring storms) that reduced underwater light levels, increased turbidity and underwater visibility for extended periods of time.

The scaling back of eelgrass vegetation in Newport Bay may also be part of a longer-term cycle of eelgrass abundance that has not been fully documented. Where data exist-for example, for giant kelp forests (*Macrocystis pyrifera*) off the southern California coast-changes in canopy cover are related to both natural (El Nino) and man-influenced (pollution) perturbations. As stated in Foster and Schiel (2010):

> "The data considered here show that there have been periods of large declines in giant kelp canopy area in southern California, and that these were invariably associated with El Niño events, and the warm water, low nutrients and storms they bring to coastal waters. The data also show that there were severe declines in kelp forests near large metropolitan areas along the southern portion of the mainland coast of southern California, associated with coastal development, sedimentation and sewage outfalls. However, recovery of kelp occurred when stressors were reduced, and there was no evidence for a general collapse of kelp forest structure or a permanent shift to a largely kelp-free state"

Systematically-collected historical eelgrass data in Newport Bay is inconsistent and sporadic at best (Figure 44). In 1969, the amount of eelgrass in Upper Newport Bay was estimated to be about 8 acres (Posjepal, 1969). The amount of shallow water eelgrass in Newport Bay was generally estimated to be about three acres in 1993 (Hoffman, in Ware, 1993), 18 acres in 1999 (Chambers Group and Coastal Resources Management 1999), 30.4 acres in 2003-2004 and 23.1 acres in 2006-2007. If navigational channel water eelgrass habitat is included, 121 acres of eelgrass was mapped in 2003-2004 and 69 acres of eelgrass was mapped in 2007-2008 (National Marine Fisheries Service, unpublished data and Coastal Resources Management, Inc., this report).

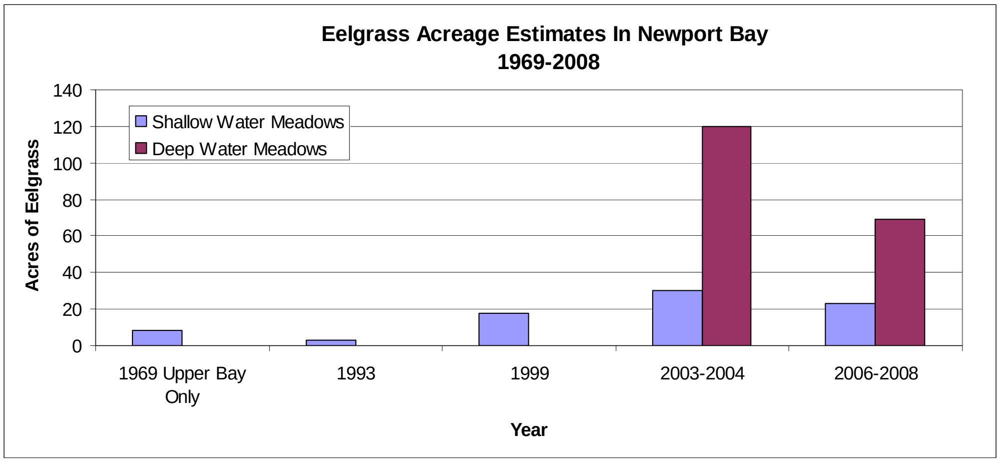


Figure 44
Sources: Posjepal, 1969; Hoffman, 1993; Chambers Consultants and Coastal Resources Management, 1999; National Marine Fisheries Service, 2003 unpublished data; Coastal Resources Management Inc., 2005 and CRM this report)

Contributing factors to the significant increases in eelgrass within Newport Bay between the 1990s and 2004 may have included:

1. Improvement in water quality related to the implementation of sediment and nutrient Total Maximum Daily Loads (TMDLs) and Water Quality Best Management Practices by the City and the County of Orange;
2. highly favorable growing conditions during prolonged "drought" dry weather years (i.e., La Niña years of low rainfall and low concentration of suspended sediments);
3. increased environmental awareness of the importance of eelgrass;
4. the implementation of federal, state, and local policies that reduce the potential loss of eelgrass and promote mitigation and restoration; and
5. the implementation of more systematic and repetitive methods of mapping eelgrass by the City of Newport Beach that have provided a scientific basis for determining eelgrass distribution and abundance patterns.

Eelgrass distribution in 2003-2004 may have represented the "peak" in eelgrass abundance for Newport Bay compared to previous years, but without prior comparable data, it is difficult to assess. However, eelgrass abundance in San Diego Bay (which has approximately 10-fold the amount of eelgrass as Newport Bay), decreased 18.6% between 2000 (peak year) and 2008, and 15% between 2004 and 2008 (U.S. Navy SWDIV Engineering Facilities Command and the Port of San Diego, 2008) which suggests the possibility that regional-wide factors may have contributed to eelgrass acreage reductions in both Newport Bay and San Diego Bay between 2000 and 2008.

4.8.6 Update on the results of the 2009-2010 third bay-wide eelgrass survey

CRM is in the process of conducting the third bay-wide eelgrass mapping survey for the City of Newport Beach. Data collected to date (through August 2010) indicates that eelgrass vegetation is still diminishing in many parts of the bay. Observations and preliminary results of GIS mapping indicate:

- Very little eelgrass (<0.001 acre) is growing in Upper Newport Bay;
- eelgrass acreage in Linda Isle inlet has decreased 1.2 acres since the last bay-wide survey;
- eelgrass on the south side of Harbor Island has decreased 0.19 acres since the last bay-wide survey;
- eelgrass in the Grand Canal decreased 0.512 acres, primarily on the north side of the Park Ave Bridge since the last bay-wide survey;
- eelgrass around Balboa Island and Collins Isle decreased by 1.5 acres, with most losses observed along the eastern perimeter of Balboa Island;

- eelgrass along the East Balboa Peninsula from the Entrance channel to the Pavilion experienced a loss of 0.1 acre compared to the last bay-wide survey; and

- Eelgrass appears to be healthy along the Corona del Mar shoreline and within the Entrance Channel, with minor changes in acreages compared to the 2006-2007 survey.

4.0 LITERATURE CITED

Anchor EQA, L.P. 2009a. Conceptual development plan. Lower Newport Bay CAD site feasibility study. Prepared for the City of Newport Beach Harbor Resources Division. April 2009. 47 pp.

Anchor EQA. L.P. 2009b. Memorandum: Field investigation results from Lower Newport Bay CAD cell location explorations. June 25th, 2009. 123 pp.

Backman, T.W. and D. C. Barilotti 1976. Irradiance and reduction: Effects on standing crops of the eelgrass *Zostera marina* in a coastal lagoon. Mar. Biol. (Berl) 34:33-40.

Beal, J. L. and B. S. Schmit. 2000. Chapter 4. The effects of dock height on light irradiance (PAR) and seagrass (*Halodule wrightii* and *Syringodium filiforme*) cover. Pages 43-63 *in:* Stephen A. Bortone, PhD, ed. Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press, Boca Raton. 318 pp.

Bintz, J. C., S. W. Nixon, B. A. Buckely, and S. L. Granger. 2003. Impacts of temperature and nutrients on coastal lagoon plant communities. Estuaries 26(3):765-776.

Boese, B. L., B. D. Robbins., and G. Thursby. 2005. Desiccation is a limiting factor for eelgrass (*Zostera marina*) distribution in the intertidal zone of a northeastern Pacific (USA) estuary. Botanica Marina (48) 4: 274-283.

Borum, J., K. Sand-Jensen, T. Binzer, O. Pedersen, and T. Greve. 2006. Nutrient dynamics in seagrass ecosystems. Chapter 9. Pages 255-270 *in:* A.W. Larkum , R. J. Orth, and C. M. Duarte (eds). Seagrasses: Biology, Ecology, and Conservation. Springer, The Netherlands. 691 pp.

California Department of Fish and Game. 1988. The speckled scallop, *Argopecten circularis*, in Agua Hedionda Lagoon, San Diego County, California. Calif Dept Fish and Game Tech Rpt No. 57. 32 pp.

Chambers Group, Inc. and Coastal Resources Management. 1998. Pre-dredging eelgrass survey in Lower Newport Bay. Prepared for the U.S. Army Corps of Engineers. Los Angeles District. 15 pp. plus figures and appendices.

Chambers Group, Inc. and Coastal Resources Management. 1999. Lower Newport Harbor eelgrass restoration project field reconnaissance report. Prepared for the U.S. Army Corps of Engineers. Los Angeles District. 18 pp. plus figures and appendices. August 1999.

Chambers Group, Inc. 2005a. First year monitoring report for the Army Corps of Engineers and City of Newport Beach pilot eelgrass transplant project. Prepared for the Army Corps of Engineers.

Chambers Group, Inc. 2005b. Newport Dunes eelgrass survey, December 2004. Prepared for Moffatt & Nichol Engineers. February 2005.

Chambers Group, Inc. 2007. Newport Dunes eelgrass, *Caulerpa*, and oyster survey. Prepared for Moffatt & Nichol Engineers. November 2007.

City of Newport Beach. 2008. Integrated Coastal Watershed Management Plan. http://www.newportbeachca.gov/index.aspx?page=1333 Dept. of Public Works

City of Newport Beach. 2009. City of Newport Beach Local Coastal Plan. Coastal Land Use Plan. Final Adoption by the California Coastal Commission July 2009.

Coastal Resources Management, Inc. (CRM) 1999. Upper Newport Bay eelgrass survey for the Army Corps of Engineers Dredging Project. Prepared for the City of Newport Beach and the County of Orange. December 1998 Survey.

Coastal Resources Management, Inc. (CRM) 2002. City of Newport Beach Local Coastal Plan. Biological Appendix. Prepared for the City of Newport Beach Planning Department. Various Paging. December 2002.

Coastal Resources Management, Inc. (CRM) 2004. Marine biological resources impact assessment: Pier and boat float renovation project. 2115 Bayside Drive, Corona del Mar, Ca. Prepared for Swift Slips, Inc. June 6th, 2004. 10 pp.

Coastal Resources Management, Inc. (CRM) 2005. Final report. Distribution and abundance of eelgrass (*Zostera marina*) in Newport Bay. 2003-2004 eelgrass habitat mapping project. Bulkhead to pierhead line surveys. Prepared for the City of Newport Beach Harbor Resources Division. April 2005. 30 pp. Maps on the City website at:

http://www6.city.newport-beach.ca.us/website/InteractiveMap/map.asp

Coastal Resources Management, Inc. (CRM) 2007. Remote video eelgrass and invasive algae survey, Dunes Marina. Prepared for Chambers Group, Inc. 5 November, 2007. 3 pp.

Coastal Resources Management, Inc. (CRM) 2008a. Distributional maps of eelgrass (*Zostera marina*) in Newport Bay. 2006-2008 eelgrass habitat mapping project. Shallow water (bulkhead to pierhead line surveys) and deeper channel survey results. Prepared for the City of Newport Beach Harbor Resources Division and the City of Newport Beach GIS Department. Maps on the City website: http://www6.city.newport-beach.ca.us/website/InteractiveMap/map.asp

Coastal Resources Management, Inc. (CRM) 2008b. Eelgrass habitat mapping survey results for the Dover Shores Community Association Dover Shores Dredging Project. November 11th, 2008. 10 pp.

Coastal Resources Management, Inc. 2009 (CRM). Appendix B: Eelgrass capacity and management tools. Prepared for the City of Newport Beach Harbor Resources Division. June 2009. 46 pp.

Committee on Environment and Natural Resources, 2000. Integrated assessment of hypoxia in the Northern Gulf of Mexico: National Science and Technology Council, 58 p.

County of Orange. 1978. Environmental studies in Newport Bay. An Environmental Health Services Report. Orange County Human Services Agency, Public Health and Medical Services, Environmental Health Division, Water Quality Control Section. June 1978. 220 pp.

County of Orange. 2003. Report of the Regional Monitoring Program for the Newport By/San Diego Creek Watershed Nutrient TMDL (Resolution No 98-0 as amended by Resolution No 90-100. Prepared with the Cities of Irvine, Tustin, Newport Beach, Lake forest, Santa Ana, Orange, Costa Mesa, and the Irvine Company and the Irvine Ranch Water District. November 2004. 99 pp.

County of Orange. 2004. Report of the Regional Monitoring Program for the Newport By/San Diego Creek Watershed Nutrient TMDL (Resolution No 98-0 as amended by Resolution No 90-100. Prepared with the Cities of Irvine, Tustin, Newport Beach, Lake forest, Santa Ana, Orange, Costa Mesa, and the Irvine Company and the Irvine Ranch Water District. November 2004. 82 pp.

County of Orange. 2005. Report of the Regional Monitoring Program for the Newport By/San Diego Creek Watershed Nutrient TMDL (Resolution No 98-0 as amended by Resolution No 90-100. Prepared with the Cities of Irvine, Tustin, Newport Beach, Lake forest, Santa Ana, Orange, Costa Mesa, and the Irvine Company and the Irvine Ranch Water District. November 2004. 28 pp.

County of Orange. 2010. Newport Bay Sediment TMDL. 2008-2009 Annual Report. Prepared for the Santa Ana Regional Water Quality Control Board. February 26th, 2010. Various paging.

Coyer, J. A., K. A. Miller, J. M. Engle, J. Veldsink, A. Cabello-Pasini, W.T. Stam, and J. L. Olsen. Eelgrass meadows in the California Channel Islands and adjacent coast reveal a mosaic of two species, evidence for introgression and variable clonality. Annals of Botany 101: 73–87, 2008

Dennison, W. C. 1987. Effects of light on seagrass photosynthesis, growth, and depth distribution. Aquat. Bot. 27:15-26

Dixon, L. K. 2000. Establishing light requirements for the seagrass *Thalassia testudinum*: An example from Tampa Bay, Florida. Pages 9-32 *in:* Stephen A. Bortone, PhD, ed. Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press, Boca Raton. 318 pp.

Duarte, C. M. 1991. Seagrass depth limits. Aquat. Bot., 40:363-377

Everest International Consultants. 2009. Appendix F: Hydrodynamic and water quality monitoring requirements technical report for the City of Newport Beach Harbor Area Management Plan (HAMP). Prepared for City of Newport Beach Harbor Resources Division. June 2009. 20 pp.

Fonseca, M.S., W.S. Kenworthy, and G.W. Thayer. 1982. *A low-cost planting technique for eelgrass (Zostera marina L.).* Coastal Engineering Tech. Aid. No. 82-66. Coastal Engineering Research Center, Kingman Bldg., Ft. Belvoir, Virginia. 15 pp.

Foss, Stephen F., P. Ode, M. Sowby, and Marian Ashe. 2007. Non-indigenous aquatic organisms in the coastal waters of California. *California Fish and Game* 93(3):111-129. Summer 2007.

Foster, M.S., and D.R. Schiel. 2010. Loss of predators and the collapse of southern California kelp forests (?): Alternatives, explanations and generalizations, J. Exp. Mar. Biol. Ecol. (2010), doi:10.1016/j.jembe.2010.07.002

Gallegos, C.L. 1994. Refining habitat requirements of submersed aquatic vegetation: role of optical models. Estuaries, 17:187-199.

Hartog, C. den. and J. Kuo. 2006. Taxonomy and biogeography of seagrasses. Chapter 1. Pages 1-123 *in:* A.W. Larkum , R. J. Orth, and C. M. Duarte (eds). Seagrasses: Biology, Ecology, and Conservation. Springer, The Netherlands.

Hoffman, R.S. 1986. Fishery utilization of eelgrass (*Zostera marina*) beds and non-vegetated shallow water areas in San Diego Bay. National Marine Fisheries Service Southwest Region, Administrative Report SWR-86-4. 29 pp.

Hoffman, R.S. 1990. Fishery utilization of natural versus transplanted eelgrass beds in Mission Bay, San Diego, California. Pages 58-64 in: K.W. Merkel and R. S. Hoffman, eds. Proceedings of the California Eelgrass Symposium. May 27 and 28, 1988. Chula Vista, California. 78 pp.

Hoffman, R.S. 1991. Relative fishery values of natural versus transplanted eelgrass beds Zostera marina) in Southern California. in: H. S. Bolton (ed). Coastal Wetlands. Coastal Zone '91. Seventh Symposium on Coastal and Ocean Management. Long Beach, California. July 8-12, 1991.

Kock, E., J. Ackerman, J. Verduin, and M. van Keulen. 2006a. Fluid dynamics in seagrass ecology-from molecules to ecosystems. Chapter 8. Pages 193-255 *in:*

A.W. Larkum , R. J. Orth, and C. M. Duarte (eds). Seagrasses: Biology, Ecology, and Conservation. Springer, The Netherlands.

Koch, E. L. Sanformad, S. Chen, D. Shafer, and J Mckee Smith. 2006b. Waves in seagrass ecosystems: Review and technical recommendations. U.S. Army Corps of Engineers System-Wide Water Resources Program. Submerged Aquatic Vegetation Restoration Research Program. Engineer Research and Development Center. ERDC TR-06-15. November 2006.

Landry, J. Brook, W. J. Kenworthy, and G. Di Carlo. 2008. The effects of docks on seagrasses, with particular emphasis on the threatened seagrass, *Halophila johnsoni*. Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina. July, 2008. 31 pp.

Lopez, F., and M. Garcia. 1998. Open-channel flow through simulated vegetation: suspended sediment transport modeling. Water Resources Research 34:2341-2352.

Marine Biological Consultants (MBC) and the Southern California Coastal Water Research Project (SCCWRP). 1980 (Dec). Irvine Ranch Water District Upper Newport Bay and Stream Augmentation Program. Final Report. October 1979-August 1980.

MBC Applied Environmental Sciences (MBC). 1986. Infauna and epifauna associated with transplants of eelgrass (Zostera marina) in Southern California. Prepared for Maguire Thomas Partners, The Huntington Partnership, National Marine Fisheries Service, and the U.S. Fish and Wildlife Service. 48 pp.

MBC Applied Environmental Sciences (MBC). 1987. Mola Development Corporation eelgrass (*Zostera marina*) mitigation project. Transplant monitoring survey results and evaluation of transplant success. Prepared for the Mola Corporation, Huntington Beach, Ca. November, 1987.

MBC Applied Environmental Sciences (MBC). 2004. Army Corps of Engineers Upper Newport Bay eelgrass mitigation project transplant report and monitoring plan", May 2004. Prepared for the U.S. Army Corps of Engineers, Los Angeles District. May 2004.

Mason, H.L. 1957. A Flora of the Southern California Marshes. University of California Press, Berkeley and Los Angeles, Ca. 878 pp,

Merkel, K. 1990. Eelgrass transplanting in San Diego Bay. Pages 24-28 in: K. W. Merkel and R. S Hoffman (editors), Proceeding of the California Eelgrass Symposium, 27-28 May, 1988. Chula Vista, Ca. 78 pp.

Moore, K and F. Short. 2006. *Zostera*: Biology, ecology, and management. Chapter 16. Pages 347-359 *in:* A.W. Larkum , R. J. Orth, and C. M. Duarte (eds). Seagrasses: Biology, Ecology, and Conservation. Springer, The Netherlands. 691 pp.

Moore, K., R. Wetzel, and R. Orth. 1997. Seasonal pulses of turbidity and their relations to eelgrass (*Zostera marina* L.) survival in an estuary. Journal of Experimental Marine Biology and Ecology 215:115-134.

National Marine Fisheries Service. 1991. *Southern California Eelgrass Mitigation Policy.* National Marine Fisheries Service, Southwest Region, Long Beach, CA. 11th Revision.

National Marine Fisheries Service. 2003. Newport Bay down-looking sonar survey maps of the harbor entrance channel and Corona del Mar Reach, Newport Harbor. Prepared for the City of Newport Beach Harbor Resources Division. Maps available on City website http://www6.city.newport-beach.ca.us/website/InteractiveMap/map.asp

National Marine Fisheries Service (NMFS). 2008a. Essential Fish Habitat (EFH) evaluation for the Balboa Marina Project, Newport Beach, Ca. February, 2008. Prepared by Robert Hoffman, NMFS, Long Beach, CA. 4 pp.

National Marine Fisheries Service. 2008b. *Caulerpa* control protocol. Version 4, March 28th, 2008. National Marine Fisheries Service Southwest Region, Long Beach, CA. 7 pp.

Nezlin, N., K. Kamer, J. Hyde, and E. Stein. Dissolved oxygen dynamics in a eutrophic estuary, Upper Newport Bay, California. Estuarine, Coastal, and Shelf Science 82 (2009): 139-151

Norman, D., J. Ruggerone, J. A June, and S. Wyllie-Echeverria. 1995. Development of a baseline monitoring program for Dumas Bay, Federal Way, Washington.

Ochieng, C.A., F. T. Short, and D.I. Walker. Photosynthetic and morphological responses of eelgrass (*Zostera marina* L.) to a gradient of light conditions. Journal of Experimental Marine Biology 382 (2010): 117-124

Orth, R. J. , K. L. Heck, and J. van Montrans. 1984. Faunal communities in seagrass beds: A review of the influence of plant structure and prey characteristics on predator-prey relationships. Estuaries 7(4a):339-350.

Phillips, R. C. 1972. Ecological life history of *Zostera marina* L (eelgrass) in Puget Sound, Washington. Ph.D. Diss. Univ. of Washington, Seattle. 154 pp.

Phillips, R. C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: A community profile. FWS/OBS-84/24. 85 pp.

Phillips, R.C. and E. G. Menez. 1988. Seagrasses. Smithsonian Contributions to the Marine Sciences: 34.

Phillips, R.C. and S. W. Echeverria. 1990. *Zostera asiatica* Miki on the Pacific Coast of North America. Pacific Science Vol 44 (2):130-134.

Posjepal, M. A. 1969. The Population Ecology of the Benthic ichthyofauna of Upper Newport Bay. M. S. Thesis, University of California, Irvine. 146 pp.

Ralph, P., D. Tomasko, K. Moore, S. Seddon, and C. Macinnis-Ng. 2006. Eutrophication, sedimentation, and contamination. Chapter 24. Pages 567-593 *in:* A.W. Larkum , R. J. Orth, and C. M. Duarte (eds). Seagrasses: Biology, Ecology, and Conservation. Springer, The Netherlands. 691 pp.

Short, F. T. and S. Wyllie-Echeverria. 1996. Natural and induced disturbances of seagrasses. Environmental Conservation 23:17-27.

Simenstad, C. A.., R.M. Thom, and A.M. Olsen eds. 1997. Mitigation between regional transportation needs and preservation of eelgrass beds. Prepared for the Washington State Transportation Commission. Washington State Transportation Center (TRAC), University of Washington, Seattle, WA.

Smith, R. D. 1989. Anaerobic metabolism in the roots of the seagrass *Zostera marina* L. PhD dissertation, The University of Chicago.

Southern California Coastal Water Research Project. 2002. Macronutrient dynamics in Upper Newport Bay. Technical report 365. Prepared by Krista Kramer, Kenneth Schiff (SCCWRP), Rachel Kennison and Peggy Fong (UCLA).
July 31, 2002. 98 pp.

State Water Quality Control Board. 1965. An Oceanographic and Biological Survey of the Southern California Mainland Shelf. Publication Number 27. State of California, The Resources Agency. 231 pp.

Stevenson, R. E., and K. O. Emery. 1958. Marshlands at Newport Bay. Allan Hancock Foundation Publications. Occasional Paper No. 20. University of Southern California Press, Los Angeles, California.

Takesue, R. L., B. J. Rosenbauer, and E. E. Grossman. 2005. Sedimentation and contaminant loading: effects on eelgrass (*Zostera marina*) bed health in northern Puget Sound. Extended Abstract, Proceedings of the 2005 Puget Sound Georgia Basin Research Conference.

Tamaki, H., M. Tokuoka, W. Mishijima, T. Terawaki, and M. Okada. Deterioration of eelgrass, *Zostera marina,* meadows by water pollution in Seto Inland Sea, Japan. Marine Pollution Bulletin 44:1253-1258.

Tetra Tech, Inc. *Balboa Marina eelgrass survey*. October 2003. Newport Beach, California. Prepared for The Bellport Group. 101 Shipyard Way, Newport Beach, CA. 5 pp. plus appendices.

Thayer, G. W., W. Judson Kenworthy, and M.S. Fonseca. 1984. The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile. U.S. Fish Wildl. Serv. FWS/OBS-84/02. 147 pp.

Thom, R.M., A.B. Borde, S. Rumrill., D.L. Woodruff., J.A. Southard, and S.L. Sargeant. 2003. Factors influencing spatial and annual variability in eelgrass (Zostera marina L.) in Willapa bay, Washington, and Coos Bay, Oregon, estuaries. Estuaries 26:1117-1129.

U. S. Army Corps of Engineers. 1992. Appendix G. Numerical modeling of Newport Bay. In: Reconnaissance Study, Upper Newport Bay, Orange County, California. Draft. December 1992. pp G1-G71.

U.S. Army Corps of Engineers. 2000 (USACOE). Upper Newport Bay Ecosystem Feasibility Study. Public Draft Report. Draft Environmental Impact Statement/Report. May 2000. Various paging.

U.S. Navy SWDIV Naval Facilities Engineering Command and the Port of San Diego. 2008. San Diego Bay 2008 Eelgrass Survey (Habitat Map).

Vaquer-Sunyer, Raquel and C. M. Duarte. 2008. Thresholds of hypoxia for marine biodiversity. PNAS 105 (40): 15472-15457.

Ware, R. R. 1993. Eelgrass (*Zostera marina*) in southern California bays and wetlands with special emphasis on Orange County, California. Shore and Beach 91:20-30

Waycott, M., C. Duarte, T. Carruthers, R. Orth, W. Dennison, S. Olyarnik, A. Calladine, J. Fourqurean, K. Heck, A. Hughes, G. Kendrick, W. Kenworthy, F. Short, and S. Williams. 2010. Accelerating loss of seagrasses across the globe threatens seagrass ecosystems. July 28, 2009. PNAS 106(30):12377-12381.

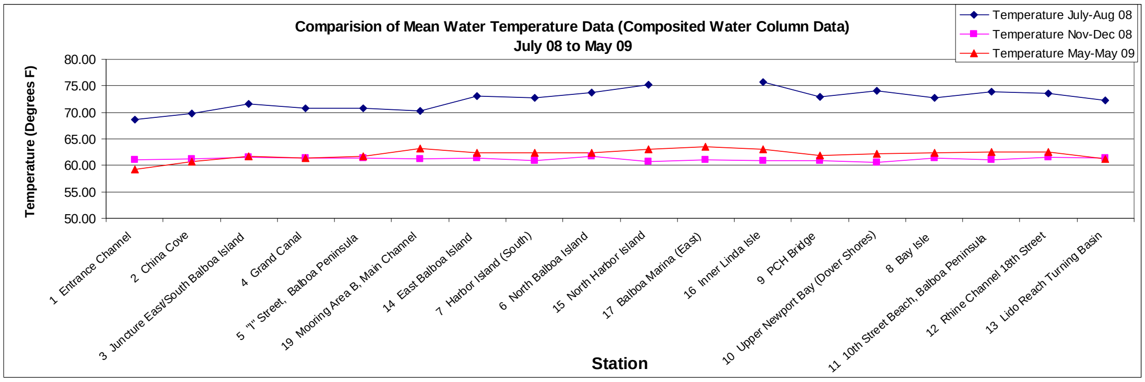
Williams, S. 2007. Introduced species in seagrass ecosystems: Status and concerns. J Exp Mar Bio Ecol 350:89-110.

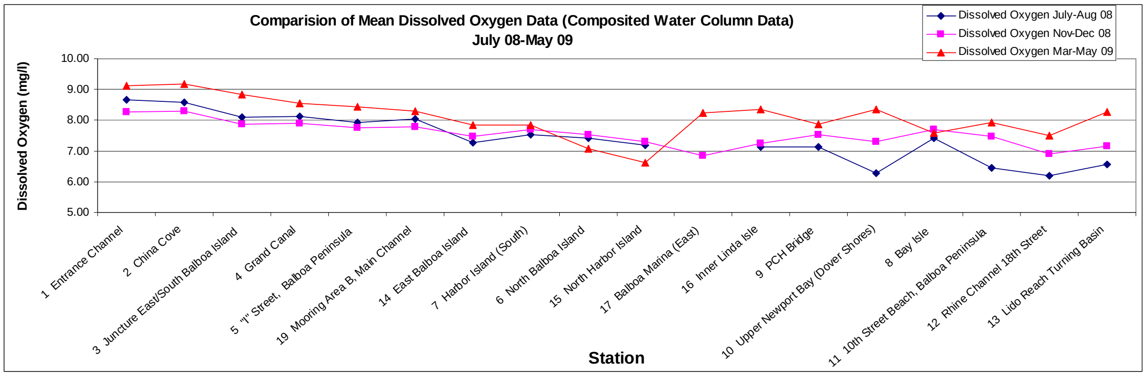
Wollf, T. 1980. Animals associated with seagrasses in the deep sea. Pages 199-224 in: R. C. Phillips and C.P McRoy (eds). Handbook of seagrass biology: An ecosystem perspective. Garland STPM Press, New York.

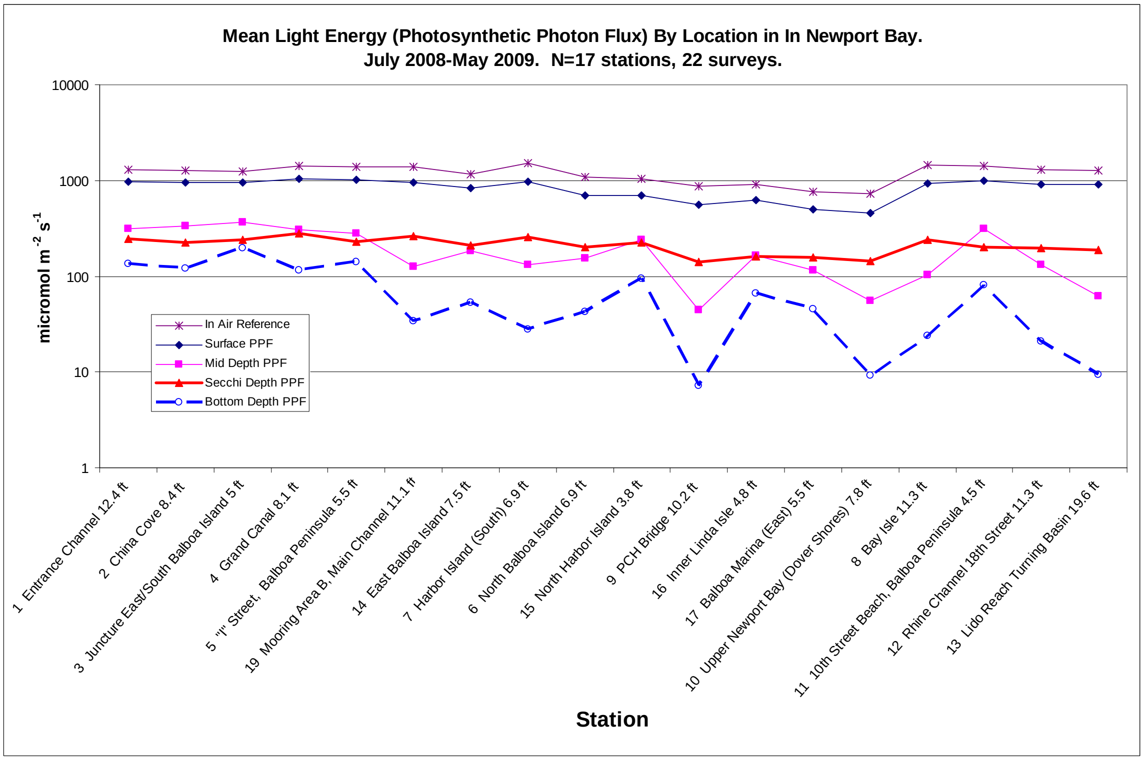
Zieman, J. C. and R. G. Wetzel. 1980. Productivity in seagrasses: methods and rates. Pages 87-115 in: R. C. Phillips and C.P McRoy (eds). Handbook of seagrass biology: An ecosystem perspective. Garland STPM Press, New York.

Zimmerman, R. C., L. Reguzzoni, S. Wyllie-Echeverria, M. Josselyn and R. S. Alberte. 1991. Assessment of environmental suitability for growth of *Zostera marina* L. (eelgrass) in San Francisco Bay. Aquatic Botany 39:353-366.

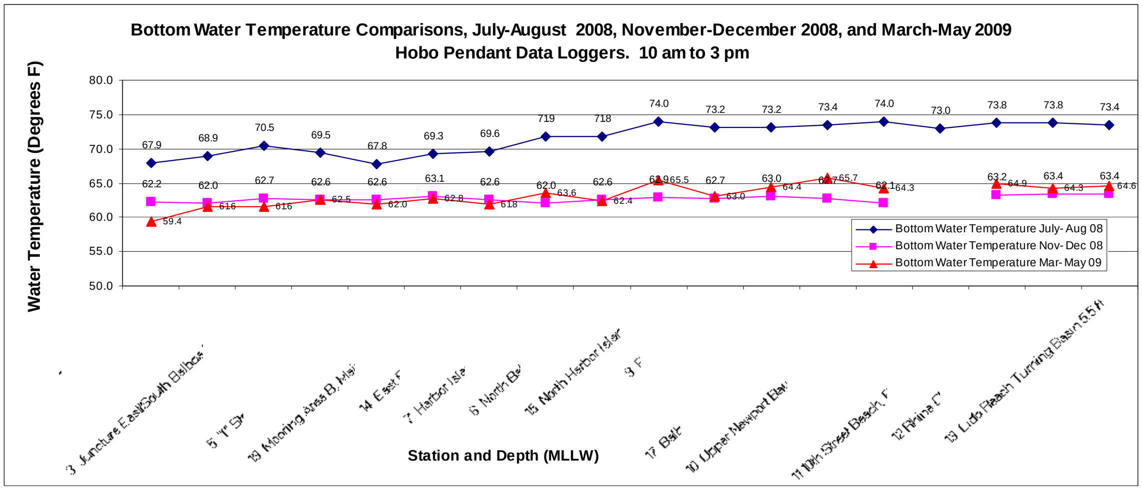
APPENDIX 1. SURVEY MEANS, OCEANOGRAPHIC SURVEYS
JULY 2008-MAY 2009

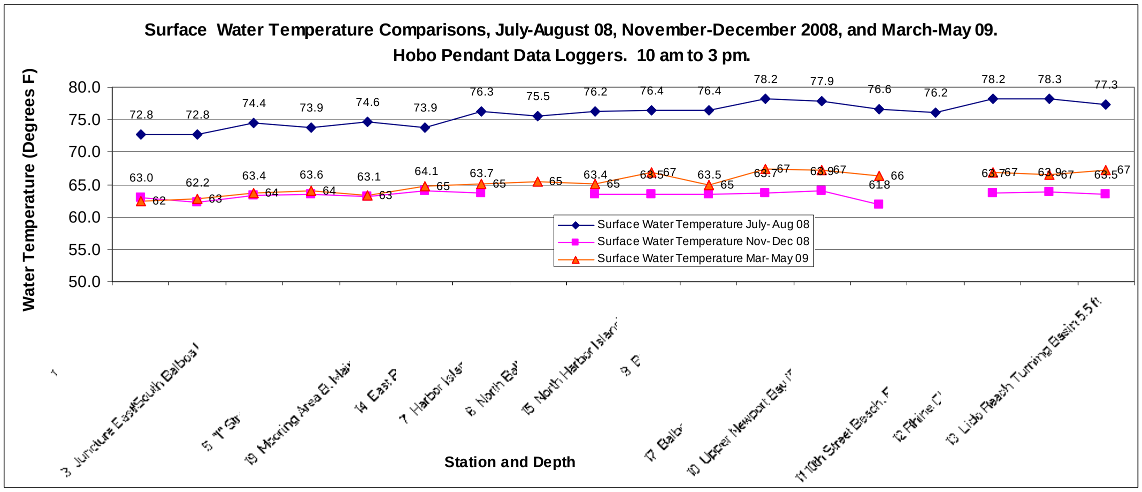


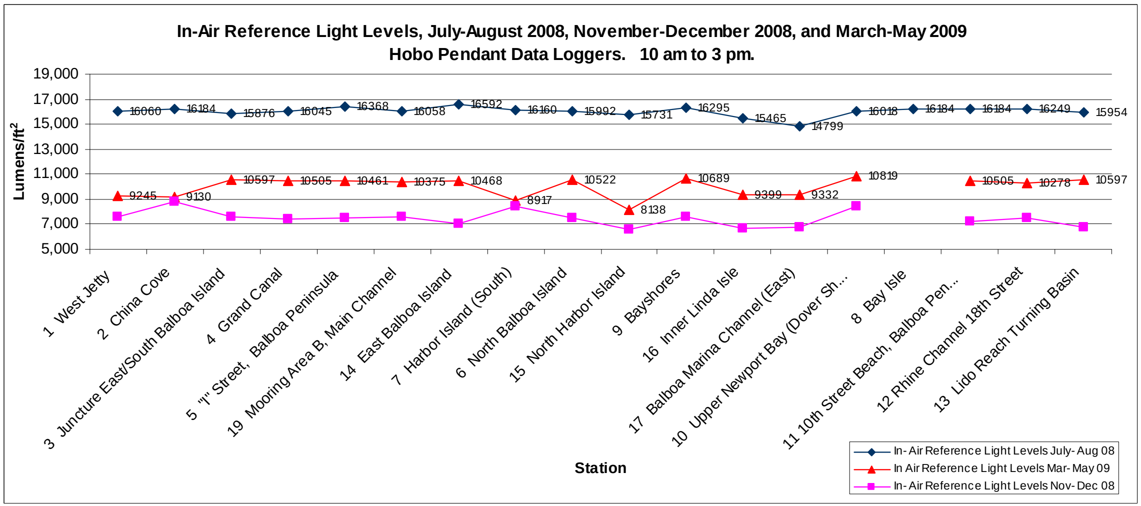


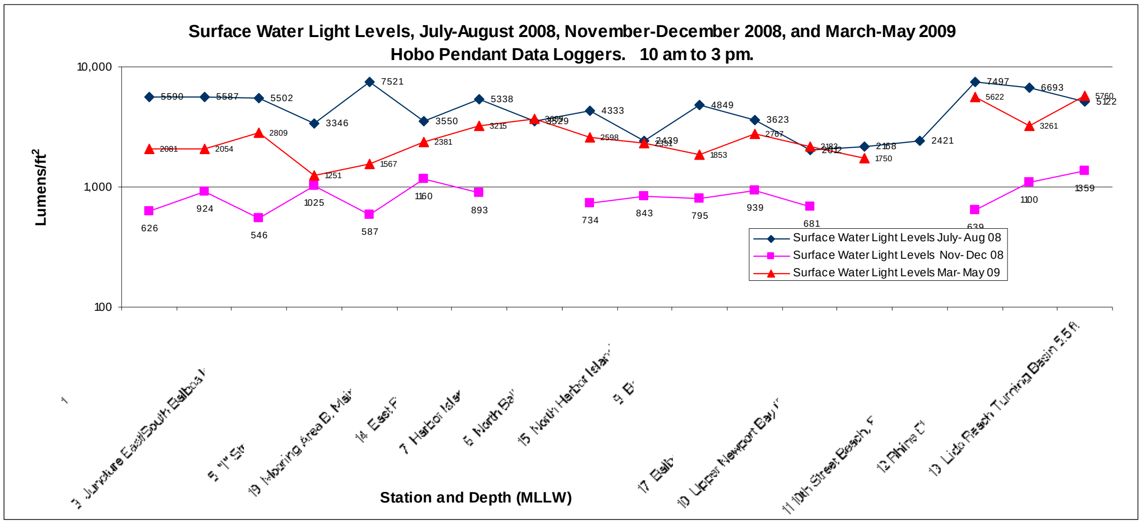

Mean Light Energy (Photosynthetic Photon Flux) By Location in In Newport Bay.
July 2008-May 2009. N=17 stations, 22 surveys.
10000
1000
100
10
1
micromol m $^{-2}$ s $^{-1}$
In Air Reference
Surface PPF
Mid Depth PPF
Secchi Depth PPF
Bottom Depth PPF
1 Entrance Channel 12.4 ft
2 China Cove 8.4 ft
3 Juncture East/South Balboa Island 5 ft
4 Grand Canal 8.1 ft
5 "I" Street, Balboa Peninsula 5.5 ft
19 Mooring Area B, Main Channel 11.1 ft
14 East Balboa Island 7.5 ft
7 Harbor Island (South) 6.9 ft
6 North Balboa Island 6.9 ft
15 North Harbor Island 3.8 ft
9 PCH Bridge 10.2 ft
16 Inner Linda Isle 4.8 ft
17 Balboa Marina (East) 5.5 ft
10 Upper Newport Bay (Dover Shores) 7.8 ft
8 Bay Isle 11.3 ft
11 10th Street Beach, Balboa Peninsula 4.5 ft
12 Rhine Channel 18th Street 11.3 ft
13 Lido Reach Turning Basin 19.6 ft
Station

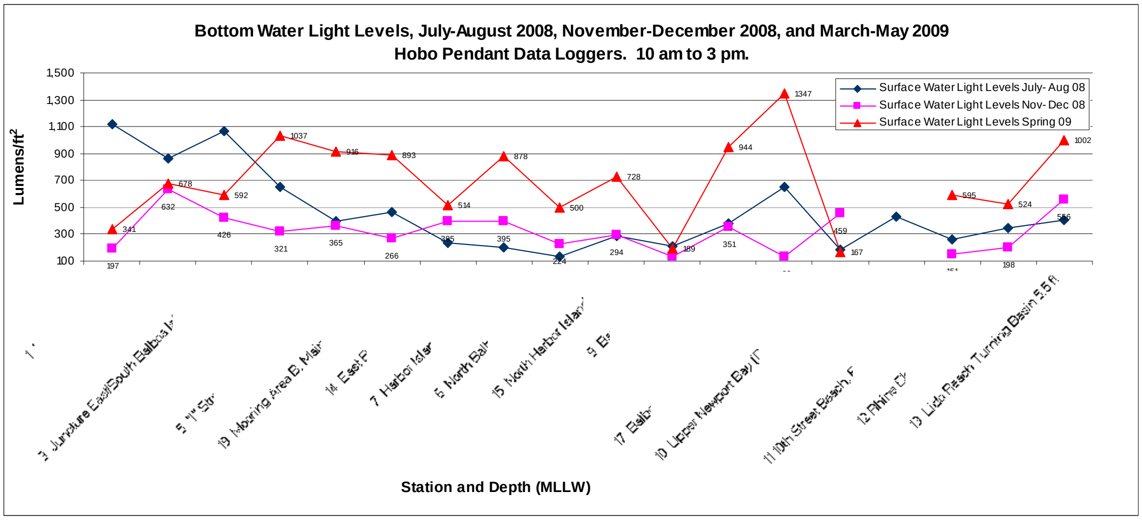
APPENDIX 2. HOBO PENDANT DATA LOGGER TEMPERATURE AND LIGHT DATA

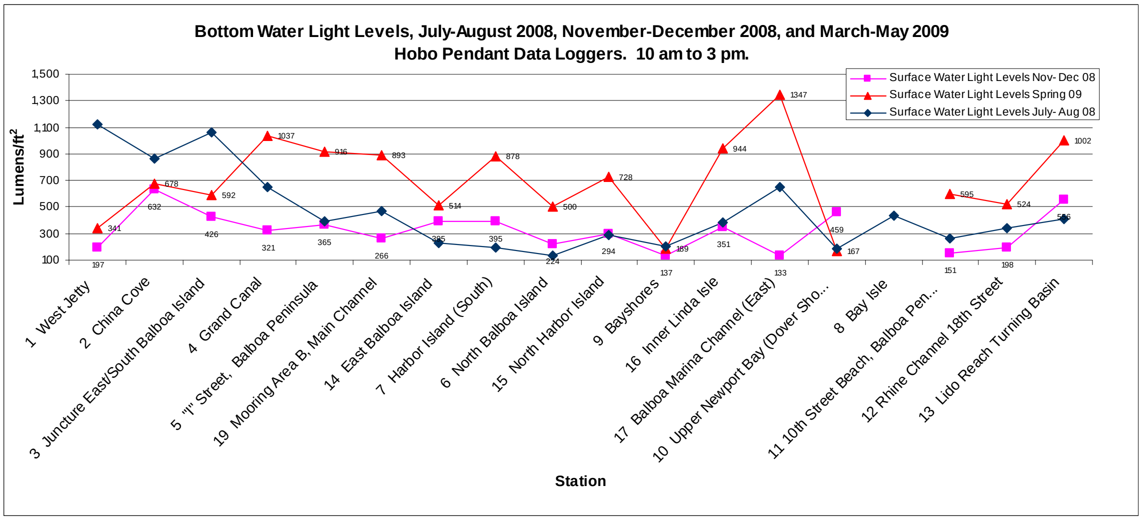

Bottom Water Temperature Comparisons, July-August 2008, November-December 2008, and March-May 2009
Hobo Pendant Data Loggers. 10 am to 3 pm

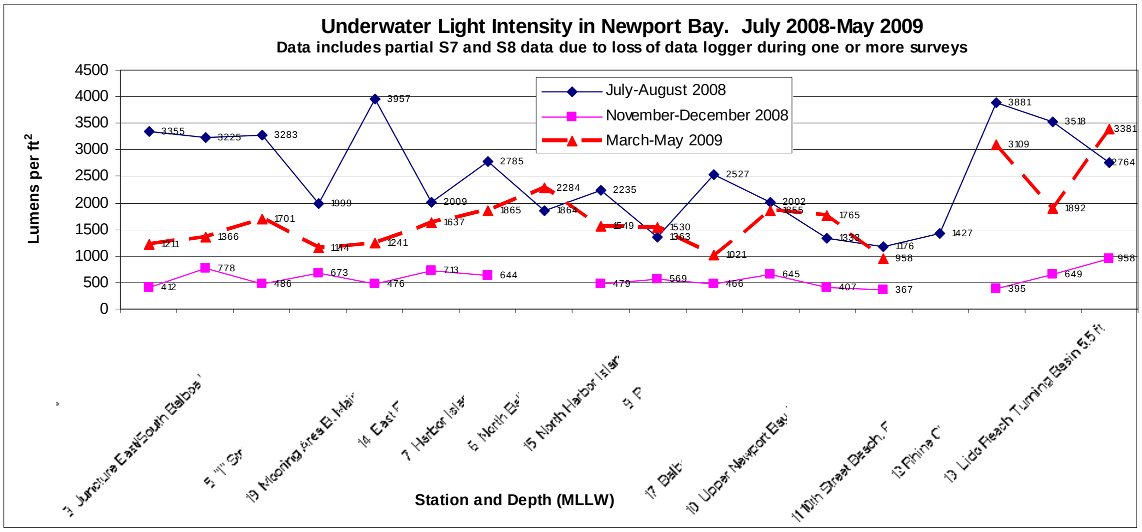

Surface Water Temperature Comparisons, July-August 08, November-December 2008, and March-May 09.
Hobo Pendant Data Loggers. 10 am to 3 pm.


In-Air Reference Light Levels, July-August 2008, November-December 2008, and March-May 2009
Hobo Pendant Data Loggers. 10 am to 3 pm.


Surface Water Light Levels, July-August 2008, November-December 2008, and March-May 2009
Hobo Pendant Data Loggers. 10 am to 3 pm.
10,000
1,000
100
Lumens/ft2
5590
5587
5502
3346
7521
3550
5338
3529
4333
2439
4849
3623
2012
2168
2421
7497
6693
5122
2081
2054
2809
1251
1567
2381
3215
3659
2598
2331
1853
2767
2183
1750
5622
3261
5760
626
924
546
1025
587
1160
893
734
843
795
939
681
639
1100
1359
Surface Water Light Levels July- Aug 08
Surface Water Light Levels Nov- Dec 08
Surface Water Light Levels Mar- May 09
3 Juncture East/South Balboa I
5 "I" Str
19 Mooring Area B, Mair
14 East F
7 Harbor Isla
6 North Bal
15 North Harbor Islan
9 B
17 Balb
10 Upper Newport Bay (
11 10th Street Beach, F
12 Rhine Ch
13 Lido Reach Turning Basin 5.5 ft
Station and Depth (MLLW)

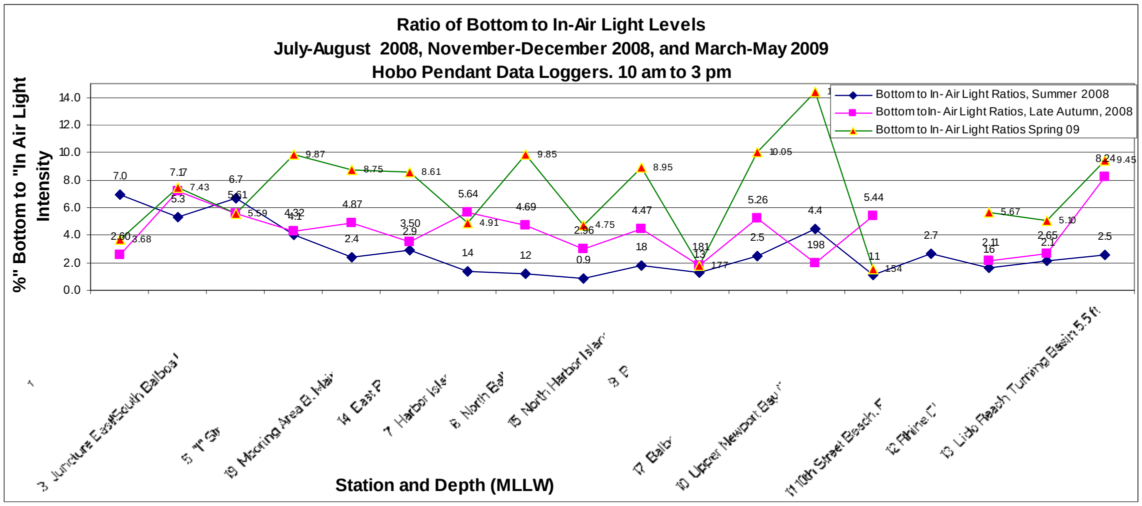

Bottom Water Light Levels, July-August 2008, November-December 2008, and March-May 2009
Hobo Pendant Data Loggers. 10 am to 3 pm.
1,500
1,300
1,100
900
700
500
300
100
Lumens/ft2
Surface Water Light Levels July- Aug 08
Surface Water Light Levels Nov- Dec 08
Surface Water Light Levels Spring 09
341
678
592
1037
916
893
514
878
500
728
189
944
1347
167
595
524
1002
197
632
426
321
365
266
395
395
224
294
351
459
198
556
3 Juncture East/South Balboa I
5 "I" Str
19 Mooring Area B, Mair
14 East F
7 Harbor Isla
6 North Bal
15 North Harbor Islan
9 B
17 Balb
10 Upper Newport Bay (
11 10th Street Beach, F
12 Rhine Ch
13 Lido Reach Turning Basin 5.5 ft
Station and Depth (MLLW)


Bottom Water Light Levels, July-August 2008, November-December 2008, and March-May 2009
Hobo Pendant Data Loggers. 10 am to 3 pm.
1,500
1,300
1,100
900
700
500
300
100
Lumens/ft2
Surface Water Light Levels Nov- Dec 08
Surface Water Light Levels Spring 09
Surface Water Light Levels July- Aug 08
341
678
592
1037
916
893
514
878
500
728
189
944
1347
167
595
524
1002
197
632
426
321
365
266
395
395
224
294
137
351
133
459
151
198
556
1 West Jetty
2 China Cove
3 Juncture East/South Balboa Island
4 Grand Canal
5 "I" Street, Balboa Peninsula
19 Mooring Area B, Main Channel
14 East Balboa Island
7 Harbor Island (South)
6 North Balboa Island
15 North Harbor Island
9 Bayshores
16 Inner Linda Isle
17 Balboa Marina Channel (East)
10 Upper Newport Bay (Dover Sho...
8 Bay Isle
11 10th Street Beach, Balboa Pen...
12 Rhine Channel 18th Street
13 Lido Reach Turning Basin
Station



Underwater Light Intensity in Newport Bay. July 2008-May 2009

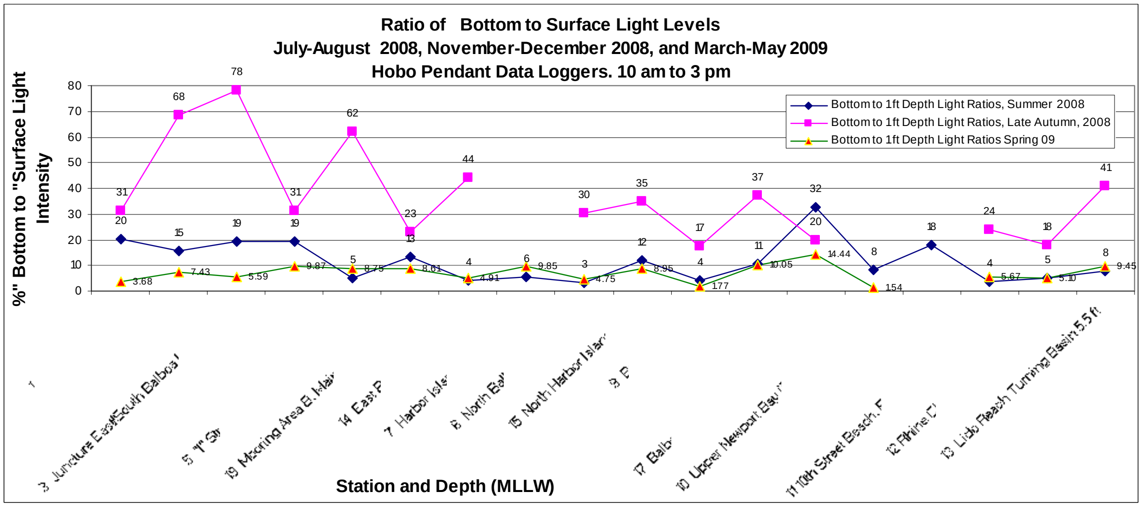
Data includes partial S7 and S8 data due to loss of data logger during one or more surveys



Ratio of Bottom to In-Air Light Levels

July-August 2008, November-December 2008, and March-May 2009

Hobo Pendant Data Loggers. 10 am to 3 pm



Ratio of Bottom to Surface Light Levels

July-August 2008, November-December 2008, and March-May 2009

Hobo Pendant Data Loggers. 10 am to 3 pm

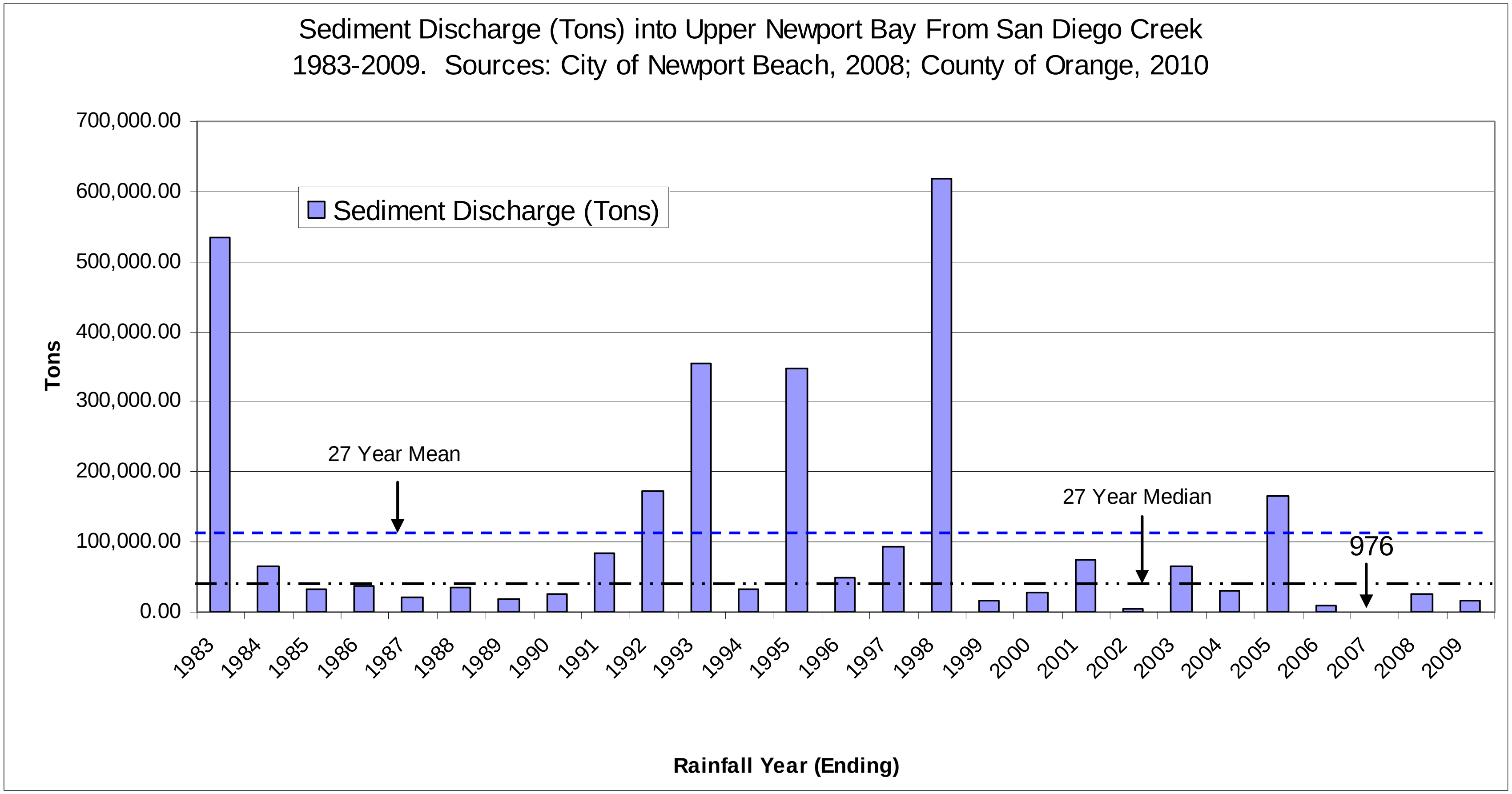
APPENDIX 3. SEDIMENT PARTICLE SIZE DATA, AND WATERSHED SEDIMENT DISCHARGE DATA

Sediment Particle Size

Eelgrass Presence	Station	**Median Grain Size**	**Description (Wentworth)**
EG	1 Entrance Channel-West	0.35	Medium Sand
EG	2 China Cove	0.2	Fine Sand
EG	3 South/East Juncture Balboa Island	0.28	Fine Sand
EG	4 Balboa Island South (Grand Canal)	0.102	Very Fine Sand
EG	5 "I" Street, Balboa Peninsula	0.26	Medium Sand
No EG	19 Mooring Area "B", Main Channel	0.015	Medium Silt
EG	14 Balboa Island (East)	0.12	Very Fine Sand
EG	7 Harbor Island (South)	0.035	Coarse Silt
No EG**	6 Balboa Island (North)	0.22	Fine Sand
EG	15 Harbor Island (North)	0.007	Fine Silt
EG	9 Bayshores Beach	0.18	Very Fine Sand
EG	16 Linda Isle Inlet	0.004	Very Fine Silt
No EG**	17 Balboa Marina Channel	0.003	Clay
No EG**	10 Upper Newport Bay (Castaways/Dover Shores	0.012	Medium Silt
EG	8 Bay Isle (East)	0.015	Medium Silt
No EG*	1110th Street Beach (TP Site)	0.4	Medium Sand
No EG*	12 17th Street Beach (TP Site)	0.45	Medium Sand
No EG*	13 Lido Isle Bridge (TP Site)	0.32	Medium Sand

Sediment Grain Size Data, Newport Bay. June 2008

			Percent by Weight					
Station	**Eelgrass Presence**	**Station Description**	**Gravel**	**Coarse Sand**	**Medium Sand**	**Fine Sand**	**Silt**	**Clay**
1	EG	Entrance Channel-West	0	0.21	27.73	66.84	3.59	1.63
2	EG	China Cove	0	0	5.02	92.22	1.28	1.49
3	EG	South/East Juncture Balboa Island	4.88	3.63	22.49	64.14	2.02	2.84
4	EG	Balboa Island South (Grand Canal)	0.14	0.31	3.07	58.37	20.57	17.54
5	EG	"I" Street, Balboa Peninsula	0.66	0.41	31.02	63.3	2.54	2.07
6	No EG**	Balboa Island (North)	0.05	0.12	10.76	84.94	2.06	2.08
7	EG	Harbor Island (South)	0.62	0.51	0.59	35.72	30.46	32.1
8	EG	Bay Isle (East)	0.02	0.12	0.57	12.09	49.8	37.41
9	EG	Bayshores Beach	0.24	0.41	9.15	69.25	10.08	10.88
10	No EG**	Upper Newport Bay (Castaways/Dover Shores	0.05	0.26	1.82	23.72	37.55	36.59
11	No EG*	10th Street Beach (TP Site)	0.16	1.13	42.06	51.01	1.62	4.03
12	No EG*	17th Street Beach (TP Site)	0.43	3.12	48.93	44.89	0.58	2.05
13	No EG*	Lido Isle Bridge (TP Site)	3.1	1.97	26.82	66.19	0.95	0.97
14	EG	Balboa Island (East)	0.27	0.73	2.81	59.64	20.73	15.83
15	EG	Harbor Island (North)	0	0	0.34	7.33	48.01	44.33
16	EG	Linda Isle Inlet	0	0	0.14	3.22	41.79	54.85
17	No EG**	Balboa Marina Channel	0	0	0.32	2.24	39.95	57.49
19	No EG	Mooring Area "B", Main Channel	0	0	0.21	7.48	57.33	34.97



Sediment Discharge (Tons) into Upper Newport Bay From San Diego Creek 1983-2009. Sources: City of Newport Beach, 2008; County of Orange, 2010

Appendix 4. Eelgrass Abundance in Newport Bay, 2003-2004 and 2006-2007 Surveys

Section of Newport Bay	2003-2004 (acres)	2006-2007 (acres)	Mean (acres)	Difference (acres)	% Difference	Shoreline Length (Miles)	Mean Acres/Linear Mile
Corona del Mar/Bayside Drive to OCHD	9.521	9.075	9.298	-0.446	-4.7	0.85	10.90
Balboa Channel Yacht Basins	2.469	1.539	2.004	-0.93	-37.7	0.58	1.02
Balboa Peninsula-East of Bay Island	1.672	1.557	1.615	-0.115	-6.9	1.58	0.03
Grand Canal	0.898	1.143	1.021	0.245	27.3	0.61	0.59
Balboa and Collins Islands	6.686	4.554	5.620	-2.132	-31.9	2.03	3.43
Bay Island	0.132	0.051	0.092	-0.081	-61.4	0.34	0.12
Balboa Peninsula-West of Bay Island	0.034	0.03	0.032	-0.004	-11.8	1.09	0.18
North Balboa Channel and Yacht Basins	0.698	0.115	0.407	-0.583	-83.5	0.69	1.35
Harbor Island	2.721	0.712	1.717	-2.009	-73.8	0.67	2.77
Linda Isle (outer channels)	2.916	0.328	1.622	-2.588	-88.8	1.20	0.27
Linda Isle (Inner basin)	0.281	3.218	1.750	2.937	1045.2	0.48	1.67
DeAnza/Bayside Peninsula (inner side)	0.209	0.009	0.109	-0.2	-95.7	0.37	1.07
DeAnza/Bayside Peninsula (Outer)	0.792	0	0.396	-0.792	-100.0	0.37	3.64
Castaways to Dover Shores	0.132	0	0.066	-0.132	-100.0	0.56	2.48
Bayshores	0.991	0.664	0.828	-0.327	-33.0	0.33	2.58
Mariner's Mile	0.234	0.066	0.150	-0.168	-71.8	0.84	0.30
Lido Isle	0.025	0.004	0.015	-0.021	-84.0	2.23	0.01
All Regions	30.411	23.065	26.738	-7.346	-24.2	14.82	1.80

Source: Coastal Resources Management, Inc. 2008

APPENDIX 5. EELGRASS TURION DENSITY DATA, 2004 AND 2008

2004	**Mean**	**Std dev**	**N**	**95% CI**
West Entrance Channel	198.3	81.6	60.0	20.6
China Cove	173.1	113.8	60.0	28.8
Carnation Cove	273.8	91.6	30.0	32.8
East Balboa-Corner	193.8	54.3	30.0	19.4
C-Street on Peninsula	273.1	104.1	60.0	37.3
Grand Canal	256.7	72.1	30.0	25.8
Bay Island	263.1	94.0	60.0	23.8
Harbor Island	252.9	112.4	60.0	28.4
Linda Isle	144.0	58.3	60.0	14.8
Bayside Private Beach	237.4	148.8	60.0	37.7
PCH Bridge	252.1	82.5	60.0	20.9
DeAnza (east, inside)	165.5	52.2	60.0	13.2
DeAnza (west, outside)	304.3	79.9	60.0	20.2
OCC	94.3	31.8	60.0	8.0
Lido YC	109.8	56.7	60.0	14.4

2008	**Mean**	**Std dev**	**N**	**95% CI**
West Entrance Channel	79.0	30.2	30.0	10.8
East Entrance Channel	188.6	51.9	30.0	18.6
China Cove	199.5	119.1	30.0	42.6
Carnation Cove	221.9	97.1	30.0	34.7
Jenkins Bayside	234.8	54.1	30.0	19.3
East Balboa-Corner	203.3	100.0	30.0	35.8
C-Street on Peninsula	100.5	52.7	30.0	18.9
Grand Canal	156.2	86.0	30.0	30.8
Bay Island	91.4	36.9	30.0	13.2
Harbor Island	105.7	42.0	30.0	15.0
Linda Isle	67.1	29.1	30.0	10.4
East Balboa Mooring 30	68.7	34.8	26.0	12.4
Bayside Private Beach	81.9	58.4	30.0	20.9
PCH Bridge	0.0 (no eelgrass)			
DeAnza (east, inside)	0.0 (no eelgrass)			
DeAnza (west, outside)	0.0 (no eelgrass)			
Lido YC	0.0 (no eelgrass)			
OCC	0.0 (no eelgrass)			

APPENDIX 6. EELGRASS BLADE LENGTH AND WIDTH GRAPHICS BY STATION