South Coast Baseline Program Final Report: Rocky Intertidal Ecosystems

Lead PI: Carol A. Blanchette

Co-PIs: Peter Raimondi, Jayson Smith, Jennifer Burnaford and Julie Bursek

Contributors: Rani Gaddam, Jessica Altstatt, Jenifer Dugan, David Hubbard

Photo Credit: Michael Blake

Baseline Characterization of the Rocky Intertidal Ecosystems of the South Coast Study Region

Carol A. Blanchette[1], Peter T. Raimondi[2], Rani Gaddam[2], Jennifer Burnaford[3], Jayson Smith[4], David M. Hubbard[1], Jenifer E. Dugan[1], Jessica Altstatt[5] and Julie Bursek[5]

[1]University of California Santa Barbara

[2]University of California Santa Cruz

[3]California State University, Fullerton

[4]Cal Poly Pomona

[5]NOAA Channel Islands National Marine Sanctuary

January 30, 2015

Table of Contents

Figures

Tables

Executive Summary

The South Coast Study Region (SCSR) encompasses a broad section of southern California including both mainland and island coastal regions. The exceptionally high diversity of marine life in this region is largely due to the mixing of several major oceanographic current systems, and the region is characterized by strong gradients in environmental conditions. Rocky shores characterize approximately 26.83% of the SCSR, and in many areas attract a large number of individuals who frequent the intertidal zone for recreation, education, and for collecting flora and fauna for food, fish bait, or decoration. Rocky intertidal ecosystems are one of the most heavily human-impacted ecosystems along the mainland southern California coast (in addition to sandy beaches) due to their ease of access, and has made them particularly vulnerable to the negative effects of human activities resulting from both extraction (harvesting and collecting) as well as physical disturbance (trampling, overturning and handling).

The SCSR Rocky Intertidal Baseline Project has been closely coordinated with the two major existing west coast regional monitoring programs for intertidal ecosystems: MARINe (Multi Agency Rocky Intertidal Network, http://www.marine.gov/), and PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans, http://www.piscoweb.org/), which has supported the Coastal Biodiversity Survey program. Our baseline characterization uses Biodiversity survey and MARINe protocols to provide the best assessment of abundance for each of the key ecosystem attributes and provide a baseline characterization of sites across the SCSR. The protocols are identical to those that have been, or are being used in other CA Marine Life Protection Act (MLPA) regions to quantify rocky intertidal biodiversity and abundance and sizes of selected key attributes in each region. Over time, we have conducted biodiversity surveys at a total of 58 rocky intertidal sites within the SCSR. Of these sites, 25 are located within Marine Protected Areas (MPAs), and 33 are located outside of MPAs. We classify sites as new MPAs (those that have been newly established in 2012 as part of the SCSR), old MPAs (sites that have a history of protection prior to 2012), and reference areas (includes all sites not within any MPAs). Of these 58 sites in the SCSR, 39 sites were surveyed as part of the Baseline Program in 2012-2014.

Community similarity of both sessile and mobile assemblages did not differ as a function of protection (MPA vs. non-MPA). The level of public access, was however, an important contributor to community similarity patterns across the sessile assemblages. This is consistent with the idea that degree of human visitation, possibly due to the trampling effects has a strong influence on sessile assemblages, those that are fixed to the rock, and may be heavily trampled by humans in places of high visitation. Importantly we found no significant interaction between protection and public access implying that the effects of human visitation on sessile assemblages did not differ depending on whether sites were inside or outside of MPAs.

We found no differences in the size distributions of owl limpets or mussels (two of the taxa known to be targeted by humans for collection) across years, across MPA status and no significant interactions indicating no initial changes in size distributions of either species during the initial implementation of the MPAs. However, the distribution of owl limpet sizes differed significantly across levels of public access. Areas of high public access lacked large limpets and were dominated by relatively small sizes classes of limpets. The

largest limpets were found only in areas of low public access. The largest initial change we observed during the baseline period was the rapid population decline of sea stars (*Pisaster ochraceus)*, due to the spread of the Sea Star Wasting Disease through southern California in winter 2013-2014.

We found strong biogeographic patterns in intertidal community structure across the south coast region. Similarity in the sessile and mobile assemblages across southern California was highest within each of the five main SCSR bioregions. Patterns of similarity were strongly correlated with geographic distance among sites. Geographic location (latitude, longitude), as well as ocean conditions (long-term mean sea surface temperature), were both strong and significant contributors to the patterns of community structure across the SCSR (Figure 1). For both sessile and mobile assemblages both the primary bench type and the surrounding coast were found to be important contributors to community pattern. This finding highlights the importance of mixed-sand rock habitats in the south coast region, and provides evidence that these habitats support unique assemblages.

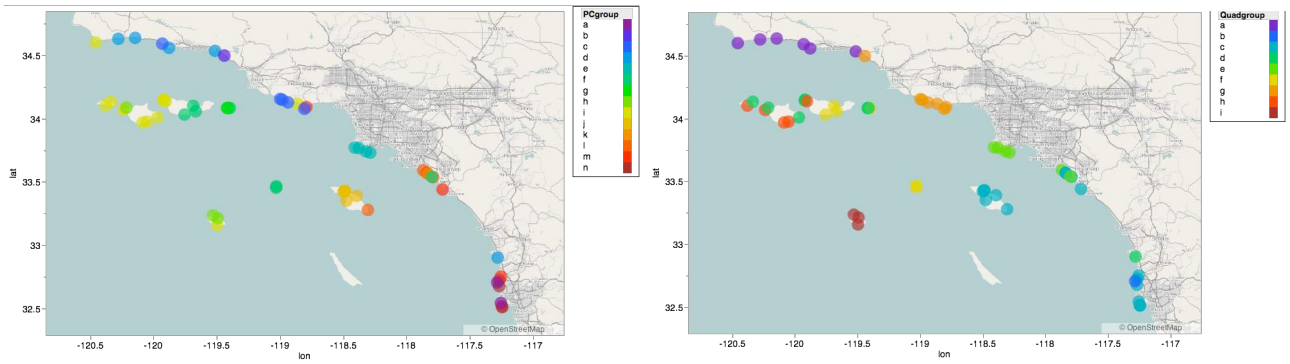

Figure 1 Map of sessile (left panel) and mobile (right panel) biodiversity community groups in the SCSR. Sites with similar colors are most similar in community composition

The abundance of key ecosystem attributes varied widely among sites across the SCSR (Figure 2). Barnacles were most common at sites along the north mainland coast, particularly in the region of coast near Malibu. *Egregia* was most abundant at several of the sites on Catalina Island. The abundance of encrusting algae and foliose red algae was relatively consistent across the SCSR. Mussels displayed a strongly patchy distribution, with peaks of abundance at sites in the Malibu area, Orange County, and Catalina Island. Rockweeds were extremely scarce at the northern sites and peaked in abundance at sites in Orange County and Catalina Island. The distribution of surfgrass was also patchy, with peaks in abundance at sites in the Santa Barbara Channel, Orange County, and San Nicolas Island. The distribution of turf algae was also relatively even across space and tended to peak in abundance at sites near San Diego.

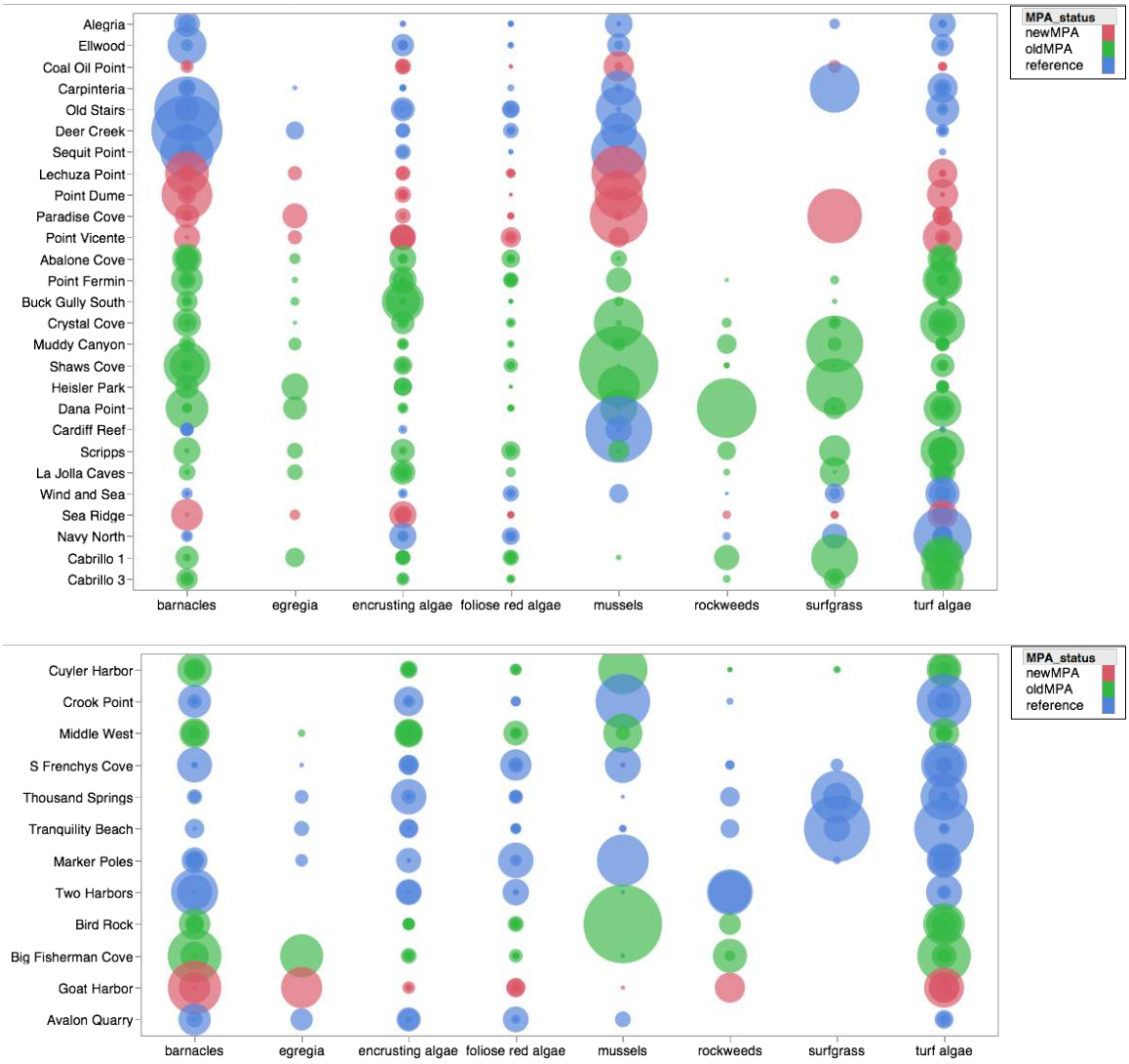

Figure 2 Bubble Plot of the relative abundance (percent cover) scaled with bubble size of sessile taxa identified as key ecosystem attributes. Bubble color indicates MPA status for each site. Sites are arranged on the y-axis in order from northwest (top) to southeast (bottom): Top panel - Mainland sites, and Bottom Panel - Island sites.

In all cases for both the sessile and the mobile taxa all measures of diversity and richness were highest in the old MPAs, lowest in the reference areas, with new MPAs having values that were most variable and on average fell between those of the old MPAs and reference ares (Figure 3). There are a variety of hypotheses that may explain this pattern, and continued biodiversity monitoring at these sites through time will allow us to evaluate changes in biodiversity through time as a function of MPA status.

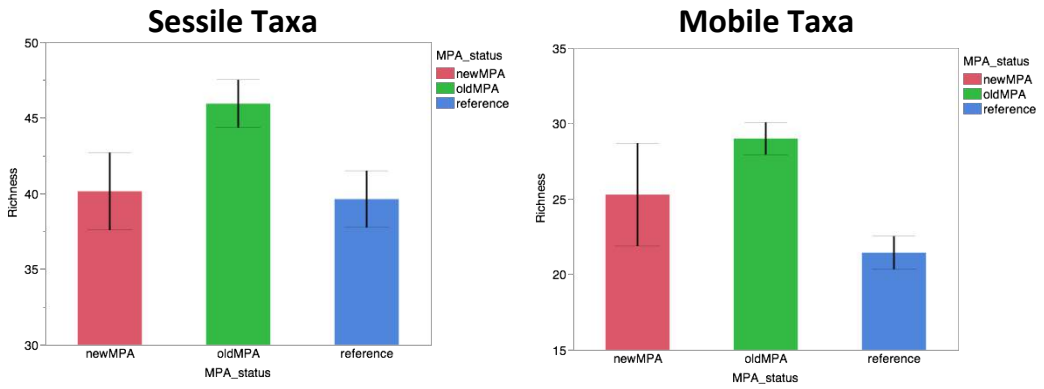

Figure 3 Mean values (± 1 s.e.) of observed taxonomic richness across sites categorized by MPA status (new MPAs, old MPAs and reference sites). Left panel – sessile assemblages, and Right panel - mobile assemblages

Although our project has largely been aimed at baseline characterization and monitoring, we are very interested in working with groups that may contribute to the long term monitoring of California MPAs. LiMPETS (Long-term Monitoring Program and Experiential Training for Students) is a citizen science program that trains students, primarily, to conduct intertidal monitoring (rocky intertidal and sandy beach) along the coast of California. We partnered with LiMPETS teachers and coordinators to compare data, methods and identify collaborative opportunities for future monitoring.

We recommend a continued monitoring program that is based on a combination of biodiversity and targeted species monitoring to characterize the status and trends of as many of the key ecosystem attributes as possible, and follow changes in key species and ecosystem features through time. The only ecosystem indicator that displayed significant differences between MPAs and reference areas was richness/diversity. The effect of this difference was strong, and the finding that richness/diversity in newly established MPAs was intermediate in most cases between those of old MPAs and reference areas suggests that this indicator might be useful for both characterizing the effects of MPAs, and also for assessing changes in MPAs through time.

Introduction

Background and Justification

South Coast Study Region

The South Coast Study Region (SCSR hereafter) is located in the northern portion of the Southern California Bight, which extends from Point Conception to Baja California in Mexico (Dailey 1993). The SCSR is characterized by high productivity, high biodiversity, diverse habitat types, and the unique oceanographic conditions of the Southern California Bight. The Southern California Bight is located within the greater context of the California Current Large Marine Ecosystem (LME), one of only four temperate upwelling systems in the world. The exceptionally high diversity of marine life in this region is largely due to the mixing of several major oceanographic current systems. Two major water masses meet at Point Conception, California—the cold, southward flowing California current, and the warm, westward flowing southern California countercurrent (Hickey 1998). This region is one of the most important biogeographic and oceanographic discontinuities on the west coast of North America (Valentine 1966; Doyle 1985; Burton 1998). The northern region is typified by consistently strong coastal upwelling bringing cold, nutrient-rich waters to the surface, resulting in both cold sea surface temperatures along the coast and high nutrient concentrations. The Santa Barbara Channel, immediately south/east of Point Conception, is typified by weak seasonal upwelling, which tends to occur in the winter months (Blanchette et al. 2002; Winant et al. 2003). The northern California Channel Islands are located just offshore from Point Conception and lie within this highly diverse oceanographic region. These oceanographic conditions exert a large influence on the species composition of biological communities across the region (Blanchette et al 2006, 2007, 2008, 2009).

Compared with other study regions in California, the SCSR is characterized by strong gradients in environmental conditions (e.g. water temperature). Figure 4 indicates a time-averaged long-term mean of sea surface temperature (SST) based on data available from MODIS satellite imagery at 1km resolution. The persistent spatial gradients in temperature across the SCSR have a strong influence on biological community structure and diversity, including a gradient of species abundances across the region. Some parts of the study region, such as the western Channel Islands, contain biotic assemblages highly similar to those of central California while others support quite different species communities resembling those found in Mexican waters to the south. Due to the high biological and oceanographic diversity across the SCSR, the MLPA Science Advisory team identified five biologically relevant subregions (bioregions) within the SCSR: (1) **North Mainland** – Point Conception to Marina del Ray, (2) **South Mainland** - Marina del Ray to the US/Mexico Border, (3) **West Channel Islands** – San Miguel, Santa Rosa and San Nicholas Islands, (4) **Mid Channel Islands** – Santa Cruz, Anacapa and Santa Barbara Islands, and (5) **East Channel Islands** – Santa Catalina and San Clemente Islands. Each of these five bioregions is characterized by a unique set environmental conditions and a distinct assemblage of marine organisms.

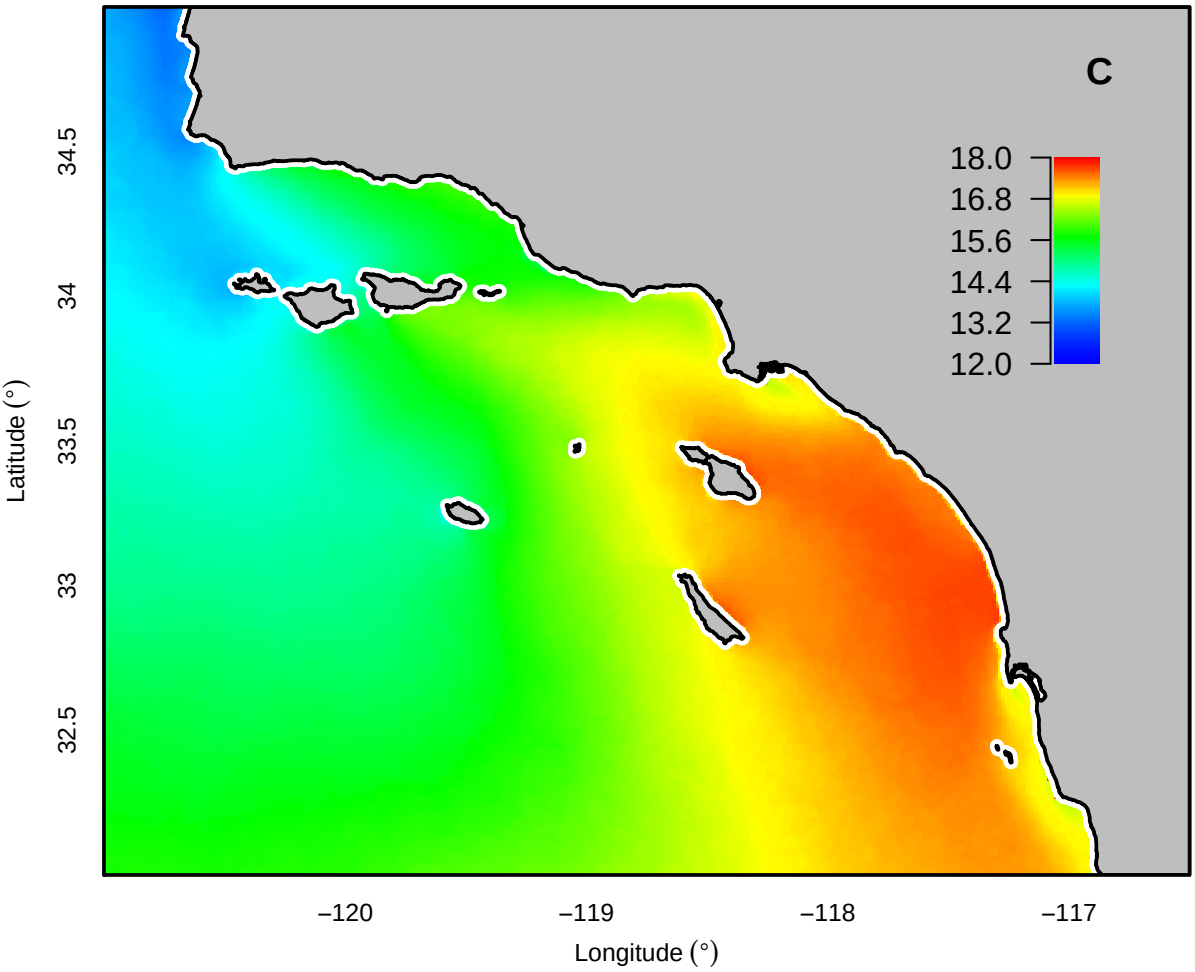

Figure 4 Spatial pattern of long-term mean SST (2000-2012) across the SCSR

In addition to the high biological diversity of natural marine communities, areas along the entire coastline within the SCSR support large human populations and extensive development, with the largest urban centers occurring in the metropolitan areas of Los Angeles and San Diego. In addition to consumptive activities (fishing and harvesting of marine resources) a variety of non-consumptive activities are also popular within the SCSR, including diving, kayaking, surfing, beach-going, tidepooling, swimming, and a number of different shore and ship-based wildlife viewing activities.

Rocky Intertidal Ecosystems

Rocky shores characterize 451.78 km (280.72 mi) of coastline within the SCSR (approximately 26.83%) and are broadly distributed throughout the SCSR, and in many areas attract a large number of individuals who frequent the intertidal zone for recreation, education, and for collecting flora and fauna for food, fish bait, or decoration (Smith, 1993; Addessi, 1994; Murray, 1997; Murray et al., 1999; Ambrose and Smith, 2004). Rocky intertidal ecosystems are one of the most heavily human-impacted ecosystems along the mainland southern California coast (in addition to sandy beaches) due to their ease of access. Beach visitation in

southern California has been documented previously to be as high as 129 million people per year with more heavily visited sandy beaches in southern California receiving over 7 million visitors per year (Dwight et al, 2007). Use within the rocky intertidal zone can also be extremely high with up to 80,000 visitors per year per 100 m shoreline (Ware 2009). Anyone who can walk can easily access and explore most southern CA rocky intertidal locations during any reasonably low tide. No swimming, diving or boating skills are required. This ease of access has made them particularly vulnerable to the negative effects of human activities resulting from both **extraction** (harvesting and collecting) as well as **physical disturbance** (trampling, overturning and handling).

Justification

Because of the great importance of rocky intertidal ecosystems in the SCSR, as well as imminent threats to these resources (due to oil spills, climate change, degradation of water quality and other increased human pressures) establishment of baseline monitoring has been widely advocated. In addition, monitoring studies have been thought to yield important data on population dynamics on a local and regional scale, which could be utilized for more effective resource management as well as provide fundamental ecological knowledge about the dynamics of the systems. As a result, a network of rocky intertidal sites along the coast of California has been established through the MARINe program, where baseline information is currently available and data are still being collected. Many of these sites were established before the MLPA process, and thus the existing network could not provide adequate coverage to address questions regarding the status and baseline biodiversity within marine protected areas or information on the differences between marine protected areas and nearby reference sites. Our baseline project has filled these gaps (in terms of both sites and important species to be monitored) to create a comprehensive baseline database for all southern California MPA sites (having rocky intertidal habitats) and reference areas.

Project Objectives, Components and Activities

The objectives of the rocky intertidal surveys and analyses for the SCSR are to: (1) Produce a quantitative baseline characterization of the structure of rocky intertidal ecosystems in all of the South Coast MPAs that have accessible rocky intertidal habitats consistent with those in the Central and North-central study regions; (2) Provide a quantitative comparison between the rocky intertidal ecosystems in these MPAs and associated reference areas in the South coast region using a combination of biodiversity surveys and targeted species sampling; (3) Analytically explore the baseline characterizations for potential indicators of the state of the rocky intertidal ecosystems using newly collected data along with historical and contextual data from the region; (4) Assess initial changes in size and abundance of targeted species across newly created MPAs, existing MPAs and reference areas; (5) Evaluate the suitability of proposed draft metrics and other metrics for long term monitoring; (6) Integrate these assessments with other components of the baseline program (e.g., Kelp Forest, Sandy Beach, etc.) to inform the role and design of those programs for a future monitoring and evaluation program.

Our baseline project is comprised of 3 main components: (1) Baseline characterization of Rocky Intertidal Communities, (2) Collaboration with the LiMPETS group, and (3) Integration of baseline data with those from

other SCSR projects. Each of these main components, along with associated activities will be described in detail in the following sections.

Methods

Baseline Characterization

Our rocky intertidal monitoring program is a product of over three decades of research at more than 200 monitoring sites ranging from Southeast Alaska to Mexico. Our approach for the SCSR involves a replication of this ongoing intertidal sampling program, coordinated with Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and Multi-Agency Rocky Intertidal Network (MARINe). We use two separate survey types to characterize the ecosystem – Long-Term Monitoring Surveys and Biodiversity Surveys. This is the same approach we used to generate baseline characterizations of rocky intertidal ecosystems in the Central Coast Study Region (CCSR), North-Central Coast Study Region (NCCSR) and the network of marine reserves in the Northern Channel Islands (NCI).

Long-Term Monitoring Surveys use fixed plots to document changes in percent cover, or abundance of targeted species or species assemblages. This fixed-plot approach allows the dynamics of rocky intertidal species to be monitored with reasonable sampling effort and provides sufficient statistical power to detect changes over space or time. Biodiversity Surveys provide detailed information about biodiversity and community structure. These surveys were designed to measure diversity and abundance of algae and invertebrates found within rocky intertidal communities on the western coast of temperate North America.

Long-Term Monitoring sites are typically established in areas where the coastline consists of contiguous rocky reef. These rocky reefs are usually quite broad (typical width between 30-50 m) and long (typical length between 50-500 m). Contiguous rocky reefs are the most stable of rocky intertidal habitats, and targeting a specific habitat type results in higher consistency among sites, which allows for better comparisons among sites and regions. This basic level of consistency in site selection is important, because targeted reefs vary immensely by rock type, shape, rugosity, exposure, surrounding habitat, human visitation levels and other factors, which all contribute to explaining patterns in long-term community dynamics.

Biodiversity Survey sites are located in the same areas as Long-Term sites, or in areas of special interest (e.g. Areas of Special Biological Significance, areas where a disturbance has occurred, remote areas). Sites are typically established in areas where there is at least 30 m of contiguous rocky reef (the length of the baseline transect), but a site can be broken into two smaller sections, or adapted as necessary to fit within the constraints of smaller rocky reefs. In combination, the long-term, targeted species approach and the biodiversity surveys provide a wealth of information about the structure and dynamics of rocky intertidal communities along the Pacific Coast of North America.

For the purposes of this baseline characterization report, we used data from the Biodiversity surveys to provide the best estimates of overall cover and abundance of all of the key ecosystem features and targeted species at each site. While long-term monitoring plots are ideal for evaluating changes in abundance of targeted assemblages over long periods of time, they do not necessarily provide the best estimate of site-wide abundance of a broad variety of taxa. Detailed information from the long-term monitoring plots for all of the targeted assemblages, showing trends through time, as well as information on our intertidal surveys, including full survey protocols, and an interactive map and graphing tool, can be found on our website at http://pacificrockyintertidal.org

Description and Location of Sites

The MPAs of the SCSR went into effect January 1, 2012. Although this new network of MPAs took effect in 2012, the existing network of MPAs in southern CA includes some MPAs that already existed as MPAs before 2012. For example, the MPAs at the Channel Islands have been in effect since 2003. It is well established that biological communities can change in response to protection, and the length of time that a site has been protected is often an important correlate of biological community structure. MPA "effects" or differences in particular attributes inside and outside MPAs are often not detectable until several years after MPA establishment. For these reasons, and particularly since so many MPAs in the SCSR have a long history of protection before 2012, we felt that it was important to distinguish between MPA sites that were newly established (with no previous history of protection) as part of the South Coast MPA process, and those that were in MPAs that had been established prior to 2012 (e.g. the Channel Islands sites). Here and for the remainder of this report, we classify sites as new MPAs (those that have been newly established in 2012 as part of the SCSR), old MPAs (sites that have a history of protection prior to 2012), and reference areas (includes all sites not within any MPAs). Figures presented in the results section are all color-coded for follow this scheme new MPAs (red), old MPAs (green) and reference (blue). Pt. Fermin is the only site that went from former MPA (old MPA) to unprotected (reference). Given that it had a history of protection prior to 2012, we consider it here as an old MPA. In all analyses of MPA effects we have replicated the analyses with Pt. Fermin classified as an old MPA, reference area and deleted without any differences in the results. Given the lack of statistical importance in any of our analyses based on the classification of Pt. Fermin, we continue to classify it here as an old MPA based on its history of protection prior to 2012. Several of our sites also lie in areas with restricted access due to military regulations (San Nicolas and San Clemente Island) private property (Government Point, Alegria) or other restrictions on access. While some of these sites might be considered de-facto MPAs, we have limited the MPA status category to describing only MPA status as defined through the MLPA process, and we include the category of public access to assess these effects of restricted human access. Additionally, for the species inhabiting rocky intertidal areas at our sites, there are no meaningful distinctions between the different categories of protection (State Marine Reserves vs. State Marine Conservation Areas), since they all effectively limit take of intertidal marine resources, and thus we consider in this report the main effects of protection (MPA vs. non-MPA) and MPA status (new MPA vs. old MPA).

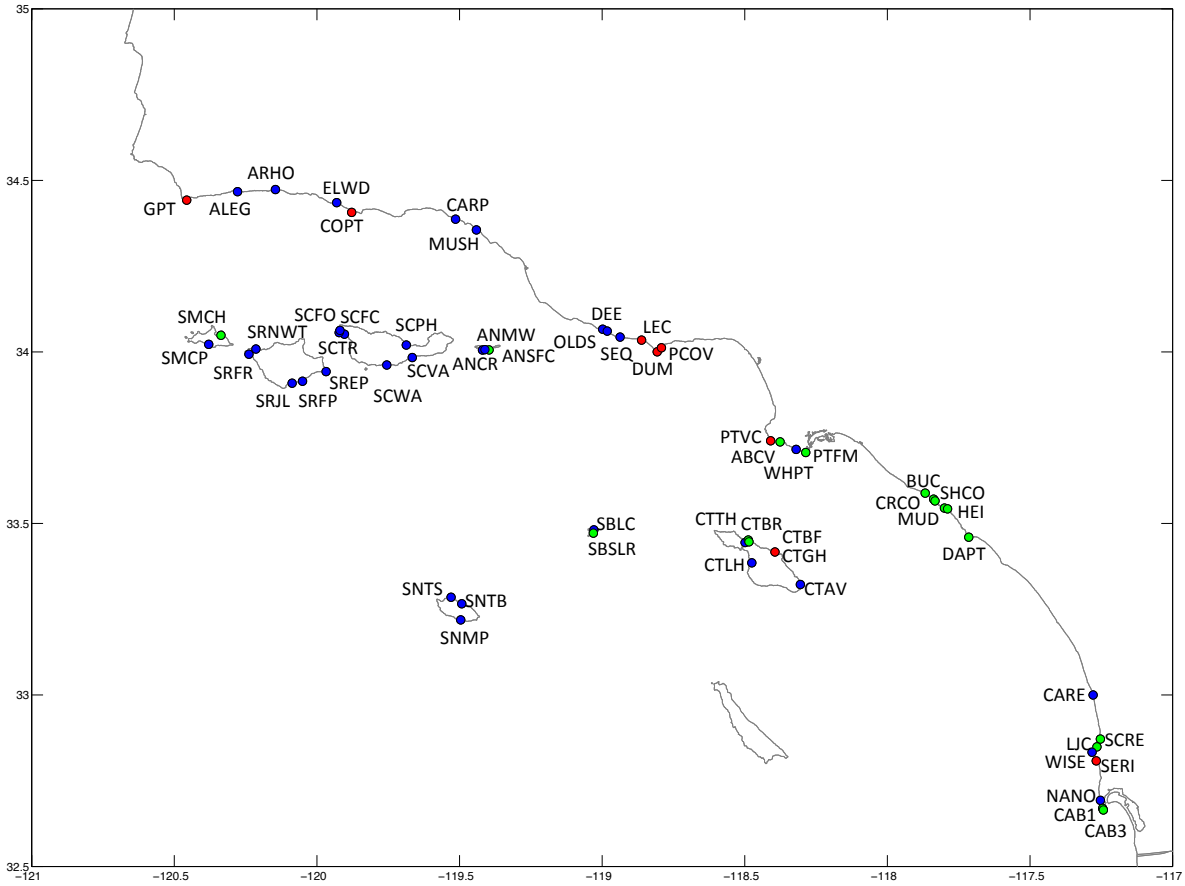

Figure 5 Map of Rocky Intertidal Biodiversity Sites in the SCSR. Old MPAs are coded green, new MPAs are coded red, and reference areas (non-MPAs) are coded blue. Site codes are referenced to names in Table 1

Over time, we have conducted biodiversity surveys at a total of 58 rocky intertidal sites within the SCSR (Figure 5). Of these sites, 25 are located within MPAs, and 33 are located outside of MPAs. Of these 58 sites, 50 of them were surveyed before implementation of the South Coast MPAs, and 8 sites were added as part of the Baseline Program (Table 1). A combined total of 39 sites were surveyed as part of the Baseline Program in 2012-2014. We aimed to resurvey any existing sites that had not been surveyed after 2009. Site descriptions for all sites surveyed in the Baseline program period are included in the **Site Descriptions** section of the Appendix. Detailed descriptions of the biological and physical attributes of all sites can be found in the Site Description section in the report Appendix. Table 1 provides summary information for each of the 58 SCSR sites, including MPA status, Bioregion and relative human access (ranging from low, medium, high) based on information from MARINe. Our approach here has been to utilize all available historical and current data from all 58 SCSR sites to characterize biogeographic patterns across the SCSR, and focus our analysis of MPA baseline conditions on the 39 sites surveyed during the 2012-2014 MPA baseline period.

Table 1 Rocky intertidal sites within the SCSR ordered from northwest to southeast. Starred sites are those that have been surveyed during the Baseline period (2012-2014).

Sitename	Sitecode	MPA_name	MPA_status	Bioregion	Access
Government Point	GPT	Point Conception SMR	newMPA	north_mainland	low
Alegria*	ALEG		reference	north_mainland	low
Arroyo Hondo	ARHO		reference	north_mainland	moderate
Ellwood*	ELWD		reference	north_mainland	moderate
Coal Oil Point*	COPT	Campus Point SMCA	newMPA	north_mainland	high
Carpinteria*	CARP		reference	north_mainland	high
Mussel Shoals	MUSH		reference	north_mainland	moderate
Old Stairs*	OLDS		reference	north_mainland	high
Deer Creek*	DEE		reference	north_mainland	moderate
Sequit Point*	SEQ		reference	north_mainland	high
Lechuza Point*	LEC	Point Dume SMCA	newMPA	north_mainland	high
Point Dume*	DUM	Point Dume SMR	newMPA	north_mainland	moderate
Paradise Cove*	PCOV	Point Dume SMR	newMPA	north_mainland	high
Point Vicente*	PTVC	Point Vicente SMCA	newMPA	south_mainland	moderate
Abalone Cove*	ABCV	Abalone Cove SMCA	oldMPA	south_mainland	high
White Point	WHPT		reference	south_mainland	high
Point Fermin*	PTFM	formerly Pt Fermin SMP	oldMPA	south_mainland	high
Buck Gully South*	BUC	Crystal Cove SMCA	oldMPA	south_mainland	high
Crystal Cove*	CRCO	Crystal Cove SMCA	oldMPA	south_mainland	high
Muddy Canyon*	MUD	Crystal Cove SMCA	oldMPA	south_mainland	high
Shaws Cove*	SHCO	Laguna Beach SMR	oldMPA	south_mainland	high
Heisler Park*	HEI	Laguna Beach SMR	oldMPA	south_mainland	high
Dana Point*	DAPT	Dana Point SMCA	oldMPA	south_mainland	high
Cardiff Reef*	CARE		reference	south_mainland	high
Scripps*	SCRE	SD-Scripps Coastal SMCA	oldMPA	south_mainland	high
La Jolla Caves*	LJC	Matlahuayl SMR	oldMPA	south_mainland	high
Wind and Sea*	WISE		reference	south_mainland	high
Sea Ridge*	SERI	South La Jolla SMR	newMPA	south_mainland	high
Navy North*	NANO		reference	south_mainland	moderate
Cabrillo 1*	CAB1	Cabrillo SMR	oldMPA	south_mainland	high
Cabrillo 3*	CAB3	Cabrillo SMR	oldMPA	south_mainland	low
Cuyler Harbor*	SMCH	Harris Point SMR	oldMPA	west_islands	low
Crook Point*	SMCP		reference	west_islands	low
Fossil Reef	SRFR		reference	west_islands	low
NW Talcott	SRNWT		reference	west_islands	low
East Point	SREP		reference	west_islands	low
Ford Point	SRFP		reference	west_islands	low
Johnsons Lee	SRJL		reference	west_islands	low
Trailer	SCTR		reference	mid_islands	low
Forney	SCFO		reference	mid_islands	low
Fraser Cove	SCFC		reference	mid_islands	low
Prisoners Harbor	SCPH		reference	mid_islands	moderate
Valley	SCVL		reference	mid_islands	low
Willows Anchorage	SCWA		reference	mid_islands	low

Cat Rock	ANCR		reference	mid_islands	low
Middle West*	ANMW	Anacapa Island SMR	oldMPA	mid_islands	low
S Frenchys Cove*	ANSFC		reference	mid_islands	moderate
Landing Cove	SBLC		reference	mid_islands	low
Sea Lion Rookery	SBSLR	Santa Barbara Island SMR	oldMPA	mid_islands	low
Thousand Springs*	SNTS		reference	west_islands	low
Tranquility Beach*	SNTB		reference	west_islands	low
Marker Poles*	SNMP		reference	west_islands	low
Two Harbors*	CTTH		reference	east_islands	high
Bird Rock*	CTBR	Blue Cavern SMCA	oldMPA	east_islands	moderate
Big Fisherman Cove*	CTBF	Blue Cavern SMCA	oldMPA	east_islands	high
Goat Harbor*	CTGH	Long Point SMR	newMPA	east_islands	moderate
Avalon Quarry*	CTAV		reference	east_islands	low
Little Harbor	CTLH		reference	east_islands	moderate

Physical Site Attributes

The physical characteristics of the rocky intertidal habitat in the SCSR are highly variable, from the dominant geology type to the slope and rugosity of the coastline. The physical attributes of each of our intertidal sites are summarized in Table 2. The associated metadata descriptions for these attributes are below:

1. **Primary Bench Type:** describes the dominant geology of the site
    a. **bedrock:** the primary bench type is consolidated bedrock at this site
    b. **bedrock/boulders:** the primary bench type is a mixture of consolidated bedrock and boulder fields at this site
    c. **bedrock/sand:** the primary bench type is a mixture of consolidated bedrock and sandy beach at this site
    d. **bedrock/boulders/sand:** the primary bench type is a mixture of consolidated bedrock, boulder fields, and sandy beach at this site
    e. **bedrock/boulders/cobble/sand:** the primary bench type is a mixture of consolidated bedrock, boulder fields, and cobble and sandy beach at this site
    f. **boulders:** the primary bench type is boulder fields at this site
2. **Slope:** describes the slope of the coastline at the site
    a. **Gentle:** the slope of this site is between 0-5 degrees
    b. **Moderate:** the slope of this site is between 5-15 degrees
3. **Relief:** describes the rugosity of the site
    a. **high:** the relief of the site consists of extremely uneven terrain, containing many deep cracks and folds, such as in some mixed consolidated bedrock and boulder fields
    b. **moderate:** the relief of the site consists of moderately uneven terrain, containing few cracks and folds, such as in boulder or cobble fields and some consolidated bedrock
    c. **low:** the relief of the site consists of flat terrain, such as a sandy beach
4. **Extent:** describes the length of the intertidal area at the site, from the land to the ocean
    a. **long:** the extent of the site is greater than 15 meters
    b. **intermediate:** the extent of the site is between 5-15 meters
    c. **short:** the extent of the site is less than 5 meters
5. **Surrounding Coast:** describes the geology of the area surrounding the site

a. **bedrock:** the surrounding coast is consolidated bedrock at this site
b. **bedrock/boulders:** the surrounding coast is a mixture of consolidated bedrock and boulder fields at this site
c. **bedrock/sand:** the surrounding coast is a mixture of consolidated bedrock and sandy beach at this site
d. **bedrock/boulders/sand:** the surrounding coast is a mixture of consolidated bedrock, boulder fields, and sandy beach at this site
e. **bedrock/boulders/cobble:** the surrounding coast is a mixture of consolidated bedrock, boulder fields, and cobble beach at this site
f. **boulders/sand:** the surrounding coast is a mixture of boulder fields and sandy beach at this site
g. **boulders/cobble/sand:** the surrounding coast is a mixture of boulder fields, cobble beach, and sandy beach at this site
h. **bedrock/boulders/cobble/sand:** the surrounding coast is a mixture of consolidated bedrock, boulder fields, and cobble and sandy beach at this site
i. **boulders:** the surrounding coast is boulder fields at this site
j. **sand:** the surrounding coast is sandy beach at this site

Table 2 Physical attributes of SCSR rocky intertidal sites

sitename	primary_bench_type	slope	relief	extent	surrounding_coast
Government Point	bedrock	gentle	moderate	long	bedrock/sand
Alegria	bedrock/boulders/sand	gentle	moderate	long	bedrock/boulders/sand
Arroyo Hondo	bedrock/sand	gentle	moderate	long	bedrock/sand
Ellwood	bedrock/boulders/cobble	gentle	high	long	bedrock/boulders/cobble/sand
Coal Oil Point	bedrock/boulders/cobble	gentle	low	long	bedrock/sand
Carpinteria	bedrock/sand	gentle	moderate	long	bedrock/sand
Mussel Shoals	bedrock/boulders/sand	moderate	moderate	long	boulders/sand
Old Stairs	bedrock/boulders/sand	moderate	moderate	long	boulders/sand
Deer Creek	bedrock/sand	gentle	moderate	short	bedrock/boulders/sand
Sequit Point	bedrock	gentle	moderate	long	bedrock/boulders/sand
Lechuza Point	bedrock/sand	moderate	moderate	long	bedrock/sand
Point Dume	bedrock/boulders/sand	gentle	moderate	intermediate	bedrock/boulders/sand
Paradise Cove	bedrock/sand	moderate	low	intermediate	sand
Point Vicente	bedrock/boulders/cobble	gentle	high	long	bedrock/boulders/cobble
Abalone Cove	bedrock/boulders	moderate	moderate	intermediate	bedrock/boulders/sand
White Point	bedrock/boulders/cobble	gentle	moderate	long	bedrock/boulders/cobble
Point Fermin	bedrock/boulders	gentle	moderate	long	bedrock/boulders/sand
Buck Gully South	bedrock/boulders	gentle	moderate	long	bedrock/boulders/sand
Crystal Cove	bedrock/boulders	gentle	low	long	bedrock/boulders/sand
Muddy Canyon	bedrock/boulders/cobble/sand	gentle	moderate	long	bedrock/boulders/cobble/sand
Shaws Cove	bedrock	gentle	low	intermediate	bedrock/sand

Heisler Park	bedrock/sand	gentle	moderate	long	bedrock/boulders/sand
Dana Point	bedrock/boulders	gentle	moderate	long	bedrock/boulders/sand
Cardiff Reef	bedrock/sand	gentle	moderate	intermediate	boulders/sand
Scripps	bedrock/boulders/sand	gentle	moderate	long	boulders/sand
La Jolla Caves	bedrock/boulders/sand	gentle	low	long	boulders/cobble/sand
Wind and Sea	bedrock/sand	gentle	moderate	long	bedrock/sand
Sea Ridge	bedrock/boulders/cobble	gentle	moderate	long	bedrock/boulders/cobble/sand
Navy North	bedrock/boulders/cobble	gentle	moderate	long	bedrock/boulders/cobble
Cabrillo 1	bedrock/boulders	gentle	moderate	long	bedrock/boulders/sand
Cabrillo 3	bedrock/boulders	gentle	moderate	long	bedrock/boulders
Cuyler Harbor	bedrock	gentle	moderate	intermediate	bedrock/sand
Crook Point	bedrock	gentle	high	long	bedrock/sand
Fossil Reef	bedrock	gentle	moderate	intermediate	bedrock/sand
NW Talcott	bedrock/boulders	gentle	moderate	intermediate	bedrock/boulders/sand
East Point	bedrock	gentle	moderate	long	bedrock/sand
Ford Point	bedrock	moderate	moderate	intermediate	bedrock
Johnsons Lee	bedrock	gentle	moderate	intermediate	bedrock/boulders/sand
Trailer	bedrock/boulders	gentle	moderate	intermediate	bedrock/boulders/sand
Forney	bedrock	gentle	moderate	long	bedrock/sand
Fraser Cove	bedrock	gentle	moderate	long	bedrock/sand
Prisoners Harbor	bedrock	moderate	moderate	short	bedrock/sand
Valley	bedrock/boulders	moderate	high	intermediate	bedrock/boulders/sand
Willows Anchorage	bedrock/sand	moderate	moderate	long	bedrock/sand
Cat Rock	bedrock/boulders/cobble	gentle	high	intermediate	bedrock/boulders/cobble
Middle West	bedrock	moderate	moderate	intermediate	bedrock
S Frenchys Cove	bedrock/sand	gentle	high	long	bedrock/sand
Landing Cove	bedrock	moderate	moderate	intermediate	bedrock
Sea Lion Rookery	bedrock	gentle	moderate	long	bedrock
Thousand Springs	bedrock/boulders	moderate	moderate	intermediate	bedrock/boulders/sand
Tranquility Beach	bedrock	gentle	moderate	long	bedrock/boulders/sand
Marker Poles	bedrock	gentle	moderate	long	bedrock/sand
Two Harbors	bedrock/boulders	moderate	moderate	intermediate	bedrock/boulders/sand
Bird Rock	bedrock	moderate	moderate	intermediate	bedrock/boulders
Big Fisherman Cove	bedrock	moderate	moderate	intermediate	bedrock/boulders
Goat Harbor	bedrock/boulders	moderate	moderate	intermediate	boulders
Avalon Quarry	boulders	moderate	moderate	intermediate	boulders
Little Harbor	bedrock/boulders	moderate	high	intermediate	bedrock/boulders/sand

Protocols

Our baseline project has been closely coordinated with the two major existing west coast regional monitoring programs for intertidal ecosystems. The first is MARINe (Multi Agency Rocky Intertidal Network, http://www.marine.gov/), which evolved from the monitoring program initiated by the Channel Islands National Park in the early 1980's (Davis 1985; Richards and Davis 1988). The MARINe monitoring program was explicitly directed at detecting temporal changes in the intertidal communities (Raimondi et al 1999). The second is PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans, http://www.piscoweb.org/), which has supported the Coastal Biodiversity Survey program (described in detail below). These biodiversity surveys have been conducted at 130 sites from central Alaska to southern Baja, California, Mexico (http://cbsurveys.ucsc.edu/). Here we make use of this extensive array of PISCO and MARINe data in southern California, and direct resources to those sites where recent information is lacking.

While the unified MARINe protocols have proven to be extraordinarily powerful for detecting changes in communities (Minchinton and Raimondi 2004) and particularly in separating anthropogenic from natural dynamics (Raimondi et al 1999), they were not designed to estimate biodiversity or evaluate the performance of MPAs. Moreover, we found that geomorphology was tremendously important in determining communities and dynamics of communities. To address these concerns we designed a spatially explicit biodiversity monitoring program. Full protocol descriptions for MARINe and Biodiversity surveys and diagrams are available online at http://www.eeb.ucsc.edu/pacificrockyintertidal/methods/index.html.

In this report we focus on the species and assemblages identified in the South Coast MPA Monitoring Plan identified as Key Attributes for Ecosystem Assessment. These Key Attributes include:

1. Sessile taxa important as food and Biogenic Habitat
    a. Mussels
    b. Barnacles
    c. Feather Boa kelp (*Egregia menziesii*)
    d. Rockweeds
    e. Surfgrass
    f. Turf algae
    g. Encrusting algae
2. Mobile consumers – predators and herbivores
    a. Urchins
    b. Turban Snails
    c. Sea stars
    d. Abalone
    e. Owl Limpets
    f. Birds
3. Species Richness and Diversity

Below we describe the Biodiversity survey and MARINe protocols used to provide the best assessment for each of these key attributes and provide a baseline characterization of sites across the SCSR. The protocols described below are identical to those that have been or are being used in other CA MLPA regions (CCSR, NCCSR and NCSR) to quantify rocky intertidal biodiversity and abundance and sizes of selected key attributes in each region. Full protocol descriptions, information and trend graphs for all taxa at all MARINe sites over time are available at http://www.pacificrockyintertidal.org.

Biodiversity Surveys

Our biodiversity monitoring at each site has consistently followed the approach used since 2000, and in other CA MPA regions. These surveys have proven useful to characterize biogeographic patterns in intertidal assemblages across both large and small scales (Blanchette et al 2008, 2009). Below we briefly describe this sampling approach.

Once an appropriate area of shoreline has been selected, the grid of the sampling area is defined by a series of parallel transect lines extending from the high zone to the low zone. To facilitate the setup of these lines, two permanent 30m horizontal baselines (parallel to the shoreline) are first established. The upper baseline is placed in the high zone above the upper limit of marine biota, such as barnacles, while the lower baseline is established farther down the shore within the low zone of biota at that site. The ends of these lines are permanently marked with either hex or carriage bolts.

Once these two baselines have been established, parallel transect lines are run perpendicular to the shoreline at 3-meter intervals crossing both the upper and lower baselines. In general the transect lines follow the contours of the site topography. When necessary, rocks are placed along the lines to prevent them from being shifted by heavy winds and a note is made of where each transect crosses the lower baseline.

Point-Contact Surveys

Each vertical transect is sampled using the point intercept method. Ideally 100 points are sampled at uniform intervals on each transect line. For each point, two types of data are collected: data that are used to determine relative abundance (percent cover), and data that are used to describe spatial distributions. The relative abundance data are collected by identifying all taxa that fall directly under each point, including rock, sand, and tar. If there is layering, the taxa occupying the different layers are identified and assigned a letter defining their vertical position within the canopy. Also recorded is whether the species under the point are found in pools, on cobble, or on boulders. A total of up to three taxa are identified under each point. If fewer than three taxa are recorded under a point, then data are collected on the identity of the next one or two species closest to that point. These data are used to describe the spatial distribution of species, and are not used when calculating relative abundances. These 'nearby' species must be different than those found under the point, and must fall within a circle centered over the point with a radius half the length of the sampling interval. When a species cannot be identified in the field, it is assigned an unknown number and a sample of it is collected.

Mobile Invertebrate Surveys, Sea Star and Abalone Swaths

Although point-contact surveys are good at determining the abundance of spatially common species, they do not sample rare or spatially uncommon species very well. Because most mobile species are not spatially common, their abundances are determined in 50 x 50 cm quadrats placed at three locations along each transect. Each transect is first divided into three zones; the low zone is the area below the mussels, the mid-zone includes the mussels and the rockweeds (e.g. *Silvetia, Pelvetiopsis*), and the high zone is the area dominated by barnacles and littorine snails. Within each zone a quadrat is randomly placed on the transect, and all mobile species found within the quadrat are identified and counted. Sub-sampling may be used when there are more than one hundred individuals of one species in a quadrat. If a quadrat lands in a deep pool or in an area dominated by sand, a new location is selected. The only mobile species not counted are worms, *Neomolgus littoralis*, and amphipods.

Sea stars and abalone play an important role in the intertidal community, but often they are also not spatially common. As such, their abundances are measured along a two-meter swath centered over each vertical transect. Within this swath, the abundance and location along the transect (to the nearest 0.5m) of the following sea stars and abalone are recorded: *Haliotis cracherodii and rufescnes, Asterina miniata, Dermasterius imbricata, Pisaster ochraceu*s, *Pisaster giganteus,* and *Pycnopodia helianthoides*.

Topography and environmental variables

Tidal elevations (relative to Mean Sea Level (MSL)) of each point in the grid are measured using standard surveying equipment (a rotating laser leveler mounted on a tripod and a stadia rod). Elevation measurements are recorded along each transect wherever there is a change in topography. Thus, measurements are taken infrequently (every few meters) for gradual slopes, but more frequently (tens of centimeters) when necessary to capture the presence of smaller ridges and pools. These measurements are referenced to tidal elevations (meters above MLLW) by recording reference measurements of sea level at the time of low tide. The tidal elevation data within the grid are later spatially interpolated to create a three-dimensional topographic map of each site. These data are an invaluable component of baseline surveys to provide physical and historical reference points to interpret potential shifts in distribution and zonation due to climate or other large scale forcing phenomena.

Site descriptions and special searches

In addition to field data collection, we take a series of site photos at each site and sample period at a series of fixed locations using protocols developed by MARINe. These photos will be used to document overall site conditions at these timepoints and will be documented and uploaded to the datacatalog as part of each dataset. Our biodiversity surveys also include an overall site search for the presence and abundance of invasive species. Marine invasive species known to occur in this region and habitat include (but are not limited to): *Caulacanthus okamurae* (synonym *C. ustulatus*)*, Lomentaria hakodatensis, Sargassum muticum* and *horneri, Undaria pinnatifida and Mytilus galloprovincialis*. Baseline information on occurrence of invasives will be of great use in measuring and predicting rates of spread.

Rocky shore birds

Data on the abundance and diversity of rocky shore associated birds was collected at a subset of our rocky intertidal sites in collaboration with J. Dugan and D. Hubbard, lead PIs on the sandy beach ecosystem baseline monitoring project for the SCSR. Dugan and Hubbard have many years of expertise in censusing bird abundance and behavior, and many of the birds of interest utilize both sandy and rocky habitats and are often found in mixed sand/rock areas. Detailed protocols for the bird surveys are available and included in the technical report for the South Coast Baseline Sandy Beach Ecosystems Project (J. Dugan, lead PI).

Assessing Initial Changes

To evaluate initial ecological changes for species most likely to be affected by MPAs, we have incorporated some methods from the MARINe protocols in addition to our Biodiversity surveys. Our focal taxa for these surveys include the three species that are typically targeted by humans for collection and most likely to be affected by MPAs: Owl Limpets (*Lottia gigantea*), Mussels (*Mytilus californianus*), and Black abalone (*Haliotis cracherodii*). For each of these taxa we measured density and size structure in year 1 (2012) and year 2 (2013) of the baseline program using the protocols described below. Not all species were abundant at all baseline sites, and these surveys were done only at sites where these species were abundant. Black abalone were not abundant enough at any of our baseline sites to characterize changes in size structure over time, so to assess initial changes we focused mainly on mussels and owl limpets.

Owl Limpets

The density and size distribution of owl limpets were monitored within 5 permanent 1-m radius circular plots per site. Plots were established in areas of high density to obtain as many counts and measurements for size-frequency as possible (preferably >20 individuals/plot for a total of >100 per site). Therefore, plot densities reflect maximum densities rather than average densities at each site. Plots are marked with one center bolt, notched to indicate the plot number. Limpets are measured within a circle (1 m radius, 3.14 m^2 area) projected around each bolt. To survey a plot, a 1 m length of line or tape is attached to the center bolt and arced around to form a circle. The maximum length of all owl limpets **≥**15 mm found within that circle (including those touched by the 1 m mark) are measured with calipers to the nearest millimeter, then temporarily marked with a yellow forestry crayon to avoid scoring duplication. If a limpet cannot be measured directly by the calipers (due to tight crevices or other irregularities), its size is estimated. Limpets are never removed from the rock.

Mussels

Mussels are an extremely important component of rocky intertidal ecosystems and are sensitive to the effects of human disturbance. Although our Biodiversity surveys provide the best estimate of mussel abundance, we utilized an additional protocol documented in Smith et al (2008) to estimate mussel size distributions across sites and over time. We established five 50 cm x 75 cm plots in the mussel zone at sites where mussels were abundant. We placed five 20 cm x 20 cm mini-quadrats in each corner and the center of each plot, and measured the length (to the nearest cm) of mussels directly under each of 2 designated

points in each min-quadrat. In situations where there was no mussel under a designated point, we measured the length of the nearest mussel to the point that could be found within the plot.

Data Analysis

Data analyses were conducted by PIs Blanchette and Raimondi using a combination of approaches described in further detail in the "Results" section, and using the statistical software and graphics packages in JMP (SAS Institute), PRIMER (Clark 1993), PERMANOVA (Anderson 2001, McArdle and Anderson 2001), R (R Core Team 2013) and zt software (Bonnet and Van De Peer 2002).

Biogeographic Patterns

In all analyses of the Biodiversity data, we analyzed the data from the sessile and mobile assemblages separately due to the differences in the sampling methods, units of measurement and species attributes. To examine biogeographic patterns, we averaged taxon abundances across years for sites that were sampled in more than one year. To examine patterns of community similarity, we used the multivariate methods of Clarke (1993) and the PRIMER 6.1.15 (Plymouth Routines in Multivariate Ecological Research) software package. The data matrix of sessile taxon abundances was fourth-root transformed to reduce the contribution of very abundant species and increase that of rare species, and the data matrix of mobile taxon abundances was log (x+1) transformed. Similarity matrices for both sessile and mobile taxa were constructed using the Bray–Curtis similarity coefficient and we used two-dimensional, non-metric multidimensional scaling (nMDS) to examine segregation among communities (Kruskal & Wish, 1978).

We used ANOSIM to evaluate the differences in assemblages based on the MLPA designated Bioregions, and used Canonical Analysis of Principal coordinates (CAP)(Anderson and Robinson 2003, Anderson and Willis 2003) to assess the strength of discrimination among sites according to the MLPA designated Bioregions. To define biodiversity community groupings, we used hierarchical cluster analysis with group averaging, and a SIMPROF test using 10000 permutations to indicate significant group structure at the 0.1% level.

To assess the importance of persistent oceanographic conditions as a contributor to community structure patterns, we created a set of site-specific long-term mean Sea Surface Temperatures (SSTs) based on data available from MODIS satellite imagery (http://spg.ucsd.edu/Satellite_data/California_Current/). These data are available from 2000 to present at 1km resolution as 15-day composites. To create site-specific long-term means, we spatially averaged a square-array of 9 pixels located just offshore from each of our study sites over the period from 2000-2012.

We used PERMANOVA to assess the relationships between biological community structure and physical site attributes. We used two independent approaches to assess geographical and environmental correlates of community similarity. We used Mantel and partial tests to examine the correlation between the matrices of community similarity and distances among sites and differences in long-term mean SST among sites. Additionally we used the Distance-based linear models (DISTLM) routine in PERMANOVA (Legendre and Anderson 1999) to examine the links between community structure and long-term mean SST among sites after fitting and removing the geographic location effects of longitude and latitude. This routine examines

how much of the spatial variation in community structure is explained by geographic position and long-term mean SST as an index of ocean conditions.

We used a PERMANOVA approach to examine the effects of humans on spatial patterns of community similarity. The 2 main effects that we considered were the effects of humans through resource extraction, and the effects of humans through physical presence via activities such as trampling, overturning, etc. To do this we examined the effects of resource extraction by comparing assemblages inside and outside of MPAs. To examine the physical disturbance impacts of humans that are un-correlated with resource extraction, we compared assemblages across a range of human access. We also examined the strength of this interaction to identify synergies or feedbacks across these main effects.

We used a stepwise DISTLM approach to identify the most significant drivers that are able to explain variation in the similarities of sessile and mobile communities across the SCSR. We used all 5 physical variables, geographic spatial variables, and human effect variables in the model. We used the An Information Criterion – AIC (Akaike 1973) to identify the most parsimonious model (one with good explanatory power, high R^2, and as simple as possible, fewest number of predictor variables).

Ecosystem Features

We analyzed differences among levels of MPA status (old MPAs, new MPAs and reference areas) in each of the main ecosystem attributes (the percent cover of Sessile taxa, density of mobile taxa and richness and diversity) using a nonparametric multiple comparisons test based on the Steel-Dwass method. This test is the non-parametric version of the Tukey HSD test and is based on ranks and controls for the overall alpha level in multiple comparisons. We analyzed data on the similarity of rocky shore bird communities across sites using an MDS approach in PRIMER, as described above for the intertidal species. We assessed differences in rocky shore bird assemblages inside and outside of MPAs based on MPA status using ANOSIM test in PRIMER.

Assessment of Initial Changes

We assessed initial changes in our baseline study by comparing changes in size and abundance over the first 2 years of the study (2012 and 2013). Our sampling focused on the species most likely to be targeted for collection by humans – mussels (*Mytilus californianus*) and owl limpets (*Lottia gigantea*). We focused the analysis on the 2 key human-related factors (MPA status and human access) likely to affect changes in sizes of these targeted species through time. For both mussels and limpets, we created a similarity matrix based on Euclidean distances from the standardized size distributions. We used PERMANOVA to examine the main effects of the human impact variables (public access and MPA status) and year (2012 and 2013) as well as the interaction between either of the human impact variables and time to assess initial changes in size distributions following MPA implementation.

Ecosystem Indicators

We followed the approach used in the NCCSR to develop a reduced list of sessile and mobile taxa that were >80% correlated with multivariate patterns produced by the full biodiversity dataset based on the full list of

both sessile and mobile taxa. We carried out this analysis for both sessile and mobile taxa using the BEST routine in PRIMER to find a small subset of 'easily-identifiable' taxa which generated a multivariate pattern that was >80% correlated to that based on the full assemblage. We ran the analysis using both random and fixed starts and chose from among the resulting models those that had the fewest and easiest to identify taxa.

As a complementary approach to identifying a reduced subset of taxa, we also evaluated the degree of correlation among matrices that were produced using increasing degrees of taxonomically and functionally aggregation. We evaluated the correlations across matrices produced using the full 'species' dataset, taxa identified to genus, order, phylum, functional group, common group, taxonomic group and trophic group. We used a second-stage MDS approach using PRIMER to represent the correlations (Spearman) among matrices generated by increasing degrees of aggregation.

Comparative Data Analysis (LiMPETS and SCPMPA)

We compared the patterns of similarity between assemblages at each of three south coast sites sampled by two different groups (LiMPETS and our baseline project –South Coast MPA (SCMPA)). Since the LiMPETS focal taxa were generally at a much more course taxonomic resolution than the SCMPA data, we lumped SCMPA species-level data to achieve similar functional taxonomic classifications. The data matrix of sessile taxon abundances was square-root transformed, and mobile abundances were log(x+1) transformed and we constructed similarity matrices for each dataset using the Bray–Curtis similarity coefficient. To examine patterns of community similarity, we used two-dimensional, non-metric multidimensional scaling (nMDS) to examine segregation among communities. We used a PERMANOVA approach to test the main effects of Method (LiMPETS vs. SCMPA) and Site in contributing to variability across sessile and mobile assemblages.

We followed an analytical approach similar to that described above for the comparative data analysis to analyze the results of an experimental evaluation of methods between the two projects to estimate percent cover. We used a PERMANOVA approach to test the main effects of Method (LiMPETS vs. SCMPA) and Site in contributing to variability across sessile assemblages.

Results and Discussion

Summary of Key Results

Spatial and Biogeographic Patterns

- Patterns of community similarity are strongly correlated with the MLPA established Bioregions (Figures 6-9)
- Sessile community structure is significantly correlated with primary bench type and surrounding coast, and mobile community structure is strongly correlated with surrounding coast (Table 3)
- Geographic location and SST are strong and significant contributors to community pattern (Table 4)
- The abundance and species composition of key ecosystem attributes varies widely across the SCSR (Figures 14-16; 18-28)

Human Effects (MPAs and Public Access)

- Sessile and mobile community structure does not differ as a function of the Level of protection (MPA vs. non-MPA) (Table 5)
- Level of public access significantly affects sessile, but not mobile community structure (Table 5)
- The effects of the level of public access on sessile and mobile community structure do not differ as a function of MPA status (Table 5)
- The abundance of key ecosystem attributes across sites is not dependent on MPA status (Tables 6-8)
- Species richness and diversity are highest in old MPAs, lowest in reference areas, and intermediate and most variable in new MPAs (Figure 29, Table 9)

Initial Changes

- There were no changes in the abundance and size distribution of mussels and owl limpets during the initial implementation period (2012-2013) (Figures 31, 33)
- Owl limpet sizes vary as a function of public access, with size distributions dominated by small individuals and lacking in large limpets in areas of high public access (Figure 32, Table 10)
- Sea star populations rapidly declined across the SCSR in early 2014 due to Sea Star Wasting Disease (Figures 53, 54)

Biogeographic Patterns of Community Structure

Community Similarity and Spatial scales of similarity across bioregions

Sessile Taxa

The similarity in sessile assemblages across southern California is strongly linked to the biogeographic differences in community structure across the bioregions (Figure 6), with a significant effect of bioregion (ANOSIM Global R = 0.491, p<0.1%).

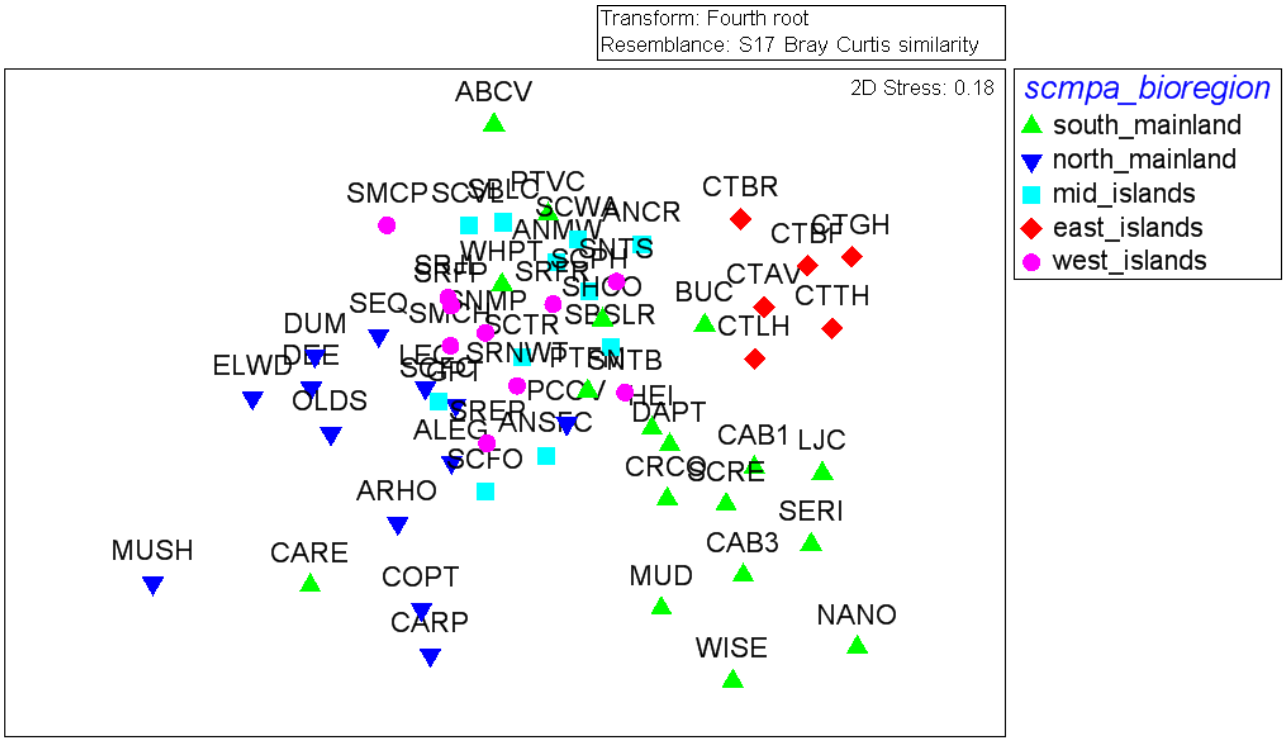

Figure 6 Non-metric multidimensional scaling plot representing the 2-dimensional patterns of spatial similarity of sessile taxa across the SCSR

These bioregional differences in sessile assemblages produced a strong pattern of separation across the canonical axes (Figure 7). The ability to discriminate among sessile assemblages based on bioregion was generally strong with a success rate of 87.93%, and a misclassification error of 12.07%. The classification success for each group was: south mainland 94.44%, north mainland 84.62%, mid islands 81.82%, east islands 83.33% and west islands 90.00%.

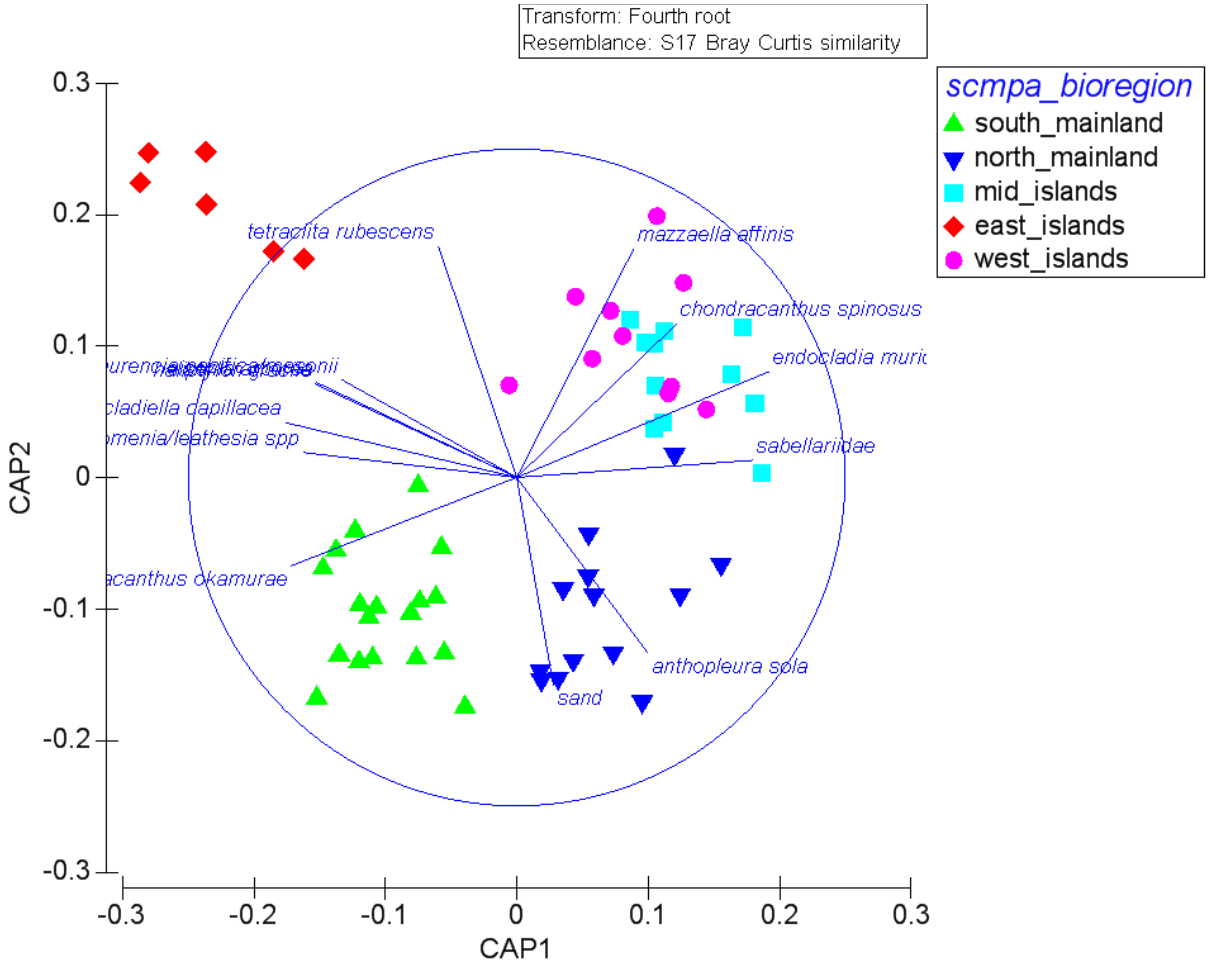

Figure 7 Canonical ordination for the discriminant analysis of sessile assemblages based on Biogregion groupings. Vector overlays show taxa with Spearman rank correlations >0.60 to the CAP axes

Mobile Taxa

The similarity in mobile assemblages across southern California was strongly linked to the biogeographic differences in community structure across the bioregions (Figure 8), with a significant effect of bioregion (ANOSIM Global R = 0.387, p<0.1%).

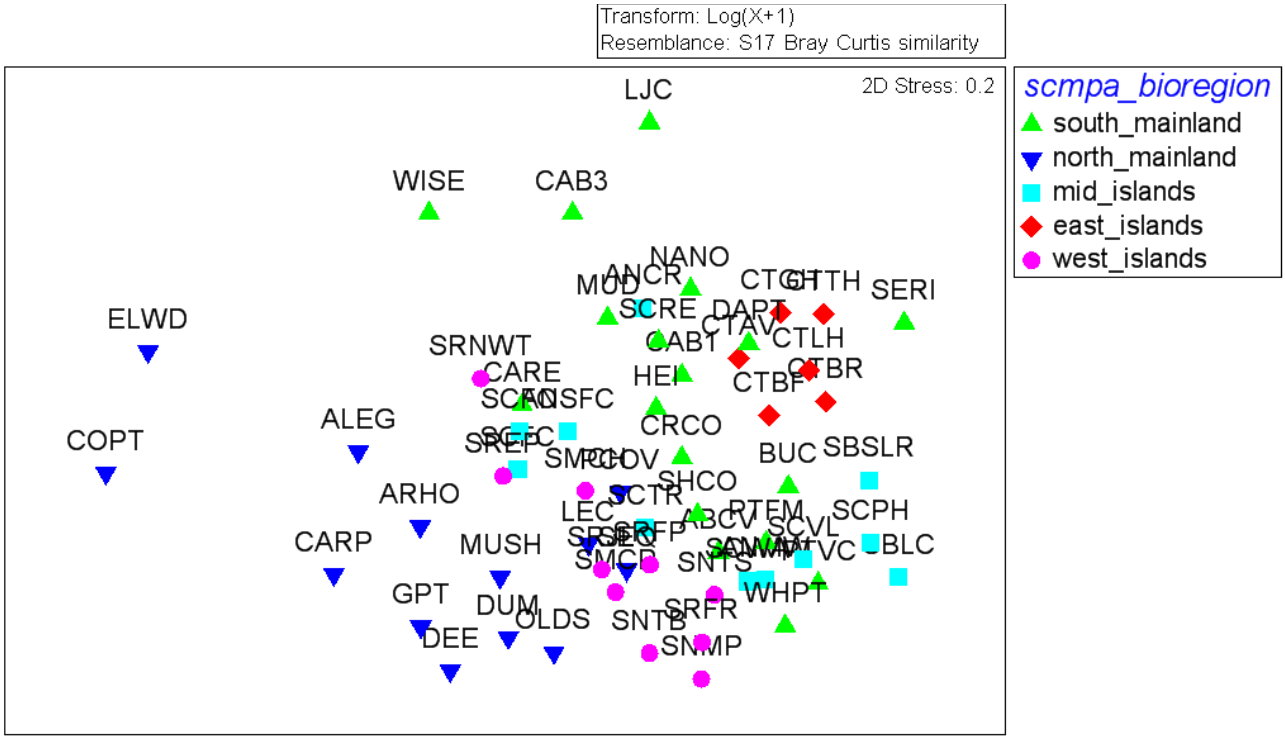

Figure 8 Nonmetric multidimensional scaling plot representing the 2-dimensional patterns of spatial similarity of mobile taxa across the SCSR

These bioregional differences in mobile assemblages produced a strong pattern of separation across the canonical axes (Figure 9). The ability to discriminate among sessile assemblages based on bioregion was generally strong, although not as strong as for the sessile taxa with a success rate of 84.48%, and a misclassification error of 15.52%. The classification success for each group was: south mainland 94.44%, north mainland 92.31%, mid islands 63.64%, east islands 83.33% and west islands 80.00%. The lowest classification success was in the mid island group, likely reflecting the nature of this area as a biogeographic and oceanographic transition zone.

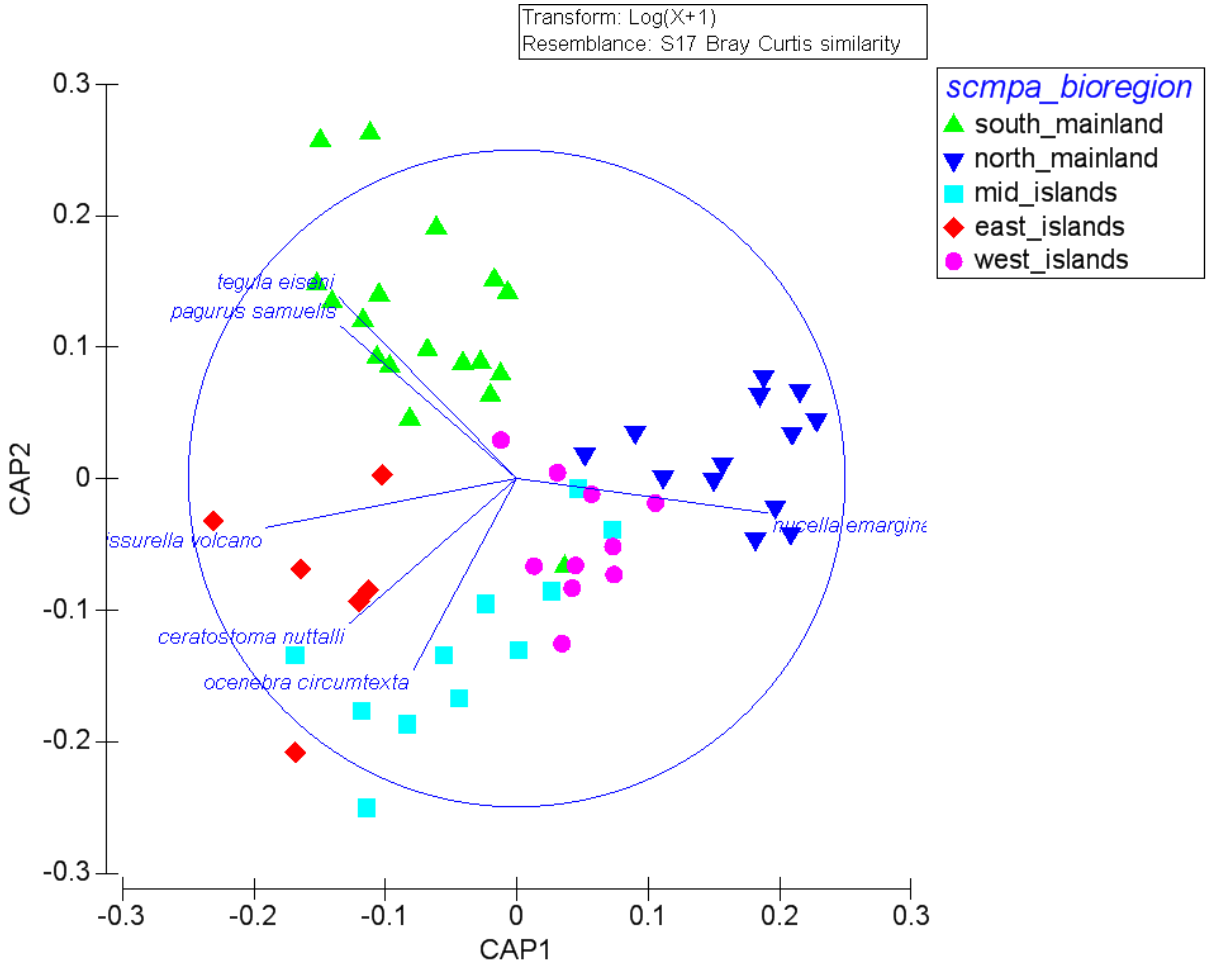

Figure 9 Canonical ordination for the discriminant analysis of mobile assemblages based on Biogregion groupings. Vector overlays show taxa with Spearman rank correlations >0.60 to the CAP axes.

Biodiversity community groupings

Sessile Taxa

We used the SIMPROF routine in PRIMER to identify sites that clustered together based on significant similarity in their sessile assemblages. We identified 14 significant community groups, with 2 of the sites (Mussel Shoals and Muddy Canyon) as outliers that did not group with any other site (Figure 10). Both of these sites are relatively low diversity sites that are heavily sand influenced.

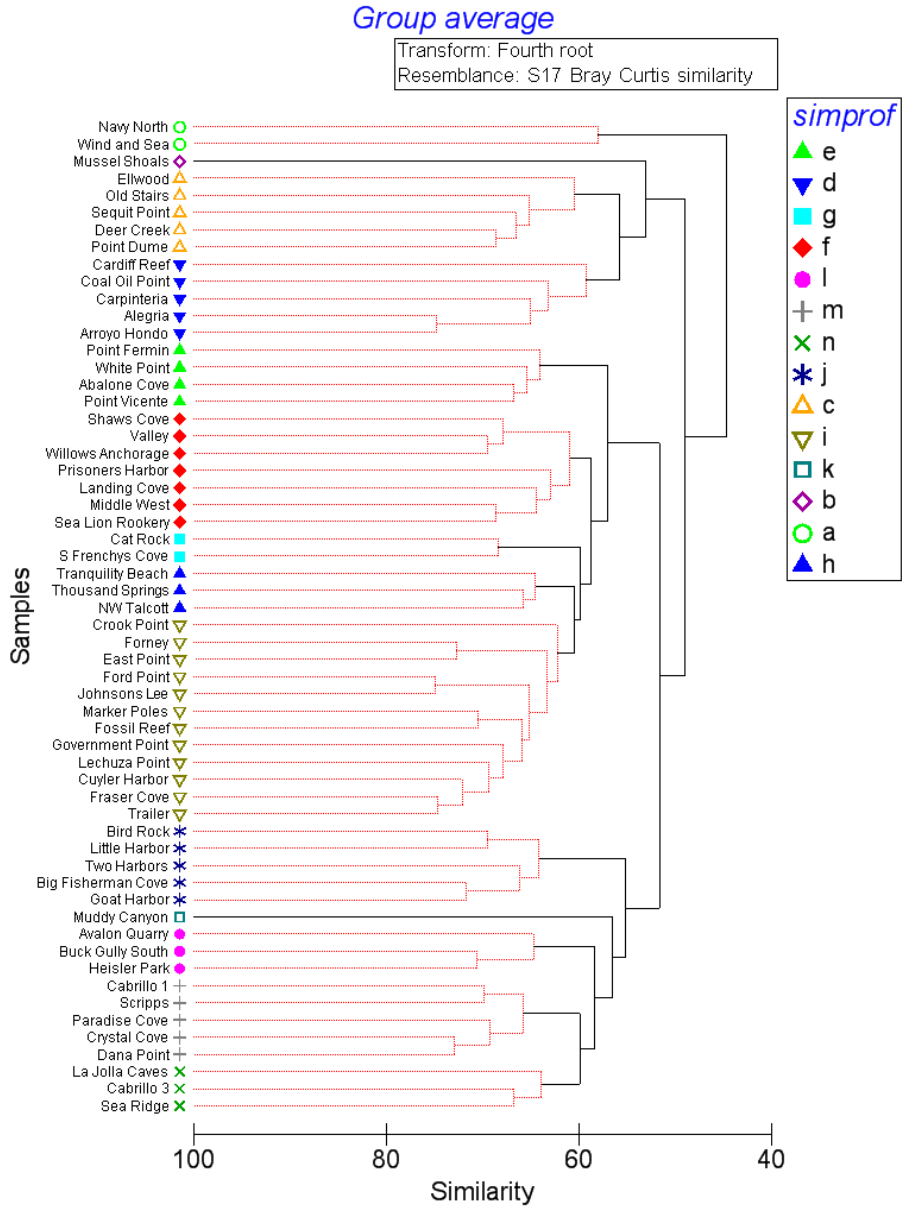

Figure 10 Dendrogram depicting SCSR sites clustered according to similarity in sessile assemblages. Solid lines indicate significant group structure at the 0.1% level.

Figure 11 shows the spatial distribution of sites according to their sessile community cluster groupings as identified by the SIMPROF test. The spatial distribution of significant groups is related to the overall Bioregional patterns, with several significant outliers from this pattern. The 14 significant cluster groups highlight a finer level of resolution in the spatial patterns of community structure than the 5 Bioregions originally identified in the MLPA planning process.

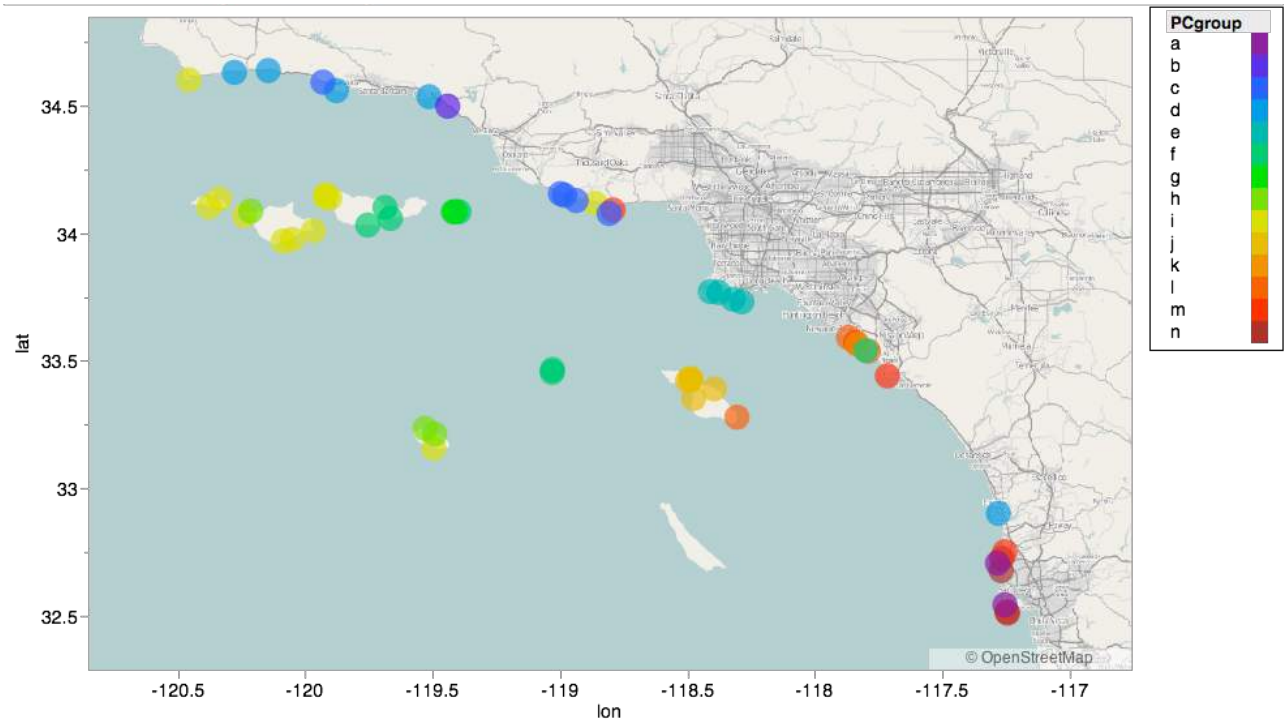

Figure 11 Map of sessile biodiversity community groupings in the SCSR

Mobile Taxa

We used the SIMPROF routine in PRIMER to identify sites that clustered together based on significant similarity in their mobile assemblages. We identified 9 significant community groups, with one site (Wind and Sea) as an outlier that did not group with any other site (Figure 12).

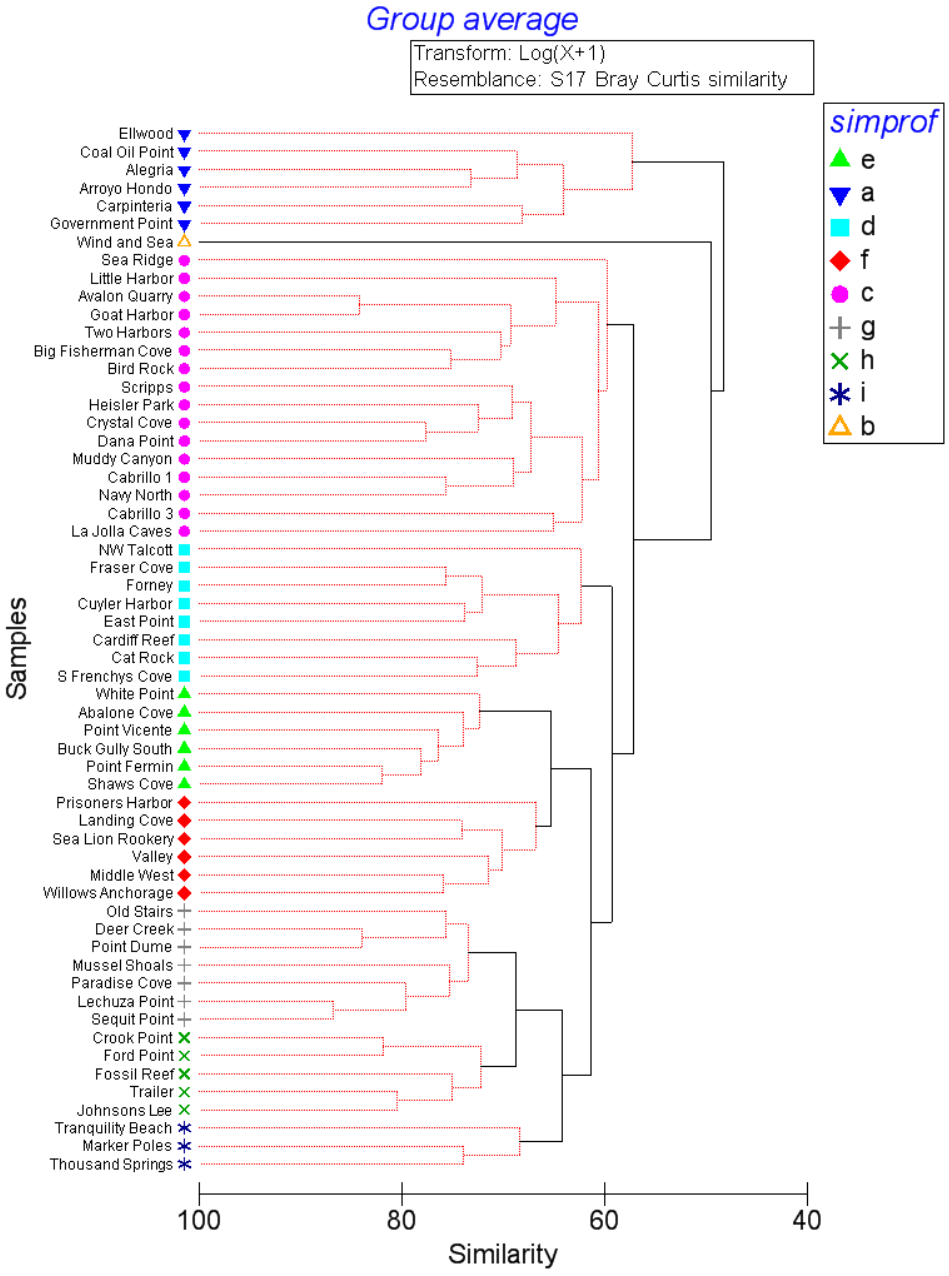

Figure 12 Dendrogram depicting SCSR sites clustered according to similarity in mobile assemblages. Solid lines indicate significant group structure at the 0.1% level.

Figure 13 shows the spatial distribution of sites according to their mobile community cluster groupings as identified by the SIMPROF test. The spatial distribution of significant groups is not as strongly related to the overall Bioregional patterns as seen in the sessile assemblages. The 9 significant cluster groups highlight a finer level of resolution in the spatial patterns of community structure than the 5 Bioregions originally identified in the MLPA planning process.

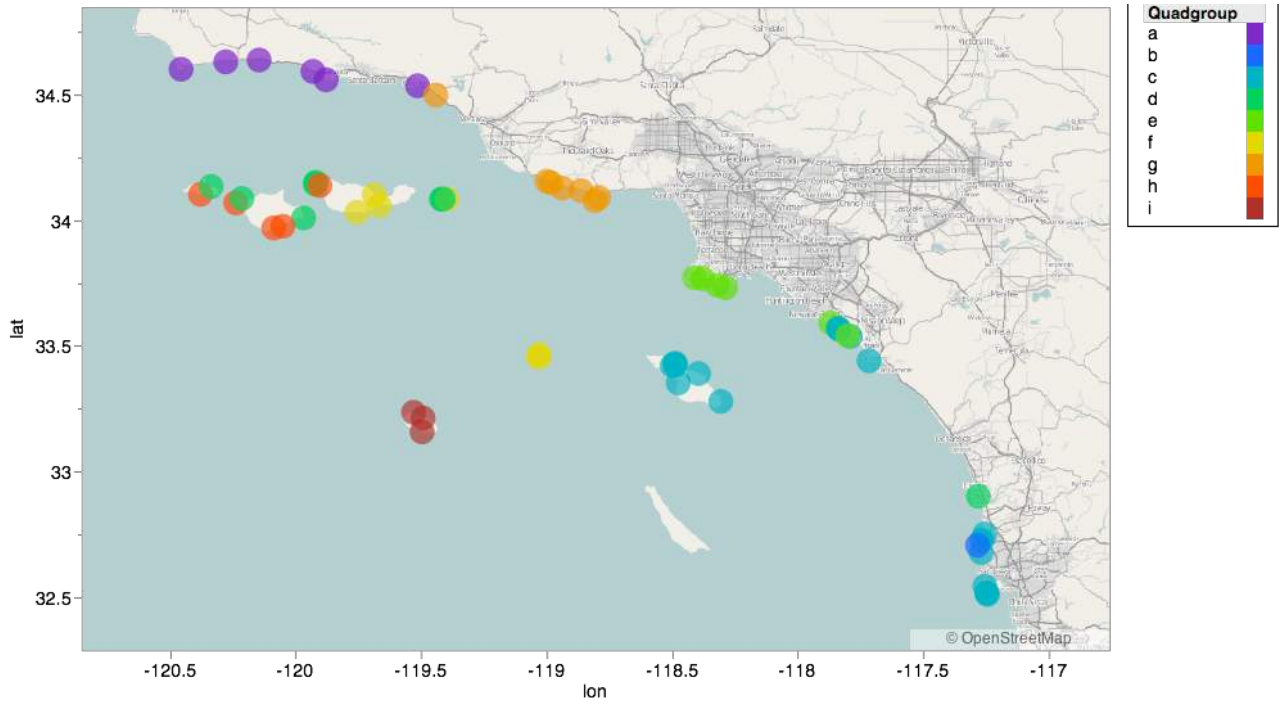

Figure 13 Map of biodiversity community groupings of mobile taxa across SCSR

Relationships among physical site attributes and biological communities

At each of our sites we also collected information on the slope, relief and extent of the reefs as well as describing the primary "bench" type of the reef and the surrounding coast (see Table 2). We examined the relationship between these physical attributes and the mobile and sessile communities using a PERMANOVA approach (Table 3). For both sessile and mobile taxa neither of the topographic reef variables (relief, extent) were significant contributors to community variation, however slope was significant for mobile taxa, and marginally significant for sessile taxa. For both sessile and mobile assemblages both the primary bench type and the surrounding coast were found to be important contributor to community pattern. This finding highlights the importance of mixed-sand rock habitats in the south coast region, and provides evidence that these habitats are important contributors to community structure. Our Sandy Beach Ecosystem collaborators (Dugan et al.) have also found these sand rock interfaces to be important zones of biodiversity, and 'hotspots' for a variety of coastal birds (J. Dugan, personal communication). These mixed sand-rock

habitats dominate the coastline in the southern California region, and are far more abundant in this region than in any other section of the coast. These habitats can transition from sand to rock dominated over relatively short periods of time, and the rocky reefs of these habitats tend to be dominated by species that are relatively sand tolerant, such as anemones and surfgrass. The primary bench type is also an important contributor to community structure, particularly for sessile taxa ($p<0.034$) that are directly attached to these rocky surfaces.

Table 3 PERMANOVA results for the relationship between biological community and physical attributes of sites for sessile and mobile taxa

PERMANOVA table of results – Sessile taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
extent	2	1436.7	718.33	0.7624	0.816
slope	1	1583.6	1583.6	1.6808	0.053
relief	2	2200.9	1100.4	1.168	0.244
primary_bench_type	6	8394.4	1399.1	1.4849	**0.008**
surrounding_coast	9	11339	1259.9	1.3372	**0.010**
Res	37	34861	942.2		
Total	57	64497			
PERMANOVA table of results – Mobile taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
extent	2	1017.9	508.96	0.68825	0.816
slope	1	1760.5	1760.5	2.3808	**0.018**
relief	2	1597.2	798.62	1.08	0.394
primary_bench_type	6	7129.4	1188.2	1.6068	**0.012**
surrounding_coast	9	11485	1276.1	1.7256	**0.003**
Res	37	27361	739.49		
Total	57	53281			

Geographic and Environmental Correlates of Community Similarity

We used two independent approaches to assess geographical and environmental correlates of community similarity. We used Mantel and partial tests to examine the correlation between the matrices of community similarity and distances among sites and differences in long-term mean SST among sites (Legendre 1993; Legendre and Legendre 1998; Legendre et al. 2005). Additionally we used the Distance-based linear models (DISTLM) routine in PERMANOVA (Legendre and Anderson 1999) to examine the links between community structure and long-term mean SST among sites after fitting and removing the geographic location effects of longitude and latitude. This routine examines how much of the spatial variation in community structure is explained by geographic position and long-term mean SST as an index of ocean conditions.

Mantel Tests

The patterns of community similarity for both sessile and mobile taxa appear to be strongly correlated with both geographic distance and oceanographic climate (Blanchette et al. 2008, 2009). However, two variables

may appear to be correlated simply because they are both linked to a third, common variable, such as location in space. Thus, in the presence of autocorrelation, it is necessary to remove the effect of this third variable before concluding that the original two variables are indeed correlated, similarly to a partial correlation. This can be done with the partial Mantel test (Smouse et al. 1986; Legendre and Troussellier 1988; Fortin and Payette 2002). A significant coefficient of correlation (**r**) for the partial Mantel test (with spatial effects removed) indicates that the relationship that exists between the two variables is not related to a common spatial structure (Legendre and Fortin 1989). We used a partial Mantel test to examine the correlation between community similarity and SST while controlling for the effects of geographic distance. The Mantel and partial Mantel tests were based on 10,000 random permutations with a Pearson correlation coefficient at a significance level of α=0.05. All Mantel tests were done using zt software (Bonnet and Van de Peer 2002).

We found similarity in the assemblage of sessile taxa among sites to be highly correlated with both geographic distance across sites (Mantel r=-0.458662, p=0.0001) and long-term mean SST (Mantel r=-0.295491, p=0.0001). The matrices of geographic distance and SST were also highly correlated (Mantel r=-0.665145, p=0.0001) confounding the interpretations of similarity due to space and ocean conditions. The partial Mantel correlation between the matrices of community similarity and SST while controlling for the effect of geographic distance was non-significant (Mantel r=-0.01447, p=0.426657), however the correlation between the matrices of community similarity and distance while controlling for the effect of SST was highly significant (Mantel r=-0.367436, p=0.0001) indicating a strong similarity by distance relationship independent of ocean conditions.

We found similar effects in the relationship among geographic distance, SST and spatial similarity for the assemblages of mobile invertebrates. . Similarity in the assemblage of mobile taxa among sites was correlated with both SST across sites (Mantel r=- -0.171276, p= 0.002200) and geographical distance (Mantel r=-0.346687, p= 0.0001). The partial Mantel correlation between the matrices of community similarity and SST while controlling for the effect of geographic distance was not significant (Mantel r=-0.084695, p=0.111589), however the correlation between the matrices of community similarity and distance while controlling for the effect of SST was highly significant (Mantel r=-0.316392, p=0.0001) indicating a strong similarity by distance relationship independent of ocean conditions.

DISTLM

To further explore the contributions of geography and ocean conditions on the spatial patterns of similarity, we used a stepwise approach in the Distance-based linear models routine in PRIMER. We found both latitude and longitude to be strongly correlated with SST in southern California due to the strong oceanographic gradients that span from north to south, and from east to west (Figure 4). We fit a stepwise model using both latitude (first), and longitude (second) in this model as explanatory variables on the Bray Curtis similarity matrices for both sessile and mobile taxa. We then fit SST as the third explanatory variable to look at how much of the spatial pattern among areas was explained by the geographic coordinates, and then whether SST explained anything further, having removed the spatial effects. We found all three variables to be significant in their explanatory power, and the best model fit for both sessile and mobile taxa

included all three variables, indicating the strong importance of both spatial location and oceanographic conditions in driving community structure patterns of sessile and mobile intertidal assemblages across the SCSR (Table 4).

Table 4 Distance-based linear model fit to the Bray Curtis similarity matrices for sessile and mobile assemblages using geographical and environmental (SST) explanatory variables

DISTLM on space and SST for Sessile Taxa								
Marginal Tests								
Group	SS(trace)	Pseudo-F	P	Prop.	res.df	regr.df		
latitude	8401.6	8.3873	**0.001**	0.13026	56	2		
longitude	8323	8.2972	**0.001**	0.12904	56	2		
Mean(sst)	8311.7	8.2842	**0.001**	0.12887	56	2		
Sequential Tests								
Group	Adj R^2	SS(trace)	Pseudo-F	P	Prop.	Cumul.	res.df	regr.df
+latitude	0.13026	8401.6	8.3873	**0.001**	0.13026	0.13026	56	2
+longitude	0.19707	4308.8	4.5762	**0.001**	6.6806E-2	0.19707	55	3
+Mean(sst)	0.25285	3597.9	4.0317	**0.001**	5.5783E-2	0.25285	54	4
Best Solution								
R^2	RSS	No.Groups	Selections					
0 .25285	48189	3	**SST, Latitude, Longitude**					
DISTLM on space and SST for Mobile Taxa								
Marginal Tests								
Group	SS(trace)	Pseudo-F	P	Prop.	res.df	regr.df		
latitude	6503.2	7.7854	**0.001**	0.12206	56	2		
longitude	6021.4	7.135	**0.001**	0.11301	56	2		
Mean(sst)	5746.3	6.7697	**0.001**	0.10785	56	2		
Sequential Tests								
Group	Adj R^2	SS(trace)	Pseudo-F	P	Prop.	Cumul.	res.df	regr.df
+latitude	0.12206	6503.2	7.7854	**0.001**	0.12206	0.12206	56	2
+longitude	0.16154	2103.8	2.5901	**0.006**	3.9486E-2	0.16154	55	3
+Mean(sst)	0.21077	2622.7	3.368	**0.002**	4.9225E-2	0.21077	54	4
Best Solution								
R^2	RSS	No.Groups	Selections					
0.21077	42051	3	**SST, Latitude, Longitude**					

Human Effects on Spatial Patterns of Community Similarity

We used a PERMANOVA approach to examine the effects of humans on spatial patterns of community similarity for both Sessile and Mobile taxa. The 2 main effects that we considered were the effects of humans through resource extraction, and the effects of humans through physical presence via activities such as trampling, overturning, etc. To do this we examined the effects of resource extraction by comparing

assemblages inside and outside of MPAs (protected vs. not protected). To examine the physical disturbance impacts of humans that are un-correlated with resource extraction, we compared assemblages across a range of human access (public access – low, moderate, high). We also examined the strength of this interaction to identify synergies or feedbacks across these main effects.

Table 5 PERMANOVA results for the relationship among biological community similarity and level of protection and human access in sessile and mobile assemblages

PERMANOVA table of results – Sessile taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Protection	1	1546.9	1546.9	1.4662	0.107
Public_access	2	3909.7	1954.8	1.8528	**0.003**
Protection x public_access	2	2518.2	1259.1	1.1934	0.198
Res	52	54863	1055		
Total	57	64497			
PERMANOVA table of results – Mobile taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Protection	1	1341	1341	1.4924	0.142
Public_access	2	2310	1155	1.2854	0.169
Protection x public_access	2	1920.7	960.33	1.0688	0.350
Res	52	46724	898.54		
Total	57	53281			

We found the level of protection (MPA vs non MPA) was not an important contributor to the patterns of community similarity across either the sessile or mobile assemblages (Table 5). We did find public access to be an important contributor to community similarity patterns across the sessile assemblages. This is consistent with the idea that degree of human visitation, possibly due to the trampling effects has the strongest influence on sessile assemblages, those that are fixed to the rock, and are heavily trampled by humans in places of high visitation. Importantly we found no significant interaction between protection and public access implying that the effects of human visitation on sessile assemblages were not different depending on whether sites were inside or outside of MPAs.

Overall Drivers of Community Patterns

We used a stepwise DISTLM approach with AIC to identify the most significant drivers that are able to explain variation in the similarities of sessile and mobile communities across the SCSR. We used all 5 physical variables, geographic spatial variables, and human effect variables in the model. We then used AIC to identify the most parsimonious model (one with good explanatory power, high R^2, and as simple as possible, fewest number of predictor variables).

For the sessile taxa the best model solution converged (AIC 395.05) at an R^2 of 0.35856 using only 3 predictor variables – Long-term mean SST, Bioregion and Latitude. For the mobile taxa, the best model solution converged (AIC 381.61) at an R^2 of 0.38421 using only 3 predictor variables –Bioregion, Slope and Longitude. The way the model is fit takes advantage of the variables first that have the highest explanatory power, and then uses additional variables to explain the remaining variation after the first variables are fit to the model. In this approach, variables may be included in model fits that are not significant contributors to explaining variation on their own, but may be good at explaining residual variation. For both the mobile and sessile assemblages, variables that were related to location in space (Bioregion and longitude) as well as SST were important in explaining variation in both models. This is consistent with the driving importance of both space and temperature at explaining most of the variation in community patterns across the west coast of the US (Blanchette et al. 2008), the Channel Islands (Blanchette et al. 2009) and southern California (Fenberg et al. 2014).

Trends for South Coast rocky intertidal communities

A web portal (Pacific Rocky Intertidal Monitoring: Trends and Synthesis - http://pacificrockyintertidal.org) has been developed by MARINe and PISCO that allows the user to examine the vast MARINe datasets that have been collected over time and space. Data collected at sites inside the SCSR (but not part of the Baseline Characterization) as well as sites outside of the SCSR are based on identical protocols to those used in this evaluation. Hence querying the complete dataset provides a more comprehensive context for the SCSR Baseline Characterization. Individual site pages including trend graphs (species vs. time or space) are available, as well as an interactive graphing tool, which allows users to generate and download customized graphs. Graphs can also be manipulated, allowing users to zoom in and select or deselect sites or species. Readers interested in trends over time or interested in examination of larger spatial areas (MARINe sites range from Alaska to Mexico) are encouraged to visit the site and create graphics to address specific questions.

Baseline Sites Ecosystem Feature Assessment across MPAs

Percent Cover of Focal Species as Biogenic Habitat

We assessed relative differences in the percentage cover of the key attributes important as biogenic habitat of the rocky intertidal ecosystem as identified in the South Coast MPA monitoring plan across sites sampled during the baseline period (2012-2014). These key attributes include barnacles, *Egregia* (feather boa kelp), encrusting algae, foliose red algae, mussels, rockweeds, surfgrass and turf algae. These are many of the iconic species that are functionally and ecologically important components of the ecosystem. We focused on describing spatial patterns of abundance of each of these key attributes across the SCSR, and among old MPAs, new MPAs and reference areas as part of the baseline characterization. We found strong spatial variation in the abundance of each of the taxa across the SCSR (Figure 14). Barnacles were most common at sites along the north mainland coast, particularly in the region of coast near Malibu. *Egregia* was most abundant at several of the sites on Catalina Island. The abundance of encrusting algae and foliose red algae was relatively consistent across the SCSR. Mussels displayed a strongly patchy distribution, with peaks of abundance at sites in the Malibu area, Orange County, and Catalina Island. Rockweeds were extremely

scarce at the northern sites and peaked in abundance at sites in Orange County and Catalina Island. The distribution of surfgrass was also patchy, with peaks in abundance at sites in the Santa Barbara Channel, Orange County, and San Nicolas Island. The distribution of turf algae was also relatively even across space and tended to peak in abundance at sites near San Diego.

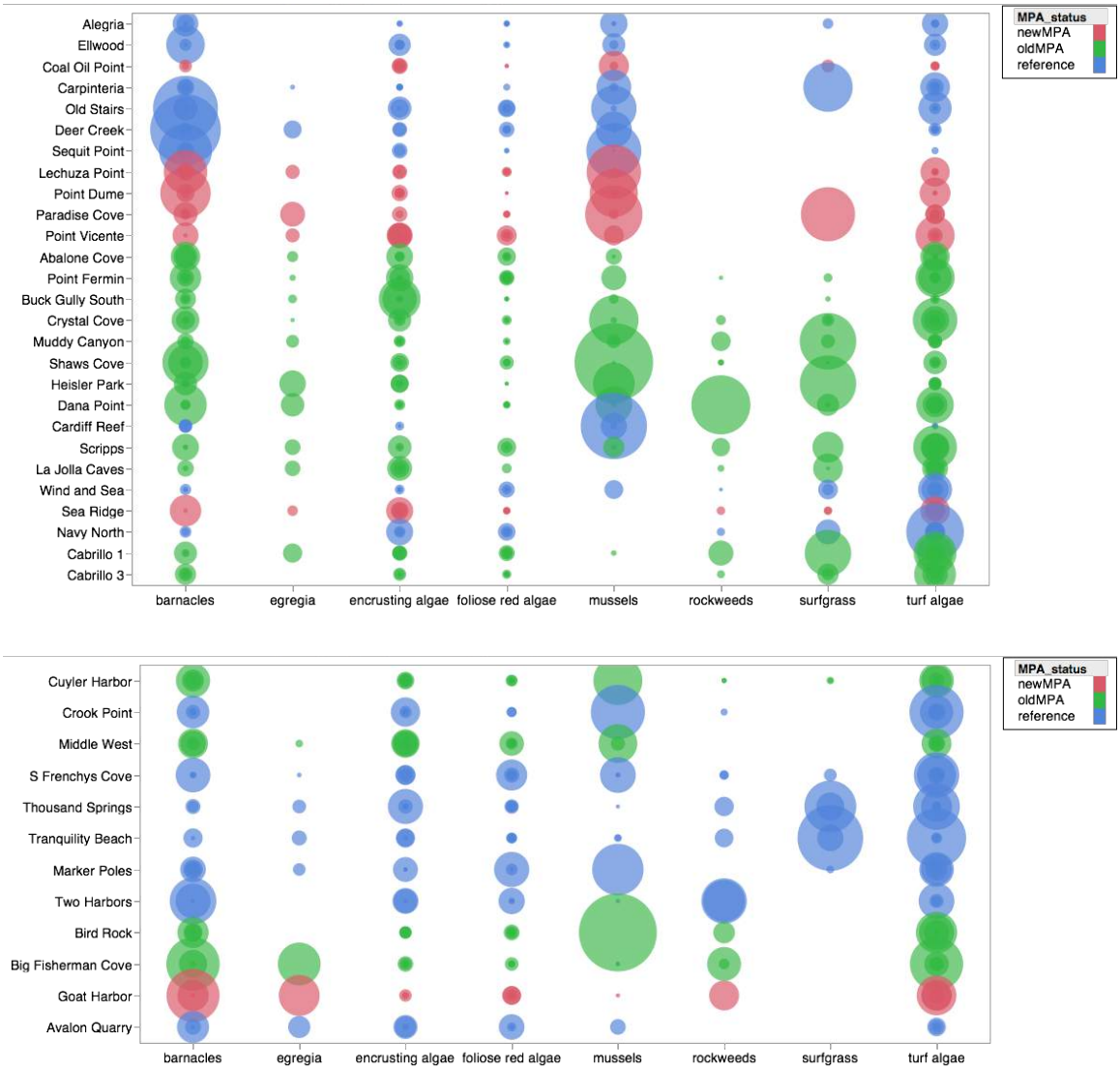

Figure 14 Bubble Plot of the relative abundance (percent cover) scaled with bubble size of sessile taxa identified as key ecosystem attributes Bubble color indicates MPA status for each site. Sites are arranged on the y-axis in order from northwest (top) to southeast (bottom): Top panel - Mainland sites, and Bottom Panel - Island sites.

For each of the key attributes, we evaluated the effect of MPAs on abundance. Across all of the biogenic habitat forming key attributes we found no significant differences in abundance among MPAs of different ages and between MPAs and reference areas (Table 6).

Table 6 Results of a non-parametric multiple comparisons test based on the Steel-Dwass method for differences in abundance of sessile key taxa among oldMPAs, newMPAs and reference areas.

Level	Level	Score Mean Dif	Std Err Dif	Z	p-Value
Mussels					
reference	oldMPA	0.12374	4.103590	0.030153	0.9995
oldMPA	newMPA	-0.75000	3.570416	-0.210060	0.9760
reference	newMPA	-1.66330	3.974656	-0.418476	0.9080
Barnacles					
oldMPA	newMPA	-0.03307	5.604939	-0.005900	1.0000
reference	newMPA	-2.70742	5.485633	-0.493547	0.8744
reference	oldMPA	-4.71866	5.973161	-0.789977	0.7092
Rockweeds					
reference	oldMPA	0.35556	2.980776	0.119283	0.9922
oldMPA	newMPA	-1.52778	2.592725	-0.589256	0.8259
reference	newMPA	-2.55000	3.798986	-0.671232	0.7802
Feather Boa Kelp					
oldMPA	newMPA	-1.69643	2.676322	-0.63387	0.8015
reference	oldMPA	-1.84167	2.687936	-0.68516	0.7722
reference	newMPA	-2.74286	2.111195	-1.29920	0.3956
Surfgrass					
reference	oldMPA	4.32071	3.258633	1.32593	0.3807
reference	newMPA	1.87500	2.611165	0.71807	0.7528
oldMPA	newMPA	-0.76389	3.589465	-0.21281	0.9753
Turf Algae					
reference	oldMPA	-0.93015	8.786975	-0.105856	0.9938
oldMPA	newMPA	-3.65451	7.458180	-0.490000	0.8761
reference	newMPA	-3.70097	8.854777	-0.417963	0.9082
Foliose Red Algae					
reference	oldMPA	6.14897	6.714844	0.915728	0.6303
reference	newMPA	1.02083	5.890334	0.173307	0.9836
oldMPA	newMPA	-2.82363	6.621511	-0.426433	0.9046
Encrusting Algae					
reference	oldMPA	1.38700	6.355867	0.218224	0.9741
reference	newMPA	-3.19762	5.319942	-0.601063	0.8195
oldMPA	newMPA	-5.62059	6.231932	-0.901901	0.6391

Density of Key Invertebrate Consumers

We assessed relative differences in the densities of the key invertebrate consumers important as predators and herbivores as identified in the South Coast MPA monitoring plan across sites sampled during the baseline period (2012-2014). These key consumers include purple urchins, ochre sea stars, turban snails, owl limpets and black abalone. These are many of the iconic species that are functionally and ecologically important components of the ecosystem. Both owl limpets and black abalone have been identified by MARINe as species of concern. For owl limpets we provide here only summary data and not site-specific information on abundance in order to protect these vulnerable species. Black abalone are also federally listed endangered species, and we restrict access to all data on these species, which were also extremely rare at most of our study sites. Here we focus on describing spatial patterns of abundance of each of these key consumers across the SCSR, and among old MPAs, new MPAs and reference areas as part of the baseline characterization. We found strong spatial variation in the abundance of each of the taxa across the SCSR (Figure 15). Purple urchins were most common at sites along the central portion of the mainland coast. They were also abundant at several island sites. The density of ochre sea stars (number per meter^2) was generally far lower than the densities for either urchins or turban snails. Sea stars were present at almost all baseline sites and only extremely common at a few sites along the mainland and the islands. Turban snails were common at most sites, with the exception of sites on the southern islands.

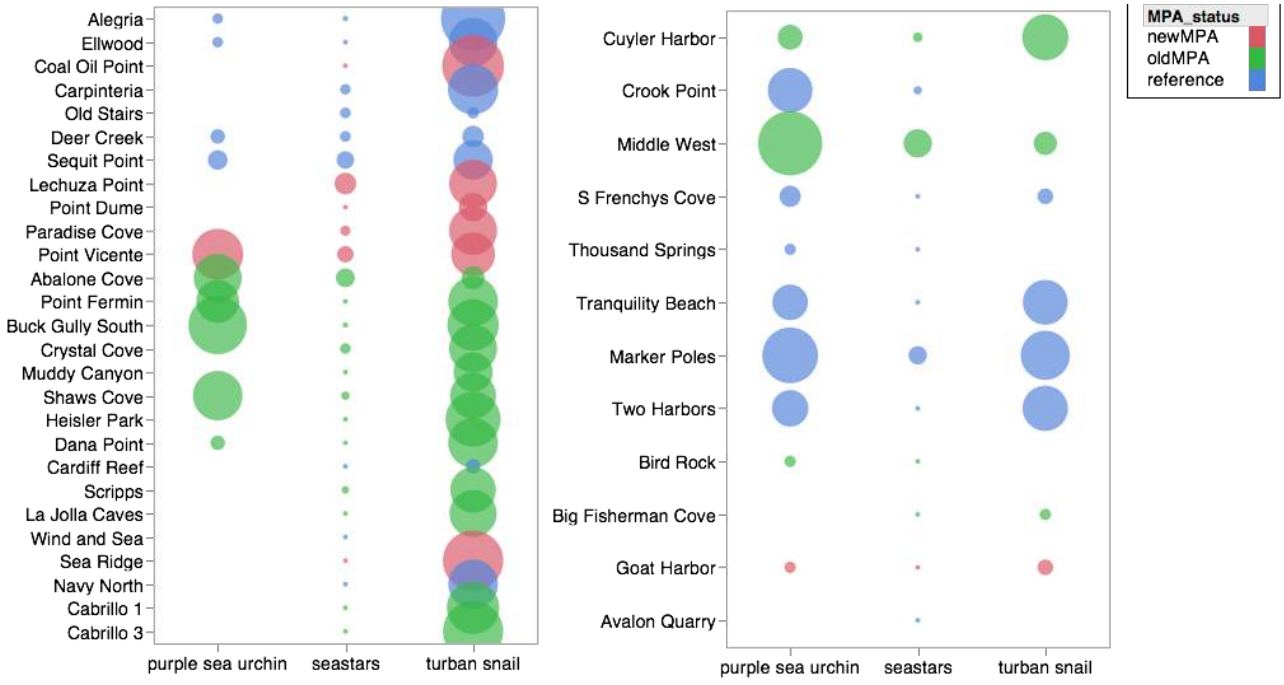

Figure 15 Bubble Plot of the relative abundance (density per meter^2) scaled with bubble size of mobile taxa identified as key ecosystem attributes. Bubble color indicates MPA status for each site. Sites are arranged on the y-axis in order from northwest (top) to southeast (bottom): Left Panel Mainland sites, and Right Panel - Island sites.

For each of the three taxa (urchins, sea stars and turban snails), we evaluated the effect of MPAs on abundance. Across all taxa we found no significant differences in abundance among MPAs of different ages and between MPAs and reference areas (Table 7).

Table 7 Results of a non-parametric multiple comparisons test based on the Steel-Dwass method for differences in abundance of mobile taxa among old MPAs, new MPAs and reference areas

Level	Level	Score Mean Dif	Std Err Dif	Z	p-Value
Purple Sea Urchins					
oldMPA	newMPA	0.62500	2.386304	0.26191	0.9629
reference	newMPA	0.00000	3.363304	0.00000	1.0000
reference	oldMPA	-4.34135	2.777312	-1.56315	0.2617
Turban Snails					
reference	oldMPA	-0.62857	2.972359	-0.21147	0.9756
reference	newMPA	-2.41758	2.769327	-0.87299	0.6574
oldMPA	newMPA	-4.09231	3.116235	-1.31322	0.3877
Ochre Sea stars					
oldMPA	newMPA	0.92411	3.065902	0.301414	0.9512
reference	newMPA	0.19549	3.361435	0.058156	0.9981
reference	oldMPA	-1.20888	3.468365	-0.348545	0.9352

Similarly we evaluated the differences in abundance of owl limpets among MPAs of different ages and between MPAs and reference areas (Table 8). We found no significant differences in the abundances of owl limpets as a function of MPA status in either of the first two years (2012 and 2013) of the MPA baseline program.

Table 8 Results of a non-parametric multiple comparisons test based on the Steel-Dwass method for differences in abundance of owl limpets in 2012 and 2013 among old MPAs, new MPAs and reference areas

Level	Level	Score Mean Dif	Std Err Dif	Z	p-Value
Owl Limpets 2012					
reference	oldMPA	3.65952	4.435917	0.824976	0.6875
reference	newMPA	0.7	4.151396	0.168618	0.9844
oldMPA	newMPA	-2.6619	4.016202	-0.662792	0.7851
Owl Limpets 2013					
reference	newMPA	5.620588	4.427641	1.269432	0.4125
reference	oldMPA	5.161064	4.445123	1.161062	0.4766
oldMPA	newMPA	0.571429	3.559408	0.16054	0.9859

Rocky Shore Associated Birds

Rocky shore associated birds are composed of a broad array of species of shorebirds, seabirds, gulls and other species (see the following section for species composition). The abundance of each of these classes of birds varied broadly across the SCSR (Figure 16).

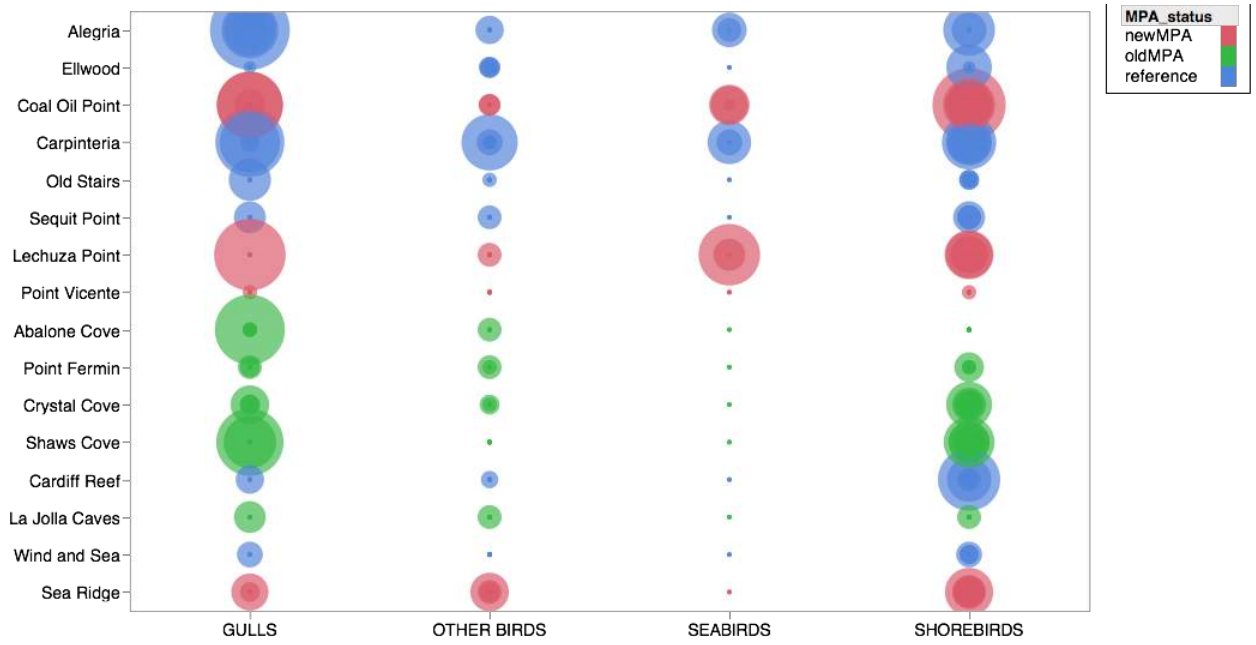

Figure 16 Abundance (log ((mean number/100m shoreline)+1)) of the four major classes of rocky shore associated birds across the SCSR colored by MPA status. Bubble size represents relative abundance. Mainland sites are arranged on the y-axis in order from northwest (top) to southeast (bottom)

To evaluate differences in the relative abundances across the suite of species of birds across the different types of MPAs, we examined the similarity in bird communities across space as a function of MPA status (Figure 17). We found no significant effect of MPA status on the bird communities across the SCSR (non-significant ANOSIM).

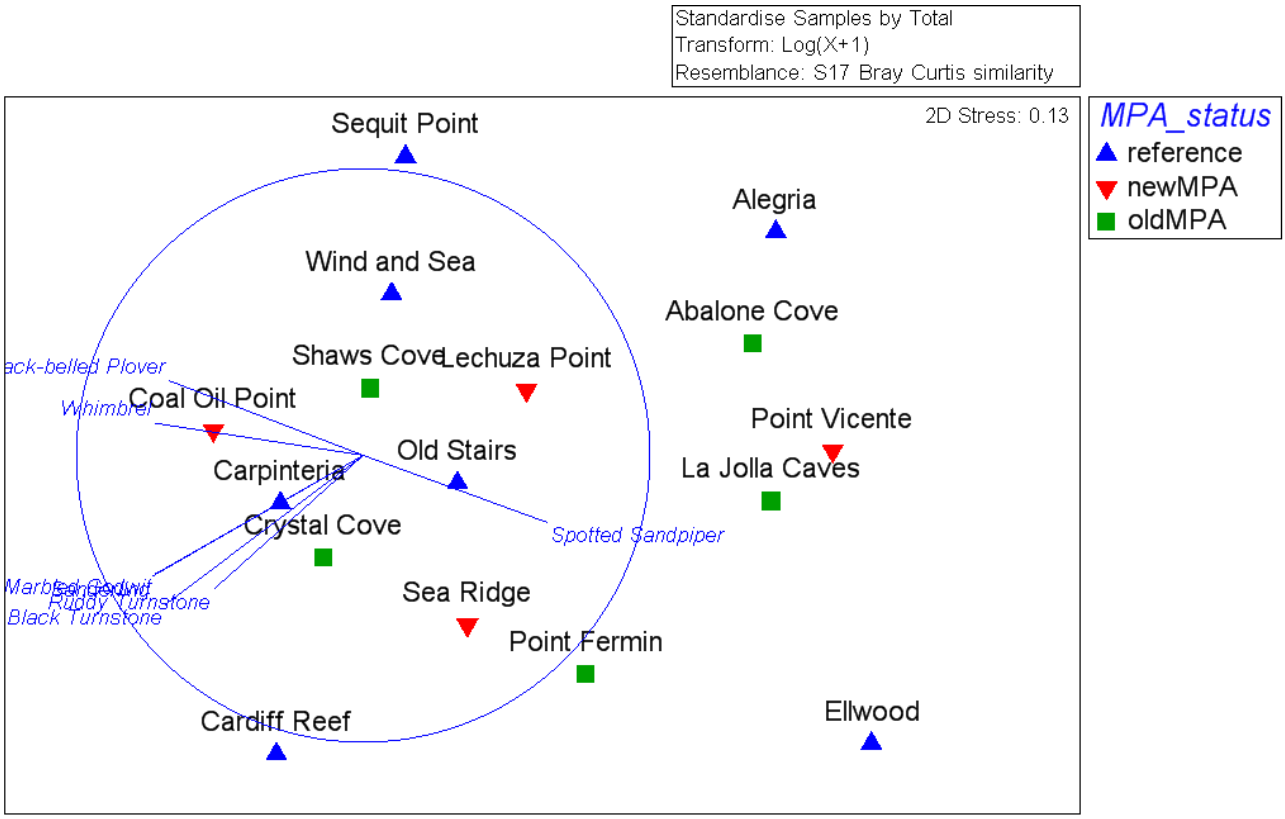

Figure 17 nMDS plot representing the 2-dimensional patterns of spatial similarity of bird communities across the SCSR as a function of MPA status

Species Composition of Key Attribute groups

Mussels

Although mussels are identified as a single functional group, this group is comprised of three separate taxa in the SCSR: *Mytilus californianus* and *galloprovincialis*, and *Septifer/Brachidontes.* These species can be difficult for inexperienced observers to properly identify, but each have unique ecological and functional roles and are not evenly distributed across the SCSR (Figure 18). *Septifer/Brachidontes* are most common at northern mainland sites, several Orange county sites and at some island sites. *M. galloprovincialis* is more patchily distributed throughout the SCSR.

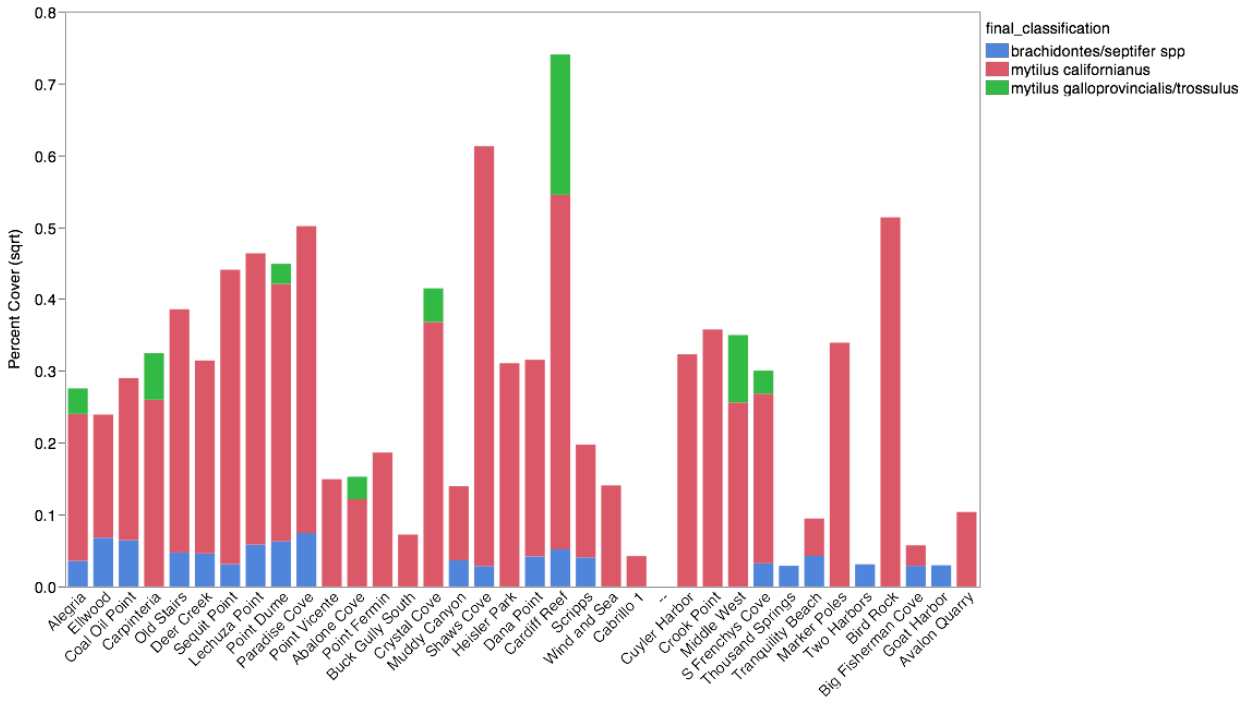

Figure 18 Percent cover (square root) of taxa contributing to mussel cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites.

Barnacles

Although barnacles are identified as a single functional group, this group is comprised of at least five separate taxa in the SCSR. These species can be difficult for inexperienced observers to properly identify, but each have unique ecological and functional roles and are not evenly distributed across the SCSR (Figure 19). *Balanus glandula* is a more typical northern species, and becomes scarce in the southern portion of the SCSR, a pattern opposite to *Tetraclita rubescens*, which becomes more abundant in the south. Both *Chthamalus* and *Pollicipes* are patchily distributed throughout the SCSR.

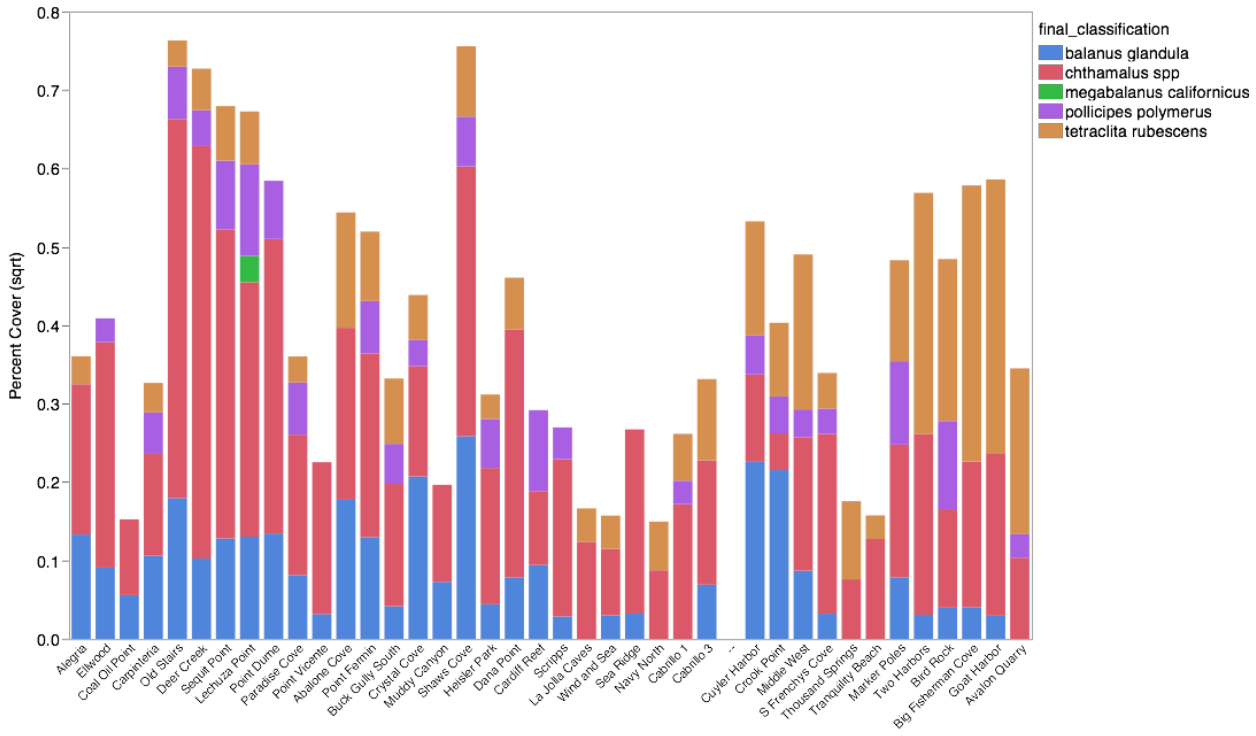

Figure 19 Percent cover (square root) of taxa contributing to barnacle cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Rockweeds

South Coast rockweeds are composed primarily of two species. *Silvetia compressa* is distributed widely across the region, while *Hesperophycus californicus* tends to be most common at island sites (Figure 20).

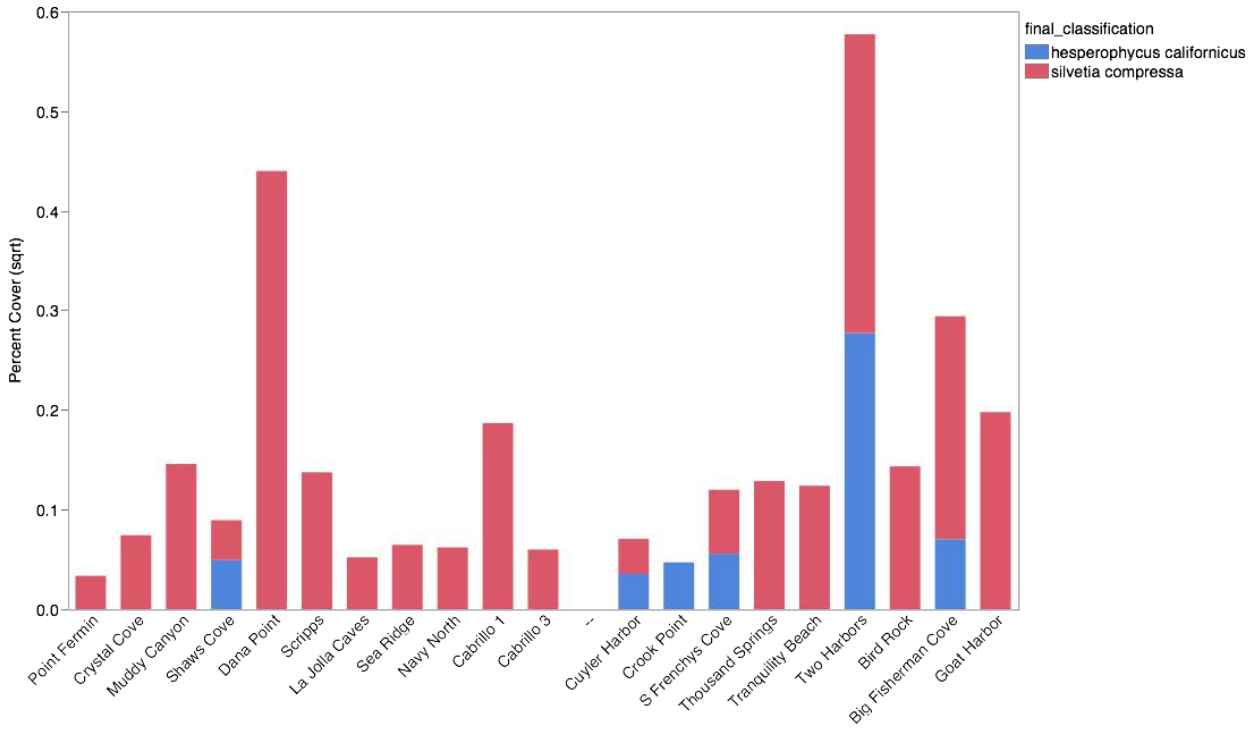

Figure 20 Percent cover (square root) of taxa contributing to rockweed cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Surfgrass

Similar to rockweeds, surfgrasses are composed primarily of two species. *Phyllospadix torreyi* dominates sites on the north mainland, and is present throughout the region, with the exception of several southern island sites, where *P. scouleri* becomes more common (Figure 21).

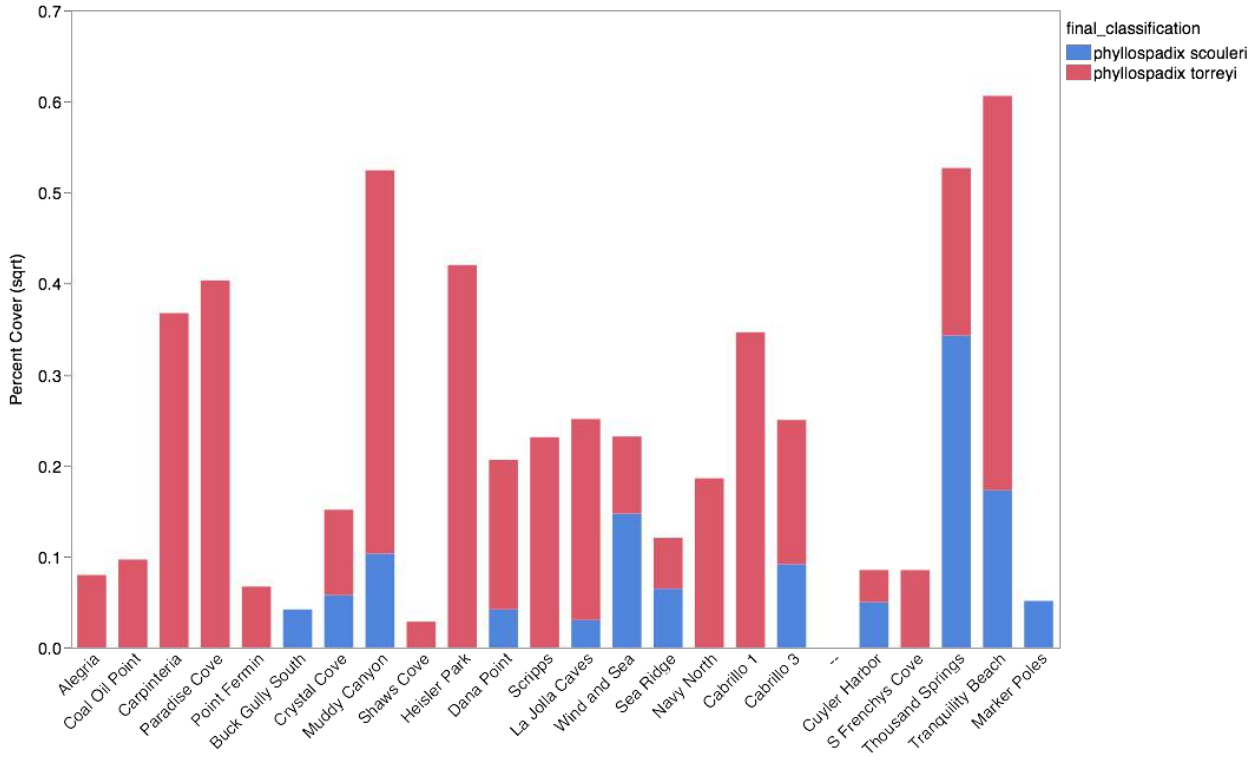

Figure 21 Percent cover (square root) of taxa contributing to surfgrass cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Turf Algae

Turf algae are the most speciose of the biogenic habitat groups and this group is composed of a broad array of species, most of which are extremely difficult to identify to species by anyone who is not a trained and experienced algal biologist (Figure 22). These species vary widely in their distributional affiliations, many of which are wide ranging, and some of which are restricted to localized regions. This group is an extremely important habitat forming assemblage at sites all across the SCSR.

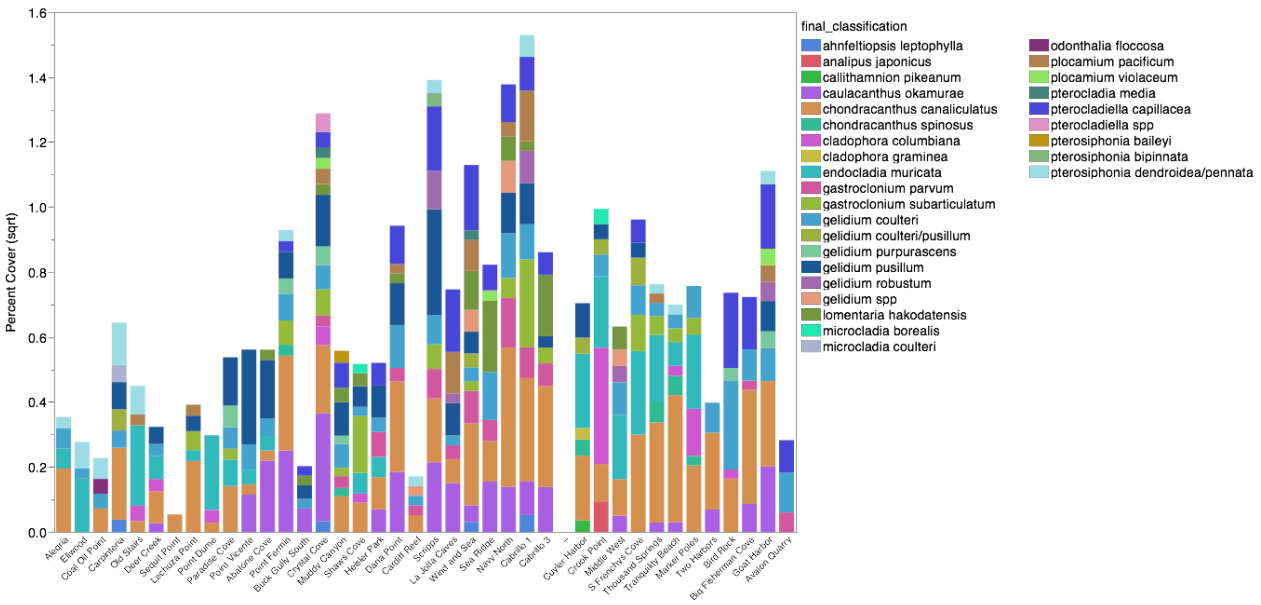

Figure 22 Percent cover (square root) of taxa contributing to turf algal cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Foliose Red Algae

Foliose red algae are also an extremely diverse assemblage, and similar to turf algae, most of which are extremely difficult to identify to species by anyone who is not a trained and experienced algal biologist (Figure 23). These species vary widely in their distributional affiliations, many of which are wide ranging, and some of which are restricted to localized regions.

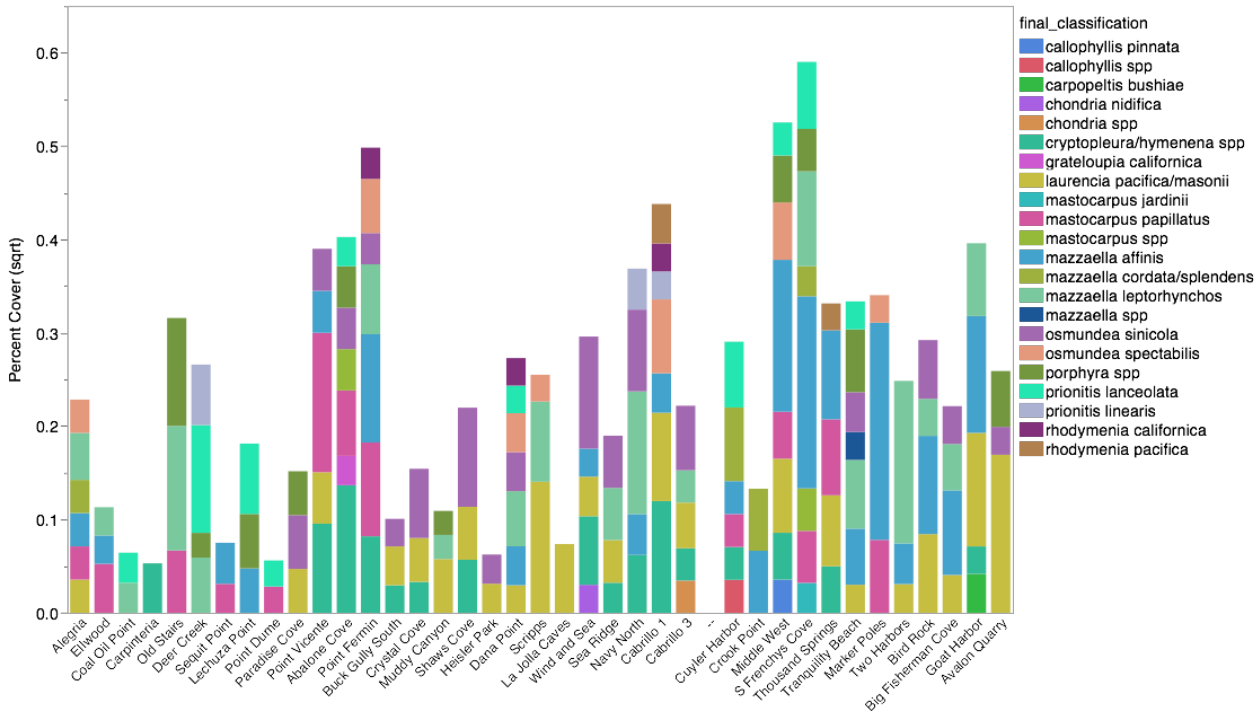

Figure 23 Percent cover (square root) of taxa contributing to foliose red algal cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island site

Encrusting Algae

Encrusting algae are also an extremely diverse assemblage, and similar to turf algae, most of which are extremely difficult to identify to species by anyone who is not a trained and experienced algal biologist (Figure 24). These species vary widely in their distributional affiliations, many of which are wide ranging, and some of which are restricted to localized regions.

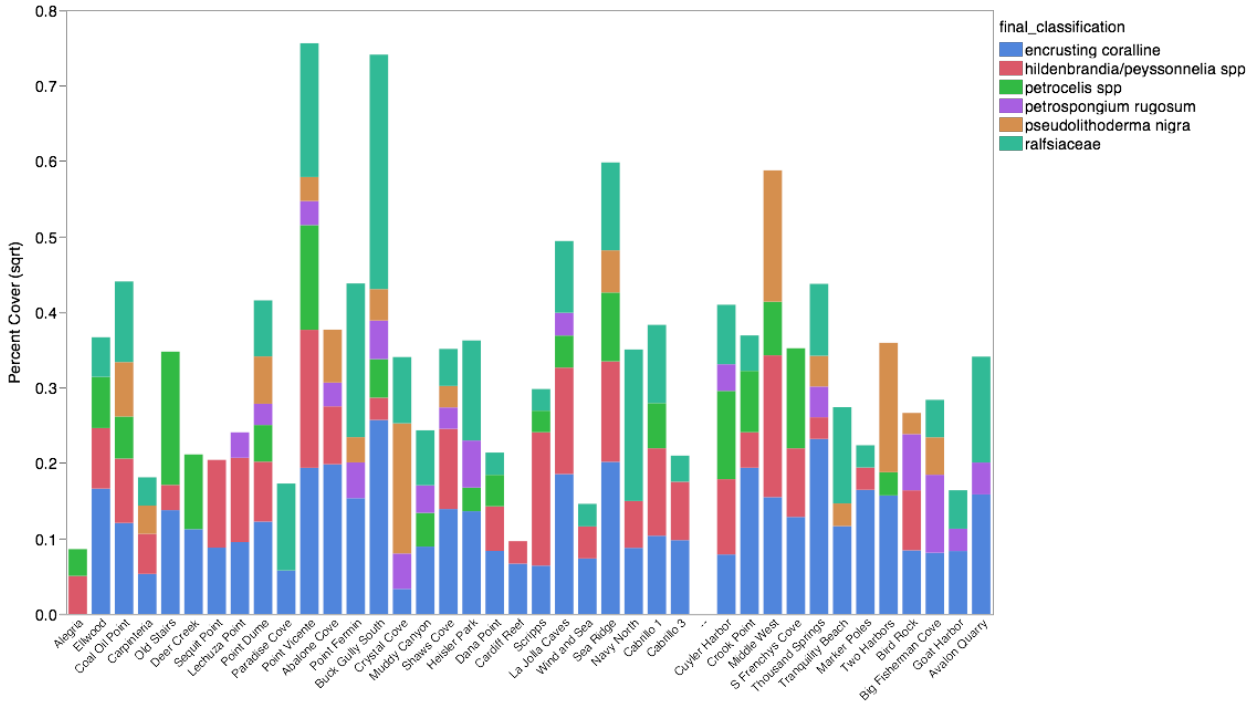

Figure 24 Percent cover (square root) of taxa contributing to encrusting algal cover arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites.

Turban Snails

Turban snails are composed of at least 4 distinct species in the genus *Tegula* (now *Chlorostoma*), most of which have strong geographical patterns of abundance (Figure 25). *T. funebralis* is most common on the northern mainland, and is replaced by a suite of *T. aureotincta*, *T. eiseni* and *T. gallina* to the south.

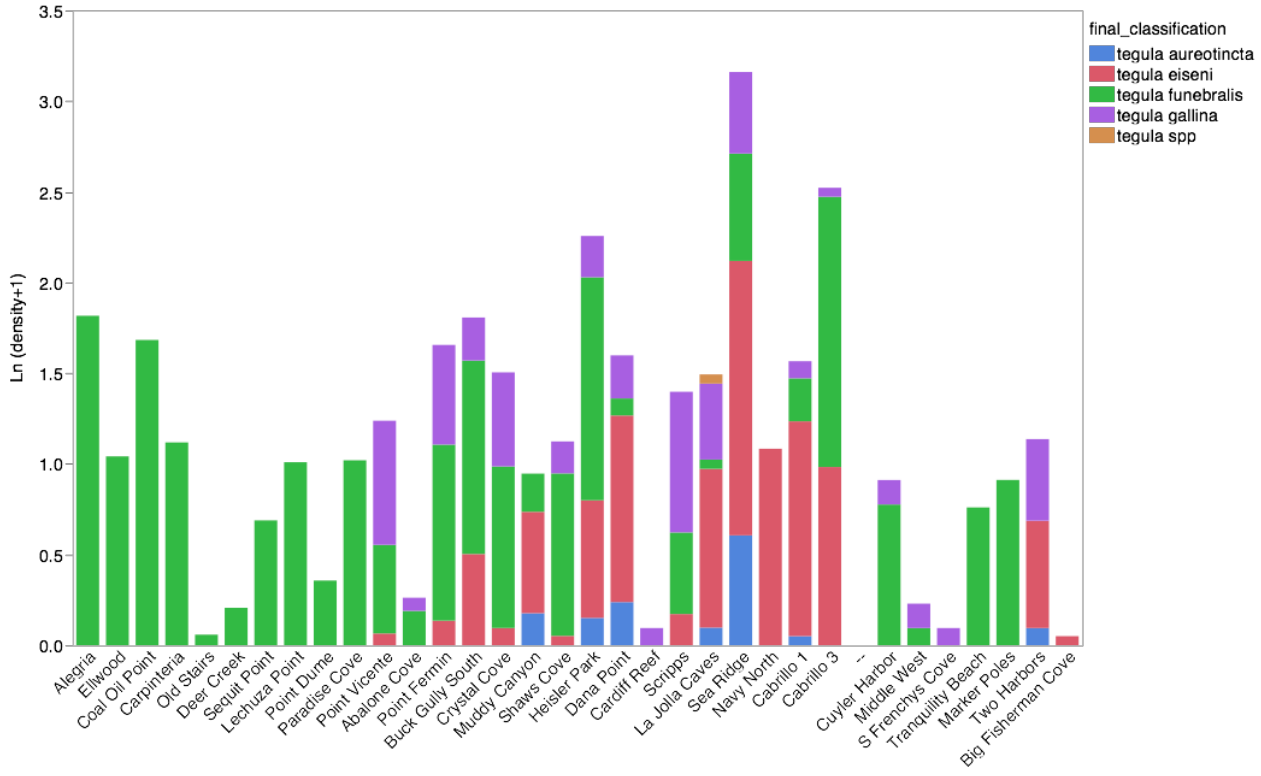

Figure 25 Densities of taxa contributing to the turban snail group arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Shorebirds

Shorebirds are composed of a diverse assemblage of species that specialize in the utilization of rocky and sandy beach habitats (Figure 26). The abundance of shorebirds varied widely across the SCSR, with peaks in abundance at Coal Oil Point, and few shorebirds found in the Palos Verdes region.

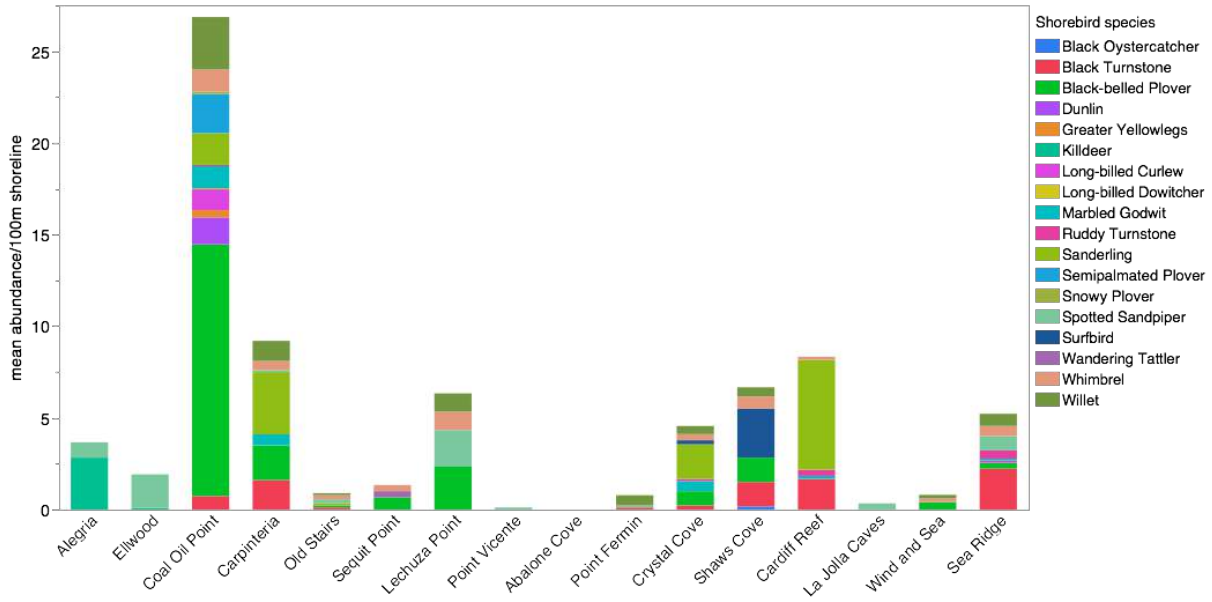

Figure 26 Mean abundance of species of shorebirds arranged in order along the x-axis from northwest to southeast

Seabird and gull species

A wide variety of seabird and gull species were found at rocky shore sites across the SCSR (Figure 27). The highest densities of seabirds were found at the northernmost site, possibly due to the proximity to the productive waters near Pt. Conception. Western gulls were the dominant gull species observed across the SCSR, and double-crested cormorants peaked in abundance at one site on the Malibu coast.

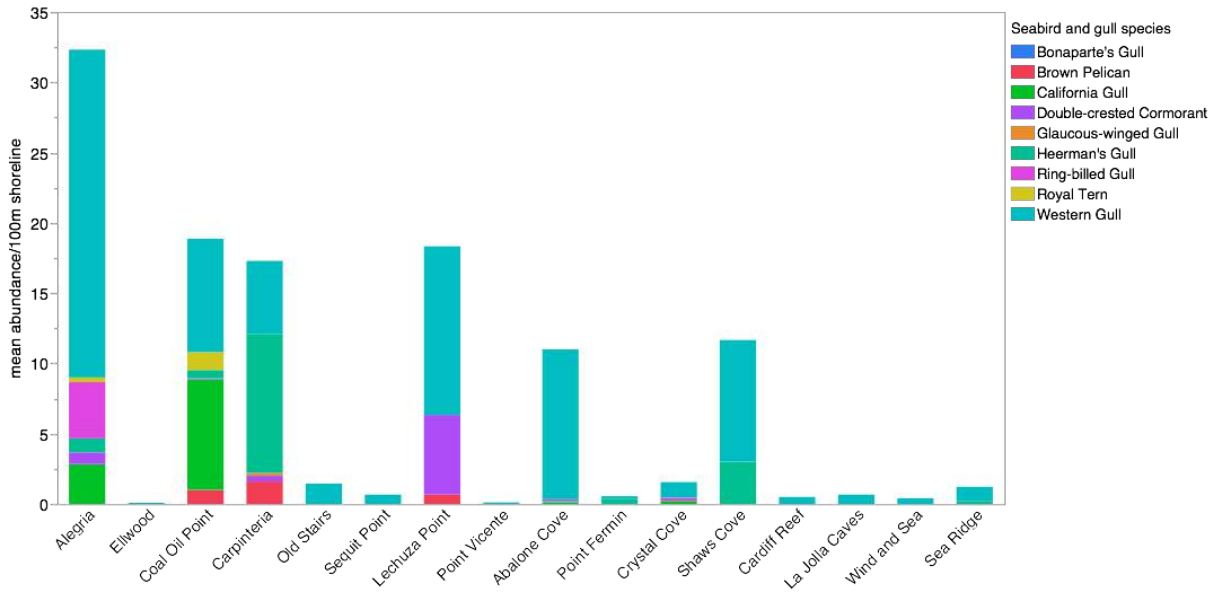

Figure 27 Mean abundance of species of seabirds and gull species arranged in order along the x-axis from northwest to southeast

Other bird species

A wide variety of other birds species were also found utilizing rocky shore habitats at sites across the SCSR (Figure 28). We observed an exceptionally high density of crows at Carpinteria, possibly due to the very close proximity of this site to a large campground, where crows commonly forage on food scraps and trash.

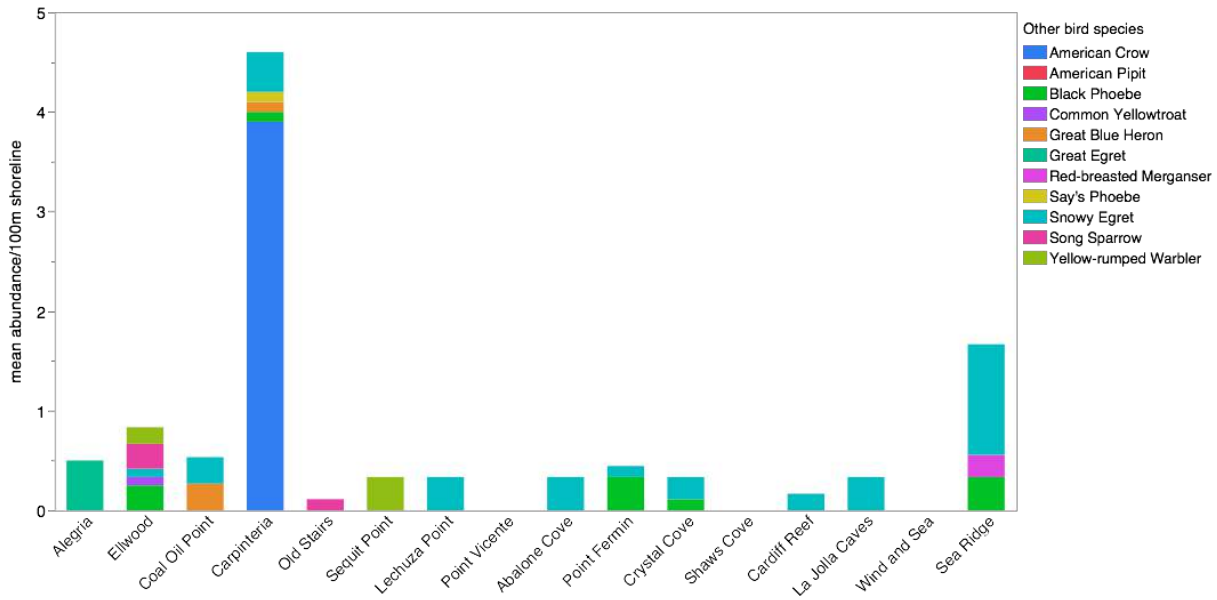

Figure 28 Mean abundance of other bird species arranged in order along the x-axis from northwest to southeast

Species Richness and Diversity

We evaluated the differences in richness and diversity of rocky intertidal communities across MPAs in the SCSR. Other studies have documented signfiicantly higher diversity of species inside reserves than outside reserves, and also that this effect can depend on the length of time an area has been protected. We evaluated three diffent measures of diversity across all sites that were sampled as part of the baseline period (44 sites, those starred in Table 1): Richness, Shannon Diversity, and Simpson Diversity. Our estimates of richness were based on the total observed number of taxa at each site. This is not true species richness, since not all taxa are identified to species, but to the lowest level of resolution (in many cases this is species richness). Our richness measures are an underestimate of the actual species richness for several reasons. Firstly, as previously described, there are many taxa that we cannot identify to species in the field, and thus are lumped. Secondly, our richness estimates are based on the taxa that are sampled under the 'first points' of our point contact method, and while there may be other species nearby that are not 'hit' by these points, we include only our sampled points. Finally, our sampling is non-destructive, and there are an array of species that utilize the structural habitat provided by larger biogenic habitat forming taxa, such as mussels, surfgrass, etc. These species are impossible to survey without destrucive sampling techniques. Although we recognize that our sampling underestimates true diversity, our main interest is in comparisons across sites, which are all sampled in the same way, thus providing an equal basis for comparison. In addition to richness we chose two of the most commonly used diversity measures in ecology for comparison. The Shannon Index takes into account both richness (the number of taxa) and evenness (the proptional distribution of abundance across species). The Simpon Index is often used for communities with unequal distributions of species and is heavily weighted towards the most abundant species, and less sensitive to species richness (Magurran 1988).

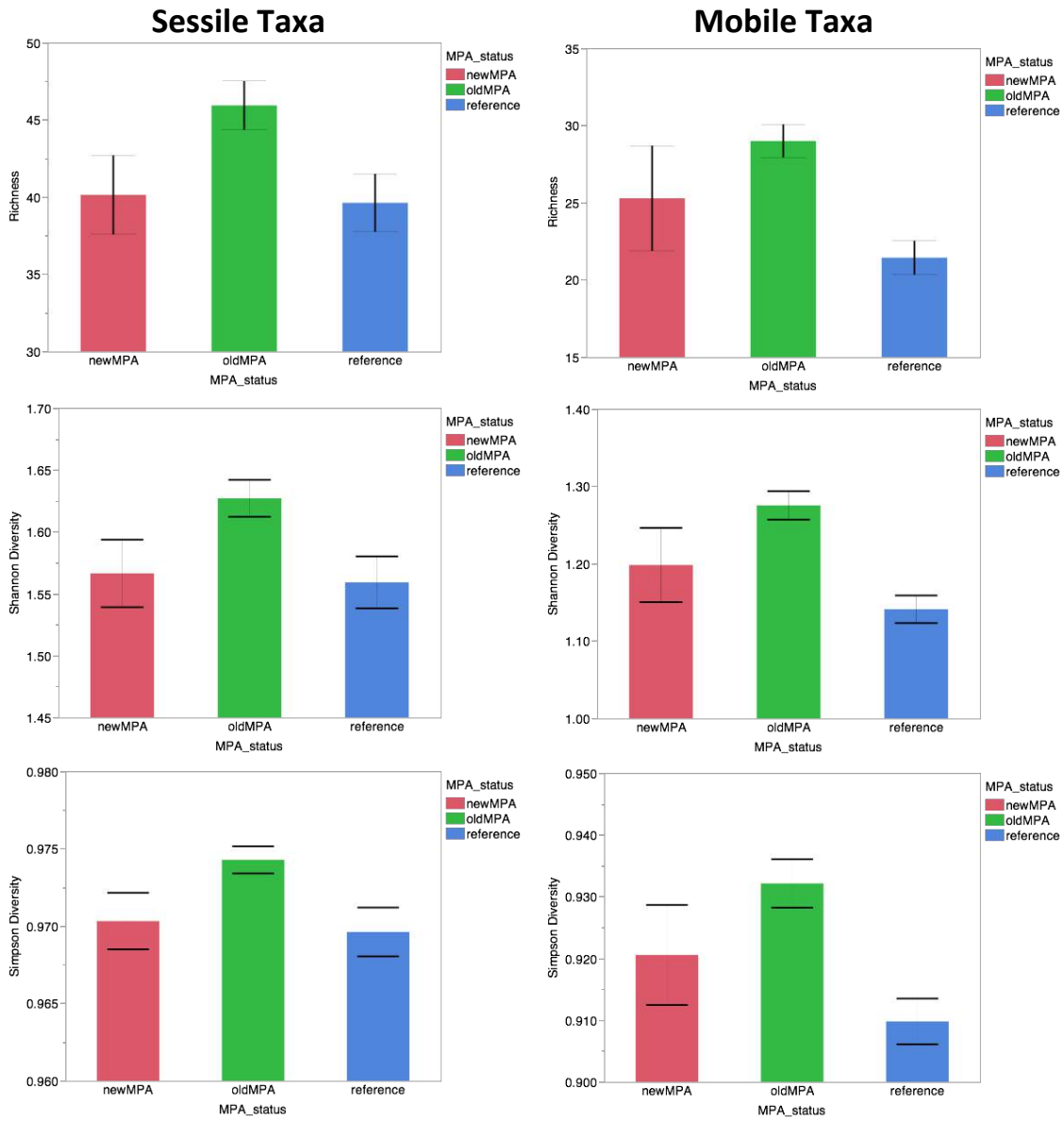

Figure 29 Mean values (± 1 s.e.) of Taxonomic Richness, Shannon Diversity and Simpsons Diversity across new MPAs, old MPAs and reference Baseline sites for both sessile and mobile assemblages

In all cases for both the sessile and the mobile taxa all measures of diversity and richness were highest in the old MPAs, lowest in the reference areas, with new MPAs having values that were most variable and on average fell between those of the old MPAs and reference ares (Figure 29). Also, in all cases the results of the non-parametric multiple comparisons indicated that all measures of richness and diversity were significantly higher in old MPAs than reference areas, and although new MPAs had values that fell between old MPAs and reference areas, they were not significantly different than either of the groups (Table 9). This result is consistent with findings in MPAs around the world (Halpern 2003), where MPAs seem to not only

protect, but enhance biodiversity. The intermediate diversity values for new MPAs suggest that perhaps these areas, which have only recently become protected, are not quite as biodiverse as old MPAs yet, but may continue to increase in diversity over time. The mechanisms for these effects are not clear, but there are several possibilities. The first, and one that has been described in other reserves around the world is based simply on the idea that species that would be collected by humans in reference areas are allowed to persist in reserve areas, thus increasing diversity. Another ecologically based hypothesis is based on the importance of indirect effects among many species in the community, many of these indirect effects are either unstudied or unobserved, but these indirect effects support high biodiversity in places where species are not removed. Another possibility is based in the historical establishment of MPAs. It is possible that when several of these older MPAs were established, they were established in locations that happened to have higher values of biodiveristy initially. We do not have equivalent historical (pre- MPA establishment) biodiversity data from sites categorized as old MPAs to evaluate this possibility. The baseline data collection of this project gives us a unique ability to directly assess this hypothesis through time. Continued biodiversity monitoring at these sites through time will allow us to see if biodiversity increases at the new MPA sites over time relative to the old MPAs and reference areas. The final explanation has to do with the geographic distribution of MPAs across the SCSR. New and old MPAs are not evenly distributed acrosss the biogeographic regions, which we know to have a strong influence on community patterns. Additionally many MPAs do not contain rocky intertidal habitat. Due to these limitations, it is not possible to assess this hypothesis with the limited number of sites that span the matrix of MPA status and bioregion.

Table 9 Results of a non-parametric multiple comparisons test based on the Steel-Dwass method for differences in richness and diversity of sessile and mobile taxa among old MPAs, new MPAs and reference areas.

Level	Level	Score Mean Dif	Std Err Dif	Z	p-Value
Sessile Taxonomic Richness					
oldMPA	newMPA	5.44196	3.068945	1.77324	0.1786
reference	newMPA	-0.30804	3.06438	-0.10052	0.9944
reference	**oldMPA**	-7.875	3.309017	-2.37986	**0.0456***
Sessile Shannon Diversity					
oldMPA	newMPA	5.64732	3.073504	1.83742	0.1575
reference	newMPA	0.30804	3.073504	0.10022	0.9945
reference	**oldMPA**	-7.8125	3.316625	-2.35556	**0.0485***
Sessile Simpson Diversity					
oldMPA	newMPA	5.44196	3.073504	1.77061	0.1795
reference	newMPA	0.30804	3.073504	0.10022	0.9945
reference	**oldMPA**	-7.5625	3.316625	-2.28018	0.0586
Mobile Taxonomic Richness					
oldMPA	newMPA	4.4152	3.062856	1.44152	0.3196
reference	newMPA	-2.2589	3.052935	-0.73992	0.7397
reference	**oldMPA**	-12.375	3.306275	-3.74288	**0.0005***
Mobile Shannon Diversity					
oldMPA	newMPA	4.0045	3.073504	1.3029	0.3935
reference	newMPA	-1.9509	3.073504	-0.63475	0.801
reference	**oldMPA**	-12.8125	3.316625	-3.86311	**0.0003***
Mobile Simpson Diversity					
oldMPA	newMPA	2.9777	3.073504	0.96882	0.5966
reference	newMPA	-2.9777	3.073504	-0.96882	0.5966
reference	**oldMPA**	-11.3125	3.316625	-3.41085	**0.0019***

Range Extensions and non-native Species

In addition to our point contact and quadrat based Biodiversity sampling, we recorded the presence of species that we found to be outside of published ranges (either northern or southern range limits based on information from Abbott and Hollenberg 1976). We identified southern range extensions for two algal species. *Annalipus japonicus*, a brown alga, was found at Crook Point (San Miguel Island) south of its published southern range limit of Point Conception. We also found *Odonthalia floccosa*, a red alga, at Crystal Cove (Orange County), south of its published range limit at Government Point (near Pt Conception). We found one northern range extension for *Osmundia sinicola*, a red alga, at Coal Oil Point, north of its published northern range limit near La Jolla.

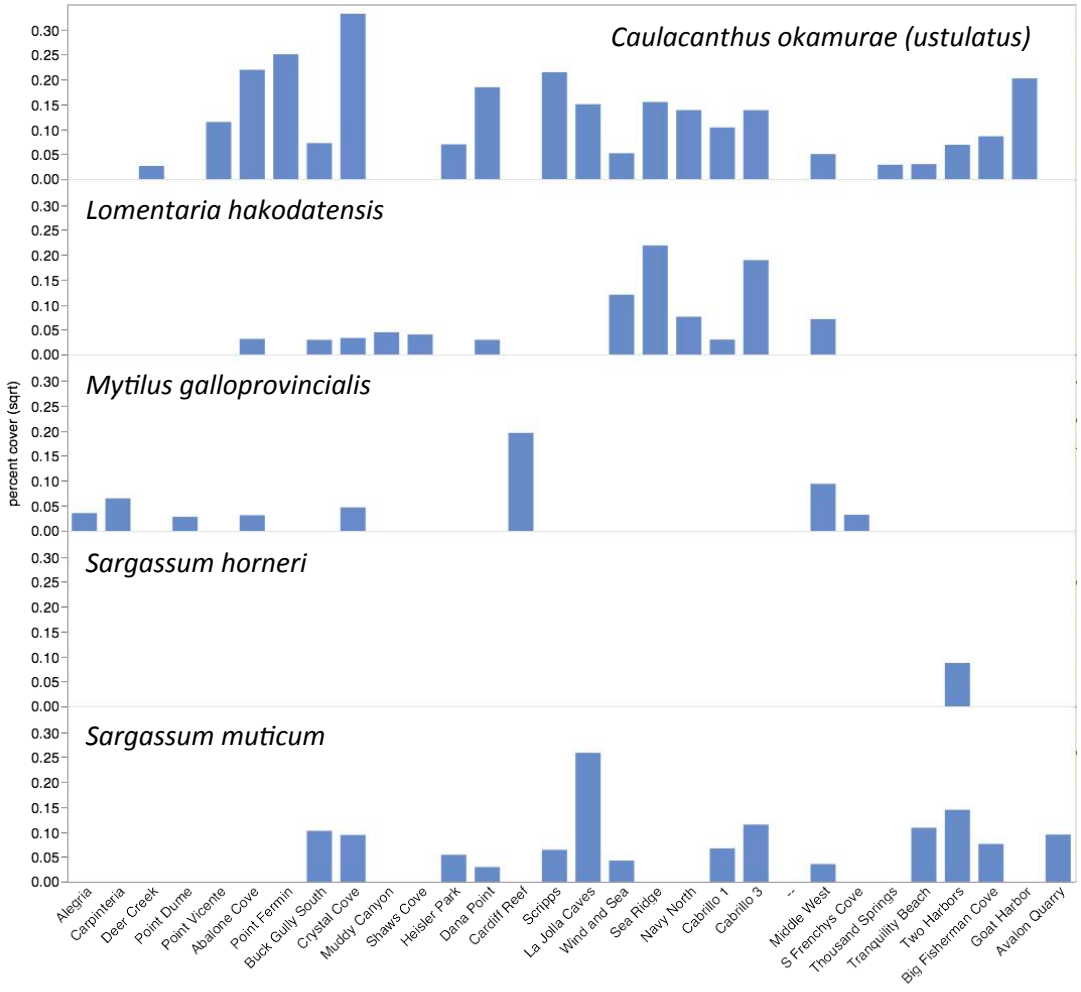

Figure 30 Abundance estimates (square root percent cover) for five non-native taxa sampled in our surveys

We quantified the abundance of non-native taxa in our biodiversity surveys, and found one mussel – *Mytilus galloprovincialis*, and four species of algae – *Caulacanthus okamurae* (formerly *ustulatus)*, *Lomentaria hakodatensis*, and *Sargassum horneri* and *muticum*. Figure 30 shows the abundance of each of these species

at sites across the SCSR. The turfy red alga *Caulacanthus okamurae* (formerly *ustulatus*) was the most common of the non-native taxa. It was first discovered in southern CA in 1999, and has become a common member of intertidal assemblages at sites along the southern mainland coast and islands (Smith et al. 2014). This species has actually been found to increase diversity of upper intertidal habitats by providing a novel habitat for a variety of meiofauna in a zone that without *Caulacanthus*, is typically occupied mainly by barnacles.

Assessment of Initial Changes

We assessed initial changes in our baseline study by comparing changes across several key species over the first 2 years of the study (2012 and 2013). Our sampling focused on the species most likely to be targeted for collection by humans – mussels (*Mytilus californianus*), owl limpets (*Lottia gigantea*) and black abalone (*Haliotis cracherodii*). Black abalone were extremely scarce at the majority of our study sites, and the data are insufficient to assess initial changes since most black abalone were absent from most sites across years. Both mussels and owl limpets were abundant at most sites, although neither group was abundant across all of our sites. Here we report on changes in the size distributions (numbers of individuals across size classes) of owl limpets and mussels between the first 2 years of the baseline program (2012-2103) at sites spanning the SCSR. We focused the analysis on the 2 key human-related factors (MPA status and human access) likely to affect changes in sizes of these targeted species.

Owl Limpets

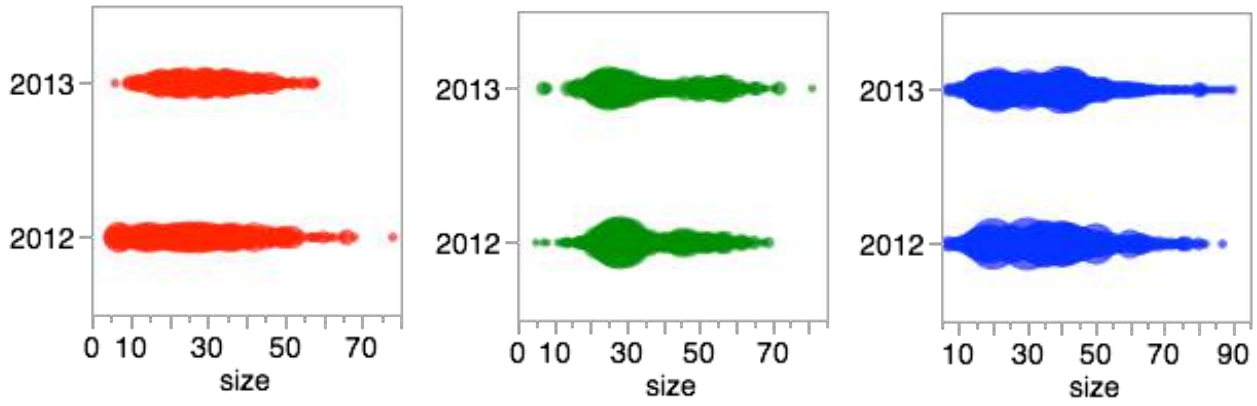

Figure 31 Bubble plots depicting the size distributions (shell length in mm) of owl limpets in 2012 and 2013 at sites in new MPAs (red), old MPAs (green) and reference areas (blue). Bubble size represents the numbers of limpets in each size class

We found no differences in the size distributions of owl limpets across years, across MPA status and no significant interactions indicating no initial changes in owl limpet sizes during the initial implementation of the MPAs (Figure 31 and Table 10).

Table 10 PERMANOVA results for the effects of year, MPA status and public access on the size distribution of owl limpets

PERMANOVA table of results – Owl limpets – Year and MPA status					
Source	df	SS	MS	Pseudo-F	P(perm)
Year	1	129.73	129.73	1.0998	0.362
MPA status	2	671.44	335.72	1.3999	0.133
Year x MPA status	2	215.56	107.78	0.44943	0.998
Residual	26	6235.1	239.81		
Total	31	7283.7			
PERMANOVA table of results – Owl limpets – Year and Public Access					
Source	df	SS	MS	Pseudo-F	P(perm)
Year	1	284.42	284.42	1.094	0.451
Public_access	2	1103.3	551.64	2.6122	**0.004**
Year x Public Access	2	528.29	264.14	1.2508	0.174
Residual	26	5490.5	211.17		
Total	31	7283.7			

We found a significant effect of public access on owl limpet size distributions (Table 40). Figure 32 shows the distribution of limpet sizes across the three categories of public access. At areas of high public access limpet sizes were dominated by relatively small size classes, and lacked large limpets. The largest limpets were only found in the areas of low public access. This is consistent with the findings of Sagarin et al. (2007) who found that sites on islands and mainland areas with restricted access had significantly larger median limpet sizes and a greater range of limpet sizes than more accessible sites. Extraction of individuals causes direct decreases in abundances and often alters the size structure of the population because humans are known to be size selective towards the largest specimens (Branch, 1975; McLachlan and Lombard, 1981; Moreno et al, 1984; Hockey and Bosman, 1986; Ortega, 1987; Lasiak and Dye, 1989, Lasiak, 1991). Sagarin et al. (2007) evaluated several hypothesis for differences in size distributions and concluded that poaching by humans on large individuals was the most consistent explanation for the differences in size distributions. This is also a likely explanation for the size differences among sites varying in the degree of human access found here, particularly since the MPA effect was non-significant, since poaching by humans can occur regardless of MPA status.

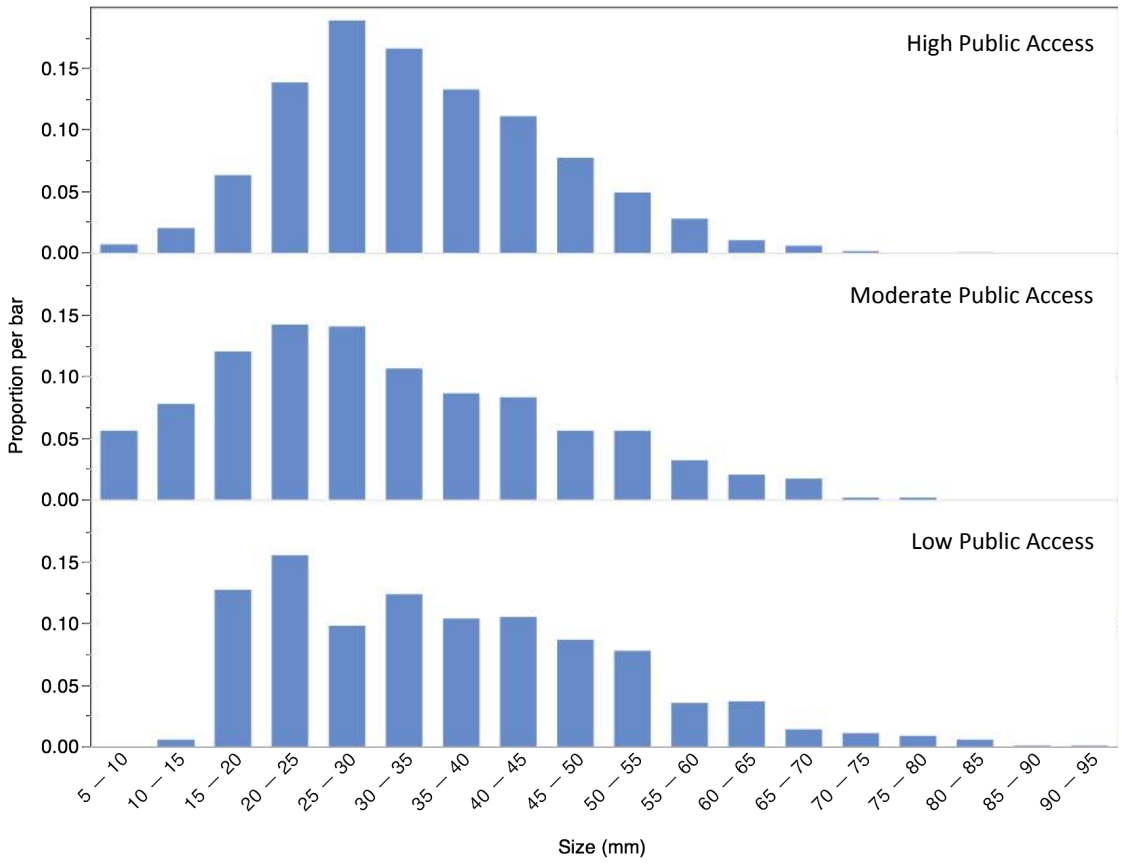

Figure 32 Size frequency histograms for owl limpet sizes across three categories of human access

Mussels

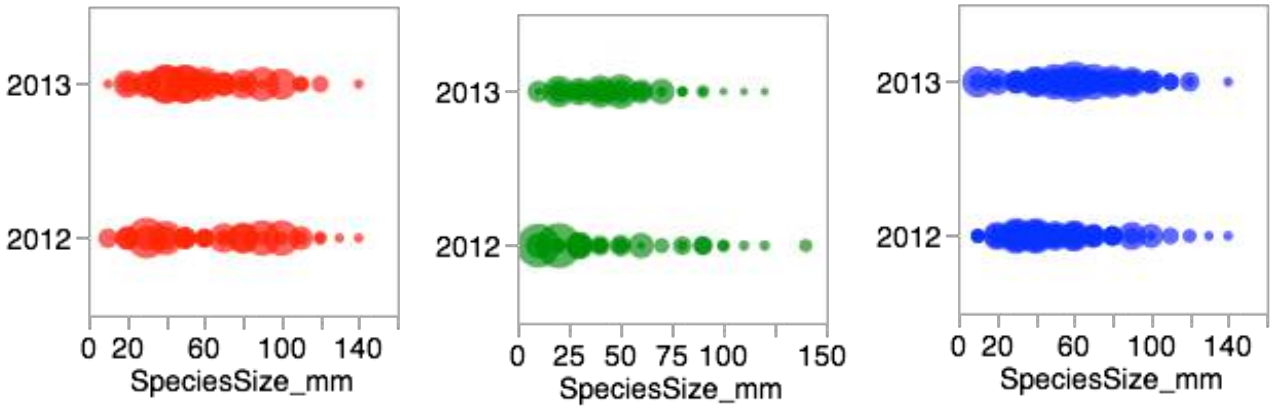

Figure 33 Bubble plots depicting the size distributions (shell length in mm) of mussels in 2012 and 2013 at sites in new MPAs (red), old MPAs (green) and reference areas (blue). Bubble size represents the numbers of mussels in each size class

We found no differences in the size distributions of mussels across years, across MPA status and no significant interactions indicating no initial changes in mussel sizes during the initial implementation of the MPAs (Figure 33 and Table 11).

Table 11 PERMANOVA results for the effects of year, MPA status and public access on the size distribution of mussels

PERMANOVA table of results – Mussels – Year and MPA status					
Source	df	SS	MS	Pseudo-F	P(perm)
Year	1	901.09	901.09	1.691	0.30
MPA status	2	2050.9	1025.5	1.2141	0.307
Year x MPA status	2	1060.5	530.27	0.62783	0.788
Residual	14	11824	844.6		
Total	19	15760			
PERMANOVA table of results – Mussels – Year and Public Access					
Source	df	SS	MS	Pseudo-F	P(perm)
Year	1	962.98	962.98	3.545	0.2485
Public_access	1	1396.3	1396.3	1.6838	0.135
Year x Public Access	1	271.64	271.64	0.32758	0.883
Residual	16	13268	829.25		
Total	19	15760			

Recommendations for long term monitoring

Ecosystem Indicators

Our analyses in this project focused on many of the Indicator/Focal species identified in the South Coast MPA monitoring plan, although there may be additional species or species assemblages that may serve as indicators at genetic, population-species or community-ecosystem levels for monitoring composition, structure, and function. There is a wide array of literature on the topic of 'Indicators' for monitoring (e.g. Noss 1990, Kremen 1992). Before deciding on the selection of indicators for monitoring, it is important to establish the goals of a monitoring program and the desirable qualities of indicators (Kremen 1992). Here we consider several important goals of an MPA monitoring program, as identified in the South Coast MPA monitoring plan:

1. Tracking ecosystem conditions over time – a status and trends approach focused on key attributes
2. Characterizing effects of MPAs, and assessing changes in MPAs through time – attributes, assemblages or species that differ inside and outside MPAs and/or would be likely to change through time as a result of protection
3. Simplifying complexity – identifying attributes, assemblages or species that are cheap or easy to measure and provide useful information on 1-3 above

Tracking ecosystem conditions over time

The MARINe group has identified a variety of criteria for selecting target species for monitoring in rocky intertidal systems:

- Species ecologically important in structuring intertidal communities.
- Species that are competitive dominants or major predators.
- Species that are abundant, conspicuous or large.
- Species whose presence provides numerous microhabitats for other organisms.
- Species that are slow growing and long-lived.
- Species that have interesting distributions along California coasts.
- Species found throughout California shores.
- Species characteristic of discrete intertidal heights.
- Species that are rare, unique, or found only in a particular intertidal habitat.
- Species approaching their biogeographic limits in California.
- Species that have been well studied, with extensive literature available.
- Species of special human interest.
- Species vulnerable and/or sensitive to human impacts, especially from oil spills.
- Species with special legal status.
- Introduced or invasive species.
- Species harvested by sport or commercial activities.
- Practical species for long-term monitoring.
- Readily identifiable species.
- Sessile or sedentary species of reasonable size.
- Non-cryptic species.
- Species located high enough in the intertidal to permit sufficient time to sample.

Based on these criteria, the MARINe monitoring is focused on the following list of target species in southern California:

- *Anthopleura* (Anemones)
- *Chthamalus/Balanus* (Acorn Barnacles)
- *Tetraclita* (Pink Barnacle)
- *Pollicipes* (Goose Barnacle)
- *Mytilus* (California Mussel)
- *Hesperophycus* (Olive Rockweed)
- *Silvetia* (Golden Rockweed)
- *Endocladia* (Turfweed)
- *Mastocarpus* (Turkish Washcloth)
- *Egregia* (Feather-Boa Kelp)
- Red Algal Turf

- *Phyllospadix* (Surfgrass)
- *Pisaster ochraceus* (Ochre Star)
- *Haliotis cracherodii* (Black Abalone)
- *Lottia gigantea* (Owl Limpet)

These taxa overlap to some degree (although not entirely) with the key attributes identified in the South Coast Monitoring Plan. There is wide agreement among most of the MARINe scientists (many of the leading rocky intertidal ecologists on the US West Coast) that these are important and appropriate taxa to monitor, and that they likely provide some indication of ecosystem conditions over time. The question then becomes how best to monitor their abundance through space and time. The MARINe group has taken a fixed plot or fixed transect approach to monitoring most of these taxa on a regular basis. Fixed plots have the advantages of being able to carefully track changes in a well-defined area, thus minimizing 'noise' due to random sampling (Murray et al. 2006). The main disadvantage of fixed plot monitoring is the lack of information on what is happening outside the plot. For example, in some cases where fixed plots were established to monitor mussel assemblages in the mussel zone, and the entire mussel zone has shifted through time, this information is lost in the time series data of mussel abundance at that site based on sampling in those plots. The gradual decline in mussel abundance through time as the mussel zone has shifted (while the plot remains fixed to the rock) gives an impression that mussels at the site have declined, when in fact their vertical distribution in the intertidal has shifted, and overall abundance at the site has remained constant. Based on the long time series of information from MARINe sites, it has become apparent that these elevational shifts of entire assemblages are relatively common, and can be due to a variety of factors ranging from changes in wave exposure, environmental conditions, coastal uplift, etc. Based on these observations, PISCO and MARINe have developed the biodiversity survey protocol (used in our baseline characterization here) that avoids the problems of fixed plots focused on a particular assemblage, and provides a wealth of additional information about total biodiversity and topography in addition to providing a more complete characterization of the abundance of focal species at the site scale. The ideal approach to monitoring would involve a combination of these two methods to characterize the status and trends of as many of the key attributes as possible, while maintaining a long time series of information on target species in fixed assemblages.

Characterizing effects of MPAs, and assessing changes in MPAs through time

We assessed the effects of MPAs (comparing across MPA status) for all the key attribute focal species and indicators described in the "Baseline Sites Ecosystem Feature Assessment" section of this report. The only ecosystem indicator that differed between MPAs and reference areas was richness/diversity. The effect of this difference was strong, and the finding that richness/diversity in newly established MPAs was intermediate in most cases between those of old MPAs and reference areas suggests that this indicator might be useful for both characterizing the effects of MPAs, and also for assessing changes in MPAs through time.

There was also some evidence that the size distribution of owl limpets was being affected by the degree of human access. Although owl limpet size distributions did not differ among MPA status, the suggestion that size distributions in this species could be affected by poaching has implications for MPA management.

Simplifying complexity

The list of taxa that we are able to identify in our biodiversity surveys is relatively large (654 taxa – see Appendix for full list), many of which are difficult to identify by anyone not having a great deal of experience and expertise in taxonomy. We followed the approach used in the NCCSR to attempt to develop a reduced list of sessile and mobile taxa that were >80% correlated with multivariate patterns produced by the full biodiversity dataset based on the full list of both sessile and mobile taxa. We carried out this analysis for both sessile and mobile taxa using the BEST routine in PRIMER to find a small subset of the most 'easily-identifiable' taxa which generated a multivariate pattern that was >80% correlated to that based on the full assemblage. We ran the analysis using both random and fixed starts and chose from among the resulting models those that had the fewest and easiest to identify taxa. A reduced set of 8 sessile taxa and 6 mobile taxa produced matrices that were >80% correlated with the original (complete set of species) matrices. These taxa for the SCRS are shown in Table 12.

Sessile Taxa		
Genus	**Species**	**Taxonomic Group**
Brachidontes/Septifer	spp	mussel
Colpomenia/Leathesia	spp	brown algae
Endocladia	muricata	red algae
Gastroclonium	subarticulatum	red algae
Petrospongium	rugosum	brown algae
Pterocladiella	capillacea	red algae
Phragmatopoma	californica	tubeworm
Strongylocentrotus	purpuratus	urchin

Mobile Taxa		
Genus	**Species**	**Taxonomic Group**
Lottia	austrodigitalis/digitalis	limpet
Lottia	scabra/conus	limpet
Lottia	limatula	limpet
Strongylocentrotus	purpuratus	urchin
Tegula	funebralis	snail
Tegula	eiseni	snail

Table 12 Set of 8 sessile and 6 mobile species that produce similarity matrices with 80% correlation to matrices for the full set of sessile and mobile taxa sampled in the SCSR.

Although these lists contain some common and easily identifiable taxa, most species on the lists would be greatly challenging for untrained observers to identify. While this approach in the NCCSR yielded a smaller list of easily identifiable taxa, the approach here did not produce a result that would be useful for implementation by citizen science. There are likely several reasons for these differences. The primary reason has to do with the much greater biodiversity and biogeographic differences among the bioregions of the south coast. Each of the bioregions is characterized by a relatively unique assemblage, and dominated by entirely different taxa. These taxa are generally the ones that drive separation across the bioregions, many of which are in the lists above. The Channel Islands is also a well-known biogeographic transition area, and the diversity of taxa across the islands is nearly as great as that along the entire west coast.

As a complementary approach to identifying a reduced subset of taxa, we also evaluated the degree of correlation among matrices that were produced using increasing degrees of taxonomic and functional aggregation. We evaluated the correlations across matrices produced using the full 'species' dataset, taxa identified to genus, order, phylum, functional group, common group, taxonomic group and trophic group (descriptions of these aggregations are included in the Appendix). We used a second-stage MDS approach in PRIMER to represent the correlations (Spearman) among matrices generated by increasing degrees of aggregation (Figure 34).

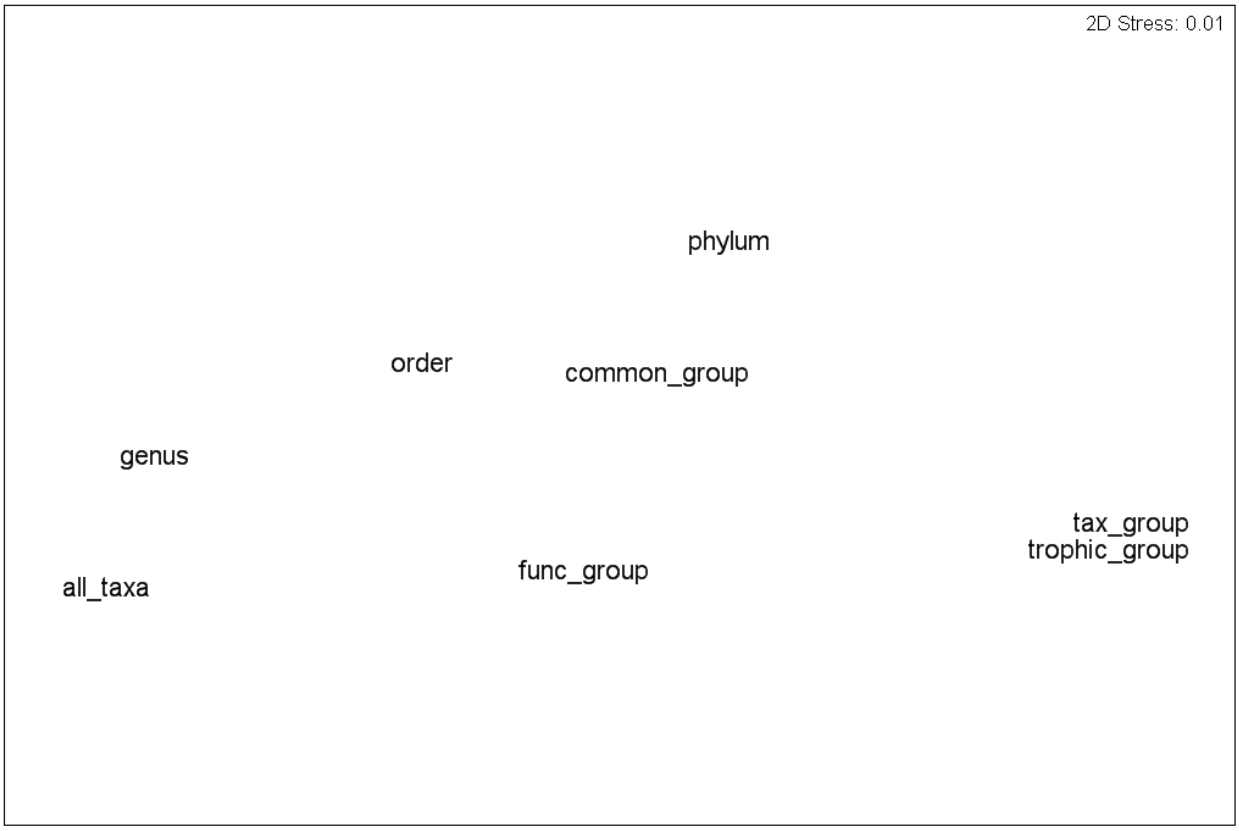

Figure 34 Second stage MDS plot based on increasing degrees of taxonomic and functional categorization. The distances between groups represent the degree of correlation of the matrices.

In general we found that, not surprisingly, the matrix of taxa aggregated to genus was most closely correlated with the full 'species' matrix (Figure 35). Aggregation to Order was the next most similar, followed closely by aggregation to common and functional groups. These two groupings are very similar, and it probably would not matter much how they were categorized across these groupings. Also, some of the functional categorizations not entirely mutually exclusive (e.g. crustose coralline algae may be considered in the group coralline algae or crustose algae) and so development of these groupings requires some decision-making.

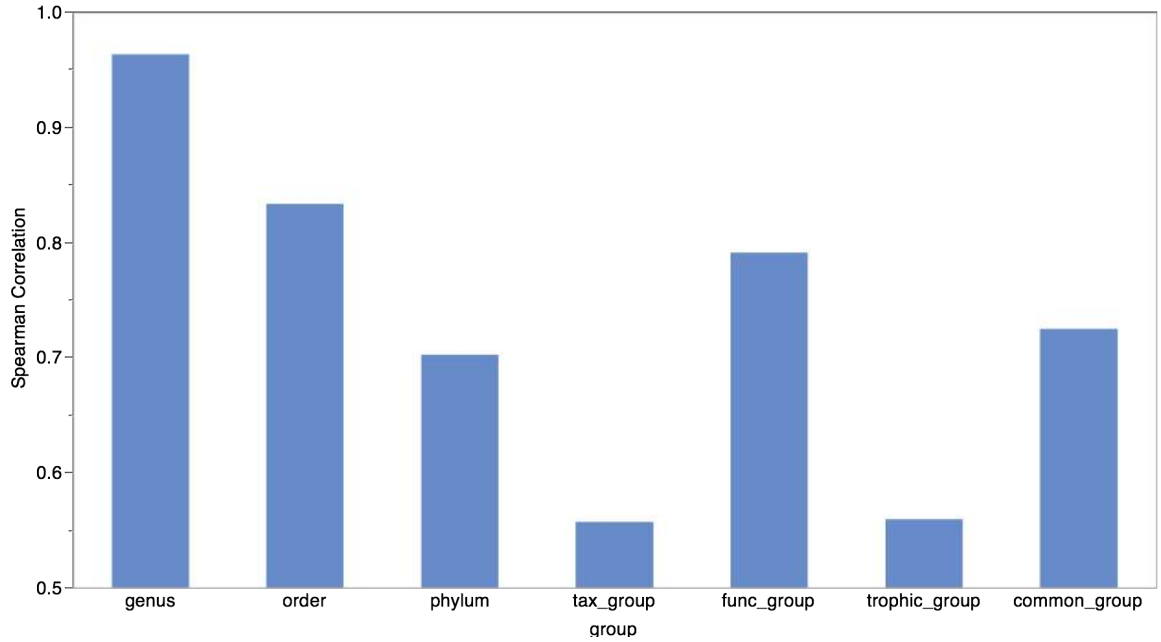

Figure 35 Spearman correlations between the full 'species' matrix and increasing levels of aggregation

This approach to deciding among levels of classification may be useful for citizen science groups deciding on an appropriate level of lumping or aggregation. For example, our partnership with LiMPETS (see next section) included a recommendation of providing a tiered approach to complexity for students of different grade or experience levels. This approach provides one way to develop and decide upon tiers that optimize the inclusion of easy to identify taxa, and maintains the closest possible correlation with the information provided by a full species list.

Partnerships

Academic and Agency Partnerships

The data collected in our South Coast Baseline Project have been made possible through the cooperation of the Multi-Agency Rocky Intertidal Network (MARINe), a large consortium of research groups working together to collect compatible data that are entered into a centralized database. Important contributors to MARINe include scientists at: the University of California – Santa Barbara, Santa Cruz and Los Angeles, California State University – Fullerton, Pomona and Long Beach, National Park Service – Channel Islands and Cabrillo, and US Navy Marine Ecology Consortium. Long-Term Monitoring and Biodiversity Surveys done by MARINe occur throughout the year at sites ranging from Southeast Alaska to Mexico. MARINe is funded entirely by the independent contributions of its members. Special recognition should go to three agencies who have provided the majority of continuous funding for the project over several decades: Bureau of Ocean Energy Management, Partnership for Interdisciplinary Studies of Coastal Oceans and The National Park Service.

Citizen Science, Education and Outreach Partnerships

Although our project has largely been aimed at baseline characterization and monitoring, we are very interested in working with groups that may contribute data to the long term monitoring of California MPAs. An active collaboration will help to ensure consistency of protocols and quality of data. Furthermore this close working relationship will allow us to troubleshoot sampling methods that may be problematic for less trained samplers. Rocky intertidal ecosystems (along with sandy beach ecosystems) are ideally suited to public participation in scientific research (frequently characterized as 'citizen science') as they are the most accessible marine habitats and do not require SCUBA, boating or any additional special certifications, and are widely accessible. In this proposal we are formally partnered with the southern California LiMPETS (Long-term Monitoring Program and Experiential Training for Students) program.

LiMPETS (Long-term Monitoring Program and Experiential Training for Students) is an environmental monitoring and education program for students, educators, and volunteer groups. This hands-on program was developed to monitor the ocean and coastal ecosystems of California's National Marine Sanctuaries to increase awareness and stewardship of these important areas. LiMPETS is a citizen science program that trains students, primarily, to conduct intertidal monitoring (rocky intertidal and sandy beach) along the coast of California. LiMPETS monitors both sandy beach and rocky intertidal sites throughout southern CA, and protocols, data and information are available at http://limpetsmonitoring.org. Through research-based monitoring and standardized protocols, students develop their problem solving skills, gain experience using tools and methods employed by field scientists, and learn to analyze data. The online data entry system on this website allows our participants to archive their data electronically and to view and analyze their results over time. The LiMPETS network provides authentic, hands-on coastal monitoring experiences that aim to empower teachers, students and the community to conduct real science and serve as ocean stewards.

Our partnership with LiMPETS was based in three main areas as described in our proposal: Comparative data Analysis, Development and Testing of new protocols, and Teacher training Workshop and Symposium. Below we describe our work in each of these three main areas, and present our results and recommendations.

Comparative Data Analysis

LiMPETS uses 4 main protocols to quantify the abundance and size of selected marine organisms: Vertical Transects in a Permanent Area, Random Quadrats in a Permanent Area, Size Measurements in a Permanent Area and Total Counts in a Permanent Area. These protocols are described briefly below, and further detailed information about the program and methods is available online at http://limpetsmonitoring.org.

Both the vertical transect and random quadrats protocols are based on abundance estimates for a selected list of taxa within a $0.25m^2$ quadrat. In the vertical transect protocol, these quadrats are placed at set intervals along a transect running from the high to low intertidal zones. In the random quadrats protocol these quadrats are placed at random locations throughout the intertidal site. The $0.25m^2$ quadrat is divided into 25 0.1m x 0.1m squares. Abundance estimates for each of the focal taxa listed on the datasheet are determined by recording presence or absence for each focal taxa in each of the 25 squares per quadrat

(hereafter referred to as 'squares' method). Estimates of 'percent cover' are calculated by summation of the total number of squares in which each of the focal taxa was recorded as present, by the total number of squares sampled (25 in all cases for these quadrats). For sessile taxa this estimate of percent cover is often very different than more traditional estimates of percent cover based on space occupation. The distribution and size of focal taxa can also contribute to high inaccuracy using the squares method to estimate percent cover. An example of this type of error is a common situation where there are a few small barnacles or small patches of rock in each of the 25 squares. The percent cover of barnacles and rock in this case would both be estimated at 100% using the squares method, however the actual occupation of space by either of these groups would be considerably less.

For each of these quadrat-based methods, there is a subset of focal taxa whose abundances are recorded as the total number of individuals per quadrat. These taxa include both mobile (e.g. chitons, whelks, turban snails) as well as some sessile taxa (e.g. Feather boa kelp, anemones).

In addition to the quadrat-based methods, the size and abundance of selected taxa are recorded within pre-determined areas at each site (the 'size' and 'count' methods). For southern California sites, sea stars are the focal taxa for total counts, and owl limpets are the focal taxa for sizes and counts, although the presence of sea stars and owl limpets varies across southern California sites, and so sizes and/or counts are only done at some sites where these organisms are present in reasonable numbers.

Description of methods

To compare data across programs, we extracted all available data from the LiMPETS database for sites within the SCSR. Five sites (Coal Oil Point, Carpinteria, Deer Creek, White's Point and South Frenchy's Cove) were sampled by both the LiMPETS program and the SCMPA baseline program (hereafter SCMPA). To ensure the best possible comparison of data, we chose sampling dates from both programs at each of the sites that matched as closely as possible. For Coal Oil Point, Carpinteria, and South Frenchy's Cove, the sample dates matched relatively closely, since both programs sampled all 3 of these sites in 2012. The best match for Deer Creek was a 2013 SCMPA sample and a 2009 LiMPETS sampling, and for White's Point the best match was a 2008 SCMPA sample date and a 2013 LiMPETS sample date.

Based on the availability of overlapping data in space and time, we chose to focus our analysis on the percentage cover and density of focal taxa sampled by both programs. Since the LiMPETS focal taxa were generally at a much broader level of taxonomic resolution than the SCMPA data, we lumped SCMPA species-level data to achieve similar functional taxonomic classifications. For the comparisons we used percentage cover data from the SCMPA biodiversity surveys. Although the MARINe group samples percent cover of selected taxa in permanent quadrats, these quadrats are located within fixed zones to target particular assemblages, while the LiMPETS quadrats are generally randomly distributed across zones or across the gradient from high to low zones, similar to the SCMPA biodiversity survey sampling design. Additionally the sample dates for 3 out of 5 sites were very similar between the LiMPETS and the SCMPA biodiversity sampling, thus minimizing temporal variability. Comparison of the size and count data for owl limpets and sea stars was not included in this analysis since these taxa were not abundant enough at many of these sites

to be sampled, and at sites where they were sampled by both programs, the location of the sample areas differed, thus greatly diminishing the information gained by making any comparisons.

We analyzed the data using methods similar to those described previously for the baseline characterization of the SCMPA sites. Percent cover and density estimates for the common focal taxa were calculated for each method at site. The abundance estimates for the common set of sessile taxa for both sampling methods are shown in Figure 36. In general the LiMPETS abundance estimates for almost all taxa were much higher than those based on the SCMPA sampling. Some taxa were found to be absent at some sites, and abundant at others depending on the method used (e.g. surfgrass at Carpinteria, and flattened rockweeds at Frenchy's Cove). These differences may be due to placement of the quadrats, variation in abundance of taxa through time (although not likely for surfgrass and rockweed), or misidentifications.

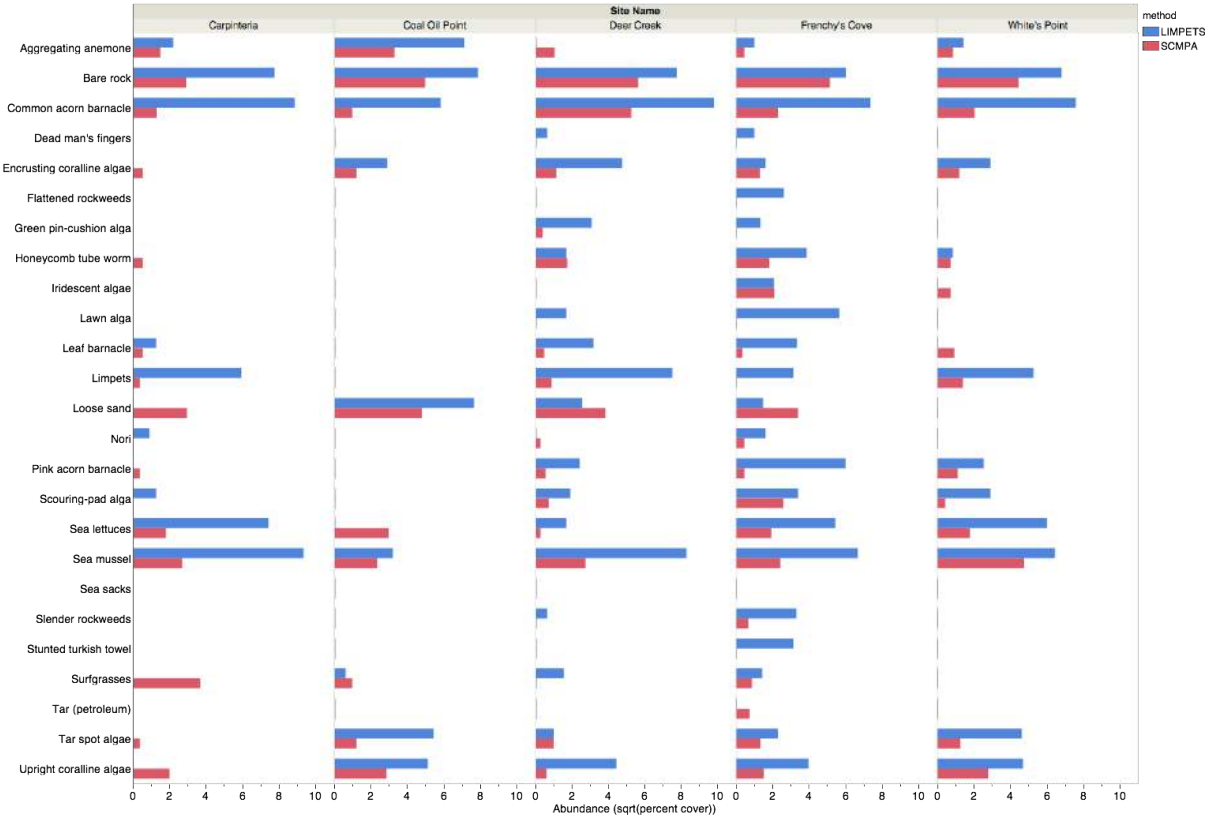

Figure 36 Estimates of abundance (percent cover – square root) at each of five sites for all LiMPETS focal taxa and SCMPA taxa lumped to comparable levels.

Abundance estimates for the mobile taxa were much more similar between sampling programs, although several taxonomic groups (e.g. hermit crabs at Carpinteria, chitons at Frenchy's cove, and purple urchins at White's Point) were only found by SCMPA samplers (Figure 37). These differences may reflect the placement of the quadrats as well as the high temporal and spatial variability that are characteristic of taxa such as turban snails and hermit crabs.

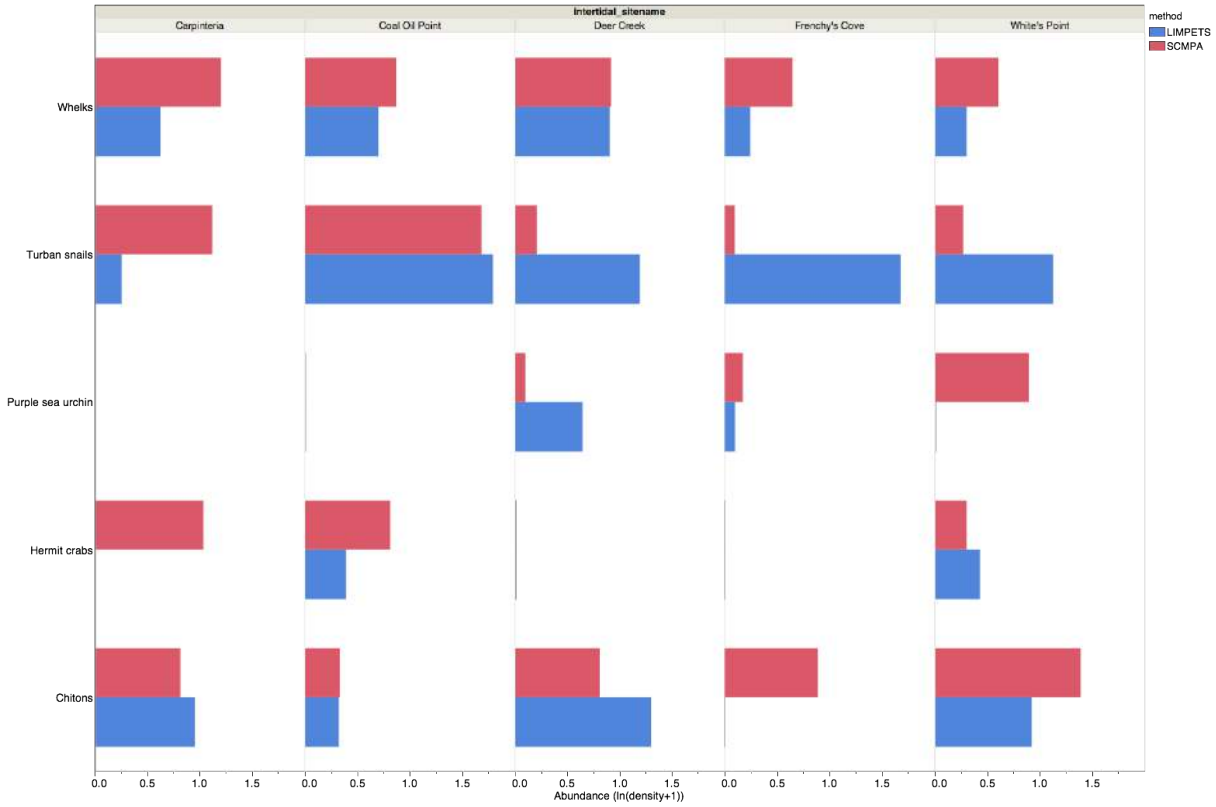

Figure 37 Estimates of abundance (log (density+1)) at each of five sites for all LiMPETS focal taxa and SCMPA taxa lumped to comparable levels.

To examine patterns of community similarity, we used the multivariate methods of Clarke (1993) and the primer 6.1.3 (Plymouth Routines in Multivariate Ecological Research) software package. The data matrix of taxon abundances was square-root transformed to reduce the contribution of very abundant species and increase that of rare species. A similarity matrix was constructed using the Bray–Curtis similarity coefficient and we used two-dimensional, non-metric multidimensional scaling (nMDS) to examine segregation among communities (Kruskal & Wish, 1978). The nMDS plot for the sessile taxa (Figure 38) highlights the drastic differences in these communities based on sampling methodology. The dominant spatial separation occurred across the 2 different sampling methods.

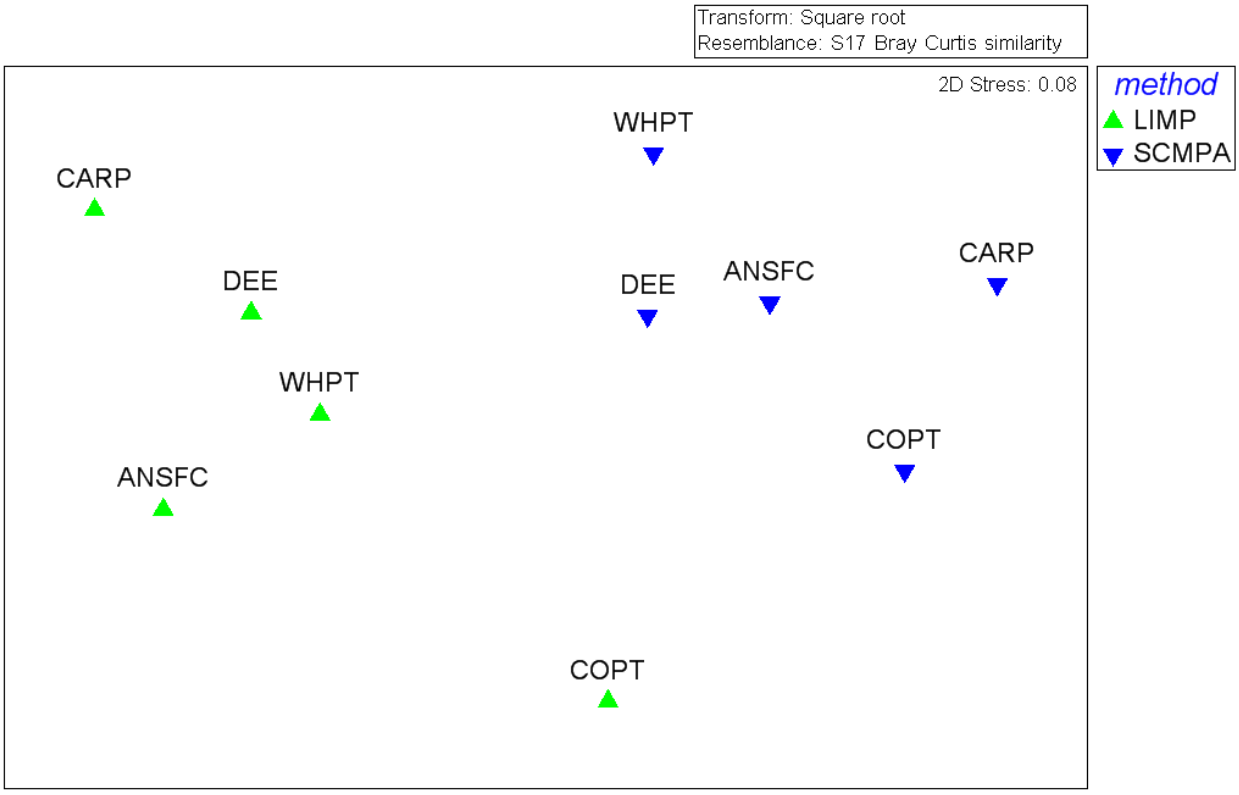

Figure 38 MDS plot of the sessile assemblages at each of the five sites as sampled by both LiMPETS and SCMPA

The nMDS plot for the mobile taxa (Figure 39) reflects high variability across both sites and sample methods. Based on the abundance of mobile taxa, there is little clear pattern across the assemblages due to spatial locations or sampling method, with the exception of Coal Oil Point, where both methods were relatively similar in quantifying abundance of the four mobile taxa. The high variability in space is likely due to the restricted number of taxa comprising the mobile assemblage (5) vs. the 25 taxa describing the sessile assemblage.

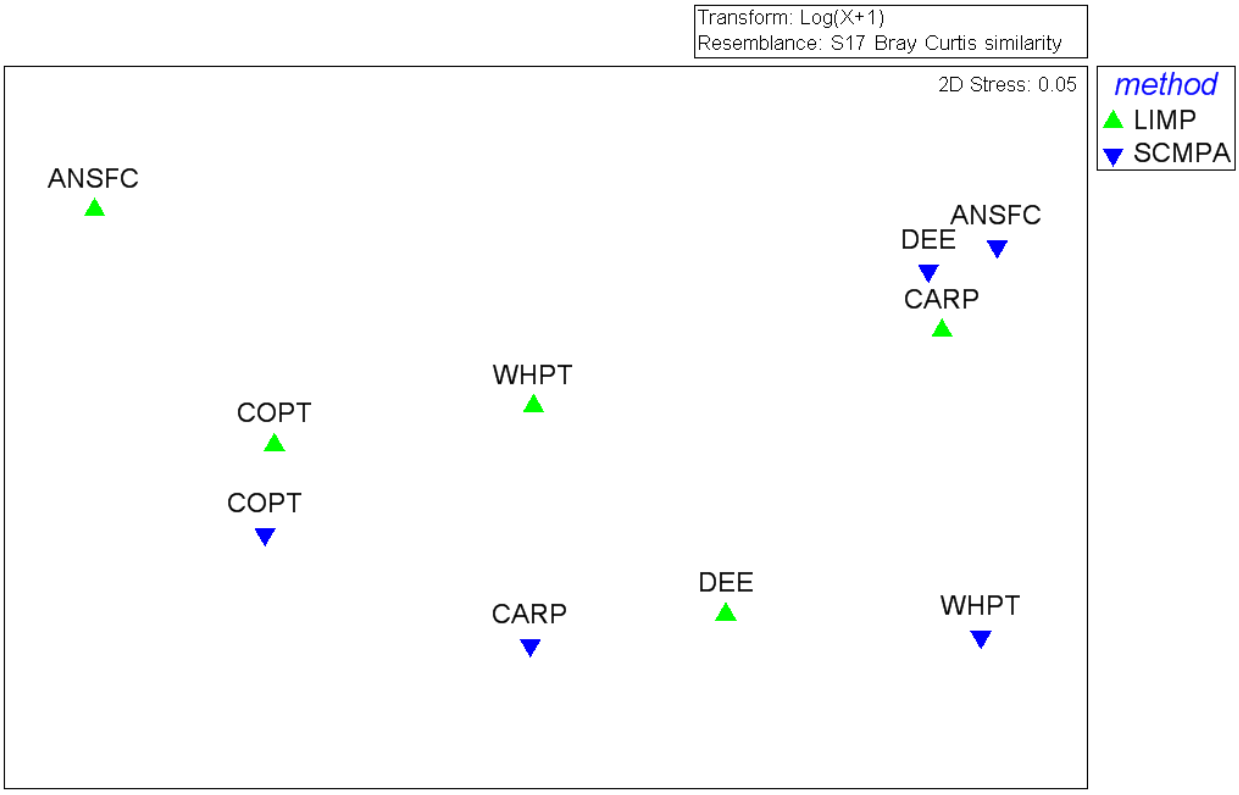

Figure 39 MDS plot of the mobile assemblages at each of the five sites as sampled by both LiMPETS and SCMPA

We used a PERMANOVA approach to test the main effects of Method (LiMPETS vs SCMPA) and Site in contributing to variability across sessile and mobile assemblages (Table 13). The main effects for Method were highly significant for the sessile assemblages and much more important at driving separation across assemblages than the differences among sites. For the mobile taxa, neither method, nor sites were significant indicating a high overall level of unexplained variability across a relatively taxonomically poor assemblage of mobile organisms.

Table 13 PERMANOVA results for the effects of method (LiMPETS vs SCMPA) and site on the communities of sessile and mobile taxa across each of the 5 study sites

PERMANOVA table of results – Sessile Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Method	1	4265.1	4265.1	8.8092	**0.001**
Site	4	3936.1	984.03	2.0325	0.065
Residual	4	1936.6	484.16		
Total	9	10138			
PERMANOVA table of results – Mobile taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Method	1	1325.6	1325.6	1.2851	0.323
Site	4	3486.9	871.72	0.84514	0.594
Residual	4	4125.8	1031.4		
Total	9	8938.2			

Protocol Development and Testing

Experimental Evaluation of Percent Cover Protocols

Based on the protocol differences to estimate percent cover between the LiMPETS and SCMPA programs, and the results of the comparative data analysis, we designed an experiment to try to tease out the effects of protocol differences from those due to variation in the placement of quadrats in space and time. We paired an experienced SCMPA and LiMPETS sampler at each of 3 sites common to both the LiMPETS and SCMPA sampling programs (Carpinteria, Coal Oil Point and Deer Creek), where we sampled 8-10 quadrats that were sampled sequentially in time in exactly the same location by each of the 2 samplers. Quadrats were haphazardly placed at each site to encompass the range of taxa representative of different zones and wave exposures. The experienced LiMPETS sampler, Jessie Altstatt sampled percent cover of the focal taxa using LiMPETS protocols, and the experienced SCMPA sampler, Carol Blanchette, sampled the same quadrat using a point contact protocol to quantify percent cover. The resulting data were then treated in a similar way to that described above, to generate estimates of percent cover for a common set of focal taxa.

The nMDS ordination plot (Figure 40) reveals a similar pattern to that shown in Figure 38, where the major division across assemblages was due to sampling method.

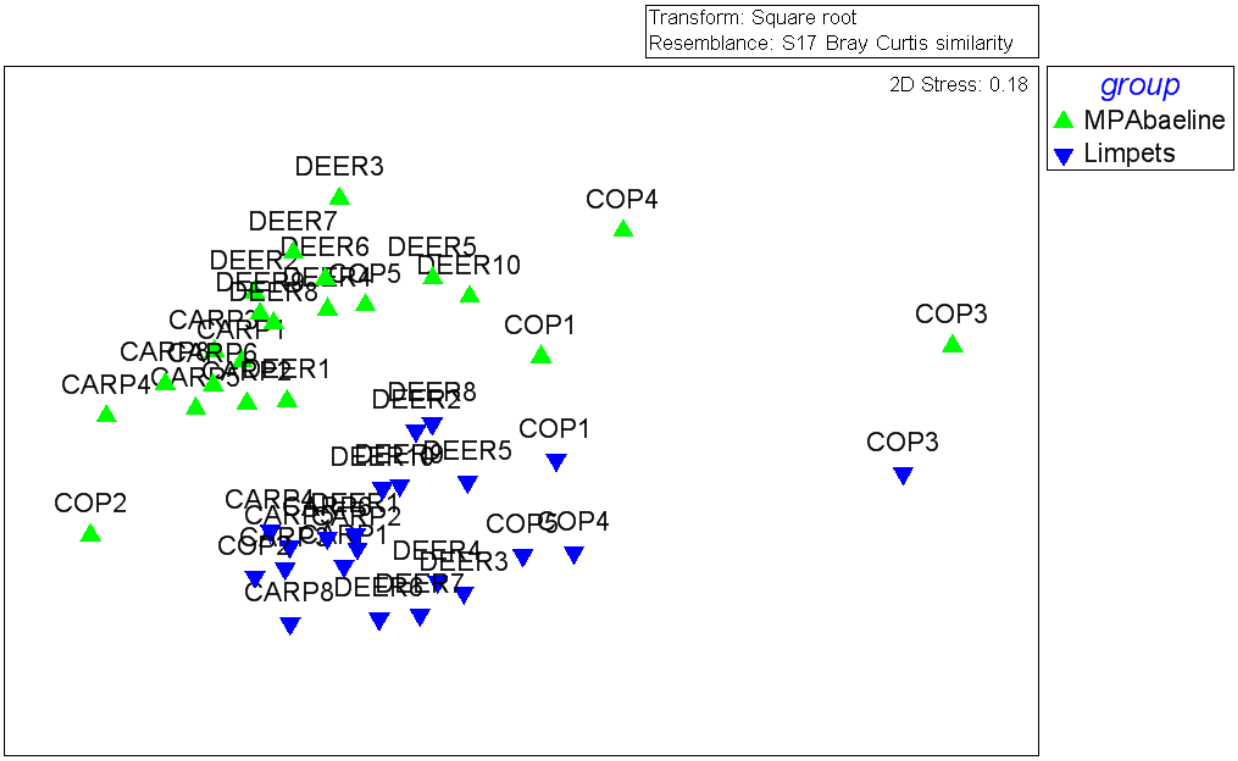

Figure 40 MDS plot of the sessile assemblages in each of the quadrats sampled by both LiMPETS and SCMPA methods

We used a PERMANOVA approach to test the main effects of Method (LiMPETS vs SCMPA) and Site in contributing to variability across sessile assemblages (Table 14). The main effects for Method and Site were highly significant indicating that our sampling methods as well as local assemblages were significant sources of variability in the data.

Table 14 PERMANOVA results for the effects of group (LiMPETS vs SCMPA) and site on the communities of sessile taxa across quadrats

PERMANOVA table of results					
Source	df	SS	MS	Pseudo-F	P(perm)
Method	1	16182	16182	44.086	**0.001**
Site	21	46560	2217.1	6.0403	**0.001**
Residual	21	7708.2	367.06		
Total	43	70450			

Consideration of Additional Protocols

Challenges

The LiMPETS program faces several challenges that are significant in comparison to other citizen science sampling programs. The majority of LiMPETS participants are students, grade 7-12 who participate in one

field trip to one monitoring site. The degree of prior experience with ocean science or even experiential learning in general varies widely both within and between classes and schools. Other citizen science groups are often comprised of adults who make more of a long-term commitment to the program, returning to events repeatedly over months or years. From an educational goal perspective, it is a benefit of the program to be able to reach and engage as many students each school year as possible. For many classes, a LiMPETS field trip is their first visit to the seashore. This experience can be a pivotal moment in their education and spur interest and a career in science. However, to meet the goal of producing high quality data, the transience of LiMPETS participants is a major obstacle to overcome. Each new group of participants requires the same training and stewardship by LiMPETS coordinators. There is currently no set way to scale the monitoring activity by student ability. There is a wide degree of variation between those classes of experienced older students that learn quickly and master the protocols, and those that find it difficult to focus during their first field trip. It could be unfair to novices to force data collection when the student might be better served by spending their time exploring or performing a simpler task.

Although there are shared objectives, the classroom setting drives inherent differences in training and protocols between LiMPETS participants and either other citizen science groups or scientists. LiMPETS participants receive ~2 hours of classroom training. They are then asked to correctly identify a list of 34 marine invertebrate and algal species in the field, collect abundance information on those species and also recognize when an observed species is NOT on their list (and should not be recorded). This can be very challenging. There might be some methods in use now by LiMPETS participants that meet some goals (stewardship, education) but are not capable of producing high quality data. Not meeting the most stringent requirements does not in any way nullify the value of the student experience. Given all the above challenges, very little of the data (~20%) that have been collected by the LiMPETS program in the south coast region are entered into the database.

Vertical Distribution Survey

Given that LiMPETS is largely a student-training program, one of the great challenges in sampling rocky intertidal habitats with students is getting them to the site during a suitable low tide. Often, the lowest tides (those that are ideal for extensive sampling) occur on nights, weekends and at other hours of the day that are difficult for field trips. Sampling rocky intertidal sites on days when tides are not very low can result in data that are skewed in their representation of high vs. mid to low intertidal taxa. Another challenge faced by the LiMPETS program is the taxonomic complexity required to accurately identify focal taxa in the field. One of our goals was to develop and propose an alternate protocol that could be used by students with limited training that would require minimal taxonomic expertise and could be implemented in the field on average low tides, thus allowing for a wide range of possible field trip days.

One additional protocol that has been proposed within the MARINe program, the Vertical Distribution Survey, may be useful to LiMPETS, since it focuses on the highest tide level, can be done on a wide variety of low tide conditions, and is limited to a small set of taxa. It is currently being tested by several MARINe teams, and the measurements consist of two basic metrics to identify the upper vertical distribution for a

targeted set of organisms: 1) its upper distributional limit, and 2) the upper limit of its 'zone' (i.e. the region of shore where it is most common). The potential benefit to the LiMPETS program of adopting this protocol would be that data would be directly comparable with the MARINe group, and that the results would be of interest to interpreting climate change effects, and the data would become potentially more valuable through time. The challenges for adoption of this protocol by the LiMPETS group include more training time, an additional protocol, and more time spent in the field if no other protocols are dropped.

Tiered Sampling Approach

One potential solution to the inherent limitation on teacher and student training in the LiMPETS program may be to break out the current species list into tiers of taxonomic complexity. The simplest tier, Tier 1, might have 11 broad categories that are the simplest to identify- barnacle, seaweed, etc. Tier 2 would be more complex, with 19 categories. Tier 3 might contain all or many of the 27 taxa of the original LiMPETS list. The exact taxa that are included in each of these tiers will involve further discussion and analysis. The tiered approach (similar to experience levels for data collection in other citizen science groups such as REEFcheck) would provide experiences for data collection for samplers at all levels. Moving from one tier to the next would require a demonstration of knowledge sufficient to collect meaningful information at the next level. The lowest tier could include most general science education; 'basic data collection 101' in rocky habitats for students and the public. The next level could include more experienced teachers/participants, who could develop a time series for internal (classroom) use. The highest level would be limited to a fully trained group of samplers that collect certain types of data that could be entered into the LiMPETS network database. The benefits of this approach would be to provide the LiMPETS program with a way to meet educational and scientific goals, without compromising data quality. The database could be set up to allow for entry into these separate tiers, thus enabling students to work with data that have been collected in similar ways by other groups or through time. Modifications to data sheets would be required. The goals, required actions and intended results for each of the proposed tiers are described in Table 15 below.

Table 15 A summary of goals, actions and intended results based on the incorporation of a tiered approach to LiMPETS sampling

TIER	GOAL	ACTION	RESULT
1	Introductory Ocean Experience, Increase Ocean Literacy, Promote ocean stewardship	Simplify species list (remove complexity), Simplify monitoring protocols	Highlight exploration during field trip (rather than data collection), Emphasis on basic science education
2	Introduction to Data Collection and Basic monitoring techniques	Modify species list (reduce complexity), Adapt monitoring protocols, Introduce basic QA/QC	Increased accuracy and precision, Collect and build upon inventory/time series for teaching purposes, Emphasis on how to be a scientist
3	Collect scientifically -sound monitoring data that meshes with other monitoring groups (e.g. MARINe partners)	Change monitoring protocols and species list, Implement QA/QC, Rigorous training, Experienced field samplers	High accuracy and precision, Emphasis on scientific goals

If adopting a complete tiered approach (complete with distinct training materials and tools, etc.) is not an option, a solution may be to reduce the species list down to a core group that are easier to identify and are regionally important space holders etc. (barnacle, mussel, rock etc.). Or, for some classrooms, perhaps the best approach would be to concentrate on different protocols that target fewer species like the Total Species Count protocols or the proposed Vertical Distribution protocol rather than on the quadrats.

Teacher Workshop and Symposium

We hosted a teacher training workshop and symposium in June 2014 at UCSB, entitled, 'Teaching Environmental Science in a Changing Climate' to provide teachers with helpful tools and resources focused on environmental and climate science education in the context of the Common Core and Next Generation Science Standards. The 5-day workshop was attended by 24 teachers, and included sessions focused on both sandy beach and rocky intertidal LiMPETS training and sampling. About 20% of the teachers had prior experience with the LiMPETS program. A classroom overview of the LiMPETS program was followed with lab activities. The lab was designed to introduce the teachers to different sampling methodologies. Additionally we used this opportunity to introduce our proposed 'Tiered' sampling approach and get feedback from teachers on how they might incorporate these tiers in their participation in LiMPETS.

For the laboratory activity, we created large (0.6m x 0.6m) high resolution, laminated photo-quadrats from a variety of intertidal assemblages across southern California. We also recently revised the LiMPETS taxonomic identification guide (to focus on the common southern California species), and datasheets including tiers for this classroom activity. The datasheet presented the LiMPETS species list (33 categories) broken down into three Tiers. In Tier 1, in the left column, were the 10 most common species including

those that were the easiest for a novice to recognize (e.g. mussels, barnacles). Tier 2 included these and some additional taxa, and Tier 3 contained nearly all of the taxa on the current LiMPETS list. The datasheet was presented in this manner so that the teachers could see how the complexity changed across tiers.

The first activity was to work with a quadrat strung with 64 points and score the species under each of the points using a standard point contact protocol (similar to that used by MARINe scientists). Teachers were allowed to select any of the 3 tiers for scoring. They were given the photo ID guide to help with identifying taxa. After about 15 minutes, the teachers were asked to score the same photo plot using the LiMPETS 25 square protocol. At the end of the exercise, teachers were given a chance to discuss the merits of both methods for field and classroom use. We solicited feedback from the teachers regarding 2 main topics: (1) the relative merits of the point contact vs. LiMPETS method for assessing percent cover, and (2) their assessment of the suitability of the tiers for students ranging in degrees of experience, and their own classrooms.

Teacher comments on methods comparison

With respect to the choice of methods (point contact vs. LiMPETS) for determining percent cover, most teachers found the point contact method to be most accurate as the best estimate of percent cover (Figure 41). Most teachers thought that both methods were equally easy to use, however most teachers ranked the LiMPETS method as most time efficient. Most teachers preferred the point contact method to use with their students, and an equal proportion of teachers chose the point contact method and both methods as their overall preference.

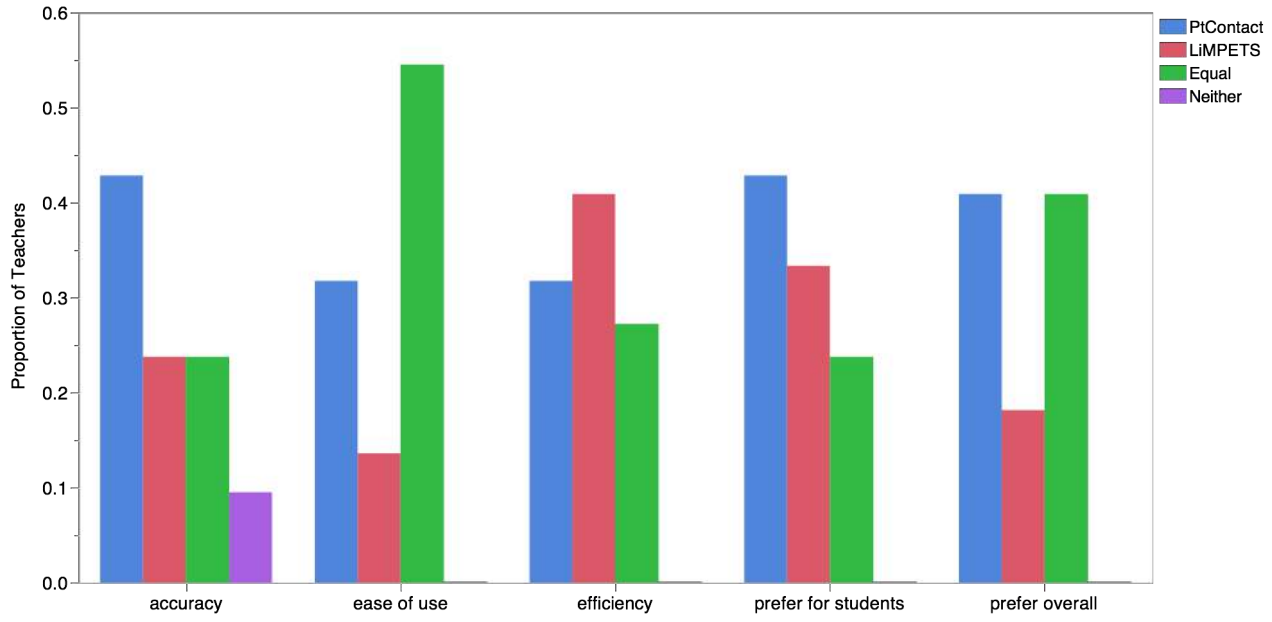

Figure 41 Results of survey from the LiMPETS teacher workshop focused on comparison of point contact vs LiMPETS method for student estimation of percent cover

In addition to the methods survey, we received a variety of comments from the teachers during the discussion of the methods. Below is a summary of the teacher comments on the topic of methods. Grade taught if indicated is shown in parentheses.

- thought both methods have value and could be used to scaffold content and skills from simpler to more complex levels (6-8)
- for point contact, I really liked having to learn the organisms and look them up repeatedly…took away a better connection to the various organisms…I really liked the idea of contributing to real data that will be used!
- the point contact method should maintain my students engagement more and it seems to be more accurate (10-12)
- equal methods because the kids would have a chance to ID more species with the LiMPETS model (6-8)
- I love the idea of having students do both and discussing the results/consequences of each method (9-12)
- I think to determine which method is best would be to complete both strategies in the field the compare species results. (9-12)
- (point contact) required us to look up all species (9-12)
- with my HS students- I would want to use % coverage methods. Challenge them and do what researchers are doing (9-12)
- at my ..6th grade level LiMPETS method may be more 'user friendly' (6-8)
- the error associated with the LiMPETS method is too high. I wouldn't teach a protocol with this much inherent error to my age group. They can handle a better method. (11-12)
- I think either method will have drawbacks. LiMPETS overestimates coverage of common species, point contact under-estimates rare species (9-12)
- think the point contact lets the students specifically focus on one organism at a time to ID/helps narrow their focus. The (#s of squares) original method, ID-ing species in each square, might get overwhelming and the observations might not be as accurate (6-8)
- (Q: which method did you find easiest to understand and implement?) Both however with LiMPETS there was more observation required (7-8)
- point contact vs LiMPETS would both be useful for my student population (low socioeconomic, English Language Learners) to differentiate learning for various levels of learners (7-8)
- …kids would have a chance to ID more species with the LiMPETS model (?)

Teacher comments on Tiered Approach

The teachers were asked which of sampling tiers on the species list would work best for their class. We allowed them to choose more than one tier if they could explain their choice. The majority of middle school teachers preferred tier 1 (the simplest list) for their classes, and most that chose tier 2, also chose tier 1 to use on the first time and tier 2 for a repeated trip or more advanced students (Figure 42). None of the middle school teachers chose tier 3 (the current LiMPETS species list) to use with their classes. Among high school teachers most preferred tier 3, however in all cases where teachers chose tier 3, they also chose either tier 1, 2 or both in addition to tier 3 as a way to differentiate across learners, or to provide options for more advanced students (e.g. AP Biology). Most teachers liked the idea of having options to choose from.

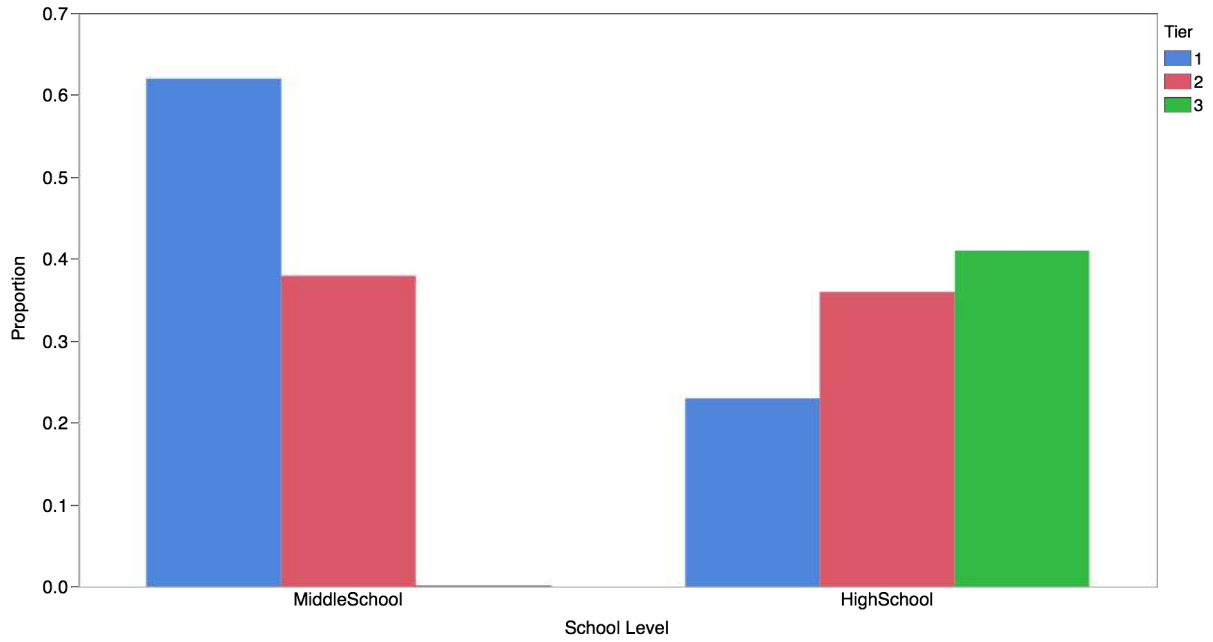

Figure 42 Proportion of middle school and high school teachers that chose tiers 1, 2 and 3 for use in their classrooms

In addition to the tiered approach survey, we received a variety of comments from the teachers during the discussion of the methods. Below is a summary of the teacher comments on the topic of methods. Grade taught if indicated is shown in parentheses.

- I like the way it (datasheet) was set up to be able to see all 3 tiers because I think it helps with understanding classification and identifying the different species in a given group (9-12)
- I would probably start my sophomores at tier 2 but it would take some experience to see where they truly fit (10-12)
- the tired system is a great idea so that all abilities can participate and feel successful. The only thing is that the current organization of the tiers on a single datasheet would be confusing to younger students. (6-8)
- it (tiered approach) was very appropriate! It will allow success at multiple levels (6-8)
- liked the cheat sheets, it would be good to have photo sheets organized in similar fashion as single taxonomy sheets you gave us (6-8)
- great idea can adapt as needed (8)
- very good, higher level students may want to "go for" higher tiers (6)
- tier 3 for 12th graders (11-12)
- I used the (Tidepool) app which required Tier 3. Tiering makes form a little complicated (6)
- re: Tiers: I like that there are options (7)
- you could even do multiple Tiers within the same class based upon students interest / prior knowledge (differentiate within the group of students) (6-8)
- potentially Tier 3 (for my class), it is especially valuable for my student population to be able to differentiate learning for students (levels of learners- appropriate tier) (7-8)
- Tier 2 for 9-10th, Tier 3 for 12th grade AP bio

- Tier 3 for 12th graders
- Tier1 6th, Tier 2 7-8th, Tier 3 High School

Recommendations

The LiMPETS program provides an exceptionally rich experience for students to expand their biological and natural history knowledge of marine species, practice different ways to estimate the abundance of organisms and further develop quantitative reasoning and critical thinking skills. These scientific practices lie at the heart of the Next Generation Science Standards (NGSS). LiMPETS is well-poised to develop their program to provide experiential training for students that is aligned with the NGSS. The teachers that we have worked with over the course of the last 2 years seem to value to opportunity to engage students in comparisons of methods for estimating abundance, and also value to opportunity to choose a level of complexity that is most appropriate for their students. Importantly most of the teachers we interacted with thought that participation in LiMPETS was a valuable experience and would be of interest to their students even if the data collected were not made available as part of a public database. In fact several teachers viewed the LiMPETS program as a great way to train and expose students to different sampling methodologies, and levels of taxonomic complexity, preparing them to assist or work with more experienced scientists engaged in monitoring studies. Based on the results of this project summarize our general recommendations:

- Recognize limitations of teachers and students with limited training and expertise.
- Consider adopting new methods (e.g. Vertical Distribution Protocol, sea star wasting surveys) that would be simpler in terms of training and would be complementary to the existing MARINe sampling
- Consider partnering with professional and experienced scientists in MARINe and PISCO to assist with protocol development, teacher training and data management

In addition to the general recommendations above we provide specific recommendations in the areas of training and data management:

- Retain flexibility to regularly update training materials, field guides and datasheets
- Develop training and documentation requirements. Examples include online study tools and modules requiring 100% completion, in-class calibration between participant and Coordinator/teacher, quizzes on methods, zones and species before sampling, in-field calibration between participant and Coordinator.
- Reduce complexity of methods by adopting a Tiered Approach to maximize assurance of data quality, while providing for education experiences for those participants unable to complete the most rigorous training.
- Develop quality control procedures for data management, and incorporate data quality control into the schema for data entry.

It is also important to recognize the importance of the strong regional differences across the LiMPETS network. The habitats, assemblages and species in southern California differ greatly than those to the north in central and northern California. Important differences ranging form the timing of low tides to the

socioeconomic status of the student populations provide a strong rationale for allowing for some level of regional differention across the network. This will be important to enable the LiMPETS program to adaptively evovle through time. We look forward to continuing to work with the LiMPETS group in the South Coast region as they continue to refine their program, and we are committed to exploring new ways to engage the public to participate in ongoing scientific research and monitoring.

Supplemental Results

In addition to the results of our sampling of abundance and sizes of organisms across the SCSR, we also provide here a section of supplemental results that may be of interest in tracking long-term change or provide important context for evaluating MPA effects through time. The two additional areas that we focus on here are the vertical distributions of key ecosystem attributes and the impacts of sea star wasting disease.

Vertical Distributions of Key Ecosystem Attributes

As part of our biodiversity surveys we measure the topography of each site in addition to the abundances of all species. We measure elevation (in meters) above Mean Sea Level for each point in our sampling grid. Often there are clear patterns of vertical 'zonation' that arise due to changes in wave exposure, with many organisms occupying higher intertidal zones (and greater elevations) with increased wave exposure. We characterized the vertical elevation profiles for a set of important taxa, those identified as key attributes important as biogenic habitat of the rocky intertidal ecosystem as identified in the South Coast MPA monitoring plan across sites sampled during the baseline period (2012-2014). These key attributes include barnacles, *Egregia* (feather boa kelp), encrusting algae, foliose red algae, mussels, rockweeds, surfgrass, turf algae, and ochre stars. These are many of the iconic species that are functionally and ecologically important components of the ecosystem.

Mussels

The vertical distribution of mussels varied widely across the SCSR from -1.4m to 3.2m above MSL (Figure 43). The geographic gradient in mussel elevation was somewhat patchy from the northwest to the southeast.

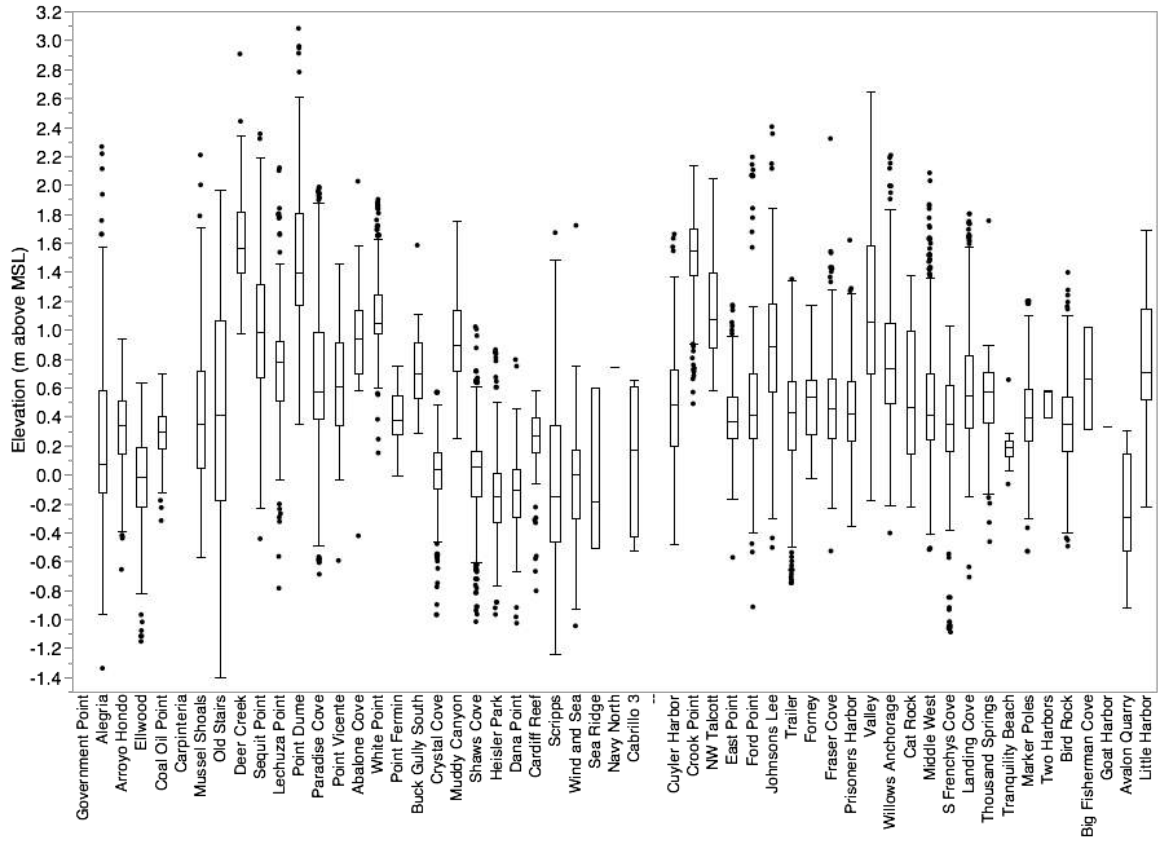

Figure 43 Vertical distribution of mussels across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Barnacles

The distribution of barnacle elevations across spaced tended to be slightly higher than that for mussels, but also occupying a wide range from -1.5M to 3.5m above MSL (Figure 44). Barnacle elevations generally tended to decline from north to south among both mainland and island sites, potentially due to differences in either wave exposure or physical stress differences associated with emersion time.

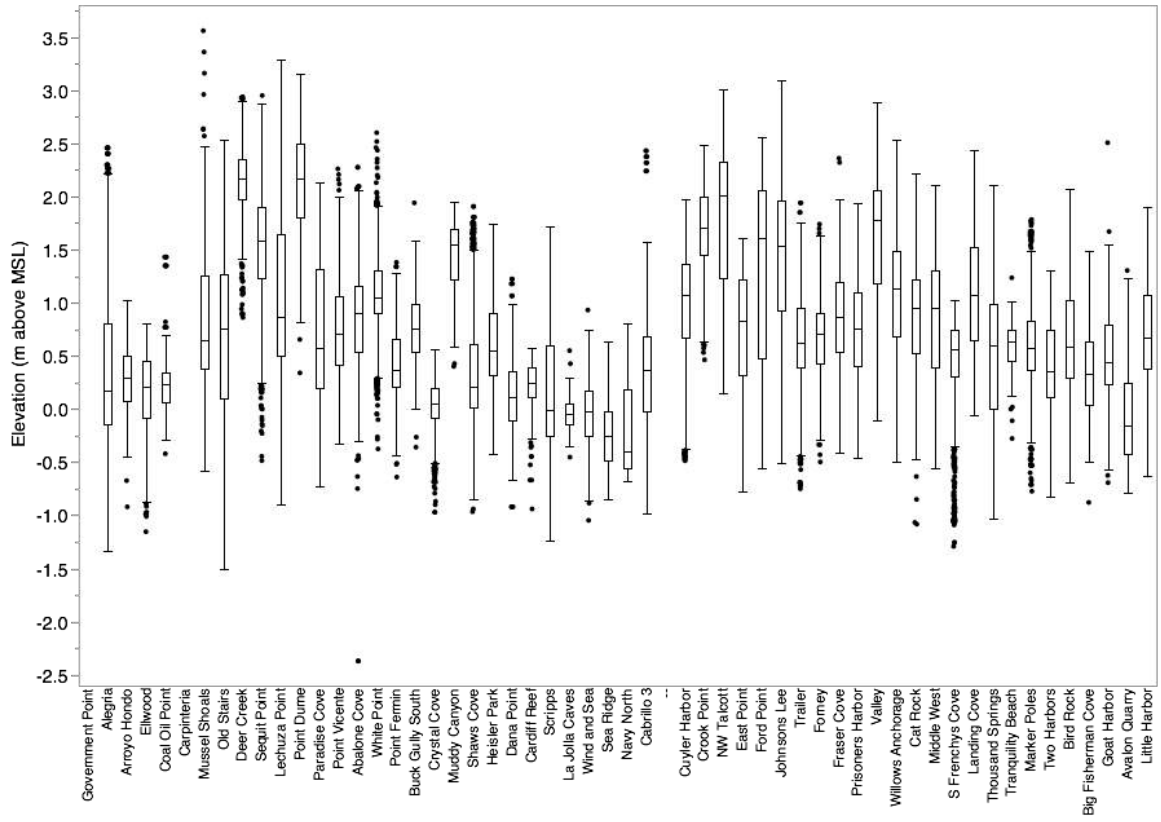

Figure 44 Vertical distribution of barnacles across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Rockweeds

Rockweeds displayed a distinct gradient in elevation from northwest to southeast at sites along both the mainland and the islands. Rockweeds occupied an elevational range from -1.0m to 2.4m above MSL at sites across the SCSR (Figure 45).

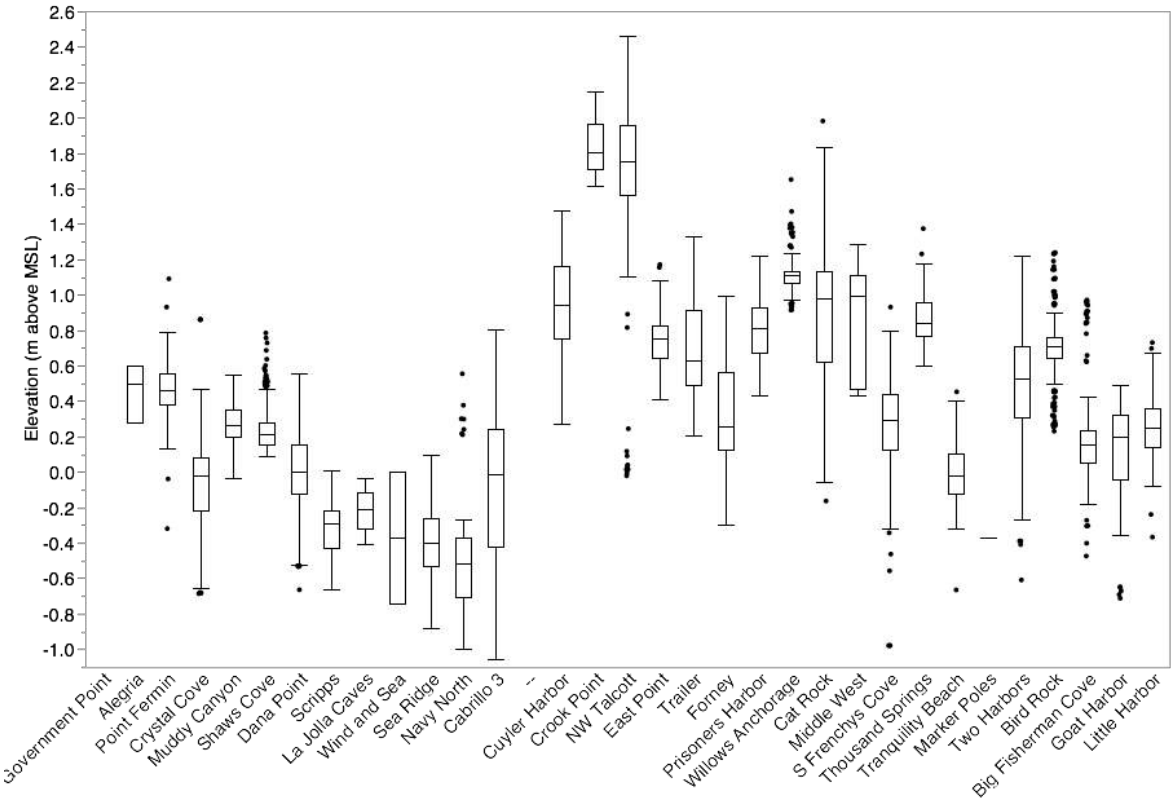

Figure 45 Vertical distribution of rockweeds across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Feather boa kelp (Egregia menziesii)

Egregia menziesii is a low intertidal species, and occupies a much lower vertical distribution than most other taxa (Figure 46). The vertical distribution of *Egregia* ranged from approximately -1.4m to 1.2m above MSL, with a clear declining trend in elevation from north to south at sites along the mainland, with the exception of sites in the Santa Barbara Channel, where *Egregia* was found only at the lower elevations.

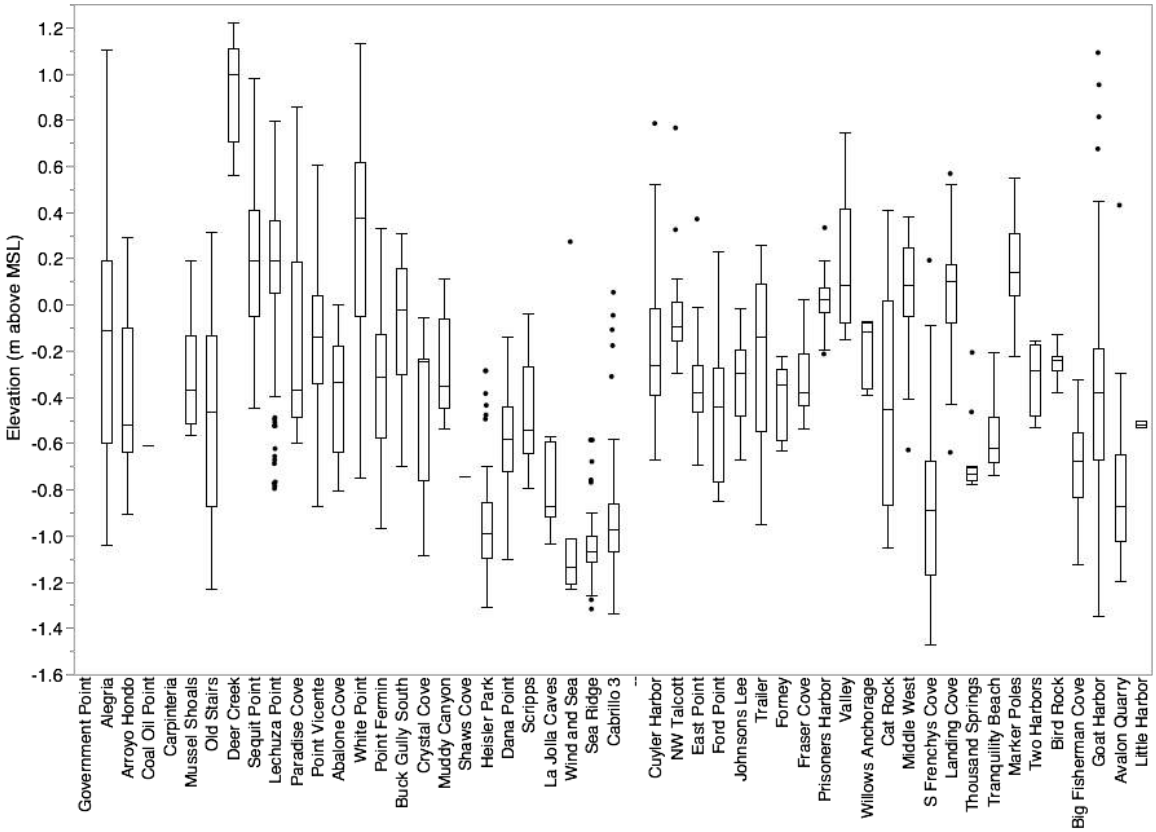

Figure 46 Vertical distribution of E*gregia* across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Surfgrass

Similar to *Egregia* surfgrass occupies a relatively low zone of the intertidal. The elevation range of surfgrass ranged from -1.6m to 1.6m above Mean Sea Level. Surfgrass did not display a strong gradient in elevation across the SCSR (Figure 47).

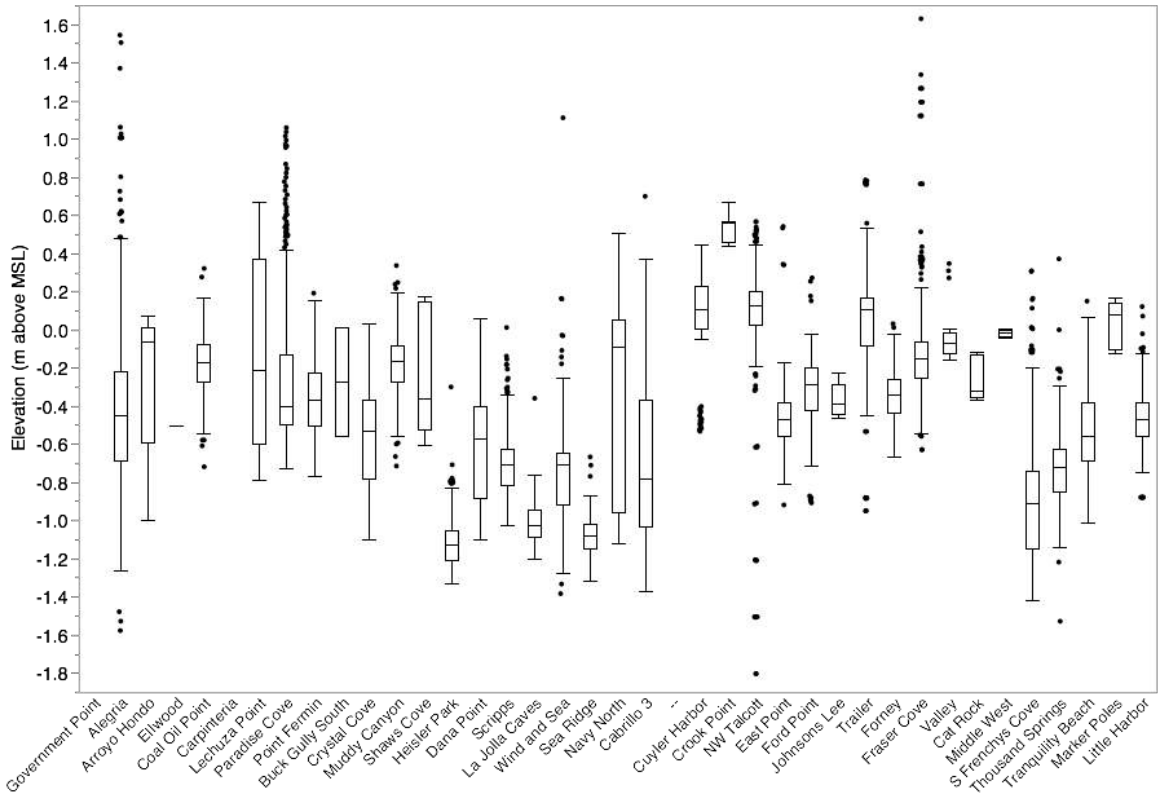

Figure 47 Vertical distribution of surfgrass across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Turf Algae

The distribution of turf algal elevations across space tended occupy a wide range from -1.8m to 3.2m above MSL (Figure 48). The turf algal group is composed of a broad suite of species, and turf algae as a group did not display a strong gradient in elevation across the SCSR.

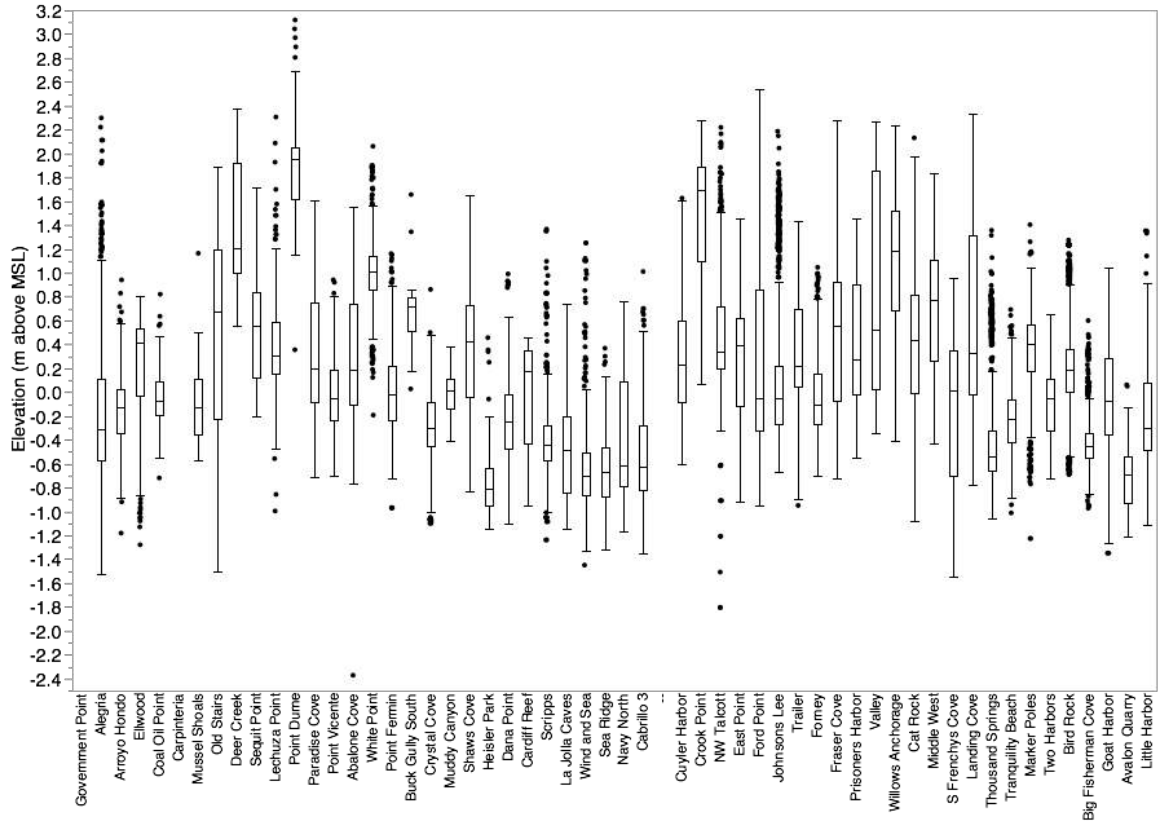

Figure 48 Vertical distribution of turf algae across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Foliose Red Algae

Foliose red algae were distributed slightly lower in elevation than turf algae and also tended occupy a wide range from -1.6m to 2.6m above MSL (Figure 49). The group of foliose red algae is composed of a broad suite of species, and foliose red algae as a group displayed a slight decline in elevation across the gradient from northwest to southeast.

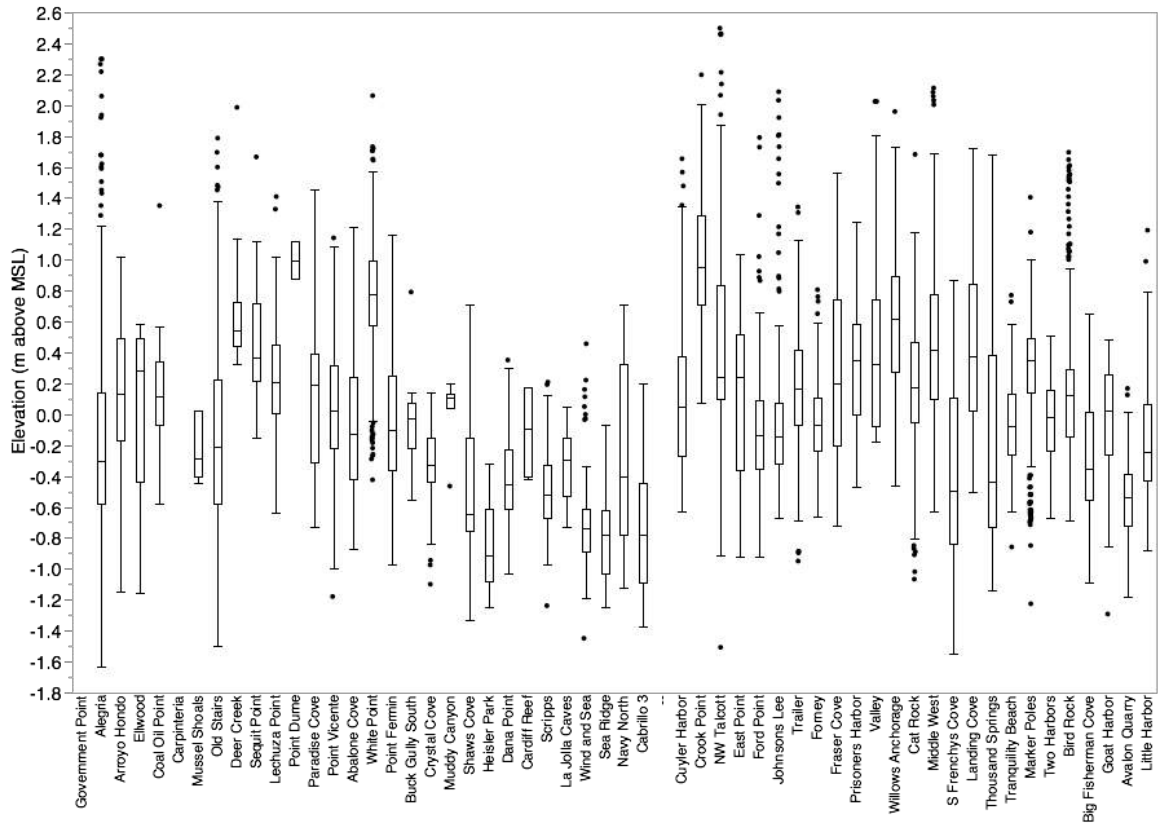

Figure 49 Vertical distribution of foliose red algae across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Encrusting Algae

The encrusting algal group also encompasses a broad array of species. Encrusting algae were distributed across a broad elevation range similar to that of turf algae from -1.6m to 3.2m above MSL (Figure 50). The encrusting algae as a group displayed a slight decline in elevation across the gradient from northwest to southeast.

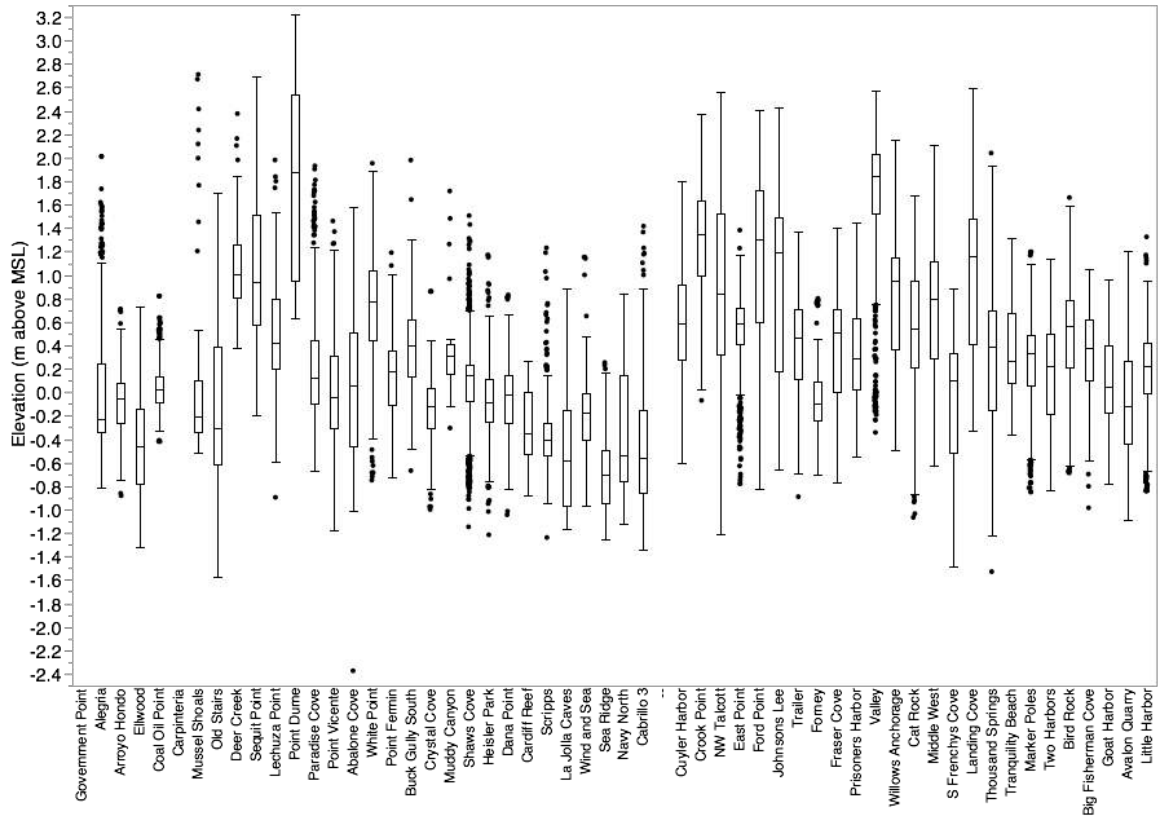

Figure 50 Vertical distribution of encrusting algae across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Ochre Stars

Although ochre stars are often found in the low intertidal, their elevations across space occupied a broad range from -1.4m to 2.4m above MSL. This group did not display a strong gradient in elevation across the geographic range (Figure 51).

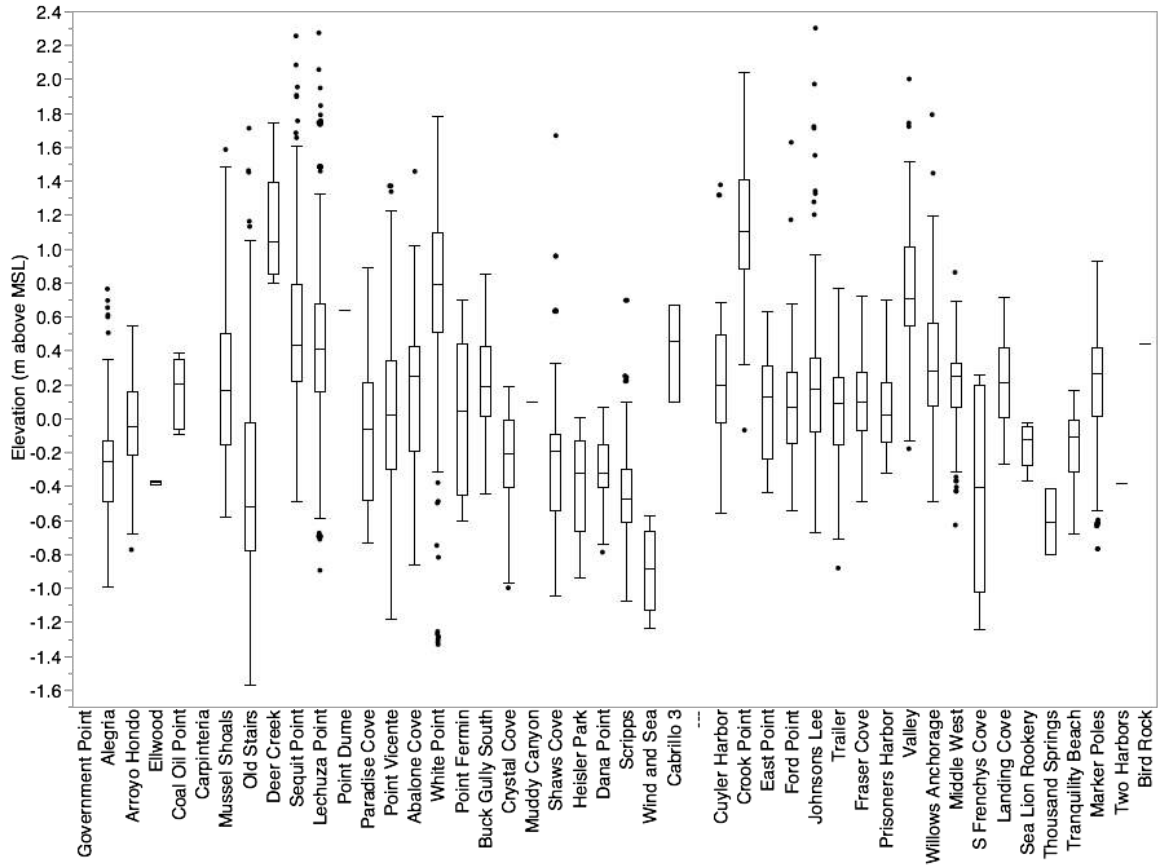

Figure 51 Vertical distribution of ochre stars across tidal elevations (meters above Mean Sea Level) across sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

Rapid Population Declines of Intertidal Sea Stars

One of the largest changes to rocky intertidal communities across southern California occurred during the end of the period of baseline sampling. Sea Star Wasting Disease (SSWD) spread across southern California in the winter of 2013-2014, resulting in the widespread declines in the populations of *Pisaster ochraces*, known to be important keystone predators in many southern California rocky intertidal communities. Here we document the state of knowledge of SSWD at the present time, and our initial sampling to characterize the spread of the disease, population declines and links to environmental conditions.

Sea Star Wasting Disease

Sea star wasting disease (SSWD) is a general description of a set of symptoms that are found in sea stars. Typically, lesions appear in the ectoderm followed by decay of tissue surrounding the lesions, which

leads to eventual fragmentation of the body and death. A deflated appearance can precede other morphological signs of the disease. All of these symptoms are also associated with ordinary attributes of unhealthy stars and can arise when an individual is stranded too high in the intertidal zone (for example) and simply desiccates. "True" wasting disease will be present in individuals that are found in suitable habitat, often in the midst of other individuals that might also be affected. The progression of wasting disease can be rapid, leading to death within a few days, and its effects can be devastating on sea star populations.

Throughout southern California, severe declines of *P. ochraceus* (and other sea star) populations have been documented in association with warm-water periods since 1978, with greatest losses during El Niño events such as occurred in 1982-1984 and 1997-1998 (Eckert et al. 1999). Population recovery, apparently due to cooler-water conditions and large recruitment events, has been documented in many, but not all areas (Blanchette et al. 2006, Raimondi et al. 2012). *P. ochraceus* wasting disease has recently been recorded as far north as British Columbia, also associated with high water temperatures (Bates et al. 2009). Sensitivity to oil spills is not well known, but Chan (1973) saw no obvious effects from a San Francisco oil spill.

The incidence and progression of wasting disease appear to be highly temperature sensitive. For instance, widespread mortality of several sea stars, including the original keystone species *Pisaster ochraceus*, occurred in association with unusually warm waters during the 1997 El Niño period in the Channel Islands (Eckert et al. 1999). A recent laboratory-based study also documented temperature- dependent mortality from wasting disease in a Mediterranean sea star, *Astropecten jonstoni* (Staehli et al. 2008). One severe case of sea star wasting disease was noted in *Heliaster kubiniji* in the Gulf of California in 1978 (Dungan et al. 1982). The species was virtually eliminated by the disease, and to date, recovery has not occurred at some sites in the Gulf of California where it used to be abundant. The sick and dead animals were coated with bacteria, but researchers were unsure if they were the culprit or just a secondary infection. The outbreak, researchers suggested, was likely related to strong winds that brought warm water into the gulf (Dungan et al. 1982). Bates et al. (2009) concluded that based on their experiments in the field and in the laboratory, increased temperature during immersion influences the progression and intensity of wasting disease in *Pisaster*, as has been reported for the Mediterranean sea star *Astropecten jonstoni* (Staehli et al. 2008). Thus, even relatively brief periods of elevated body temperature, as occur during periods of upwelling relaxation (Sanford 1999) and when warm weather coincides with daylight low tides (Helmuth et al. 2002, Harley 2008, Pincebourde et al. 2008), could result in large-scale disease outbreaks.

A recent study (Hewson et al. 2014) has identified a virus-sized microorganism as the most promising candidate disease agent responsible for SSWD. Hewson et al. (2014) found the sea star-associated densovirus (SSaDV) in greater abundance in diseased than in healthy stars, and found SSaDV in plankton, sediments and in non-asteroid echinoderms, providing a potential mechanism for disease spread. SSaDV was also detected in museum specimens of asteroids from 1942, suggesting that it has been present on the Pacific Coast of North America for at least 72 years. Although Hewson et al (2014) present strong evidence that SSaDV the most likely pathogen responsible for SSWD, many questions remain regarding the

environmental factors that may influence disease transmission and virulence, as well as the susceptibility of the host to disease.

Sea Star Natural History

The ochre sea star is the most commonly observed sea star in rocky intertidal ecosystems across the west coast of the US, and ochre sea stars are common in the middle to low intertidal zones on wave-swept rocky shores. Juveniles are cryptic and are often found in crevices, under rocks and within mussel beds. The geographic range of *Pisaster ochraceus* spans from Prince William Sound (Alaska) to Baja California, Mexico (Lamb & Hanby 2005). Ochre sea stars are highly variable in color; most commonly purple, but can also be orange, orange-ochre, yellow, reddish, or shades of brown. Ochre sea stars stand out in the intertidal due to their vibrantly contrasting color differences. Data from long term monitoring has shown a consistent color frequency of approximately 20% orange stars across a large geographic range of exposed coast (Raimondi et al. 2007). The underlying cause of color polymorphism in *P. ochraceus* is not fully understood, but it has been suggested that diet may play a key role (Harley et al. 2006). Average arm radius in CA/OR is around 9 cm (Harley et al. 2006, Raimondi et al. 2012) but can reach 3x this size. Individuals usually have 5 arms but this can vary from 4 to 7. Aboral surfaces have many small white spines arranged in detached groups or in a reticulate pattern, generally forming a star-shaped design on central part of disk (Morris et al. 1980). Tube feet on the undersides of arms have suckers that allow them to remain attached to rock in high wave energy shores.

Pisaster ochraceus is a broadcast spawner, with fertilization occurring in the water and development resulting in a free-swimming, feeding larva (Morris et al. 1980). These sea stars are able to regenerate arms that are lost and are thought to live up to 20 years (Morris et al. 1980). Ochre stars have few predators, but seagulls and sea otters occasionally eat them, and they are often collected by curious tidepool visitors due to their striking colors. *Pisaster ochraceus* sea stars have long been referred to as keystone species in the rocky intertidal (Paine 1966, Menge 2004) and, while they are known to have a wide diet (including barnacles, snails, limpets, and chitons), mussels are their primary prey items on the open coast (Morris et al. 1980, Harley et al 2006). Interactions between ochre stars and their prey have been well researched, especially the role of *P. ochraceus* in determining the lower limit of northern mussel beds (Paine 1966, 1974; Dayton 1971). A study examining the effect of low tide body temperature of *P. ochraceus* on feeding rates showed that aerial body temperatures experienced by *P. ochraceus* can have profound effects on predation rates (Pincebourde et al. 2008).

Sea stars vary widely in their abundance across southern CA. Figure 52 shows an average (across all sample years) density of sea stars (number per meter^2) per site. Sites are color coded by MPA status. Sea star abundance tends to be greatest at sites in the north mainland area, as well as several of the more northern and cooler water island sites.

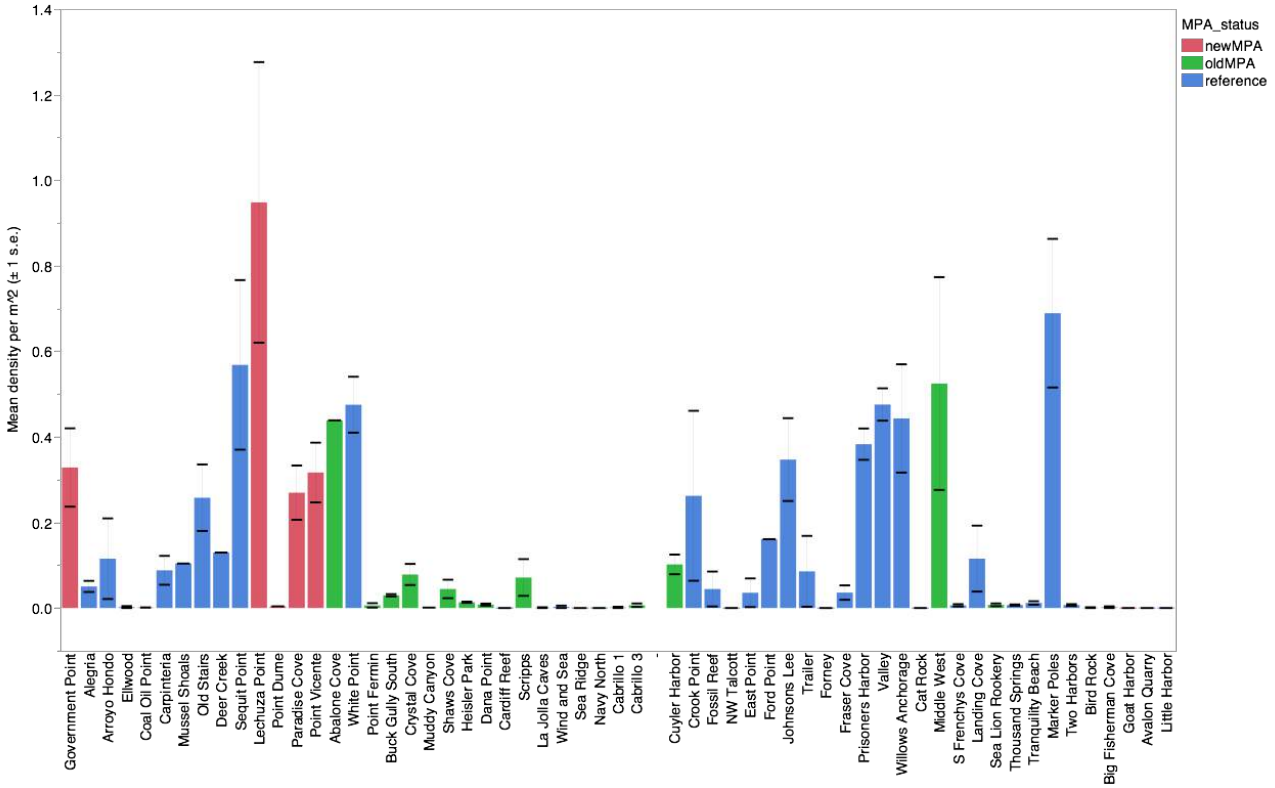

Figure 52 Mean abundance (across all years of surveys) of sea stars (number per meter^2) at all sample sites arranged in order along the x-axis from northwest to southeast, with a separation between mainland and island sites

2013-2104 Sea star wasting syndrome event

In June 2013, biologists at Olympic National Park in Washington noticed lesions and signs of illness in more than 25% of the sea stars at Starfish Point, a site located on the outer coast of Washington. More than a quarter of the point's sea stars were dotted with lesions or other signs of illness. Shortly thereafter, scientists in British Columbia and the Puget Sound noted high numbers of dead and dying sea stars across a range of sea star species. The MARINe group has mapped and continues to update the locations and spread of the disease at http://sea starwasting.org. MARINe monitoring groups have since documented wasting in *Pisaster ochraceus* from Alaska through California (see wasting map for specific locations). Two common attributes for many of the sites are: (1) the period prior to wasting was characterized by warm water temperatures, and (2) the effects are dramatic – the onset of disease and death can occur extremely rapidly, within days. Similar die-offs have occurred before in the 1970s, 80s, and the 90s, but never before at this magnitude and over such a wide geographic area.

The majority of early observations were made in intertidal habitats and as a result most of the early reports were for ochre stars, the most common in the habitat, but others species affected include the mottled star (*Evasterias troschelii*), leather star (*Dermasterias imbricata*), and six-armed stars (*Leptasterias*). In subtidal habitats, the sunflower star is typically the first species to succumb, followed by the rainbow star

(*Orthasterias koehleri*), giant pink star (*Pisaster brevispinus*), giant star (*Pisaster giganteus*), mottled star, ochre star and sun star (*Solaster*), leather star (*Dermasterias imbricata*), vermilion star (*Mediaster aequalis*), six-armed stars, and bat star (*Patiria miniata*). We do not know whether the syndrome spreads sequentially from one species to the next, or if some species simply take longer to express symptoms, but the usually large populations of ochre and sunflower stars have experienced massive, geographically expansive (if patchy) and well-documented declines. Other species are less abundant, so the impact of the syndrome is not as clear.

Southern California Sea star Wasting Syndrome Sampling

Based on the observations of sea star wasting at other CA sites in the fall of 2013, we monitored sites near Santa Barbara (Coal Oil Point, Alegria and Carpinteria) in the fall of 2013 to look for the presence of diseased individuals. We did not observe any diseased sea stars at our local sites until January 2014, although there have been other reports of small numbers of diseased sea stars at other southern California sites in November and December 2013. We first observed diseased individuals at Coal Oil Point in early January 2014, and decided to re-sample a subset of our SCSR sites using the swath protocols from our baseline surveys to document effects on sea star populations at sites where we had baseline data immediately before the onset of the disease in order to document population-level effects of SWS in southern California.

Given the limited time and resources to extend our sampling efforts, we chose to focus on sites that were spread across southern CA, and sites where we had existing baseline data, focusing on those sites where sea stars were reasonably abundant, or sites that were easily accessible. Our quantitative survey data are supported by qualitative observations from colleagues and our own informal surveys during low tide periods that were not sufficiently low to establish a sampling grid to accurately survey sea stars across the entire site. Our initial observations of small percentages of infected sea stars at sites in the northern region of the SCSR are supported by observations from colleagues and informal observations from citizen scientists at sea starwasting.org. Our own observations and those of colleagues indicate that SWS was not present at any of the island sites prior to 2014. Additionally, southern island sites and sites near San Diego were not significantly affected by disease until April 2014. Based on our collective observations, and our limited sampling data, the general pattern of disease spread appeared to move from northwest (Pt. Conception) to southeast (San Diego and the southern islands) from late 2013 to April 2014. By May 2014 sea star populations at most sites had declined to zero to few individuals. Since May we have observed that the remaining few sea stars at sites where populations were not completely decimated (e.g. Scripps), seem to be persisting. We have also observed recruitment of young sea stars, particularly at Sequit and Lechuza Points, on the Malibu coast.

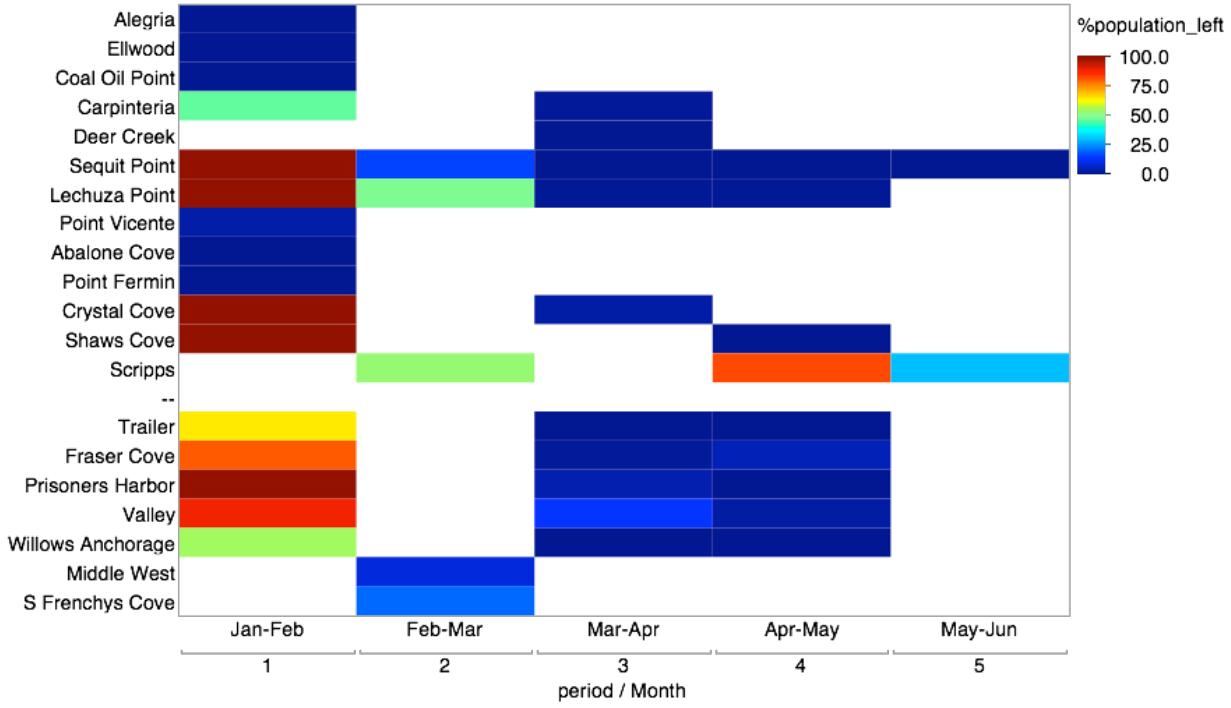

Figure 53 Heatmap depicting the percentage of the 2012-2013 baseline sea star abundance surveyed in identical sample grids at each site through time. Colors represent percentages from 100 (darkest red) to 0 (darkest blue).

Figure 53 shows the results of our quantitative swath sampling at a subset of sites across the SCSR in early 2014. The sampling periods are divided into 5 monthly periods spanning from mid-month to mid-month (e.g. Jan 15 to Feb 15). At sites where populations declined to zero, or near zero, we generally discontinued sampling, and focused on sites where sea stars were still present. In our first sample period (Jan-Feb 2014) sea stars were generally still abundant at sites in Malibu and Orange county, but populations at all sites along the Santa Barbara coast had crashed to zero by the time of our sampling, with the exception of Carpinteria (sampled in February), where sea stars were still somewhat abundant. Sea star populations on Santa Cruz Island had significantly declined at several sites around the island in this first sampling period. We also recorded the percentages of diseased individuals at each site as part of these surveys.

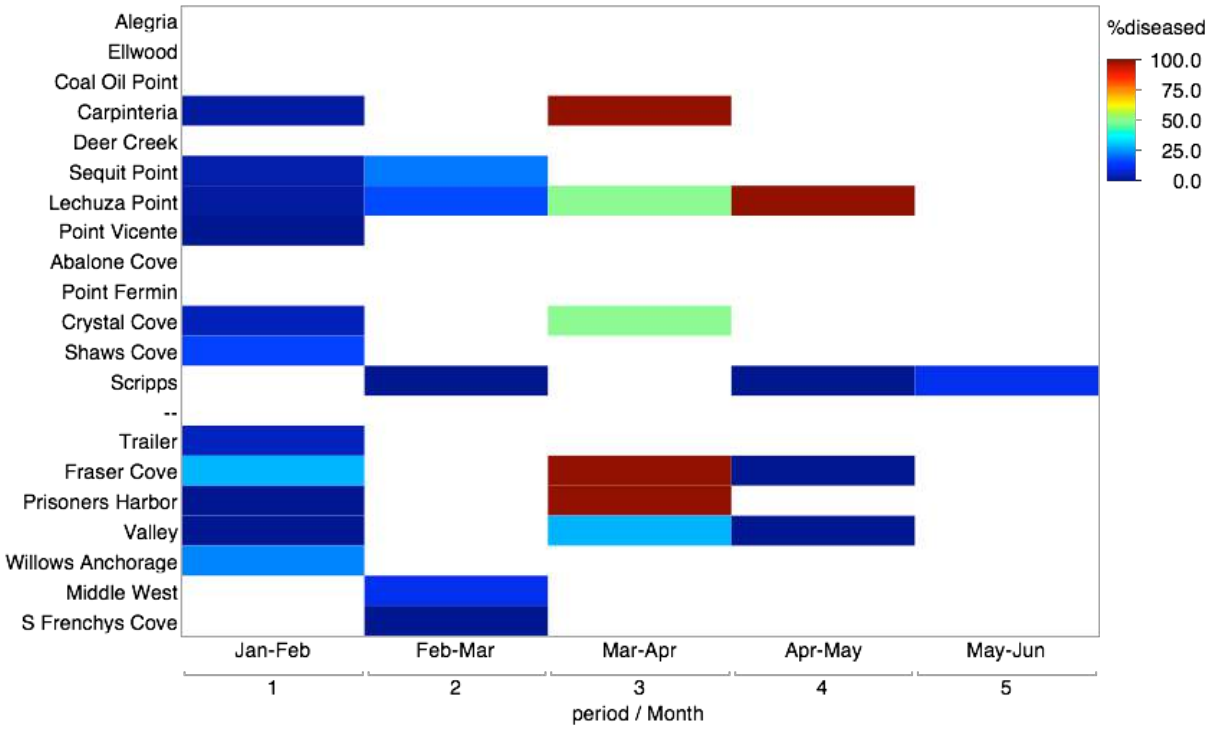

Figure 54 Heatmap depicting the percentage of the sea stars at each of the survey sites that exhibited symptoms of disease. Colors represent percentages from 100 (darkest red) to 0 (darkest blue).

Figure 54 shows the percentages of diseased sea stars at each of the survey sites over time. The observations of diseased individuals supported our observations that population declines of sea stars across the SCSR were largely driven by SWS. The lack of data on percentage of diseased sea stars at some sites was due to the rapid population declines of sea stars at some sites, where they were all absent by the time of our sampling. We suspect that the low percentages of diseased stars at many of the sites in the early months of 2014 is driven by our own observations (in the lab and field) of rapid death of sea stars immediately following observable symptoms of disease (in some cases, hours to days). Infected sea stars likely died and disappeared before we could document their occurrence in our surveys. The relatively high proportions of diseased sea stars in the March to April period is driven mostly by the low population sizes at any of the sites that still had sea stars by this time period. The majority of the few remaining sea stars at this time at these sites were diseased. Overall these data from the swath surveys support our observations of rapid population declines across the south coast region from January 2014 to May 2014.

Based on the significance of temperature in all other SWS events that have been documented over time, and the significant temperature effects in SWS field and laboratory experiments, we explored ocean temperatures across southern California before and during the acute phase of SWS in southern CA (January to April 2014). To visualize spatial patterns of temperature during these periods we created monthly average temperature plots from the 15-day composited MODIS satellite temperature at 1 km resolution.

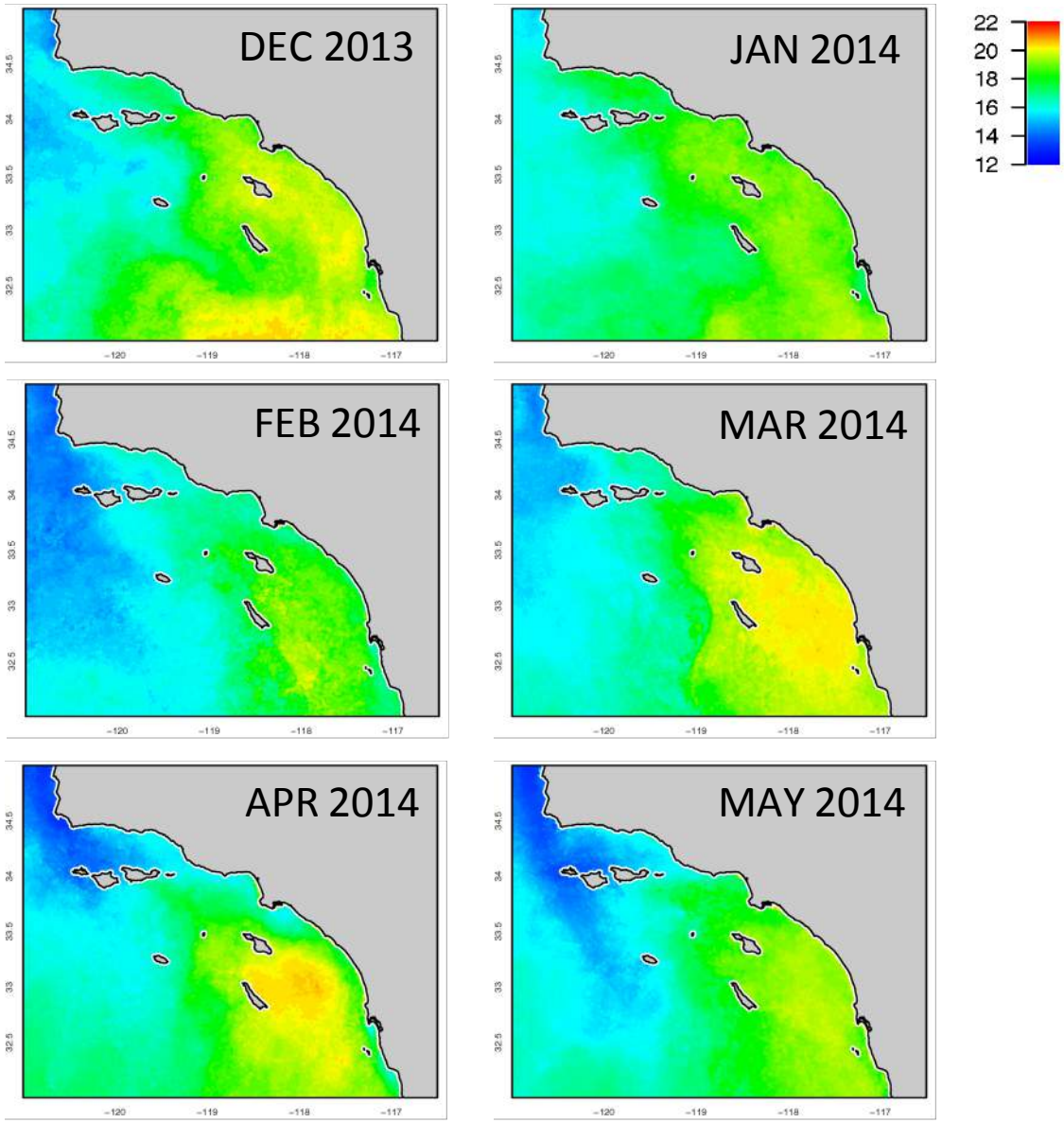

Figure 55 Monthly mean sea surface temperatures across the southern CA region during the time period from December 2013 to May 2014

Figure 55 shows average monthly sea surface temperatures across the southern CA region during the time period from December 2013 immediately before the onset of SWS in southern CA to May 2014 the time by which most sea star populations had declined to near zero as a result of SWS. This time period from December 2013 to May 2014 is generally winter in southern California, and temperatures are not as warm as would be expected for summer conditions (when most SWS events have been observed). To evaluate if these winter temperatures were warmer than would be expected for normal winter conditions, we created anomaly plots based on the difference between each of the months from December 2013 to May 2014 and the long-term monthly means based on all available satellite images in the MODIS dataset. We created long term monthly average SSTs for December, January, February, March, April and May based on satellite

images from 2000 to 2012-2013. We then subtracted each of the monthly periods from December 2013 to May 2014 from their respective monthly long-term means to create monthly anomaly plots. These plots represent the spatial distribution of cooler or warmer than average temperatures across southern California during this time period.

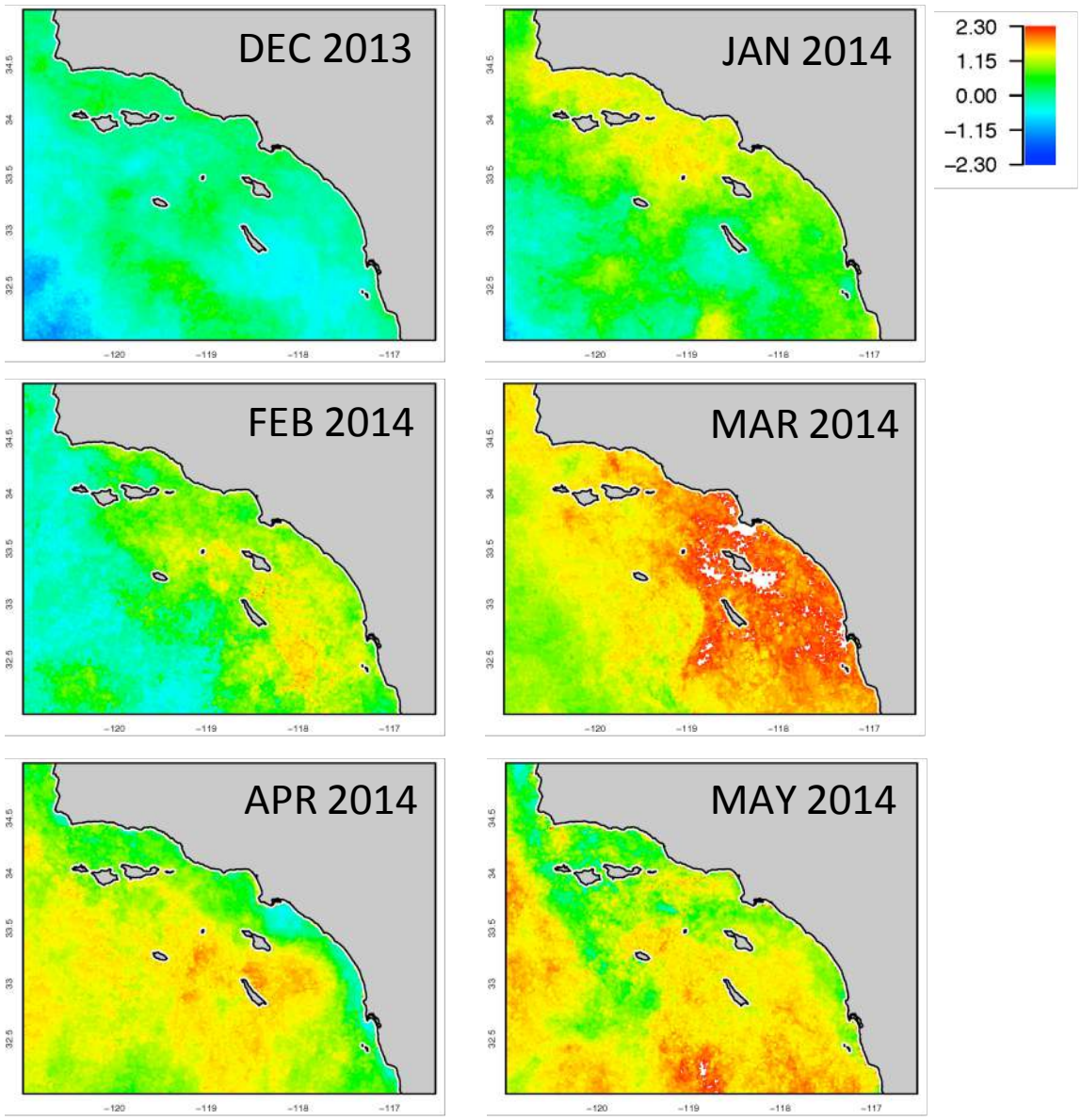

Figure 56 Monthly mean SST anomalies across southern CA from December 2013 to May 2014.

The monthly anomaly plots (Figure 56) indicate that temperatures across southern CA were not unusually warm until January 2014 when a large section of the coastal region in the northern part of the region became unusually warm. This unusually warm water then appeared in the southern and southern island regions in February. March 2014 was an exceptionally warm month across all of southern CA. By April, unusually warm water persisted in the southern islands, but temperatures along much of the mainland coast

returned to normal or even cooler than normal conditions. Although we have no evidence for the mechanism by which unusually warm water could cause or facilitate the spread of disease, the correlation between onset and spread of SWS across southern California and the distribution of temperature anomalies during this time period is consistent with the previously documented links between SWS and temperature, and the possible role of temperature or some environmental stress as a contributor to the rapid populations declines in *Pisaster ochraceus* following the onset of SWS in southern California.

Historical and Contextual Information

The MPAs of the SCSR went into effect January 1, 2012, and here we consider the period of time from 2012 (the start of our project) to 2014 (our last year of sampling) to be the baseline period of characterization for the Rocky Intertidal Ecosystems of the SCSR. Since this period of time sets the stage for the baseline characterization, it is important to understand the environmental context in which this baseline characterization is based. Here we provide information on variability through time in four of the dominant environmental drivers to provide a relative baseline for the contextual environmental conditions during the baseline period relative to recent decades.

PDO

The Pacific Decadal Oscillation (PDO) Index is defined as the leading principal component of North Pacific monthly sea surface temperature variability (poleward of 20N for the 1900-93 period). The Pacific Decadal Oscillation (PDO) is often described as a long-lived El Niño-like pattern of Pacific climate variability (Zhang et al. 1997). As seen with the better-known El Niño/Southern Oscillation (ENSO), extremes in the PDO pattern are marked by widespread variations in the Pacific Basin and the North American climate. In parallel with the ENSO phenomenon, the extreme phases of the PDO have been classified as being either warm or cool, as defined by ocean temperature anomalies in the northeast and tropical Pacific Ocean. When SSTs are anomalously cool in the interior North Pacific and warm along the Pacific Coast, and when sea level pressures are below average over the North Pacific, the PDO has a positive value. When the climate anomaly patterns are reversed, with warm SST anomalies in the interior and cool SST anomalies along the North American coast, or above average sea level pressures over the North Pacific, the PDO has a negative value (Mantua, 1999). Since the early 2000s, the PDO has been in a neutral to cool phase, however, based on previous cycles, we may expect the PDO to return to a warm phase in the near future (Figure 57).

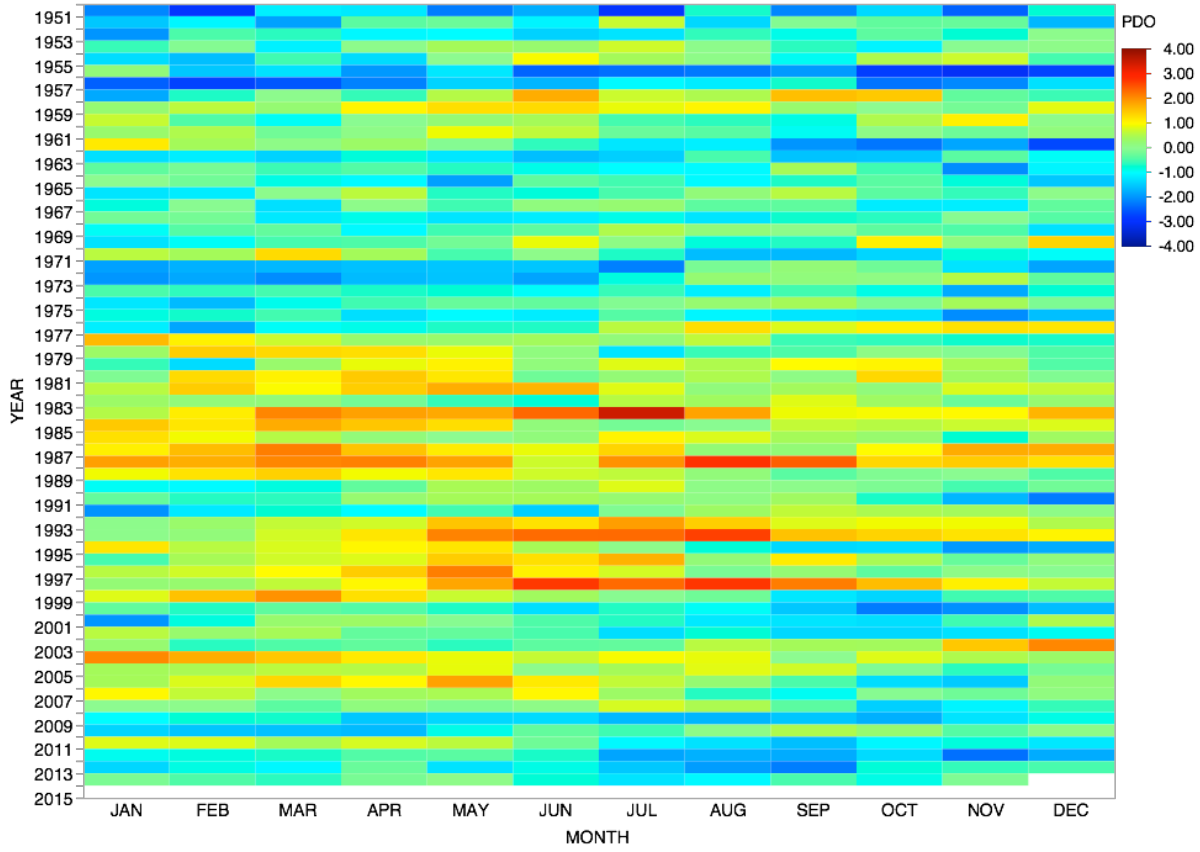

Figure 57 Monthly values of the PDO Index from 1950 to 2013

NPGO

The North Pacific Gyre Oscillation (NPGO) is a climate pattern that emerges as the 2nd dominant mode of sea surface height variability (2nd EOF SSH) in the Northeast Pacific (Di Lorenzo et al. 2008). Along the coast the atmospheric forcing associated with both the PDO and NPGO control decadal modulation of the upwelling cells, resulting in non-spatially-uniform responses of coastal upwelling. The PDO signal is strong north of 38N and the NPGO is strong south of 38N along the California Current System. The PDO and NPGO are the oceanic expression of the two dominant modes of North Pacific atmospheric variability -- the Aleutian Low (AL) and the North Pacific Oscillation (NPO), which are linked to the different phases of the ENSO cycle. This variability leads to changes in the strength and position of the winds that run along the California Coast and work to “pull” a current of water from the depths. The NPGO is significantly correlated with previously unexplained fluctuations of salinity, nutrients and chlorophyll-a measured in long-term observations in the California Current (CalCOFI) and Gulf of Alaska. Compared to negative NPGO years, average end of winter water conditions during positive NPGO years feature nitrate concentrations that are about 25 percent higher, chlorophyll concentrations about 15 percent higher and zooplankton numbers that are about 20 percent higher. These nutrients and zooplankton feed commercially important fish species and

seabirds. The NPGO has been in a warm phase since around 2007, and a shift to a cooler phase is expected in the next few years (Figure 58).

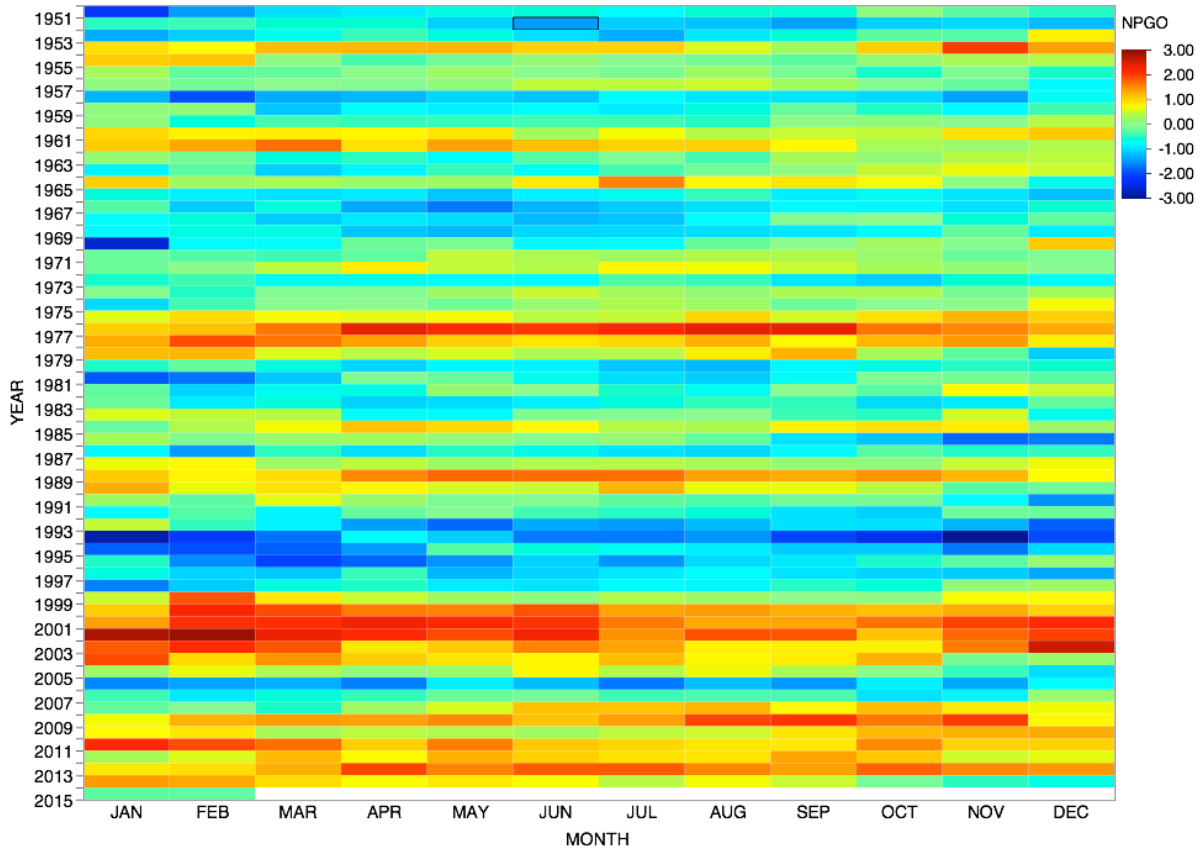

Figure 58 Monthly values of the NPGO from 1950 to 2014

MEI

The Multivariate ENSO Index (MEI) is probably the best-known climate index, and is particularly important in southern California, where El Niño and La Niña events have been shown to have significant impacts on coastal ecosystems. El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. The Multivariate ENSO Index (MEI) is based on the first un-rotated Principal Component (PC) of six main observed variables over the tropical Pacific. These six variables are: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). Positive phases of the MEI are associated with El Niño like conditions, and negative phases typify La Niña conditions. The baseline period of 2012-2014 has generally been characterized by neutral to weak ENSO conditions, with the prediction for a weak to moderate El Niño set to begin in fall 2014 (Figure 59).

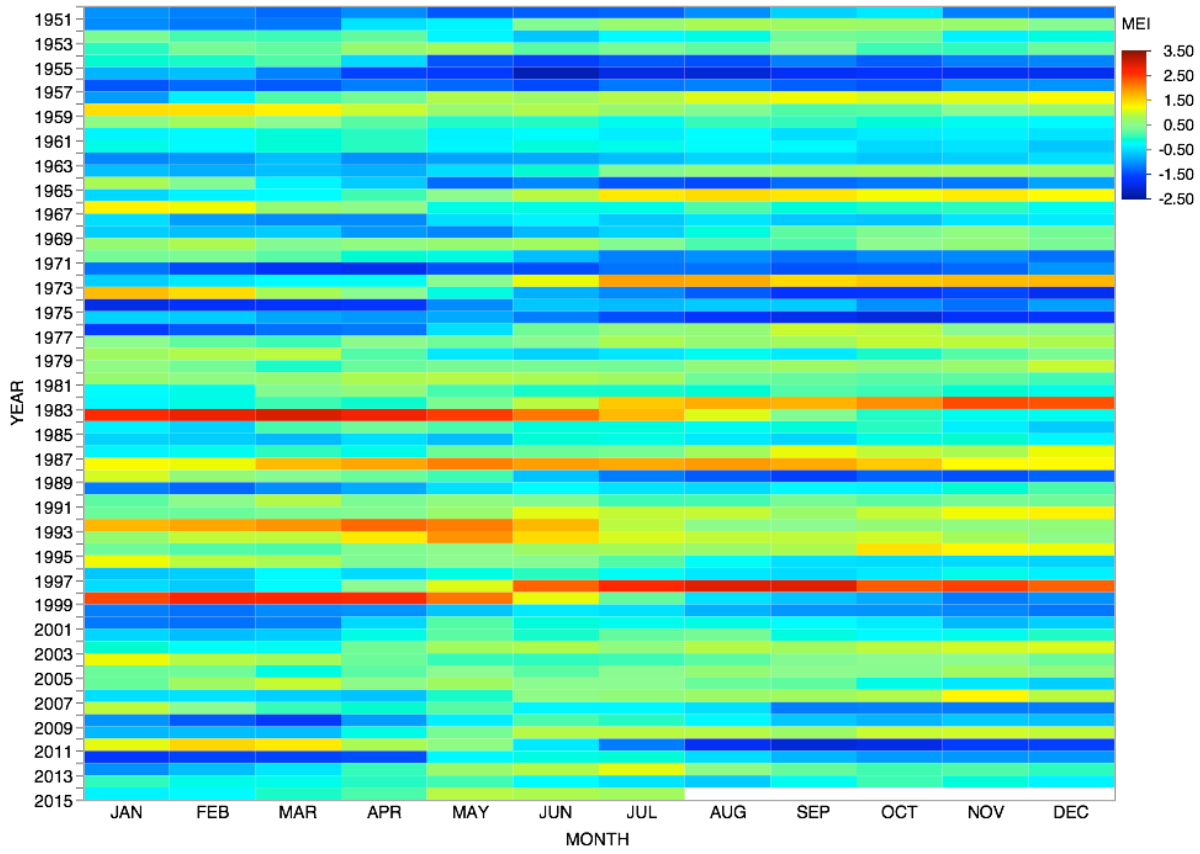

Figure 59 Monthly values of the MEI from 1950 to 2014

Upwelling Index

Upwelling is a dominant and important process along the California coast. Scientists at the Pacific Fisheries Environmental Laboratory (PFEL) generate monthly indices of the intensity of large-scale, wind-induced coastal upwelling at 15 standard locations along the west coast of North America. The indices are based on estimates of offshore Ekman transport driven by geostrophic wind stress. PFEL coastal upwelling indices are calculated based upon Ekman's theory of mass transport due to wind stress. Assuming homogeneity, uniform wind and steady state conditions, the mass transport of the surface water due to wind stress is 90° to the right of the wind direction in the Northern Hemisphere. Ekman mass transport is defined as the wind stress divided by the Coriolis parameter (a function of the earth's rotation and latitude). Ekman transports are resolved into components parallel and normal to the local coastline orientation. The magnitude of the offshore component is considered to be an index of the amount of water upwelled from the base of the Ekman layer. Positive values are, in general, the result of equatorward wind stress. Negative values imply downwelling, the onshore advection of surface waters accompanied by a downward displacement of water. The upwelling indices shown in Figure 60 are based on data for southern California from the 33 degrees N latitude station. The seasonal cycle of upwelling is apparent in Figure 60. The baseline period was characterized by a typical seasonal pattern of upwelling, with strong upwelling during May and June 2012.

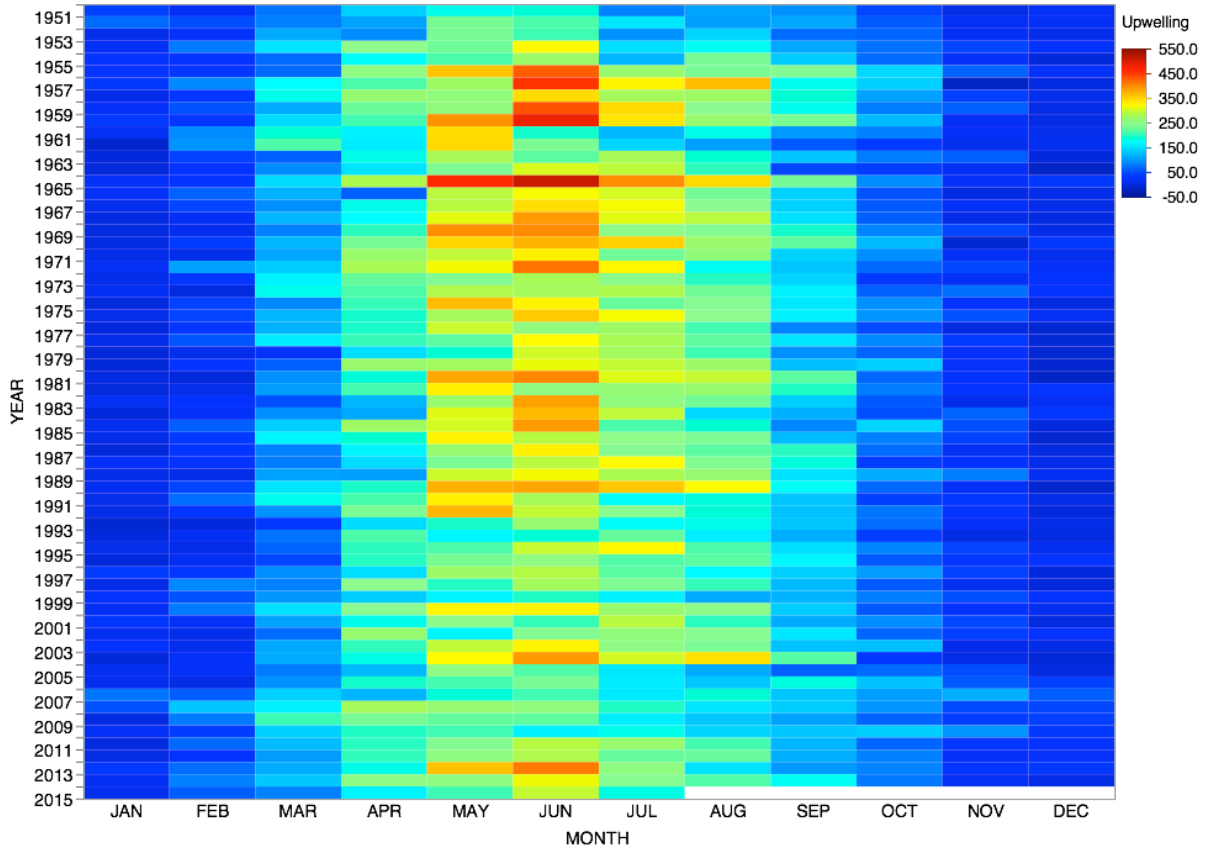

Figure 60 Monthly values of the PFEL Upwelling Index from 1950 to 2014

Integration

The concept of Ecosystem Based Management is rooted in this holistic view of ecosystems, and the idea that ecosystems should be adaptively managed, and decision-making should be informed by the best available scientific information. These ideas lie at the heart of the monitoring and management plans for the network of Marine Protected Areas (MPAs) across the state of California. Meeting the requirements of the MLPA means taking an ecosystems approach to monitoring in which ecosystems are the top level of the monitoring hierarchy and provide the umbrella that encompasses species, populations, habitats and humans. Although many marine habitats and their constituent communities have been extensively studied along the coast of California (e.g. kelp forest, rocky intertidal) studies of how these habitats are linked via species (e.g. birds, fish) that utilize multiple habitats within the ecosystem are rare. Information about the non-consumptive roles of humans in these coastal ecosystems is also relatively lacking, particularly in the context of how these systems might best be monitored in the future to meet a broad array of goals.

Here we provide a brief summary of the areas in which data from our South Coast Rocky Intertidal Baseline Project are being used to address integrative issues, beyond the Rocky Intertidal Ecosystem, and involving data collected across other South Coast MPA Baseline Projects.

1. Biogeographic patterns of communities across multiple marine ecosystems in southern California

Title of Proposed Paper: "Biogeographic patterns of communities across multiple marine ecosystems in southern California"

Authors: *Jeremy Claisse, Carol Blanchette, Jennifer E. Caselle , Jonathan P. Williams, Daniel J. Pondella, Laurel A. Zahn, Chelsea M. Williams, Jenifer Dugan, James Lindholm, Ashley Knight, Dan Robinette, Meredith Elliott, Rani Gaddam, Katie Davis*

Abstract

With the implementation of ecosystem based management approaches becoming more common, broad scale questions are increasingly dominant in conservation and management, requiring marine ecologists to examine linkages between patterns and processes operating at large spatial scales across ecosystems. The Southern California Bight is a complex biogeographic region as it is a transitional zone between the cold temperate fauna fueled by the California Current to the north and the warm temperate fauna from the south. A large scale sampling effort in 2011 and 2012 created a novel opportunity to compare patterns in community structure across multiple community and ecosystem types. Here we used non-metric multidimensional scaling analyses to quantify spatial patterns of community structures in eight different community types (rocky intertidal invertebrates, sandy beach invertebrates, shorebirds, kelp forest fishes, kelp forest invertebrates, deep water fishes, deep water benthic invertebrates, juvenile fishes indexed through Least Tern diet) which inhabit multiple marine ecosystems across this region. We found a high degree of spatial structure in the similarity within and across these communities. Patterns related to the complex environmental gradients that occur across the region, but key differences were revealed among some community types which have important implications for the scales at which they are managed.

2. Coastal Recreation Valuation

Title of Proposed Paper: "Beachgoers of a Feather Flock Together: Ecosystem Service Valuation for Coastal Recreation in Southern California"

Authors: *Noah Enelow, Mike Mertens, Cheryl Chen. Aaron McGregor, Taylor Hesselgrave, Matt Perry and Nick Lyman*

Abstract: Coastal recreation is an important activity to residents in Southern California. Yet the very features that make coastal recreation attractive are often threatened by its popularity. Economic development and land use pressures have created significant impacts on key environmental attributes such as water quality and marine mammal, seabird and fish habitat. This study examines the preferences of the Southern California coastal recreation population for specific environmental attributes with relevance to the process of marine protected areas (MPA) planning, including mammal haulouts, seabird colonies, shoreline type and fishing access, while controlling for amenities and economic development variables. We use an innovative method of spatial clustering to define sites based on patterns of user behavior, thereby avoiding the

Modifiable Areal Unit Problem (MAUP). Our results reveal that specific groups of recreational users are willing to pay (WTP) significant positive amounts for proximity to environmental attributes of interest to MPA planners and coastal managers.

3. Citizen Science

Title of Proposed Paper: "Citizen science monitoring of marine protected areas: case studies and recommendations for integration for among monitoring programs".

Authors: *Jan Friewald, Jennifer Caselle, Ryan Meyer, Doug Neilson, Kevin Hovel, Dina Liebowitz, Carol Blanchette, Jenny Dugan, and Julie Bursek.*

Ecosystem-based management and conservation approaches such as marine protected areas (MPAs) require large amounts of ecological data to be implemented, adaptively managed towards their goals and in order to evaluate their achievements or failures. Implementation of MPAs under the Marine Life Protection Act (MLPA) Initiative in southern California was followed by a monitoring program to establish a comprehensive baseline of marine ecosystems at the time of MPA implementation. The baseline monitoring consortium involved several citizen science monitoring programs alongside more traditional academic monitoring programs. We are investigating different citizen science models and their program goals with respect to their involvement in MPA baseline monitoring and examine their respective monitoring protocols and data quality assurance measures in light of the goals of the MLPA baseline monitoring program. We focus on three case studies: volunteer divers monitoring rocky reefs with the Reef Check California (RCCA) program, high school students monitoring rocky intertidal and sandy beach ecosystems with the LIMPETS program, and commercial fishermen and other volunteers collaborating with researchers to study the California spiny lobster. Through analysis of the experiences from each of these very different projects, and drawing on broader literature focused on citizen science, we elucidate capacities and potential of citizen science approaches for MPA baseline monitoring and for building capacity towards sustainable long-term monitoring of MPAs. In two of the three cases, comparison with academic monitoring programs surveying the same ecosystems, kelp forests and rocky intertidal, will inform recommendations for best practices for citizen science MPA monitoring and the creation of a framework of what types of monitoring questions can be addressed by citizen science. Results from this study will be relevant and timely as the monitoring of California's MPAs transitions from baseline to long-term monitoring, and as citizen science continues to becoming more prevalent in California and elsewhere in marine ecosystem monitoring.

4. Extensions, Invasions and Rarities

Title of Proposed Paper: "Where The Weird Things Are: A synthesis of range extensions, rarities, invasive species encounters, and unique occurrences in the Southern California Bight as a product of South Coast MPA Baseline Monitoring projects"

Authors: *Jonathan Williams et al. TBD.*

The Southern California Bight (SCB) spans a significant environmental gradient and is subject to the influx and removal of species based upon subtle regional changes as well as large-scale changes in climate and oceanographic conditions. Past reports of new or unusual species to the SCB were typically a product of large-scale oceanographic phenomena such as El Niño/Southern Oscillation events, increases in invasive species vectors through port expansion, new technologies, and stocking efforts, or simply a product of motive and opportunity. The opportunity to observe and document a unique or rare species across the entirety of the bight presented itself with the establishment of marine protected areas (MPAs) in southern California and the subsequent baseline monitoring program for those newly established MPAs. Here we describe range extensions and unique occurrences of several species of marine fish, invertebrates, algae and birds as observed during the 2011-2012 South Coast MPA Baseline Program as well as other recent monitoring efforts.

5. Distribution of Birds as a Higher Trophic level Indicators

Title of Proposed Paper: "Distribution of birds as high trophic level indicators"

Authors: *Jenifer Dugan, Dave Hubbard, Dan Robinette and Carol Blanchette*

Abstract: Higher trophic levels, as exemplified by shorebirds, can respond to prey resources in different ways depending on the foraging environment. Changes in the diversity, abundance and availability of key prey resources can strongly affect the composition and distribution of birds. Here we evaluate the responses of birds to variation in biodiversity, abundance and biomass of prey resources in two coastal ecosystems, sandy beaches and rocky shores, in southern California.

6. Improving classification success of aerial imagery

Title of Project: Nearshore Substrate Mapping and Change Analysis Using Historical and Concurrent Mulit-Spectral Aerial Imagery - Intertidal Habitat Classification Accuracy Assessment

Authors: Jan Svejkovsky and Mark Hess

Abstract: For this project we selected 16 of the South Coast Baseline Rocky Intertidal Biodiversity Survey sites to both aid in the creation of classification training sets and for the accuracy assessment described below. Each of the sites contained up to 1,100 biodiversity sampling points gridded inside survey bolts, which were located in the OI imagery and classifications using GPS locations. The field data were digitized as points in ArcGIS using the GPS locations of the survey site boundary bolts noted above and tied geospatially accurate base maps matching the corresponding locations in the mosaicked, georectified imagery and classification rasters. Conveniently, the points are spaced roughly 33cm apart which is a close match in spatial resolution to the 30cm imagery used to generate the classification products. The selection of the 16 sites was based on the field data sampling dates, the location as well as the grid/matrix set up of each site and how the transects overlaid on the classification data. This resulted in over 18,000 points available for use in training the classification algorithms and for the accuracy assessment. Roughly half of the survey data (roughly 8,450 points) were set aside for the accuracy assessment work and the other half used to guide the classification training sets. The field data were spatially compared to the image-derived classes. The

comparison results were then used to re-train the classifications to produce a more accurate product. Since the biodiversity survey points were much more specific in their identification of the substrate or vegetation type, the names/classes were grouped to match the equivalent class in the remote sensing-derived habitat classification. Next, over 8,450 of the biodiversity survey points selected were spatially joined in ArcGIS to the habitat classification raster for each survey site. This represented roughly half of the points for each site – the other half having been used in the classification process. Once the two databases were joined, each survey point corresponding to the pixel in the classification, the classes for each point were entered into the Congalton matrix to show the accuracy of the reference data to the image-derived classifications. Having a limited number of OI-collected photographs and field samples compared to the over 8,450 field sample points provided by the South Coast Rocky Intertidal Baseline Project offered both a unique and extremely valuable data set to aid in the assessment of the OI-Aerial habitat classification products.

References

Addessi, L. 1994. Human disturbances and long-term changes on a rocky intertidal community. Ecological Applications. 4:786-797.

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. In *2nd International Symposium on Information Theory* (B. N.Petrov and F.Csaki) Budapest :Akademia Kiado, pp. 267–81.

Ambrose, R.F. and J.R. Smith. 2004. Restoring rocky intertidal habitats in Santa Monica Bay. Technical Report for the Santa Monica Bay Restoration Commission.

Anderson, MJ, J Robinson. 2003. Generalized discriminant analysis based on distances. Australian & New Zealand Journal of Statistics 45 (3), 301-318

Anderson, MJ, TJ Willis. 2003. Canonical analysis of principal coordinates: a useful method of constrained ordination for ecology. Ecology 84 (2), 511-525

Anderson, MJ. 2001. A new method for non-parametric multivariate analysis of variance. Austral ecology 26 (1), 32-46

Bates AE, Hilton BJ, Harley CDG. 2009. Effects of temperature, season and locality on wasting disease in the keystone predatory sea star *Pisaster ochraceus*. Dis Aquat Org 86:245–251

Blanchette, C. A. and S. D. Gaines. 2007. Distribution, abundance, size and recruitment of the mussel, *Mytilus californianus*, across a major oceanographic and biogeographic boundary at Point Conception, California, USA. Journal of Experimental Marine Biology and Ecology 340:268-279.

Blanchette, C. A., B. G. Miner, and S. D. Gaines. 2002. Geographic variability in form, size and survival of Egregia menziesii around Point Conception, California. Marine Ecology-Progress Series 239:69-82.

Blanchette, C. A., B. R. Broitman, and S. D. Gaines. 2006. Intertidal community structure and oceanographic patterns around Santa Cruz Island, CA, USA. Marine Biology 149:689-701.

Blanchette, C. A., C. M. Miner, P. T. Raimondi, D. Lohse, K. E. K. Heady, and B. R. Broitman. 2008. Biogeographic patterns of rocky intertidal communities along the Pacific coast of North America. Journal of Biogeography 35:1593-1607.

Blanchette, C.A., P.T. Raimondi, and B.R. Broitman. 2009. Spatial patterns of intertidal community structure across the California Channel Islands and links to ocean temperature Pages 161-173 in Damiani, C.C. and D.K. Garcelon (eds.) *Proceedings of the 7th California Islands Symposium* Institute for Wildlife Studies, Arcata, CA.

Bonnet, E. & Van De Peer, Y. 2002. Zt: A softtware tool for simple and partial mantel tests. *Journal of Statistical Software*, **7**, 1-12.

Branch, G.M. 1975. Notes on the ecology of *Patella concolor* and *Cellana capensis*, and the effect of human consumption on limpet populations. Zoologica Africana. 10(1):75-85.

Burton, R. S. 1998. Intraspecific phylogeography across the Point Conception biogeographic boundary. Evolution 52:734-745.

Chan GL. 1973. A study of the effects of the San Francisco oil spill on marine organisms. In Proceedings of joint conference on prevention and control of oil spills. American Petroleum Institute, Washington, D.C., pp 741–782

Clarke, K.R. 1993. Nonparametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, **18**, 117-143.

Davis, G.E. 1985. Kelp forest monitoring program: a preliminary report on Biological sampling design. Univ. Calif. Davis Coop. National Park Resources Studies Unit. Tech. Rept. No. 19. 46 p.

Dayton PK. 1971. Competition, disturbance and community organization: the provision and subsequent utilization of space in a rocky intertidal community. Ecol Monogr 41:351–389

Di Lorenzo E., Schneider N., Cobb K. M., Chhak, K, Franks P. J. S., Miller A. J., McWilliams J. C., Bograd S. J., Arango H., Curchister E., Powell T. M. and P. Rivere, 2008: North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophys. Res. Lett., 35, L08607, doi:10.1029/2007GL032838

Doyle, R. F. 1985. Biogeographical studies of rocky shores near Point Conception, California. PhD dissertation. University of Californa, Santa Barbara, California.

Dungan ML, Miller TE, Thomson DA. 1982. Catastrophic decline of a top carnivore in the Gulf of California rocky intertidal zone. Science 216:989–991

Dwight, R.H., M.V. Brinks, G. SharavanaKumar, and J.C. Semenza. 2007. Beach attendance and bathing rates for southern California beaches. Ocean and Coastal Management 50:847-858.

Eckert GL, Engle JM, Kushner DJ. 1999. Sea star disease and population declines at the Channel Islands. In *Proceedings of the Fifth California Islands Symposium*, (Browne DR, Mitchell KL & Chaney HW, eds.), US Minerals Management Service, pp.390–393

Fenberg, P.B, BA Menge, PT Raimondi, MM Rivadeneira. 2014 Biogeographic structure of the northeastern Pacific rocky intertidal: the role of upwelling and dispersal to drive patterns. Ecography 37: 001–013, doi: 10.1111/ecog.00880

Fortin, M.J. & Payette, S. 2002. How to test the significance of the relation between spatially autocorrelated data at the landcape scale: A case study using fire and forest maps. *Ecoscience*, **9**, 213-218.

Halpern, B.S. 2003. The impact of marine reserves: do reserves work and does Reserve size matter? Ecological Applications, 13(1) Supplement, 2003, pp. S117–S137.

Harley CDG, Pankey MS, Wares JP, Grosberg RK, and Wonham MJ. 2006. Color polymorphism and genetic structure in the sea star *Pisaster ochraceus*. Biol Bull 211:248–262

Harley CDG. 2008. Tidal dynamics, topographic orientation, and temperature-mediated mass mortalities on rocky shores. Mar Ecol Prog Ser 371:37–46

Harley, C.D.G. 2008. Tidal dynamics, topography, and temperature-mediated mass mortalities on rocky shores. *Marine Ecology Progress Series* 371:37-46.

Helmuth, B., Harley, C.D.G., Halpin, P.M., O'donnell, M., Hofmann, G.E. & Blanchette, C.A. 2002. Climate change and latitudinal patterns of intertidal thermal stress. *Science*, **298**, 1015-1017.

Hewson, I, Jason B Button, Brent M Gudenkauf, Benjamin Miner, Alisa L Newton, Joseph K Gaydos, Janna Wynne, Cathy L Groves, Gordon Hendler, Michael Murray, Steven Fradkin, Mya Breitbart, Elizabeth Fahsbender, Kevin D Lafferty, A Marm Kilpatrick, C Melissa Miner, Peter Raimondi, Lesanna Lahner, Carolyn S Friedman, Stephen Daniels, Martin Haulena, Jeffrey Marliave, Colleen A Burge, Morgan E Eisenlord, C Drew Harvell. 2014. Densovirus associated with sea-star wasting disease and mass mortality. Proceedings of the National Academy of Sciences 111 (48), 17278-17283.

Hickey, B. M. 1998. Coastal oceanography of western North America from the tip of Baja California to Vancouver Island. Sea 11:345–393.

Hockey, P.A.R. and A.L. Bosman. 1986. Man as an intertidal predator in Transkei: disturbance, community convergence and management of a natural food resource. Oikos. 46:3-14.

Kremen, C. 1992. Assessing the Indicator Properties of Species Assemblages for Natural Areas Monitoring. Ecological Applications, Vol. 2, No. 2 (May, 1992), pp. 203-217

Kruskal, J.B. & Wish, M. 1978. *Multidimensional scaling*. Sage Publications, Beverly Hills, CA.

Kushmaro A, Rosenberg E, Fine M, Ben Haim Y, Loya Y. 1998. Effect of temperature on bleaching of the coral *Oculina patagonica* by Vibrio AK-1. Mar Ecol Prog Ser 171:131–137

Lamb A and Hanby BP. 2005. Marine Life of the Pacific Northwest. Harbour Pub.

Lasiak, T. 1991. The susceptibility and/or resilience of rocky littoral mollusks to stock depletion by the indigenous coastal people of Transkei, southern Africa. Biological conservation. 56:245-264.

Lasiak, T. and A. Dye. 1989. The ecology of the brown mussel *Perna perna* in Transkei, southern Africa: Implications for the management of a traditional food resource. Biological Conservation. 47:245-257.

Legendre P, MJ Anderson. 1999. Distance-based redundancy analysis: testing multispecies responses in multifactorial ecological experiments. Ecological Monographs 69 (1), 1-24

Legendre, P. & Fortin, M.J. 1989. Spatial pattern and ecological analysis. *Vegetatio*, **80**, 107-138.

Legendre, P. & Legendre, L. 1998. *Numerical ecology*, 2nd Edition edn. Elsevier, Amsterdam.

Legendre, P. & Troussellier, M. 1988. Aquatic heterotrophic bacteria - modeling in the presence of spatial auto-correlation. *Limnology and Oceanography*, **33**, 1055-1067.

Legendre, P. 1993. Spatial autocorrelation - trouble or new paradigm. *Ecology*, **74**, 1659-1673.

Legendre, P., Borcard, D. & Peres-Neto, P.R. 2005. Analyzing beta diversity: Partitioning the spatial variation of community composition data. *Ecological Monographs*, **75**, 435-450.

Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Croom Helm. 179 pages

Mantua, N.J. 1999: The Pacific Decadal Oscillation and Climate Forecasting for North America. "Climate Risk Solutions" newsletter.

McArdle, BH, MJ Anderson. 2001. Fitting multivariate models to community data: a comment on distance-based redundancy analysis. Ecology 82 (1), 290-297

McLachlan, A. and H.W. Lombard. 1981. Growth and production in exploited and unexploited populations of a rocky shore gastropod, *Turbo sarmaticus*. The Veliger. 23(3):221-229.

Menge BA, Blanchette CA, Raimondi P, Freidenburg T, Gaines S, Lubchenco J, Lohse D, Hudson G, Foley M, and Pamplin J. 2004. Species interaction strength: Testing model predictions along an upwelling gradient. Ecol Monogr 74:663–684

Minchinton T.E and P.T Raimondi. 2004. Effect of temporal and spatial separation of samples on estimation of Impacts. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Numbers 14-35-0001-30758. 89 pages.

Moreno, C.A., K.M. Lunecke, and M.I. Lepez. 1986. The response of an intertidal *Concholepas concholepas* (Gastropoda) population to protection from Man in southern Chile and the effects on benthic sessile assemblages. Oikos. 46: 359-364.

Morris RH, Abbott DL, and Haderlie EC. 1980. Intertidal invertebrates of California. Stanford University Press, Stanford

Murray, S.N. 1997. Effectiveness of marine life refuges on southern California shores. California and the World Ocean 1997. 1453-1465.

Murray, S.N., T.G. Denis, J.S. Kido, and J.R. Smith. 1999. Human visitation and the frequency and potential effects of collecting on rocky intertidal populations in southern California marine reserves. CalCOFI Report. 40: 100-106.

Murray, SN, RF Ambrose and MN Dethier. 2006. Monitoring Rocky Shores. University of California Press, Los Angeles, 240 pages.

Nicolas JL, Basuyaux O, Mazurié J, Thébault A. 2002. *Vibrio carchariae*, a pathogen of the abalone *Haliotis tuberculata*. Dis Aquat Org 50:35–43.

Noss, R. F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Ortega, S. 1987. The effect of human predation on the size distribution of *Siphonaria gigas* (Mollusca: Pulmonata) on the Pacific Coast of Costa Rica. The Veliger. 29(3):251-255.

Paine RT. 1966. Food web complexity and species diversity. Amer Nat 100:65–75

Paine, R.T., 1974. Intertidal community structure - experimental studies on relationship between a dominant competitor and its principal predator. Oecologia 15, 93-120.

Pincebourde S, Sanford E, and Helmuth B. 2008. Body temperature during low tide alters the feeding performance of a top intertidal predator. Limnology and Oceanography 53(4):1562–1573

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Raimondi PT, Sagarin RD, Ambrose RF, et al. 2007. Consistent frequency of color morphs in the sea star *Pisaster ochraceus* (Echimodermata : Asteriidae) across open-coast habitats in the northeastern Pacific. Pacific Science 61:201–210

Raimondi, P., K. Schiff and D. Gregorio. 2012 Characterization of the rocky intertidal ecological communities associated with southern California Areas of Special Biological Significance. Southern California Coastal Water Research Project. Technical Report 703.

Raimondi, P.T., R.F. Ambrose, J.M. Engle, S.N. Murray and M. Wilson. 1999. Monitoring of rocky intertidal resources along the central and southern California mainland. 3-year report for San Luis Obispo, Santa Barbara and Orange Counties (Fall 1995 – Spring 1998). Technical Report. U.S. Department of Interior, Minerals Management Service, Pacific OCS Region (MMS Cooperative Agreement No. 14-35-0001-30761 with Southern California Educational Initiative, Marine Science Institute, University of California, Santa Barbara).

Richards DV and GE Davis. 1993. Early warnings of modern population collapse in black abalone *Haliotis cracherodii*, Leach, 1814 at the California Channel Islands. J. Shellfish Res. 12(2):189-194.

Sagarin RD, Ambrose RF, Becker BJ, Engle JT, Kido J, Lee SF, Miner CM, Murray SN, Raimondi PT, Richards DV, Roe C. 2007. Ecological impacts on the limpet *Lottia gigantea* populations: human pressure over a broad scale on islands and mainland intertidal zones. Marine Biology 150:399–415.

Sanford E. 1999. Regulation of keystone predation by small changes in ocean temperature. Science 283:2095–2097

Smith, E.H. 1993. James V. Fitzgerald Marine Reserve Baseline and Carrying Capacity Study. Harding Lawson Associates Technical Report prepared for the County of San Mateo, Department of Environmental Services, 158 pp.

Smith, J.R., R.F. Ambrose, and P. Fong. 2008. Anthropogenic disturbance and the effectiveness of Marine Protected Areas for protecting mussel bed communities along the California coast. Environmental Management 41:599-612.

Smith, JR, SC Vogt, F Creedon, BJ Lucas, DJ Eernisse. 2014. The non-native turf-forming alga Caulacanthus ustulatus displaces space-occupants but increases diversity. Biological Invasions 16:2195–2208, DOI 10.1007/s10530-014-0658-5.

Smouse, P.E., Long, J.C. & Sokal, R.R. 1986. Multiple-regression and correlation extensions of the mantel test of matrix correspondence. *Systematic Zoology*, **35**, 627-632.

Staehli A, Schaerer R, Hoelzle K, Ribi G. 2008. Temperature induced disease in the starfish *Astropecten jonstoni*. JMBA2 Biodiversity Records, available at www.mba.ac. uk/jmba/pdf/5846.pdf

Valentine, J. W. 1966. Numerical analysis of marine molluscan ranges on the extratropical northeastern Pacific shelf. LO 11:198-211.

Ware, R. 2009. Central Orange County Areas of Special Biological Significance public use monitoring program. Technical Report prepared for Weston Soultions, Inc. 79 pp

Winant, C. D., E. P. Dever, and M. C. Hendershott. 2003. Characteristic patterns of shelf circulation at the boundary between central and southern California. Journal of Geophysical Research-Oceans 108:doi: 10:1029/2001JC001302.

Zhang, Y., J.M. Wallace and D.S. Battisti. 1997: ENSO-like Interdecadal Variability: 1900-93. Journal of Climate, Vol. 10, 1004-1020.

Baseline Characterization of the Rocky Intertidal Ecosystems of the South Coast Study Region - Appendix

Carol A. Blanchette[1], Peter T. Raimondi[2], Rani Gaddam[2], Jennifer Burnaford[3], Jayson Smith[4], David M. Hubbard[1], Jenifer E. Dugan[1], Jessica Altstatt[5] and Julie Bursek[5]

[1]University of California Santa Barbara

[2]University of California Santa Cruz

[3]California State University, Fullerton

[4]Cal Poly Pomona

[5]NOAA Channel Islands National Marine Sanctuary

January 30, 2015

Table of Contents

Figures

Tables

Site Descriptions

Included in the following pages are descriptions, photos, and biological characteristics of each of the SCSR rocky intertidal sites that were sampled during the Baseline Period (2012-2014). For sites where only Long-Term Monitoring has been done, no biological summary has been provided. In addition, species of concern have not been included in these summaries.

Alegria

Physical Description

Alegria is located in the South Coast region of California, within Hollister Ranch, which requires special access approval to visit and sample. Alegria is very sand influenced and portions of the site may be inundated with sand. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 1. Biodiversity survey overview at Alegria

Alegria is dominated by a mixture of consolidated sandstone and mudstone bedrock, boulder fields, and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is south.

Long-Term Monitoring Surveys at Alegria were established in 1992, and are done by University of California Los Angeles. Long-Term MARINe surveys currently target the following species and/or areas: *Anthopleura* (Anemones), *Chthamalus/Balanus* (Acorn Barnacles), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), Rock (Above Barnacles), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2003, 2004, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 33 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Alegria (> 2% cover or > 1 per m^2) are displayed in Table 1 and 2 below.

Table 1. The most common sessile taxa (>2% cover) observed at Alegria

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Alegria	2012	*Anthopleura elegantissima*	invertebrate	anemone
Alegria	2012	*Mytilus californianus*	invertebrate	mussel
Alegria	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Alegria	2012	*Chthamalus spp*	invertebrate	barnacle
Alegria	2012	*Ulva spp*	macrophyte	green algae

Table 2. The most common mobile taxa (>1 per m^2) observed at Alegria

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Alegria	2012	*Tegula funebralis*	invertebrate	snail
Alegria	2012	*Littorina spp*	invertebrate	snail
Alegria	2012	*Littorina keenae*	invertebrate	snail
Alegria	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Alegria	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Alegria	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet

Ellwood

Physical Description

Ellwood is located in the South Coast region of California. This site is located upcoast of the Ellwood Pier, and there is a popular surfing location near the site. This gently sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Figure 2. Biodiversity survey overview at Ellwood

Ellwood is dominated by a mixture of consolidated bedrock, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and cobble and sandy beach. The primary coastal orientation of this site is south.

Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 20 meters (seaward).

Figure 3. Long-term monitoring at Ellwood

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Ellwood (> 2% cover or > 1 per m^2) are displayed in Table 3 and 4 below.

Table 3. The most common sessile taxa (>2% cover) observed at Ellwood

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Ellwood	2012	*Chthamalus spp*	invertebrate	barnacle
Ellwood	2012	*Mytilus californianus*	invertebrate	mussel
Ellwood	2012	Encrusting Coralline	macrophyte	coralline algae
Ellwood	2012	*Endocladia muricata*	macrophyte	red algae
Ellwood	2012	*Anthopleura elegantissima*	invertebrate	anemone

Table 4. The most common mobile taxa (>1 per m^2) observed at Ellwood

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Ellwood	2012	*Littorina keenae*	invertebrate	snail
Ellwood	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Ellwood	2012	*Littorina spp*	invertebrate	snail
Ellwood	2012	*Tegula funebralis*	invertebrate	snail
Ellwood	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Ellwood	2012	*Lacuna spp*	invertebrate	snail
Ellwood	2012	*Pachygrapsus crassipes*	invertebrate	crab

Coal Oil Point (Campus Point SMCA)

Physical Description

Coal Oil Point is located in the South Coast region of California, in the University of California Coal Oil Point Natural Reserve. The site is located within the Campus Point State Marine Conservation Area, and is near the Santa Barbara Point Mussel Watch site. This gently sloping site consists of relatively flat terrain.

Figure 4. Biodiversity survey overview at Coal Oil Point

Coal Oil Point is dominated by a mixture of consolidated sandstone and mudstone bedrock, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. Sand innundation of the plots (sometimes 100% cover in the *Anthopleura* plots) is common at this site. The primary coastal orientation of this site is south.

Figure 5. Coal Oil Point site overview

Long-Term Monitoring Surveys at Coal Oil Point were established in 1992, and are done by University of California Los Angeles. Long-Term MARINe surveys currently target the following species: *Anthopleura* (Anemones), *Mytilus* (California Mussel), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2002, 2006, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 50 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Coal Oil Point (> 2% cover or > 1 per m^2) are displayed in Table 5 and 6 below.

Table 5. The most common sessile taxa (>2% cover) observed at Coal Oil Point

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Coal Oil Point	2012	*Anthopleura elegantissima*	invertebrate	anemone
Coal Oil Point	2012	*Ulva spp*	macrophyte	green algae
Coal Oil Point	2012	*Corallina spp*	macrophyte	coralline algae
Coal Oil Point	2012	*Mytilus californianus*	invertebrate	mussel
Coal Oil Point	2012	*Anthopleura sola*	invertebrate	anemone

Table 6. The most common mobile taxa (>1 per m^2) observed at Coal Oil Point

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Coal Oil Point	2012	*Lacuna spp*	invertebrate	snail
Coal Oil Point	2012	*Tegula funebralis*	invertebrate	snail
Coal Oil Point	2012	*Littorina keenae*	invertebrate	snail
Coal Oil Point	2012	*Littorina spp*	invertebrate	snail
Coal Oil Point	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Coal Oil Point	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Coal Oil Point	2012	*Acanthinucella spp*	invertebrate	whelk
Coal Oil Point	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Coal Oil Point	2012	*Littorina plena/scutulata*	invertebrate	snail
Coal Oil Point	2012	*Mopalia spp*	invertebrate	chiton

Carpinteria

Physical Description

Carpinteria is located in the South Coast region of California, on Carpinteria State Beach, and is near the Carpinteria State Beach Mussel Watch site. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 6. Biodiversity survey overview at Carpinteria

Carpinteria is dominated by a mixture of consolidated sandstone and mudstone bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The primary coastal orientation of this site is southwest.

Long-Term Monitoring Surveys at Carpinteria were established in 1992, and are done by University of California Los Angeles. Long-Term MARINe surveys currently target the following species and/or areas: *Anthopleura* (Anemones), *Chthamalus/Balanus* (Acorn Barnacles), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site

Figure 7. Long-term monitoring at Carpinteria

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2012. The Biodiversity Survey grid encompasses one section that is approximately 27 meters (along shore) x 50 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Carpinteria (> 2% cover or > 1 per m^2) are displayed in Table 7 and 8 below.

Table 7. The most common sessile taxa (>2% cover) observed at Carpinteria

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Carpinteria	2012	*Phyllospadix torreyi*	macrophyte	surfgrass
Carpinteria	2012	*Anthopleura sola*	invertebrate	anemone
Carpinteria	2012	*Gracilariopsis andersonii/papenfussii*	macrophyte	red algae
Carpinteria	2012	*Mytilus californianus*	invertebrate	mussel
Carpinteria	2012	*Polysiphonia spp*	macrophyte	red algae
Carpinteria	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Carpinteria	2012	*Corallina spp*	macrophyte	coralline algae
Carpinteria	2012	*Ulva spp*	macrophyte	green algae
Carpinteria	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Carpinteria	2012	*Anthopleura elegantissima*	invertebrate	anemone

Table 8. The most common mobile taxa (>1 per m^2) observed at Carpinteria

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Carpinteria	2012	*Lacuna spp*	invertebrate	snail
Carpinteria	2012	*Littorina spp*	invertebrate	snail
Carpinteria	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Carpinteria	2012	*Littorina keenae*	invertebrate	snail
Carpinteria	2012	*Tegula funebralis*	invertebrate	snail
Carpinteria	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Carpinteria	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Carpinteria	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Carpinteria	2012	*Nuttalina spp*	invertebrate	chiton
Carpinteria	2012	*Acanthinucella spp*	invertebrate	whelk
Carpinteria	2012	*Lottia scabra/conus*	invertebrate	limpet
Carpinteria	2012	*Pachygrapsus crassipes*	invertebrate	crab
Carpinteria	2012	Small limpet	invertebrate	limpet
Carpinteria	2012	*Mopalia spp*	invertebrate	chiton

Old Stairs

Physical Description

Old Stairs is located in the South Coast region of California. This site is located in an Area of Special Biological Significance (Mugu Lagoon to Latigo Point ASBS). This site is near the Point Mugu Old Stairs Mussel Watch site. This moderately sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Figure 8. Biodiversity survey overview at Old Stairs

Old Stairs is dominated by a mixture of consolidated sandstone bedrock, riprap, boulder fields, and sandy beach, and the area surrounding the site is comprised of a mixture of boulder fields and sandy beach at this site. The primary coastal orientation of this site is southwest.

Figure 9. Intertidal emersion at Old Stairs

Long-Term Monitoring Surveys at Old Stairs were established in 1994, and are done by University of California Los Angeles. Long-Term MARINe surveys currently target the following species and/or areas: *Anthopleura* (Anemones), *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Endocladia* (Turfweed), Rock (Above Barnacles), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001. The Biodiversity Survey grid encompasses two sections that are approximately 6 meters (along shore) x 20 meters (seaward), and 21 meters (along shore) x 20 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Old Stairs (> 2% cover or > 1 per m^2) are displayed in Table 9 and 10 below.

Table 9. The most common sessile taxa (>2% cover) observed at Old Stairs

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Old Stairs	2013	*Chthamalus spp*	invertebrate	barnacle
Old Stairs	2013	*Mytilus californianus*	invertebrate	mussel
Old Stairs	2013	*Endocladia muricata*	macrophyte	red algae
Old Stairs	2013	*Balanus glandula*	invertebrate	barnacle
Old Stairs	2013	*Anthopleura elegantissima*	invertebrate	anemone
Old Stairs	2013	*Petrocelis spp*	macrophyte	red algae

Table 10. The most common mobile taxa (>1 per m^2) observed at Old Stairs

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Old Stairs	2013	*Littorina keenae*	invertebrate	snail
Old Stairs	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Old Stairs	2013	*Littorina spp*	invertebrate	snail
Old Stairs	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Old Stairs	2013	*Small limpet*	invertebrate	limpet
Old Stairs	2013	*Littorina plena/scutulata*	invertebrate	snail
Old Stairs	2013	*Nucella emarginata/ostrina*	invertebrate	whelk
Old Stairs	2013	*Lottia pelta*	invertebrate	limpet
Old Stairs	2013	*Nuttalina spp*	invertebrate	chiton
Old Stairs	2013	*Lottia scabra/conus*	invertebrate	limpet

Deer Creek

Physical Description

Deer Creek is located in the South Coast region of California. This site is located in an Area of Special Biological Significance (Mugu Lagoon to Latigo Point ASBS). This site is near the Point Mugu Old Stairs Mussel Watch site, and is also used for the NOAA LiMPETS program. This gently sloping site is greatly sand influenced with a steep drop-off into a channel, and consists of moderately uneven terrain, containing few cracks and folds.

Figure 10. Biodiversity survey overview at Deer Creek

Deer Creek is dominated by a mixture of consolidated basalt and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is southeast.

Biodiversity Surveys were done by University of California Santa Cruz in 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 5 meters (seaward).

Figure 11. Long -term monitoring at Deer Creek

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Deer Creek (> 2% cover or > 1 per m^2) are displayed in Table 11 and 12 below.

Table 11. The most common sessile taxa (>2% cover) observed at Deer Creek

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Deer Creek	2013	*Chthamalus spp*	invertebrate	barnacle
Deer Creek	2013	*Mytilus californianus*	invertebrate	mussel
Deer Creek	2013	*Phragmatopoma californica*	invertebrate	worm

Table 12. The most common mobile taxa (>1 per m^2) observed at Deer Creek

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Deer Creek	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Deer Creek	2013	*Littorina keenae*	invertebrate	snail
Deer Creek	2013	*Littorina spp*	invertebrate	snail
Deer Creek	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Deer Creek	2013	*Littorina plena/scutulata*	invertebrate	snail
Deer Creek	2013	*Nucella emarginata/ostrina*	invertebrate	whelk
Deer Creek	2013	*Lottia scabra/conus*	invertebrate	limpet
Deer Creek	2013	*Lottia pelta*	invertebrate	limpet
Deer Creek	2013	*Nuttalina spp*	invertebrate	chiton

Sequit Point

Physical Description

Sequit Point is located in the South Coast region of California, within an Area of Special Biological Significance (Mugu Lagoon to Latigo Point ASBS). This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 12. Biodiversity survey overview at Sequit Point

Sequit Point is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is south.

Biodiversity Surveys were done by University of California Santa Cruz in 2009 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 25 meters (seaward).

Figure 13. Intertidal emersion at Sequit Point

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Sequit Point (> 2% cover or > 1 per m^2) are displayed in Table 13 and 14 below.

Table 13. The most common sessile taxa (>2% cover) observed at Sequit Point

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Sequit Point	2013	*Mytilus californianus*	invertebrate	mussel
Sequit Point	2013	*Chthamalus spp*	invertebrate	barnacle
Sequit Point	2013	*Phragmatopoma californica*	invertebrate	worm

Table 14. The most common mobile taxa (>1 per m^2) observed at Sequit Point

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Sequit Point	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Sequit Point	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Sequit Point	2013	*Littorina keenae*	invertebrate	snail
Sequit Point	2013	*Littorina plena/scutulata*	invertebrate	snail
Sequit Point	2013	*Lottia pelta*	invertebrate	limpet
Sequit Point	2013	*Lottia scabra/conus*	invertebrate	limpet
Sequit Point	2013	*Littorina spp*	invertebrate	snail
Sequit Point	2013	*Nucella emarginata/ostrina*	invertebrate	whelk
Sequit Point	2013	*Tegula funebralis*	invertebrate	snail
Sequit Point	2013	*Nuttalina spp*	invertebrate	chiton
Sequit Point	2013	*Mopalia spp*	invertebrate	chiton
Sequit Point	2013	Small limpet	invertebrate	limpet
Sequit Point	2013	*Pachygrapsus crassipes*	invertebrate	crab

Lechuza Point (Point Dume SMCA)

Physical Description

Lechuza Point is located in the South Coast region of California, within the Point Dume State Marine Conservation Area, and is located in an Area of Special Biological Significance (Mugu Lagoon to Latigo Point ASBS). This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 14. Biodiversity survey overview at Lechuza Point

Lechuza Point is dominated by a mixture of consolidated bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The primary coastal orientation of this site is south.

Figure 15. Intertidal emersion at Lechuza Point

Biodiversity Surveys were done by University of California Santa Cruz in 2009 and 2013. The Biodiversity Survey grid encompasses two sections that are approximately 14 meters (along shore) x 40 meters (seaward), and 4 meters (along shore) x 25 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Lechuza Point (> 2% cover or > 1 per m^2) are displayed in Table 15 and 16 below.

Table 15. The most common sessile taxa (>2% cover) observed at Lechuza Point

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Lechuza Point	2013	*Mytilus californianus*	invertebrate	mussel
Lechuza Point	2013	*Chthamalus spp*	invertebrate	barnacle
Lechuza Point	2013	*Phragmatopoma californica*	invertebrate	worm
Lechuza Point	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Lechuza Point	2013	*Anthopleura elegantissima*	invertebrate	anemone
Lechuza Point	2013	*Corallina spp*	macrophyte	coralline algae

Table 16. The most common mobile taxa (>1 per m^2) observed at Lechuza Point

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Lechuza Point	2013	*Littorina keenae*	invertebrate	snail
Lechuza Point	2013	*Littorina spp*	invertebrate	snail
Lechuza Point	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Lechuza Point	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Lechuza Point	2013	*Littorina plena/scutulata*	invertebrate	snail
Lechuza Point	2013	*Lottia pelta*	invertebrate	limpet
Lechuza Point	2013	*Lottia scabra/conus*	invertebrate	limpet
Lechuza Point	2013	*Nucella emarginata/ostrina*	invertebrate	whelk
Lechuza Point	2013	*Tegula funebralis*	invertebrate	snail
Lechuza Point	2013	*Mopalia spp*	invertebrate	chiton
Lechuza Point	2013	*Nuttalina spp*	invertebrate	chiton
Lechuza Point	2013	Small limpet	invertebrate	limpet
Lechuza Point	2013	*Fissurella volcano*	invertebrate	limpet
Lechuza Point	2013	*Pachygrapsus crassipes*	invertebrate	crab

Point Dume (Point Dume SMR)

Physical Description

Point Dume is located in the South Coast region of California, within the Point Dume State Marine Reserve. This site is located in an Area of Special Biological Significance (Mugu Lagoon to Latigo Point ASBS). This site is near the Point Dume Mussel Watch site. This site is accessed through Point Dume State Beach. This gently sloping site has a steep drop-off at the end of the reef, and consists of moderately uneven terrain, containing few cracks and folds.

Figure 16. Biodiversity survey overview at Point Dume

There are tidepools downcoast of this site that are easily accessed by a stairway, however the site itself is likely infrequently visited due to tide dependent access around the rocky point. The Native Californian Chumash tribe inhabited this coastline for thousands of years and used this area as a sacred space. In 1542, the point was an important navigational marker for Spanish explorer Juan Rodriguez Cabrillo, but only received its name in 1793 when British sea captain George Vancouver named the craggy headlands Point Dume after Father Francisco Dumetz from the Mission San Buenaventura. During World War II, the U.S. Army used this site as an anti-aircraft artillery training area. It is believed that the top of the headlands was flattened after the war for commercial construction purposes. In 1979, Point Dume was acquired by the State of California and is being carefully and gradually restored to its pristine state.

Figure 17. Long-term monitoring at Point Dume

Point Dume is dominated by a mixture of consolidated basalt, boulder fields, and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is south.

Biodiversity Surveys were done by University of California Santa Cruz in 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Point Dume (> 2% cover or > 1 per m^2) are displayed in Table 17 and 18 below.

Table 17. The most common sessile taxa (>2% cover) observed at Point Dume

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Point Dume	2013	*Chthamalus spp*	invertebrate	barnacle
Point Dume	2013	*Mytilus californianus*	invertebrate	mussel
Point Dume	2013	*Endocladia muricata*	macrophyte	red algae
Point Dume	2013	*Anthopleura elegantissima*	invertebrate	anemone
Point Dume	2013	*Ulva spp*	macrophyte	green algae
Point Dume	2013	*Chaetomorpha spiralis*	macrophyte	green algae
Point Dume	2013	*Anthopleura sola*	invertebrate	anemone
Point Dume	2013	Other crust	macrophyte	red algae

Table 18. The most common mobile taxa (>1 per m^2) observed at Point Dume

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Point Dume	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Point Dume	2013	*Littorina keenae*	invertebrate	snail
Point Dume	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Point Dume	2013	*Littorina plena/scutulata*	invertebrate	snail
Point Dume	2013	*Lottia pelta*	invertebrate	limpet
Point Dume	2013	*Nucella emarginata/ostrina*	invertebrate	whelk
Point Dume	2013	*Nuttalina spp*	invertebrate	chiton
Point Dume	2013	Small limpet	invertebrate	limpet
Point Dume	2013	*Lottia scabra/conus*	invertebrate	limpet
Point Dume	2013	*Littorina spp*	invertebrate	snail
Point Dume	2013	*Tegula funebralis*	invertebrate	snail

Paradise Cove (Point Dume SMR)

Physical Description

Paradise Cove is located in the South Coast region of California. The site is located in an Area of Special Biological Significance (Mugu Lagoon to Latigo Point ASBS), within the Point Dume State Marine Conservation Area. There is at least one storm water discharge in the vicinity of this site, and this site is 1.2 miles northeast of the Point Dume Mussel Watch site. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 18. Biodiversity survey overview at Paradise Cove

Paradise Cove is dominated by a mixture of consolidated sandstone bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The primary coastal orientation of this site is southeast.

Long-Term Monitoring Surveys at Paradise Cove were established in 1994, and are done by University of California Los Angeles. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Endocladia* (Turfweed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site.

Figure 19. Site overview at Paradise Cove

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2006, and 2010. The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 10 meters (seaward), and 15 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Paradise Cove (> 2% cover or > 1 per m^2) are displayed in Table 19 and 20 below.

Table 19. The most common sessile taxa (>2% cover) observed at Paradise Cove

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Paradise Cove	2013	*Mytilus californianus*	invertebrate	mussel
Paradise Cove	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Paradise Cove	2013	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Paradise Cove	2013	*Corallina spp*	macrophyte	coralline algae
Paradise Cove	2013	*Egregia menziesii*	macrophyte	brown algae
Paradise Cove	2013	*Chthamalus spp*	invertebrate	barnacle
Paradise Cove	2013	*Anthopleura sola*	invertebrate	anemone
Paradise Cove	2013	*Gelidium pusillum*	macrophyte	red algae

Table 20. The most common mobile taxa (>1 per m^2) observed at Paradise Cove

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Paradise Cove	2013	*Littorina keenae*	invertebrate	snail
Paradise Cove	2013	*Littorina plena/scutulata*	invertebrate	snail
Paradise Cove	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Paradise Cove	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Paradise Cove	2013	*Lottia scabra/conus*	invertebrate	limpet
Paradise Cove	2013	*Littorina spp*	invertebrate	snail
Paradise Cove	2013	*Tegula funebralis*	invertebrate	snail
Paradise Cove	2013	*Lottia pelta*	invertebrate	limpet
Paradise Cove	2013	*Nuttalina spp*	invertebrate	chiton
Paradise Cove	2013	*Fissurella volcano*	invertebrate	limpet
Paradise Cove	2013	*Epitonium tinctum*	invertebrate	snail
Paradise Cove	2013	*Pachygrapsus crassipes*	invertebrate	crab
Paradise Cove	2013	*Nucella emarginata/ostrina*	invertebrate	whelk

Point Vicente (Point Vicente SMCA)

Physical Description

Point Vicente is located in the South Coast region of California. This site is accessed through Pelican Cove Park, which has been owned by the city of Rancho Palos Verdes since May 2004. There is a parking lot with an access trail down to the beach. Almost directly up the steep cliff from the site (though not accessible directly from the site) is Point Vicente Lighthouse. This gently sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Figure 20. Biodiversity survey overview at Point Vicente

Point Vicente is dominated by a mixture of consolidated sandstone and mudstone, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and cobble beach. The primary coastal orientation of this site is south/southwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 20 meters (seaward).

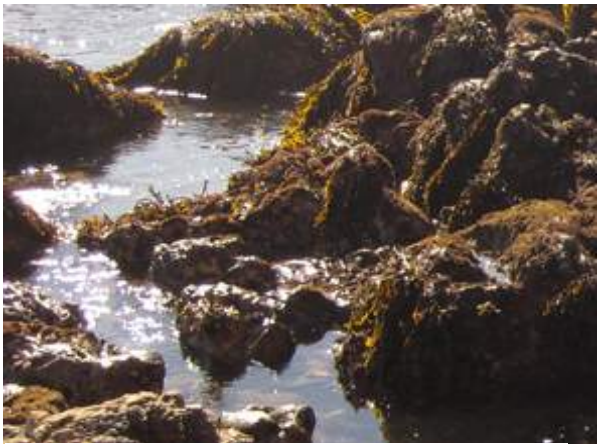

Figure 21. Intertidal emersion at Point Vicente

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Point Vicente (> 2% cover or > 1 per m^2) are displayed in Table 21 and 22 below.

Table 21. The most common sessile taxa (>2% cover) observed at Point Vicente

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Point Vicente	2012	*Corallina spp*	macrophyte	coralline algae
Point Vicente	2012	*Gelidium pusillum*	macrophyte	red algae
Point Vicente	2012	*Chthamalus spp*	invertebrate	barnacle
Point Vicente	2012	Encrusting Coralline	macrophyte	coralline algae
Point Vicente	2012	*Hildenbrandia/Peyssonnelia spp*	macrophyte	red algae
Point Vicente	2012	*Ralfsiaceae spp*	macrophyte	brown algae
Point Vicente	2012	*Mastocarpus papillatus*	macrophyte	red algae
Point Vicente	2012	*Mytilus californianus*	invertebrate	mussel
Point Vicente	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin

Table 22. The most common mobile taxa (>1 per m^2) observed at Point Vicente

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Point Vicente	2012	*Lottia scabra/conus*	invertebrate	limpet
Point Vicente	2012	*Nuttalina spp*	invertebrate	chiton
Point Vicente	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Point Vicente	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Point Vicente	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Point Vicente	2012	*Lottia limatula*	invertebrate	limpet
Point Vicente	2012	*Fissurella volcano*	invertebrate	limpet
Point Vicente	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin
Point Vicente	2012	*Pagurus samuelis*	invertebrate	crab
Point Vicente	2012	*Littorina keenae*	invertebrate	snail
Point Vicente	2012	*Lottia pelta*	invertebrate	limpet
Point Vicente	2012	*Littorina plena/scutulata*	invertebrate	snail
Point Vicente	2012	*Pachygrapsus crassipes*	invertebrate	crab
Point Vicente	2012	*Tegula gallina*	invertebrate	snail
Point Vicente	2012	Small limpet	invertebrate	limpet
Point Vicente	2012	*Lottia scutum*	invertebrate	limpet
Point Vicente	2012	*Homalopoma baculum/luridum*	invertebrate	snail
Point Vicente	2012	*Cyanoplax hartwegii*	invertebrate	chiton
Point Vicente	2012	*Tegula funebralis*	invertebrate	snail

Abalone Cove (Abalone Cove SMCA)

Physical Description

Abalone Cove is located in the South Coast region of California, in Palos Verdes Open Space District, within the Abalone Cove State Marine Conservation Area. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 22. Site overview at Abalone Cove

Abalone Cove is dominated by a mixture of consolidated basalt bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is west.

Figure 23. Biodiversity survey overview at Abalone Cove

Long-Term Monitoring Surveys at Abalone Cove were established in 2009, and were previously done by University of California Los Angeles, but are currently done by California State University Long Beach. Long-Term MARINe surveys currently target the following species and/or areas: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Endocladia* (Turfweed), Rock (Above Barnacles), and *Pisaster* (Ochre Star). Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Abalone Cove (> 2% cover or > 1 per m^2) are displayed in Table 23 and 24 below.

Table 23. The most common sessile taxa (>2% cover) observed at Abalone Cove

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Abalone Cove	2012	*Corallina spp*	macrophyte	coralline algae
Abalone Cove	2012	*Caulacanthus okamurae*	macrophyte	red algae
Abalone Cove	2012	*Chthamalus spp*	invertebrate	barnacle
Abalone Cove	2012	*Littorina keenae*	invertebrate	snail
Abalone Cove	2012	Encrusting Coralline	macrophyte	coralline algae
Abalone Cove	2012	*Gelidium pusillum*	macrophyte	red algae
Abalone Cove	2012	*Balanus glandula*	invertebrate	barnacle
Abalone Cove	2012	*Tetraclita rubescens*	invertebrate	barnacle
Abalone Cove	2012	*Corallina spp*	macrophyte	coralline algae

Table 24. The most common mobile taxa (>1 per m^2) observed at Abalone Cove

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Abalone Cove	2012	*Littorina keenae*	invertebrate	snail
Abalone Cove	2012	*Lottia scabra/conus*	invertebrate	limpet
Abalone Cove	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Abalone Cove	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Abalone Cove	2012	Small limpet	invertebrate	limpet
Abalone Cove	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin
Abalone Cove	2012	*Littorina spp*	invertebrate	snail
Abalone Cove	2012	*Littorina plena/scutulata*	invertebrate	snail
Abalone Cove	2012	*Lottia limatula*	invertebrate	limpet
Abalone Cove	2012	*Nuttalina spp*	invertebrate	chiton
Abalone Cove	2012	*Pachygrapsus crassipes*	invertebrate	crab
Abalone Cove	2012	*Lottia pelta*	invertebrate	limpet
Abalone Cove	2012	*Pagurus samuelis*	invertebrate	crab
Abalone Cove	2012	*Cyanoplax hartwegii*	invertebrate	chiton
Abalone Cove	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Abalone Cove	2012	*Lottia insessa*	invertebrate	limpet
Abalone Cove	2012	*Lottia scutum*	invertebrate	limpet
Abalone Cove	2012	*Pisaster ochraceus*	invertebrate	sea star

Point Fermin

Physical Description

Point Fermin is located in the South Coast region of California. This site is near the San Pedro Fishing Pier Mussel Watch site. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 24. Biodiversity survey overview at Point Fermin

Point Fermin is dominated by a mixture of consolidated sandstone and basalt bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is southeast.

Long-Term Monitoring Surveys at Point Fermin were established in 1999, and are done by University of California Los Angeles. Long-Term MARINe surveys currently target the following species and/or areas: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), Rock (Above Barnacle), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates and mussel size structure are monitored at this site.

Figure 25. Intertidal emersion at Point Fermin

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2012. The Biodiversity Survey grid encompasses two sections that are approximately 18 meters (along shore) x 50 meters (seaward), and 9 meters (along shore) x 50 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Point Fermin (> 2% cover or > 1 per m^2) are displayed in Table 25 and 26 below.

Table 25. The most common sessile taxa (>2% cover) observed at Point Fermin

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Point Fermin	2012	*Corallina spp*	macrophyte	coralline algae
Point Fermin	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Point Fermin	2012	*Caulacanthus okamurae*	macrophyte	red algae
Point Fermin	2012	*Chthamalus spp*	invertebrate	barnacle
Point Fermin	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Point Fermin	2012	*Ralfsiaceae spp*	macrophyte	brown algae
Point Fermin	2012	*Mytilus californianus*	invertebrate	mussel
Point Fermin	2012	Encrusting Coralline	macrophyte	coralline algae
Point Fermin	2012	*Phragmatopoma californica*	invertebrate	worm

Table 26. The most common mobile taxa (>1 per m^2) observed at Point Fermin

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Point Fermin	2012	*Lottia scabra/conus*	invertebrate	limpet
Point Fermin	2012	*Littorina keenae*	invertebrate	snail
Point Fermin	2012	*Nuttalina spp*	invertebrate	chiton
Point Fermin	2012	*Littorina plena/scutulata*	invertebrate	snail
Point Fermin	2012	Small limpet	invertebrate	limpet
Point Fermin	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Point Fermin	2012	*Fissurella volcano*	invertebrate	limpet
Point Fermin	2012	*Pagurus samuelis*	invertebrate	crab
Point Fermin	2012	*Lottia limatula*	invertebrate	limpet
Point Fermin	2012	*Pachygrapsus crassipes*	invertebrate	crab
Point Fermin	2012	*Tegula funebralis*	invertebrate	snail
Point Fermin	2012	*Cyanoplax hartwegii*	invertebrate	chiton
Point Fermin	2012	*Littorina spp*	invertebrate	snail
Point Fermin	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin
Point Fermin	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Point Fermin	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Point Fermin	2012	*Lottia pelta*	invertebrate	limpet
Point Fermin	2012	*Tegula gallina*	invertebrate	snail
Point Fermin	2012	*Acanthinucella spp*	invertebrate	whelk
Point Fermin	2012	*Mopalia spp*	invertebrate	chiton
Point Fermin	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Point Fermin	2012	*Ocenebra circumtexta*	invertebrate	whelk

Buck Gully South (Crystal Cove SMCA)

Physical Description

Buck Gully South is located in the South Coast region of California, within the Crystal Cove State Marine Conservation Area. This site is near the West Jetty Mussel Watch site. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 26. Biodiversity survey overview at Buck Gully South

Buck Gully South is dominated by a mixture of consolidated bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is southwest.

Figure 27. Intertidal emersion at Buck Gully South

Biodiversity Surveys were done by University of California Santa Cruz in 2009 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 33 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Buck Gully South (> 2% cover or > 1 per m^2) are displayed in Table 27 and 28 below.

Table 27. The most common sessile taxa (>2% cover) observed at Buck Gully South

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Buck Gully South	2013	*Corallina spp*	macrophyte	coralline algae
Buck Gully South	2013	*Ralfsiaceae spp*	macrophyte	brown algae
Buck Gully South	2013	Encrusting Coralline	macrophyte	coralline algae
Buck Gully South	2013	*Strongylocentrotus purpuratus*	invertebrate	urchin
Buck Gully South	2013	*Chthamalus spp*	invertebrate	barnacle

Table 28. The most common mobile taxa (>1 per m^2) observed at Buck Gully South

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Buck Gully South	2013	*Lottia scabra/conus*	invertebrate	limpet
Buck Gully South	2013	*Littorina keenae*	invertebrate	snail
Buck Gully South	2013	*Littorina plena/scutulata*	invertebrate	snail
Buck Gully South	2013	*Nuttalina spp*	invertebrate	chiton
Buck Gully South	2013	*Littorina spp*	invertebrate	snail
Buck Gully South	2013	*Strongylocentrotus purpuratus*	invertebrate	urchin
Buck Gully South	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Buck Gully South	2013	*Fissurella volcano*	invertebrate	limpet
Buck Gully South	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Buck Gully South	2013	*Tegula funebralis*	invertebrate	snail
Buck Gully South	2013	*Pagurus samuelis*	invertebrate	crab
Buck Gully South	2013	*Lottia pelta*	invertebrate	limpet
Buck Gully South	2013	*Lottia limatula*	invertebrate	limpet
Buck Gully South	2013	*Cyanoplax hartwegii*	invertebrate	chiton
Buck Gully South	2013	*Pachygrapsus crassipes*	invertebrate	crab
Buck Gully South	2013	*Tegula eiseni*	invertebrate	snail

Crystal Cove (Crystal Cove SMCA)

Physical Description

Crystal Cove is located in the South Coast region of California, in Crystal Cove State Park. The site is located in an Area of Special Biological Significance (Irvine Coast Marine Life Refuge ASBS) within the Crystal Cove State Marine Conservation Area, and is near the Crystal Cove State Beach Mussel Watch site. This site is one of many rocky reefs located on the Crystal Cove State Park grounds, which receives a high number of visitors, including tidepoolers. Reef Point, where the site is located, has a flattened and angled bench separated by crevices resulting from uplifted bedding planes.

Figure 28. Biodiversity survey overview at Crystal Cove

Figure 29. Intertidal emersion at Crystal Cove

Crystal Cove is dominated by a mixture of consolidated bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. Sand levels in the splash and upper intertidal zone vary greatly within a year, sometimes covering the upper limits of barnacles. The primary coastal orientation of this site is west/southwest.

Long-Term Monitoring Surveys at Crystal Cove were established in 1996, and are conducted by California State University Fullerton. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, mussel size structure, and water temperature are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2003, 2004, and 2012. The Biodiversity survey grid encompasses one section that is approximately 30 meters (along shore) x 33 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Crystal Cove (> 2% cover or > 1 per m^2) are displayed in Table 29 and 30 below.

Table 29. The most common sessile taxa (>2% cover) observed at Crystal Cove

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Crystal Cove	2012	*Mytilus californianus*	invertebrate	mussel
Crystal Cove	2012	*Caulacanthus okamurae*	macrophyte	red algae
Crystal Cove	2012	*Corallina spp*	macrophyte	coralline algae
Crystal Cove	2012	*Pseudochama exogyra*	invertebrate	clam
Crystal Cove	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Crystal Cove	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Crystal Cove	2012	*Balanus glandula*	invertebrate	barnacle
Crystal Cove	2012	*Lithothrix aspergillum*	macrophyte	coralline algae
Crystal Cove	2012	*Anthopleura sola*	invertebrate	anemone
Crystal Cove	2012	*Pseudolithoderma nigra*	macrophyte	brown algae
Crystal Cove	2012	*Gelidium pusillum*	macrophyte	red algae
Crystal Cove	2012	*Anthopleura elegantissima*	invertebrate	anemone

Table 30. The most common mobile taxa (>1 per m^2) observed at Crystal Cove

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Crystal Cove	2012	*Lottia scabra/conus*	invertebrate	limpet
Crystal Cove	2012	Small limpet	invertebrate	limpet
Crystal Cove	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Crystal Cove	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Crystal Cove	2012	*Pagurus samuelis*	invertebrate	crab
Crystal Cove	2012	*Littorina plena/scutulata*	invertebrate	snail
Crystal Cove	2012	*Tegula funebralis*	invertebrate	snail
Crystal Cove	2012	*Nuttalina spp*	invertebrate	chiton
Crystal Cove	2012	*Littorina keenae*	invertebrate	snail
Crystal Cove	2012	*Mopalia spp*	invertebrate	chiton
Crystal Cove	2012	*Pachygrapsus crassipes*	invertebrate	crab
Crystal Cove	2012	*Lottia limatula*	invertebrate	limpet
Crystal Cove	2012	*Lottia pelta*	invertebrate	limpet
Crystal Cove	2012	*Tegula gallina*	invertebrate	snail
Crystal Cove	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Crystal Cove	2012	*Acanthinucella spp*	invertebrate	whelk
Crystal Cove	2012	*Epitonium tinctum*	invertebrate	snail
Crystal Cove	2012	*Cyanoplax hartwegii*	invertebrate	chiton
Crystal Cove	2012	*Nucella emarginata/ostrina*	invertebrate	whelk

Muddy Canyon (Crystal Cove SMCA)

Physical Description

Muddy Canyon is located in the South Coast region of California, within the Crystal Cove State Marine Conservation Area. This site is located in an Area of Special Biological Significance (Irvine Coast Marine Life Refuge ASBS). This site is near the Crystal Cove State Park Mussel Watch site. This site is accessed through Crystal Cove State Park, and has very high visitation by tidepoolers, surfers, SCUBA divers, and swimmers. The offshore waters are designated as an underwater park. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Muddy Canyon is dominated by a mixture of consolidated mudstone and sandstone, boulder fields, cobble, and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, cobble beach, and sandy beach. The primary coastal orientation of this site is southwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 33 meters (seaward).

Figure 30. Intertidal emmersion at Muddy Canyon

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Muddy Canyon (> 2% cover or > 1 per m^2) are displayed in Table 31 and 32 below.

Table 31. The most common sessile taxa (>2% cover) observed at Muddy Canyon

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Muddy Canyon	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Muddy Canyon	2013	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Muddy Canyon	2013	*Corallina spp*	macrophyte	coralline algae
Muddy Canyon	2013	*Anthopleura sola*	invertebrate	anemone
Muddy Canyon	2013	*Silvetia compressa*	macrophyte	brown algae

Table 32. The most common mobile taxa (>1 per m^2) observed at Muddy Canyon

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Muddy Canyon	2013	*Littorina keenae*	invertebrate	snail
Muddy Canyon	2013	*Littorina spp*	invertebrate	snail
Muddy Canyon	2013	*Littorina plena/scutulata*	invertebrate	snail
Muddy Canyon	2013	*Lottia scabra/conus*	invertebrate	limpet
Muddy Canyon	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Muddy Canyon	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Muddy Canyon	2013	*Nuttalina spp*	invertebrate	chiton
Muddy Canyon	2013	*Fissurella volcano*	invertebrate	limpet
Muddy Canyon	2013	*Tegula eiseni*	invertebrate	snail
Muddy Canyon	2013	*Lottia pelta*	invertebrate	limpet

Shaws Cove (Laguna Beach SMR)

Physical Description

Shaws Cove is located in the South Coast region of California, within the Laguna Beach State Marine Reserve. This site is popular for fishing, diving, recreational visitors, and educational field trips resulting in multiple anthropogenic disturbances. Docent educators are frequently on site. The site is characterized by flattened and gently sloping bedrock benches separated by crevices and channels.

Figure 31. Biodiversity survey overview at Shaws Cove

Shaws Cove is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The primary coastal orientation of this site is south.

Long-Term Monitoring Surveys at Shaws Cove were established in 1996, and are conducted by California State University Fullerton. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), *and Pisaster* (Ochre Star). In addition, motile invertebrates, mussel size structure, and water temperature are monitored at this site.

Figure 32. Site overview at Shaws Cove

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2005, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Shaws Cove (> 2% cover or > 1 per m^2) are displayed in Table 33 and 34 below.

Table 33. The most common sessile taxa (>2% cover) observed at Shaws Cove

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Shaws Cove	2012	*Mytilus californianus*	invertebrate	mussel
Shaws Cove	2012	*Chthamalus spp*	invertebrate	barnacle
Shaws Cove	2012	*Corallina spp*	macrophyte	coralline algae
Shaws Cove	2012	*Balanus glandula*	invertebrate	barnacle
Shaws Cove	2012	*Gastroclonium subarticulatum*	macrophyte	red algae

Table 34. The most common mobile taxa (>1 per m^2) observed at Shaws Cove

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Shaws Cove	2012	*Littorina keenae*	invertebrate	snail
Shaws Cove	2012	*Littorina plena/scutulata*	invertebrate	snail
Shaws Cove	2012	*Littorina spp*	invertebrate	snail
Shaws Cove	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Shaws Cove	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Shaws Cove	2012	*Nuttalina spp*	invertebrate	chiton
Shaws Cove	2012	*Lottia scabra/conus*	invertebrate	limpet
Shaws Cove	2012	*Lottia limatula*	invertebrate	limpet
Shaws Cove	2012	*Fissurella volcano*	invertebrate	limpet
Shaws Cove	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin
Shaws Cove	2012	*Tegula funebralis*	invertebrate	snail
Shaws Cove	2012	*Lottia pelta*	invertebrate	limpet
Shaws Cove	2012	*Pachygrapsus crassipes*	invertebrate	crab
Shaws Cove	2012	Small limpet	invertebrate	limpet
Shaws Cove	2012	*Pagurus samuelis*	invertebrate	crab
Shaws Cove	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Shaws Cove	2012	*Mopalia spp*	invertebrate	chiton
Shaws Cove	2012	*Cyanoplax hartwegii*	invertebrate	chiton

Heisler Park (Laguna Beach SMR)

Physical Description

Heisler Park is located in the South Coast region of California, within the Laguna Beach State Marine Reserve. This site is located in an Area of Special Biological Significance (Heisler Park Ecological Reserve ASBS). This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 33. Biodiversity survey overview at Heisler Park

Heisler Park is dominated by a mixture of consolidated bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is southwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2009 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 33.3 meters (seaward).

Figure 34. Long term monitoring at Heisler Park

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Heisler Park (> 2% cover or > 1 per m^2) are displayed in Table 35 and 36 below.

Table 35. The most common sessile taxa (>2% cover) observed at Heisler Park

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Heisler Park	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Heisler Park	2013	*Mytilus californianus*	invertebrate	mussel
Heisler Park	2013	*Corallina spp*	macrophyte	coralline algae
Heisler Park	2013	*Egregia menziesii*	macrophyte	brown algae
Heisler Park	2013	*Chthamalus spp*	invertebrate	barnacle
Heisler Park	2013	Bluegreen algae	microalgae	microalgae
Heisler Park	2013	*Lithothrix aspergillum*	macrophyte	coralline algae

Table 36. The most common mobile taxa (>1 per m^2) observed at Heisler Park

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Heisler Park	2013	*Littorina keenae*	invertebrate	snail
Heisler Park	2013	*Lottia scabra/conus*	invertebrate	limpet
Heisler Park	2013	*Littorina spp*	invertebrate	snail
Heisler Park	2013	*Tegula funebralis*	invertebrate	snail
Heisler Park	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Heisler Park	2013	*Littorina plena/scutulata*	invertebrate	snail
Heisler Park	2013	*Lottia persona*	invertebrate	limpet
Heisler Park	2013	*Nuttalina spp*	invertebrate	chiton
Heisler Park	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Heisler Park	2013	*Lottia pelta*	invertebrate	limpet
Heisler Park	2013	*Tegula eiseni*	invertebrate	snail
Heisler Park	2013	*Pachygrapsus crassipes*	invertebrate	crab
Heisler Park	2013	*Pagurus samuelis*	invertebrate	crab
Heisler Park	2013	*Lottia limatula*	invertebrate	limpet
Heisler Park	2013	*Fissurella volcano*	invertebrate	limpet
Heisler Park	2013	*Pagurus hirsutiusculus*	invertebrate	crab
Heisler Park	2013	*Acanthina lugubris*	invertebrate	whelk
Heisler Park	2013	*Cyanoplax hartwegii*	invertebrate	chiton

Dana Point (Dana Point SMCA)

Physical Description

Dana Point is located in the South Coast region of California, within the Dana Point State Marine Conservation Area, and is near the Dana Point Mussel Watch site. The Ocean Institute is located at the entrance of the long reef and provides educational materials to the numerous schools that visit this site, some that make the hike to the monitoring location at the end of the reef. The site is located at the upcoast portion of this reef and is characterized by granitic boulders mixed with flattened benches.

Figure 35. Biodiversity survey overview at Dana Point

Dana Point is dominated by a mixture of consolidated bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and boulder fields. The primary coastal orientation of this site is south.

Figure 36. Site overview at Dana Point

Long-Term Monitoring Surveys at Dana Point were established in 1996, and are conducted by California State University Fullerton. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), and *Pisaster* (Ochre Star). In addition, motile invertebrates, mussel size structure, and water temperature are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2006, and 2010. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 25 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Dana Point (> 2% cover or > 1 per m^2) are displayed in Table 37 and 38 below.

Table 37. The most common sessile taxa (>2% cover) observed at Dana Point

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Dana Point	2013	*Silvetia compressa*	macrophyte	brown algae
Dana Point	2013	*Chthamalus spp*	invertebrate	barnacle
Dana Point	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Dana Point	2013	*Mytilus californianus*	invertebrate	mussel
Dana Point	2013	*Corallina spp*	macrophyte	coralline algae
Dana Point	2013	*Caulacanthus okamurae*	macrophyte	red algae
Dana Point	2013	*Egregia menziesii*	macrophyte	brown algae
Dana Point	2013	*Phyllospadix torreyi*	macrophyte	surfgrass

Table 38. The most common mobile taxa (>1 per m^2) observed at Dana Point

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Dana Point	2013	*Littorina spp*	invertebrate	snail
Dana Point	2013	*Littorina plena/scutulata*	invertebrate	snail
Dana Point	2013	*Littorina keenae*	invertebrate	snail
Dana Point	2013	*Lottia scabra/conus*	invertebrate	limpet
Dana Point	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Dana Point	2013	*Tegula eiseni*	invertebrate	snail
Dana Point	2013	*Fissurella volcano*	invertebrate	limpet
Dana Point	2013	*Pagurus samuelis*	invertebrate	crab
Dana Point	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Dana Point	2013	*Nuttalina spp*	invertebrate	chiton
Dana Point	2013	*Lottia pelta*	invertebrate	limpet
Dana Point	2013	*Pagurus hirsutiusculus*	invertebrate	crab
Dana Point	2013	*Pachygrapsus crassipes*	invertebrate	crab
Dana Point	2013	*Conus californicus*	invertebrate	snail
Dana Point	2013	*Acanthinucella spp*	invertebrate	whelk
Dana Point	2013	*Macron lividus*	invertebrate	whelk

Cardiff Reef

Physical Description

Cardiff Reef is located in the South Coast region of California, at the south end of Cardiff State Beach. This site is on the border of the Swami's State Marine Conservation Area, and is near the Cardiff Reef Mussel Watch site. This site is roughly 1.7 km south of the entrance to San Elijo Lagoon, and is about 100 meters south of a large beach parking lot. This site receives a high number of visitors, including tidepoolers. This gently sloping site consists of moderately uneven terrain, containing relatively few large crevices and folds.

Figure 37. Site overview at Cardiff Reef

Cardiff Reef is dominated by a mixture of consolidated sedimentary bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of cobble/gravel fields and sandy beach at this site. Sand can fluctuate by more than one meter in less than a year at this site, resulting in a heavily scoured site. The primary coastal orientation of this site is west.

Figure 38. Biodiversity survey at Cardiff Reef.

Long-Term MARINe surveys at Cardiff Reef were established in 1997, and were previously done by University of California Santa Barbara, but are currently done by Cabrillo National Monument. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), Red Algal Turf, *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star).

Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Cardiff Reef (> 2% cover or > 1 per m^2) are displayed in Table 39 and 40 below.

Table 39. The most common sessile taxa (>2% cover) observed at Cardiff Reef

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cardiff Reef	2012	*Mytilus californianus*	invertebrate	mussel
Cardiff Reef	2012	Diatoms	microalgae	microalgae
Cardiff Reef	2012	*Ulva spp*	macrophyte	green algae
Cardiff Reef	2012	*Anthopleura elegantissima*	invertebrate	anemone
Cardiff Reef	2012	*Mytilus galloprovincialis/trossulus*	invertebrate	mussel

Table 40. The most common mobile taxa (>1 per m^2) observed at Cardiff Reef

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cardiff Reef	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Cardiff Reef	2012	*Lottia scabra/conus*	invertebrate	limpet
Cardiff Reef	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Cardiff Reef	2012	*Pachygrapsus crassipes*	invertebrate	crab
Cardiff Reef	2012	*Littorina plena/scutulata*	invertebrate	snail
Cardiff Reef	2012	*Lottia pelta*	invertebrate	limpet
Cardiff Reef	2012	*Nuttalina spp*	invertebrate	chiton
Cardiff Reef	2012	*Acanthinucella spp*	invertebrate	whelk
Cardiff Reef	2012	*Epitonium tinctum*	invertebrate	snail
Cardiff Reef	2012	Small limpet	invertebrate	limpet
Cardiff Reef	2012	*Mopalia spp*	invertebrate	chiton

Scripps (San Diego-Scripps Coastal SMCA)

Physical Description

Scripps is located in the South Coast region of California, midway between the Scripps Institution of Oceanography Pier and Black's Canyon in La Jolla, in the Scripps UC Coastal Reserve. The site is located in an Area of Special Biological Significance (San Diego Marine Life Refuge ASBS), within the San Diego-Scripps Coastal State Marine Conservation Area, and is near the Scripps Reef Mussel Watch site. This site receives a high number of visitors, including tidepoolers, students, and scientists. Various class projects and research studies have been conducted here by UC San Diego and Scripps personnel, with authorization and documentation by the Scripps Coastal Reserve. This gently sloping site consists of moderately uneven terrain, containing many boulders and crevices.

Figure 39. Biodiversity survey overview at Scripps

Scripps is dominated by a mixture of consolidated sedimentary and metamorphic bedrock, boulder fields, and sandy beach, and the area surrounding the site is comprised of sandy beach with upper intertidal boulders and rock outcrops. Sand can fluctuate over one meter within a single year at this site and may play a dominant role in structuring the community. The primary coastal orientation of this site is west.

Long-Term Monitoring Surveys at Scripps were established in 1997, and were previously done by University of California Santa Barbara, but are currently done by Cabrillo National Monument. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), Red Algal Turf, *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star).

Figure 40. Intertidal emersion at Scripps

Biodiversity Surveys were done by University of California Santa Cruz in 2002, 2006 and 2010. The Biodiversity Survey grid encompasses one section that is approximately 29.6 meters (along shore) x 40 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Scripps (> 2% cover or > 1 per m^2) are displayed in Table 41 and 42 below.

Table 41. The most common sessile taxa (>2% cover) observed at Scripps

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Scripps	2013	*Corallina spp*	macrophyte	coralline algae
Scripps	2013	*Gelidium pusillum*	macrophyte	red algae
Scripps	2013	*Eisenia arborea*	macrophyte	brown algae
Scripps	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Scripps	2013	*Caulacanthus okamurae*	macrophyte	red algae
Scripps	2013	*Chthamalus spp*	invertebrate	barnacle
Scripps	2013	*Pterocladiella capillacea*	macrophyte	red algae
Scripps	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Scripps	2013	*Hildenbrandia/Peyssonnelia spp*	macrophyte	red algae
Scripps	2013	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Scripps	2013	*Mytilus californianus*	invertebrate	mussel
Scripps	2013	*Anthopleura elegantissima*	invertebrate	anemone
Scripps	2013	*Polysiphonia spp*	macrophyte	red algae
Scripps	2013	*Corallina spp*	macrophyte	coralline algae
Scripps	2013	*Gelidium pusillum*	macrophyte	red algae

Table 42. The most common mobile taxa (>1 per m^2) observed at Scripps

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Scripps	2013	*Littorina plena/scutulata*	invertebrate	snail
Scripps	2013	*Littorina spp*	invertebrate	snail
Scripps	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Scripps	2013	*Littorina keenae*	invertebrate	snail
Scripps	2013	*Lottia scabra/conus*	invertebrate	limpet
Scripps	2013	*Lottia pelta*	invertebrate	limpet
Scripps	2013	*Acanthina lugubris*	invertebrate	whelk
Scripps	2013	*Nuttalina spp*	invertebrate	chiton
Scripps	2013	*Tegula gallina*	invertebrate	snail
Scripps	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Scripps	2013	*Pagurus samuelis*	invertebrate	crab
Scripps	2013	*Tegula funebralis*	invertebrate	snail
Scripps	2013	*Fissurella volcano*	invertebrate	limpet
Scripps	2013	*Pagurus hirsutiusculus*	invertebrate	crab
Scripps	2013	*Cyanoplax hartwegii*	invertebrate	chiton

La Jolla Caves (Matlahuayl SMR)

Physical Description

La Jolla Caves is located in the South Coast region of California, within the Matlahuayl State Marine Reserve. and is near the Point La Jolla Mussel Watch site. This gently sloping site consists of relatively flat terrain.

Figure 41. Biodiversity survey overview at La Jolla Caves

La Jolla Caves is dominated by a mixture of consolidated bedrock, boulder fields, and sandy beach, and the area surrounding the site is comprised of a mixture of boulder fields and cobble and sandy beach. The primary coastal orientation of this site is north.

Biodiversity Surveys were done by University of California Santa Cruz in 2009 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 50 meters (seaward).

Figure 42. Intertidal emersion at La Jolla Caves

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at La Jolla Caves (> 2% cover or > 1 per m^2) are displayed in Table 43 and 44 below.

Table 43. The most common sessile taxa (>2% cover) observed at La Jolla Caves

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
La Jolla Caves	2013	*Corallina spp*	macrophyte	coralline algae
La Jolla Caves	2013	*Sargassum muticum*	macrophyte	brown algae
La Jolla Caves	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
La Jolla Caves	2013	*Pterocladiella capillacea*	macrophyte	red algae
La Jolla Caves	2013	Encrusting Coralline	macrophyte	coralline algae
La Jolla Caves	2013	*Caulacanthus okamurae*	macrophyte	red algae

Table 44. The most common mobile taxa (>1 per m^2) observed at La Jolla Caves

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
La Jolla Caves	2013	*Littorina plena/scutulata*	invertebrate	snail
La Jolla Caves	2013	*Lottia scabra/conus*	invertebrate	limpet
La Jolla Caves	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
La Jolla Caves	2013	*Pagurus samuelis*	invertebrate	crab
La Jolla Caves	2013	*Tegula eiseni*	invertebrate	snail
La Jolla Caves	2013	*Littorina keenae*	invertebrate	snail
La Jolla Caves	2013	*Pachygrapsus crassipes*	invertebrate	crab
La Jolla Caves	2013	Small limpet	invertebrate	limpet
La Jolla Caves	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
La Jolla Caves	2013	*Fissurella volcano*	invertebrate	limpet
La Jolla Caves	2013	*Lottia limatula*	invertebrate	limpet
La Jolla Caves	2013	*Tegula gallina*	invertebrate	snail

Wind and Sea

Physical Description

Wind and Sea is located in the South Coast region of California. This site is part of Windansea Beach, located in La Jolla. In addition to being known for surf breaks created by underwater reefs, this site has high visitation due to easy access and nearby neighborhoods. This site is highly sand influenced. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 43. Biodiversity survey overview at Wind and Sea

Figure 44. Intertidal emersion at Wind and Sea

Wind and Sea is dominated by a mixture of consolidated sandstone and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The primary coastal orientation of this site is west/northwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 40 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Wind and Sea (> 2% cover or > 1 per m^2) are displayed in Table 45 and 46 below.

Table 45. The most common sessile taxa (>2% cover) observed at Wind and Sea

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Wind and Sea	2012	*Lithothrix aspergillum*	macrophyte	coralline algae
Wind and Sea	2012	*Corallina spp*	macrophyte	coralline algae
Wind and Sea	2012	*Ulva spp*	macrophyte	green algae
Wind and Sea	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Wind and Sea	2012	*Jania crassa*	macrophyte	coralline algae
Wind and Sea	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Wind and Sea	2012	*Pterocladiella capillacea*	macrophyte	red algae
Wind and Sea	2012	*Phyllospadix scouleri*	macrophyte	surfgrass

Table 46. The most common mobile taxa (>1 per m^2) observed at Wind and Sea

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Wind and Sea	2012	*Lottia scabra/conus*	invertebrate	limpet
Wind and Sea	2012	*Nuttalina spp*	invertebrate	chiton
Wind and Sea	2012	*Littorina plena/scutulata*	invertebrate	snail
Wind and Sea	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Wind and Sea	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Wind and Sea	2012	*Acanthina lugubris*	invertebrate	whelk
Wind and Sea	2012	*Lacuna spp*	invertebrate	snail
Wind and Sea	2012	*Pachygrapsus crassipes*	invertebrate	crab
Wind and Sea	2012	*Mopalia spp*	invertebrate	chiton

Sea Ridge (South La Jolla SMR)

Physical Description

Sea Ridge is located in the South Coast region of California. This site is accessible by stairway, then walking across a boulder field. The site has high visitation due to easy access and nearby neighborhoods. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 45. Biodiversity survey at Sea Ridge

Sea Ridge is dominated by a mixture of consolidated conglomerate bedrock, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and cobble and sandy beach. The primary coastal orientation of this site is southwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 60 meters (seaward).

Figure 46. Intertidal emersion at Sea Ridge

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Sea Ridge (> 2% cover or > 1 per m^2) are displayed in Table 47 and 48 below.

Table 47. The most common sessile taxa (>2% cover) observed at Sea Ridge

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Sea Ridge	2012	*Corallina spp*	macrophyte	coralline algae
Sea Ridge	2012	*Ulva spp*	macrophyte	green algae
Sea Ridge	2012	*Lithothrix aspergillum*	macrophyte	coralline algae
Sea Ridge	2012	*Chthamalus spp*	invertebrate	barnacle
Sea Ridge	2012	*Lomentaria hakodatensis*	macrophyte	red algae
Sea Ridge	2012	Encrusting Coralline	macrophyte	coralline algae
Sea Ridge	2012	*Jania crassa*	macrophyte	coralline algae
Sea Ridge	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Sea Ridge	2012	*Caulacanthus okamurae*	macrophyte	red algae
Sea Ridge	2012	*Gelidium coulteri*	macrophyte	red algae

Table 48. The most common mobile taxa (>1 per m^2) observed at Sea Ridge

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Sea Ridge	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Sea Ridge	2012	*Lottia scabra/conus*	invertebrate	limpet
Sea Ridge	2012	*Littorina plena/scutulata*	invertebrate	snail
Sea Ridge	2012	*Littorina spp*	invertebrate	snail
Sea Ridge	2012	*Tegula eiseni*	invertebrate	snail
Sea Ridge	2012	Small limpet	invertebrate	limpet
Sea Ridge	2012	*Fissurella volcano*	invertebrate	limpet
Sea Ridge	2012	*Lottia limatula*	invertebrate	limpet
Sea Ridge	2012	*Pachygrapsus crassipes*	invertebrate	crab
Sea Ridge	2012	*Pagurus samuelis*	invertebrate	crab
Sea Ridge	2012	*Lottia pelta*	invertebrate	limpet
Sea Ridge	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Sea Ridge	2012	*Tegula aureotincta*	invertebrate	snail
Sea Ridge	2012	*Tegula funebralis*	invertebrate	snail
Sea Ridge	2012	*Lottia ochracea*	invertebrate	limpet
Sea Ridge	2012	*Nuttalina spp*	invertebrate	chiton
Sea Ridge	2012	*Stenoplax conspicua*	invertebrate	chiton
Sea Ridge	2012	*Tegula gallina*	invertebrate	snail
Sea Ridge	2012	*Littorina keenae*	invertebrate	snail
Sea Ridge	2012	*Acanthina lugubris*	invertebrate	whelk
Sea Ridge	2012	*Roperia poulsoni*	invertebrate	whelk

Navy North

Physical Description

Navy North is located in the South Coast region of California, on the outer Point Loma Peninsula in San Diego. This site is located on a Navy base, and receives few visitors due to access restrictions and high coastal bluffs. This gently sloping site consists of moderately uneven terrain, containing relatively few large crevices and folds.

Figure 47. Biodiversity survey overview at Navy North

Navy North is dominated by a mixture of consolidated sedimentary bedrock, boulder fields, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and cobble beach. The primary coastal orientation of this site is west.

Long-Term MARINe surveys at Navy North were established in 1995, and were previously done by University of California Santa Barbara, but are currently done by Cabrillo National Monument. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Tetraclita* (Pink Barnacle), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), Red Algal Turf, *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star).

Figure 48. Intertisal emersion at Navy North

Biodiversity Surveys were done by University of California Santa Cruz in 2012. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 25 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Navy North (> 2% cover or > 1 per m^2) are displayed in Table 49 and 50 below.

Table 49. The most common sessile taxa (>2% cover) observed at Navy North

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Navy North	2012	*Corallina* spp	macrophyte	coralline algae
Navy North	2012	*Chondracanthus* canaliculatus	macrophyte	red algae
Navy North	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Navy North	2012	*Ulva* spp	macrophyte	green algae
Navy North	2012	*Ralfsiaceae spp*	macrophyte	brown algae
Navy North	2012	*Phyllospadix* torreyi	macrophyte	surfgrass
Navy North	2012	*Gastroclonium* parvum	macrophyte	red algae

Table 50. The most common mobile taxa (>1 per m^2) observed at Navy North

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Navy North	2012	*Lottia scabra/conus*	invertebrate	limpet
Navy North	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Navy North	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Navy North	2012	*Littorina plena/scutulata*	invertebrate	snail
Navy North	2012	*Tegula eiseni*	invertebrate	snail
Navy North	2012	*Littorina spp*	invertebrate	snail
Navy North	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Navy North	2012	*Fissurella volcano*	invertebrate	limpet
Navy North	2012	*Pagurus samuelis*	invertebrate	crab
Navy North	2012	Small limpet	invertebrate	limpet
Navy North	2012	*Pachygrapsus crassipes*	invertebrate	crab
Navy North	2012	*Lottia limatula*	invertebrate	limpet
Navy North	2012	*Cyanoplax hartwegii*	invertebrate	chiton

Cabrillo 1 (Cabrillo SMR)

Physical Description

Cabrillo 1 is located in the South Coast region of California, in Cabrillo National Monument. The site is located within the Cabrillo State Marine Reserve. This site receives approximately 150,000 visitors per year, and is patrolled by volunteers of the National Park Service who educate visitors and enforce no-take regulations. The Point Loma Waste Water Treatment Plant is a short distance to the north, though the outfall is more than three miles offshore and is not thought to be a regular source of pollution for this site. Cabrillo 1 forms the upper end of a steep visitation gradient with Cabrillo 3. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 49. Biodiversity survey overview at Cabrillo 1

Cabrillo 1 is dominated by a mixture of consolidated sandstone, mudstone, and granite bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock and boulder fields. There is a small sandy beach at the southern end of the site. The primary coastal orientation of this site is west.

Figure 50. Intertidal emersion at Cabrillo 1

Long-Term Monitoring Surveys at Cabrillo 1 were established in 1990, and are done by Cabrillo National Monument. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Tetraclita* (Pink Barnacle), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Egregia* (Feather-Boa Kelp), Red Algal Turf, *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, water temperature is monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2002, 2004, and 2009. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 40 meters (seaward

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Cabrillo 1 (> 2% cover or > 1 per m^2) are displayed in Table 51 and 52 below.

Table 51. The most common sessile taxa (>2% cover) observed at Cabrillo 1

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cabrillo 1	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Cabrillo 1	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Cabrillo 1	2013	*Gastroclonium subarticulatum*	macrophyte	red algae
Cabrillo 1	2013	*Corallina spp*	macrophyte	coralline algae
Cabrillo 1	2013	*Silvetia compressa*	macrophyte	brown algae
Cabrillo 1	2013	*Chthamalus spp*	invertebrate	barnacle
Cabrillo 1	2013	*Plocamium pacificum*	macrophyte	red algae
Cabrillo 1	2013	*Egregia menziesii*	macrophyte	brown algae

Table 52. The most common mobile taxa (>1 per m^2) observed at Cabrillo 1

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cabrillo 1	2013	*Lottia scabra/conus*	invertebrate	limpet
Cabrillo 1	2013	*Tegula eiseni*	invertebrate	snail
Cabrillo 1	2013	*Mopalia spp*	invertebrate	chiton
Cabrillo 1	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Cabrillo 1	2013	*Pagurus samuelis*	invertebrate	crab
Cabrillo 1	2013	Small limpet	invertebrate	limpet
Cabrillo 1	2013	*Littorina plena/scutulata*	invertebrate	snail
Cabrillo 1	2013	*Littorina spp*	invertebrate	snail
Cabrillo 1	2013	*Fissurella volcano*	invertebrate	limpet
Cabrillo 1	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Cabrillo 1	2013	*Acanthina lugubris*	invertebrate	whelk
Cabrillo 1	2013	*Lottia pelta*	invertebrate	limpet
Cabrillo 1	2013	*Leptasterias spp*	invertebrate	sea star
Cabrillo 1	2013	*Lottia limatula*	invertebrate	limpet

Cabrillo 3 (Cabrillo SMR)

Physical Description

Cabrillo 3 is located in the South Coast region of California, in Cabrillo National Monument. The site is located within the Cabrillo State Marine Reserve. This site is off limits to human visitors and receives very low visitation. As such it forms a steep visitation gradient with Cabrillo 1. This site may occasionally be exposed to San Diego Bay water, which is a potential source of pollution. There is heavy boat traffic offshore coming and going from San Diego Bay. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 51. Biodiversity survey overview at Cabrillo 3

Cabrillo 3 is dominated by a mixture of consolidated sandstone, mudstone, and granite bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock and boulder fields. The primary coastal orientation of this site is south, since Cabrillo 3 is at the southern tip of Point Loma but weather often comes from the west and southwest. Cabrillo 3 is exposed to sun and wind from the east.

Long-Term Monitoring Surveys at Cabrillo 3 were established in 1990, and are done by Cabrillo National Monument. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Tetraclita* (Pink Barnacle), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Egregia* (Feather-Boa Kelp), Red Algal Turf, *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, water temperature is monitored at this site.

Figure 52. Intertidal emersion at Cabrillo 3

Biodiversity Surveys were done by University of California Santa Cruz 2002 and 2012. The Biodiversity Survey grid encompasses two sections that are approximately 21 meters (along shore) x 60 meters (seaward), and 4 meters (along shore) x 60 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Cabrillo 3 (> 2% cover or > 1 per m^2) are displayed in Table 53 and 54 below.

Table 53. The most common sessile taxa (>2% cover) observed at Cabrillo 3

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cabrillo 3	2012	*Corallina spp*	macrophyte	coralline algae
Cabrillo 3	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Cabrillo 3	2012	*Ulva spp*	macrophyte	green algae
Cabrillo 3	2012	*Lithothrix aspergillum*	macrophyte	coralline algae
Cabrillo 3	2012	*Lomentaria hakodatensis*	macrophyte	red algae
Cabrillo 3	2012	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Cabrillo 3	2012	Diatoms	microalgae	microalgae
Cabrillo 3	2012	*Chthamalus spp*	invertebrate	barnacle
Cabrillo 3	2012	*Phyllospadix torreyi*	macrophyte	surfgrass

Table 54. The most common mobile taxa (>1 per m^2) observed at Cabrillo 3

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cabrillo 3	2012	*Littorina spp*	invertebrate	snail
Cabrillo 3	2012	*Lottia scabra/conus*	invertebrate	limpet
Cabrillo 3	2012	*Tegula funebralis*	invertebrate	snail
Cabrillo 3	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Cabrillo 3	2012	*Tegula eiseni*	invertebrate	snail
Cabrillo 3	2012	*Pachygrapsus crassipes*	invertebrate	crab
Cabrillo 3	2012	*Littorina plena/scutulata*	invertebrate	snail
Cabrillo 3	2012	*Littorina keenae*	invertebrate	snail
Cabrillo 3	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Cabrillo 3	2012	*Fissurella volcano*	invertebrate	limpet
Cabrillo 3	2012	*Lottia limatula*	invertebrate	limpet
Cabrillo 3	2012	*Nuttalina spp*	invertebrate	chiton
Cabrillo 3	2012	*Lacuna spp*	invertebrate	snail
Cabrillo 3	2012	Small limpet	invertebrate	limpet
Cabrillo 3	2012	*Conus californicus*	invertebrate	snail
Cabrillo 3	2012	*Pagurus samuelis*	invertebrate	crab

Cuyler Harbor (Harris Point SMR)

Physical Description

Cuyler Harbor is located in the Northern Channel Islands, within the Channel Islands National Marine Sanctuary, on San Miguel Island, California. This site is located in an Area of Special Biological Significance (San Miguel, Santa Rosa, and Santa Cruz Islands ASBS) within the Harris Point State Marine Reserve in Channel Islands National Park. This site was established in the same location as one of the historic study sites used for a baseline study of the Southern California Bight (conducted by the Bureau of Land Management in 1978-79). This site may receive a small number of visitors camping in the summer. The gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 53. Site overview at Cuyler Harbor

Cuyler Harbor is dominated by consolidated basalt bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The high ridge on the northern, exposed side protects the monitoring site from swells and some weather. A small surge channel on the north side of the site provides a nice example of zonation and holds a broad diversity of algae. Lower reaches are heavily influenced by sand.

Figure 54. Biodiversity survery overview at Cuyler Harbor

Long-Term Monitoring Surveys at Cuyler Harbor were established in 1985, and are done by Channel Islands National Park. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), and *Endocladia* (Turfweed). In addition, motile invertebrates and mussel size structure are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2002, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 29 meters (along shore) x 15 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Cuyler Harbor (> 2% cover or > 1 per m^2) are displayed in Table 55 and 56 below.

Table 55. The most common sessile taxa (>2% cover) observed at Cuyler Harbor

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cuyler Harbor	2012	*Phragmatopoma californica*	invertebrate	worm
Cuyler Harbor	2012	*Mytilus californianus*	invertebrate	mussel
Cuyler Harbor	2012	*Endocladia muricata*	macrophyte	red algae
Cuyler Harbor	2012	*Balanus glandula*	invertebrate	barnacle
Cuyler Harbor	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
Cuyler Harbor	2012	Bluegreen algae	microalgae	microalgae
Cuyler Harbor	2012	*Tetraclita rubescens*	invertebrate	barnacle

Table 56. The most common mobile taxa (>1 per m^2) observed at Cuyler Harbor

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Cuyler Harbor	2012	*Littorina keenae*	invertebrate	snail
Cuyler Harbor	2012	*Littorina plena/scutulata*	invertebrate	snail
Cuyler Harbor	2012	*Lottia scabra/conus*	invertebrate	limpet
Cuyler Harbor	2012	*Littorina spp*	invertebrate	snail
Cuyler Harbor	2012	*Nuttalina spp*	invertebrate	chiton
Cuyler Harbor	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Cuyler Harbor	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Cuyler Harbor	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Cuyler Harbor	2012	*Tegula funebralis*	invertebrate	snail
Cuyler Harbor	2012	*Lottia pelta*	invertebrate	limpet
Cuyler Harbor	2012	*Pagurus samuelis*	invertebrate	crab

Crook Point

Physical Description

Crook Point is located in the Northern Channel Islands, within the Channel Islands National Marine Sanctuary, on San Miguel Island, California. This site is located in an Area of Special Biological Significance (San Miguel, Santa Rosa, and Santa Cruz Islands ASBS) in Channel Islands National Park. This site was established in the same location as one of the historic study sites used for a baseline study of the Southern California Bight (conducted by the Bureau of Land Management in 1978-79). The gently sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Figure 55. Biodiversity survey overview at Crook Point

Crook Point is dominated by consolidated sandstone bedrock, (some of which is quite soft in areas and easily eroded), and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The site is at the two western most outcrops of the series along the Crook Point area. All the outcrop peninsulas point southeast. The outer reef absorbs most of the impacts from the heavy south westerly swells that pound this area. While the inner reef is quite smooth, the outer reef is very pock marked with many pools and areas of very rough surface.

Long-Term Monitoring Surveys at Crook Point were established in 1985, and are done by Channel Islands National Park. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), and *Endocladia* (Turfweed). In addition, motile invertebrates, mussel size structure, and water temperature are monitored at this site.

Figure 56. Intertidal emersion at Crook Point

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 20 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Crook Point (> 2% cover or > 1 per m^2) are displayed in Table 57 and 58 below.

Table 57. The most common sessile taxa (>2% cover) observed at Crook Point

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Crook Point	2012	*Cladophora columbiana*	macrophyte	green algae
Crook Point	2012	*Mytilus californianus*	invertebrate	mussel
Crook Point	2012	*Endocladia muricata*	macrophyte	red algae
Crook Point	2012	*Balanus glandula*	invertebrate	barnacle
Crook Point	2012	*Corallina spp*	macrophyte	coralline algae
Crook Point	2012	*Phragmatopoma californica*	invertebrate	worm
Crook Point	2012	Encrusting Coralline	macrophyte	coralline algae

Table 58. The most common mobile taxa (>1 per m^2) observed at Crook Point

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Crook Point	2012	*Littorina keenae*	invertebrate	snail
Crook Point	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Crook Point	2012	*Littorina plena/scutulata*	invertebrate	snail
Crook Point	2012	*Littorina spp*	invertebrate	snail
Crook Point	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Crook Point	2012	*Lottia scabra/conus*	invertebrate	limpet
Crook Point	2012	Small limpet	invertebrate	limpet
Crook Point	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
Crook Point	2012	*Nuttalina spp*	invertebrate	chiton
Crook Point	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin
Crook Point	2012	*Lottia limatula*	invertebrate	limpet
Crook Point	2012	*Pachygrapsus crassipes*	invertebrate	crab

Middle West (Anacapa Island SMR)

Physical Description

Middle West is located in the Northern Channel Islands, within the Channel Islands National Marine Sanctuary, on Anacapa Island. This site is located in an Area of Special Biological Significance (Santa Barbara Island and Anacapa Island ASBS) within the Anacapa Island State Marine Reserve in Channel Islands National Park, and is near the Anacapa Island Mussel Watch site. Deep surge channels separate this site from Middle East, and what little landing occurs at Middle Island occurs at Middle West. The site is typically lower and has more relief than Middle East.

Figure 57. Biodiversity survey overview at Middle West

Middle West is dominated by consolidated volcanic bedrock, and the area surrounding the site is comprised of consolidated bedrock. The primary coastal orientation of this site is north.

Figure 58. Intertidal emersion at Middle West

Long-Term Monitoring Surveys at Middle West were established in 1982, and are done by Channel Islands National Park. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), and *Endocladia* (Turfweed). In addition, motile invertebrates, mussel size structure, and water temperature are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2005, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 29 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Middle West (> 2% cover or > 1 per m^2) are displayed in Table 59 and 60 below.

Table 59. The most common sessile taxa (>2% cover) observed at Middle West

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Middle West	2012	*Mytilus californianus*	invertebrate	mussel
Middle West	2012	*Corallina spp*	macrophyte	coralline algae
Middle West	2012	*Ulva spp*	macrophyte	green algae
Middle West	2012	*Endocladia muricata*	macrophyte	red algae
Middle West	2012	*Tetraclita rubescens*	invertebrate	barnacle
Middle West	2012	*Hildenbrandia/Peyssonnelia spp*	macrophyte	red algae
Middle West	2012	*Pseudolithoderma nigra*	macrophyte	brown algae
Middle West	2012	*Chthamalus spp*	invertebrate	barnacle
Middle West	2012	*Mazzaella affinis*	macrophyte	red algae
Middle West	2012	Encrusting Coralline	macrophyte	coralline algae
Middle West	2012	*Phragmatopoma californica*	invertebrate	worm

Table 60. The most common mobile taxa (>1 per m^2) observed at Middle West

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Middle West	2012	*Littorina spp*	invertebrate	snail
Middle West	2012	*Littorina keenae*	invertebrate	snail
Middle West	2012	*Littorina plena/scutulata*	invertebrate	snail
Middle West	2012	*Strongylocentrotus purpuratus*	invertebrate	urchin
Middle West	2012	*Lottia scabra/conus*	invertebrate	limpet
Middle West	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Middle West	2012	*Acanthinucella spp*	invertebrate	whelk
Middle West	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Middle West	2012	*Lottia pelta*	invertebrate	limpet
Middle West	2012	*Fissurella volcano*	invertebrate	limpet
Middle West	2012	*Pagurus hirsutiusculus*	invertebrate	crab
Middle West	2012	*Lottia insessa*	invertebrate	limpet
Middle West	2012	*Pachygrapsus crassipes*	invertebrate	crab
Middle West	2012	*Lottia limatula*	invertebrate	limpet
Middle West	2012	*Ocenebra circumtexta*	invertebrate	whelk
Middle West	2012	Small limpet	invertebrate	limpet
Middle West	2012	*Pisaster ochraceus*	invertebrate	sea star
Middle West	2012	*Pagurus samuelis*	invertebrate	crab
Middle West	2012	*Nuttalina spp*	invertebrate	chiton
Middle West	2012	*Mopalia spp*	invertebrate	chiton

S Frenchys Cove

Physical Description

S Frenchys Cove is located in the Northern Channel Islands, within the Channel Islands National Marine Sanctuary, on Anacapa Island. This site is located in an Area of Special Biological Significance (Santa Barbara Island and Anacapa Island ASBS) within the Anacapa Island Special Closure in Channel Islands National Park. The site is the first reef from the access point, or gap, near the east end of West Anacapa Island. This reef is also used for the NOAA LiMPETS program. The second reef (first major point) includes one of the historic study sites used for a baseline study of the Southern California Bight (conducted by the Bureau of Land Management in 1978-79). This second reef is also referred to as the "blowhole", and is where the majority of visitors go. This site receives 1500-3000 visitors per year, primarily tidepoolers. The site consists of a number of solid rocky reefs one to almost two meters above zero tide level. The reef is quite level with little change in elevation from the cliff out to the end of the mussel plots.

Figure 59. Biodiversity survey overview at S Frenchys Cove

S Frenchys Cove is dominated by a mixture of consolidated volcanic bedrock and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The outer reef has a fairly dense mussel bed and even at low tide is washed by large swells. The primary coastal orientation of this site is south.

Long-Term Monitoring Surveys at S Frenchys Cove were established in 1982, and are done by Channel Islands National Park. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), and *Endocladia* (Turfweed). In addition, motile invertebrates, mussel size structure, and water temperature are monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2005, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 33 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at S Frenchys Cove (> 2% cover or > 1 per m^2) are displayed in Table 61 and 62 below.

Table 61. The most common sessile taxa (>2% cover) observed at S Frenchys Cove

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
S Frenchys Cove	2012	*Chondracanthus canaliculatus*	macrophyte	red algae
S Frenchys Cove	2012	*Endocladia muricata*	macrophyte	red algae
S Frenchys Cove	2012	*Mytilus californianus*	invertebrate	mussel
S Frenchys Cove	2012	*Chthamalus spp*	invertebrate	barnacle
S Frenchys Cove	2012	*Mazzaella affinis*	macrophyte	red algae
S Frenchys Cove	2012	*Ulva spp*	macrophyte	green algae
S Frenchys Cove	2012	*Phragmatopoma californica*	invertebrate	worm
S Frenchys Cove	2012	*Chaetomorpha spiralis*	macrophyte	green algae
S Frenchys Cove	2012	*Corallina spp*	macrophyte	coralline algae

Table 62. The most common mobile taxa (>1 per m^2) observed at S Frenchys Cove

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
S Frenchys Cove	2012	*Littorina spp*	invertebrate	snail
S Frenchys Cove	2012	*Littorina keenae*	invertebrate	snail
S Frenchys Cove	2012	*Littorina plena/scutulata*	invertebrate	snail
S Frenchys Cove	2012	*Lottia scabra/conus*	invertebrate	limpet
S Frenchys Cove	2012	*Lottia paradigitalis/strigatella*	invertebrate	limpet
S Frenchys Cove	2012	*Lottia pelta*	invertebrate	limpet
S Frenchys Cove	2012	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
S Frenchys Cove	2012	*Nuttalina spp*	invertebrate	chiton
S Frenchys Cove	2012	*Pachygrapsus crassipes*	invertebrate	crab
S Frenchys Cove	2012	*Nucella emarginata/ostrina*	invertebrate	whelk
S Frenchys Cove	2012	Small limpet	invertebrate	limpet
S Frenchys Cove	2012	*Lottia limatula*	invertebrate	limpet
S Frenchys Cove	2012	*Fissurella volcano*	invertebrate	limpet
S Frenchys Cove	2012	*Mopalia spp*	invertebrate	chiton
S Frenchys Cove	2012	*Acanthinucella spp*	invertebrate	whelk

Thousand Springs

Physical Description

Thousand Springs is located in the Southern Channel Islands. This site is not accessible by the public, as it is on navy-owned San Nicolas Island. Visitation to this site is limited to fishing and tidepooling navy personnel and a handful of researchers. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 60. Biodiversity survey overview at Thousand Springs

Thousand Springs is dominated by a mixture of consolidated bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is north/northeast.

Biodiversity Surveys were done by University of California Santa Cruz in 2003, 2007, and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Figure 61. Intertidal emersion at Thousand Springs

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Thousand Springs (> 2% cover or > 1 per m^2) are displayed in Table 63 and 64 below.

Table 63. The most common sessile taxa (>2% cover) observed at Thousand Springs

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Thousand Springs	2013	*Phyllospadix scouleri*	macrophyte	surfgrass
Thousand Springs	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Thousand Springs	2013	Bluegreen algae	microalgae	microalgae
Thousand Springs	2013	Encrusting Coralline	macrophyte	coralline algae
Thousand Springs	2013	*Corallina spp*	macrophyte	coralline algae
Thousand Springs	2013	*Endocladia muricata*	macrophyte	red algae
Thousand Springs	2013	Other crust	macrophyte	red algae
Thousand Springs	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Thousand Springs	2013	Other red crust	macrophyte	red algae

Table 64. The most common mobile taxa (>1 per m^2) observed at Thousand Springs

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Thousand Springs	2013	*Littorina keenae*	invertebrate	snail
Thousand Springs	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Thousand Springs	2013	*Lottia scabra/conus*	invertebrate	limpet
Thousand Springs	2013	*Littorina plena/scutulata*	invertebrate	snail
Thousand Springs	2013	*Littorina spp*	invertebrate	snail
Thousand Springs	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Thousand Springs	2013	Small limpet	invertebrate	limpet
Thousand Springs	2013	*Nuttalina spp*	invertebrate	chiton
Thousand Springs	2013	*Cyanoplax hartwegii*	invertebrate	chiton
Thousand Springs	2013	*Fissurella volcano*	invertebrate	limpet
Thousand Springs	2013	*Lottia pelta*	invertebrate	limpet
Thousand Springs	2013	*Homalopoma baculum/luridum*	invertebrate	snail
Thousand Springs	2013	*Lottia limatula*	invertebrate	limpet
Thousand Springs	2013	*Pagurus samuelis*	invertebrate	crab

Tranquility Beach

Physical Description

Tranquility Beach is located in the Southern Channel Islands. This site is not accessible by the public, as it is on navy-owned San Nicolas Island. Visitation to this site is limited to fishing and tidepooling navy personnel and a handful of researchers. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 62. Biodiversity survey overview at Tranquility Beach

Figure 63. Long term monitoring at Tranquility Beach

Tranquility Beach is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is north/northwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2009 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 40 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Tranquility Beach (> 2% cover or > 1 per m^2) are displayed in Table 65 and 66 below.

Table 65. The most common sessile taxa (>2% cover) observed at Tranquility Beach

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Tranquility Beach	2013	*Phyllospadix torreyi*	macrophyte	surfgrass
Tranquility Beach	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Tranquility Beach	2013	Bluegreen algae	microalgae	microalgae
Tranquility Beach	2013	*Corallina spp*	macrophyte	coralline algae
Tranquility Beach	2013	*Phyllospadix scouleri*	macrophyte	surfgrass
Tranquility Beach	2013	*Phragmatopoma californica*	invertebrate	worm

Table 66. The most common mobile taxa (>1 per m^2) observed at Tranquility Beach

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Tranquility Beach	2013	*Littorina keenae*	invertebrate	snail
Tranquility Beach	2013	*Lottia scabra/conus*	invertebrate	limpet
Tranquility Beach	2013	Small limpet	invertebrate	limpet
Tranquility Beach	2013	*Littorina spp*	invertebrate	snail
Tranquility Beach	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Tranquility Beach	2013	*Littorina plena/scutulata*	invertebrate	snail
Tranquility Beach	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Tranquility Beach	2013	*Lottia limatula*	invertebrate	limpet
Tranquility Beach	2013	*Pagurus hirsutiusculus*	invertebrate	crab
Tranquility Beach	2013	*Nuttalina spp*	invertebrate	chiton
Tranquility Beach	2013	*Pachygrapsus crassipes*	invertebrate	crab
Tranquility Beach	2013	*Tegula funebralis*	invertebrate	snail
Tranquility Beach	2013	*Acanthinucella spp*	invertebrate	whelk
Tranquility Beach	2013	*Fissurella volcano*	invertebrate	limpet
Tranquility Beach	2013	*Cyanoplax hartwegii*	invertebrate	chiton
Tranquility Beach	2013	*Lottia pelta*	invertebrate	limpet
Tranquility Beach	2013	*Strongylocentrotus purpuratus*	invertebrate	urchin
Tranquility Beach	2013	*Homalopoma baculum/luridum*	invertebrate	snail
Tranquility Beach	2013	*Ocenebra circumtexta*	invertebrate	whelk

Marker Poles

Physical Description

Marker Poles is located in the Southern Channel Islands. This site is near the San Nicolas Island/Freighter dock Mussel Watch site and is not accessible by the public, as it is on navy-owned San Nicolas Island. Visitation to this site is limited to fishing and tidepooling navy personnel and a handful of researchers. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 64. Biodiversity survey overview at Marker Poles

Marker Poles is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. The primary coastal orientation of this site is southwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2003, 2007, and 2013. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 33 meters (seaward).

Figure 65. Intertidal emersion at Marker Poles

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Marker Poles (> 2% cover or > 1 per m^2) are displayed in Table 67 and 68 below.

Table 67. The most common sessile taxa (>2% cover) observed at Marker Poles

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Marker Poles	2013	*Phragmatopoma californica*	invertebrate	worm
Marker Poles	2013	*Mytilus californianus*	invertebrate	mussel
Marker Poles	2013	*Corallina spp*	macrophyte	coralline algae
Marker Poles	2013	*Mazzaella affinis*	macrophyte	red algae
Marker Poles	2013	*Endocladia muricata*	macrophyte	red algae
Marker Poles	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Marker Poles	2013	Other crust	macrophyte	red algae
Marker Poles	2013	*Chthamalus spp*	invertebrate	barnacle
Marker Poles	2013	*Anthopleura sola*	invertebrate	anemone
Marker Poles	2013	Encrusting Coralline	macrophyte	coralline algae
Marker Poles	2013	*Anthopleura elegantissima*	invertebrate	anemone
Marker Poles	2013	*Cladophora columbiana*	macrophyte	green algae

Table 68. The most common mobile taxa (>1 per m^2) observed at Marker Poles

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Marker Poles	2013	*Littorina keenae*	invertebrate	snail
Marker Poles	2013	*Lottia scabra/conus*	invertebrate	limpet
Marker Poles	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Marker Poles	2013	*Littorina plena/scutulata*	invertebrate	snail
Marker Poles	2013	*Strongylocentrotus purpuratus*	invertebrate	urchin
Marker Poles	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Marker Poles	2013	*Lottia limatula*	invertebrate	limpet
Marker Poles	2013	*Tegula funebralis*	invertebrate	snail
Marker Poles	2013	*Acanthinucella spp*	invertebrate	whelk
Marker Poles	2013	Small limpet	invertebrate	limpet
Marker Poles	2013	*Nuttalina spp*	invertebrate	chiton
Marker Poles	2013	*Littorina spp*	invertebrate	snail
Marker Poles	2013	*Lottia pelta*	invertebrate	limpet
Marker Poles	2013	*Pagurus samuelis*	invertebrate	crab

Two Harbors

Physical Description

Two Harbors is located in the Southern Channel Islands, on Santa Catalina Island, California. This site is located in an Area of Special Biological Significance (Santa Catalina Island - Subarea One, Isthmus Cove to Catalina Head ASBS). This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 66. Biodiversity survey overview at Two Harbors

Figure 67. Long term monitoring at Two Harbors

Two Harbors is dominated by a mixture of consolidated bedrock and boulder fields, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is southeast.

Biodiversity Surveys were done by University of California Santa Cruz in 2010 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Two Harbors (> 2% cover or > 1 per m^2) are displayed in Table 69 and 70 below.

Table 69. The most common sessile taxa (>2% cover) observed at Two Harbors

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Two Harbors	2013	*Corallina spp*	macrophyte	coralline algae
Two Harbors	2013	*Tetraclita rubescens*	invertebrate	barnacle
Two Harbors	2013	*Silvetia compressa*	macrophyte	brown algae
Two Harbors	2013	Hesperophycus *californicus*	macrophyte	brown algae
Two Harbors	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Two Harbors	2013	*Chthamalus spp*	invertebrate	barnacle
Two Harbors	2013	*Mazzaella leptorhynchos*	macrophyte	red algae
Two Harbors	2013	*Pseudolithoderma nigra*	macrophyte	brown algae
Two Harbors	2013	Encrusting Coralline	macrophyte	coralline algae
Two Harbors	2013	*Sargassum muticum*	macrophyte	brown algae

Table 70. The most common mobile taxa (>1 per m^2) observed at Two Harbors

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Two Harbors	2013	*Littorina keenae*	invertebrate	snail
Two Harbors	2013	*Lottia scabra/conus*	invertebrate	limpet
Two Harbors	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Two Harbors	2013	*Fissurella volcano*	invertebrate	limpet
Two Harbors	2013	*Lottia pelta*	invertebrate	limpet
Two Harbors	2013	*Littorina plena/scutulata*	invertebrate	snail
Two Harbors	2013	*Tegula eiseni*	invertebrate	snail
Two Harbors	2013	*Strongylocentrotus purpuratus*	invertebrate	urchin
Two Harbors	2013	*Lottia limatula*	invertebrate	limpet
Two Harbors	2013	*Pachygrapsus crassipes*	invertebrate	crab
Two Harbors	2013	*Tegula gallina*	invertebrate	snail
Two Harbors	2013	*Ocenebra circumtexta*	invertebrate	whelk
Two Harbors	2013	*Pagurus samuelis*	invertebrate	crab
Two Harbors	2013	Small limpet	invertebrate	limpet
Two Harbors	2013	*Cyanoplax hartwegii*	invertebrate	chiton

Bird Rock (Blue Cavern SMCA)

Physical Description

Bird Rock is located in the Southern Channel Islands, on the northeast side of Santa Catalina Island, California. This site is located in an Area of Special Biological Significance (Santa Catalina Island - Subarea One, Isthmus Cove to Catalina Head ASBS) within the Blue Cavern State Marine Conservation Area, and is near the Bird Rock Mussel Watch site. This site lies approximately 500 meters offshore of the University of Southern California Wrigley Marine Science Center. This site receives moderately low visitation due to its offshore location; however, USC Marine Lab classes and scientists focus studies there because of its excellent intertidal habitat. California State University Los Angeles researchers have conducted experimental studies here since the 1980's. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 68. Biodiversity survey overview at Bird Rock

Bird Rock is dominated by consolidated volcanic breccia bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and boulders. The primary coastal orientation of this site is west/northwest.

Figure 69. Long term monitoring at Bird Rock

Long-Term Monitoring Surveys at Bird Rock were established in 1982, and are done by University of California Los Angeles and University of California Santa Barbara (Tatman Foundation). Long-Term MARINe surveys currently target the following species and/or areas: *Chthamalus/Balanus* (Acorn Barnacles), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), Rock (Above Barnacles), Red Algal Turf (Photo Plot), and *Pisaster* (Ochre Star).

Biodiversity Surveys were done by University of California Santa Cruz in 2002, 2004, and 2007. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Bird Rock (> 2% cover or > 1 per m^2) are displayed in Table 71 and 72 below.

Table 71. The most common sessile taxa (>2% cover) observed at Bird Rock

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Bird Rock	2013	*Mytilus californianus*	invertebrate	mussel
Bird Rock	2013	*Halidrys dioica*	macrophyte	brown algae
Bird Rock	2013	*Gelidium coulteri*	macrophyte	red algae
Bird Rock	2013	*Pterocladiella capillacea*	macrophyte	red algae
Bird Rock	2013	*Tetraclita rubescens*	invertebrate	barnacle
Bird Rock	2013	*Corallina spp*	macrophyte	coralline algae
Bird Rock	2013	*Eisenia arborea*	macrophyte	brown algae
Bird Rock	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Bird Rock	2013	*Littorina keenae*	invertebrate	snail
Bird Rock	2013	*Silvetia compressa*	macrophyte	brown algae

Table 72. The most common mobile taxa (>1 per m^2) observed at Bird Rock

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Bird Rock	2013	*Littorina keenae*	invertebrate	snail
Bird Rock	2013	*Fissurella volcano*	invertebrate	limpet
Bird Rock	2013	*Lottia scabra/conus*	invertebrate	limpet
Bird Rock	2013	*Lottia pelta*	invertebrate	limpet
Bird Rock	2013	*Nuttalina spp*	invertebrate	chiton
Bird Rock	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Bird Rock	2013	*Acanthinucella spp*	invertebrate	whelk
Bird Rock	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Bird Rock	2013	Small limpet	invertebrate	limpet
Bird Rock	2013	*Pachygrapsus crassipes*	invertebrate	crab
Bird Rock	2013	*Lottia limatula*	invertebrate	limpet
Bird Rock	2013	*Ceratostoma nuttalli*	invertebrate	snail
Bird Rock	2013	*Cyanoplax spp*	invertebrate	chiton

Big Fisherman Cove (Blue Cavern SMCA)

Physical Description

Big Fisherman Cove is located in the Southern Channel Islands, on Santa Catalina Island, California, within the Blue Cavern State Marine Conservation Area. This site is near the USC Wrigley Marine Science Center and is located in an Area of Special Biological Significance (Santa Catalina Island - Subarea One, Isthmus Cove to Catalina Head ASBS). This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 70. Biodiversity survey overview at Big Fisherman Cove

Big Fisherman Cove is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and boulder fields. The primary coastal orientation of this site is west/northwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2010 and 2013. The Biodiversity Survey grid encompasses two sections that are approximately 8 meters (along shore) x 10 meters (seaward), and 10 meters (along shore) x 10 meters (seaward).

Figure 71. Intertidal emersion at Big Fisherman Cove

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Big Fisherman Cove (> 2% cover or > 1 per m^2) are displayed in Table 73 and 74 below.

Table 73. The most common sessile taxa (>2% cover) observed at Big Fisherman Cove

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Big Fisherman Cove	2013	*Tetraclita rubescens*	invertebrate	barnacle
Big Fisherman Cove	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Big Fisherman Cove	2013	*Egregia menziesii*	macrophyte	brown algae
Big Fisherman Cove	2013	*Silvetia compressa*	macrophyte	brown algae
Big Fisherman Cove	2013	*Halidrys dioica*	macrophyte	brown algae
Big Fisherman Cove	2013	*Chthamalus spp*	invertebrate	barnacle
Big Fisherman Cove	2013	*Pterocladiella capillacea*	macrophyte	red algae
Big Fisherman Cove	2013	*Corallina spp*	macrophyte	coralline algae
Big Fisherman Cove	2013	*Eisenia arborea*	macrophyte	brown algae

Table 74. The most common mobile taxa (>1 per m^2) observed at Big Fisherman Cove

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Big Fisherman Cove	2013	*Littorina keenae*	invertebrate	snail
Big Fisherman Cove	2013	*Lottia scabra/conus*	invertebrate	limpet
Big Fisherman Cove	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Big Fisherman Cove	2013	*Littorina spp*	invertebrate	snail
Big Fisherman Cove	2013	*Fissurella volcano*	invertebrate	limpet
Big Fisherman Cove	2013	*Littorina plena/scutulata*	invertebrate	snail
Big Fisherman Cove	2013	*Nuttalina spp*	invertebrate	chiton
Big Fisherman Cove	2013	*Lottia limatula*	invertebrate	limpet
Big Fisherman Cove	2013	*Lottia pelta*	invertebrate	limpet
Big Fisherman Cove	2013	*Pagurus samuelis*	invertebrate	crab
Big Fisherman Cove	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Big Fisherman Cove	2013	*Pachygrapsus crassipes*	invertebrate	crab
Big Fisherman Cove	2013	*Cyanoplax spp*	invertebrate	chiton

Goat Harbor (Long Point SMR)

Physical Description

Goat Harbor is located in the Southern Channel Islands, on Santa Catalina Island, California, within the Long Point State Marine Reserve. This steep site consists of extremely uneven terrain, containing many deep cracks and folds.

Figure 72. Biodiversity survey overview at Goat Harbor

Figure 73. Intertidal emersion at Goat Harbor

Goat Harbor is dominated by a mixture of consolidated bedrock and boulder fields, and the area surrounding the site is comprised of boulder fields. The primary coastal orientation of this site is north/northwest.

Biodiversity Surveys were done by University of California Santa Cruz in 2010 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Goat Harbor (> 2% cover or > 1 per m^2) are displayed in Table 75 and 76 below.

Table 75. The most common sessile taxa (>2% cover) observed at Goat Harbor

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Goat Harbor	2013	*Tetraclita rubescens*	invertebrate	barnacle
Goat Harbor	2013	*Egregia menziesii*	macrophyte	brown algae
Goat Harbor	2013	*Chondracanthus canaliculatus*	macrophyte	red algae
Goat Harbor	2013	*Chthamalus spp*	invertebrate	barnacle
Goat Harbor	2013	*Caulacanthus okamurae*	macrophyte	red algae
Goat Harbor	2013	*Pterocladiella capillacea*	macrophyte	red algae
Goat Harbor	2013	*Silvetia compressa*	macrophyte	brown algae
Goat Harbor	2013	*Corallina spp*	macrophyte	coralline algae
Goat Harbor	2013	*Halidrys dioica*	macrophyte	brown algae

Table 76. The most common mobile taxa (>1 per m^2) observed at Goat Harbor

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Goat Harbor	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Goat Harbor	2013	*Lottia scabra/conus*	invertebrate	limpet
Goat Harbor	2013	*Littorina keenae*	invertebrate	snail
Goat Harbor	2013	*Littorina spp*	invertebrate	snail
Goat Harbor	2013	*Fissurella volcano*	invertebrate	limpet
Goat Harbor	2013	*Lottia ochracea*	invertebrate	limpet
Goat Harbor	2013	*Lottia pelta*	invertebrate	limpet
Goat Harbor	2013	*Littorina plena/scutulata*	invertebrate	snail
Goat Harbor	2013	*Nuttalina spp*	invertebrate	chiton
Goat Harbor	2013	*Pachygrapsus crassipes*	invertebrate	crab
Goat Harbor	2013	*Lottia limatula*	invertebrate	limpet
Goat Harbor	2013	*Lottia scabra/conus*	invertebrate	limpet

Avalon Quarry

Physical Description

Avalon Quarry is located in the Southern Channel Islands, on Santa Catalina Island, California. This site is located in an Area of Special Biological Significance (Santa Catalina Island - Subarea Four, Binnacle Rock to Jewfish Point ASBS). This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Figure 74. Biodiversity survey overview at Avalon Quarry

Avalon Quarry is dominated by natural boulder fields, and the area surrounding the site is comprised of boulder fields. The primary coastal orientation of this site is east/northeast.

Biodiversity Surveys were done by University of California Santa Cruz in 2010 and 2013. The Biodiversity Survey grid encompasses one section that is approximately 20 meters (along shore) x 10 meters (seaward).

Figure 75. Intertidal emersion at Avalon Quarry

Biological Summary

The most common sessile and mobile taxa observed during the 2012 Biodiversity Survey done at Avalon Quarry (> 2% cover or > 1 per m^2) are displayed in Table 77 and 77 below.

Table 77. The most common sessile taxa (>2% cover) observed at Avalon Quarry

Sessile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Avalon Quarry	2013	Diatoms	microalgae	microalgae
Avalon Quarry	2013	*Corallina spp*	macrophyte	coralline algae
Avalon Quarry	2013	*Tetraclita rubescens*	invertebrate	barnacle
Avalon Quarry	2013	*Ulva spp*	macrophyte	green algae
Avalon Quarry	2013	*Laurencia pacifica/masonii*	macrophyte	red algae
Avalon Quarry	2013	Encrusting Coralline	macrophyte	coralline algae
Avalon Quarry	2013	*Centroceras/Ceramium/Corallophila spp*	macrophyte	red algae
Avalon Quarry	2013	*Egregia menziesii*	macrophyte	brown algae

Table 78. The most common mobile taxa (>1 per m^2) observed at Avalon Quarry

Mobile taxa				
Site Name	**Year**	**Taxa name**	**Category**	**General Taxa Name**
Avalon Quarry	2013	*Littorina keenae*	invertebrate	snail
Avalon Quarry	2013	*Lottia paradigitalis/strigatella*	invertebrate	limpet
Avalon Quarry	2013	*Lottia scabra/conus*	invertebrate	limpet
Avalon Quarry	2013	*Fissurella volcano*	invertebrate	limpet
Avalon Quarry	2013	*Pachygrapsus crassipes*	invertebrate	crab
Avalon Quarry	2013	*Lottia austrodigitalis/digitalis*	invertebrate	limpet
Avalon Quarry	2013	*Lottia pelta*	invertebrate	limpet
Avalon Quarry	2013	Small limpet	invertebrate	limpet
Avalon Quarry	2013	*Lottia limatula*	invertebrate	limpet
Avalon Quarry	2013	*Nuttalina spp*	invertebrate	chiton
Avalon Quarry	2013	*Littorina spp*	invertebrate	snail
Avalon Quarry	2013	*Cyanoplax hartwegii*	invertebrate	chiton

Functional and Morphological Classifications

The sections below describe classifications used for all taxa identified in the SCSR.

Taxonomic Groups

macroalgae, microalgae, mobile invert, nonbiological, sessile invert, surfgrass, vertebrate

Trophic Groups

algae, carnivore, filter-feeder, herbivore, nonbiological, omnivore, surfgrass

Functional Groups

abalone, anemone, barnacle, bivalve, bryozoan, chiton, clam, coralline algae, corticated, crab, crust, cucumber, filamentous, fish, fucoid, hydroid, kelp, limpet, microalgae, mussel, nonbiological, sea slug, sea star, snail, sponge, surfgrass, tunicate, turf, urchin, whelk, worm, wormsnail

Common Groups

abalone, anemone, barnacle, bivalve, brown algae, bryozoan, chiton, clam, coralline algae, crab, cucumber, exclude, fish, green algae, hydroid, limpet, microalgae, mussel, red algae, rock, sand, sea slug, sea star, snail, sponge, substrate, surfgrass, tar, tunicate, urchin, whelk, worm

Taxonomic Classifications

Phyla (13)

Annelida, Arthropoda, Chlorophyta, Chordata, Cnidaria, Cyanobacteria, Echinodermata, Ectoprocta, Heterokontophyta, Mollusca, Porifera, Rhodophyta, Tracheophyta

Orders (43)

Actiniaria, Actinopterygii, Alismatales, Anaspidea, Archaeogastropoda, Bangiales, Basommatophora, Bryopsidales, Canalipalpata, Ceramiales, Cheilostomata, Cladophorales, Corallinales, Decapoda, Dendrochirotida, Dictyotales, Echinoida, Ectocarpales, Enterogona, Forcipulatida, Fucales, Gigartinales, Gracilariales, Halymeniales, Haplosclerida, Hydroida, Laminariales, Myoida, Mytiloida, Nemaliales, Neogastropoda, Neoloricata, Neotaenioglossa, Ostreoida, Patellogastropoda, Pedunculata, Pleurogona, Poecilosclerida, Rhodymeniales, Scytosiphonales, Sessilia, Sphacelariales, Ulotrichales

Genera (146)

Acanthina, Acanthinucella, Acrosorium, Aglaophenia, Ahnfeltia, Ahnfeltiopsis, Analipus, Anisocladella, Anthopleura, Aplidium, Aplysia, Archidistoma, Balanus, Bangia, Bossiella, Brachidontes/Septifer, Bryopsis, Bugula, Calliarthron, Calliostoma, Callithamnion, Callophyllis, Cancer, Carpopeltis, Caulacanthus, Ceratostoma, Chaetomorpha, Chondracanthus, Chondria, Chthamalus, Cladophora, Codium, Colpomenia/Leathesia, Conus, Corallina, Cryptopleura/Hymenena, Cucumaria/Pseudocnus, Cumagloia, Cyanoplax, Dasya, Dendropoma, Dendropoma/Petaloconchus, Dictyopteris, Dictyota,

Dodecaceria, Egregia, Eisenia, Endarachne, Endocladia, Epiactis, Eurystomella, Fissurella, Gastroclonium, Gelidium, Gloiopeltis, Gracilaria, Gracilariopsis, Grateloupia, Haliclona, Halidrys, Haliotis, Haliptylon, Halymenia/Schizymenia, Haplogloia, Herposiphonia, Hesperophycus, Hypnea, Jania, Laminaria, Laurencia, Leptasterias, Lithophyllum/Lithothamnion, Lithothrix, Littorina, Lomentaria, Lottia, Macrocystis, Mastocarpus, Mazzaella, Megabalanus, Megastraea, Membranipora, Microcladia, Mopalia, Mytilus, Nemalion, Neoptilota/Ptilota, Neorhodomela, Nienburgia, Norrisia, Nucella, Nuttallina, Ocenebra, Odonthalia, Ophlitaspongia, Osmundea, Pachygrapsus, Pagurus, Pelvetiopsis, Penitella, Petaloconchus, Petalonia, Petrocelis, Petrospongium, Phaeostrophion, Phycodrys, Phyllospadix, Pisaster, Pista, Plocamium, Pollicipes, Polysiphonia, Porphyra, Prionitis, Pseudochama, Pseudolithoderma, Pterocladia, Pterocladiella, Pterosiphonia, Rhodymenia, Roperia, Sarcodiotheca, Sargassum, Scytosiphon, Semibalanus, Serpula, Serpulorbis, Silvetia, Siphonaria, Sorella, Sphacelaria, Spirobranchus, Spirorbis, Spyridia, Stenogramme, Stephanocystis, Strongylocentrotus, Styela, Taonia, Tegula, Tetraclita, Thalamoporella, Tiffaniella, Ulothrix, Ulva, Zonaria

All taxa identified to lowest level of resolution (mostly species) -654 taxa

Abietinaria greenei, Abietinaria spp, Acanthina lugubris, Acanthina paucilirata, Acanthinucella spp, Acarnus erithacus, Acmaea mitra, Acrosiphonia spp, Acrosiphonia/Cladophora spp, Acrosorium ciliolatum, Adula/lithophaga spp, Aeolidia papillosa, Aglaophenia latirostris, Ahnfeltia fastigiata, Ahnfeltiopsis gigartinoides, Ahnfeltiopsis leptophylla, Ahnfeltiopsis linearis, Ahnfeltiopsis/ahnfeltia spp, Alaria marginata, Alaria nana, Alaria spp, Alaria taeniata, Alia spp, Amphipholis squamata, Amphiroa beauvoisii, Amphiroa spp, Amphissa columbiana, Amphissa spp, Amphissa versicolor, Analipus japonicus, Anisocladella pacifica, Anisodoris nobilis, Anthopleura artemisia, Anthopleura elegantissima, Anthopleura sola, Anthopleura spp, Anthopleura xanthogrammica, Antithamnionella spp, Aplidium arenatum/propinquum, Aplidium californicum/solidum, Aplidium spp, Aplysia californica, Aplysina fistularis, Archidistoma diaphanes, Archidistoma ritteri, Archidoris montereyensis, Asterina miniata, Astrometis sertulifera, Balanophyllia elegans, Balanus crenatus, Balanus glandula, Balanus glandula/semibalanus balanoides, Balanus nubilus, Bangia spp, Bittium armillatum, Bittium attenuatum, Bittium eschrichtii, Bittium munitum, Blidingia subsalsa, Bluegreen algae, Boringclam, Bossiella spp, Botrylloides spp, Botryllus spp, Brachidontes/septifer spp, Bryopsis spp, Bugula neritina, Bugula spp, Bulla gouldiana, Cadlina luteomarginata, Calliarthron spp, Calliostoma annulatum, Calliostoma canaliculatum, Calliostoma ligatum, Calliostoma spp, Calliostoma supragranosum, Callithamnion pikeanum, Callithamnion rupicola, Callophyllis pinnata, Callophyllis spp, Callophyllis violacea, Cancer antennarius, Cancer branneri, Cancer jordani, Cancer oregonensis, Cancer productus, Cancer spp, Cantharus gemmatus, Carpopeltis bushiae, Caulacanthus okamurae, Cauloramphus echinus, Centroceras/Ceramium/Corallophila spp, Centroceras/Ceramium/Polysiphonia spp, Ceramium spp, Ceramium washingtoniense, Ceratostoma foliatum, Ceratostoma nuttalli, Ceratostoma spp, Cerithiopsis spp, Chaetomorpha aerea, Chaetomorpha linum, Chaetomorpha spiralis, Chaetomorpha spp, Chlamys rubida, Chondracanthus canaliculatus, Chondracanthus corymbiferus/exaspertata, Chondracanthus harveyanus, Chondracanthus spinosus, Chondria acrorhizophora, Chondria arcuata, Chondria dasyphylla, Chondria decipiens, Chondria nidifica, Chondria oppositiclada, Chondria spp, Chone minuta,

Chthamalus spp, Cirolana spp, Cladophora columbiana, Cladophora graminea, Cladophora microcladioides, Cladophora spp, Clathromangelia interfossa, Clathromorphum reclinatum, Clathurella canfieldi, Clavelina huntsmani, Cnemidocarpa finmarkiensis, Codium fragile, Codium setchellii, Colonial diatom, Colonial tunicate, Colpomenia phaeodactyla, Colpomenia tuberculata, Colpomenia/leathesia spp, Constantinea simplex, Conus californicus, Corallina spp, Corynactis californica, Costaria costata, Crangon spp, Crepidula spp, Crepipatella lingulata, Crisulipora occidentalis, Crucibulum spinosum, Cryptochiton stelleri, Cryptolithodes sitchensis, Cryptolithodes typicus, Cryptonemia obovata, Cryptonemia spp, Cryptopleura/hymenena spp, Cryptosiphonia woodii, Cucumaria miniata, Cucumaria/pseudocnus spp, Cucumber, Cumagloia andersonii, Cuthona lagunae, Cyanoplax fernaldi, Cyanoplax hartwegii, Cyanoplax spp, Cycloxanthops novemdentatus, Cymakra gracilior, Cypraea spadicea, Cystoseira osmundacea, Dasya binghamiae, Dasya sinicola/californica, Dasya spp, Delesseria decipiens, Dendrobeania laxa, Dendrobeania lichenoides, Dendronotus subramosus, Dendropoma lituella, Dendropoma/petaloconchus spp, Derbesia marina, Dermasterias imbricata, Desmarestia aculeata, Desmarestia ligulata, Diaperoecia californica, Diaperoecia punctulata, Diatoms, Diaulula sandiegensis, Dictyoneurum californicum, Dictyopteris spp, Dictyopteris undulata, Dictyota coriacea, Dictyota spp, Didemnum spp, Dilsea californica, Diodora aspera, Diopatra ornata, Dirona albolineata, Dirona picta, Distaplia occidentalis, Distaplia smithi, Dodecaceria spp, Doriopsilla albopunctata, Doris odhneri, Dysidea fragilis, Echinaster spp, Ectocarpus spp, Egregia menziesii, Eisenia arborea, Emplectonema gracile, Encrusting coralline, Endarachne binghamiae, Endarachne/petalonia spp, Endocladia muricata, Epiactis prolifera, Epiactis ritteri, Epiactis spp, Epialtoides hiltoni, Epitonium tinctum, Erect coralline, Erythroglossum californicum, Erythrophyllum delesserioides, Eudendrium californicum, Eudistoma psammion, Eudistylia polymorpha, Eugorgia rubens, Euherdmania claviformis, Eupentacta quinquesemita, Eurystomella bilabiata, Evasterias troschelii, Farlowia compressa, Farlowia mollis, Farlowia/pikea spp, Fauchea laciniata, Fissurella rubropicta, Fissurella spp, Fissurella volcano, Fissurellidea bimaculata, Flabellina iodinea, Flabellina trilineata, Flatworm, Flustrellidra corniculata, Fucus spp, Fusinus luteopictus, Gastroclonium parvum, Gastroclonium subarticulatum, Gelidiaceae, Gelidium coulteri, Gelidium coulteri/pusillum, Gelidium purpurascens, Gelidium pusillum, Gelidium robustum, Gelidium spp, Gersemia rubiformis, Girella nigricans, Glans carpenteri, Gloiopeltis furcata, Gloiosiphonia californica, Gobiesox spp, Gracilaria robusta, Gracilaria spp, Gracilaria textorii, Gracilariopsis andersonii/papenfussii, Grateloupia californica, Grateloupia/prionitis spp, Griffithsia pacifica, Gunnel, Gymnogongrus chiton, Halichondria panicea, Halichondria spp, Haliclona spp, Halicystis ovalis, Halidrys dioica, Haliotis cracherodii, Haliotis fulgens, Haliotis rufescens, Haliptylon gracile, Halosaccion glandiforme, Halymenia/schizymenia spp, Haminoea spp, Haminoea vesicula, Haminoea virescens, Haplogloia andersonii, Harmothoe imbricata, Hedophyllum sessile, Heliaster kubiniji, Hemigrapsus nudus, Hemigrapsus oregonensis, Henricia spp, Heptacarpus pictus, Hermissenda crassicornis, Hermit crab, Herposiphonia littoralis, Herposiphonia plumula, Herposiphonia spp, Herposiphonia verticillata, Hesperophycus californicus, Heteropora alaskensis, Heterosiphonia erecta, Heterosiphonia japonica, Hildenbrandia/Peyssonnelia spp, Hinnites giganteus, Hippodiplosia insculpta, Hippodiplosia spp, Hipponix cranioides, Homalopoma baculum/luridum, Hydroid, Hymenamphiastra cyanocrypta, Hymeniacidon ungodon, Hypnea johnstonii, Hypnea spp, Hypnea valentiae, Idotea spp,

Jania crassa, Jania rosea, Jania spp, Jania tenella, Jania verrucosa, Janolus barbarensis, Jenneria pustulata, Katharina tunicata, Kelletia kelletii, Lacuna spp, Laila cockerelli, Laminaria bongardiana, Laminaria dentigera, Laminaria ephemera, Laminaria farlowii, Laminaria saccharina, Laminaria setchellii, Laminaria sinclairii, Laminaria spp, Lasaea spp, Laurencia decidua, Laurencia pacifica/masonii, Laurencia snyderae, Laurencia spp, Laurencia subopposita, Lepidozona spp, Leptasterias spp, Leptocladia binghamiae, Leptopecten spp, Lessoniopsis littoralis, Leucetta losangelensis, Leucilla nuttingi, Leucosolenia eleanor, Lichen, Ligia spp, Lirabuccinum dirum, Lirobittium munitoide, Lirularia/margarites spp, Lithophaga plumula, Lithophyllum/lithothamnion spp, Lithopoma gibberosum, Lithothrix aspergillum, Littorina keenae, Littorina plena/scutulata, Littorina sitkana/subrotundata, Littorina spp, Lomentaria hakodatensis, Lomentaria spp, Lophogorgia chilensis, Lophopanopeus bellus, Lottia asmi, Lottia austrodigitalis/digitalis, Lottia fenestrata, Lottia gigantea, Lottia insessa, Lottia limatula, Lottia maccleani, Lottia ochracea, Lottia ochracea/pelta, Lottia pelta, Lottia paradigitalis/strigatella, Lottia persona, Lottia polyfacies, Lottia scabra/*conus*, Lottia scutum, Loxorhynchus crispatus, Lucapinella callomarginata, Macrocystis spp, Macron aethiops, Macron lividus, Mastocarpus jardinii, Mastocarpus papillatus, Mastocarpus spp, Maxwellia gemma, Mazzaella affinis, Mazzaella californica, Mazzaella cordata/splendens, Mazzaella leptorhynchos, Mazzaella linearis, Mazzaella oregona, Mazzaella parksii, Mazzaella parva, Mazzaella phyllocarpa, Mazzaella spp, Mazzaella volans, Megabalanus californicus, Megastraea undosa, Megatebennus bimaculatus, Melanosiphon intestinalis, Membranipora spp, Metandrocarpa taylori, Metridium senile, Microcladia borealis, Microcladia coulteri, Mimulus foliatus, Mitra idae, Modiolus spp, Mopalia spectabilis, Mopalia spp, Muricea californica, Muricidae, Mycale macginitiei, Mytilus californianus, Mytilus galloprovincialis/trossulus, Mytilus spp, Navanax inermis, Nemalion helminthoides, Nemalion spp, Neomolgus littoralis, Neoptilota/ptilota spp, Neorhodomela larix, Neorhodomela oregona, Nereocystis luetkeana, Nienburgia andersoniana, Norrisia norrisi, Notoacmea paleacea, Nucella canaliculata, Nucella emarginata/ostrina, Nucella lamellosa, Nuttallina spp, Nymphopsis spinosissima, Obelia spp, Ocenebra atropurpurea, Ocenebra circumtexta, Ocenebra folliata, Ocenebra gracillima, Ocenebra interfossa, Ocenebra lurida, Ocenebra pusilla, Ocenebra sclera, Ocenebra spp, Ocenebra subangulata, Octopus spp, Odonthalia floccosa, Odonthalia washingtoniensis, Oedignathus inermis, Olivella biplicata, Onchidella borealis, Onchidoris bilamellata, Opalia borealis, Opalia funiculata, Opalia montereyensis, Ophionereis annulata, Ophiothrix spiculata, Ophiuroid, Ophlitaspongia pennata, Opuntiella californica, Oregonia gracilis, Osmundea sinicola, Osmundea spectabilis, Osmundea splendens, Oyster, Pachyarthron cretaceum, Pachycheles spp, Pachygrapsus crassipes, Pachythyone rubra, Padina spp, Pagurus beringanus, Pagurus caurinus, Pagurus granosimanus, Pagurus hemphilli, Pagurus hirsutiusculus, Pagurus samuelis, Pagurus spp, Palmaria callophylloides, Palmaria hecatensis, Palmaria mollis, Panulirus interruptus, Paranemertes peregrina, Paraxanthias taylori, Pelia tumida, Pelvetiopsis spp, Penitella spp, Perophora annectens, Petaloconchus montereyensis, Petalonia fascia, Petrocelis spp, Petroglossum parvum, Petrolisthes spp, Petrospongium rugosum, Phaeostrophion irregulare, Pharia pyramidata, Phataria unifascialis, Phidiana hiltoni, Phycodrys riggii, Phycodrys setchellii, Phycodrys spp, Phyllospadix scouleri, Phyllospadix serrulatus, Phyllospadix torreyi, Pilayella littoralis, Pilumnus spinohirsutus, Pisaster brevispinus, Pisaster giganteus, Pisaster ochraceus, Pisaster spp, Pista spp, Placiphorella velata, Pleonosporium spp, Plocamium

oregonum, Plocamium pacificum, Plocamium violaceum, Pododesmus macrochisma, Pollicipes polymerus, Polyneura latissima, Polyp, Polysiphonia spp, Porphyra spp, Postelsia palmaeformis, Potamilla occelata, Prasiola spp, Prionitis angusta, Prionitis cornea, Prionitis filiformis, Prionitis lanceolata, Prionitis linearis, Prionitis lyallii, Prionitis spp, Pseudochama exogyra, Pseudolithoderma nigra, Pseudomelatoma penicillata, Pseudomelatoma torosa, Pterocladia media, Pterocladiella caloglossoides, Pterocladiella capillacea, Pterocladiella spp, Pteropurpura trialata, Pterosiphonia baileyi, Pterosiphonia bipinnata, Pterosiphonia dendroidea/pennata, Pterosiphonia spp, Pterothamnion spp, Pterygophora californica, Pugetia firma, Pugettia gracilis/richii, Pugettia producta, Pycnoclavella stanleyi, Pycnogonida, Pycnopodia helianthoides, Pyura haustor, Ralfsiaceae, Rhodymenia californica, Rhodymenia pacifica, Rhodymenia spp, Rictaxis punctocaelatus, Ritterella rubra, Ritterella spp, Roperia poulsoni, Rostanga pulchra, Sabellariidae, Saccharina groenlandica, Saccharina spp, Salmacina tribranchiata, Sarcodiotheca gaudichaudii, Sargassum agardhianum, Sargassum horneri, Sargassum muticum, Sargassum palmeri, Schizoplax brandtii, Schizoporella unicornis, Scinaia confusa, Scinaia spp, Sculpin, Scytosiphon canaliculatus, Scytosiphon spp, Sea star, Seila montereyensis, Semibalanus balanoides, Semibalanus cariosus, Serpula vermicularis, Serpulorbis squamigerus, Serraticardia macmillanii, Sertularella turgida, Sertularella/sertularia spp, Shrimp, Silvetia compressa, Siphonaria brannii, Siphonaria thersites, Sipuncula, Small balanus/semibalanus spp, Smalllimpet, Small mytilus spp, Snilimpet, Soranthera ulvoidea, Sorella delicatula, Sparlingia pertusa, Sphacelaria californica, Sphacelaria norrisii, Sphacelaria plumigera, Sphacelaria spp, Spheciospongia confoederata, Spirobranchus spinosus, Spirorbis spp, Spyridia filamentosa, Stenogramme interrupta, Stenoplax conspicua, Stephanocystis osmundacea, Stephanocystis spp, Strongylocentrotus droebachiensis, Strongylocentrotus franciscanus, Strongylocentrotus purpuratus, Styela montereyensis, Styela yakutatensis, Suberites ficus, Suberites spp, Taliepus nuttallii, Taonia lennebackerae, Tedanione obscurata, Tegula aureotincta, Tegula brunnea, Tegula eiseni, Tegula funebralis, Tegula funebralis/gallina, Tegula gallina, Tegula pulligo, Tegula spp, Terebellid, Tetraclita rubescens, Thais biserialis, Thalamoporella spp, Thelepus crispus, Tiffaniella snyderiae, Tonicella lineata/lokii, Tonicella spp, Tricellaria occidentalis, Tricolia pulloides, Trimusculus reticulatus, Triopha catalinae, Trivia californiana, Trivia solandri, Trivia spp, Tubeworm, Tubularia marina, Tubularia spp, Ulothrix spp, Ulva spp, Ulva taeniata, Urosalpinx cinerea, Urosalpinx subangulata, Urospora spp, Urticina crassicornis, Velutina rubra, Velutina spp, Velutina velutina, Verrucaria maura, Volvarina taeniolata, Williamia peltoides, Zonaria farlowii, Zostera spp