



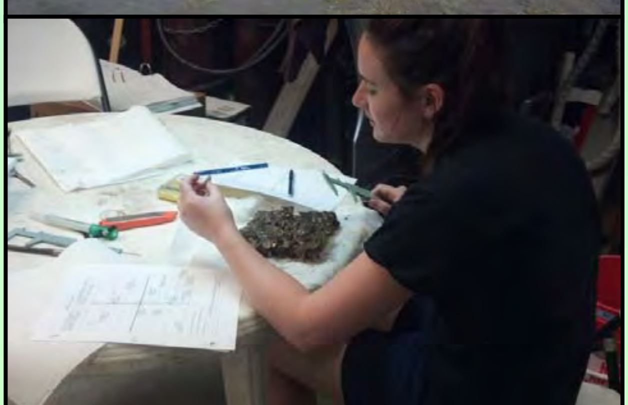

San Diego Bay Native Oyster Restoration Plan

May 2015

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May 2015

INTRODUCTION

PROJECT BACKGROUND

Natural resource managers and scientists are increasingly aware of the threats of continuing shoreline erosion, sea level rise, and climate change. In an effort to prevent large scale armoring of shorelines through placement of engineered riprap, seawalls, and bulkheads that do not provide maximum ecological values, natural resource managers are implementing a number of pilot coastal "living shoreline" programs through public and private partnerships. Living shorelines utilize natural habitat elements to protect shorelines from erosion while providing important habitat for fish, wetlands and aquatic plants, as well as wildlife. Living shorelines provide additional benefits including improving water quality by settling sediments and filtering pollution, providing shoreline access and functional habitat for ecologically and commercially important wildlife, and increasing connectivity of wetlands and deeper intertidal and subtidal lands.

Living shoreline programs have been underway along the Gulf and East Coasts for a number of years through projects such as the Chesapeake Bay Foundation's Living Shorelines Project and the Partnership for the Delaware Estuary's Shellfish-based Living Shorelines for Salt Marsh Erosion Control and Environmental Enhancement. Recently, the California State Coastal Conservancy (Conservancy) has partnered to implement the San Francisco Bay Living Shorelines - Nearshore Linkages Project. The San Francisco Bay project is the first of its kind on the West Coast, with an overarching project goal of creating biologically rich and diverse subtidal and low intertidal habitats, including eelgrass and oyster reefs[1], as part of a self-sustaining estuary system that restores ecological function and is resilient to changing environmental conditions.

While living shoreline research is ongoing in other estuarine systems, research has only recently begun in San Diego Bay. The San Diego Unified Port District (SDUPD), along with the U.S. Navy, has developed an Integrated Natural Resources Management Plan (INRMP) for San Diego Bay (U.S. Navy 2013). Many of the key objectives of the San Diego Bay INRMP revolve around improving the ecological resource values of the shoreline interface area, while maintaining the intended protection of the economically and sometimes ecologically valuable adjacent areas. One of the core initiatives of the INRMP is "sustainability by design", which seeks to maintain the SDUPD's and the Navy's assets and objectives as well as the natural resources of San Diego Bay in the face of anticipated climate change and sea level rise. This is directly related to a second core initiative of "habitat enhancement of shoreline structures", which calls for construction of shoreline structures

[1] Oyster bed is used to describe the natural low relief (< 1 ft vertical relief) habitat configurations that likely historically occurred in West Coast bays and estuaries. This document utilizes the term oyster reefs to describe high relief structures (≥ 1 ft vertical relief) restored to provide habitat for native Olympia oysters (*Ostrea lurida*) as well as to provide wave reduction and shoreline protection benefits. The term restoration is applied generally to any habitat created to promote expansion of populations of *O. lurida*.

that achieve multiple objectives in addition to shore stabilization, including providing habitat for native organisms, contributing to sustainability of the Bay's natural resources and accommodating expected sea level rise. In support of these initiatives, the INRMP identifies the improvement of the habitat values of shoreline infrastructure to be among the top nine highest priority projects for implementation. These INRMP initiatives and goals tie into the SDUPD's COMPASS Strategic Plan goal of creating "a Port with a healthy sustainable bay and its environment" through strategies that include planning and adapting for sea level rise and climate change and by preserving and promoting habitat restoration, and indigenous wildlife within the Bay.

Elsewhere in the INRMP, objectives are established for protecting existing coastal wetlands and expanding these resources where possible. However, coastal wetlands fringing the Bay are diminishing at a rapid rate due to shoreline erosion derived principally from wind waves and vessel wakes. Additional losses are anticipated in the future as a result of sea level rise, and from degradation of an optimal physical environment resulting from climate change. Absent the historic sediment influxes from coastal drainages, these marshland losses are irretrievable and will continue to result in significant wetland losses into the future. Protection against erosion of these Bay marsh interface areas is essential if existing wetlands are to be sustained.

Oyster reefs are particularly suited to living shoreline projects. Native Olympia oysters (*Ostrea lurida*) were a dominant commercial species along the West Coast until natural populations were depleted in the early 1900's due to a combination of over-harvesting, dredging, pollution, and filling and draining of wetlands (Coastal Conservancy et al. 2010). Like eelgrass, oysters are considered ecosystem engineers and a foundation species, because they are one of the building blocks of the benthic community. They create very important "reef" or structurally complex beds of habitat for other organisms. Some of the many important organisms found in association with oyster reefs include barnacles, mussels, algae, crabs, scallops, octopus, as well as many kinds of fish. Fish, in particular, use oyster reefs as refuge in their juvenile stages. Restored oyster reefs create more structured habitat that acts as living space for a whole community of organisms (Coastal Conservancy et al. 2010). Additionally, healthy oyster reefs play an important role in improving water quality within the estuary environment, through active filter feeding of adult oysters. Finally, oyster reefs help to curb shoreline erosion by buffering wind waves and boat wakes (Coastal Conservancy et al. 2010)

For the reasons described above, several agencies formed a partnership to implement a project in San Diego Bay (the Bay) that integrates intertidal shoreline stabilization with restoration of native O. *lurida*. To this end, the San Diego Bay Native Oyster Restoration Plan (Plan) has been funded by the SDUPD's environmental fund, and the Conservancy, through a grant from the National Oceanic and Atmospheric Administration (NOAA). The Plan addresses the need for sound demonstration projects in San Diego Bay that work synergistically with other tools to protect shorelines from erosion and sea level rise, while providing improved intertidal and shallow subtidal habitat values. The Plan builds upon lessons learned from other living shoreline projects including the San Francisco Bay Living Shorelines - Nearshore Linkages Project. It also builds upon knowledge gained through *O. lurida* restoration programs in southern California including those underway in Newport and Alamitos Bays. It provides a key step towards achieving the initiatives and goals of the INRMP regarding implementation of shoreline protection in an ecologically friendly manner while also sustaining the natural and economic values of the Bay.

This Plan has benefited from the input and guidance of the following project team and Technical Advisory Committee (TAC):

Project Team Members

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Dr. Theresa Talley, California Sea Grant

The contents of this Plan do not necessarily represent the opinions of the individual team or TAC members.

Goals and Objectives

The goal of the Plan is to create a biologically rich native *Ostrea lurida* oyster reef in San Diego Bay as part of a complete marsh system, which restores an ecological niche that was historically present, is ecologically functional and resilient to changing environmental conditions, and also protects Bay tidelands and shoreline.

In order to meet this goal, the following Plan objectives have been identified:

1. Evaluate existing and historical distribution of oysters in the Bay.

2. Determine suitable locations for oyster reef restoration, using existing and new data.

3. Identify appropriate energy environments and sites in the Bay that could most benefit (in terms of erosion control and ecological function) from oyster reef creation.

4. Use a pilot-scale approach to establish demonstration oyster reefs.

5. Determine the extent to which oyster reefs enhance habitat for invertebrates, fish, and birds, relative to areas lacking structure and relative to pre-restoration conditions.

6. Evaluate the potential for oyster reefs to reduce water flow velocities, attenuate waves, reduce erosion, and promote sediment capture shoreward of the reefs.

ELEMENTS OF THE PLAN

The Plan includes the following elements:

1. **Literature Review** to determine historic presence and distribution of *O. lurida* oysters in San Diego Bay

2. **Preliminary Oyster Recruitment and Growth Studies** including the following tasks:

    a. Qualitative survey of San Diego Bay shorelines to identify presence and general abundance of native *O. lurida* and non-native *C. gigas* oysters in the Bay
    b. Oyster settlement and growth studies at six sites in south San Diego Bay to determine oyster spat settlement rates, survivorship, density, and growth rates, with data collected from settling plates placed along the intertidal shoreline
    c. Collection of quantitative oyster abundance and density at the six study sites in south San Diego Bay

3. **Preliminary Physical Studies** including the following tasks:

    a. Collection of existing data for San Diego Bay to document a regional setting and to support restoration site(s) selection and conceptual oyster reef design. Data collected include: bathymetry and topography, water quality, habitat type, shoreline habitat (e.g. hardened or natural), sediment type, wind speed and direction, sea level rise predictions, and property ownership and planning jurisdictions.

4. **Conceptual Restoration Design** including the following tasks:

    a. Wave energy studies including creation of a predictive wave energy model as well as field groundtruthing using wave gauges place at predicted high and low energy sites in south San Diego Bay
    b. Identification and selection of restoration site(s) based on integration of all physical data collected, wave energy studies, and oyster recruitment and growth studies
    c. Preparation of conceptual design drawings (plan and section) for the restoration site(s) showing size and configuration, elevation, orientation, oyster reef substrate type, and other relevant features

5. **Study Plan** including the following elements:

   a. Clearly stated project goals and objectives and specific scientific research questions to be addressed.
   b. Identification of study and reference sites and site selection criteria for oyster reef restoration.
   c. Conceptual design and configuration of oyster beds/reefs at specific restoration sites.
   d. A detailed pre- and post-installation physical and biological monitoring program.
   e. Development of physical and biological success criteria based on project goals and objectives.
   f. A proposed schedule for all second phase work elements.
   g. Draft cost estimates for the second phase of project work including permitting and environmental compliance and final engineering.

SAN DIEGO REGIONAL SETTING

PHYSICAL FEATURES

San Diego Bay is a nearly enclosed, naturally formed embayment (Figure 1). The Bay was formed from the alluvial floodplains of the Otay, Sweetwater, and San Diego Rivers, and was historically shallow. The re-direction and channelization of the San Diego River beginning in the 1940's along with multiple dredging and channel deepening projects have resulted in deep waters in the northern and central portion of the Bay (with deepest waters of 59 feet occurring at the mouth of the Bay), transitioning to shallow waters (less than 3 feet) at the south end of the Bay (U.S. Navy 2013) (Figure 2). The INRMP divides the Bay into multiple depth categories including: deep (> -20 feet (ft) MLLW), moderately deep (-12 to -20 ft MLLW), shallow (-2.2 to -12 ft MLLW), and intertidal (-2.2 to +7.8 ft MLLW) (Figure 3). Currently, deep and moderately deep waters account for more than 50% of total Bay surface area (U.S. Navy 2013). In contrast, shallow subtidal habitat accounts for approximately 28% of Bay surface area, primarily in south San Diego Bay. This represents a loss of shallow water and intertidal habitat of over 40% since the late 1800's. Similarly, intertidal habitat currently accounts for only 7% of the Bay surface area, representing a more than 90% loss since the late 1800's.

MANAGEMENT ENTITIES AND STAKEHOLDERS

The management entities and stakeholders within the shoreline and tidelands of San Diego Bay include the San Diego Unified Port District, the U.S. Navy, U.S. Fish and Wildlife Service (which owns and/or manages approximately 2,600 acres in south San Diego Bay as part of the South Bay National Wildlife Refuge), the State of California (including the State Lands Commission, California Department of Parks and Recreation, and CalTrans), the County of San Diego, and the Cities of San

Project Vicinity Map
San Diego Bay Native Oyster Restoration Plan

Figure 1

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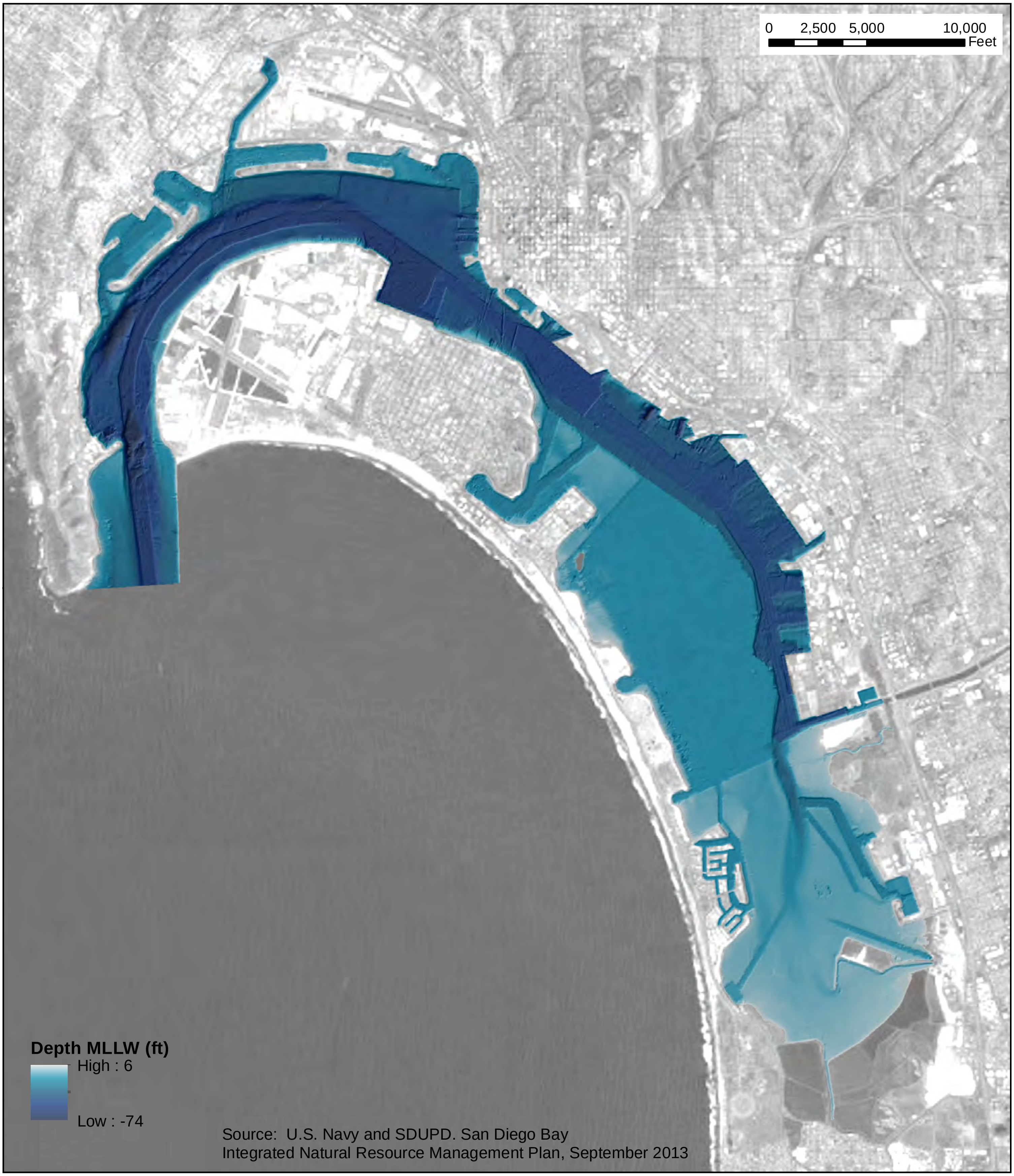
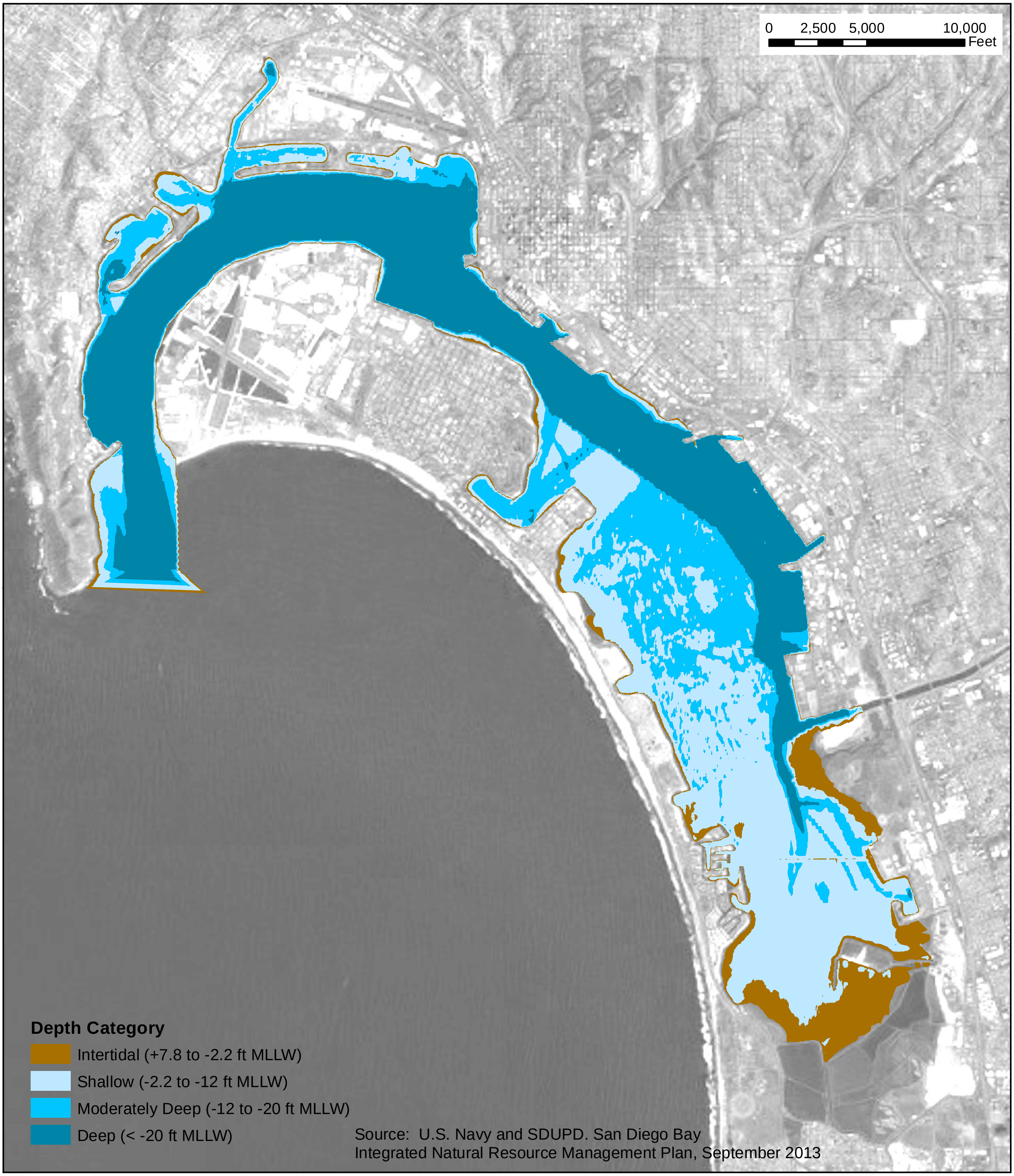


Bathymetry of San Diego

San Diego Bay Native Oyster Restoration Plan

Figure 2



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Water Depth Categories for San Diego Bay

San Diego Bay Native Oyster Restoration Plan

Figure 3

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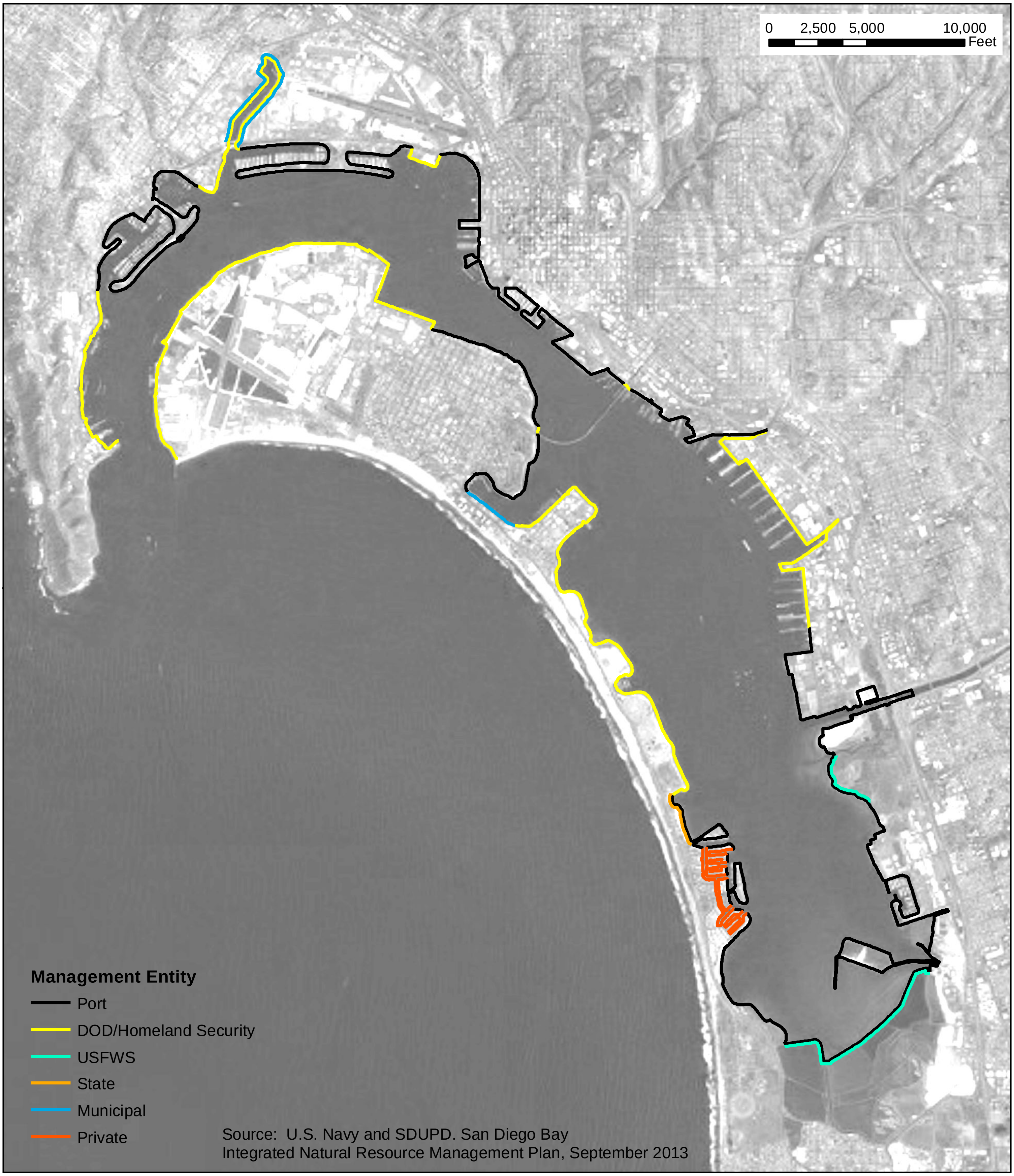
Diego, Coronado, Chula Vista, National City, and Imperial Beach. Figure 4 illustrates the planning and management entities that exist within the Bay.

HABITATS

The habitats of San Diego Bay are reflective of water depth and presence or absence of shoreline structures. More than 70% of the shoreline (45.4 miles out of a total 64.4 miles) of San Diego Bay is currently armored (U.S. Navy 2013). Armoring is primarily rock rip rap, but also includes vertical bulkhead walls, boat launch ramps, earthen dikes, and wharves and pile walls. Additionally, there are over 130 acres of surface structures (piers, docks, etc.) within the Bay that currently shade intertidal and subtidal waters. The majority of the lands in the northern and central portion of the Bay are developed with a mix of commercial, recreational, and military use. The largest unarmored areas occur in the southern portion of the Bay. As such, the majority of undeveloped habitat also occurs in the southern portion of the Bay. Habitats in the southern portion of the Bay include southern coastal salt marsh, intertidal sand and mudflats, salt flats, and southern coastal foredune (Figure 5). The dominant vegetated subtidal habitat in San Diego Bay is eelgrass (*Zostera marina*); the most recent baywide eelgrass survey, completed in 2014, found 1,996 acres of eelgrass (Merkel & Associates, Inc. 2014). This accounts for approximately 10.5% of the Bay surface area, with a majority of the total occurring in the shallow waters of the southern portion of the Bay. Salt marshes currently cover approximately 800 acres of San Diego Bay, representing a 70% decline since the late 1800's (U.S. Navy 2013). Nearly the entire salt marsh habitat in the Bay occurs in the southern portion of the Bay. The current network of marshes forms a non-contiguous patchwork in the south Bay (Figure 5). This fragmentation, along with channelization and re-direction of rivers and creeks that historically drained into marshlands, and the threat of sea level rise, puts the remaining marshes at risk of decline. Many of the marshes in south San Diego Bay occur along unarmored shorelines, the largest of which is the E Street and Sweetwater Marsh complex located south of the Sweetwater River Channel along the southeastern shoreline of the Bay within the San Diego Bay National Wildlife Refuge. Other large marsh areas along unarmored shorelines include the J Street Marsh, and Emory Cove. Still other marshes (including the Chula Vista Wildlife Reserve, the D Street Fill, and within the South Bay Salt Ponds) have been restored and are currently protected from erosion by permeable dikes and rip rap armoring.

PREDICTED EFFECTS OF SEA LEVEL RISE

Climate change and sea level rise pose an alarming threat to both developed lands and the remaining undeveloped habitats within San Diego Bay. Resource managers are faced with tough choices of how to protect fragile ecosystems in the face of increased temperatures, weather extremes (including both drought and storm events), and rising oceans. The remaining marshlands in San Diego Bay face a potential for increased erosion from storm waves and rising tides, habitat conversion from changes in tidal inundation as water levels rise, and threat from continued shoreline armoring to protect adjacent developed lands. Predictions from the California Climate Change Center indicate that sea level in San Diego Bay could rise between 5 and 35 inches by 2100 (Cayan et al. 2006). Other recent projections suggest that sea level could increase by up to 6.5 ft (2 meter (m)) by the end of the 21st century (Gersberg et al. 2014). According to the recent integration of a Digital Terrain Model for San Diego Bay with the Sea Level Rise of Marshes model



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Management Entities and Stakeholders for San Diego Bay

San Diego Bay Native Oyster Restoration Plan

Figure 4

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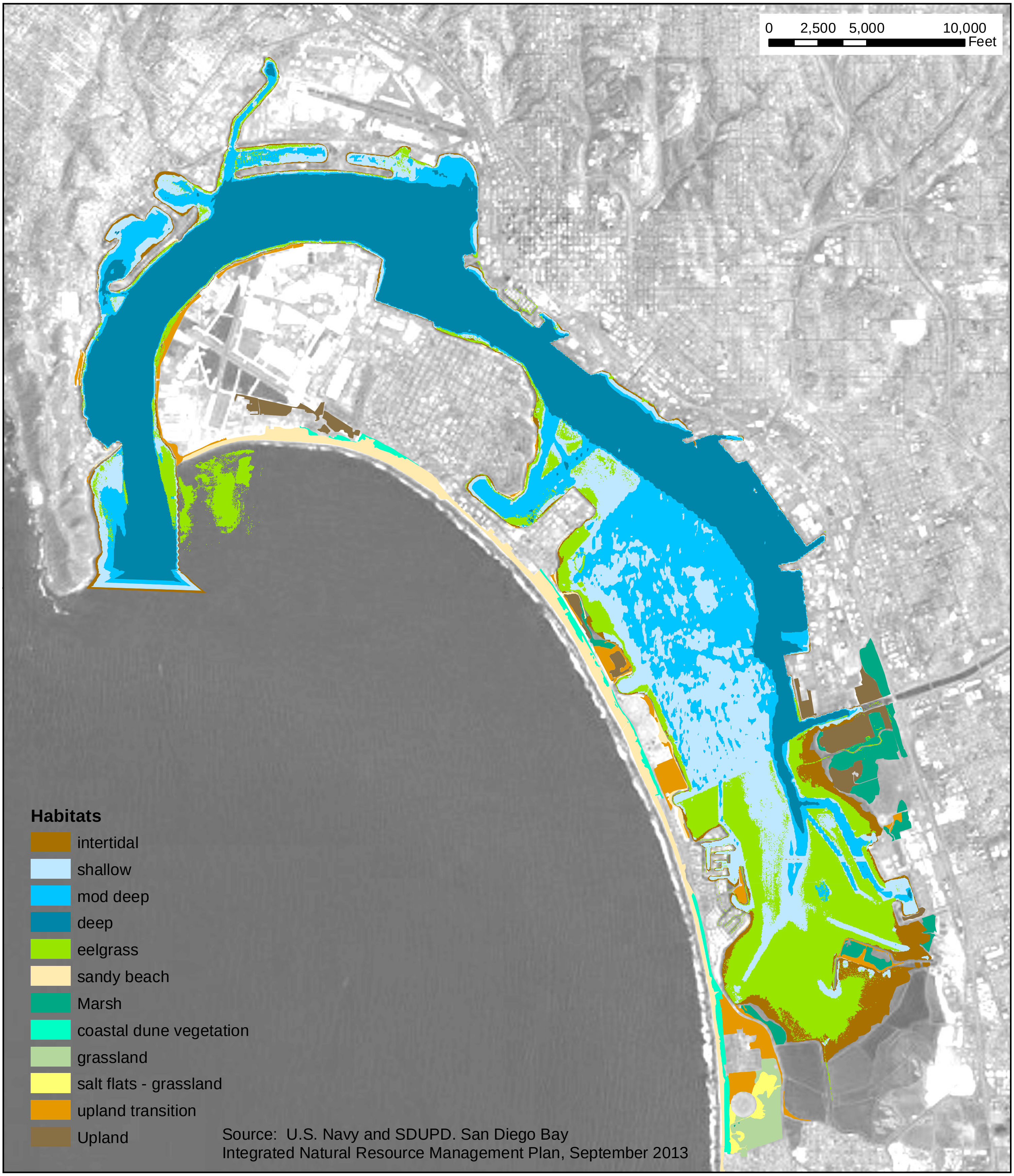

Habitats of San Diego Bay

San Diego Bay Native Oyster Restoration Plan

Figure 5

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(SLAMM), researches indicated that San Diego Bay would experience a nearly 100% loss of marshes using the two meter sea level rise benchmark (Gersberg et al. 2014). Under a USGS modeling effort performed specifically for the Sweetwater Marsh, over 91% of the marsh would be lost and/or converted to mudflat by 2110 under a 5.2 ft (1.6 m) sea level rise scenario (Thorne et al. 2014).

PRELIMINARY PHASE I STUDIES

Preliminary studies included a combination of collection of new data and analysis of existing data, and implementation of field studies to fill data gaps. The following text summarizes existing data gathered, and where applicable, summarizes results of field studies. Complete methods, results, discussion, and data for field studies are presented as technical memoranda in Appendices A-E.

BIOLOGICAL STUDIES

Historic Distribution of Oysters

Along the North American West Coast, from Alaska to central Baja, Mexico, *O. lurida* is the only native oyster species. While native *O. lurida* currently exists in San Diego Bay, its historic distribution and abundance in the Bay is not known. Additionally, no baywide quantitative surveys have been performed to determine abundance and density of the species within San Diego Bay. As a result, a literature and fossil records search was completed to determine the historic presence and distribution of native *O. lurida* within San Diego Bay.

Results of the study (presented in Appendix A), indicate that *O. lurida* has been part of the San Diego landscape since at least the Pliocene epoch (2.5 - 5 mya) during the Cenozoic era. Literature from the 1800's indicates that oysters present in San Diego Bay provided a food resource for Native Americans and were potentially abundant enough for commercial harvesting. Recent studies (Davis et al. 2002, and Polson and Zacherl 2009) have quantified *O. lurida* densities (among other species along armored shorelines) at localized sites within San Diego Bay, with highest densities found at Harbor Island.

<u>Conclusion:</u> The literature search confirms that *O. lurida* was present in San Diego Bay as early as 2.5 million years ago, and was once abundant enough to provide a food source for native people and early settlers. Very little is known about the configuration of oysters in the historic landscape and it is not known whether *O. lurida* formed low relief beds or high relief reefs within the Bay. Recent studies continue to identify the species along hard shorelines within the Bay; however, O. lurida is only found growing on man-made hardened structures (e.g. rip rap rubble, cobble fill, or pier pilings) rather than on natural beds or reefs.

Current Distribution of Oysters

A qualitative survey of the shorelines of San Diego Bay was completed in order to determine the presence and general density of *O. lurida* and non-native Pacific oyster (*Crassostrea gigas*) along as much of the publically accessible shoreline of San Diego Bay as possible. These data were used to inform restoration site selection and the ability of *O. lurida* oyster to grow and survive in the Bay.

Results of the study (presented in Appendix B) indicate that San Diego Bay supports abundant populations of both *O. lurida* and *C. gigas* along a majority of hardened shorelines and structures (e.g. pier pilings, fences, etc.). In a majority of locations surveyed, *O. lurida* and *C. gigas* were found to co-exist. At most locations the two species displayed a distinctive pattern of zonation, with the highest percent cover of *O. lurida* occurring at a lower tidal elevation than the highest percent cover of *C. gigas*. *O. lurida* was present throughout the Bay, including on hard surfaces (e.g. tires, remnant dock piles, etc.) found on mudflats that otherwise did not have hardened shorelines.

<u>Conclusion:</u> Native O. *lurida* and non-native *C. gigas* are present along a majority of the hardened shorelines of San Diego Bay, and the two species display vertical zonation at sites where they co-exist. These results strongly suggest that settlement and growth rates for *O. lurida* are sufficient to support populations of this species where appropriate hard substrates are present.

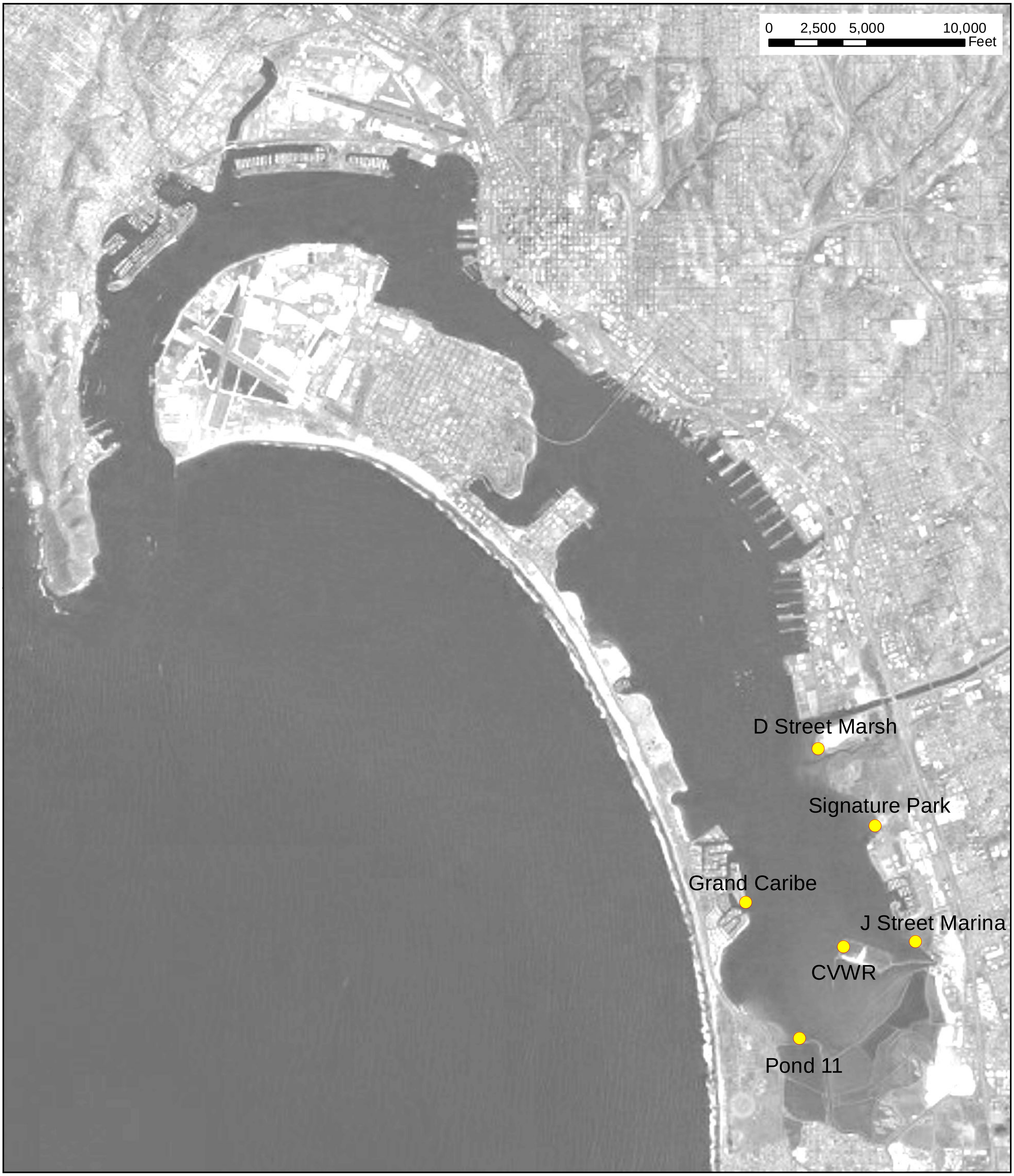
Oyster Settlement and Growth Studies

The ability for oyster spat to naturally recruit to new substrate within San Diego Bay and to grow is important for the establishment and success of restored reefs. However, the recruitment, survivorship, and growth rates of *O. lurida* in San Diego Bay are not known. A study was implemented at six sites within south San Diego Bay (Figure 6) during the summer of 2013, in order to quantify settlement and growth rates for *O. lurida*, as well as for *C. gigas*. Priorities for study site selection included:

- Areas adjacent to unarmored shoreline
- Areas with intertidal and shallow subtidal habitat
- Areas known to currently support oysters or have potential for oyster settlement
- Areas along eroding shorelines and/or exposed to high wind wave energies
- Areas with low foot and boat traffic
- Areas that are accessible and those that are owned or managed by entities willing to participate in the study

Oyster recruitment collectors (ceramic tiles attached to PVC moorings) were placed in the intertidal zone at each of the six study sites. Tiles were collected every two weeks and settled oyster spat were counted on each tile using a dissecting microscope in the laboratory. Two additional tiles were left in place and collected once per month to measure the growth of selecting oyster recruits.

Complete results of the study are presented in Appendix C. The settlement rates of *O. lurida* at the six study sites ranged from 642 to 6,569 recruits/m^2/day in June 2013. In early July, recruitment significantly declined, and ranged from 5 to 377 recruits/m^2/day. For *C. gigas*, the timing of peak recruitment was similar, with maximum recruitment again occurring at all sites during June 2013, ranging from 0.8 to 196 recruits/m^2/day. Minimal recruitment of either species was noted in August. These results indicate high rate of recruitment of *O. lurida* in San Diego Bay as compared to studies completed in Newport Bay during the same time period. In Newport Bay, recruitment peaked during the same time and ranged from 1.5 – 85 oysters/m^2/day in June 2013, except at one site (15th street) during one census, which received ~400 oysters/m^2/day (D. Zacherl, unpublished data).



Location of Six Study Sites in South San Diego Bay

San Diego Bay Native Oyster Restoration Plan

Figure 6

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The mean growth rate for settled *O. lurida* oysters at each study site ranged from 0.1 to 0.6 mm/day, with a total average of 0.25 mm/day. The growth rate was generally highest at most study sites approximately one month after settlement, however, percent recovery of oysters utilized in the growth study declined over time. This was due to a range of factors including death of oysters, overgrowth of oysters by space competitors including bryozoans and tunicates, and/or dense growth of oysters making re-location of specific individuals impossible.

Conclusion: None of the six study sites in south San Diego Bay are recruitment limited and all of the sites display settlement and growth rates of *O. lurida* sufficient to implement an oyster reef restoration.

Physical Studies

Water Quality

San Diego Bay supports primarily marine water quality conditions throughout the year, due to a combination of minimal freshwater inputs (rivers and creeks), low rainfall, and a moderate to rapid water turnover rate with the Pacific Ocean (depending on location within the Bay) (U.S. Navy 2013).

Several long-term data sets have been collected within the Bay and the summarized data provide a general picture of water quality conditions. Multi-year studies within south San Diego Bay were performed by Tenera Environmental et al. (2004) in 2003 and Merkel & Associates (2000) from 1997 to 1999 in order to assess the effects of the now closed South Bay Power Plant cooling water discharge on adjacent Bay waters. Hydrolab® multi-probe instruments were deployed continuously at ten stations within the south Bay waters between 1997 and 1999 (Merkel & Associates, Inc. 2000). Similar Hydrolab® multi-probes were deployed at seven south Bay stations in a subsequent study completed in 2003 (Tenera Environmental et al. 2004). During the 1997-1999 studies, mean monthly salinity ranged from 29 ppt to 39 ppt at all stations, and weekly averages never fell below 27 ppt at any of the ten stations (Merkel & Associates, Inc. 2000). In the same study, mean monthly temperatures ranged from 14 ^{o}C during winter months to 29 ^{o}C during summer months, mean daily dissolved oxygen ranged 5.7 mg/L to 7.2 mg/L, and mean monthly turbidity ranged from 0 NTU to 30 NTU. Sedimentation rates were measured to be very low, and turbidity was determined to be primarily from wind-generated re-suspension of bottom sediments in shallow south Bay waters rather than from sediment input from adjacent creeks. Data collected during 2003 were consistent with the earlier data set for stations representing the ambient water conditions outside of the influence of the South Bay Power Plant (Tenera Environmental et al. 2004).

More, recently, water quality data were collected in the northern and central regions of the Bay during 2008-2009 (Tierra Data, Inc. 2010). During this period, water temperature ranged from 11.9°C to 23.3°C at the two monitoring stations (both located north of the Coronado Bridge), and salinity ranged from 28.37 ppt to 37.77 ppt. Turbidity levels during the study period remained low (typically lower than 11 NTU), with highest values occurring in winter months following rain events.

Conclusion: San Diego Bay is a predominantly marine environment, with typically marine water salinity, temperature and dissolved oxygen, as well as low rates of sediment deposition. As such, all potential restoration sites in the Bay would have suitable water quality to support *O. lurida* oysters.

Wave Energy Studies

Wind power modeling and subsequent groundtruthing was conducted in order to identify shorelines within San Diego that receive the greatest wind wave energy, and consequently, may be most susceptible to shoreline erosion. A wave power model was created for San Diego Bay using bathymetry in conjunction with wind speed and direction data collected at weather stations within the Bay. The model was used to identify one high energy site and one low energy site within south San Diego Bay. Tide loggers were then deployed at each of these two sites in order to groundtruth the model.

Results of the wave power model (presented in Appendix D) indicate that the shoreline with the highest wind wave power, and possibly higher rates of erosion along the shoreline, is located along the east shore of the south San Diego Bay, especially near National City. Since the most frequent and fastest wind speed within the Bay comes from the west to northwest, the area near National City experiences the longest fetch and, therefore, the most wave power in the Bay. In contrast, the west shore in the south Bay and the north shore in the northern portion of the Bay are sheltered from the stronger west to northwest winds, so these shorelines experience the least wave power. Results of the tide logger studies were consistent with the wave power model.

Conclusion: The southeastern shoreline of San Diego Bay receives the highest wind wave power. While actual rates of erosion along the shoreline were not measured in this study, results of the study suggest that potential for shoreline erosion may be greatest in this area. Thus, this area of the Bay will provide the best opportunity to achieve the Plan objective to evaluate the potential for on oyster reef to reduce shoreline erosion.

RESTORATION SITE SELECTION

In order to select a site to implement oyster reef restoration, the project team and TAC evaluated the results of the preliminary studies and the ability of each of the six originally selected study sites to meet the Plan objectives. The preferred characteristics for the selected restoration site include:

- **Areas known to currently support oysters and with settlement and growth rates of native *O. lurida* sufficient to naturally colonize a restored reef.** Results of the settlement and growth studies, along with quantitative sampling of native *O. lurida* oyster densities along the shorelines of the six study sites, indicate that any of the six study sites in south San Diego Bay have sufficient settlement and growth rates to naturally colonize a restored oyster reef.

- **Areas along eroding shorelines and/or exposed to high wind wave energies**. Results of the wave power model created as part of the first phase of work for this project, indicate that the eastern shoreline of San Diego Bay receives the highest wind wave energy (due to long fetch westerly winds that cross the bay).

- **Areas with sufficient water quality and sediment conditions to support restoration of *O. lurida* oysters.** The recently published Guide to Olympia Oyster Restoration and Conservation (Wasson et al. 2014) identifies key environmental conditions that positively affect *O. lurida* in central California (the guide has not yet been expanded to include southern California sites). The guide indicates that the most important factors for sustainable populations of *O. lurida* include availability of hard substrate, abundance of phytoplankton, and relatively warm water temperatures. In contrast, low salinity, low dissolved oxygen, warm air temperatures, and abundant predatory oyster drills were found to be the most important stressors negatively affecting oysters. A review of the existing water and sediment quality data for San Diego Bay indicate that the Bay functions more as a dominantly marine water body than as an estuary with variable water temperature, salinity, and dissolved oxygen levels. Additionally, San Diego Bay experiences low sedimentation rates, with turbidity primarily resulting from wind-generated re-suspension of bottom sediments in shallow south Bay waters rather than from sediment input from creeks. This indicates that any of the selected study sites in south San Diego Bay have water quality and sediment conditions capable of sustaining populations of *O. lurida*.

- **Areas adjacent to unarmored shoreline, preferably adjacent to marsh habitat**. A primary Plan goal is to assess the ability of restored oyster reefs to protect adjacent shorelines from erosion. The majority of shoreline in San Diego Bay (greater than 70%) is currently armored (U.S. Navy 2013). While restored oyster reefs adjacent to armored rip rap shorelines could improve habitat quality, they would provide minimal, if any, additional protection from erosion in these areas. A location along unarmored shorelines is a priority for the selected restoration site(s).

- **Areas with sufficient intertidal and shallow subtidal habitat.** *O. lurida* is typically found on hard substrate within interidal and shallow subtidal waters. Much of San Diego Bay has been dredged and the north and central portions of the Bay consist of a moderately deep to deep water embayment with little or no gradually sloping intertidal habitat (U.S. Navy 2013). In contrast, extensive intertidal and shallow subtidal mudflats capable of supporting restored oyster reefs exist in south San Diego Bay. The majority of these intertidal flats transition to subtidal eelgrass habitat. A location along gradually sloping mudflats is a priority for the selected restoration site(s).

- **Areas with sufficient shoreline length**. The shoreline of a selected site must be long enough to support installation of a reef of a size required to test wave reduction. Additionally, the shoreline must support multiple replicates of a restored oyster reef, in order to allow for statistical comparisons of results.

- **Areas that would not impact large amounts of eelgrass**. Eelgrass is a protected habitat within San Diego Bay. Restoration site(s) where oyster reefs could be installed without impacting eelgrass resources is a priority.

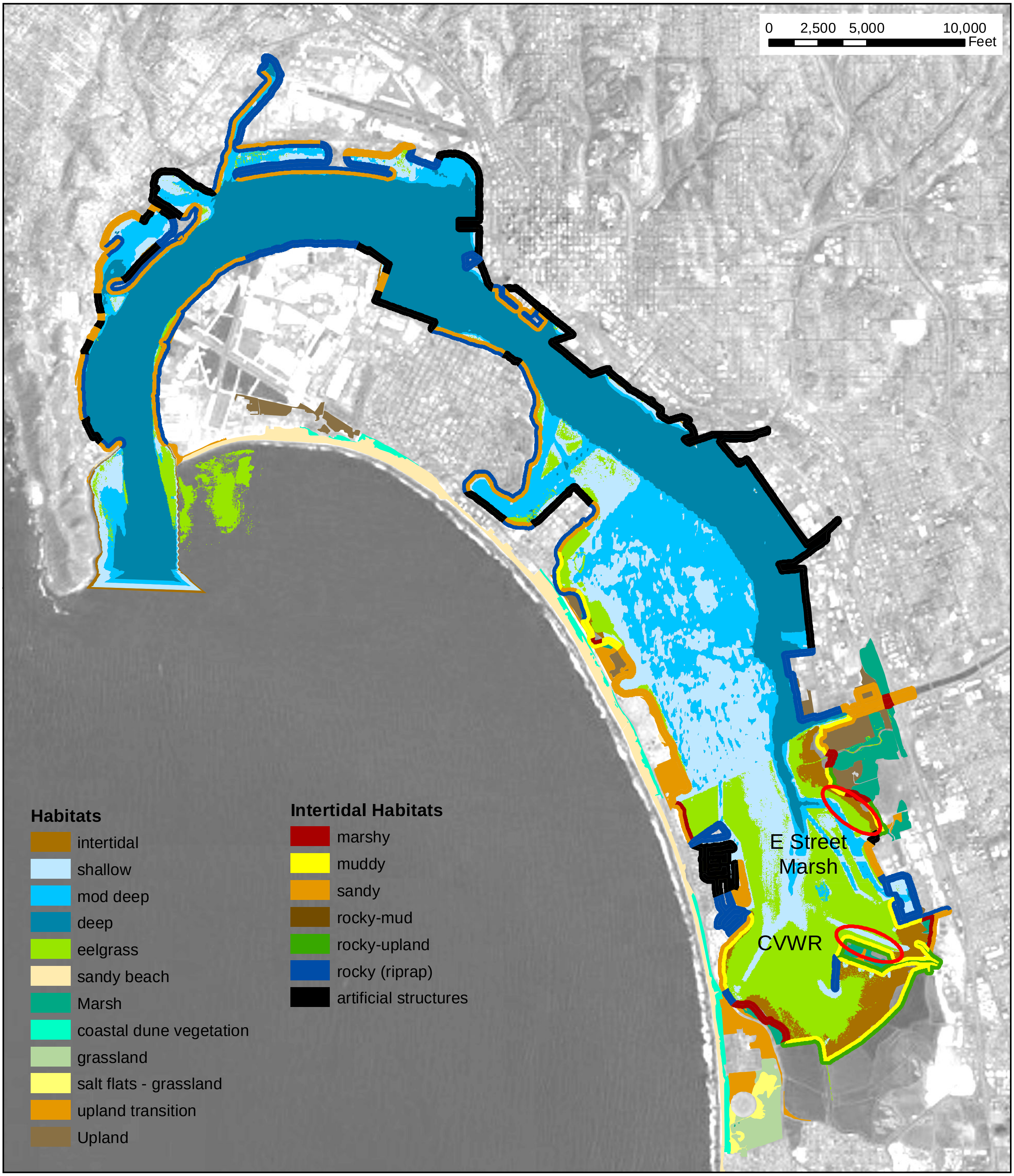
- **Areas with low foot and boat traffic**. San Diego Bay uses include abundant, military, commercial and recreational boating. In order to prevent physical damage and tampering of study plots, a location in a quiet area with minimal boat and foot traffic is a priority.

- **Site ownership and ease of access**. Many areas in San Diego Bay have restricted access, due to military and commercial operations, or due to presence of sensitive species and habitats. Ease of access, while not a primary selection criteria, was considered during restoration site selection.

Based on these criteria and priorities, two potential restoration sites were identified: E Street Marsh (to the south of Sweetwater Marsh, part of the San Diego Bay National Wildlife Refuge) and the eastern shoreline of the Chula Vista Wildlife Reserve (CVWR). The E Street Marsh shoreline is defined as the shoreline adjacent to the E Street Marsh and is bracketed by the D Street and Signature Park study areas that were defined for preliminary oyster recruitment and wave energy studies described above. Figure 7 provides the habitats and shoreline materials (armored vs. unarmored) of San Diego Bay and identifies the two sites that meet the restoration site selection criteria. Figure 8 provides a larger scale image of each site with the results of the wave power model superimposed to illustrate the energy environment along each shoreline. Table 1 summarizes the physical and habitat conditions at each of the two potential sites and illustrates how the two sites address selection criteria.

Table 1. Summary of Conditions at Potential Restoration Sites

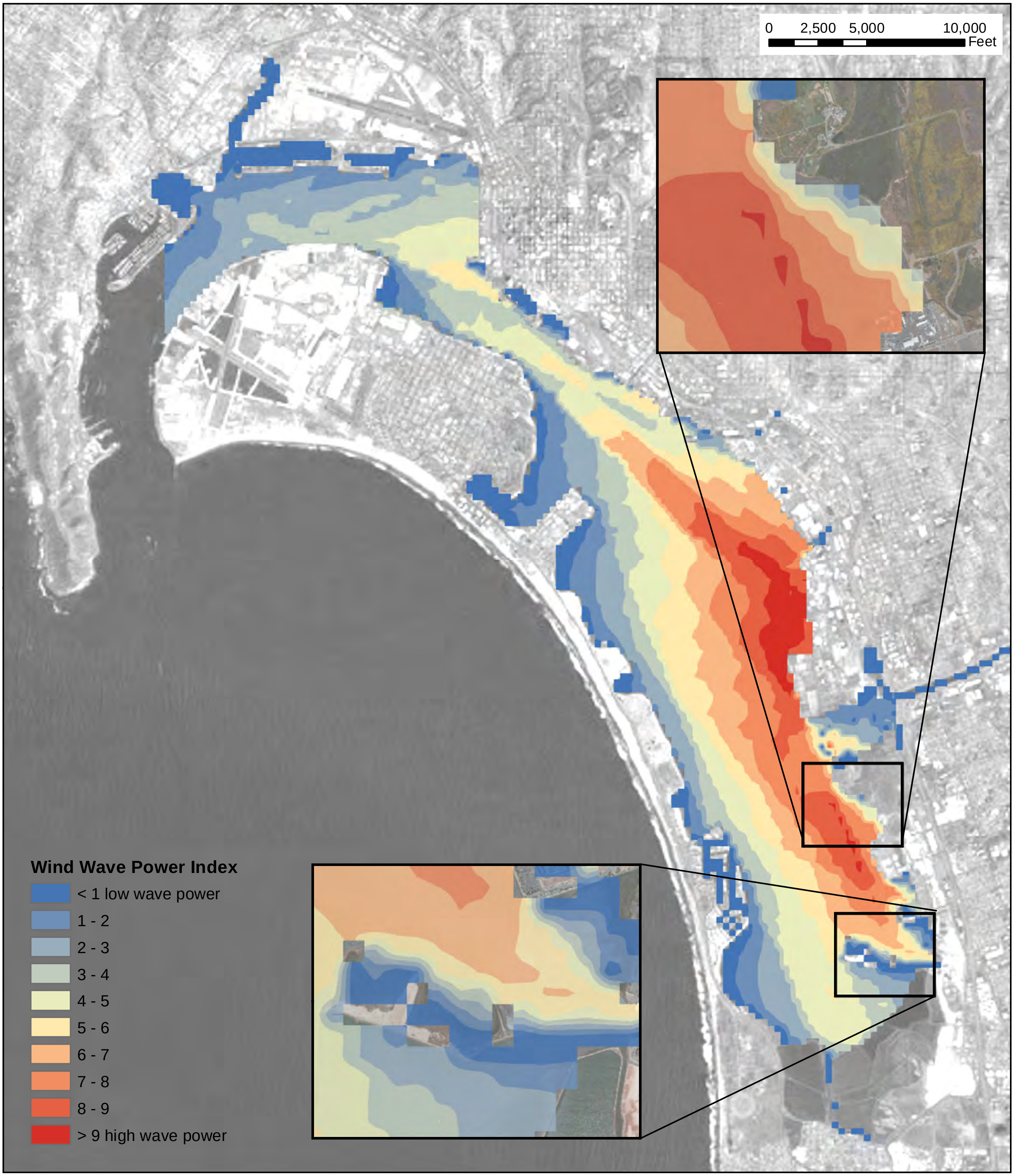
Selection Criteria	Restoration Site	
	E Street Marsh	**Chula Vista Wildlife Reserve (CVWR)**
Sufficient settlement and growth of *O. lurida*	Yes	Yes
Wind Wave Energy	Moderate	Moderate/High
Water Quality and Rates of Sediment Deposition	Marine water conditions, low sedimentation rate	Marine water conditions, low sedimentation rate
Armored/Unarmored Shoreline	Marsh is remnant of historic Sweetwater River marsh that is open to shoreline	Marsh is recently created and expanded and is separated from shoreline by an earthen dike
Shoreline Erosion Conditions	Current rate of erosion unknown, but shoreline appears stable	Current rate of erosion unknown; constructed earthen dike has experienced past erosion
Intertidal and Shallow Subtidal Mudflat	Wide intertidal mudflat along entire shoreline	Narrow intertidal mudflat drops to dredged subtidal channel
Shoreline Length	1,000 linear feet (lf) in front of marsh; 2,500 lf along entire shoreline	2,300 lf in front of marsh
Eelgrass Presence	Present intertidally	Present intertidally
Foot and Boat Traffic	Low and minimal, outside of navigation channels	Low and minimal, outside of navigation channels
Accessibility and Ownership	Managed/owned by USFWS and SDUPD. Accessible by land or boat with joint approval.	Managed/owned by SDUPD. Accessible by land or boat with SDUPD approval.



Potential Restoration Sites within South San Diego Bay

San Diego Bay Native Oyster Restoration Plan

Figure 7



Wind Wave Power at Potential Restoration Sites

San Diego Bay Native Oyster Restoration Plan

Figure 8

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Following identification of restoration site criteria, and comparison of the two sites, the Technical Advisory Committee (TAC) was asked for input on restoration site selection. E Street Marsh was selected by the committee based on priorities including overall size of the restoration area (both linear feet along the shoreline and width of intertidal mudflat available for oyster reef restoration), adjacency to the E Street Marsh portion of the South San Diego Bay National Wildlife Refuge, and sufficient wind wave energy to test for the ability of a constructed reef to reduce wave energy. In contrast, the TAC expressed concern that the narrow width and more steeply sloped mudflat along the Chula Vista Wildlife Reserve would not provide optimal substrate or sufficient area for construction of high relief oyster reefs. Based on this preference, the following study plan has been developed for the E Street Marsh restoration site.

STUDY PLAN

DEFINITIONS

The features described in the following sections of this document are defined as follows:

- Oyster reef element: a single mound of oyster shell measuring 7 ft long x 7 ft wide x 2 ft high
- Oyster reef array: a checkerboard arrangement of fifteen elements that serve as an oyster reef
- Tidal elevation treatment: an oyster reef array placed along the shoreline so that the crests of the oyster reef elements are at a specific tidal elevation
- Control area: an area along the shoreline consisting of mudflat that is the same size as an oyster reef array
- Zone of effect: the area shoreward of an oyster reef array that is likely to show reduced wind wave energy
- Study block: an area along the shoreline consisting of replicate oyster reef arrays and paired control areas
- Project: the oyster reefs proposed to be constructed and monitored to meet the goals and objectives of the San Diego Bay Native Oyster Restoration Plan

STUDY QUESTIONS

Based on the goals and objectives for the Plan, the following study questions have been developed:

1. Does native *O. lurida* recruit (settle, survive, and grow) on constructed oyster reef elements?

2. Does tidal elevation of constructed oyster reef elements affect recruitment of native *O. lurida* and non-native *C. gigas* and other species that compete for space with native oysters?

3. Do constructed oyster reef arrays reduce water flow velocities, attenuate waves, and reduce rates of erosion/increase rates of deposition shoreward of the reef arrays? Does this result in a measurable change in shoreline morphology?

4. Do constructed oyster reef arrays (including oyster reef elements and mudflat habitat between the elements) support increased diversity and abundance of organisms (including invertebrates, fish, and birds) over adjacent mudflat habitat?

The following conceptual project design for oyster reefs and study design have been created to address these specific study questions for the Plan.

Conceptual Project Design for Oyster Reefs

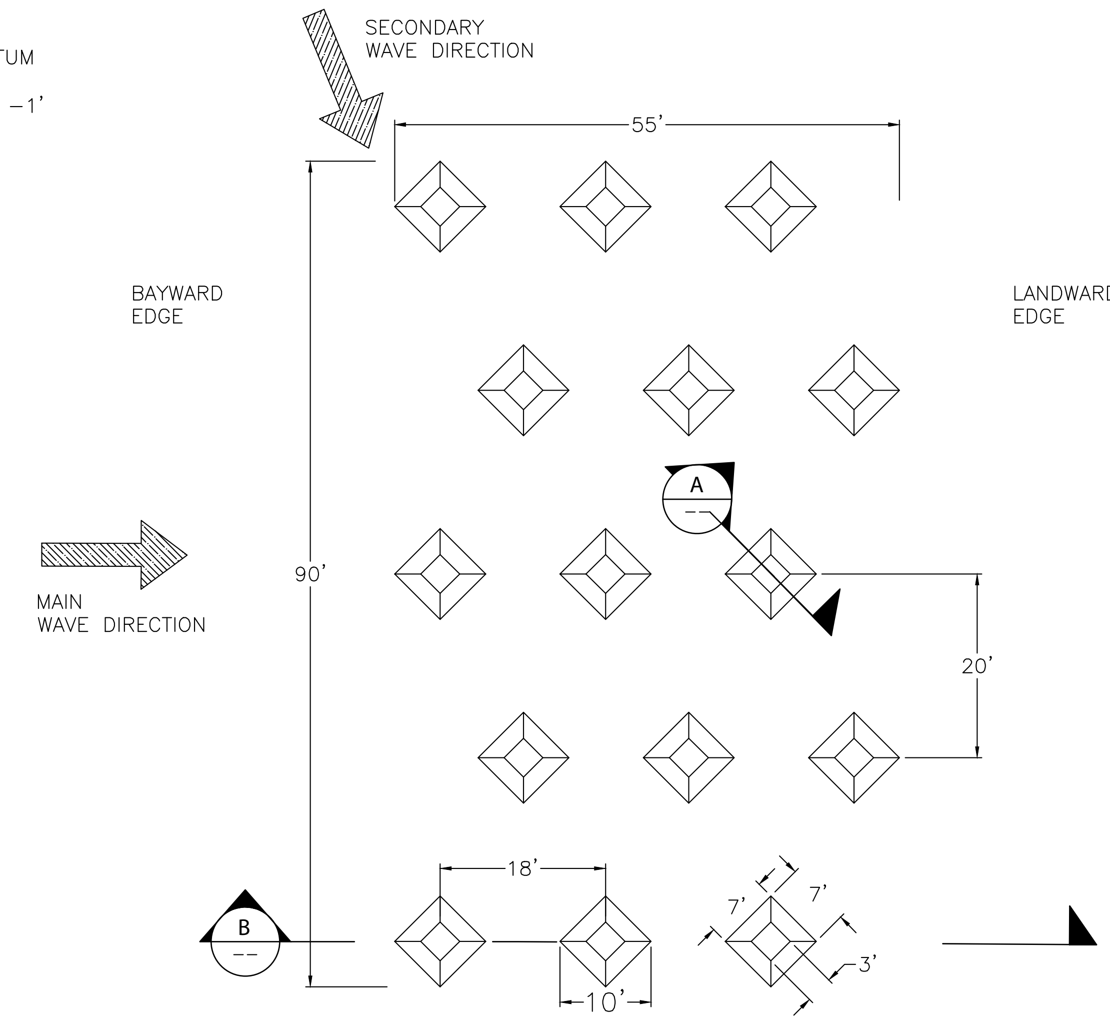
The conceptual project design for the oyster reefs is based on modeling completed as part of this effort as well as on lessons learned from restoration projects and studies completed in other systems, particularly the San Francisco Bay Living Shorelines Project. The methods and results of modeling and rationale for the conceptual project design are presented in Appendix E. A modular design approach has been utilized for the conceptual project design, where oyster reef elements (serving as modules) are placed in arrays at varying tidal elevations along the mudflat. The study design associated with the conceptual design has been prepared specifically for the E Street Marsh shoreline, but may be replicated along other shorelines, including the Chula Vista Wildlife Reserve, as resources allow.

Oyster Reef Elements

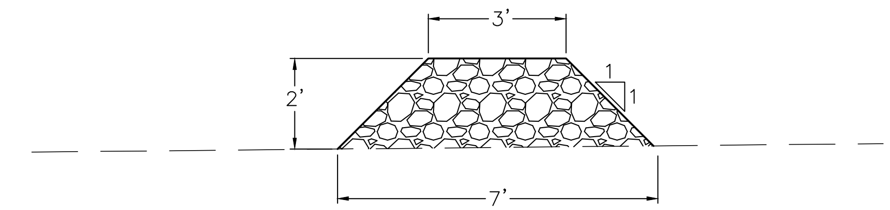
Each oyster reef element will be constructed of mesh bags of oyster shell anchored together into a trapezoidal shape with a wide base tapering to a narrower crest (Figure 9, cross-section A). Each element will have a 7 ft x 7 ft base that tapers at an approximate 1:1 slope to a 3 ft x 3 ft crest. The height of each element from base to crest will be 2 ft. The shape and size of the elements is based on several factors. A trapezoid is a generally stable structure that will minimize sloughing or collapse of the shell material. Additionally, a wide base will spread the weight of the shell horizontally to minimize local subsidence of individual elements. The height of elements allows for analysis of zonation of oyster species, including native *O. lurida* and non-native *C. gigas*, as well as analysis of study questions related to wave velocity and energy reduction. Further, the design allows for comparisons with oyster shell bag structures placed in San Francisco Bay. Finally, the height will increase the likelihood that an element will have some surface area that is at the tidal elevation where oyster recruitment is greatest. Low relief structures, in contrast, have a lower tolerance for variation in tidal elevation, and therefore, run a higher risk of failure. It may be possible to construct elements greater than 2 ft in height, but this would require placement of elements in deeper waters and a greater slope of the structures which would likely result in increased instability. Therefore, higher elements would require a larger trapezoidal base and would require substantially more shell material.

Oyster shell will be bagged in either nylon or jute netting. Individual bags will be of a small enough size to allow for ease of transport and placement at the restoration site, as well as to allow for hand manipulation of bags to form the shape for each element. The use of small bags of shell also allows

NOTES:
1. ALL ELEVATIONS ARE REFERENCED TO MLLW DATUM
2. REEF CREST ELEVATIONS ARE SHOWN AS APPROXIMATE AND REFERENCED TO EITHER THE –1' OR 0' CONTOUR



OYSTER REEF ARRAY PLAN VIEW



A
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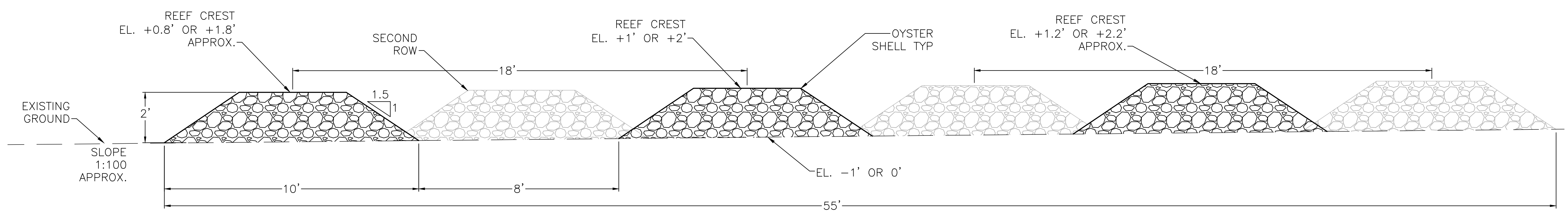
OYSTER REEF ELEMENT CROSS-SECTION



B
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OYSTER REEF ROW CROSS-SECTION

Figure 9

Conceptual Oyster Bed Configuration

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PRELIMINARY
NOT FOR CONSTRUCTION

Prepared by Environmental Science Associates (ESA) for placement of additional bags should the elements subside. Previous studies have shown that jute netting biodegrades within a four month period following installation (D. Zacherl, unpublished data). Therefore, should jute netting be used, bags of shell would be bound together with cloth or plastic straps in order to maintain the vertical integrity of elements. The straps may be removed at a later date, if warranted. Other natural fiber, non-plastic netting with a longer degradation time may be available and should be investigated during final design and engineering for the project.

The oyster reef elements and arrays have been designed to provide the maximum wave energy reduction benefit while also minimizing the amount of shell material for construction. Each element is anticipated to require 2 cubic yards of bagged shell material. Oyster shell has been proven to be the best substrate for settlement of oyster spat (as compared to concrete reef balls or castles) (K. Wasson, unpublished data, White et al. 2009). However, it is known that there is a limited supply of oyster shell available for use in oyster reef restoration, and that oyster shell may be a size-limiting resource for large scale restoration projects. Should a reduction of oyster shell material be required due to limited supply, oyster shell may be combined with clam shell and mussel shell, or with gravel. Alternately, the base and central portion of the oyster reef elements may be constructed with bags of gravel or rock, and the surface of the elements may consist of bagged oyster shell suitable for oyster recruitment. This decision should be made following a complete assessment of availability of oyster shell prior to project construction. Shell material will require a period of drying prior to use to ensure that any living organisms and propagules present in the material are not transported to the restoration area.

Oyster Reef Arrays

Oyster reef elements will be arranged into arrays. The design of the oyster reef elements and arrays is based on 1D and 2D modeling efforts for the shoreline adjacent to the E Street Marsh. The methods and results of modeling are presented in Appendix E. Each array will be 90 ft long x 55 ft wide, with a total of 15 oyster reef elements placed in staggered rows (Figure 9). The distance between elements will be 18 ft from crest to crest (Figure 9, Cross-section B). This distance has been shown to maximize wave reduction potential as waves encounter multiple oyster reef elements over the full width of the array (Appendix E).

Arrays will be oriented along the shoreline so that the 90-ft length of the array will be perpendicular to the main wave direction within south San Diego Bay (202.5 degrees North, determined from wave power model, Appendix D). The staggered or checkerboard placement of the oyster reef elements within each array will also allow for wave energy reduction along the secondary wave direction within the Bay (270 degrees North) (as illustrated in Figure 9).

Study Design

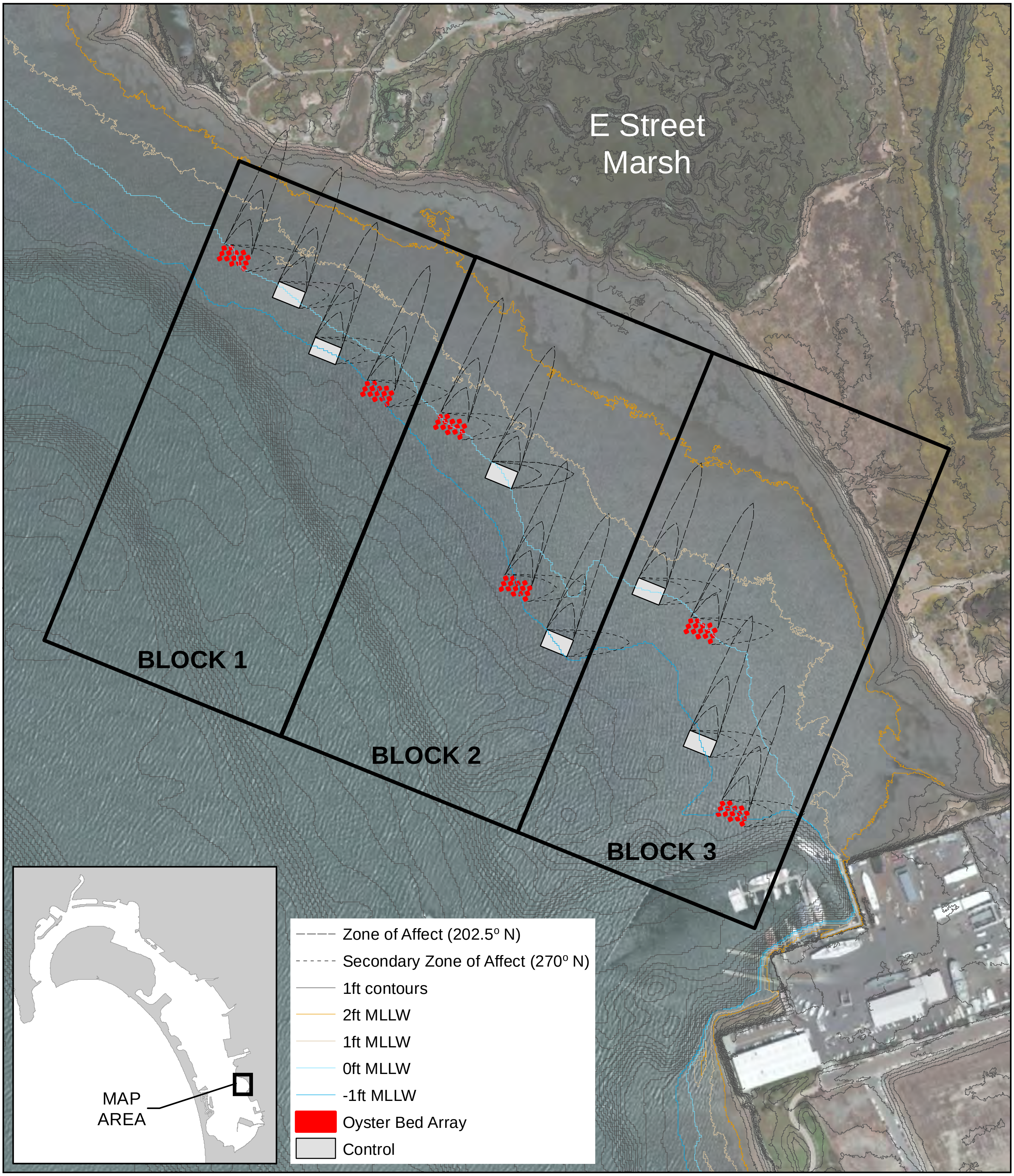
Oyster reef arrays will be constructed at one of two tidal elevations along the E Street Marsh shoreline. Each tidal elevation is considered to be a study treatment. The two tidal elevation treatments are +1 ft MLLW and +2 ft MLLW. These elevations all within the best known range of elevations for recruitment of native *O. lurida* oysters, that also intersect with tidal elevations required to measurably reduce wave energy (as determined by modeling efforts described in

Appendix E). Additionally, the use of multiple tidal elevations will address study questions related to vertical zonation of *O. lurida* and *C. gigas* oyster species, and settlement and density of other space competing organisms. While arrays constructed at higher tidal elevations would better reduce wind wave energy, they would be unlikely to support healthy populations of native *O. lurida.* In contrast, arrays placed at lower tidal elevations may be optimal for recruitment of native *O. lurida*, but would be unlikely to adequately reduce wind wave energy. Additionally, the results of modeling indicate that arrays placed directly in front of each other at multiple tidal elevations along a single stretch of shoreline may provide additional wave energy reduction; however, these arrays could not be considered independent and would not allow for testing of other, biological study questions related to tidal elevation. The two, independent tidal elevations selected for this study are the best treatment elevations to evaluate study questions related to both biological and physical processes.

While vertical zonation of native *O. lurid*a and non-native *C. gigas* has been observed in San Diego Bay (Appendix B), the mechanisms for this zonation have not been determined. In order to meet the goals of this Plan, the tidal elevation treatments selected for this project correspond to elevations of known highest recruitment (Appendix C) and observed highest percent cover for *O. lurida* (Appendix B). However, recruitment levels and densities of *O. lurida* and *C. gigas* on complex, three-dimensional reef elements placed on the mudflat could differ from the observed patterns within the Bay, with *O. lurida* potentially occurring at higher tidal elevations than observed at other locations in the Bay. As higher tidal elevation reefs would result in greater wave attenuation, the potential for *O. lurida* to recruit to higher elevation structures should be explored. Small-scale studies should be performed at higher tidal elevations in order to inform the final design of the project. These small scale baseline studies should include installation of ceramic tiles and small bags of oyster shell at higher tidal elevations (≥ +3 ft MLLW) to measure oyster recruitment, survival, and growth, as described for the Pre-construction Monitoring Program below. If *O. lurida* recruits to higher tidal elevations, then the final project design may be altered to include a higher tidal elevation treatment.

Arrays will be placed at one of the two tidal elevation treatments so that the crests of the oyster reef elements within an array are at the treatment elevation (Figure 9, Cross-section B). Each array is 55 ft wide, and as such, tidal elevation will change slightly across the full width of each array. The mudflat along the E Street Marsh shoreline is very wide, with gradual changes in tidal elevation. Based on bathymetry for the shoreline, it has been calculated that there will be a 0.4 ft variation between the crests of the shoreward (shallower) and bayward (deeper) elements within an array. This variation is considered acceptable for testing study questions. However, the monitoring plan has been designed to assess any biological effects of variation in tidal elevation within an array (see below).

Three replicate oyster reef arrays will be placed at each of the treatment tidal elevations along the E Street Marsh shoreline in a blocked design (Figure 10). Each study block will consist of one haphazardly placed +2 ft MLLW oyster reef array and a paired control area of similar size, and one haphazardly placed +1 ft MLLW oyster reef array and a paired control area of similar size. A total of three study blocks will extend along the shoreline (Figure 10). Arrays and control areas will be separated by a minimum distance of 80 ft along the shoreline. Study blocks will be separated by a minimum distance of 200 ft along the shoreline. This will ensure that the zone of effect for wind



Study Design

San Diego Bay Native Oyster Restoration Plan

Figure 10

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wave energy reduction does not overlap with adjacent control areas or arrays. The zones of effect are indicated in Figure 10 by dashed gray arcs extending shoreward of reef arrays. The smallest arc extends 100 feet from each array and indicates the zone of expected effect. The middle arc extends 200 feet from each array and indicates the zone of likely effect. The largest arc extends 400 feet from each arry and indicates the zone of possible effect.

For illustration purposes in Figure 10, the control area for each treatment is has been placed at the same tidal depth as the base of the oyster reef elements in an associated array. However, the control area surveyed will vary by monitoring element. For physical processes, the zone of effect shoreward of a control area as well as a control at the same tidal depth as the base of the oyster reef elements in an associated array will be monitored. For oyster recruitment and percent cover studies, the control area will be at a the same tidal elevation monitored on oyster reef elements. As such, the control areas for this monitoring element will be approximately 200 to 300 feet shoreward of each array (due to the very gradual elevation change across the mudflat). For other biological monitoring elements, the control area will be adjacent to and at the same tidal depth as the base of the oyster reef elements in an associated array.

The six oyster reef arrays (3 replicates x 2 tidal elevation treatments) will require 90 oyster reef elements to construct (15 elements per array x 6 arrays). Each oyster reef element will require 2 cubic yards (cy) of shell material. Based on this volume, 180 cubic yards of shell material will be required to construct the full study design (2 cy/element x 15 elements/array x 6 arrays). As described above for oyster reef elements, options that reduce the amount of oyster shell required for project construction may be possible, and should be considered following an assessment of availability of oyster shell.

Biological and Physical Monitoring Program

The monitoring program encompasses multiple types of monitoring including:

- Baseline monitoring: methods to provide data that will be needed to complete final design, engineering, and permitting for the project
- Pre-construction monitoring: methods that provide data used for pre- and post-construction comparisons
- Post-construction monitoring: methods employed following construction that provide data to answer specific study questions
- Reference monitoring: methods employed pre- and/or post-construction to assist with analysis of other data. (As an example, water quality data will not be collected to answer a specific study question, but may be required help analyze observed patterns of oyster recruitment on constructed reefs.)

A summary of all monitoring methods is provided in Table 2, and descriptions of each monitoring method are described in the following sections. Table 2 also prioritizes data as “high” or “mid” priority. High priority data are recommended to be collected as outlined in this study plan. Mid priority data are recommended to be collected as outlined; however, frequency and/or periodicity of data collection may be reduced if funding is limited.

Table 2. Summary of Monitoring Elements

Measure	Parameter	Method	Location: Control	Array	Bayward of Array	Shoreward of Array	Reference Station*	Monitoring Type	Priority	Periodicity	Frequency	Seasonality
Oysters												
Recruitment	#oysters/area/time	6-9 dried shells collected from study bags in each array		x				Post	High	2 times/year	once	May, Sept
Growth	mm/time	6-9 dried shells collected from study bags in each array		x				Post	High	2 times/year	once	May, Sept
Competitors	% cover or count/area	point intercept in 0.25 m^2 quadrats in each array	x	x				Post	High	2 times/year	once	May, Sept
Reference Recruitment	#oysters/area/time	ceramic tees placed at ~+1 ft MLLW	x			x		Pre, Post	High	1/year	once	May-Sept
Reference Substrate/Oysters	% cover or count/area	50 m transects, with random 0.25 m^2 quadrats at ~+1 ft MLLW	x			x		Pre-Post	High	1/year	once	July
Fish/Epibenthic Invert												
Structured Associates/Demersal	#/m^2, mass/m^2	minnow traps and hoop traps	x	x				Post	Mid	quarterly yr 1; 1/yr 2-5	once	Jan, Apr, Jul, Oct; July
Pelagic Fish	#/m^2, mass/m^2	small beach seine	x	x				Post	Mid	quarterly yr 1; 1/yr 2-5	once	Jan, Apr, Jul, Oct; July
Avian												
shorebird density	#/m^2	low tide shore surveys with spotting scopes	x	x				Post	Mid	quarterly	15 counts in 1.5 hr survey	Jan, Apr, Jul, Oct
waterfowl density	#/m^2	high tide shore surveys with spotting scopes	x	x				Post	Mid	quarterly	15 counts in 1.5 hr survey	Jan, Apr, Jul, Oct
Benthic Invertebrates												
invertebrates	#/m^2, mass/m^2	replicate 7 cm cores in 1m^2 quadrats, sorted to lowest practical taxonomic group	x	x				Post	Mid	1/year	once	Aug-Sept
Eelgrass												
Eelgrass Area	m^2	sidescan sonar, aerial photography	x	x	x	x		B, Post	High, Mid	1/year	once	Jul-Aug
Physical Processes, Water Quality, and Sediment												
Wind Speed and Direction	m/s	weather station				x		Pre, Post	High	continuous	15-30 mins	Jan-Dec
Weather Data	temp °C, rain inches	weather station				x		Pre, Post	Mid	continuous	15-30 mins	Jan-Dec
Wave height	H_s (m)	ADV			x	x	x	Post	High	continuous	12 min bursts	Jan-Dec
Wave period	T_m, T_p (s)	ADV			x	x	x	Post	High	continuous	12 min bursts	Jan-Dec
Current velocity	u (m/s)	ADV			x	x	x	Post	High	continuous	12 min bursts	Jan-Dec
Current direction	θ (°)	ADV			x	x	x	Post	High	continuous	12 min bursts	Jan-Dec
Temperature	°C	Hydrolab® or YSI® Sonde		x				Pre, Post	Mid	continuous	15-30 mins	Jan-Dec
Salinity	ppt	Hydrolab® or YSI® Sonde		x				Pre, Post	Mid	continuous	15-30 mins	Jan-Dec
Dissolved Oxygen	mg/L	Hydrolab® or YSI® Sonde		x				Pre, Post	Mid	continuous	30 mins	Jan, Apr, Jul, Oct
pH	pH units	Hydrolab® or YSI® Sonde		x				Pre, Post	Mid	continuous	30 mins	Jan, Apr, Jul, Oct
Turbidity	NTU	Hydrolab® or YSI® Sonde		x				Pre, Post	Mid	continuous	30 mins	Jan, Apr, Jul, Oct
Chlorophyll a	nm	Grab sample, fluorometer		x				Pre, Post	Mid	quarterly	once	Jan, Apr, Jul, Oct
Sedimentation	y (m/s)	sediment cones or plates		x	x	x	x	Pre, Post	High	monthly	once	Jan-Dec
Geotechnical Investigations	-	sediment cores	x	x				B	High	once	once	July
Sediment Grain Size	d50 (mm)	sediment cores		x	x	x		B, Post	Mid	5	once	Jan-Dec
Aerial Photography	-	high resolution orthorectified true vertical, 1"=425 '	x	x	x	x		Pre, Post	Mid	1/year	once	Aug-Sept
Bathymetry	m	interferometric sidescan sonar	x	x	x	x		B, Post	High, Mid	1/year	once	July
Subsidence/Bathymetry Groundtruth	m/time	total station surveyed transects	x	x	x	x		B, Post	High	1/year; possible 2/yr in first 3 years	once	July

Monitoring Type: **B**=Baseline; **Pre**=Pre-construction including reference data; **Post**=Post-construction

Priority: **High**=Recommended to be completed according to study plan; **Mid**=Frequency of monitoring may be reduced if funding is limited

*Reference Station identified as Emory Cove

Baseline Monitoring Program

The baseline monitoring, required for project design, engineering, and permitting, will include both physical and biological monitoring elements. The following baseline monitoring is proposed:

- Bathymetric survey of the E Street Marsh shoreline, stretching from Gunpowder Point at the E Street Marsh, south to the Marine Group Boatworks boatyard adjacent to Signature Park. Survey methods may include interferometric sidescan sonar, or multibeam sonar, in conjunction with an in situ tidal gauge. Data will be groundtruthed using total station survey equipment deployed along fixed transects oriented perpendicular to the shoreline. A sufficient number of transects to cross each of the proposed reef array locations and control areas will be required. Transects will be re-surveyed each year post-construction as described below.
- Baseline eelgrass mapping for the same project area described above. This may be done in conjunction with a bathymetric survey, as remote sensing methods (sidescan or multibeam sonar) allow for simultaneous collection of eelgrass data.
- Geotechnical investigation to determine potential for subsidence of oyster reef elements (this will include collection and analysis of sediment cores). This information will be used to inform the final engineering of oyster reef elements and arrays. Sediment cores will be analyzed for sediment grain size to compare to sediment data collected following project construction.

Pre-Construction Monitoring Program

The pre-construction monitoring program will consist of both collection of reference data that will be used to characterize natural conditions within the project area, as well as data collected for comparison of pre-construction and post-construction conditions to address specific study questions. The following pre-construction monitoring is proposed:

- High resolution, low tide, orthorectified, true vertical aerial photography of the project area collected in spring/summer. Minimum resolution for the survey should be 1 inch = 425 ft.
- Continuous weather data, including temperature, rainfall, wind speed and wind direction. It is possible that the weather station currently in operation at the San Diego Unified Port District's National City Marine Terminal would provide sufficient data. Alternately, a weather station may be installed at Gunpowder Point within the National Wildlife Refuge lands.
- Water quality data collected continuously using a Hydrolab® or YSI® multiparameter logger moored subtidally along the E Street Marsh shoreline. Data collected should include at minimum temperature, salinity, dissolved oxygen, pH, and turbidity. Grab samples for chlorophyll a should be collected quarterly for fluorometry analysis.
- Sedimentation rate using replicate sediment plates or cones placed intertidally along the E Street Marsh shoreline at study tidal depths of +2 ft and +1 ft MLLW. Locations will include both treatment and control areas, to allow for a before-after-control-impact (BACI) analysis of sedimentation rate.

To date, oyster recruitment data for one recruitment season (summer 2013) has been collected in San Diego Bay (complete results in Appendix C). As such, it is not known whether this year represents a typical or atypical recruitment year within the Bay. As settlement and post-settlement processes will drive the colonization of oyster reef elements placed in the Bay, it is important to gather as much settlement and recruitment data as possible, both prior to and during and after construction of the project. Pre-construction monitoring will consist of oyster recruitment studies conducted as follows:

- Oyster recruitment tiles will be deployed on PVC tees (2 tiles per tee) in mid-May of each year prior to project construction. Five replicate tees will be deployed at each of five tidal heights (-1.0, 0, +1.0, +2.0, and +3.0 ft MLLW) for a total of 25 tees and 50 tiles. One tile from each tee will be swapped out every two weeks until October of each year. The second tile on each tee will remain in place through the entire study period.
- Additional tiles, along with small bags of dried oyster shell should be placed at higher tidal elevations (≥ +3.0ft MLLW), should funding permit. Data from these additional tidal elevations could inform final project design tidal elevation treatments.
- The tiles collected every two weeks will be analyzed in the laboratory to assess the settlement dynamics for both native *O. lurid*a and non-native *C. gigas*.
- The tiles left in place on each tee will be collected and analyzed at the conclusion of the recruitment season (October) to measure recruitment and size frequency distributions for each species of oyster. These data will provide inferred information about survival and growth of oysters over the recruitment season.
- Percent cover of oysters, and other sessile species along the existing mudflat of the E Street Marsh shoreline will be determined once per year during summer using 50 m x 2 m transects established in the oyster zone along the shoreline. Each transect will be placed parallel to the water line and centered at ~+0.3 m (~ +1 ft) MLLW. Thirty 0.25 m^2 gridded quadrats will be randomly placed along each transect to assess species percent cover. Cover at each of 49 intercepts within a quadrat will be recorded as mud, sand, dead shell, *Mytilus* spp., *O. lurida*, *C. gigas*, etc.

Post-construction Monitoring Program

The proposed post-construction monitoring program is a five year program, with sampling in years 1, 2, 3, 4, and 5, following construction. As biological systems take many years to stabilize, it is recommended that a year 10 monitoring interval be added, should funding be available. Monitoring intervals within sampling years vary by study question. The following text re-iterates each study question and provides monitoring elements required to address each question.

1. **Does native *O. lurida* recruit (settle, survive, and grow) on constructed oyster reef elements?**

At the time of construction, small study bags (consisting of approximately 50 to 60 dried oyster shells) will be labeled and anchored to oyster reef elements. A total of twelve study bags will be anchored on each oyster reef element: four along the base of the reef element, four along the middle, and three on the top. Each study bag will be oriented in one of four directions (north, east, south, or west) on the sides of an element. The study will require a total of 1,080 small study bags (12 bags per element x 15 elements per array x 6 arrays).

It is hypothesized that settlement and growth of *O. lurida* may vary at multiple spatial scales (as illustrated in Figure 11) including:

- Location within each array: exposure to wind waves and tidal depth are anticipated to vary across the length of an array, with differences observed between oyster reef elements located on the bayward edge, the middle, and the shoreward edge of an array.
- Solar aspect: exposure to settling oyster spat, and desiccation stress are anticipated to vary along different sides (e.g. north, east, south, or west orientation) of an oyster reef element.
- Vertical elevation rates of recruitment for each oyster species are anticipated to vary by vertical location on an oyster reef element (e.g. bottom, middle, or crest, encompassing a 2 ft change in tidal elevation due to the 2 ft height of oyster reef elements).

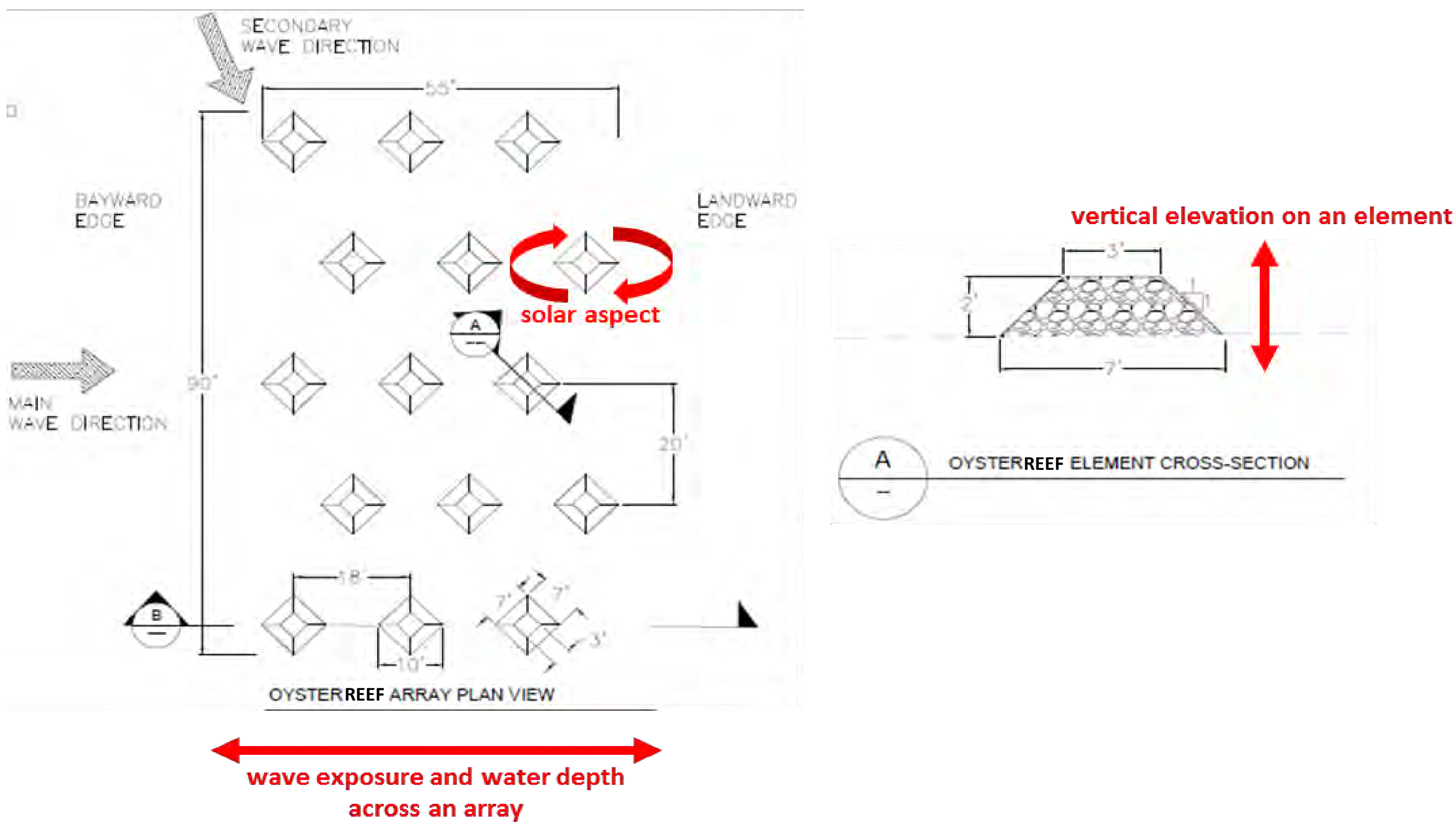
Therefore, a stratified random sampling protocol (as suggested by Baggett et al. 2014) will be employed during an initial study performed within one +2 ft MLLW oyster reef array within a single study block. The initial study will take place approximately eight weeks prior to the first full survey event, preferably in July-August. This timing will ensure that data from the initial study may be analyzed prior to a first full survey event in October-November following construction of oyster reef arrays. The selection of a +2 ft MLLW treatment array for the initial study is based on the fact that the oyster reef elements in this treatment will encompass the range of tidal elevations preferred by both oyster species for recruitment.

For the initial study, three study bags will be randomly selected within each of three locations within the array (bayward edge , middle, and shoreward edge) and at four solar aspects (north, east, south, and west orientation) for a total of 36 bags. All study bags will be collected at a standardized middle vertical elevation on oyster reef elements. Variation at vertical elevation (Figure 11) on oyster reef elements will not be tested in the initial study, as this source of variation is a primary component of study question #2 and will be sampled as part of the main project study. Figure 12 illustrates the stratified sampling method proposed for the initial study.

A total of 12 oyster shells will be collected from each study bag, and transported to the laboratory, for a total of 432 shells. Study bags will remain in place with all remaining dried shells. Laboratory analyses for shells from each of the study bags will include:

1) Measure each substrate shell in three dimensions (to calculate oyster recruits/unit area)
2) Count and measure all oyster recruits of both *O. lurida* and *C. gigas* oyster species
3) Identify and count other sessile species that recruit to the shells (e.g. tunicates, bryozoans, scale worms)

Data will be analyzed statistically to determine whether oyster recruitment varies as a function of location within the array, and/or solar aspect . A power analysis will be performed to determine the appropriate number of shells to sample from each study bag. The results from the initial study will guide sampling protocols in subsequent survey events.

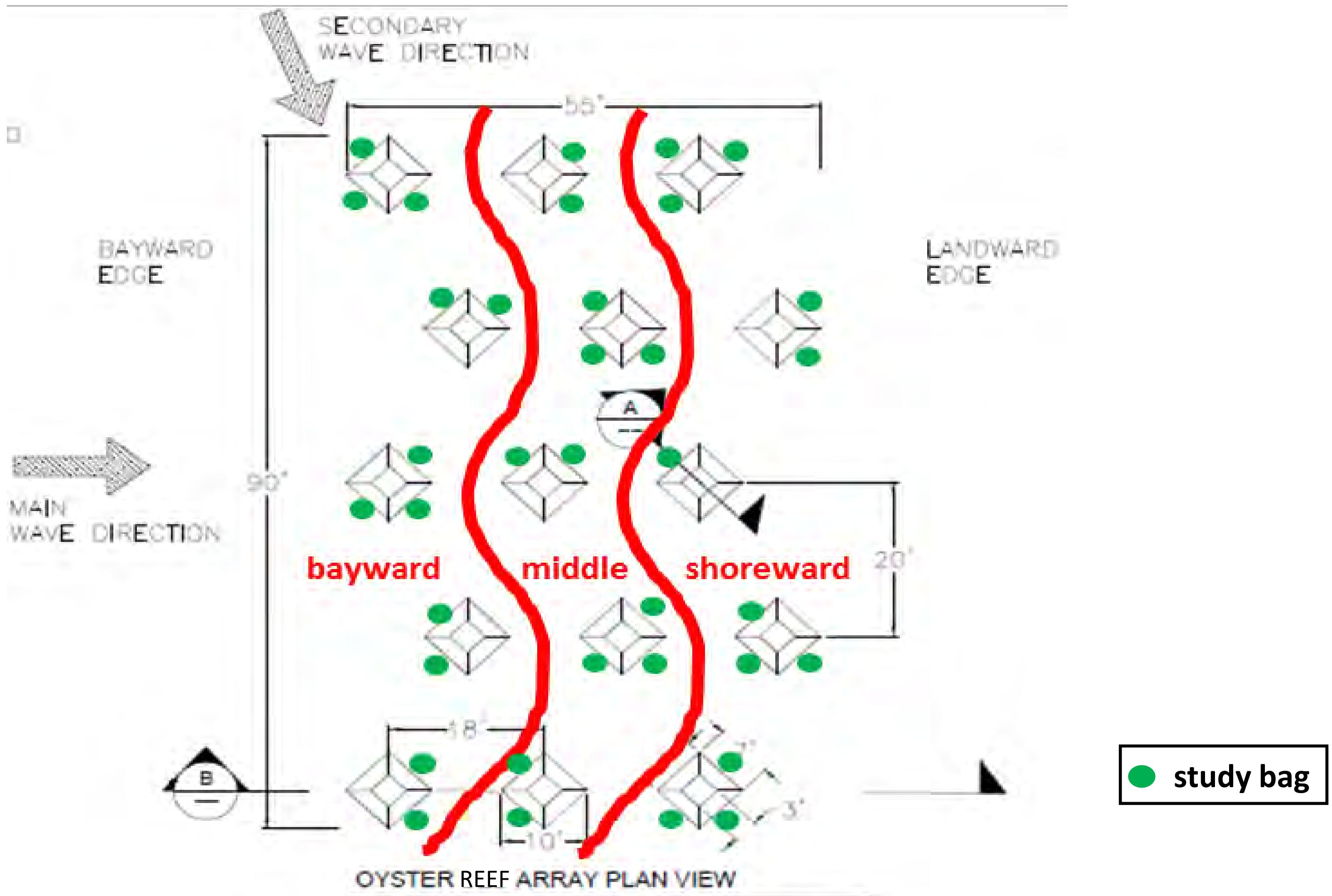


Sources of Spatial Variation within Oyster Reef Elements and Arrays

San Diego Bay Native Oyster Restoration Plan

Figure 11

Merkel & Associates, Inc.



Stratified Random Sampling Design for Initial Study

San Diego Bay Native Oyster Restoration Plan

Figure 12

Merkel & Associates, Inc.

Following the initial study, the first full survey event will take place in late fall (October-November) of the first survey year, following predicted oyster spawning. Sampling in years 2 through 5 will take place twice per year, once in late spring (April-May) prior to oyster spawning, and once in late fall (October-November) following spawning. During each monitoring event, between 6 and 12 oyster shells will be collected from a designated number of study bags (based on results of initial study) in each of the six oyster reef arrays. Should the initial study indicate that spatial variability is statistically significant, then a full stratified random sampling approach may continue in subsequent survey events. Alternately, one or more spatial components may be standardized in subsequent survey events, substantially reducing the number of total study bags selected during each survey. For purposes of estimating cost and work effort, it should be assumed that between 6 and 9 dried shells will be collected from each of 24 bags on each of the six arrays, for a total of between 864 and 1,296 shells collected for analysis during each survey event.

For each survey event, laboratory analyses for shells from each of the study bags will include:

1) Photograph each shell from true vertical
2) Measure each substrate shell in three dimensions (to calculate oyster recruits/unit area)
3) Count and measure all oyster recruits of both *O. lurida* and *C. gigas* oyster species
4) Identify and count other sessile species that recruit to the shells (e.g. tunicates, bryozoans, scale worms)
5) Rinse all six to nine shells from each study bag through a known volume of water and measure displacement to estimate sedimentation
6) Rinse all shells through a 500µ filter. Collect and preserve all invertebrate epifauna. Collect wet weight for entire sample. If funds are available, or become available at a future date, sort samples to lowest practical taxonomic group (e.g. gastropods, amphipods, polychaetes, etc.)

Oyster recruitment for the E Street Marsh shoreline will be measured each year during the study using the methods described for the pre-construction monitoring. Recruitment and size frequency distributions for each species of oyster will be calculated from data collected on ceramic tiles placed on PVC tees along the E Street Marsh shoreline. Physical monitoring elements will include water quality monitoring and measurements for rate of sedimentation. Methods for physical monitoring elements are described for study question #3 below.

2. Does tidal elevation of constructed oyster reef elements affect recruitment of native *O. lurida* and non-native *C. gigas* and other species that compete for space with native oysters?

This study question will be addressed in part using the same methods as described above for study question #1. Additionally, percent cover of oysters and organisms that compete with native *O. lurida* oysters will be measured using replicate 0.25 m^2 gridded quadrats placed within each oyster reef array. The quadrat will be gridded with string to form 49 intercepts. Surveys will take place twice per year, once in late spring (April-May) prior to oyster spawning, and once in late fall (October-November) following spawning. The number of quadrats sampled in each oyster reef array, and the spatial stratification of samples will be informed by the initial study described above. For purposes of estimating cost and work effort, it should be assumed that 24 quadrats will be sampled on each of the six arrays and in each paired control, for a total of 288 quadrats sampled during each survey.

Data collected for each quadrat will include:

1) Depth of sediment (in mm) will be measured using a small ruler placed vertically at five haphazard locations within each quadrat
2) A point intercept method will be used to measure substrate and sessile invertebrates. For each of the 49 intercepts within a quadrat, the dominant species will be recorded as *O. lurida* oyster, *C. gigas* oyster, mussel, bryozoan, tunicate, algae, or other species. Mud or oyster shell will be recorded for intercepts that contain no living organisms.
3) Unknown species may be vouchered, preserved, and returned to the laboratory for identification

Once per year, in later summer, percent cover of other sessile organisms that may compete with oysters for space, will be assessed along 50 m x 2 m transects in the oyster zone along the shoreline immediately shoreward of each oyster reef array and control, for a total of 12 transects. Each transect will be placed parallel to the water line and centered at ~+0.3 m (~ +1 ft) MLLW. Thirty 0.25 m^2 gridded quadrats will be randomly placed along each transect to assess species percent cover. Similar to above, cover at each of 49 intercepts within a quadrat will be recorded as mud, sand, dead shell, *Mytilus* spp., *O. lurida*, *C. gigas*, etc.

3. Do constructed oyster reef arrays reduce water flow velocities, attenuate waves, and reduce rates of erosion/increase rates of deposition shoreward of the reef arrays? Does this result in a measurable change in shoreline morphology?

Physical monitoring will include installation of Acoustic Doppler Velocitometers (ADVs) to measure wave current velocity and pressure sensors to measure wave height and period for at least one block of +1 ft and +2 ft MLLW arrays and controls. This would include both an ADV and a pressure sensor bayward and shoreward (within the zone of effect) of each array within the block, as well as within paired control zones of effect, for a total of six ADVs. One additional ADV will be installed bayward of all study blocks (at approximately -4 ft MLLW) to measure open bay wave conditions. ADVs would be continuously deployed during the first year of the study, with data collected at 12 minute bursts. In subsequent years, deployment time may be reduced based on results from the initial monitoring year. For example, it may only be necessary to deploy ADVs from November to March, to capture winter storm events. Replicate treatments could be installed and monitored in the same way in more than one study block if funding is available; or, wave monitoring could be focused on one pair of treatments and controls (e.g. just the +2 ft MLLW treatment arrays and controls). Wave monitoring prioritizes wave current measurements because the arrays are expected to have more of an effect on wave currents than wave heights based on modeling and experience from the San Francisco Bay Living Shorelines Project.

Of note, it may be possible to coordinate or collaborate with a Scripps Institute of Oceanography (SIO) wave monitoring program that uses radar to collect spatial wave data along the open coast. A brief review of the existing SIO data indicates minimal data points in South Bay; however, SIO may be able to modify their program to collect data for South Bay. In this case, the replicates would still be monitored for sedimentation/erosion (as described below) to monitor the effects of reducing wave energy or velocities.

Rates of sedimentation will be measured using either sediment cones or plates placed within and shoreward of each of the six oyster reef arrays and within associated controls, with a minimum of three cones or plates placed at each location. The sediment from each collection cone will be emptied and weighed (dry weight) monthly during the five year study period. Post-construction sedimentation rates will be compared across each oyster reef array (bayward vs. shoreward) and post-construction data will be compared to pre-construction data collected at the same locations. One additional ADV and a minimum of three sediment cones or plates, will be placed along the shoreline of Emory Cove on the western side of south San Diego Bay. This location was utilized as a low wind wave energy location for groundtruthing of the wind power model created for this project (Appendix D). Collection of physical data at this reference site will allow comparison of study data with a known low energy area within the Bay, and will provide reference data for ambient Bay conditions.

To analyze subsidence of arrays and to analyze patterns or erosion or deposition, a bathymetric survey of the project area will be completed once per year during spring/summer. Survey methods will include interferometric sidescan sonar, or multibeam sonar, in conjunction with an in situ tidal gauge, as described for baseline monitoring methods above. This method will allow for simultaneous survey of eelgrass within the project area. High resolution, low tide orthorectified aerial photography of the project area will be collected each year during the same time period as the survey work. Minimum resolution for the aerial photography should be 1 inch = 425 ft. Additionally, fixed transects established during baseline monitoring oriented perpendicular to the shoreline will be monitored once per year at the time of the bathymetric survey using total station survey equipment. A minimum of one survey transect will be measured through each oyster reef array, zone of effect, and control area. Total station survey equipment will also be used to measure the crest and base elevation of each oyster reef element within each of the six arrays. The first bathymetric and transect surveys will be completed immediately following construction of oyster reef arrays. These data will be used to groundtruth bathymetric surveys, and will be compared to data collected in subsequent years to analyze rates of subsidence. A second total station survey may be added in monitoring years 1 through 3 following construction of oyster reef arrays, should funding permit, as it is anticipated that subsidence will be greatest earlier in the monitoring period.

The sediment composition within and adjacent to oyster reef arrays may change due to the presence of the arrays. Sediment cores will be collected for grain sizing along the E Street Marsh shoreline immediately following project construction. A minimum of three cores should be collected within each oyster reef array, within the zone of effect for each array, and in associated control areas, with each location marked with dGPS. The top 10 cm of each core will be processed for grain size. A second set of cores will be collected at the same locations at the end of the study to compare the evolution of the reef sediment grain size distribution. Both sets of data will be compared to sediment grain size data collected as part of baseline geotechnical surveys.

Water quality parameters of salinity and water temperature have been determined to be the most important negative stressors for *O. lurida* growth (Wasson et al. 2014). To measure these water quality variables, a Hydrolab® or YSI® multiparameter logger will be deployed subtidally along the E

Street Marsh shoreline for the duration of the post-construction monitoring period. Data collected will include temperature, salinity, dissolved oxygen, pH, and turbidity. Grab samples for chlorophyll a will be collected quarterly within each study block for fluorometry analysis.

4. **Do constructed oyster reef arrays (including oyster reef elements and mudflat habitat between the elements) support increased diversity and abundance of organisms (including invertebrates, fish, and birds) over adjacent mudflat habitat?**

This study question will be addressed in part by quadrats sampled within oyster reef arrays and associated control areas (methods described under study question #2) and by analysis of epibenthic invertebrates collected from shells taken out of study bags (methods described under study question #1).

Large mobile invertebrates and structure-associated fish will be sampled with a combination of funnel/minnow traps and collapsible hoop traps baited and deployed adjacent to oyster reef elements within each oyster reef array, and within control mudflats. A minimum of three replicate traps will be placed within each array and each control area. Traps will be deployed for two weeks during each quarter of the first monitoring year following construction, and then once each year during early summer (July-August) for the remainder of the study. Traps will be checked daily to minimize mortality of fish that become trapped at high tide and are then exposed at low tide. Pelagic fish populations will be assessed using a small beach seine (4.6m x 1.2m net with 0.3cm mesh). This size of seine has been selected as it may be easily maneuvered between oyster reef elements without snagging. A minimum of three replicate seines will be pulled perpendicular to the shore within each of the six oyster reef arrays and associated control areas. Seines will be pulled when tides reach the crest of oyster reef elements within arrays (allowing for approximately two feet of water in sampled areas), and the length of each haul will be measured (to calculate density and biomass). Seining will take place quarterly during the first monitoring year, and then once each year during early summer (July-August) for the remainder of the study. For each sampling method, collected fish will be identified, measured as standard length (to the nearest mm), and weighed (g). Invertebrate species captured with all survey gear types will be identified and counted.

Avian usage will be assessed once per quarter during each study year. Surveys will be conducted from shore by qualified biologists using spotting scopes. Each of the three study blocks will be surveyed simultaneously to ensure identical tide conditions and to prevent double counts. Surveys will consist of a paired low tide (shorebird use) and high tide (waterfowl and piscivore use) survey completed on the same day, if tides permit. Biologists will simultaneously survey each oyster reef array and control area within each study block. During each survey, biologists using spotting scopes will scan the survey blocks for a period of 5 minutes, followed by a 5 minute rest, repeated continuously for 1.5 hours. This will provide 10 discrete counts for each survey period. Data recorded will include species, count, activity (foraging, resting, courting, etc.), and habitat (mudflat, or oyster reef element). A second 1.5 hour survey will be completed at high tide. The purpose of quarterly survey intervals is to capture seasonal migration patterns for shorebirds, waterfowl, and aerial fish foragers. The purpose of the 1.5 hour survey length is to maximize the likelihood of observing avifauna within the study area over the entire peak and lowest tide. The pupose of conducting multiple repeat counts is to provide statistically comparable means between study and control areas.

Benthic invertebrates will be sampled from mudflat adjacent to oyster reef elements within each oyster reef array, and within control mudflats. Sampling will take place immediately following construction of oyster reef arrays, and then once per year during late summer (August) of each monitoring year, prior winter storm events. Benthic invertebrates can be spatially patchy and seasonally variable. The effort and costs associated with collection and processing of sufficient samples to overcome these sources of variability can be prohibitive. In order to maximize sampled area with the most efficient use of effort, a 1 m^2 quadrat will be placed at 10 random locations within each array and control area. Within each quadrat, 4 small cores (7 cm diameter by 10 cm deep) will be collected and rinsed as one sample through a 1.0 mm sieve. Each sample will be preserved, sorted to lowest practical taxonomic group, counted and wet weighed.

Should funding permit, a full year of pre-construction monitoring for fish, avian, and benthic invertebrates, as well as for oyster recruitment (ceramic tees) and shoreline transects (% cover quadrats along shoreline transects) is recommended to be conducted at the project site and at a reference site in south San Diego Bay. It is also recommended that the reference site be monitored in conjunction with the project site during the post-construction monitoring program. This would allow for BACI analysis to separate temporal and environmental effects from effects of constructed oyster reef arrays. Data collected prior to construction of oyster reef arrays will also help analyze whether early post-construction metrics are typical for conditions in south San Diego Bay or are a result of experimental treatments. Potential reference site mudflats include the northeastern shoreline of the Chula Vista Wildlife Reserve (Figures 7 and 8) investigated as a potential project site, or the D Street Marsh shoreline north of the project site (Figure 6), which was one of the six study sites initially investigated for this Plan. These two sites are located in south San Diego Bay, are adjacent to unarmored shorelines, and experience moderate to high wind wave energy.

SUCCESS CRITERIA

The following success criteria have been developed based on project objectives:

- Increased settlement and growth of native *O. lurida* oysters on constructed reefs compared to controls
- Conclusive data on the effects of tidal depth on settlement and growth of native *O. lurida* and non-native *C. gigas* oysters
- Reduced wave energy and water flow velocity measurable shoreward of reef arrays
- Increased sediment deposition shoreward of reef arrays
- Increased ecosystem function of restored reefs as evidenced by an increase in habitat usage by fish and birds over adjacent mudflat habitat

NEXT STEPS

The next phase of work toward implementation of the Plan and construction of an oyster reef project includes final design and engineering for oyster reef elements and arrays, permit preparation and environmental review, and implementation of baseline field investigations to support both of these tasks. The following text summarizes each of these tasks. While it is difficult to estimate costs for project construction and post-construction monitoring prior to final design and engineering, a range of estimates for these elements is also provided below for planning purposes.

Baseline Monitoring Program

As described above, additional survey work is required to move forward with final design and engineering for the project, as well as for permitting and environmental review. The following baseline monitoring tasks are required:

- Bathymetric survey of the E Street Marsh shoreline
- Baseline eelgrass mapping E Street Marsh shoreline
- Geotechnical investigation to determine potential for subsidence of oyster reef elements (this will include collection and analysis of sediment cores)

Bathymetry and eelgrass survey work may be completed simultaneously as a single survey event using remote sensing survey equipment such as interferometric sidescan sonar. Survey data will be used to prepare a basemap, which is needed to inform the engineering design. In addition to remote sensing, transects will be surveyed through each of the six proposed oyster reef array locations and at each of the six control areas. The surveyed transects will inform both the technical analysis and design tasks described below, and will also serve as the pre-construction conditions baseline for construction and ongoing monitoring activities. Surveys will be accomplished with standard survey equipment, such as a total station laser level and stadia rod or RTK equipment, as site conditions permit. Survey transects will be performed during low tide and accessed by foot, which may require wading in shallow water or walking short distance across mudflats. A basemap will be prepared to inform the analysis and design, and will be used in the construction drawings. The basemap will rely on compilation of collected bathymetry and available LiDAR data, which will be ground-truthed with the survey transects.

A geotechnical investigation and analysis performed by a licensed geotechnical engineer is recommended to determine detailed site-specific estimates of subsidence rates for the oyster reef elements over time. This effort would include gathering/collecting and interpreting subsurface data in the vicinity of the project site, describing subgrade composition and properties, and estimating settlement rates due to the weight/loading of the reef elements. A geotechnical analysis is recommended if precise reef elevations are desired for experimental purposes. If a wider tolerance in reef elevations is deemed acceptable, then a reduced level of effort for a geotechnical review/consultation and/or review of data and information available from other oyster reef projects (such as the San Francisco Bay Living Shorelines Project) may suffice. A complete investigation has been assumed for cost estimates.

Final Design and Engineering

This work element has been broken into the following tasks:

- Basis of design
- Final design

- Permitting support
- Construction coordination and support
- Hydrodynamic wave modeling (optional)

A basis of design should be completed to inform development of the construction documents, including the plans and specifications, as well as to provide sufficient understanding and quantification of the project for permitting and environmental review. The basis of design will summarize several outstanding technical questions related to the composition and performance of the oyster reef elements and will include the following technical analyses:

- Review of Similar Projects: Living shorelines and oyster restoration projects that have been implemented, especially those on the west coast in San Francisco Bay and others such as Newport Bay if appropriate, will be researched to develop comparison of the site conditions to San Diego Bay.
- Waves and Hydrodynamics: Additional modeling of potential wind waves incident to the proposed deployment sites will be performed to assess the range in wave heights for typical and anticipated extreme conditions, which will be used for design of the elements.
- Wave Loadings: The relative magnitude of San Diego Bay/E St site wave loadings will be assessed.
- Subgrade Characterization, Scour and Sedimentation: A reconnaissance characterization of the San Diego Bay mudflat soils will be performed to serve as a preliminary basis for assessing the potential for the reef elements to settle on the mudflat and the relative potential for scour and sedimentation. This primarily qualitative characterization will be based on field observations and general comparisons to other sites. More detailed geotechnical information and assessment is described above and included as optional.
- Materials: A review of the materials used in similar projects will be used to inform the range of possible materials for constructing individual reef elements, including material types, sourcing, and performance specifications.
- Quantities and Costs: Approximate quantities will be estimated for planning purposes, and a preliminary construction cost estimate will be developed.

In addition to the basis of design tasks outlined above, additional hydrodynamic and wave modeling beyond the modeling performed for this Plan may be useful for refining the reef design, study hypotheses, and monitoring plan. For example, additional two-dimensional modeling of reefs effects on waves, currents, and sediment transport could be performed to supplement the one-dimensional (cross-section) modeling performed for the current Plan and to provide information on spatial processes at the scale of the reef and shoreline. Note that the one-dimensional modeling completed for this Plan adequately indicates that the reefs are expected to have a measurable effect on wave currents and sediment transport. Additional modeling is therefore included as an optional task. If additional information (e.g., more detailed predictions of the spatial effects of the reef) is desired during the design and permitting phase, then additional hydrodynamic modeling is recommended that couples wind waves, tidal currents, and sediment transport at an appropriate scale for providing the desired information.

The final design process will include development of construction plans and documents that will provide sufficient detail for implementing the proposed project. Design milestones are anticipated at the 60%-complete and 90%-complete designs, at which points the design will be reviewed and comments and revisions will be incorporated to the subsequent level of design. The final design package will consist of 100%-complete stamped and signed plans, complete final set of performance specifications and the engineer's estimate of construction costs.

It is anticipated that the project will require ongoing engineering support, through permitting and construction phases. The permitting process will rely on quantitative information of the proposed project and the engineering design. The design and permitting leads will work together to provide approximate areas and volumes of project and construction impacts, fill and earthwork. Engineering support during construction will be required. Other members of the project team should also be involved to maintain conformance with performance specifications. This coordination will include meetings, revisions and responses regarding design drawings, materials, and construction methods.

If the contractor for project implementation will be selected through an open construction bid process, the design effort will need to provide construction documents in a standard bid package, including stamped and signed plans and technical specifications, and engineer's estimate of construction costs. This approach would require a higher level of detailed analysis and design than the design effort to develop a performance specification design described above (i.e., a standard construction bid package for a "design-bid-build" process would require additional design effort compared to a performance specification design, wherein the design is detailed by the construction contractor/installer with the involvement of the designers during construction).

Permit Processing and Environmental Review

The tasks associated with permit processing and environmental review incude:

- Baseline biological assessment
- Essential fish habitat (EFH) assessment
- Preparation of Mitigated Negative Declaration (MND) in accordance with CEQA
- Permit preparation and consultation with resource and regulatory agencies

The baseline biological assessment and EFH assessment will utilize the eelgrass survey data collected as part of the baseline monitoring described above, and will include methods, results, and discussion for a baseline eelgrass survey. The assessements will also utilize existing biological and sensitive species information for south San Diego Bay and the project area. These documents will be prepared to comply with CEQA and permit needs for the project.

The proposed project will require the following environmental documentation, permits and approvals (described in detail below):

- Compliance with the California Environmental Quality Act (CEQA) through preparation of a Mitigated Negative Declaration (MND)

- Coastal Development Permit issued by the San Diego Unified Port District
- Rivers & Harbors Act Section 10 and a Section 404 Permit under the Clean Water Act issued by the Army Corps of Engineers (USACOE); USACE Nationwide Permit 27, which permits "the construction of oyster habitat over unvegetated bottom in tidal waters" may apply to the project.
- Section 401 Water Quality Certification issued by the Regional Water Quality Control Board
- Essential Fish Habitat (EFH) Assessment for compliance with Magnuson-Stevens Fisheries Conservation and Management Act (NMFS 1998), and consultation with NOAA National Marine Fisheries (NMFS) for EFH [which will include endangered green sea turtle (*Chelonia mydas*)]
- Eelgrass surveys and reporting for compliance with the California Eelgrass Mitigation Policy (NMFS 2014)
- Informal consultation with the U.S. Fish and Wildlife Service for endangered species including California least tern (*Sternula antillarum browni*), and potentially, Ridgway's (clapper) rail (*Rallus obsoletus levipes*) due to adjacency of the E Street and Sweetwater Marshes
- A survey for the invasive seaweed *Caulerpa taxifolia*, not more than 90 days prior to the initiation of construction, by a certified *Caulerpa* surveyor (NMFS 2004)
- Compliance with Section 106 of the National Historic Preservation Act

The proposed project site is considered submerged tidelands San Diego Bay and falls within the jurisdiction of the SDUPD under the Port Master Plan (PMP). Between the bulkhead and pierhead lines, the Port has Coastal Act permitting authority under its PMP. The project will require issuance of Coastal Development Permits (CDP) by SDUPD. A Mitigated Negative Declaration (MND) would be required to comply with CEQA, as the project consists of a single alternative and any impacts would be mitigated to less than significant.

The project will also require issuance of Clean Water Act (CWA) section 401 State Water Quality Certification. A CWA section 404 permit as well as a Rivers & Harbors Act section 10 permit from the USACOE will be required. for the placement of fill and structures (bags of oyster shell) into waters of the U.S. The project may comply with conditions of USACOE Nationwide Permit 27, which permits "the construction of oyster habitat over unvegetated bottom in tidal waters".

The USACOE must consult with National Marine Fisheries Service (NMFS) on projects that may affect Essential Fish Habitat (EFH) according to the requirements of Section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). In addition, the USACOE must consult with NMFS and/or the U.S. Fish and Wildlife Services (USFWS) if it determines the project may affect listed species managed by these agencies. Because the project may affect eelgrass resources, the project will comply with the California Eelgrass Mitigation Policy (CEMP) (NMFS 2014). The project will also comply with the *Caulerpa* Control Protocol (CCP, ver. 4) (NMFS 1998). Under the CCP, projects involving subtidal bottom disturbing activities are required to complete a pre-activity survey for invasive *Caulerpa taxifolia* prior to initiation of work. This survey will be completed for the project actions.

In the event the project results in eelgrass impacts, mitigation for impacts in accordance with the SCEMP will be required. A baseline eelgrass survey will be completed prior initiation of project work. The distribution of eelgrass intertidally in San Diego Bay varies seasonally; eelgrass occurs higher in the intertidal zone during winter months when desiccation stress is lower, and retreats subtidally during summer months as desiccation stress increases. A determination of eelgrass impacts will be made through a comparison of pre-construction (completed within 60 days prior to initiation of construction) and post-construction eelgrass surveys (completed within 30 days following completion of construction). Impacts to eelgrass, if any, could be mitigated through restoration of eelgrass in San Diego Bay, or through use of SDUPD restored, banked eelgrass areas. A cost estimate for eelgrass restoration and monitoring are provided in this Plan, as a potential line item cost for the next phase of work.

It is anticipated that the full permit processing and environmental review process will require six to eight months.

PROJECT CONSTRUCTION

Costs for the construction of oyster reef arrays will vary depending on materials selected, availability and cost of materials, transportation costs, and installation methods. The E Street Marsh shoreline is readily accessible from the J Street Marina and Pier 32 Marina (near the Sweetwater River). However, the wide intertidal mudflat at the project site, will require materials to be transported to the site at high tide, restricting available work times and limiting construction vessels to small, shallow-draft boats. Further, the availability of locally sourced dried oyster shell is not known. Shell material may need to be trucked to the project site from a distant source. Alternately, if sufficient shell material is not available, the project design may require modification to utilize a different substrate material (e.g. mixed oyster and mussel shell, baycrete, etc.).

The costs for the San Francisco Living Shorelines project were reportedly $85,000 per acre for shell material purchase and transportation cost (M. Latta, pers. com.). A recent analysis of methods and costs associated with restoration of oyster reefs in San Francisco Bay associated with creosote piling removal provided a range of costs for oyster reef restoration of $80,000-$360,000 per acre for construction and placement of reefs (Merkel & Associates, Inc. 2015). That study noted that with good water access and a nearby staging area, such as exist in San Diego Bay, construction costs may be controlled by loading units off the land to a shallow draft vessel for placement. The study also noted that the range of costs is comparable to that of construction and placement of fish enhancement reefs using similar methods (e.g. concrete reef balls and concrete jacks). Placement of reefs would require oversight by a biologist, engineer, and survey crew to ensure accurate tidal elevations and to ensure proper placement and construction of each reef element. Based on this range, and the 0.68 acre proposed footprint for the project (6 total 55 ft x 90 ft arrays), rounded restoration costs would be between $54,000-$244,000.

PRE-CONSTRUCTION AND POST-CONSTRUCTION MONITORING PROGRAMS

Similar to construction costs, the monitoring costs for the project will vary based on survey type, survey frequency, survey periodicity, and survey intensity for each monitoring element. The costs will also vary by staff performing each monitoring element (e.g. university staff vs. private consultants). As such, the following range of costs is provided for planning purposes only. The costs assume a one year pre-construction and a five year post-construction monitoring program, with monitoring intervals described in Table 2. The costs assume quarterly progress reports (which describe methods, list tasks completed, and provide summary data tables and charts) and an annual report to be prepared for each monitoring year.

Pre-construction monitoring will include collection of aerial photography, analysis of existing weather data (assuming that a dedicated weather station is not required for this project), collection of water quality data and sedimentation rate, and completion of annual oyster recruitment and density studies. Pre-construction monitoring would also include a year at minimum of fish, avian, and benthic infauna studies. The range of costs for this work is $150,000-$200,000.

Post-construction monitoring will include physical and biological data including weather data, water quality data, aerial photography, bathmetry surveys, wave and current monitoring, sedimentation rate, oyster recruitment studies, epibenthic invertebrate studies, fish studies, avian studies, and benthic infauana studies. The range of costs for this work is $1,250,000-$1,500,000.

COSTS

Table 3 provides costs estimates for the work described above. These have been developed for the primary purpose of scoping and seeking funding for future work elements.

SCHEDULE

A proposed schedule for subsequent phases of work is provided as Table 4.

Table 3. Cost Estimates for Scoping Future Work

Task Description	Fee
Baseline Monitoring Program	
Bathymetry Survey (remote sensing and survey transects) and Basemap	$20,000
Geotechnical Investigations	$35,000
Final Design and Engineering	
Basis of Design	$66,000
Final Design	$70,000
Permitting Support	$17,000
Construction Coordination and Support	$30,000
Optional Task: Hydrodynamic Wave Modeling	$50,000
Optional Task: Standard Construction Bid Package	$70,000
Permit Processing and Environmental Review	
Baseline Biological Assessment	$15,000
Essential Fish Habitat (EFH) Assessment	$5,000
CEQA Mitigated Negative Declaration	$40,000
Permits Preparation and Consultation with Resource and Regulatory Agencies	$30,000
Project Cosntruction	
Construction and Placement Costs	$54,000-$244,000
Pre- and Post-Construction Monitoring	
Pre-Construction Costs (1 year)	$150,000-$200,000
Post-Construction Costs (5 years)	$1,250,000-$1,500,000
TOTAL BASE COST	**$1,782,000-$2,272,000**
TOTAL BASE COST + OPTIONAL COSTS	**$1,902,000-$2,392,000**

Table 4. Schedule of Work Elements

	2016			2017				2018			
WORK ELEMENT	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**
Second Phase Project Award											
Baseline Monitoring Program											
Final Oyster Bed Design and Engineering											
Permitting and Environmental Compliance											
Pre-construction Monitoring Program											
Project Construction						2021 (see below)					
Post-construction Monitoring Program											

*dashed lines indicate option for a full year of pre-construction monitoring, which would delay project construction to the following spring, and extend the post-construction monitoring program.

	2017	2018	2019	2020	2021
WORK ELEMENT	**J F M A M J J A S O N D**	**J F M A M J J A S O N D**	**J F M A M J J A S O N D**	**J F M A M J J A S O N D**	**J F M A M J J A S O N D**
Project Construction					
Post-Construction Monitoring Program					
Biological Monitoring					
Oyster Recruitment Initial Study					
Oyster Recruitment Studies					
Quadrat Samples (other invertebrates)					
Oyster Recruitment Reference Studies					
Shoreline Transects Reference Studies					
Fisheries Studies					
Avian Studies					
Benthic Studies					
Physical Monitoring					
Bathymetry and Eelgrass Survey					
Aerial Photography					
Wave Studies					
Sedimentation Studies					
Water Quality (multiparameter sonde)					

REFERENCES

Baggett, L.P., S.P. Powers, R. Brumbaugh, L.D. Coen, B. DeAngelis, J. Greene, B. Hancock, and S. Morlock. 2014. Oyster Habitat Restoration Monitoring and Assessment Handbook. The Nature Conservancy, Arlington, VA, USA., 96 pages. Downloaded from: http://www.oyster-restoration.org/oyster-habitat-restoration-monitoring-and-assessment-handbook/

Cayan D., A.L. Luers, M. Hanemann, G. Franco, and B. Croes. 2006. Scenarios of climate change in California: an overview. Prepared for the California Energy Commission and the California Environmental Protection Agency. February 2006. 47 pages. Downloaded from: http://www.energy.ca.gov/2005publications/CEC-500-2005-186/CEC-500-2005-186-SF.PDF

Gersberg, R.M. 2014. San Diego Bay Terrain Model Final Report. Prepared for the San Diego Unified Port District. January 2014. 32 pages. Downloaded from: https://www.portofsandiego.org/bpc-policies/doc_view/5666-san-diego-bay-terrain-modelfinalreport-feb-2014.html

Merkel & Associates, Inc. 2000. Environmental controls on the distribution of eelgrass (*Zostera marina* L.) in south San Diego Bay: An assessment of the relative rolls of light, temperature, and turbidity in dictating the development and persistence of seagrass in a shallow back-bay environment. Prepared for Duke Energy, South Bay LLC, and California Regional Water Quality Control Board. January 2000. 146 pages.

Merkel & Associates, Inc. 2014. 2014 San Diego Bay Eelgrass Inventory and Bathymetry Update. Prepared for U.S. Navy and San Diego Unified Port District. May 2015. In publication.

Merkel & Associates, Inc. 2015. San Francisco Bay Creosote Piling Removal and Pacific Herring Habitat Restoration Project. Prepared for California State Coastal Conservancy and AECOM. May 2015. 59 pages.

[NMFS] National Marine Fisheries Service. 2014. California Eelgrass Mitigation Policy and Implementing Guidelines. October 2014. 45 pages.

[NMFS] National Marine Fisheries Service. 1998. Essential fish habitat: new marine fish habitat conservation mandate for federal agencies. National Marine Fisheries Service Southwest Regional Office.

[NMFS] National Marine Fisheries Service Southwest Region, 2004. Caulerpa Control Protocol (Version 1.2b).

Tenera Environmental and Merkel & Associates, Inc. 2004. SBPP Cooling Water System Effects on San Diego Bay. Volume I: Compliance with Section 316(a) of the Clean Water Act A.2 for the South Bay Power Plant. Prepared for Duke Energy LLC. August 2004. 309 pages.

Thorne, K.M, K.J. Buffington, C.M. Freeman, K.W. Powelson, G.M. Block, and J.Y. Takekawa. 2014. Projecting tidal marsh response to sea-level rise using local site conditions: San Diego Bay National Wildlife Refuge: Sweetwater Unit. Prepared for U.S. Geological Survey, Western Ecological Research Center, Vallejo, CA. 41pages.

Tierra Data Incorporated. 2010. Characterizing the spatial and temporal variation in turbidity and physical water quality characteristics in San Diego Bay: A study to determine a cost-efficient strategy for long term monitoring. Prepared for the San Diego Unified Port District. March 2010. 24 pages.

[U.S. Navy] U.S. Department of the Navy, Naval Facilities Engineering Command Southwest and Port of San Diego. 2013. San Diego Bay Integrated Natural Resources Management Plan, Final September 2013. San Diego, California. Prepared by Tierra Data Inc., Escondido, California.

Wasson, K., C. Zabin, J. Bible, E. Ceballos, A. Chang, B. Cheng, A. Deck, T. Grosholz, M. Latta, and M. Ferner. 2014. A Guide to Olympia Oyster Restoration and Conservation: Environmental Conditions and Sites that Support Sustainable Populations in Central California. 43 pages.

White, J.M., E.R. Buhle, J.L. Ruesink, and A.C Trimble. 2009. Evaluation of Olympia Oyster (*Ostrea lurida* Carpenter 1864) Status and Restoration Techniques in Puget Sound, Washington, United States. **Journal of Shellfish Research** 28(1):107-112.

APPENDICES

APPENDIX A

San Diego Bay
Native Oyster Restoration Plan

Technical Memorandum

Historic Presence and Distribution of Oysters in San Diego Bay

Prepared by:

California State University Fullerton

Lead Scientist: Dr. Danielle Zacherl

May 2015

INTRODUCTION

The San Diego Bay Native Oyster Restoration Plan is a collaborative effort being undertaken by the San Diego Unified Port District (SDUPD) and the California State Coastal Conservancy (Conservancy). The Plan goal is to create a biologically rich native oyster, *Ostrea lurida,* bed in San Diego Bay as part of a complete marsh system that restores an ecological niche that was historically present, is ecologically functional and resilient to changing environmental conditions, and protects bay tidelands and shoreline.

O. lurida currently exists in San Diego Bay, but little is known about how long the species has been present in the Bay or how abundant the species was historically. Peer-reviewed and grey literature on the historic presence of Olympia oysters in southern California (and specifically within San Diego Bay) was gathered to address this question. This memo includes a summary of literature gathered, provides some background information on the Olympia oyster, and provides an overall assessment of the presence of this species in San Diego Bay as recorded in the literature. An annotated bibliography is included.

BACKGROUND

Along the North American West Coast, from Alaska to central Baja, Mexico, there is only one native oyster species, the Olympia oyster, *Ostrea lurida* Carpenter 1864[1]. Within the last century it was a widely distributed habitat-forming species in bays and estuaries (Bonnot 1935, Baker 1995), including in California, and was exploited as a food resource by California native Americans. In the early 1900s, some combination of over-harvesting (Kirby 2004), pollution (Hopkins 1935), and habitat loss/degradation (Dahl et al. 1991, Lotze et al. 2006) led to significant declines throughout this species' range. Oyster beds[2] are now absent in California estuaries, though remnant low-density populations exist (Polson & Zacherl 2009).

There are no quantitative data describing *O. lurida* densities, abundances, or the spatial extent of beds prior to their decline in southern California estuaries. However, evidence from fossil deposits and historic documents clearly indicate the presence of oysters and oyster beds in several southern California estuaries. Below, I detail records from the primary literature as well as records of museum collections that oysters have been a part of the San Diego landscape since at least the Pliocene epoch (2.5 - 5 mya) during the Cenozoic era.

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[1] The taxonomy of the Olympia oyster has changed several times within the past several decades (see Polson et al. 2009 for discussion). Most relevant to this paper is that Harry (1985) proposed to synonymize *Ostrea lurida* Carpenter 1984 and *Ostrea conchaphila* Carpenter 1857. Some (e.g. Baker, 1995) questioned the synonymy while others used one name or the other. In 2009, Polson et al. published molecular evidence that the species as originally described were, in fact, distinct species. An unpublished follow-up study that provides more evidence for the original species definitions (Raith et al.) is in review.

[2] At the 2006 West Coast Native Oyster Restoration Workshop, Olympia oyster scientists and conservationists discussed and agreed upon use of the term "oyster bed" as opposed to "oyster reef" to describe Olympia oyster aggregations. The evidence provided by fossil deposits, photographs, and qualitative descriptions of historical and extant oyster populations suggest that Olympia oysters form low-relief "beds" as opposed to "reefs" with large vertical relief as are formed by other oysters (e.g. *Crassostrea gigas*). (NOAA, 2007)

RESULTS AND DISCUSSION

SAN DIEGO-SPECIFIC REFERENCES IN THE LITERATURE AND MUSEUM COLLECTIONS

Pre - Holocene Fossil evidence

The San Diego Museum of Natural History (SDMNH) receives fossil specimens from collectors as well as from consultants associated with construction and development projects. Since the museum has digitized the records associated with at least part of their collections, it is possible to request documentation on the collections that includes a description of the specific lot (how many shells and a brief description of the lot contents, as well as the locality where the specimens were collected, species ID, name of the identifier and the identification date). In May 2013, as part of a master's thesis project at CSU Fullerton in the Department of Geology, graduate student Kelly Kathe requested a record of all SDMNH collections that included the genus *Ostrea* at least as far back as the Pliocene (Appendix 1) from the San Diego Formation (K. Kathe, personal communication). Figure 1 provides a diagram of the geological time scale for reference.

For context, the San Diego Formation is a mix of sandstone and cobble and shell conglomerate associated with a large bay in the San Diego area during the Pliocene-Pleistocene transition 3.5-1.5 mya (Donahue 2013). Based upon the deposits, the Bay was probably much like Monterey Bay - crescent shaped and very large - extending from San Diego County to Northern Baja California, Mexico near Rosarito Beach. Researchers at the SDMNH have hypothesized that environmental conditions may have been more tropical than modern times because of the presence of more tropical-associated species in the fossil record. It is interesting to note that besides invertebrate fossils, the bones of whales, seals and sea cows were also present in the formation. (Rugh accessed Oct 2014, Donahue 2013)

Among the SDMNH collections from this formation formed during the Pliocene epoch (5 to 2.5 mya), there is extensive evidence of the presence of the genus *Ostrea* (identified as *Ostrea* sp.) as well as several other species that are no longer extant (e.g. the very common *Dendostrea vespertina,* which exists in the fossil record in California from 23 to 2.5 mya) but is now present only in the Sea of Cortez and southward (e.g. *Ostrea angelica*, now *Myrakeena angelica*). Figure 2 illustrates site locations for study references where specific locations were indicated.

Among the SDMNH collections from this formation formed during the Pleistocene epoch (2.5 mya - 12,000 ya), *O. lurida* is by far the most common fossil oyster species (Appendix 1). Its common presence in the fossil record occurred throughout the Pleistocene in other formations besides the San Diego Formation. For example, Kern (1971) and Demere (1980) noted that *O. lurida* fossils were commonly found among Late Pleistocene sediments of the Bay Point Formation in Carmel Valley, San Diego County and from San Dieguito Valley. Donahue (2013) noted that *O. lurida* predominated with scallops and jingle shells in Pleistocene deposits excavated in 2006 near Old Town, San Diego in the Bay Point Formation. In addition, evidence from fossil deposits indicates this species' presence in multiple locations in southern California in general extending back to the

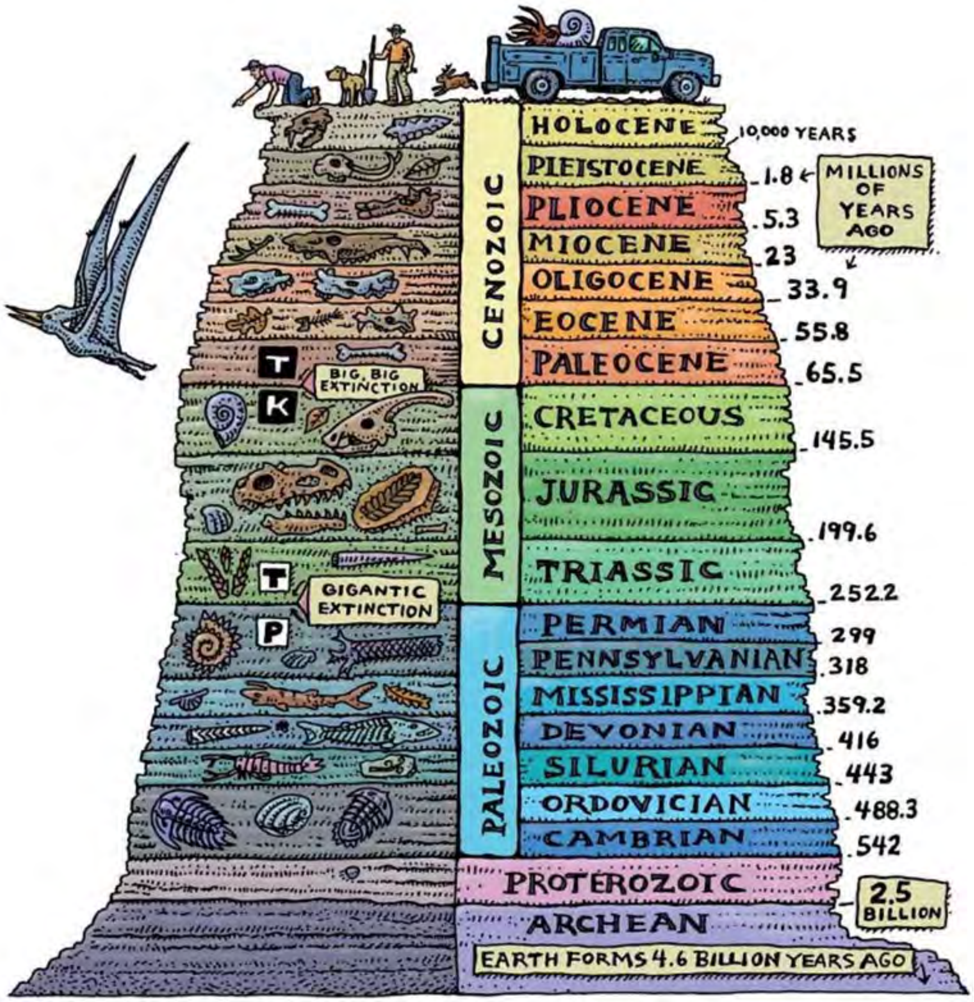

Figure 1. Diagram of the Geological Time Scale (source: "Ages of Rock" by Ray Troll, 2007).

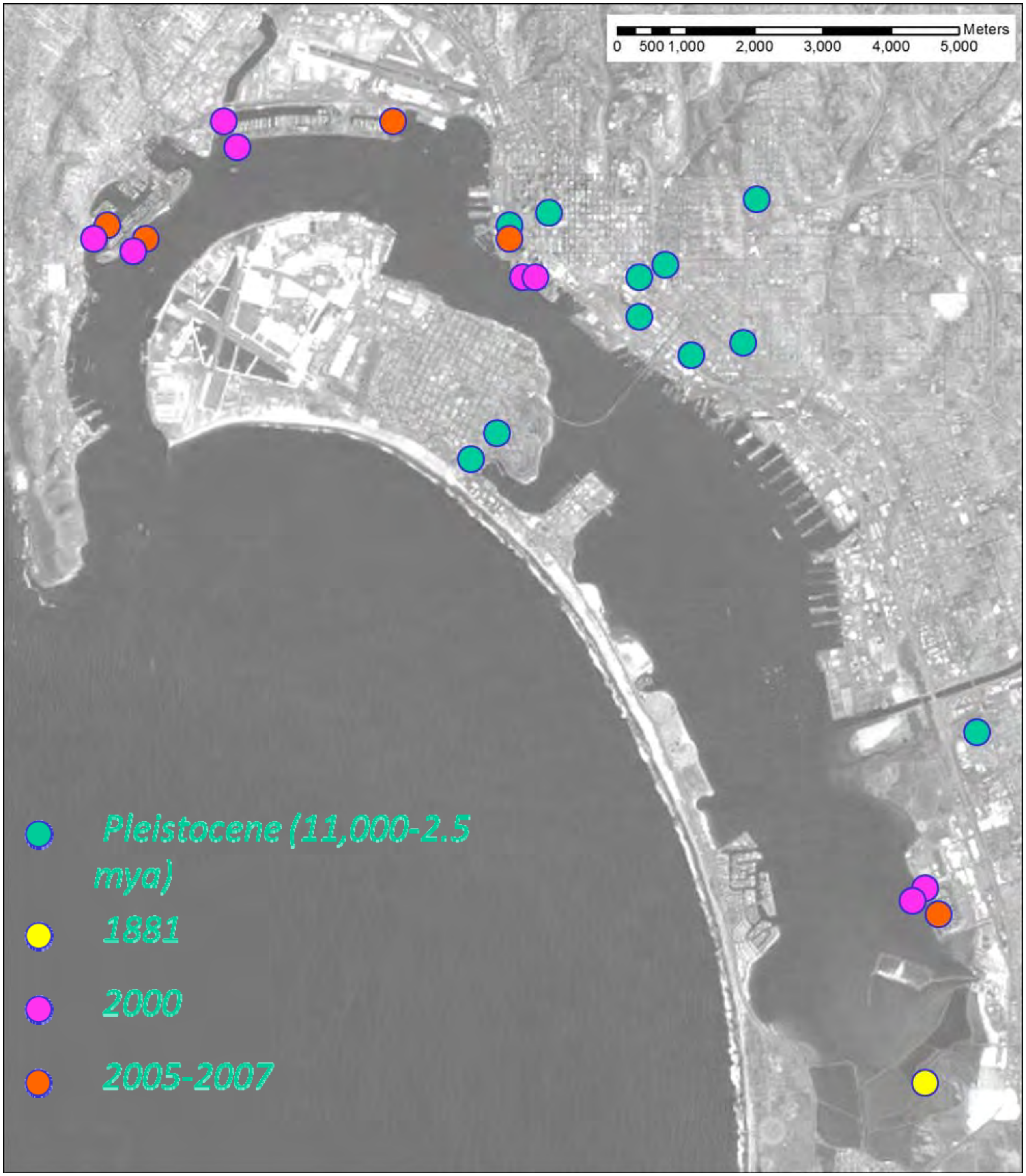

Figure 2. Summary of Locations for Selected Study References

[**References:** SDMNH sites 54, 2528, 2991, 3020, 3147, 4040, 4728, 4985, 5289, 5432A, 6468; Ingersoll (1881), Davis et al. (2002); Carson (2010) Polson and Zacherl (2009)] late Pleistocene, including at Coyote Hills, near Fullerton in Orange County, California (Powell and Stevens 2000), and at the Midway-Sunset Oil Field in Kern County (Howard, 1935). In sum, there is a rich history of the presence of this species, and oysters in general, in San Diego that extends back at least as far as the Pliocene epoch 5 mya.

Holocene archaeological deposits and references from modern literature

The Holocene epoch began 11,700 ya, and much of the evidence of continued oyster presence in the area comes from archaeological excavation of shell middens. In a review of 44 San Diego County archaeological sites/middens, Laylander and Iversen (2008) provide evidence that *O. lurida* ranged from not present to as high as 50% by weight of shellfish recovered; *O. lurida* typically represented between 5-10% of the total shellfish by weight. In general, the most important food resources for prehistoric inhabitants included the following mix of shellfish: *Chione, Argopecten, Mytilus, Ostrea, Donax and Pseudochama*, and the relative representation of each shellfish species ranged widely from archaeological site to site throughout San Diego County.

Oysters seem to have continued to play an important role as a food resource from the 1600's through the early 1900's. Davidson (1887) provides excerpts of the explorations of Cabrillo, Viscaino and others that include mention of oysters as a food resource in San Diego Bay. In Viscaino's description of his experience in San Diego in 1602, he notes that, "in this harbor there is a great variety of fish, as oysters, mussels, lobsters…abounded." More recently, Ingersoll (1881) mentions that at La Punta on the south side of San Diego Bay, there were large enough numbers of oysters of sufficient size to have potential commercial importance (but he noted their coppery flavor). Gilbert (1889) and Bonnet (1935) described the presence of oyster beds in several southern California estuaries, including Alamitos Bay and Newport Bay in Orange County, and Mission Bay, San Diego Bay, and the Tijuana River Estuary in San Diego County. Bonnet (1935) noted the presence of small quantities of oysters everywhere in Mission and San Diego Bays, but noted that clamming activities in Mission Bay and sewage pollution in San Diego Bay would make these bays unlikely candidates for initiating an oyster industry. Coe (1931a, 1931b, 1932) noted *O. lurida's* presence in the San Diego area in several studies on gamete development and setting season based upon an unusual open-coast population of oysters at Scripps Pier. Lastly, Hector (2002) examined the patterns of shellfish consumption of urban San Diego residents at around turn of the century by examining the shellfish remains from two archaeological deposits – one dated at the turn of the 20th century and the other from ~1920s. These deposits indicated that *O. lurida* was a food resource at the turn of the century, but it was replaced by C*. virginica* as a food resource in subsequent decades. Collectively, in the literature there is extensive evidence that *O. lurida* was present in San Diego Bay and nearby areas, that the species was an exploited food resource by native American Indians prior to Spanish exploration, and that it continued to be exploited through the turn of the 20th century.

1960's - 2000

While the *O. lurida* was not mentioned in several extensive surveys of San Diego Bay undertaken by various consulting firms in the 1960s-1990s (Ford 1968, Browning and Speth 1973, Peeling 1974, MacDonald et al. 1990), it was noted as "common" by Lockheed Environmental Services at one site along the Coronado Bayfront in 1979. It is important to note, however, that the majority of these surveys targeted soft-sediment habitat using cores or using water column sampling methods such as gill netting (e.g., Ford 1968, Peeling 1974, MacDonald et al 1990). Surveys were not as commonly conducted along rubble, shell beds, or riprap in the intertidal areas. Therefore, it is not likely that oysters, which are found along hard substrate, were adequately sampled during these surveys, and it can be concluded that *O. lurida* is under-represented in survey results. As an example, MacDonald et al. (1990) made only brief mention of the very common *Mytilus* sp. (which frequently co-occurs with *O. lurida*) in two of eight studies reviewed. This suggests that the habitat on which these species occurs was not sampled.

2000 - Current Day

Most recently, Davis et al. (2002) conducted surveys of armored shorelines at 10 sites throughout San Diego Bay. *O.lurida* was present at all sites surveyed with the highest percent cover reported at Harbor Island (5-10%). Percent cover was <5% elsewhere, including at False Point, Ocean Beach, Shelter Island, Embarcadero Park and Chula Vista. Healey and Hovel (2004) also found *O. lurida* at a site adjacent to the Chula Vista Wildlife Refuge. The oysters were found attached to out-planted artificial eelgrass units at shallow subtidal depths. Polson and Zacherl (2009) provided the first recorded density data on *O. lurida* in San Diego Bay based upon intertidal surveys performed in 2006. In their study, they targeted the areas with the highest density of oysters in each estuary along the US West Coast where *O. lurida* was historically present (with the notable exception of Puget Sound, where surveys were not performed but where Olympia oysters were known to exist historically in the subtidal zone). The maximum density in San Diego Bay measured 25 oysters/0.25 m^2 at Harbor Island; the only location along the US West Coast with a higher measured density was at Point San Quentin in San Francisco Bay with 37 oysters/0.25m^2 at a location just adjacent to a recent oyster restoration site. Finally, the most recent published account of the presence of *O. lurida* in San Diego Bay is by Carson (2010), who studied population connectivity of *O. lurida* among several estuaries in southern California from Agua Hedionda southward to San Diego Bay. He regularly sampled adults for the presence of brooded larvae every two weeks throughout the reproductive season of the oyster (May to early September) from three locations within San Diego Bay that were characterized as the sites with the apparently highest abundances of oysters in the bay, including Shelter Island, Harbor Island and Chula Vista. Carson (2010) did not, however, record density at these locations.

SUMMARY

There is ample evidence in the historic record that native *O. lurida* has had a significant presence in San Diego Bay since the Pleistocene epoch. While quantitative studies are rare [with only a single study reporting percent cover (Davis et al. 2002) and a single study reporting density (Polson and Zacherl 2009)], the majority of historic studies reviewed for this document indicate some presence of *O. lurida* in the Bay. It is difficult to determine whether presence of this species has been continuous or whether, rather, it has occasionally gone locally extinct. For example, there is a notable absence of mention of *O. lurida* from 1935 to 1968 in the published literature. However, it is clear that over recorded history, *O. lurida* played a key role as a habitat provider and as a food resource for humans within San Diego Bay and adjacent areas.

ANNOTATED BIBLIOGRAPHY

Baker, P. 1995. Review of ecology and fishery of the Olympia oyster, *Ostrea lurida*, with annotated bibliography. **Journal of Shellfish Research** 14:501-518.

Bonnot, P. 1935. The California oyster industry. **California Fish and Game** 21:65-80. [Surveyed and commented upon all the bays and estuaries of California – he was expressly looking for locations where California oysters had some commercial value]

Browning, B.M., and J.W. Speth. 1973. The natural resources of San Diego Bay: their status and future. State of California Department of Fish and Game. Coastal Wetlands Series No. 5. [This report was prepared as a guide for citizens, administrators and planners of the city of San Diego and provides an interesting read on the history of the Bay as well as a broad view of the natural resources. Unfortunately, it is not well referenced, and so it is difficult to judge the accuracy of the lack of information on oyster presence.]

Carson, H. 2010. Population Connectivity of the Olympia Oyster in Southern California. **Limnology and Oceanography** 55(1): 134-148. [The author used chemical fingerprinting technique in shells of recruit oysters to assign them to their birth locations. He sampled adults from three locations within San Diego Bay that were characterized as the sites with the apparently highest abundances of oysters in the Bay. Sites included Shelter Island, Harbor Island and Chula Vista. Approximately 10-20% of oysters were brooding young from late May through early September and ~80% of recruiting oysters were characterized as having originated within the Bay.]

Coe, Wesley R. 1931a. Sexual rhythm in the California oyster (*Ostrea lurida*). **Science** 74: 247-249.

Coe, Wesley R. 1931b. Spermatogenesis in the California oyster (*Ostrea lurida*). **Biological Bulletin**: 309-315.

Coe, Wesley R. 1932. Development of the gonads and the sequence of the sexual phases in the California oyster (*Ostrea lurida*). Scripps Institution of Oceanography.

Dahl, T. E., C. E. Johnson, and W. Frayer. 1991. Wetlands, status and trends in the conterminous United States mid-1970's to mid-1980's. US Fish and Wildlife Service.

Davidson, George. Voyages of Discovery and Exploration on the Northwest Coast of America from 1539 to 1603. US Government Printing Office, 1887. [Professor George Davison of the US Coast and Geologic Survey translated and annotated the travel logs of explorers of the US West Coast to locate the specific locations of their voyages of discovery. He sets up the descriptions in four columns – one for Cabrillo, one for Ferrello, one for Ulloa and Viscaino and one with his annotations. For each locality, then, the four columns can be matched up to witness the verbiage of each explorer as well as Davidson's notes.]

Davis, J., L. Levin, and S. Walther. 2002. Artificial armored shorelines: sites for open-coast species in a southern California bay. **Marine Biology** 140.6: 1249-1262.[conducted surveys of armored shorelines, specifically riprap, at 10 sites (two open coast, 8 bay) in 2000, and assessed community composition as well as whether level of exposure and distance from the mouth of the Bay affected intertidal height of individual species. Found *O. lurida* throughout the Bay at all sites, but with highest % cover at Harbor Island.]

Demere, T.A. 1980. A Late Pleistocene Molluscan Fauna from San Dieguito Valley, San Diego County, California. **Transactions of the San Diego Society of Natural History** 19(15): 217-226.
[The fauna from a late Pleistocene deposit of a protected marine embayment, ~ 250,000 B.P., are described. *O. lurida* and jingle shells are described as common in these deposits.]

Donahue, S.L. and T.A. Demere. 2013. Paleontological Resource assessment of Old Town San Diego and Midway-Pacific Highway Corridor. Community Plan Updates, City of San Diego, San Diego County, CA. Prepared by Department of Paleoservices, San Diego Museum of Natural History, San Diego, CA. 28 p. [This technical report provides an assessment of paleontological resources within the Old Town San Diego Community Plan Area and the adjacent Midway-Pacific Highway Corridor Community Plan Area. Some fossil localities (SDSNH Localities 5761, 5810, and 5816-5819) were located within the Pleistocene (700,000 – 10,000 ya) Bay Point Formation where collected fossils were predominantly oysters (*O. lurida*), scallops (*Argopecten* sp.) and jingle shells (*Anomia peruviana*).]

Ford, R.F. 1968. Marine Organisms of South San Diego Bay and the Ecological Effects of Power Station Cooling Water Discharge. Prepared for San Diego Gas and Electric Company, San Diego, CA, 278 p. [This pilot study associated with the San Diego Gas & Electric Company was undertaken to develop a comprehensive and extensive characterization of the physical and biological characteristic in south San Diego Bay, especially including in the immediate vicinity of the power plant. There was a notable absence of any mention of oysters, but the authors were sampling soft sediment habitat with benthic grab samples, so they were not targeting the particular habitat where *O. lurida* are most abundant.]

Gilbert, C.H. 1889. Report on certain investigations regarding the planting of oysters in Southern California; Alamitos Bay and Newport Bay, California. **U. S. Fish Comm., Bull**. 9:p. 95-97.

Harry, H. 1985. Synopsis of the supraspecific classification of living oysters (Bivalvia: Gryphaeidae and Ostreidae). **Veliger** 28:121-158.

Healey, D., and K.A. Hovel. 2004. Seagrass bed patchiness: effects on epifaunal communities in San Diego Bay, USA. **Journal of Experimental Marine Biology and Ecology** 313.1: 155-174. [study of eelgrass that was outplanted to evaluate impact of eelgrass patchiness on community diversity of eelgrass epifauna. Site was adjacent to Chula Vista Wildlife Reserve in shallow subtidal habitat in 2002]

Hector, S.M. 2002. Shellfish Consumption in Early 20th Century Urban San Diego. 2002. **Pacific Coast Archaeological Society Quarterly** 38 (2&3). pp. 105-116. [Historical shellfish remains from two early 20th century sites were analyzed to examine patterns of shellfish consumption in urbanizing San Diego. One site, the County Hall of Justice, had archaeological deposits from filled wells and residential trash deposits from the turn of the century that were in excellent condition. *O. lurida* was found among the deposits and accounted for about 1% of the total weight of the finds (included several species of abalone, clams and tegula snails, among others. A second site contained trash deposits estimated to be from the 1920s-1930s, and included, interestingly, *Crassostrea virginica* shells.]

Hopkins, A. E., P. S. Galtsoff, and H. C. McMillin. 1931. Effects of pulp mill pollution on oysters. US Government Printing Office.

Howard, P. 1935. Report on Buena Vista Hills, a portion of the Midway Sunset oil field. California Oil Fields 20:5-22.

Ingersoll, E.. The oyster industry. US Government Printing Office, 1881. [In a section describing the potential for an oyster industry in estuaries and bays south of San Francisco, Ingersoll notes that only San Diego Bay has them in "sufficient size and flavor" and they are "got" in La Punta, but are small in size and have a coppery flavor.]

Kern, J. P. 1971. Paleoenvironmental analysis of a late Pleistocene estuary in southern California. **Journal of Paleontology** 45:810--823. [*O. lurida* fossils were found among Late Pleistocene sediments among other marine invertebrate fauna of the Bay Point Formation in Carmel Valley, San Diego County, California. They were found in 5 of 8 fossil beds examined attached to rock or shell. The authors noted that the average size was small (~25 mm) compared to contemporary maximum sizes for this species].

Kirby, M.X. 2004. Fishing down the coast: Historical expansion and collapse of oyster fisheries along continental margins. **Proceedings of the National Academy of Sciences of the United States of America** 101:13096-13099.

Laylander, D. and D. Iversen. 2008. SDI-4553, Major Shellfish Genera and Prehistoric Change on the San Diego County Coast. **Pacific Coast Archaeological Society Quarterly**, Volume 39 (4), p. 39-48. [This paper provides a useful overview of archaeological analyses of shell midden sites throughout western San Diego County. While at the particular site they analyzed, *O. lurida* was less than 1% of the total shells by weight, their overview of 43 other sites demonstrates that *O. lurida* was often at least 10% of the shell and as much as 50% of the shells collected at the other midden sites. This suggests that *O. lurida* was regularly exploited as a food resource throughout the Holocene.]

Lockheed Center for Marine Research. 1979. Biological Reconnaissance of Selected Sites of San Diego Bay. Technical Report submitted to the San Diego Unified Port District, San Diego, CA. [Authors characterized the biological resources at 6 sites selected by the Port of San Diego. The six study sites (24^{th} St. Marine Terminal, Chula Vista Boat Basin, Coronado Cays, Coronado Bayfront, S. San Diego Bay, Commercial Basin) were thought to be areas sensitive to future development or areas where information about biological resources were lacking. Habitats surveyed included several eelgrass beds, mudflats, dredged channels, and, at one site, seawall and pier pilings. Methods were a little unclear, but intertidal macro-biota appear to have been surveyed via 3 replicate 0.25m^2 quadrats per site, randomly placed. Not all species' presences were noted – only those deemed "common" to 2 of 3 replicates were reported. *O. lurida* was "common" at Coronado Bayfront in substrata characterized as hard/soft but its presence was not noted at other sites.]

Lotze, H. K., H.S. Lenihan, B.J. Bourque, R.H. Bradbury, R.G. Cooke, M.C. Kay, S.M. Kidwell, M.X. Kirby, C.H. Peterson, and J.B. Jackson. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. **Science** 312:1806-1809.

MacDonald, K.B., R.F. Ford, E.B. Copper, P. Unitt, and J.P. Haltiner. 1990. South San Diego Bay Enhancement Plan Resource Atlas, Volume One: Bay History, Physical Environment and Marine Ecological Characterization. Prepared for San Diego Unified Port District and California State Coastal Conservancy by Michael Brandman Associates, Inc. [This massive four-volume tome is a compilation of multiple ecological survey studies performed from 1968-1989 (many undertaken to assay effects of the South Bay Power Plant on adjacent communities), but primarily of habitats and using methods not likely to detect oysters. However, it is surprising that eelgrass beds were surveyed and subtidal grabs taken, but mention of oysters is non-existent. It is important to emphasize that even the extremely common bay mussel *Mytilus galloprovincialus,* is only briefly mentioned in two of 8 studies reviewed, underscoring that the studies were really undertaken to examine soft-sediment habitats and pelagic communities versus hard-bottom intertidal areas.]

NOAA. 2007. U.S. Department of Commerce, NOAA Restoration Center, West Coast Native Oyster Restoration: 2006 Workshop Proceedings: 108 pp.

Peeling, Thomas J. 1974. A Proximate Biological Survey of San Diego Bay, California. No. NUC-TP-389. Naval Undersea Center, San Diego, CA., 1974. [Surveys were undertaken to establish baseline data for environmental assessments and also to, "document existing conditions within the Bay." Methods to assess biological resources included sampling 10 stations using gill nets, fish traps, bacteriological sampling, and bottom samples to examine micromollusks. Note that none of those methods would sample the appropriate habitat for oysters. There was brief and non-descriptive information mentioned about dives conducted to examine pier pilings on the east and west sides of the Bay, but these surveys turned up no mention of oysters.]

Polson M., W.E. Hewson, D.J. Eernisse, P.K. Baker, and D.C. Zacherl. 2009. You say *conchaphila*, I say *lurida*: Molecular evidence for restricting the Olympia oyster (*Ostrea lurida* Carpenter 1864) to temperate western North America. **Journal of Shellfish Research** 28: 11-2. [Authors used 16S and CO3 molecular markers to test whether *O.lurida* and *Ostrea conchaphila* were distinct species. The molecular data supported the two species as reciprocally monophyletic sister species, however post-hoc morphological comparisons did not uncover morphological distinctions between species. The authors called for the revival of the species *O. lurida* Carpenter 1864 as originally described.]

Polson, M., and D.C. Zacherl. 2009. Geographic distribution and intertidal population status for the Olympia oyster, *Ostrea lurida* Carpenter 1864, from Alaska to Baja California. **Journal of Shellfish Research** 28:69-77.

Powell, C.L. II and D. Stevens. 2000. Age and Paleoenvironmental significance of mega-invertebrates from the "San Pedro" formation in the Coyote Hills, Fullerton and Buena Park, Orange County, Southern California. U.S. Geological Survey Open File Report 00-319. U.S. Department of the Interior. [*Ostrea lurida* (referenced as *conchaphila* in this publication) was among fossils from mid-Pleistocene deposits]

Raith, M., D.C. Zacherl, E.M. Pilgrim, and D.J. Eernisse (in review) Phylogeny and species diversity of Gulf of California oysters (Ostreidae) inferred from mitochondrial DNA.

Rugh, S. 2014. Clams of Champions: The San Diego Formation, from sdnhm.org, the San Diego Natural History Museum website accessed October 14, 2014. http://www.sdnhm.org/archive/research/paleontology/sdform.html

APPENDIX 1.
HISTORIC RECORDS FROM SAN DIEGO MUSEUM OF NATURAL HISTORY

SAN DIEGO NATURAL HISTORY MUSEUM
DEPARTMENT OF PALEONTOLOGY
LIST OF SELECTED GENERA AND SPECIES

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
54	15296	26th St. at San Diego Bay	27 valves, whole and partial	*Ostrea lurida*	T.A. Demere 1979
67	12545	La Jolla and La Jolla Hermosa	11 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1979
68	12527	Torrey Pines State Park, Stairway Canyon	13 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1979
69	15283	San Dieguito Valley	9 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1979
69	16464	San Dieguito Valley	2 valves, whole	*Ostrea lurida*	T.A. Demere 1979
86	12757	Loma Portal	39 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1979
99	13103	Newport Beach	2 valves, whole, left & right	*Ostrea lurida*	0
146	13369	Morena Blvd. - Santa Fe Railroad	1 valve, partial	*Ostrea angelica*	M.X. Kirby 2008
149	8130	Point Loma, east side	13 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1979
288	15725	Hilltop Quarry, San Pedro	1 valve, whole, left	*Ostrea lurida*	0
289	11293	Pacific Beach - Loring Street	1 valve, partial	*Ostrea lurida*	T.A. Demere 1979
325	15586	Tierrasanta	6 valve, whole and partial, worn	*Ostrea sp.*	H.P. Don Vito 1999
327	12491	New Lumberyard, San Pedro	2 pair, disarticulated	*Ostrea lurida*	E.P. Baker 0
412	14991	Chollas Valley, Greely St & 32nd St.	1 valve, whole	*Ostrea lurida*	T.A. Demere 1996
510	6543	Crown Point	4 valves, whole, 3 embedded in matrix	*Ostrea lurida*	0
605	8722	Isla Coronados - Belvedere Expedition	20 valves, whole, left & right	*Ostrea angelica*	N.S. Rugh 2005
605	8734	Isla Coronados - Belvedere Expedition	8 valves, whole, left & right	*Ostrea palmula*	W.K. Emerson 1962
614	13692	Isla Cerralvo - Belvedere Expedition	1 valve fragment	*Ostrea sp.*	T.A. Demere 1986
617	8572	Isla San Diego - Belvedere Expedition	1 valve fragment	*Ostrea sp.*	T.A. Demere 1981
624	5327	Turtle Bay	18 valves, whole, left & right	*Ostrea angelica*	E.P. Chace 1956
631	7723	Isla Salsipuedes	1 valve, whole	*Ostrea megodon*	0
631	13073	Isla Salsipuedes	7 valves, whole & partial, left & right	*Ostrea palmula*	T.A. Demere 1982
701	5016	San Quintin	1 valve, whole, right	*Ostrea lurida*	K. Stephens ? 0
711	5577	Playa del Rey	3 valves, whole, left	*Ostrea sp.*	H.P. Don Vito 2004
1885	13094	Nob Hill	6 valves, left & right; cluster of pairs	*Ostrea lurida*	T.S. Oldroyd 0
1899	6785	San Pedro Railroad Cut	1 valve, whole, right	*Ostrea lurida*	0
1960	13331	New Lumberyard - San Pedro	4 valves, whole & fragment	*Ostrea lurida*	E.P. Chace 0
1960A	16139	New Lumberyard - San Pedro	1 valve, whole	*Ostrea lurida*	0
1967	6818	San Pedro Lumberyard	1 valve, whole, left	*Ostrea lurida*	H.P. Don Vito 2009
1967	6819	San Pedro Lumberyard	6 valves, whole, left & right	*Ostrea lurida*	2009
1977	16282	South of Union Oil Company Property	2 valve, whole, left	*Ostrea lurida*	0
2128	13804	Magdalena Bay	3 valves, whole	*Ostrea lurida*	W.K. Emerson 0
2138	4743	San Pedro High School (15th & Leland Sts.)	65 valves, whole & partial, left & right	*Ostrea lurida*	E.P. Chace 1966
2138	6627	San Pedro High School (15th & Leland Sts.)	2 valves, whole, left & right	*Ostrea lurida*	T.A. Demere 1982
2528	12353	Coronado Island, Coronado Beach	2 valves, whole	*Ostrea lurida*	0

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LIST OF SELECTED GENERA AND SPECIES

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2578	8229	Espirito Santu Island	1 valve, partial	*Ostrea sp.*	H.P. Don Vito 2007
2619	121337	Upper Newport Bay, East Mesa	32 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 0
2623	12646	Pacific Beach	6 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1980
2624	6990	Tecolote Creek	6 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1980
2626	7914	Torrey Pines State Park	5 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1979
2659	15132	Puerto Penasco	8 valves, whole, left & right	*Ostrea palmula*	0
2660	15878	3rd & Mesa Streets, San Pedro	21 valves, whole & partial, left & right	*Ostrea lurida*	E.P. Chace 0
2660A	16318	San Pedro	2 valves, whole, left	*Ostrea lurida*	E.P. Chace 0
2666	6922	Tecolote Creek	8 valves, whole, left and right	*Ostrea angelica*	W.K. Emerson 1959
2666	6927	Tecolote Creek	15 valves, whole & partial, left & right	*Ostrea lurida*	W.K. Emerson 1959
2666	6965	Tecolote Creek	1 valves, attached to cobble	*Ostrea angelica*	W.K. Emerson 1959
2721	17951	Wilmington	2 valves, whole, right	*Ostrea lurida*	0
2724	15489	Upper Newport Bay, East Mesa	14 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 1971
2725	14457	Upper Newport Bay, East Mesa	7 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 1971
2726	15421	Upper Newport Bay, East Mesa	6 valves, whole, left & right	*Ostrea lurida*	G.L. Kennedy 1971
2726	121276	Upper Newport Bay, East Mesa	1 valve, whole, juvenile	*Ostrea sp.*	H.P. Don Vito 2009
2728	15490	Upper Newport Bay, East Mesa	1 valve, whole, left	*Ostrea lurida*	G.L. Kennedy 1971
2751	18303	San Pedro #1 - Union Oil Company	13 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
2751	18373	San Pedro #1 - Union Oil Company	56 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
2800	18808	Scammons Lagoon	10 valves, whole & partial, left & right	*Ostrea angelica*	T.A. Demere 1982
2853	20115	Carmel Valley Road	2 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1979
2870	129482	Coal Oil Point	1 valve, whole	*Ostrea sp.*	H.P. Don Vito 2011
2881	12477	Crown Point	13 valves, whole & partial, left & right	*Ostrea lurida*	0
2882	6522	Crown Point	5 valves, whole	*Ostrea lurida*	0
2904	20397	Flower Hill Shopping Center	175 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1979
2948	12685	Point Loma	1 valve, whole, left	*Ostrea lurida*	0
2966	20906	Solana Beach	57 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1979
2983	13403	Morena Blvd. - Santa Fe Railroad	5 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1979
2988	13418	Crown Point	2 valves, whole, left and right	*Ostrea lurida*	0
2991	12418	Broadway and 3rd Ave.	1 valve, whole	*Ostrea lurida*	T.A. Demere 1980
2992	81969	Upper Newport Bay, East Mesa	22 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 1971
3013	109603	Batiquitos Lagoon	10 valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2006
3020	21206	Greely and 32nd Street	15 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1980
3020	21207	Greely and 32nd Street	8 valves, whole, left and right	*Ostrea lurida*	M.X. Kirby 2008
3061	21300	E Street	2 valves, whole and partial	*Ostrea lurida*	T.A. Demere 1980

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
3062	21328	E Street	5 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1980
3064	21383	Broadway and 2nd Ave.	1 valve, whole	*Ostrea lurida*	T.A. Demere 1980
3065	21402	26th Street	26 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1980
3074	22067	Harbor Drive	876 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1982
3080	7755	San Ignacio Lagoon	4 shells in matrix	*Ostrea palmula*	N.S. Rugh 2005
3082	55058	San Ignacio	1 valve, whole, right	*Ostrea megodon*	N.S. Rugh 2007
3121A	22554	Coronado Peninsula	2 valves, 1 whole, 1 partial	*Ostrea lurida*	T.A. Demere 1982
3121B	55522	Coronado Peninsula	4 valves, whole and partial	*Ostrea lurida*	T.A. Demere 1981
3121C	23516	Coronado Peninsula	3 valves, partial	*Ostrea lurida*	T.A. Demere 1981
3133A	24621	Logan Heights, Greely Ave. & 32nd St.	31 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1981
3133B	57478	Logan Heights, Greely Ave. & 32nd St.	1 valve, whole	*Ostrea lurida*	T.A. Demere 1981
3133C	24654	Logan Heights, Greely Ave. & 32nd St.	2 valves, whole and partial	*Ostrea lurida*	T.A. Demere 1981
3133D	24616	Logan Heights, Greely Ave. & 32nd St.	87 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1981
3147	31056	Broadway & E Street, Front & First	36 valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1981
3171B	24658	Horton Plaza Redevelopment Project	15 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1983
3237A	129760	Gibson Boulevard	14 valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
3237A	129795	Gibson Boulevard	11 valves, whole, left & right	*Ostrea lurida*	H.P. Don Vito 2011
3237A	129819	Gibson Boulevard	27 valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
3237A	129862	Gibson Boulevard	25 valves, whole, left & right	*Ostrea lurida*	H.P. Don Vito 2011
3237D	29940	Gibson Boulevard	55 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1983
3237E	29844	Gibson Boulevard	227 valves, whole & partial, left & right	*Ostrea lurida*	+.A. Demere 1983
3237E	30175	Gibson Boulevard	264 valves, whole & partial, left & right	*Ostrea sp.*	T.A. Demere 1983
3239A	30522	Butcher Pit	10 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
3239A	30547	Butcher Pit	32 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
3239B	30578	Butcher Pit	20 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
3239B	30598	Butcher Pit	14 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
3239D	30479	Butcher Pit	83 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3239D	30629	Butcher Pit	54 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3239E	29957	Butcher Pit	7 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3239E	30704	Butcher Pit	3 valve, whole, left; fragments	*Ostrea lurida*	T.A. Demere 1986
3239E	30724	Butcher Pit	3 valves, partial	*Ostrea lurida*	T.A. Demere 1986
3239F	30058	Butcher Pit	1 valve, partial, right	*Ostrea sp.*	T.A. Demere 2006
3239F	30064	Butcher Pit	16 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 2006
3239F	30660	Butcher Pit	76 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3240A	30284	Chandler Pit - Bed A	15 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
3240B	30375	Chandler Pit - Bed B	56 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3240C	30237	Chandler Pit - Bed C	231 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3241	31011	San Elijo Lagoon	72 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3242	31046	San Elijo Lagoon	9 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3243	27380	Chandler Quarry	119 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1985
3243	30205	Chandler Quarry	205 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3245	30411	Bixby Slough	107 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3246A	30920	Naval Defense Fuel Reserve Quarry	332 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3246B	30974	Naval Defense Fuel Reserve Quarry	262 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3246D	30990	Naval Defense Fuel Reserve Quarry	76 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3247	30874	Naval Defense Fuel Reserve Quarry	225 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1986
3249	26474	Mulege	43 valves, whole & partial, left & right	*Ostrea angelica*	J.R. Ashby 1985
3250	26606	Mulege	5 valves, whole, left & right	*Ostrea angelica*	J.R. Ashby 1984
3256	26555	Mulege	2 valves, whole	*Ostrea angelica*	J.R. Ashby 1984
3256	26571	Mulege	2 pair, disarticulated	*Ostrea palmula*	J.R. Ashby 1984
3258	26527	Mulege	11 valves, whole & partial, left & right	*Ostrea angelica*	Minch & Ashby 1985
3258	126500	Mulege	1 valve, whole, juvenile	*Ostrea sp.*	H.P. Don Vito 2010
3259	26724	Mulege	24 valves, whole & partial, left & right	*Ostrea angelica*	J.R. Ashby 1985
3260	26633	Mulege	5 valves, whole, left & right; pair	*Ostrea palmula*	J.R. Ashby 1984
3261	26500	Mulege	120 valves, whole & partial, left & right	*Ostrea angelica*	J.R. Ashby 1985
3262	26758	Mulege	28 valves, whole & partial, left & right	*Ostrea angelica*	Ashby and Minch 1985
3263	26394	Mulege	59 valves, whole & partial, left & right	*Ostrea angelica*	J.R. Ashby 1984
3263	26429	Mulege	3 valves, whole, right	*Ostrea megodon*	J.R. Ashby 1984
3309	117046	Batiquitos Lagoon - North Side	262 valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2008
3412	88609	Ash Street and Kettner Boulevard	220 valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2003
3501	40546	Sail Bay, Mission Bay	157 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1990
3540	122612	Aviara - Phase II	2 pair, disarticulated, drilled	*Ostrea lurida*	H.P. Don Vito 2009
3540	122613	Aviara - Phase II	1 pair, articulated, juvenile	*Ostrea lurida*	H.P. Don Vito 2009
3540	122614	Aviara - Phase II	2 valves, whole, attached to Anomia valves	*Ostrea lurida*	H.P. Don Vito 2009
3540	122615	Aviara - Phase II	248 valves, whole, left & right; juveniles	*Ostrea lurida*	H.P. Don Vito 2009
3541	112796	Aviara - Phase II	915 valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2007
3541	112797	Aviara - Phase II	1 valve growing on Pecten	*Ostrea sp.*	H.P. Don Vito 2007
3632	88586	Point Loma Sludge Pipeline (Lotus St.)	3 valves, whole, left & right	*Ostrea lurida*	H.P. Don Vito 2003
3643	45002	Aviara - Pleistocene, Bed II	260 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1996
3644	45077	Aviara - Pleistocene, Bed I	204 valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1992

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION		GENUS AND SPECIES	IDENTIFIER/DATE
3645	70139	Aviara	5	valves, whole, left and right	*Ostrea lurida*	H.P. Don Vito 1999
3646	44937	Aviara - Pleistocene, Bed III	490	valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1992
3647	45341	Aviara - Unit C	41	valves, whole & partial, left & right	*Ostrea lurida*	T.A. Demere 1992
3675	45723	Morena Boulevard Pipeline 1	27	valves, whole & partial, left & right	*Ostrea lurida*	T.A.Demere 1992
3761	45977	Morena Boulevard Pipeline 2	45	valves, whole & partial, left & right	*Ostrea lurida*	T.A.Demere 1993
3764	108634	4930 West Point Loma Blvd.	6	valves, whole, left & right	*Ostrea sp.*	H.P. Don Vito 2005
3766	70900	Prospect & Herschel	1	valve, whole, left	*Ostrea sp.*	H.P. Don Vito 1999
3768	91617	Mission Bay Sewage Interceptor System	106	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2003
3861	68657	Interstate 5 and State Route 56	49	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 1999
3904	53764	Carmel Valley	3	valves, whole, left & right	*Ostrea sp.*	H.P. Don Vito 2004
3938	57816	Sambi Seaside Heights	11	valves, whole, left and right	*Ostrea lurida*	T.A. Demere 1996
4008	59256	Mission Bay Sewage Interceptor System/Pit 72	4	valves, whole, & partial, right	*Ostrea lurida*	T.A. Demere 1996
4011	89164	Wells Fargo Bank Building	39	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2003
4014B	57944	Franklin Street & Bancroft Street	2	valve fragments	*Ostrea sp.*	H.P. Don Vito 2003
4025	61197	Pacific Coast Plaza	34	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 1997
4027	61372	Pacific Coast Plaza	25	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 1997
4027	61373	Pacific Coast Plaza	1	shell fragment, edge of valve	*Ostrea sp.*	N.S. Rugh 1997
4028	61269	Pacific Coast Plaza	79	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 1997
4030	61421	Pacific Coast Plaza	11	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 1997
4031	61284	Pacific Coast Plaza	10	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 1997
4033	61318	Pacific Coast Plaza	19	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 1997
4033	61319	Pacific Coast Plaza	1	valve, fragment	*Ostrea sp.*	T.A. Demere 1997
4039	59407	Coast Boulevard	1	valve, whole, left	*Ostrea lurida*	N.S. Rugh 1997
4040	77494	Harbor Dr. & Beardsley St.-Pump Station #5	255	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 1997
4040	77495	Harbor Dr. & Beardsley St.-Pump Station #5	1	5 valves attached to Eupleura shell	*Ostrea conchaphila*	G.L. Kennedy 1997
4040	77496	Harbor Dr. & Beardsley St.-Pump Station #5	3	valves attached to cobbles	*Ostrea conchaphila*	G.L. Kennedy 1997
4097	64269	Point Loma, San Diego WWTP - NSP	3	valves, partial, left and right	*Ostrea lurida*	N.S. Rugh 1997
4098	64172	Point Loma, San Diego WWTP - NSP	3	valves, partial, left and right	*Ostrea lurida*	N.S. Rugh 1997
4099	64065	Point Loma, San Diego WWTP - NSP	1	valve, whole, right	*Ostrea lurida*	N.S. Rugh 1997
4102	63950	Point Loma, San Diego WWTP - NSP	2	valves, left and right, whole	*Ostrea lurida*	N.S. Rugh 1997
4128	60000	Legoland #3	1	steinkern	*Ostrea sp.*	N.S. Rugh 1998
4129	64991	Legoland #4	2	steinkerns	*Ostrea sp.*	N.S. Rugh 1998
4130	64998	Legoland #5	16	steinkerns	*Ostrea sp.*	N.S. Rugh 1998
4210	73800	Torrey Reserve Heights/Hills	402	valves, left & right, some in clusters	*Ostrea sp.*	R.Q. Gutzler 1998
4295	70457	Macario Bridge	1	valve, whole, right	*Ostrea lurida*	N.S. Rugh 1999

SAN DIEGO NATURAL HISTORY MUSEUM
DEPARTMENT OF PALEONTOLOGY
LIST OF SELECTED GENERA AND SPECIES

LOC #	SPEC #	LOCALITY NAME	NO.	ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
4298	74961	San Onofre Bluff	6	valves, whole, left & right	*Ostrea lurida*	H.P. Don Vito 1999
4299	74279	La Jolla Bay	1	valve, partial, right	*Ostrea lurida*	J.P. Kern 0
4303	120091	Point Loma, Point Loma Lighthouse	1	valve, whole, right	*Ostrea lurida*	J.P. Kern 1977
4304	74418	Meadow Grove Drive	605	valves, whole & partial, left & right	*Ostrea lurida*	J.P. Kern 0
4304	74419	Meadow Grove Drive	2	valves, whole, right	*Ostrea sp.*	H.P. Don Vito 1999
4306	71073	Solana Beach Grade Change	29	valves, whole and partial, left & right	*Ostrea lurida*	N.S. Rugh 1999
4313	71115	Solana Beach Grade Change	2	valve impressions	*Ostrea sp.*	N.S. Rugh 1999
4327	71123	Solana Beach Grade Change	4	steinkerns, valves, partial,left & right	*Ostrea lurida*	N.S. Rugh 1999
4351	74144	La Jolla Shores Pipeline	3	valves, whole, left & right	*Ostrea lurida*	Carol Stadum 1997
4371	75032	Holy Apostles Mausoleum, Holy Cross Cemetery	1	cast, valve, right, poorly preserved	*Ostrea sp.*	N.S. Rugh 1999
4418	75410	235 On Market	5	valves, whole & partial, some on 1 clam	*Ostrea lurida*	N.S. Rugh 2000
4447	80424	Newport Blvd. near Santa Isabella Ave.	33	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2001
4447	80425	Newport Blvd. near Santa Isabella Ave.	20	valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 2001
4556	80004	Parkloft Apartments, Island Street	101	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2001
4557	80021	Parkloft Apartments, Island Street	52	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2001
4558	80043	Parkloft Apartments, Island Street	150	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2001
4648	95503	Crown Point, 3543 Riviera Drive	47	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2004
4660	108806	Crown Point, 3543 Riviera Drive	19	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2005
4661	104100	Crown Point, 3543 Riviera Drive	104	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2005
4686A	85429	Avenida Vista Hermosa ES 75+58m	18	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Anderson 2002
4686B	85489	Avenida Vista Hermosa ES 75+58m	8	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Anderson 2002
4686C	85292	Avenida Vista Hermosa ES 75+58m	97	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2002
4687	86380	Avenida Vista Hermosa ES 73+43m	4	valves, whole and partial	*Ostrea lurida*	N.S. Rugh 2002
4688A	84770	Avenida Vista Hermosa ES 74+81m	249	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2002
4688A	84771	Avenida Vista Hermosa ES 74+81m	1	valve attached to Protothaca valve	*Ostrea lurida*	N.S. Rugh 2002
4688B	84671	Avenida Vista Hermosa ES 74+81m	2	valves, whole & partial, worn	*Ostrea lurida*	N.S. Rugh 2002
4689	84636	Avenida Vista Hermosa ES 74+58m	11	valves, partial, worn	*Ostrea lurida*	N.S. Rugh 2002
4690B	84904	Avenida Vista Hermosa ES 74+20m	1	valve, partial	*Ostrea lurida*	M.K. Anderson 2002
4727B	92724	Pacific Coast Highway & West F Street	4	valves, whole & partial	*Ostrea sp.*	H.P. Don Vito 2003
4727C	95355	Pacific Coast Highway & West F Street	1	valve, whole, right	*Ostrea sp.*	H.P. Don Vito 2004
4727E	92795	Pacific Coast Highway & West F Street	3	articulated pair & valve fragments	*Ostrea sp.*	H.P. Don Vito 2004
4727F	95174	Pacific Coast Highway & West F Street	2	valve, whole and fragment	*Ostrea sp.*	H.P. Don Vito 2004
4728	88005	Market Square Manor (14th St. & Market St.)	238	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2002
4729	86846	Market Square Manor (14th St. & Market St.)	187	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2002
4731	103595	Crown Point, 3543 Riviera Drive	7	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2005

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4781	91499	Park Avenue West - Main Shell Bed	909	valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2003
4820	86885	Sewer & Water Group 697, Site #1	128	valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2002
4841	91549	Park Avenue West - Chione Pair Bed	18	valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2003
4859	93994	Coronado Island, Glorietta Bay	1	valve, partial	*Ostrea sp.*	H.P. Don Vito 2004
4868	90206	Sewer Group 632	29	valves, whole & partial, left & right	*Ostrea conchaphila*	J.L.D. 2003
4909	99514	Sewer Group 719 - Ocean Beach	9	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2004
4911	99663	Sewer Group 719 - Ocean Beach	6	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2004
4912	90899	Tower 23 Hotel & Restaurant	1	valve, partial, left	*Ostrea conchaphila*	G.L. Kennedy 2004
4948	91700	Sewer Group 722	68	valves, whole, left & right	*Ostrea lurida*	M.K. Anderson 2003
4948	91701	Sewer Group 722	5	clusters attached to Argopecten valves	*Ostrea lurida*	M.K. Anderson 2003
4949	91467	Sewer Group 722	689	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Anderson 2003
4951	91933	Sewer Group 722	162	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Anderson 2003
4952	92211	Gaslamp Square (4th and Island)	4	valves, whole, and clusters	*Ostrea lurida*	N.S. Rugh 2003
4952	92237	Gaslamp Square (4th and Island)	7	valves, whole, left & right, and pairs	*Ostrea lurida*	N.S. Rugh 2003
4985	93397	Coronado - Pacific Bell Building Addition	2	valve, whole and fragment	*Ostrea lurida*	N.S. Rugh 2004
4986A	102993	Coronado - Pacific Bell Building Addition	8	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2005
4986B	95997	Coronado - Pacific Bell Building Addition	10	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2004
4986C	95864	Coronado - Pacific Bell Building Addition	2	valves, whole, worn	*Ostrea sp.*	H.P. Don Vito 2004
4986D	102528	Coronado - Pacific Bell Building Addition	2	valve fragments, very worn	*Ostrea lurida*	N.S. Rugh 2005
5002	107976	La Costa Development	3	valves, whole & partial, left & right	*Ostrea lurida*	G. VanSlyke 1965
5003	49078	Point Loma, west side	5	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2005
5008	91720	San Elijo Lagoon - Southeast Fork	2	valve, partial, left and fragment	*Ostrea lurida*	D.E. Thompson 1966
5009	92607	San Dieguito Valley - I-5 & Via de la Valle	29	valves, whole & partial, left & right	*Ostrea lurida*	D.E. Thompson 0
5010	114733	Sorrento Valley	11	valves, whole, left & right	*Ostrea lurida*	J.P. Kern 1971
5016	114794	Crown Point	17	valves, whole & partial, left & right	*Ostrea lurida*	SDSC student 0
5077	125108	Pacific Ave. & Bonita Streets, San Pedro	68	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2010
5107	91948	Tecolote Creek	1	valve, whole, left	*Ostrea lurida*	H.P. Don Vito 2003
5125	93036	Punta Chivato	33	valves, whole, left & right	*Ostrea angelica*	N.S. Rugh 2003
5125	93038	Punta Chivato	3	valves, juvenile	*Ostrea sp.*	H.P. Don Vito 2004
5230	81374	Bahia San Francisquito	1	hinge, worn	*Ostrea sp.*	N.S. Rugh 2001
5236	91980	Tecolote Creek	26	valves, whole & partial, left & right	*Ostrea lurida*	R.G. Reed 1966
5276	116052	Upper Newport Bay - East Mesa	17	valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 0
5277	4290	Upper Newport Bay - East Mesa	1	valve, whole, left	*Ostrea lurida*	G.L. Kennedy 1971
5278	121886	Upper Newport Bay - East Mesa	7	valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 0
5279	121911	Upper Newport Bay - East Mesa	19	valves, whole & partial, left & right	*Ostrea sp.*	G.L. Kennedy 0

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5280	121958	Upper Newport Bay - East Mesa	19	valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 0
5281	121995	Upper Newport Bay - East Mesa	1	valve, whole, left	*Ostrea lurida*	G.L. Kennedy 0
5289	112360	Coronado Island, Glorietta Bay	2	valves, whole, left	*Ostrea lurida*	SDSC student 0
5293	119455	Parkside Terrace	1670	valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2008
5294	124909	New Lumberyard - San Pedro	53	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2010
5295	125405	San Pedro - 3rd & Mesa Streets	16	valves, whole, left & right	*Ostrea lurida*	H.P. Don Vito 2010
5298	126082	Morena Blvd. - Santa Fe Railroad Tracks	10	valves, whole & partial, left & right	*Ostrea angelica*	T.A. Demere 2009
5298	126083	Morena Blvd. - Santa Fe Railroad Tracks	7	valves, whole & partial, left & right	*Ostrea lurida*	J.P. Kern 0
5299	126168	Morena Blvd. - Santa Fe Railroad	15	valves, whole & partial, left & right	*Ostrea lurida*	J.P. Kern 1971
5301A	126550	Morena Blvd. - Santa Fe Railroad Tracks	32	valves, whole & partial, left & right	*Ostrea lurida*	J.P. Kern 1971
5301B	126674	Morena Blvd. - Santa Fe Railroad Tracks	46	valves, whole & partial, left & right	*Ostrea lurida*	J.P. Kern 1971
5301C	126702	Morena Blvd. - Santa Fe Railroad Tracks	10	valves, partial & fragment	*Ostrea lurida*	J.P. Kern 1971
5303	125242	San Pedro	47	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2010
5304	125336	Potrero Canyon	5	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2010
5424	93902	Park East - Anomia Bed	423	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2004
5425	93912	Park East - Pecten Bed	37	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2004
5431	59058	I-5 and Evans Street - #1	29	valves, whole, left & right; cluster	*Ostrea lurida*	N.S. Rugh 2007
5431	59059	I-5 and Evans Street - #1	7	valves, left, attached to Argopectens	*Ostrea lurida*	N.S. Rugh 2007
5432	59093	I-5 and Evans Street - #2 - General Locality	127	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2008
5432A	59116	I-5 and Evans Street - #2 - Lower	197	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2008
5432B	59142	I-5 and Evans Street - #2 - Upper	85	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2008
5432B	59143	I-5 and Evans Street - #2 - Upper	1	paris attached to large Argopecten valve	*Ostrea lurida*	N.S. Rugh 2008
5433	59172	I-5 and Evans Street - #3	16	valves, whole, left & right	*Ostrea lurida*	H.P. Don Vito 2008
5433	59178	I-5 and Evans Street - #3	12	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2008
5434	59187	I-5 and Evans Street - #4	54	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2008
5442	102213	Metrome - Bed A	15	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Soetaert 2005
5443	102216	Metrome - Bed B	6	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Soetaert 2005
5444	102168	Metrome - Bed C	583	valves, whole, left & right, 1 pair	*Ostrea lurida*	N.S. Rugh 2005
5444	102169	Metrome - Bed C	4	valves attached to pectens	*Ostrea lurida*	N.S. Rugh 2005
5447	102221	Metrome - Bed F	4	valves, partial	*Ostrea lurida*	M.K. Soetaert 2005
5479	99030	Sewer Pump Station 18 Rehabilitation	3	valves, whole, left & right	*Ostrea sp.*	G.L. Kennedy 2005
5481	104720	Sewer Pump Station 18 Rehabilitation	1	valve fragment	*Ostrea sp.*	G.L. Kennedy 2005
5491	99111	M2i - Pecten Bed	317	valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2004
5494	101375	Gaslamp II - Turritella Bed	14	valves, left & right, and 1 pair	*Ostrea lurida*	N.S. Rugh 2005
5495	101404	Gaslamp II - Pecten Bed	603	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2005

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5525	102089	Sewer Group 733	200	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2005
5617	106007	11th & K Streets	63	valves, whole, left & right	*Ostrea sp.*	N.S. Rugh 2005
5617	106008	11th & K Streets	1	cluster of valves & articulated pairs	*Ostrea sp.*	N.S. Rugh 2005
5617	106009	11th & K Streets	2	articulated pair, separated	*Ostrea sp.*	N.S. Rugh 2005
5635	123261	Point Loma, East Side, South of Ballast Pt.	2	valves, whole & partial	*Ostrea lurida*	J.P. Kern 1972
5636	126761	Point Loma, East Side, South of Ballast Pt.	4	valves, partial, left & right	*Ostrea lurida*	J.P. Kern 1972
5663	124582	Alta	56	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2010
5664	124610	Alta	4	valves, whole & partial, right	*Ostrea lurida*	H.P. Don Vito 2010
5670	108896	4065 Gresham Street	3	valves, whole, left, juveniles	*Ostrea sp.*	H.P. Don Vito 2006
5671	108960	4065 Gresham Street	3	valves, whole, right, juveniles	*Ostrea sp.*	H.P. Don Vito 2006
5727	110010	Nexus A	7	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5728	111060	Nexus B - Upper Broadway Horizon	6	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Soetaert 2006
5729	111164	Nexus C - Lower Broadway Float	19	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2006
5730	111117	Nexus C - Lower Broadway Eastern Collection	311	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5731	111191	Nexus C - Lower Broadway Western Collection	1	articulated pair	*Ostrea lurida*	N.S. Rugh 2006
5731	111192	Nexus C - Lower Broadway Western Collection	1	oyster valves attached to Anomia valve	*Ostrea lurida*	N.S. Rugh 2006
5731	111193	Nexus C - Lower Broadway Western Collection	2	oyster valves attached to pecten valves	*Ostrea lurida*	N.S. Rugh 2006
5731	111194	Nexus C - Lower Broadway Western Collection	179	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5732	111238	Nexus D	2	pair, disarticulated	*Ostrea lurida*	N.S. Rugh 2006
5732	111239	Nexus D	52	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5750	108146	Diamond View Tower - Pecten Bed	408	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2006
5751	108183	Diamond View Tower - Oyster Stringer	2	valves, partial	*Ostrea lurida*	M.K. Soetaert 2006
5761	116483	Cabrillo-Point Loma	224	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
5790	109713	Sea Port Housing Development	23	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2006
5810	116493	Cabrillo-Point Loma	43	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Soetaert 2008
5816	116498	Cabrillo-Point Loma	155	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
5817	116508	Cabrillo-Point Loma	101	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
5818	116517	Cabrillo-Point Loma	62	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
5819	116526	Cabrillo-Point Loma	143	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
5832	111582	Hotel Del Coronado, Bed A	54	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5833	111776	Hotel Del Coronado, Bed B	26	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5834	112864	Hotel Del Coronado, Bed C	4	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2006
5894	114079	SDG&E OMPPA Transmission Project	1186	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2007
5894	114080	SDG&E OMPPA Transmission Project	3	articulated pairs	*Ostrea lurida*	M.K. Soetaert 2007
5894	114081	SDG&E OMPPA Transmission Project	3	valves attached to other shells	*Ostrea lurida*	M.K. Soetaert 2007

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5895	114198	SDG&E OMPPA Transmission Project	1	articulated pair	*Ostrea lurida*	M.K. Soetaert 2007
5895	114199	SDG&E OMPPA Transmission Project	173	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2007
5896	11427	SDG&E OMPPA Transmission Project	1	valve attached to Eupleura shell	*Ostrea lurida*	M.K. Soetaert 2007
5896	114275	SDG&E OMPPA Transmission Project	2	articulated pairs, whole	*Ostrea lurida*	M.K. Soetaert 2007
5896	114276	SDG&E OMPPA Transmission Project	152	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Soetaert 2007
5899	112259	Gateway 1	2	steinkern & mold,valve, part-counterpart	*Ostrea sp.*	N.S. Rugh 2006
5899	112260	Gateway 1	2	steinkern & mold, valve, partial	*Ostrea sp.*	N.S. Rugh 2006
5900	112277	Gateway 1	1	steinkern, valve, left	*Ostrea lurida*	N.S. Rugh 2006
5910	112048	Gardenwalk, Phase 1	2	valve, fragments, very worn	*Ostrea sp.*	N.S. Rugh 2006
5935	112197	Interstate 5/805 Merge	29	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2006
5936	114394	SDG&E OMPPA Transmission Project	12	valves attached to other shells	*Ostrea lurida*	N.S. Rugh 2007
5936	114395	SDG&E OMPPA Transmission Project	1006	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2007
5954	112590	Crown Point - 3330 Jewell Street	37	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2007
5958	113612	Central Police Garage Remediation-Anomia Bed	101	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2007
5958	113613	Central Police Garage Remediation-Anomia Bed	3	valves attached to pecten valve fragment	*Ostrea lurida*	M.K. Soetaert 2007
5959	113639	Central Police Garage Remediation-Pecten Bed	132	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2007
5959	113640	Central Police Garage Remediation-Pecten Bed	1	pair, on Pecten vogdesi valve fragment	*Ostrea lurida*	M.K. Soetaert 2007
5959	113641	Central Police Garage Remediation-Pecten Bed	7	valves,left on pecten fragments & Anomia	*Ostrea lurida*	N.S. Rugh 2007
6021	116202	I-5 Ramp Widening & Retaining Wall - Bed C	8	valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2007
6021	116203	I-5 Ramp Widening & Retaining Wall - Bed C	17	valves, whole, left, juvenile	*Ostrea lurida*	N.S. Rugh 2007
6021	116204	I-5 Ramp Widening & Retaining Wall - Bed C	2	valves, whole, left	*Ostrea lurida*	N.S. Rugh 2007
6022	116242	I-5 Ramp Widening & Retaining Wall - Bed E	1	cluster of 2 pairs	*Ostrea lurida*	N.S. Rugh 2007
6022	116243	I-5 Ramp Widening & Retaining Wall - Bed E	8	articulated pairs	*Ostrea lurida*	N.S. Rugh 2007
6022	116244	I-5 Ramp Widening & Retaining Wall - Bed E	8	clusters of valves and pairs	*Ostrea lurida*	N.S. Rugh 2007
6022	116245	I-5 Ramp Widening & Retaining Wall - Bed E	29	valves, whole & partial, left and right	*Ostrea lurida*	N.S. Rugh 2007
6022	116246	I-5 Ramp Widening & Retaining Wall - Bed E	134	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2007
6023	116818	1353 La Palma - Bed A	22	valves, whole & partial, left & right	*Ostrea lurida*	M.K. Soetaert 2008
6024	116597	1353 La Palma - Bed B	249	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2008
6025	115681	1353 La Palma - Bed C	166	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2007
6026	115414	1353 La Palma - Bed D	3	valves, whole & partial, juveniles	*Ostrea sp.*	H.P. Don Vito 2007
6095	119192	SDG&E Silvergate Substation	1762	valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2008
6097	119491	SDG&E Silvergate Substation	6	valves, right, most on matrix	*Ostrea lurida*	N.S. Rugh 2008
6098	118949	SDG&E Silvergate Substation	1294	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
6098	118950	SDG&E Silvergate Substation	1	valve attached to Eupleura shell	*Ostrea lurida*	M.K. Soetaert 2008
6099	120298	SDG&E Silvergate Substation	10	valves attached to various shells	*Ostrea lurida*	H.P. Don Vito 2008

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
6099	120299	SDG&E Silvergate Substation	314 valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2008
6100	119098	SDG&E Silvergate Substation	864 valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2008
6101	119531	SDG&E Silvergate Substation - Boreholes	5 valves, right, attached to other shells	*Ostrea lurida*	M.K. Soetaert 2008
6101	119532	SDG&E Silvergate Substation - Boreholes	151 valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
6101	119533	SDG&E Silvergate Substation - Boreholes	6 left & right valves of pair, & juveniles	*Ostrea lurida*	M.K. Soetaert 2008
6101	119534	SDG&E Silvergate Substation - Boreholes	2 valves, whole, left & right, of a pair	*Ostrea lurida*	M.K. Soetaert 2008
6103	118881	SDG&E Silvergate Substation - Pecten Bed	31 valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
6104	118773	SDG&E Silvergate Substation	16 left valve clusters	*Ostrea lurida*	N.S. Rugh 2008
6104	118774	SDG&E Silvergate Substation	185 valves, whole, left and right	*Ostrea lurida*	N.S. Rugh 2008
6104	118775	SDG&E Silvergate Substation	8 valves, whole, left & right, 4 pairs	*Ostrea lurida*	N.S. Rugh 2008
6104	118776	SDG&E Silvergate Substation	1 valves, whole, left, on Dosina valve	*Ostrea lurida*	N.S. Rugh 2008
6104	118777	SDG&E Silvergate Substation	12 valves, whole, left, on misc. shells	*Ostrea lurida*	N.S. Rugh 2008
6105	119312	SDG&E Silvergate Substation	539 valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2008
6105	119313	SDG&E Silvergate Substation	1 valves attached to Dosina valve	*Ostrea lurida*	M.K. Soetaert 2008
6105	119314	SDG&E Silvergate Substation	9 valves attached to snails	*Ostrea lurida*	M.K. Soetaert 2008
6106	119036	SDG&E Silvergate Substation	710 valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2008
6124	118186	Marriott Residence Inn	10 steinkern, valve, poorly preserved	*Ostrea sp.*	N.S. Rugh 2008
6125	118196	Marriott Residence Inn	17 valves, whole & partial, left and right	*Ostrea lurida*	N.S. Rugh 2008
6129	116178	Strata Condominiums	17 valves, whole and partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2008
6131	119410	Hotel Indigo - northeast corner of project	398 valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2008
6131	119411	Hotel Indigo - northeast corner of project	5 valves, whole, left, on other shells	*Ostrea conchaphila*	G.L. Kennedy 2008
6132	119392	Hotel Indigo - northwest corner of project	16 valves, whole & partial, left & right	*Ostrea conchaphila*	G.L. Kennedy 2008
6170	121056	Ten Fifty B Street - Upper Concreted Bed	2 valves, whole & partial, 1 on matrix	*Ostrea vespertina*	N.S. Rugh 2008
6192	120701	Robertson Ranch PA 12 & 13, Wildlife Corridor	1 valve, worn	*Ostrea lurida*	N.S. Rugh 2008
6194	120719	Robertson Ranch PA 12 & 13, Wildlife Corridor	1 valve, partial	*Ostrea sp.*	N.S. Rugh 2008
6203	120776	Robertson Ranch PA 12 & 13, Wildlife Corridor	3 valves, whole, right	*Ostrea lurida*	N.S. Rugh 2008
6204	120812	Robertson Ranch PA 12 & 13, Wildlife Corridor	1 valve, whole, right	*Ostrea lurida*	N.S. Rugh 2008
6285	123305	SDG&E TL650/651 Split	18 valves, whole, partial,& valve fragments	*Ostrea lurida*	H.P. Don Vito 2009
6285	123306	SDG&E TL650/651 Split	1 valve, whole, from spoils pile	*Ostrea lurida*	H.P. Don Vito 2009
6293	123465	Harbor Dr. & Beardsley St.-Pump Station #5	581 valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2009
6293	123466	Harbor Dr. & Beardsley St.-Pump Station #5	1 articulated pair	*Ostrea lurida*	H.P. Don Vito 2009
6293	123467	Harbor Dr. & Beardsley St.-Pump Station #5	15 valves attached to various shells	*Ostrea lurida*	H.P. Don Vito 2009
6294	124339	Thomas Jefferson School of Law-Anomia/Pecten	1 articulated pair	*Ostrea lurida*	N.S. Rugh 2009
6294	124340	Thomas Jefferson School of Law-Anomia/Pecten	2 articulated pairs	*Ostrea lurida*	N.S. Rugh 2009
6294	124341	Thomas Jefferson School of Law-Anomia/Pecten	363 valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2009

LOC #	SPEC #	LOCALITY NAME	NO.	ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
6294	124342	Thomas Jefferson School of Law-Anomia/Pecten	1	valve, left, partial on pecten fragment	*Ostrea lurida*	N.S. Rugh 2009
6296	124370	Thomas Jefferson School of Law-Anomia bed 1	6	disarticulated pairs (3)	*Ostrea lurida*	N.S. Rugh 2009
6296	124371	Thomas Jefferson School of Law-Anomia bed 1	5	articulated pairs, with matrix inside	*Ostrea lurida*	N.S. Rugh 2009
6296	124372	Thomas Jefferson School of Law-Anomia bed 1	3	valves and pairs in clusters	*Ostrea lurida*	N.S. Rugh 2009
6296	124373	Thomas Jefferson School of Law-Anomia bed 1	216	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2009
6297	124390	Thomas Jefferson School of Law-Anomia bed 2	16	valves, whole, left & right	*Ostrea lurida*	N.S. Rugh 2009
6298	124398	Thomas Jefferson School of Law - Pecten bed	106	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2009
6303	126017	Thomas Jefferson School of Law - Whale Site	2	valves, whole	*Ostrea lurida*	H.P. Don Vito 2010
6336	125780	Water Group Job 793	260	valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2010
6338	126367	Famosa Accelerated Water & Sewer Main	1	internal mold of valve, whole	*Ostrea sp.*	G.L. Kennedy 2010
6352	130516	Sunset Cliffs Trunk Sewer	232	valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2011
6353	130425	Sunset Cliffs Trunk Sewer	24	valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2011
6354	130785	Sunset Cliffs Trunk Sewer	97	valves, whole & partial, left & right	*Ostrea lurida*	G.L Kennedy 2011
6362	125916	7th and Market - Turritella Bed	1	valve, attached to Turritella	*Ostrea lurida*	N.S. Rugh 2010
6362	125917	7th and Market - Turritella Bed	1	articulated pair attached to Megapitaria	*Ostrea lurida*	N.S. Rugh 2010
6362	125918	7th and Market - Turritella Bed	1	valve, attached to Megapitaria valve	*Ostrea lurida*	N.S. Rugh 2010
6362	125919	7th and Market - Turritella Bed	119	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2010
6362	125920	7th and Market - Turritella Bed	5	cluster on Anomia & Argopecten valves	*Ostrea lurida*	N.S. Rugh 2010
6364	126950	Borderfield State Park	1	valve, whole	*Ostrea lurida*	H.P. Don Vito 2010
6365	129586	New Border Fence	14	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
6366	127221	New Border Fence	13	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2010
6367	129668	New Border Fence	3	valves, whole, right	*Ostrea sp.*	H.P. Don Vito 2011
6367	129669	New Border Fence	1	valve with bryozoa on it	*Ostrea sp.*	H.P. Don Vito 2011
6430	127977	Deadman's Island - Grouard Collection	10	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2007
6437	128230	Sewer Group 745	296	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
6437	128231	Sewer Group 745	5	valves, whole, left, attached to chione	*Ostrea lurida*	H.P. Don Vito 2011
6438	128269	Sewer Group 745	11	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
6438	128270	Sewer Group 745	9	valves attached to chiones & pectens	*Ostrea lurida*	H.P. Don Vito 2011
6438	128314	Sewer Group 745	20	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
6438	128315	Sewer Group 745	3	articulated pairs	*Ostrea lurida*	H.P. Don Vito 2011
6438	128316	Sewer Group 745	1	valves attached to chione valve	*Ostrea lurida*	H.P. Don Vito 2011
6438	128317	Sewer Group 745	1	valves attached to inside of ostrea	*Ostrea lurida*	H.P. Don Vito 2011
6439	128358	Sewer Group 745	22	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
6442	128449	Restaurant Depot	190	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2011
6442	128450	Restaurant Depot	1	articulated pair attached to Eupleura	*Ostrea lurida*	M.K. Soetaert 2011

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6442	128451	Restaurant Depot	1	valve attached to Tagelus valve	*Ostrea lurida*	M.K. Soetaert 2011
6443	128517	Restaurant Depot	70	valves, whole, left & right	*Ostrea lurida*	M.K. Soetaert 2011
6467	129899	San Diego New Central Library - Chione Bed	17	valves, partial, left & right	*Ostrea lurida*	E.G. Ekdale 2011
6468	129911	San Diego New Central Library - Oyster Bed	1	pair, articulated w/ oysters attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129912	San Diego New Central Library - Oyster Bed	1	pair, articulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129913	San Diego New Central Library - Oyster Bed	1	pair, articulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129914	San Diego New Central Library - Oyster Bed	1	pair, articulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129915	San Diego New Central Library - Oyster Bed	1	pair, articulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129916	San Diego New Central Library - Oyster Bed	1	pair, articulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129917	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129918	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oyster attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129919	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129920	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129921	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129922	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129923	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oysters attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129924	San Diego New Central Library - Oyster Bed	3	pairs, disarticulated, attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129925	San Diego New Central Library - Oyster Bed	3	pairs, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129926	San Diego New Central Library - Oyster Bed	3	pairs, disarticulated, attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129927	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129928	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129929	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129930	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129931	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129932	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oysters attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129933	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129934	San Diego New Central Library - Oyster Bed	3	pairs, disarticulated, attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129935	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129936	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oyster attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129937	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129938	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oyster attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129939	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ internal mold	*Ostrea lurida*	E.G. Ekdale 2011
6468	129940	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129941	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oyster attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129942	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oysters attached	*Ostrea lurida*	E.G. Ekdale 2011

LOC #	SPEC #	LOCALITY NAME	NO.	ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
6468	129943	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ cluster attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129944	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129945	San Diego New Central Library - Oyster Bed	2	pair, partial, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129946	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129947	San Diego New Central Library - Oyster Bed	2	pair, disarticulated w/ oyster attached	*Ostrea lurida*	E.G. Ekdale 2011
6468	129948	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129949	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129950	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129951	San Diego New Central Library - Oyster Bed	2	pair, disarticulated	*Ostrea lurida*	E.G. Ekdale 2011
6468	129952	San Diego New Central Library - Oyster Bed	2	valve, whole, with internal mold	*Ostrea lurida*	E.G. Ekdale 2011
6468	129953	San Diego New Central Library - Oyster Bed	248	valves, whole & partial, left & right	*Ostrea lurida*	E.G. Ekdale 2011
6469	129966	San Diego New Central Library - Pecten Bed	16	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2011
6469	129967	San Diego New Central Library - Pecten Bed	2	valves attached to Argopecten	*Ostrea lurida*	H.P. Don Vito 2011
6469	129986	San Diego New Central Library - Pecten Bed	114	valves, whole & partial, left & right	*Ostrea lurida*	E.G. Ekdale 2011
6469	130004	San Diego New Central Library - Pecten Bed	1	pair, articulated	*Ostrea lurida*	E.G. Ekdale 2011
6469	130005	San Diego New Central Library - Pecten Bed	2	valves, partial, left & right	*Ostrea lurida*	E.G. Ekdale 2011
6470	129957	San Diego New Central Library - Anomia Bed	326	valves, whole & partial, left & right	*Ostrea lurida*	E.G. Ekdale 2011
6471	128137	Sewer and Water Group 728	101	valves, partial and whole	*Ostrea lurida*	G L Kennedy 2011
6472	128144	Sewer and Water Group 728	101	valvles, partial and whole	*Ostrea lurida*	G L Kennedy 2011
6473	128150	Sewer and Water Group 728	128	valves, partial and whole	*Ostrea lurida*	G L Kennedy 2011
6474	128072	15th and Island	121	partial valves	*Ostrea lurida*	G. L. Kennedy 2011
6553	131695	Flower Hill Promenade	3	valves attached to Pinna valve fragments	*Ostrea lurida*	H.P. Don Vito 2012
6553	131696	Flower Hill Promenade	1	valve attached to snail shell	*Ostrea lurida*	H.P. Don Vito 2012
6553	131697	Flower Hill Promenade	1	pair, articulated	*Ostrea lurida*	H.P. Don Vito 2012
6553	131698	Flower Hill Promenade	630	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2012
6555	132579	Flower Hill Promenade	38	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2012
6558	133554	Flower Hill Promenade	1	pair, articulated, juvenile	*Ostrea lurida*	H.P. Don Vito 2012
6558	133555	Flower Hill Promenade	137	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2012
6561	132014	Flower Hill Promenade	7	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2012
6561	133454	Flower Hill Promenade	27	valves, whole & partial, left & right	*Ostrea lurida*	H.P. Don Vito 2012
6562	133701	Flower Hill Promenade	8	valves, whole, left & right, juveniles	*Ostrea lurida*	H.P. Don Vito 2012
6584	131357	Mercado del Barrio	48	valves, partial, left & right, fragments	*Ostrea lurida*	G.L. Kennedy 2012
6586	131553	Carmel Valley Residence Inn	34	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2012
6586	131554	Carmel Valley Residence Inn	1	valve, right	*Ostrea palmula*	G.L. Kennedy 2012
6591	132486	SDCC Business Tech/Arts & Humanities Bld.	9	valves, whole & partial, right	*Ostrea sp.*	T.A. Demere 2012

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
6605	133207	13th and Market Street	9 valve fragments	*Ostrea sp.*	G.L. Kennedy 2012
6606	133227	13th and Market Street	188 valves, whole & partial, left	*Ostrea lurida*	G.L. Kennedy 2012
6607	133274	13th and Market Street	525 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2012
6608	133286	13th and Market Street	38 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2012
6609	133300	13th and Market Street	57 valves, whole & partial, left	*Ostrea lurida*	G.L. Kennedy 2012
6610	133781	13th and Market Street	80 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2012
6620	132348	Broadstone Little Italy	1 mold, internal	*Ostrea sp.*	T.A. Demere 2012
6622	132357	Broadstone Little Italy	2 molds, internal & external	*Ostrea sp.*	T.A. Demere 2012
6635	133246	13th and Market Street	20 valves, whole & partial, left & right	*Ostrea lurida*	G.L. Kennedy 2012
6637	133876	Ariel Suites (Beech & Kettner)	2734 valves, whole & partial, left & right	*Ostrea lurida*	Kennedy & Rugh 2013
6637	133877	Ariel Suites (Beech & Kettner)	6 valves, partial	*Ostrea sp.*	Kennedy & Rugh 2013
6638	133813	Ariel Suites (Beech & Kettner)	34 valves, whole & partial, left & right	*Ostrea lurida*	Kennedy & Rugh 2013
6638	133814	Ariel Suites (Beech & Kettner)	3 hinges, worn	*Ostrea sp.*	Kennedy & Rugh 2013
6639	134029	Ariel Suites (Beech & Kettner)	37 valves, whole & partial, left & right	*Ostrea sp.*	Kennedy & Rugh 2013
6640	134043	Ariel Suites (Beech & Kettner)	4 valves, whole, left & right	*Ostrea palmula*	Kennedy & Rugh 2013
6640	134044	Ariel Suites (Beech & Kettner)	18 valves, whole & partial, left & right	*Ostrea sp.*	Kennedy & Rugh 2013
6641	134051	Ariel Suites (Beech & Kettner)	22 valves, whole & partial, left & right	*Ostrea sp.*	Kennedy & Rugh 2013
6642	134019	Ariel Suites (Beech & Kettner)	1 valve, whole, left	*Ostrea palmula*	Kennedy & Rugh 2013
6665	135111	SDCC Science Building Project	13 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2013
6666	135113	SDCC Science Building Project	16 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2013
6669	135145	SDCC Science Building Project	1 valves,left	*Dendostrea vespertina*	R.M. Hubscher 2013
6669	135146	SDCC Science Building Project	8 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2013

DATE 05/16/13
TIME 15:39:15

SAN DIEGO NATURAL HISTORY MUSEUM
DEPARTMENT OF PALEONTOLOGY
LIST OF SELECTED GENERA AND SPECIES

LOC #	SPEC #	LOCALITY NAME	NO.	ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
3173	25067	Chollas Valley, Beech St. & 38th St.	1	attached valves (3)	*Ostrea sp.*	T.A. Demere 1983
3281C	28901	Gateway Center East - Bed C	1	valve, whole, right	*Ostrea sp.*	T.A. Demere 1986
3281D	28902	Gateway Center East - Bed D	1	valve, whole, right	*Ostrea sp.*	T.A. Demere 1986
3281U	28802	Gateway Center East - Bed U	215	valves, whole, left & right	*Dendostrea angelica*	T.A. Demere 1986
3281U	28914	Gateway Center East - Bed U	15	valve, whole, left & right	*Dendostrea angelica*	T.A. Demere 1986
3281U	75444	Gateway Center East - Bed U	1	steinkern, valve	*Ostrea sp.*	N.S. Rugh 2000
5061	90167	Mt. Soledad - Blackmore Court	10	valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2003
5062	82060	Mt. Soledad - Blackmore Court	18	valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2001
5063	90116	Mt. Soledad - Blackmore Court	20	valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 2003

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20	14988	Balboa Park, South Side near Old Well	17 valves, whole, left & right	*Dendostrea vespertina*	T.A. Demere 1980
20	14990	Balboa Park, South Side near Old Well	2 valves, whole, left & right	*Ostrea sp.*	0
37	14981	Pacific Beach	2 valves, whole	*Ostrea megodon*	0
37	14986	Pacific Beach	2 valve, whole & articulated pair	*Dendostrea vespertina*	L.G. Hertlein 0
45	12335	Barrett Canyon, Coyote Mountain	4 valves, whole	*Dendostrea vespertina*	1993
48	20341	Carrizo Creek Station	2 valves, whole	*Dendostrea vespertina*	T.A. Demere 1981
51	12295	Carrizo Creek	2 valves, partial in matrix	*Dendostrea vespertina*	T.A. Demere 1981
53	20340	Mud Hills - Carrizo Station	1 valve, partial, left	*Dendostrea vespertina*	M.X. Kirby 2008
53	23459	Mud Hills - Carrizo Station	24 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
80	14992	Mt. Soledad	3 valves, whole & partial, left & right	*Ostrea sp.*	0
80	14997	Mt. Soledad	7 valves, whole & partial, left & right	*Ostrea sp.*	0
168	14180	Balboa Park, Cabrillo Canyon, East Side	13 valves, whole & partial, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
168	14242	Balboa Park, Cabrillo Canyon, East Side	5 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
168	14987	Balboa Park, Cabrillo Canyon, East Side	4 valves, whole, left & right	*Dendostrea vespertina*	Hertlein/Grant 0
169	21741	Imperial Avenue	36 valves, whole, left & right	*Ostrea angelica*	I. Perlingieri 1980
178	14995	Fir and Boundary Streets	4 valves, whole, left	*Dendostrea vespertina*	Hertlein/Grant 0
211	11721	San Fernando Pass	1 articulated pair	*Dendostrea vespertina*	T.A. Demere 1986
214	11739	San Fernando Pass	2 valves, whole	*Dendostrea vespertina*	T.A. Demere 1986
217	116	Val Verde - Holser Canyon	1 valve, whole, left	*Dendostrea vespertina*	Grant and Gale 1931
217	11128	Val Verde - Holser Canyon	4 articulated pair; valves, left & right	*Dendostrea vespertina*	T.A. Demere 1986
258	11672	Val Verde	2 valves, whole, right	*Ostrea sp.*	T.A. Demere 1986
258	11836	Val Verde	8 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1986
272	14653	International Boundary	2 valves, whole in matrix	*Dendostrea vespertina*	I.S.Perlingieri 1997
273	14508	International Boundary	7 valves, whole, left & right	*Dendostrea vespertina*	I.S.Perlingieri 1980
328	15833	Telegraph Canyon Rd.	12 valves, whole and partial	*Dendostrea vespertina*	E.J. Moore 1970
331	14993	International Boundary	1 valve, whole, left	*Ostrea sp.*	0
365	14982	Mt. Soledad	2 valves, whole, left & right	*Dendostrea vespertina*	T. Susuki 0
386	23456	Painted Gorge	7 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
387	20330	Carrizo Creek	4 valves, whole, left; 1 articulated pair	*Dendostrea vespertina*	0
387	20336	Carrizo Creek	34 valves, whole & partial, left & right	*Dendostrea vespertina*	0
408	14983	Market & Euclid St. - East San Diego	1 valve, whole, right	*Ostrea sp.*	T. Susuki 0
408	14984	Market & Euclid St. - East San Diego	2 valves, whole, right	*Dendostrea vespertina*	I. Perlingieri 1980
409	14985	East San Diego	1 vale, whole, in matrix	*Dendostrea vespertina*	T. Susuki 0
409	14996	East San Diego	4 valves, whole, right	*Dendostrea vespertina*	T. Susuki 0
409	15005	East San Diego	1 valve, whole, right	*Ostrea angelica*	G.L. Kennedy 1967

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413	14994	Chollas Valley, Market Street Bridge	1 valve, whole, left	*Dendostrea vespertina*	I. Perlingieri 1980
416	59841	International Boundary	10 valves, whole, left & right	*Dendostrea vespertina*	I.S.Perlingieri 1980
429	14535	International Boundary	8 valves, whole & partial, left & right	*Ostrea sp.*	I.S.Perlingieri 1980
429	14537	International Boundary	38 valves, whole, left and right	*Dendostrea vespertina*	I.S.Perlingieri 1980
430	14482	International Boundary	7 valves, whole, left and right	*Dendostrea vespertina*	I.S.Perlingieri 1980
430	22142	International Boundary	1 valve fragment	*Dendostrea vespertina*	I.S.Perlingieri 1980
470	21882	Telegraph Canyon	1 valve, whole	*Dendostrea vespertina*	I. Perlingieri 1980
484	16037	Telegraph Canyon	540 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1997
518	23100	Painted Gorge	7 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
544	22240	International Boundary - Horizon A	60 valves, whole, left & right	*Dendostrea vespertina*	I.S.Perlingieri 1980
547	22302	International Boundary - Horizon B	9 valves, whole & partial, left & right	*Dendostrea vespertina*	I.S.Perlingieri 1980
600	802	Isla Angel de la Guarda-Belvedere Expedition	1 valve, whole, right; w/ oyster attached	*Ostrea angelica*	W.K. Emerson 1964
600	8239	Isla Angel de la Guarda-Belvedere Expedition	1 valve, whole, right	*Ostrea angelica*	W.K. Emerson 0
600	13690	Isla Angel de la Guarda-Belvedere Expedition	2 valves, whole, right	*Ostrea angelica*	W.K. Emerson 0
600	13693	Isla Angel de la Guarda-Belvedere Expedition	22 valves, whole, left & right	*Ostrea angelica*	W.K. Emerson 0
600	13748	Isla Angel de la Guarda-Belvedere Expedition	17 valves, whole, left & right	*Ostrea angelica*	W.K. Emerson 0
601	15148	Isla San Esteban - Belvedere Expedition	10 valves, whole & partial, left & right	*Ostrea sp.*	T.A. Demere 1986
606	6749	Isla Carmen - Belvedere Expedition	21 valves, whole, left & right	*Ostrea angelica*	T.A. Demere 1986
608	13551	Isla Carmen - Belvedere Expedition	17 valves, whole, left & right	*Ostrea angelica*	T.A. Demere 1986
610	13664	Isla Monserrat - Belvedere Expedition	2 articulated pair, separated	*Ostrea megodon*	T.A. Demere 1986
610	13671	Isla Monserrat - Belvedere Expedition	7 valves, whole, left & right	*Ostrea angelica*	T.A. Demere 1986
612	13489	Isla San Jose - Belvedere Expedition	10 valves, whole, left & right	*Ostrea angelica*	T.A. Demere 1986
612	13600	Isla San Jose - Belvedere Expedition	1 valve, whole	*Ostrea megodon*	T.A. Demere 1986
615	13495	Isla Cerralvo - Belvedere Expedition	1 valve, partial, hinge area	*Ostrea heermanni*	T.A. Demere 1986
623	10516	Turtle Bay	5 valves, whole, left & right	*Ostrea megodon*	T.A. Demere 1986
623	10518	Turtle Bay	1 valve, partial, left	*Ostrea sp.*	T.A. Demere 1986
623	10519	Turtle Bay	20 valves, whole, left & right	*Dendostrea vespertina*	T.A. Demere 1986
713	14274	Pacific Beach	2 valves, whole, left & right	*Ostrea sp.*	T.A. Demere 1980
1965	53314	Balboa Park, Cabrillo Bridge	9 valves, whole, left & right	*Dendostrea vespertina*	E.C. Wilson 1966
2139	10510	Isla Cedros	4 valves, whole, left and right	*Ostrea megodon*	T.A. Demere 1986
2377	53324	Balboa Park - across from tennis courts	5 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
2383	53409	Reynard Way - Miscellaneous Locality	2 valves, whole, left & right	*Dendostrea vespertina*	T.A. Demere 1980
2413	13078	Isla Salsipuedes	48 valves, whole & partial, left & right	*Ostrea angelica*	T.A. Demere 1982
2451	21803	East San Diego, Market St. east of Euclid	6 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1988
2617	14619	East San Diego, Fairmount & Home Ave.	3 valves, whole, left and right	*Dendostrea vespertina*	I. Perlingieri 1980

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2617	77226	East San Diego, Fairmount & Home Ave.	1	valve, whole, right in matrix	*Dendostrea vespertina*	I. Perlingieri 1981
2623A	12651	Pacific Beach	2	valves, whole, left	*Dendostrea vespertina*	T.A. Demere 1980
2640	14624	Mt. Soledad	7	valves, whole & partial, left & right	*Dendostrea vespertina*	0
2641	14596	Mt. Soledad	3	valve, whole, left & right	*Dendostrea vespertina*	0
2693	16706	Yuha Buttes region	14	valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2001
2694	16709	Yuha Buttes region	1	matrix sample of oyter hash	*Ostrea sp.*	Jan W. Tobiska 1975
2703	17735	Vallecito Badlands - Mud Hills	20	valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2703	17738	Vallecito Badlands - Mud Hills	5	valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2704	17773	Fish Creek Badlands	1	vavle, whole, in matrix	*Dendostrea vespertina*	T.A. Demere 1981
2704	17776	Fish Creek Badlands	5	valves, whole, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2705	17744	Alverson Canyon	1	valve, partial, right, in matrix	*Ostrea sp.*	T.A. Demere 1981
2706	17752	Coyote Mountains	1	oyster shell base	*Ostrea sp.*	T.A. Demere 1981
2706	17753	Coyote Mountains	4	articulated pairs	*Dendostrea vespertina*	N.S. Rugh 2001
2757	21571	Mt. Soledad	30	valves, whole & partial, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
2757	67059	Mt. Soledad	2	valves, whole, juvenile	*Ostrea sp.*	H.P. Don Vito 1998
2761	23317	Yuha Buttes	5	valves, partial & fragments	*Dendostrea vespertina*	T.A. Demere 1981
2762	23345	Yuha Buttes	1	valve, whole, in matrix	*Dendostrea vespertina*	T.A. Demere 1981
2764	23302	Yuha Buttes	10	valves, partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2764	23308	Yuha Buttes	10	valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2764	23310	Yuha Buttes	5	valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2001
2769	18592	Fish Creek Badlands	26	valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2807	21785	Market and Euclid Streets	6	valves, whole, left & right	*Ostrea sp.*	I. Perlingieri 1980
2809	12321	International Boundary	10	valves, whole & partial in matrix	*Dendostrea vespertina*	I.S.Perlingieri 1980
2851	21597	Pacific Beach	4	valves, whole; some attached	*Dendostrea vespertina*	I. Perlingieri 1980
2895A	20329	Coyote Mountain - misc. collection	4	articulated pairs	*Dendostrea vespertina*	T.A. Demere 1981
2895A	23124	Coyote Mountain - misc. collection	2	valve, right; group of attached valves	*Dendostrea vespertina*	L.G. Hertlein 0
2897	20334	Painted Gorge Road north of Coyote Wash	3	valves, whole and partial	*Dendostrea vespertina*	0
2897	23096	Painted Gorge Road north of Coyote Wash	38	valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2898	20339	Colorado Desert	94	valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2898	23458	Colorado Desert	6	valves, whole, left & right	*Dendostrea vespertina*	T.A. Demere 1981
2899	20344	Coyote Mountain	19	articulated pairs	*Dendostrea vespertina*	T.A. Demere 1981
3006	78149	8th Street and Plaza Blvd.	1	valve, whole, left	*Ostrea sp.*	H.P. Don Vito 2001
3012	21765	Chollas Valley, near I-15 & SR 94	22	valves, whole, partial, fragments, worn	*Ostrea sp.*	I. Perlingieri 1980
3023	22364	International Border	16	valves, whole, left & right	*Dendostrea vespertina*	I.S.Perlingieri 1980
3038	53370	India Street	1	valve fragment	*Ostrea sp.*	N.S. Rugh 2000

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3043	53328	Balboa Park, Cabrillo Bridge	4 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3044	14126	Balboa Park, Miscellaneous Localities	1 valve, whole, left	*Dendostrea vespertina*	I. Perlingieri 1980
3044	14209	Balboa Park, Miscellaneous Localities	2 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3044	53336	Balboa Park, Miscellaneous Localities	10 valves, whole, left & right	*Ostrea sp.*	I. Perlingieri 1980
3044	53352	Balboa Park, Miscellaneous Localities	7 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3044A	21722	Balboa Park, South Side	2 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3044A	21729	Balboa Park, South Side	53 valves, whole & partial, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3044A	21731	Balboa Park, South Side	6 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3045	21736	Balboa Park, Naval Hospital	3 valves, whole, left & right	*Dendostrea vespertina*	I. Perlingieri 1980
3050	14567	Telegraph Canyon	1 valve, whole with matrix in it	*Ostrea sp.*	0
3069	15004	Mt. Hope Cemetery	3 valves, whole, left & right	*Ostrea angelica*	G.L. Kennedy 0
3120	23322	Yuha Buttes	4 valves, partial, in matrix	*Dendostrea vespertina*	T.A. Demere 1981
3153	23894	Hidden Vista Development	23 valves, whole & partial, left & right	*Ostrea sp.*	T.A. Demere 1982
3154	23988	Hidden Vista Development	2 valves, whole	*Ostrea sp.*	T.A. Demere 1982
3154	24022	Hidden Vista Development	1 articulated pair, matrix filled	*Ostrea sp.*	T.A. Demere 1982
3159	24248	Hidden Vista Village Project	4 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1983
3163	24052	Hidden Vista Village Project	2 valve, whole, left, & partial valve	*Dendostrea vespertina*	T.A. Demere 1982
3163	34818	Hidden Vista Village Project	1 cluster, 2 attached left valves	*Dendostrea vespertina*	T.A. Demere 1982
3165	24173	Hidden Vista Village Project	2 valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 1997
3167	24270	Hidden Vista Village Project	2 valve, whole, right, & fragment	*Dendostrea vespertina*	T.A. Demere 1983
3168	24323	Hidden Vista Village Project	65 valves, whole & partial, left & right	*Ostrea sp.*	T.A. Demere 1982
3172	77655	Balboa Park, Florida Canyon	3 valves, whole, left & right	*Ostrea sp.*	N.S. Rugh 1999
3172	77695	Balboa Park, Florida Canyon	27 valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2000
3176	24811	East H Street Extension	2 valves, whole and fragment	*Ostrea sp.*	T.A. Demere 1983
3182	35777	Hidden Vista Village Project	7 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1988
3184	59436	Hidden Vista Village Project	3 valves, whole and partial	*Ostrea sp.*	T.A. Demere 1997
3187	35737	Hidden Vista Village Project	1 valve, partial	*Dendostrea vespertina*	T.A. Demere 1983
3188	34804	Hidden Vista Village Project	3 valves, whole, left & right	*Ostrea sp.*	T.A. Demere 1987
3190	59594	Hidden Vista Village Project	4 valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 1997
3320	29677	Little League Park	2 valves, whole, right	*Ostrea sp.*	T.A. Demere 1986
3321	29649	Market Street (East of Euclid)	3 valves, whole, left	*Ostrea sp.*	T.A. Demere 1986
3322	29693	Home Avenue North of Fairmount Avenue	7 valves, whole, left & right	*Dendostrea vespertina*	T.A. Demere 1986
3329	29750	Azufre Canyon	2 valves, whole, left and right	*Ostrea megodon*	T.A. Demere 1986
3396	63327	H Street Widening	2 valves, whole	*Ostrea sp.*	H.P. Don Vito 1997
3422	35675	H Street Extension	2 valves, whole	*Ostrea sp.*	T.A. Demere 1988

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3423	35929	Rancho Del Sur (Sunbow)	2 valves attached to cobbles	*Dendostrea vespertina*	T.A. Demere 1988
3423	35931	Rancho Del Sur (Sunbow)	7 valves, whole attached to cobbles	*Dendostrea vespertina*	T.A. Demere 1988
3423	35938	Rancho Del Sur (Sunbow)	142 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1988
3455	65876	Rancho Del Rey, SPA 1, Business Center	1 valve, whole, right	*Ostrea sp.*	N.S. Rugh 1998
3581	65800	Rancho Del Rey, SPA 1, Business Center	1 shell fragment, with muscle scar	*Ostrea sp.*	N.S. Rugh 1998
3628	64556	Rancho Del Rey, SPA 1, Hill 2	33 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1997
3630	64492	Rancho Del Rey, SPA 1, Hill 2	6 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1997
3631	65803	Rancho Del Rey, SPA 1, Hill 6	3 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1998
3877	57217	Malcolm X Library (Market & Euclid Sts.)	2 whole and partial valves	*Dendostrea vespertina*	T.A. Demere 1996
3888	61849	Rancho Del Rey, SPA 1, Hill 9	6 valves, whole, left & right, & clusters	*Dendostrea vespertina*	N.S. Rugh 1997
3888	61865	Rancho Del Rey, SPA 1, Hill 9	147 valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 1997
3888	65344	Rancho Del Rey, SPA 1, Hill 9	1 valve, left, attached to blue schist	*Ostrea sp.*	N.S. Rugh 1998
3997	61727	Rancho Del Rey, SPA 3, School site	14 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1997
4021	61478	I-15/40th Street	1 valve, partial	*Ostrea sp.*	T.A. Demere 1997
4044	59739	Hidden Vista Village Project	12 valves, whole, left & right, & fragments	*Ostrea sp.*	H.P. Don Vito 1997
4048	61617	Rancho Del Rey, SPA 3	12 valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 1997
4056	61672	Rancho Del Rey, SPA 3	4 valves, whole & partial, left	*Ostrea sp.*	N.S. Rugh 1997
4080	73409	Nellie Gale Ranch #1	2 valves, partial-REWORKED FROM MIOCENE	*Ostrea sp.*	N.S. Rugh 1999
4080	73410	Nellie Gale Ranch #1	5 valves, whole - MAY BE REWORKED	*Ostrea spp.*	N.S. Rugh 1999
4080	73411	Nellie Gale Ranch #1	7 valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 1999
4150	66949	Balboa Park, Hall of Champions	3 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1998
4177	68321	Chula Vista Veteran's Home	1 valves, left, on large cobble stone	*Ostrea sp.*	N.S. Rugh 1998
4177	68322	Chula Vista Veteran's Home	13 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1998
4177	68334	Chula Vista Veteran's Home	1 valves, left, on cobble stone	*Ostrea sp.*	N.S. Rugh 1998
4177	68335	Chula Vista Veteran's Home	12 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1998
4177	68344	Chula Vista Veteran's Home	1 valves, left, on cobble stone	*Ostrea sp.*	N.S. Rugh 1998
4177	68345	Chula Vista Veteran's Home	1 valves	*Ostrea sp.*	N.S. Rugh 1998
4177	68347	Chula Vista Veteran's Home	1 valves, left on mysticete rib	*Ostrea sp.*	N.S. Rugh 1998
4177	68349	Chula Vista Veteran's Home	2 valves, left, on cobble stones	*Ostrea sp.*	N.S. Rugh 1998
4177	68350	Chula Vista Veteran's Home	75 valves, whole & partial, left and right	*Ostrea sp.*	N.S. Rugh 1998
4188	68923	Otay Ranch Village 1 - Phase 2B	1 valve, whole, right	*Ostrea sp.*	N.S. Rugh 1999
4188	68924	Otay Ranch Village 1 - Phase 2B	13 shell, fragments, in matrix	*Ostrea sp.*	N.S. Rugh 1999
4258	68493	Sunbow II #4	28 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 1998
4260	68520	Sunbow II #6	1 valve, whole, left	*Ostrea sp.*	N.S. Rugh 1998
4381	32235	El Rancho Del Rey, Unit 6B	31 valves, whole & partial, left & right	*Ostrea sp.*	T.A. Demere 1987

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4383	32204	El Rancho Del Rey, Unit 6B	72 valves, whole & partial, left & right	*Ostrea sp.*	T.A. Demere 1987
4383	35627	El Rancho Del Rey, Unit 6B	78 valves, whole & partial, left & right	*Dendostrea vespertina*	T.A. Demere 1988
4384	34209	El Rancho Del Rey, Unit 6A	35 valves & articulated pairs on cobbles	*Dendostrea vespertina*	T.A. Demere 1987
4384	34856	El Rancho Del Rey, Unit 6A	37 valves, whole, left & right, in clusters	*Dendostrea vespertina*	T.A. Demere 1987
4389	32231	El Rancho Del Rey, Unit 6C	15 valves, whole, left & right	*Ostrea sp.*	T.A. Demere 1987
4470	77197	Otay Ranch Village 1 - Phase 7	3 valves, whole, right	*Ostrea sp.*	N.S. Rugh 2000
4471	77209	Otay Ranch Village 1 - Phase 7	1 valve, whole, left	*Dendostrea vespertina*	N.S. Rugh 2000
4505	88042	Discovery at Cortez Hill, Site 2	3 valve, whole, right; fragments, worn	*Dendostrea vespertina*	N.S. Rugh 2002
4506	88128	Discovery at Cortez Hill, Site 1 & 3	1 valve, whole, right, worn	*Ostrea sp.*	N.S. Rugh 2002
4507	88064	Discovery at Cortez Hill, Export Site	1 valve, right, worn	*Dendostrea vespertina*	N.S. Rugh 2002
4543	81509	Fox Hollow Apartments	43 valves, whole and partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2001
4588	81284	Laurel Bay Apartments	112 valves, whole & partial, left & right	*Dendostrea vespertina*	G.L. Kennedy 2001
4636	82142	Laurel Bay Apartments	93 valves, whole & partial, left & right	*Dendostrea vespertina*	G.L. Kennedy 2001
4639	82166	Laurel Bay Apartments	172 valves, whole & partial, left & right	*Dendostrea vespertina*	G.L. Kennedy 2001
4642	82204	Laurel Bay Apartments	33 valves, whole & partial, left & right	*Dendostrea vespertina*	G.L. Kennedy 2001
4673	82239	Hortensia Street, Old Town	35 valves, whole & partial, left & right	*Ostrea sp.*	G.L. Kennedy 2002
4674	82275	Hortensia Street, Old Town	85 valves, whole, left & right	*Dendostrea vespertina*	G.L. Kennedy 2002
4826	88522	Sewer and Water Group 673 #2	1 steinkern of valve in matrix, right	*Ostrea sp.*	N.S. Rugh 2003
4913	98853	Tower 23 Hotel & Restaurant	1 valve, whole, left	*Ostrea sp.*	G.L. Kennedy 2004
4981	97258	Painted Gorge - Anomia bed	17 valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 2004
4983A	117794	Spruce Street - Terracina - Site 1	1 valve fragment, worn	*Dendostrea vespertina*	N.S. Rugh 2008
5029	83878	Mt. Soledad - Archer Street	1 valve, whole, left	*Dendostrea vespertina*	Hord et. al. 1963
5031	83889	Mt. Soledad - Archer Street	3 valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2002
5035	88891	Border Field State Park	7 valves, whole & partial, left & right	*Dendostrea vespertina*	M. Blanchard 1961
5036	90025	Border Field State Park	121 valves, whole & partial, left & right	*Dendostrea vespertina*	J.P. Dwyer 1961
5036	90026	Border Field State Park	2 valves, partial	*Ostrea sp.*	N.S. Rugh 2003
5039	84504	Mt. Soledad - Foothill Boulevard	4 valves, whole, left and right	*Dendostrea vespertina*	N.S. Rugh 2002
5040	84509	Mt. Soledad - Foothill Boulevard	1 valve, whole, left	*Dendostrea vespertina*	N.S. Rugh 2002
5041	84515	Mt. Soledad - Foothill Boulevard	10 valves, whole, left and right	*Dendostrea vespertina*	N.S. Rugh 2002
5041	84516	Mt. Soledad - Foothill Boulevard	1 valve, whole, dulled	*Ostrea sp.*	H.P. Don Vito 2002
5042	84525	Mt. Soledad - Foothill Boulevard	5 valves, whole, left & right, clusters	*Dendostrea vespertina*	N.S. Rugh 2002
5043	84530	Mt. Soledad - Foothill Boulevard	10 valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 2002
5044	84538	Mt. Soledad - Foothill Boulevard	1 valve, whole, right	*Dendostrea vespertina*	N.S. Rugh 2002
5045	84544	Mt. Soledad - Foothill Boulevard	31 valves, whole, left & right	*Dendostrea vespertina*	M.X. Kirby 2008
5046	88745	Border Field State Park	9 valves, whole, left & right	*Dendostrea vespertina*	E.C. Allison 1961

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
5047	88771	Border Field State Park	25 valves, whole, left & right, 1 pair	*Dendostrea vespertina*	E.C. Allison 1961
5050	88862	Border Field State Park	5 valves, whole, left & right, 1 pair	*Dendostrea vespertina*	E.C. Allison 1961
5050	88863	Border Field State Park	3 valves, whole & partial, on matrix	*Ostrea sp.*	N.S. Rugh 2003
5052	88839	Border Field State Park	10 valves, whole, left & right, 3 pairs	*Dendostrea vespertina*	E.C. Allison 1961
5082	84460	Dove and Maple - South End of Old Brickyard	3 valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 2002
5083	83859	Mt. Soledad - Castle Hills Drive	11 valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 2002
5084	83861	Mt. Soledad - Castle Hills Boulevard	8 valves, whole & partial, left & right	*Dendostrea vespertina*	A. Tolbert 1963
5085	83864	Mt. Soledad - Castle Hills Boulevard	23 valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2002
5087	83867	Mt. Soledad - Castle Hills Boulevard	2 valves, whole, right	*Dendostrea vespertina*	A. Tolbert 1963
5088	83874	Mt. Soledad - Castle Hills Boulevard	1 valve, whole, left	*Dendostrea vespertina*	N.S. Rugh 2002
5090	89425	Playas de Tijuana	8 valves, whole & partial, left & right	*Dendostrea vespertina*	N.S. Rugh 2003
5091	89537	Playas de Tijuana	7 valves, partial, left and right	*Dendostrea vespertina*	N.S. Rugh 2003
5092	95282	Playas de Tijuana	2 valves, whole and partial	*Ostrea sp.*	N.S. Rugh 2004
5095	89462	Playas de Tijuana	9 valves, whole & partial, left & right	*Dendostrea vespertina*	Minch; McGee 1963
5095	89463	Playas de Tijuana	1 valve, whole, right, unusual sculpture	*Ostrea sp.*	Minch; McGee 1963
5102	88680	Border Field State Park	113 valves, whole, left & right	*Dendostrea vespertina*	R. Schatzinger 1971
5103	88447	Border Field State Park	5 3 articulated pairs	*Dendostrea vespertina*	N.S. Rugh 2003
5103	88448	Border Field State Park	14 valves, whole and partial, right	*Dendostrea vespertina*	N.S. Rugh 2003
5103	88449	Border Field State Park	249 valves, whole & partial, left & right	*Dendostrea vespertina*	R. Schatzinger 1971
5104	88253	Border Field State Park	38 valves, whole & partial, left & right	*Dendostrea vespertina*	R. Schatzinger 1971
5229	88810	Border Field State Park	4 valves, whole, left & right	*Dendostrea vespertina*	E.C. Allison 1961
5250	95788	Tijuana River Valley	21 valves, whole & partial, left & right	*Ostrea lurida*	N.S. Rugh 2004
5250	95789	Tijuana River Valley	4 valves, whole & partial, right	*Dendostrea vespertina*	N.S. Rugh 2004
5263	97107	Mount Soledad	4 valves, whole, left & right	*Dendostrea vespertina*	Nelson 1966
5263	97108	Mount Soledad	2 pair, whole	*Dendostrea vespertina*	Nelson 1966
5264	97109	Mount Soledad	2 valves, whole, left & right	*Dendostrea vespertina*	N.S. Rugh 2004
5269	107415	El Rosario-inland north of La Langosta Cr.	1 valve, whole, right	*Ostrea sp.*	N.S. Rugh 2005
5272	107429	El Rosario-inland south of Amargo Creek	2 valves, valves, whole, left & right	*Ostrea sp.*	N.S. Rugh 2005
5427	98429	Sewer Group 680 - In Situ Oyster Bed	10 valves, whole, left and right	*Dendostrea vespertina*	N.S. Rugh 2004
5428	98434	Sewer Group 680 - In Situ Pecten Bed	3 valves, whole and partial, left	*Dendostrea vespertina*	N.S. Rugh 2004
5429	98447	Sewer Group 680 - Oyster Bed Spoils Pile	42 valves, whole, left and right	*Dendostrea vespertina*	N.S. Rugh 2004
5429	98448	Sewer Group 680 - Oyster Bed Spoils Pile	1 pair, with internal matrix	*Dendostrea vespertina*	N.S. Rugh 2004
5430	98471	Sewer Group 680 - Pecten Bed Spoils Pile	12 valves, left & right, whole and partial	*Dendostrea vespertina*	N.S. Rugh 2004
5461	98496	Sewer Group 680 - Union Street Oyster Bed	59 valves, whole, left and right	*Dendostrea vespertina*	N.S. Rugh 2004
5464	98578	La Joya #2	2 valves, partial	*Dendostrea vespertina*	N.S. Rugh 2004

LOC #	SPEC #	LOCALITY NAME	NO.	ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
5467	103154	Cortez Blu Condominiums - Argopecten Bed	7	valves, whole & partial, worn	*Ostrea lurida*	N.S. Rugh 2005
5543	103422	Coyote Mountains-North Side, Anomia Hill	15	valves, whole & partial, left & right	*Ostrea sp.*	H.P. Don Vito 2005
5675	107211	1814 Malden Street - Bore Hole Collection	1	valve, whole, right	*Ostrea sp.*	N.S. Rugh 2005
5902	113839	SDG&E OMPPA Transmission Project - SP 170	2	valve, worn fragment; part/counter-part	*Ostrea sp.*	N.S. Rugh 2007
5933	113949	SDG&E OMPPA Transmission Project - SP 210	18	valves, partial,left & right,& fragments	*Dendostrea vespertina*	N.S. Rugh 2007
6036	116457	Otay Ranch Heritage Road	2	valves, partial, in matrix	*Ostrea sp.*	M.K. Soetaert 2007
6069	118645	Otay Ranch Village 2 North	1	valve, partial, right, poorly preserved	*Dendostrea vespertina*	N.S. Rugh 2008
6071	118657	Otay Ranch Village 2 North - Oyster Bed	4	articulated pairs, whole & partial	*Dendostrea vespertina*	N.S. Rugh 2008
6071	118658	Otay Ranch Village 2 North - Oyster Bed	2	articulated pairs (2), attached together	*Dendostrea vespertina*	N.S. Rugh 2008
6071	118659	Otay Ranch Village 2 North - Oyster Bed	39	valves, left & right, single; 2 attached	*Dendostrea vespertina*	N.S. Rugh 2008
6071	118660	Otay Ranch Village 2 North - Oyster Bed	8	valves, whole, left & right; juveniles	*Dendostrea vespertina*	N.S. Rugh 2008
6071	118661	Otay Ranch Village 2 North - Oyster Bed	8	clusters of valves	*Dendostrea vespertina*	N.S. Rugh 2008
6072	120398	Otay Ranch Village 2 North-Oyster Bed North	2	valves, whole, left & right of pair	*Dendostrea vespertina*	N.S. Rugh 2008
6072	120399	Otay Ranch Village 2 North-Oyster Bed North	6	articulted pairs, whole	*Dendostrea vespertina*	N.S. Rugh 2008
6072	120400	Otay Ranch Village 2 North-Oyster Bed North	26	valves, single and clusters	*Dendostrea vespertina*	N.S. Rugh 2008
6074	120511	Otay Ranch Village 2 North	1	valve fragment	*Dendostrea vespertina*	N.S. Rugh 2008
6075	120519	Otay Ranch Village 2 North	1	valve, right, on matrix	*Dendostrea vespertina*	N.S. Rugh 2008
6076	121608	Otay Ranch Village 2 North- Macoma Bed, North	1	valve, partial	*Dendostrea vespertina*	N.S. Rugh 2009
6114	117913	C Street Geotechnical Trench	3	valves, whole & partial, left & right	*Ostrea sp.*	N.S. Rugh 2008
6174	121167	Ten Fifty B Street - Soft Sandstone/Hash Bed	1	valve, partial, right	*Ostrea sp.*	H.P. Don Vito 2008
6360	128036	1907 Columbia Street	3	valves, partial	*Ostrea sp.*	G.L. Kennedy 2011
6417	127711	Cedar Gateway - Lower Concreted Bed	2	valve fragments	*Dendostrea sp.*	H.P. Don Vito 2011
6417	127751	Cedar Gateway - Lower Concreted Bed	5	valves, whole & partial in matrix	*Dendostrea sp.*	T.A. Demere 2011
6419	127821	Cedar Gateway - friable sandstone bed	5	valves, partial	*Dendostrea sp.*	H.P. Don Vito 2011
6419	127834	Cedar Gateway - friable sandstone bed	1	valve, whole	*Dendostrea sp.*	H.P. Don Vito 2011
6419	128014	Cedar Gateway - friable sandstone bed	2	valves, partial & fragments	*Dendostrea sp.*	H.P. Don Vito 2011
6483	129388	Laurel & Kettner Parking Structure Expansion	2	whole valves	*Dendostrea angelica*	E. Ekdale 2011
6485	129405	Laurel & Kettner Parking Structure Expansion	39	valves, whole and partial	*Dendostrea angelica*	E. Ekdale 2011
6487	129422	Laurel & Kettner Parking Structure Expansion	23	valves, whole and partial	*Dendostrea angelica*	E. Ekdale 2011
6507	134299	Sunrise Powerlink	1	valves, whole & partial, left & right	*Dendostrea vespertina*	R.M Hubscher 2012
6508	134304	Sunrise Powerlink	1	valves, whole & partial, left & right	*Dendostrea vespertina*	R.M Hubscher 2012
6509	134308	Sunrise Powerlink	5	valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6511	134897	Sunrise Powerlink	863	valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6511	134898	Sunrise Powerlink	10	valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6512	134905	Sunrise Powerlink	36	valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012

LOC #	SPEC #	LOCALITY NAME	NO. ITEMS AND DESCRIPTION	GENUS AND SPECIES	IDENTIFIER/DATE
6516	134945	Sunrise Powerlink	10 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6518	134821	Sunrise Powerlink	3 valves, partial	*Dendostrea vespertina*	R.M. Hubscher 2012
6518	134822	Sunrise Powerlink	2 valves, partial	*Dendostrea vespertina*	R.M. Hubscher 2012
6518	134823	Sunrise Powerlink	65 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6521	134852	Sunrise Powerlink	1 valve; whole, left	*Dendostrea vespertina*	R.M. Hubscher 2012
6522	134857	Sunrise Powerlink	67 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6526	134883	Sunrise Powerlink	29 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6527	134976	Sunrise Powerlink	4 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6527	134977	Sunrise Powerlink	130 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6527	134978	Sunrise Powerlink	3 valve, fragments	*Dendostrea vespertina*	R.M. Hubscher 2012
6527	134979	Sunrise Powerlink	1 valve, fragment	*Dendostrea vespertina*	R.M. Hubscher 2012
6528	135017	Sunrise Powerlink	8 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012
6529	135025	Sunrise Powerlink	9 valves, fragments & partial, left & rght	*Dendostrea vespertina*	R.M. Hubscher 2012
6529	135026	Sunrise Powerlink	7 valves, whole & partial, left & right	*Dendostrea vespertina*	R.M. Hubscher 2012

APPENDIX B

San Diego Bay
Native Oyster Restoration Plan

Technical Memorandum

Current Distribution of Oysters in San Diego Bay

Prepared by:

Merkel & Associates, Inc.

May 2015

INTRODUCTION

A qualitative survey of the shorelines of San Diego Bay was completed in order to determine the presence and general percent cover of native Olympia oyster (*Ostrea lurida*) and non-native Pacific oyster (*Crassostrea gigas*) along as much of the publically accessible shoreline of San Diego Bay as possible. These data were used to inform restoration site selection and the ability of *O. lurida* to grow and survive in the Bay. This survey was not intended to provide quantitative abundance and density data for oyster species.

METHODS

Field surveys to determine current oyster distribution were performed on September 20, 2013 (coinciding with a -0.4 feet MLLW low tide event at 1630 hours) and November 19, 2013 (coinciding with a -0.4 feet MLLW low tide event at 1642 hours). During each survey date, a team of biologists surveyed the exposed shoreline within all accessible areas of the Bay on-foot. Inaccessible shorelines included all U.S. Navy secured lands and facilities located along the northern shoreline of Coronado, along the Silver Strand, and at the tip of Point Loma at the mouth of the Bay. Other inaccessible areas included the secured commercial and naval shipyards and port terminals on the eastern shoreline of the Bay, located north and south of the Coronado bridge, and the dikes along the bayward edge of the South Bay Salt Ponds located within the South Bay National Wildlife Refuge.

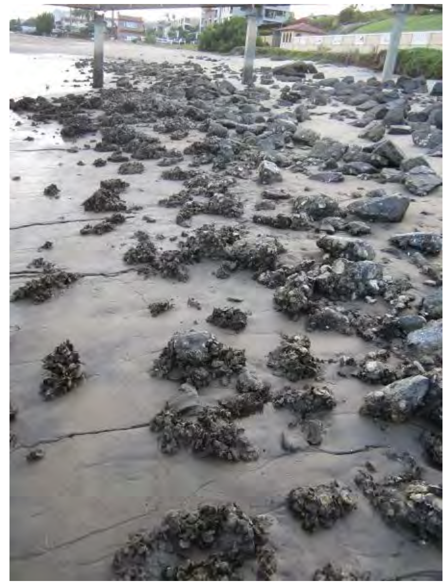
Data collected along each accessible shoreline included presence and/or absence of Olympia and Pacific oyster, and general percent cover estimates for each species. Percent cover was estimated at each shoreline location as one of three categories: high coverage was considered to be ≥ 50% occupation of available substrate, moderate coverage was considered to be between 25%-50% occupation available substrate and low coverage was considered to be ≤ 25% occupation of available substrate. Figure 1 provides photographs of high, moderate, and low coverage shorelines. The presence of dead oyster shells was noted, but not included in cover estimates. As availability of hard substrate varies by location, the data indicate the presence of oysters on available substrate rather than over an entire shoreline. This was intended to be a qualitative study, and densities of each oyster species were not measured. Data were recorded on hard copy true color vertical aerial photographs of San Diego Bay. Photographs were collected along all shorelines.

RESULTS AND DISCUSSION

Figure 2 illustrates the percent cover category of each oyster species along the surveyed accessible shorelines of San Diego Bay. Un-surveyed shorelines are indicated by a dashed black line to differentiate between these areas from surveyed shorelines with no oysters. Representative photo points are indicated by numbers, and photos are referenced in the following text.

Results of the survey indicate that oysters are present along a majority of hardened shorelines and structures (e.g. pier pilings, fences, etc.) within San Diego Bay. High percent cover of native Olympia oyster was found at locations throughout the Bay. Sites with the highest qualitative

High coverage of* C. gigas *along rip rap shoreline



High coverage of O.* lurida *along lower edge of rip rap rubble

***Moderate coverage of* C. gigas**

***Moderate coverage of* O. lurida**

Low coverage of both oyster species near Coronado Yacht Club. Rip rap was placed relatively recently compared to other sites.

Figure 1. Examples of High, Moderate, and Low Percent Cover Categories

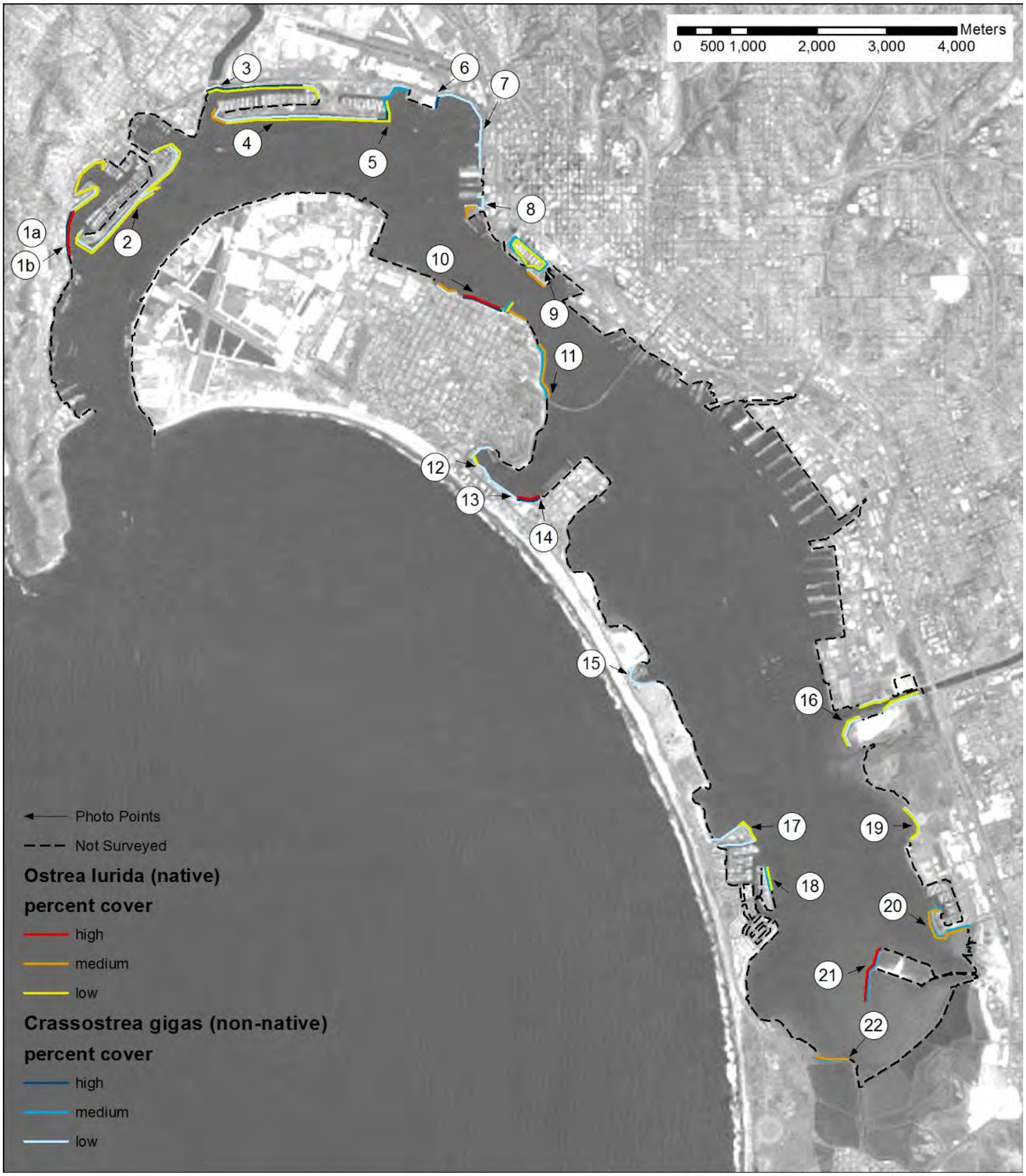


Figure 2. Qualitative Percent Cover of *Ostrea lurida* and *Crassostrea gigas* along Shorelines of San Diego Bay

percent cover of *O. lurida* include Point Loma, along the beaches facing the western edge of Shelter Island (Photos 1a and 1b), at the Coronado Ferry landing (Photo 10), along the shoreline of Glorietta Bay (Photos 13 and 14), and at the northern shoreline of the Chula Vista Wildlife Reserve (Photo 21). Highest percent cover of *C. gigas* was found along the northern edge of Harbor Island adjacent to the Naval Training Center (NTC) channel (Photo 3), and adjacent to the U.S. Coast Guard facility near the San Diego International Airport (Photo 6), at the Coronado Ferry landing (Photo 10), and along the shoreline of Glorietta Bay (Photos 13 and 14).

In a majority of locations, native *O. lurida* and non-native *C. gigas* were found to co-exist. However, where they co-occurred, the two species displayed a distinctive pattern of zonation, with the highest coverage of *O. lurida* occurring at a lower tidal elevation than the highest coverage of *C. gigas* (best illustrated in Photos 1a, 10, 13, and 14). The cause of the zonation is not known and merits further study.

This survey indicates that San Diego Bay supports abundant populations of both native Olympia oyster and non-native Pacific oyster. The southern portion of the Bay has fewer hardened shorelines than the predominantly rip rap-lined shores of the northern portion of the Bay. However, native *O. lurida* was present along all hardened shorelines surveyed in the south Bay, as well as on hard surfaces (e.g. tires, remnant dock piles, etc.) found on mudflats that otherwise did not have hardened shorelines (Photos 16 and 19). This suggests that settlement and growth rates for *O. lurida* are sufficient to support populations of this species where appropriate hard substrates are present.

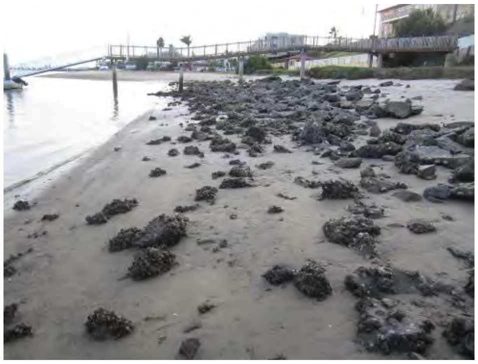


***Photo 1a – high coverage of* O. lurida**

Photo 1b – closeup of* O. lurida *on rock rubble

Photo 2 – low coverage of both species

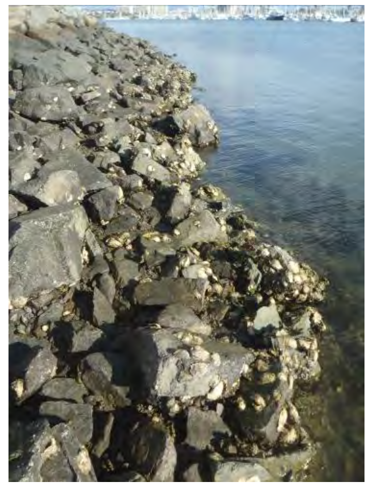


Photo 3 – high coverage of* C. gigas *near NTC channel

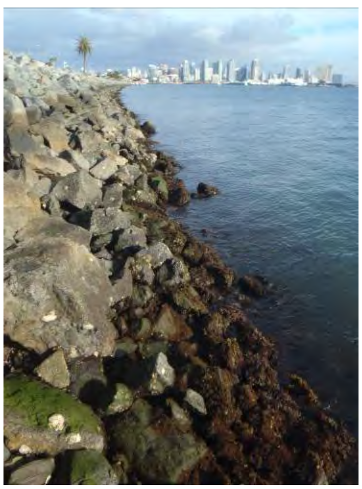


Photo 4 – low coverage of both species

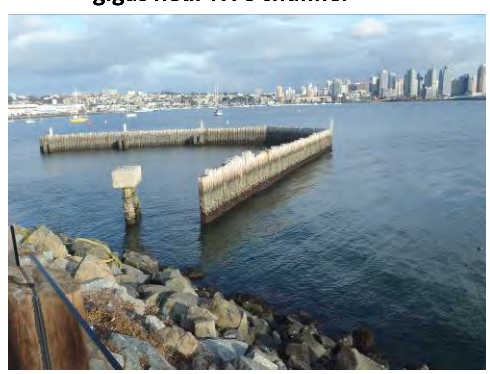


Photo 5 – high coverage of* C. gigas *on sea wall.

Photo 6 – high coverage of* C. gigas *near U.S. Coastguard Station

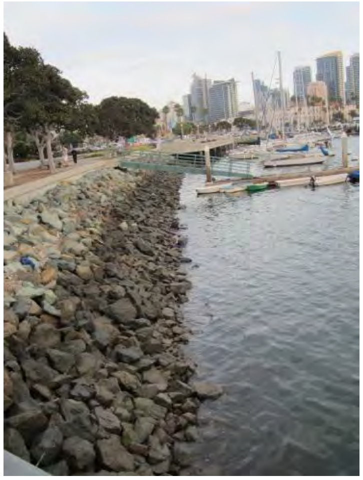


***Photo 7 – low coverage of* C. gigas**

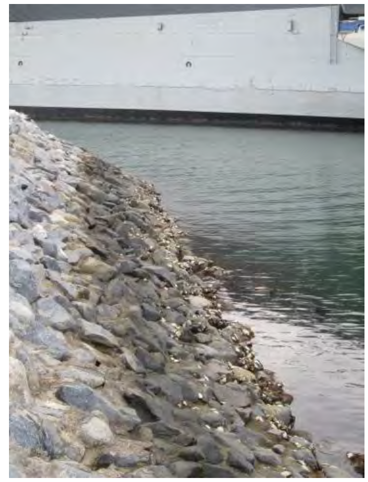


Photo 8 – moderate coverage of* C. gigas *near USS Midway

Photo 9 – low coverage of both species

Photo 10 – high coverage of both species at Coronado Ferry Landing

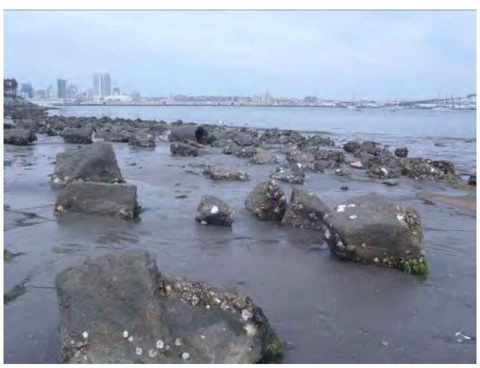


Photo 11 – moderate coverage of both species near Coronado Bridge

Photo 12 – low coverage of both species

Photo 13 – high coverage of both species in Glorietta Bay

Photo 14 – zonation of species on fence in Glorietta Bay

Photo 15 – low coverage of both species

Photo 16– very little hard substrate and low coverage at D Street

Photo 17 – low coverage of both species at Loew's Coronado Bay Resort

Photo 18 – moderate coverage of* C. gigas *at Grand Caribe

Photo 19 – low coverage of both species at Signature Park

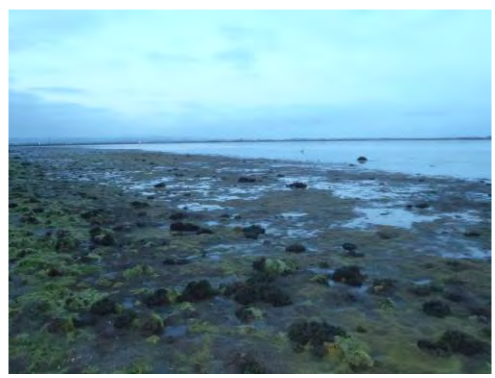


Photo 20 – moderate coverage of both species at J Street Marina

Photo 21 – high coverage of* O. lurida *at the Chula Vista Wildlife Reserve

***Photo 22 – moderate coverage of* both species near South Bay Saltworks Pond 11**

APPENDIX C

San Diego Bay
Native Oyster Restoration Plan

Technical Memorandum

Settlement and Growth of Oysters in San Diego Bay

Prepared by:

California State University Fullerton

Lead Scientist: Dr. Danielle Zacherl

And

Merkel & Associates, Inc.

Lead Biologist: Holly Henderson

May 2015

INTRODUCTION

The San Diego Bay Native Oyster Restoration Plan (Plan) is a collaborative effort being undertaken by the San Diego Unified Port District (SDUPD) and the California State Coastal Conservancy (Conservancy). The Plan goal is to create a biologically rich native oyster, *Ostrea lurida,* reef in San Diego Bay as part of a complete marsh system, which restores an ecological niche that was historically present, is ecologically functional and resilient to changing environmental conditions, and also protects bay tidelands and shoreline.

The ability for oyster spat to naturally recruit to new substrate within San Diego Bay and to grow is important for the establishment and success of restored reefs. However, the recruitment, survivorship, and growth rates of *O. lurida* in San Diego Bay are not known. Therefore, a study was implemented at six sites within south San Diego Bay during the summer and fall of 2013, in order to quantify the adult oyster density, and settlement and growth rates for native *O. lurida*, as well as for non-native Pacific oyster (*Crassostrea gigas*).

METHODS

STUDY SITE SELECTION

Six study sites were selected for study within San Diego Bay. The sites were selected based on a consideration of Plan goals and the following criteria:

- **Areas adjacent to unarmored shoreline**. A primary Plan goal is to assess the ability of restored oyster reefs to protect adjacent shorelines from erosion. The majority of shoreline in San Diego Bay (greater than 70%) is currently armored (U.S. Navy 2010). While restored oyster reefs adjacent to armored rip rap shorelines could improve habitat quality, they would provide minimal, if any, additional protection from erosion in these areas. Study sites along unarmored shorelines were prioritized.

- **Areas with intertidal and shallow subtidal habitat**. *O. lurida* is typically found on hard substrate within interidal and shallow subtidal waters. Much of San Diego Bay has been dredged and the north and central portions of the Bay consist of a moderately deep to deep water embayment with little or no gradually sloping intertidal habitat (U.S. Navy 2010). In contrast, extensive intertidal and shallow subtidal mudflats capable of supporting restored oyster reefs exist in south San Diego Bay. The majority of these intertidal flats transition to subtidal eelgrass habitat. Study sites along gradually sloping mudflats were prioritized.

- **Areas known to currently support oysters or have potential for oyster settlement.** While the quantitative distribution and density of oysters within San Diego Bay has not been determined, the presence of native *O. lurida* on hard structures was assessed via a shoreline survey of south San Diego Bay. While not quantitative, the presence of native oysters provides a crude but effective way to assess if an area has appropriate physical and biological conditions to support native oysters. Study sites were selected along shorelines that had evidence of native oysters.

- **Areas along eroding shorelines and/or exposed to high wind wave energies**. As stated previously, a primary Plan goal is to assess the ability of restored oyster beds to protect adjacent shorelines from erosion. A wave energy model created as part of the first phase of work for this Plan, identified the eastern shoreline of San Diego Bay as receiving the highest wind wave energy (due to long fetch westerly winds that cross the bay). Study sites were selected to include areas of high wave energy.

- **Areas with low foot and boat traffic**. San Diego Bay uses include abundant, military, commercial and recreational boating. In order to prevent physical damage and tampering of study plots, sites located in quiet areas with minimal boat and foot traffic were prioritized.

- **Site ownership and ease of access**. Many areas in San Diego Bay have restricted access, due to military and commercial operations, or due to presence of sensitive species and habitats. Ease of access, while not a primary selection criteria, was considered during study site selection.

The selected study sites are identified in Figure 1 and photographs of each site are presented in Figure 2. Sites include:

- **D Street Marsh** - The study site is located at the mouth of the Sweetwater River, along mudflat habitat at the northern edge of the D Street fill. Adjacent habitat includes a sandy California least tern nesting site, and restored coastal salt marsh habitat to the east. The site has minimal hard substrate, but *O. lurida* was observed on metal posts, tires, and rubble along the shoreline.

- **Signature Park** - The study site is located south of and adjacent to the Sweetwater Marsh, a component of the U.S. Fish and Wildlife Service South Bay National Wildlife Refuge. The site consists of a sandy beach transitioning to mudflat. Hard substrate is minimal, but *O. lurida* was present along rock rubble and the remnants of a pier that exist on-site.

- **J Street Marina** - The study sites is located on mudflat habitat at the base of a rip rap shoreline. However, there is abundant adjacent mudflat habitat and O*. lurida* is present on rip rap rubble along the shoreline.

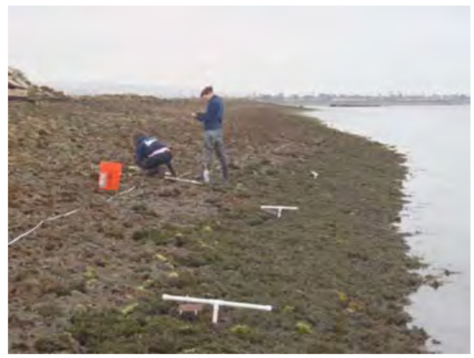
- **Chula Vista Wildlife Reserve (CVWR)** – The study site is along the northern edge of the CVWR, an area of extensive erosion. The shoreline consists of cobble that abuts a sandy beach with an eroding earthen dike. The eroding dike currently protects coastal salt marsh habitat. The cobble supports a dense population of *O. lurida*.

Figure 1. Locations of Study Sites in South San Diego Bay

D Street Marsh

Signature Park

J Street Marina



Chula Vista Wildlife Reserve

Pond 11 South

Pond 11 North

Grand Caribe

Figure 2. Photos of six study sites in south San Diego Bay

- **Pond 11 South** - The study site is along an earthen and rocky dike that separates restored mudflat and coastal salt marsh habitat from open Bay waters. Both the bayward/windward, and protected leeward side of the dike were studied. Pond 11 south is along the protected side. Hard substrate is minimal and limited to rocks in the earthen dike. The rock along the dike supports some *O. lurida*.

- **Pond 11 North** - The study site is along the windward side of the dike at Pond 11. This site transitions to mudflat and subtidal eelgrass habitat. Hard substrate is limited to rocks in the earthen dike. The rock along the dike supports some *O. lurida*.

- **Grand Caribe** - The study site is along a sandy beach that is part of a housing development in south San Diego Bay. Part of the shoreline is protected by a seawall, but the remainder is unarmored or protected by slumping rip rap. The seawall supports some *O. lurida*.

ADULT OYSTER DENSITY

Adult oyster density and habitat percent cover surveys were completed at the six sites described above. Surveys were completed at low tide over several survey dates (Table1). At each site, a 50 m X 2 m transect was placed parallel to the water line and centered at ~+0.3 m MLLW. Thirty quadrats were randomly placed along each transect to assess habitat percent cover (except at Chula Vista Wildlife Reserve, where n=24 quadrats). The quadrat was 50 cm x 50 cm and gridded. Habitat typed was recorded at each intersection of the grid for a total 49 data points. Habitat cover was recorded as mud, sand, dead shell, *Mytilus spp., O. lurida, C. gigas*, etc. For the purposes of these surveys, habitat types were combined into hard and soft substrata. Percent cover of each habitat type was then determined for each quadrat and average percent cover of hard substrata was reported by site.

To determine densities of *O. lurida* and *C. gigas* for each site, the number of each species was recorded for each quadrat. The mean density and standard error was then determined by species by site. At sites where no oysters were encountered within the quadrats, the site was haphazardly surveyed to take note of the presence or absence of both oyster species. Lastly, the upper and lower tidal heights of each transect were measured at the beginning of the transect using surveying gear and a meter stick. The 2 m width of each transect along with surveyed tidal heights were then used to calculate slope (as percent).

To analyze whether there was a significant relationship between percent cover of hard substrata and oyster density, the correlation among site-averaged percent cover and site-averaged *O. lurida* and *C. gigas* densities was explored. The density data were not normally distributed so the significance of the correlations was tested using Kendall's Ʈ, a nonparametric correlation test useful when data are not normally distributed and with small sample sizes (in this case, n=7 study sites).

Table 1. Study site names, dates surveyed, GPS coordinates, tidal range of surveyed transect, slope, oyster density, and percent cover of hard substrata from surveys performed from May-Dec., 2013 in San Diego Bay, CA. CVWR= Chula Vista Wildlife Reserve, MLLW= mean low lower water, SE = standard error. * = oyster species present (were detected at the site during qualitative surveys but not in quadrat counts).

Site Name	Date Surveyed	GPS Coordinates	Tidal Ht Range (m MLLW)	Slope (%)	*O. lurida*/0.25m^2 (SE)	*C. gigas*/0.25m^2 (SE)	% cover hard substrata (SE)
CVWR	28-May-13	32.614325°N -117.113834°W	0.10-0.38	10.20	54.83 (6.84)	1.75 (0.62)	98.64 (0.44)
D Street Marsh	30-May-13	32.647127°N -117.1162016°W	-0.08-0.20	13.80	0.00* (0)	0.00* (0)	0.07 (0.07)
Signature Park	30-May-13	32.633349°N -117.1075841°W	0.11-0.19	0.00	0.00* (0)	0.00* (0)	0.00 (0.00)
J Street Marina	24-Jul-13	32.620833°N -117.104444°W	0.30-0.44	6.70	8.63 (3.06)	5.90 (1.27)	41.26 (3.62)
Grand Caribe	25-Jul-13	32.626389°N -117.129444°W	0.39-0.93	15.10	0.77 (0.27)	11.03 (2.19)	26.10 (4.49)
Pond 11 - North	13-Dec-13	32.602702°N -117.117987°W	0.15-0.44	6.70	0.37 (0.37)	0.00* (0)	0.82 (0.44)
Pond 11 - South	13-Dec-13	32.602535°N -117.117912°W	0.36-0.81	17.70	7.20 (2.08)	1.10 (0.32)	23.54 (2.69)

OYSTER SPAT RECRUITMENT RATE

To assess recruitment rates of *O. lurida* and *C. gigas* oyster spat, recruitment collectors (n=4) were deployed at each of the six study sites from May 30, 2013 - October 17, 2013, with recruitment collectors deployed at Pond 11 on both the north and south-facing sides of the earthen dike (Figure 2, Table 1). The recruitment collectors consisted of ceramic tiles that were attached to tees made of schedule 80 gray ¾" PVC. The vertical component of the tee was driven into the mud at ~ 0.0 MLLW so that the tile was suspended approximately 10-15 cm above the substrate. Tiles were collected and replaced during every spring tide, approximately every two weeks, and brought to the laboratory. Settled oyster s were counted and mapped using a dissecting microscope. Density of settlers was determined for each tile. For comparative purposes, once oysters were counted per unit area of tile, the number of oysters settled/m^2/day was calculated in order to standardize the data relative to other ongoing recruitment data studies in southern California.

A ceramic tile attached to a PVC tee was used as an oyster spat recruitment collector.

Settled oysters were counted and mapped in the laboratory.

OYSTER SURVIVORSHIP AND GROWTH

Two additional recruitment collectors (again, ceramic tiles attached to tees) were deployed on May 30, 2013 and were collected monthly throughout the study period in order to measure growth rates of individual oysters and survival rates per species. Ten oysters per tile were individually mapped and measured for growth (maximum length and width in mm) and survival. After monthly inspections, tiles were returned to the field. Because some of the tiles became so heavily fouled, it was difficult to re-locate some oysters over time, and thus data were reported as percent recovery rather than percent survival. "Recovered" translates into both found and survived; this leaves open the possibility that some oysters survived but were not found in subsequent searches. Thus, the perent recovery measure should be considered a conservative measure of survival.

Because of a lack of adequate replication, results of the recovery study were not statistically analyzed; however, percent recovery was averaged across the two replicate tiles measured at each study site. Qualitative observations on overall percent cover of oysters were also recorded significant fouling organisms that could serve as competitors for space with *O. lurida* were noted.

In the case of the growth data, there was a strong relationship between measures of length and width (regression, y = 0.7452x + 0.9852, R^2 = 0.8807), so only length data are presented only.

Preliminary T-tests were utilized to test whether growth (length) varied within study sites among tiles (T-tests, p>0.05 for all sites), and since it did not, individuals were pooled across tiles and analyzed for differences in growth as a function of site across the entire study period using ANOVA. Data were checked for homoscedasticity and normality prior to ANOVA.

RESULTS

Adult Oyster Density

Both species of oysters were present at all sites, though quantitative quadrat sampling did not intersect oysters of either species at D Street Marsh and Signature Park. For *O. lurida*, measured densities ranged from 0 at D-street Marsh and Signature Park to 56.3 ± 7.7 per $0.25m^2$ at Chula Vista Wildlife Reserve (CVWR) (Figure 3, Table 1). For *C. gigas*, measured densities ranged from 0 at D street Marsh, Signature Park, and Pond 11 North to 11.0 ± 2.2 per $0.25m^2$ at Grand Caribe (Figure 3, Table 1).

There were strong habitat differences among the sites sampled; percent hard substrate varied widely across sites at the tidal elevation surveyed, ranging from 0% at Signature Park to 98.64% at CVWR. Two sites, Signature Park and D Street Marsh, were dominated by mud. CVWR was dominated by cobble. The other sites were a mix of mud, sand, cobble, shell rubble, and rip-rap. There was a strong relationship between the % hard substrata present at a site and *O. lurida* density (Kendall's Ʈ, R=0.95, p=0.0062, Figure 4), but there was a marginally insignificant relationship between % hard substrata and *C. gigas* density (Kendall's Ʈ, R= 0.22, p = 0.0599, Figure 4).

A ceramic tile with oyster recruits as observed with the naked eye.

Oyster Spat Recruitment Rate

When examining tiles and quantifying recruitment, native from non-native oyster recruits were distinguished from each other based primarily upon two distinctive morphological characters. The first was the shape of the umbo. *C. gigas* has a distinctive left-leaning hook to the umbo, while *O. lurida*'s umbo appears "bubble-shaped". We also noted a darker pigmentation to the tissue underneath the upper valve of *C. gigas* providing a greyish brown hue to the shell versus *O. lurida*'s more golden yellow hue (see photos to left).

Oyster recruits as observed with a dissecting microscope. Native* O. lurida *is to the right and non-native* C. gigas *is to the left.

For *O. lurida*, highest recruitment occurred at all sites during June 2013, ranging from 642 to 6,569 recruits/m^2/day (Figure 5). In early July, recruitment significantly declined, and ranged from 5 to 377 recruits/m^2/day.

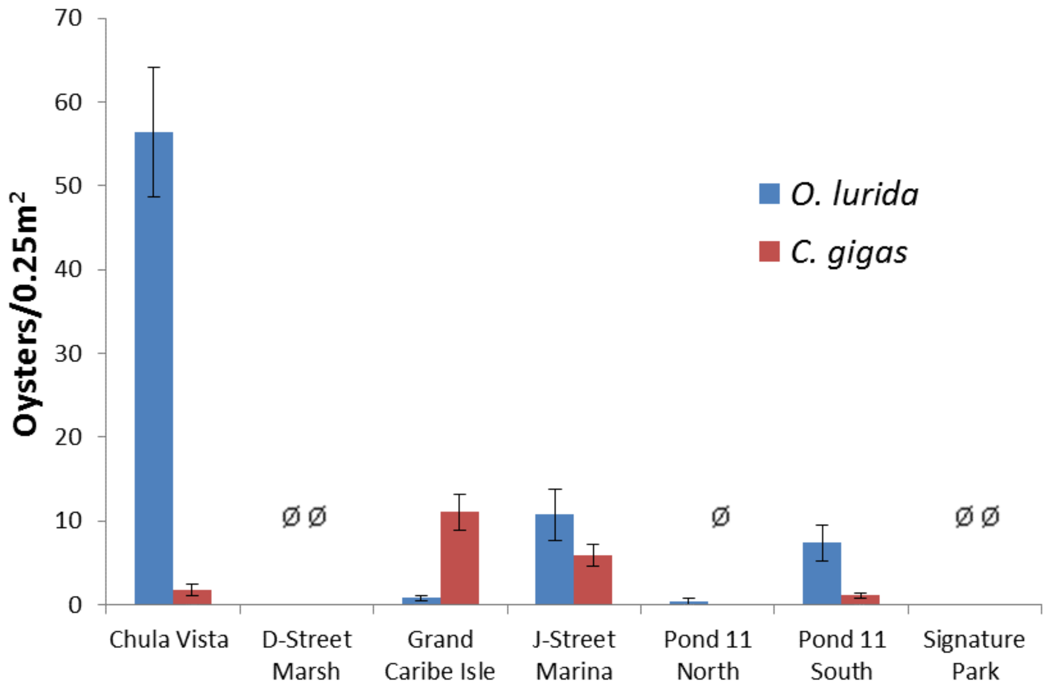


Figure 3. Mean density (± 1 SE, n= 24 to 30 randomly placed 0.25m^2 quadrats) of native *Ostrea lurida* and non-native *Crassostrea gigas* oysters at six sites within San Diego Bay, California during 2013. (Ø = present at site but not recorded within randomly placed quadrats.)

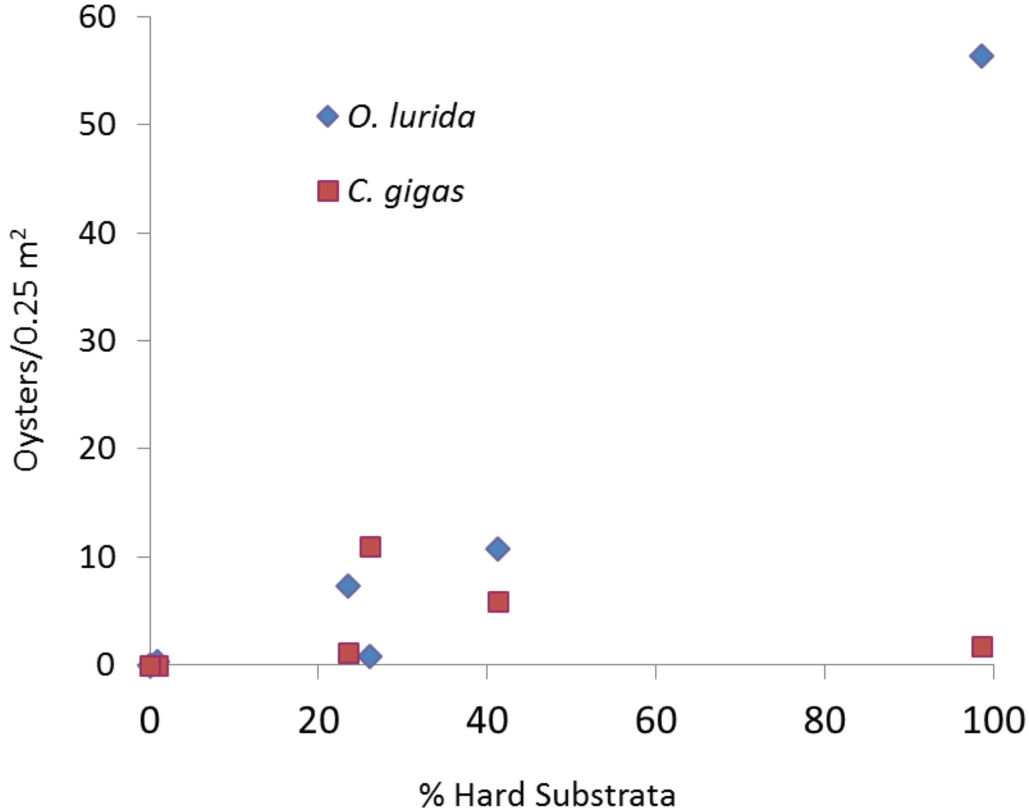


Figure 4. Relationship between the number of oysters per m^2 and percent of hard substrata for native *Ostrea lurida* and non-native *Crassostrea gigas*. Each data point represents the mean density and mean % hard substrata measured at a study site within San Diego Bay.

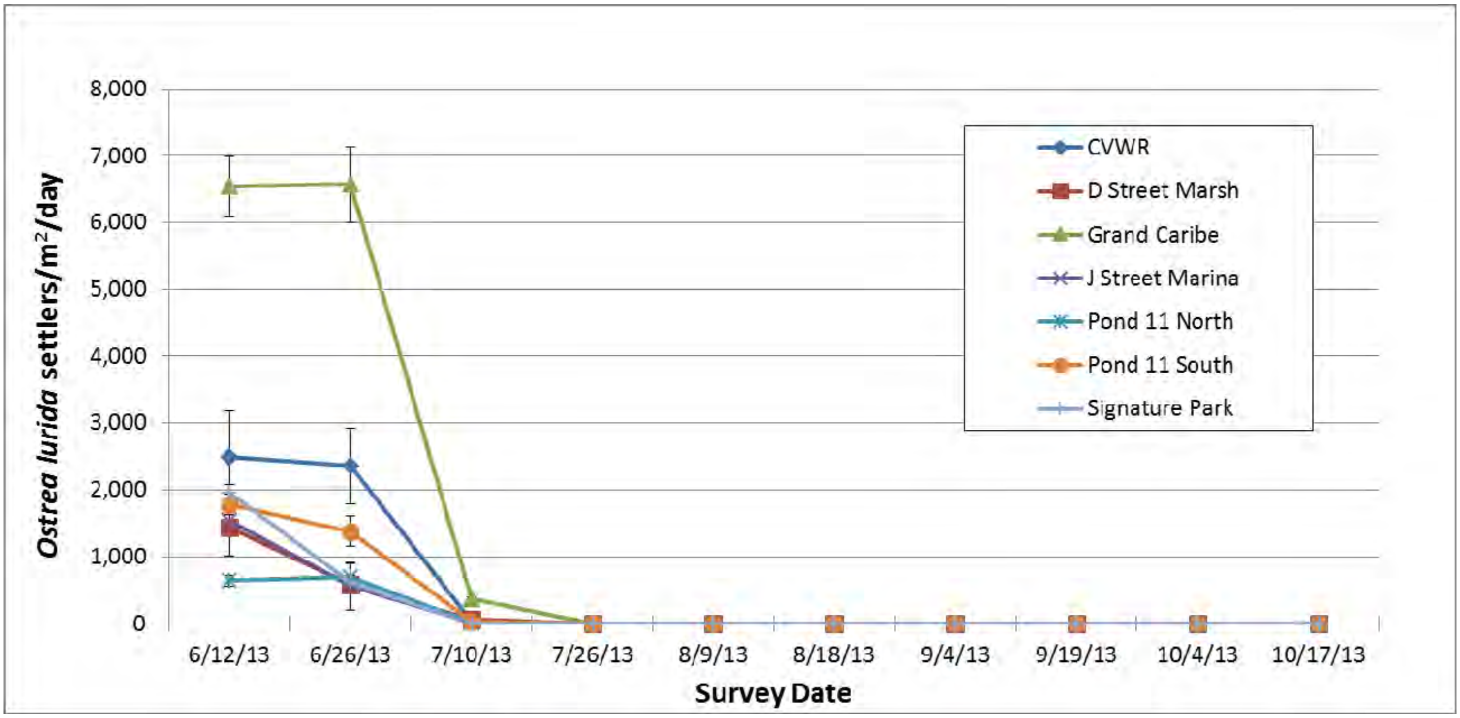


Figure 5. Mean recruitment (recruits/m^2/day) (± 1 SE, n=4) of native *Ostrea lurida* oysters at six study sites within San Diego Bay, California during 2013.

After mid-July, recruitment was < 5 recruits/m^2/day at all sites through the end of the recruitment collector deployment period in mid-October. Grande Caribe consistently recruited the highest numbers of *O. lurida*, with ~ 2.6 to 10 times more recruits than any other site.

For *C. gigas*, the timing of peak recruitment was similar, with maximum recruitment again occurring at all sites during June 2013 (except Pond 11 South), ranging from 0.8 to 196 recruits/m^2/day (Figure 6). The D Street Marsh site had the highest recruitment of *C. gigas*, with 2 to 200 times more recruits than other sites. Grand Caribe had the second highest recruitment of this species. As with *O. lurida,* recruitment of *C. gigas* declined dramatically in early July. After mid-July, zero *C. gigas* recruits were recorded at all sites through the end of the recruitment collector deployment period in mid-October.

OYSTER SURVIVORSHIP AND GROWTH

Recovery of the ten individual *O. lurida* that were tracked on each tile over the entire course of the growth rate study varied by study site and ranged from 5% to 45% (Figure 7). The best recovery of individuals was measured at D Street Marsh, Pond 11 and Chula Vista (each with ≥40% recovery), and the worst recovery was measured at J Street Marina, Grande Caribe and Signature Park (each with < 25% recovery). There were several reasons for the inability to recover individual oysters, including death of the individual oyster, inability to re-orient the grid on a tile (the grid allows for the re-location of oysters in a particular quadrant or cell of the tile; see photo above for a sample grid), high density of oysters making it difficult to identify an individual, and overgrowth by other species (see photos). Significant fouling and overgrowth occurred at several sites. For example, tiles from J Street Marina had >80% cover of bryozoans, with much evidence of overgrowth over oysters, while tiles from D Street Marsh had 40-50% cover of tunicates. In contrast, tiles from Grande Caribe, CVWR and at Pond 11 did not exhibit extensive overgrowth of other species, and displayed a high total percent cover (>50%) of *O. lurida*. Lastly, a couple of sites displayed an interesting growth pattern of oysters, with *O. lurida* oysters common on the sides of tiles facing downward, and *C. gigas* dominating on the sides facing upward. The *C. gigas* that settled on the growth tiles displayed clearly faster growth over the time period of the study.

Two growth tiles at the end of the study. The top tile shows a high oyster density, while the bottom tile has experienced overgrowth by bryozoans.

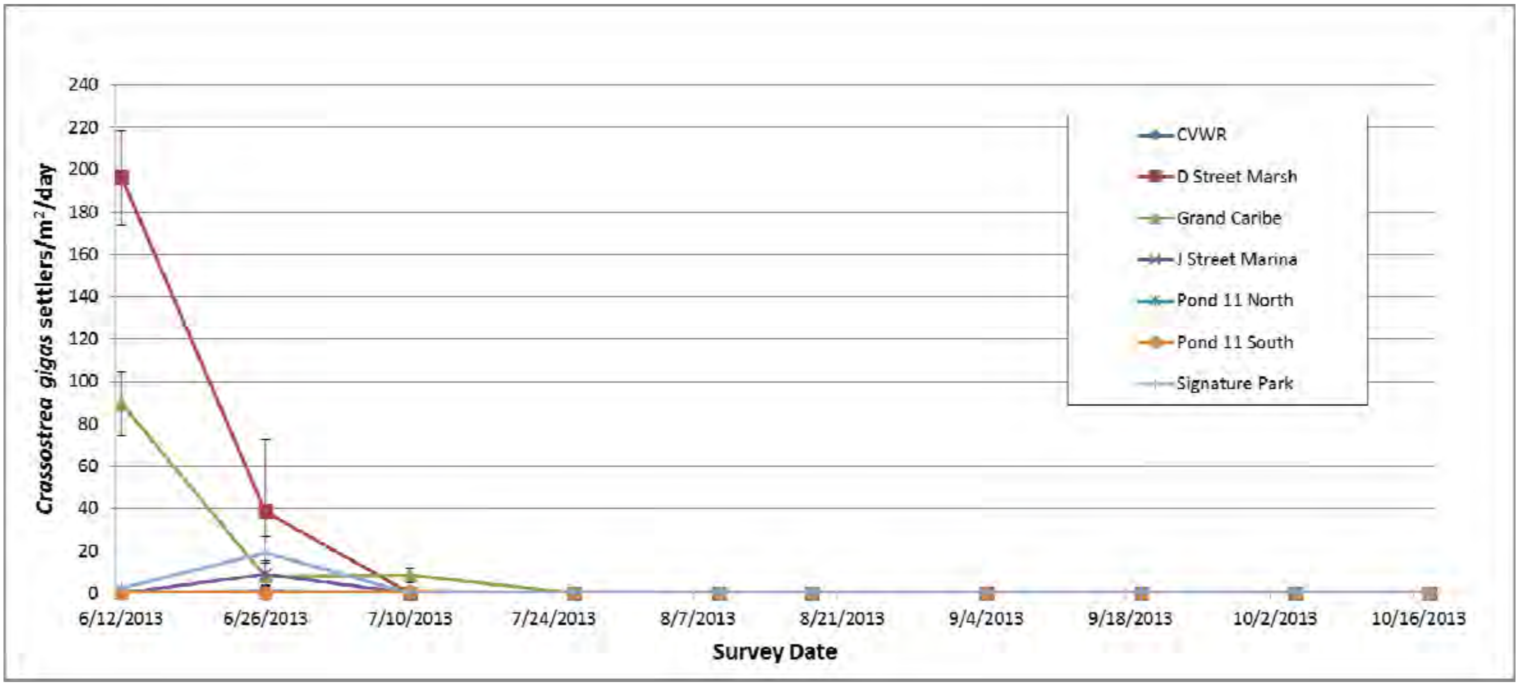


Figure 6. Mean recruitment (recruits/m^2/day) (± 1 SE, n=4) of non-native *Crassostrea gigas* oysters at six study sites within San Diego Bay, California during 2013.

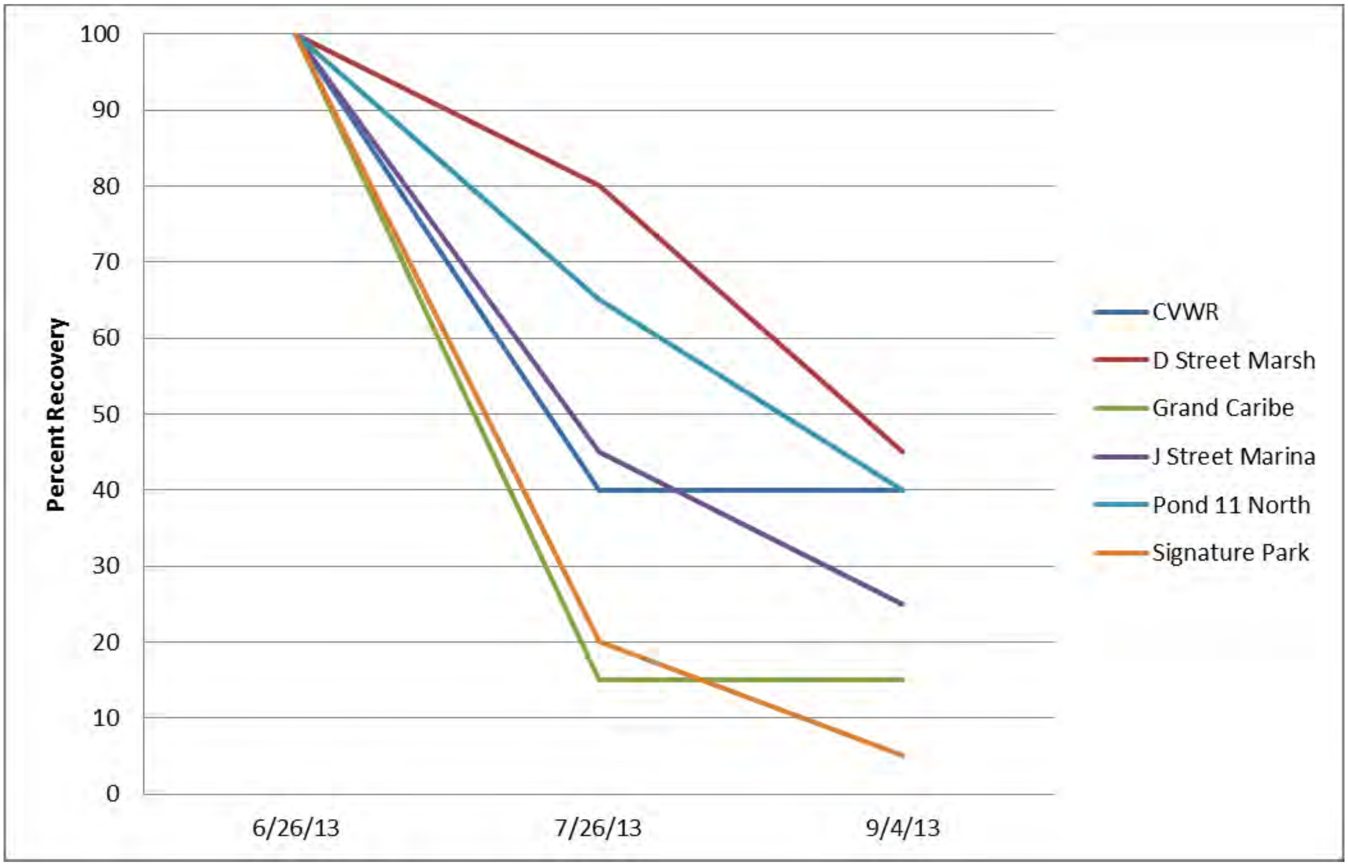


Figure 7. Percent recovery (n= 2 tiles/site) of native *Ostrea lurida* oysters at six study sites within San Diego Bay, California during 2013.

Total oyster growth of *O. lurida* over the entire study period (97 days) did not differ significantly among study sites (ANOVA, n = 5-8 individuals per sites, p= 0.1285, Figure 8) and averaged 24.09 ± 1.58 mm, ranging from 11 to 42.7 mm. Grande Caribe and Signature park were excluded from the statistical analysis because they had 0 and 1 individual oysters recovered, respectively. The mean growth rate at the study sites ranged from 0.1 to 0.6 mm/day, with a total average of 0.25 mm/day. The growth rate was generally highest at most study sites approximately one month after settlement (Figure 9). A notable exception was Pond 11, where growth was fastest approximately 2 months after settlement.

DISCUSSION

One way to assess whether a constructed oyster reef would be naturally populated via local oyster production is to examine the status of oysters at the location of interest to assay whether adult oysters are present and thriving and whether they recruit to the location. In this study, results illustrate that both native *O. lurida* and non-native *C. gigas* oysters are present at and recruiting to all of the six study locations.

Densities of adult *O. lurida* in San Diego Bay are generally comparable to other locations in southern California that have been surveyed in the past several years, including Newport Bay and Alamitos Bay, where densities range from ~ 0-45 oysters/m^2 on a variety of substrata (including seawalls, pier piles, cobble, rip-rap and mudflat, D. Zacherl, unpublished data). The one exceptional location within San Diego was the Chula Vista Wildlife Reserve (CVWR), with > 200 *O. lurida*/m^2, or about 4 times the maximum densities observed elsewhere in southern California. Non-native *C. gigas*, on the other hand, are 7 times more abundant, on average, in San Diego Bay than elsewhere in southern California (D. Zacherl unpublished data).

The very high density of native *O. lurida* at CVWR may partly be attributed to the high % cover of hard substrata, particularly cobble, which seems to provide excellent attachment substrate for oysters. In fact, survey data from this study indicate that native oyster density is correlated with % hard substrata. On the other hand, the density of non-native *C. gigas* did not show the same correlation. This lack of correlation may be partly an artifact of the interaction between the shallow slope at the site with highest percent hard substrate cover (CVWR) and the tidal elevation at which we surveyed that site. Because we used a 2m-wide band transect, the shallow slope at CVWR meant that the surveyed tidal elevation fell below the tidal elevation where *C. gigas* become more abundant (at tidal elevations >0.4 m, D. Zacherl and T. Parker, unpublished data). So, while *C. gigas* were present at the six study site, this survey was not specifically designed to maximally capture *C. gigas* density. In fact, the tidal elevation of maximum *C. gigas* distribution was only recently characterized for southern California (D. Zacherl and T. Parker, unpublished data). This sampling bias may imply that density estimates for *C. gigas,* were, in general, conservative.

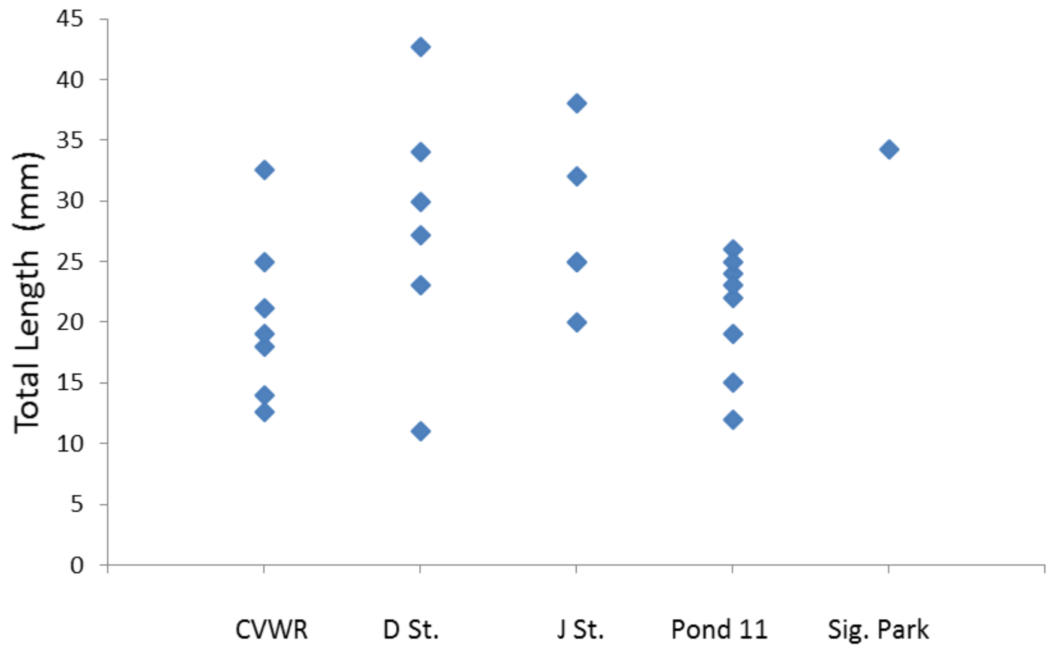


Figure 8. Total growth of *Ostrea lurida* recruits over a 97-day period at five sites within San Diego Bay, California during summer 2013. Individuals depicted each survived the entire study period and were pooled across two ceramic growth tiles per site. No individuals were recovered at termination of the study period at Grande Caribe.

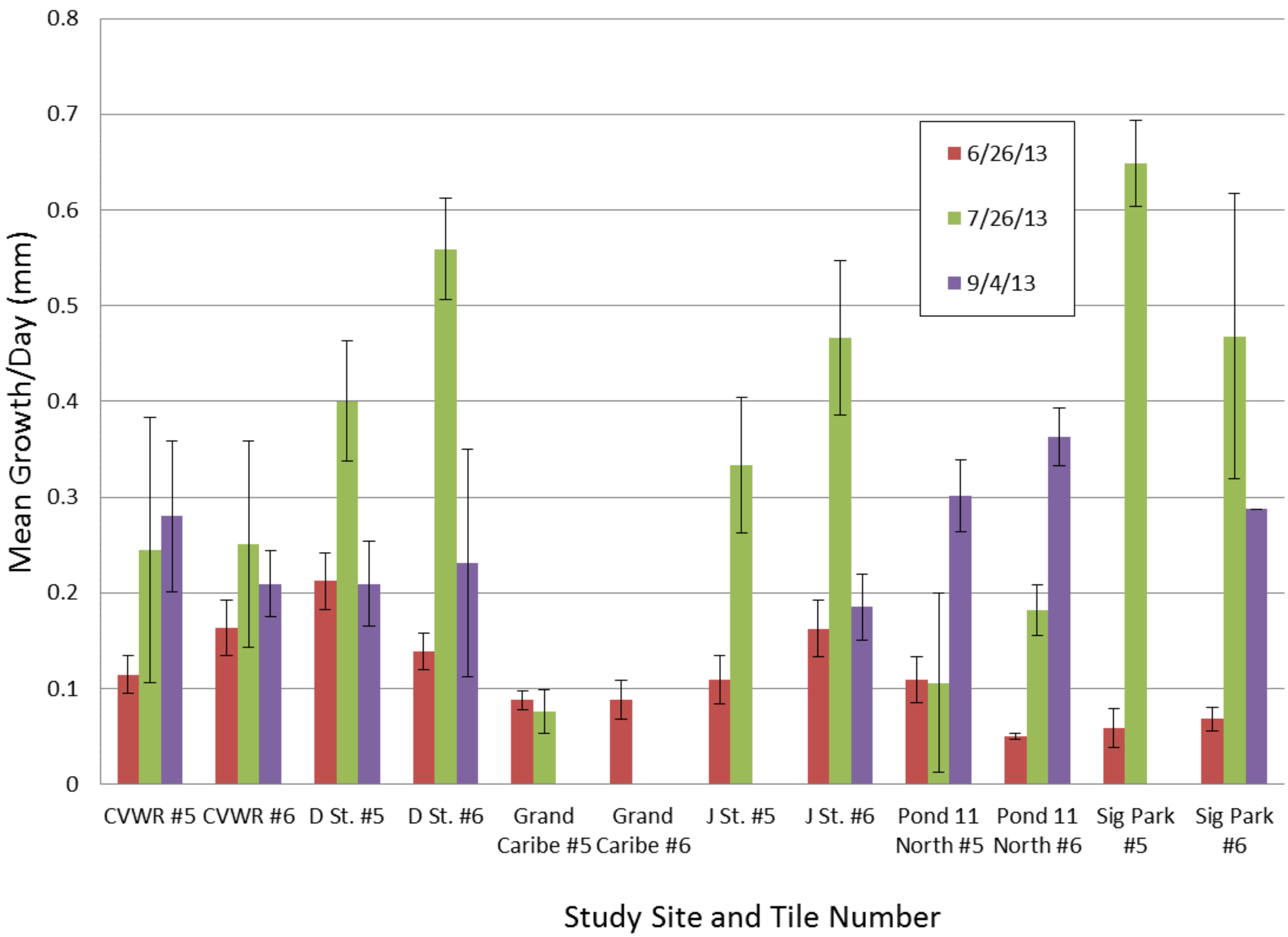


Figure 9. Mean growth rate (mm/day) (± 1 SE, n = variable based on recovery of oysters) of native *Ostrea lurida* by tile at six study sites within San Diego Bay, CA during 2013. Two ceramic tiles (denoted as #5 and #6) were deployed per site.

None of the six study sites surveyed appear recruitment limited for *O. lurida*, with each site receiving > 600 *O. lurida* recruits/m^2/day. The recruitment rate for each study site in this study is much greater than for Newport Bay in summer 2013, where recruitment of oysters was assayed throughout the same time period. In Newport Bay, recruitment ranged from 1.5 – 85oysters/m^2/day in June 2013, except at one site (15th street) during one census, which received ~400 oysters/m^2/day (D. Zacherl, unpublished data).

For sites that lacked significant hard substrata and that were dominated by mudflat, oysters were present and common on the very limited hard substrata available (e.g., old tires, rebar, other refuse). That observation, coupled with the fact that strong recruitment was measured at all study sites in June 2013, suggests that if a mudflat habitat is augmented with hard substrate at any of the study sites that currently lacks significant hard substrata (e.g., D Street Marsh), oysters have the potential to thrive.

The low replication in our oyster growth and recovery study prevented statistical analysis due to a lack of power. Further, the amount of overgrowth by fouling organisms such as tunicates and bryozoans made recovery of tracked individuals extremely challenging. Therefore it is difficult to know whether sites with low recovery truly experience highest mortality, or rather, simply were sites where overgrowth and fouling prevented the tracking of individuals. It was clear that some sites suffered higher fouling rates than others, notably J Street Marina, where growth tiles displayed >80% cover of bryozoans. Nonetheless, the overall observation of reasonably high percent cover of *O. lurida* again suggests that most sites (excepting possibly J Street Marina) would be good choices for a constructed oyster reef.

CONCLUSION

Based upon the density, recruitment, recovery and growth data collected during 2013, all six study sites in south San Diego Bay could be viable locations for construction of an oyster reef, though J Street Marina experienced very high rates of fouling by potential space competitors. All sites surveyed already support both *O. lurida* and *C. gigas* where hard substrata were present, and all sites received adequate recruitment. D Street Marsh was the site with the highest percent recovery of growing oysters, but it also experienced the highest non-native oyster recruitment. If the objective is to restore a functional oyster reef with native *O. lurida* oysters, then particular attention should be paid to the tidal elevation of constructed reefs. Given that *C. gigas* become more abundant at tidal elevations >0.4 m MLLW and that *O. lurida* are most abundant at < 0 m MLLW (D. Zacherl and T. Parker, unpublished data), a tidal elevation of < 0 m MLLW is recommended for constructed reefs.

ACKNOWLEDGEMENTS

Danielle Zacherl would like to acknowledge the participants in the field and laboratory work, including Holly Henderson and Mike Jilka from Merkel & Associates, Inc., CSUF graduate students Joanne Linnenbrink, Sara Briley, and Kim Walker, and CSUF undergraduates Thomas Parker, Nicole Tronske, and Cristina Fuentes. The San Diego Unified Port District facilitated much-appreciated access to field sites, and funds were provided by the SDUPD and California State Coastal Conservancy. Special thanks to Thomas Parker, Joanne Linnenbrink and Nicole Tronske, who trained and assisted Merkel staff in the settlement tile scoring and growth rate study.

APPENDIX D

San Diego Bay
Native Oyster Restoration Plan

Technical Memorandum

Wind Wave Modeling and Groundtruthing in San Diego Bay

Prepared by:

Environmental Science Associates (ESA)

Lead Engineer: Nick Garrity

May 2015

INTRODUCTION

The San Diego Bay Native Oyster Restoration Plan (Plan) is a collaborative effort being undertaken by the San Diego Unified Port District (SDUPD) and the California State Coastal Conservancy (Conservancy). The Plan goal is to create a biologically rich native Olympia oyster, *Ostrea lurida,* bed in San Diego Bay as part of a complete marsh system that restores an ecological niche that was historically present, is ecologically functional and resilient to changing environmental conditions, and protects bay tidelands and shoreline.

Primary objectives of the Plan include identification of appropriate energy environments and sites that could most benefit (in terms of erosion control and ecological function) from oyster bed creation, and then evaluation of the potential for restored oyster beds to reduce water flow velocities, attenuate waves, reduce erosion, and promote sediment capture. Higher wave energy sites would be best suited to address these Plan objectives. Wind power modeling and subsequent groundtruthing was conducted in order to identify shorelines within San Diego that receive the greatest wind wave energy, and consequently, may be most susceptible to shoreline erosion.

WAVE POWER

METHODS

Wave power was calculated within San Diego Bay to identify the areas that are at the greatest risk of erosion. The Hasselmann Method from the Shore Protection Manual (SPM) was used for calculating the wind-wave climatology of the site (USACE 1984). The SPM method was chosen because it considers shallow water and deep water wave equations separately. Since the deepest part of the Bay is less than 300 feet deep, the adjusted shallow-water forecasting equations can be applied. Required input in the wave equations included water depth, wind speed, and fetch length (the straight line distance over which the wind blows). In GIS, a grid was created with points spaced 100 feet apart throughout the Bay. Using an elevation raster created by Merkel & Associates, Inc. (M&A 2008, unpublished data) the elevation of the Bay at each point was subtracted from MHHW (5.29 feet NAVD) to find the average daily maximum water depth.

Wind data (direction and speed) was collected from existing stations throughout the Bay. Figure 1 shows the location of the local wind data stations near San Diego Bay. The CIMIS station (#184) had the longest record of wind data near the Bay. Both the CDIP (#73) and MET (#23188) stations had a longer record, but the CDIP station was too far from the Bay and the MET station data was not current (data collected prior to 1992). Therefore, eleven years of hourly averaged wind data from the CIMIS station were used to establish a percent occurrence table for the Bay (Table 1). The dominant winds originate from the W and WNW. Later, data from the National City Marina Terminal (NCMT) wind gage (height of 80 ft) was compared to the CIMIS station data. The NCMT data showed higher peak wind speeds than the CIMIS data (Figure 2). Because the CIMIS station is more inland, it may be missing some of the peak wind speeds coming from offshore.

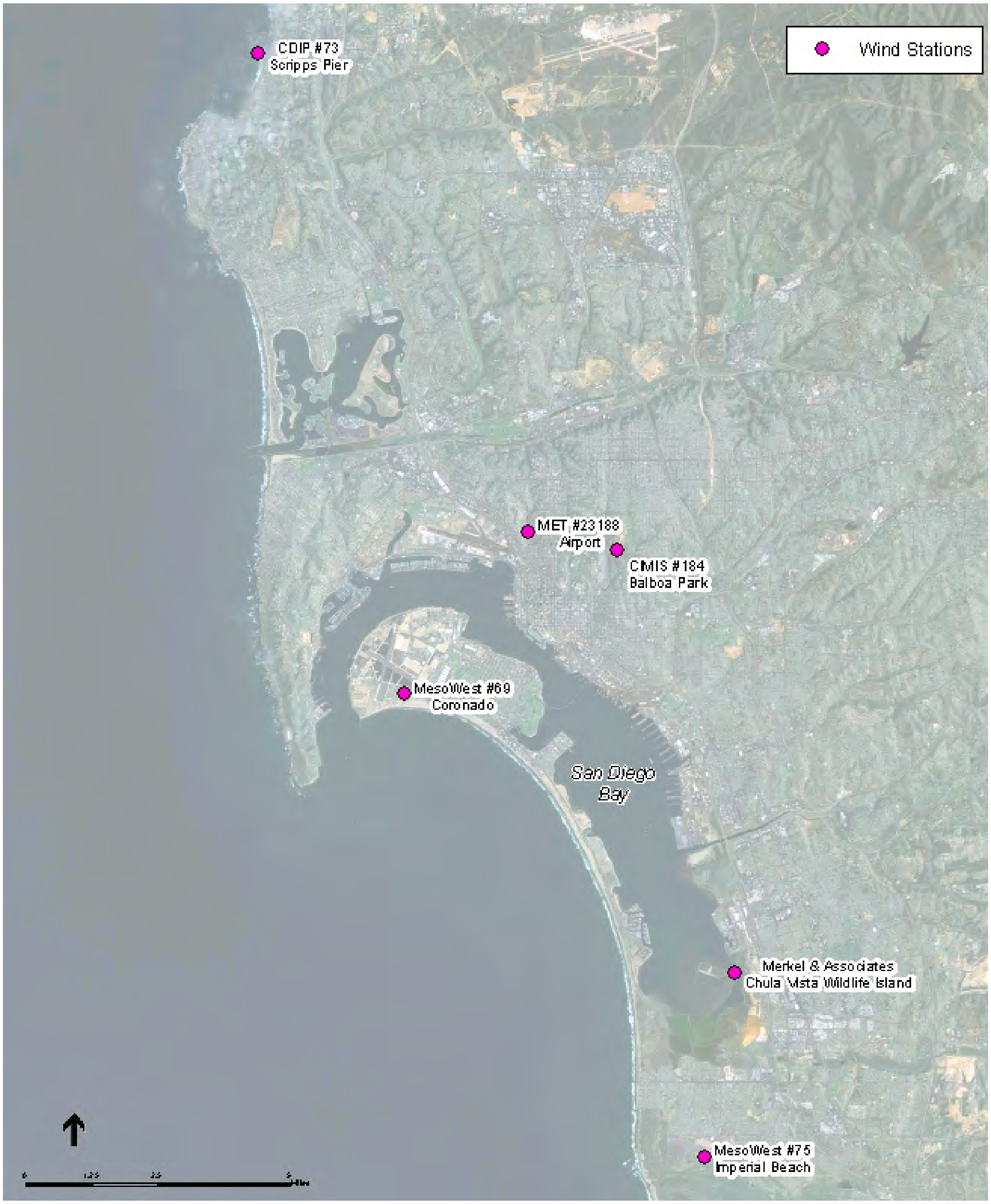


Figure 1. Wind Stations Near San Diego Bay

Table 1. Wind Occurrence

Wind Speed (m/s)	Wind Direction															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.0 - 0.5	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
0.5 - 2.0	7%	5%	3%	3%	2%	2%	2%	2%	4%	4%	3%	3%	6%	4%	4%	6%
2.0 - 3.5	1%	0%	0%	0%	0%	0%	0%	1%	1%	3%	2%	4%	8%	4%	2%	1%
3.5 - 5.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	0%
5.0 - 6.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6.5 - 8.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8.0 - 9.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
>= 9.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	9%	5%	4%	3%	2%	2%	3%	4%	6%	7%	5%	7%	17%	10%	8%	8%

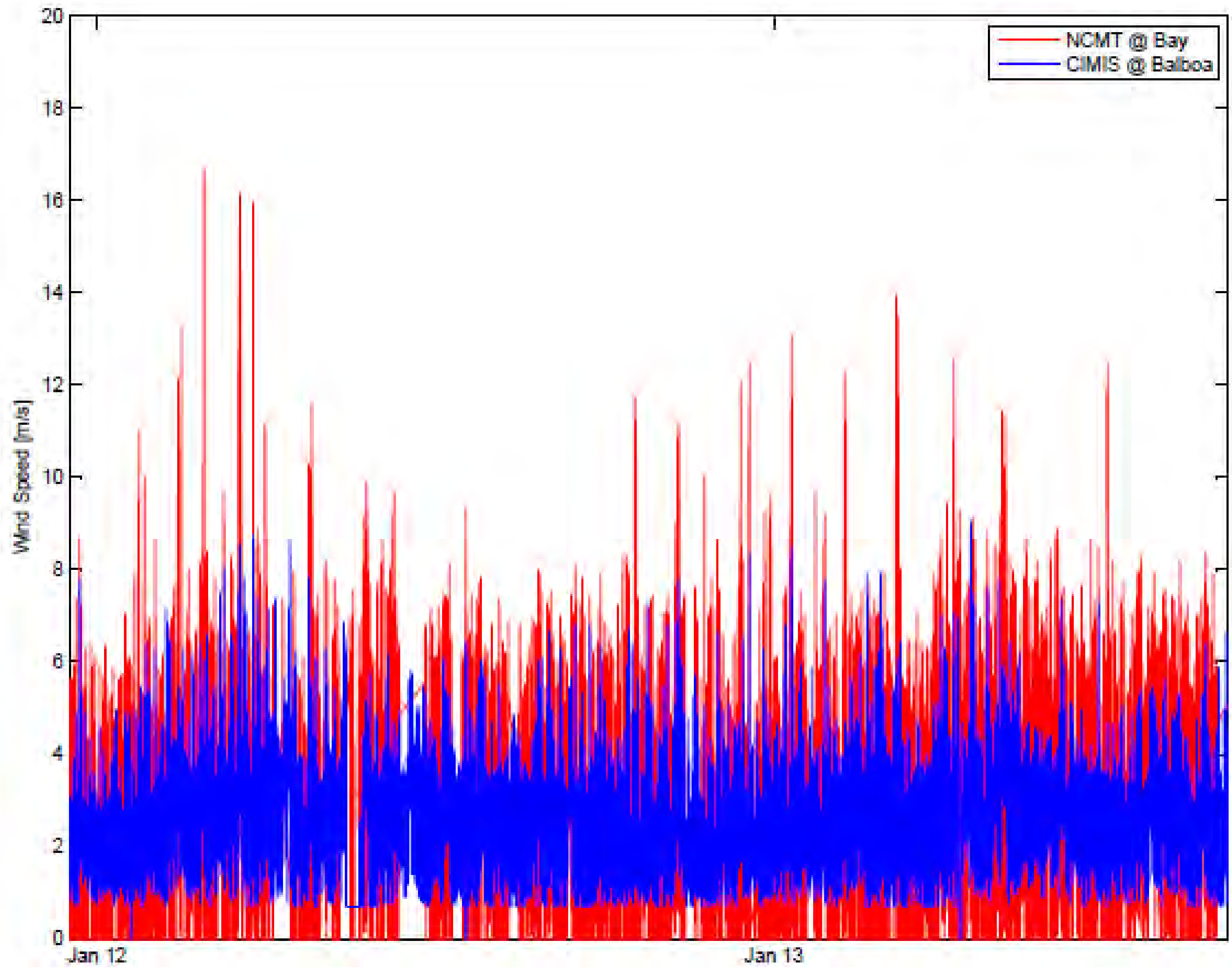


Figure 2. Comparison of Wind Data

Fetch lengths were calculated from each point of the grid to the nearest point above MHHW (generally the shoreline or levees) in the primary 16 wind directions. For each point on the grid, each wind direction, and each wind speed, the Hasselmann Method was used to calculate the wave height and period (see Equations 1 and 2).

Equation 1

$$H_s = \frac{0.283u^2}{g} tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right] tan\left\{\frac{0.00565\sqrt{\frac{gF}{u^2}}}{tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right]}\right\}$$

where H_s is the wave height in feet, u is wind speed at the water in ft/s, g is gravitational acceleration or 32.2 ft/s^2, d is water depth in feet, and F is the fetch length.

Equation 2

$$T_s = \frac{7.54u}{g} tanh\left[0.033\left(\frac{gd}{u^2}\right)^{0.375}\right] tanh\left\{\frac{0.0379\left(\frac{gF}{u^2}\right)^{0.33}}{tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right]}\right\}$$

where T_s is the wave period in seconds.

Once the respective wave heights and periods were calculated, the wave power could be calculated for each point, wind speed, and wind direction using Equation 3. In other words, 128 values of wave power were calculated for each point on the grid for the 16 wind directions and the 8 wind speeds.

Equation 3

$$P = \frac{\rho g^2 H_s{}^2 T_s}{64\pi}$$

where ρ is the density of salt water (1.99 slug/ft^3).

To estimate the annual wave power, each wind speed and direction pair was weighted by its percent occurrence (Table 1). For example, the wave energy calculated for a wind from the west at 1.25 m/s would be multiplied by 6% to account for the amount of time during a typical year that the wind blows from the west at 1.25 m/s. The annual wave power could then be calculated by adding together the weighted wave power for each direction and speed.

RESULTS AND DISCUSSION

The results of the wind wave analysis are shown in Figure 3. The east shore of the south San Diego Bay, especially near National City, is at the highest risk for coastal erosion due to wave power. Since the most frequent and fastest wind speed comes from the west to northwest, the area near National City experiences the longest fetch and therefore the most wave power in the bay. The west shore in the south bay and the north shore in the northern portion of the bay are sheltered from the stronger west to northwest winds, so these shorelines experience the least wave power.

The wave power variation by location is more important than the actual wave power values. This analysis assumes a constant water depth at MHHW in order to look at waves in intertidal as well as subtidal areas. This assumption overestimates wave power, since intertidal areas are dry and experience no waves for part of the day, and other areas experience smaller waves when the water depth are shallower at lower tides. Additionally, waves take time to develop from a constant wind, and since this analysis assumes a fully developed sea, wave power is again overestimated. However, this analysis does provide a way to compare wave power between locations, which can be used to help select sites for future restoration.

WAVE DATA GROUNDTRUTHING

METHODS

In order to groundtruth the wave power model created for this Plan, wave data were collected within the Bay using RBR Virtuoso® tide loggers, which measure water pressure and are able to measure both wave and tide data. Based on results of the wave modeling, a high and low wave energy site were chosen to capture wave variation in the Bay. The high energy site was at D Street Marsh on the eastern shoreline of south San Diego Bay, and the low energy site was in Emory Cove on the western shoreline of the south Bay (Figure 4). At each site, two gages were placed at +2 ft MLLW and -2 ft MLLW to capture waves at both high and low tides. Monitoring was continuous from June through November 2014.

RESULTS AND DISCUSSION

The wave data were compared to the model for the entire data set. However, due to the large size of the complete data set, a small segment of time is shown in Figure 5. Results of the groundtruthing indicate that the model accurately captured the wave events, but showed wave height peaks coming at the end of the events instead of for the full duration. This may be due to the CIMIS wind data, which showed lower wind speed peaks than the NCMT gage which is right on the Bay. Subsequent assessments may incorporate NCMT wind data; however, differences between the NCMT and the CIMIS wind data used for this assessment is not expected to significantly change the results for the purposes of this assessment. The results indicate that wind power model is able to identify high and low wave energy sites within San Diego Bay, and may be used to predict the potential for erosion along shorelines.

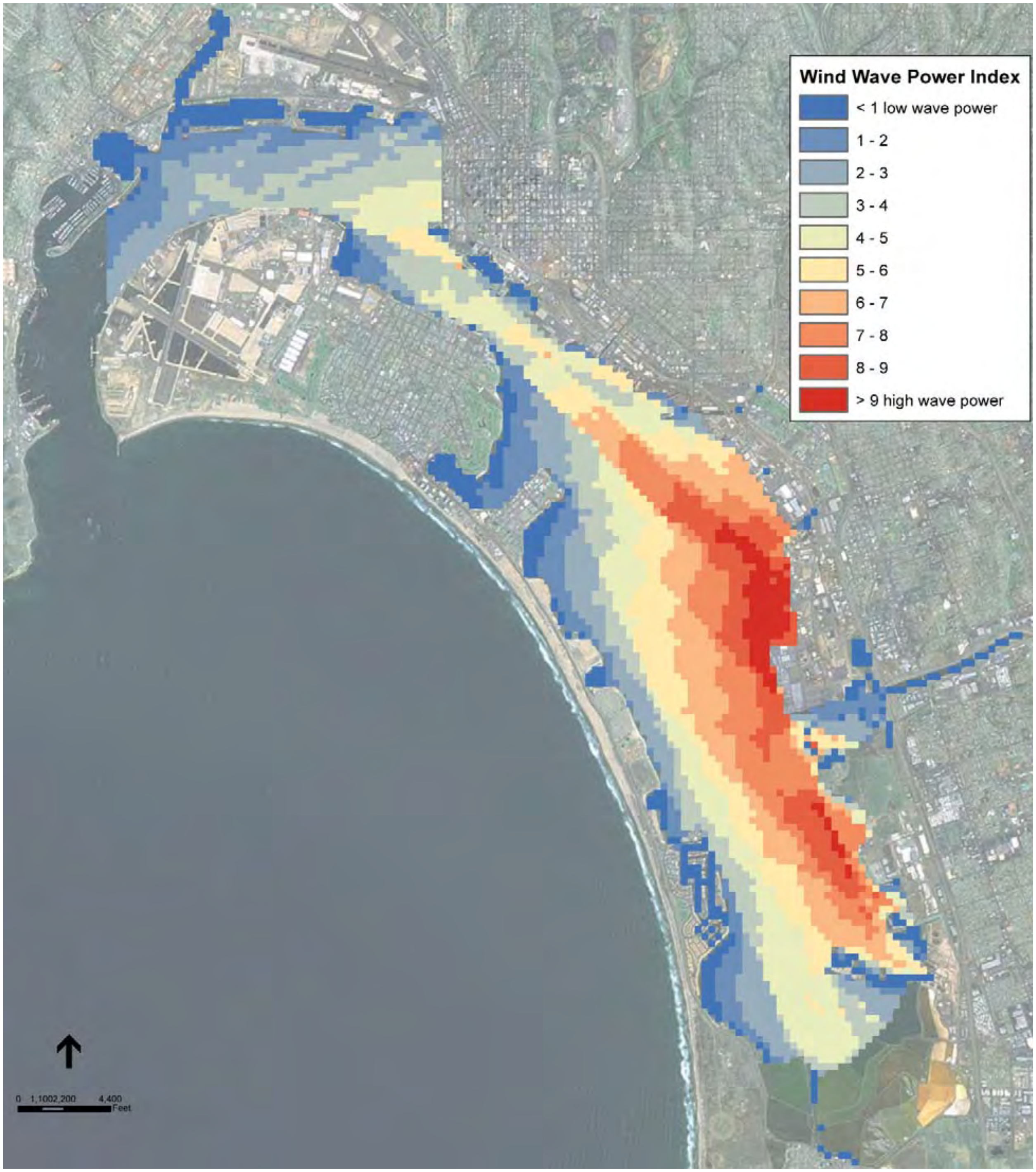


Figure 3. Wind Wave Power in San Diego Bay

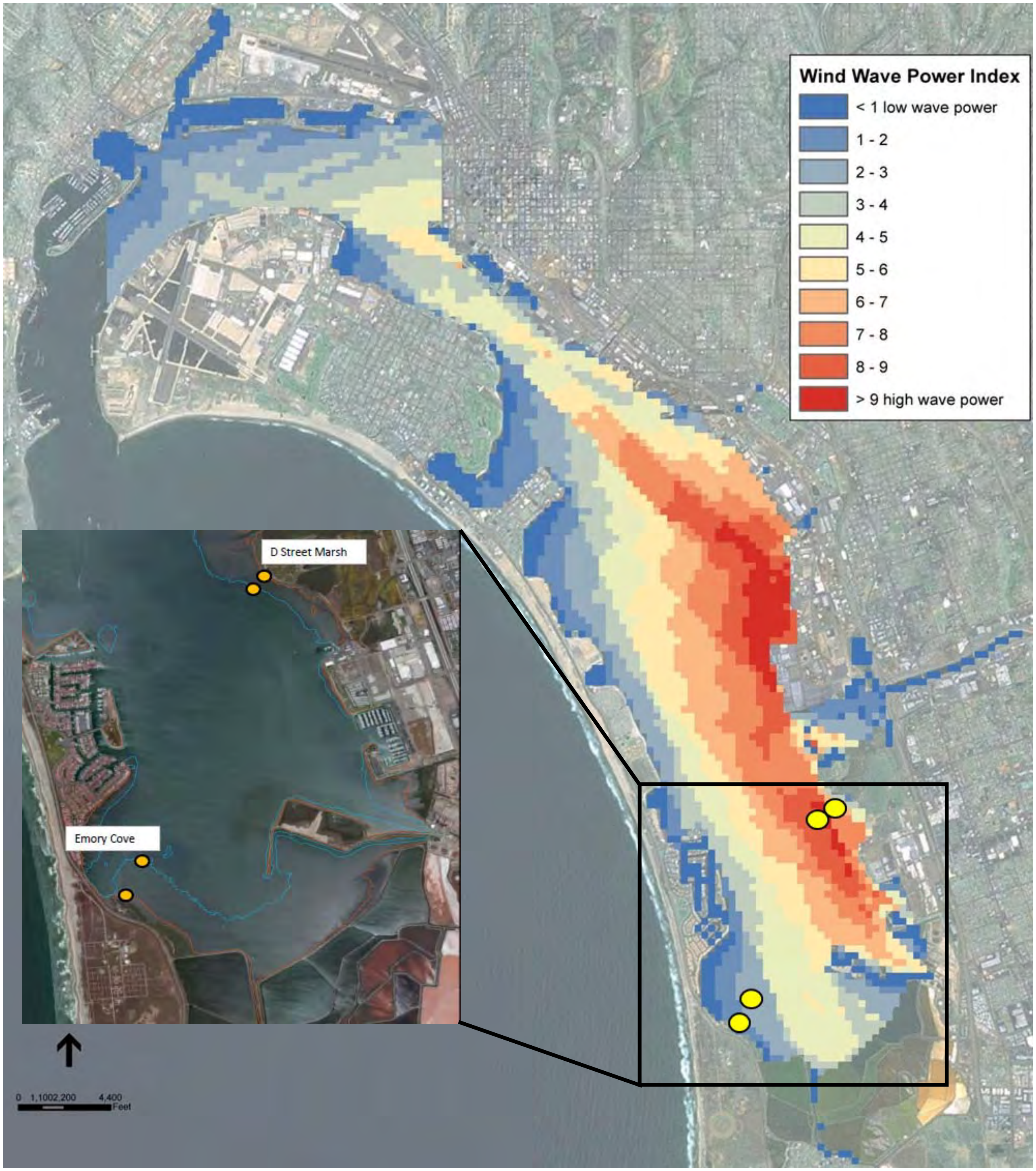


Figure 4. Location of Tide Loggers

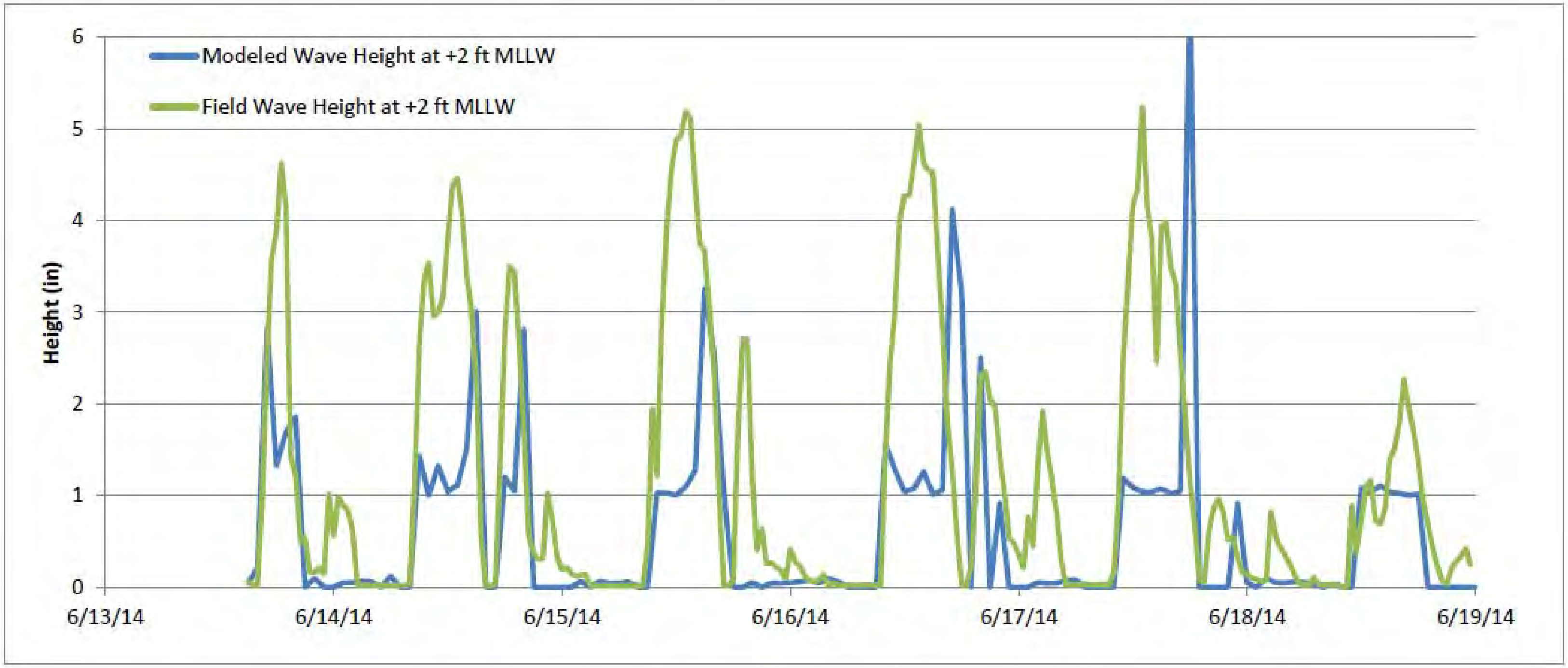


Figure 5. Comparison of Modeled and Measured Waves

REFERENCES

Bay Area Air Quality Management District. 2005. Sonoma Baylands BAAQMD met station. http://www.baaqmd.gov/

U.S. Army Corps of Engineers. 1984. Shore Protection Manual. Washington D.C. Vol. 1.

APPENDIX E

San Diego Bay
Native Oyster Restoration Plan

Technical Memorandum

Oyster Reef Concept Design and Assessment of Wave Energy Dissipation and Sediment Transport

Prepared by:

Environmental Science Associates (ESA)

Lead Engineer: Nick Garrity

May 2015

INTRODUCTION

The San Diego Bay Native Oyster Restoration Plan (Plan) is a collaborative effort being undertaken by the San Diego Unified Port District (SDUPD) and the California State Coastal Conservancy (Conservancy). The Plan goal is to create a biologically rich native Olympia oyster, *Ostrea lurida,* reef in San Diego Bay as part of a complete marsh system that restores an ecological niche that was historically present, is ecologically functional and resilient to changing environmental conditions, and protects bay tidelands and shoreline.

This technical memorandum documents the conceptual design for the oyster reefs proposed for the Plan and the assessment of wave energy dissipation and sediment erosion and transport for the proposed oyster reefs. A range in oyster reef elevations and configurations were assessed to inform the design of reefs that will provide increased wave energy dissipation and Bay mudflat deposition while achieving objectives for native oyster recruitment.

BACKGROUND

It has been shown from an engineering perspective that reef building species, such as mussels and oysters, enhance the habitat complexity and might be helpful in protecting intertidal flats against erosion by locally modifying the hydrodynamics and the sedimentation rates (Borsje et al. 2011, Reidenbach et al. 2013, Folkard and Gascoigne 2009, and Van Leeuwen et al. 2010). The ability of these intertidal species to stabilize intertidal flats, accumulate sediment, and increase mudflat elevations (Allen and Duffy 1998, Van der Wall and Pye 2004, and Borsje et al. 2011) makes them ideal as a sustainable and cost-effective coastal protection and sea-level rise adaptation measure.

The effect of oyster reefs or beds on waves and hydrodynamics depends strongly on reef configuration, location, and elevation. A key consideration is that, as filter feeders, oysters' optimal habitat requires long periods of submersion to assure food availability. Therefore, oyster reefs typically occur at lower elevations on the mudflat, whereas higher elevation reefs provide a greater benefit for reducing wave energy (Herlyn 2005, Borsje et al. 2011). A key objective of the San Diego Bay Native Oyster Restoration Plan is, therefore, to evaluate and identify the optimal oyster reef elevation that provides for the ecological needs of *O. lurida*, and also provides maximum wave reduction and shoreline protection benefits.

METHODS

Waves are a major factor determining the geometry and composition of the shoreline. An accurate understanding and prediction of wave propagation and dissipation is of vital importance to the management and ecology of the shoreline. A wave model was used to assess the wave transformation across the mudflat under existing conditions (to assess wave energy dissipation due to the mudflat itself) and with several oyster reef configurations. The energy dissipation at the oyster reefs is a function of the incident wave conditions, water level over the oyster reef and the size, height, configuration and location of the oyster reef itself.

A process based morphodynamic model for the nearshore and coast called XBeach (Roelvink et al. 2009) was used to model the wave propagation, mean flow, sediment transport and morphological changes on the mudflat. The model includes wave breaking, bottom friction, surf and swash zone process. The use of a model like XBeach allows a quantitative estimate of complex process involved on wave dissipation and sediment transport. The model has proven to be accurate and capable of handling flow discontinuities (wetting and drying), representing highly dissipative bottoms, and accurately describing the hydrodynamic interaction with complex structures.

SITE DESCRIPTION

The study area was the E Street Marsh shoreline, selected as the preferred project location within south San Diego Bay. The site consists of a wide, gently sloping mudflat that abuts an unarmored shoreline with a total length of approximately 2,300 linear feet (lf). Approximately one third of the shoreline consists of southern coastal salt marsh habitat of the E Street Marsh within the Sweetwater Unit of the U.S. Fish and Wildlife Service San Diego Bay National Wildlife Refuge.

The most recent baywide bathymetric survey of San Diego Bay (Merkel & Associates, Inc. 2008) and LiDAR data from NOAA's 2009-2011 Digital Coast, Coastal LiDAR Project were merged. A transect from this data set was used to define a typical profile on the study area. The slope of the mudflat in the study area generally ranges from 1:100 to 1:150. The topographic transect used for this study is shown in Figure 1. Water levels records and tide datums were evaluated and obtained from the San Diego Bay station (NOAA, Id. 9410170). Table 1 shows the tidal datum values from the San Diego Bay tide station.

Table 1: Tide Datum for San Diego Tide Station

Datum (ft, MLLW)	San Diego[1] (1983 – 2001)
Highest Measured Record	8.14
Mean Higher High Water (MHHW)	5.72
Mean High Water (MHW)	4.99
Mean Sea Level (MSL)	2.94
Mean Low Water (MLW)	0.94
Mean Lower Low Water (MLLW)	0.0
NAVD 88	-0.43

1. Source: NOAA, 2014. ID Station 9410170

WAVE MODEL IMPLEMENTATION

XBeach was applied in one dimension (1D) to predict and estimate the wave energy propagation and dissipation through the mudflat and estimate the cross-shore profile changes (erosion and accretion) with and without the different reef configurations. The 1D profile of the site and the output locations of the wave model are shown in Figure 1 and Table 2. The different oyster reef configurations that were evaluated with the model are shown in Figure 2.

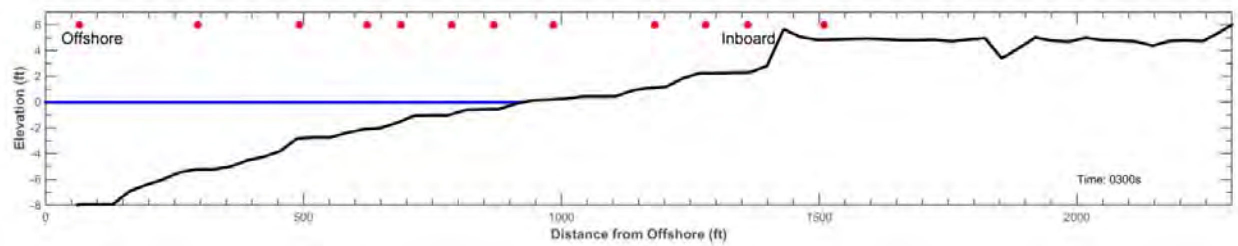


Figure 1. 1D Wave Model Setup and Existing Conditions Profile (E.C.)

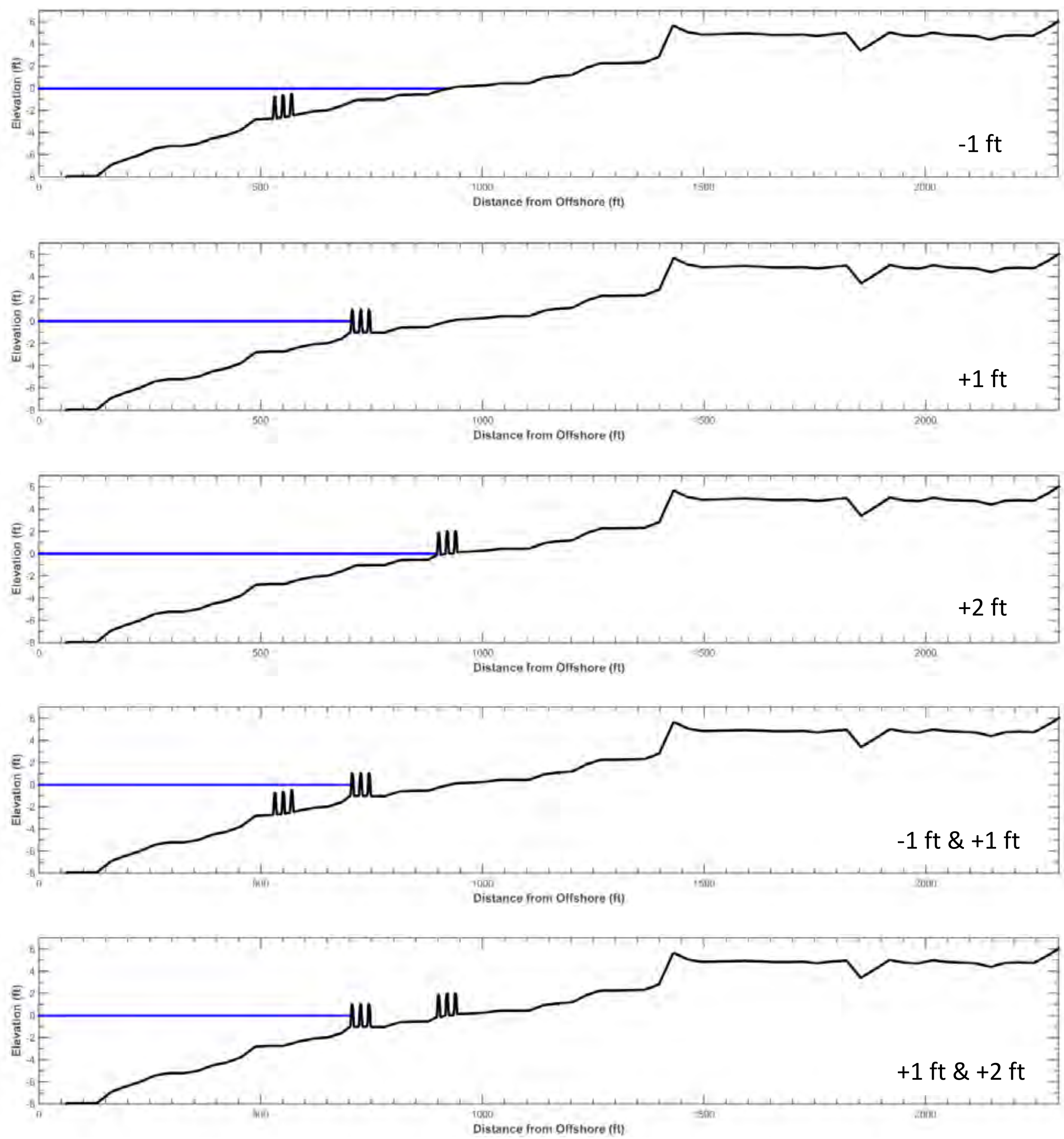


Figure 2. Oyster Reef Configurations

Table 2: Wave Model Output Locations

#	X (location)	Description
1	66	Offshore
2	295	Offshore 2
3	492	-1 FT outboard
4	623	-1 FT inboard
5	689	+1 FT outboard
6	787	+1 FT inboard
7	869	+2 FT outboard
8	984	+2 FT inboard
9	1181	Lower Beach
10	1280	Inboard 1
11	1362	Inboard 2
12	1509	Overtopping

Five different reef configurations at different elevations were evaluated, with reef crest elevations at -1 ft MLLW, +1 ft MLLW and +2 ft MLLW, and two combinations with two reefs at different elevations, one combination of -1 ft and +1 ft reefs and a second combination with +1 ft and +2 ft reefs. The different configurations are referred to by the reef crest elevation, e.g., -1 FT, +1FT & +2 FT, etc.

The model was run at a 0.5 m resolution and simulated a twenty four hour tide record for six different significant wave heights (Hm_0) from 0.5 to 3 ft and with a typical wave peak period (T_p) of 3 s. The water level elevations (tide record) used for this simulation was from January 8, 2015 from 00:00 to 23:00 hours and is shown on in Figure 3. The water surface elevation in the tide record start close to MLLW, then increases to reach the first peak at 4.7 ft, close to MHW (4.99 ft), decrease to the higher low tide, and then increases again and reaches a higher high tide of 5.9 ft, which is slightly above the MHHW elevation (5.72 ft).

The mudflat and the oyster reef configurations evaluated are exposed during low tide except for -1 FT. Due to the short wave heights and wave period and shallow water wave propagation in very shallow water, the bottom friction coefficient is an important parameter in the model. The drag coefficient used for the mudflat was 0.03, which is a common value reported for sands and muds (Gross and Nowell 1983). The drag coefficient for the oyster reef was based on experiments from Reidenbach et al. (2013), which found that oyster beds had a drag coefficient of 0.019 +/- 0.004, which is approximately six times larger than the value reported for muds. The drag coefficient can also be estimated from Reynolds stress measurements computed from velocity fluctuations, which yields a Reynolds stress value of 0.021 +/- 0.004 (Reidenbach et al. 2013). For this study a drag coefficient of 0.021 was chosen, which is close to the average of the two estimated ranges.

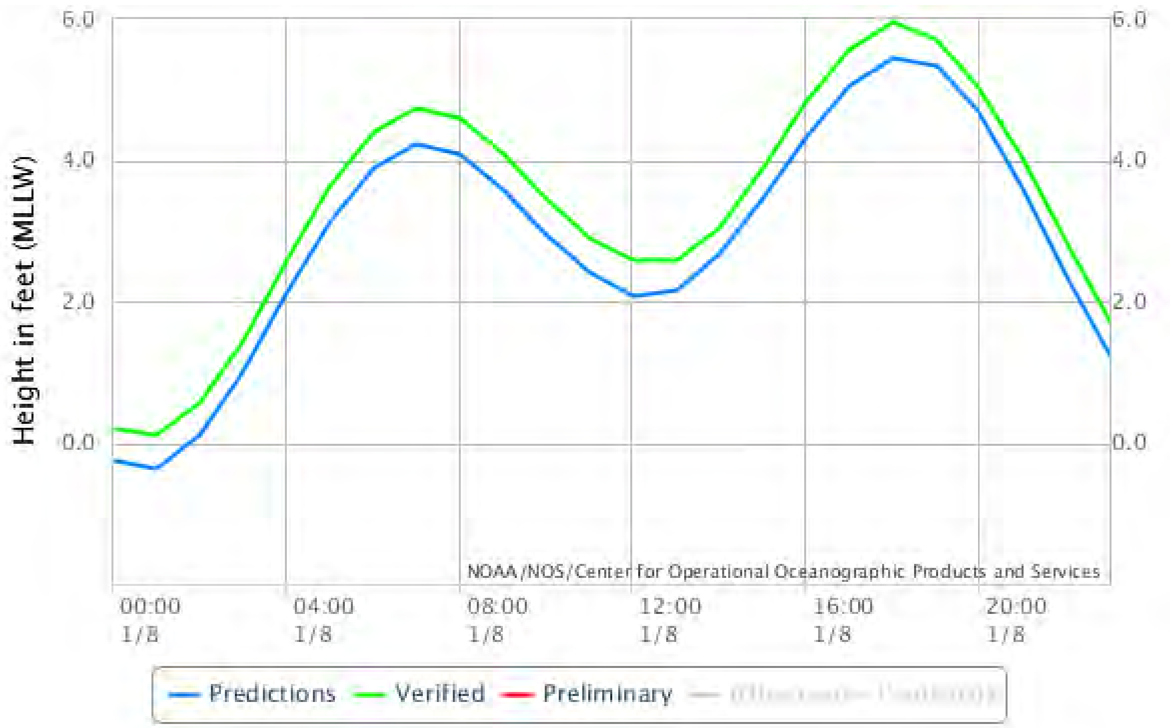


Figure 3. Twenty Four Hours Tide Record from San Diego Tide Station Used on the Wave Model. From 01/08/2015 00:00 to 01/08/2015 23:00 (MLLW Datum).

REEF CONFIGURATION

The conceptual configuration of the oyster reefs consist of individual reef elements, each a truncated pyramid of shell bags or other material, arranged in an array consisting of rows of elements perpendicular to the shoreline and primary wind wave direction. A reef element height of 2 ft was selected as a height likely to provide a measurable effect on waves, constructability, and similarity to shell bag reefs from the San Francisco Bay Living Shorelines Project.

The spacing of reef elements within a row was selected to optimize the roughness energy dissipation potential of the reef. In general, the roughness of a bed or reef can be defined by the roughness wavelength (λ), which is the space between the roughness elements, and the height of the elements (*k*). The roughness wavelength to height ratio defines what is known as the pitch ratio (λ/k). The pitch ratio indicates the periodicity of the bed or reef form. This type of bed-form roughness has been typically divided into *d*-type and *k*-type based on the assumption that the energy loss in the water column is due largely to the formation of wakes behind each roughness element (Figure 4). The vorticity in the wake may influence the turbulence characteristics in the water column depending on the pitch ratio. The *d* type roughness corresponds to $\lambda/k < 2$, when the turbulence in grooves is confined and a boundary layer develops above the bed or reef form. The flow on top of the bed-form roughness behaves similar to that over a smooth bed or reef at the elevation of the roughness elements (Raudkivi 1998). The k-type roughness with $\lambda/k > 4$, the higher pitch ratio results in significant shedding of turbulence into the outer flow and the effect of individual roughness elements can be observed in the water column (Raudkivi 1998 and Leonardi 2003).

The friction factor of *k*-type roughness varies with the pitch ratio and from numerical and physical experiments it has been shown that this roughness becomes maximum around λ/k = 6 to 10 in the absence of a free surface (Leonardi et al. 2003, Quiroga and Cheung 2013). For pitch ratios of 20 or larger, there is negligible interaction of the turbulence between roughness elements. In order to produce a k-type roughness, a pitch ratio of 9 was selected.

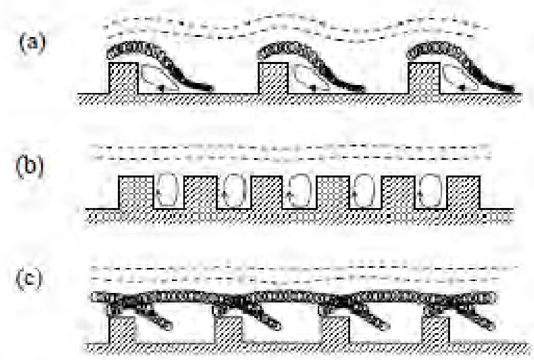


Figure 1.5 Types of rough-surface flows: (a) k-type; (b) d-type; (c) transitional (Chow, 1959).

Figure 4. Types of rough-surface flows a) k-type,b) d-type and c) transitional (From Chow 1959)

RESULTS

WAVE ENERGY DISSIPATION

Wave energy dissipation was estimated from offshore to the inboard edge of the mudflat (at the marsh edge) and also for the local energy dissipation between the outboard and inboard for each oyster reef configuration. The energy was estimated based on the observed spectral properties of the entire modeled record of water surface elevation. Welch's method was used to estimate the wave energy spectrum for each record. The results show that all oyster reef configurations do not significantly increase wave energy dissipation at the shoreline compared to the mudflat (existing conditions) (Figure 5). The oyster reef arrays had little effect on the total wave energy dissipation due to their scale and location when compared with total amount of energy dissipated across the entire mudflat. Nevertheless, the local wave energy dissipation effect from the front to the back of the reefs is considerable and reduces the wave energy locally by a factor of 2 to 2.5 compared to the mudflat (Figure 6). In order for the oyster reef to have a discernible effect on the total energy dissipated through the mudflat, oyster reefs would need to be higher or would need to be placed across the entire mudflat. Even then, their effects during regular and extreme high tides, when erosion potential at the shoreline is greatest, would minimal. These results indicate that the reefs are expected to have localized effects on the mudflat behind the reefs, but may not have a significant effect on the shoreline or marsh edge.

CURRENT VELOCITY

From previous field studies on mudflats, it has been shown that current velocities greater than 0.3 to 0.5 ft/s cause erosion and a shift from deposition to erosion starts at a critical threshold of 0.65 to 0.8 ft/s (Reidenbach et al. 2013). Table 3 and Figure 7 show the percentage of the time that the current velocities induced by waves exceed an erosive velocity of 0.5 ft/s at the inboard edge of the mudflat (near the marsh edge) for existing conditions and the different reef configurations. The results show that +2 FT and +1 & +2 FT configurations reduce the potential erosion the most (by 2.9 to 3.6%). In contrast, the -1 FT configuration only reduces the percentage of potential erosion by 1.2% when compared with existing conditions.

Table 3: Percent Exceedance of Potential Erosion[1]

H_o (ft)	Existing Conditions	-1 FT	+1 FT	+2 FT	-1 & +1 FT	+1 & +2 FT
0.5	16.5	16.0	15.2	14.9	15.0	14.8
1	20.2	19.5	16.7	15.9	16.3	15.1
1.5	21.2	19.6	17.6	17.0	17.2	15.9
2	21.2	19.0	18.4	17.6	17.9	16.6
2.5	20.6	19.0	18.6	18.4	18.6	17.5
3	20.6	19.7	19.6	19.0	19.6	18.4
Average	**20.0**	**18.8**	**17.7**	**17.1**	**17.4**	**16.4**

1. *Potential Erosion exceedance is defined as any current velocity > 0.5 ft/s*

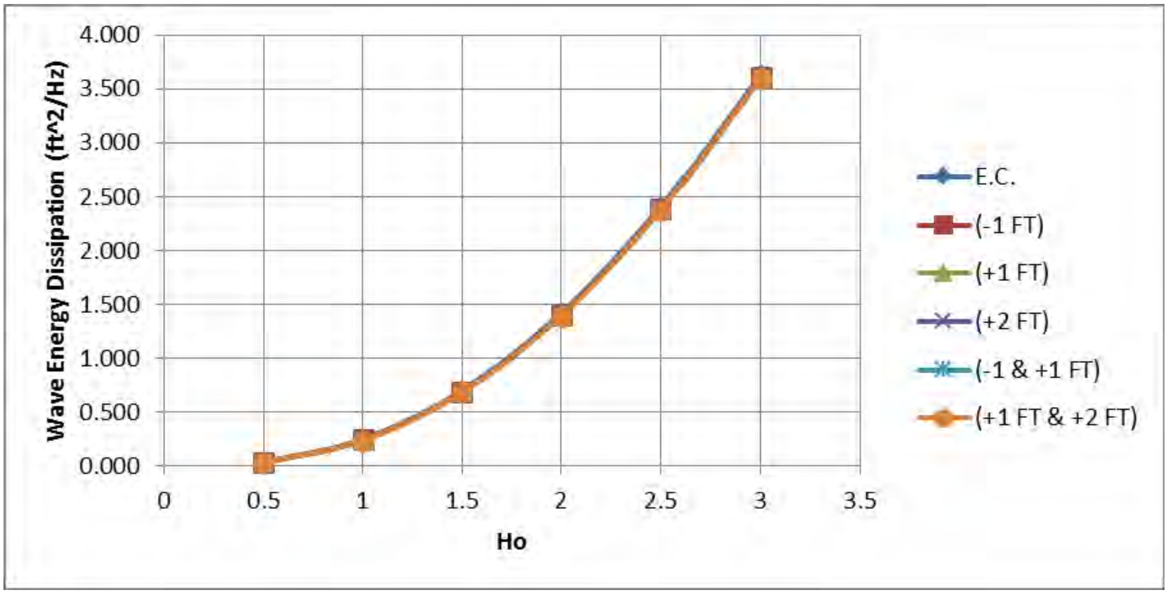


Figure 5. Wave Energy Dissipation from Offshore to Inboard for the Different Wave Heights and Reef Configurations

1.

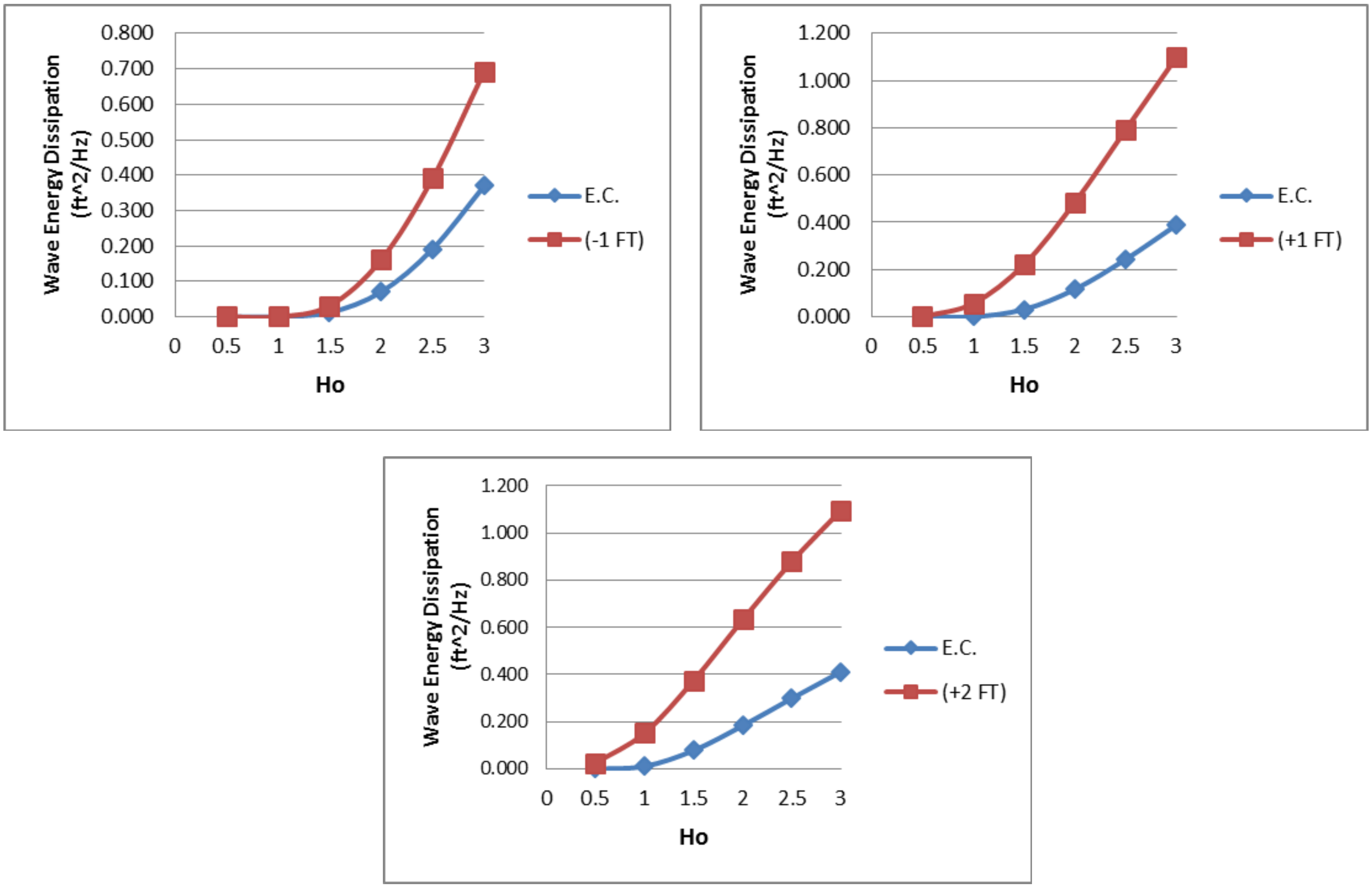


Figure 6. Wave Energy Dissipation from Local Inboard to Outboard for the Different Wave Heights and Reef Configurations -1 FT to +2 FT.

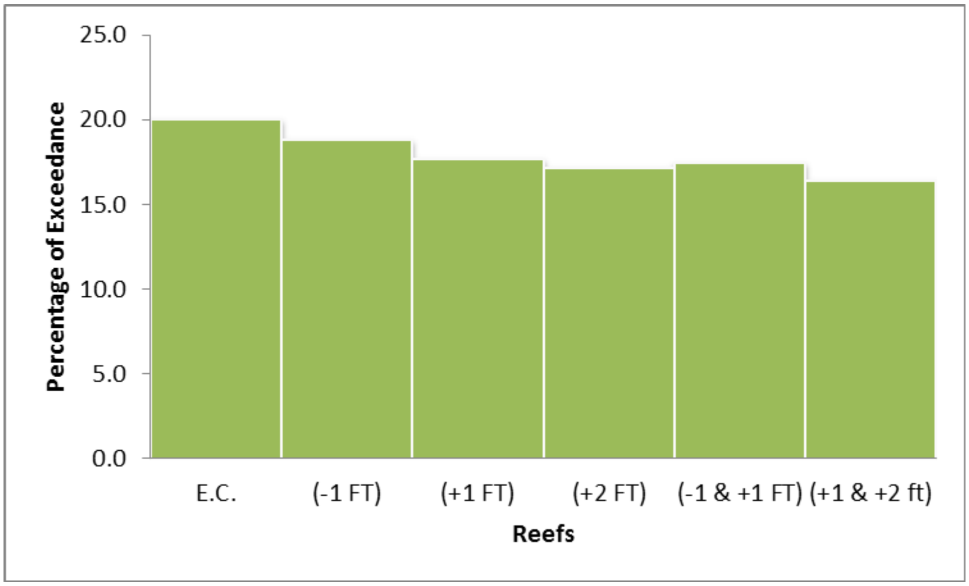


Figure 7. Percentage of Exceedance of Potential Erosion for the Different Reef Configurations

Table 4 and Figure 8 show the reduction in the percent exceedance of potential erosion from Table 3 as a relative percent change from existing conditions. These results show that the oyster reefs reduce the percentage of the time that the modeled velocity is potentially erosive by 15 to 20% for the +2 FT and +1 & +2 FT configurations and only of 7% for the -1 FT configuration.

Table 4: Relative Percent Exceedance[1] of Potential Erosion[2]

H_o (ft)	-1 FT	+1 FT	+2 FT	-1 &+1 FT	+1 &+2 FT
0.5	3.4	7.9	9.8	9.4	10.5
1	3.4	17.3	21.5	19.2	25.1
1.5	7.3	16.9	19.7	18.8	25.0
2	10.3	13.0	16.9	15.3	21.7
2.5	7.9	9.5	10.7	9.6	14.8
3	4.3	4.9	7.4	4.6	10.7
Average	**6.7**	**12.3**	**15.2**	**13.5**	**19.5**

1. *The relative percentage is estimated as percent change from existing conditions (Table 3).*
2. *Potential Erosion exceedance is defined as any current velocity > 0.5 ft/s*

Figure 9 compares the wave current velocity distribution at the inboard edge of the mudflat (near the marsh edge) for a significant wave height of 2 ft for the different oyster reef configurations against the mudflat (existing conditions. The results show that the +2 FT, and +1 & +2 FT configurations had a significant effect on the distribution of the wave velocities at the mudflat/marsh edge shoreline, reducing the wave velocity by +/- 0.8 ft/s. The current velocity is shown as positive for the offshore to onshore direction (which could mean accretion in that direction) and negative from the onshore to offshore direction (which could mean erosion in that direction). The maximum velocity in the onshore to offshore direction is shown in Figure 10 and 11. The results show that the +2 FT and +1 & +2 FT reef configurations reduce the maximum velocity between about 900 and 1275 ft from offshore. In this location on the profile, the maximum velocities under existing conditions are above the 0.5 ft/s erosive threshold, whereas the 2 FT and +1 & +2 FT reef configurations reduce the velocity to around 0.5 ft/s. All of the oyster reef configurations except for -1 FT had some effect on reducing current velocities from about 900 to 1,175 ft from offshore.

Erosion and Deposition

Even though the oyster reefs appear not to have an effect on the wave energy, they show a discernible effect on the current velocity induced by waves. They slow down the waves, reducing the induced wave current and therefore reducing the potential for erosion on the profile. The modeled erosion/deposition changes due to the oyster reefs appear to be mostly only local effects around the oyster reef arrays (Figure 12), although there is a significant effect on the area just before the inboard edge of mudflat (near the marsh edge) for the +2 FT and +1 & +2 FT oyster reef configurations, where they appear to stabilize the profile and even create some deposition 300 to 350 ft behind the reef (Figure 12 and 13). For the other oyster reef configurations, the effect on erosion and deposition appears to be only local.

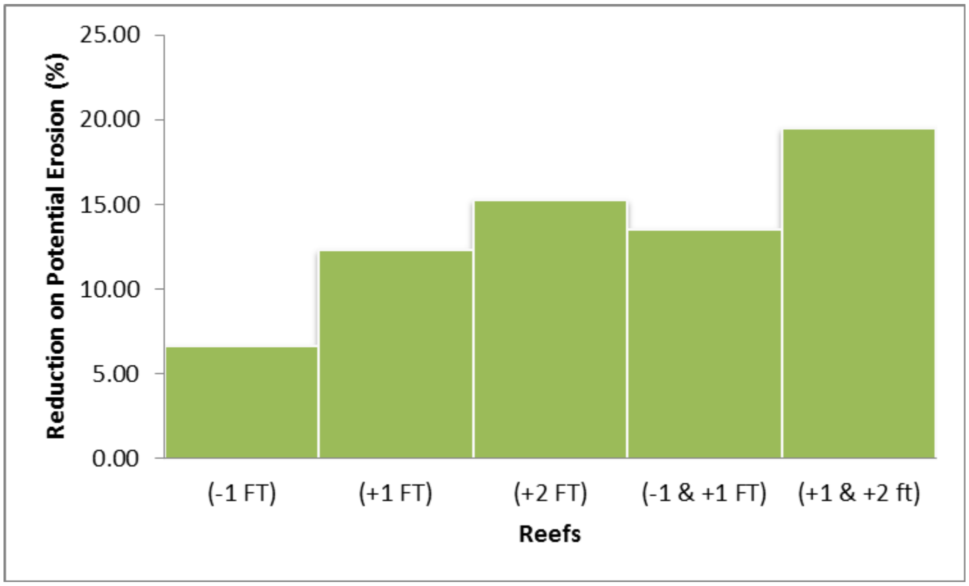


Figure 8. Relative Percentage of Exceedance of Potential Erosion for the Different Reef Configurations

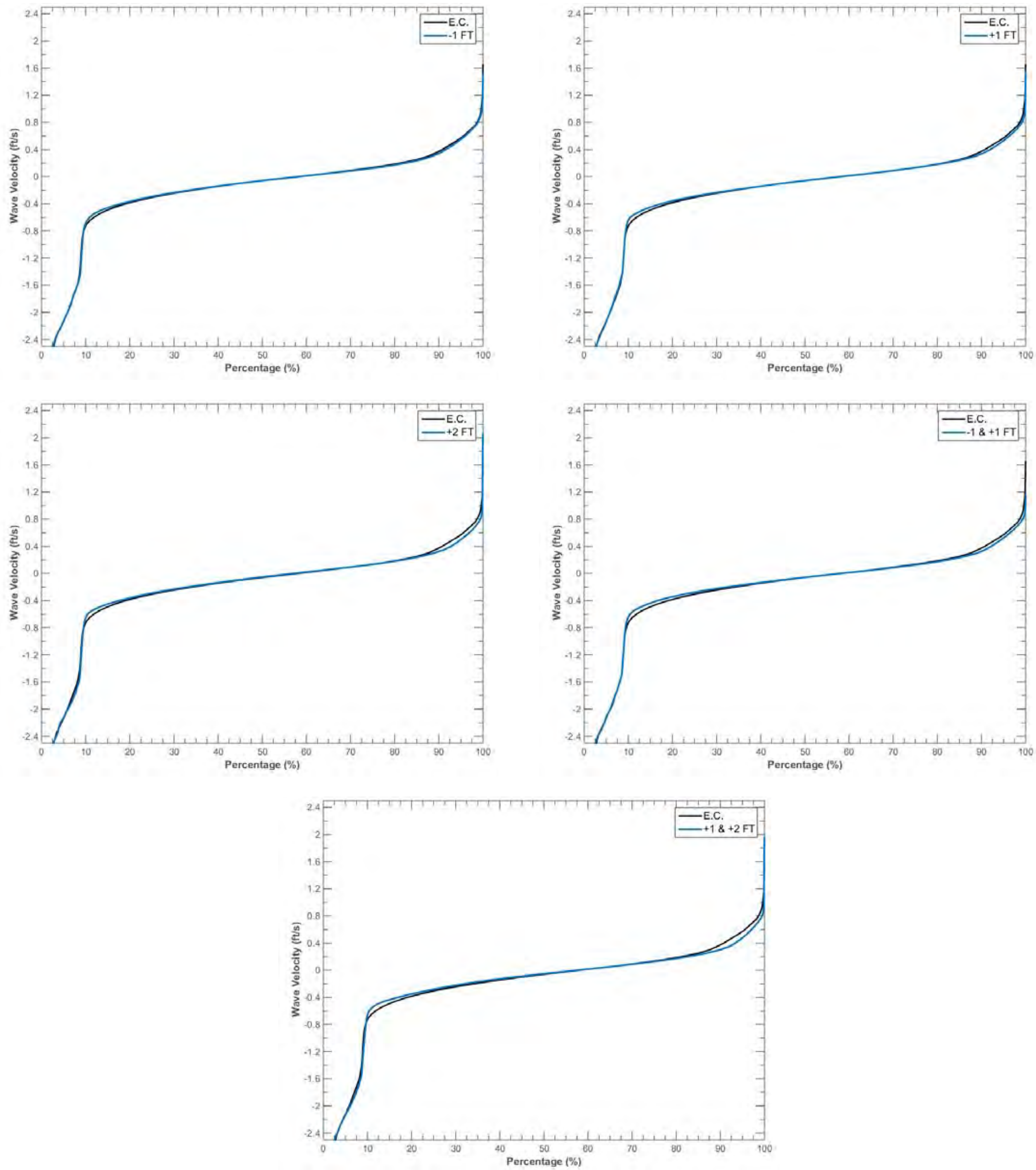


Figure 9. Wave Velocity Distribution for Ho = 2 ft. at the Inboard Location for the Different Reef configurations and Mudflat (E.C.)

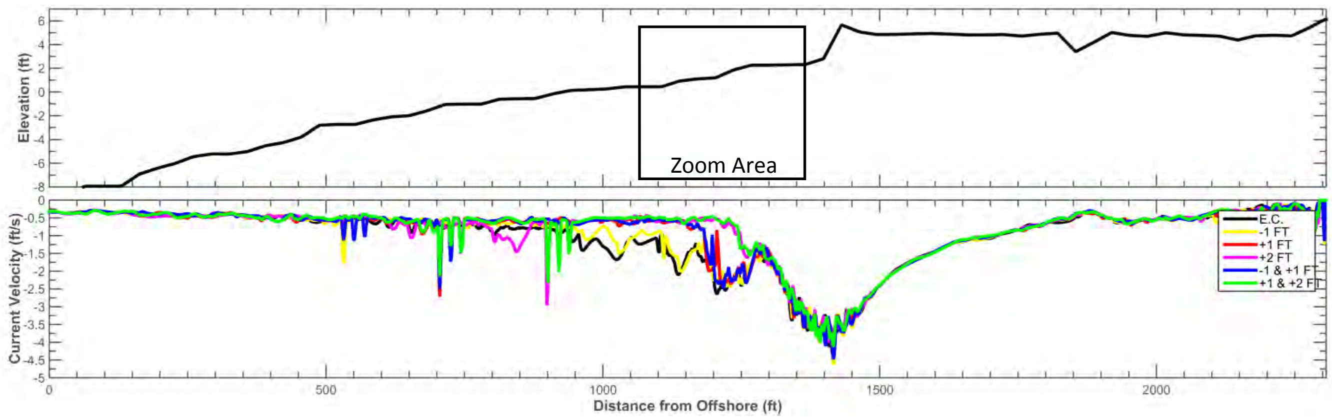


Figure 10. Maximum Velocity Distribution along the Profile

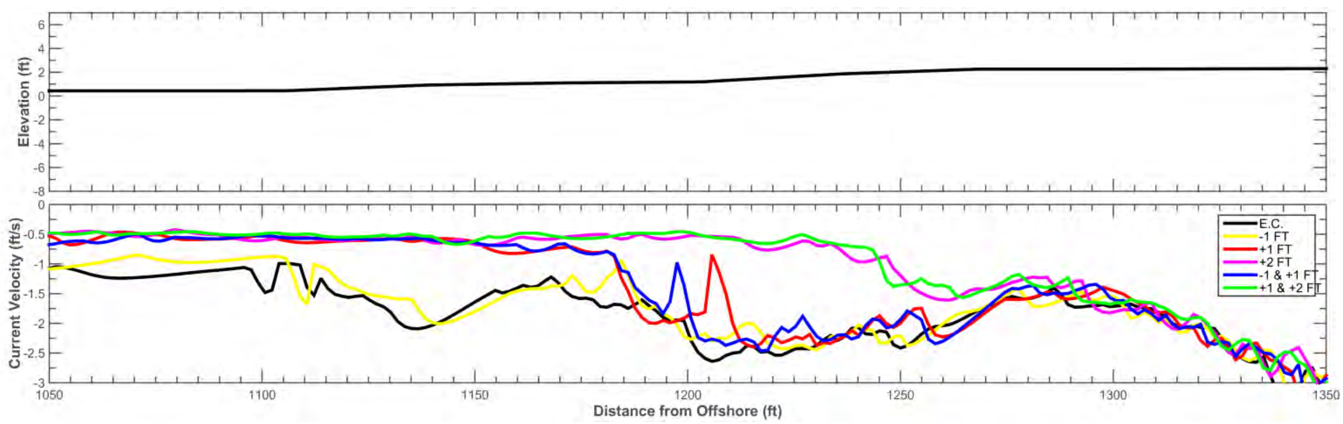


Figure 11. Maximum Velocity Distribution along the Profile. Zoom Area

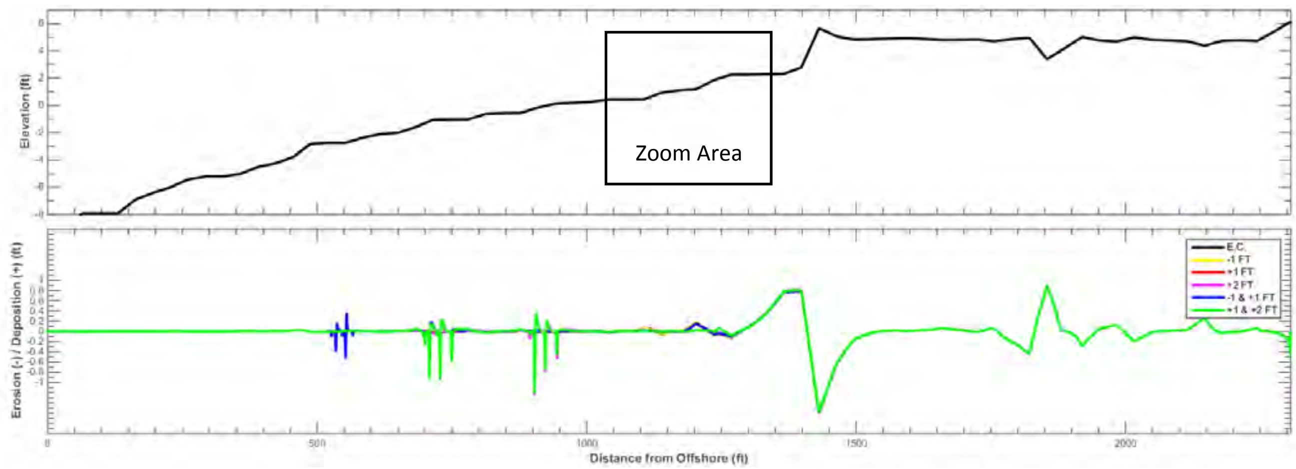


Figure 12. Erosion/Deposition of the Mudflat and the Different Reef Configurations

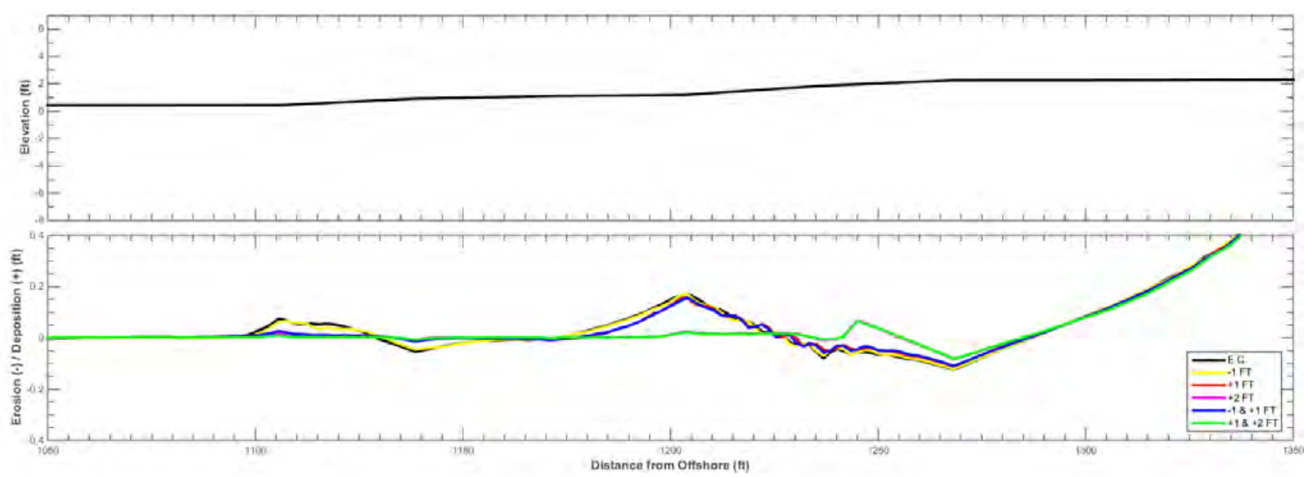


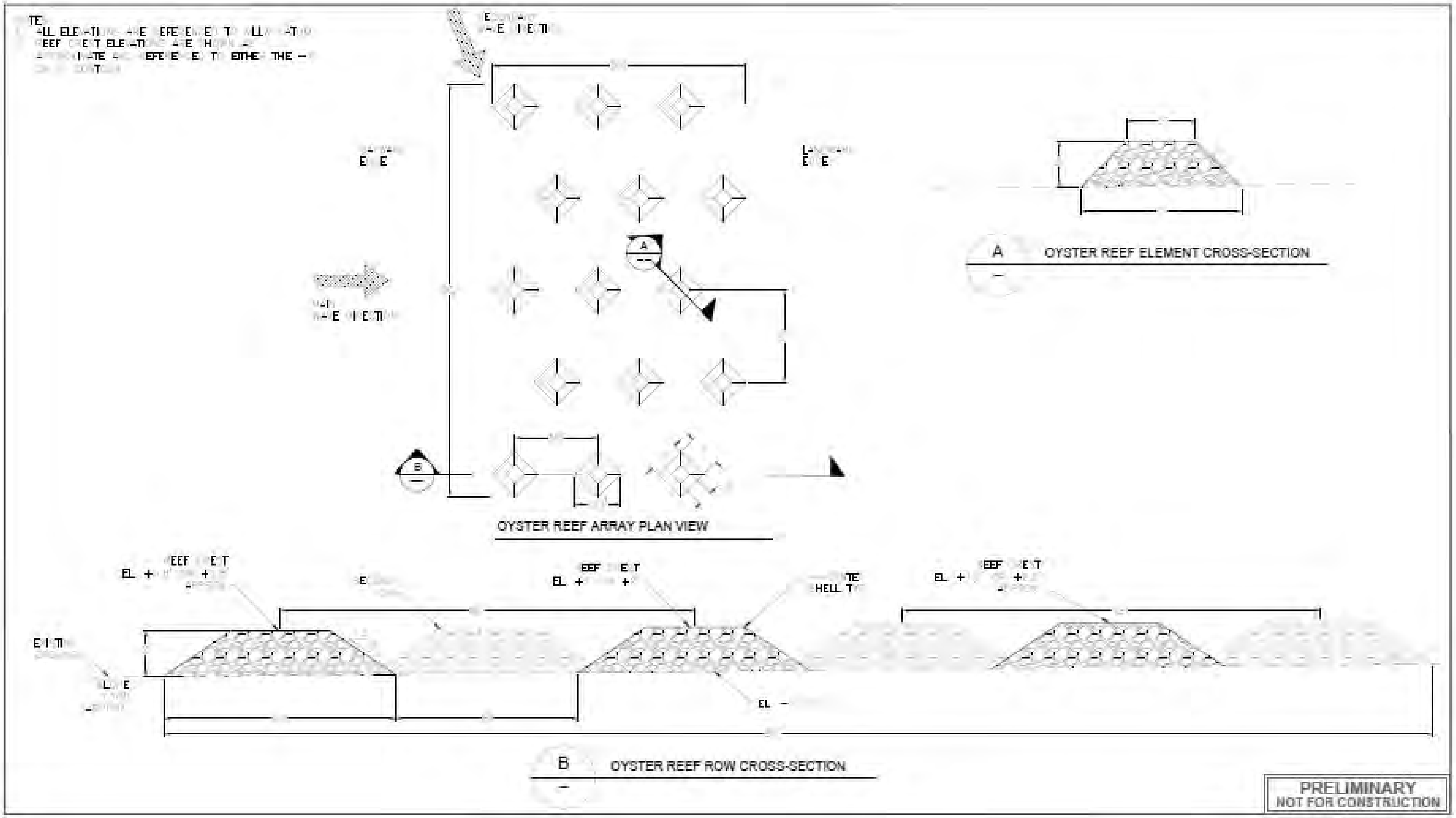
Figure 13. Erosion/Deposition of the Mudflat and the Different Reef Configurations. Zoom Area

OYSTER REEF ARRAY CONFIGURATION

A conceptual oyster reef configuration is proposed based on the previous results to optimize the potential erosion and increase deposition on the mudflat behind the reefs (Figure 14). The space of 18 ft between reef elements in a row is proposed based on this study and previous studies where the maximum roughness of this elements is reach with a pitch ratio between 6 to 10. In this case the value is 9. The rows of the array are offset or staggered to create a complex array. The overall length of a reef array is 90 ft, which is between 1.5 to 4 times larger than the typical wave length (i.e., typical wave lengths of 20 to 60 ft depending of the wave period and water depth). Given that the reef length is greater than the wave length, the reefs are expected to affect spatial wave patterns behind the reefs.

Figure 15 shows the wind rose from the National City Marine Terminal adjacent to the project site at E St. The reef array is oriented perpendicular to the primary wind wave direction (southwest), which is roughly parallel to the shoreline. The oyster reef elements are rotated to increase surface area or width of the reef in the primary wave direction. There is a secondary dominant wind direction from the northwest (WNW to be precise). The 20 ft spacing between the staggered rows within the arrays creates diagonal rows in the secondary wind direction that will affect waves from the secondary wind direction.

The volume of each reef element is around 2 cubic yards (CY). Each array includes 15 elements, which would be a volume of 30 CY per array and a total of 180 CY for 6 arrays.



San Diego Bay Native Oyster Restoration 120710.01
FIGURE 14
Conceptual Oyster Reef Configuration

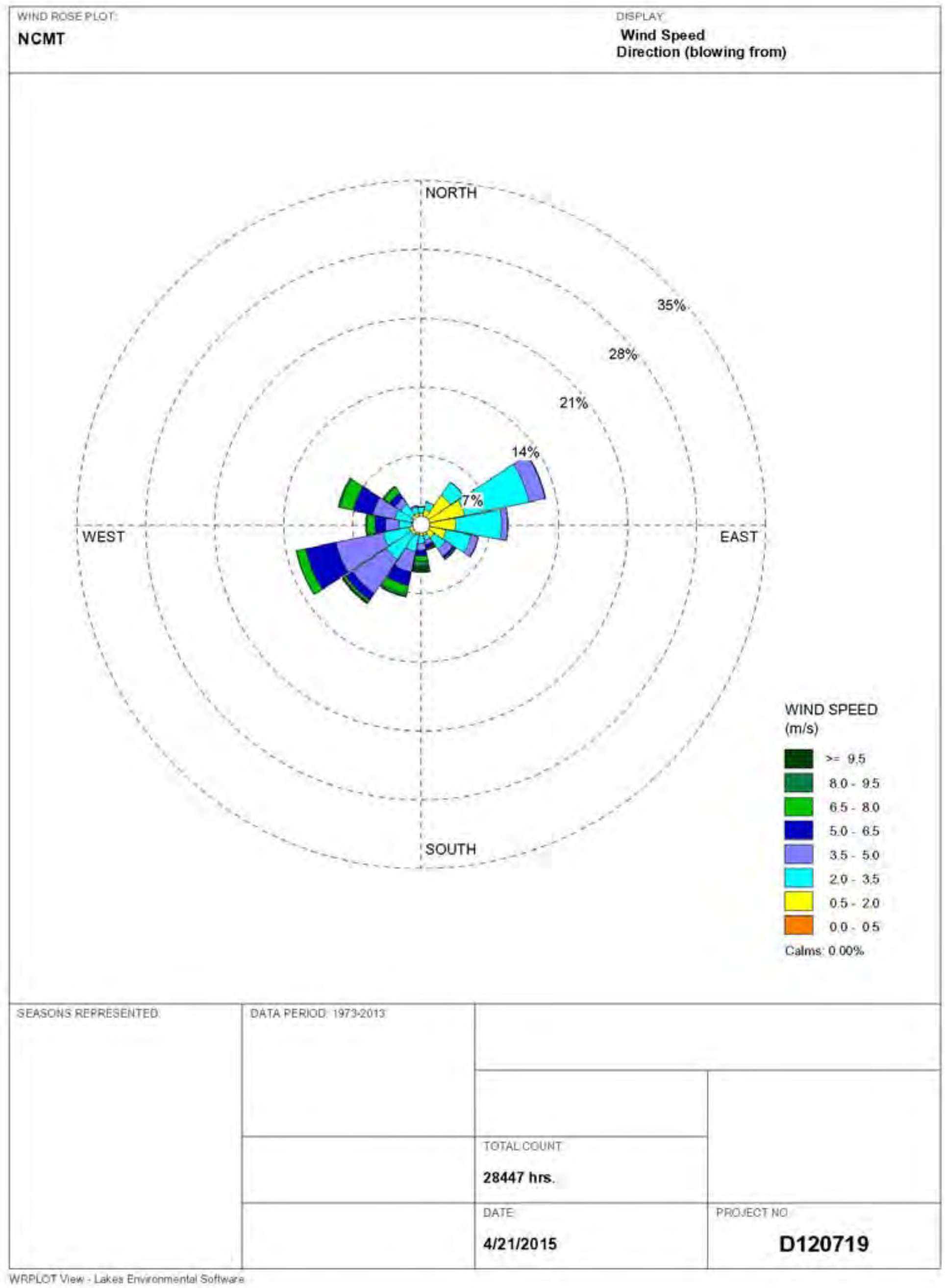


Figure 15. Wind Rose from National City Marine Terminal

REFERENCES

Allen, J.R.L. and M.J. Duffy. 1998. Temporal and spatial depositional patterns in the Severn Estuary, southwestern Britain: intertidal studies at spring-neap and seasonal scales, 1991–1993. **Mar. Geol.** 146: 147–171.

Borsje, B. W., B. K. van Wesenbeeck, F. Dekker, P. Paalvast, T. J. Bouma, M. M. van Katwijk, and M. B. de Vries. 2011. How ecological engineering can serve in coastal protection. **Ecological Engineering** *37*(2): 113–122.

Chow, V. T. 1959. Open-Channel Hydraulics, McGraw-Hill. New York 680 pp

Folkard, A.M., and J.C.Gascoigne. 2009. Hydrodynamics of discontinuous mussel beds: laboratory flume simulations**. J. Sea Res**. 62, 250–257.

Herlyn, M. 2005. Quantitative assessment of intertidal blue mussel(Mytilus edulis L.) stocks: combined methods of remote sensing, field investigation and sampling. **J. Sea Res**. 53: 243–253.

Merkel & Associates, Inc. 2008. 2008 San Diego Bay Eelgrass Inventory and Bathymetry Update. Prepared for U.S. Navy and San Diego Unified Port District. January 2009. 9 pages.

Quiroga, P. D. and K. F. Cheung 2013. Laboratory study of solitary-wave transformation over bed-form roughness on fringing reefs. **Coastal Engineering**, Elsevier B.V., 80: 35–48.

Reidenbach, M.A., P. Berg, A. Hume, J.C.R. Hansen, and E.R. Whitman. 2013. Hydrodynamics of intertidal oyster reefs: The influence of boundary layer flow processes on sediment and oxygen exchange. **Limnology & Oceanography: Fluids & Environments** 3: 225–239.

Roelvink, D., A. Reniers, A. van Dongeren, J. van Thiel de Vries, R. McCall, and J. Lescinski. 2009. Modelling storm impacts on beaches, dunes and barrier islands. **Coastal Engineering**, 56(11-12): 1133–1152.

Van Leeuwen, B., D.C.M. Augustijn, B.K. van Wesenbeeck, S.J.M.H. Hulscher, M.B. de Vries. 2010. Modeling the influence of a young mussel bed on fine sediment dynamics on an intertidal flat in the Wadden Sea. **Ecol. Eng.** 36: 145–153.

VanderWal,D. and K. Pye.2004. Patterns, rates and possible causes of saltmarsh erosion in the Greater Thames area (UK). **Geomorphology** 61: 373–391.