OCS Study
BOEM 2015-011

Pacific Rocky Intertidal Monitoring: Trends and Synthesis Update - 2015

pacificrockyintertidal.org

Final Report

US Department of the Interior
Bureau of Ocean Energy Management
Pacific OCS Region

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FINAL TECHNICAL SUMMARY

STUDY TITLE: Bureau of Ocean Energy Management (BOEM) – MARINe: Study of Rocky Intertidal Communities

REPORT TITLE: Pacific Rocky Intertidal Monitoring: Trends and Synthesis – Update 2015

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BACKGROUND: This report compiles the results of several studies, both long and short term, which all share a common goal of increasing our ability to assess impact to rocky intertidal communities that could result from activities associated with nearshore ocean energy facilities. These facilities range from the long-existing oil platforms in southern California to the not-yet developed wave energy conversion devices proposed for Oregon. Background information for each of the studies and projects associated with these studies is outlined below:

Rocky Intertidal Monitoring in Southern and Central California: Oil and gas activities, especially the tankering of oil along the California coast and the extraction of oil from OCS activities, raise the possibility of an oil spill or other impact to coastal resources. Population monitoring of coastal biota in central and southern California provides baseline information in case an event such as a spill damaged these resources. In 1997, the Bureau of Ocean Energy Management (BOEM) initiated the formation of a long-term monitoring program, the Multi-Agency Rocky Intertidal Network (MARINe), which currently includes 42 partners consisting of federal, state and local government agencies, universities, tribes and private organizations. The MARINe consortium monitors 245 rocky shore sites (159 of these include Long-Term Monitoring; 161 include Biodiversity) and is the largest and longest-running program of its kind; sites in some regions have been sampled for over 30 years. Through this study, BOEM funded biannual monitoring at 24 established rocky intertidal sites along the southern and central California mainland adjacent to OCS operations.

Investigating Potential Impacts of Wave Energy Conversion Devices to Rocky Intertidal Areas in Oregon: In recent years, there has been increased interest in developing alternative energy facilities along the west coast, in the form of wave and wind energy conversion devices (WECD), especially along the coast of Oregon. Wave energy conversion devices could lead to a dampening of wave height, which could in turn affect the abundance, distribution, and makeup of nearby rocky intertidal communities. Eight sites (five pre-existing and three new locations) were monitored along the Oregon coast during this effort using established Long-term and Biodiversity protocols, and also new protocols that focus on the vertical distribution of focal species. In addition, instruments measuring physical parameters (pressure sensors and temperature loggers) were deployed to characterize wave climate.

Database Upgrade: The MARINe Access database, originally developed by SCCWRP in 2002 was upgraded over this period to make it more functional, given the large number of MARINe groups collecting and entering data. A complete re-structuring of the MARINe database was initiated, moving data from the existing, outdated Access system to a new MySQL database.

Utility of Photos for Assessing Impacts of Oil Spills: In the Cosco Busan spill, 32 locations were photographed, including many pre-existing MARINe sites, inside and outside San Francisco Bay. They were photo-sampled within a few days to a few weeks of the spill and revisited a year later. In the Dubai Star spill, sites were photo-sampled within hours of the spill and revisited six months later. Photographic data from existing MARINe sites in the area that were not affected by these spills were used as controls to determine whether data from photos taken using the rapid post-spill method are comparable to data from permanent MARINe plots. UCSC was funded by BOEM to determine the efficacy of re-occupying the exact plot locations using the initial photo and site notes.

Black Abalone Study for NOAA: NOAA NMFS provided funding in 2013 to augment our core black abalone monitoring, which includes counting, measuring, and collecting nearest neighbor information.

SIGNIFICANT CONCLUSIONS: In 2014, substantial numbers of stars at all sites fell victim to sea star wasting syndrome (SSWS), and significant declines occurred at every site within the region, as well as at other MARINe sites further north and south. Detailed discussions of the extent of impact of SSWS are included in the trend graph descriptions for each site on pacificrockyintertidal.org. As of fall 2014, no site within the BOEM funded region of California had seen substantial recruitment of new individuals, but moderate numbers of juveniles were recorded at a few sites (Shell Beach, Occulto, Stairs, Mussel Shoals, and Old Stairs). Recovery of *Pisaster ochraceus* is dependent upon the survival of these juveniles through the coming years, and recruitment of new individuals to additional sites.

Abundance of black abalone, which declined substantially between 1992-2005 at nearly all BOEM funded sites, stabilized during 2011-2015. However, almost no recruitment of black abalone occurred at any site in this region during this study period. The black abalone has been placed on the Endangered Species List as a result, in part, of trends documented by this study.

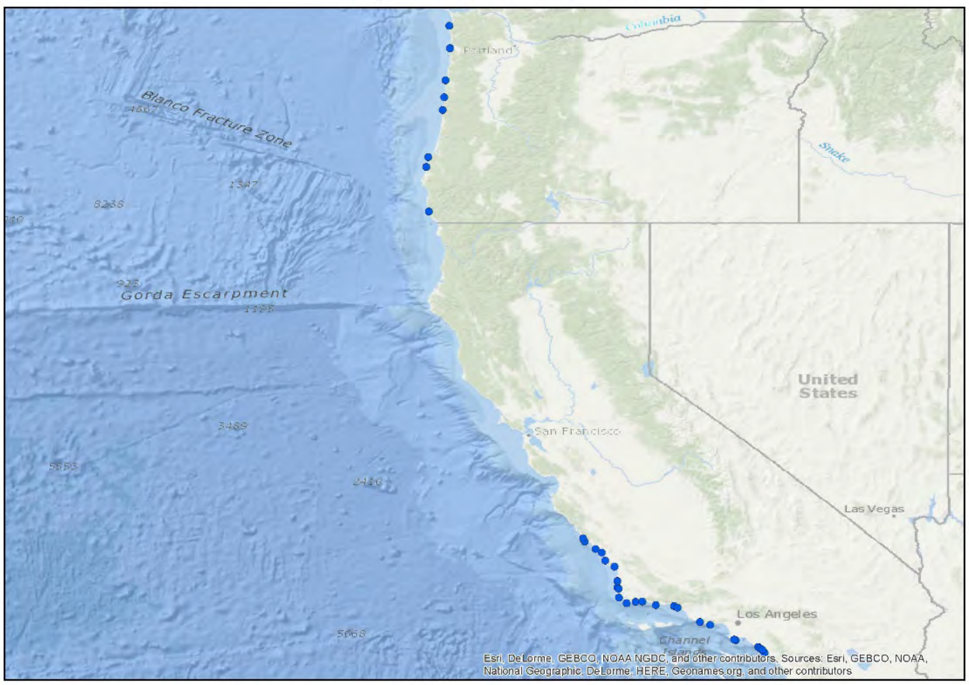
The results of the wave climate and vertical distribution analyses done for the 8 Oregon sites demonstrate that small changes in wave climate and upper distributional limits of core species are likely to be detectable using the methods employed in this study. Hence, we conclude that there is high likelihood that should WECD be installed on the Oregon coast and our assessment methods utilized, even small impacts to the biological community resulting from reduction of waves will be detectable.

STUDY PRODUCTS:

1. pacificrockyintertidal.org, a comprehensive web-based data report and general information source for all rocky intertidal monitoring sites within the MARINe network (including sites in CA, OR, WA, and AK). This web-based product includes detailed information about the MARINe project including methods, descriptive information about regions, sites, and species targeted, as well as extensive summaries of trends and patterns observed within sites and among regions. Long-Term and Biodiversity survey data can be viewed either in static summary graph form or by using an interactive graphing tool, which displays user-defined site and species summary data. This synthesis of long-term, rocky intertidal monitoring data in a centralized, easily accessible location is unprecedented in scope, and it is our hope that this information will be of great value to resource managers, researchers, and the general public.
2. seastarwasting.org, (2014) a website linked to pacificrockyintertidal.org, but focused specifically on the sea star wasting epidemic that has plagued sea stars at all MARINe sites coast-wide. This site provides general information about sea star wasting syndrome (SSWS), updates on recent findings related to the disease, information about how users can contribute to the sea star monitoring effort, and an interactive "tracking" map that allows users to see where SSWS is present, and which species have been affected.
3. Online availability of MARINe data on the PISCO data catalog (www.piscoweb.org) and DATAOne (www.dataone.org)
4. Rocky intertidal webpage developed for the State of California's Coastal Water Quality Monitoring Council (http://www.mywaterquality.ca.gov/eco_health/ocean/tide_pools/)

5. Over 130 presentations, and 19 publications and reports resulted directly from this BOEM funded study; an additional 101 presentations and 66 publications and reports resulted from work done within the larger MARINe network. See Study Products (Part IV) for details.
6. New MARINe MySQL database, including structure for all "core" data. Business rules and QA/QC process for data checking now in place.
7. Collection and archival of photos and specimens

BOEM - MARINe Rocky Intertidal Sites
Oregon to Southern California



STUDY REPORT

PART I: INTRODUCTION, OBJECTIVES, AND APPROACH

1.1 Introduction

Rocky intertidal shores occur at the interface between the terrestrial and marine environments. This unique location results in a physical complexity that leads to high biological diversity, including many species that are found only in this narrow band of coastal habitat. Rocky shores are also the most accessible marine habitat, which fosters a strong public appreciation of these communities, but also makes them vulnerable to degradation resulting from human activities. Natural temporal variation in rocky intertidal systems can be quite high, and can occur on the scale of months (seasonal), years, and even decades. Thus, long-term monitoring is essential for separating natural change from human-induced.

Because rocky intertidal communities are highly diverse and subject to constant change, monitoring of these areas must be done in a well-designed, systematic manner, over long periods of time. Our monitoring program began with the goal of developing an approach that would enable researchers to collect statistically sound data using methods that were simple enough to maintain over the long-term, using minimal resources. This program has grown into a consortium—the Multi-Agency Rocky Intertidal Network (MARINe)—that monitors sites along the entire Pacific Coast of North America (from southern Alaska to San Diego, California), as well as several East Coast sites in Maine and New Hampshire.

Federal, state and local agencies have recognized the importance of baseline information on coastal ecological resources by funding the establishment of a network of monitoring stations. Of the more than 160 established Long-Term Monitoring sites, over half are funded by Federal agencies, (Bureau of Ocean Energy Management and The National Park Service), and the balance are funded by private, State, and non-governmental entities. The biological information acquired during these surveys is incorporated into resource databases hosted by MARINe and the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO). This innovative monitoring approach was initiated by the Channel Islands National Park in the early 1980's (Davis 1985; Richards and Davis 1988). In 1990, the Cabrillo National Monument in San Diego County began long-term rocky intertidal monitoring (Davis and Engle 1991). Monitoring in Santa Barbara County began in 1992 with a project funded jointly by BOEM, formerly the Minerals Management Service (MMS), which funded monitoring of intertidal and subtidal resources (Ambrose et al. 1992a, b), and the County of Santa Barbara, which funded monitoring of wetland resources (Ambrose et al. 1993). In 1994, it was expanded by the California Coastal Commission (CCC) to include the northern Channel Islands (particularly Santa Cruz Island) and Ventura and Los Angeles Counties (Engle et al. 1994). The CCC projects included monitoring of subtidal, rocky and sandy intertidal and, for Los Angeles/Ventura Counties, wetland resources. Although the monitoring network is principally motivated by oil and gas activities, the data it generates provide valuable information about the status and trends of the biological resources of the region, similar to the Environmental Protection Agency (EPA)'s Environmental Monitoring &

Assessment Program (EMAP) but on a finer spatial scale. The National Research Council (NRC) has also emphasized the value of coordinated regional monitoring efforts (NRC 1990a, b).

Central California Rocky Intertidal Habitats

Rocky intertidal communities in Central California (Pigeon Point to Point Conception) are known for their diverse and relatively pristine biota. Much of the coast is remote and undeveloped but the natural beauty and coastal resources of this region, (which includes Monterey Bay, the Big Sur Coastline, and San Luis Obispo), make it a popular tourist destination. The Central California region is dominated by the cold-temperate Oregonian biogeographic province, but warmer-water species more characteristic of the southern (Californian) biogeographic province begin to show up in the southern portion of the region, and can move far to the north during El Niño events.

The rocky shore communities of Central California are vulnerable to oil spills, primarily from major coastal tanker traffic, but also from terminal operations and onshore pipeline breaks. Natural oil seeps also exist, resulting in the presence of tar on many rocky shores, particularly in the southern portion of the region. Spills from onshore and offshore operations have occurred at Avila (1992), Guadalupe (1994), and Vandenberg Air Force Base (1997) and spills from tankers have occurred in San Francisco (2007, 2009). All have affected marine resources to some degree.

A portion of the Central California region is included in the Monterey Bay National Marine Sanctuary (Pigeon Point to Cambria). The region includes thirteen State Marine Reserves, in which all fishing is prohibited, and fifteen State Marine Conservation Areas, in which limited commercial or recreational take is allowed (California Department of Fish and Game, 2007).

Extensive historical information about marine communities in this region is available, particularly for the Monterey Bay area, where several university marine labs (Long, Moss Landing, Hopkins) and research facilities (MBARI, NOAA, Elkhorn Slough NERR) are located. Farther south, long-term surveys were done to assess the impact of the Diablo Canyon Nuclear Power Plant on intertidal and near shore communities (North et al. 1989, Tenera Environmental 1988a, b, 1994). Research on seasonal and successional variation in intertidal community structure was done at three sites within the region (Kinnetics Laboratories, Inc. 1992a, b), and MARINe Long-Term monitoring has been done in the Central California region since 1992. Baseline monitoring for newly established Marine Protected Areas began in 2007. Within this region, 40 Long-Term sites have been established, 10 of which are BOEM-funded.

Southern California Rocky Intertidal Habitats

The Southern California region begins at Point Conception (Government Point), an important biogeographical transition area for rocky intertidal organisms, and extends to the Mexican border. Much of the region occurs within the Southern California Bight, where the coast turns sharply inward to the east and receives protection from prevailing northwesterly winds and swells by the Channel Islands offshore. This results in relatively benign oceanographic conditions most of the time, though periodic southern storms can have a devastating impact on south facing stretches of the coast. A large gyre that exists within the bight creates sea surface temperatures that are warmer, on average, than coastal sections to the north and (to a certain extent) to the south.

Sandy habitats comprise a much greater proportion (approximately 75%) of the shoreline in southern California than they do in central and northern California (Littler and Littler, 1979). Many of the monitoring sites are located on isolated rocky habitats that are flanked by wide stretches of beach, and experience frequent periods of burial and scour. This, along with abundant sunshine and the predominance of warmer coastal air temperatures, creates harsh conditions for species that are intolerant to desiccation. Thus, rocky intertidal communities are largely devoid of larger foliose algae, such as the fleshy reds that are common to the north. These are replaced by abundant turf forming species such as corallines and filamentous red algae, and sun-tolerant rockweeds.

Much of the Southern California coastline is heavily urbanized and subject to multiple anthropogenic influences, including storm water run-off, harvesting, and trampling. At monitoring sites that are closer to urban centers, the direct influence of people on the rocky intertidal community is substantial (Thompson et al. 1993). The mainland region includes eight State Marine Reserves, in which all fishing is prohibited, eighteen State Marine Conservation Areas (SMCAs), in which limited commercial or recreational take is allowed, and eleven no-take SMCAs (California Department of Fish and Game, 2012).

The threat of an oil spill from offshore tanker ships and onshore pipelines, offshore production platforms, and terminal operations is high. On May 19, 2015 an onshore oil pipeline leaked into the ocean reaching approximately 7 miles of coastline. Natural oil seeps are prominent features, especially at Point Conception (Government Point), Coal Oil Point, and Carpinteria where emissions are approximately100 barrels a day (Farwell et al 2009).

The southern California coast has been well-studied, with numerous universities supporting marine-focused programs located within the region. Previous monitoring studies include surveys at 7 mainland locations in the 1970’s by the U.S. Bureau of Land Management (now BOEM) for the Southern California Bight Baseline Study (Littler 1979), and long-term surveys (since 1975) at 4 sites along the Palos Verdes Peninsula. Mussel bed communities were characterized at several sites within the region in the 1970’s (Straughan and Kanter, 1977) and resampled in the 2000’s (Smith, 2005). Seaweed abundances and diversity were examined at numerous sites in the 1950’s and 1960’s (Dawson, 1965), with some locations resampled in the 1970’s (Thom and Widdowson, 1978) and again in the 2000’s (Goodson, 2004, Gerrard, 2005). MARINe Long-Term Monitoring Surveys have been done in this region since 1990. Baseline monitoring for newly established Marine Protected Areas began in 2012. Within this region, 27 Long-Term sites have been established, 14 of which are BOEM-funded sites.

Central and Southern California Rocky Shoreline

The extent of rocky shoreline varies substantially in central and southern California (Ambrose et al. 1989). The northern section of the region is predominantly rocky (Table 1). San Luis Obispo County has the most extensive stretch of rocky shores (54 mi, or 58% of its coastline) in the region, (except for the Channel Islands). Ventura and Orange Counties have the least rocky shoreline, each with 3 miles or 7% of the coastline.

Table 1: Extent of rocky and sandy shores for central/southern California. (Mainland data from Littler and Littler, 1979. Island data from Littler and Littler 1980)

Location	Coastline Length (mi)	Miles Rocky	Miles Sandy	% Rocky	% Sandy
San Luis Obispo Co.	93	54	39	58	42
Santa Barbara Co.*	110	26	84	24	76
Ventura Co.*	41	3	38	7	93
Los Angeles Co.*^	77	26	51	34	66
Orange Co.	41	3	38	7	93
San Diego Co.	76	11	65	14	86
Channel Islands	273	211	62	77	23

* excludes Channel Islands ^ includes harbor breakwaters

The biological communities of the mainland from San Luis Obispo County in the north to Orange County in the south are distinctly different north and south of Point Conception (Murray and Littler 1981, Ambrose et al., 1992a, b).

Oregon Rocky Intertidal Habitats, and Potential Impacts of Offshore Wave Energy Collection Devices

The nearly 600 km of Oregon coastline contains numerous rocky headlands and extensive rocky benches, separated by long stretches of sandy beaches. Rocky habitat is estimated to be approximately 21% of the coastline. An important feature of the Oregon coast is the extensive system of rivers that empty into the near shore environment, providing substantial estuarine habitat, and replenishing sandy shores. Freshwater and sediment input from the Columbia River in the north is particularly high, draining one of the largest river basins in North America, and forming a mainly freshwater estuary that is larger than all of Oregon’s other estuaries combined.

Highway 101 follows the coast through much of Oregon, allowing easy access to the shore. Oregon tidepools attract hundreds of thousands of visitors annually, which provides important revenue for coastal communities, but concerns have arisen about the impacts of so many visitors to rocky shores. Efforts have been made to reduce this impact, including the conversion of a coastal quarry to artificial tidepools at Yaquina Head. The Oregon Department of Fish & Wildlife recently designated 5 areas as marine reserves in order to improve the balance between recreation and resource protection.

As with other regions, the threat of oil spills is an important concern for the Oregon Coast. The most recent major spill was in 1999, when the New Carissa freighter ran aground near Coos Bay, eventually breaking in half and spilling fuel into the marine environment. A portion of the ship could not be salvaged and was sunk offshore of Waldport.

A more recently recognized threat to Oregon's coastal marine communities involves a change in near-shore water movement patterns, which results in hypoxic (low oxygen) conditions. Periodic coastal upwelling in the summer, which brings cold, nutrient rich, but oxygen poor water to the surface, is normally interspersed with down-welling events, which mix in oxygen-rich water. However, since 2002, upwelling conditions have persisted longer than normal, and persistent hypoxic conditions have led to massive die-offs of fish, shellfish and sea stars.

Numerous intertidal studies along the Oregon coast have originated from the Hatfield Marine Science Center (Oregon State), located in Newport, and from the Oregon Institute of Marine Biology (University of Oregon) in Charleston. MARINe Long-Term monitoring has been done in this region since 2000 and Biodiversity surveys since 2001.

In recent years, there has been increased interest in developing alternative energy facilities along the west coast, in the form of wave and wind energy conversion devices. Because the wave energy devices require considerable wave energy to make this a viable venture, the wave regime of Oregon appears to be an ideal area for these devices. Wave energy facilities, and their associated construction and development activities, have the potential to impact coastal resources, and BOEM has funded several studies to begin investigating these potential impacts. Wave energy collection devices could lead to a dampening of wave height, which could in turn affect the abundance, distribution, and makeup of nearby rocky intertidal communities. Determining an approach that would allow for the assessment of these potential impacts was the focus of this study.

1.2 Objectives

Rocky Intertidal Monitoring in Central and Southern California

A primary objective for this research was to continue the ongoing monitoring program that provides a basis for determining if change in rocky shoreline communities adjacent to producing OCS facilities can be attributed to operations or accidents from OCS facilities. The 24 BOEM-funded sites are on the shorelines adjacent to existing oil and gas OCS facilities. Resource data from the MARINe database also support information needs for BOEM's renewable energy program along the Pacific coast. Another important objective was to provide an ecological context for the 24 BOEM-funded sites, by comparing trends and patterns in community dynamics to other sites monitored using identical MARINe methods, ranging from southern Alaska to San Diego, California. The long-term nature of this monitoring project, coupled with its large spatial scale, allows for a better understanding of changes to rocky intertidal communities in the Southern California Bight that have occurred since the OCS program was initiated. A monitoring program of this temporal and spatial magnitude provides insight into whether changes might be attributed to natural (e.g. El Niño events, disease) or human induced (e.g. trampling, climate change) factors. This large-scale monitoring effort is a collaboration between MARINe and many other groups. Two major MARINe partners that support monitoring efforts at numerous sites are the National Park Service (NPS), and the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO). A complimentary biodiversity monitoring effort was developed by Dr. Pete Raimondi and the MARINe Science Panel, funded initially by BOEM and PISCO. These Biodiversity surveys were continuously funded by PISCO over a period of 10 years, and over 160 sites have been established and sampled using this protocol.

An additional goal for this study is to continue to expand pacificrockyintertidal.org, a comprehensive web-based data report and general information source for all rocky intertidal monitoring sites within the MARINe network (sites range from Alaska to Mexico). This web-based product includes detailed information about the MARINe project including methods, descriptive information about regions, sites, and species targeted, as well as extensive summaries of trends and patterns observed within sites and among regional groupings of sites. Trend data can be viewed either in static summary graph form or by using an interactive graphing tool, which displays user-defined site and species summary data. This website will allow evaluation of Long-Term and Biodiversity survey data and comparison to similar historic data. This synthesis of long-term, rocky intertidal monitoring data in a centralized, easily accessible location is unprecedented in scope, and it is our hope that this information will be of great value to resource managers, researchers, and the general public.

In 2014, we developed seastarwasting.org, a website linked to pacificrockyintertidal.org, but focused specifically on the sea star wasting epidemic that has plagued sea stars at all MARINe sites coast-wide. This site provides general information about sea star wasting syndrome (SSWS), updates on recent findings related to the disease, information about how users can contribute to the sea star monitoring effort, and an interactive “tracking” map that allows users to see where SSWS is present, and which species have been affected.

A final goal for this study was to develop a new database that would meet the growing demands of the MARINe program, both in terms of data storage needs, but also for data entry and retrieval, which are complex with so many different users in different locations. In 2013, the decision was made to move from an Access database to a MySQL database, which would accommodate the growing data storage needs of MARINe and also allow for greater flexibility in developing a better approach for data entry and retrieval.

Investigating Potential Impacts of Offshore Wave Energy Conversion Devices to Rocky Intertidal Areas in Oregon

Wave Energy Conversion Devices (WECD) have the potential to reduce wave energy inshore of the devices by up to 15% (Faber Maunsell et al. 2007; Largier et al. 2008), depending upon the type, size, and configuration of the devices installed. It is therefore critical to understand the impact that reduced wave energy will have on nearshore communities. An essential component of this understanding is to develop a baseline assessment of the biological communities and physical conditions in areas potentially affected by WECD as well as in reference areas.

Goals of this project include:

1) Collect baseline monitoring data on 5 established MARINe Oregon sites using Long-term and Biodiversity protocols
2) Establish 3 additional sites (Biodiversity only), to provide a baseline characterization of the rocky intertidal biological communities close to proposed WECD facilities
3) Collect additional information about the distribution of focal species at all 8 sites, using Vertical Distribution Surveys and Pansects.
4) Collect baseline information on temperature and wave climate at all 8 sites using thermistors and pressure sensors.
5) Provide an analysis of the ability of the sensors to detect change in wave climate.

1.3 Approach

Rocky Intertidal Monitoring in Central and Southern California

Rocky intertidal areas tend to be dominated by several "key" species, which often form distinct vertical bands/zones along the shoreline. These species shape the community by creating habitat for other species, or through activities such as grazing or predation. The Long-Term Monitoring approach developed by MARINe focuses on these key species, with the idea that changes in these species will impact other species in the community. This targeted approach allows us to detect relatively small changes in the abundance of species, at effort levels that can be sustained for the long-term. Targeted species are monitored within fixed plots annually or semi-annually. Layered upon this "core" approach are the additional goals of documenting species richness and changes in the distribution of species within and among sites over time. Biodiversity Surveys, designed to capture information about the rocky intertidal community as a whole (rather than targeted species) are used to address these goals. These surveys are much more intensive and require a high-level of expertise and consistency in the identification of marine organisms, and are thus done by a single group at UC Santa Cruz (cbsurveys.ucsc.edu) and on a less frequent schedule, typically every 3-5 years.

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. Our monitoring program is the largest, and longest-running of its kind; sites in some regions have been sampled for 20-30 years. The long-term information about the dynamics and diversity of rocky intertidal habitats enables us to: 1) Assess impacts due to natural and human induced disturbance events (e.g. El Niño events, oil spills), 2) Detect shifts in community make-up due to factors such as disease, species introductions, and climate change, and 3) Provide context for more focused experimental work.

Survey Methods

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 time and space. The MARINe survey methods can be divided into two tiers: "core" procedures that are done by all groups at all sites, and "optional" procedures that are done by groups with funding and staffing to support additional work. Long-Term Monitoring Surveys currently target 25 key species or species assemblages. Not all target species are sampled at each site. For more information regarding the sampling methods, please consult the Long-Term Monitoring Protocol (available at www.pacificrockyintertidal.org).

The 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. Biodiversity Surveys are comprised of four components, all sampled along the same transects: 1) point contact estimates of intertidal cover and substrate characteristics; 2) quadrat sampling to estimate the density of mobile invertebrates; 3) swath transects to estimate the density of sea stars, abalone, and other large mobile invertebrates; and 4) topography (elevation relative to mean low low water). Although Biodiversity Surveys have been done at all BOEM-funded sites, the findings are not included in this report. This report summarizes findings from Long-Term monitoring surveys at the 24 BOEM-funded sites. To view Biodiversity Survey findings, and for more information regarding the sampling methods, please consult the Biodiversity Survey Protocol (available at www.pacificrockyintertidal.org).

Target Species Monitoring

To accomplish the first objective, target species at 24 established rocky intertidal sites along the mainland coast of Southern and Central California adjacent to producing platforms are monitored (Table 2, Figures 1 and 2).

Table 2: Sites sampled from north to south, group and Principle Investigator (PI) responsible for sampling. (*Government Point was not sampled 2006-2013 due to access restrictions).

Site Name	SiteID	North/ South Order	Group	Principal Investigator	Year Established	Last Sampled
Point Sierra Nevada	PSN	1	UCSC	Pete Raimondi	1995	2014 Fall
Piedras Blancas	PBL	2	UCSC	Pete Raimondi	1997	2014 Fall
Cambria/Rancho Marino	RMR	3	UCSC	Pete Raimondi	2001	2014 Fall
Cayucos	CAY	4	UCSC	Pete Raimondi	1995	2014 Fall
Hazards	HAZ	5	UCSC	Pete Raimondi	1995	2014 Fall
Shell Beach	SHB	6	UCSC	Pete Raimondi	1995	2014 Fall
Occulto	OCC	7	UCSC	Pete Raimondi	1992	2014 Fall
Purisima	PUR	8	UCSC	Pete Raimondi	1993	2014 Fall
Stairs	STA	9	UCSC	Pete Raimondi	1992	2014 Fall
Boat House	BOA	10	UCSC	Pete Raimondi	1992	2014 Fall
Government Point*	GPT	11	UCSC	Pete Raimondi	1992	2014 Fall
Alegria	ALEG	12	UCLA	Rich Ambrose	1992	2014 Fall
Arroyo Hondo	ARHO	13	UCLA	Rich Ambrose	1992	2014 Fall
Coal Oil Point	COPT	14	UCLA	Rich Ambrose	1992	2014 Fall
Carpinteria	CARP	15	UCLA	Rich Ambrose	1992	2014 Fall
Mussel Shoals	MUSH	16	UCLA	Rich Ambrose	1994	2014 Fall
Old Stairs	OLDS	17	UCLA	Rich Ambrose	1994	2014 Fall
Paradise Cove	PCOV	18	UCLA	Rich Ambrose	1994	2014 Fall
White Point	WHPT	19	UCLA	Rich Ambrose	1994	2014 Fall
Point Fermin	PTFM	20	UCLA	Rich Ambrose	1999	2014 Fall
Crystal Cove	CRCO	21	CSUF/ CPP	Jayson Smith/Jennifer Burnaford	1996	2014 Fall
Shaws Cove	SHCO	22	CSUF/ CPP	Jayson Smith/Jennifer Burnaford	1996	2014 Fall
Treasure Island	TRIS	23	CSUF/ CPP	Jayson Smith/Jennifer Burnaford	1996	2014 Fall
Dana Point	DAPT	24	CSUF/ CPP	Jayson Smith/Jennifer Burnaford	1996	2014 Fall

Figure 1. Location of Sampling Sites in Central California

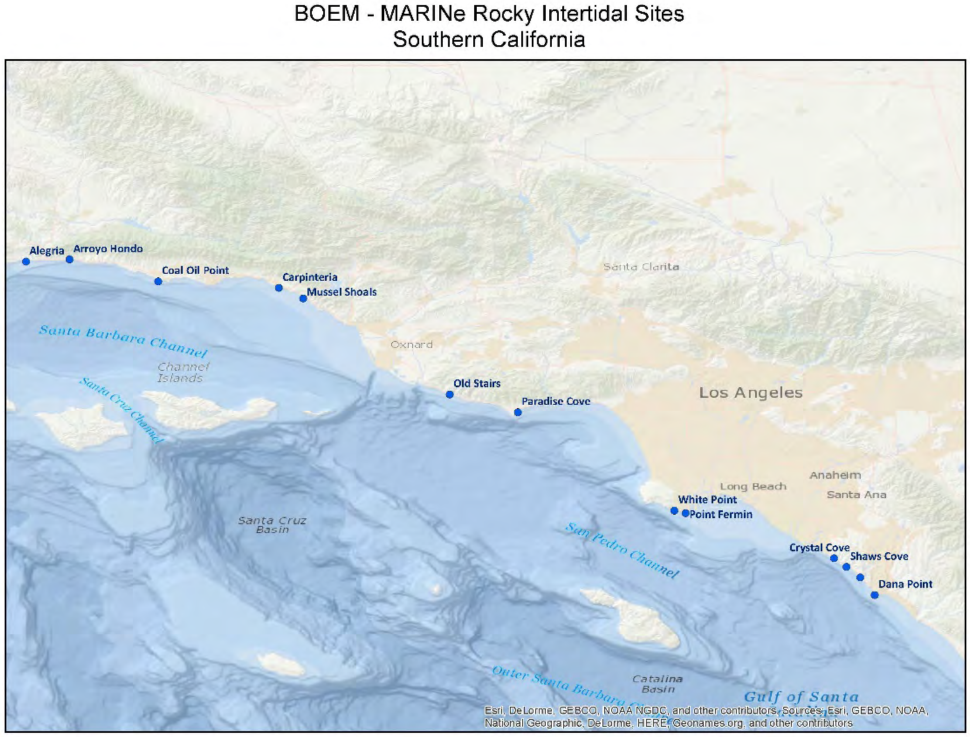


Figure 2. Location of Sampling Sites in Southern California

Target species include: rockweeds (*Silvetia compressa* and *Hesperophycus harveyanus*), turfweed (*Endocladia muricata*), red algae *Mastocarpus* and *Mazzaella* spp., anemones (*Anthopleura elegantissima/sola*), barnacles (*Chthamalus* spp. and *Balanus glandula*), goose barnacles (*Pollicipes polymerus*), mussels (*Mytilus californianus*), surfgrass (*Phyllospadix scouleri/torreyi*), sea stars (*Pisaster ochraceus*), owl limpets (*Lottia gigantea*), and black abalone (*Haliotis cracherodii*). Not all target species are sampled at each site, and additional species are targeted at other sites in the MARINe network. Table 3 shows the target species at each of the sites sampled. Detailed descriptions for all species targeted by MARINe surveys, (including habitat, geographic range, and natural history) are available in Appendix 1 and at www.pacificrockyintertidal.org.

Table 3: Target species sampled (X) at the 24 sample sites.

	Target Species/Assemblage															
	anthopleura	acorn barnacle	endocladia	haliotis	hesperophycus	lottia	mastocarpus	mazzaella	mytilus	phyllospadix	pisaster	pollicipes	postelsia	recovery	"rock"	silvetia
Pt. Sierra Nevada		X		X	X		X	X	X	X	X		X			X
Piedras Blancas		X		X			X		X		X		X			X
Rancho Marino				X		X										
Cayucos		X	X	X	X	X			X	X	X					X
Hazards		X	X			X		X	X	X	X					X
Shell Beach		X	X				X		X	X	X					X
Occulto		X	X						X		X					
Purisima				X												
Stairs		X	X	X		X			X	X	X			X		X
Boat House	X	X	X	X		X			X		X					X
Government Pt.		X	X	X		X			X	X	X	X				X
Alegria	X	X				X			X	X	X	X			X	
Arroyo Hondo		X							X	X	X				X	
Coal Oil Pt.	X								X	X	X					
Carpinteria	X	X				X			X	X	X	X				
Mussel Shoals	X	X				X			X	X	X				X	
Old Stairs	X	X	X			X			X		X				X	
Paradise Cove		X	X			X			X	X	X					
White Pt.		X	X			X			X		X					
Pt. Fermin		X				X			X	X	X				X	X
Crystal Cove		X				X			X	X	X					X
Shaws Cove		X	X			X			X		X				X	X
Treasure Island		X				X			X		X				X	X
Dana Pt.		X				X			X		X					X

Mussels, barnacles, anemones and algal species are photographed in fixed rectangular plots and scored in the lab or field by scoring species occurring under 100 points overlaid onto each image or plot. Five replicate plots per target species are photographed and sampled each time a site is surveyed. Surfgrass cover is estimated using a point contact method along 10-meter long transects. Owl limpets are measured and counted in five replicate, 1-meter radius circular plots. Abalone are counted and measured, and nearest neighbor information is recorded in three replicate irregular plots. Sea stars are counted, measured and assigned a disease category from 0 (healthy) to 4 (significant tissue degradation/arm loss) in either 2-meter wide x 10-meter long band transects or irregular plots, depending on the habitat. Historically, sea star color was also recorded, but this was dropped in 2013. At some sites, we sample the motile species within photoplots (Table 4). Historically motile invertebrate counts were done at more sites, but this method was dropped in 2013 in some areas due to time constraints (see Appendix 7 for justification). It is important to note that the motile invertebrate protocol is "supplemental", and not part of the "core" set of protocols done at all MARINe sites. To optimize future environmental impact assessments, sites have been established systematically over a broad geographic range and each target species is monitored at several sites within that range.

Monitoring of long-term sites is typically done in fall and spring each year, although the motile species are now sampled only once per year (see Table 4). There can be considerable seasonal changes in the rocky intertidal community, especially after stormy winters and hot summers. October or November is usually the first period after summer with low tides during the daytime (daylight is required for photographing plots), and is appropriate for determining the post-summer community. Daytime low tides typically occur again in March and April, an appropriate time to determine the post-winter community.

Table 4: Target species plots in which motile organisms are sampled

	Target Species/Assemblage								
Site	acorn barnacle	endocladia	hesperophycus	mastocarpus	mytilus	pollicipes	"rock"	silvetia	Motile Sampling Notes
Pt. Sierra Nevada	X		X	X	X			X	discontinued 2013
Cayucos	X	X	X		X			X	discontinued 2013
Hazards	X	X			X			X	discontinued 2013
Shell Beach	X	X		X	X			X	discontinued 2013
Occulto	X	X			X				discontinued 2013
Stairs	X	X			X			X	discontinued 2013
Boat House	X	X			X			X	discontinued 2013
Government Pt.	X	X			X	X		X	discontinued 2006
Alegria	X				X	X	X		spring sampling only
Arroyo Hondo	X				X		X		spring sampling only
Coal Oil Pt.					X				spring sampling only
Carpinteria	X				X	X			spring sampling only
Mussel Shoals	X				X		X		spring sampling only
Old Stairs	X	X			X		X		spring sampling only
Paradise Cove	X	X			X				spring sampling only
White Pt.	X	X			X				spring sampling only
Pt. Fermin	X				X		X	X	spring sampling only
Crystal Cove	X				X			X	spring sampling only
Shaws Cove	X	X			X		X	X	spring sampling only
Treasure Island	X				X		X	X	spring sampling only
Dana Pt.	X				X			X	spring sampling only

Depending on the size of the site and the number of target species being monitored, 2-5 samplers (minimum of 2 trained biologists) are typically needed to complete the collection of field data on a given tide. Biologists with the Pacific Region Intertidal Survey and Monitoring (PRISM) Team, formerly MMS Intertidal Team (MINT), assist in the collection of the field data at as many as 20 of the sites depending on tidal cycles. Travel to and from sites benefited from cost sharing since several sites can be surveyed during one tide cycle.

Protocols used to collect the data are standardized, coordinated with other members of MARINe, and are not altered without prior approval of BOEM. A "core" set of protocols was standardized across the Bight among MARINe members and was maintained at each site; additional, "supplemental" protocols needed to address site specific problems or answer species-specific questions are sometimes added with BOEM approval. "Supplemental" protocols which do not add to field costs overall are accommodated in order to address important research questions, so long as they are disseminated to and agreed upon (where appropriate) by all MARINe members.

Collection of field data is carried out by the University of California, Santa Cruz (UCSC), University of California, Los Angeles (UCLA), California State University, Fullerton (CSUF), and California State Polytechnic University, Pomona (CPP) (Table 2).

Coordination—Internal and with MARINe

Because several teams of biologists are needed to collect data at over 160 established sites (including the 24 BOEM-funded sites), coordination among field teams is essential to ensuring that the data collected are of the highest quality and are comparable across sites. Therefore, strong coordination is needed between the Principal Investigators (PI)'s to ensure continuity since the tasks are inherently integrated among Universities. This coordination includes regular meetings, email, phone calls and joint participation in the field to ensure that individual PIs are not inadvertently making changes in protocols or data processing which affect other teams.

Strong coordination is also needed between BOEM and MARINe to ensure that MARINe is providing data in a timely fashion to BOEM and that MARINe products directly meet the needs of the scientists, including the BOEM PIs. BOEM agreed to provide a MARINe coordinator to that end. The duties of the coordinator include:

1. Facilitating the development of the database by:
    a. Acting as a liaison between the database consultant and MARINe researchers in developing timely responses to database questions.
    b. Coordinating with the BOEM researchers in particular and MARINe researchers in general to ensure their data and metadata inputs are complete and timely.
    c. Providing a broad range of knowledge regarding the MARINe sites and technical issues to the database consultant to ensure that the database will be useful to researchers when it is completed.
2. Organizing and moderating biannual Steering Committee, Science Panel and Database Panel meetings for MARINe.
3. Providing ongoing coordination with the MARINe committee representatives and organizations outside MARINe to facilitate continued long-term funding of MARINe sites.
4. Working with MARINe to develop automated standardized field datasheets.
5. Working with MARINe to reach agreement and develop procedures which promote timely release of data to the public.

These tasks are done at all campuses but the responsibility for coordination was centered at the University of California, Santa Barbara (UCSB).

Data management

Data management is centralized at UCSC. Duties include administering data in the MARINe database and Excel spreadsheets. All campuses are responsible for entering data using data forms, but no alterations to the database are made without approval from the data administrator. New data are uploaded two times per year (March 1 and October 1). Data are available to all agencies and interested parties that make specific requests, or online through the PISCO data catalog (www.piscoweb.org) and DATAOne (www.dataone.org). During the final year of this contract period, UCSC began the process of creating a new MySQL database, which will allow for greater flexibility in terms of data entry, management, and retrieval. We are currently in a "transition" period, where data are still entered and stored in the Access database and Excel spreadsheets, but are also loaded into the new MySQL database. In the next contract period, we will develop data entry forms that will link directly to the MySQL database, eliminating the need for the Access database and Excel spreadsheets. See Part V for more detail.

Project management

The UCSC portion of the program (monitoring in San Luis Obispo and northern Santa Barbara County) is managed by the Principal Investigator, Dr. Pete Raimondi. Dr. Raimondi has been a Principal Investigator of the BOEM-funded rocky intertidal inventory project since its inception and has been responsible for data analysis of the project for over 20 years. Dr. Raimondi is responsible for overseeing financial aspects of the project, and in particular, is responsible for ensuring completion of project objectives and deliverables. This is done, in part, through coordination meetings and conference calls. However, the main means of ensuring performance is through the yearly workshops where all PIs get together along with staff to review the status of the project.

Dr. Rich Ambrose at UCLA does companion monitoring for southern Santa Barbara and Los Angeles Counties. Dr. Jennifer Burnaford at CSUF, and Dr. Jayson Smith at CPP monitor sites in Orange County. Dr. Jack Engle at UCSB coordinates MARINe efforts, particularly with regard to protocol standardization and documentation. In addition, the BOEM Pacific Regional Intertidal Survey and Monitoring (PRISM) Team participates in the sampling, and other program functions to assure continued coordination with BOEM is maintained.

Rocky Intertidal Monitoring in Oregon

Survey Methods and Target Species Monitoring

For each of the 8 BOEM-funded sites in Oregon, detailed information is now available through the www.pacificrockyintertidal.org website. The information on each site page includes (where applicable): regional location, access restrictions, visitation, physical and geological characteristics, and coastal orientation. Long-Term Monitoring and Biodiversity Survey information such as year established, research (monitoring) group, and species targeted is also included on each site page. To view site pages for the 8 BOEM-funded sites, see Appendix 8.

Site specific graphs and trend descriptions for the 8 BOEM-funded sites in Oregon are available on our website, and also in Appendix 9. For site specific graphs and trend descriptions for species of concern (*Haliotis*, *Lottia*, and *Postelsia*), see Appendix 10 (available in CONFIDENTIAL report only).

PART II: ROCKY INTERTIDAL MONITORING STUDY IN SOUTHERN AND CENTRAL CALIFORNIA

2.1 Long-Term Monitoring

Description of sites

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.

For each of the 24 BOEM-funded sites, detailed information is now available through the www.pacificrockyintertidal.org website. The information on each site page includes (where applicable): regional location, access restrictions, visitation, physical and geological characteristics, and coastal orientation. Long-Term Monitoring Survey information such as year established, research (monitoring) group, and species targeted is also included on each site page. To view site pages for the 24 BOEM-funded sites, see Appendix 2.

Study Results: Summary of Trends

For each Long-Term Monitoring site, a detailed description of the trends and patterns in species' abundances, along with trend graphs for each plot type is available at www.pacificrockyintertidal.org.

Long-Term percent cover trend graphs for photo plots and transect data show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. For motile invertebrate species counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. A mean count across all plots is also displayed for *Lottia*. For *Pisaster*, *Haliotis,* and *Postelsia* counts, the sum of all individuals across all plots is displayed.

The report summarizes Long-Term Monitoring trends for the 24 BOEM-funded sites, as well as regional trends for the study region encompassing these sites. Additional coast-wide trends and site-specific results (including Biodiversity Survey findings) can be viewed at: www.pacificrockyintertidal.org. Trends are summarized for the entire period over which a site has been monitored, up to fall 2014.

To view site specific graphs and trend descriptions for the 24 BOEM-funded sites, see Appendix 3. For site specific graphs and trend descriptions for species of concern (*Haliotis, Lottia,* and *Postelsia*), see Appendix 4 (available in CONFIDENTIAL report only).

Discussion

The following is a brief summary of individual species trends for the central/southern California region specified for this report. Additional, coast-wide trends and site-specific results can be viewed at: www.pacificrockyintertidal.org. Trends are summarized for the entire period over which a site has been monitored

Silvetia (golden rockweed) initially declined in cover at all sites north of Point Conception, except Boathouse, which lies just to the north of this important biogeographic barrier (approx. 25 km north), but then recovered and stabilized at nearly all sites during recent years. A slight decline occurred at Point Fermin, but cover at all other sites south of Point Conception was quite stable over the 18-22 year monitoring period. *Silvetia* cover tended to fluctuate seasonally, with slightly higher cover in fall than in spring at all sites. At both sites where *Hesperophycus* (olive rockweed) was sampled, cover decreased substantially in the first few years of monitoring, then leveled off for a number of years, followed by a recovery in 2012/2013, and finally a recent decline. Cover of *Endocladia* (turfweed) declined at all sites where it was sampled, although the degree of decline ranged from slight or moderate (6 sites) to severe (5 sites). As with *Silvetia*, cover of *Endocladia* fluctuated seasonally at most sites, but in the opposite direction, with higher cover in spring than in fall.

Mastocarpus (Turkish washcloth) cover was relatively stable at Point Sierra Nevada, but experienced a slight decline overall at Shell Beach. *Mazzaella* (iridescent weed) cover remained relatively stable over time at both sites where these algae were sampled. *Anthopleura* (anemone) cover was stable over time at all sites where this species was sampled. Extreme fluctuations in sand cover occurred at five sites in the low-lying fixed plots used for monitoring *Anthopleura* abundance. *Chthamalus/Balanus* (acorn barnacle) cover varied over time and among sites, which was not surprising for these relatively short-lived species. Overall, barnacle cover was relatively stable over time at eight sites, declined slightly at seven sites, and declined moderately to severely at five sites. *Pollicipes* (goose barnacle) cover was constant over time at all three sites where it is monitored, but showed a seasonal trend (with higher cover in fall) at Carpinteria. Mussel cover was relatively stable over time at nine of the twenty-one sites where it is sampled. Six sites showed a slight decreasing trend in mussel cover over time, while at six sites the decline was substantial. The 1997/98 El Niño event was associated with a decline in mussel cover at seven sites; five sites recovered from this impact, but two did not. Recovery plots contained high cover of bare rock and non-coralline crusts, but *Silvetia* cover has gradually been increasing over time, and recently surpassed rock as the dominant space occupier.

Phyllospadix (surfgrass) cover was highly seasonal, with higher cover in fall than in spring at all sites except Cayucos, where transects are located in pools, and Hazards, where transects are located in the extreme low zone. Sand cover in surfgrass plots was an important factor at several sites, particularly at Coal Oil Point, where plants were frequently partially covered and, on one occasion, completely buried by sand. Surfgrass cover along transects was stable at nine sites, declined slightly over time at two sites, and substantially at just one, Coal Oil Point. Surfgrass at many sites was hit hard by the 1997/98 El Niño, with plants and in some cases, portions of the reef itself, getting ripped out or removed by powerful storm waves. This was especially true at Stairs, where surfgrass declined by nearly 80%. El Niño associated decline was also seen at Arroyo Hondo, Carpinteria, and Paradise Cove.

Pisaster (sea star) counts were variable from sample to sample until 2013 at nearly all sites for this highly mobile species. Then, in 2014, substantial numbers of stars at all sites fell victim to sea star wasting syndrome (SSWS), and significant declines occurred at every site within the region, as well as at other MARINe sites further north and south. Detailed discussions of the extent of impact of SSWS are included in the trend graph descriptions for each site on pacificrockyintertidal.org. As of fall 2014, no site within the BOEM funded region of California had seen substantial recruitment of new individuals, but moderate numbers of juveniles were recorded at a few sites (Shell Beach, Occulto, Stairs, Mussel Shoals, and Old Stairs). Recovery of *Pisaster ochraceus* is dependent upon the survival of these juveniles through the coming years, and recruitment of new individuals to additional sites. *Lottia* (owl limpet) abundance was quite variable over time at many sites. The mean number of owl limpets per plot increased slightly at 2 sites and substantially at one site, remained about the same at six sites, and decreased slightly at five sites and substantially at two sites.

Major declines of black abalone occurred at nearly all sites within the regions funded by BOEM between 1992-2005. The black abalone has been placed on the Endangered Species List as a result, in part, of trends documented by this study. After 2005, populations (where still present), were relatively stable, but this has been a period with no major ENSO events, and we believe that declines will continue and spread farther north during a warm water event. Also significant is that there has been almost no recruitment of black abalone to any site in this region during the post-decline period, indicating that recovery, if it occurs, will be slow.

In an effort to better characterize the communities targeted by photoplots, motile invertebrates were counted in select plot types for several years. However, the time and effort required to collect the data wasn't justified since the motile community data did not help to explain much of the variation within sessile species'communities (Appendix 7), these counts were discontinued in 2013 at all sites monitored by UCSC. Limpets and littorines were the most abundant (and most variable) motile invertebrates, present mostly in barnacle and *Endocladia* plots. The turban snail, *Tegula funebralis,* was common in *Silvetia*, *Endocladia*, and mussel plots. Mussel plots also contained the whelk, *Nucella* spp. and the chiton *Nuttallina* spp. *Lepidochitona hartwegii* was found nearly exclusively in *Silvetia* plots.

2.2 Significant Results

The MARINe monitoring program is the largest and longest-running project of its kind; some BOEM-funded sites have been sampled for over 20 years. A significant result of the BOEM-MARINe study is the fact that these data have been instrumental in assisting in several California State analyses, including Marine Protected Areas (MPAs), Areas of Special Biological Significance (ASBS) and Natural Resource Damage Assessment (NRDA). This program has specifically been recognized by the California Water Quality Monitoring Council for allowing "state agencies and other users to obtain an increasingly detailed understanding of the extent and condition of rocky intertidal habitats, and the impacts of both natural and anthropogenic stressors on those habitats" (Jonathan Bishop and Dale Hoffman-Floerke, personal communication, February 29, 2012).

With the 2011 launch of the web-based report at www.pacificrockyintertidal.org, graphical displays depicting trends and patterns in the abundance of targeted species for all MARINe sites over time are easily accessible, and can be regularly updated. In addition, the website's Interactive Map and Graphing Tool allows users to select specific regions or sites to view, and design summary graphs to include specific species and/or years of interest. Long-term data from within the BOEM-funded region have been invaluable for rocky intertidal community damage assessment and resource management (see examples below) and it is our hope that this new web-based interactive tool will increase the accessibility and usability of MARINe data.

Black abalone status

One of the most important results of the MARINe long-term monitoring program is the documentation of massive declines in black abalone populations due to withering syndrome, and the nearly complete lack of recruitment to areas where populations have been decimated (Miner et al. 2006). Declines were first detected on the mainland at BOEM-funded sites in Santa Barbara County (Altstatt et al. 1996). Long-term monitoring has allowed us to document patterns in decline related to water temperature, and map the northward progression of the disease (Raimondi et al. 2002). Additional studies coupled to the MARINe monitoring surveys were carried out to determine the extent of the critical habitat for the species. These two data sets were combined to estimate the population size of black abalone and results were used to argue for the listing of the species as endangered.

Sea Star Wasting Syndrome (SSWS)

Another, more recent, disease event has impacted countless numbers of sea stars along the west coast of North America, including *Pisaster ochraceus*, a MARINe target species. Sea star wasting syndrome (SSWS) has resulted in massive declines of *P. ochraceus* at all BOEM funded sites, and long-term count and size data have been essential for estimating impact, and will be critical for documenting recovery. In 2013, we developed seastarwasting.org, a website linked to pacificrockyintertidal.org, but focused specifically on the sea star wasting epidemic that has plagued sea stars at all MARINe sites coast-wide. This site provides general information about SSWS, updates on recent findings related to the disease, information about how users can contribute to the sea star monitoring effort, and an interactive "tracking" map that allows users to see where SSWS is present, and which species have been affected.

Marine Protected Areas (MPAs)

MARINe long-term monitoring data were used by the State of California to aid in the design of the Marine Protected Area (MPA) network mandated by the Marine Life Protection Act. Long-Term and Biodiversity intertidal datasets were used to delineate biogeographic regions and calculate optimal sizes for intertidal MPAs. MARINe long-term data will also be used to assess the effectiveness of these newly established MPAs (California Department of Fish and Game, 2008).

Areas of Special Biological Significance (ASBS)

Data from MARINe surveys have been used to compare areas within and outside of Areas of Biological Significance (ASBS), and have been the foundation for studies that have ranged from simple assessment of potential impact to baseline characterization of whole regions (Raimondi, et al. 2011b). Study areas range from a single ASBS (e.g. Mugu Lagoon to Latigo Point ASBS) to locations on a regional scales, (e.g. Los Angeles Regional Board, etc.).

Oil Spills and Natural Resource Damage Assessment (NRDA)

A primary objective for our research is to continue the ongoing monitoring program that provides a basis for determining if change in rocky shoreline communities adjacent to producing OCS facilities can be attributed to operations or accidents from these facilities. Our goal was to develop methods that would detect effects of oiling (~20% change) on intertidal communities.

In 1997, analyses following the Torch/Platform Irene Oil Spill showed that it was possible to detect change in percent cover of barnacles and mussels as small as 8-15% using our fixed plot sampling protocol. Importantly, it was also possible to differentiate between natural changes such as the El Niño storms and the effects of the oil spill (Raimondi et. al, 1999).

During the 2007-2010 funding cycle, we had the opportunity to test our methodology in the Natural Resource Damage Assessment (NRDA) process for two oil spills: Cosco Busan and Dubai Star/San Francisco Bay. Although oiling from both of these spills was patchy in coverage (heavy in some places but moderate to light in most), we were able to use Long-Term Monitoring data to detect the effects of the oil spill and provide a basis for the determination of NRDA impact as well as calculation of the size of the impact (Raimondi et. al, 2009, 2011a). Our long-term monitoring data will again be critical in the assessment of damage due to the 2015 Refugio oil spill in Santa Barbara County.

In each of these cases, damage assessment would not have been possible without a measure of natural long-term variation both within and outside of the area impacted by the oil spill. The results of these analyses indicate that our sampling does pick up anthropogenic effects due to oil spills. Previously, our protocols had not been tested in this manner, but they are now an accepted approach for the assessment of impacts to intertidal hard surfaces (natural and man-made). This accomplishment led to a contract to modify our protocol to use in the NRDA assessment for hard surface areas affected by the Deep Water Horizon oil spill that occurred in the Gulf of Mexico in 2010. This elevates the acceptance of the MARINe Long-Term Monitoring methods to a national scale.

PART III: INVESTIGATING POTENTIAL IMPACTS OF WAVE ENERGY COLLECTION DEVICES TO ROCKY INTERTIDAL AREAS IN OREGON

3.1 Assessment of wave climate – detection of change in wave climate

History

In 2012 BOEM made an award to UCSC to evaluate the ability to detect a change in wave climate due to the deployment of wave energy collection devices (WECD). There were three general tasks in the agreement. First, biodiversity surveys were to be done at the "WECD" sites. This task was completed and is discussed as part of the biological diversity portion of the report. Second, new approaches to more easily (than biodiversity surveys) assess change in the vertical distribution of species were to be evaluated. This task was also completed and is discussed in the biological diversity section of the report. Third, we were tasked with evaluating the ability to detect small changes in the wave climate of a site that could result from installation of WECD. This task was based on environmental analyses, which predicted that WECD could dampen wave height 3-10%. This project was aimed at determining if a change in wave climate of 10% could be reliably detected. We used two approaches: (1) collection of pressure data and (2) collection of temperature data. Temperature profiles can be used to estimate the time of immersion of a location based on a sudden shift in temperature followed by a period of stability. It is a crude but effective and cheap approach to the measurement of time of immersion. As it can be used to model wave climate, these data were part of a backup plan to be used in the event the pressure sensors did not work or have sufficient resolution to resolve the wave climate. This was not the case so no analyses with temperature were done.

Originally, we were going to use custom built pressure sensors that appeared almost ready to put in use for our study in Oregon. BOEM strongly supported the use of these instruments but there were delays in the production of these devices and so in 2013 we decided to implement a trial of commercially available Onset Titanium Water Level Data Loggers (http://www.onsetcomp.com). The specifications are shown below (table 5). The key limitation of these instruments is the memory (64K) that is currently available. This value should increase in the future, but for our trials it limited the number of observations to 21,700. We set our sampling interval to every 5 minutes, which provided a ~2.5 month record of pressure measurements. During 2013 we purchased two devices and experimented with housings for the devices. This was done at Terrace Point, just below the Long Marine Lab at UCSC. The goal was to devise a protective case that would not diminish or bias the pressure readings. Once we devised a suitable housing, we deployed the devices at two sites in Oregon: Seal Rock and Fogarty Creek to see how they fared in the field in Oregon. We did not put out a full set of devices (8) because BOEM strongly advocated the use of the custom sensors, which were not yet ready for deployment and we did not want to spend the funds for additional Onset loggers if we were going to purchase the custom loggers. The trials went smoothly and based on initial analysis we decided that they would be suitable for our task should the custom loggers not be ready by 2014. In early 2014, it was clear that the custom loggers would not be ready in time for the 2014 summer sampling period (summer sampling was part of the agreement with BOEM) and as a result we purchased a full complement of loggers from Onset. These were deployed and the data presented below all came from Onset loggers deployed in summer 2014 at 8 sites.

For the purpose of clarifying terminology used in this report we are defining:

Wave climate: the profile of waves that characterize a defined location. The temporal framework is defined by the period of sampling and the temporal frequency of observations.

Wave amplitude: ½ the distance from wave trough to wave crest

Pressure: a metric of water depth over the instrument. Changes in depth can be due to tidal level and wave climate

Table 5: Specifications for Onset Data Loggers

Specifications

Pressure (Absolute) and Water Level Measurements U20-001-01 and U20-001-01-Ti

Operation Range	0 to 207 kPa (0 to 30 psia); approximately 0 to 9 m (0 to 30 ft) of water depth at sea level, or 0 to 12 m (0 to 40 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 207 kPa (10 to 30 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 0.5 cm (0.015 ft) water Maximum error: ±0.1% FS, 1.0 cm (0.03 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.62 kPa (0.09 psi) maximum error
Resolution	<0.02 kPa (0.003 psi), 0.21 cm (0.007 ft) water
Pressure Response Time (90%)***	<1 second; measurement accuracy also depends on temperature response time

Temperature Measurements (All Models)

Operation Range	-20° to 50°C (-4° to 122°F)
Accuracy	±0.44°C from 0° to 50°C (±0.79°F from 32° to 122°F), see Plot A
Resolution	0.10°C at 25°C (0.18°F at 77°F), see Plot A
Response Time (90%)	5 minutes in water (typical)
Stability (Drift)	0.1°C (0.18°F) per year

Logger

Real-time Clock	± 1 minute per month 0° to 50°C (32° to 122°F)
Battery	2/3 AA, 3.6 Volt lithium, factory-replaceable
Battery Life (Typical Use)	5 years with 1 minute or greater logging interval
Memory (Non-volatile)	64K bytes memory (approx. 21,700 pressure and temperature samples)
Weight	Stainless steel models: approximately 210 g (7.4 oz) Titanium models: approximately 140 g (4.8 oz)
Dimensions	2.46 cm (0.97 inches) diameter, 15 cm (5.9 inches) length; mounting hole 6.3 mm (0.25 inches) diameter
Wetted Materials	Stainless Steel models: 316 stainless steel, Viton® o-rings, acetyl cap, ceramic sensor Titanium models: Titanium, Viton o-rings, acetyl cap, ceramic sensor
Logging Interval	Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to the HOBOware software manual.
Launch Modes	Immediate start and delayed start
Offload Modes	Offload while logging; stop and offload
Battery Indication	Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Rationale

As described above one goal of the BOEM Oregon project was to assess the ability to detect a change in wave climate that might arise from the installation of wave energy collection devices. Clearly, such ability would also have implications for detecting changes in wave climate due to other factors such changes in wind patterns, and barometric pressure. We installed commercially available Onset pressure sensors (Onset U20-001-04-Ti) in the mid-intertidal at 8 locations in Oregon (from north to south): Ecola State Park

(ESP), Cape Meares (MEA), Fogarty Creek (FOG), Seal Rock (SEA), Bob Creek (BOB), Cape Arago (ARG), Coquille Point (COQ), and Burnt Hill (BRN) (Figure 3).

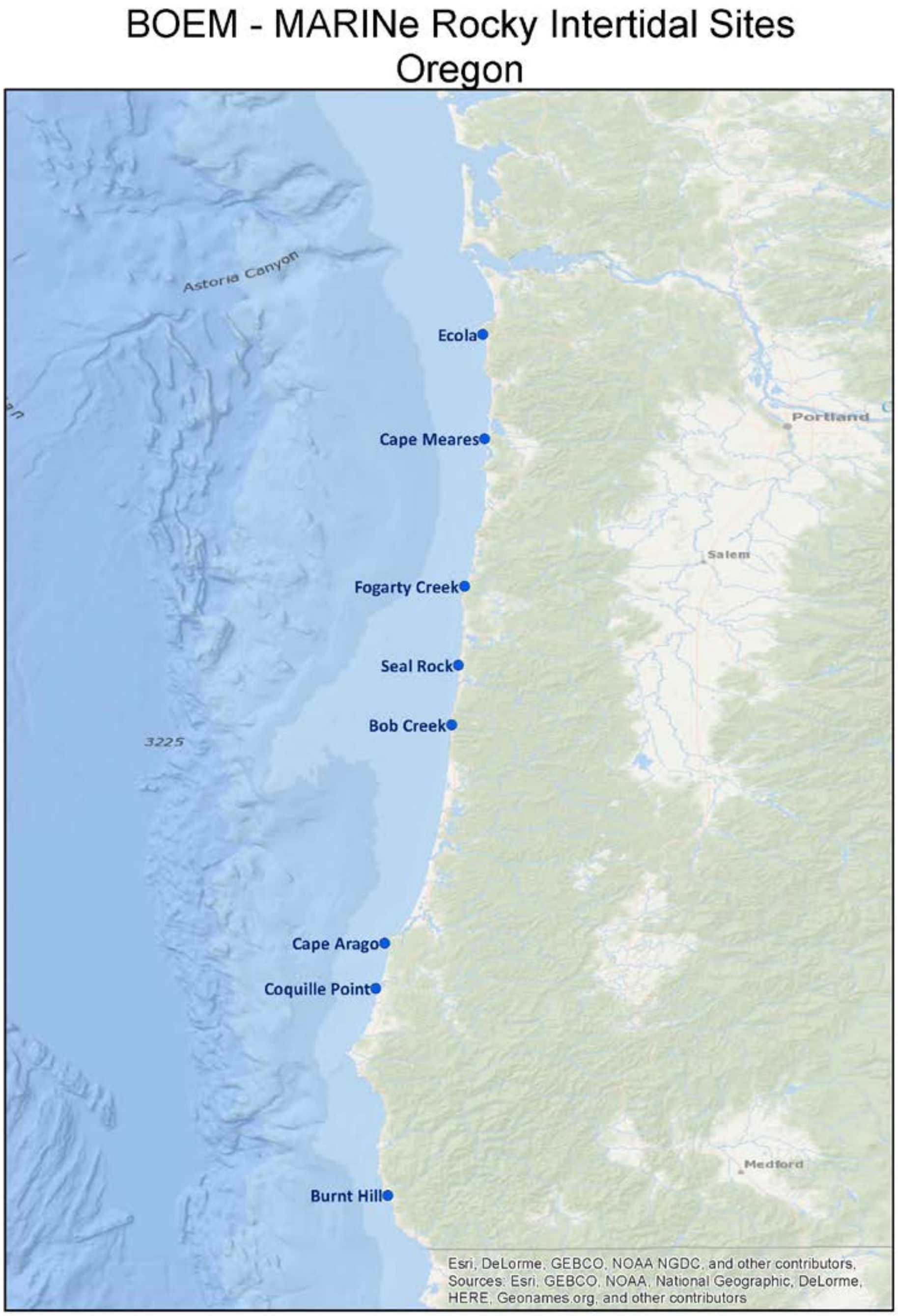


Figure 3. Location of Sampling Sites in Oregon

Both pressure (a proxy for wave height) and temperature were recorded every 5 minutes during summer and fall of 2014 (Figures 6 and 7). Because of logistic constraints, not all sensors were deployed or collected simultaneously, but there was a substantial period of overlap that allowed WECD assessment of any asymmetrical spatial spectral signature (we did not expect one, see below). All data were recovered using proprietary HOBOWARE software. The derived CSV files were concatenated and then analyzed using a time series analysis implemented in JMP 12 (SAS). Details of the analysis and results are described below.

Step one: Determine the spectral signature of the time series of pressure data.
Wave data can be thought of as the “noise” that exists after filtering out the spectral harmonics associated with tides. Spectral harmonics refer to the nested set of oscillatory elements in a data series. Each element is characterized by a specific frequency. There are a series of potential temporal tidal harmonics:

1) Yearly: having to do with the relative inclination of the moon relative to the sun (Figure 4)
2) Lunar phase: having to do with sequences of full and new moons (resulting in spring and neap tides), usually at ~28, ~14 and ~7 days (Figures 4 & 5)
3) ~Daily: having to do with the full daily tidal sequence (Figure 5)
4) ~12 hours: having to do with the return time of tides (for semi diurnal tides) (Figure 5)
5) ~ 6 hours : having to do with the transition between ebb and flood tides (Figure 5)

Data from all 8 sites were individually analyzed using spectral decomposition (Fourier analysis)[1]. This approach models data and essentially seeks out oscillatory sequences and provides an estimate of the spectral density of the oscillatory period. For example, if a signal repeats sharply at a specific interval, the signature spectral density will be steep with a short period. The results of the spectral decomposition are shown in Figure 8 for all sites for a relatively short time period. The key result is that three clear signatures are present and consistent across all sites: 6, 12 and 24 hours. Note also the 6 hour signature is comprised of two small peaks, probably representing the shift between falling and rising tide.

Step two: using the spectral signature, smooth the data series to allow separation of wave from tidal climate.
This was done for all sites but as an example two sites with a long period of sampling overlap were selected as a test case: Cape Arago and Fogarty Creek. The goal was to smooth the data so as to model only the tidal signal (made up from the series of spectral elements). If this is successful, the deviation (residuals) between the smoothed and actual series represents the wave climate. The values for the wave climate are both positive (pressure higher than expected by tidal forcing) and negative (pressure lower than expected). These represent (for a given wave amplitude) the maximum wave height and trough. The results for the analysis are shown in Figure 9. Fogarty Creek typically had higher pressure values and also bigger waves during the sample period. It is worth pointing out that an alternative approach would be to use tidal predictions, rather than empirically based tidal smoothing (as described) as the core smoothed dataset. This was not chosen as

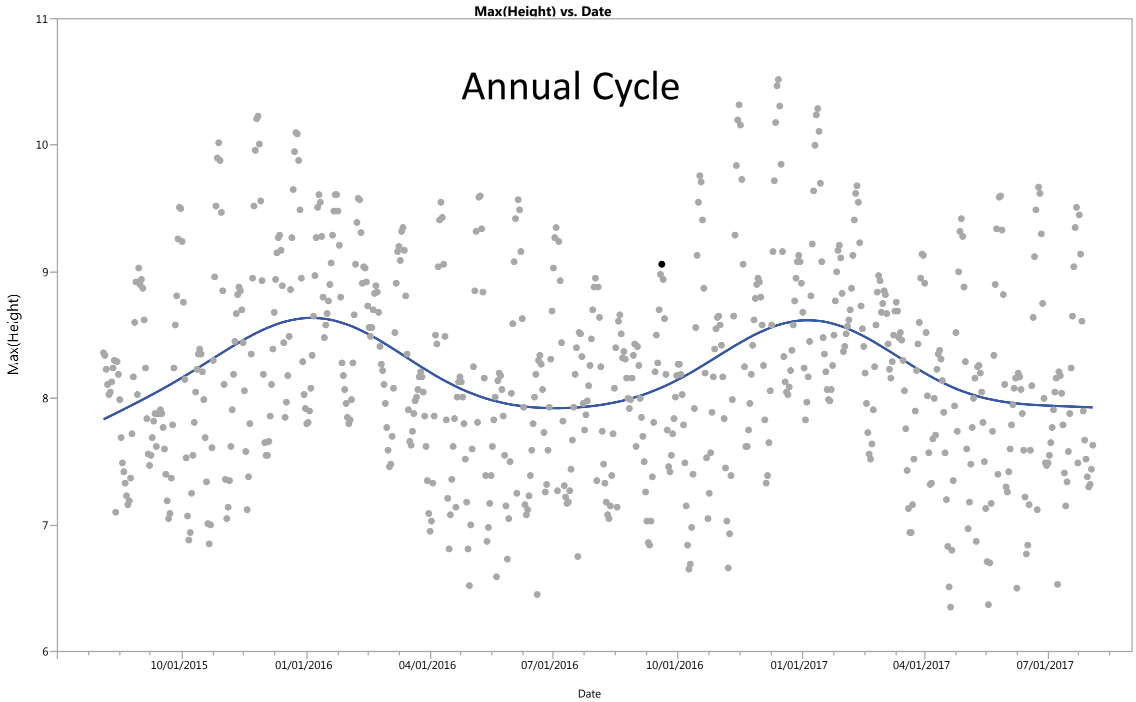
to do this as this approach would either: (1) rely on untested assumption concerning local barometric pressure, wind fields and local geomorphology or, (2) require these parameters to be input into the tidal prediction.

Step three: Using BACIP approach, model the power to detect a change in wave climate.

The key to this approach in assessing change in wave climate is the use of a BACIP design (Before After Impact Control Paired). Here, the wave climate pre and post development of wave energy collection devices (WECD) is not being compared. To do so would be to assume that the only change that could affect wave climate over time is that associated with the WECD. This assumption is logically flawed. Instead one can use two sites, the first where a WECD was installed and the other where a WECD was not installed. Both are sampled pre- and post-WECD. The difference between sites in wave climate pre-WECD represents the non-WECD difference in wave climate. This can then be assessed against the difference post-WECD to determine the effect of WECD at the impact site. The more reference sites sampled, the more robust the assessment, so spatial replication pre WECD is essential. As noted, Cape Arago and Fogarty Creek were used in this test assessment. If this project were to go forward, it would be important to maintain spatial replication and maximize the overlap in data acquisition among sites as observations under BACIP should be paired in time.

The residuals (the wave signature) from our example, Cape Arago and Fogarty Creek (step 2), were paired temporally and the set of differences was calculated (N= 21,405, Figure 10). The mean difference in pressure was -0.030738 between the two sites. Using the standard deviation of the set of differences (0.1725), a power analysis was run to examine the relationship between effect size and power, given alpha of 0.05 and N=21,405. Here effect size is defined as a change in the mean pre WECD difference (-0.030738) following development of WECD at one of the sites. The power function is shown in Figure 11. For reference, an arrow at the intersection of the power curve and power=0.8 was included, which is a traditional goal for power in a sampling design. The minimum effect size that yields power of 0.8 or greater is around 0.003.

The summary results for all sites (note that ESP was left out of this analysis because of a signal failure for half of the observations) are shown in Figure 12. Shown is the relative Minimum Detectable Effect Size (MDES), which is the change in wave induced pressure that could be detected relative to the average wave induced wave pressure at each site. To calculate the mean MDES, all pairwise comparisons were used (using BACIP), which resulted in 6 values for each site. The range in MDES was between 1 and 5%, with the lower values being associated generally with alpha = 0.20. These values suggest that by using this statistical approach and these instruments this is a very powerful method to detect very small changes in wave climate.



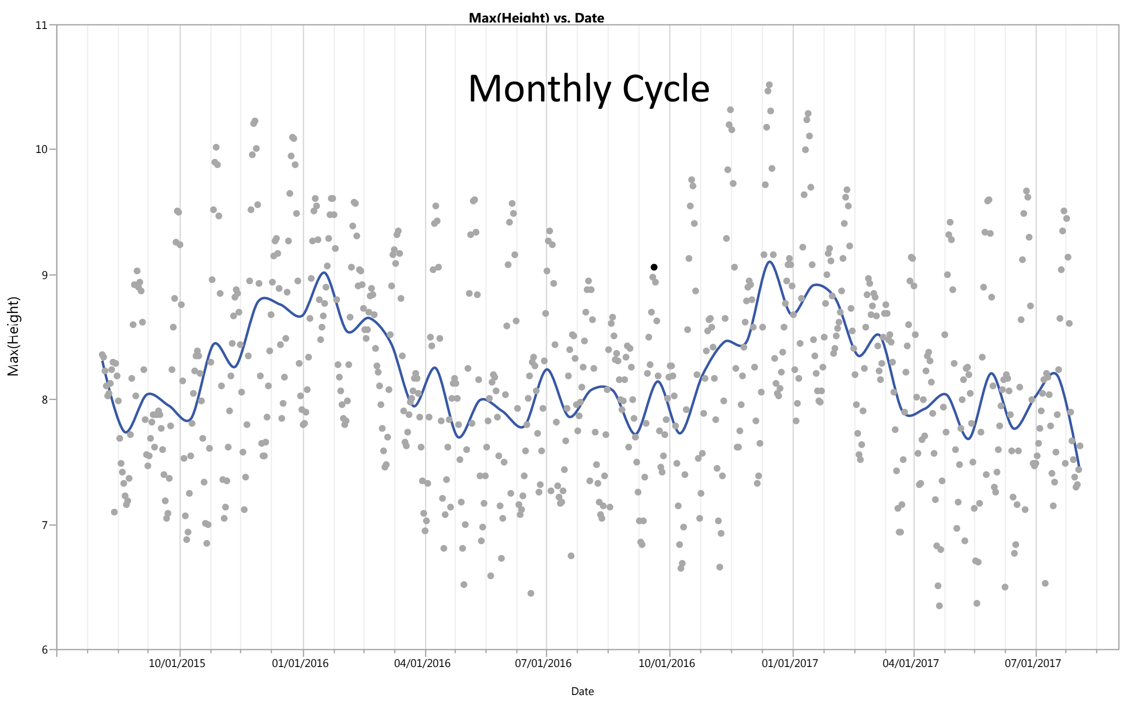


Figure 4. Set tide height data (tidal maximum in feet) of data from Oregon smoothed at different Lambda values. Top – the annual cycle. Bottom- monthly cycle (~28 days)

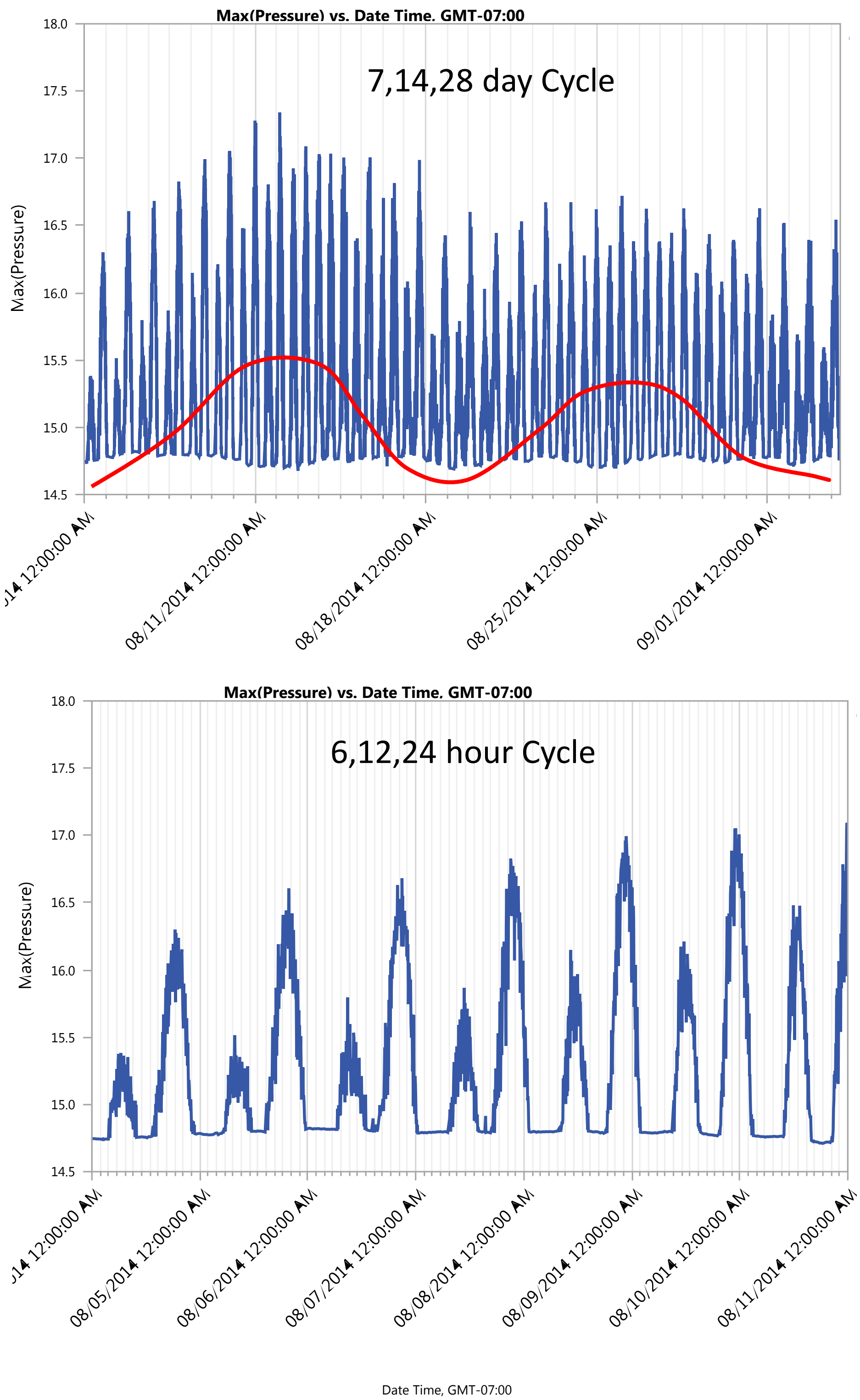


Figure 5. Pressure data from Cape Arago showing: Top – 7, 14, and 28 day cycles. Bottom- 6, 12, and 24 hour cycles.

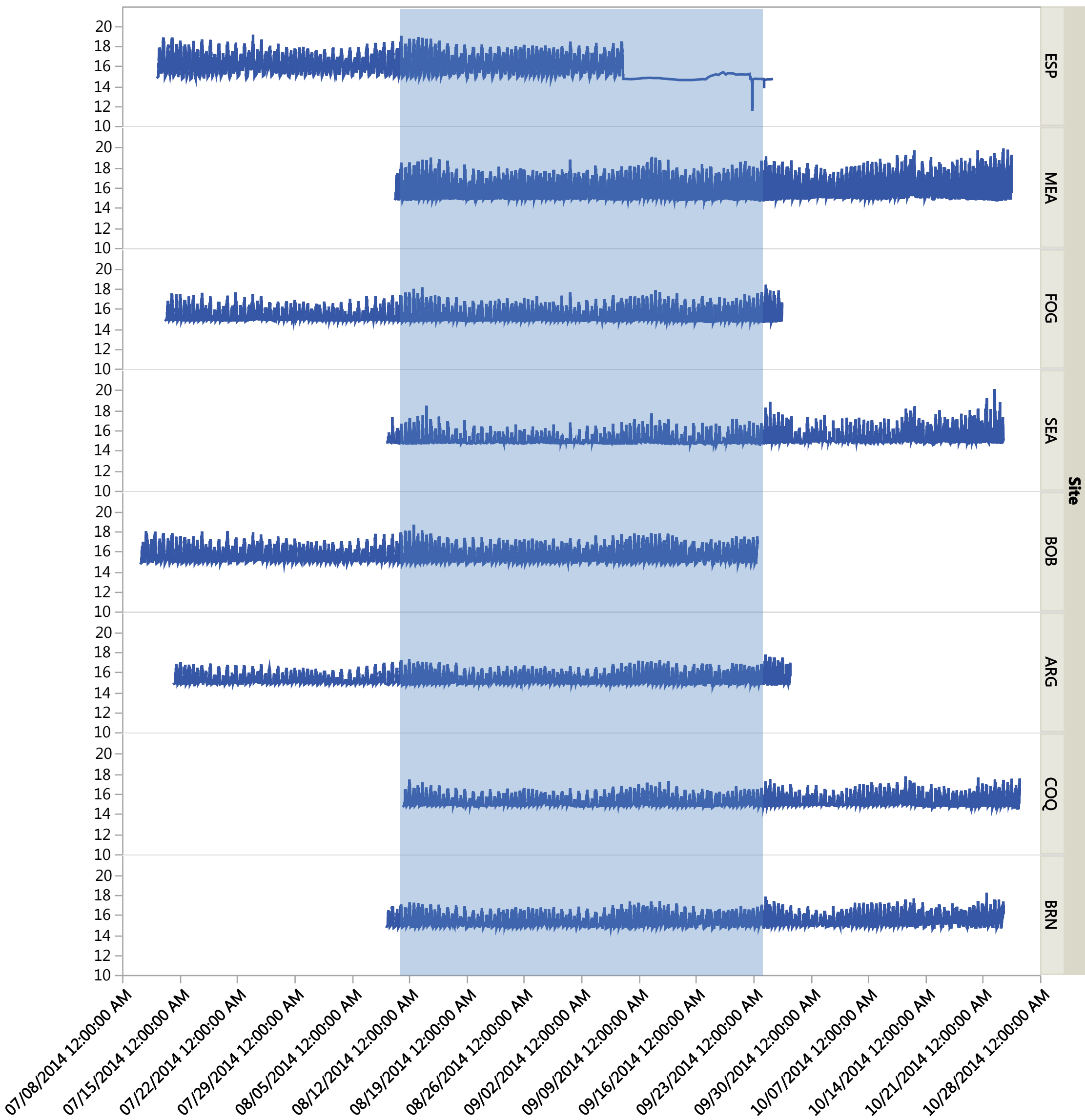


Figure 6. Pressure readings for all sites (sites north to south). Note the oscillating behavior of the pressure at all sites. Blue rectangle shows the period of overlap for all sites. This section is shown in Figure 7.

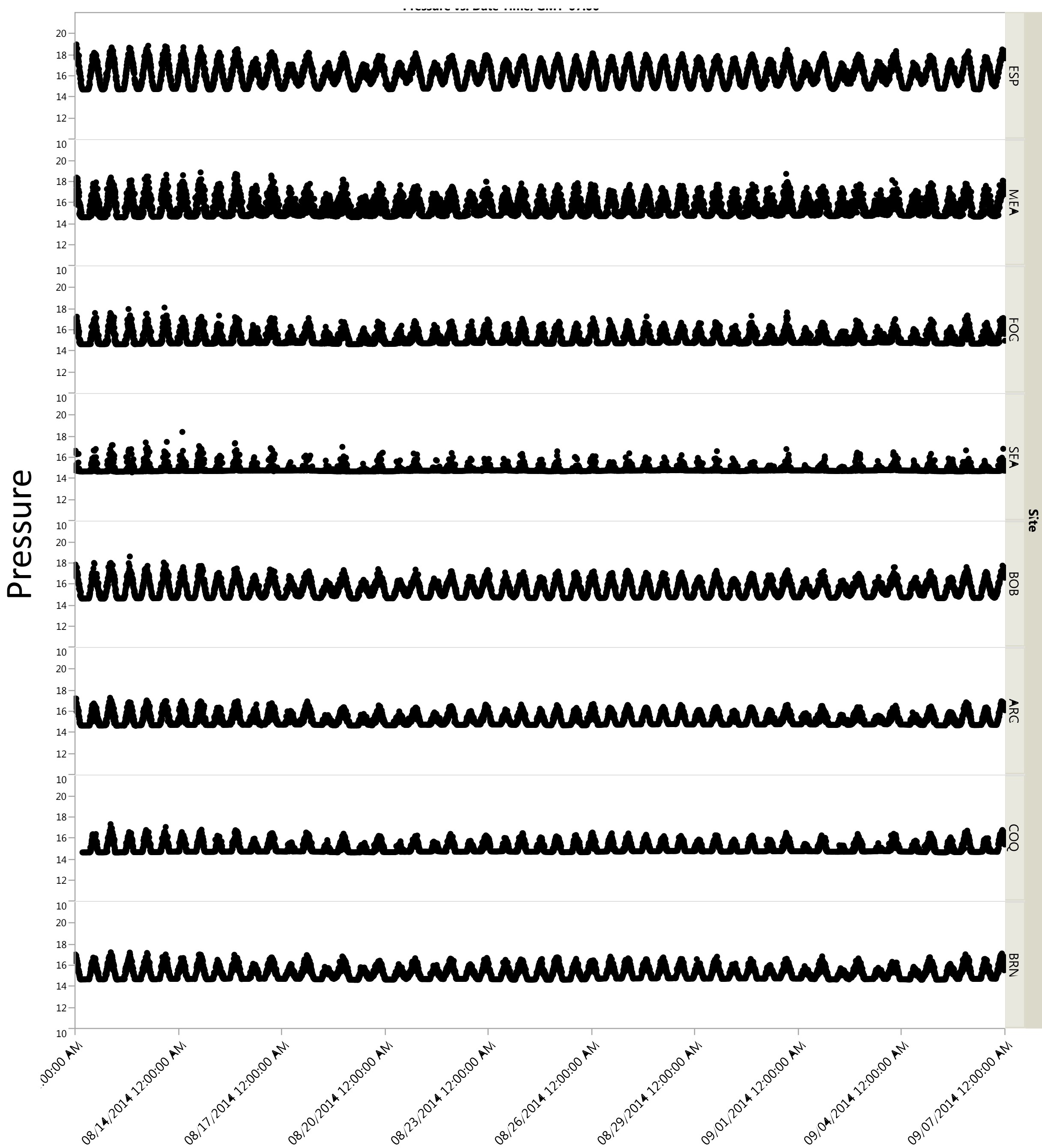


Figure 7. Pressure vs time for all sites during period of sampling overlap (sites north to south). Increased resolution shows tidal oscillation and also noise (scatter) around the tidal signal.

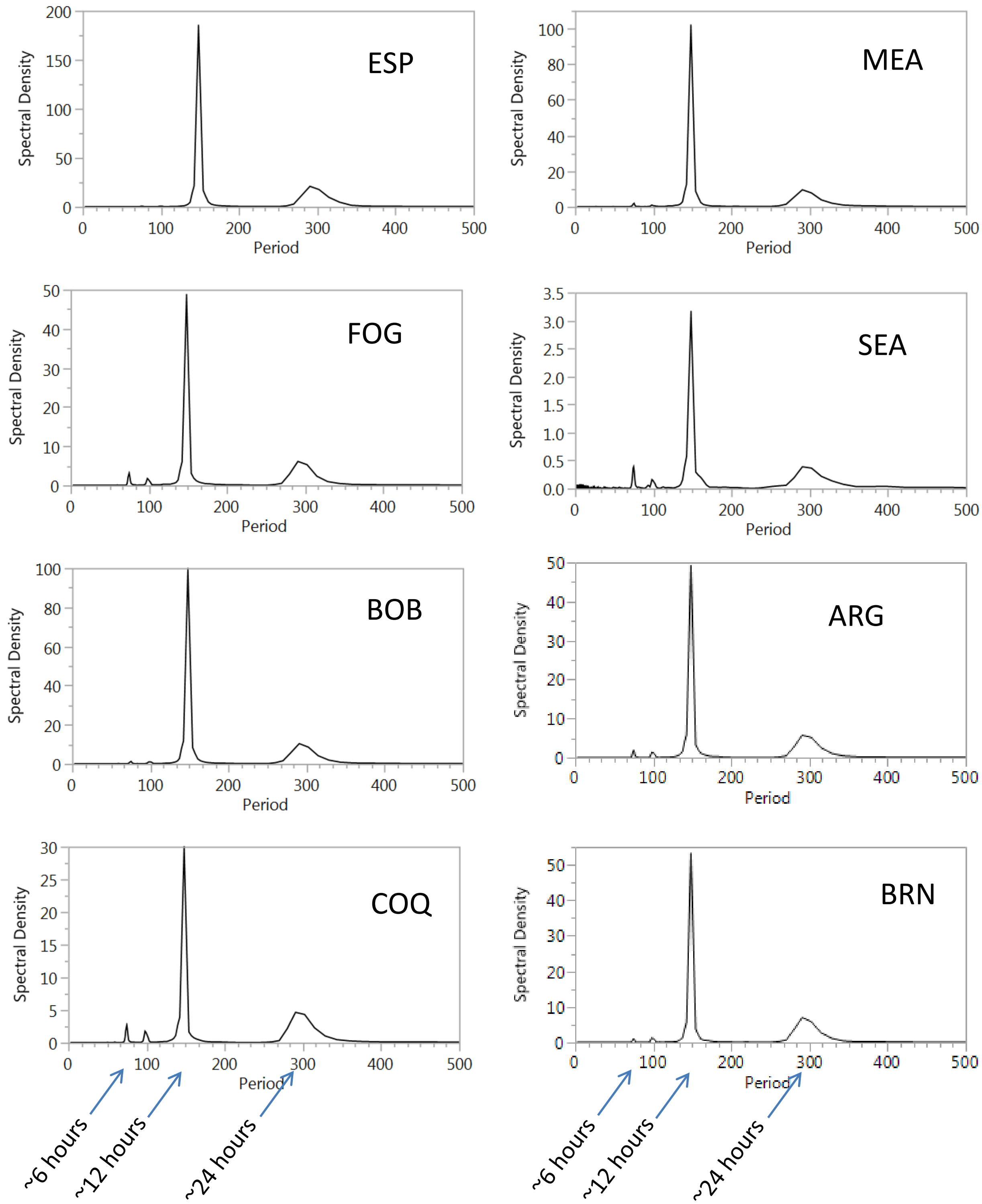


Figure 8. Spectral Decomposition (Fourier Analysis) for all sites (sites north to south). Note similarity in spectral signature for all sites

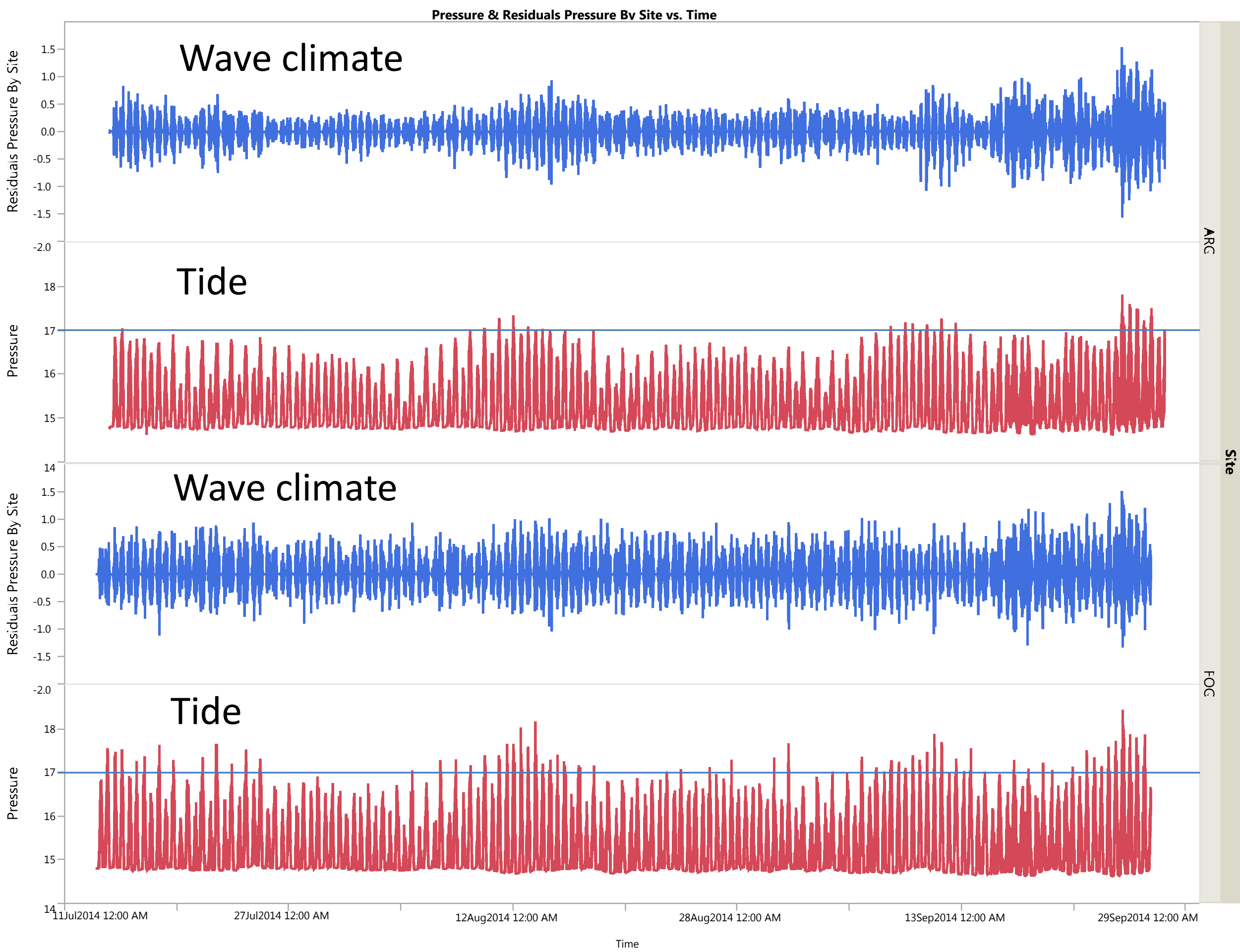
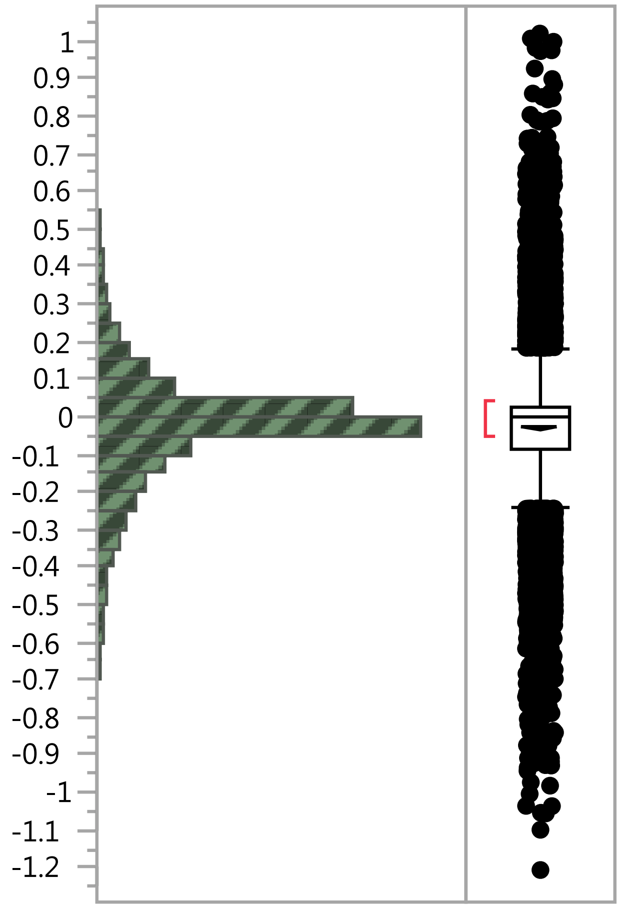


Figure 9. Tide and wave climate at Cape Arago (top) and Fogarty Creek (bottom). Red is the fitted pressure data based on decomposition of signal and isolation of cyclical tidal elements: hourly, ~6 hour, ~12 hour, ~daily and lunar (~14, 28 days). Blue is the residuals of the pressure data (actual – fitted) and is the signal of waves.



Summary Statistics	
Mean	-0.030738
Std Dev	0.1725082
Std Err Mean	0.0011791
Upper 95% Mean	-0.028427
Lower 95% Mean	-0.033049
N	21405

Test Mean	
Hypothesized Value	0
Actual Estimate	-0.0307
DF	21404
Std Dev	0.17251

	t Test
Test Statistic	-26.069
Prob > |t|	<.0001*
Prob > t	1.0000
Prob < t	<.0001*

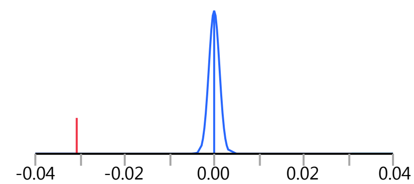


Figure 10. Left – Histogram of 21,405 paired differences in pressure between Cape Arago and Fogarty Creek. Upper Right – Summary statistics for the paired differences. Lower Right – one sample T-test on difference between Cape Arago and Fogarty Creek. Null hypothesis was that the difference was zero. In the figure in the lower right corner the red line is the actual difference and the blue probability density curve is the null distribution (Ho: difference = 0).

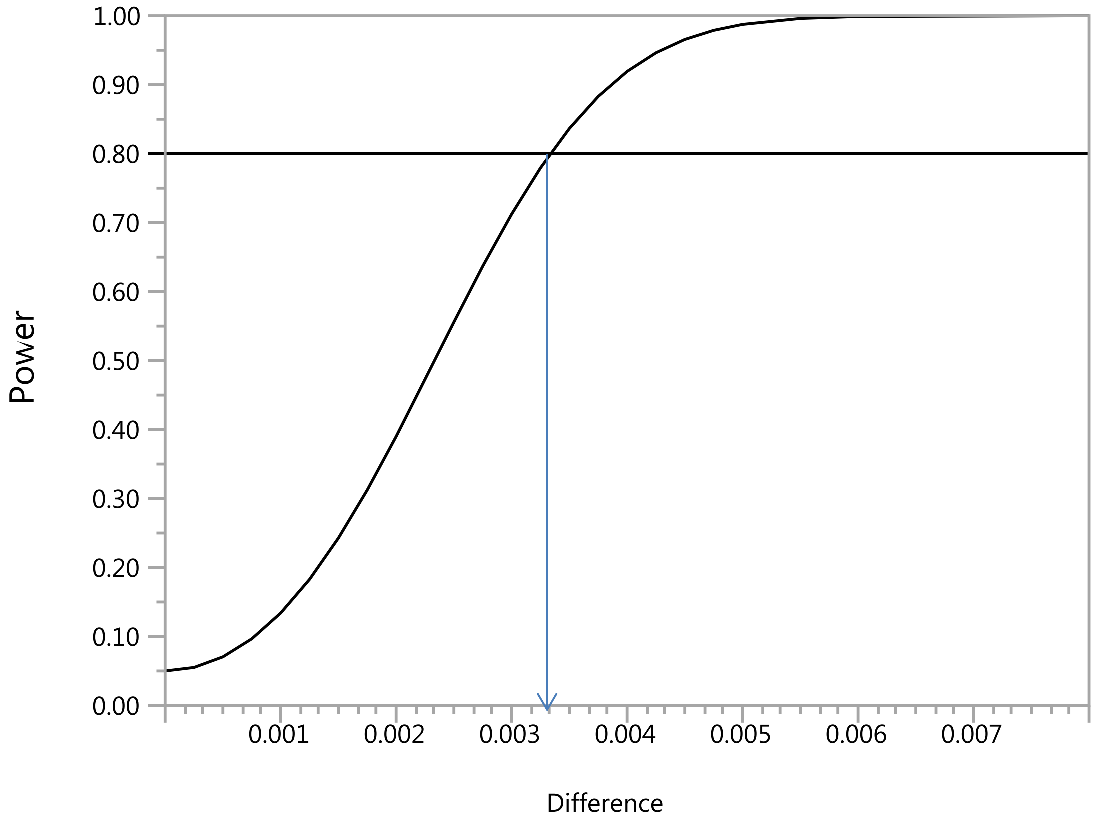


Figure 11. Power analysis. The power to detect a difference of given level (x-axis) between pre and post WECD wave climate at an impact site (e.g. at Cape Arago using Fogarty Creek as the reference site). For this simulation an alpha of 0.05 was used with a sample size of 21,405.

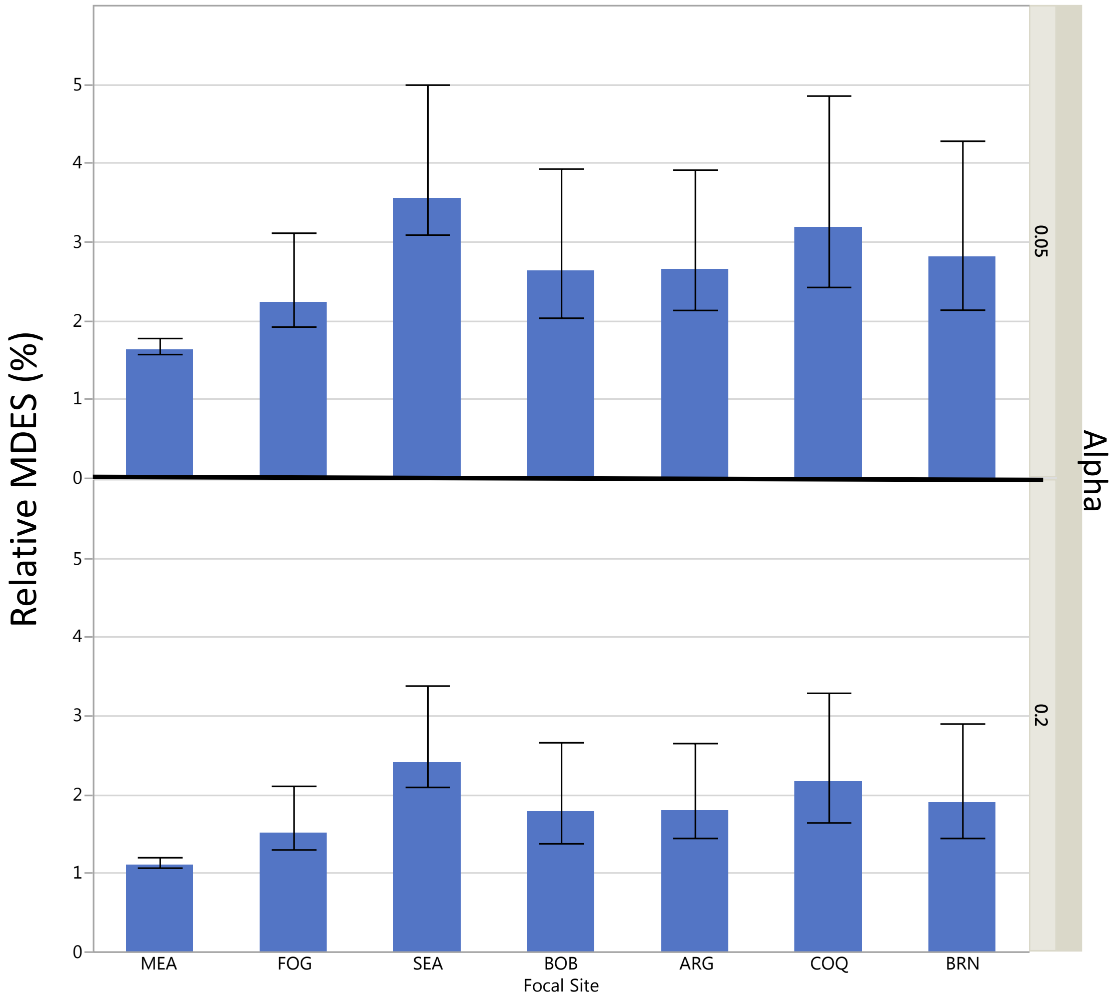


Figure 12. Results of power analysis for seven sites. ESP (Ecola State Park was left out of analysis because of insufficient temporal overlap with other sites; see Figure 6). Shown is the mean minimum detectable effect size (MDES) for power =0.80, expressed as a percentage of the wave signature (pressure attributable to waves) for each focal site. Error bars are the range in values derived from comparison to all other sites.

3.2 Assessment of wave climate – detection of shifts in vertical distribution of species

Background (from Lohse, Gaddam and Raimondi 2008)

The impacts of Wave Energy Collection Devices (WECD) on biological communities in the nearshore environment are likely to result from a) the direct effects due to the structures themselves, and b) the reduction of wave energy inshore of the devices. The direct effects of the installation, operation, and upkeep of these devices are relatively straightforward to predict. However, determining how changes in wave energy will affect nearshore communities is more problematic. Although wave energy is a continuous variable, most studies dealing with the effects of 'exposure' (a phrase that has been used to grossly describe the wave energy climate of an area) on communities have treated it as a categorical variable (Lindegarth and Gamfeldt 2005). Thus, there is limited knowledge about how biological communities vary along a gradient in wave energy (see Denny et al. 2004). Such information is needed, particularly since the relationship could be non-linear rather than linear (Lindegarth and Gamfeldt 2005; Burrows et al. 2008).

In nearshore environments species' distributions are, in part, determined by how well they can tolerate the physical conditions of a given location. For example, because of the tidal cycle, intertidal organisms spend part of their time exposed to the air and part immersed in the water. Typically, locations higher on the shore spend more time in air and less time submerged than those lower on the shore. Because species differ in their ability to tolerate this gradient, they are not distributed uniformly throughout the intertidal zone. Instead they are found in bands along the shore, a phenomenon known as vertical zonation.

Although intertidal zonation patterns are largely determined by the tidal cycle, wave exposure also plays an important role. Specifically, due to wave run-up and wave splash, incoming waves extend the upper boundary of the intertidal zone above that set by the tidal cycle. In general, the larger the wave, the greater the run-up, the higher the intertidal zone extends on the shore. Thus, the zone each species occupies tends to be both broader and located higher on the shore at wave exposed sites.

If the wave exposure of a given intertidal site were reduced, there would be less wave splash and shorter run-up. Consequently, species distributions would change to resemble that seen at more wave protected sites (see Harley and Helmuth 2003). That is, the zone occupied by each species would both shift downward and decrease in size (width). Just how much each zone would shrink would depend upon the amount of wave reduction, and the slope of the shore. Since each species occupies less total area, the number of individuals in the population would decrease. The extent of this loss can be calculated by multiplying the area lost by the average density of the species at that site.

Because the zonation of many marine species is so sharply defined and so clearly affected by immersion, the upper limit of species distribution is likely to be the most sensitive indicator of community level change due to WECD. While it is quite likely that WECD could affect the wave climate inshore from the physical array of devices, it is also likely that the effect could be quite small (Largier et al. 2008). In order to determine the level of change that could be detected we did "Vertical Distribution" (methods described below) surveys at the eight sites listed above and then carried out power analyses to determine the level of distributional shift that could reasonably be detected.

Methods

Vertical Distribution Surveys

Vertical distributions were measured for a targeted set of organisms using the Coastal Biodiversity Survey (CBS) transects already established at each site. For each species we were interested in 1) determining its upper distributional limit (i.e. how high up on the shore does this species get), and 2) identifying the upper and lower limit of its "zone" (i.e. that region of the shore where it is most common).

Out of the 11 established CBS transects at each site, 6 were selected for Vertical Distribution Surveys (VDS). The primary criterion for selection was that the transect either sloped upward or was flat in elevation gain when moving from the low to high intertidal zone. Transects that had elevation loss/downward slope, particularly in the high intertidal were not selected because species zones would be disjunct and any changes resulting from a reduction in wave energy would be difficult to interpret. For example, a transect with a downward sloping section in the upper intertidal might have a section of mussels in the mid intertidal, then barnacles, with mussels again present in the downward sloping section near the top of the transect. For each selected transect, we recorded the location of the uppermost 3 individuals of each targeted species within a 2m wide band centered on the transect. If individuals were found above the 0m mark on the transect, we recorded their locations as negative values. Individuals found in standing pools of water, or in crevices where environmental conditions may be different, were not be counted; however, epibiotic individuals were counted.

Commonness was determined using a 1m rod subdivided into ten 10cm. Starting at the 0m mark on each transect, the rod was placed onto the substrate (centered over the transect) at every meter mark (see Figure 13). In a 10cm band above this rod, we recorded the number of subdivisions in which each targeted species was present.

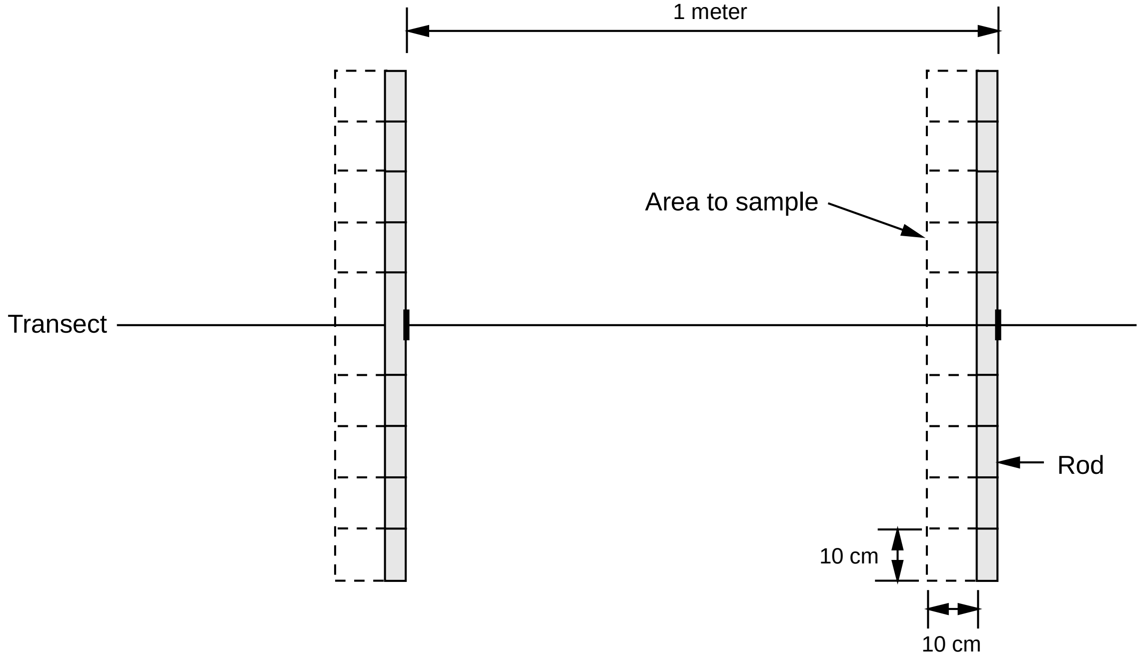


Figure 13. Sampling scheme for vertical transects

Here we evaluated 18 species for the minimum detectable effect size (MDES) for a change in vertical distribution that could be detected with a statistical power of 80%. The variance structure was derived from the variability among transect lines in the upper limit of distribution for each species. Separate analyses were done at the eight focal sites where we also had water pressure devices.

The results of the analyses are presented in Figure 14 (site and species names are in table 6). Very small changes in the upper limit (2.5 or 5%) were detectable at 80% power (alpha=0.2) for most of our core species (*Mastocarpus, Balanus, Chthamalus, Pelvetioposis, Fucus, Endocladia* and *Mytilus californianus* (except Burnt Hill)).

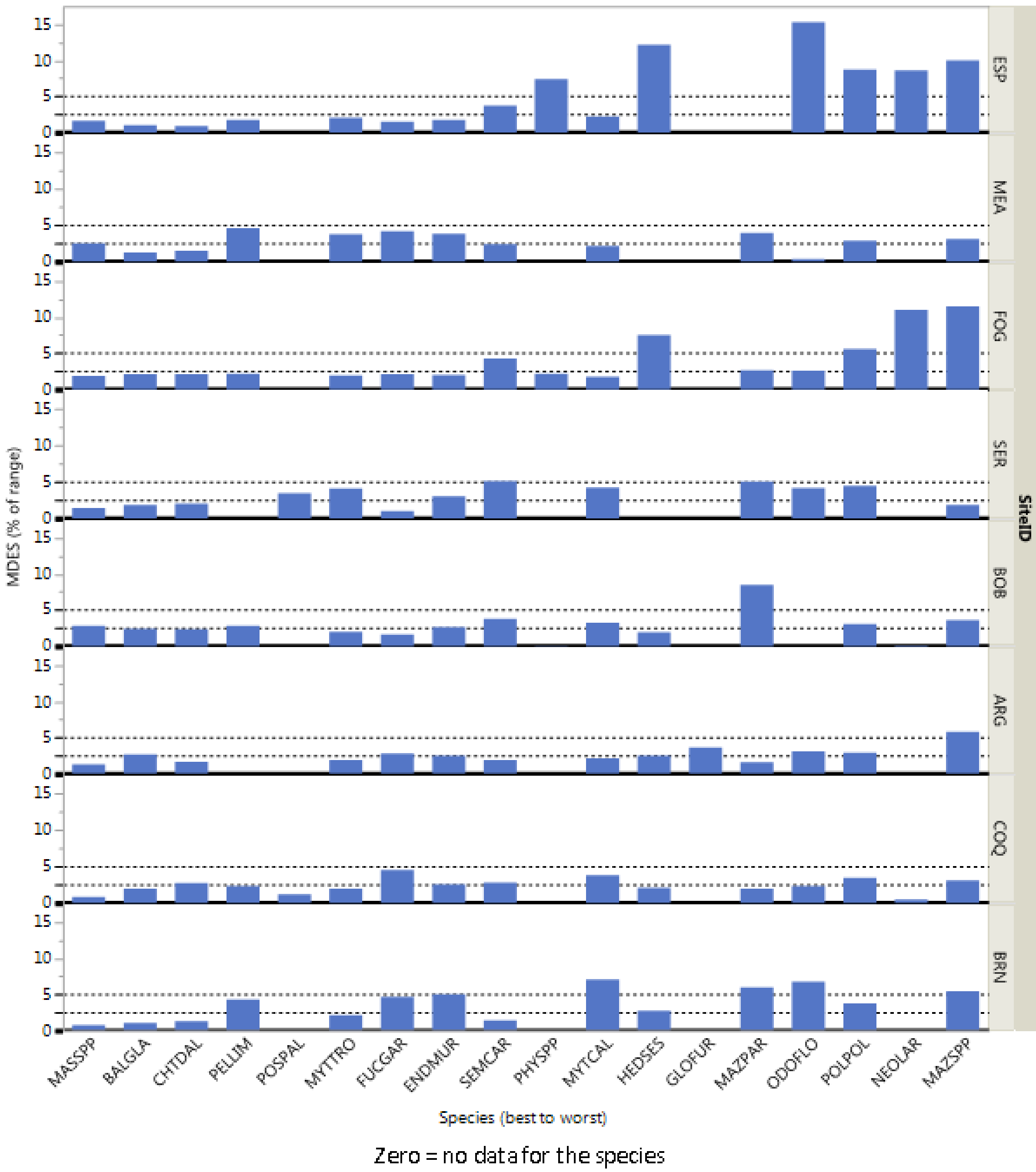


Figure 14. Minimum detectable effect size (%) for change in upper limit for 18 species at each of 8 sites. Horizontal lines are at 2.5 and 5% MDES. Lower values are better. Species are ordered from left to right with respect to ability to detect shift in upper limit. Smaller changes are detectable for those species on the left portion of the graph.

3.3 Assessment of wave climate – synthesis

The results of the wave climate and vertical distribution analyses demonstrate that small changes in wave climate and upper distributional limits of core species are likely to be detectable using the methods employed in this study. Hence, we conclude that there is high likelihood that should WECD be installed on the Oregon coast and our assessment methods utilized, even small impacts to the biological community resulting from reduction of waves will be detectable.

Table 6: Site and species names

Site ID	*Intertidal sitename*
ESP	*Ecola*
MEA	*Cape Meares*
FOG	*Fogarty Creek*
SER	*Seal Rock*
BOB	*Bob Creek*
ARG	*Cape Arago*
COQ	*Coquille Point*
BRN	*Burnt Hill*

Six Letter Code	*Name*
BALGLA	*balanus glandula*
CHTDAL	*chthamalus dalli/fissus*
ENDMUR	*endocladia muricata*
FUCGAR	*fucus gardneri*
MASSPP	*mastocarpus papillatus/jardinii*
MAZPAR	*mazzaella parksii*
MAZSPP	*mazzaella spp (=iridaea spp)*
MYTTRO	*mytilus trossulus*
MYTCAL	*mytilus californianus*
ODOFLO	*odonthalia floccosa*
PELLIM	*pelvetiopsis limitata*
POLPOL	*pollicipes polymerus*
SEMCAR	*semibalanus cariosus*
HEDSES	*hedophyllum sessile*
GLOFUR	*gloiopeltis furcata*
NEOLAR	*neorhodomela larix*
PHYSPP	*phyllospadix scouleri/torreyi*
POSPAL	*postelsia palmaeformis*

PART IV: STUDY PRODUCTS

4.1 Website and Interactive Map

Pacific Rocky Intertidal Monitoring: Trends and Synthesis

The www.pacificrockyintertidal.org website was launched in 2011, and is a comprehensive assessment of the entire MARINe region that covers species dynamics at spatial scales from tens to thousands of kilometers and temporal scales from seasons to decades. This is the most comprehensive assessment of a marine ecosystem ever done, and includes data from over 250 sites ranging from Southeast Alaska to Mexico. In addition to data summary features, the website includes details about MARINe monitoring methods, site information, data interpretation, and products resulting from the research. Importantly, all information, including changes in methods and data updates, can be incorporated rapidly to ensure that all information is accurate and current. It is anticipated that this web-based product becomes a useful tool for researchers and resources managers, as well as a go-to source of information for the general public about the coastal environment.

Interactive Map and Graphing Tool

The Interactive Map and Graphing Tool is designed to allow a customized display of the specific sites of interest on a map. In addition, customized plots can be created for specific site/species combinations.

When a specific site is selected, summary information is displayed underneath the map, with a link to the specific site page on www.pacificrockyintertidal.org. In addition, visitors can use the "polygon" feature to select a region of interest and then display the sites located within that region. Additional filter tools are also available on the Interactive Map to view the sites of specific interest to each user.

The Graphing Tool allows users to display graphs by survey type (Long-Term or Biodiversity), and by method (Percent Cover vs. Species Counts vs. Species Size for Long-Term; Point Contact vs. Quadrat vs. Swath data for Biodiversity). These dynamic graphs are a powerful way to view data for the specific site, survey and species of interest.

Broad Scale Patterns

Regional Mosaic Plots show broad patterns of abundance over space and time for the most commonly occurring target species. Abundance is depicted as a function of color (darker=more abundant).

Seastarwasting.org

Seastarwasting.org is a publically accessible website linked to pacificrockyintertidal.org, but focused specifically on the sea star wasting epidemic that has plagued sea stars at all MARINe sites coast-wide. This site provides general information about sea star wasting syndrome (SSWS), updates on recent findings related to the disease, information about how users can contribute to the sea star monitoring effort, and an interactive “tracking” map that allows users to see where SSWS is present, and which species have been affected. Since the tracking map was first released in early 2014, there have been over 10,000 unique visitors to the page.

4.2 Publications, Reports, Presentations, and Data Requests

Products include the following: upgrade of the MARINe Database; updates to the public MARINe website, (which includes current news and research); restructuring of the private website; online availability of MARINe data on the PISCO data catalog (www.piscoweb.org) and DATAOne (www.dataone.org); archival of photos and specimens; conference presentations, peer reviewed papers, posters, and reports; and organization and recording of data and info requests.

In addition, since the onset of SSWS, there have been numerous requests for sea star data by fellow researchers as well as the media. A separate MySQL database was developed to allow web entry and management of the over 2000 observations received since 2013. MARINe personnel have also participated in countless interviews (telephone and field based), news broadcasts, and documentaries regarding SSWS since 2013. Many of these articles and interviews can be found here:

http://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting/articles.html

MARINe has produced 41 papers, 44 reports, and 235 presentations over the period from 2011 to 2015. The complete list of MARINe products can be found on pacificrockyintertidal.org. Listed below is the subset of that research which has been funded by BOEM, either collected at BOEM-funded sites, published by PI's funded by BOEM or presented at a BOEM funded workshop.

Publications (2011-2015)

Beldade, R., C.A. Bell, P.T. Raimondi, M.K. George, C.M. Miner, and G. Bernardi. 2012. Isolation and characterization of 8 novel microsatellites for the black abalone, *Haliotis cracherodii*, a marine gastropod decimated by the withering disease. Conservation Genetic Resources 4:1071-1073.

Conway-Cranos L.L. 2012. Geographic variation in resilience: an experimental evaluation of four rocky intertidal assemblages Marine Ecology Progress Series 457:67-83.

Dawson M, C Hays, R Grosberg and P Raimondi. 2014. Dispersal potential and population genetic structure of synchronously diverging co-distributed marine intertidal taxa. Ecological Monographs 84:435–456

Fenberg PB, BA. Menge, PT. Raimondi, and MM Rivadeneira. 2015. Biogeographic structure of the northeastern Pacific rocky intertidal: The role of upwelling and dispersal to drive patterns. Ecography 37: 001–013

Fenberg, P.B. and M.M. Rivadeneira. 2011. Range limits and geographic patterns of abundance of the rocky intertidal owl limpet, *Lottia gigantea*. Journal of Biogeography 38:2286-2298.

Goddard, J.H.R., M.C. Schaefer, C. Hoover, and A. Valdes. 2013. Regional extinction of a conspicuous dorid nudibranch (Mollusca: Gastropoda) in California. Marine Biology160:1497-1510.

Hewson, I., J.B. Button, B.M. Gudenkauf, B.G. Miner, A.L. Newton, J.K. Gaydos, J. Wynne, C.L. Groves, G. Hendler, M. Murray, S. Fradkin, M. Breitbart, E. Fahsbender, K.D. Lafferty, A.M. Kilpatrick, C.M. Miner, P. Raimondi, L. Lahner, C.S. Friedman, S. Daniels, M. Haulena, J. Marliave, C.A.

Burge, M.E. Eisenlord, and C.D. Harvell (2014). Densovirus associated with sea-star wasting disease and mass mortality. Proceedings of the National Academy of Sciences 111:17278-17283.

Huff, T.M. 2011. Effects of human trampling on macro- and meiofauna communities associated with intertidal algal turfs and implications for management of protected areas on rocky shores (Southern California). Marine Ecology 32:335-345.

Jurgens LJ, L Rogers-Bennett, PT Raimondi, LM Schiebelhut, MN Dawson, RK Grosberg, B Gaylord. Patterns of mass mortality among rocky shore invertebrates across 100 km of northeastern Pacific coastline. In Press, PLOS One

Mislan, K., C. Blanchette, B. Broitman and L. Washburn. 2011. Spatial variability of emergence, splash, surge and submergence in wave-exposed rocky-shore ecosystems. Limnology and Oceanography 56:857-866.

Murray, S.N., S.B. Weisberg, P.T. Raimondi, R.F. Ambrose, C.A. Bell, C.A. Blanchette, J.L. Burnaford, M.N. Dethier, J.M. Engle, M.S. Foster, C.M. Miner, K.J. Nielsen, J.S. Pearse, D.V. Richards,, J.R. Smith (2015). Evaluating Ecological States of West Coast Rocky Intertidal Communities: A Best Professional Judgment Exercise. Ecological Indicators.

Raimondi, PT, Jurgens LT, and MT Tinker. : Evaluating potential conservation conflicts between two listed species: sea otters and black abalone. In Press Ecology

Rivadeneira MM, AH Alballay, JA Villafaña, PT Raimondi, CA Blanchette, PB Fenberg. Geographic Patterns of Diversification and the Latitudinal Gradient of Richness of Rocky Intertidal Gastropods: The 'Into the Tropical Museum' Hypothesis. In Press: Global Ecology and Biogeography

Watson, J., C. Hays, P. Raimondi, S. Mitarai, C. Dong, J. McWilliams, C. Blanchette and D. Siegel. 2011. Currents connecting communities: nearshore community similarity and ocean circulation. Ecology 92:1193-1200.

Woodson, C. B., M. A. McManus, J. A. Tyburczy, J. A. Barth, L. Washburn, J. E. Caselle, M. H. Carr, D. P. Malone, P. T. Raimondi, B. A. Menge, and S. R. Palumbi. 2012. Coastal fronts set recruitment and connectivity patterns across multiple taxa. Limnology and Oceanography 57:582-596.

Reports (2011-2015)

Ammann, K. N. 2012. Monitoring of rocky intertidal communities of Redwood National and State Parks, California: 2009 annual report. Natural Resource Technical Report NPS/KLMN/NRTR— 2012/521. National Park Service, Fort Collins, Colorado.

Ammann, K.N., P.T. Raimondi and D. Lohse. 2011. Monitoring of rocky intertidal communities of Redwood National and State Parks, California: 2008 annual report. Natural Resource Technical Report NPS/KLMN/NRTR—2011/434. National Park Service, Fort Collins, Colorado.

Blanchette, C., P. Raimondi, R. Gaddam, J. Burnaford, J. Smith, D.M. Hubbard, J.E. Dugan, J. Altstatt, and J. Bursek. 2015. Baseline Characterization of the Rocky Intertidal Ecosystems of the South Coast Study Region: a report prepared for Sea Grant. 111 pages.

Gaddam, R.N., C.M. Miner, and P.T. Raimondi. 2012. Pacific Rocky Intertidal Monitoring: Trends and Synthesis. 2012. BOEM OCS Study 2012-014. Center for Ocean Health, Long Marine Laboratory, University of California, Santa Cruz, California. BOEM Cooperative Agreement Number M10AC20000. 35 pages (plus appendix).

Miller, K.A. 2012. Summary of nomenclatural and taxonomic changes for California seaweeds. University of California, Berkeley Herbarium.

Ocean Science Trust and California Department of Fish and Wildlife. 2013. State of the California Central Coast: results of from baseline monitoring of Marine Protected Areas 2007-2012. Sacramento, CA.

Raimondi P, D Orr, N Fletcher, M Redfield, D Lohse, M Miner, M George. R Gaddam, J Engle, S Lee, S Whitaker. 2012. Estimation of population size of the black abalone, Haliotis cracherodii, on San Clemente Island. Report to NMFS and US NAVY. 20 pages.

Raimondi P, K Schiff, D. Gregorio. 2012. Characterization of the rocky intertidal ecological communities associated with southern California Areas of Special Biological Significance. SCCWRP Technical Report. 80 pages

Raimondi P, M Miner, D Orr, C Bell, M George, S Worden, M Redfield, R Gaddam, L Anderson, D Lohse. 2011. Determination of the extent and type of injury to rocky intertidal algae and animals during and after the initial spill (Dubai Star): a report prepared for California Department of Fish and Game Office of Spill Prevention and Response (DFG-OSPR). 22 pages

Raimondi, P.; C. Bell, M. George, M. Redfield, K. Ammann, D. Orr, N. Fletcher and S. Worden. 2012. Estimation of the amount of suitable habitat and population size of black abalone in the North-Central coastal region of California (Año Nuevo – Point Arena) (a report prepared for NMFS -will be completed by May 2012)

Raimondi, P.; M. Miner, D. Orr, C. Bell, M. George, M. Redfield, N. Fletcher and D. Lohse. 2011. Estimation of population size of the black abalone, *Haliotis cracherodii*, on San Clemente Island (report to the NAVY. July 2011).

Raimondi, PT, M George, M Redfield, S Worden, R Williams, N Fletcher, L Anderson, D Lohse, R Gaddam. 2015. Characterization of the Rocky Intertidal Ecological Communities Associated with Northern Southern California Areas of Special Biological Significance. 33 p

Raimondi, PT. 2014. Characterization of the Rocky Intertidal Ecological Communities Associated with Southern California Areas of Special Biological Significance: Phase II

Smith, J.R., S.C. Vogt, and F.N. Creedon. 2011. Biological assessment of three rocky intertidal sites in San Diego. Report prepared for Weston Solutions, Inc. 56p.

Tierra Data, Inc. 2011. San Clemente Island rocky intertidal monitoring surveys. Naval Facilities Engineering Command Southwest, Coastal IPT (contract N68711-05-D-8004/Task Order 0058).

Presentations (2011-2015)

Agler, S.T. and J.R. Smith. 2014. Population declines in Orange County, CA of the rocky intertidal Ochre Sea Star Pisaster ochraceus from wasting disease. Cal Poly Pomona Science Symposium, Pomona, CA.

Altstatt, J. 2012. Updating BOEM intertidal site maps. MARINe Annual Workshop, Santa Cruz, CA.

Ambrose, R. 2013. Summary of Citizen Scientist Session. MARINe Annual Workshop, Forks, WA.

Ambrose, R. 2014. Use of drones for intertidal mapping. MARINe Annual Workshop, Newport Beach, CA.

Ambrose, R. and T. Yap. 2012. Panorama photo evaluation. MARINe Annual Workshop, Santa Cruz, CA.

Ammann, K. and D. Lohse. 2011. Monitoring species range shifts: potential implications of global climate change. MARINe Annual Workshop, Santa Barbara, CA.

Ammann, K., L. Anderson, C.M. Miner, M. Moritsch, C. Bell, and P. Raimondi. 2015. Intertidal research at UCSC, including sea star wasting syndrome. Seymour Marine Discovery Center docent training class. Santa Cruz, CA.

Ammann, K., M. George, C. Bell, N. Fletcher, and P. Raimondi. 2014. Long-term monitoring program detects sea star wasting syndrome in the Monterey Bay National Marine Sanctuary. Poster at the Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

Ammann, K., M. Miner, and M. George. 2015. Documenting the impacts of sea star wasting syndrome. Presentation to Monterey Bay National Marine Research Activity Panel. CSU Monterey Bay, Seaside, CA.

Ammann, K., N. Fletcher, M. George, M. Redfield, C. Bell. 2014. Documenting the impacts of sea star wasting syndrome through long-term surveys in the Monterey Bay National Marine Sanctuary. Monterey National Marine Sanctuary Symposium, Monterey, CA.

Ammann, K.N., P.T. Raimondi, C.M. Miner, C.A. Bell, and M.K. George. 2013. Two decades of monitoring the owl limpet (Lottia gigantea) along the Central Coast. Presentation and Poster at the State of the Central Coast MPA Symposium. Monterey, CA.

Ammann, K.N., P.T. Raimondi, C.M. Miner, C.A. Bell, and M.K. George. 2013. Two decades of monitoring the owl limpet (Lottia gigantea) along the Central Coast. Poster at the Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

Ammann. K and L. Gilbane. 2012. Monitoring intertidal temperature. MARINe Annual Workshop, Santa Cruz, CA.

Ammann. K. 2012. Range shifts species identification. MARINe Annual Workshop, Santa Cruz, CA.

Anderson, L., C.M. Miner, M. Moritsch, C. Bell, and P. Raimondi. 2014. Intertidal research at UCSC, including sea star wasting syndrome. Seymour Marine Discovery Center docent training class. Santa Cruz, CA.

Anderson, L., C.M. Miner, M. Moritsch, R. Gaddam, and P. Raimondi. 2014. Intertidal monitoring: tracking the progression of sea star wasting syndrome. California State University Monterey Bay seminar. Monterey, CA.

Anderson, L., C.M. Miner, R. Gaddam, and P. Raimondi. 2014. Sea star wasting syndrome: Detecting and tracking the progression. Poster at Point Lobos State Natural Reserve Underwater Parks Day. Carmel, CA.

Anderson, L., M. Miner, M. Moritsch, R. Gaddam, and P. T. Raimondi. 2014. The progression of sea star wasting syndrome: an update for the Monterey Bay National Marine Sanctuary Advisory Council Santa Cruz Police Department, Santa Cruz, CA.

Anderson, L., M. Miner, M. Moritsch, R. Gaddam, and P.T. Raimondi. 2014. Monitoring sea star wasting syndrome in the intertidal zone. Rocky Shores Training for Oregon Parks. Yaquina Head Interpretive Center, Newport, OR.

Anderson, L., R. Gaddam, and P. Raimondi. 2014. Pacific rocky intertidal monitoring. Poster at Point Lobos State Natural Reserve Underwater Parks Day. Carmel, CA.

Anderson, L., R. Williams, M. Redfield, R. Gaddam, M. Miner, M. Frenock, and P. Raimondi. 2014. Tracking sea star wasting syndrome: a collaborative effort by researchers and citizen scientists. Poster at the Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

Anderson, L.A, M.Frenock, R.N. Gaddam, C.M. Miner, P.T. Raimondi, M. Redfield, and R. Williams. 2014. Tracking Sea Star Wasting Syndrome: A Collaborative Effort by Researchers and Citizen Scientists. Monterey Bay National Marine Sanctuary Currents Symposium, Monterey, CA.

Anderson, M. 2011. Dubai Star oil spill & the mobilization of MARINe. MARINe Annual Workshop, Santa Barbara, CA.

Bell, C. 2015. Photoplot Layering Protocol. MARINe Annual Workshop. Moss Landing Marine Lab, CA.

Bell, C., D. Orr and P. Raimondi.2013. Why rocky intertidal monitoring matters? The Sea Ranch Association Task Force meeting. The Sea Ranch, Gualala, CA.

Bell, C., K. Ammann, M. George and P. Raimondi. 2011. Assessing suitable habitat and the population size of black abalone (Haliotis cracherodii) for critical habitat designation. Beyond the Golden Gate Research Symposium, San Francisco, CA.

Bell, C., K. Ammann, N. Fletcher, M. George, D. Lohse, M. Miner, D. Orr, P. Raimondi and M. Redfield. 2012. Black abalone habitat surveys and the restoration of intertidal recruitment habitat on San Clemente Island – A pilot study to aid in the species recovery. The Western Section of the Wildlife Society 2012 Annual Conference. Sacramento, CA.

Bell, C.A., K.N. Ammann, M.K. George, and P.T. Raimondi. 2013. Assessing suitable habitat and the population size of black abalone (Haliotis cracherodii) for critical habitat designation. Poster at Discover the Natural Reserve System: a conference celebrating the UCSB NRS. Santa Barbara, CA.

Bell, C.A., M.K. George, C.M. Miner, and P.T. Raimondi. 2013. Black abalone (Haliotis cracherodii) surveys on the Central Coast - an overview of 20 years of monitoring data. Presentation and Poster at the State of the Central Coast MPA Symposium. Monterey, CA.

Blanchette, C. 2011. Drafting a Climate Change protocol. MARINe Annual Workshop, Santa Barbara, CA.

Blanchette, C. 2011. Southern California low intertidal invertebrates. MARINe Annual Workshop, Santa Barbara, CA.

Burnaford, J.L. 2015. Invertebrate Voucher Protocol. MARINe Annual Workshop. Moss Landing Marine Lab, CA.

Carr, M. 2012. Applications of monitoring kelp forest ecosystems. MARINe Annual Workshop, Santa Cruz, CA.

Degrassi, A. And J. Smith. 2011. Potential drivers of macroalgal preferences in southern California marine consumers. Southern California Academy of Sciences Annual Meeting, Pomona, CA.

deNesnera, K., L. Anderson, and P. Raimondi. 2012. Exploring mussel bed restoration strategies on Vandenberg Air Force Base. The Western Section of the Wildlife Society 2012 Annual Conference. Sacramento, CA.

deNesnera, K., L. Anderson, and P. Raimondi. 2012. Mussel restoration strategies. MARINe Annual Workshop, Santa Cruz, CA.

deNesnera, K.L.. and Anderson, L.M. 2011. Mussel transplantation as a strategy for restoration of injured mussel beds. Western Society of Naturalists Meeting. Vancouver, WA.

Denny, M. 2011. Worst-case scenarios: predicting extreme ecological events. MARINe Annual Workshop, Santa Barbara, CA.

Engle, J. 2011. Multi-Agency Rocky Intertidal Network status. MARINe Annual Workshop, Santa Barbara, CA.

Engle, J. 2012. Intertidal species master spreadsheet. MARINe Annual Workshop, Santa Cruz, CA.

Engle, J. 2012. Multi-Agency Rocky Intertidal Network status. MARINe Annual Workshop, Santa Cruz, CA.

Engle, J. 2013. Multi-Agency Rocky Intertidal Network status. MARINe Annual Workshop, Forks, WA.

Engle, J. 2014. Multi-Agency Rocky Intertidal Network status. MARINe Annual Workshop, Newport Beach, CA.

Engle, J. and C. Bell. 2012. Mussel measurement protocol. MARINe Annual Workshop, Santa Cruz, CA.

Fletcher, N. K. Ammann, P. Raimondi, C. Bell, and M. George. 2014. Long-term monitoring program detects sea star wasting syndrome in the Monterey Bay National Marine Sanctuary. Poster at the Marine Annual Oceans Colloquium, Moss Landing, CA.

Fletcher, N., M. Redfield, D. Orr, and P. Raimondi. 2011. Long-term rocky intertidal monitoring informs design of Marine Protected Areas for the North Central Coast study region. Beyond the Golden Gate Research Symposium, San Francisco, CA.

Fong, D., M. Anderson & I. Oshima. 2012. San Francisco Bay intertidal monitoring. MARINe Annual Workshop, Santa Cruz, CA.

Gaddam, R. 2013. Updates on MARINe website Pacificrockyintertidal.org. MARINe Annual Workshop, Forks, WA.

Gaddam, R. and K. Ammann. 2014. Pacific Rocky Intertidal Monitoring. Monterey Bay Aquarium World Oceans Day. Monterey, CA.

Gaddam, R. and M. Miner. 2012. MARINe web report and data trends. MARINe Annual Workshop, Santa Cruz, CA.

Gaddam, R. and M. Miner. 2014. MARINe database update. MARINe Annual Workshop, Newport Beach, CA.

Gaddam, R. and M. Miner. 2015. Database Updates, Needs and Goals. MARINe Annual Workshop. Moss Landing Marine Lab, CA.

Gaddam, R., K. Ammann, C. Bell, N. Fletcher, M. George, M. Miner, M. Redfield, and R. Williams. 2015. Citizen science enhances the ability of long-term monitoring to track sea star wasting syndrome. Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

Gaddam, R., M. Miner, and P. Raimondi. 2013. Pacific rocky intertidal monitoring: trends and synthesis along the Central Coast and beyond. State of the Central Coast MPA Symposium. Monterey, CA.

Gaddam, R., M. Miner, and P. Raimondi. 2013. Pacific rocky intertidal monitoring: trends and synthesis. Poster at the Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

George, M., K. Ammann, C. Bell, N. Fletcher, M. Redfield and R. Williams. 2015. Documenting the impacts of sea star wasting syndrome through long-term surveys in the Monterey Bay National Marine Sanctuary. Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

Gilbane, L. 2011. Drafting a protocol for data archival. MARINe Annual Workshop, Santa Barbara, CA.

Gilbane, L. 2012. Synopsis of Workshop Science Meeting. MARINe Annual Workshop, Santa Cruz, CA.

Gilbane, L. 2013. Voucher specimen projects. MARINe Annual Workshop, Forks, WA.

Graham, S. 2012. San Clemente Island intertidal monitoring. MARINe Annual Workshop, Santa Cruz, CA.

Helix, M.E. 2011. Drafting Outreach articles for magazines. MARINe Annual Workshop, Santa Barbara, CA.

Helix, M.E. 2011. Overview of Multi-Agency Rocky Intertidal Network. MARINe Annual Workshop, Santa Barbara, CA.

Helix, M.E. 2012. Overview of Multi-Agency Rocky Intertidal Network. MARINe Annual Workshop, Santa Cruz, CA.

Helix, M.E. 2013. Overview of Multi-Agency Rocky Intertidal Network. MARINe Annual Workshop, Forks, WA.

Johnston, K. 2012. Santa Monica Bay Monitoring. MARINe Annual Workshop, Santa Cruz, CA.

Kenner, M. 2012. San Nicolas Island intertidal monitoring program. MARINe Annual Workshop, Santa Cruz, CA.

Kusic-Heady, K. 2012. Patterns from biodiversity data. MARINe Annual Workshop, Santa Cruz, CA.

Lee, L. 2013. Summary of database session. MARINe Annual Workshop. Forks, WA.

Lee, S. 2011. Sampling surfgrass (*Phyllospadix* spp.) transects. MARINe Annual Workshop, Santa Barbara, CA.

Lohse, D. 2012. Monitoring intertidal species vertical distributions. MARINe Annual Workshop, Santa Cruz, CA.

Lohse, D. 2012. Surveys for climate change and invasive species. MARINe Annual Workshop, Santa Cruz, CA.

Lohse, D. 2013. Monitoring vertical distribution of intertidal species: lessons for detecting global climate change. State of the Central Coast MPA Symposium. Monterey, CA.

Lohse, D. 2014. Vertical distribution survey group meeting. MARINe Annual Workshop, Newport Beach, CA.

Lohse, D. and C. Bell. 2012. Barnacle plot close-up photographs. MARINe Annual Workshop, Santa Cruz, CA.

Lohse, D. and K. Ammann. 2012. Monitoring intertidal species range shifts. MARINe Annual Workshop, Santa Cruz, CA.

Mazzone, S. 2012. Quinault Nation intertidal monitoring in Washington. MARINe Annual Workshop, Santa Cruz, CA.

Miller. K.A. 2012. Intertidal seaweed voucher protocol. MARINe Annual Workshop, Santa Cruz, CA.

Miner, B., M. Miner, I. Hewson, D. Harvell, and P. Raimondi. 2014 Wasting syndrome in sea stars along the west coast of North America. Salish Sea Ecosystem Conference. Seattle, WA.

Miner, C.M. 2013. Sea star wasting syndrome: detecting, tracking and following the progression. Edmonds Underwater Park Volunteer Divers. Edmonds, WA.

Miner, C.M. 2013. Sea star wasting syndrome: detecting, tracking and following the progression. Webinar presentation to Local Environmental Observer Network. AK.

Miner, C.M. 2014. Documenting the Impacts of Sea Star Wasting Syndrome through Long Term Surveys and Citizen Science Monitoring. Island County Beach Watchers, Camano Island, WA.

Miner, C.M. 2014. Sea star wasting syndrome. MARINe Annual Workshop, Newport Beach, CA.

Miner, C.M. 2014. Sea Star Wasting Syndrome: Citizen Science Effort. Sea Star Wasting Syndrome: Status of the Science and Identification of response Actions. A 2-Day Workshop on Sea Star Wasting Syndrome along the West Coast. Hatfield Marine Science Center, Newport, OR.

Miner, C.M. 2014. Sea Star Wasting Syndrome: detecting, tracking and following the progression. Presentation to Haystack Rock Awareness Program, City Hall, Cannon Beach, OR.

Miner, C.M. 2014. Sea Star Wasting Syndrome: detecting, tracking and following the progression. Hatfield Marine Science Center, Newport, OR.

Miner, C.M. 2014. Sea Star Wasting Syndrome: detecting, tracking and following the progression. Padilla Bay National Estuarine Research Reserve, Mount Vernon, WA.

Miner, C.M. 2014. Sea star wasting syndrome: detecting, tracking and following the progression. ReSources for Sustainable Communities. Bellingham, WA.

Miner, C.M. 2014. Sea star wasting syndrome: detecting, tracking and following the progression. Port Townsend Marine Science Center. Port Townsend, WA.

Miner, C.M. 2014. Sea Star Wasting Syndrome: Long-term Surveys, Disease Studies, and Citizen Science Effort. Sound Living 4th Annual "Communiversity", Everett Community College, WA.

Miner, C.M. 2014. Sea Star Wasting Syndrome: Long-term Surveys, Disease Studies, and Citizen Science Effort. Feiro Marine Life Center, Port Angeles, WA.

Miner, C.M. 2014. Sea Star Wasting Syndrome: Long-term Surveys, Disease Studies, and Citizen Science Effort. Northwest Aquatic and Marine Educators, 39th Annual Conference. Bandon, OR.

Miner, C.M. 2014. Sea Star Wasting Syndrome: Long-term Surveys, Disease Studies, and Citizen Science Effort. ReSources public presentation. Bellingham, WA.

Miner, C.M. 2014. Sea Star Wasting Syndrome: Long-term Surveys, Disease Studies, and Citizen Science Effort. Presentation to Oregon Coast Watch. Bandon, OR.

Miner, C.M. 2015. Documenting the Impacts of Sea Star Wasting Syndrome through Long Term Surveys and Citizen Science Monitoring. Storming the Sound, La Conner, WA.

Miner, C.M. 2015. Documenting the Impacts of Sea Star Wasting Syndrome through Long Term Surveys and Citizen Science Monitoring. Olympic National Park, Port Angeles, WA

Miner, C.M. and R. Gaddam. 2014. MARINe database group meeting. MARINe Annual Workshop, Newport Beach, CA.

Miner, C.M., MARINe. 2014. Documenting the Impacts of Sea Star Wasting Syndrome through Long Term Surveys and Citizen Science Monitoring. Western Society of Naturalists, Tacoma, WA.

Miner, M. 2012. Intertidal species reconnaissance protocol. MARINe Annual Workshop, Santa Cruz, CA.

Miner, M. 2013. Monitoring for Potential Impacts of Wave Energy Collection Devices. MARINe Annual Workshop, Forks, WA.

Miner, M. 2015. Wasted Stars: A brief overview of what we've learned. MARINe Annual Workshop. Moss Landing Marine Lab, CA.

Miner, M. and R. Gaddam. 2012. MARINe web report trend graphs. MARINe Annual Workshop, Santa Cruz, CA.

Moritsch, M, C.M. Miner, R. Gaddam, and P. Raimondi. 2013. Sea star wasting syndrome: detecting, tracking and following the progression. Western Society of Naturalists Meeting. Oxnard, CA.

Moritsch, M. 2015. Sea star wasting syndrome models. MARINe Annual Workshop. Moss Landing Marine Lab, CA.

Moritsch, M., J. Maynard, D. Harvell, M. Miner, R. Gaddam, and P. Raimondi. 2014. Identifying environmental and anthropogenic factors associated with sea star wasting disease through large-scale geospatial analysis. Poster at the Monterey Bay National Marine Sanctuary Currents Symposium. Seaside, CA.

Murray, S. 2014. Level of expert agreement achieved in a BPJ exercise on rocky shores. MARINe Annual Workshop, Newport Beach, CA.

Murray, S., R.F. Ambrose, J. Engle, P. Raimondi and S. Weisberg. 2011. Developing indicators for monitoring the status of rocky shores. MARINe Annual Workshop, Santa Barbara, CA.

Neuman, M., D. Witting, S. Wang and G. VanBlaricom. 2011. Endangered species status of black abalone (*Haliotis cracherodii* Leach, 1814): ESA listing process and demographic signs of small-scale recovery in an isolated location. MARINe Annual Workshop, Santa Barbara, CA.

Orr, D., C. Bell. D. Lohse, and P. Raimondi. 2011. Why long-term rocky intertidal monitoring matters? Beyond the Golden Gate Research Symposium, San Francisco, CA.

Orr, D., M. Redfield, C. Bell N. Fletcher and P. Raimondi. 2011. How rocky intertidal monitoring in the Monterey Bay National Marine Sanctuary informs Natural Resource Damage Assessments: A case study of the Cosco Busan oil spill. Monterey Bay National Marine Sanctuary Currents Symposium, Monterey, CA.

Pister, B. and T. Philippi. 2011. 20 Years of rocky intertidal monitoring at Cabrillo National Monument: analysis of long-term trends. MARINe Annual Workshop, Santa Barbara, CA.

Raimondi, P. 2011. How MARINe and Go-Kit data informed assessment of the Cosco Busan spill. MARINe Annual Workshop, Santa Barbara, CA.

Raimondi, P. 2012. Black abalone and sea otters. MARINe Annual Workshop, Santa Cruz, CA.

Raimondi, P. 2013. Development of Indicator Species for a Citizen Scientist Protocol. MARINe Annual Workshop. Forks, WA.

Raimondi, P. 2014. The progression of SSWS in CA, OR, and WA. SSWD workshop at the Hatfield Marine Science Center in Newport, OR.

Raimondi, P. and C. Bell. 2012. MARINe black abalone data trends. MARINe Annual Workshop, Santa Cruz, CA.

Raimondi, P.T. 2013. Characterization of and initial changes in intertidal communities in MPA's along the Central California coastline. State of the Central Coast MPA Symposium. Monterey, CA.

Raimondi, P.T., M. Miner, L. Anderson, C. Bell, R. Gaddam, and D. Lohse. 2013: BOEM briefing and Go-Kit demonstration. Camarillo, CA.

Redfield, M. 2011. Marine Protected Areas Monitoring. MARINe Annual Workshop, Santa Barbara, CA.

Redfield, M., L. Anderson, M. Frenock, R. Gaddam, M. Miner, P. Raimondi and R. Williams. 2014. Tracking sea star wasting syndrome: a collaborative effort by researchers and citizen scientists. Poster at the Monterey Bay National Marine Sanctuary Currents Symposium, Seaside, CA.

Redfield, M., N. Fletcher, C.M. Miner, R. Gaddam, and P. Raimondi. 2015. Sea star wasting syndrome: Detecting and tracking the progression. Poster at Point Lobos State Natural Reserve Underwater Parks Day. Carmel, CA.

Smith, J. 2012. Updating Orange County intertidal site maps. MARINe Annual Workshop, Santa Cruz, CA.

Smith, J. 2012. Water Quality Monitoring Council intertidal web portal. MARINe Annual Workshop, Santa Cruz, CA.

Smith, J., S. Vogt, K.A. Miller, S. Lee and J. Engle. 2011. Conspicuous low intertidal macrophytes. MARINe Annual Workshop, Santa Barbara, CA.

Smith, J.R. and J.L. Burnaford. 2013. MARINe goals and sampling efforts in Orange County. Poster at Orange County Marine Protected Area Council Research Symposium. Dana Point, CA.

Smith, J.R. and J.L. Burnaford. 2015. Urchin sampling protocol. MARINe Annual Workshop. Moss Landing Marine Lab, CA.

Smith, J.R. and M. Miner. 2014. Sea Star Wasting Disease in Orange County. Orange County Marine Docent Program, Dana Point, CA.

Smith, J.R., S.N. Murray, S.C. Vogt, F.N. Creedon, D.J. Eernisse and C.N. Navarro. 2011. Introduced seaweeds on urban southern California shores: effects on native community structure and trophic dynamics. Western Society of Naturalists Meeting. Vancouver, WA.

Valentich-Scott, P. 2011. Common rocky intertidal bivalves of the West Coast. MARINe Annual Workshop, Santa Barbara, CA.

VanBlaricom, G. and M. Neuman. 2012. Black abalone recovery projects. MARINe Annual Workshop, Santa Cruz, CA.

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Sample Data Requests (2011-2015)

The data requests below are a representative sample of over 100 data requests completed between 2011 and 2015. A * indicates a request regarding data collected at a BOEM-funded site. Each data request involves anywhere from 15 minutes to ~ 2 hours to complete, depending on the complexity of the request, follow up questions and consultation, and subsequent requests regarding the same project.

Archipelago Marine Research Ltd. – Mary Morris
Project: Aerial Imagery comparison
Data Request: Oregon site information and survey data

**Caltrans – Andrew Domingos*
Project: Review of Primary Constituent Elements for black abalone
Data Request: Temperature data for Piedras Blancas

**Center for Ocean Solutions – Melissa Foley and Corina Marks*
Project: Cumulative impact model using ecosystem condition metrics
Data Request: Percent cover and size density data to ground truth model

**Ecotrust/Point 97 – Cheryl Chen*
Project: Coastal recreation analysis map for southern California
Data Request: Biodiversity taxonomy table and summary datasets

Monterey Bay Aquarium Research Institute (MBARI) – Julio Harvey
Project: Prediction of spawning for Monterey Bay region
Data Request: Barnacle and mussel recruitment and fecundity data

**Ocean Imaging*
Project: Aerial Imagery classification and accuracy assessments
Data Request: Site coordinates and data to compare with Aerial Imagery to determine accuracy of general species classifications

**Oregon State University – Phillip Fenberg*
Project: Phylogeography paper on *Mexacanthina lugubris*
Data Request: Density data for *Mexacanthina lugubris*

Scripps Institute of Oceanography – Christina Bonsell
Project: Replication of intertidal surveys done in San Diego in the 1960-70s
Data Request: Photo plot, transect, and biodiversity data for San Diego sites
**University of California, Santa Barbara – Cat Fong*
Project: Model for macroecology and maximum entropy theory
Data Request: Long-Term and Biodiversity data for Santa Barbara County sites

**University of California, Davis – Laura Jurgens*
Project: Species comparison across sites compared with temperature and tide regimes
Data Request: Density data for *Neorhodemela*

**Virginia Tech Department of Geosciences*
Project: Examination of gastropod community composition related to predatory crab density (in and out of MPAs)
Data Request: Gastropod abundance and species richness data

Willamette University – Javan Bailey
Project: Changes in rocky marine invertebrate biodiversity along the Oregon Coast
Data Request: Percent cover data for all OR sites

**Yale School of Forestry & Environmental Studies – Aaron Reuben*
Project: Artificial reef creation/potential marine contamination
Data Request: Dana Point datasets

PART V: DATABASE UPGRADE

5.1 Planning for database upgrade

One of the goals during the 2010-2015 contract period was to upgrade the existing MARINe database from Microsoft Access. It was determined that because of the large number of MARINe groups that collect and enter data, MARINe needed to convert to a web based database (MySQL). MySQL is an open source database management system that is extremely flexible, easy to use, and integrates well with web based applications (more information at https://www.mysql.com/). This will allow users to enter data online, as well as retrieve and display data online, all of which will enhance the turnaround time for data requests and allow MARINe groups to share data in real time.

5.2 Business Rules

A large part of updating the MARINe database was to clearly define the 'business rules' for the database. These rules are the guidelines for how the tables within the database are structured and how they are related. Many of these rules were defined in the MARINe Handbook; however the Microsoft Access database did not enforce all of these rules. By having clearly defined business rules and creating a robust database structure that follows these rules, data integrity is enhanced. In addition, additional error checks have been instituted that have allowed corrections of errors that were not previously detected. In the next contract period, additional data verification checks will be added to improve data quality.

5.3 Data Storage and Data Entry

MARINe data are now *extracted* from Access, *transformed* based on the enhanced business rules, and *loaded* into the new database. To date, all data from the MARINe Access database have been uploaded into the MySQL MARINe Database, with the exception of data from Channel Islands National Park and Cabrillo National Monument. These groups have always entered data into their own Access databases, and data were subsequently ported into the MARINe Access database. However, both groups have recently upgraded and restructured their respective databases, and those data will be incorporated into the MySQL database during the next contract period.

New data will continue to be entered into the Access database until web entry forms are developed during the next contract period. Web entry forms are currently in the development phase, and have been tested with positive results.

5.4 Data Retrieval and Display

A separate query database is being developed where summary data will be uploaded after data are entered and verified. These summary datasets include the calculated mean percent cover (photo plots and transects) and total counts and size frequency for sea stars, abalone, and *Lottia*. This query database will be extremely useful in responding to data requests as well as for generating summary graphs and other outputs that MARINe groups may need. Currently there are static graphs on the website (pacificrockyintertidal.org) as well as an interactive graphing tool; however, updates to these need to be done manually. Once the query database is linked to the graphing tool, the updated graphs for each season will be available immediately.

5.5 Next Steps

As mentioned above, one of the next steps for the database upgrade project will be to create data entry forms for all of the types of data that are entered into the Microsoft Access database. Once that has been completed, there will be no need to extract, transform, and load data from Access—data will be immediately available in the MySQL database. After that has been completed, entry forms will be created for additional types of data that were never included in the Access database, so that everything will be entered and stored together. Data from Channel Islands National Park and Cabrillo National Monument will be added once a process is developed to extract, transform, and load those data. The query database will continue to be developed, including creating forms for MARINe groups and others to easily query and extract data. In addition, the graphing tool available at pacificrockyintertidal.org will be upgraded so that it is linked directly with the query database for updates in real time.

ACKNOWLEDGEMENTS

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APPENDICES

The Appendices for this report consists of pages extracted from the web report in April, 2015 (www.pacificrockyintertidal.org). For the most up to date versions of the following pages, please visit the website.

Appendix 1: Target Species

Anthopleura (Anemones)

Chthamalus/Balanus (Acorn Barnacles)

Semibalanus (Thatched Barnacle)

Tetraclita (Pink Barnacle)

Pollicipes (Goose Barnacle)

Mytilus (California Mussel)

Fucus (Northern Rockweed)

Hesperophycus (Olive Rockweed)

Pelvetiopsis (Dwarf Rockweed)

Silvetia (Golden Rockweed)

Endocladia (Turfweed)

Mastocarpus (Turkish Washcloth)

Mazzaella (Iridescent Weed)

Neorhodomela (Black Pine)

Red Algal Turf

Tar

Recovery

Rock (Above Barnacles)

Egregia (Feather-Boa Kelp)

Saccharina (Sea Cabbage)

Red Algal Turf

Phyllospadix (Surfgrass)

Pisaster (Ochre Star)

Katharina

Haliotis cracherodii

Haliotis rufescens

Lottia gigantea (Owl Limpet)

Postelsia (Sea Palm)

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Anthopleura (Anemones)

Anthopleura elegantissima (Brandt 1835), *Anthopleura sola* (Pearse & Francis 2000)

Phylum Cnidaria, class Anthozoa, order Actiniaria, family Actiniidae

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Click here for a Target Species Reference pop-up.

Description

A. elegantissima: clonal anemone with radiating lines on oral disk, up to 8 cm across tentacular crown (generally smaller than *A. sola*). Column is greenish to white in color, often covered with shell debris. Tentacles are greenish to pinkish in color (Morris et al. 1980).

A. sola: solitary anemone with radiating lines on oral disk, up to 25 cm across tentacular crown (generally larger than *A. elegantissima*). Previously thought to be the same species as *A. elegantissima*, but now recognized as a sibling species (Pearse and Francis 2000). Small individuals located relatively close together can be confused with *A. elegantissima* and the two species have been grouped together for Long-Term Monitoring.

Habitat and Geographic Range

Anemones are abundant on rocks, in tidepools or crevices, and on pier pilings; they are characteristic of the middle intertidal zones of semi-protected rocky shores of both bays and outer coasts. *A. elegantissima* ranges from Alaska to Baja California (Morris et al. 1980) and *A. sola* from central California to Baja California.

Synonyms

Cribina xanthogrammica, C. elegantissima

Similar species

Anthopleura xanthogrammica has a solid green oral disk and a frmer column when withdrawn. It also has small, closely arranged, irregularly shaped tubercles on the column (in contrast to *A. sola*, which has prominent rounded bumps arranged in rows). *A. xanthogrammica* has a tighter oral sphincter muscle than *A. sola*.

Natural History

Previously thought to be a single species, *Anthopleura elegantissima* and *Anthopleura sola* were described as genetically, ecologically, and developmentally distinct by Pearse and Francis (2000). While the two species are similar in appearance, *A. sola* grows larger (to 25 cm) and is solitary compared to the smaller (to 8 cm) *A. elegantissima*, whose clones are typically aggregated. *Anthopleura elegantissima* is able to persist practically indefnitely and in great abundance under normal conditions because genetically-identical individuals are periodically produced by longitudinal fssion (Sebens 1982). Non-clonemates are spatially separated after aggressive stinging battles. *Anthopleura sola* does not divide and can be confused with *A. xanthogrammica*, which occurs south of Point Conception only in areas up upwelling. The three species of *Anthopleura* typically host symbiotic unicellular algae (zooxanthellae and/or zoochorellae) that can contribute to their overall energy budget (Muller-Parker and Davy 2001). The symbiotic algal type present within a given anemone depends on a number of factors, including light condition, tidal height, and temperature (Verde and McCloskey 2007). At latitudes south of 38˚N, zooxanthellae are the exclusive symbionts in *Anthopleura* species and the green color of most individuals is due to pigments produced by the animal itself, not the alga (which is golden-brown in color) (Secord and Augustine 2000). Above 38˚N, symbiotic zoochorellae increase in abundance northward, and are responsible for the “grass green” anemones found in low light conditions, such as dimly lit caves (Secord and Augustine 2000, Pearse 2007).

Both *A. sola* and *A. elegantissima* are abundant on semi-protected rocky shores. *A. sola* is common in tidepools and subtidally, and *A. elegantissima* often occurs as small densely aggregated clones in middle intertidal zones, especially sand-infuenced habitats (Morris et al. 1980). Extensive carpets of these clones may occur, but often go unrecognized under low tide conditions because the anemones contract to small blobs covered with sand and shell fragments that provide protection from desiccation. Anemone mats create a moist microenvironment that allows the development of some other species, such as coralline algae and sand tube worms (*Phragmatopoma californica*) at higher intertidal levels than they would normally occur (Taylor and Littler 1982).

Anthopleura species are quite resistant to disturbances from shifting sands (Raimondi et al. 1999). They not only withstand moderate sand abrasion, but also resist shallow sand burial by extending their columns to re-expose the tentacles and oral disk. If buried deeper, they can survive for at least 3 months by metabolizing body tissue (Sebens 1980). *Anthopleura* spp. are not known to be unusually sensitive to oiling. Recovery from major disturbances may take 1-2 years or more (see Vesco & Gillard 1980).

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Chthamalus/Balanus (Acorn Barnacles)

Chthamalus fssus (Darwin 1854), Chthamalus dalli (Pilsbry 1916), *Balanus glandula* (Darwin 1854)

Phylum Arthropoda, class Maxillopoda, order Sessilia

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Description

C. fssus/dalli : small barnacle, up to 8 mm in diameter. Shell is brown-grey in color and smooth. Operculum is oval. These species are virtually indistinguishable in the feld.

B. glandula: bigger barnacle than *C. fssus/dalli* , up to 22 mm in diameter. Shell is white to gray in color. Operculum is white and diamond-shaped. Plates are deeply ridged (Morris et al. 1980).

Habitat and Geographic Range

C. fssus/dalli : common on rocks, pier pilings, and hard-shelled organisms, high and upper middle intertidal zones. *C. fssus* extends from San Francisco, CA to Baja California; *C. dalli* is found from Alaska to San Diego California (Morris et al. 1980).

B. glandula: abundant on rocks, pier pilings, and hard-shelled animals within the high and middle intertidal zones of bays and the outer coast from the Aleutian Islands (Alaska) to Bahía de San Quintín (Baja California) (Morris et al. 1980).

Synonyms

Chthamalus microtretus

Similar species

Balanus crenatus typically occurs subtidally, but is occasionally present in the very low intertidal and can be distinguished from *B. glandula* by the shape and margins of the opercular plates. The exoskeleton plates are generally more smooth and fragile.

Juvenile *Semibalanus cariosus* can be distinguished by the margins of the opercular plates.

Natural History

Acorn barnacles, *Chthamalus fssus/dalli* and *Balanus glandula*, typically dominate the high intertidal zone along the western coast of North America. Acorn barnacle species can be diffcult to identify in photographic monitoring, but *Balanus glandula* can be distinguished from *Chthamalus fssus/dalli* by its larger size (to 22 mm), whiter color, and diamond-shaped operculum. The confgurations of their exoskeletal plates also differ. To distinguish *C. fssus* from *C. dalli* requires dissection and microscopic examination of the opercular plates. A bent morph of *Chthamalus fssus* , similar to that seen in the Gulf of California species *Chthamalus anisopoma*, has been documented at several Long-Term Monitoring sites (Miner et al. 2005).

Acorn barnacles are hermaphroditic as adults and spawn often, at variable times throughout the year (Hines 1978). The planktonic larvae can settle in incredible densities (to 70,000/m²), forming a distinct band along the upper intertidal that contain few other invertebrates except littorines and the heartiest limpets. *Balanus* can out-compete *Chthamalus* by crowding or smothering, but *Chthamalus* can occupy higher tide levels than Balanus because it is more resistant to desiccation. Lower on the shore, acorn barnacles mix in with the *Endocladia* (Turfweed) assemblage, and are also common on mussel shells. *Chthamalus* grows rapidly, but only survives a few months to a few years. *Balanus* can live longer (to 10 years), but its larger size and lower tidal position subject it to higher levels of mortality from predatory gastropods and ochre sea stars. Acorn barnacles (particularly *Balanus glandula*) facilitate the recruitment of *Endocladia* and fucoid algae by reducing the grazing pressure of limpets (Farrell 1991). Long-Term Monitoring data have shown this facilitation at several sites, where barnacle plots have become slowly inundated by *Endocladia, Pelvetiopsis*, and *Silvetia* (Miner et al. 2005).

Acorn barnacles are highly vulnerable to smothering from oil spills because foating oil often sticks along the uppermost tidal levels. Signifcant, widespread barnacle impacts were reported after the 1969 Santa Barbara oil platform blow-out (Foster et al.1971) and the 1971 collision of two tankers off San Francisco (Chan 1973). However, high recruitment rates may promote relatively rapid recovery of acorn barnacles; disturbance recovery times ranging from several months to several years have been reported (see Vesco & Gillard 1980).

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Semibalanus (Thatched Barnacle)

Semibalanus cariosus (Pallas 1788)

Phylum Arthropoda, class Maxillopoda, order Sessilia, family Archaeobalanidae

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Click here for a Target Species Reference pop-up

Description

Sessile barnacle with a diameter up to 60 mm comprised of 6 white wall plates that may be brownish, gray, or greenish. The wall plates are composed of vertical tube-like ribs, which, especially in the lower half, become downward-pointing fngerlike or “thatchlike” projections.

Habitat and Geographic Range

Attached to rocks, foats, or pilings along exposed shores, mid intertidal to shallow subtidal. Common in the low intertidal zone, below the densest band of *Balanus glandula* and near *Mytilus californianus*; Bering Sea to Morro Bay, Central California; Japan (Morris et al. 1980).

Synonyms

Balanus cariosus

Similar species

Tetraclita rubescens has a similar thatched appearance but it is a pinkish red color and has only 4 plates.

Natural History

Eggs of *Semibalanus cariosus* are brooded in the winter and the planktonic cyprid larvae settle in the spring (fall and winter on the open Washington coast). The larvae preferentially settle near adult barnacle shells. Lifespan is up to 15 years (Morris et al. 1980). Within the Salish Sea, *S. cariosus* prefers steep shores with strong currents and waves but on the open coast it is found in deep cracks, overhanging ledges and protected locations (Ricketts et al. 1985). In central California this species grows individually, but in the Pacifc Northwest colonies can sometimes be so dense that the thatched appearance is not immediately evident. These barnacles grow very tall and narrow when densely aggregated. These dense patches of *Semibalanus* can signifcantly reduce survivorship and recruitment of conspecifc as well as other barnacle species through direct predation of cyprids (Navarrete and Wieters 2000). When *Semibalanus* are small they may be bulldozed off the rocks by grazing limpets such as *Lottia digitalis*. The large size of adults likely protects them from major predators such as *Nucella* (whelks) and the ochre seastar, *Pisaster ochraceus*.

A disturbance study in Kachemak Bay AK, done as part of the Exxon Valdez oil spill assessment, concluded that *S. cariosus* requires more than 2.5 years to fully recover from scraping disturbance. *Semibalanus* had not recovered to control levels in cleared plots after the three year study was completed (Highsmith et al. 2001).

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Tetraclita (Pink Barnacle)

Tetraclita rubescens (Darwin 1854)

Phylum Arthropoda, class Maxillopoda, order Sessilia, family Tetraclitidae

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Description

Sessile barnacle with a diameter usually to 30 mm, rarely to 50 mm. Exoskeletal wall consists of four plates with no basal plate (all other local acorn barnacles have 6 plates). The shells of adults are pink to reddish and appear thatched, while the shells of (uneroded) juveniles are white (Morris et al. 1980).

Habitat and Geographic Range

Common in middle to low intertidal zones on rocks exposed to strong surf from Cape Mendocino, Northern Califonia to Baja California (Carlton 2007).

Synonyms

Tetraclita squamosa rubescens

Similar species

Megabalanus californicus, which is pink and has a smoother operculum and smooth area between plates. Also, the shell of young *T. rubescens* can resemble *Semibalanus cariousus,* but it has four wall plates instead of six.

Natural History

Thatched barnacles are usually found growing as solitary individuals rather than in aggregations, like acorn barnacles (Engle and Davis 1996). Thatched barnacles are brooders, and do not become reproductive until they are about 2 years old (18mm in diameter). In California, as many as 3 broods of 1,000-50,000 nauplius larvae (depending on parent size) can be released by an individual in one summer (Morris et al. 1980). *Tetraclita rubescens* may live as long as 15 years (Hines 1978). These barnacles are effective competitors for space, and may infuence the distribution of mussels and other species (Foster et al. 1988). In the lower intertidal zone, individuals may grow large enough to avoid predation by sea stars and gastropods (Morris et al. 1980). Up until the 1990s the northern range limit was thought to be San Francisco; however; more recent studies have placed the northern limit several hundred kilometers farther north into Northern California (Connolly and Roughgarden 1998), possibly in response to global climate change (Dawson et al. 2010). Barnacles might be sensitive to sewage pollution (Littler and Murray 1975) and recovery from disturbance may take more than 2 years.

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Pollicipes (Goose Barnacle)

Pollicipes polymerus (Sowerby 1833)

Phylum Arthropoda, class Maxillopoda, order Pedunculata, family Pollicipedidae

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Description

A stalked barnacle that grows to 8 cm tall with more than 5 white shell plates surrounded by scales and a black, tough, feshy peduncle roughened by inconspicuous calcareous spicules (Morris et al. 1980). The mantle (upper portion of body under plates) is typically black, but can be a brilliant red in low-light areas, such as in caves or on the undersides of rocks (J. Pearse, pers. com.).

Habitat and Geographic Range

Common species that usually grows in clusters but is also found mixed with the California Mussel, *Mytilus californianus*, *P. polymerus* inhabits the middle intertidal zone on wave-exposed, rocky shores (Morris et al. 1980) from Sitka, Alaska south to at least Punta Abreojos (Baja California) (Ricketts 1985).

Synonyms

Mitella polymerus

Similar species

Other goose barnacles such as *Lepas* are oceanic and attach to foating logs, net foats and other objects that sometimes wash ashore.

Natural History

Pollicipes polymerus feed on particles of detritus in the backwash of waves (Morris et al. 1980) and, for this reason, are found in crevices or areas that channel water back to the ocean (Kozloff 1983). *Pollicipes* are brooders, and swimming nauplii larvae are released about 30 days after fertilization (Morris et al. 1980). Young goose barnacles settle preferentially among other *Pollicipes*, forming tight clusters on exposed outcrops, ridges and walls, just above or intermixed with mussel beds. Goose barnacles are slow-growing, reaching sexual maturity at around 5 years and living up to 20 years (Morris et al. 1980). The body temperature of *P. polymerus* can be colder than expected from corresponding ambient temperatures due to evaporation from the peduncle (Morris et al. 1980). They are resistant to desiccation and can withstand all but the highest wave exposures. *Pollicipes* have been shown to be susceptible to oiling (Foster et al. 1971, Chan 1973) and recovery from disturbance may be slow. Another *Pollicipes* species (*Pollicipes pollicipes*) is collected for human consumption in European countries. Since *P. pollicipes* has been in short supply, *Pollicipes polymerus* has been exported from British Columbia to these countries

(Morris et al. 1980). Populations have been reduced in accessible areas where goose barnacles are collected for food.

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Mytilus (California mussel)

Mytilus californianus (Conrad 1837)

Phylum Mollusca, class Bivalvia, order Mytiloida, family Mytilidae

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Description

Mussel shell to about 130 mm long. Shell is a bluish-black color, often with eroded white valves and darker at margins. Anterior end of shell is sharply pointed. Prominent radial ribbing but also concentric growth lines present (Morris 1980).

Habitat and Geographic Range

Abundant, often on surf-exposed rocks and pier pilings. Found mainly in upper-middle intertidal zone on outer coast and can be found subtidal and offshore to 24 m (depth). Aleutian Islands, Alaska to southern Baja, California (Morris 1980).

Synonyms

None

Similar species

Bay mussels, *Mytilus galloprovincialis and Mytilus trossulus*, can co-occur with *M. californianus* but are most common in sheltered habitats because of their weaker byssal threads (Morris et al. 1980). They have smooth valves, lacking radiating ridges, with strong, elbow-curve at umbo and are less eroded than *M. californianus*.

Natural History

The California mussel forms extensive beds, which may be multi-layered (usually in the northern part of its range). Mussels attach to hard substrate by secreting byssal threads at the base of the foot (Morris et al. 1980). Byssal thread production appears to be possible only when water fow is < 50 cm/s. Although wave action in the intertidal results in fow rates much higher than this, mussel aggregations greatly reduce water fow within the beds and make possible the production of byssal threads (Carrington et al. 2008). Thick (³ 20 cm) beds of California mussels trap water, sediment, and detritus that provide food and shelter for an incredible diversity of plants and animals, including cryptic forms inhabiting spaces between mussels as well as biota attached to mussel shells (Paine 1966; MacGinitie & MacGinitie 1968; Suchanek 1979; Kanter 1980, Lohse 1993). For example, MacGinitie & MacGinitie (1968) counted 625 mussels and 4,096 other invertebrates in a single 25 cm² clump, and Kanter (1980) identifed 610 species of animals and 141 species of algae from mussel beds at the Channel Islands. Kinnetics (1992) documented locational differences in the composition and abundance of mussel bed species. Northern sites had densely packed, multi-layered beds, but the more open southern sites had higher species diversity.

The California mussel spawns all year but spawning peaks in July and December in CA. Young mussels settle preferentially into existing beds at irregular intervals, grow at variable rates depending on environmental conditions and eventually reach ages of 8 years or more (see Morris et al. 1980, Ricketts et al. 1985). *M. californianus* is a flter feeder , and is quarantined from collection/consumption from late spring to early autumn because the toxin from a dinofagellate accumulates in the tissue (Kozlof f 1983). This toxin can cause paralysis and death.

While mussels can tolerate typical rigors of intertidal life quite successfully, desiccation likely limits the upper extent of mussel beds, storms tear out various-sized mussel patches and sea stars prey especially on lower zone mussels. Beds that are already patchy or thinned by human disturbance (e.g. via trampling or collection for bait) have increased susceptibility to wave damage. Mussels have also been found to be adversely affected by oil spills (Chan 1973; Foster et al. 1971). Recovery from disturbance varies from fairly rapid (if clearings are small and surrounded by mussels that can move in) to periods greater than 10 years (if clearings are large and recruitment is necessary for recolonization) (Vesco & Gillard 1980, Kinnetics 1992).

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Fucus (Northern Rockweed)

Fucus distichus (Linnaeus)

Kingdom Chromista, phylum Ochrophyta, class Phaeophyceae, order Fucales, family Fucaceae

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Description

This olive-brown thallus can reach up to 50 cm tall and 15-25 mm wide. Individuals in protected sites are often larger than those at exposed ones. Branches are fattened and dichotomously branched with a distinct midrib. Reproductive conceptacles are concentrated at branch tips (swollen when mature).

Habitat and Geographic Range

Fucus is common in the upper mid-intertidal zone, in exposed to protected outer and inner coast locals, from Alaska to Southern California (Lamb and Hanby 2005). In the Pacifc Northwest and Alaska (particularly on sheltered shorelines), *Fucus* is often the dominant species of algae, forming a broad, distinctive band in the mid-intertidal.

Synonyms

Fucus gardneri

Similar species

Can be confused with the other common rockweeds: *Hesperophycus californicus, Pelvetiopsis limitata,* and *Silvetia compressa*. In California, *Fucus* has broader fronds and larger receptacles than the other species and, unlike *H. californicus*, can have irregularly spaced white hairs along the midrib rather than paired hairs and has less ruffed fronds . Fronds of *Silvetia* and *Pelvetiopsis* lack a midrib.

Natural History

Fucus forms broad, dense canopies in the mid intertidal zone and can extend well into the high zone, with plants becoming smaller and less dense at the upper edge of its tidal range. This fucoid is tolerant of a wide range of salinities, and occurs on the outer coast, on protected inland shores, and even in areas inundated by freshwater (O'Clair and Lindstrom 2000). *Fucus* canopies are important for providing protection from desiccation to a suite of other algae and invertebrates. Some grazers inhabiting the *Fucus* understory have been shown to facilitate the persistence of the rockweed by selectively grazing other algae that compete with Fucus for space. For example, the littorine, *Littorina sitkana* aids in the succession of *Fucus* by preferentially consuming more ephemeral algae like *Ulva lactuca* and *Enteromorpha* (Lubchenco 1983).

The life history of this algal species is diplontic, with a diploid thallus and gamete formation via meiosis (Searles 1980). When mature, receptacles (swollen, yellowish bumps) on the blade tips release gametes at low tide. Eggs are fertilized with the incoming tide, and the resulting zygotes secrete adhesive and attach to the substratum (O'Clair and Lindstrom 2000). Individuals are thought to live approximately 2-3 years at exposed sites, and approximately 4-5 years in protected areas (O'Clair and Lindstrom 2000).

It has been shown that desiccation, which affects this upper-intertidal species, can weaken *Fucus* thalli and thereby increase mortality from water motion via stipe breakage (Haring et al. 2002). However, *Fucus* is able to recover rapidly from desiccation when submerged; the same study showed that it is capable of recouping enough water within in 30 seconds to be able to withstand a dynamic load which broke experimentally desiccated stipes. In addition to desiccation, this alga is highly sensitive to oil contamination as shown by the documented dramatic population collapse following the *Cosco Busan* oil spill in 2007 (Cosco Busan Oil Spill Trustees 2012). However, it appears to be even more sensitive to heat, as was demonstrated by the increased *Fucus* mortality in hot water cleaned areas versus un-treated rocks following the Exxon Valdez oil spill in 1989 (De Vogelaere and Foster 1994). Despite high initial mortality rates following the Exxon Valdez spill, *Fucus* cover increased to match levels in reference areas by 1992; however, the uniform age structure of the cohort that recruited post-spill created an unstable population that precluded full recovery for more than seven years after the spill (Driskell et al. 2001).

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Hesperophycus (Olive Rockweed)

Hesperophycus californicus (Decaisne 1864)

Kingdom Chromista, phylum Ochrophyta, class Phaeophyceae, order Fucales, family Fucaceae

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Description

This perennial thallus ranges from olive green to brown in color and 10-50 cm in height. *H. californicus* is dichotomously branched although it often appears irregularly branched due to axis breakage. Midribs are fattened in terminal thallus portions and paired white hairs along the mid-rib are present. Tips of branches swell up when reproductive, resulting in gas-flled, oval receptacles (Abbott and Hollenberg 1976).

Habitat and Geographic Range

Locally abundant to infrequent in upper intertidal, usually at higher tidal levels but sometimes mixed with *Fucus* on rocks in central California. In southern California, *Hesperophycus* characteristically occurs at tidal elevations immediately above *Silvetia,* replacing *Fucus* south of Pt. Conception. The range of this species reaches from Santa Cruz, California to Islas San Benito, Baja California (Abbott and Hollenberg 1976).

Synonyms

Previously known as *Hesperophycus harveyanus*

Similar species

Can be confused with the other common rockweeds: *Fucus gardneri, Pelvetiopsis limitata,* and *Silvetia compressa*. In California, *Fucus* has broader, less ruffed fronds and larger receptacles than the other species and, unlike *H. californicus*, can have unpaired white hairs along the midrib rather than paired. Fronds of *Silvetia* and *Pelvetiopsis* lack a midrib.

Natural History

Hesperophycus is a fairly common fucoid alga along the central coast of California, found in the upper-mid tidal regions sometimes mixed with *Silvetia* or *Fucus* (Raimondi et al. 1999). A study on Santa Cruz Island by Blanchette et al. (2000) found that *H. californicus* size is reduced by increased wave strength due to tattering; this reduction in thallus size may then increase survivorship by reducing drag without damaging the alga's staying power. *Hesperophycus* is particularly susceptible to oiling (Dawson and Foster 1982), and is believed to have declined in abundance along the southern California mainland.

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Pelvetiopsis (Dwarf Rockweed)

Pelvetiopsis limitata (Gardner 1910)

Kingdom Chromista, phylum Ochrophyta, class Phaeophyceae, order Fucales, family Fucaceae

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Description

This perennial brown alga stands between 4-8cm tall and is light tan to olive in color arising from a small discoid holdfast. The densely branched thallus is cylindrical at the base, becoming fattened to cylindrical in the upper fronds. The dichotomously divided branches tend to arch inward and lack midribs (Abbott and Hollenberg 1976).

Habitat and Geographic Range

Found on tops of rocks, rarely on sides, in the upper intertidal zone; frequents more wave-exposed sites. Range extends from Vancouver Island, British Columbia, to Cambria (San Luis Obispo County), CA (Abbott and Hollenberg 1976).

Synonyms

Pelvetia fastigiata limitata

Similar species

Can be confused with the other common rockweeds: *Fucus gardneri,* *Hesperophycus californicus,* and *Silvetia compressa*. *Fucus* and *Hesperophycus* generally have wider fronds with midribs, whereas *Silvetia* and *Pelvetiopsis* have narrower fronds that lack a midrib. *Silvetia* has a longer basal stipe and is typically found at lower tidal levels than *Pelvetiopsis* (Abbott and Hollenberg 1976).

Natural History

Pelvetiopsis limitata is considered a good indicator organism of exposed rocky coasts. It forms extensive zones in the high intertidal region and is fed on by limpets and other invertebrate grazers. *Pelvetiopsis* is most closely related to *Hesperophycus* (Serrão et al. 1999), with both genera producing one large egg per oogonium. Two species of *Pelvetiopsis* occur in California, *P. limitata* and *P. arborescens*. The former species more closely resembles a dwarf *Fucus*, whereas the latter is similar in appearance to a small *Silvetia* due to its more cylindrical branches (Abott and Hollenberg 1976). In central California, *Pelvetiopsis* can co-occur with *Silvetia compressa* although *Pelvetiopsis* is generally found at higher tidal elevations. When identifcation is in doubt, specimens can be examined microscopically to determine the number of eggs per oogonium. *Pelvetiopsis* has only one egg per oogonium while *Silvetia* has two and *Fucus* eight. Little scientifc attention has been given to *Pelvetiopsis,* leaving much of its reproductive periodicity, longevity, and ecology unknown. *Pelvetiopsis* may be an indicator species of human traffc. A study on human trampling effects showed that *P. limitata* was markedly absent from the most heavily trampled sites and suggested that it may be highly susceptible to breakage especially when growing on the edges of rocks (Beauchamp and Gowing 1982). *Pelvetiopsis* also becomes detached from the substrate during winter storms which are predicted to increase in intensity and frequency due to climate change. Recruitment and survival of *Pelvetiopsis* embryos are higher under the canopy of adults especially in higher tidal elevations (Skene 2009). Predicted effects of climate change and the resulting sea level rises on this high zone species include increased rates of adult mortality and limited ability to shift its distribution to higher elevations (Skene 2009).

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Silvetia (Golden Rockweed)

Silvetia compressa (J.Agardh, E.Serrão, T.O.Cho, S.M.Boo & Brawley, 1999), *Silvetia compressa deliquescens* (P.C.Silva, 2004)

Kingdom Chromista, phylum Ochrophyta, class Phaeophyceae, order Fucales, family Fucaceae

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Description

Silvetia compressa: The typical mainland form is an olive green or yellowish brown plant about 30 cm long (up to 90 cm long), composed of thick, narrow, dichotomous fronds that often appear irregularly branched because of axis breakage. A fner-branched, lighter-colored form is more typical of the Channel Islands (Abbott and Hollenberg 1976; Silva et al. 2004).

Silvetia compressa deliquescens: Thalli slender relative to *S. compressa*, with more branches (Abbott and Hollenberg 1976).

Habitat and Geographic Range

Silvetia compressa: Locally abundant in the midtidal zone, forming beds on rocks somewhat protected from open surf. Ranges from Horswell Channel, British Columbia to Punta Baja, Baja California (Abbott and Hollenberg 1976).

Silvetia compressa deliquescens: Found in Pebble Beach (Monterey Co.) and Channel Islands, where it is abundant and replaces *S. compressa* (Abbott and Hollenberg 1976).

Synonyms

S. compressa previously known as *Pelvetia fastigiata* and *Pelvetia compressa*

Silvetia compressa deliquescens previously known as *Pelvetia fastigiata* f. *gracilis*

Similar species

Can be confused with the other common rockweeds: *Hesperophycus californicus, Pelvetiopsis limitata,* and *Fucus gardneri*. *Fucus* and *Hesperophycus* generally have wider fronds with midribs, whereas *Silvetia* and *Pelvetiopsis* have narrower fronds that lack a midrib. *Pelvetiopsis* develops tiny pits (cryptostomata) with white hairs but these are inconspicuous (Abbott and Hollenberg 1976). Silvetia generally occurs lower than *Pelvetiopsis*.

Natural History

Silvetia is a dominant perennial alga that allows algae and many animals to live higher up on the shore by creating a moist microhabitat (Hill 1980, Gunnill 1983, Sapper and Murray 2003). Like other rockweeds, reproductive structures are produced in swollen branch termini called receptacles. Unlike *Fucus* and *Hesperophycus*, these are rarely infated with gases. Gametangia occur in pits (conceptacles) that dot the surface of fertile receptacles. Gametes are released during receding tides and dispersal is very limited (Johnson and Brawley 1998). In spite of being a tough and long-lived species, *Silvetia* is slow-growing, experiences irregular recruitment and has low survivorship (Gunnill 1980). *Silvetia* is susceptible to trampling (Denis and Murray 2001) and oiling because of its midtidal height and recovery from disturbance is believed to be long

(Hill 1980, Vesco and Gillard 1980). A recent study has shown that *Silvetia* can be transplanted and reestablished for restorative purposes (Whitaker et al. 2010).

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Endocladia (Turfweed)

Endocladia muricata (J. Agardh 1841)

Kingdom Plantae, phylum Rhodophyta, class Florideophyceae, order Gigartinales

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Description

Thalli are densely bushy, dark red to blackish brown tufts, 4-8 cm tall. Branches are cylindrical throughout, covered with small conical spines (Abbott and Hollenberg 1976)

Habitat and Geographic Range

Locally abundant on tops or vertical faces of rocks or epiphytic on other organisms (e.g. mussels and barnacles) in the high to mid-intertidal zones. Alaska to Punto Santo Tomas, Baja California, including Channel

Islands (Abbott and Hollenberg 1976).

Synonyms

Previously known as *Gigartina muricata*

Similar species

Gelidium pusillum and *Caulacanthus ustulatus*. *G. pusillum* lacks spines on its branches and has more spatulate tips. *C. ustulatus* is redder, fner , and not as rough to the touch.

Natural History

Endocladia is common north of Point Conception and one of the most common algae in central California, forming distinctive dark bands along the upper shoreline. *Endocladia* abundance fades in warmer waters to the south, being largely replaced in lower portions of its zone by other small red algae (e.g. *Gelidium* spp.) *Endocladia* often grows with other small reds (e.g. *Mastocarpus papillatus*, *Gelidium* spp.) to form a low, tight turf that traps sediment and moisture, and provides a sheltered microhabitat for a host of small organisms. Glynn (1965) found over 90 species associated with *Endocladia* clumps in Monterey. *Endocladia* has been shown to facilitate recruitment of *Silvetia compressa*, possibly by providing propagules protection from dislodgement, grazing, and/or desiccation (Johnson and Brawley 1998). Turfweed also can provide habitat for attachment of young mussels. Expanding mussel patches may displace *Endocladia*, but it can then grow on the mussel shells, creating a layered assemblage. Some *Endocladia* clumps appear donut- or crescent-shaped; this condition may be caused by storms tearing out center areas possibly weakened by accumulated anoxic sediment.

Endocladia is hardy and quite resistant to desiccation, yet vulnerable to oiling from spills due to its location in the high intertidal. Recovery from natural or human disturbances may vary from 1 to more than 6 years (see Kinnetics 1992).

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Mastocarpus (Turkish Washcloth)

Mastocarpus complex (C.Agardh 1821)

Kingdom Plantae, phylum Rhodophyta, class Florideophyceae, order Gigartinales

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Description

The *Mastocarpus* complex targeted by MARINe includes morphologies previously identifed as *Mastocarpus papillatus* (Lindstrom et al 2011). Morphology within the complex can be highly variable. Each thallus stands less than15 cm tall, with fattened dark to brownish red blades that are thin yet tough. Blades vary in width, are covered thickly or sparsely with papillae of various sizes, are ribbed along the margin, and have tips which are usually divided dichotomously. Male plants lack papillae and are light rose to greenish or yellowish in color (Abbott and Hollenberg 1976, Kozloff 2000).

Habitat and Geographic Range

Common in the high to mid-intertidal zones, this alga complex often dominates these zones in central and northern California and but is less abundant south of Santa Barbara. Range extends from Alaska to Pta. Baja, Baja California (Abbott and Hollenberg 1976).

Synonyms

Gigartina papillata

Similar species

Members of another species complex, formerly identifed as *Mastocarpus jardinii,* can be confused with members of the *M. papillatus* complex. *Mazzaella affnis* is similar in color and shape to male *M. papillatus*, but is usually shorter and grows in dense continuous mats rather than as discrete individuals. All *Mastocarpus* species and another red alga, *Pikea* have crustose phases in their life histories, making feld-identifcation of the crusts to species level diffcult. *Hildenbrandia* and *Ralfsa* are other dark crusts but these are thinner than “Petrocelis” (the crustose phase of the *M. papillatus* complex).

Natural History

There is great variability in the growth forms of the *Mastocarpus papillatus* complex. Individuals vary in the size and density of papillae present, amount of branching, and thallus thickness. Surprisingly, Carrington (1990) found that the amount of drag force that an individual was subjected to in high fow environments did not correlate strongly with morphology, including thallus diameter (the area where breakage most commonly occurs). However, Kitzes and Denny (2005) did fnd a positive relationship between both thallus cross-sectional area and material strength with increasing wave force, indicating a selective force or adaptive ability of individuals living in high wave energy environments.

Mastocarpus exhibits two distinct life cycles: a sexual alternation of generations involving three separate stages, and an asexual direct life cycle that produces only female fronds. The distribution of sexual and asexual populations varies both with latitude, and tidal height within a given site, a pattern of spatial separation called geographic parthenogenesis (Fierst et al.2010). In sexual populations, the upright thallus is the haploid, gametophytic stage, with separate male (typically greenish or yellowish) and female (typically dark red) blades. Males release spermatia, which fertilize ova retained by females. The fertilized diploid zygotes remain attached to the female blades, and are visible as bumps (carposporophytes), on the surface. Carposporophytes release diploid carpospores, which settle and grow into diploid tetrasporophytes, smooth, dark black-red to olive brown crusts typically 2-2.5 mm thick. These crusts were once thought to be a separate species, called “Petrocelis”. “Petrocelis” produces tetraspores via meiosis, which are released and settle to grow into the haploid male or female blades.

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Mazzaella (Iridescent Weed)

Mazzaella splendens, Mazzaella faccida (Setchell & Gardner 1937)

Division Rhodophyta, class Rhodophyceae, order Gigartinales

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Description

Mazzaella faccida has rubbery blades 20-30 (140) cm long, 8-20 cm wide that are elongate to heart-shaped and iridescent yellow-green with purple or brown near base of blade. Thallus has a short stipe (<2 cm long) and a perennial discoid holdfast (Abbott and Hollenberg 1976).

Mazzaella splendens blades range from 20-40 cm (2m) long and 12-24 (40) cm wide. Blades are typically heart-shaped, rubbery, and violet to blackish in color, with a blue, iridescent sheen when wet. This alga has a perennial, feshy holdfast out of which a 3-6 cm stipe grows (Abbott and Hollenberg 1976).

Habitat and Geographic Range

Mazzaella faccida is abundant in the mid to low intertidal zones. It also grows on mid-shore rocks (saxicolous) and the upper limit is close to mid-tide level (~+1 m). It is the most conspicuous blade-like alga in Central CA.

Mazzaella splendens is a common saxicolous alga found from the low intertidal to subtidal (7m) on exposed coasts. The two subspecies of *M. splendens* have a combined range that extends from southeast Alaska to Punta Baja, Baja California (Hughey and Hommersand 2010).

Synonyms

Mazzaella faccida: Iridea faccida

Mazzaella splendens: Iridea cordata var.cordata, Iridea cordata var. splendens

Similar species

M. faccida and *M. splendens* are most similar to one another (see above descriptions) and can be virtually indistinguishable in the feld. *M. splendens* has a slightly longer stipe and occurs lower on the shore. *M. faccida* has a shorter stipe and is iridescent yellowish-green with purple or brown only on basal portion of blade (Abbott and Hollenberg 1976). For Long-Term Monitoring purposes *M. faccida and M. splendens* are combined into the Mazzaella category.

Natural History

The similarities in thalus shape and color of the many species of *Mazzaella* have resulted in numerous taxonomic reorganizations within the group with 24 currently recognized species.Within this complex group, the *splendens* clade currently includes four species (*Mazzaella faccida, Mazzaella linearis, Mazzaella sanguinea* and *Mazzaella splendens*) with recent molecular and morphological work identifying six clades and two subspecies within this taxonomically challenged clade (Hughey and Hommersand 2010).

M. faccida and *M. splendens* are red algae with separate male and female thalli and three different life history phases. Within each species, individuals of all phases are isomorphic (the same size and shape) despite differences in tissue ploidy (i.e. 1N gametophyte versus 2N tetrasporophyte). For both *M. faccida* and *M. splendens*, individuals of different phases can be differentiated visually when reproductive—the male gametophyte thallus will be smooth, the 1N female gametophyte thallus will have large, rough bumps, and the tetrasporophyte thallus will have many, closely-packed small bumps (Thornber et al. 2006)—or via chemical analysis when non-reproductive by looking at the carrageenan content (McCandless et al. 1975). In a feld study by Thornber et al. (2004) they found *M. faccida* and *M. splendens* gametophytes to be more abundant in the feld than the sporophytes, resulting in part from a more fecund sporophyte generation which creates the gametophytes. However, while *M. splendens* adhered closely to the predicted ratio of ~60% haploid: 40% diploid, *M. faccida* exhibited a dramatically higher proportion of gametophytes. This is possibly due to the fact that per capita mortality rates for *M. faccida* were 11% greater for haploids than diploids (Thornber 2004). Relative abundances of the different *M. faccida* tissue ploidy's (1N gametophyte versus 2N tetrasporophyte) in the feld have also been shown to be impacted by herbivory seeing as herbivores, e.g. the snail *Tegula funebralis*, have shown preferences for gametophyte over sporophyte, as well as reproductive over non-reproductive, tissue (Thornber 2006).

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Neorhodomela (Black Pine)

Neorhodomela larix (Turner 1819)

Kingdom Plantae, phylum Rhodophyta, class Florideophyceae, order Ceramiales

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Description

This red alga forms brownish-black turfs with thalli that fall mostly between 10-20 (maximum 30) cm. Thalli consist of several to many erect axes which whorl around a common base, like a bottle brush. The short, wiry branches and branchletts are blunt and mostly uniform in length (Abbott and Hollenberg 1976).

Habitat and Geographic Range

An abundant species in wave restricted areas on rocks, primarily on sand-swept reefs. *Neorhodomela larix* ranges from the North Alaska to Baja California, Mexico (Lamb and Hanby 2005). Rare south of Government Pt. (Santa Barbara Co.).

Synonyms

Rhodomela larix

Similar species

Odonthalia foccosa have loose bushy tufts of branches with sharp tips compared to the tighter tufts with blunt tips of *N. larix*. *O.washingotniensis* has branches distinctly and markedly fattened resembling a fattened "primitive" Christmas tree. *Neorhodomela oregona* is quite similar in appearance to *N. larix*, but it is not quite as coarse and stiff, it has more orders of branching, and its branchlets are not so obviously bunched (O'Clair and Lindstrom 2000).

Natural History

N. larix is a tough perennial alga with annual thalli that either get beaten back or torn loose by winter storms, leaving behind small tufts or encrusting holdfasts (Abbott and Hollenberg 1976, D'Antonio 1985). When a thallus is broken off, rather than pulled up from the base, the remaining attached portion may persist throughout the following spring and summer (D'Antonio 1982). It is thought that individual axes may live 1 to 3 years while the boundaries of *N. larix* clumps may be maintained for >25 years (D'Antonio 1985). A study of turf-forming algal communities in the low intertidal region of the Oregon coast described *Neorhodomela larix* as one of the most abundant, wave-sheltered red algal species (Menge et al. 1993). *Neorhodomela larix* has an isomorphic life cycle; gametophytes look identical to tetrasporophytes (O'Clair and Lindstrom 2000). Spore release can occur at all times during the year except during winter, but Menge et al. (1993) documented low recruitment, suggesting that the high abundance of this alga depends on vegetative growth and long persistence. *N. larix* is a host for at least 17 species of sessile plants and animals on the central coast in Oregon (D'Antonio 1985). D' Antonio (1985) suggests that epiphytes decrease the growth rate of *N. larix*, increase the probability of axis breakage, and decrease reproductive output while providing food for littorine snails and gammarid amphipods that live in the beds of this alga.

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Red Algal Turf - Photo Plots

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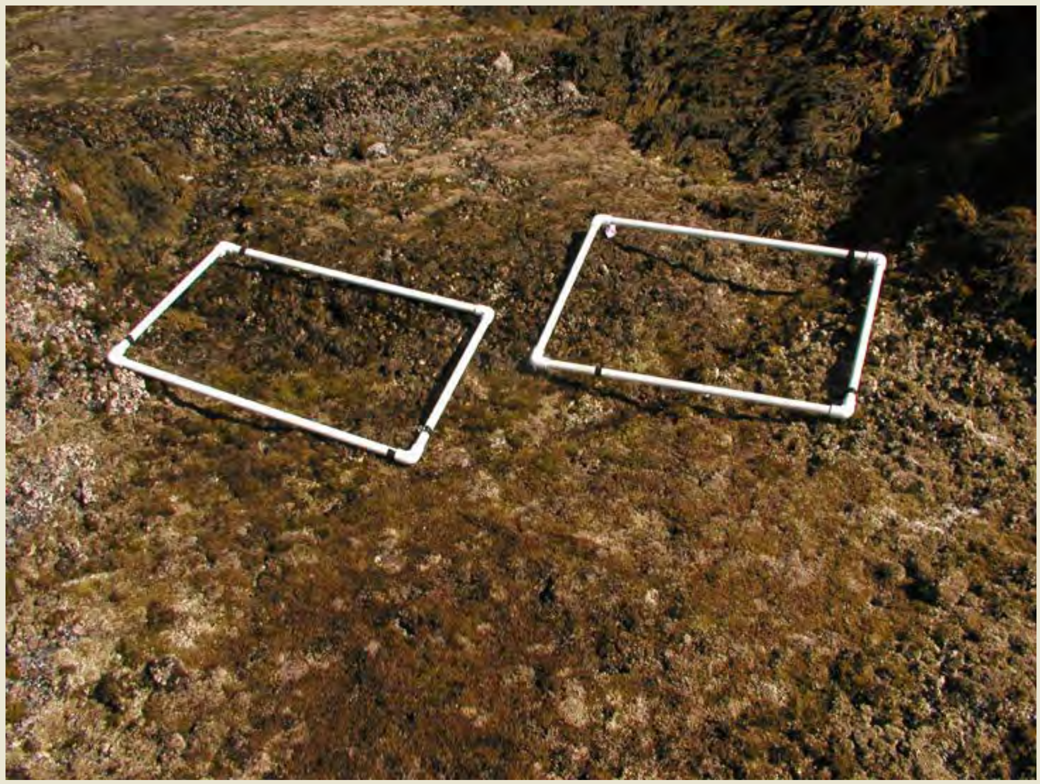

Some photoplots at Southern California monitoring locations target single or mixed species of turfy flamentous red algae (other than *Endocladia muricata*), primarily *Gelidium* spp and *Chondracanthus canaliculatus*. These species or species groups were chosen because they were especially prominent at certain sites, representing unique tidal zones. Such turfs can form low thickets that support communities of tiny invertebrates that are highly productive and important as food for larger organisms such as fshes and shore birds (see also Red Algal Turf - Transects).

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Tar - Photo Plots

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Petroleum tar is a non-biological feature targeted in some photoplots. For monitoring purposes, tar includes fresh or weathered oil or thicker tar coating the substrate. Both natural and anthropogenic in origin, foating oil and tar from seeps, leaks, and spills can wash ashore and stick to intertidal rocks. The Santa Barbara region in particular is rich with oil feld deposits, with coastal tar seeps utilized historically by Native Americans to caulk their boats. Gas and oil/tar have been documented seeping from beneath shallow coastal waters such as off Coal Oil Point and from other deeper-water locations in the region. As a result, some shoreline areas along the islands and mainland can have locally dense tar cover in the upper intertidal, especially where wave action is slow to erode it. These areas may signify nearby seeps, or be a refection of local conditions (e.g., currents, winds, swells and topography such as coves) that foster the accumulation of foating debris.

Tar was selected as a target feature to evaluate the longevity of tar patches, the frequency of fresh depositing, and its biological effects. Tar may smother barnacles, limpets, and other creatures; coat seaweeds (reducing their ability to utilize sunlight); and interfere with settlement and grazing by intertidal life. Seasonal and long-term interactions can be elucidated by monitoring both tar and marine species abundance trends.

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Recovery Plots

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At two MARINe sites, we have been provided with the opportunity to study the natural recovery of an intertidal community following extreme disturbance events. In 1997/98, powerful surf caused by a strong El Niño event removed huge sections of reef (up to 17m x 5m) at Stairs, a Central California region site. This massive disturbance event left several large, newly exposed areas of bare rock, within which we established "Recovery" plots to document community succession in the mid-intertidal region. Nearly all succession studies are done in artifcially cleared patches which, because they are usually small relative to the size of the reef, often recover via encroachment by surrounding species. Because the newly exposed areas at Stairs were so large, they were likely to recover via colonization by propagules and thus had the potential to develop into communities quite different from surrounding, undisturbed areas. Eight recovery plots were originally set-up, but four have been lost over time due to additional large-wave events that have removed more sections of reef.

Two recovery plots were also established in 2003 at Sandhill Bluff, another Central California site, where an area of mussel bed (3m x 2m) was cleared when a section of rock exfoliated. Monitoring recovery from natural disturbance events helps us to better understand patterns of community change in the rocky intertidal.

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Rock Plots

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One of the most conspicuous patterns observed in this long term monitoring program is a trend toward zonal transitions among species assemblages. At sites distributed across the latitudinal breadth of the MARINe monitoring network, species assemblages have exhibited periodic, upward shifts in the intertidal. For example, *Silvetia* assemblages have encroached upon the *Endocladia* plots, and *Endocladia* has moved into barnacle plots. These upward shifts appear to be cyclic, with zonal transitions reversing after some time period and assemblages returning to their “original” state. However, with sea-level rise and other climate-change related factors, it is possible that these short-term cyclic zonal shifts could instead become long-term directional change. At most MARINe sites, the area above the barnacles consists primarily of bare rock, but we have not been specifcally targeting the “extreme high” zone for change, and thus would be unable to document an upward shift of the barnacle zone.

To address this issue, “Rock Plots” have been recently added at a number of MARINe sites in the Southern California region and on the Channel Islands. These plots will aid in documenting any upward shifts of communities into the extreme high zone, and could potentially serve as an early warning sign of rising sea level or other effects of climate change.

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Egregia (Feather-Boa Kelp)

Egregia menziesii (Turner 1808)

Kingdom Chromista, Phylum Ochrophyta, Class Phaeophyceae, Order Laminariales

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Description

Thick, fattened, and strap-like axes (each referred to as a rachis), with numerous small, lateral blades (can be fat, broad, narrow , fliform to cylindrical) and foats along the margin. Thallus arises from a dense, hapterous holdfast which can become feshy and cone-like in large plants (Abbott and Hollenberg 1976). Thallus morphology approximately correlated with geographic distribution: northern populations (Alaska to Cape Mendicino) have tuberculate rachi, smooth sporophylls, and narrow, thick spatulate laterals (Blanchette et al. 2002); populations from Los Angeles to Baja California have smooth rachi, wrinkled sporophylls, and both broad, spatulate and narrow, fliform laterals; populations located in between have mixed and variable morphologies; southern California thalli initially produce spatulate laterals but then begin producing fliform laterals as they grow (Henkel 2003).

Habitat and Geographic Range

Common on lower intertidal rocks, in protected to moderately wave-exposed areas from mid- to subtidal (20m), *E. menziesii* is often found mixed with *Macrocystis* at the inner edges of kelp beds as well as growing in mixed stands with *Phyllospadix* spp. This species inhabits a geographic range from Alaska to Punta Eugenia, Baja California (Abbott and Hollenberg 1976).

Synonyms

Includes entities previously assigned *Egregia laevigata*

Similar species

Juvenile *Eisenia arborea* is corrugated on the blade surface, whereas *Egregia* is smooth (southern) or uncorrugated and tuberculate (northern).

Natural History

Egregia is one of the most conspicuous algae in the intertidal zone. It provides shelter for many species of understory algae and invertebrates (Humphrey 1965). *Notoacmea insessa* is a limpet only found on *Egregia*, where it grazes on the rachis, producing oval scars or pits. This grazing activity can result in axis breakage and cause mortality in the kelp (Black 1974). *Egregia* is sensitive to desiccation and heat stress on the lowest midday tides (Engle and Davis 1996). High mortality has been associated with warm water events, such as during the 1982/83 El Niño period (Gunhill 1985). Poor water quality might also affect *Egregia,* as it was noticeably absent near a sewage outfall (Littler and Murray 1975). If recruitment is successful, recovery of *Egregia* populations can occur in as little as fve months to 2 years due to fast growth rates (Murray and Littler 1979, Vesco and Gillard 1980).

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Saccharina (Sea Cabbage)

Saccharina sessile (C. Agardh 1824)

Kingdom Chromista, phylum Ochrophyta, class Phaeophyceae, order Laminariales, Family Laminariaceae

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Description

This brown kelp has no stipe as an adult, with an often well-developed holdfast. The blades vary between bright and dark brown and can grow to 150 cm in length and 80 cm wide, more commonly 30-50 cm long. There is much variation in morphology among individuals from a broad, ruffed or bullate blade to a smooth and deeply divided blade (Abbott and Hollenberg 1976).

Habitat and Geographic Range

Saccharina sessile is dominant in the lower intertidal from AK to OR, especially areas of low to moderate wave exposure (Graham et al. 2000) Found on rocks in the mid to low-intertidal zones in sheltered bays to open coasts from Aleutian Islands, AK to Monterey, CA. Rare in California (Armstrong 1984, Abbott and Hollenberg 1976).

Synonyms

Hedophyllum sessile

Similar species

None

Natural History

Saccharina sessile blade morphology differs between exposed and sheltered areas. In protected locations the blades are broad, ruffed and generally longer (30-50 cm), which, according to Armstrong (1989), is an adaptation to life in low fow areas which increases water fow across the thallus for nutrient absorption and gas exchange. In exposed areas the blades are smooth and deeply divided, rarely more than 30 cm tall, allowing for a more compact shape at high current speeds (Armstrong 1989), although thallus size, not morphology appears to be the most important factor in reducing drag (Milligan & DeWreede 2004). Individuals at wave exposed sites have also been shown to have stiffer and stronger tissues and larger mean breaking strains than those found at more sheltered locations (Armstrong 1982).

Saccharina becomes fertile in the late fall and winter with maximum sporophyte growth during the summer (O'Clair and Lindstrom 2000). As with other kelps, *Saccharina* has a microscopic gametophyte stage that produces gametes that fuse and form microscopic sporophytes that eventually grow into the visible macrophytes. These microscopic stages are found primarily near adult macrophytes, and may be able to persist until environmental conditions are favorable for reproduction or growth (Fox and Swanson 2007). *Saccharina* is a poor competitor with other algae, and thrives in the presence of grazers, which generally prefer other algae, thus freeing up space for the kelp (O'Clair and Sandstrom 2000). *Saccharina* provides canopy cover for many low intertidal species, including the chiton *Katharina tunicata*. Unlike most other grazers, *Katharina* will eat *Saccharina*, and chews on and burrows into the holdfasts of young plants. This action degrades holdfast integrity and makes these smaller individuals susceptible to wave-induced mortality (Markel and DeWreede 1998).

Saccharina may be sensitive to warming oceanic water temperatures; Lüning and Neushul (1978) found that female gametophyte fertility peaked at 12˚ C and dropped to 0% at 17˚ C in samples from central CA and individuals of this species from Friday Harbor, WA and Vancouver Is, British Columbia demonstrated positive net photosynthesis only in the -1.5 ˚ C – 15 ˚ C water temperature range (Lüning and Freshwater 1988).

Climate change coupled with anthropogenic eutrophication may also indirectly impact *Saccharina* productivity through increased phytoplankton blooms. A study by Kavanaough et al. (2010) showed that *S. sessile* is negatively affected by shading that mimics phytoplankton-induced light limitation. The results link light limitation with strongly decreased growth rates and abundances of *S. sessile* and conclude that in open coast systems, where perennial macrophytes such as kelp and surf grasses are important habitat modifers, large-scale reduction of macrophytes via phytoplankton shading could lead to profound modifcations of coastal ecosystem dynamics.

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Red Algal Turf - Transects

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Red algal turf is a mixed species assemblage of low-growing (<7 cm high) algae that carpets the middle intertidal zones of coastal reefs, particularly in southern California. Species composition within the turf community varies geographically. In San Diego County this turf can contain as many as 67 types of small red, brown, and green algae; however, red algae predominate - in particular calcium carbonate containing articulated coralline algae of the genus *Corallina*. (Stewart & Myers 1980; Stewart 1982; Stewart 1989a,b).

Red turf is best developed on relatively fat reefs where the algal mat forms a meshwork that traps sand and shell particles. By cementing frmly to the rock, the perennial calcareous algae form a low , but highly structured thicket that supports diverse epiphytic plants and infaunal animals. These smaller, inconspicuous organisms are of high ecological importance due to their abundance, high productivity, and importance as prey for larger organisms like shore birds (Brown and Taylor 1999). The sea anemone, *Anthopleura*, is the most conspicuous invertebrate within the turf assemblage. Turf may also enhance recruitment of mussels by providing attachment surfaces and a relatively sheltered micro-environment. Typically, the algal turf zone is located just above the surf grass zone, because turf is better able to withstand desiccation (Stewart 1989a). The *Corallina* species dominating the turf can bleach and die-back during daytime exposures to dry air, or flaments may be broken of f by storm waves, but erect portions grow back from the crusts that persist after such disturbances (Stewart 1989b). They also are highly resistant to sand abrasion and burial which commonly occurs on low-sloping reefs. *Corallina* crusts can survive more than a year under sand; once re-exposed, they regain pink color and start growing erect portions within two weeks (Stewart 1989b).

Red algal turf was chosen for long-term monitoring at San Diego County sites because it is widespread in the middle intertidal zone; may bleach or die in response to oil, municipal wastes, or other pollutants (Foster et al. 1988); and typically occurs on fat reefs where most tidepool visitors walk during mid and low tide periods. Trampling can “wear down” the turf, break crusty *Corallina* flaments, and crush tiny invertebrate inhabitants. Huff (2011) conducted experimental trampling studies in San Diego, fnding that bare space increased in trampled plots, and that trampled plots exhibited shifts in invertebrate species composition as well as signifcant declines in marine life richness and abundance.

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Phyllospadix (Surfgrass)

Phyllospadix scouleri, Phyllospadix torreyi (W.J. Hooker 1838)

Kingdom Plantae, phylum Tracheophyta, class Monocots, order Alismatales, family Cymodoceaceae

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Description

Surfgrass is an angiosperm with true leaves, stems, and rootstocks; not an alga.

P. scouleri leaf blades are characteristically fat and wide (2-4 mm) reaching no longer than 3 feet in length. Leaves arise from a congested rhizotomous base and fowers are found near the base on short stalks (1-6 cm).

P. torreyi leaves are characteristically less than 2 mm wide and are generally more frm, cylindrical, and wiry than *P. scouleri*. Leaf blades can reach up to 10ft long. The leaves arise from a congested rhizotomous base with fowers on elongate stalks (>10 cm long). (Adams 2006).

Habitat and Geographic Range

P. scouleri can be found at or below zero tide level or in mid-low tide pools from Sitka, Alaska, to Baja California (O'Clair and Lindstrom 2000). Mostly found on rocks without sand inundation. (Kozloff 1996).

P. torreyi can be found at or below zero tide level or in mid-low tide pools from Vancouver Island California to Baja California (Phillips and Ernani 1988). *P. torreyi* is more likely to be found in sand-scoured areas than is *P. scouleri* (Kozloff 1996).

Synonyms

None

Similar species

Zostera marina has broader leaves and occurs in more wave-protected locations. *Phyllospadix serrulatus* has serrated margins that can be felt by stroking the leaf margin and occurs from Cape Arago, Oregon north to Alaska

Natural History

Surf grasses grow as perennials and adult plants are reproductively dioecious with male and female fowers on dif ferent adult plants. Surf grasses can pollinate both underwater and at the surface in sea water. Surfgrass ranks amongst the most productive of the marine primary producers (Duarte and Chiscano 1999), with these habitats providing shelter for many invertebrates and supporting many species of algae

(Stewart and Myers 1980). The red algae *Smithora naiadum* and *Melobesia mediocris* are exclusively epiphytic on sea grasses (Abbott and Hollenberg 1976). Surfgrass also provides nursery habitat for fshes and invertebrates, some of which are commercially important, such as the California spiny lobster (Engle 1979).

Surfgrass beds increase water clarity by fltering water and trapping sediments and can stabilize the sediment, preventing erosion. Seagrass metabolism changes the concentration of carbon and oxygen in water by sequestering carbon dioxide and respiring oxygen. Surfgrass forests can modify the severity of water currents, making near shore habitats relatively protected from big surf. The structure of surfgrass canopies modifes water current velocity and waves, enhancing sedimentation of suspended particles and preventing sediment resuspension (Garcia and Duarte 2001).

Phyllospadix is susceptible to desiccation and heat stress during low midday tides (Raimondi et al. 1999). It is also sensitive to sewage (Littler and Murray 1975) and oiling (Foster et al. 1988). If the rhizome systems remain viable, recovery following disturbance can be fairly rapid; however, if the entire bed is lost recovery is slow because recruitment is sporadic and restoration projects have thus far been unsuccessful (Turner 1983, 1985). Other threats to surfgrasses include coastal development, thermal pollution (power plants), invasion of non-natives (e.g. *Caulerpa taxifolia*), and dislodgement caused by anchors. The sensitivity of seagrass habitats to declines in ecosystem health coupled with their fundamental role in sheltering countless other species (many of which have commercial value) has led to their protection at the United States federal level under Section 404 of the Clean Water Act as well as in Section 10 of the Rivers and Harbors Act. The Environmental Protection Agency holds the responsibility of enforcing these pieces of legislation which aim to protect these habitats from unpermitted dredging and flling activities (Green 2003).

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Pisaster (Ochre Star)

Pisaster ochraceus (Brandt 1835)

Phylum Echinodermata, class Asteroidea, order Forcipulatida

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Sea Star Wasting Syndrome

Since summer, 2013, sea stars along much of the North American Pacifc coast are dying in great numbers from a mysterious wasting syndrome. For more information about this, please click here.

Description

Highly variable in color; most commonly purple, but can also be orange, orange-ochre, yellow, reddish, or shades of brown. A “brilliant purple” morph is common in the inland waters of Washington and British Columbia. 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.

Habitat and Geographic Range

Common in the middle to low intertidal zones on wave-swept rocky shores. Also found subtidally on rocks to 90 m. Juveniles are cryptic and are often found in crevices, under rocks and within mussel beds. Prince William Sound (Alaska) to Baja California, Mexico (Lamb & Hanby 2005)

Synonyms

None

Similar species

Pisaster giganteus has fewer, bigger, and longer aboral spines surrounded by blue rings than *P. ochraceus* and these spines are more uniformly spaced and never form a star-shaped pattern. *Pisaster brevispinus* is pink with small, white spines and is a low intertidal to subtidal species (Morris et al. 1980). *Evasterias troschelii* has longer, more slender arms than *P. ochraceus*, and spines on the central part of the disk do not form a star-shaped pattern.

Natural History

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). In the protected inland waters of Washington and British Columbia, mussels are often rare and *Pisaster* feeds primarily on barnacles and whelks (Harley et al. 2006). Using their tube feet to pull the valves apart,*Pisaster* are able to evert their stomachs and insert them between the valves of a mussel (Morris et al. 1980). 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). Motile prey have been shown to exhibit escape responses to the chemical presence of *Pisaster* (Morris et al. 1980). A study examining the effect of low tide body temperature of *P. ochracheus* on feeding rates showed that aerial body temperatures experienced by *P. ochraceus* can have profound effects on predation rates (Pincebourde et al. 2008).

Ochre sea stars stand out in the intertidal due to their vibrantly contrasting color differences, ranging from bright orange to purple. 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).

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. Throughout southern California, severe declines of *P. ochraceus* (and other seastar) 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. 2000). The causative agent for this seastar "wasting disease" has not been confrmed, but may be a *Vibrio* bacterium (Eckert et al. 2000). 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.

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Katharina (Black Katy Chiton)

Katharina tunicata (Wood, 1815)

Phylum Mollusca, class Polyplacophora, order Neoloricata, family Mopaliidae

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Description

An elongated oval chiton that grows to 12 cm in length. The girdle (dorsal portion of the mantle that borders the 8 shell plates) is shiny black, thick and leathery and covers all but the mid-dorsal area (Morris et al. 1980).

Habitat and Geographic Range

Common in the middle and low intertidal zones attached to rocky substrate from Alaska to Point Conception, CA, and Kamchatka, Russia (Morris et al. 1980).

Synonyms

Similar species

The thick black girdle distinguishes this chiton from other species.

Natural History

Katharina are slow moving grazers that feed on many species of brown and red algae as well as benthic diatoms. Predators include leather stars, urchins, birds, sea otters and humans. Black Katy chitons are dioecious with external fertilization. An annual cycle of spawning has been noted with some seasonal variation among geographic regions (Himmelman 1978). Spawning is triggered by increasing temperature and may be linked to phytoplankton blooms. The females release small (about 230 mm in diameter) brown-colored eggs which are fertilized when the male releases his sperm. Once fertilized, the zygote develops into a free-swimming trochophore larvae. In laboratory studies these swimming larvae preferentially settled on a specifc genus of coralline algae, *Lithothamnium* spp. (Rumrill and Cameron 1983), and rapidly metamorphosed into juveniles (within approximately 2.5 hours). Metamorphosis is considerably delayed when the chiton settles on a substrate lacking *Lithothamnium sp*. *Katharina tunicata* typically reaches sexual maturity after two years (about 35 mm in length). After reaching maturity, adults live for about 3 years.

Where *K. tunicata* attain both high densities and biomass they have been shown to have ecological importance in shaping community composition (Dethier and Duggins 1988). When *K. tunicata* feeds on large algae, more sunlight reaches the substrate on which they live. This increase in sunlight promotes the growth of diatoms, which are a favored dietary component of limpets and other chitons and may shift the composition of the algal community. Removal experiments of *K. tunicata* in Washington resulted in dramatic changes to the community structure (Dethier and Duggins 1988) with a resulting multilayered algal canopy and decrease in limpet cover. However; results in Alaska did not show a strong interaction between *Katharina* removal and community composition.

A study by Salomon et al. (2007) looked at various factors contributing to the recent (10-15 years) decline in *K. tunicata* densities and sizes on the outer Kenai Peninsula, Alaska. Harvesting of *Katharina* occurs in this region and the species is part of a culturally important subsistence fshery for Sugpiaq (Chugach Alutiiq) natives. Human harvesting in this region dates back 3000 years. The study suggests the reduction in *Katharina* is due to multiple factors including the recent recovery of sea otters and increased fshing effciency and ef fort in part due to indirect socioeconomic effects of the 1989 Exxon Valdez oil spill.

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Katharina (Black Katy Chiton)

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Haliotis cracherodii (Black Abalone)

Haliotis cracherodii (Leach 1814)

Phylum Mollusca, class Gastropoda, order Archaeogastropoda

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Description

Shell exterior is dark blue, dark green, or black, smooth and usually epiphyte-free; up to 20cm in length. There are usually fve to nine open respiratory pores sitting fush with the shell' s surface. Shell interior is pearly, with pink and green iridescence. The mantle and tentacles are black (Morris et al. 1980).

Habitat and Geographic Range

Black abalone inhabit suitable rocky substrate from the high intertidal zone to 6 m depth but are most abundant in the mid-low intertidal. Their current range is from about Point Arena in northern California to Southern Baja California (MARINe). Black abalone are rare north of San Francisco and south of Punta Eugenia, Baja with unconfrmed sightings reported as far north as Coos Bay, Oregon (Cox 1962, Morris et al 1980).

Synonyms

Similar species

A smooth dark shell and 5-9 round, fat shell holes distinguishes black from other abalone species. *H. rufescens*, which sometimes occurs intertidally, has a reddish to pink colored shell, commonly overgrown, and 3-4 open shell holes which are externally raised. Pink (*H. corrugata*) and green (*H. fulgens*) abalone occasionally occur in the intertidal. Pinks are dull green to reddish brown, highly corrugated, with 2-4 large, elevated holes, and the edge of the shell is usually quite scalloped. Greens are olive green to reddish brown, with numerous, broad, fat-topped ribs, and 5-7 small, circular, slightly elevated holes.

Natural History

Black abalone are typically found clustered in crevices, under boulders, or on the walls of surge channels along exposed shores. Little is known about the requirements of newly settled black abalone, but they are believed to inhabit cryptic locations such as narrow crevices, undersides of boulders, and the interstices of mussel beds (Tissot 1995, Dan Richards pers. com.). Juveniles appear to be fairly motile, and likely graze on crustose coralline algae and micro fora, such as diatom flms (Garland et al. 1985, Shepherd and Turner 1985); adults tend to be more sessile, feeding primarily on drift algae, especially brown kelps (Bergen, 1971, Blecha et al.,1992, Leighton and Boolootian1963, Morris et al. 1980). Growth varies with size, location, and other environmental factors, but does appear to be slow—about 20mm in the frst year , and 10-20mm per year over the next several years, then slowing at sizes of approximately 100mm (Leighton and Boolootian1963, Morris et al. 1980). Black abalone become reproductively mature at around 45mm (between 3-7 years old) (Ault 1985). Absolute longevity has not been determined, but ages greater than 30 years appear likely based on tagging and other population studies (e.g. VanBlaricom 1993). Before recent catastrophic declines (see below), black abalone were very abundant and could occasionally be seen stacked on top of each other, reaching densities of more than 100/m² (Douros 1987, Richards and Davis 1993).

Black abalone are broadcast spawners, and fecundity (number of gametes produced) is directly related to adult size, with older, larger individuals producing signifcantly higher numbers of gametes than newly mature, smaller animals. Because gametes are released into the turbulent intertidal environment, close proximity of male and female abalone is assumed to be necessary for successful fertilization to occur (Prince et al. 1987, Miller & Lawrenz-Miller 1993). The requirements of black abalone larvae are not well known, but based on studies of other abalone species, it is thought that they spend 3-10 days in the water column before settling (e.g. McShane 1992). Larvae are thought to be relatively passive, and recruitment is believed to be generally localized, particularly in areas with offshore features such as kelp beds, which have been shown to retain larvae of other abalone species (McShane et al. 1988, Prince et al. 1988, Hamm & Burton 2000, Chambers et al. 2006). Other abalone species require the presence of crustose coralline algae to induce settlement (Morse et al 1979), and it is assumed (although not verifed) that black abalone share this requirement.

Although once an important human resource, the black abalone fshery was closed in 1993 due to massive population declines. Intense fshing may have been responsible for declines in southern California, but the primary cause of decline throughout much of the black abalone's range is a fatal disease called withering syndrome (WS). WS is caused by a gastrointestinal Rickettsiales-like prokaryote that interferes with digestion and results in the shrinking of an animal's foot and eventual weakening so it can no longer attach to the substratum (Friedman et al. 2000). Declines were frst documented on the Channel Islands in 1985 and subsequently spread to the mainland in 1992 (Lafferty & Kuris 1993, Richards & Davis 1993, Altstatt et al. 1996, Raimondi et al. 2002). Now a federally listed endangered species, *H. cracherodii's* decline continues to spread north, with little to no signs of recovery at impacted sites. WS tends to move rapidly during El Niño events, when ocean temperatures are warm; hence cooler water sites to the north may only be temporarily protected (Raimondi et al. 2002). The general pattern of mortality once die-offs begin is that the population decreases by > 95%, leaving a few scattered individuals. This scarcity of survivors is a serious threat to black abalone recovery, because individuals are often too distant from one another for successful fertilization to occur (see reproduction above). We have seen virtually no recruitment of new individuals to mainland sites that have been impacted by WS, and, only recently, minimal recruitment to island sites. Ironically, successful recruitment into areas impacted by mass mortality events may be dependent on the presence of healthy, conspecifc adults. These large, long-lived grazers may maintain suitable conditions for recruitment of conspecifcs by preventing colonization of other organisms by pre-empting space on the substratum and dislodging newly settled larvae or algal spores through their movements and grazing (Cox 1962, Leighton & Boolootian 1963, Blecha et al. 1992, Richards & Davis 1993, Miner et al 2006). Our work suggests that following mass mortality events, communities that formerly supported large numbers of abalone change from open areas dominated by crustose coralline algae and bare rock to habitat encrusted with increased cover of sessile invertebrates and feshy algae (Miner et al. 2006).

In addition to WS, other sources of mortality include: smothering by sand burial, dislodgment by storm waves, and predation by octopus, sea stars, fshes, and sea otters (Morris et al. 1980; VanBlaricom 1993). Oil impacts are not well known, but black abalone mortality was documented following an oil spill in Baja California (North et al. 1965). In response to the mass mortalities along the coast of California, black abalone are now protected under the USA Endangered Species Act. An Abalone Recovery Management Plan was adopted by the state of California in 2005. In October 2011, the National Marine Fisheries Service designated critical habitat for black abalone. Various projects are in place to monitor the species' status, better understand WS, increase knowledge about the requirements for successful reproduction and recruitment, protect and restore (where appropriate) black abalone habitat, and minimize illegal harvest.

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Haliotis rufescens (Red Abalone)

Haliotis rufescens (Swainson 1822)

Phylum Mollusca, class Gastropoda, order Archaeogastropoda

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Description

Shell exterior is brick red to pink and commonly overgrown with epiphytes reaching a maximum of 30 cm. There are usually 3-4 oval, open respiratory pores which are externally raised above the shell's surface. The shell interior is iridescent with a large, oval muscle scar. (Morris et al. 1980). The mantle and tentacles are black and the underside of the foot is yellowish.

Habitat and Geographic Range

Red abalone inhabit rocky areas with kelp. They are uncommon in the low intertidal zone and more abundant subtidally to around 40 m depth (up to 180 m). Their current range is from Oregon to Baja (California Fish and Game Commission 2005).

Synonyms

Similar species

Haliotis cracherodii, (black abalone), is the primary species encountered in the intertidal, and has a smooth dark shell with 5-9 round, fat shell holes. Pink (*H. corrugata*) and green (*H. fulgens*) abalone occasionally occur in the intertidal. Pinks are dull green to reddish brown, highly corrugated, with 2-4 large, elevated holes, and the edge of the shell is usually quite scalloped. Greens are olive green to reddish brown, with numerous, broad, fat-topped ribs, and 5-7 small, circular , slightly elevated holes.

Natural History

The red abalone is the largest species of abalone in the world and the most common abalone found in Northern California. Red abalone sometimes occur intertidally, but are more common subtidally. Most California abalones mature at between 3 and 7 years of age and may live for 35 to 54 years (Haaker et al., 1986). They are slow-growing herbivores, feeding mostly on drift kelp. Sea otters and humans are the main predators of adults. Where sea otters are present red abalone occur mostly in deep cracks and crevices, but they may be seen out in the open in regions lacking sea otters (Hines and Pearse 1982).

Abalone broadcast spawn, releasing their eggs and sperm into the ocean. Fecundity (number of gametes produced) is directly related to adult size, with older, larger individuals producing signifcantly higher numbers of gametes than newly mature, smaller animals. Because gametes are broadcast into the nearshore environment, successful fertilization relies on large adult populations living in close proximity (Prince et al. 1987). Warm water was shown to have deleterious affects on sperm production of red abalone suggesting the importance of considering ocean warming trends in recovery and management plans (Rogers-Bennett et. al. 2010). Larval development rate and length of the swimming larval period are also infuenced by temperature. At their optimum temperature (14-16 ^{o} C), red abalone larvae hatch about one day after fertilization, develop into a morphologically mature veliger larvae after three days and are capable of metamorphosis after about seven days (Morse et al. 1979). Red abalone settlement and metamorphosis are strongly associated with the presence of crustose coralline algae (Morse et al. 1984, Boxshall 2000).

Red abalone populations have declined mainly due to overharvesting, predation by sea otters and disease. A chronic wasting disease called withering syndrome (WS) has affected red abalone populations, although, the disease is not well studied for this species. See the black abalone species description for more information on WS. The presence of WS in red abalone has been most notable in red abalone commercial farms, especially during oceanic warming events such as the 1997-98 El Niño (Moore et al. 2000). The recovery of sea otters (Enhydra lutris) along the California coast, during the 1900s, has created contention within the commercial and recreational fsheries for red abalone. Sea otters have been shown to affect abalone densities, sizes and behavior. The challenge of protecting both sea otters and abalone populations requires special consideration. Fanshawe et al. suggest that where sea otters limit the sustainability of red abalone it may be necessary to create two spatially separated categories of marine protected areas (2003).

Human uses of red abalone dates to prehistoric times with shells found in Channel Island archaeological sites dated to between 11,500 and 12,000 years before present (Braje et. Al. 2009). Red abalone shells are abundant in Chumash middens (refuse deposits) of the Northern Channel Islands dated between about 7500 and 3300 years ago. The modern Californian fshery for abalone peaked in the 1950s and '60s with a subsequent decline in populations. Due to drastic population declines, the commercial fshery of red abalone was closed in 1997. Currently , red abalone are legally harvested on a restricted, recreational basis only in Northern California (north of San Francisco). An Abalone Recovery and Management Plan (ARMP) was adopted in 2005 by the Fish and Game Commission to manage the recreational fshery in Northern California and aid in the recovery of the depleted abalone in the rest of California (California Fish and Game Commission 2005).

Since most of the wild populations of abalone have been decimated, abalone farming has become an increasingly successful mariculture. Attempts to culture abalone began in California in the 1960s and developed into a successful business by the 1980s (Leighton 1989). Red and green abalone are the only species farmed on a large scale in California with red abalone farming concentrated north of Point

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Lottia gigantea (Owl Limpet)

Lottia gigantea (Sowerby 1834)

Phylum Mollusca, class Gastropoda, order Patellogastropoda

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Description

Shell length can be 100mm (Lindberg 1981) or greater (Raimondi et al.

2012). Shell is oval with a low profle and anterior apex. Exterior surface is chocolate brown with white markings (can have checker board pattern) and often rough and eroded. The interior is dark with a brown margin and prominent owl-shaped markings within bluish muscle scar. Side of foot is gray and sole is orange or yellow (Morris et al. 1980). When on mussel beds apex is more centered and resembles *Lotia pelta* (i.e., smooth).

Habitat and Geographic Range

Common on cliff faces and rocks on wave-exposed shores in the high and middle intertidal zone. Washington to Baja California (Morris et al. 1980). Scarce north of San Francisco.

Synonyms

Similar species

Distinguished from other *Lottia* spp. by large size, low height and anterior apex.

Natural History

Lottia gigantea can either be territorial, maintaining and defending clearings of thick algal flm, or non-territorial, intruding on other limpets' algal farms to graze (Stimson 1969. Shanks 2002). *L. gigantea* are protandrous hermaphrodites, with a transformation from male to female generally occurring in association with increased size, and the acquisition of a territory (Wright 1989). Thus non-territorial individuals tend to be the smaller males, while larger individuals are typically females with farms (Lindberg and Wright 1985). *L. gigantea* maintain territories on rocks by grazing or bulldozing other competitors for rock space (Stimpson 1970). This action creates space and promotes the algal growth upon which they graze (Stimson 1973). Territorial owl limpets, which can occupy the same farms for at least 4 years, have been shown to graze at much lower rates than non-territorial owl limpets, who must acquire food rapidly from another limpet's farm before they are bulldozed off (Shanks 2002). Algal farms vary in appearance with *L. gigantea* size and structural features of the substrate, creating a patchwork of differing microhabitats. Lindberg et al. (1998) have shown that if *L. gigantea* are removed from an area, cover of erect, feshy algae increases, followed by increases in the number of small limpets, thus changes in *L. gigantea* populations may greatly affect abundances of other species (Kido and Murray 2003). *L.*

gigantea tend to occupy one or more characteristic "home scars" within their territories. Here the shell margin conforms to the rock surface, making a tight seal to hold moisture during low tide. The owl limpet can be found at the edge of mussel beds or under rock faces to prevent desiccation or decrease wave exposure (Raimondi et al. 1999). The largest limpets are estimated at 10-15 years old and are believed to breed in the fall and early winter in California (Morris et al. 1980).

Although limpets and their feeding territories may be vulnerable to oiling, oil impacts are unclear. Owl limpets were not obviously affected by the 1971 San Francisco oil spill (Chan 1973), but recovery from any major disturbance likely would be lengthy (Raimondi et al. 1999). Commercial harvesting of *L. gigantea* is illegal throughout California, but recreational take of up to 35 individuals per day is allowed outside areas designated as marine reserves. Harvesters typically collect large, likely female individuals, which may skew the gender ratio of *L. gigantea* populations and decrease reproduction (Kido and Murray 2003). Illegal take is among the biggest threats to owl limpet populations, and assessment of long-term monitoring of *L. gigantea* shows that the amount of enforcement against poaching is a better predictor of size structure than proximity to population centers or visitation to intertidal sites (Engle et al. 2006).

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Postelsia (Sea palm)

Postelsia palmaeformis (Ruprecht 1852)

Kingdom Chromista, phylum Ochrophyta, class Phaeophyceae, order Laminariales, Family Laminariaceae

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Description

Resembles a small palm tree, up to 60 cm tall with a thick, fexible, cylindrical stipe and small hapterous holdfast. Plants can have as many as 100+ grooved blades that reach 25 cm long and hang down when plants are exposed at low tide. Mature plants turn from green to golden brown. Usually found growing in extensive stands (Abbott and Hollenberg 1976).

Habitat and Geographic Range

Found in mid-intertidal zone in areas of high wave exposure; distribution patchy, but typically abundant where present. Vancover I., Br. Columbia, to San Luis Obispo Co., Calif. (Abbott and Hollenberg 1976).

Synonyms

None

Similar species

None

Natural History

This annual brown alga exhibits heteromorphic alternation of generations, with two distinct phenotypic phases: the macroscopic diploid (2N) sporophyte and the microscopic haploid gametophyte (1N) (Blanchette 1996). *Postelsia* sporophytes generally frst appear in winter , grow rapidly in spring, become reproductive in late spring/early summer and are typically ripped out by large winter storms (Blanchette 1996). Spores are released during low tide and remain in grooves of blades, dripping off the slender tips onto the surrounding substrate, which results in very limited dispersal (Abbott and Hollenberg 1976). These spores grow into haploid gametophytes, which release gametes that fuse and grow into the visible sporophytes.

Postelsia appears to have a complex relationship with the mussel, *Mytilus californianus*. The microscopic female and male gametophytes establish themselves within mussel beds, which may be ideal for germination and protection from wave exposure. When mussels are cleared from the rocks by harsh waves or predation, the diploid sporophytes resulting from gamete release can begin to grow (Blanchette 1996). Without a disturbance to open up space within the mussel beds, the juvenile *Postelsia* sporophytes would be excluded by the competitively dominant mussels (Paine 1988). *Postelsia* can recruit to areas other than gaps in mussel beds (e.g. on mussels, barnacled, turf algae), but populations are more stable and densities are highest within these bare patches (Paine 1988). Range of this alga is limited by physical (light/dessication) and biological (competition with mussels) factors (Nielsen et al. 2006).

Edible seaweed harvesting has been a cottage industry since the late 1970s, which has historically included the collection of *Postelsia*. However, the sea palm is now a protected species and illegal to harvest in British Columbia, Washington and Oregon. In California, recreational harvesting is illegal, but commercial harvesting remains legal. Between 2000 and 2001, it is estimated that between 2 and 3 tons of *Postelsia* were harvested in California. The blades are eaten raw or are dried, and dried blades sell for up to US$45 per pound. Commercial harvesters of *Postelsia* must purchase a US$100 license, pay a royalty to the State of California (US$24 per wet ton of algae harvested), and submit a monthly harvest log (Miller 2002). Common practice is to clip blades above the meristem which allows for regeneration of new blades. However, removing blades can limit a sporophyte's ability to produce spores and contribute to subsequent populations. Recovery from harvesting depends greatly on the season of collection, suggesting that additional regulation of the timing of harvest could help to protect *Postelsia* from overharvesting (Thompson et al. 2007).

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Appendix 2: Southern and Central California Site Descriptions

Point Sierra Nevada

Piedras Blancas

Rancho Marino; Cambria

Cayucos

Hazards

Shell Beach

Occulto

Purisima

Stairs

Boat House

Government Point

Alegria

Arroyo Hondo

Coal Oil Point

Carpinteria

Mussel Shoals

Old Stairs

Paradise Cove

White Point

Point Fermin

Crystal Cove

Shaws Cove

Treasure Island

Dana Point

Point Sierra Nevada

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Click here for Biodiversity Survey fndings

Point Sierra Nevada is located in the Central Coast region of California, within the Monterey Bay National Marine Sanctuary. When the site was established in 1995, it was accessible only by crossing private property (Hearst Corporation), and received very little visitation (occasional trespassers). Then in 2005 the land was transferred to CA State Parks (now part of Hearst San Simeon State Park) and human visitation, particularly by fshermen, increased substantially. The site is fairly remote, which affords it protection from large numbers of visitors, but fshermen are now seen nearly every time the site is sampled. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Point Sierra Nevada is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and pebble beach. The primary coastal orientation of this site is southwest.

Long-Term Monitoring Surveys at Point Sierra Nevada were established in 1995, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Hesperophycus* (Olive Rockweed), *Silvetia* (Golden Rockweed), *Mastocarpus* (Turkish Washcloth), *Mazzaella* (Iridescent Weed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2003, and 2004. The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 20 meters (seaward), and 15 meters (along shore) x 20 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Point Sierra Nevada, please contact Pete Raimondi.

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Piedras Blancas

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Piedras Blancas is located in the Central Coast region of California, within the Monterey Bay National Marine Sanctuary. This site is located within the Piedras Blancas State Marine Reserve. The property adjacent to Piedras Blancas is an old lighthouse station and public access to the area is restricted. The land is managed by the Bureau of Land Management, and docent-led public tours are occasionally done, but access to the intertidal has been limited to researchers. The area to the south is an important elephant seal rookery, and an offshore island is heavily used by shorebirds and pinnepeds, so localized nutrient levels are likely quite high. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

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

Long-Term Monitoring Surveys at Piedras Blancas were established in 1997 (with expanded monitoring implemented in 2007 as part of the MLPA), and are done by University of California Santa Cruz. Surveys at this site are not done on a regular basis. Long-Term MARINe surveys target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Mastocarpus* (Turkish Washcloth), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2008. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 50 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Piedras Blancas, please contact Pete Raimondi.

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Rancho Marino; Cambria

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Rancho Marino; Cambria is located in the Central Coast region of California, in the Kenneth S. Norris Rancho Marino Reserve (part of the University of California Research Reserve Network). The site is located within the White Rock (Cambria) State Marine Conservation Area. Access to the site is restricted due to its location on the UC Reserve. This moderately sloping site consists of consolidated bedrock benches and large boulders separated by surge channels.

Rancho Marino; Cambria is dominated by a mixture of consolidated bedrock and boulder felds, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and cobble beach. The primary coastal orientation of this site is south/southwest.

Long-Term Monitoring Surveys at Rancho Marino; Cambria were established in 2001, and are done by University of California Santa Cruz. Water temperature is monitored at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2005. The Biodiversity Survey grid encompasses one section that is approximately 29.6 meters (along shore) x 33 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Rancho Marino; Cambria, please contact Pete Raimondi.

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Cayucos

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Cayucos is located in the Central Coast region of California. Prior to 1998, the coastal land adjacent to the site was privately owned, although public use of the property was common. The property was then purchased by the state, and in 2002, the area was converted to CA State Park land (Estero Bluffs State Park), further opening up access to the general public. This site is near the Morro Bay/Virg's Mussel Watch site. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Cayucos is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, and boulder felds. The primary coastal orientation of this site is southwest.

Long-Term Monitoring Surveys at Cayucos were established in 1995, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Hesperophycus* (Olive Rockweed), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2008. The Biodiversity Survey grid encompasses two sections that are approximately 9 meters (along shore) x 25 meters (seaward), and 18 meters (along shore) x 25 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Cayucos, please contact Pete Raimondi.

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Hazards

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Hazards is located in the Central Coast region of California, within Montaña de Oro State Park. This site is near the Morro Bay/Virg's Mussel Watch site. Visitation by tidepoolers and surfers at this park is fairly high. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Hazards is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and sandy beach. The primary coastal orientation of this site is northwest.

Long-Term Monitoring Surveys at Hazards were established in 1995, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), *Mazzaella* (Iridescent Weed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of

California Santa Cruz in 2001 and 2005. The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 50 meters (seaward), and 14.5 meters (along shore) x 50 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Hazards, please contact Pete Raimondi.

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Shell Beach

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Shell Beach is located in the Central Coast region of California. This site is near the San Luis Obispo Bay/Point San Luis Mussel Watch site. The site is located within a developed stretch of coastline, with stairs leading to the beach downcoast of the site, and human use is fairly high. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

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

Long-Term Monitoring Surveys at Shell Beach were established in 1995, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), *Mastocarpus* (Turkish Washcloth), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2006. The

Biodiversity Survey grid encompasses two sections that are approximately 9 meters (along shore) x 33 meters (seaward), and 18 meters (along shore) x 33 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Shell Beach, please contact Pete Raimondi.

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Occulto

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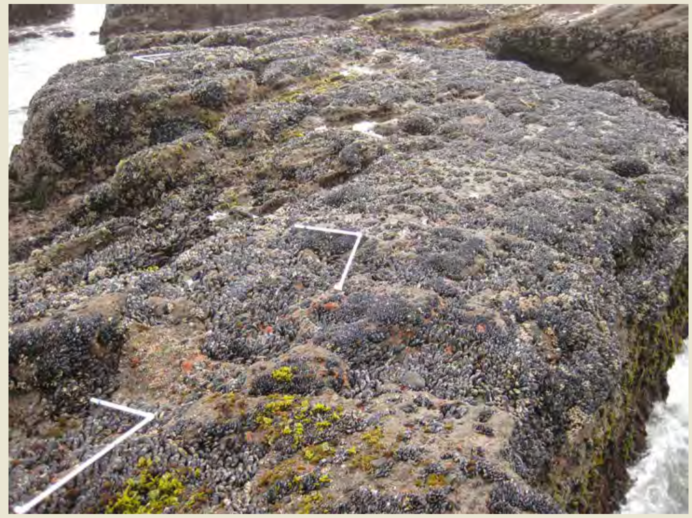
Occulto is located in the Central Coast region of California, on Vandenberg Air Force Base (VAFB). The site's location on VAFB largely restricts human use, although the reef is used by military personnel for fshing. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds, which are separated by large sandy surge channels.

Occulto is dominated by consolidated bedrock, which is bordered upcoast and downcoast by sandy beaches. The primary coastal orientation of this site is west/northwest.

Long-Term Monitoring Surveys at Occulto were established in 1992, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), Mytilus (California Mussel), *Endocladia* (Turfweed), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at



this site.

For more information about Occulto, please contact Pete Raimondi.

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Purisima

Purisima is located in the Central Coast region of California, on Vandenberg Air Force Base (VAFB). Purisima is accessed via a trail through sand dunes and along a beach and this remote location on VAFB severely limits human visitation. This gently sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Purisima is on a long, rocky point dominated by a mixture of consolidated bedrock and boulder felds, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, cobble and sandy beach.

Long-Term Monitoring Surveys at Purisima were established in 1993, and are done by University of California Santa Cruz. Water temperature is monitored at this site.

For more information about Purisima, please contact Pete Raimondi.

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Stairs

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Stairs is located in the Central Coast region of California, on Vandenberg Air Force Base (VAFB). This site is located within the Vandenberg State Marine Reserve. The site's location on VAFB largely restricts human use, although the reef is occasionally used by military personnel for fshing. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Stairs 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 west/southwest.

Long-Term Monitoring Surveys at Stairs were established in 1992, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species and/or areas: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), Recovery, *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of

California Santa Cruz in 2001, 2003, and 2004. The Biodiversity Survey grid encompasses two sections that are approximately 9 meters (along shore) x 50 meters (seaward), and 18 meters (along shore) x 50 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Stairs, please contact Pete Raimondi.

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Boat House

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Boat House is located in the Central Coast region of California, on Vandenberg Air Force Base (VAFB). Boat House's location on VAFB limits human visitation, but it is a popular destination for military personnel, and the area is used by surfers, scuba divers and fshermen. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Boat House is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and sandy beach. The primary coastal orientation of this site is south/southwest.

Long-Term Monitoring Surveys at Boat House were established in 1992, and are done by University of California Santa Cruz. Long-Term MARINe surveys currently target the following species: *Anthopleura* (Anemones), *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, mussel size structure, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2007. The Biodiversity Survey grid encompasses two sections that are approximately 21 meters (along shore) x 20 meters (seaward), and 6 meters (along shore) x 10 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Boat House, please contact Pete Raimondi.

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Government Point

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Government Point is located in the South Coast region of California, within the Point Conception State Marine Reserve. This site is approximately 1.5 km downcoast from Point Conception, an important biogeographical barrier, and is near the Point Conception Mussel Watch site.

Government Point is arguably one of the most important sites monitored by the MARINe group because it is located at the junction of two major biogeographic provinces (cold-temperate Oregonian and warm-temperate Californian), where the ranges of many marine species begin or end. Thus, it gives us the unique opportunity to study species that might be living at their maximum tolerance level to certain environmental stressors, such as temperature or wave exposure. Monitoring community change in the marine environment at this unique location provides important insight to understanding the impacts of global climate change.

Government Point is accessed via private property, and there is almost no human visitation. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Government Point is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock and sandy beach. Some unique features of the site include deep water directly offshore and numerous natural hydrocarbon seeps in the surrounding offshore benthos. Naturally occuring tar is common at this site, particularly in the high zone. The primary coastal orientation of this site is south/southwest.

Long-Term Monitoring Surveys at Government Point were established in 1992, and are done by University of California Santa Cruz. Surveys were not done between 2007-2013, when ownership of the land adjacent to the site changed hands, but the site was revisited in 2014.Long-Term MARINe surveys target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Pollicipes* (Goose Barnacle), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and water temperature are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2006. The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 25 meters (seaward), and 15 meters (along shore) x 25 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Government Point, please contact Pete Raimondi.

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Alegria

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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 infuenced and portions of the site may be inundated with sand. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Alegria is dominated by a mixture of consolidated sandstone and mudstone bedrock, boulder felds, and sandy beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, 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. Click here to view Long-Term trends 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). Click here to view Biodiversity Survey fndings at this site.

For more information about Alegria, please contact Rich Ambrose.

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Arroyo Hondo

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Arroyo Hondo is located in the South Coast region of California. This site is 0.2 miles west of the Arroyo Hondo Canyon Mouth Mussel Watch site. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Arroyo Hondo 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 south.

Long-Term Monitoring Surveys at Arroyo Hondo 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: *Chthamalus/Balanus* (Acorn Barnacles), *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. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2005. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 20 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Arroyo Hondo, please contact Rich Ambrose.

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Coal Oil Point

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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 fat terrain.

Coal Oil Point is dominated by a mixture of consolidated sandstone and mudstone bedrock, boulder felds, 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.

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. Click here to view Long-Term trends 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). Click here to view Biodiversity Survey fndings at this site.

For more information about Coal Oil Point, please

contact Rich Ambrose.

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Carpinteria

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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.

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. Click here to view Long-Term trends at this site.

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). Click here to view Biodiversity Survey fndings at this site.

For more information about Carpinteria, please contact Rich Ambrose.

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Mussel Shoals

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Mussel Shoals is located in the South Coast region of California. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Mussel Shoals is dominated by a mixture of consolidated sandstone bedrock, riprap, boulder felds, and sandy beach, and the area surrounding the site is comprised of a mixture of boulder felds and sandy beach at this site. The primary coastal orientation of this site is south.

Long-Term Monitoring Surveys at Mussel Shoals 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), Rock (Above Barnacles), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 20 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Mussel Shoals, please contact Rich Ambrose.

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Old Stairs

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Old Stairs is located in the South Coast region of California. This site is located in an Area of Special Biological Signifcance (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.

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

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. Click here to view Long-Term trends 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). Click here to view Biodiversity Survey fndings at this site.

For more information about Old Stairs, please contact Rich Ambrose.

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Paradise Cove

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Paradise Cove is located in the South Coast region of California. The site is located in an Area of Special Biological Signifcance (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.

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. Click here to view Long-Term trends at this site.

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). Click here to view Biodiversity Survey fndings at this site.

For more information about Paradise Cove, please contact Rich Ambrose.

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White Point

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White Point is located in the South Coast region of California, and is 0.2 miles southeast of the Palos Verdes Royal Palms Mussel Watch site. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

White Point is dominated by a mixture of consolidated basalt bedrock, boulder felds, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and cobble beach. The primary coastal orientation of this site is southwest.

Long-Term Monitoring Surveys at White Point 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), and *Pisaster* (Ochre Star). In addition, motile invertebrates, barnacle recruitment, and mussel size structure are monitored at this site. Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001 and 2008. The Biodiversity Survey grid encompasses two sections that are approximately 6 meters (along shore) x 25 meters (seaward), and 21 meters (along shore) x 25 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about White Point, please contact Rich Ambrose.

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Point Fermin

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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.

Point Fermin is dominated by a mixture of consolidated sandstone and basalt bedrock and boulder felds, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, 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. Click here to view Long-Term trends at this site.

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). Click here to view Biodiversity Survey fndings at this site.

For more information about Point Fermin, please contact Rich Ambrose.

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Crystal Cove

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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 Signifcance (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 fattened and angled bench separated by crevices resulting from uplifted bedding planes.

Crystal Cove is dominated by a mixture of consolidated bedrock and boulder felds, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, 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 done by California State University Fullerton and California State Polytechnic University, Pomona. 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 and mussel size structure are monitored at this site. Click here to view Long-Term trends 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). Click here to view Biodiversity Survey fndings at this site.

For more information about Crystal Cove, please contact Jayson Smith and Jennifer Burnaford.

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Shaws Cove

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

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.

Click here to view Long-Term trends at this site.Long-Term Monitoring Surveys at Shaws Cove were established in 1996, and are conducted by California State University Fullerton and California State Polytechnic University, Pomona. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), *Endocladia* (Turfweed), Rock (Above Barnacles), and *Pisaster* (Ochre Star). 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, 2005, and 2012. The Biodiversity Survey grid encompasses one section that is approximately 30 meters (along shore) x 10 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Shaws Cove, please contact Jayson Smith and Jennifer Burnaford.

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Treasure Island

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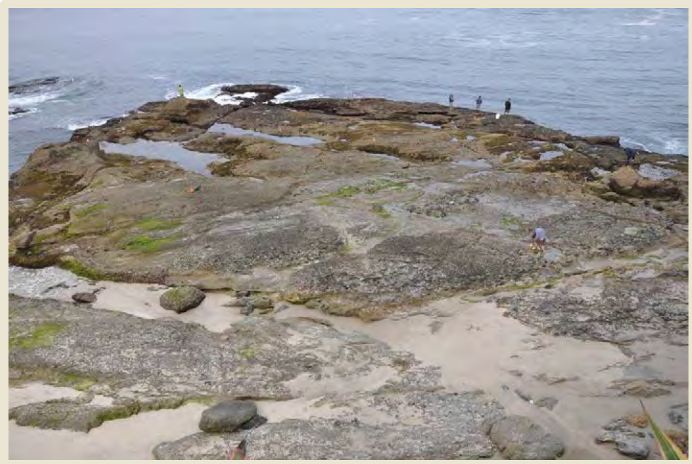
Treasure Island is located in the South Coast region of California, within the Laguna Beach State Marine Conservation Area. This site is located just below a luxury resort and is heavily impacted by high levels of human visitors. Docent educators are frequently on site. The site is a gently sloping bedrock bench separated by large pools and channels.

Treasure Island is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and sandy beach. Sand levels in the splash and upper intertidal zones vary greatly throughout the year. The primary coastal orientation of this site is west.



Long-Term Monitoring Surveys at Treasure Island were established in 1996, and are done by California State University Fullerton and California State Polytechnic University, Pomona. Long-Term MARINe surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Silvetia* (Golden Rockweed), Rock (Above Barnacles), and *Pisaster* (Ochre Star). In addition, motile invertebrates and mussel size structure are monitored at this site. Click here to view Long-Term trends at this site.

For more information about Treasure Island, please contact Jayson Smith and Jennifer Burnaford.

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Dana Point

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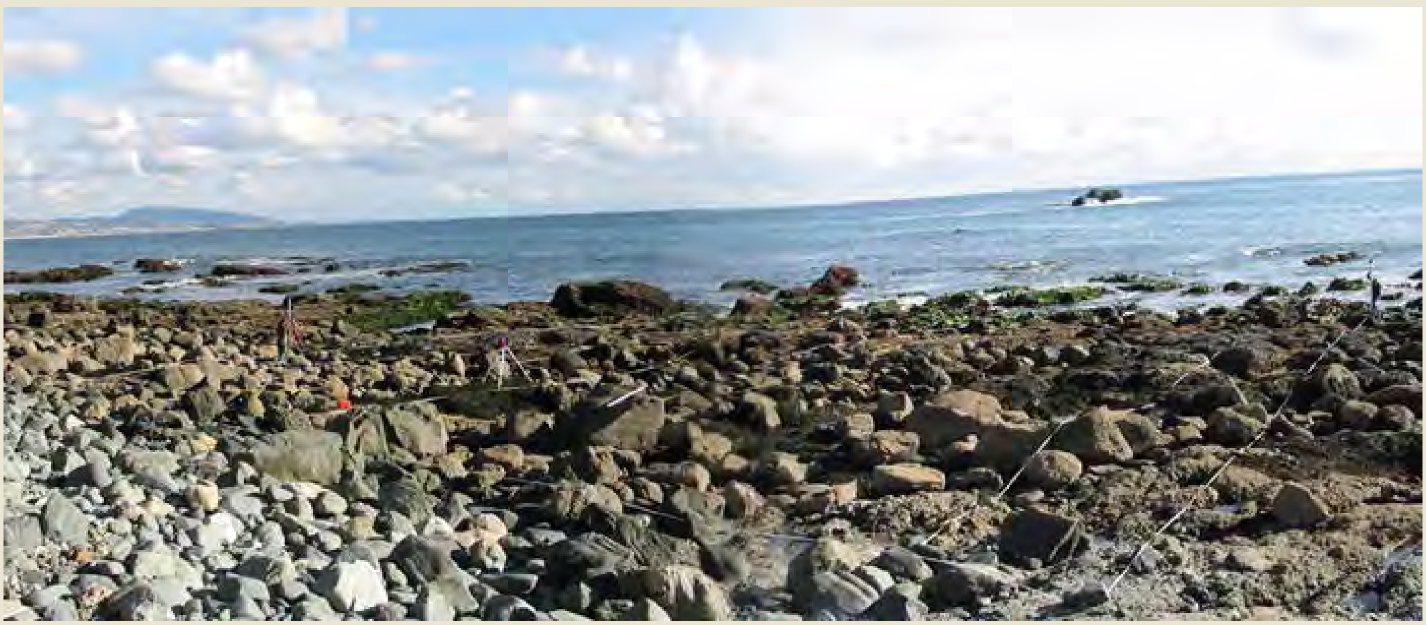
Dana Point is located in the South Coast region of California, within the Dana Point State Marine Conservation Area, and is near the Dana Point Mussel Watch site. The Ocean Institute is located at the entrance of the long reef and provides educational materials to the numerous schools that visit this 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 fattened benches.



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 felds. The primary coastal orientation of this site is south.

Long-Term Monitoring Surveys at Dana Point were established in 1996, and are conducted by California State University Fullerton and California State Polytechnic University, Pomona. 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 and mussel size structure are monitored at this site. Click here to view Long-Term trends 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). Click here to view Biodiversity Survey fndings at this site.

For more information about Dana Point, please contact Jayson Smith and Jennifer Burnaford.

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Appendix 3: Southern and Central California Summary of Trends by Site

Point Sierra Nevada

Cayucos

Hazards

Shell Beach

Occulto

Stairs

Boat House

Government Point

Alegria

Arroyo Hondo

Coal Oil Point

Carpinteria

Mussel Shoals

Old Stairs

Paradise Cove

White Point

Point Fermin

Crystal Cove

Shaws Cove

Treasure Island

Dana Point

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Point Sierra Nevada Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle plots at Point Sierra Nevada consist almost exclusively of *Chthamalus dalli/fssus* , although *Balanus glandula* are recorded on rare occasion (note that species were not distinguished until 2001). Cover of *Chthamalus* spp. varied inversely with rock cover nearly perfectly, with little else occurring in these plots. Littorines were consistently common in the barnacle plots and limpets were also present in moderate numbers.

Mytilus cover in mussel plots remained high and extremely stable at Point Sierra Nevada, hovering just above 80% for nearly the entire 20 year monitoring period. Rock and the goose neck barnacle, *Pollicipes* generally made up the remainder of cover within the plots. Limpets were the most common motile invertebrate within the mussel plots, and exhibited a seasonal fuctuation in abundance, with higher numbers in fall than in spring. Other motile inverts consistently found within the mussel plots included three types of snails (littorines, *Tegula*, and *Nucella*), a chiton (*Nuttallina*), and the lined shore crab (*Pachygrapsus*).

Hesperophycus cover within its target plots started out high (around 90%) and then declined precipitously to around 15%, where it hovered for several years before recovering slightly and stabilizing at around 30%. Beginning in 2010, *Hesperophycus* cover gradually increased to roughly 75%. However, it has recently declined again and in fall 2014, much of the *Hesperophycus* appeared to be sunburned or heat-stressed and in many cases only the stipes remained. Declines of this rockweed corresponded with increases in cover of bare rock and *Endocladia*. Littorines were variable in abundance, but generally quite common in the *Hesperophycus* plots. Limpets were less abundant, but still common in these rockweed plots, and the black turban snail, *Tegula*, was consistently present in low numbers.

Another species of rockweed, *Silvetia*, has also declined over time in plots where it is targeted at Point Sierra Nevada. Initial mean cover was >90%, then steadily declined and stabilized at around 50%, although recent years have seen small increases in cover. In some plots, *Mytilus*, *Hesperophycus*, *Endocladia*, or *Mastocarpus* has moved in, but a fair amount of bare space (rock) remains. Littorines and limpets were generally common, but variable in abundance over time within *Silvetia* plots. The black turban snail, *Tegula*, was also consistently common.

In *Mastocarpus* plots, cover of the red alga is highly seasonal, with higher cover in fall than in spring. The seasonal pattern of *Mastocarpus* varies inversely with cover of the red turf alga, *Endocladia*, also present in the plots. The way in which hydrodynamic forces affect intertidal plants may help to explain seasonal variation in size of *Mastocarpus* populations. When water velocities are low, such as during the summer months in central California, hydrodynamic forces do not limit thallus size (Carrington 1990). However, as water velocity increases, larger plants are torn out. Small plants may be able to better withstand large hydrodynamic forces associated with winter swell. Indeed, our plots generally contain smaller plants (and hence lower cover) in the spring.

Mean cover of *Mazzaella* was relatively constant over time within plots where it is targeted, although some seasonal variation was apparent (commonly higher in fall than spring). Reductions in *Mazzaella* cover were often associated with increases in cover of articulated corallines, suggesting that coralline algae persisted as a stable understory below *Mazzaella*, and reduced canopy cover of *Mazzaella* simply exposed more corallines. Dominant species in the broad group “other red algae” included *Chondracanthus canaliculatus*, and *Gelidium* spp. As with *Mastocarpus*, larger blades of *Mazzaella* tend to be ripped out during winter storms, leaving a perennial basal crust behind. In early spring, our plots tended to have mostly small plants that had just begun to grow back.

Surfgrass (*Phyllospadix*) cover hovered at around 80% along the transects where this species is targeted. Mean cover exhibited slight seasonal variation, with lower cover in the spring following winter storms that ripped out plants and abraded leaves.

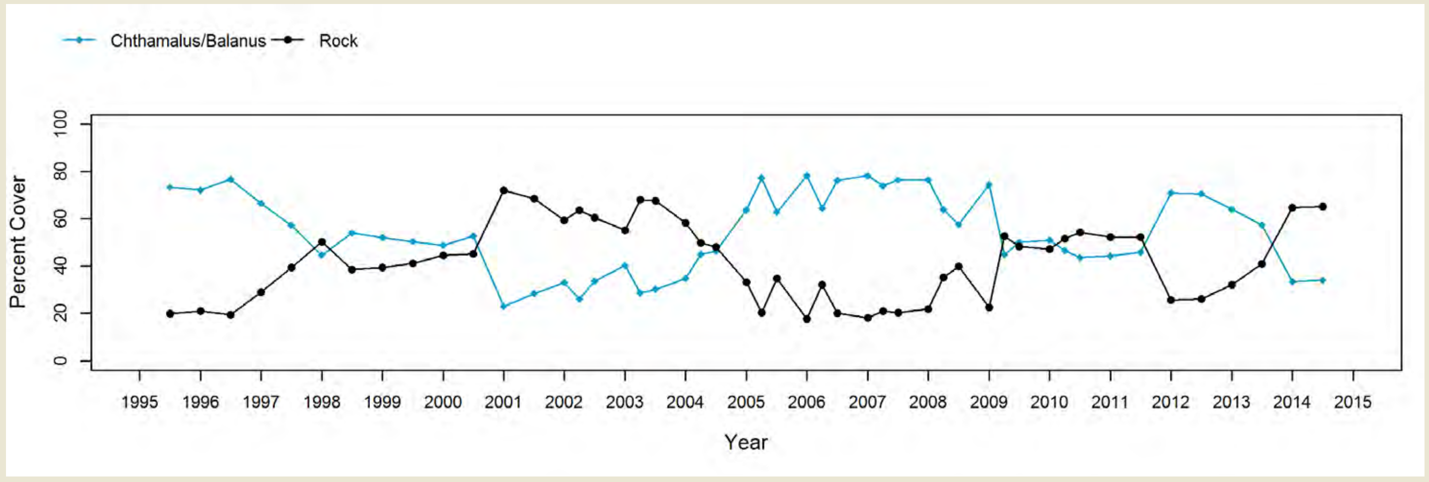
Counts for the ochre star, *Pisaster ochraceus*, in the seastar plots at Point Sierra Nevada varied substantially over time, and showed a slight decreasing trend over time through 2013. In 2014, sea star numbers plummeted due to wasting syndrome. Individuals were generally large, with only a few samples where signifcant numbers of small individuals were recorded, suggesting that recruitment to this site tends to be patchy, which could negatively infuence recovery . The ochre star was the only species recorded in our plots at Point Sierra Nevada, but biodiversity surveys also documented the bat star, *Patiria*, the sunfower star , *Pycnopodia*, and the leather star, *Dermasterias*. Point Sierra Nevada is the southernmost site at which we fnd the katy chiton, *Katharina tunicata*, in our sea star plots, albeit at very low numbers.

Photo Plots

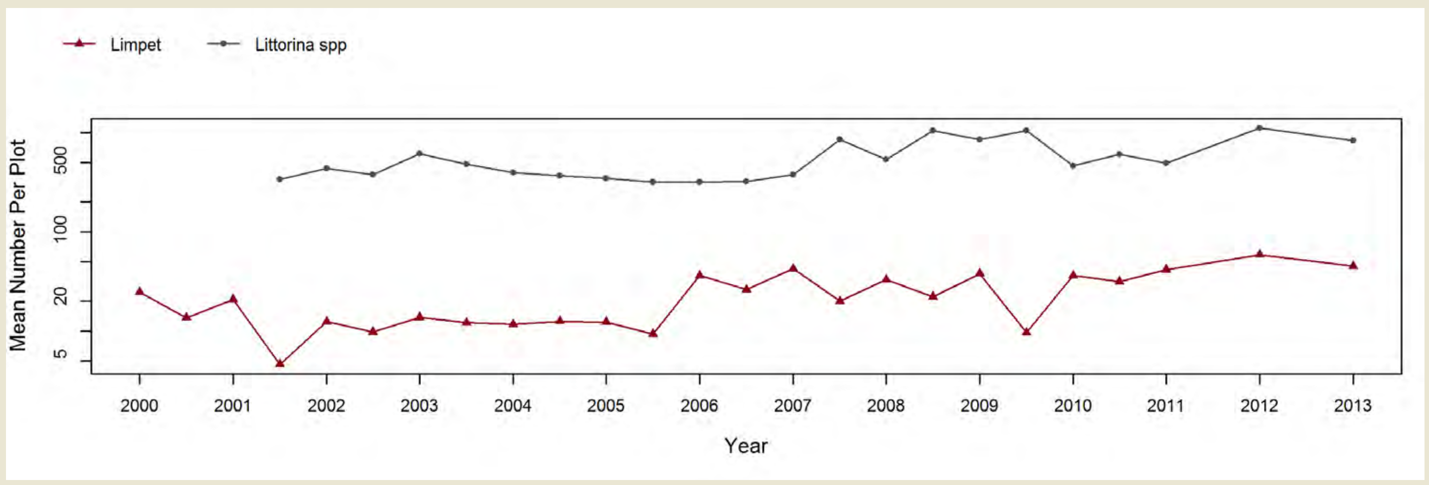
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since spring 2013. For motile invertebrate size trend graphs by site, please use the Interactive Map.

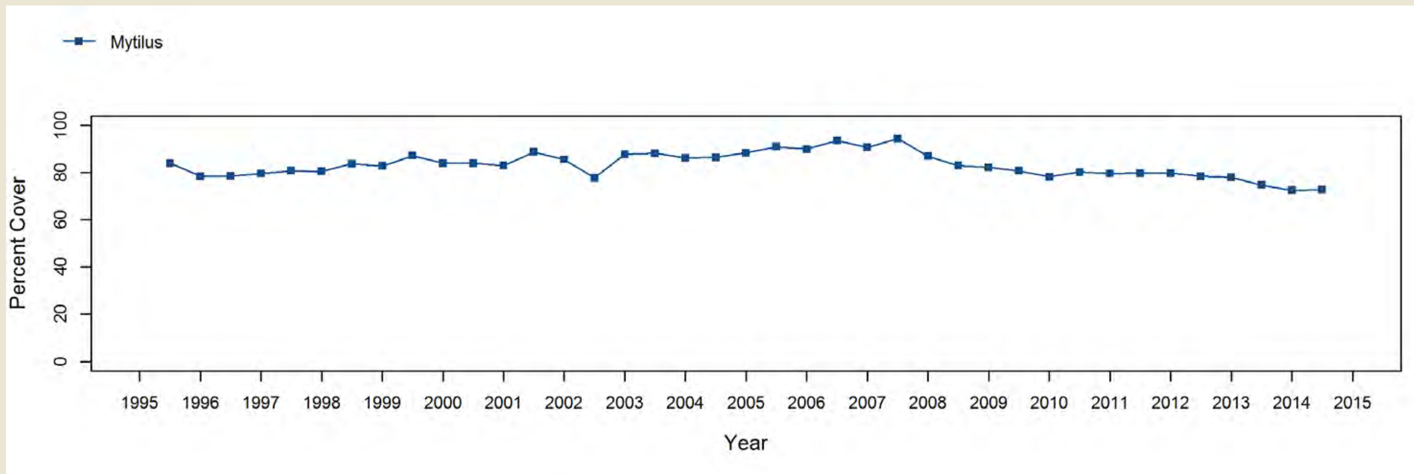
Chthamalus/Balanus (Acorn Barnacles) - percent cover



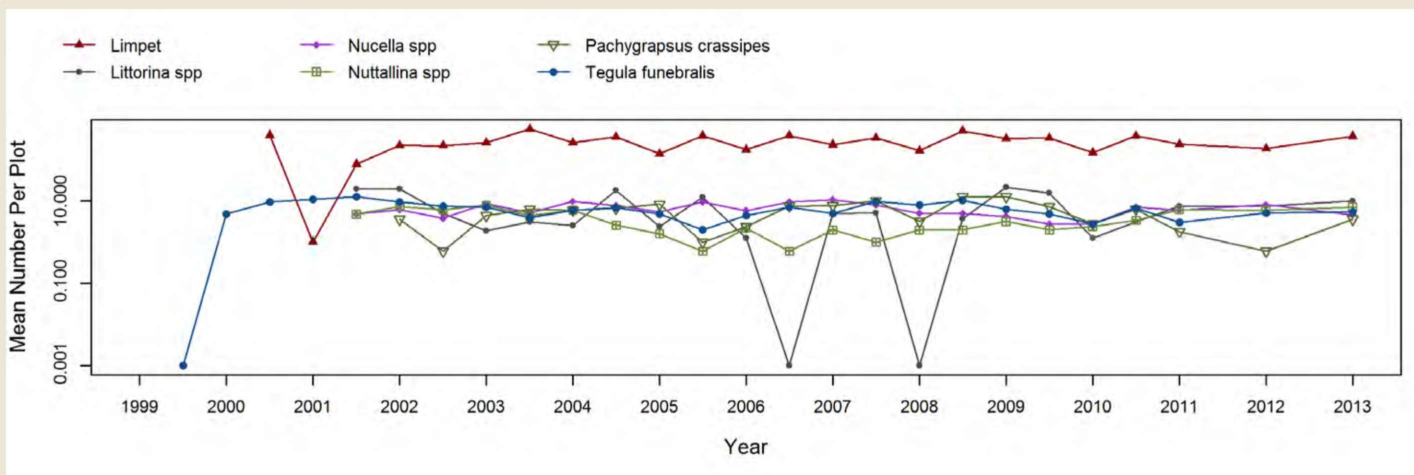
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



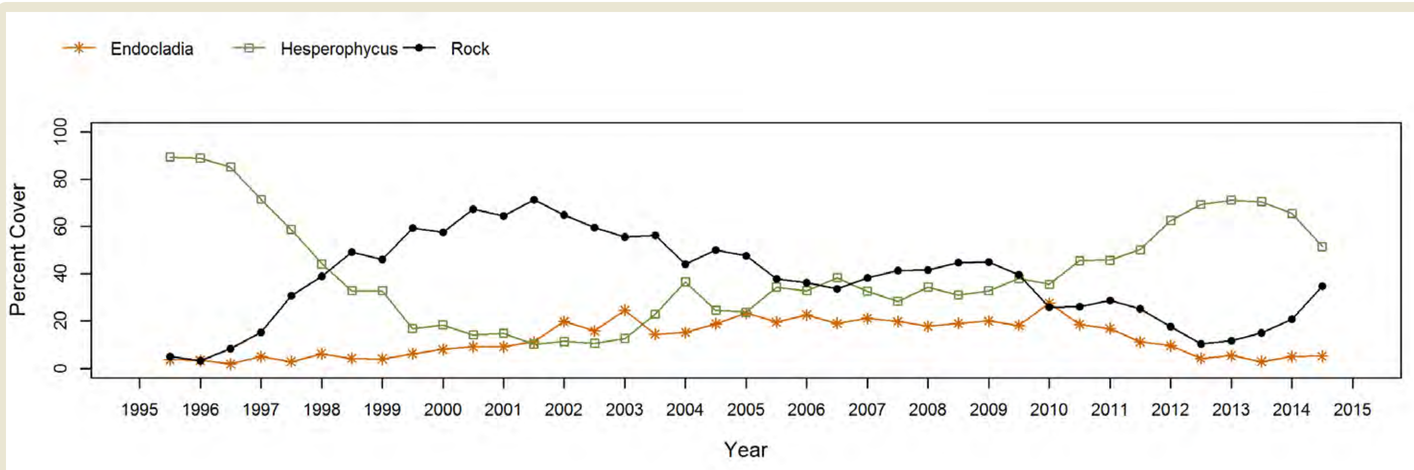
Mytilus (California Mussel) - percent cover



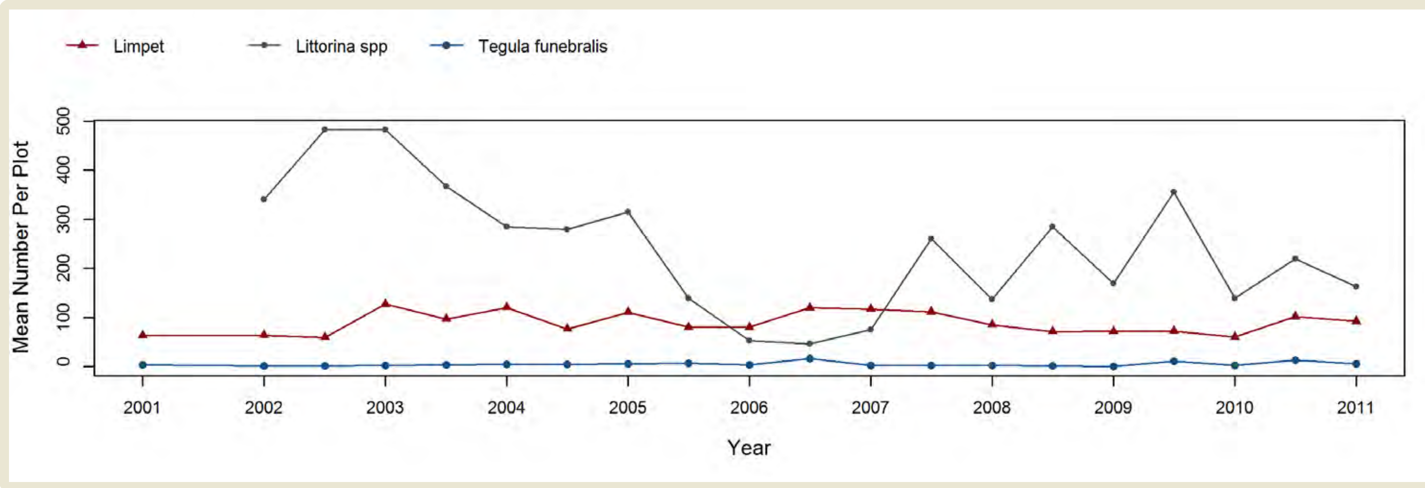
Mytilus (California Mussel) - motile invertebrate counts



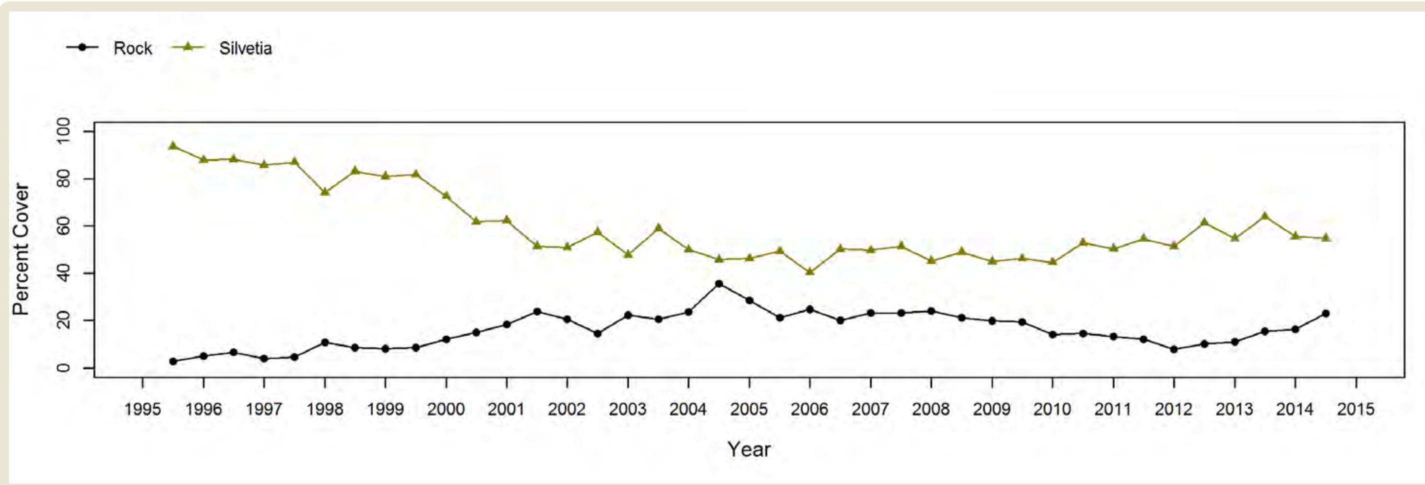
Hesperophycus (Olive Rockweed) - percent cover



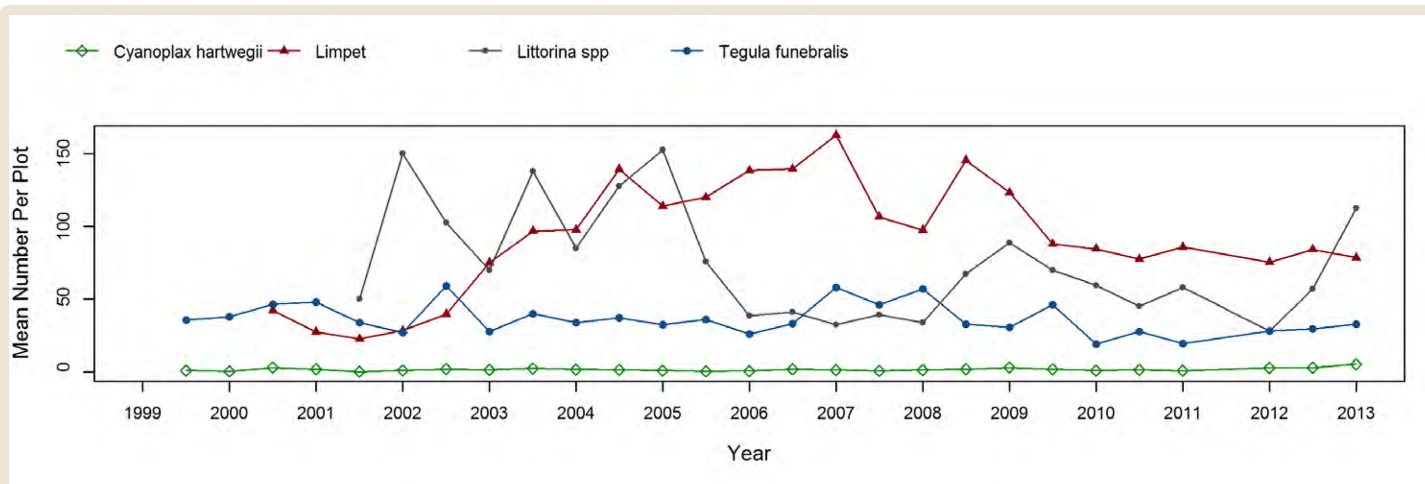
Hesperophycus (Olive Rockweed) - motile invertebrate counts



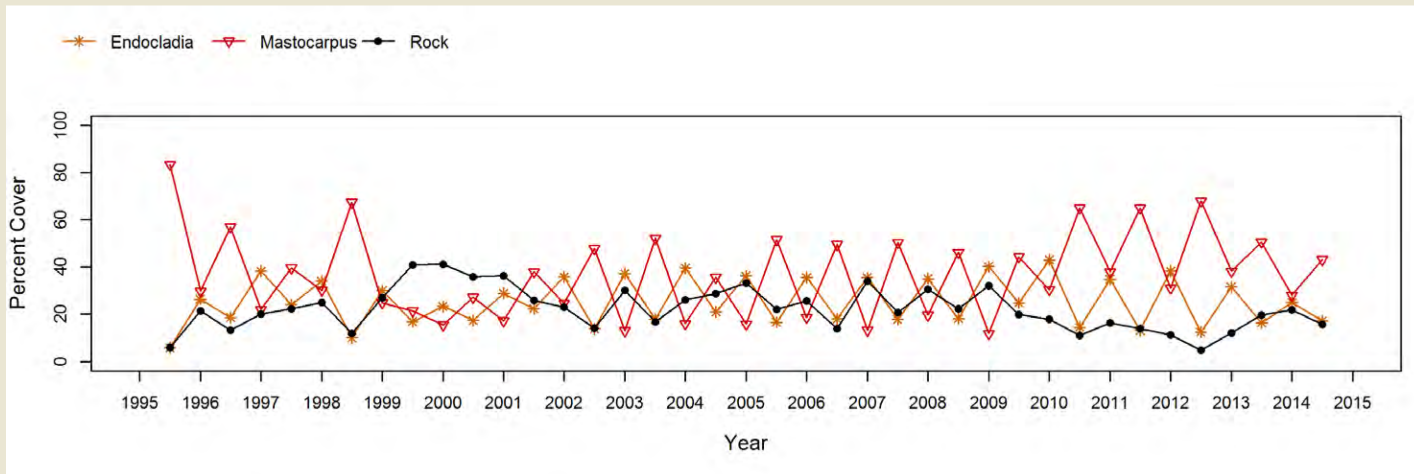
Silvetia (Golden Rockweed) - percent cover



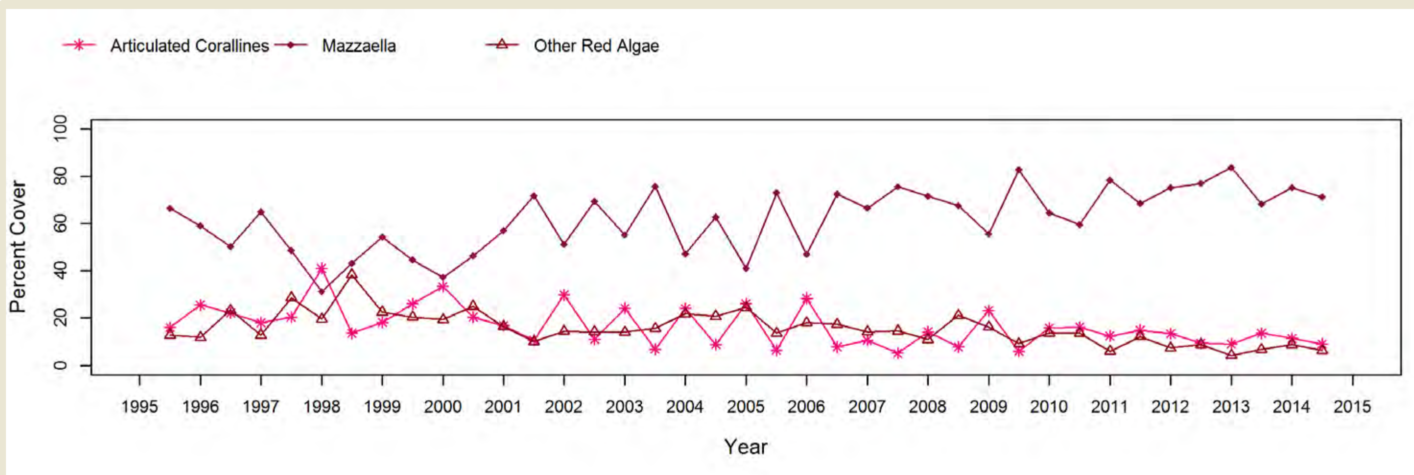
Silvetia (Golden Rockweed) - motile invertebrate counts



Mastocarpus (Turkish Washcloth) - percent cover



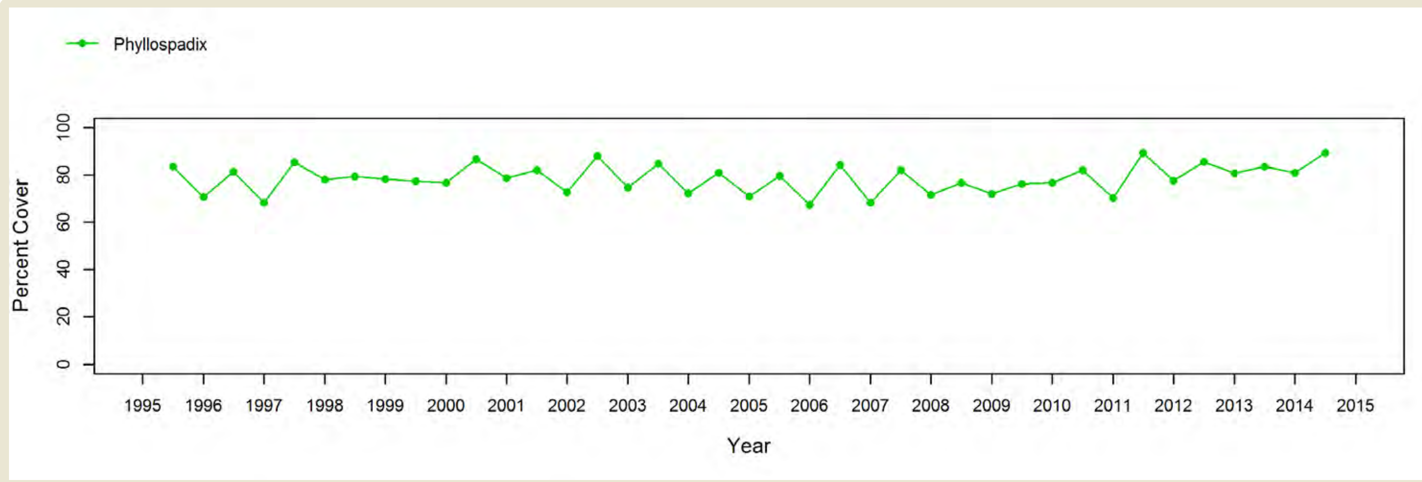
Mazzaella (Iridescent Weed)



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

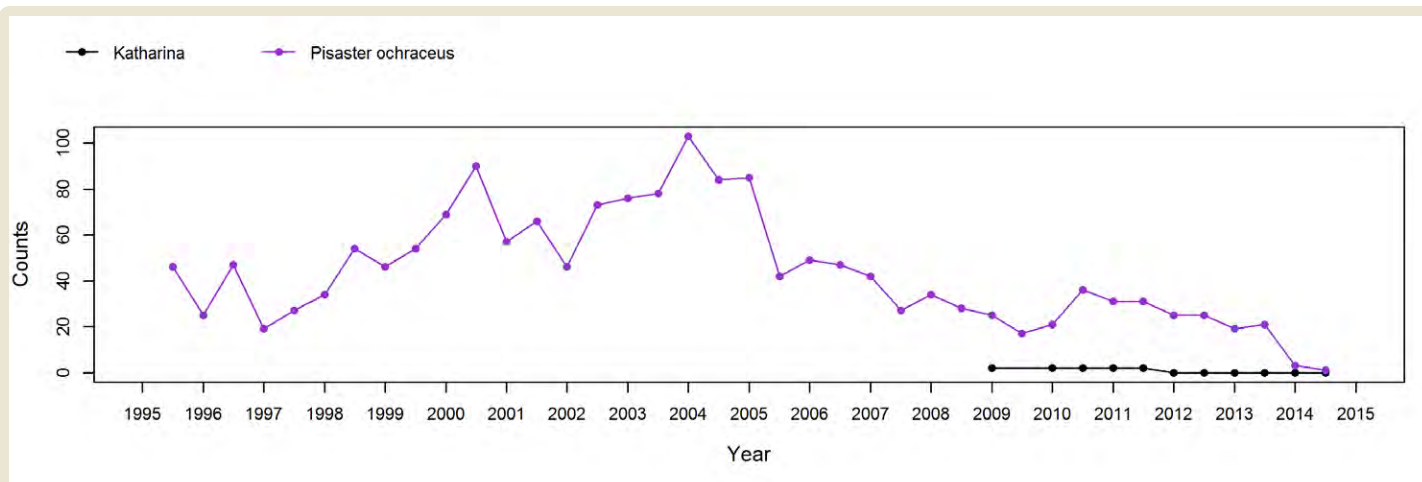
Phyllospadix (Surfgrass)



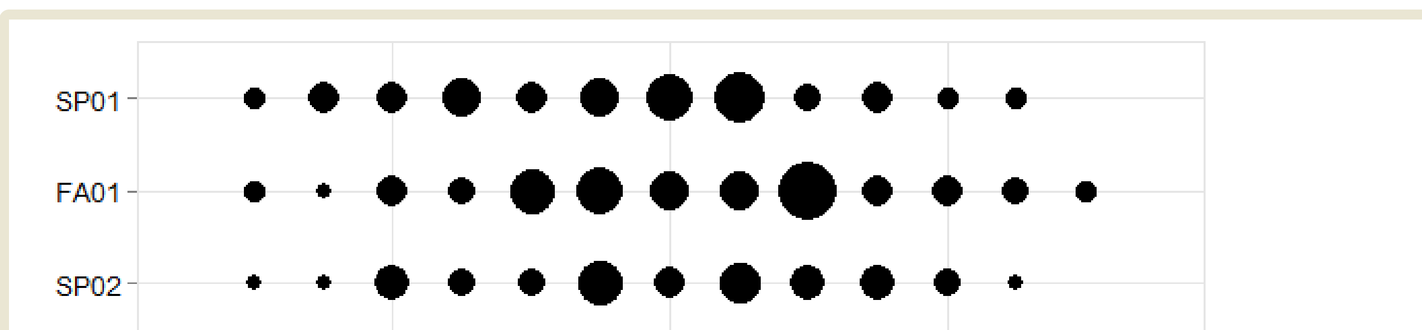
Species Counts and Sizes

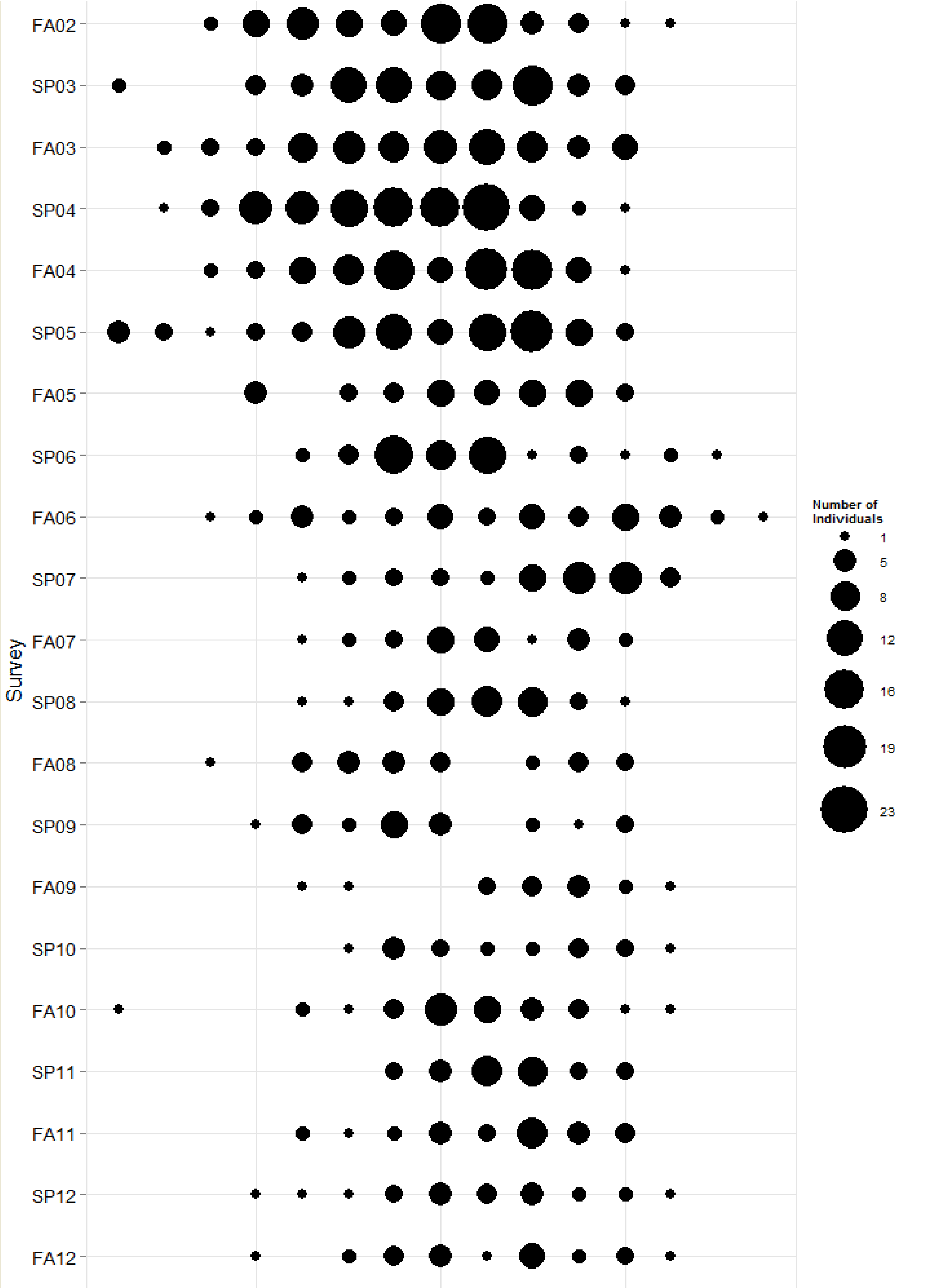
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes




Survey
FA02
SP03
FA03
SP04
FA04
SP05
FA05
SP06
FA06
SP07
FA07
SP08
FA08
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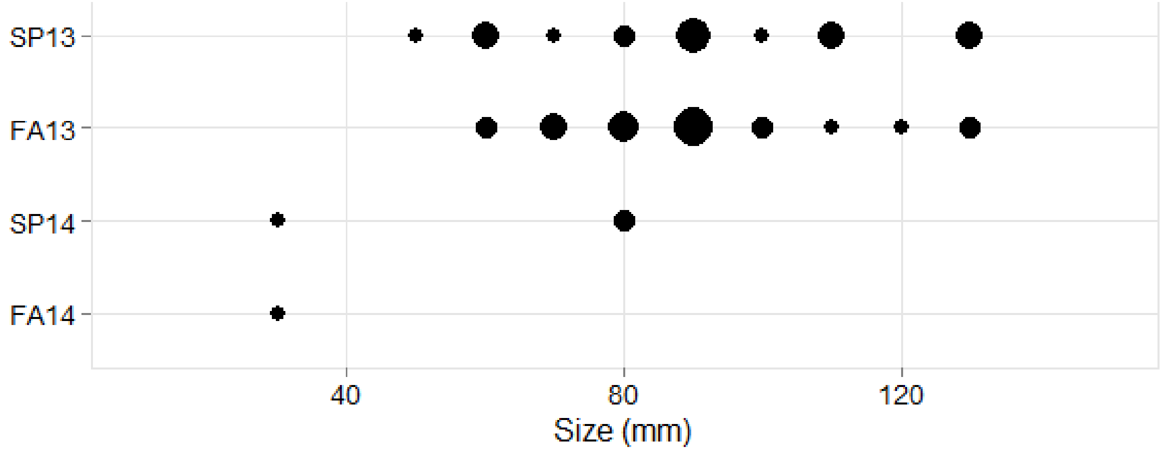
8
12
16
19
23



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Cayucos Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle plots at Cayucos historically contained mostly *Chthamalus dalli/fssus* , with very few *Balanus glandula* recorded (note that species were not distinguished until 2001). However, *Balanus* has increased slightly in recent years, especially in plot 5. In general, the cover of barnacles varied inversely with rock cover, with little else occurring in these plots. Littorines were common in the barnacle plots and limpets were also present in moderate numbers. The turban snail, *Tegula funebralis*, occurred consistently in the plots in low numbers.

Mussel plots at Cayucos consisted mainly of their targeted species, *Mytilus californianus*. When cover of *Mytilus* declined, rock cover increased, indicating that bare space was generally not colonized by other species. Mussel cover declined somewhat between 1999-2001, and then increased to over 90% cover in 2005-2006, followed again by a gradual decline between 2007-2014. Limpets were abundant in the mussel plots and exhibited strong seasonal variation, with much higher numbers in fall than in spring.

Decline of the upper-shore rockweed, *Hesperophycus*, was striking at Cayucos during the frst few years it was monitored, where cover dropped from over 90% to less than 20%. *Hesperophycus* cover then stabilized at around 20-30% for nearly 13 years, but then increased to near original levels. However, prior to fall 2014 *Hesperophycus* declined again throughout the site. Limpets, littorines, and the turban snail, *Tegula funebralis*, were all common within *Hesperophycus* plots.

Silvetia cover was quite high during the frst 5 years at Cayucos, but experienced a substantial decline in 2001, followed by more gradual decline until 2006, when cover appeared to stabilize. Beginning in 2010, cover began to increase, and is currently around 80%. *Endocladia* and *Hesperophycus* have increased in these plots during times when *Silvetia* cover was low, flling in some of the space vacated by *Silvetia*. In addition, *Fucus* has increased slightly in these plots over recent years. *Silvetia* cover was highly seasonal, with lower values in spring vs. fall samples. This pattern is present at many sites, and may be due to a combination of factors including seasonal growth cycles, physical removal by winter storms and desiccation from extreme low tides that occurred in the middle of the day in the spring (timing of low tide is cyclical, so low tides are not always mid-day in spring in this region). *Tegula funebralis* and limpets were abundant in *Silvetia* plots, and the chiton, *Lepidochitona hartwegii*, was consistently present. This chiton is frequently associated with *Silvetia*, which it uses for protection from desiccation.

Endocladia cover was relatively stable over time. A signifcant drop in 1998 was followed by a recovery to near-original levels. Beginning in 2009, *Hesperophycus* cover began to increase in *Endocladia* plots, resulting in a decrease in cover of bare rock. While *Endocladia* appeared to have decreased between 2011-2013, it was still present (but not captured by the point contact data) under *Hesperophycus*. However, as mentioned above, prior to Fall 2014 a dramatic decrease in both *Hesperophycus* and *Endocladia* occurred throughout these plots. This may have been a consequence of scouring or some other stress, since the plots are now comprised of a fair amount of bare rock. Limpets and littorines were common in the *Endocladia* plots, which had a large amount of bare space, where diatoms typically grow and provide food for these grazers.

Surfgrass cover at Cayucos was consistently high over time, with only slight dips during the 1997/98 El Niño event, and again in 2001 and 2013. The lack of a seasonal pattern in surfgrass cover at Cayucos is likely due to the unique location of the transects at this site. Unlike other sites, where surfgrass transects were established in areas that drain during low tide, transects at Cayucos are located in large pools, which reduces the amount of stress experienced by the plants due to air exposure, and perhaps also abrasion.

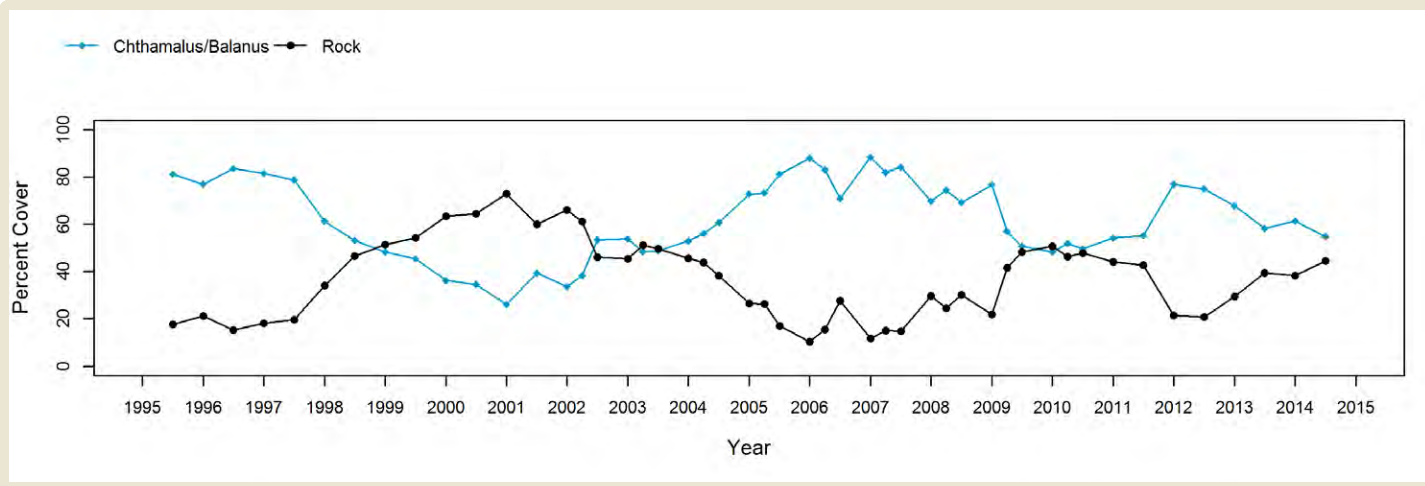
Pisaster numbers have been variable, but were generally increasing between 2000-2007 at Cayucos. A gradual decline in numbers began in 2009, and sea star deaths due to wasting syndrome in 2014 furthered this decline. Very few small stars (< 50 mm radius) have been counted over time at this site, suggesting that recovery could be slow.

Photo Plots

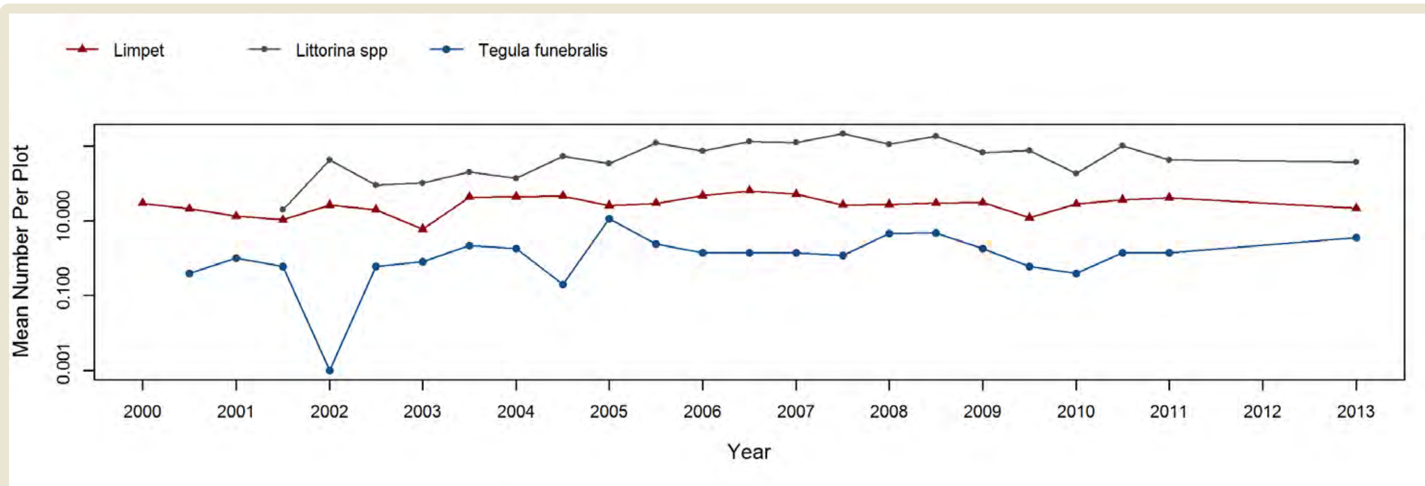
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since spring 2013. For motile invertebrate size trend graphs by site, please use the Interactive Map.

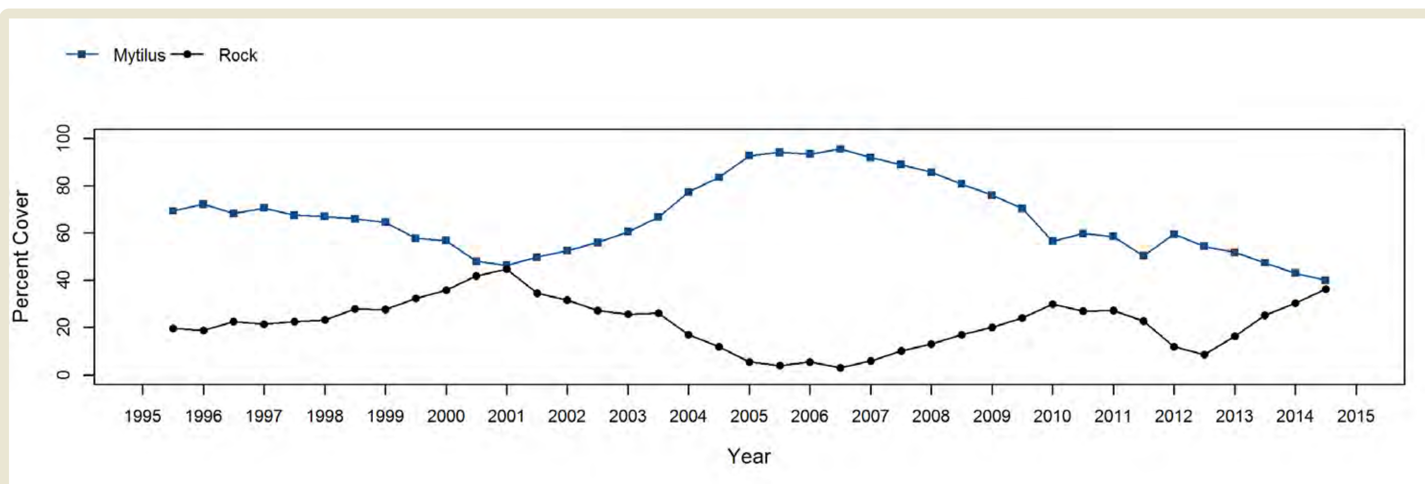
Chthamalus/Balanus (Acorn Barnacles) - percent cover



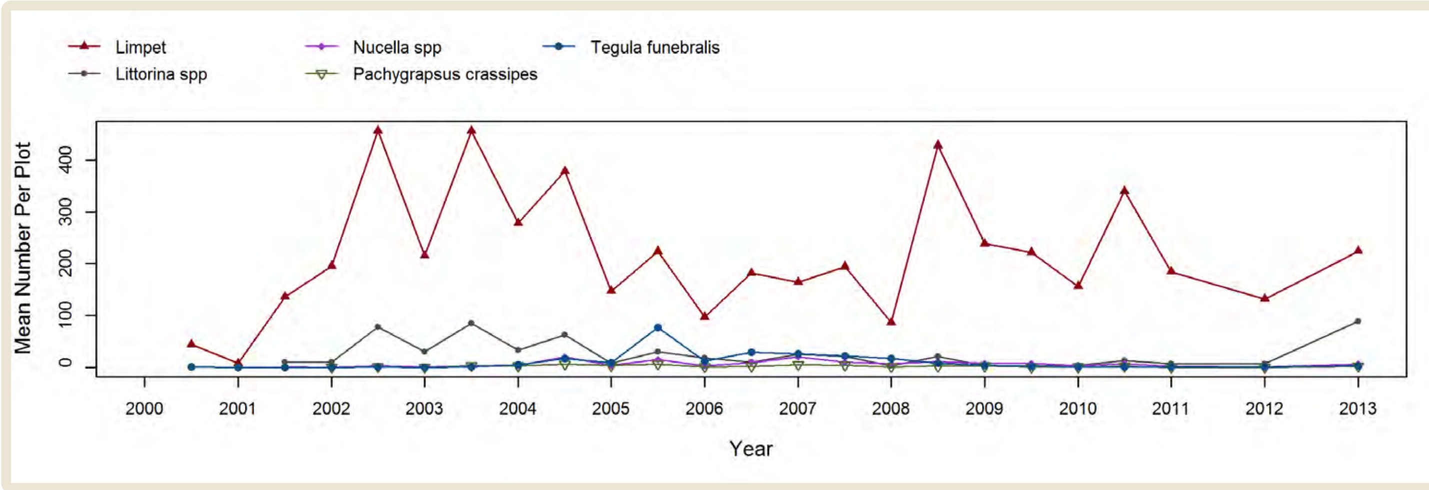
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



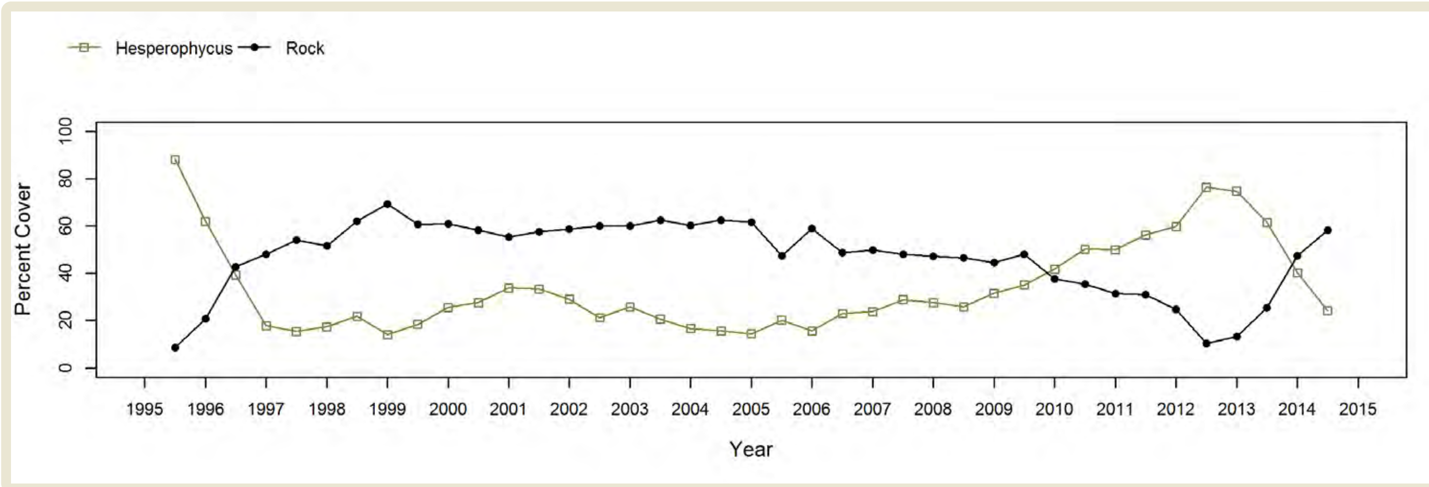
Mytilus (California Mussel) - percent cover



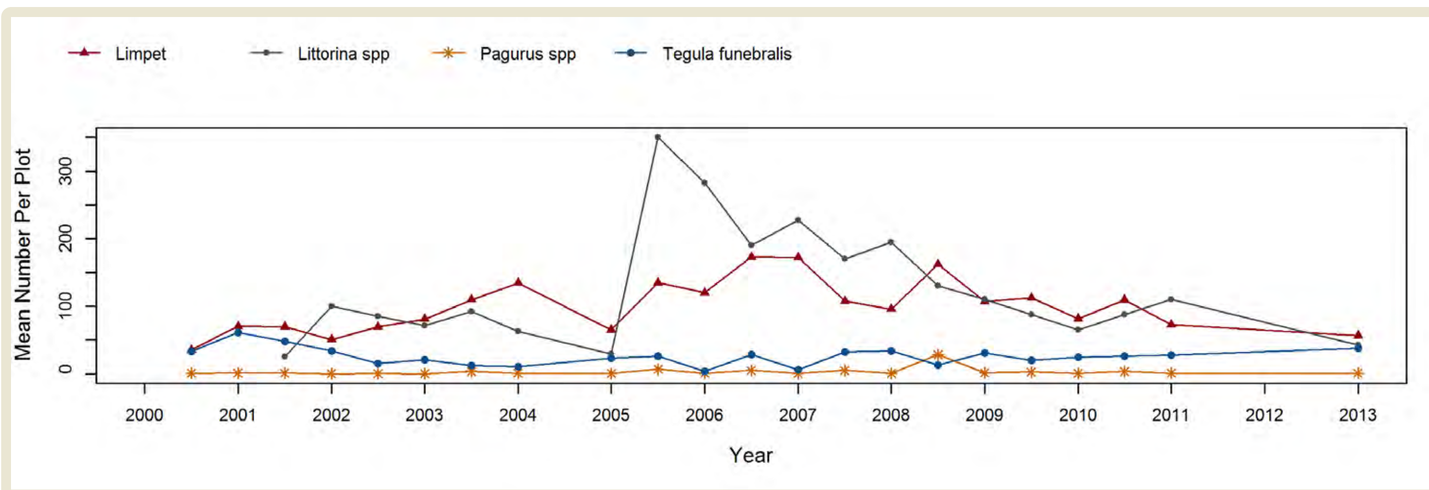
Mytilus (California Mussel) - motile invertebrate counts



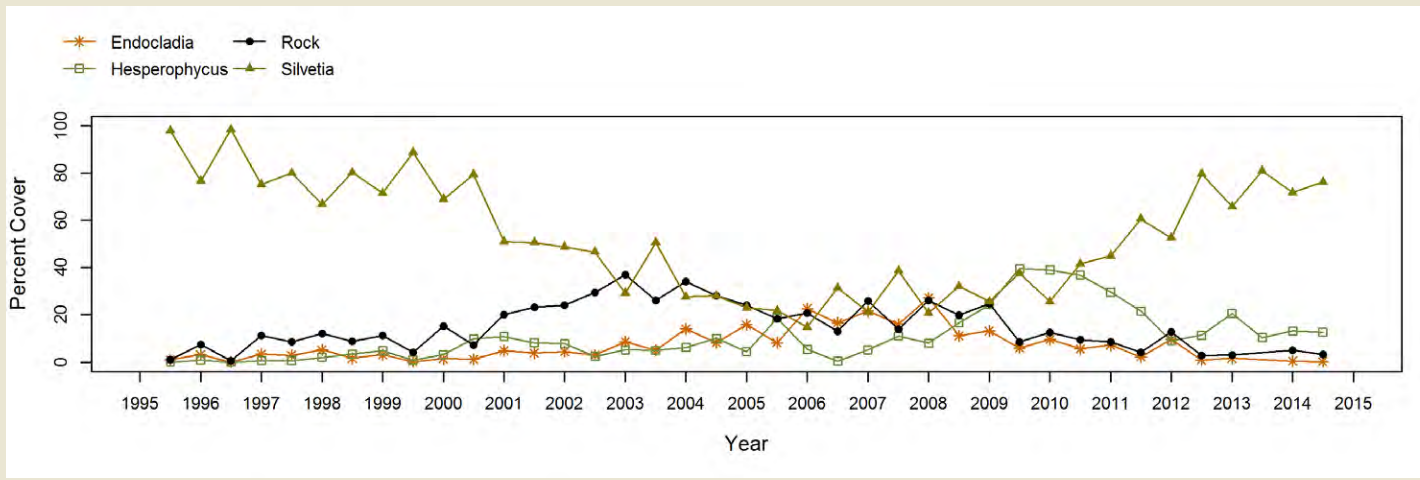
Hesperophycus (Olive Rockweed) - percent cover



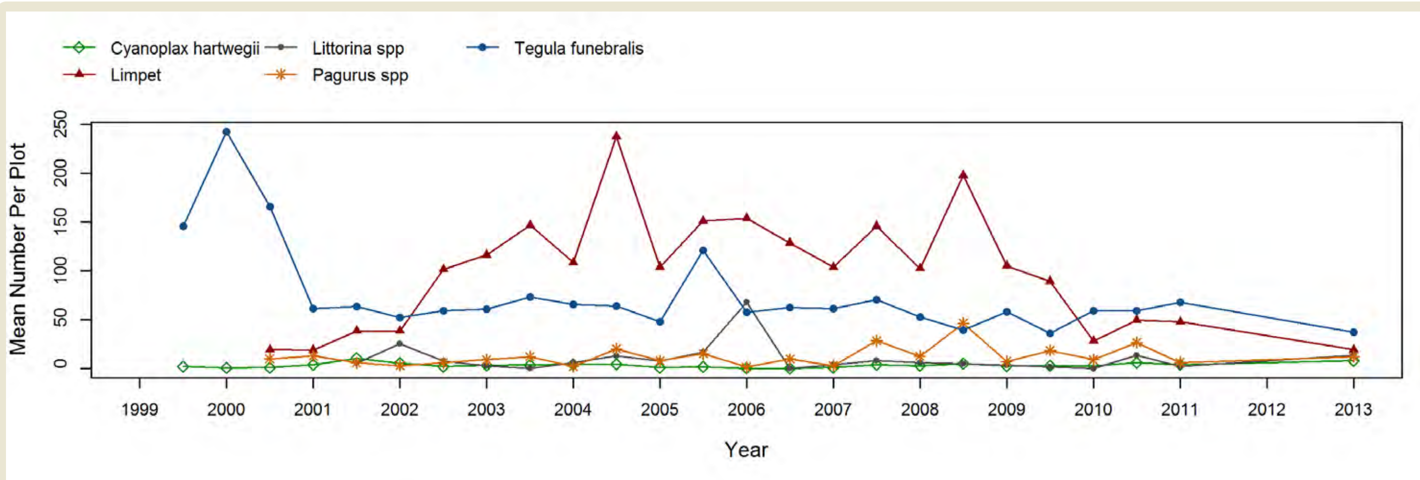
Hesperophycus (Olive Rockweed) - motile invertebrate counts



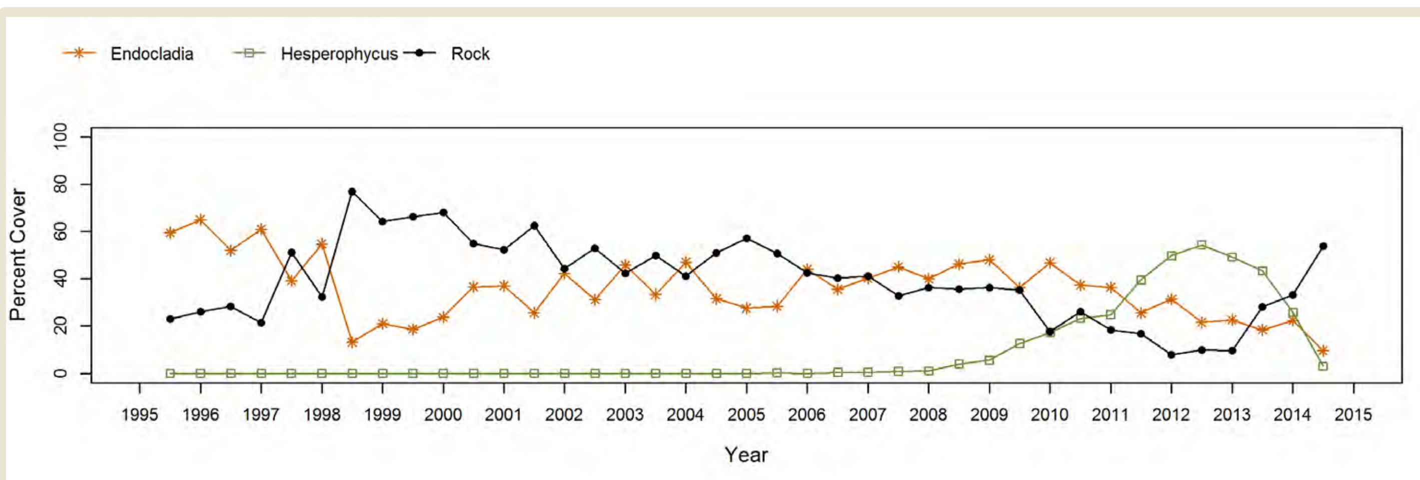
Silvetia (Golden Rockweed) - percent cover



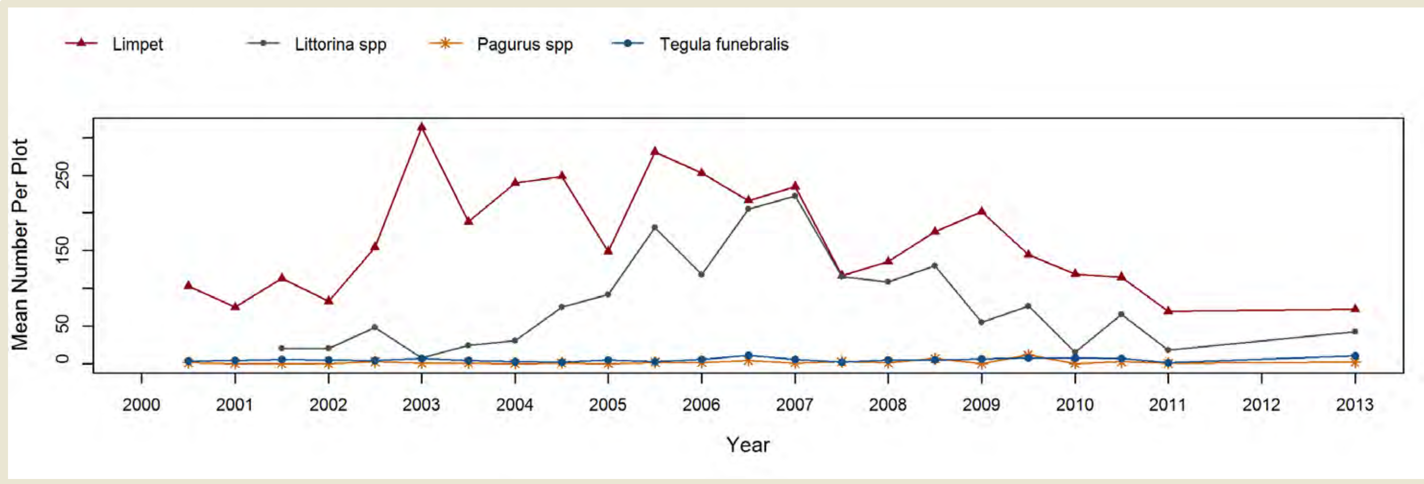
Silvetia (Golden Rockweed) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



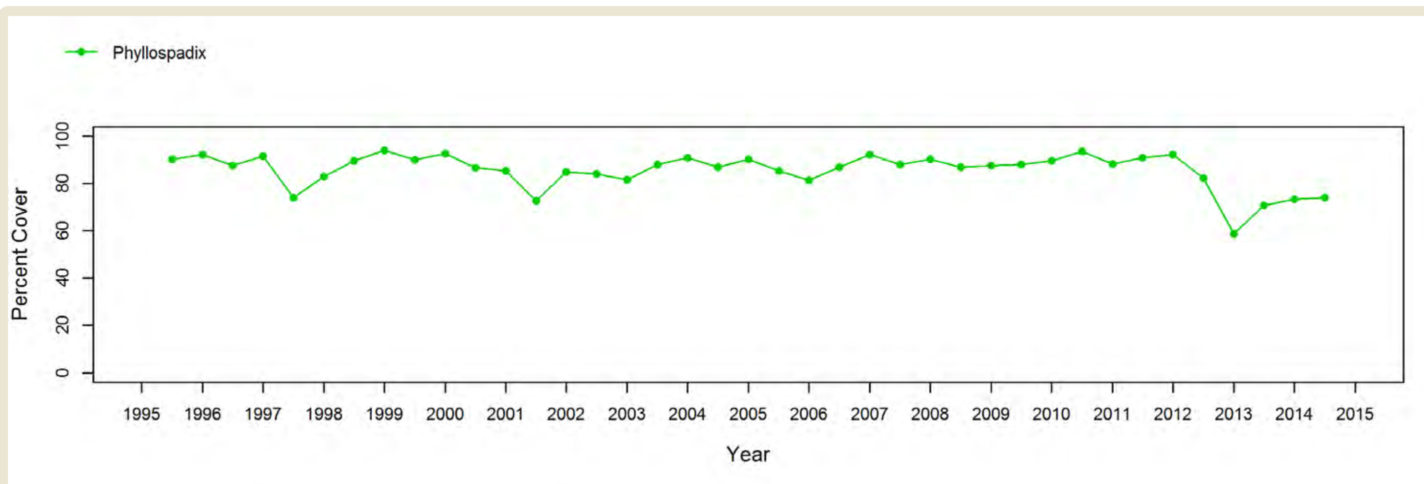
Endocladia (Turfweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

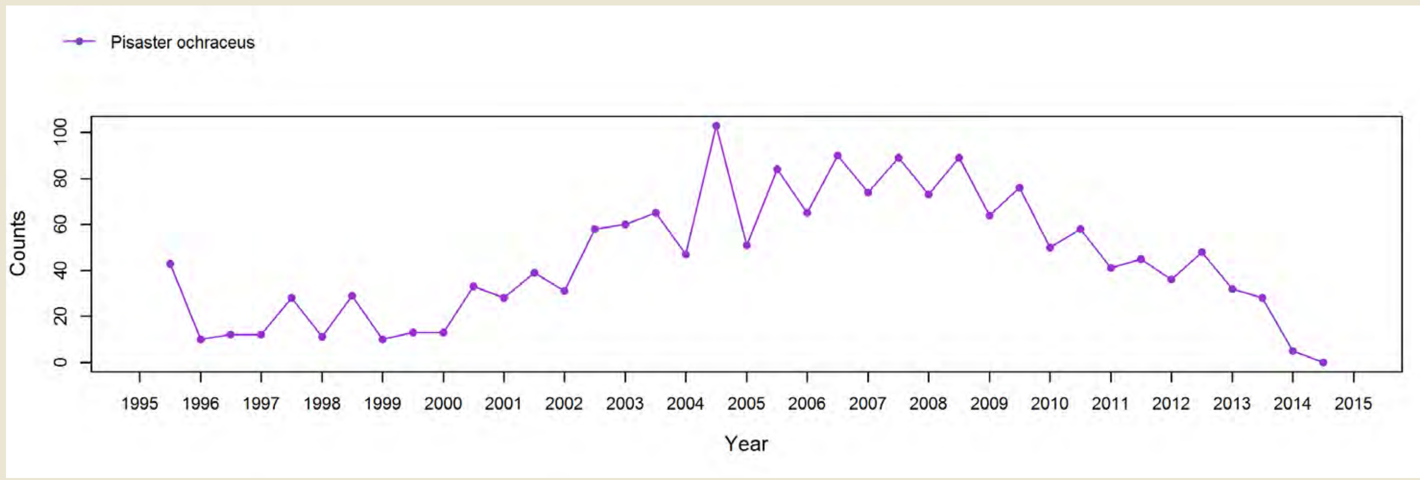
Phyllospadix (Surfgrass)



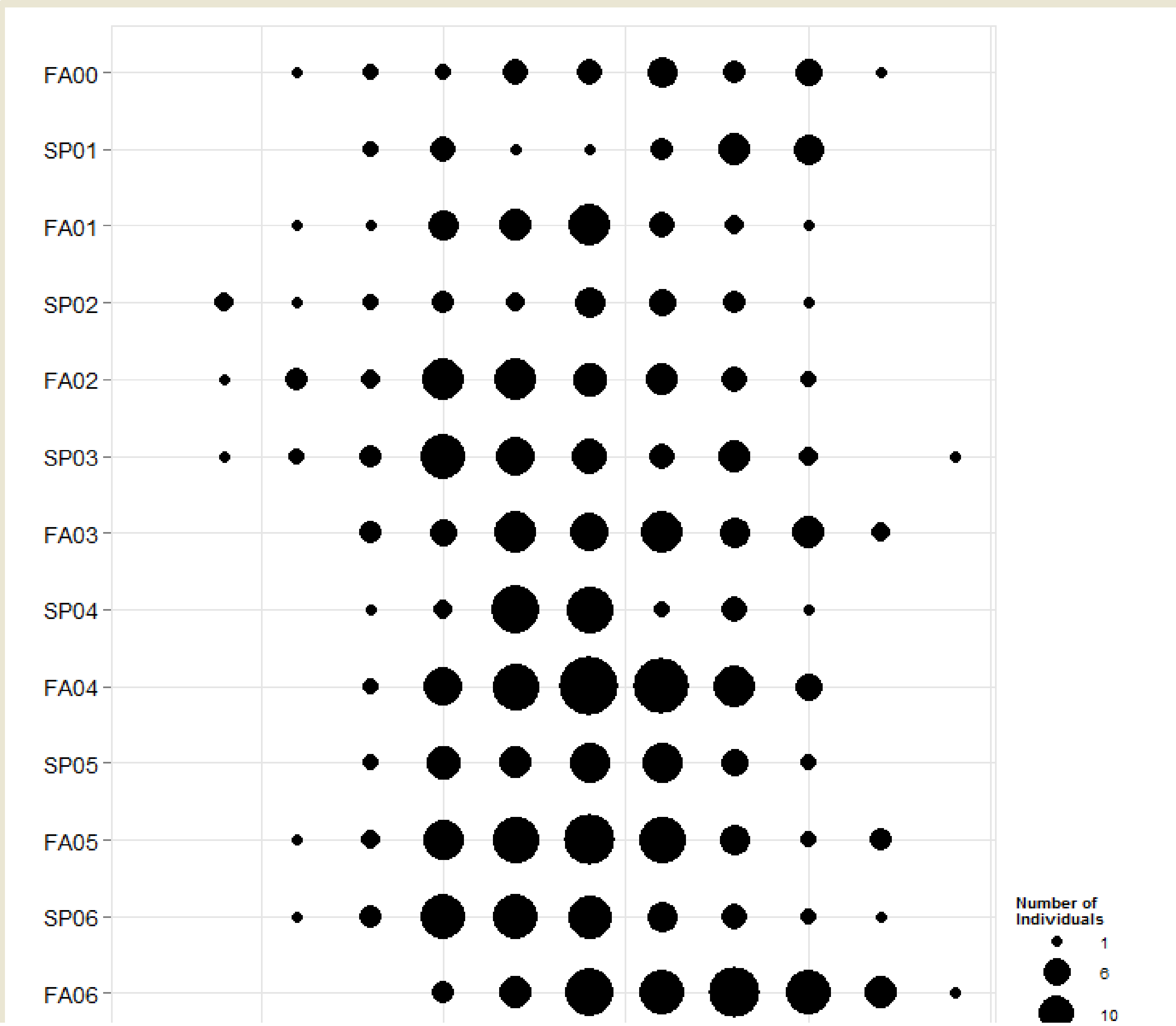
Species Counts and Sizes

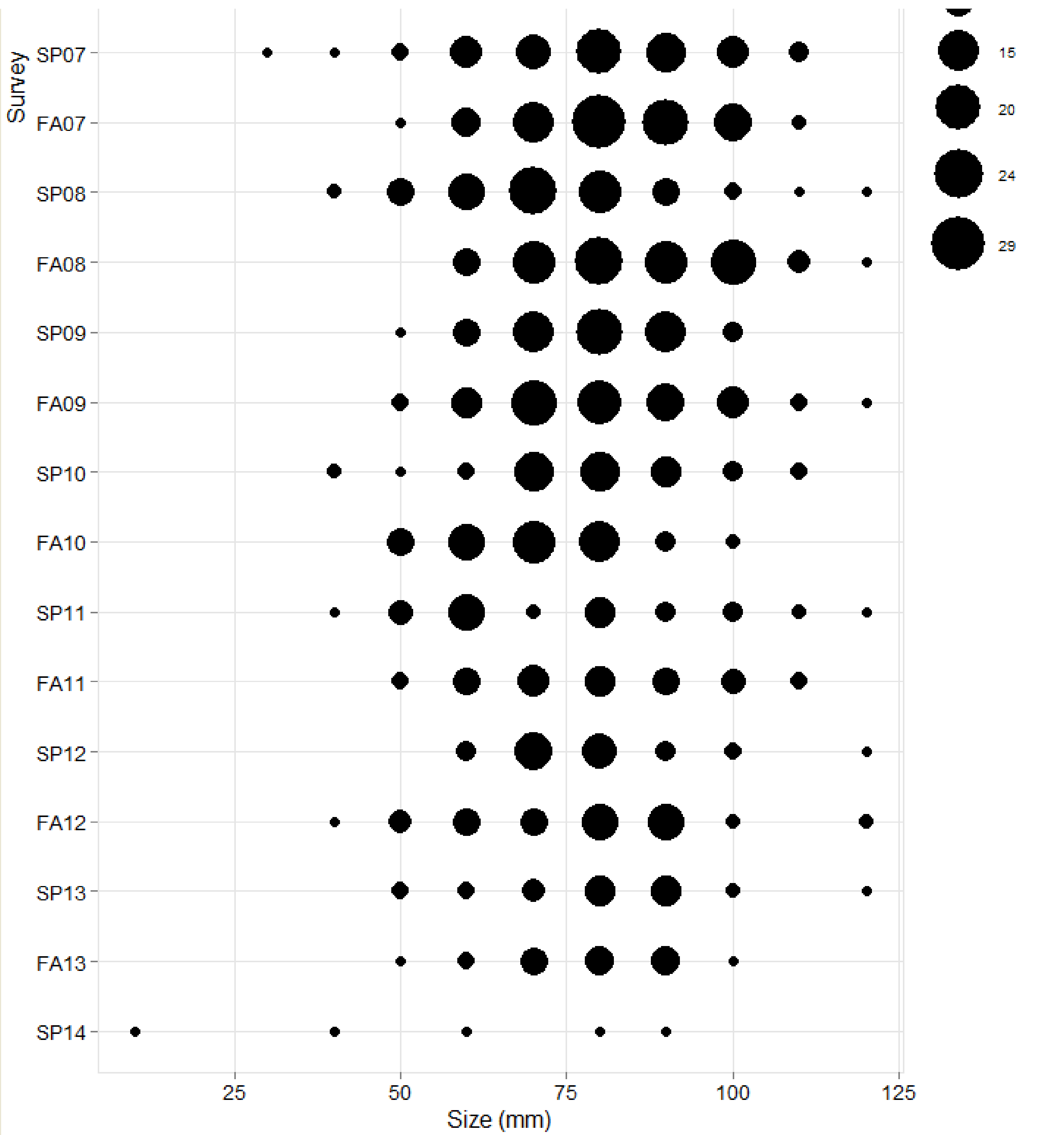
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Hazards Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The barnacle plots at Hazards are located in an area heavily infuenced by sand, and declines were often associated with scouring events. This was particularly true in spring 2003 and fall 2014, when opportunistic red and green algae, *Porphyra* and *Ulva*, colonized large patches of bare space recently cleared by sand scour. The 2014 scouring event nearly wiped out barnacles in these plots. A mixture of *Chthamalus* and *Balanus* was present in these plots. Littorines were typically present in very high numbers, often upwards of 1000 individuals per plot, while limpets tended to be an order of magnitude less common.

Initial mussel cover was somewhat low at Hazards (approximately 45%) because plots were established fairly high in the mussel zone to make sampling easier when large swells were present at the site. Denser mussel beds were present at Hazards, but were located on exposed outer reefs. An added benefit to placing the mussel plots higher in the intertidal is that *Pollicipes* cover was fairly high in the plots (almost 20%), so goose barnacles could be monitored along with the mussels. Both *Mytilus* and *Pollicipes* cover have been relatively stable at Hazards. Limpets were the most abundant motile invertebrate in the mussel plots and varied seasonally, with higher counts in fall than in spring. *Tegula funebralis* and *Nucella* spp. (mostly *N. emarginata/ostrina*) were also common.

Silvetia declined gradually between 1995-2010, but has steadily increased over the past 5 years. *Silvetia* cover was roughly 65% in Fall 2014, driven primarily by the recovery of plots 4 and 5. As *Silvetia* cover decreased, limpet cover increased, likely due to the additional “open” space (crustose algae covered rock) available for grazing. The turban snail, *Tegula funebralis* is also common in the *Silvetia* plots at Hazards.

Endocladia declined during the frst few years that it was monitored at Hazards, but has hovered around 10-20% cover since this initial decline. As with many other sites, turfweed cover fuctuated seasonally, with higher cover in spring than in fall. The open space resulting from the reduced cover of *Endocladia* has been colonized by barnacles, which gradually increased in cover until 2009, then declined somewhat and stabilized around 30% cover. Littorines are the most abundant motile invertebrate present in the *Endocladia* plots. *Tegula funebralis* and limpets are also common.

Mean cover of *Mazzaella* remained relatively constant over time at Hazards. Unlike Pt. Sierra

Nevada, the only other site where *Mazzaella* is targeted, there was no apparent seasonal variation in cover. "Other Red Algae" consisted mainly of *Chondracanthus canaliculatus*.

Phyllospadix cover at Hazards remained high over time, although it should be noted that averages are not always based on all three transects. Transects at this site were established in the very low intertidal, and thus cannot always be sampled. In SP02, FA04, FA11, SP12, FA12, FA13, SP14 and FA14 transects were not accessible for sampling. In FA02, SP03, SP09, FA09 and FA10 only the highest transect could be sampled. In FA05, SP06, FA07, FA08, and SP10 only two transects were accessible.

Pisaster ochraceus were abundant but variable for the frst several years they were monitored at Hazards. Numbers increased substantially in 2006/2007, and size data suggest that this increase may have been due to a large recruitment event just before this period as large numbers of juveniles were recorded. In 2008, a declining trend began, and counts of ochre stars are currently quite low, following recent further decline due to sea star wasting syndrome. In addition, the plots were buried in sand from early August 2014 through mid-Spetember 2014, as evidenced by data collected from our temperature logger (which is located at the edge of plot 1), extremely high scour seen throughout the plots, and an enormous berm of drift found just above the sea star and barnacle plots in fall 2014. This sand burial and subsequent scour likely impacted the sea star counts at this site, as healthy stars were found outside the plots.

Photo Plots

Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

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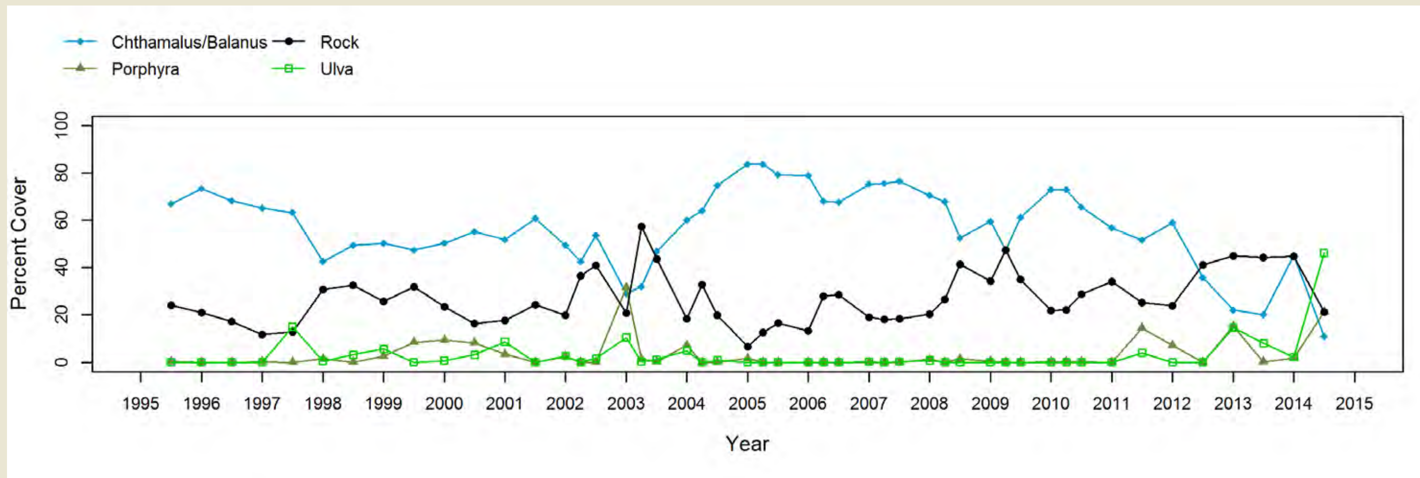
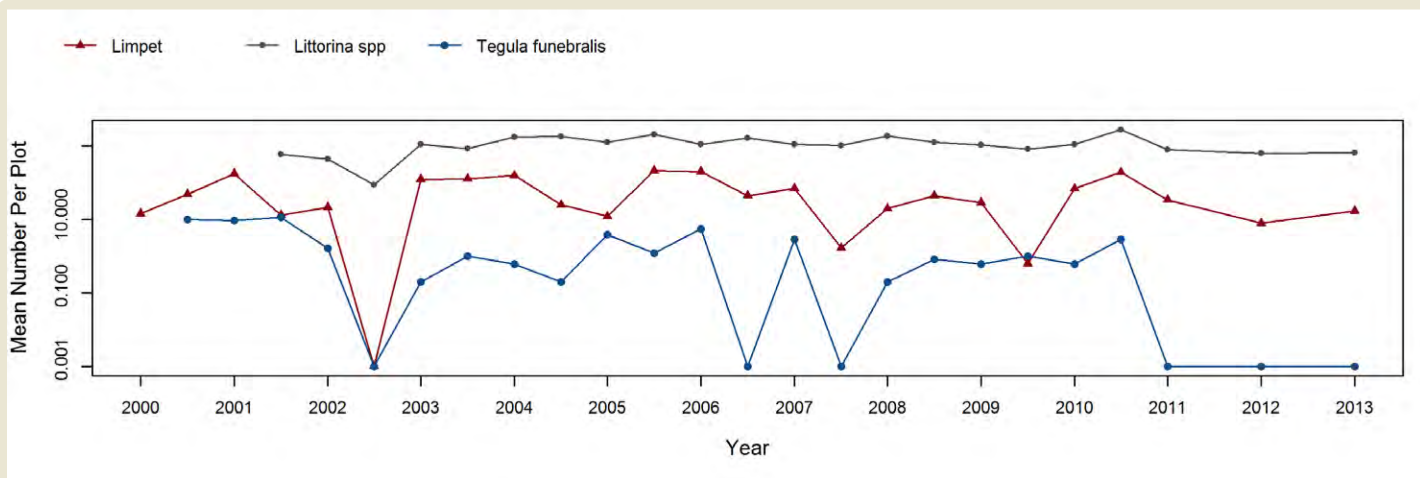
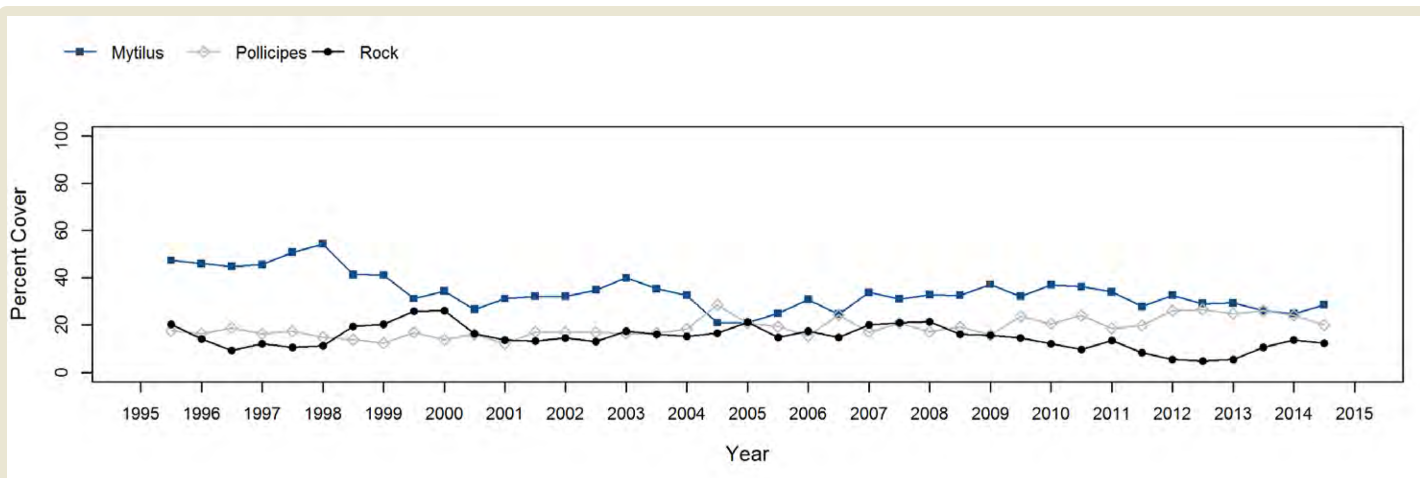
Chthamalus/Balanus (Acorn Barnacles) - percent cover



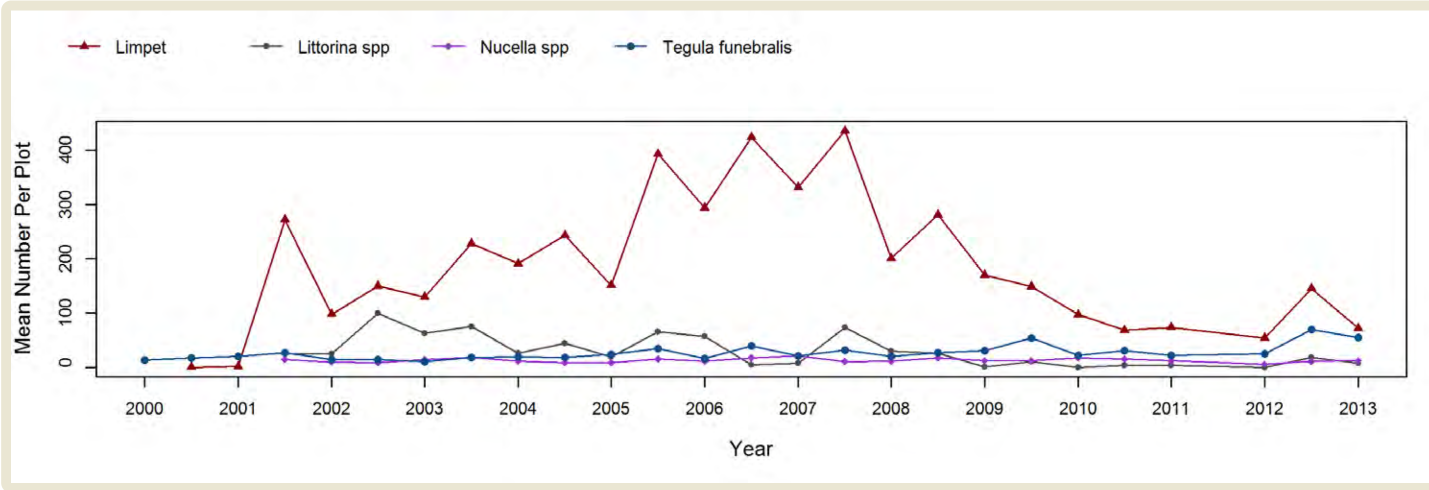
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



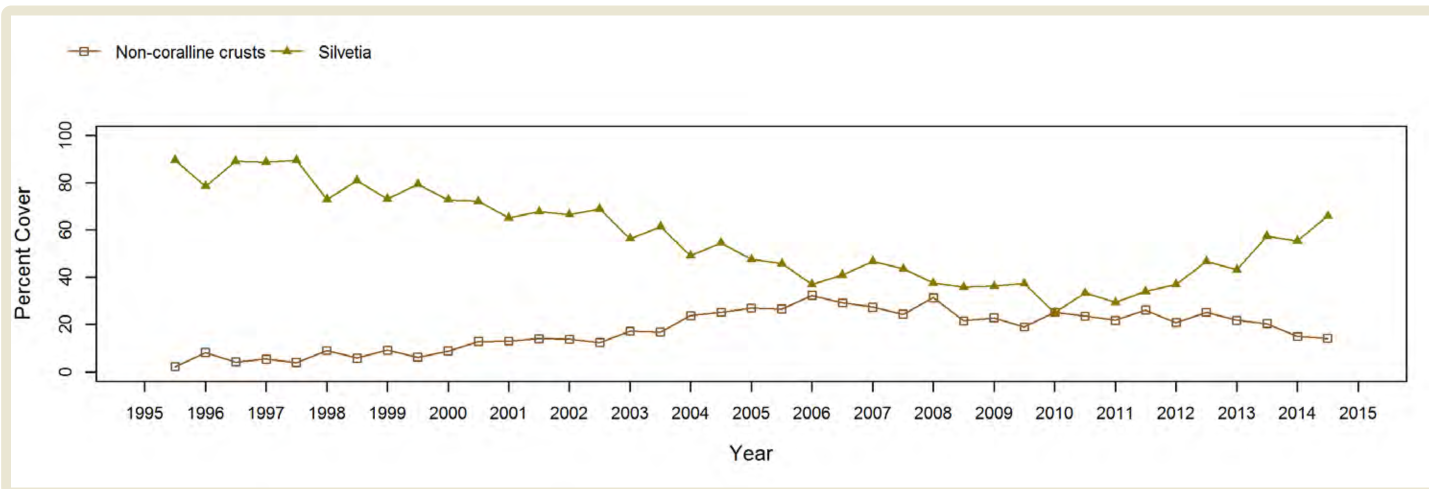
Mytilus (California Mussel) - percent cover



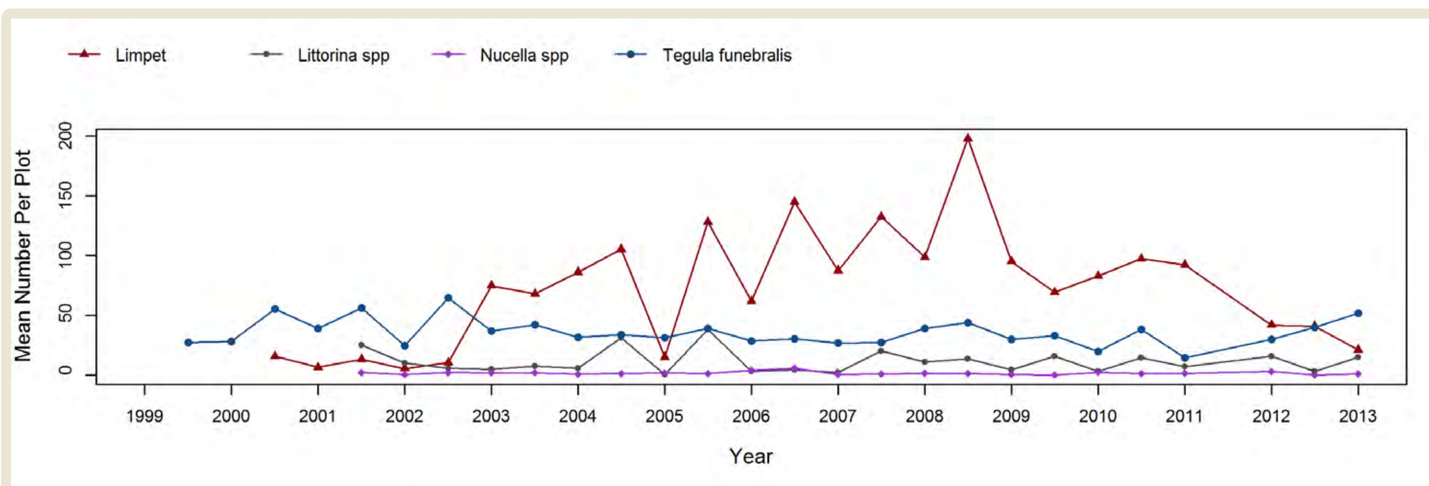
Mytilus (California Mussel) - motile invertebrate counts



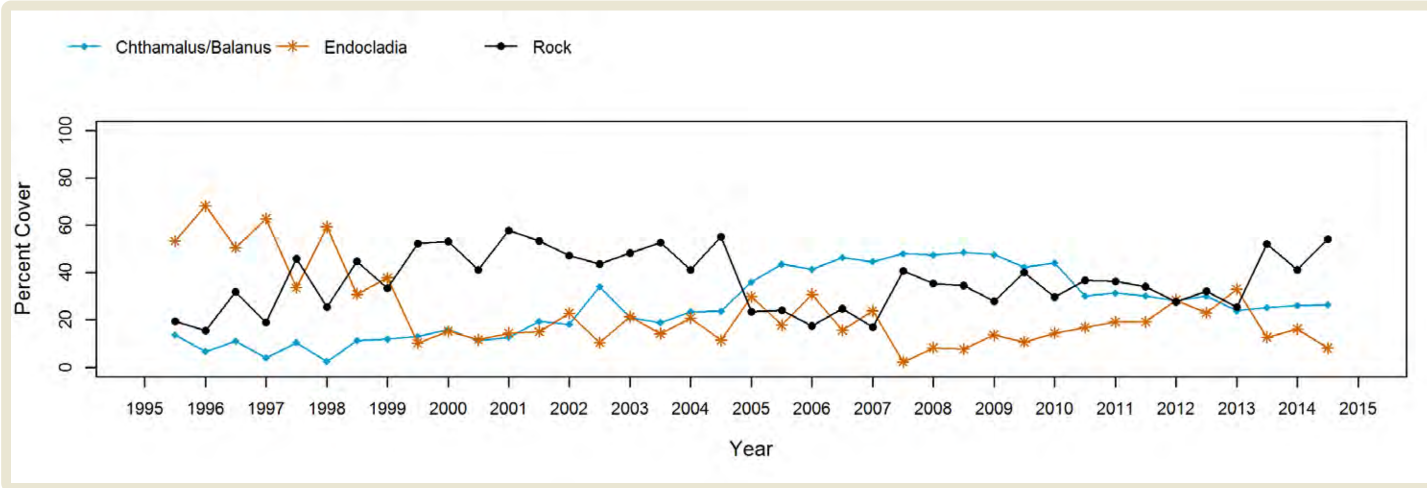
Silvetia (Golden Rockweed) - percent cover



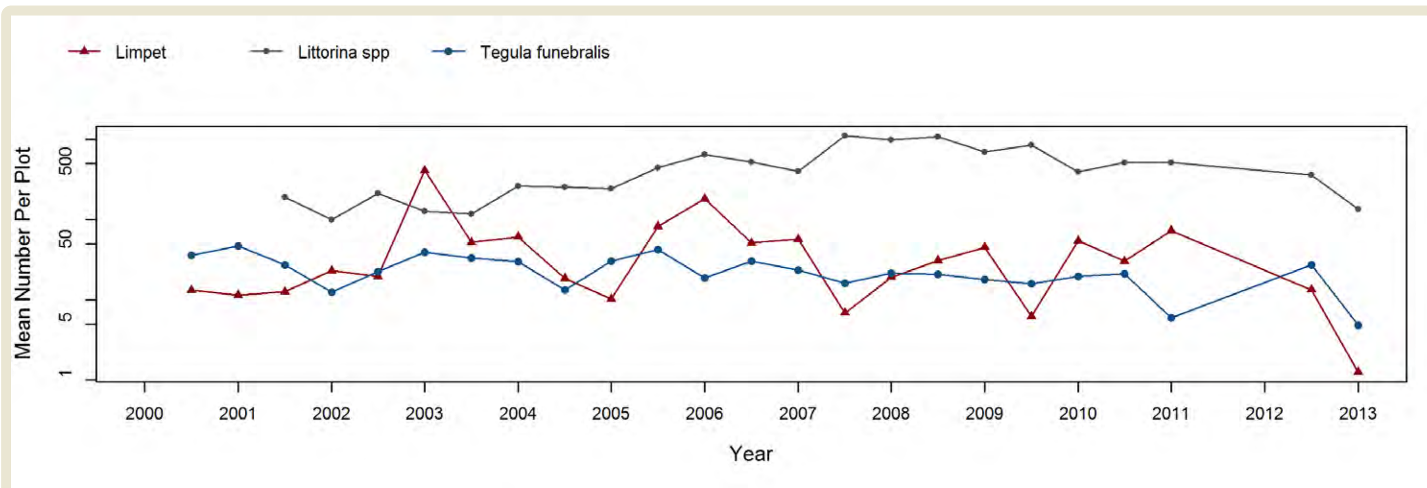
Silvetia (Golden Rockweed) - motile invertebrate counts



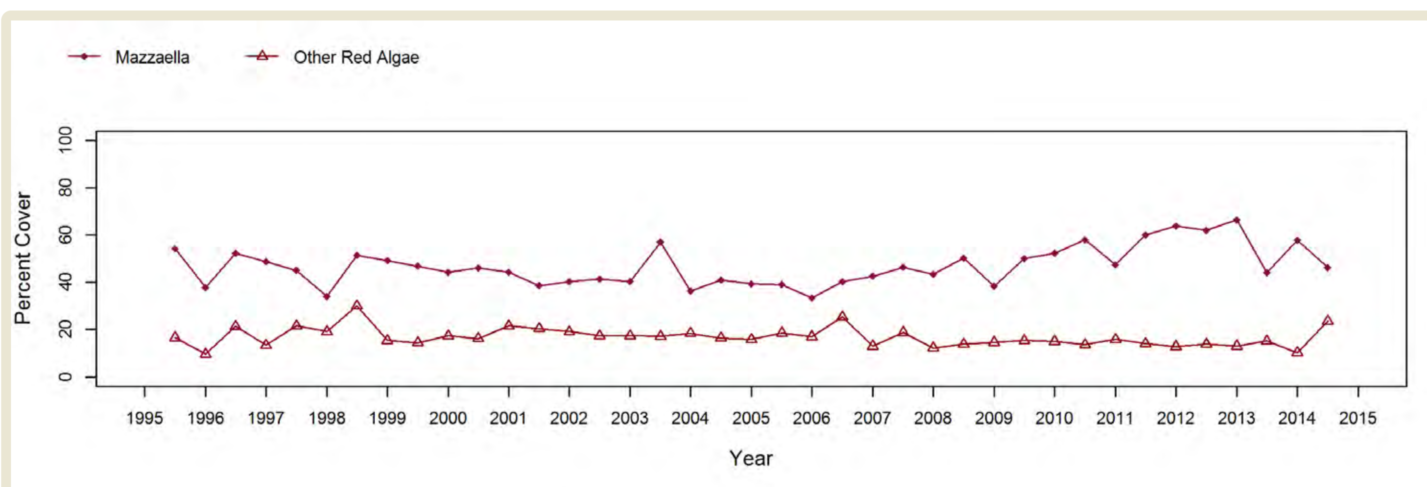
Endocladia (Turfweed) - percent cover



Endocladia (Turfweed) - motile invertebrate counts



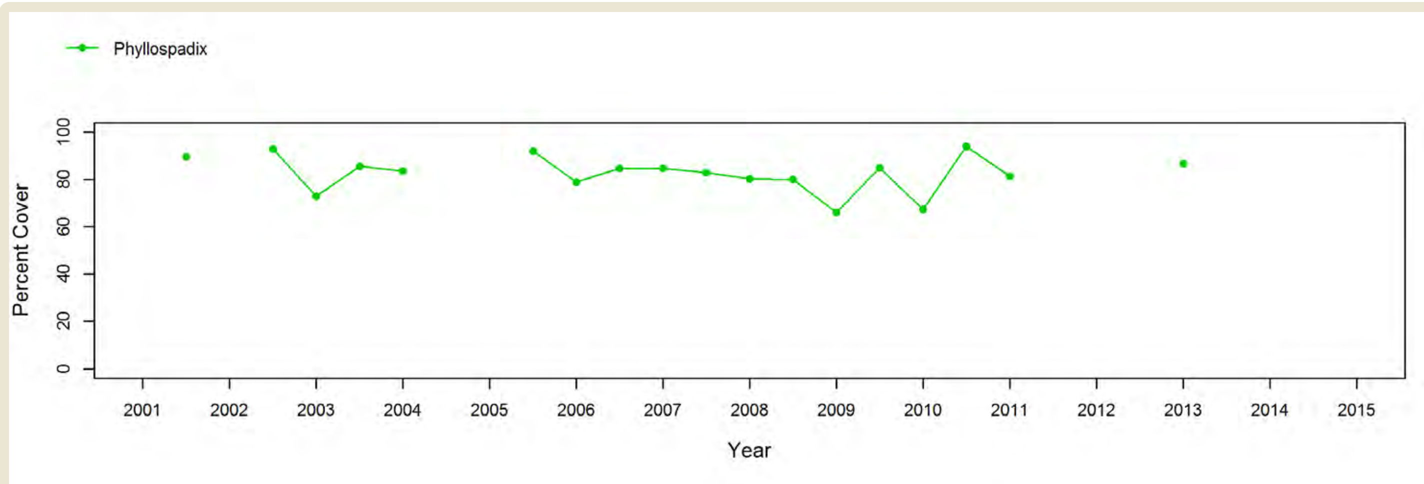
Mazzaella (Iridescent Weed)



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

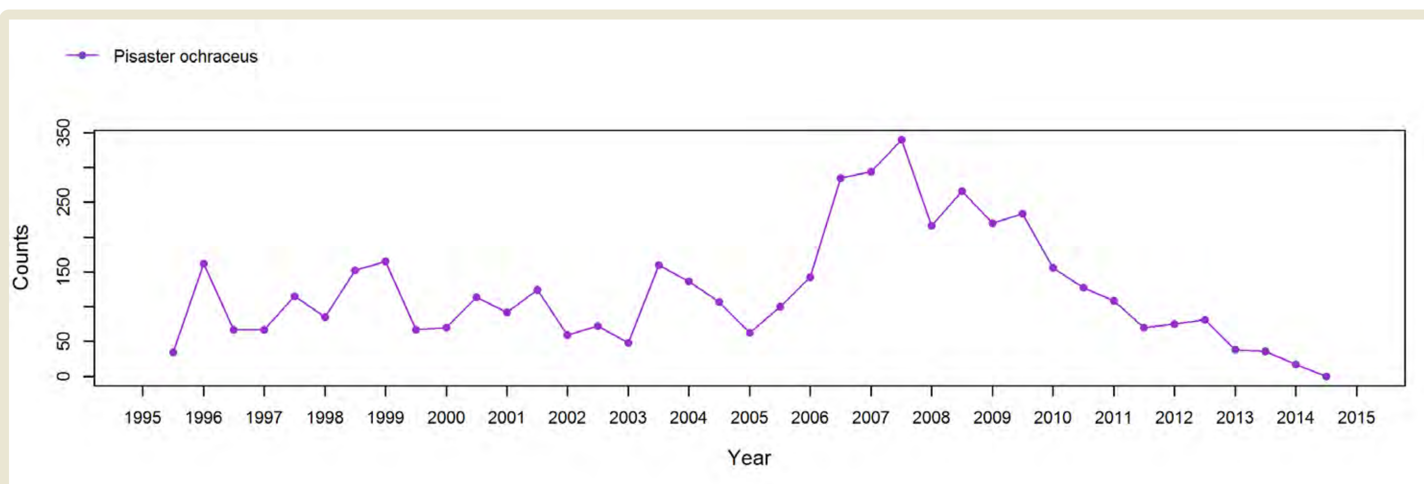
Phyllospadix (Surfgrass)



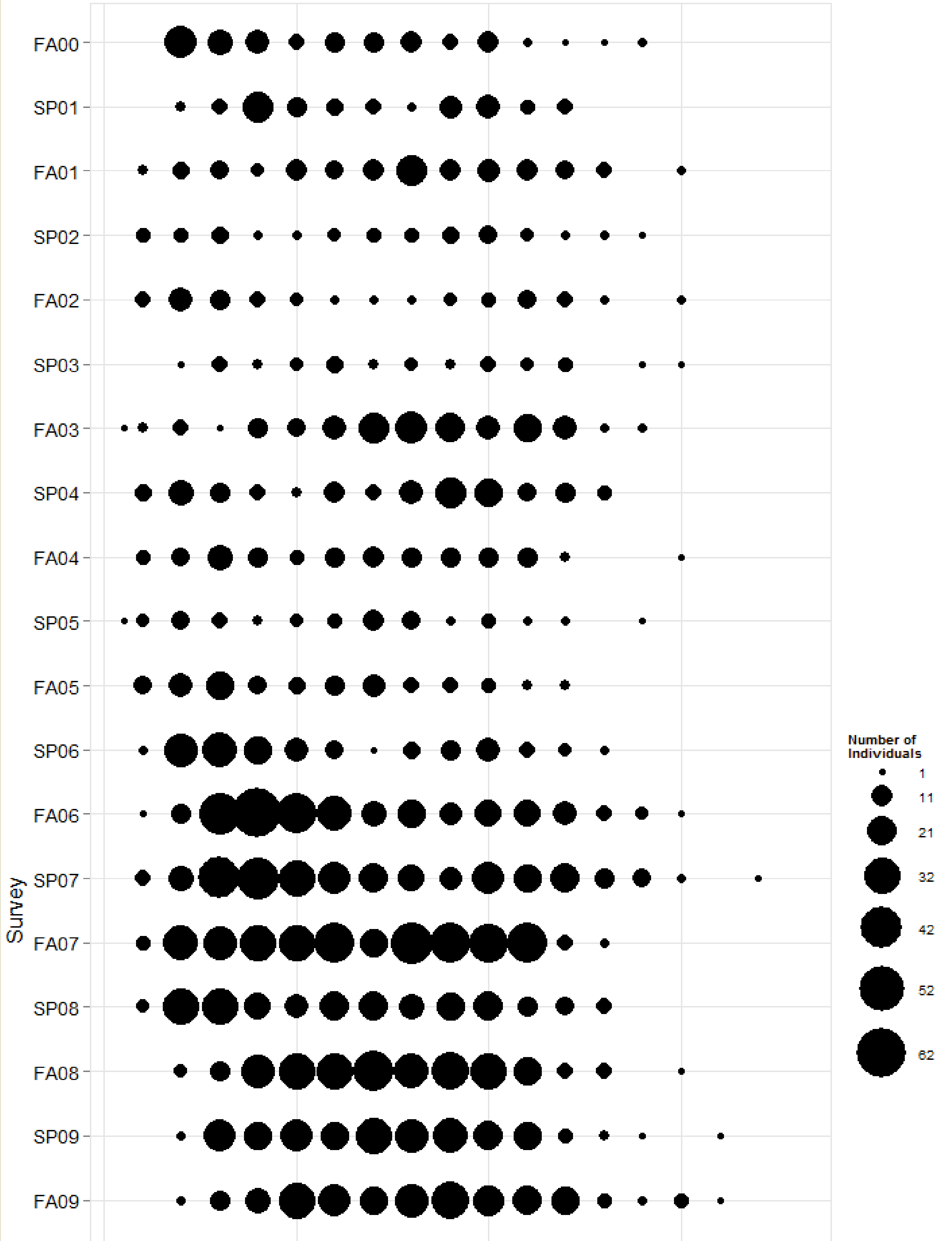
Species Counts and Sizes

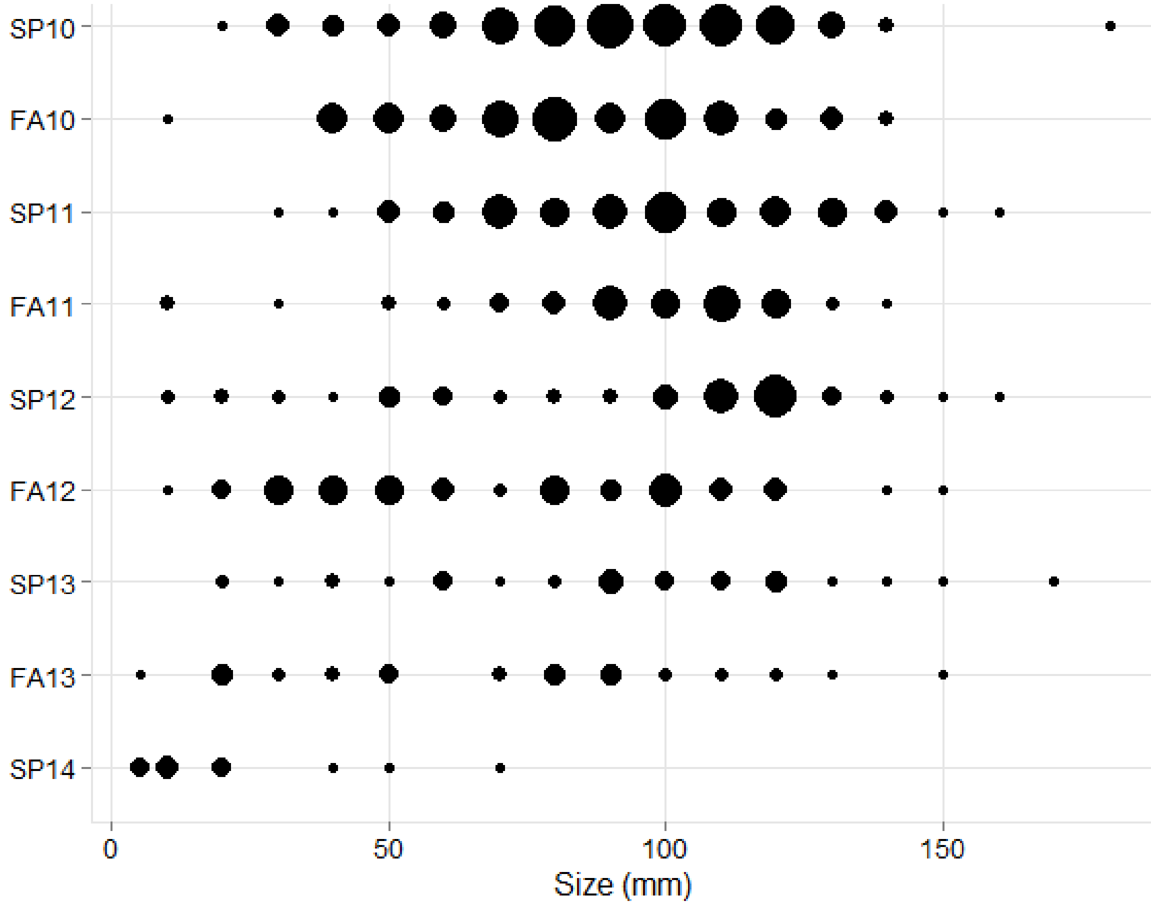
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Shell Beach Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle plots at Shell Beach consist almost exclusively of *Chthamalus dalli/fssus* , although *Balanus glandula* are recorded on rare occasion (note that species were not distinguished until 2001). Barnacle cover was consistently high at this site until 2008, when a sharp drop occurred. Barnacles had been steadily recovering, and were nearly at initial levels, until they experienced a substantial drop again in Fall 2013 due to a possible scouring event. In the fall 2014, barnacle cover in the plots ranged from 40-77%, with the lowest cover in plot 4. Barnacle plot 4 was dominated by bare rock. Littorines were the most abundant motile invertebrate in these plots, followed by limpets. *Tegula funebralis* was commonly found in low numbers.

Mussel cover at Shell Beach was initially high, but then declined during the 1997/98 El Niño event. Mussels experienced a brief recovery in 2003/2004, but then rapidly declined to low levels in subsequent years. Shell Beach is a highly accessible site and thus decline may be due, in part, to trampling and collection for food or bait. The mussel bed at Shell Beach is extremely small, and would be highly impacted by even a small level of collecting. *Endocladia* has slowly colonized the open space within the mussel plots, which could potentially enhance any future settlement of mussels, as this turf alga can act as an ideal recruitment environment for mussels. Fluctuations in the broad group “other invertebrates” largely consisted of periodic mass settlement events of the tube worm *Phragmatopoma*, followed by gradual die-offs. However, in recent years *Phragmatopoma* appears to be increasing throughout the site. Limpets, and the turban snail *Tegula funebralis*, were quite common in mussel plots at Shell Beach.

Endocladia dominates the mid-intertidal at Shell Beach. This is evident in the trend plots for *Silvetia*, where rockweed cover steadily declined over time, and was replaced largely by turf weed. *Endocladia* was also the most abundant species in *Mastocarpus* plots. Plots established to target *Endocladia* are located in the upper-mid intertidal zone, where the turf weed appeared to be near its upper limit, sharing dominance with barnacles. Littorines, limpets, and *Tegula funebralis* were variable but generally abundant in both *Silvetia* and *Endocladia* plots (motile invertebrates are not counted in *Mastocarpus* plots). *Cyanoplax hartwegii* was present in *Silvetia* plots initially when the shelter-providing rockweed was more common, but became much rarer after cover declined to near zero.

Phyllospadix cover remained relatively high over time at Shell Beach, and exhibited the strong seasonal variation seen at many other sites, with higher cover in fall than in spring. "Other Red Algae" consisted mainly of *Chondracanthus canaliculatus* and *Gastroclonium subarticulatum*.

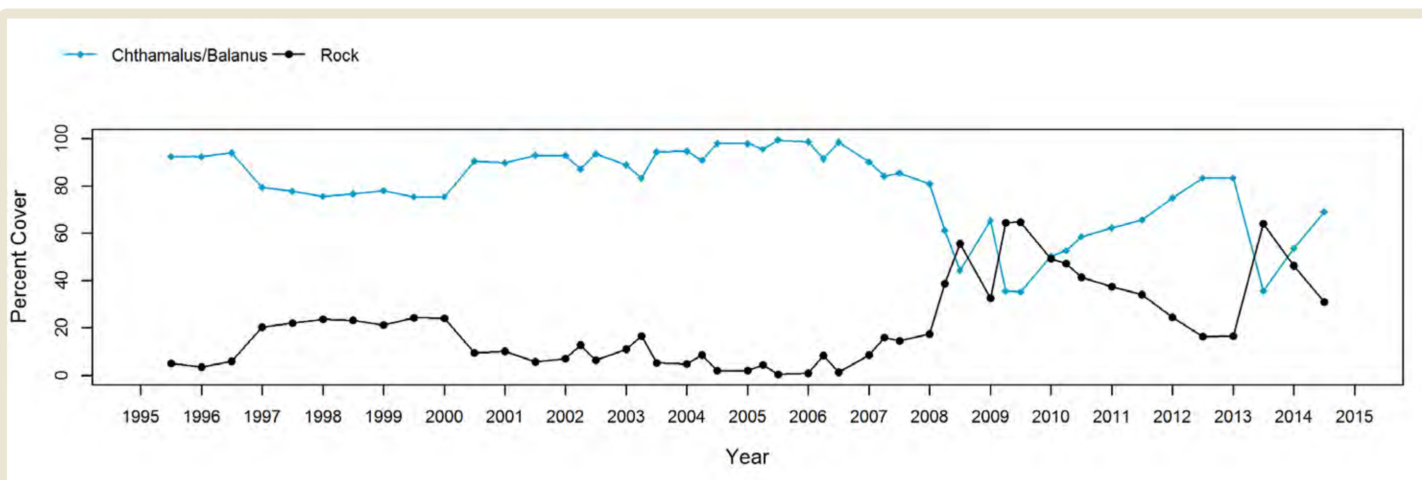
Counts of the seastar, *Pisaster ochraceus*, were variable over time, but in general not very high when compared to other sites, and sea star wasting syndrome resulted in the near-disappearance of stars at Shell Beach in spring 2014. Evidence of SSWS was frst detected during our site visit in November 2013 and by spring 2014, no sea stars were observed in our plots, however, 3 Pisaster were found during a site-wide search. As of fall 2014, 6 Pisaster were found in the plots, with the majority being <40mm and only 1 being >100mm. As discussed above, the mussel bed at Shell Beach is small and not very dense; thus the low number of sea stars at this site is likely a result of low food availability.

Photo Plots

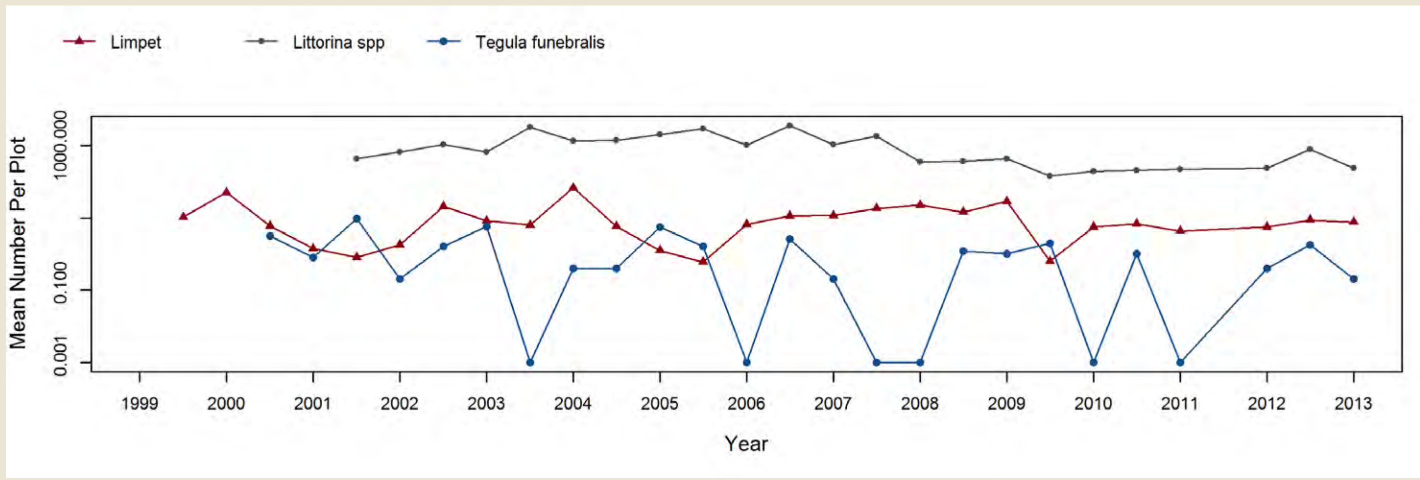
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since spring 2013. For motile invertebrate size trend graphs by site, please use the Interactive Map.

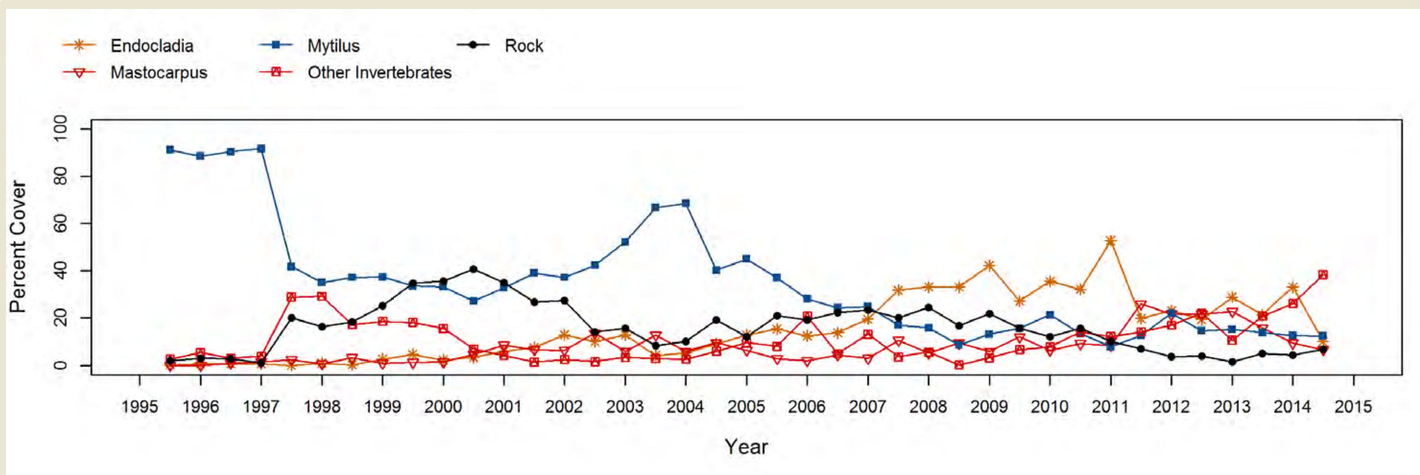
Chthamalus/Balanus (Acorn Barnacles) - percent cover



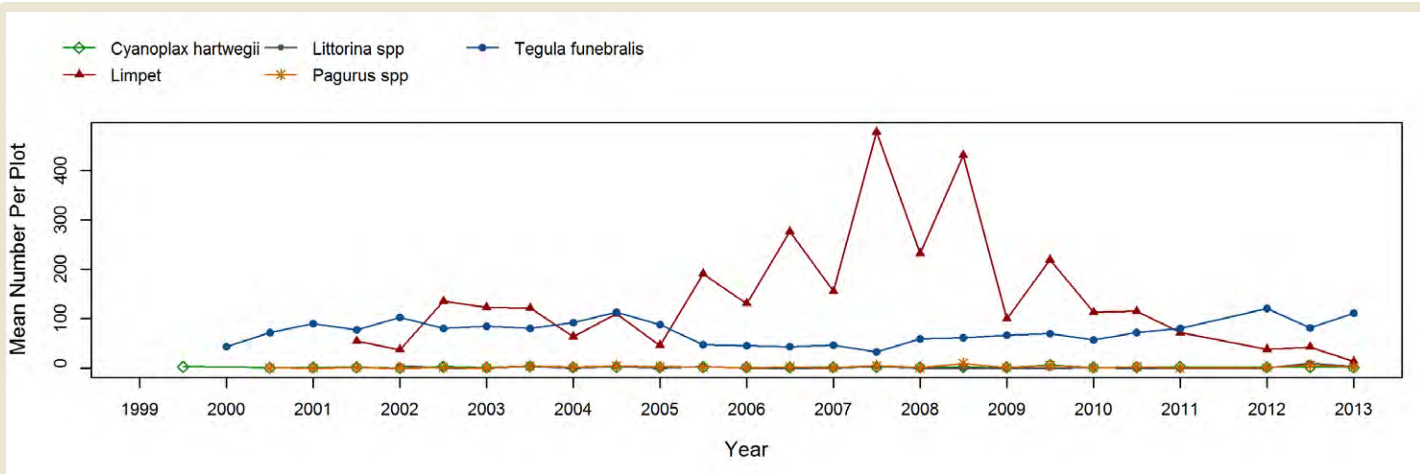
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



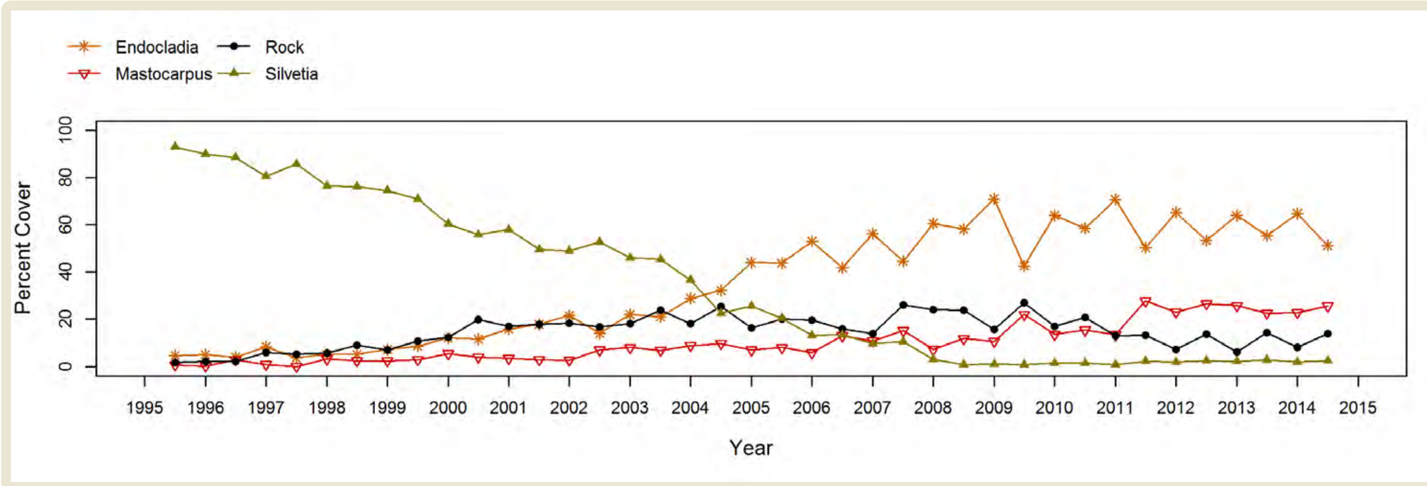
Mytilus (California Mussel) - percent cover



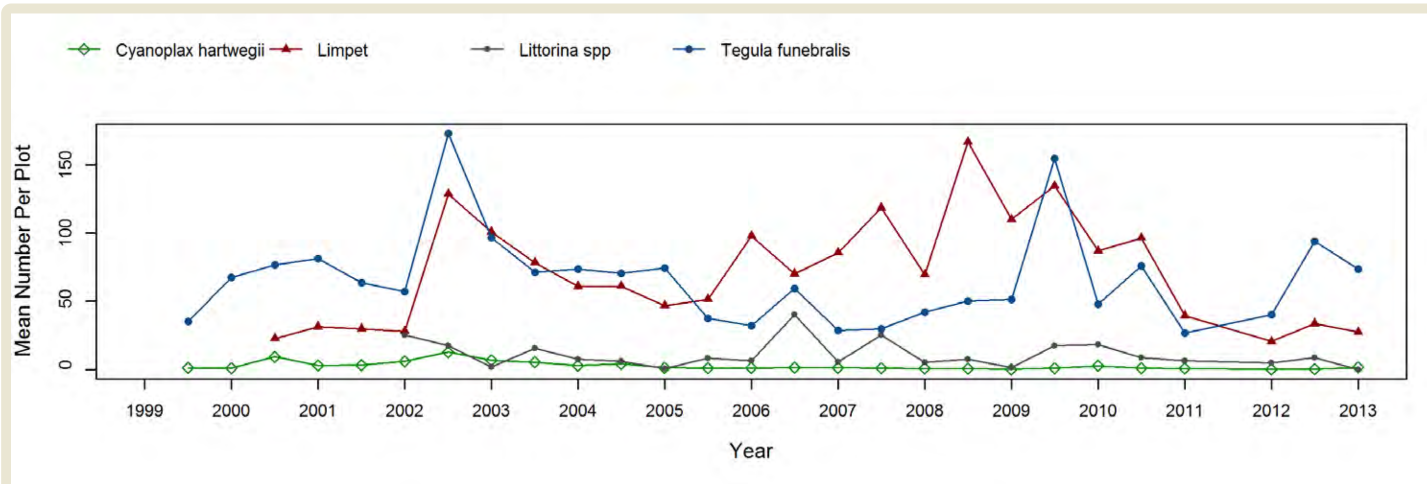
Mytilus (California Mussel) - motile invertebrate counts



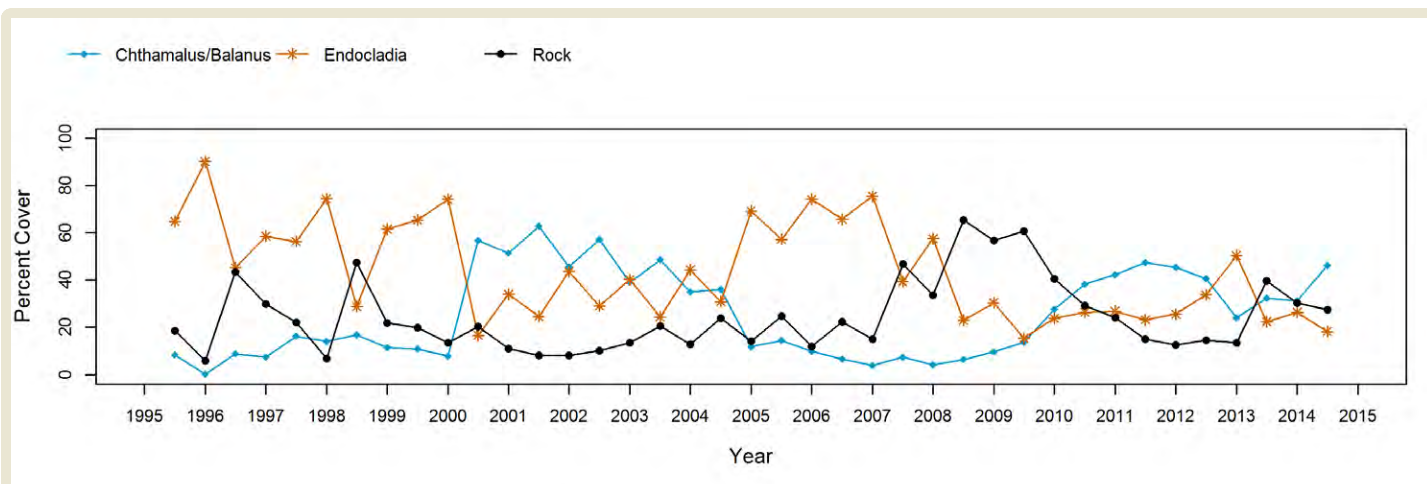
Silvetia (Golden Rockweed) - percent cover



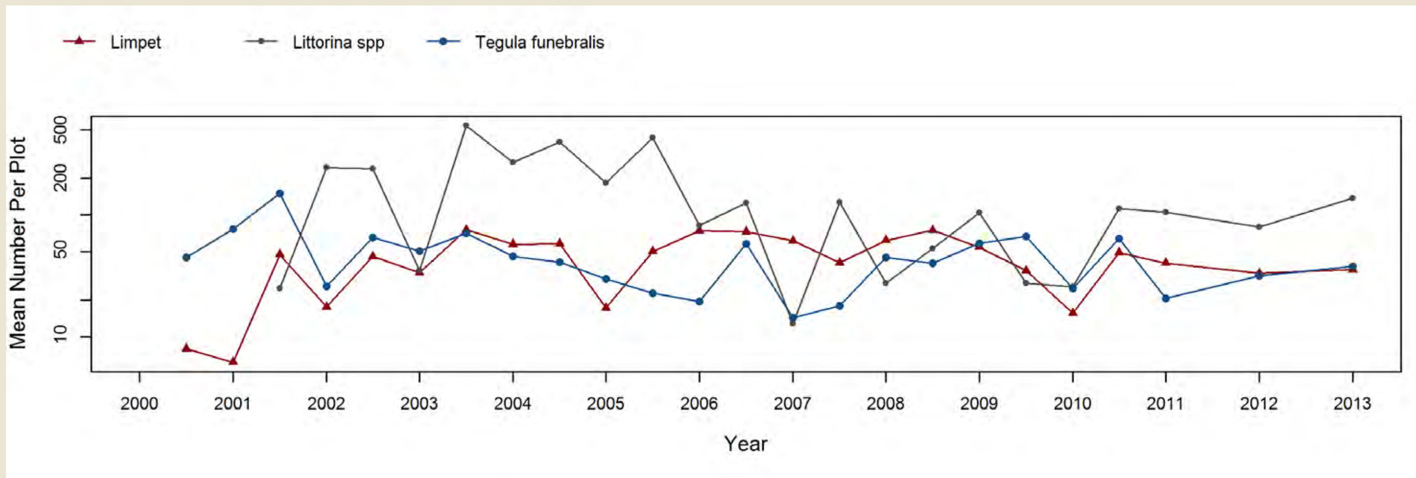
Silvetia (Golden Rockweed) - motile invertebrate counts



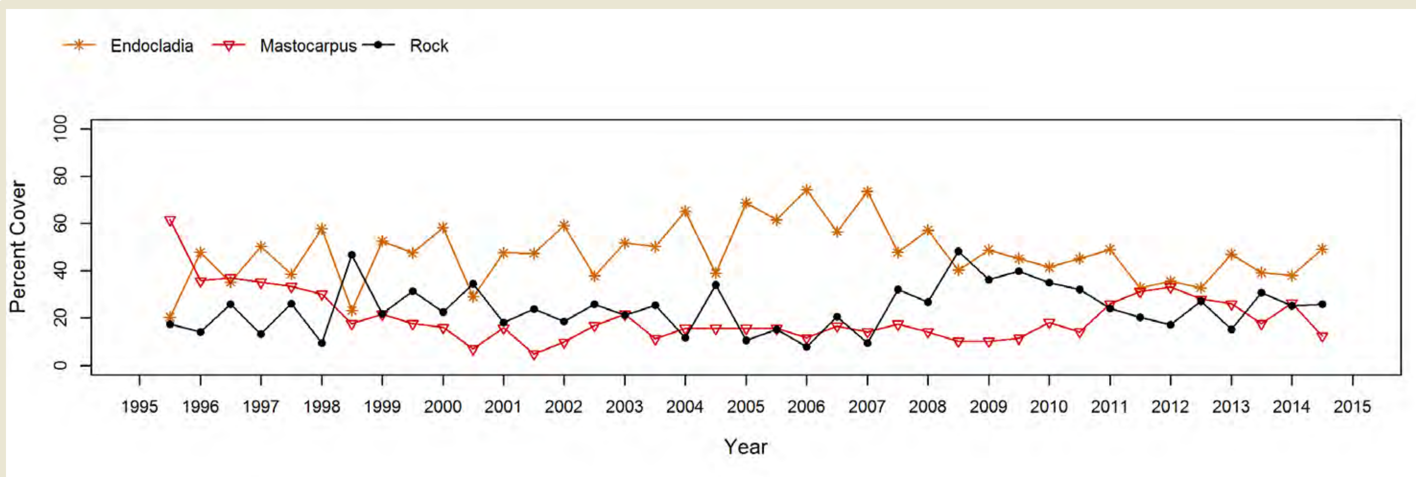
Endocladia (Turfweed) - percent cover



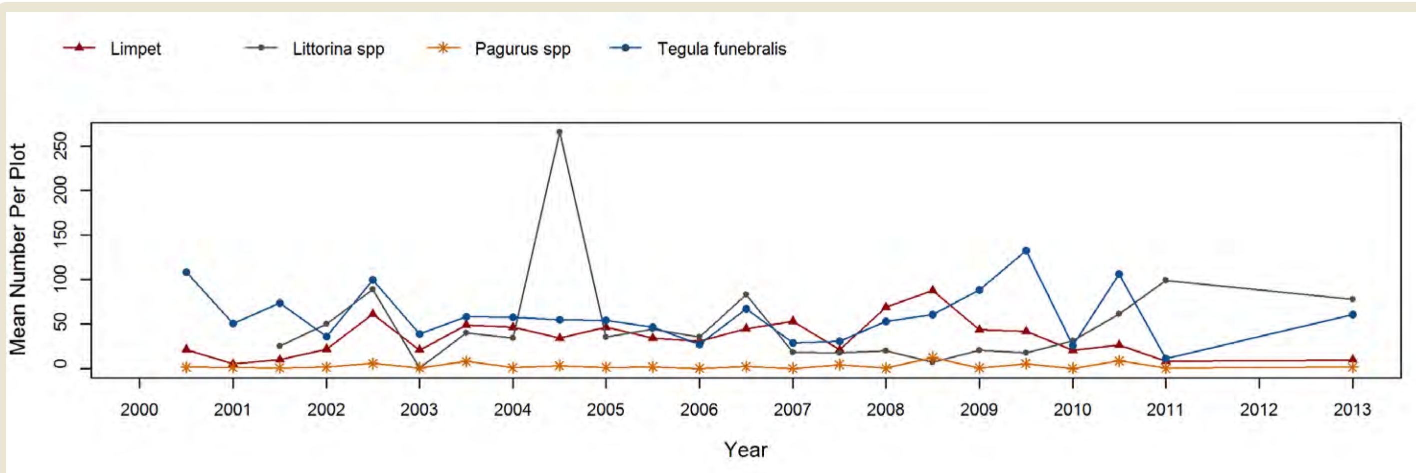
Endocladia (Turfweed) - motile invertebrate counts



Mastocarpus (Turkish Washcloth) - percent cover



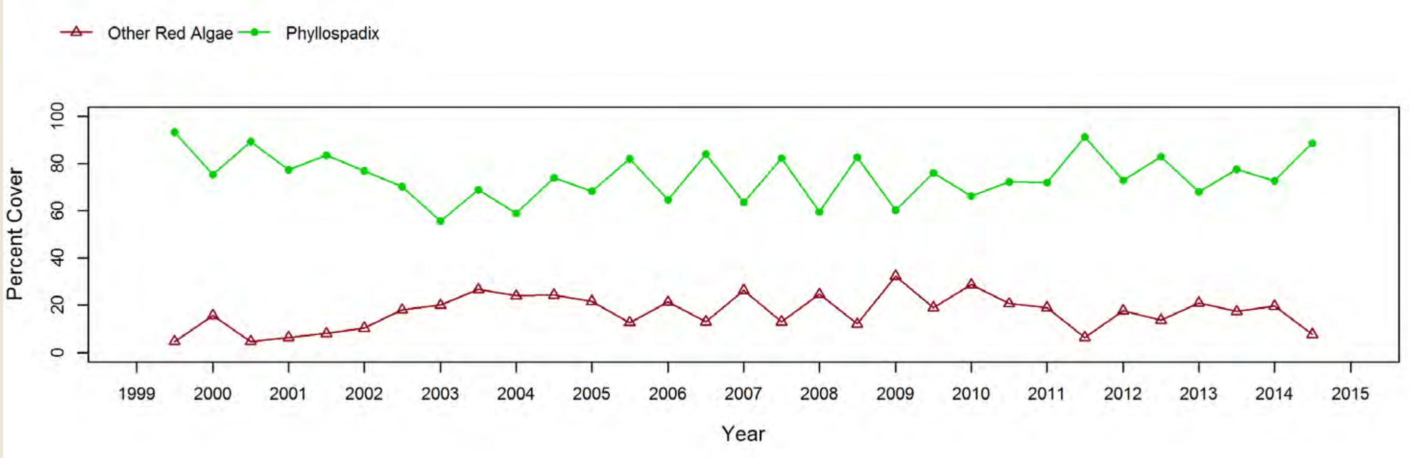
Mastocarpus (Turkish Washcloth) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

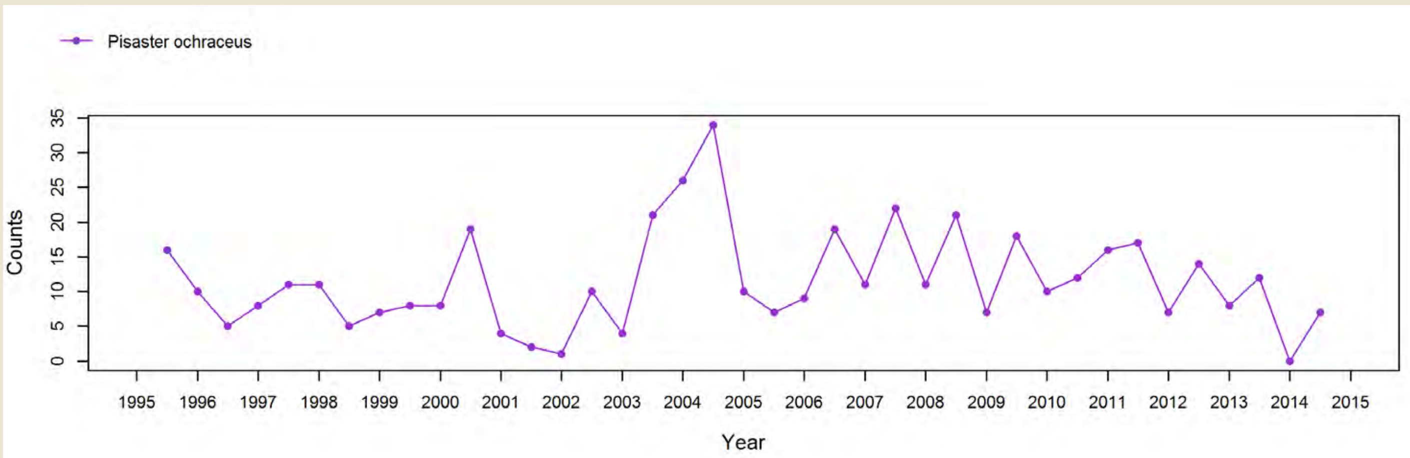
Phyllospadix (Surfgrass)



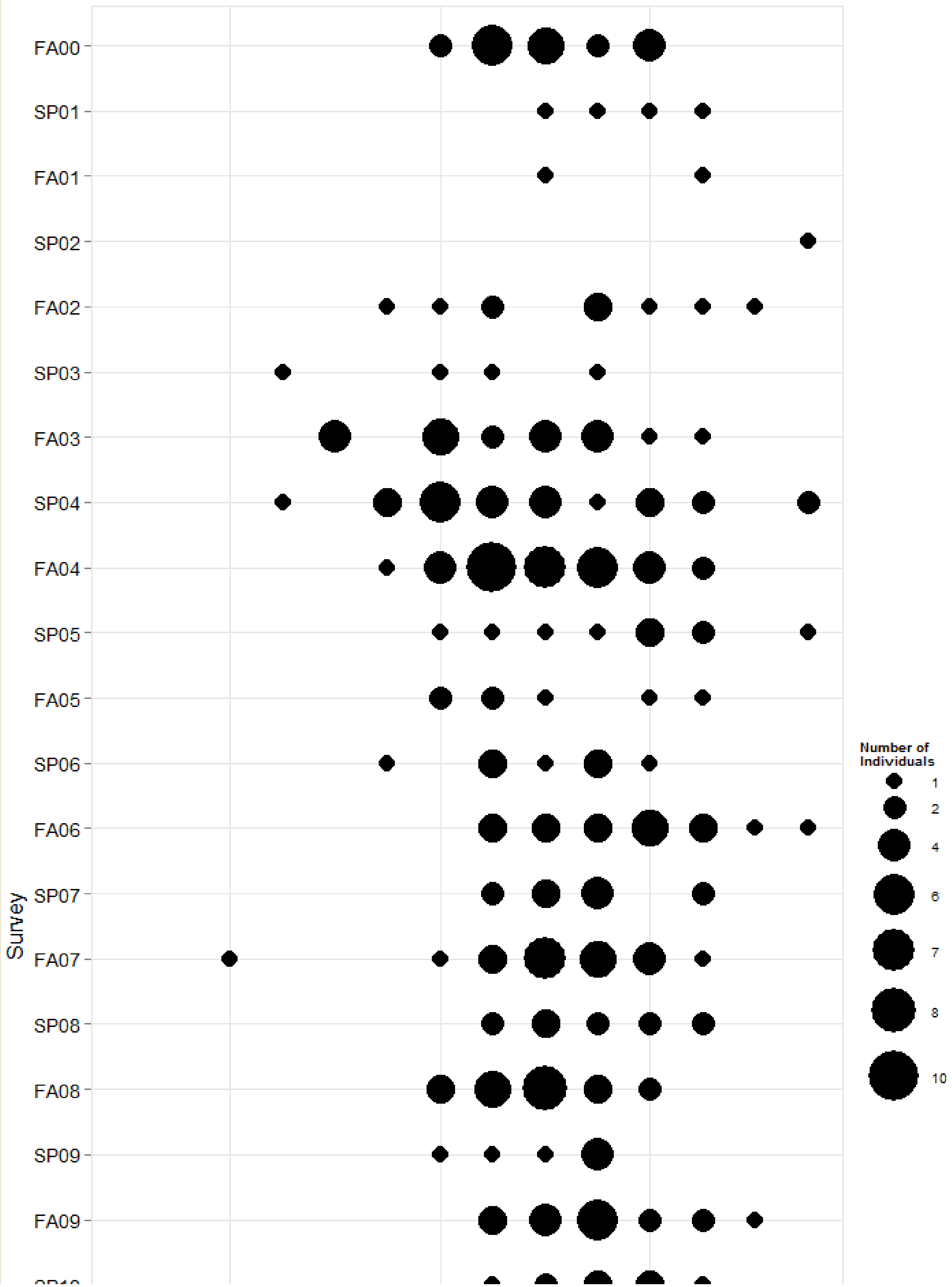
Species Counts and Sizes

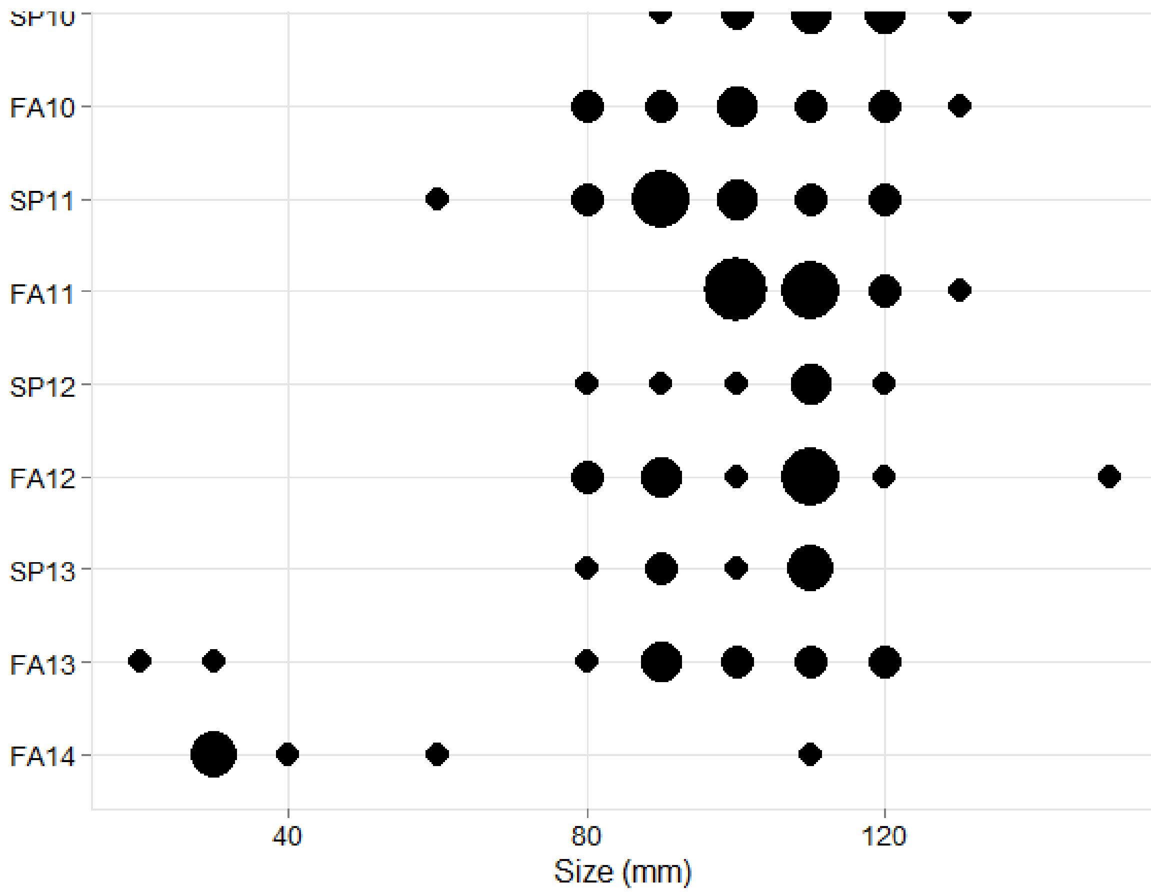
Species Counts and Sizes (where recorded) for Pisaster are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Occulto Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacles (a mixture of *Chthamalus fssus/dalli* and *Balanus glandula*) within plots at Occulto declined substantially during the frst few years of monitoring, but recovered somewhat in more recent years. While bare space was still present in the plots, much of it has become occupied by mussels and several algal species, including *Endocladia, Silvetia* and *Cladophora*. Barnacles recruiting into this site tended to settle above the barnacle plots, in an area that is at a higher tidal elevation than barnacles were commonly found when monitoring began at Occulto over 20 years ago. Thus, although barnacles in the plots have declined substantially, they are still common at the site overall. Limpets and littorines were common in these high intertidal plots, and a few *Nucella* spp. were found amongst the mussels.

Mytilus cover within the mussel plots at Occulto has, on average, remained high over time. Storm-associated wave disturbance has removed mussels on occasion, and available space was temporarily colonized by other species, including *Mazzaella*, *Phragmatopoma*, and articulated corallines. However, mussels have always recovered. Limpets are the most abundant motile invertebrate counted in the mussel plots, but other species such as the whelk, *Nucella* spp. (mostly *N. emarginata/ostrina*), and the chiton, *Nuttallina* spp., were also commonly found.

Mytilus has steadily recruited into the *Endocladia* plots and is now a dominant part of what used to be a turf weed dominated community at Occulto. Presence of *Mytilus* does not necessarily exclude *Endocladia*, as the alga can grow on top of mussels. In recent years, *Endocladia* has declined site-wide and is now considered to be “present”, but by no means “common to abundant” as previously described. The *Endocladia* plots are now primarily composed of bare rock and *Mytilus*. Limpets and littorines were the most common motile invertebrate found in the *Endocladia* plots, with a few *Nucella* present within mussel patches.

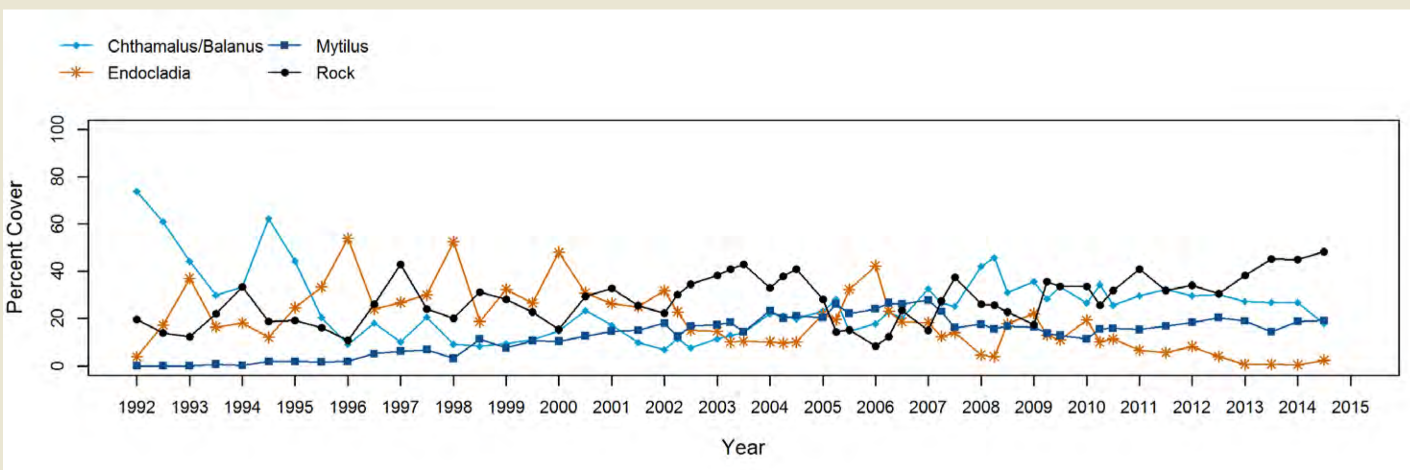
Pisaster counts at Occulto were highly variable, largely because they are infuenced by sampling conditions, as much of the plot consists of steep reef edges that can be diffcult to sample when the swell is large. However, as with other sites in Santa Barbara County, ochre stars declined substantially with the arrival of sea star wasting syndrome. Sea star size typically spanned the entire range with both juvenile and large individuals commonly found, so hopefully new individuals will recruit to the site soon and lead to recovery.

Photo Plots

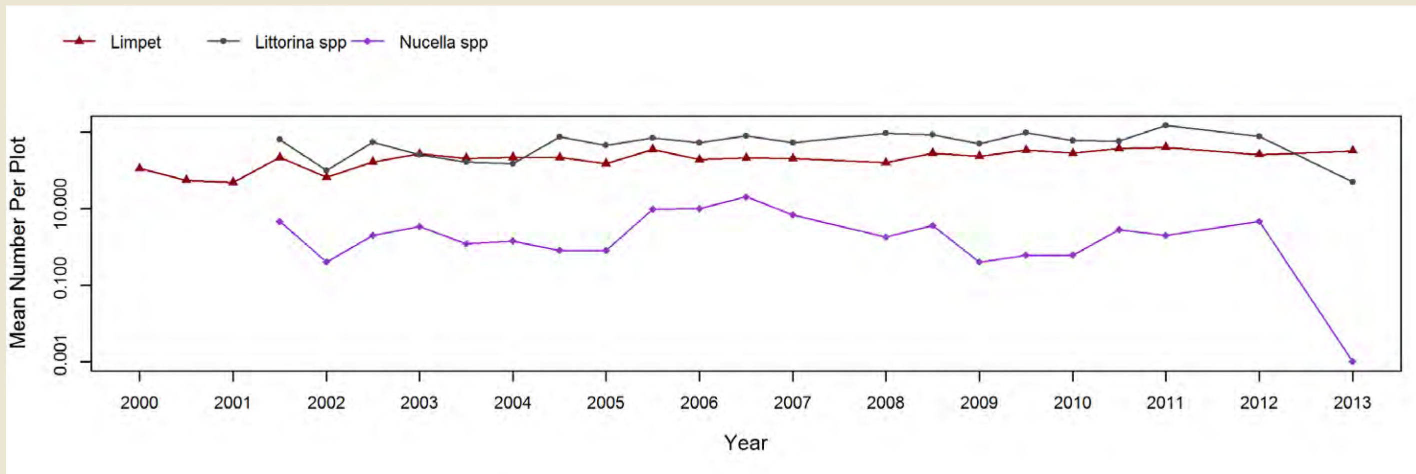
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

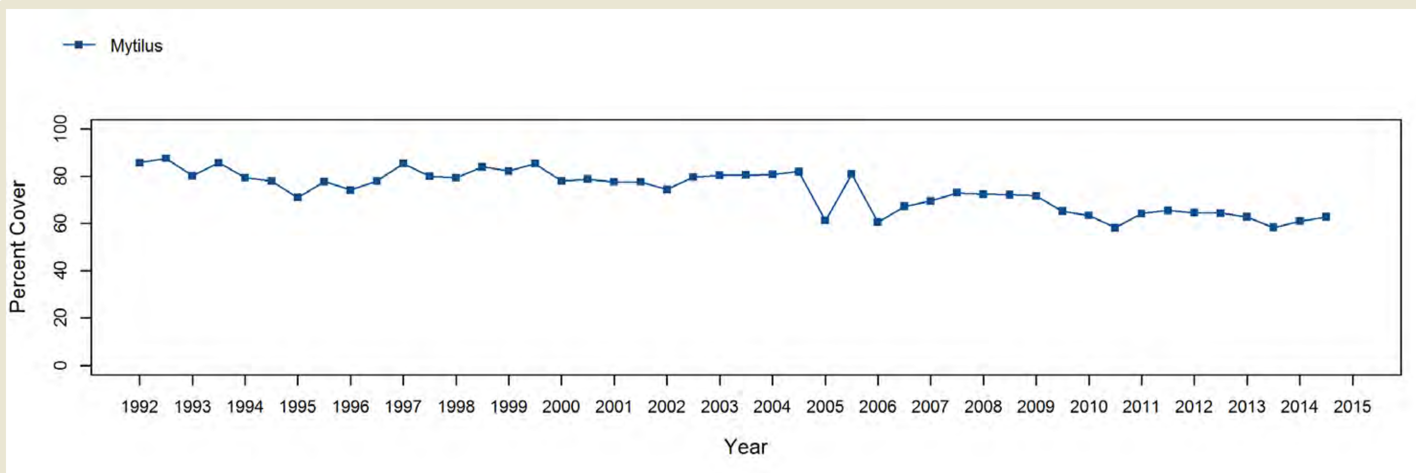
Chthamalus/Balanus (Acorn Barnacles) - percent cover



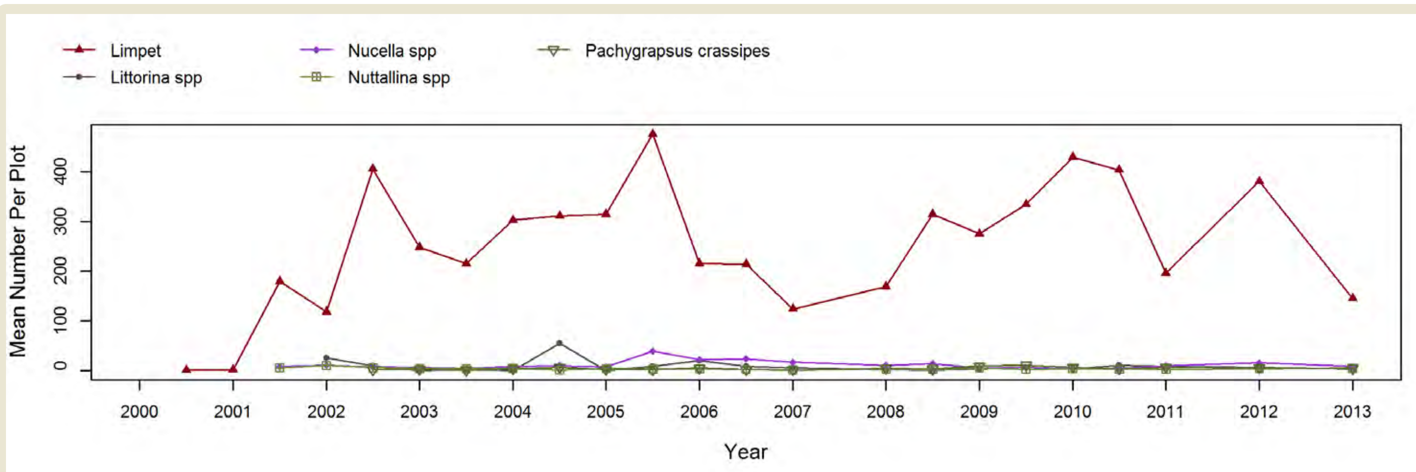
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



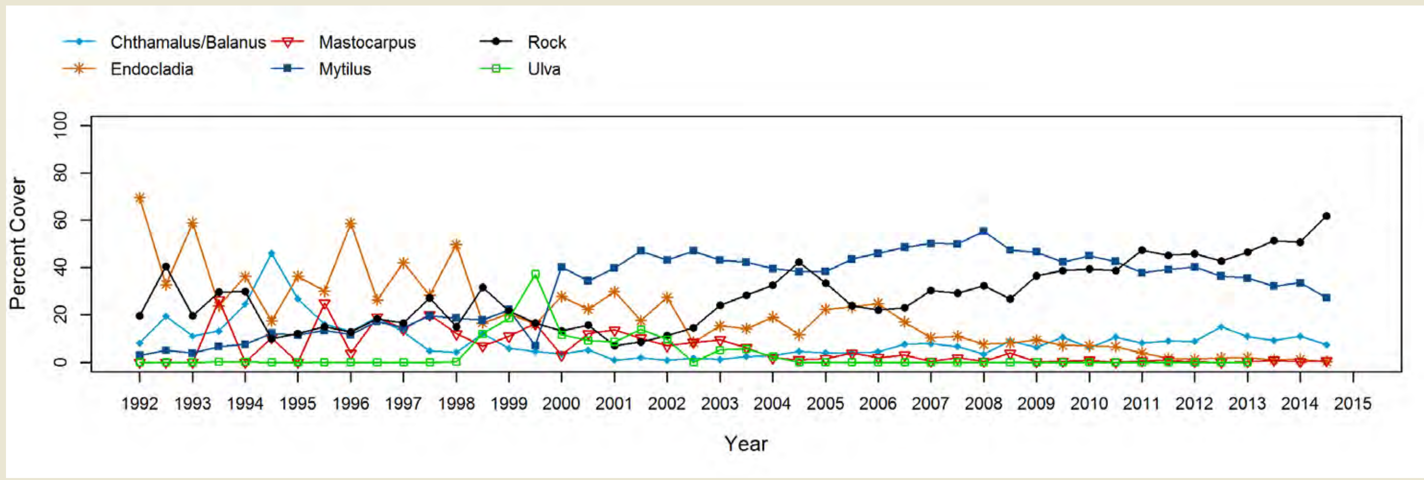
Mytilus (California Mussel) - percent cover



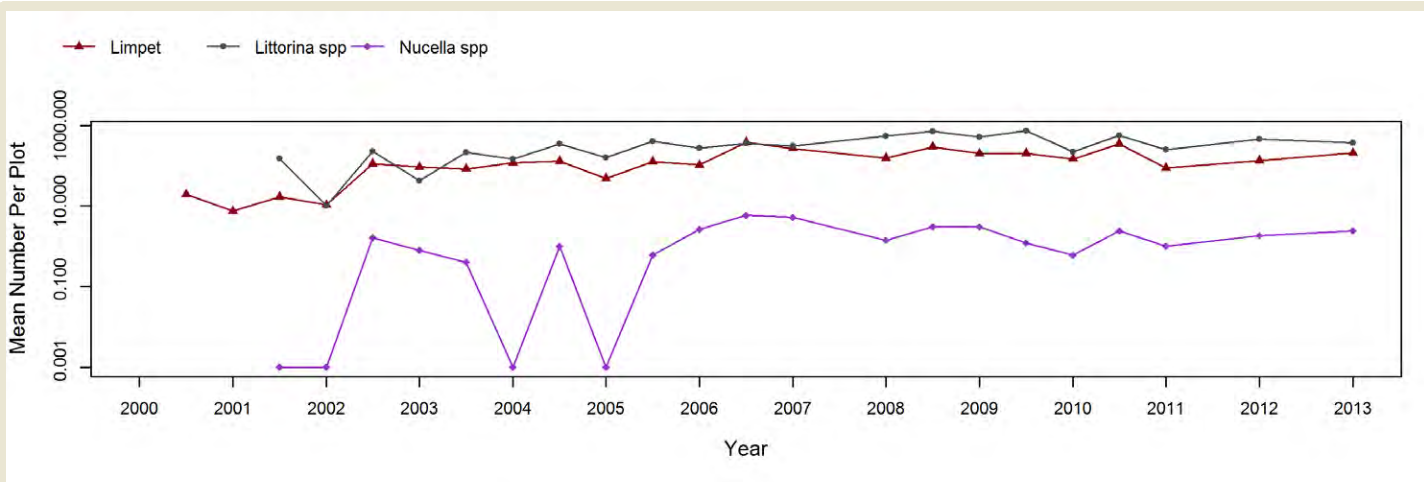
Mytilus (California Mussel) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



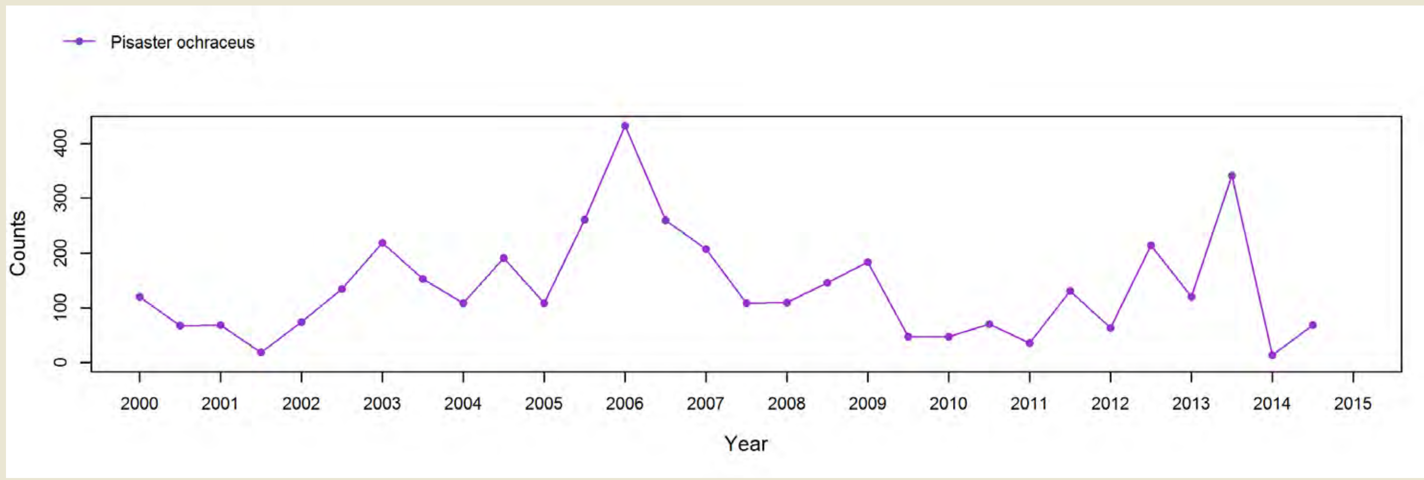
Endocladia (Turfweed) - motile invertebrate counts



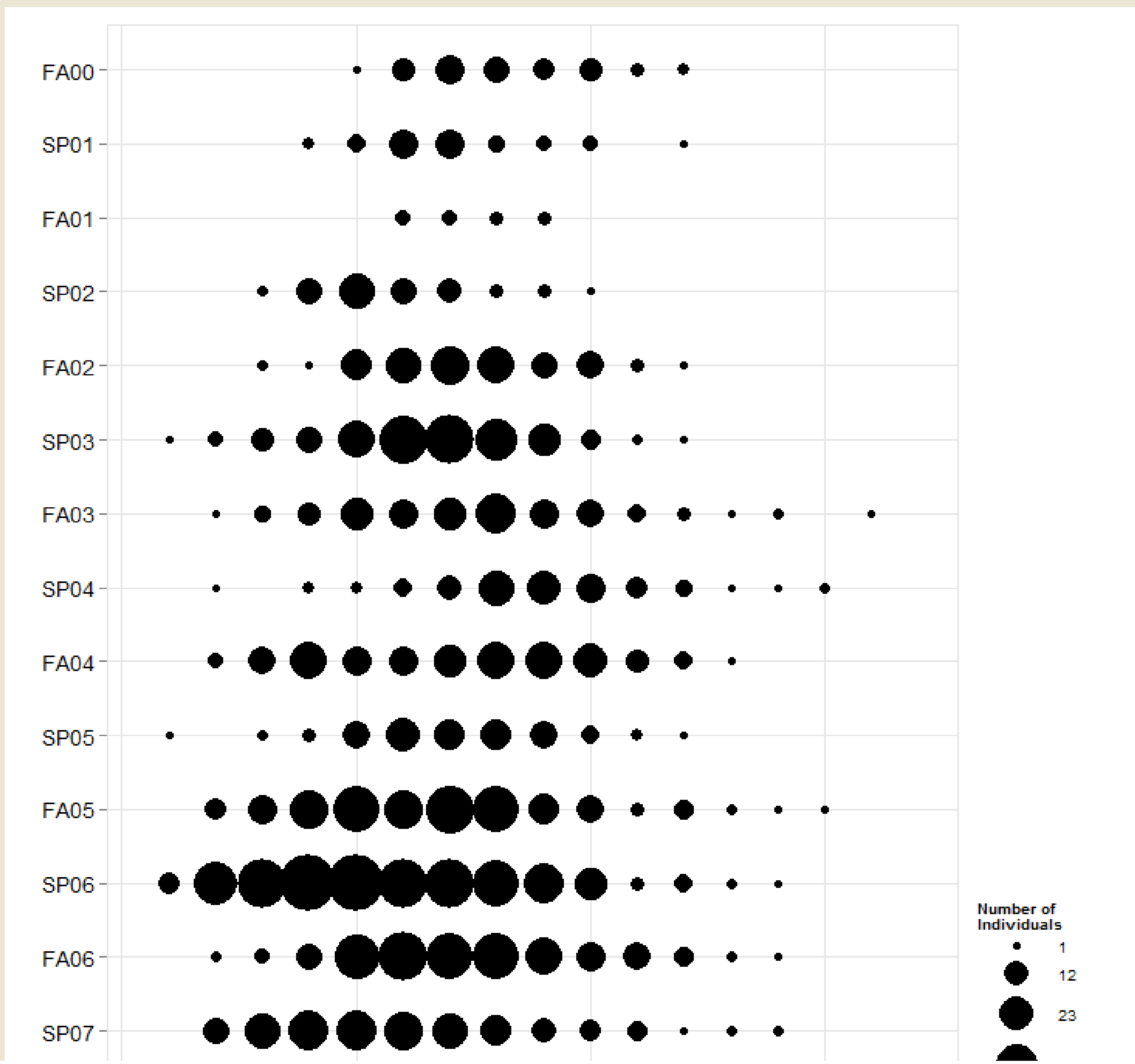
Species Counts and Sizes

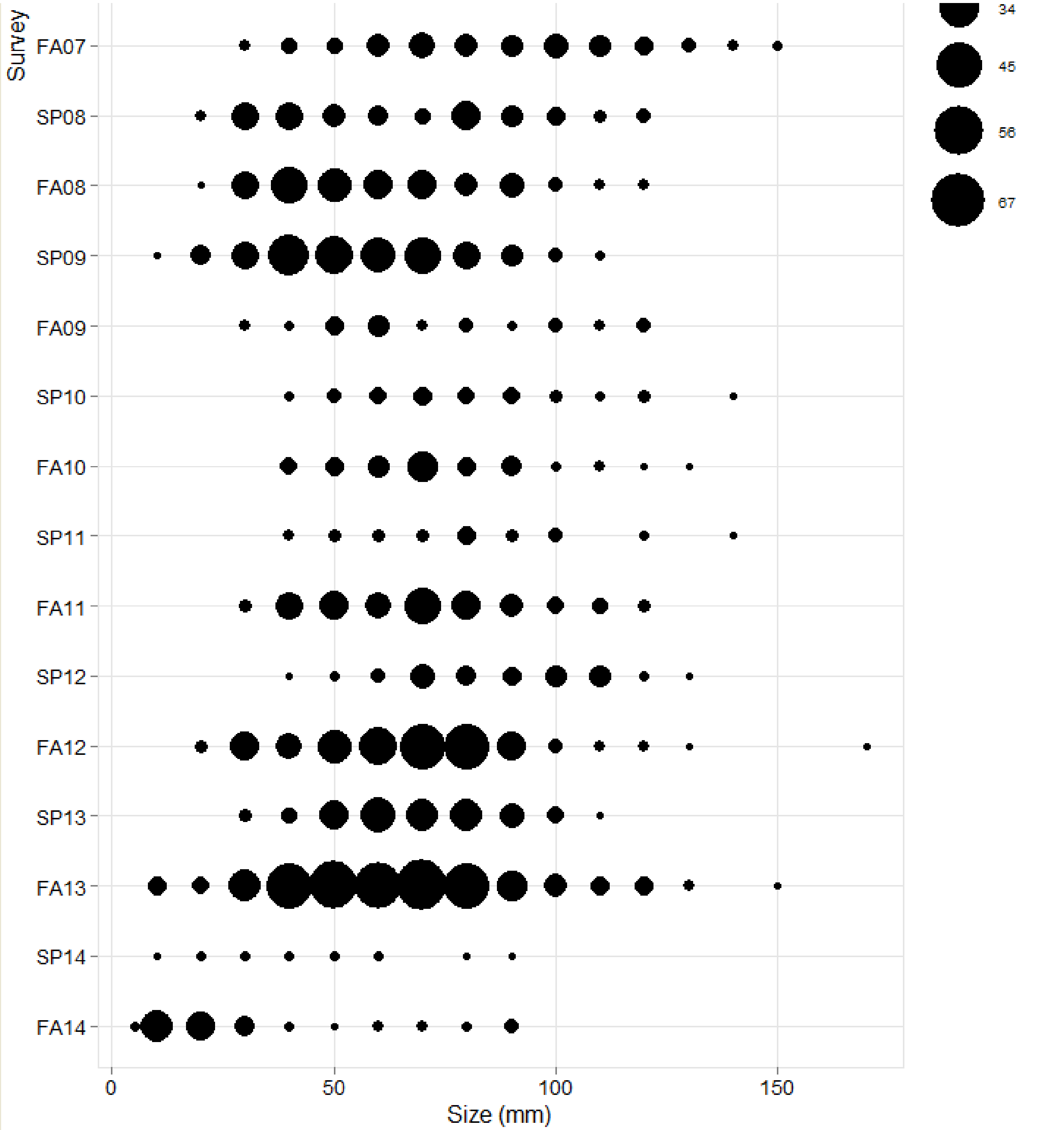
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Stairs Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle plots at Stairs consist solely of *Chthamalus fssus/dalli* (note that species were not distinguished until 2001). Barnacle cover remained fairly high until 1997/1998, when both a large El Niño event and an oil spill impacted the site, and may have affected barnacles (see discussion below and "Publications and Data Products" section). Barnacle cover continued to plummet until around 1999/2000, when levels in all plots were less than 10%. Unfortunately, the slight recovery that was seen in four plots beginning in 2004, did not persist. No other species was recorded at any signifcant level within these plots. Limpets and littorines were present in the barnacle plots at Stairs, but were not as abundant as at most other sites.

Mytilus californianus cover in mussel plots was quite high until 1997, when Stairs was hit hard by a series of large-wave events associated with the 1997/98 El Niño. Mussels were likely stressed by the warmer water, and were ripped out in two plots by large waves. Some recovery has occurred in these plots over time, but slow, steady decline in two other plots has resulted in a mean cover of around 40% since 1998. In addition, a large wave event in the winter of 2002/03 altered the rock surface in plot 2 and to date the plot has not recovered. Species flling in the available space within mussel plots include: *Mazzaella* spp, articulated corallines, and non-coralline crusts (crustose forms of non-coralline red algae). Limpets were by far the most common motile invertebrate present in mussel plots at Stairs. Other species present included the snails, *Tegula funebralis*, *Nucella* spp. (mostly *N. emarginata/ostrina*) and littorines, and the chiton, *Nuttallina* spp.

Cover of the rockweed, *Silvetia*, within plots where it was targeted was initially high, and then declined somewhat in 1995. As with most other species at Stairs, *Silvetia* was severely impacted by the 1997/98 El Niño event, and cover declined and then stabilized (with seasonal variation) at around 25%. This decline was accompanied by a slight increase of *Endocladia*, but rock cover also increased, indicating that some open space was not colonized by other species. Non-coralline crusts increased in several plots, and another rockweed, *Fucus,* colonized one plot. Although *Silvetia* cover has declined in the plots, it is common at the site overall. In fact, Stairs is one of the only sites in the entire MARINe network where all four west-coast rockweed species are present (*Pelvetiopsis*, *Hesperophycus*, *Silvetia*, and *Fucus*). Limpets and the turban snail, *Tegula funebralis,* were the most common species found within *Silvetia* plots at Stairs. Littorines were also present.

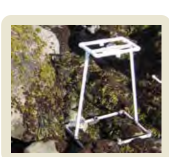
Endocladia cover in the *Endocladia* plots remained relatively constant through 2009, with strong seasonal variation (higher in spring). This seasonal fuctuation is typical of *Endocladia* and was observed at other sites. In 2009 *Endocladia* cover declined and then stabilized at around 30%. Limpets and littorines were abundant in these high intertidal plots.

"Recovery" plots were established after the 1997/98 El Niño event, when huge sections of reef (up to 17m x 5m) were removed by extreme wave events, leaving several large, newly exposed areas of bare rock. These natural clearings provided us with a unique opportunity to document community succession in the mid-intertidal. Nearly all succession studies are done in artifcially cleared patches, which are small relative to the reef size and often recover via encroachment by surrounding species. Because newly exposed sections of reef at Stairs were so large, they were likely to "recover" via colonization by propagules and thus had the potential to develop into communities quite different from surrounding, undisturbed areas. Eight recovery plots were originally set-up, but four have been lost over time due to subsequent large-wave events that have removed additional sections of reef. "Non-coralline crusts", the crustose forms of red and brown algae, were among the earliest colonizers of these completely bare plots. In these plots, non-coralline crusts consisted primarily of *Ralfsia* spp., *Petrospongium rugosum*, and the crustose form of *Mastocarpus* (formerly called "*Petrocelis*"). Unexpectedly, the green alga, *Cladophora*, also colonized a few plots early on and then disappeared. Non-coralline crusts have persisted in all remaining recovery plots, and the rockweed, *Silvetia* has also moved in and steadily increased over time. A signifcant amount of bare rock is still present, so it is likely that it will be several more years before these plots reach a "stable state".

Surfgrass (*Phyllospadix*) was impacted more than any other species by the 1997/98 El Niño event, experiencing a nearly 80% loss between fall 1997 (pre-storm destruction) and spring 1998 (post-destruction). Surfgrass grows from rhizome-like holdfasts, and has diffcultly re-establishing itself once these holdfasts have been removed. The large wave events associated with the El Niño storms ripped out nearly all rhizomes, and even removed large sections of rock within the transects where surfgrass is sampled. Thus, it is surprising and encouraging that surfgrass has been steadily recovering in the years following this destructive event. Only two transects were sampled in fall 1998.

Pisaster (ochre star) numbers have fuctuated substantially at Stairs, and appeared to be declining between 2008-2013. In 2014 numbers were further reduced by sea star wasting syndrome. *Pisaster* sizes have generally been fairly evenly distributed for most samples, with radius measurements between 30mm-130mm, indicating good recruitment and retention of adults. Hopefully this indicates that continued recruitment will occur, and sea star numbers will slowly recover.

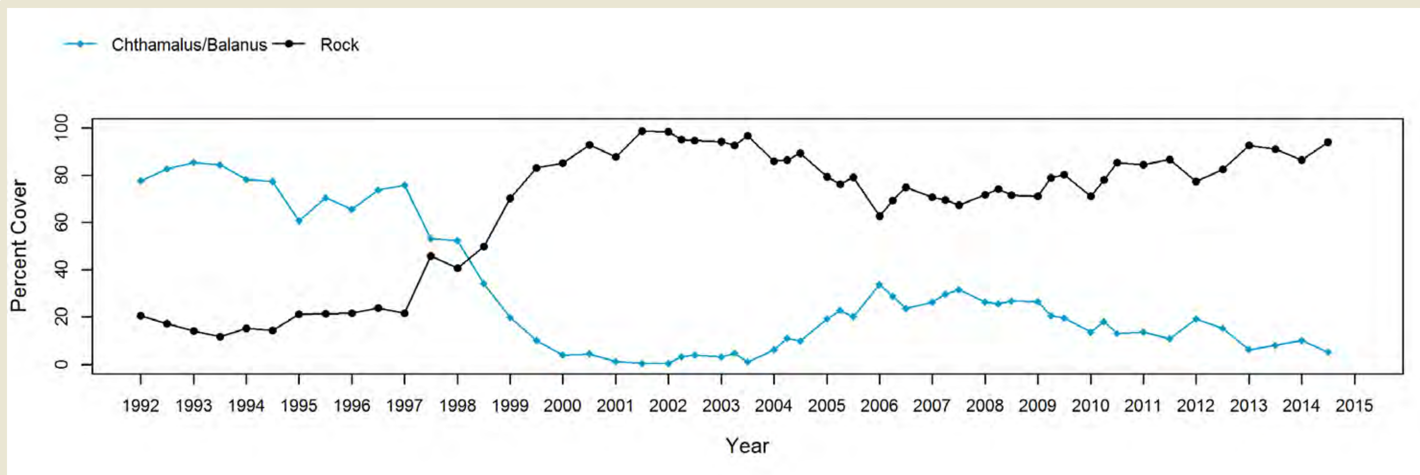
Photo Plots



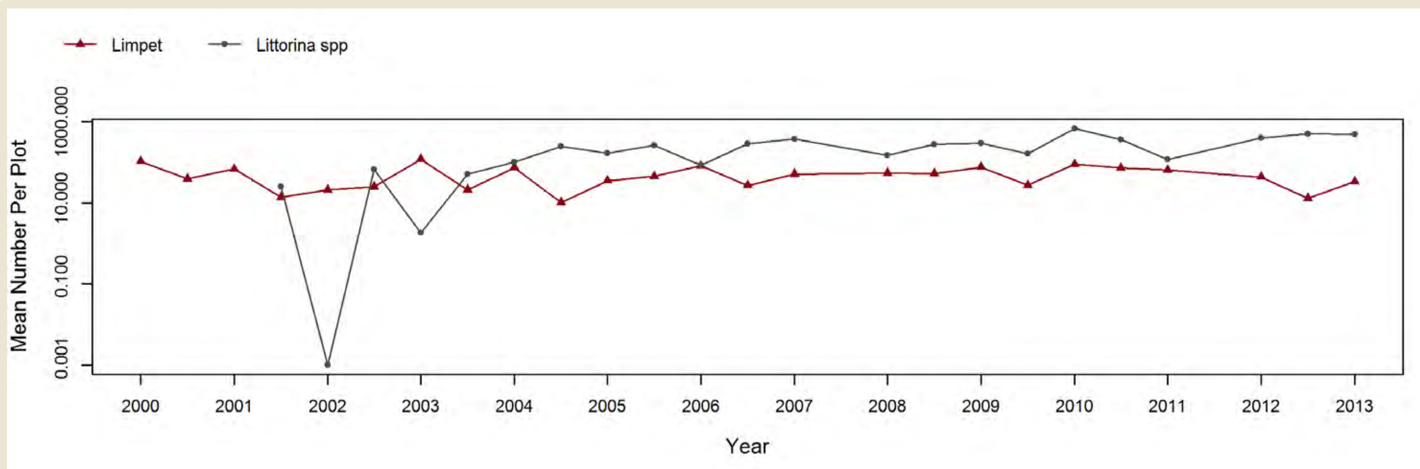
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since spring 2013. For motile invertebrate size trend graphs by site, please use the Interactive Map.

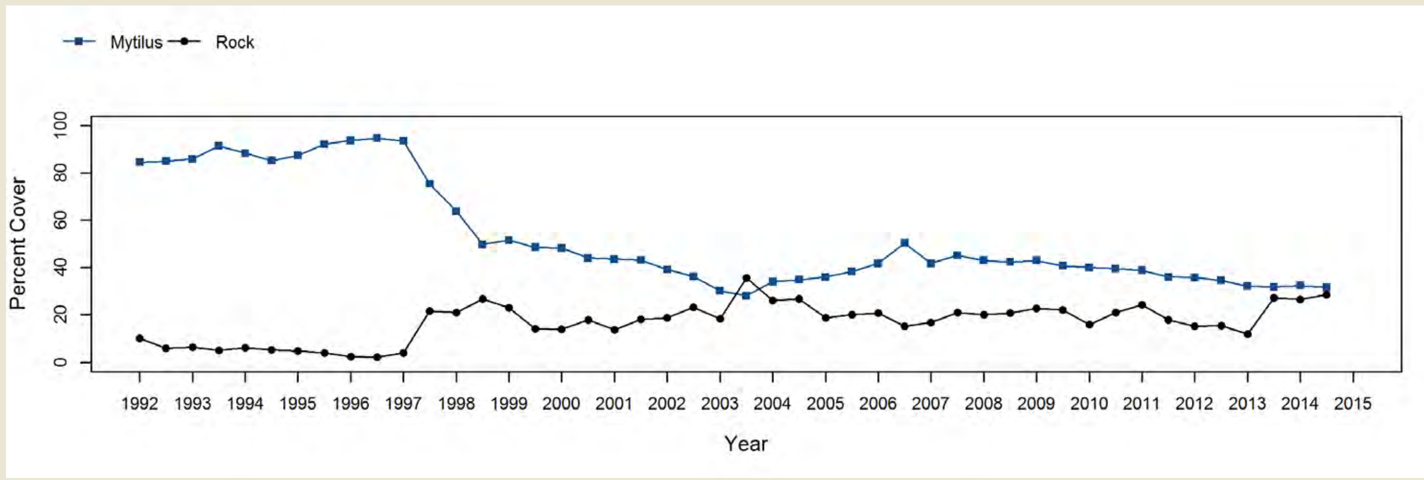
Chthamalus/Balanus (Acorn Barnacles) - percent cover



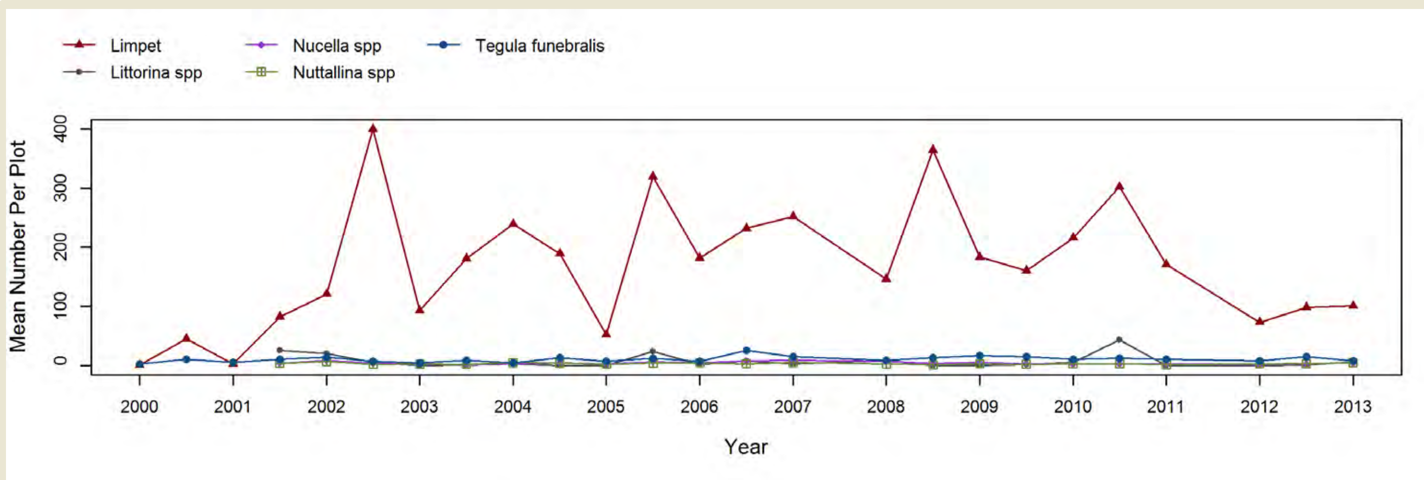
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



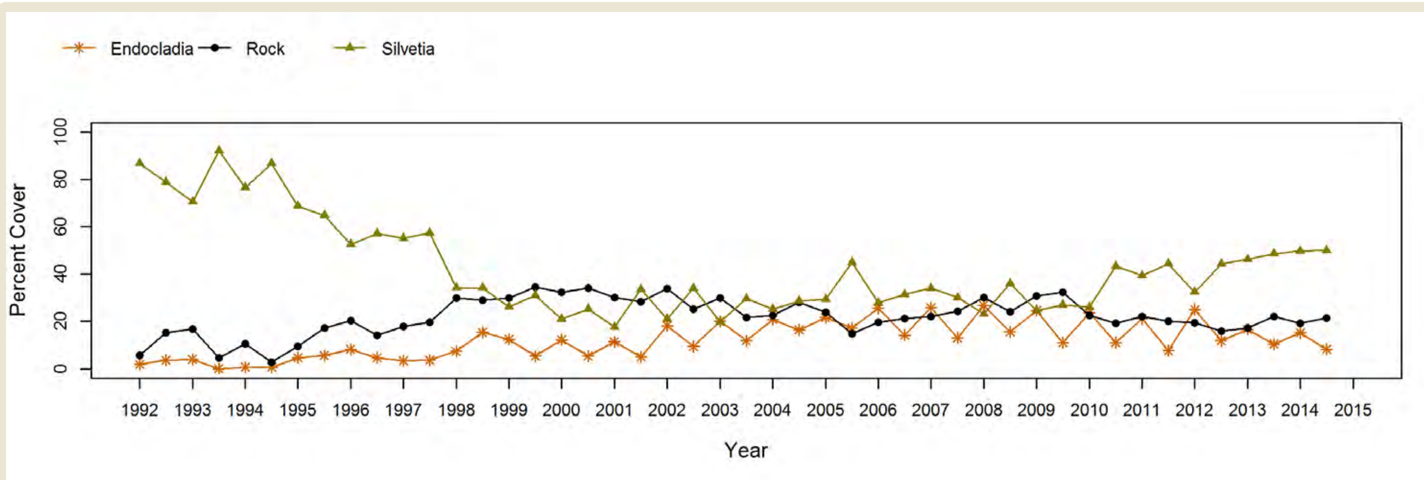
Mytilus (California Mussel) - percent cover



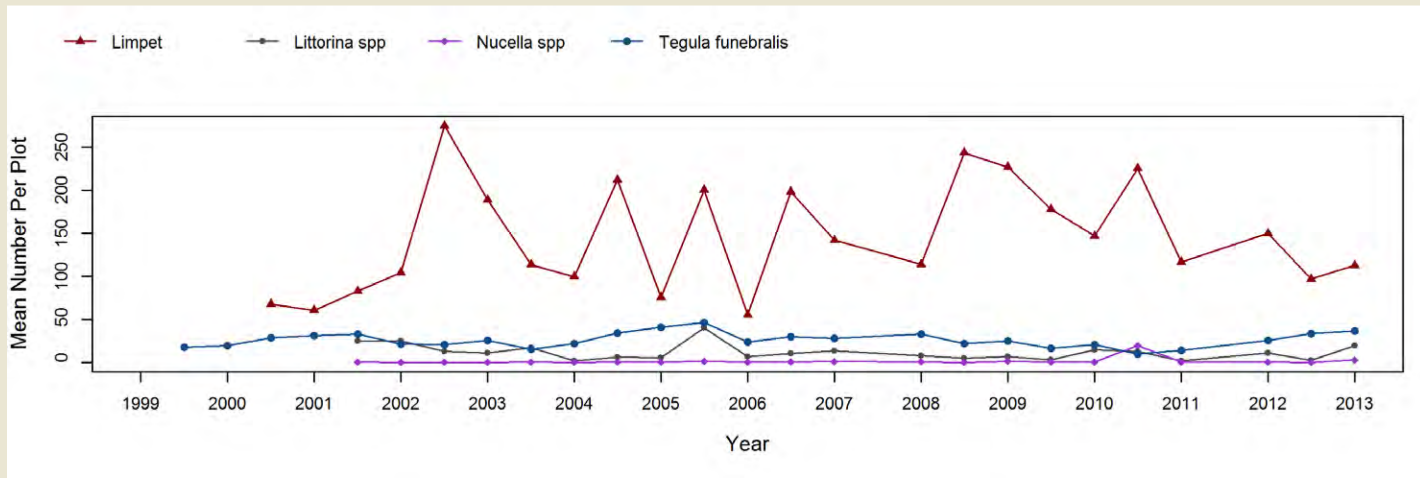
Mytilus (California Mussel) - motile invertebrate counts



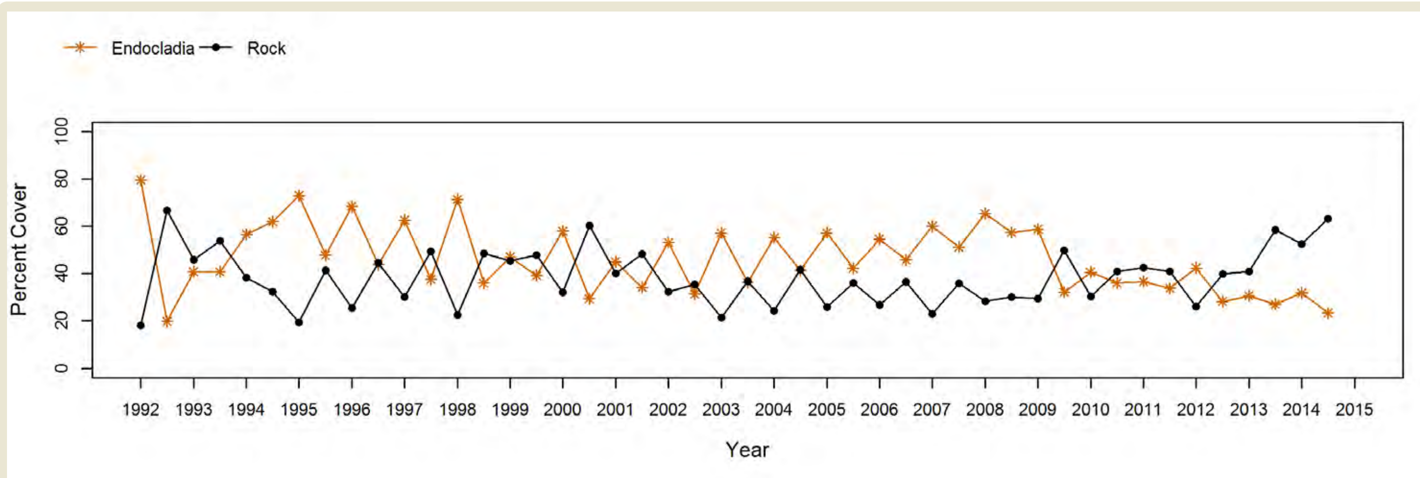
Silvetia (Golden Rockweed) - percent cover



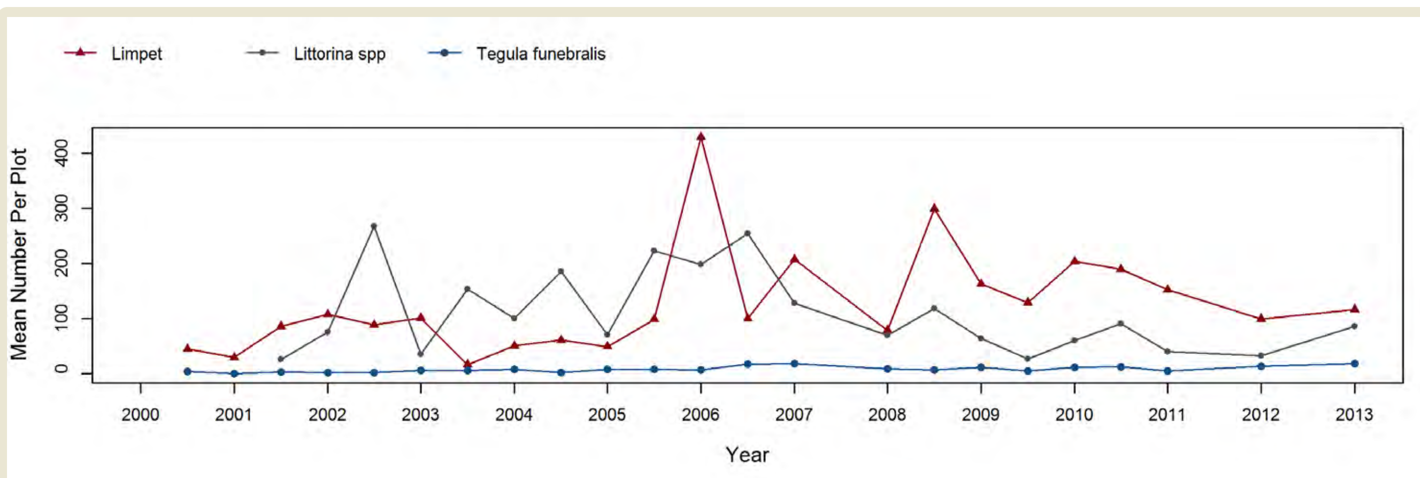
Silvetia (Golden Rockweed) - motile invertebrate counts



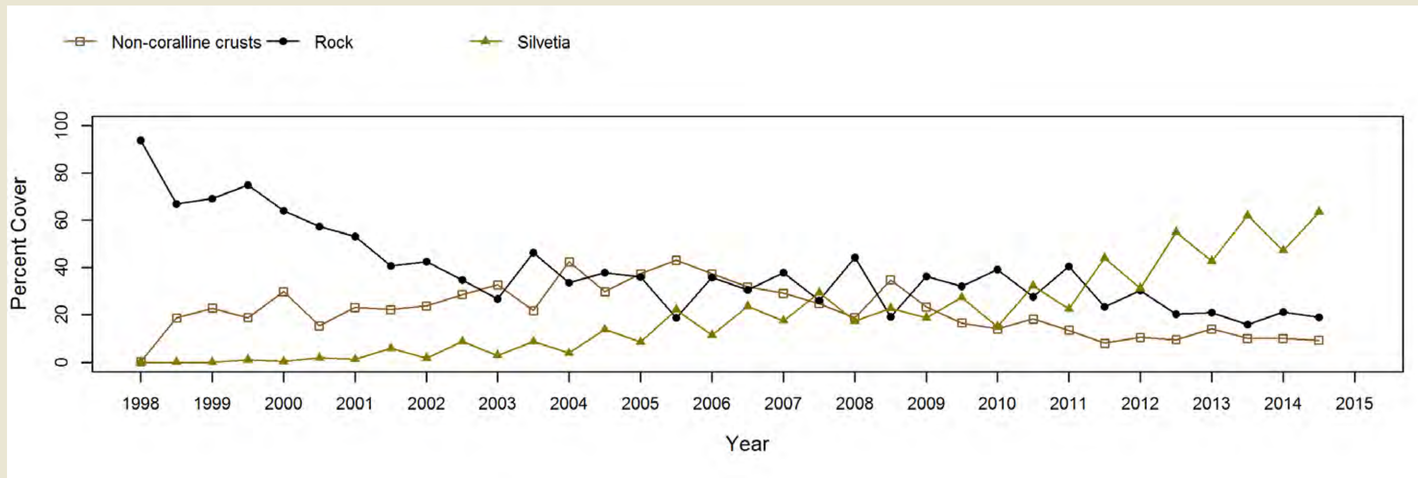
Endocladia (Turfweed) - percent cover



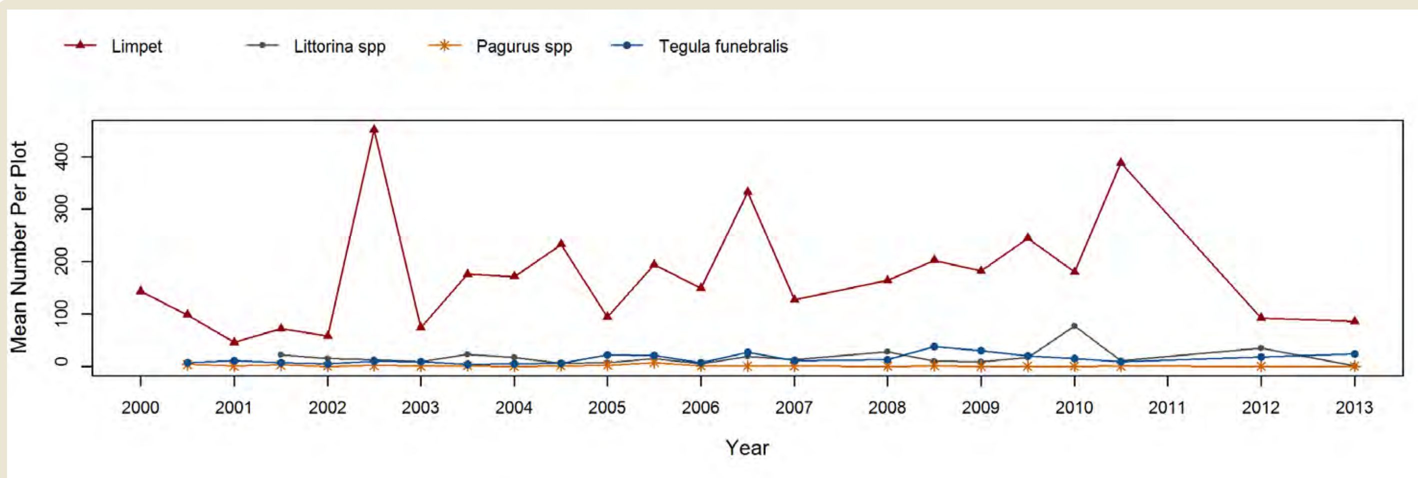
Endocladia (Turfweed) - motile invertebrate counts



Recovery - percent cover



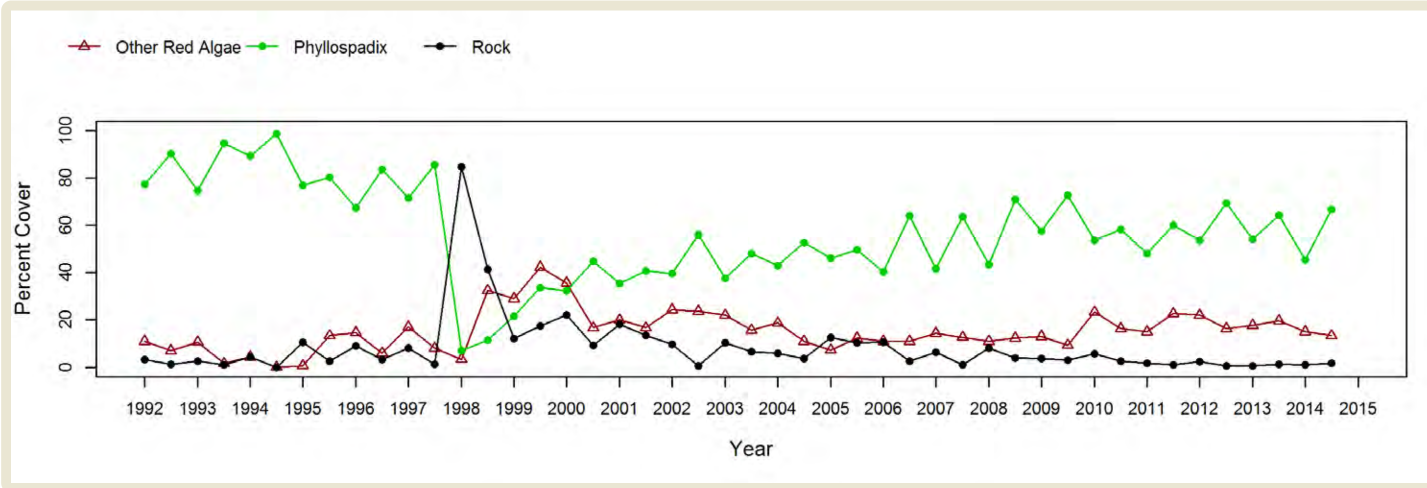
Recovery - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

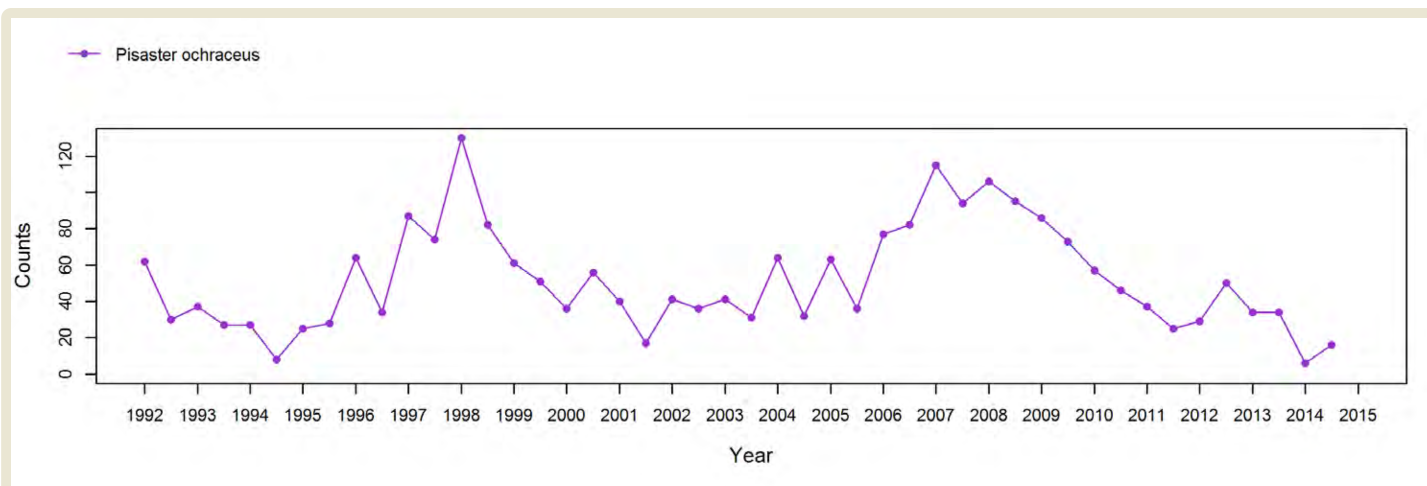
Phyllospadix (Surfgrass)



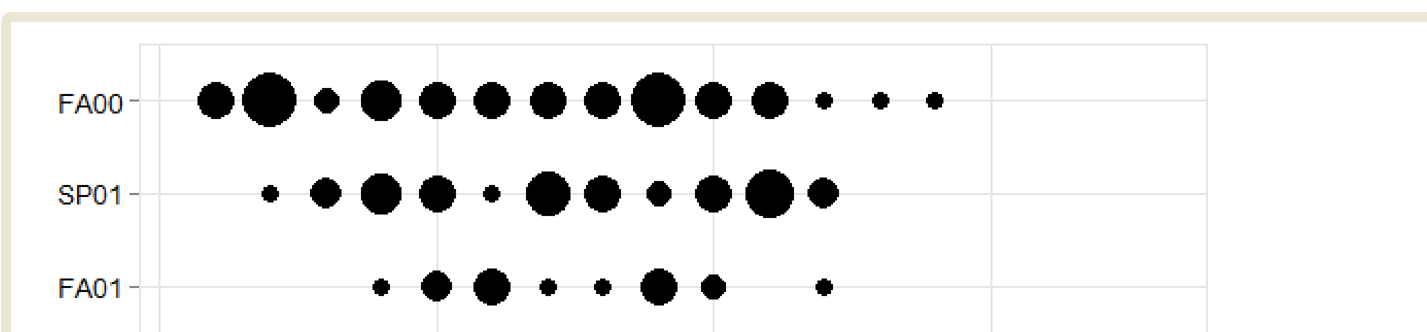
Species Counts and Sizes

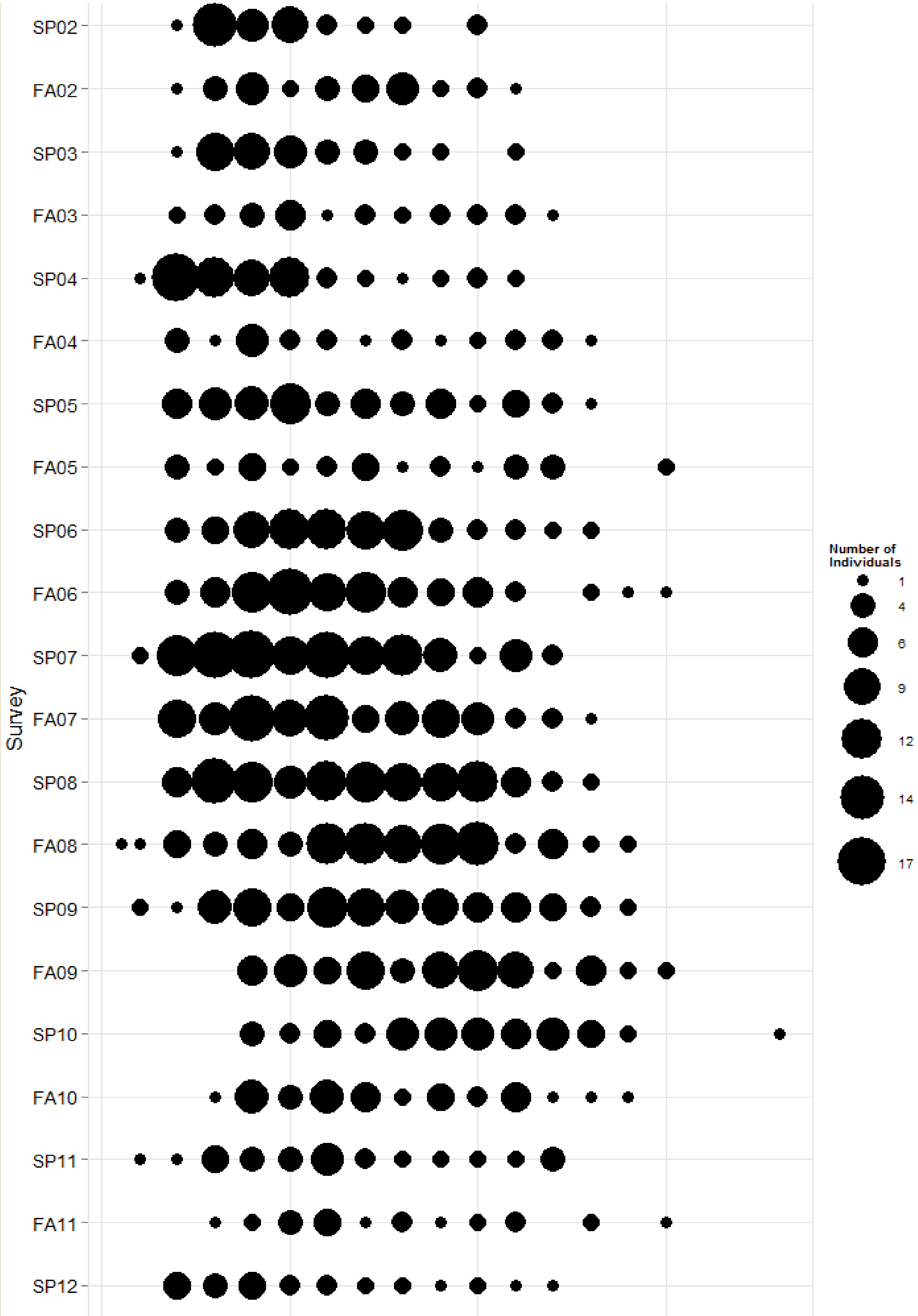
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes

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14
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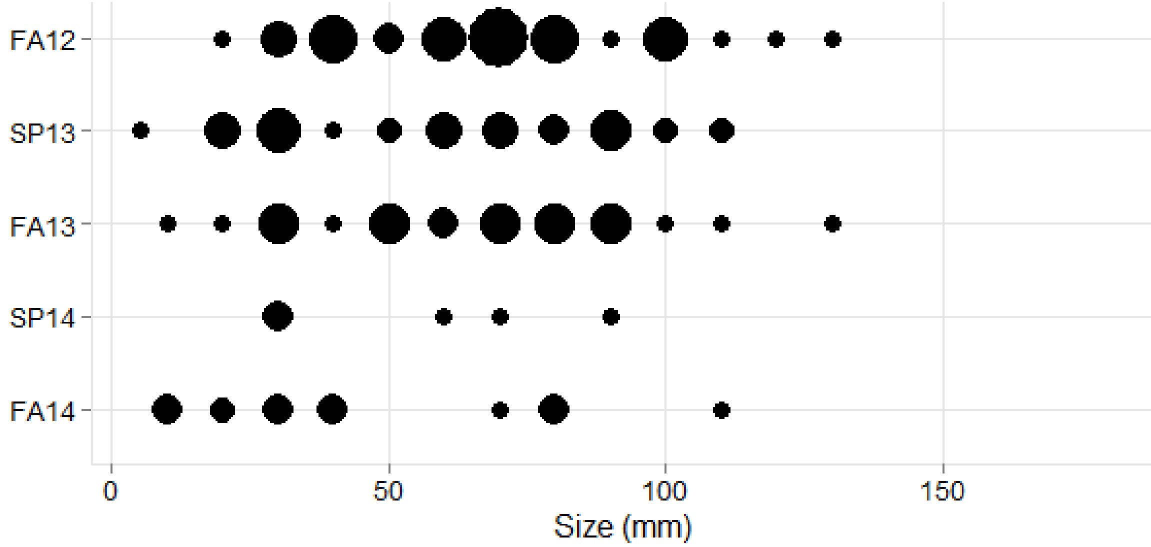

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Boat House Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Anemone plots at Boat House are mainly a mixture of medium-sized, solitary *Anthopleura sola*, and several small species of red algae (primarily *Chondracanthus canaliculatus*). *Chondracanthus canaliculatus* has been recorded as having high cover at this site overall by the biodiversity surveys. Anemone cover has been fairly low but constant over the 23 year span that this long-lived species has been monitored.

Barnacle plots at Boat House mainly consist of *Chthamalus dalli/fssus* , although *Balanus glandula* has occasionally reached cover levels as high as 15-20% in three of the fve plots (note that species were not distinguished until 2001). Cover of *Chthamalus/Balanus* in the barnacle plots at Boat House was initially high (approximately 80%) and then plummeted to around 20% for the next several years, replaced largely by the red turf alga, *Endocladia*. *Endocladia* cover remained fairly high in most plots until around 2001, when it experienced a sharp decline in all fve photoplots. *Endocladia* cover remained low in all but one plot, which is somewhat lower in tidal elevation, and thus desiccation stress on the alga is likely lower. The decline in *Endocladia* cover was accompanied by an increase in *Chthamalus/Balanus* cover, which steadily rose until 2004, and has since remained relatively stable at around 80%.

A similar swapping of species occurred in the *Endocladia* plots, where declines of the red turf alga in 1992 and 1998 were followed by steady increases in the rockweed, *Silvetia*. *Silvetia* cover experienced a sharp decline in 2008, and it appears that barnacles have recruited to the available bare space. In some of the plots *Endoclaida* has increased in recent years, while in other plots barnacles remain dominant.

Silvetia cover in *Silvetia* plots remained high over much of the 23 year monitoring period, although cover declined somewhat around 2008/2009 and remained at this slightly reduced level through 2014. In some plots this open space remains bare, whereas in others it has been flled in somewhat by *Endocladia*, the red blade alga *Mazzaella*, and *Phragmatopoma*, which has also increased site wide in recent years. *Silvetia* plots were not sampled in fall 1995.

Further investigation into the dynamic interaction among barnacles, *Endocladia*, and *Silvetia* over space in the upper intertidal has revealed that the barnacle zone has experienced periods where it shifted upward, into areas that were previously bare rock. It had long been assumed that the upper limits of species' zones were set by physical factors such as temperature and emersion time, and were thus stable, while the lower limits were set by biological interactions (e.g. competition and predation). However, the upward shifts of species zones documented in this study suggest that facilitation, a biological factor, is important for establishing species' upper limits. In this case, barnacles are facilitating the upward movement of *Endocladia* by providing favorable settlement substrate and a refuge from grazers, and *Endocladia* is providing suitable habitat for *Silvetia*, above the zone where it previously occurred. The process is likely "reset" every so often by an extreme event (e.g. large storm waves or a period of above average warm weather), which removes *Endocladia* and *Silvetia* living above their "normal" tidal level, freeing up bare space for new settlement of barnacles.

Limpets and littorines were the dominant motile invertebrates in the barnacle and *Endocladia* plots. These species were also present in the *Silvetia* plots, but generally to a lesser degree. A third species, *Tegula funebralis* was common in all three plot types, increasing in abundance with decreasing tidal height, with counts generally highest in *Silvetia* plots and lowest in barnacle plots. A fourth species, *Pagurus* spp. was common only in *Silvetia* plots.

Mytilus cover remained relatively high throughout most of the 23 year period that mussel plots have been monitored at Boat House. One exception was plot 4, which was accidently cleared in winter 2005 by another researcher working at the site. Recovery of *Mytilus* has been slow in this plot, likely because a number of owl limpets (*Lottia gigantea*) moved into the open space. These large grazers maintain algal "farms", within which they remove most newly settled organisms in order to provide a large area for diatoms to grow. Limpets were by far the most common motile invertebrate counted in the mussel plots. These were largely small individuals that we do not identify to species, but as stated above, there has been an increase in *Lottia gigantea* numbers in these plots, particularly in plot 4.

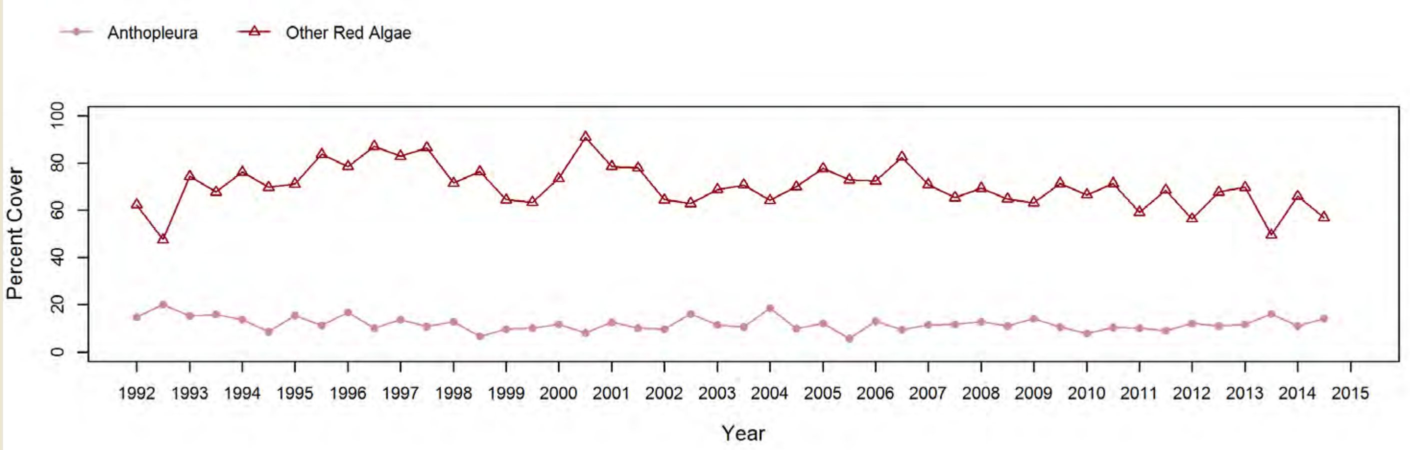
Seastars at Boat House were variable in number over time, but were relatively stable overall until sea star wasting syndrome (SSWS) caused numbers of the ochre star, *Pisaster ochraceus*, to plummet in spring 2014. Prior to 2014, relatively small (<50mm) *Pisaster ochraceus* were common at this site, indicating that recruitment to the region was fairly constant. Hopefully this indicates that recovery at this site will not take too many years. Boat House is one of the few sites monitored by MARINe where the bat star, *Patiria miniata*, is found consistently in sea star plots. This species typically occurs in the subtidal, or very low intertidal, below our monitoring plots. However, several *Patiria miniata* were observed to have disease symptoms at this site, and it is likely that SSWS has impacted the *Patiria* population at Boat House.

Photo Plots

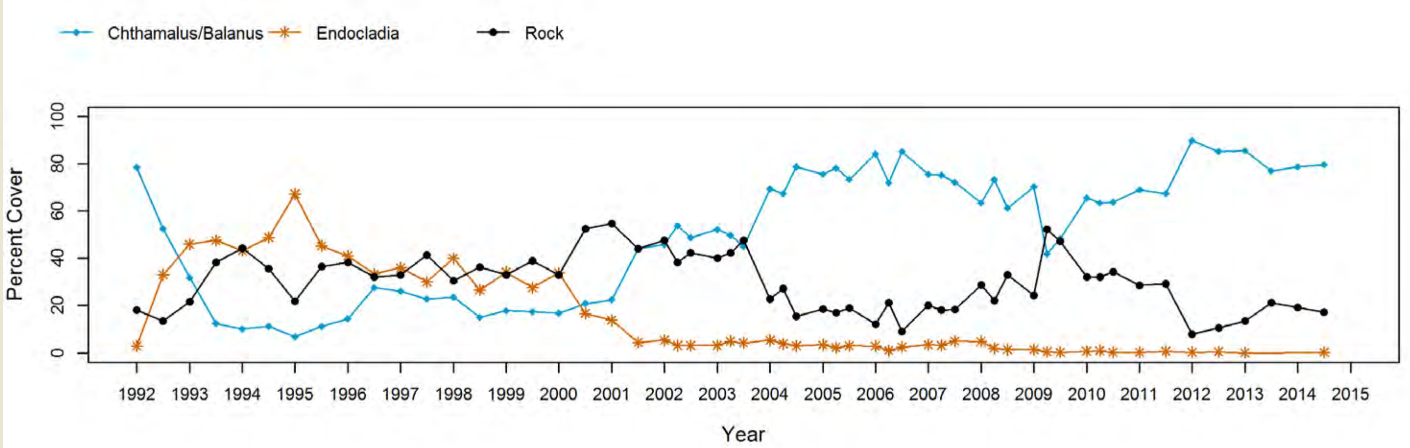
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since spring 2013. For motile invertebrate size trend graphs by site, please use the Interactive Map.

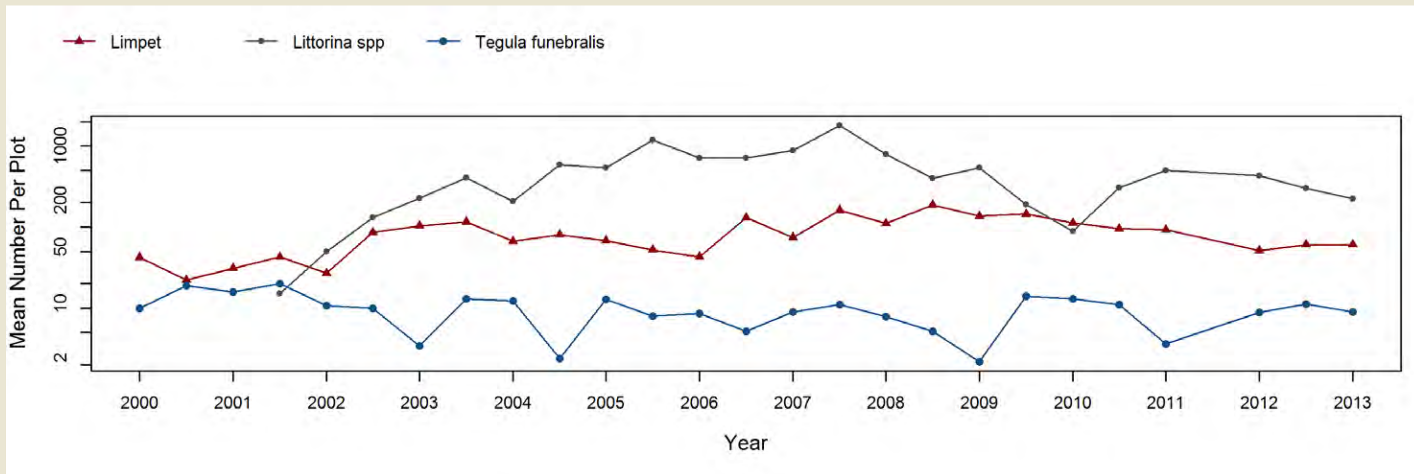
Anthopleura (Anemones)



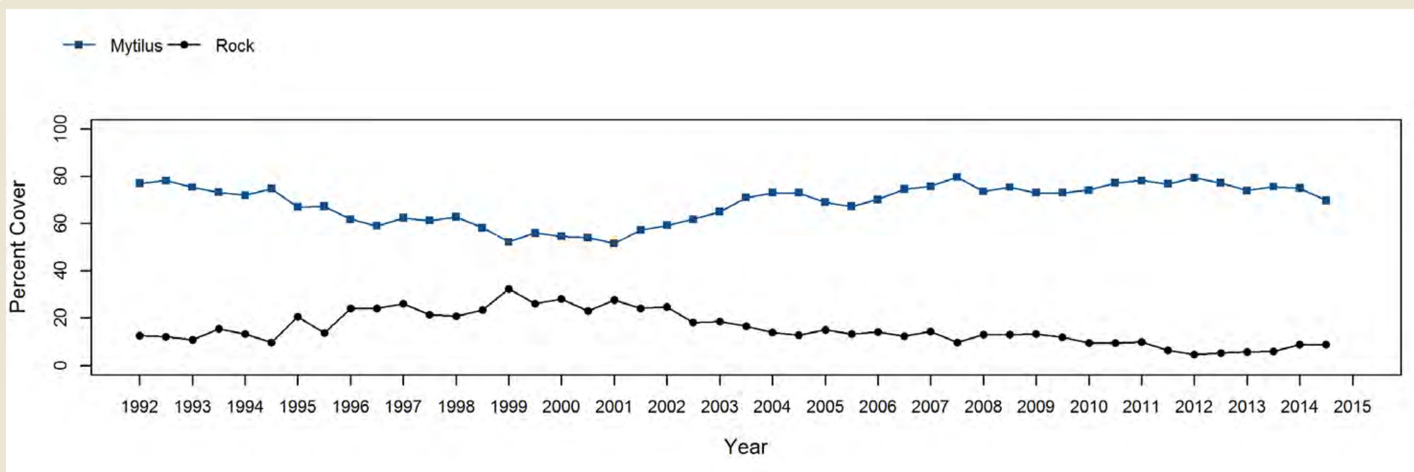
Chthamalus/Balanus (Acorn Barnacles) - percent cover



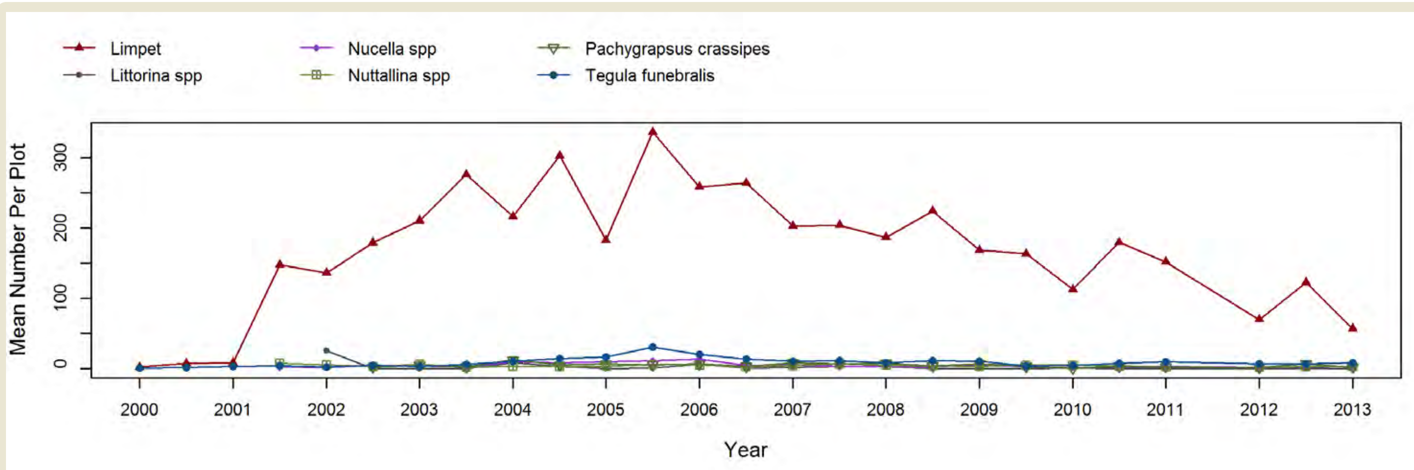
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



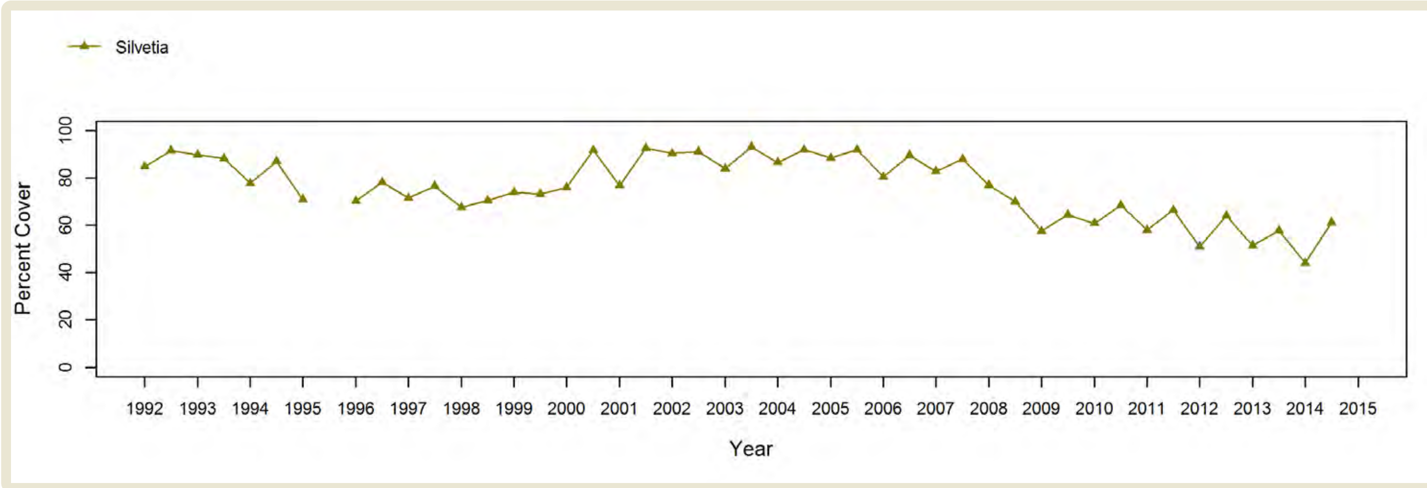
Mytilus (California Mussel) - percent cover



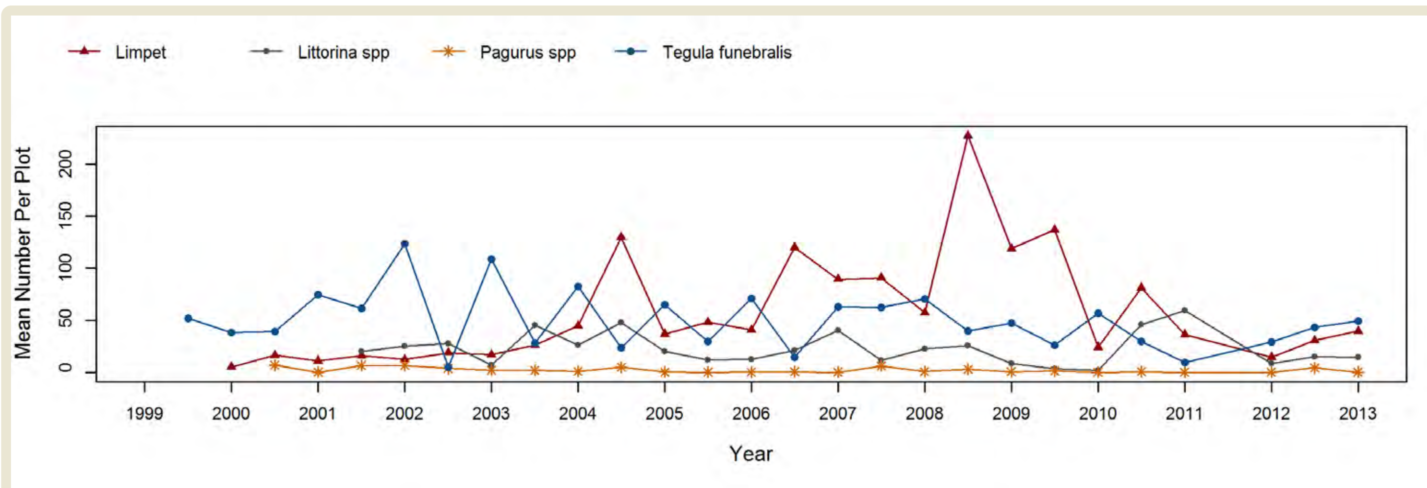
Mytilus (California Mussel) - motile invertebrate counts



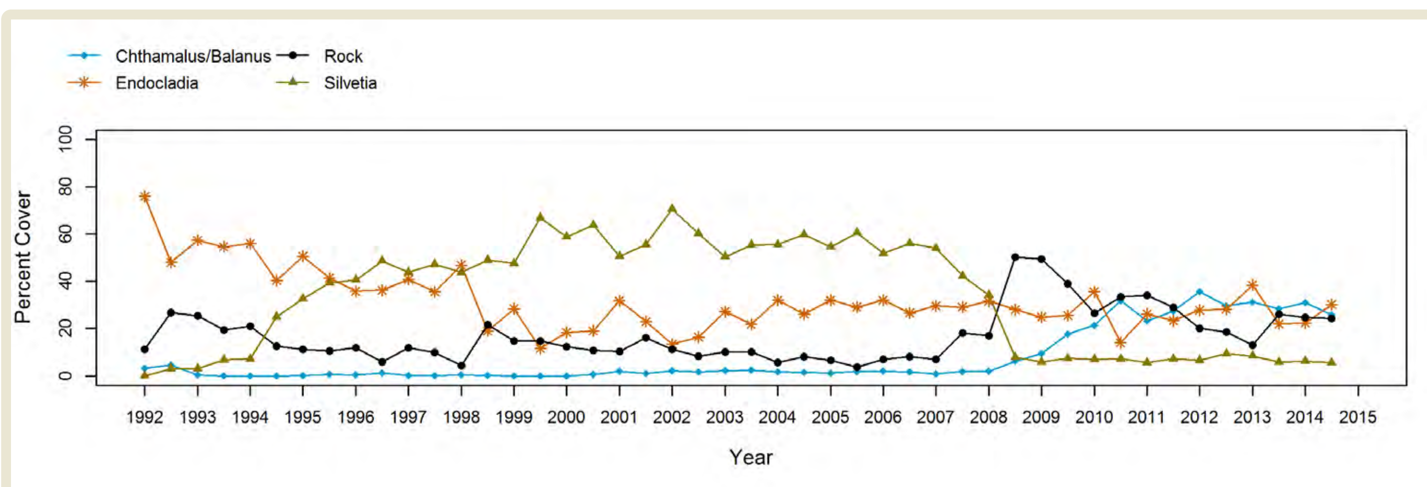
Silvetia (Golden Rockweed) - percent cover



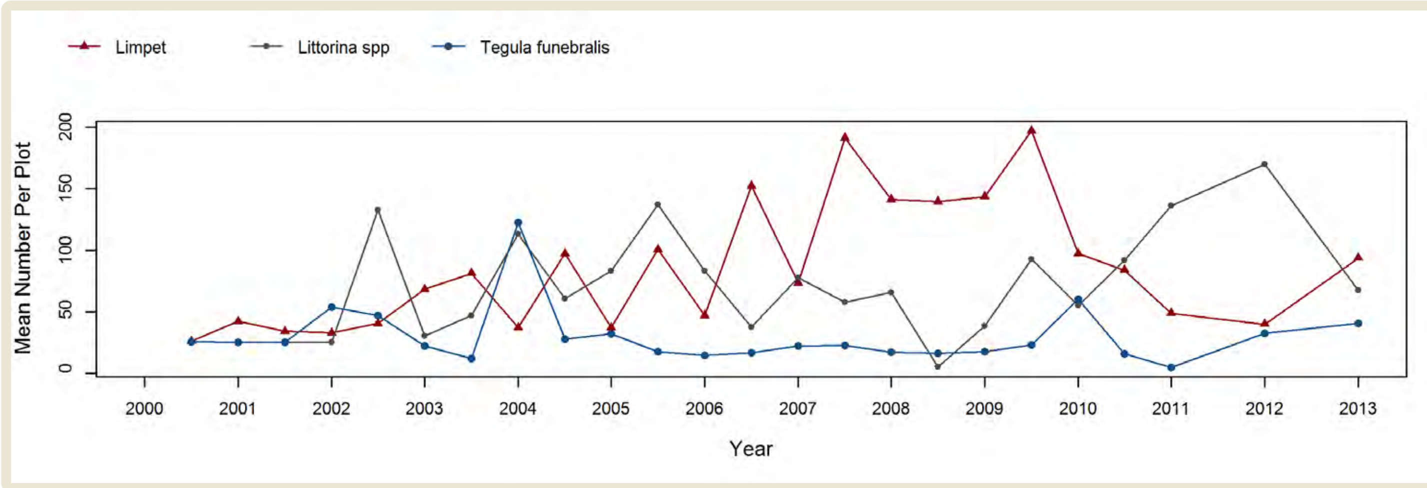
Silvetia (Golden Rockweed) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



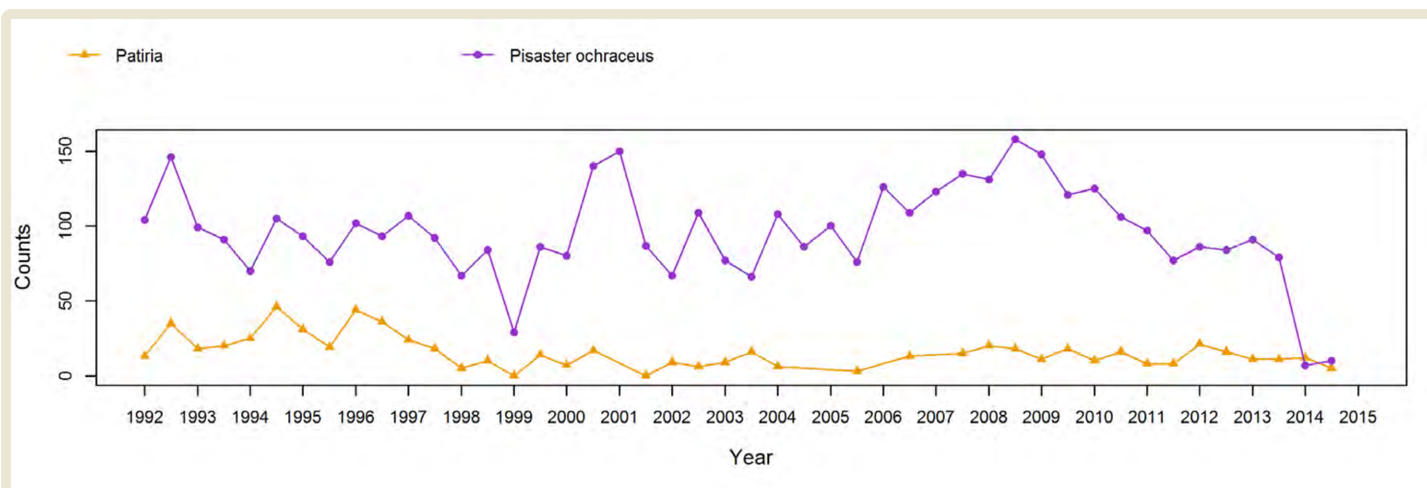
Endocladia (Turfweed) - motile invertebrate counts



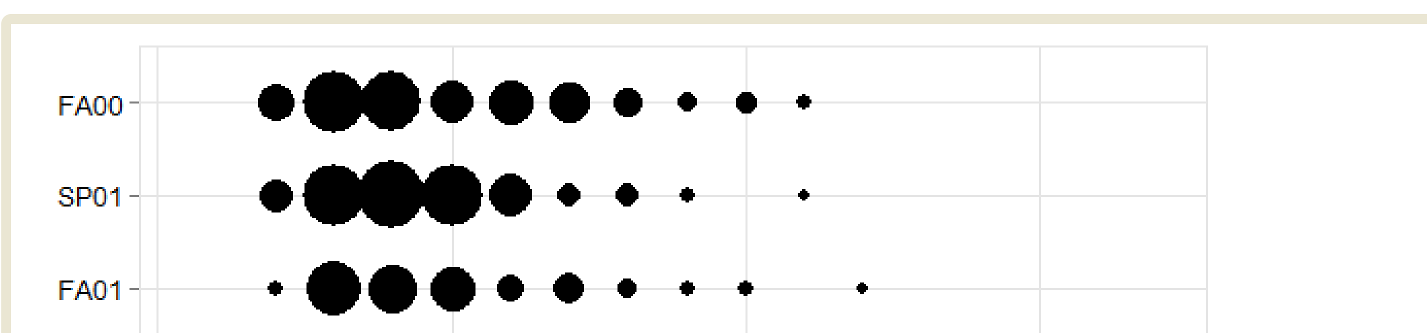
Species Counts and Sizes

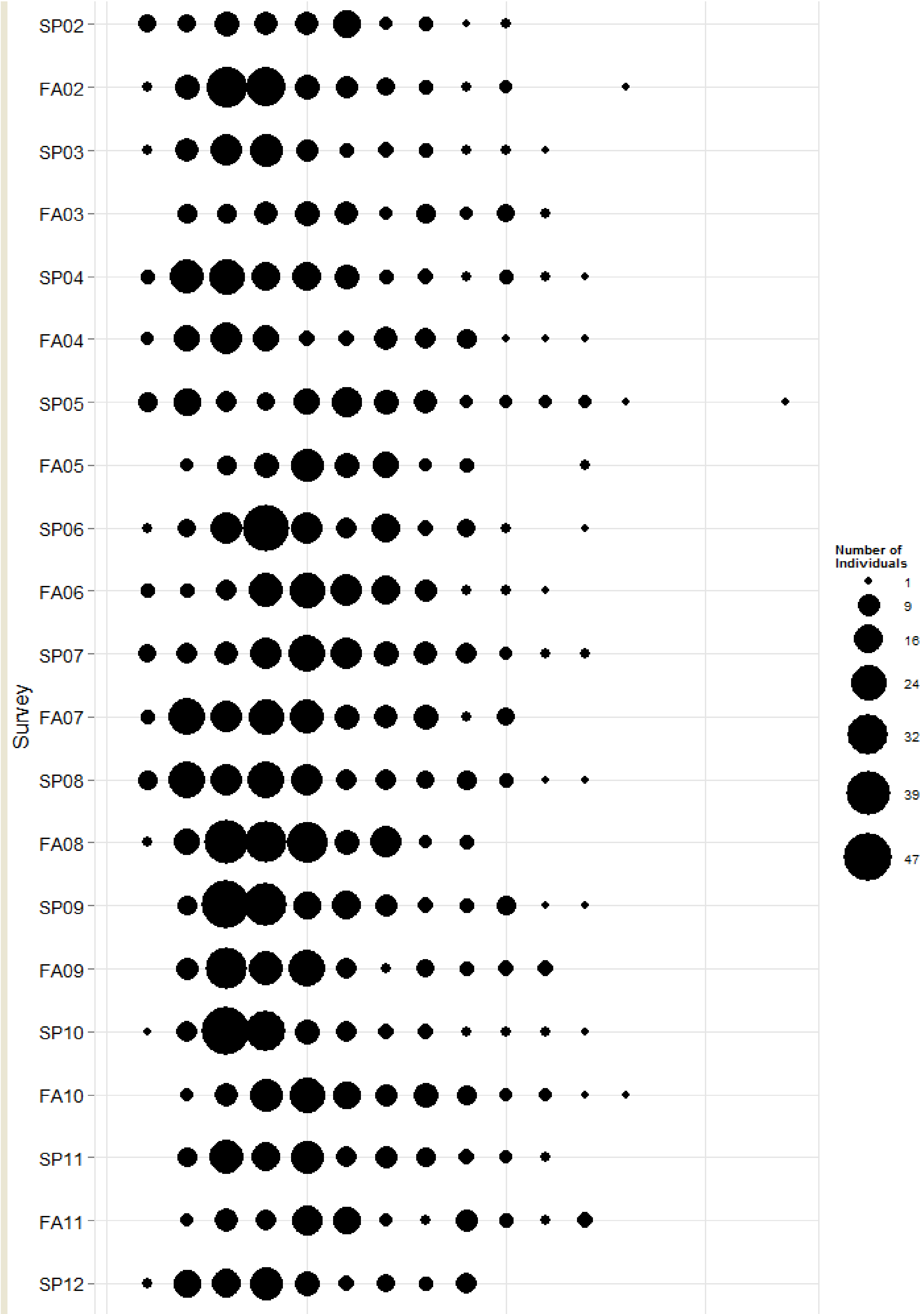
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes

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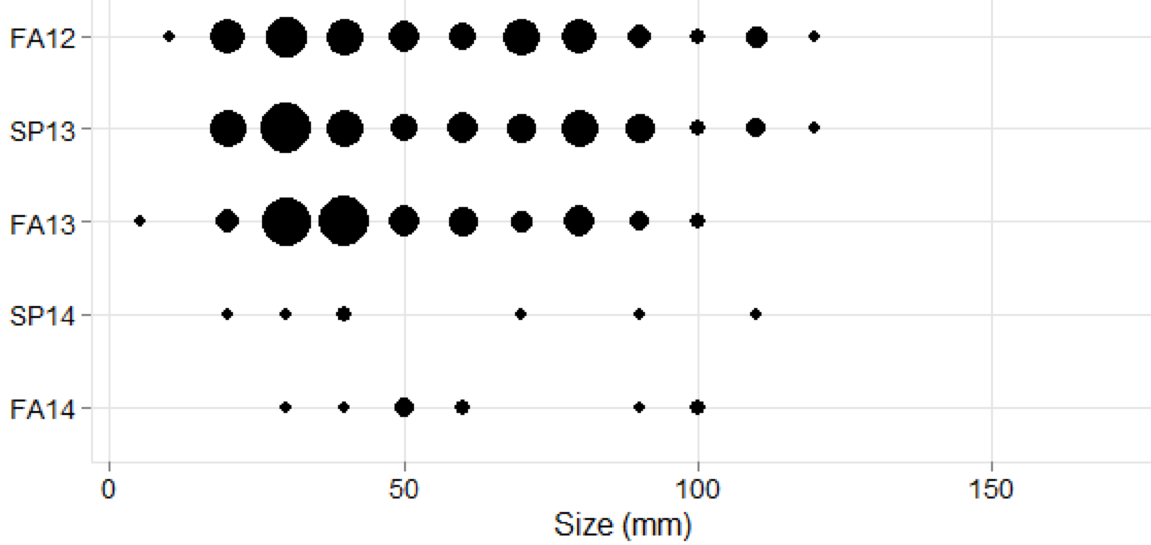

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Government Point Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Long-term monitoring at Government Pt. was not done in fall 1999, and also between 2006-2013, due to site access restrictions. We were able to re-visit the site in 2014, and hope access continues, as the location of this site at the junction of two major biogeographic provinces ranks it among the most important in our program.

A mixture of *Chthamalus fssus/dalli and Balanus glandula* was present in the barnacle plots at Government Pt. These barnacles facilitate recruitment of the turfweed*, Endocladia muricata*, by reducing grazing pressure by limpets. We have observed this facilitation at Government Pt., where dips in barnacle cover are associated with increases in turfweed cover in the plots. Limpets and littorines were both abundant within these plots.

Cover of the gooseneck barnacle, *Pollicipes,* was quite constant between 1992-2006 at Government Pt, then increased slightly in 2014. These long-lived barnacles are harvested for food in many areas accessible to the public, but are protected from collection pressure at Government Pt.

The California mussel (*Mytilus californianus*), forms a dense bed in the mid-low intertidal zones of Government Pt., which provides food and shelter for an incredible diversity of organisms. Large storm events can tear out patches of mussels, as is evidenced by the dip in mussel cover during the 1997/98 El Niño period. This storm-induced decline was followed by rapid recovery, and long-term cover of mussels at Government Pt. was quite stable through 2006, and had not changed substantially when the plots were re-surveyed in 2014. Limpets were the most common motile invertebrate found in the mussel plots, but a number of other species were also common, including the snails, *Tegula funebralis*, *Nucella* spp. and littorines, and the shore crab, *Pachygrapsus crassipes*.

A signifcant downward trend in the cover of *Silvetia compressa* at Government Pt. was evident through 2006, and appeared to continue through recent years, with mean cover in 2014 around 30%. The pattern is largely driven by plots 3 and 5. When plot 3 was established it had an understory of mussel cover, which has persisted while *Silvetia* cover has declined. In Plot 5 there were a few *Pollicipes* in the understory and the drop in 2006 was likely due to winter storms in 2005 dislodging *Silvetia*. To date, plot 5 has not recovered and is now dominated by *Pollicipes*. As with many other sites, *Silvetia* showed a seasonal pattern in cover, with lower values in spring vs. fall samples. *Silvetia* plots contained high numbers of *Tegula funebralis* and limpets. Littorines and *Nucella* spp. were also common.

Turfweed (*Endocladia muricata*) forms distinctive dark red bands in the high zone of rocky intertidal shores north of Pt. Conception/Government Point. Turfweed abundance fades in warmer waters to the south, thus monitoring at Government Pt. is critical for detecting the potential effects of warming water trends that might be associated with climate change. Turfweed provides habitat for a host of tiny organisms, and facilitates the recruitment of rockweeds. Turfweed abundance at Government Pt. has been highly variable over time, with typically much higher cover in spring than in fall. However, since the site was last sampled in Fall 2006, the *Endocladia* cover has decreased dramatically, while barnacle and rock cover have increased. Littorines and limpets were the most common motile invertebrates found in these high intertidal plots.

Surfgrass (*Phyllospadix* spp.) beds are highly productive ecosystems, providing structurally complex microhabitats for a rich variety of organisms. Surfgrass provides nursery habitat for various fshes and invertebrates, including the California spiny lobster. Surfgrass can be particularly sensitive to pollution and oil spills, and large patches can be removed by high wave energy events, such as those associated with El Niño periods. Indeed, the surfgrass cover at Government Pt. experienced substantial decline only once in the 15 years that we monitored it—during the 1997/98 El Niño event. As observed at most other sites, *Phyllospadix* cover fuctuated seasonally , with higher cover in fall than in spring.

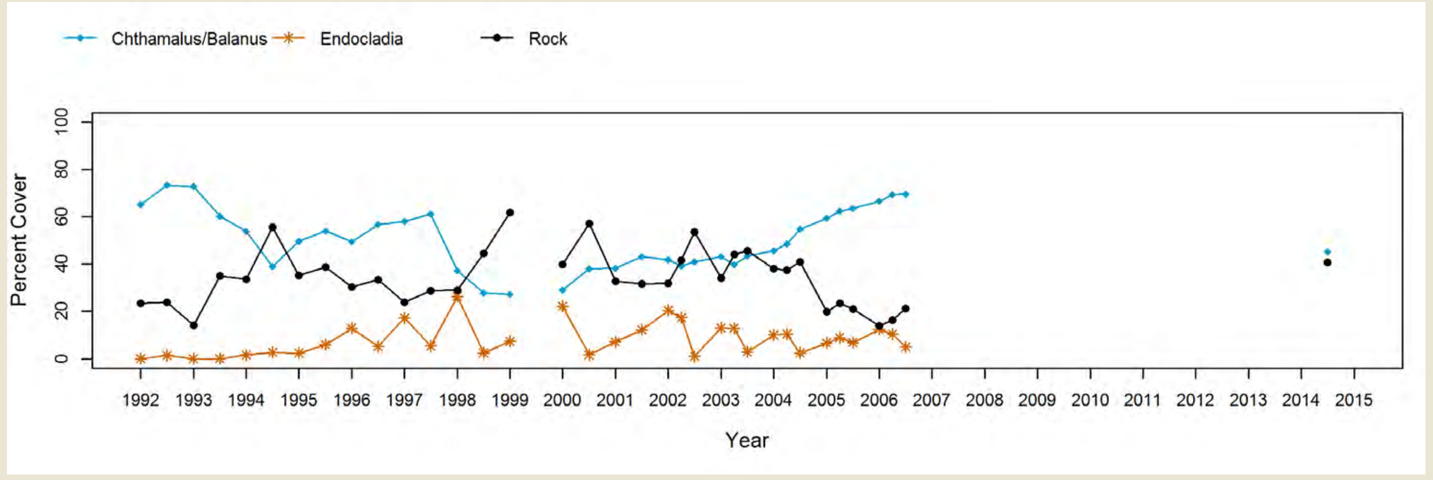
The ochre star (*Pisaster ochraceus*) is much more common north of Pt. Conception/Government Pt. than it is south of this biogeographic barrier, making Government Pt. an important site for detecting any impacts to this species that might spread northward up the coast, such as disease, or declines due to warming ocean temperatures. Sea star numbers were variable at Government Pt., but appeared to be increasing between 2000-2006. In 2006 there were more than 400 sea stars in the plots at Government Pt., but in 2014 only 30 individuals were found. Evidence of Sea Star Wasting Syndrome (SSWS) was found at the site in 2014 and it appears that the disease is likely responsible for the sharp decline in sea stars at this site. Sea star sizes spanned the entire range, with abundant large individuals and juveniles commonly found, indicating a healthy population with ample recruitment. Plot 1 at Government Pt. is quite low in tidal height and cannot be sampled when waves are large, as was the case in spring 1992 and spring 2001. No sea star plots could be sampled in spring 1993.

Photo Plots

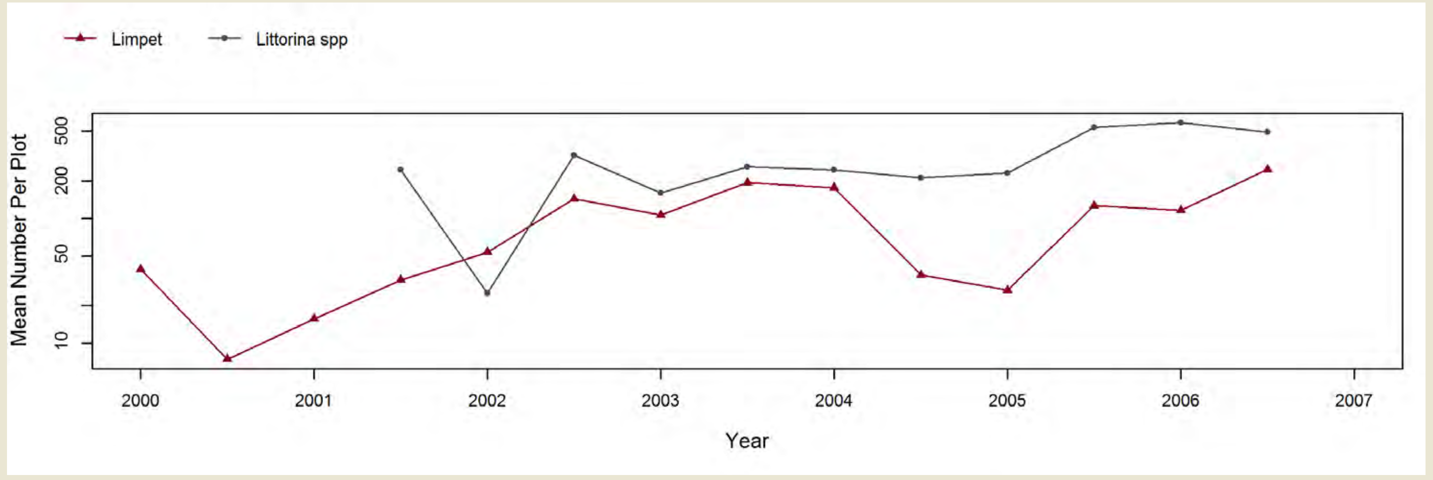
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

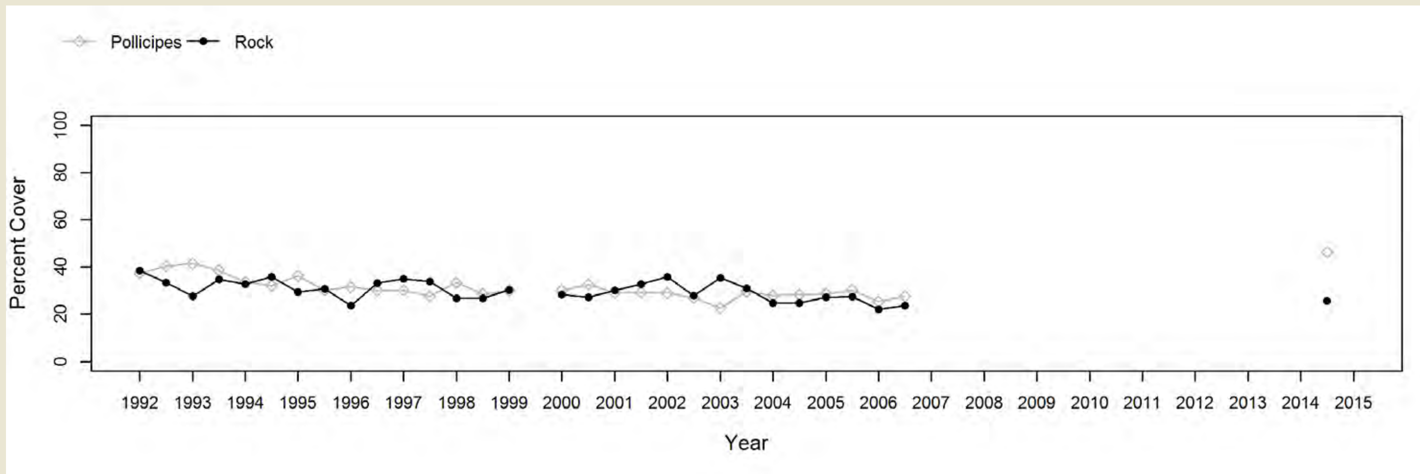
Chthamalus/Balanus (Acorn Barnacles) - percent cover



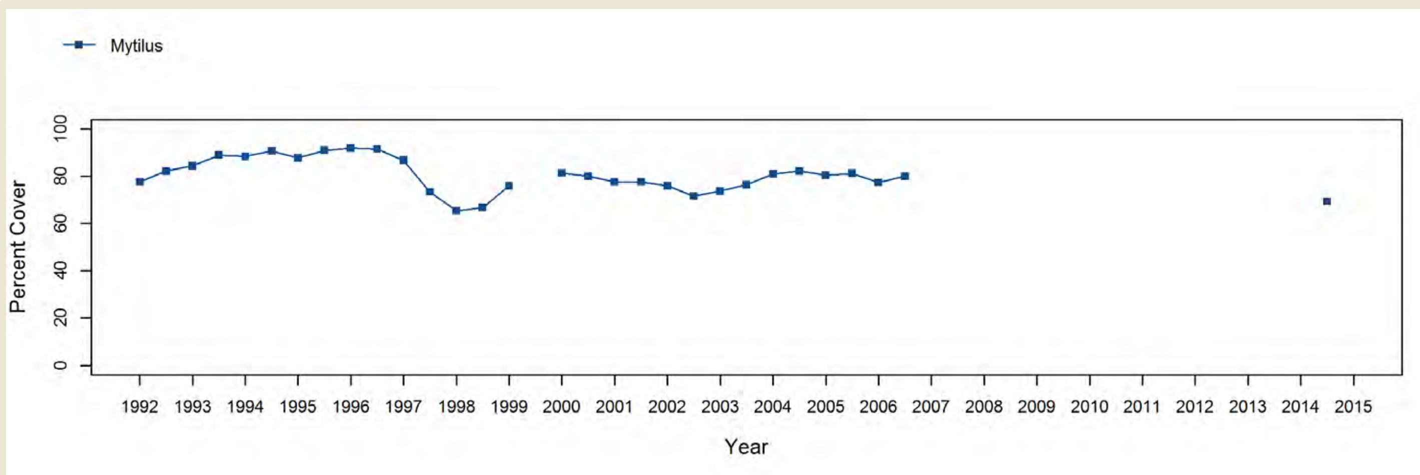
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



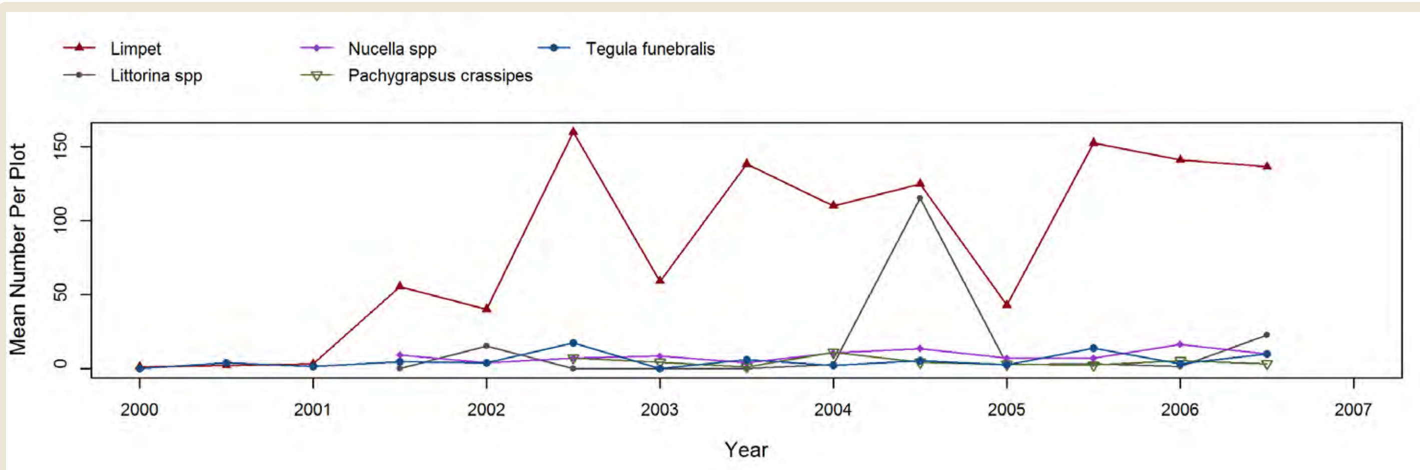
Pollicipes (Goose Barnacle)



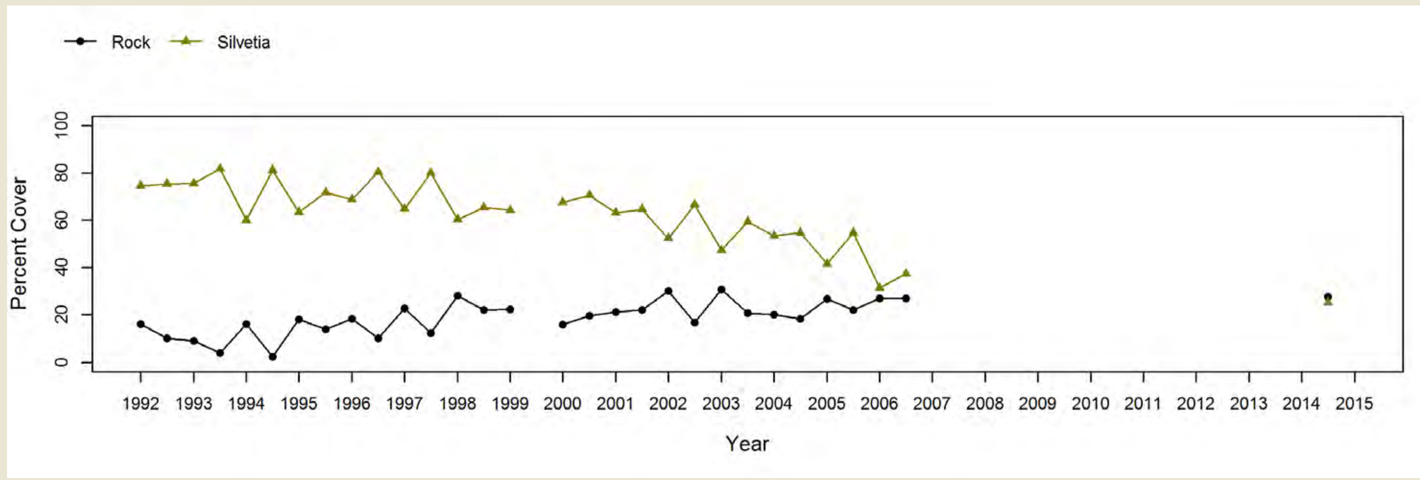
Mytilus (California Mussel) - percent cover



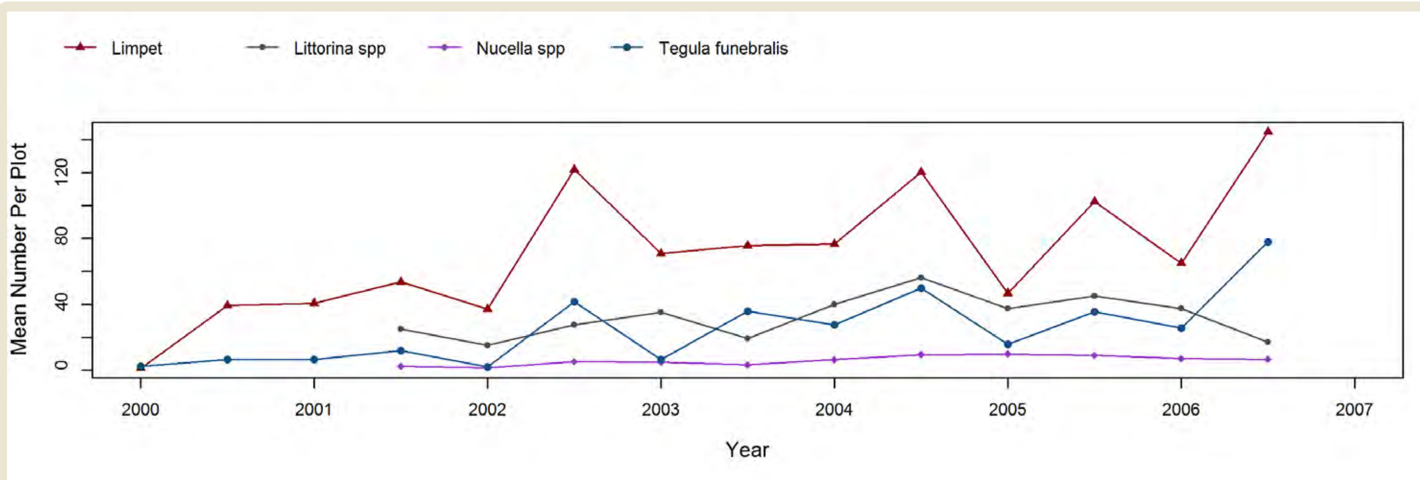
Mytilus (California Mussel - motile invertebrate counts)



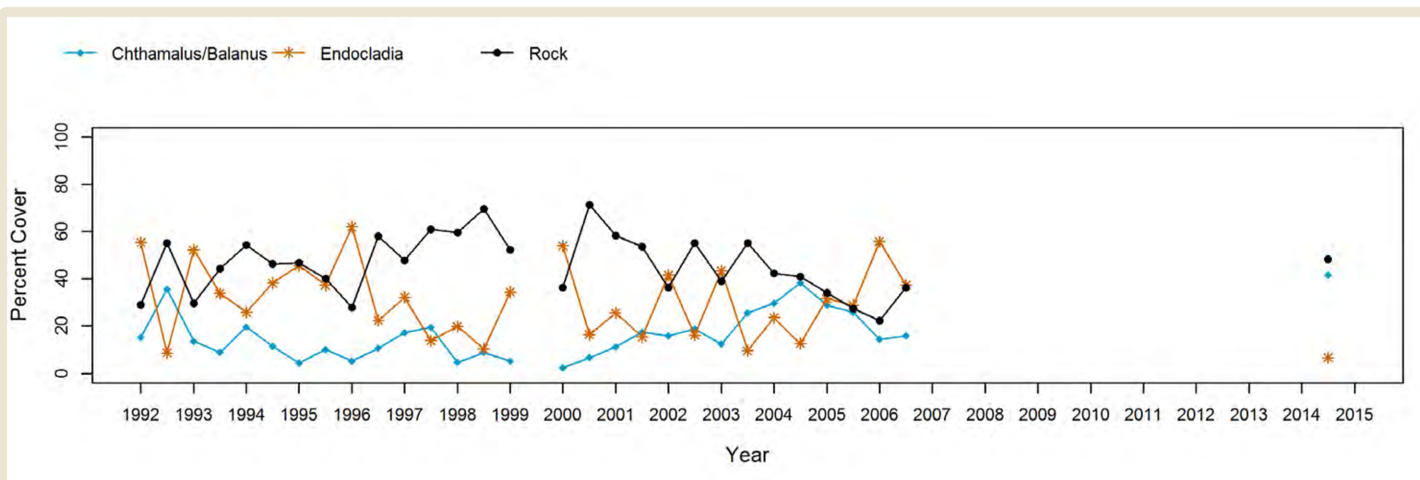
Silvetia (Golden Rockweed) - percent cover



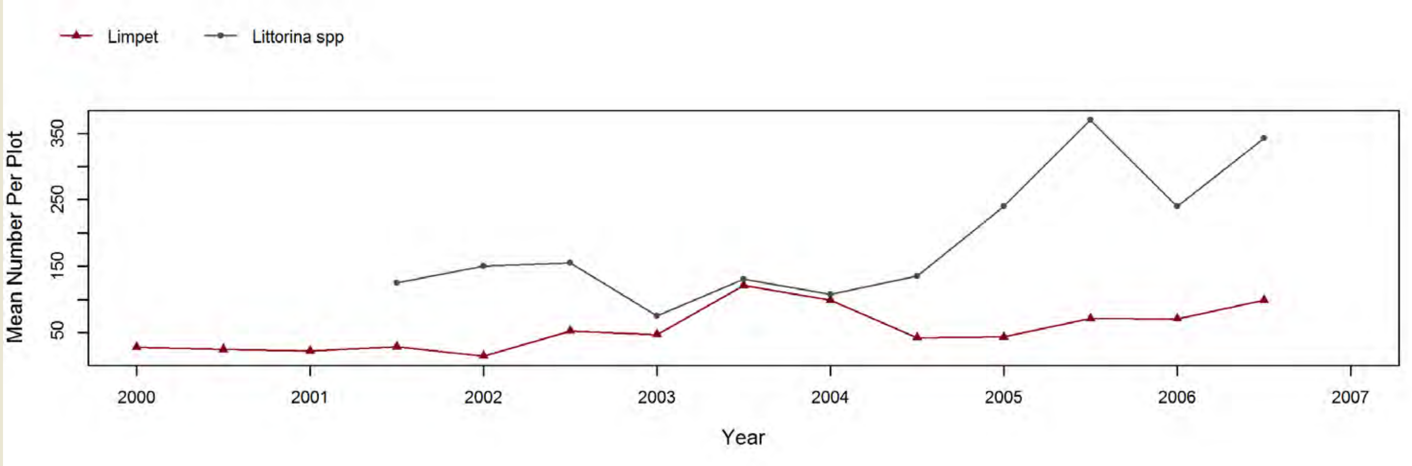
Silvetia (Golden Rockweed) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



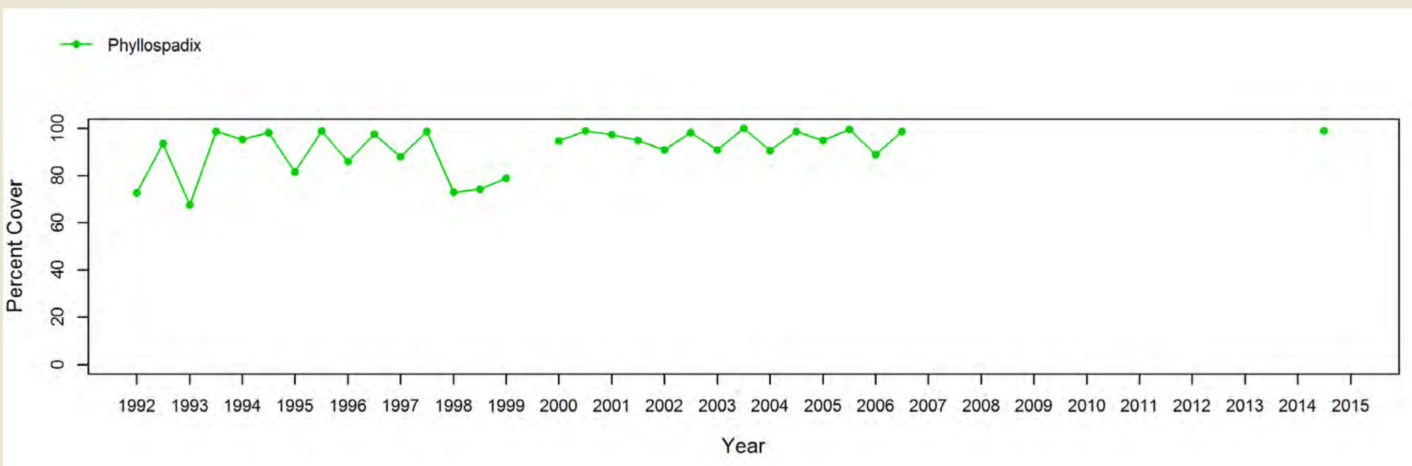
Endocladia (Turfweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

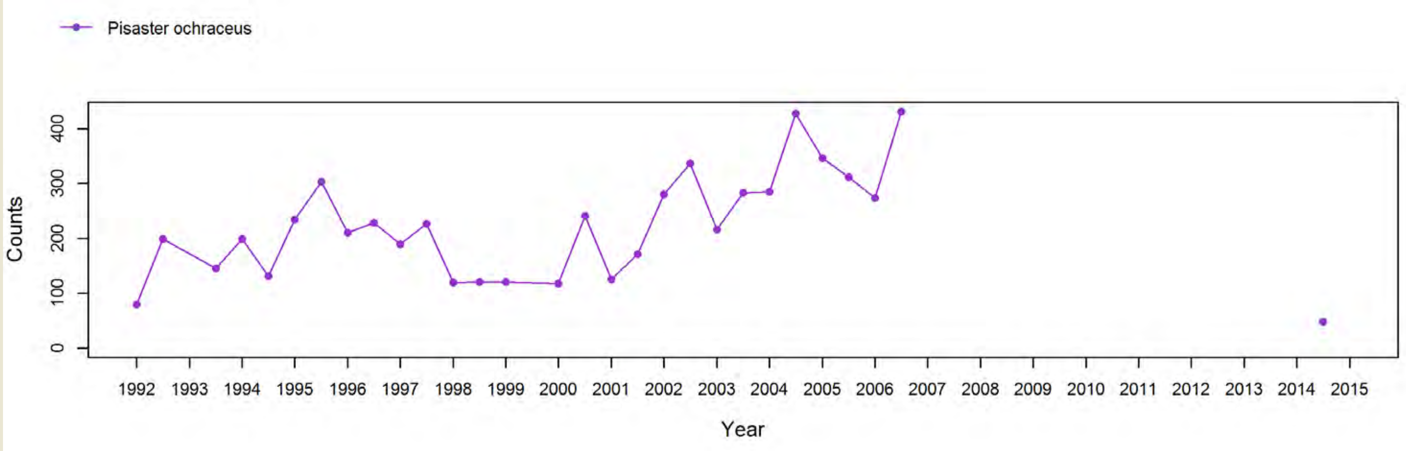
Phyllospadix (Surfgrass)



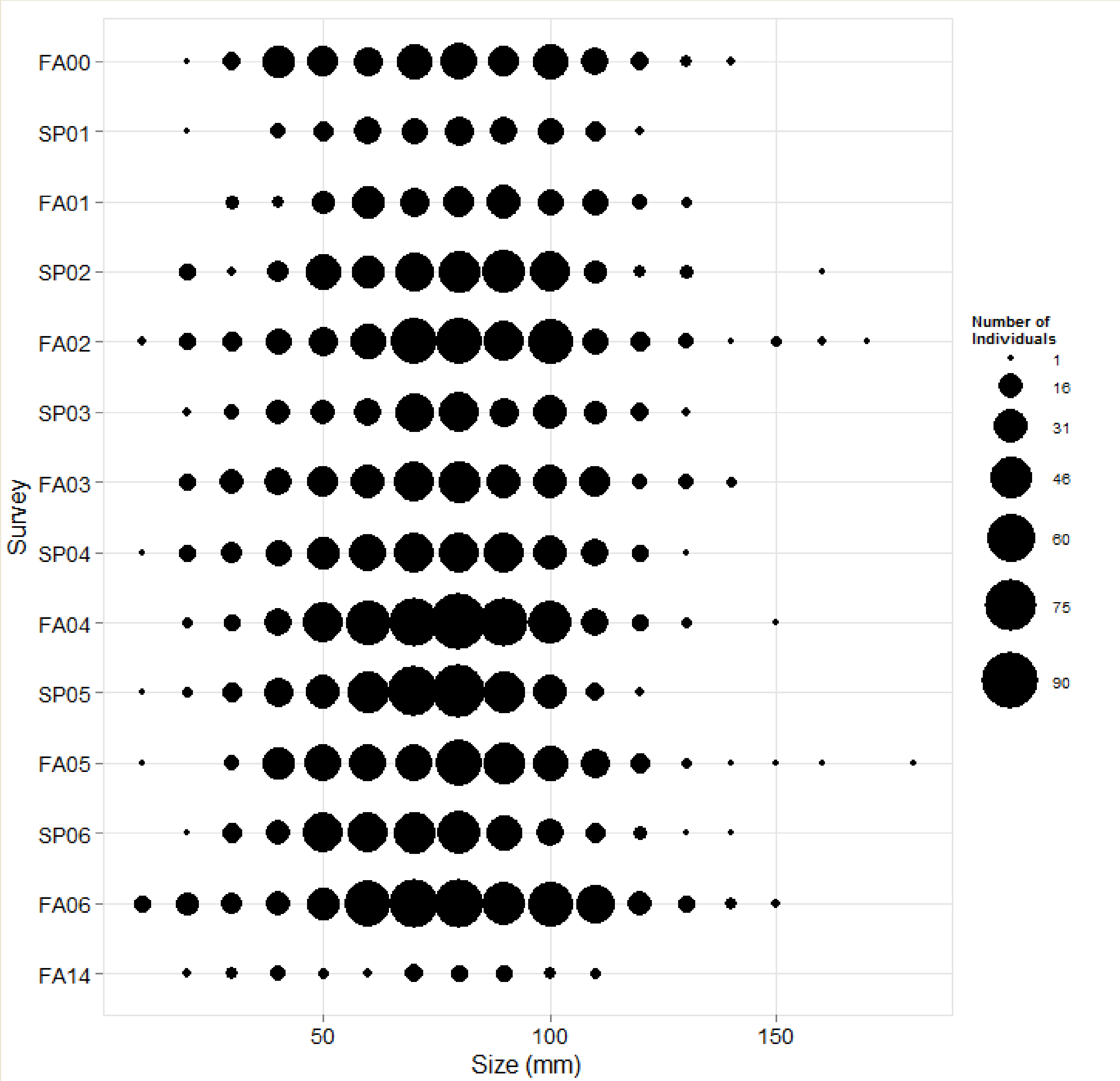
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster ochraceus (Ochre Star) - counts



Pisaster ochraceus (Ochre Star) - sizes



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Alegria Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The anemone plots at Alegria consist primarily of the colonial anemone, *Anthopleura elegantissima* rather than the solitary anemone *Anthopleura sola* (note that these were considered a single species prior to the past several years and they are not distinguished in our sampling methods). *Anthopleura* cover declined steadily from plot establishment in 1992 through 1999, after which there have been fuctuations between 40% and 80% cover. These plots, are subject to periodic sand burial and several of the large dips in *Anthopleura* cover are due to temporary sand inundation at the time of our sampling, rather than true loss of anemone cover. These animals are quite hardy and can withstand extended periods of sand inundation.

The barnacle plots at Alegria consist of a mixture of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula* with the former dominating some plots and a more even mixture in others. One of the original plots at this site was lost completely due to a rock breakout while another became dominated by a persistent *Lottia gigantea* farm. Two plots were added in recent years (spring 2007 and spring 2008) as replacements. Barnacle cover varied inversely with rock as periodic scour episodes have occurred. Variability has declined in recent years in the absence of major scour episodes; concurrently, *Endocladia*, mussels and anemones have begun encroaching on three of the plots, but the average cover has yet to meet the threshold for inclusion in the graphs. Motile invertebrate counts at this site began seasonally in the Fall of 2000 (with littorines added the following fall of 2001) and were changed to annual sampling in 2004. Both littorines and limpets have been steadily abundant in the *Chthamalus* plots with the former ranging around 1000 individuals per plot and the latter ranging more variably between 10 and 100 individuals per plot. Whelks (*Nucella* sp.) have also been present in low numbers except in 2002, 2006 and 2014 when the numbers dropped to zero.

The *Pollicipes* plots at this site have remained stable throughout the years with around 20% cover *Pollicipes*, 40-50% cover mussels, and rock varying from about 20-40%. Motile invertebrate counts show that limpets have been common and highly variable within the *Pollicipes* plots with abundance as high as 80 individuals per plot on two occasions. Littorines have been less common in these plots at less than 40 individuals per plot. In addition, whelk snails (*Nucella* spp.) and shore crabs (*Pachygrapsus crassipes*) have been present in low numbers. A decision was made in 2014 to cease motile invertebrate counts in *Pollicipes* plots.

Mytilus cover in the mussel plots began around 80% on average in 1992, declined gradually to about half that in 1998, then gradually rebounded to over 60% by 2004. Then a reef-wide crash occurred in 2006 with cover dropping to zero in, and in the vicinity of, the photoplots. These plots are located on a wide, low-relief reef fat that was presumably scoured during a large winter storm. Mussels are still present in other, more high-relief areas within the site, such as the reef where the *Pollicipes* plots are located. The reef fat population has yet to recover . In the meantime, the plots have become dominated by a mixture of barnacles, colonial anemones, prostrate *Phragmatopoma*, articulated corallines and other turf algae, and patches of *Phyllospadix*. One small recruitment event offered some promise of recovery in the spring of 2011, but those mussels had disappeared by the following fall sampling. Motile invertebrate sampling show frequent but low numbers of whelks (*Nucella* spp), shore crabs (*Pachygrapsus crassipes*) and volcano limpets (*Fissurella volcano*). On the other hand, *Tegula funebralis* snails have been more common and increased to large numbers (over 120 individuals per plot) until 2006 when the mussel population, and the *Tegula* population with it, crashed. Following the mussel crash, limpet numbers began to increase as bare rock became more prevalent. A decision was made in 2014 to stop sampling limpets and littorines in these mussel plots.

Rock ("Above Barnacles") plots were added to this site in the fall of 2008 to document any upward spread of intertidal species as a result of global climate change or other factors. These plots are expected to remain dominated by bare substrates unless barnacles or other species begin to encroach upon them. Other than a few spots of tar, these plots have yet to see any barnacle recruitment. These plots are subject to occasional scour; certain plots have been found partially obscured by small boulders and cobbles. It is assumed that these scour events would be detrimental to recruits of barnacles or other taxa.

Surfgrass (*Phyllospadix*) transects were added to Alegria in the fall of 2001. Since that time the mean cover of surfgrass has hovered in the 70-80% range with seasonal oscillation (lower cover in the spring following winter storms that ripped out plants and abraded leaves; recovery by fall). There have been no long-term trends in surfgrass cover. These transects were established at the inshore margin of an extensive, thick surfgrass bed which extends into the subtidal.

Seastar (*Pisaster ochraceus*) plots were added to this site in the spring of 2002 and consist of three large irregular plots surrounding an area of high relief rock pinnacles and deep tidepools. At the frst sampling, the total number of seastars counted and measured was around 120. That number increased to over 200 by the following fall, but declined sharply thereafter and then hovered around 20-30 seastars from 2006 to 2009. After 2010, the number of stars found dropped below 20 except for the spring of 2012 when around 50 stars were found. While a few smaller (<50mm radius) stars have been found at this site throughout the years, those encountered tend to be larger (>60mm). General observations, along with the size distribution depicted in the trend graph, suggest that stars are moving in and out from the subtidal rather than recruiting to the monitoring site. In the fall of

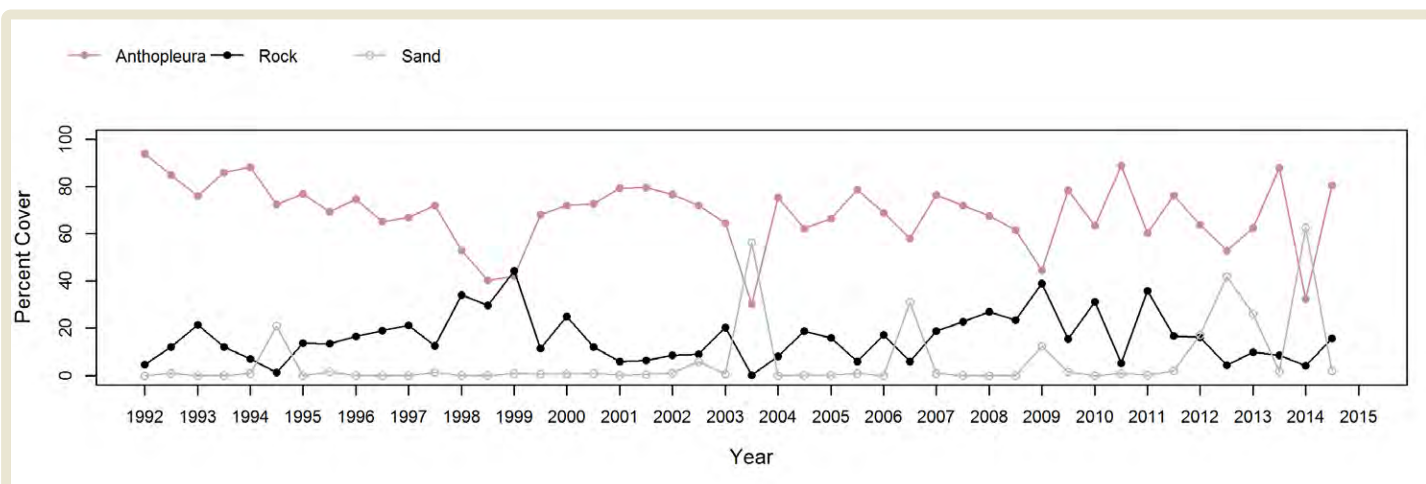
2013, the seastar wasting disease arrived at this site. During that sampling season, only four seastars were found in the established plots though none of them showed evidence of the disease. Elsewhere at the site, several stars were found with lesions and others were found detached or loosely attached on inshore reef fats where stars are not normally seen, including a small and fast moving Pycnopodia. While this disease has been known to decimate the population in some areas, we did see 1-2 healthy stars in each of the subsequent sampling seasons in the fxed plots, and another few sitewide, indicating that there may have been some resistant stars that survived.

Photo Plots

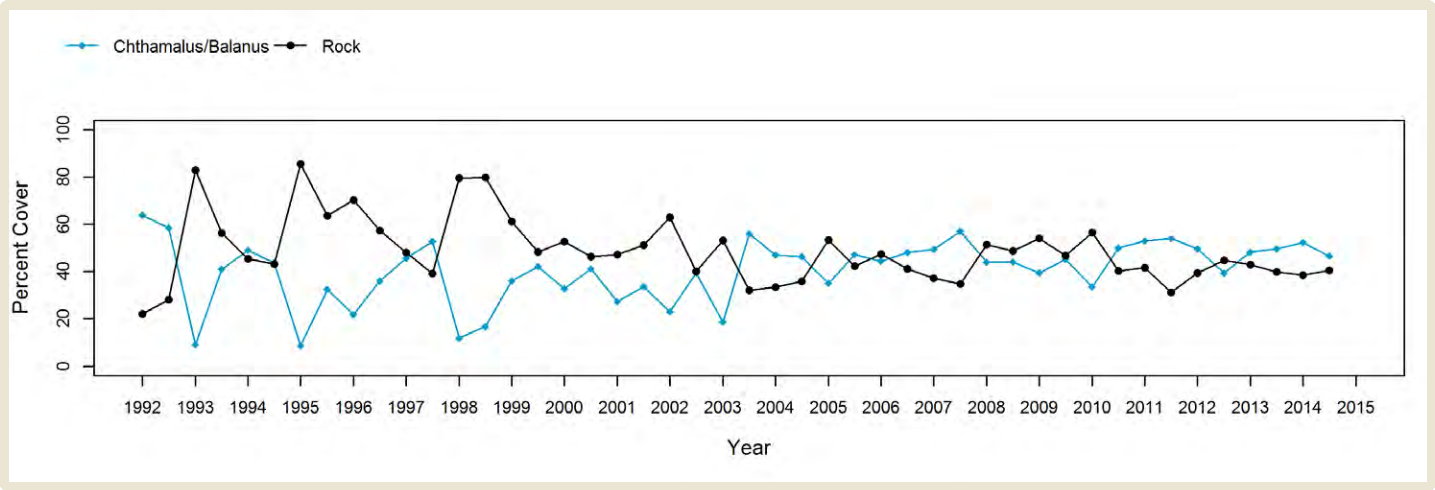
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

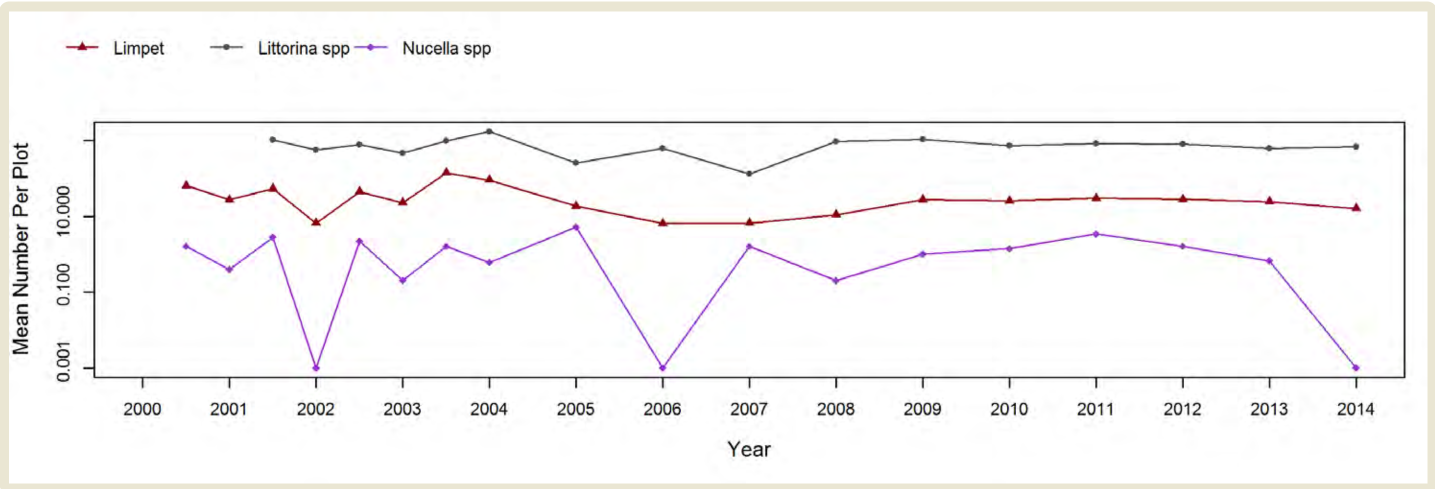
Anthopleura (Anemones)



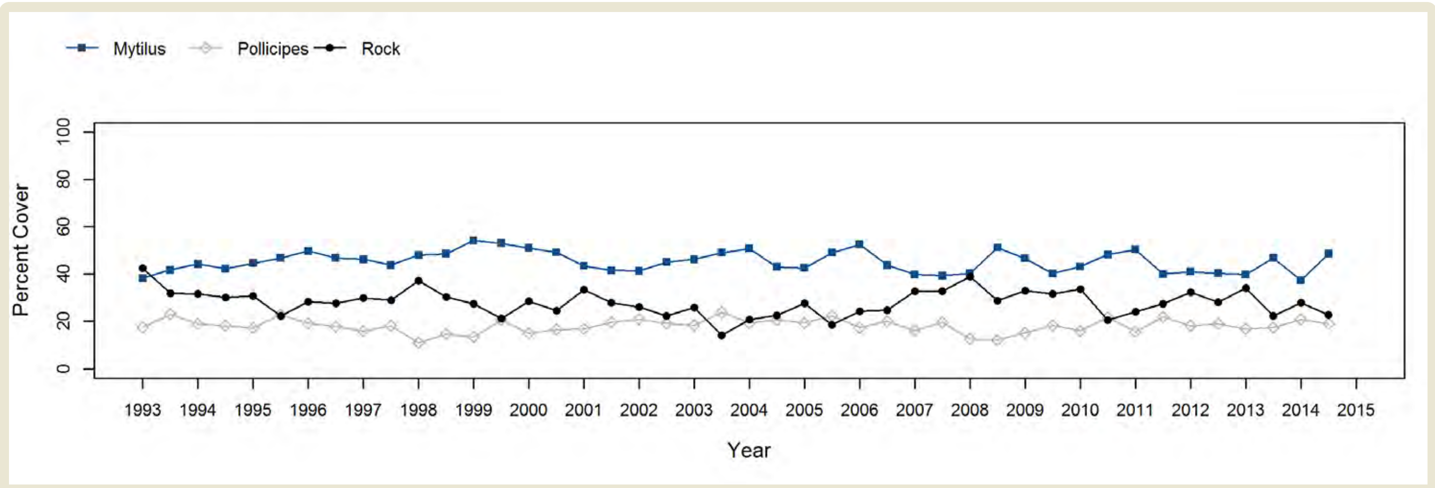
Chthamalus/Balanus (Acorn Barnacles) - percent cover



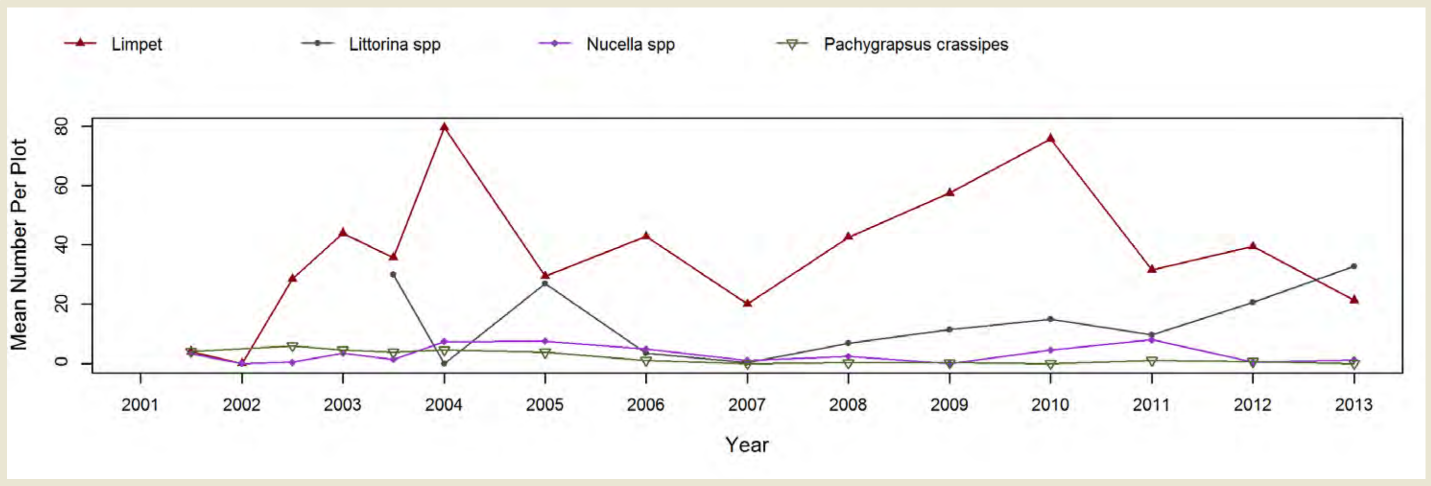
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



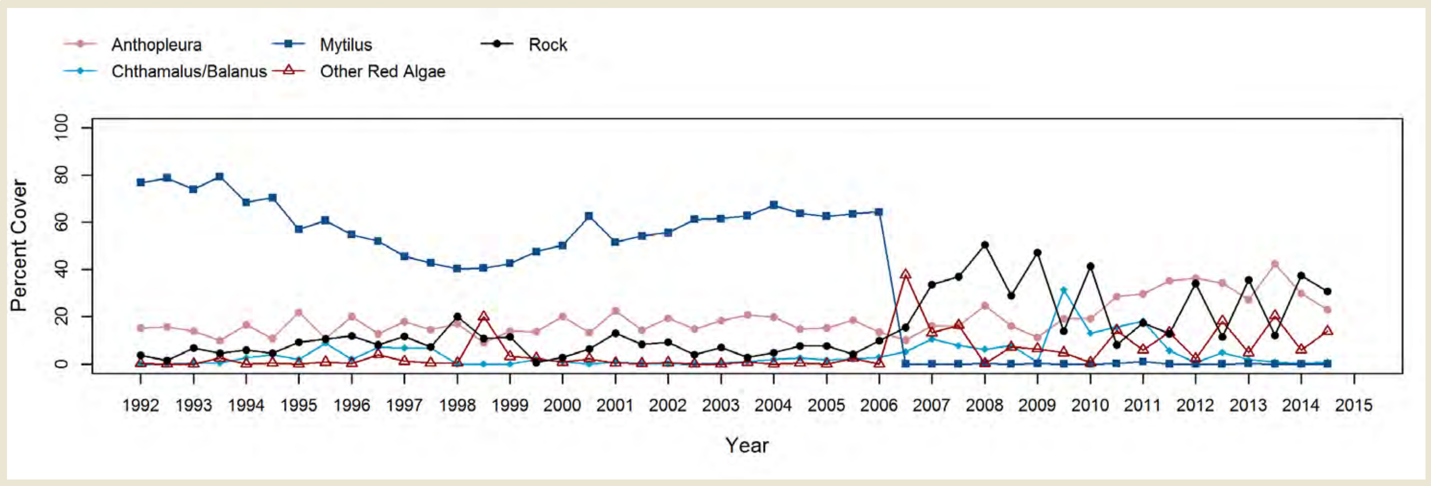
Pollicipes (Goose Barnacle) - percent cover



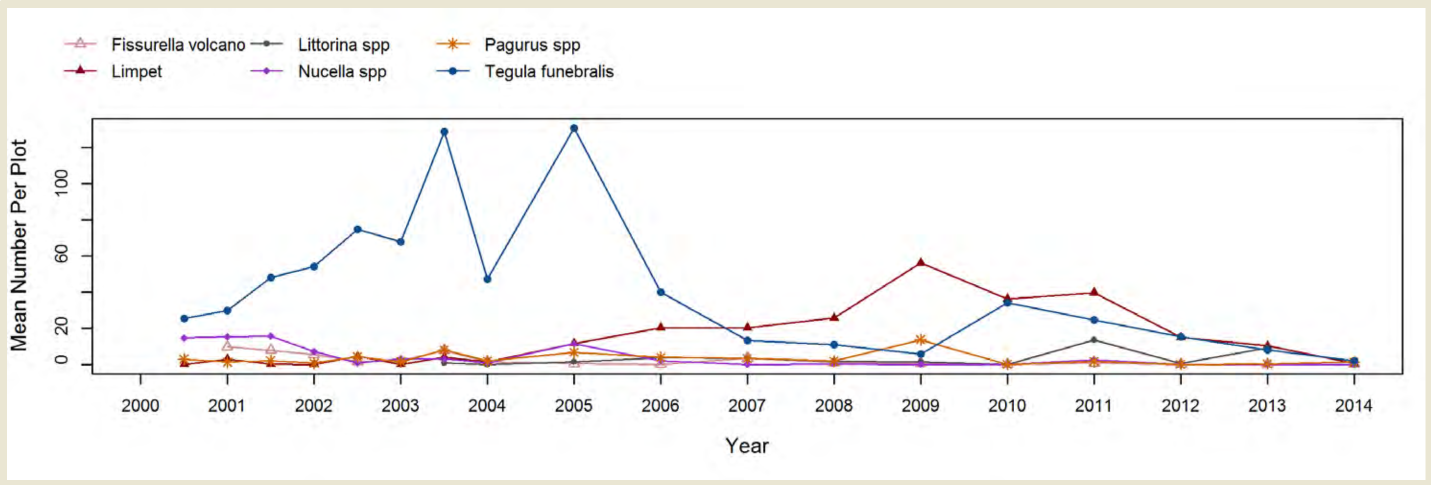
Pollicipes (Goose Barnacle) - motile invertebrate counts



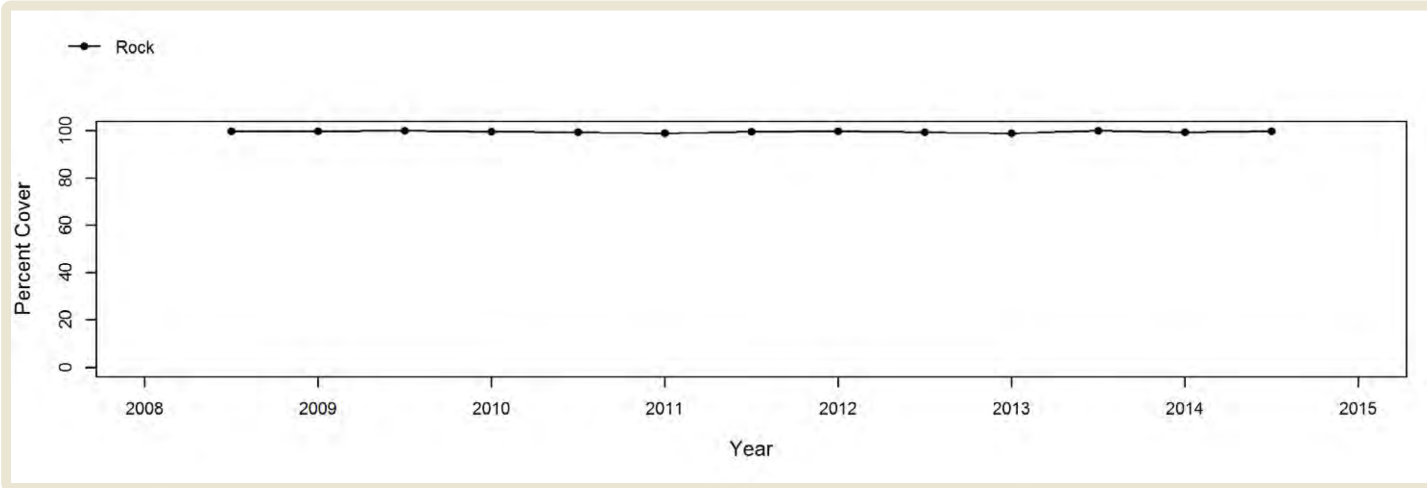
Mytilus (California Mussel) - percent cover



Mytilus (California Mussel) - motile invertebrate counts



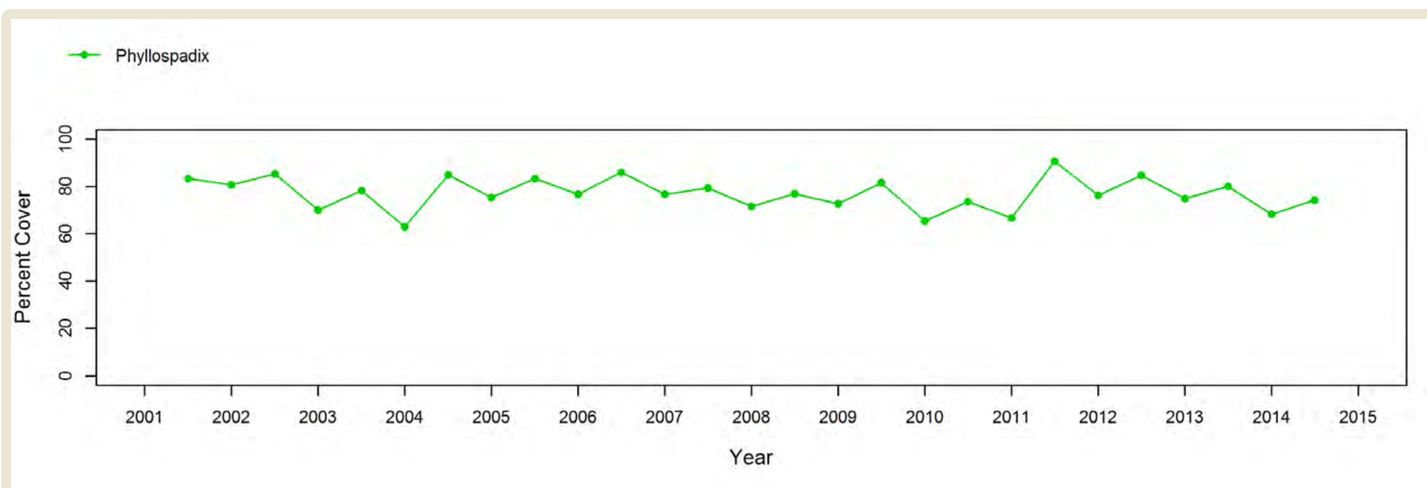
Rock (Above Barnacles)



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

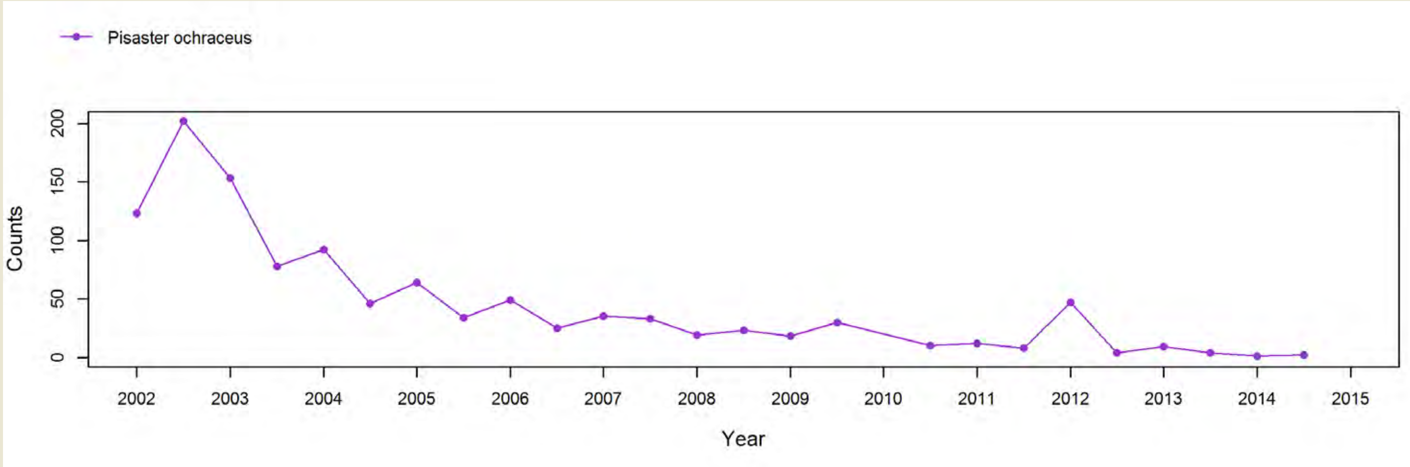
Phyllospadix (Surfgrass)



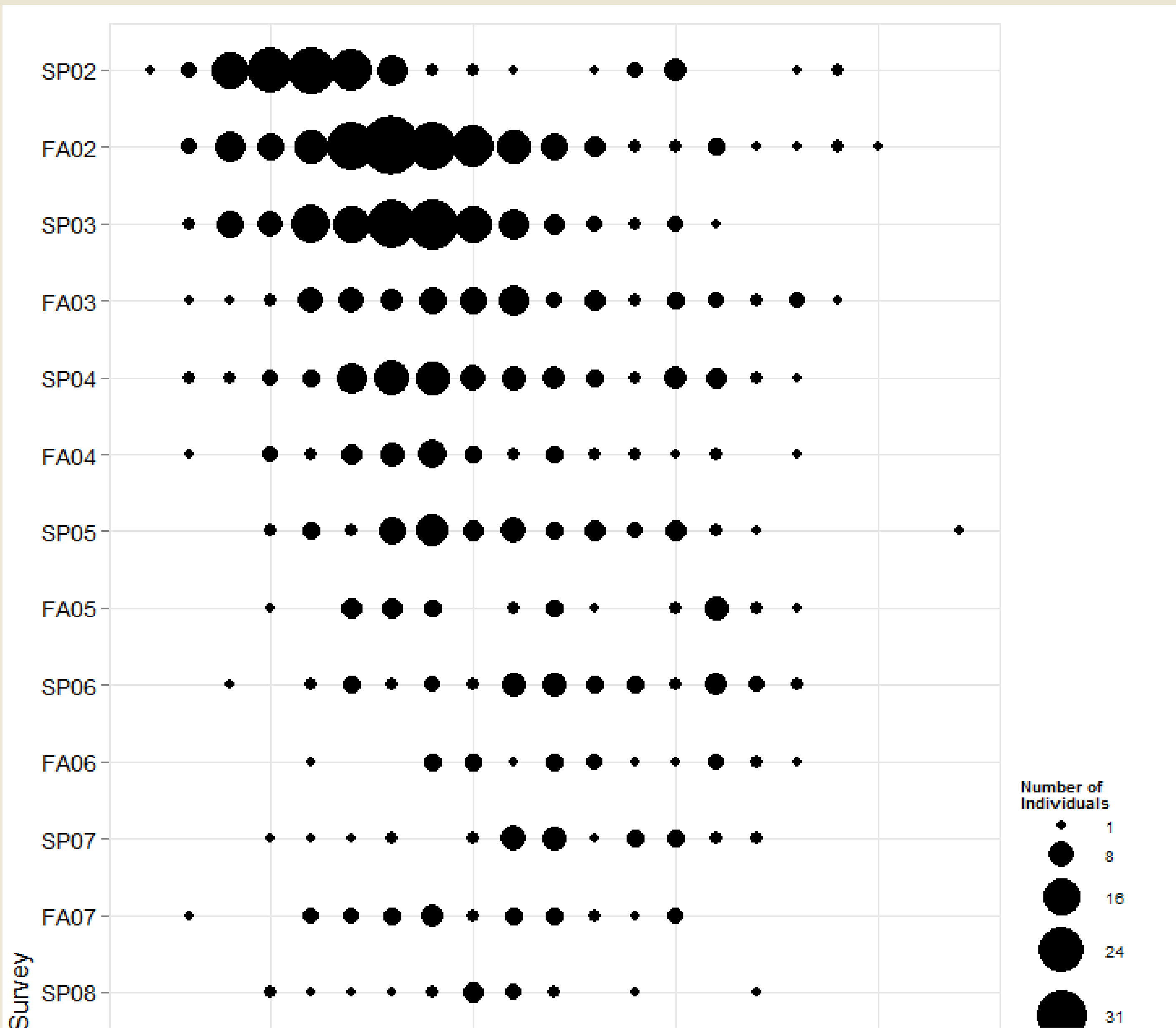
Species Counts and Sizes

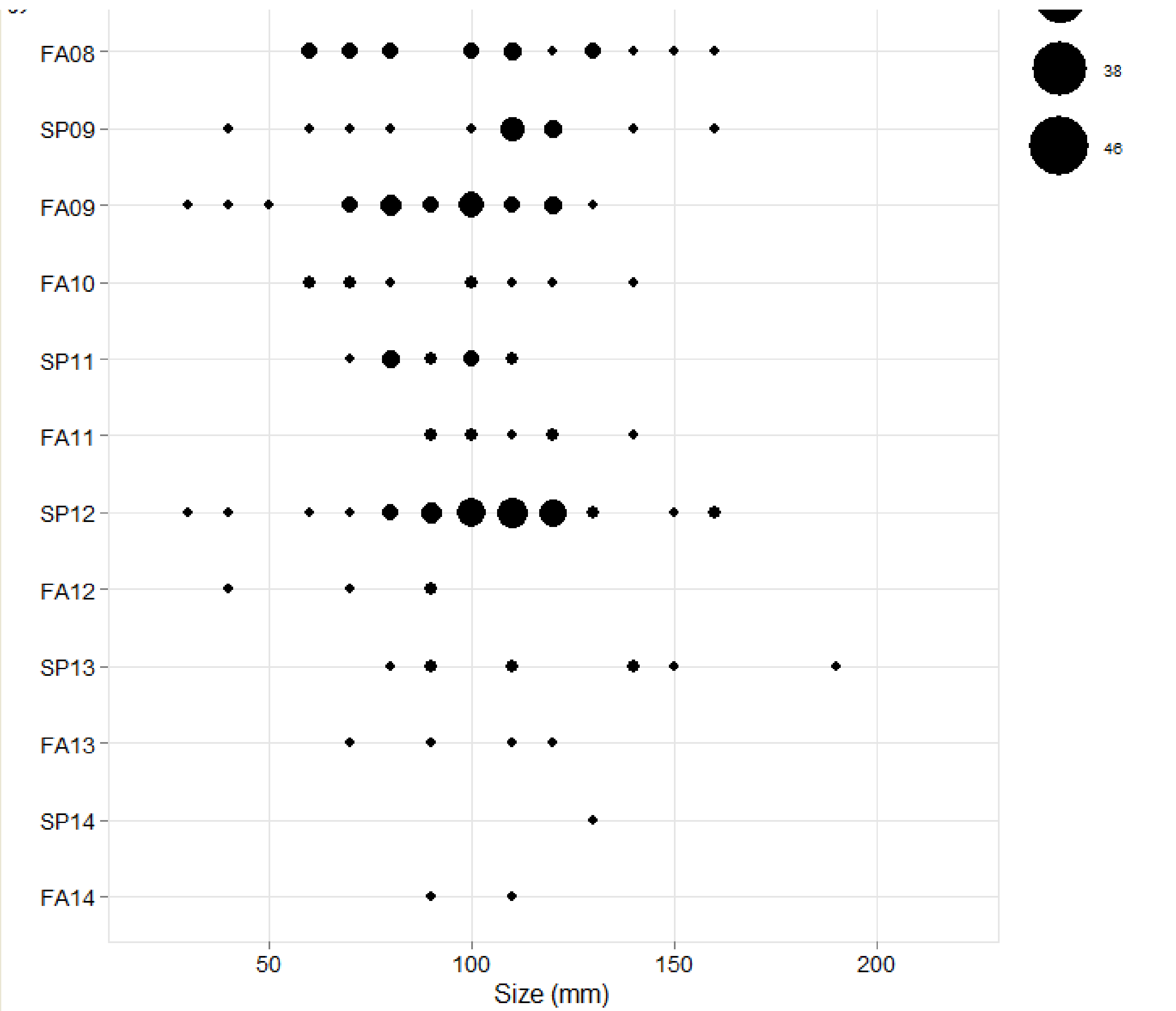
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster ochraceus (Ochre Star) - counts



Pisaster ochraceus (Ochre Star) - sizes





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Arroyo Hondo Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The barnacle plots at Arroyo Hondo consist of a mixture of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula*. Two plots are located on a smooth, nearly vertical sandstone reef outcrop and consist almost completely of *Chthamalus* spp. barnacles, while the other three plots are on rougher, lower sloped outcrops and have approximately 25% relative cover of *Balanus*. Barnacle cover varied inversely with rock as periodic scour episodes have occurred. This scour has been especially pronounced in the two plots on smooth sandstone where near 100% barnacle removal has occurred several times. The other three plots are more stable and have been encroached upon to varying degrees by a mixture of *Endocladia*, mussels and anemones. The average cover of these taxa has yet to meet the threshold for inclusion in the graphs. Motile invertebrate counts at this site began seasonally in the fall of 2000 and were changed to annual sampling in 2004. Within the barnacle plots, limpets and littorine numbers have remained high and reasonably steady throughout this time. Snails (*Nucella* spp. and *Tegula funebralis*) have been present in low numbers during most sampling events.

Mytilus cover in the mussel plots began around 80% on average in 1992, declined gradually to under 60% through 1997, then declined precipitously to about 10% by fall 1998. After that mussel cover rebounded to about 70% by 2002 where it remained for several sampling seasons, then declined to around 50% by 2005 where it has remained ever since. Both the decline of the late 1990s and the 2002 recovery were represented by all fve mussel photoplots. The subsequent cover reduction since 2005 has primarily been the result of a single plot which has exhibited very low (near zero) mussel cover since that time, with clonal anemones becoming the primary space occupier of that plot outside of bare rock. Three other plots have remained high in mussel cover, save for the occasional small breakout, while the remaining plot has been mixture of bare rock with recurring mussel patches. As with the barnacle plots, motile invertebrate counts within the mussel plots began seasonally in fall 2000 and were changed to annual sampling in 2004. Within the mussel plots, limpets numbers have exhibited moderate fuctuations with mean numbers ranging from near zero to over 250 per plot. These fuctuations are the result of recruitment pulses of small (<5mm) limpets. The factors contributing to these pulses, and the fate of these individuals through time, is not clear. Aside from limpets, littorines and other snails (*Nucella* spp. and *Tegula funebralis*) are typically found in the plots in low numbers and chitons (*Nutallina* spp.) are found occasionally. Littorines have been encountered more frequently in recent seasons, though it should be pointed out that these were not consistently sampled in the mussel plots prior to 2006. Littorine sampling ceased in 2014.

Rock ("Above Barnacles") plots were added to this site in the fall of 2008 to document any upward spread of intertidal species as a result of global climate change or other factors. These plots are expected to remain dominated by bare substrates unless barnacles or other species begin to encroach upon them. Other than bare rock and a few bits of tar, a few barnacles (up to 1-5% cover in some plots) were found in most plots by the fall of 2009. These plots are subject to occasional sand burial and scour. Sand burial events occurred in the spring of 2010 and the fall of 2012; other scour events may have occurred in between our regular sampling intervals.

The mean cover of Surfgrass (*Phyllospadix* spp.) has fuctuated widely throughout the years at Arroyo Hondo. Throughout the 1990's and up to 2002, mean surfgrass cover varied from a high of around 90% to a low of around 30%, but with cover rebounding to the higher end every few seasons or so and the long-term mean remaining around 80%. Since 2002, *Phyllospadix* has undergone a decline with cover now fuctuating between 25 and 60% for the last several years. Declines in surfgrass have been met with increases in red algae (mostly *Chondracanthus* sp. and articulated corallines). Initially, only two transects were installed at this site due to limited habitat on a single horizontal reef top. However, a third transect was added in the spring of 2001 to achieve consistency with other sites. The addition of this third transect coincides with the start of a decline in surfgrass cover at the site.

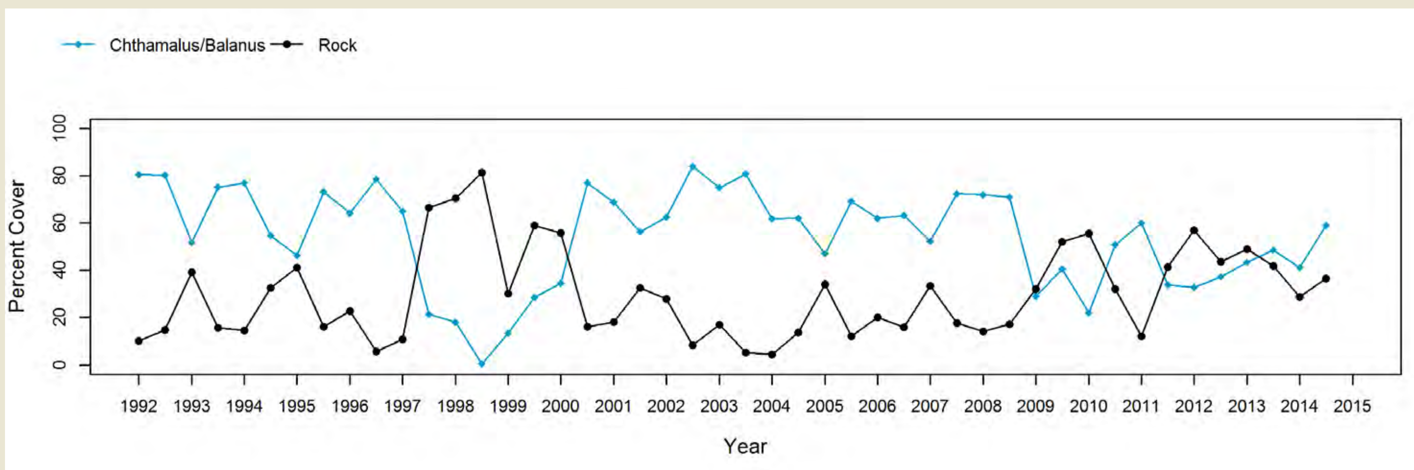
Seastar (*Pisaster ochraceus*) numbers have fuctuated widely at this site from over 60 stars counted and measured to just a few, with peaks in 1992, 1997 and 2002. Since 2002, there has been a general decline in seastar numbers to nearly zero in 2010. In some periods, seastar numbers show some suggestion of seasonal variation with higher numbers in the spring compared to the fall. These data have historically been collected within three short transect swaths. However, in the spring of 2004, the push for methodological consistency among sites prompted the addition of a series of three large irregular plots encompassing most of the monitoring site to be sampled alongside the transects. These plots contained a higher number of stars, compared to the transect data, during their frst few seasons of sampling (expected given the greater amount of area sampled), but with declines converging toward the transect data numbers in more recent seasons and likewise approaching zero by 2010. Seastar sizes have been measured since the fall of 2000. A large recruitment pulse occurred in the fall of 2001 and the growth of these stars is evident in these trend graphs. No other signifcant recruitment events have observed. Despite the fact that our monitoring reef is separated from other reefs by expanses of sand, it seems from our size and abundance data that stars are able to migrate to and from the reef. While the seastar wasting disease arrived at this part of the coast in fall 2013 and a couple possibly sick stars were observed during that sampling season, no conclusive evidence of the disease was ever recorded at this site. That said, the numbers of stars in fxed plots dropped from 10 in fall 2013 (irregular plots) to two in spring 2014 and one in fall 2014. An additional sitewide search in fall 2014 turned up three more stars. It seems likely that the disease struck this site, but did so without being detected directly.

Photo Plots

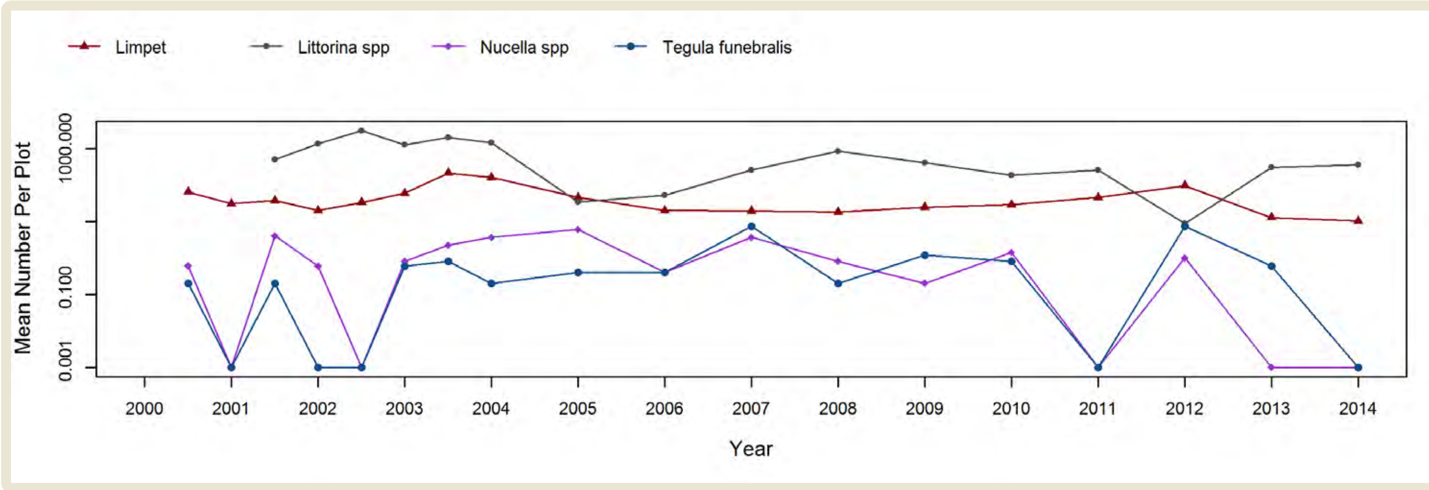
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

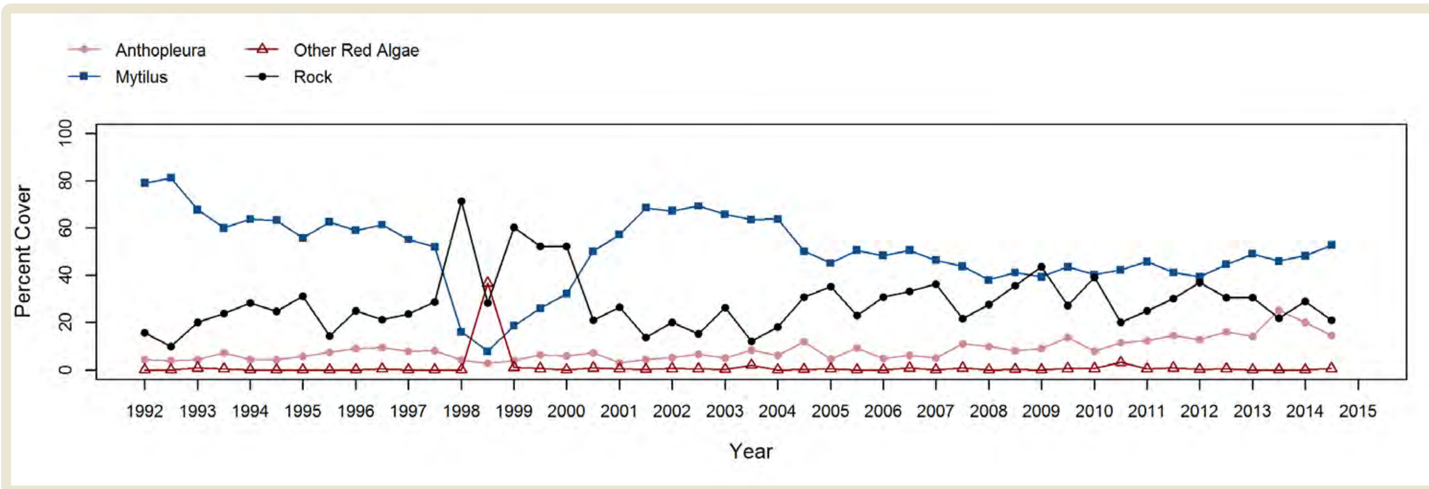
Chthamalus/Balanus (Acorn Barnacles) - percent cover



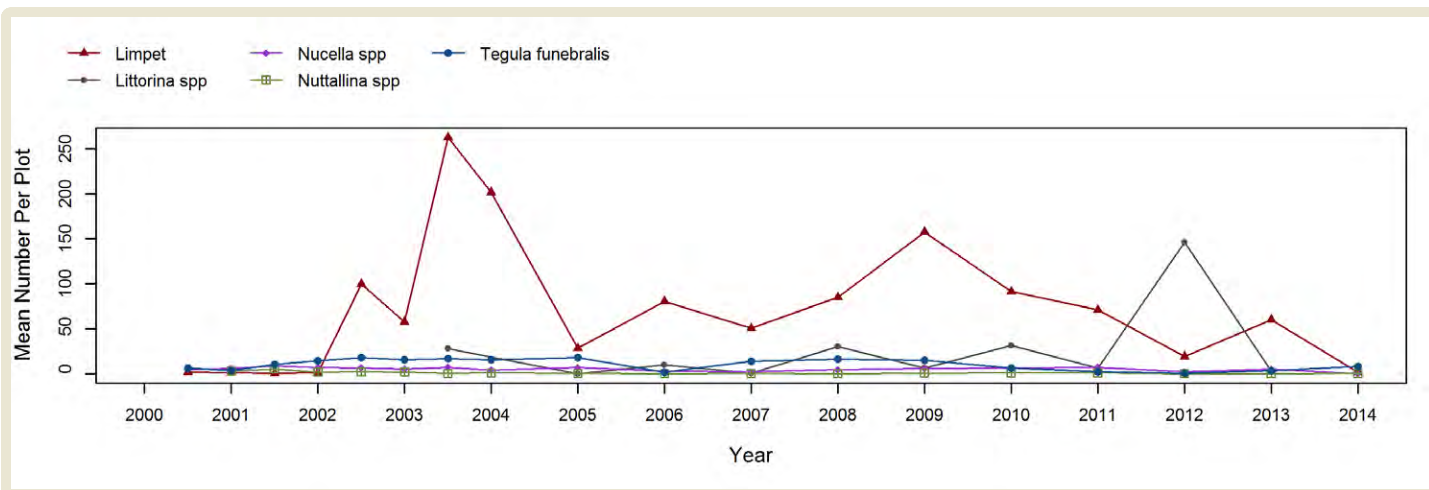
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



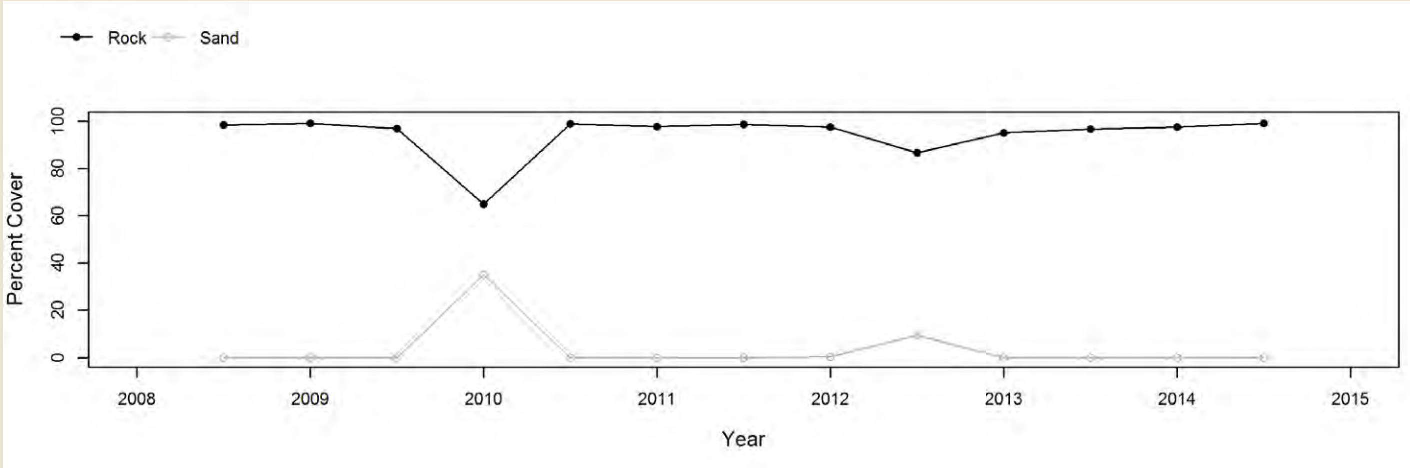
Mytilus (California Mussel) - percent cover



Mytilus (California Mussel) - motile invertebrate counts



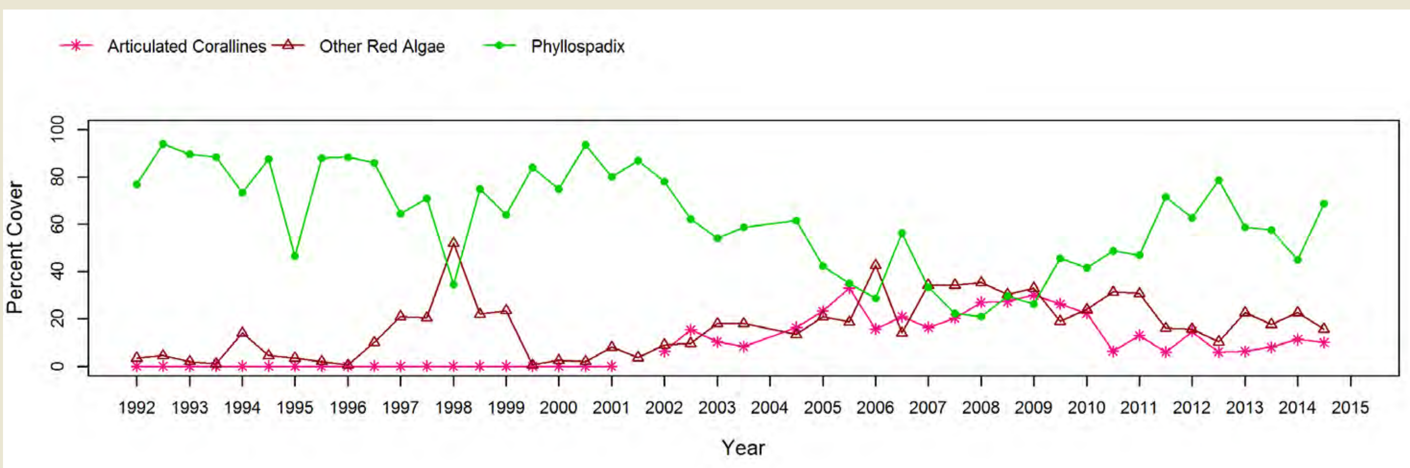
Rock (Above Barnacles)



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

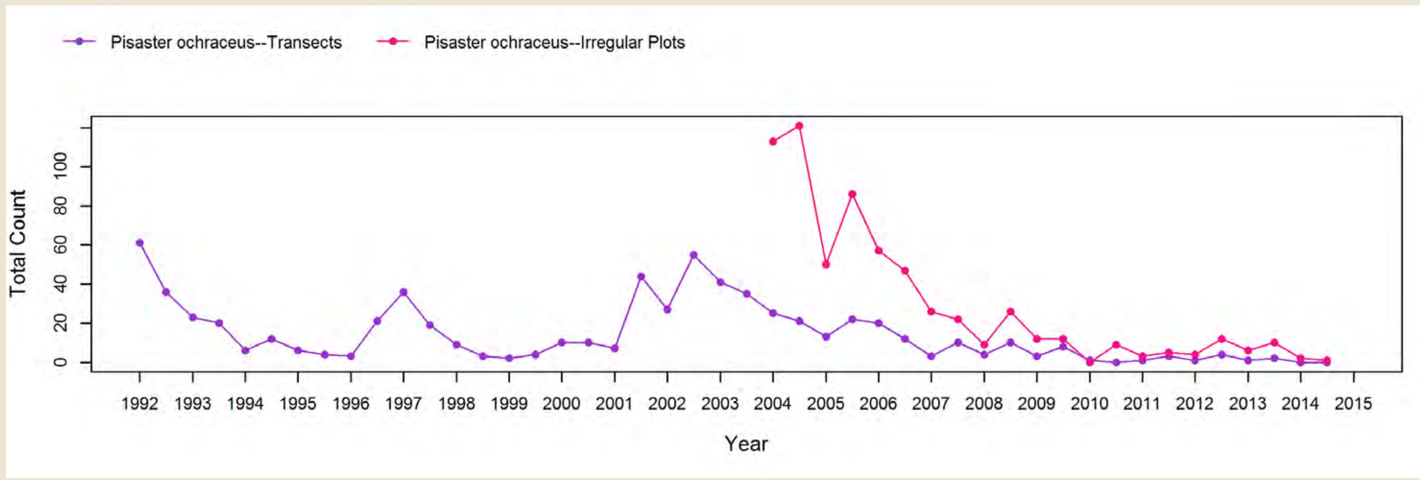
Phyllospadix (Surfgrass)



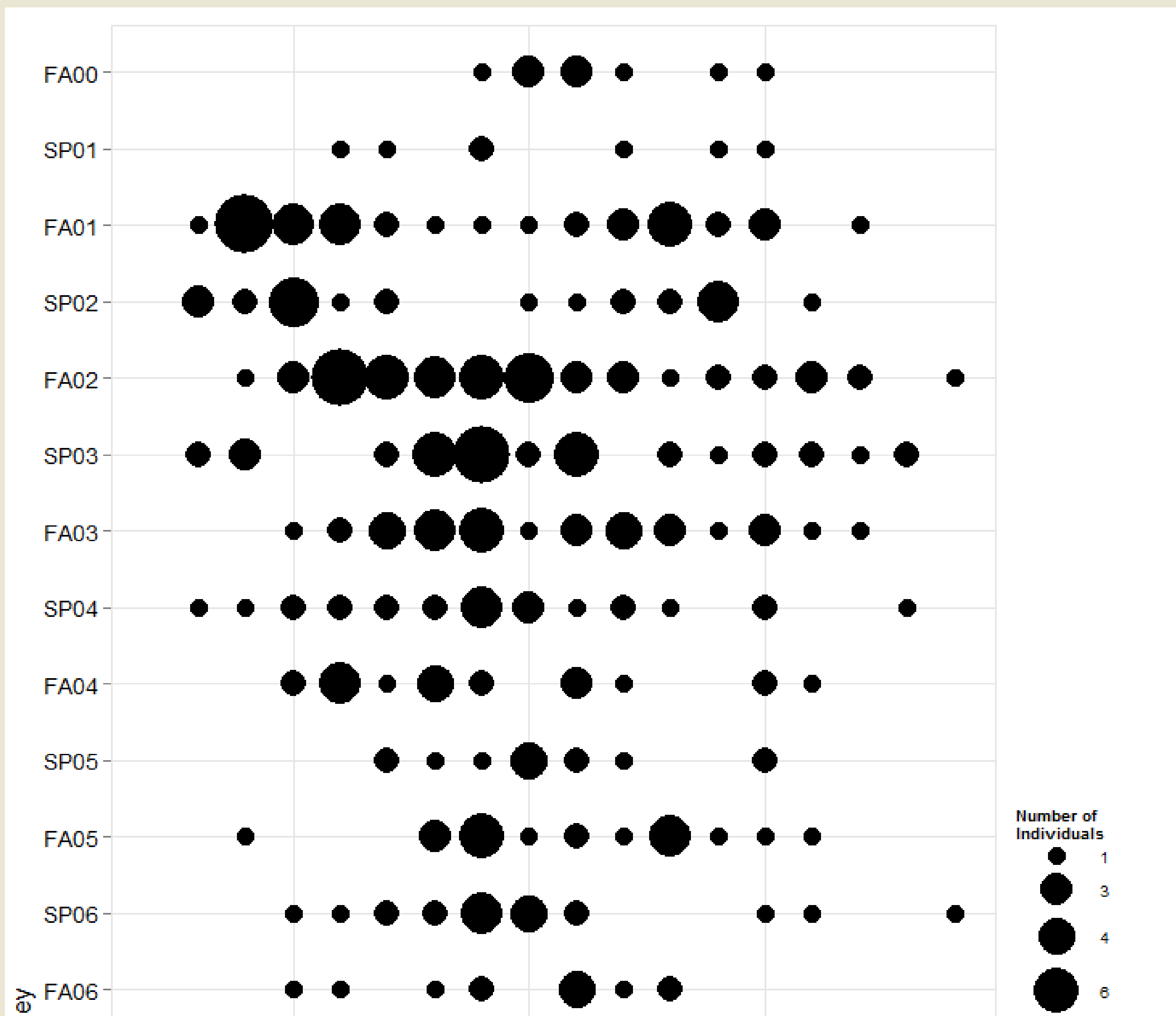
Species Counts and Sizes

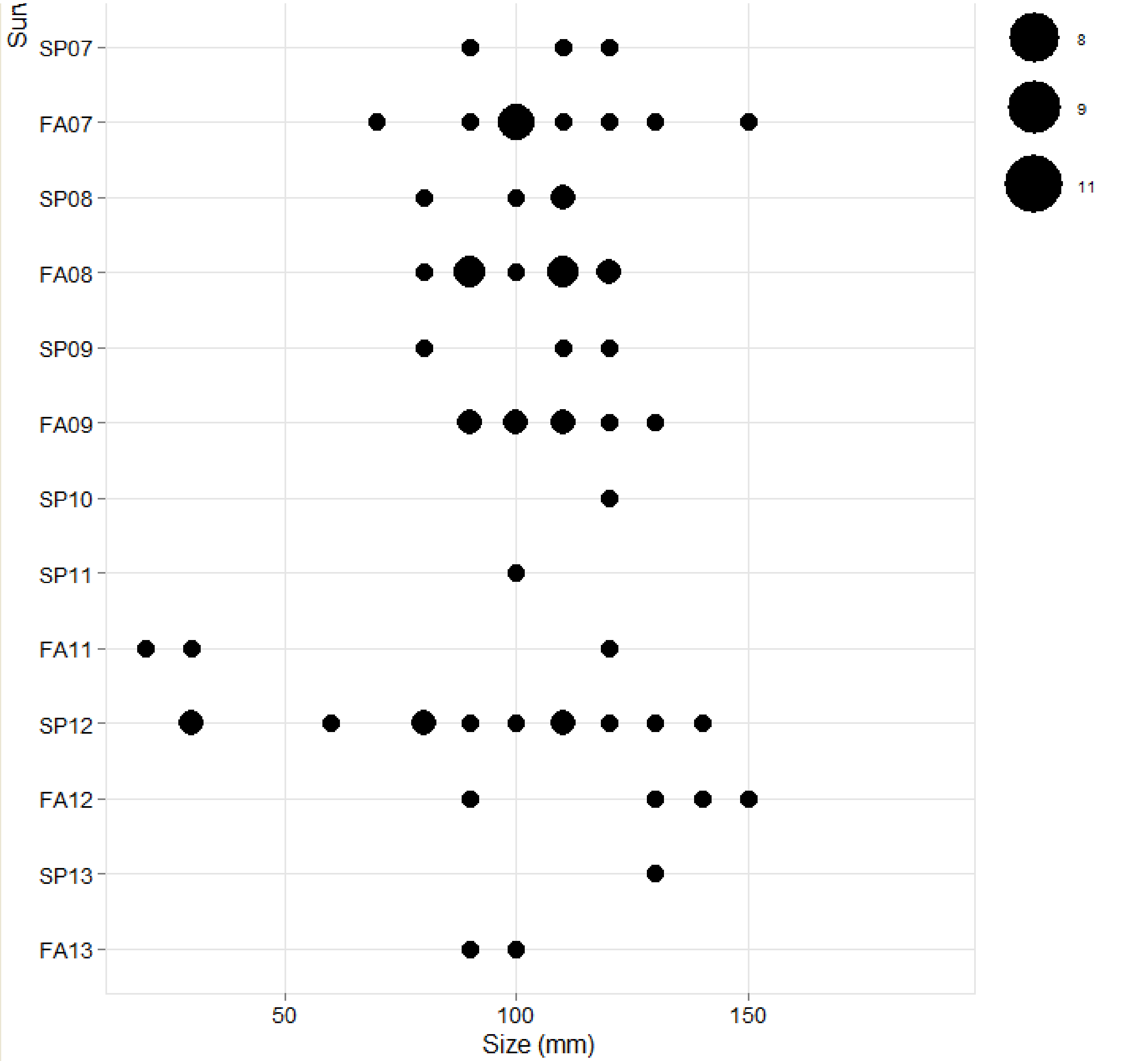
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes in Transects





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Coal Oil Point Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The anemone plots at Coal Oil Point consist primarily of the solitary anemone, *Anthopleura sola* rather than the colonial anemone *Anthopleura elegantissima* (note that these were considered a single species prior to the past several years and they are not distinguished in our sampling methods). Cover of *Anthopleura* has undergone a gradual decline from around 25% in 1992 to less than 10% in 2010 with cover estimates interrupted every few seasons by periods of near complete sand burial. Aside from sand, the dominant taxa occupying these plots are species of flamentous red algae which have been lumped with a few other seldom-encountered species into the "other red algae" category. Red algae have fuctuated wildly in relation to sand burial, though in recent years they seem to have become more stable in the 40-50% cover range. Alternatively, bare rock and the ephemeral alga *Ulva* both increased in cover after 2008, though *Ulva* has declined again in recent seasons.

Mussel plots were added to this site in the fall of 2003. Since that time, the mean cover of *Mytilus* declined initially from around 80% to around 60% by the fall of 2004, but has remained generally steady in the 60-70% range thereafter. Mussel cover is currently at the lower end of the range at 54% in fall 2014. Much of the decline is the result of a single plot in which a mussel breakout gave way to an open patch of rock and barnacles that has persisted since that time. Annual motile invertebrate sampling has occurred in these plots since their inception (always in the spring, though with an additional sampling in the fall of 2003). Limpets along with *Nucella* spp. and *Tegula funebralis* snails have undergone slight fuctuations during this time, until the dramatic increase in *Tegula* in 2010.

The mean cover of Surfgrass (*Phyllospadix*) has fuctuated widely throughout the years at Coal Oil Point with seasonal variation (lower in spring, higher in fall) along with intermittent periods of sand burial. Throughout the years, the cover of *Phyllospadix* hovered around the 60% to 80% range. Dips below that level were the result of sand burial, rather than plant and/or rhizome loss. Even where leaves were lost the plants would quickly regenerate from the rhizomes upon emergence from burial. Beginning in 2003 the seasonal pattern began to break down and surfgrass cover increased steadily until 2005. Seasonal variation returned in 2006, but then in 2007 the surfgrass population crashed in the absence of sand burial, and this time there was extensive rhizome loss as well. Mean surfgrass cover declined to almost zero by the spring of 2008 and has recovered slowly since that time. Filamentous red algae and bare rock increased in the wake of the surfgrass declines. As of fall 2014, *Phyllospadix* cover was back over 40%..

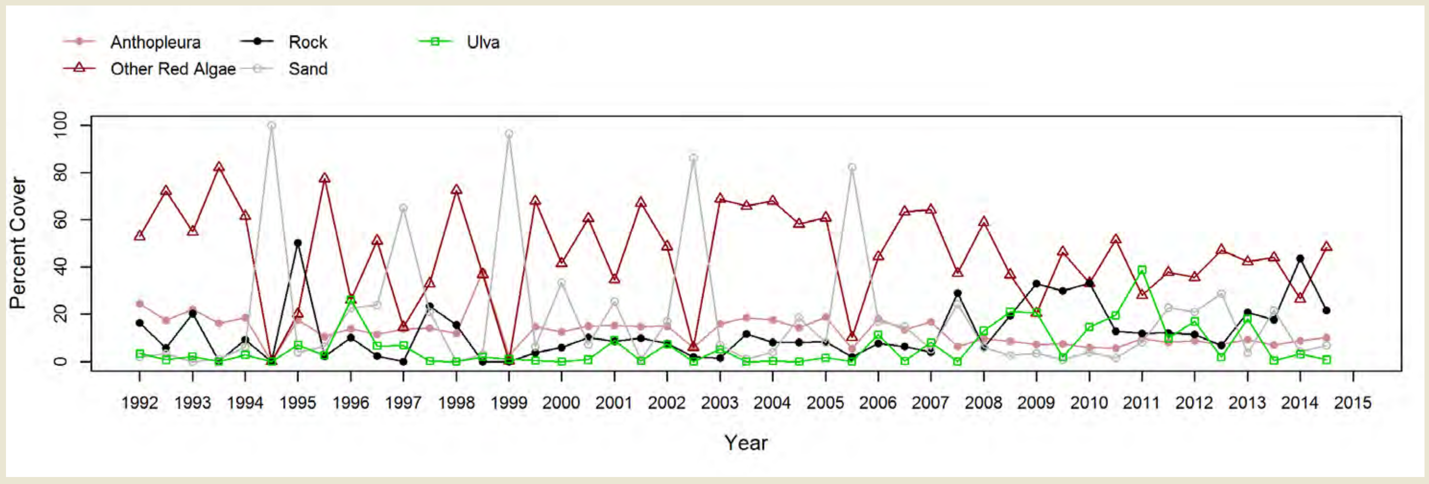
In the time since this site was established in 1992, the numbers of sea stars at Coal Oil Point have never been high enough to warrant the establishment of permanent plots. However, sitewide searches for sea stars have been performed each sampling event since the spring of 2010. Between 5-10 stars were found in each of the frst fve sampling seasons. Then over 15 stars were found in the fall of 2012 and in the fall of 2013, when the seastar wasting disease was starting to spread in Santa Barbara County, over 30 stars were found. One of those stars in fall 2013 was recorded as diseased as it contained a small, though questionable, lesion; all other stars appeared healthy. But then all the stars were gone by the next sampling event in spring 2014 and no stars were found in fall 2014 either. Smaller stars (<50mm) have yet to measured at Coal Oil Point. Movement of stars in and out of the subtidal, rather than recruitment, seems to be controlling the size and numbers of stars found at this site.

Photo Plots

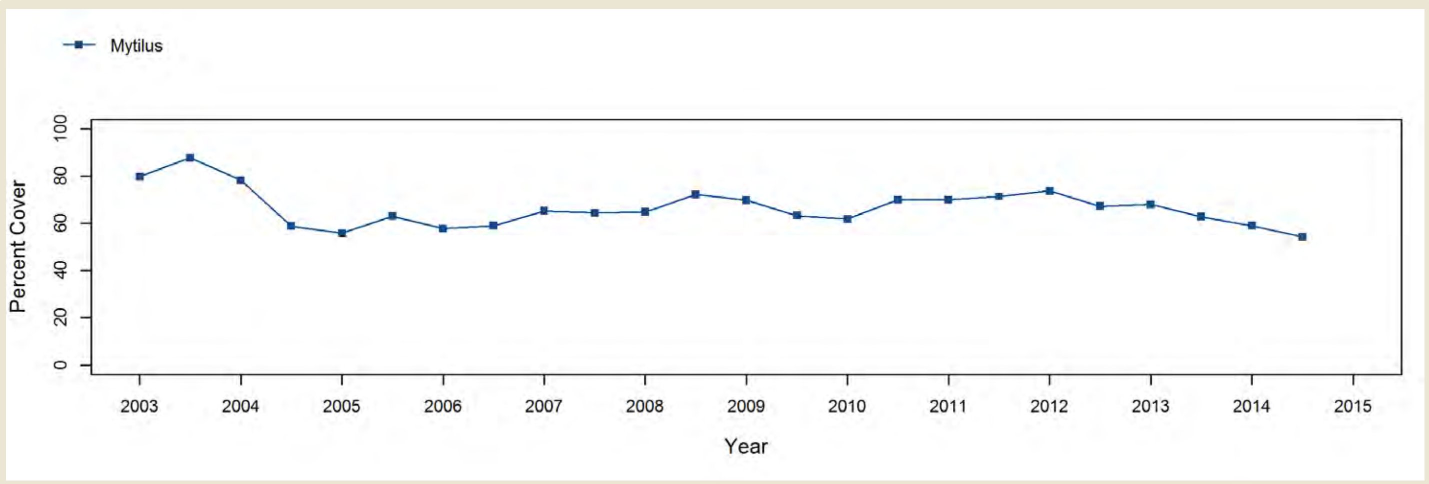
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

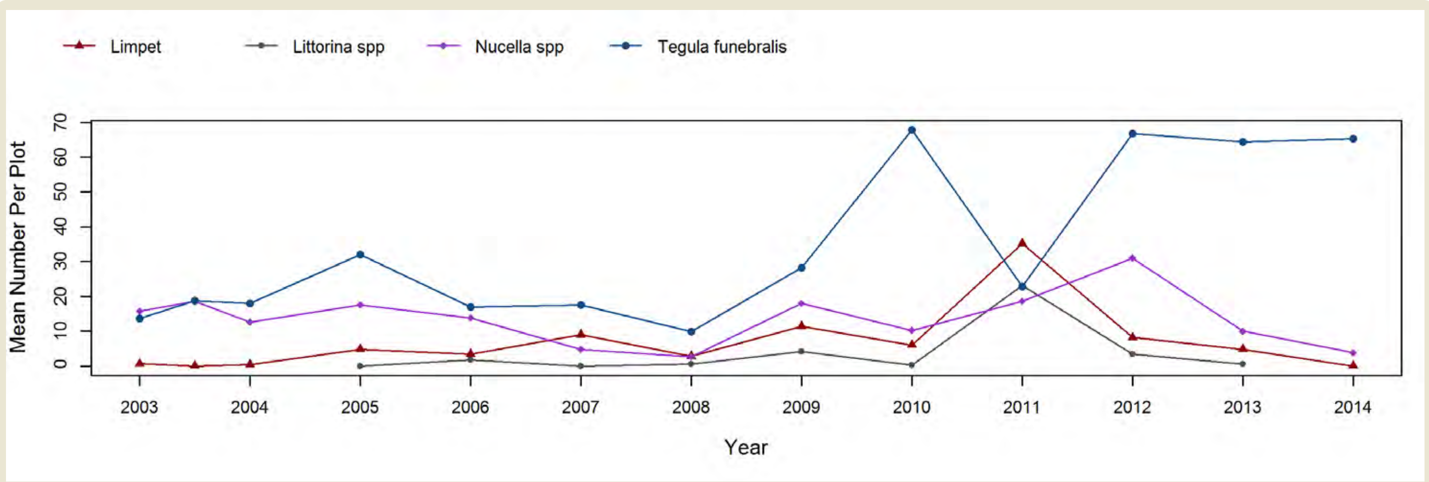
Anthopleura (Anemones)



Mytilus (California Mussel) - percent cover



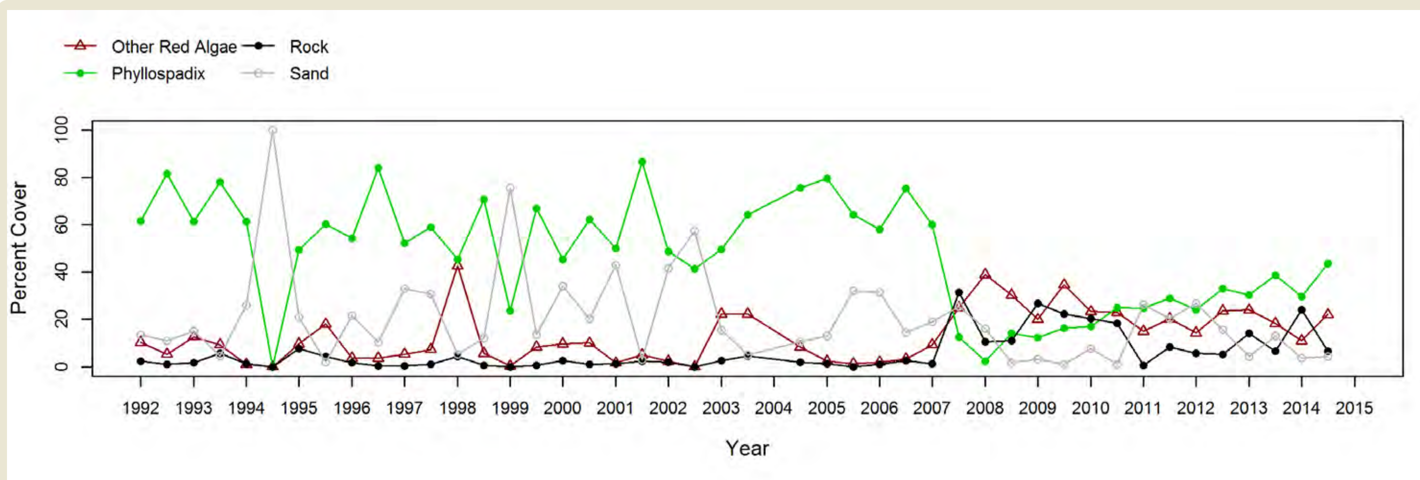
Mytilus (California Mussel) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

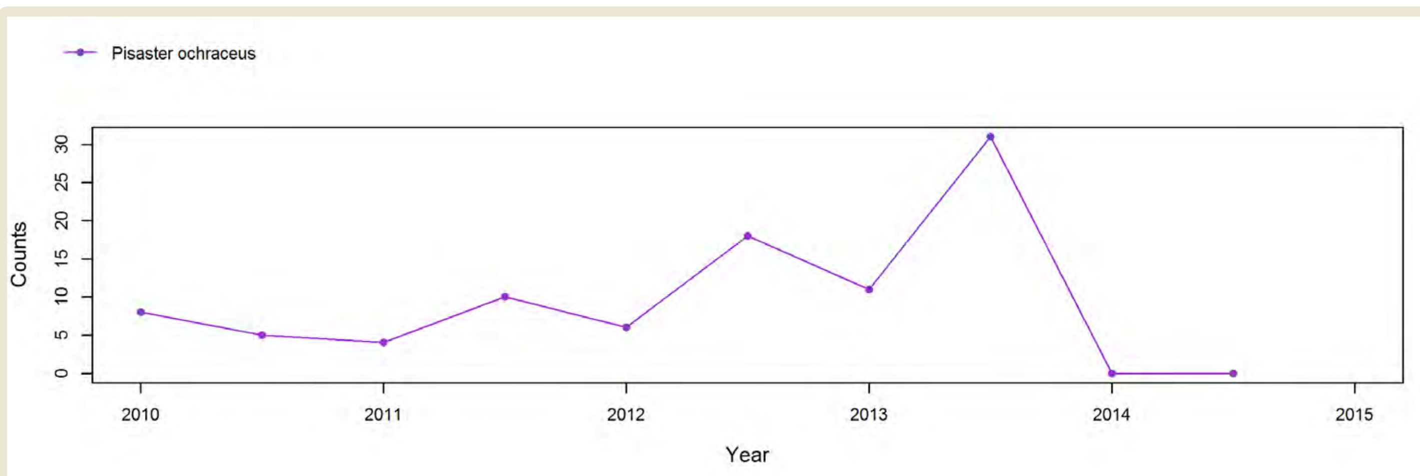
Phyllospadix (Surfgrass)



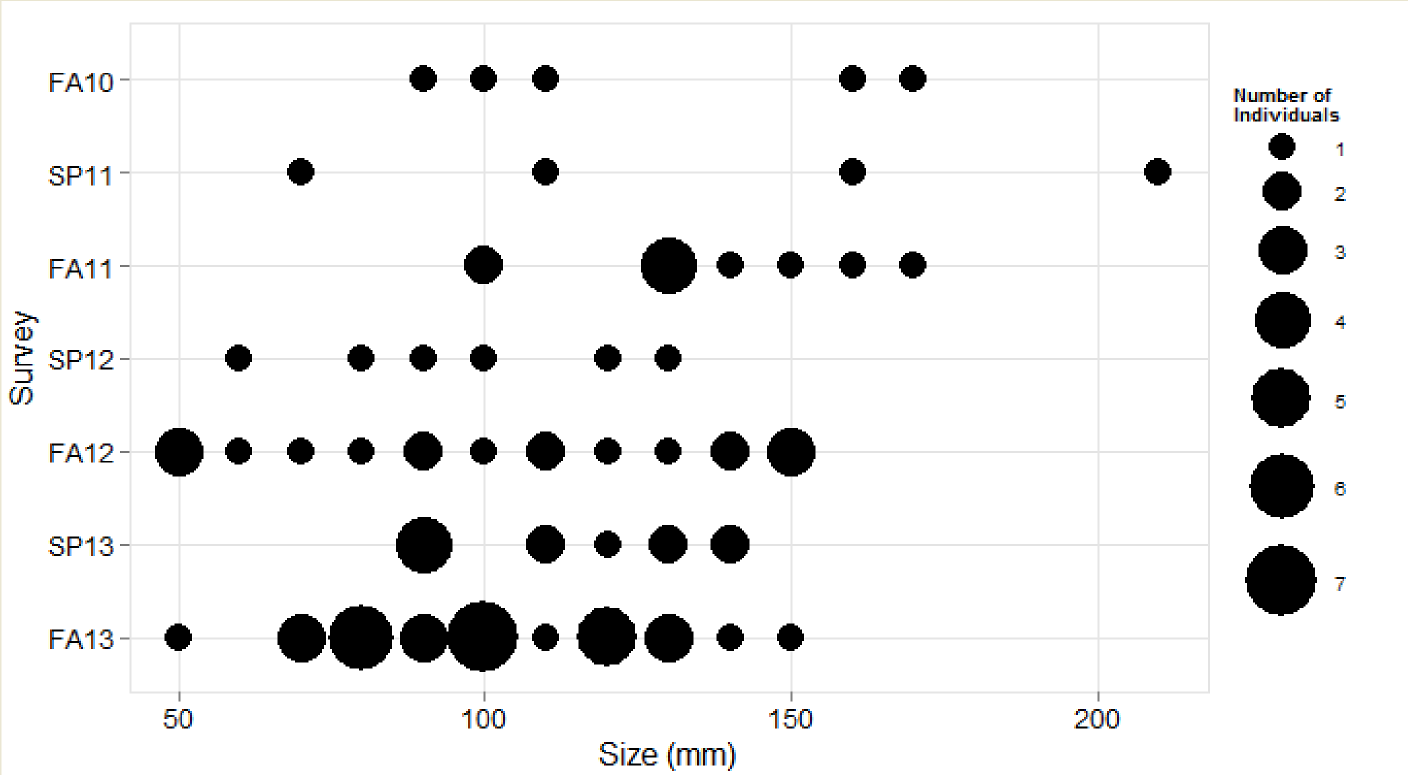
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster ochraceus (Ochre Star) - sizes



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Carpinteria Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The anemone plots at Carpinteria consist primarily of the solitary anemone, *Anthopleura sola* rather than the colonial anemone *Anthopleura elegantissima* (note that these were considered a single species prior to the past several years and they are not distinguished in our sampling methods). Cover of *Anthopleura* has hovered around 30% plus or minus 10% since plot inception in 1992. At the same time, other red algae (a lumped group with flamentous red algae as its primary component) have fuctuated wildly from 10 to nearly 80% cover , largely coincident with periods of sand inundation. In recent years, one species of red algae (*Chondria nidifica*) along with patches of *Phyllospadix* sp. have been increasing within and around the anemone photoplots, though these trends are not apparent in the fgure.

The barnacle plots at this site consist of a mixture of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula* with the former dominating some plots and a more even mixture in others. Unlike some other monitoring sites, most of these barnacle plots are located atop rock outcrops and, with one exception, are not subject to periodic sand scour and/or burial. Thus they have not experienced dramatic fuctuations in barnacle cover as a whole, though one plot is subjected to regular scour and is nearly always covered by ephemeral *Ulva* with little barnacle cover. The plots experienced a strong recruitment pulse in 1994 resulting in a mean barnacle cover around 90%. This was followed by a gradual decline to less than 40% cover through 1998, an increase to 60% by 2004, and a decline to below 20% by 2012. Presently the mean cover is around 30%. Motile invertebrate counts at this site began seasonally in the fall of 2000 and were changed to annual sampling in 2004. Within the barnacle plots, limpets are abundant and have fuctuated between 50 and 200 individuals per plot on average. Littorines are also abundant and have varied widely throughout the years from around 1000 individuals per plot in 2002 to very few in 2007 and in 2012-2013. Presently the numbers of both limpets and littorines are in the range of 50-100 individuals per plot.

The *Pollicipes* plots at this site started out in 1992 with abundant *Pollicipes* cover (~60%) compared to mussel cover (~10%). Throughout the years, there has been a gradual convergence in the relative cover of these two species with mussels often exceeding *Pollicipes* in cover. Presently, Mussels are around 40% cover with *Pollicipes* cover around 30%. *Pollicipes* has shown seasonal variation (lower in spring, higher in fall) with the inverse pattern refected in bare rock. Motile invertebrate counts within the *Pollicipes* plots show the regular occurrence of whelk snails (*Nucella* spp.) and shore crabs (*Pachygrapsus crassipes*) in the range of 5-10 individuals per plot on average. Limpets are generally more abundant but have fuctuated wildly from just a few to nearly 100 individuals per plot on average. A decision was made to cease motiles counts in *Pollicipes* plots in 2014.

The Mussel plots at Carpinteria have been highly variable throughout the years ranging from over 90% mean cover of *Mytlius* to nearly zero. Mussel cover has been more consistent over the past few years hovering around 50%. Periods of mussel decline were caused by extensive mussel bed breakouts that are in turn the result of frequent episodes of pounding surf on the outer reef at this site. Pulses in cover of the ephemeral alga *Ulva* spp. have occurred in the wake of these mussel breakouts. Data gaps are caused by the presence of harbor seals on this portion of the site which, when present, prevent access to the plots. Motile invertebrate sampling shows that chitons (*Nuttalina* spp.) and snails (*Nucella* spp. and *Tegula funebralis*) are regular occupants of these mussel plots, along with littorines, which were more common in the spring of 2004, and limpets, which show two strong abundance peaks in fall of 2003 and fall of 2009. The sampling of littorines within these mussel plots ceased in 2014..

The mean cover of Surfgrass (*Phyllospadix* spp.) at this site has fuctuated throughout the years from about 10 to 90%, with seasonal variation (lower in spring, higher in fall) and one period of particularly low cover from the fall of 1998 to the spring of 2000. During that latter period, the apparent decline in *Phyllospadix* was met by a corresponding increase in the kelp *Egregia menziesii*, while seasonal dips through the years resulted in increases of red algae (primarily flamentous red algae but also including *Chondria nidifica* and a few other species). *Egregia* had another pulse of cover in the fall of 2008 but this did not coincide with an apparent *Phyllospadix* decline. The disparity between these two events is likely the result of changes in sampling methodology: in the early years, samplers would record the topmost species encountered at the sampling point, but after 2000, in situations where fronds of *Egregia* lay atop a *Phyllospadix* understory, both species would be recorded for that sampling point. Thus, some portion of the apparent *Phyllospadix* decline of the late 1990's may be misleading as the increasing *Egregia* may have been merely covering over a healthy *Phyllospadix* understory. In recent years, *Phyllospadix* cover has been fuctuating seasonally between about 60-80%%.

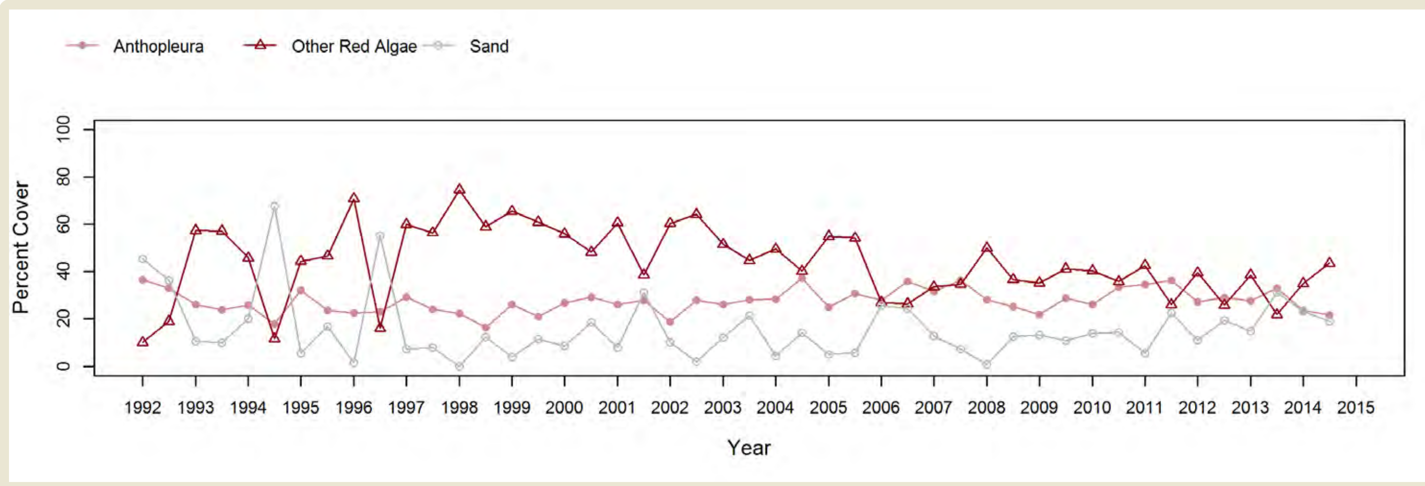
Seastar (*Pisaster ochraceus*) abundance within the original transect swaths has been variable at this site from over 70 stars counted and measured to just a few. Seastar numbers were particularly low from 1994 through 1999 followed by a period of higher numbers from 2002 to 2006. Then after another decline, seastar numbers started to increase in 2009 to a high of over 100 stars in the fall of 2012, shortly before the advent of the seastar wasting disease. In the spring of 2004, the push for methodological consistency among sites prompted the addition of a series of three large irregular plots to be sampled alongside the transects. Compared to the transect data, these plots contained a higher number of stars during their frst few seasons of sampling (expected given the greater amount of area sampled), but with declines converging toward the transect data numbers in more recent seasons. Seastar sizes have been measured since fall 2000. Large recruitment pulses occurred in the spring of 2002 and again in the spring of 2011. The growth of these seastars through time can be seen in these trend graphs through spring 2006 and fall 2012 respectively. Another pulse of larger stars occurred in spring 2010. Given this observation, it seems that the population of seastars at Carpinteria is supported both by recruitment and by migration of existing stars in and out of the contiguous subtidal. The seastar wasting disease struck this site in the spring of 2014. During an initial site visit in late February, a large number of stars (46) were counted in the transects one of which was clearly diseased. Hazardous conditions prevented us from completing the sampling that day (including seastar surveys within the irregular plots), but general observations at the site determined that more diseased stars were present and that a large number of seemingly stressed stars were found detached or loosely attached on the inner reef fats where they do not regularly occur. Then when we returned to the site a month later in late March, no stars could be found in any of the fxed plots and just fve stars, including one diseased star , could be found in a supplemental sitewide search. Essentially the entire seastar population at Carpinteria crashed in that one month span. A similar fnding was obtained during the following sampling event in fall 2014 with no stars found in any of the fxed plots and just six stars found sitewide. On a positive note, no diseased stars were found during the fall 2014 sampling indicating that the disease may have moved through the site and the remaining stars may have had some sort of resistence to the disease.

Photo Plots

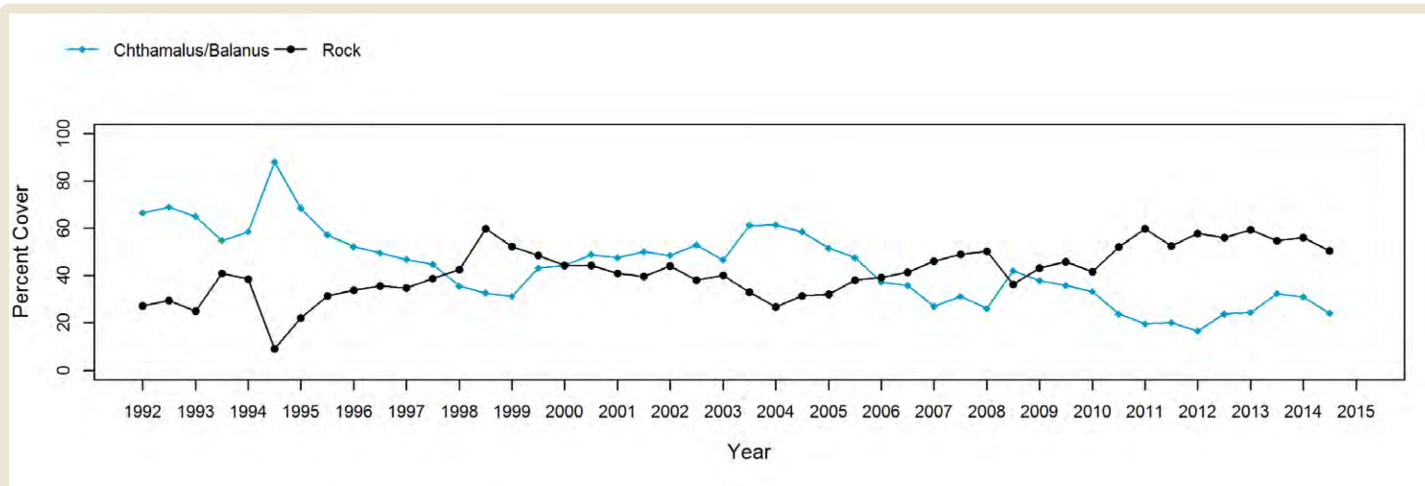
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

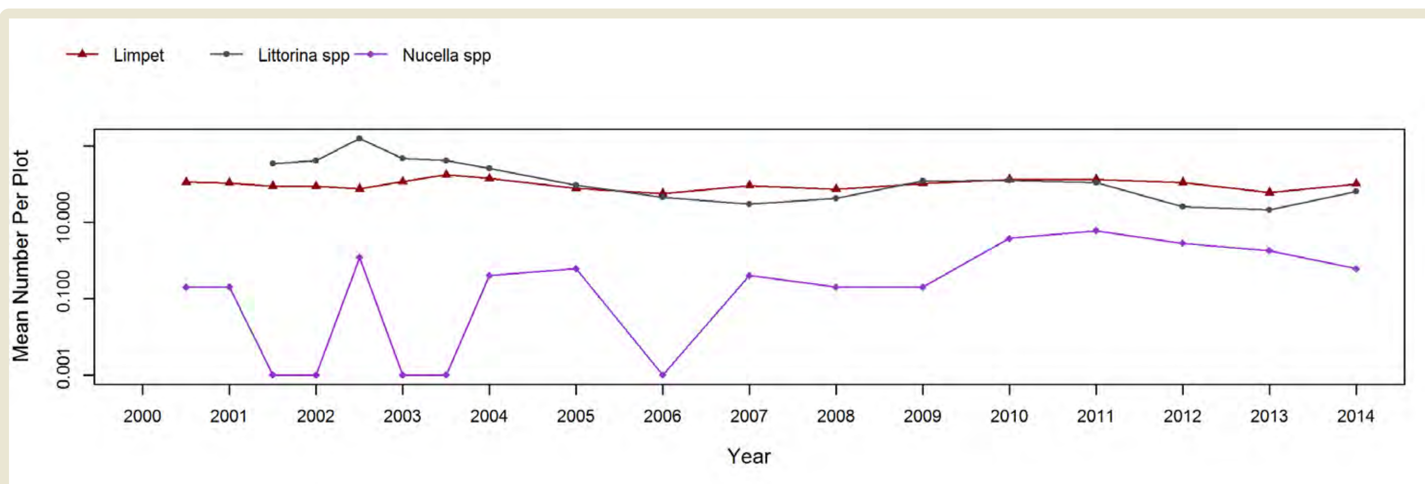
Anthopleura (Anemones)



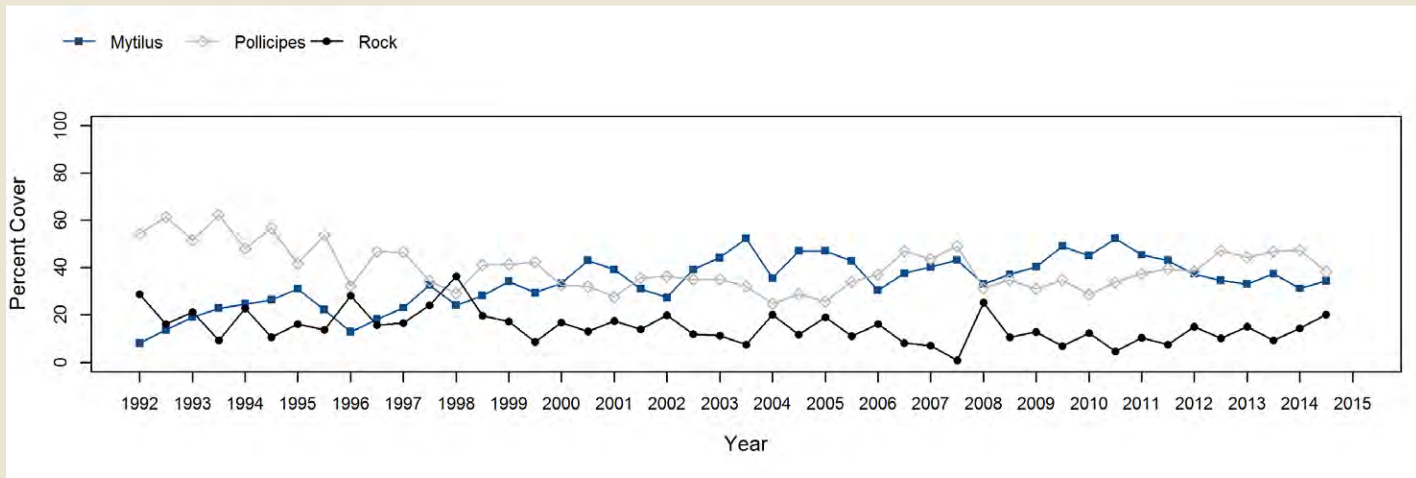
Chthamalus/Balanus (Acorn Barnacles) - percent cover



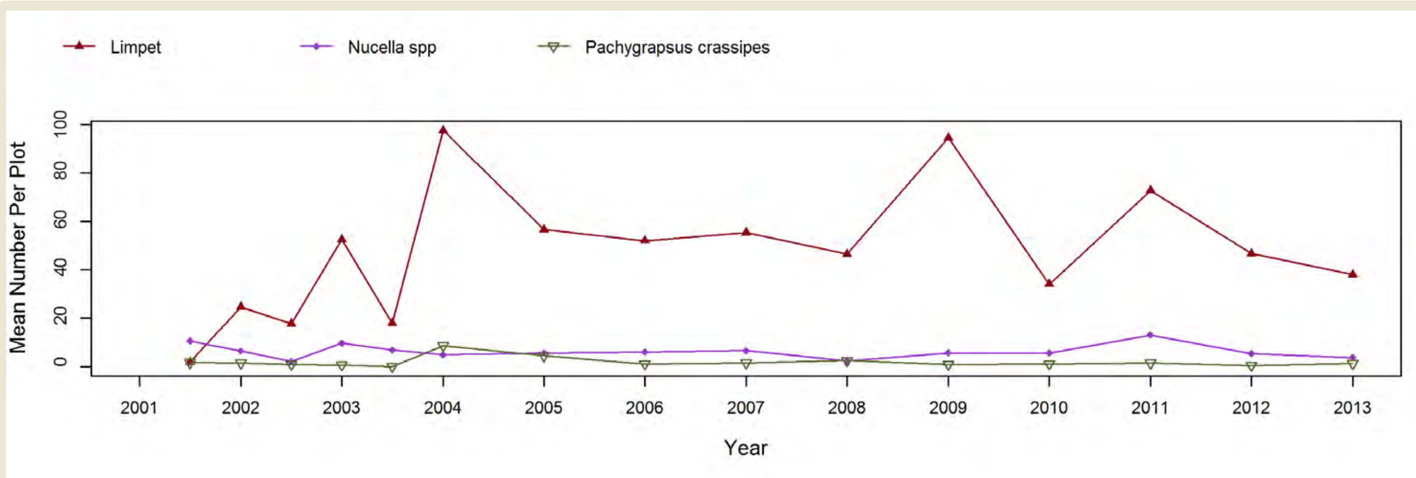
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



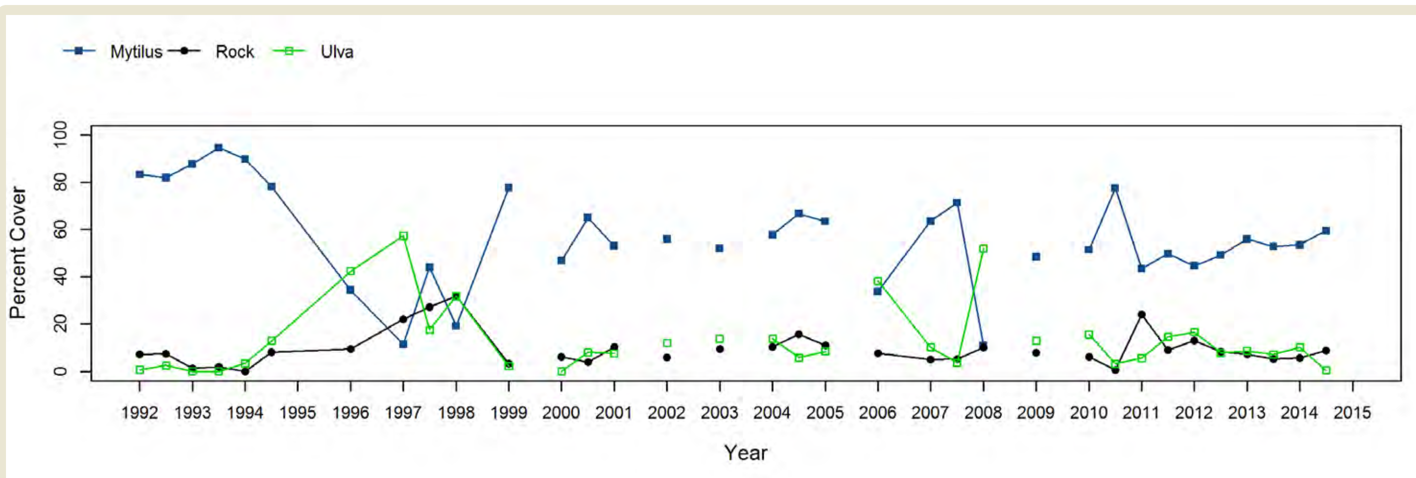
Pollicipes (Goose Barnacle) - percent cover



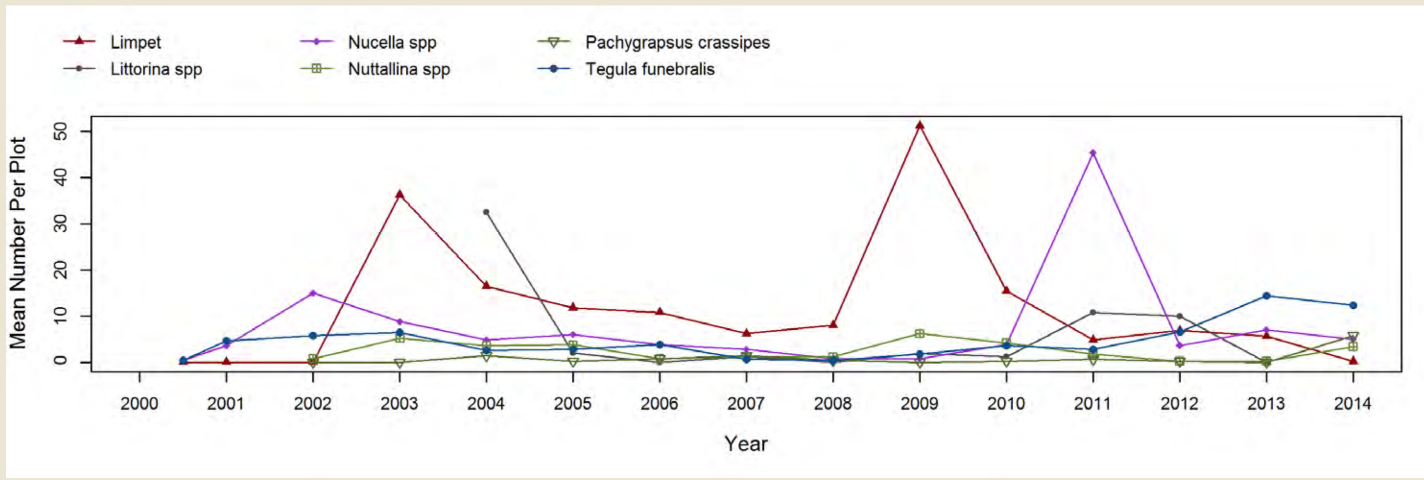
Pollicipes (Goose Barnacle) - motile invertebrate counts



Mytilus (California Mussel) - percent cover



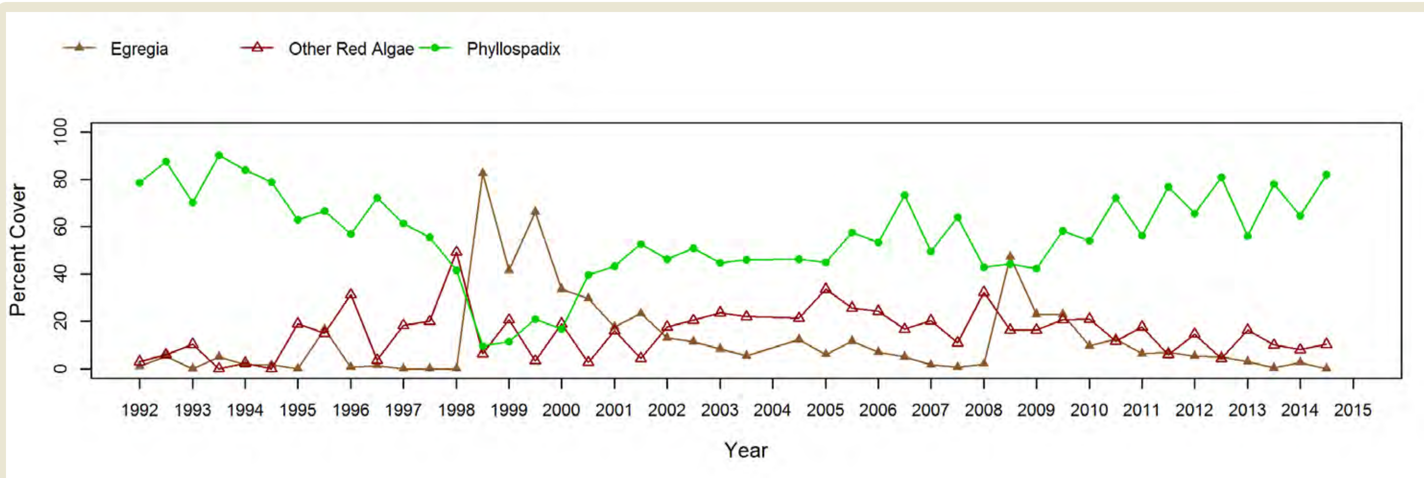
Mytilus (California Mussel) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

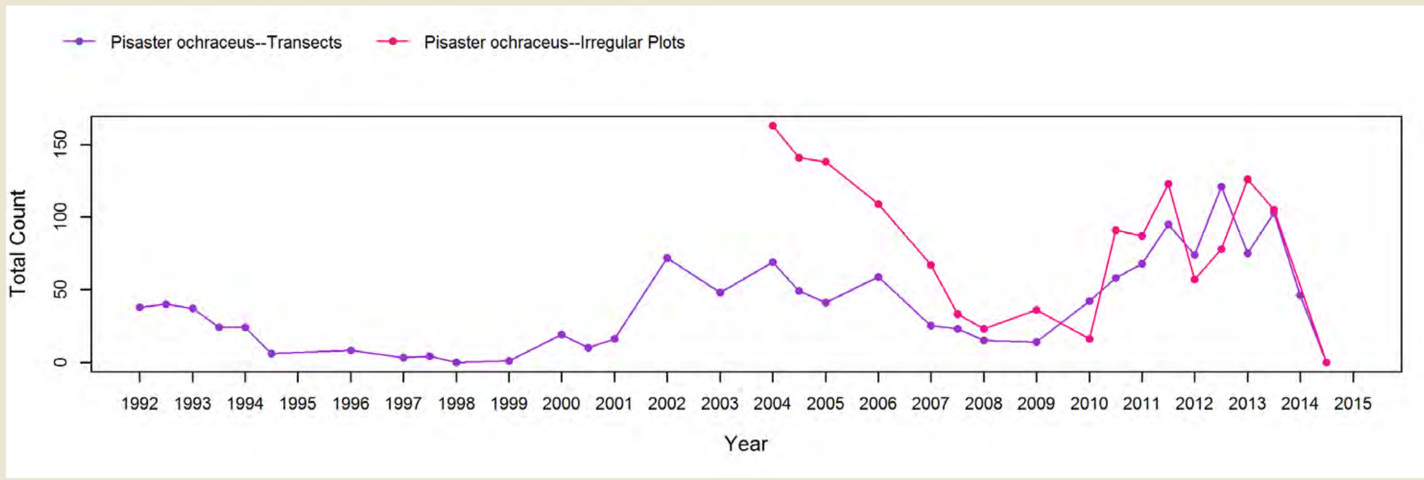
Phyllospadix (Surfgrass)



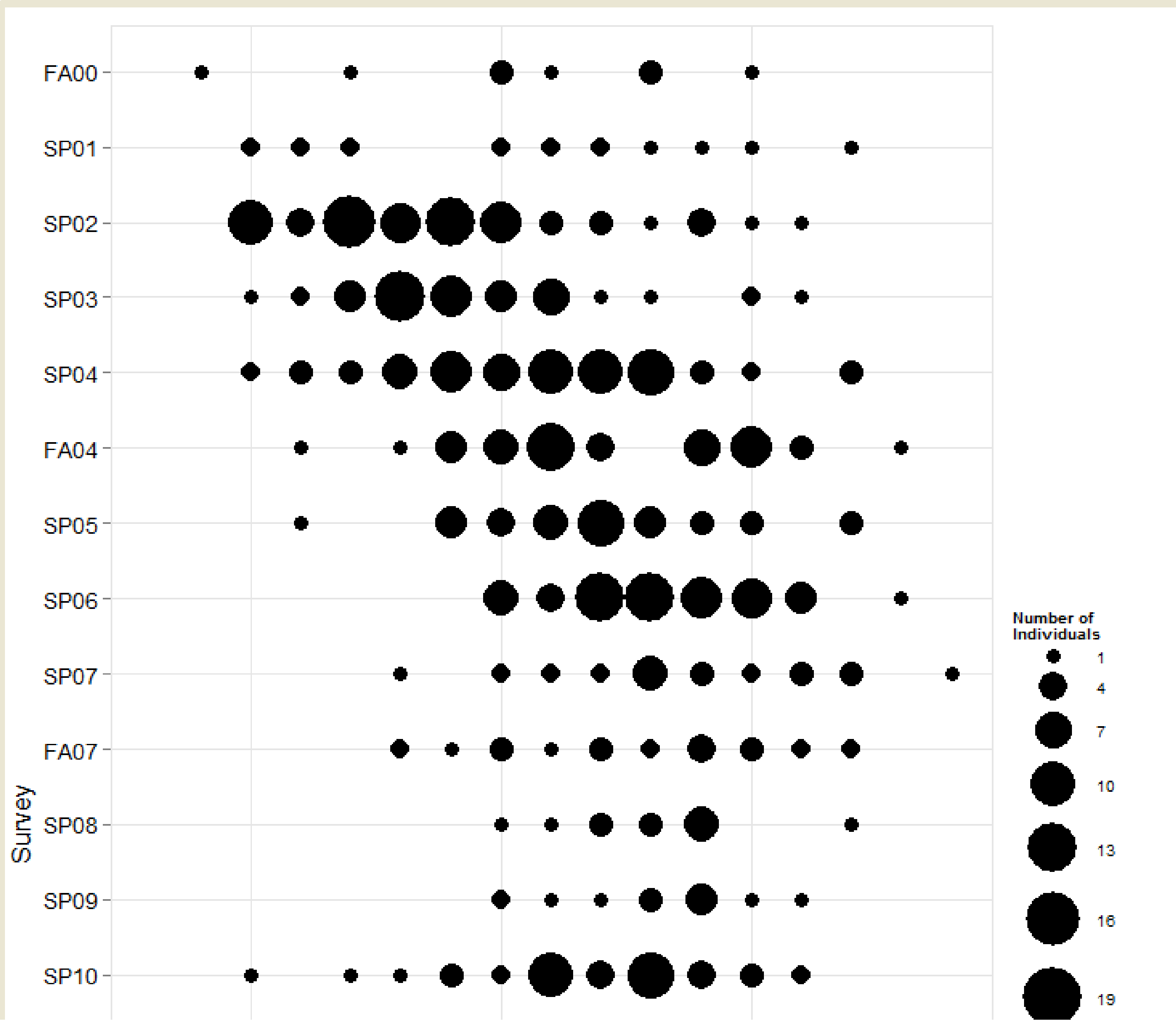
Species Counts and Sizes

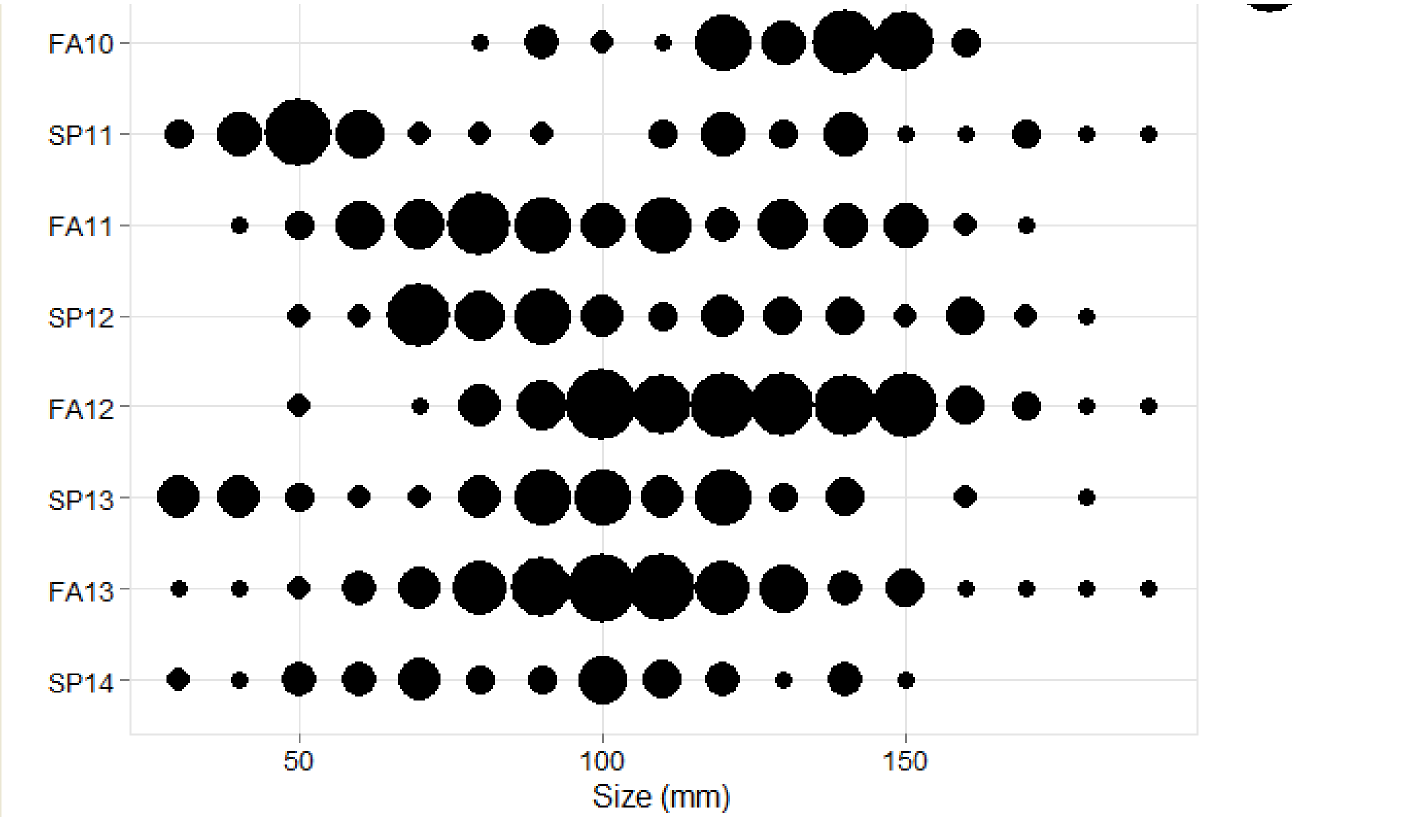
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes in Transects





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Mussel Shoals Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The anemone plots at Mussel Shoals consist primarily of the colonial anemone, *Anthopleura elegantissima* rather than the solitary anemone *Anthopleura sola* (note that these were considered a single species prior to the past several years and they are not distinguished in our sampling methods). Within the anemone plots, the mean cover of *Anthopleura* began close to 100% in 1994, declined gradually to under 60% by 1998, then hovered around 80% for several years through 2004. After that, two cycles of decline and recovery occurred through 2009, each with anemone cover returning to about 80%. Since then, the plots have experienced increasing seasonal variability with the mean anemone cover occilating between 60-90%. Much of the early variability was the result of a single plot which, since its inception, had alternated back and forth between anemone dominated and mussel dominated cover. The more recent variability is the result of seasonal sand burial episodes which affect four of the fve plots to varying degrees. These anemones are quite resistant to these periods of sand burial. Despite being obscured by sand during data collection, their actual cover hasn't changed that much throughout these burial episodes. In fact, one of these plots has had a consistent anemone clone separation line in the same position for at least 15 years.

The barnacle plots at this site consist of a mixture of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula* with the former dominating some plots and a more even mixture in others. These plots are located on riprap boulders in an area subjected to recurring scour by sand and cobbles. This is refected in the data which show barnacle cover (and, inversely, bare rock), fuctuating extensively and repeatedly throughout the years. Barnacle cover has been reduced to near zero twice during the monitoring period (spring of 1996 and spring of 2007) with less signifcant declines to around 40% occurring four other times. In each case, high recruitment has allowed these plots to rebound within a single sampling season with cover usually reaching levels of 80 to 90%. One plot disappeared completely in the late 1990's as the boulder it was housed on became dislodged and overturned. A replacement plot was installed, but shortly thereafter, a subsequent storm fipped the boulder over again allowing the sampling of that missing plot to resume. While the orientation of that plot has changed somewhat, making it more susceptible to encroachment by mussels, anemones and turf algae, it continues to be sampled along with its replacement plot. Motile invertebrate counts at this site began seasonally in the fall of 2000 and were changed to annual sampling in 2004. Within the barnacle plots, littorines and limpets are both highly abundant with the former varying in the neighborhood of 500 individuals per plot and the latter around 50 per plot. Like barnacles, limpets were scoured to nearly zero in the spring of 2006. Limpets were less common in the last two years of sampling.

The mussel plots at this site have been fairly stable throughout the years with mussel cover in the 80 to 90% range most of that time. A decline occurred in 2005 and 2006 reducing mussel cover to about 60%. After that, mussel cover gradually increased to near 100% in 2009 where it remained until 2012 (note that there is a data gap for Fall, 2009). Since then, mussels have declined with cover reaching the 50% range in fall 2014. These plots are mostly comprised of small and tightly packed mussels, and are located on the shoreward side of a large rock ridge which presumably makes them more resistant to scour or breakout. Scour does occur as sand and cobbles build up at the base of the mussel reef and move back and forth with the wave surge. This causes mussel loss at the lowest portions of some plots. The data from the motile invertebrate sampling show that snails (*Nucella* spp. and *Tegula funebralis*) were more common in the mussel plots in the frst few years of sampling. Shore crabs (*Pachygrapsus crassipes*) were also a bit higher then as well. In recent years, the abundance of these motiles, along with littorines, has been low (less than ten individuals per plot). Limpets, on the other hand, started out low in the early years, but with increases to over 50 individuals per plot in the later years. This may be partly due to methodological changes: prior to 2006, only limpets on rock were included in the counts whereas limpets occurring on mussel shells were added after that. Littorine sampling in these plots ceased in 2014.

Rock ("Above Barnacles") plots were added to this site in the fall of 2008 to document any upward spread of intertidal species as a result of global climate change or other factors. These plots are expected to remain dominated by bare substrates unless barnacles or other species begin to encroach upon them. Barnacles have been observed within these plots since their inception, though their percent cover has remained low or undetected in data collection. One plot is a bit lower than the others and has yielded up to 5% barnacle cover. Littorines have been common in most of these plots since their inception.

The mean cover of Surfgrass (*Phyllospadix* spp.) at this site started out near 80% in 1994-1995 but then underwent a precipitous decline to around 40% where it remained for several years between 1998-2005. It declined further to almost 20% in 2009, but has rebounded since then and is now around 75% as of fall 2014. *Egregia*, red algae (primarily *Chondracanthus* sp., *Gastroclonium* sp. and flamentous species) and bare rock increased during periods of *Phyllospadix decline*. The reasons for these population fuctuations are not known. Throughout this time, *Phyllospadix* has also varied seasonally with higher cover typically found in the fall and lower cover in the spring.

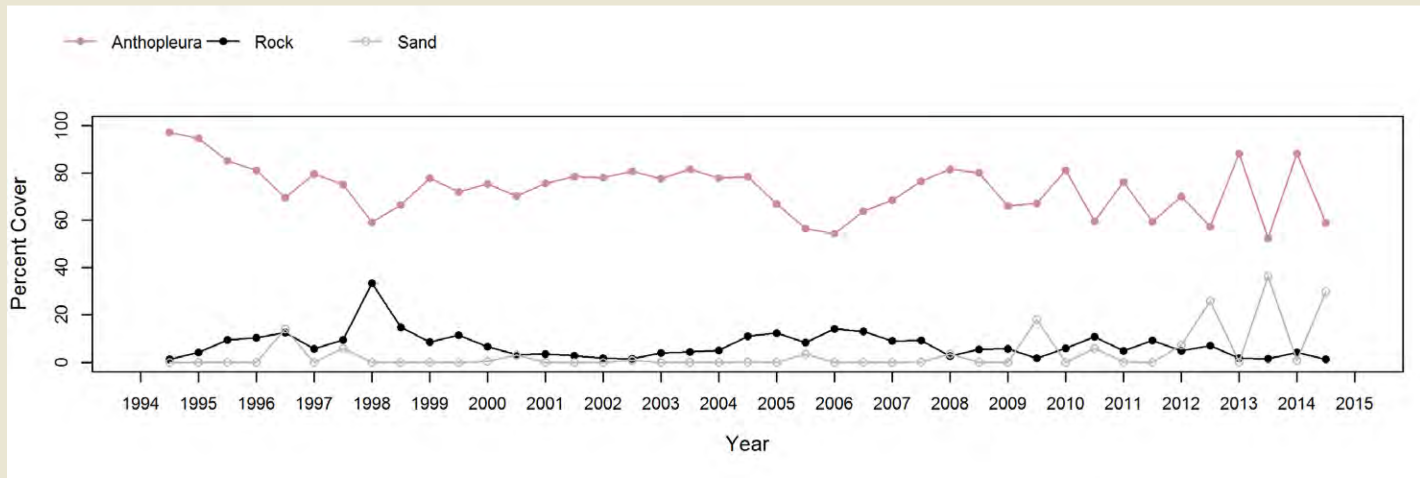
Sea star (*Pisaster ochraceus*) abundance has been variable at this site over the years vacillating between about 70-80 stars during some periods and closer to 20 stars during others. More recently, however, seastars have become much more abundant with numbers exceeding 200 individuals in fall of 2011 and well over 100 stars still being present until fall 2013 when the seastar wasting disease began affecting coastal sites in southern California The disease was not confrmed at this site until spring 2014 when multiple sick, drooping and "melting" stars were observed during our sampling in late February. Well over 50 stars were counted during that sampling event, but when the site was revisited a month later in late March, only a few stars remained. Fortunately, while some sites remained devoid of stars long after the disease swept through, this site seemed to rebound quickly with about 20 stars counted in fall 2014, all of which were healthy in appearance. Seastar sizes have been measured since the fall of 2000. Their sizes tend to be relatively large at this site compared to others with relatively low recruitment of small (<50mm) individuals during most years. This suggested that, despite extensive sand barriers offshore of the sites, the seastar population at the site was maintained through migration in and out of the site rather than through recruitment. But then in the fall of 2010, a large recruitment pulse of small individuals was observed and those growing stars were responsible for the greater abundance of stars observed at this site in recent years. Likewise, recruitment of young stars is largely responsible for the recovery of stars we have seen since the disease struck this site.

Photo Plots

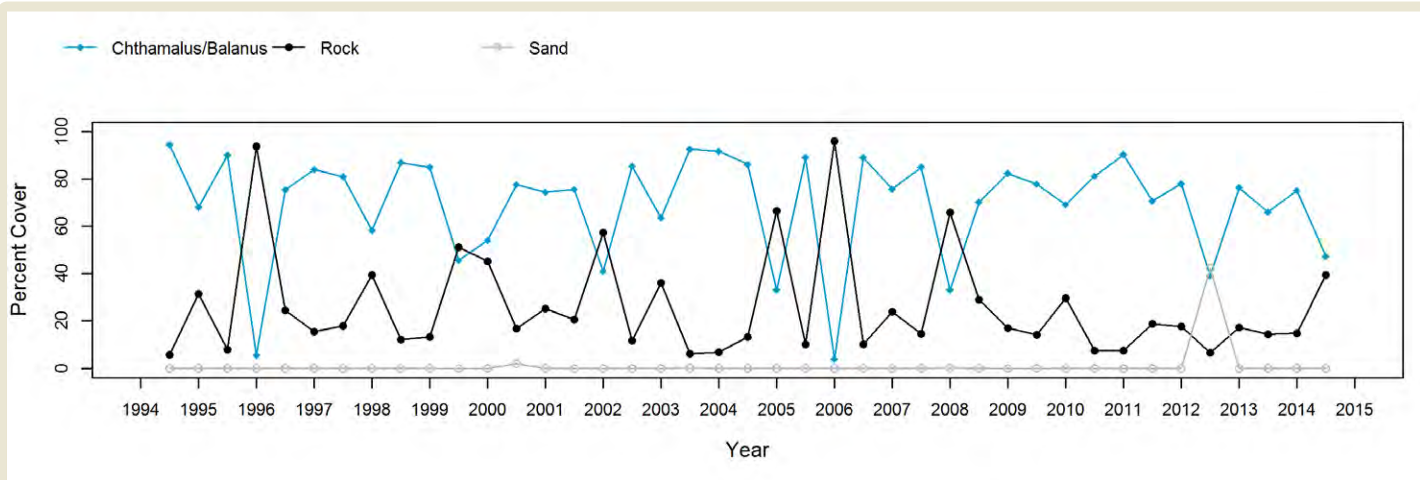
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

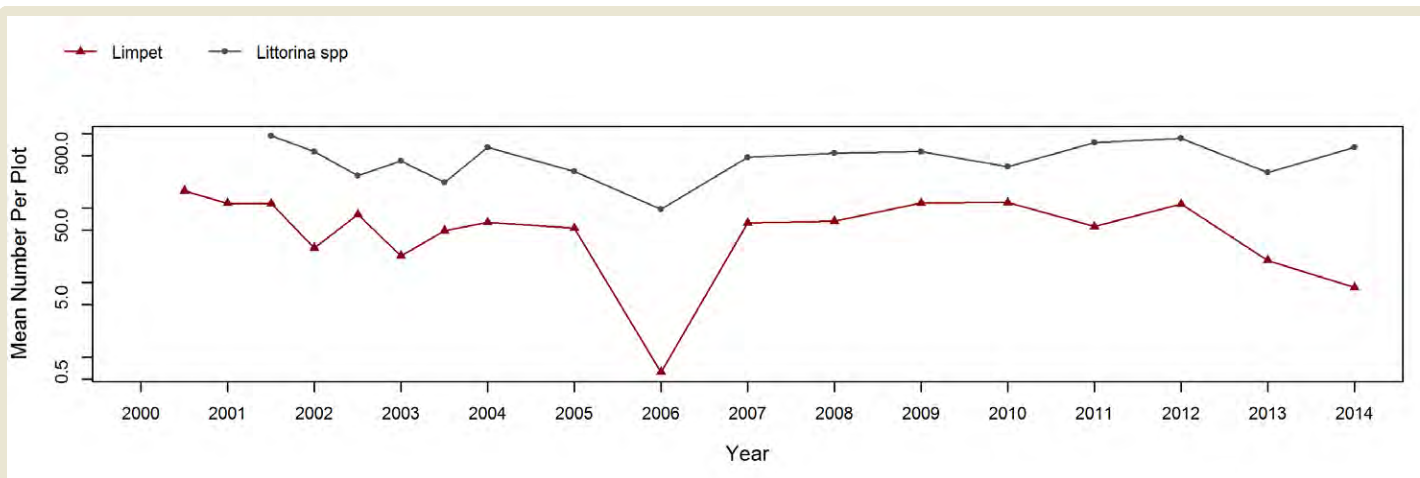
Anthopleura (Anemones)



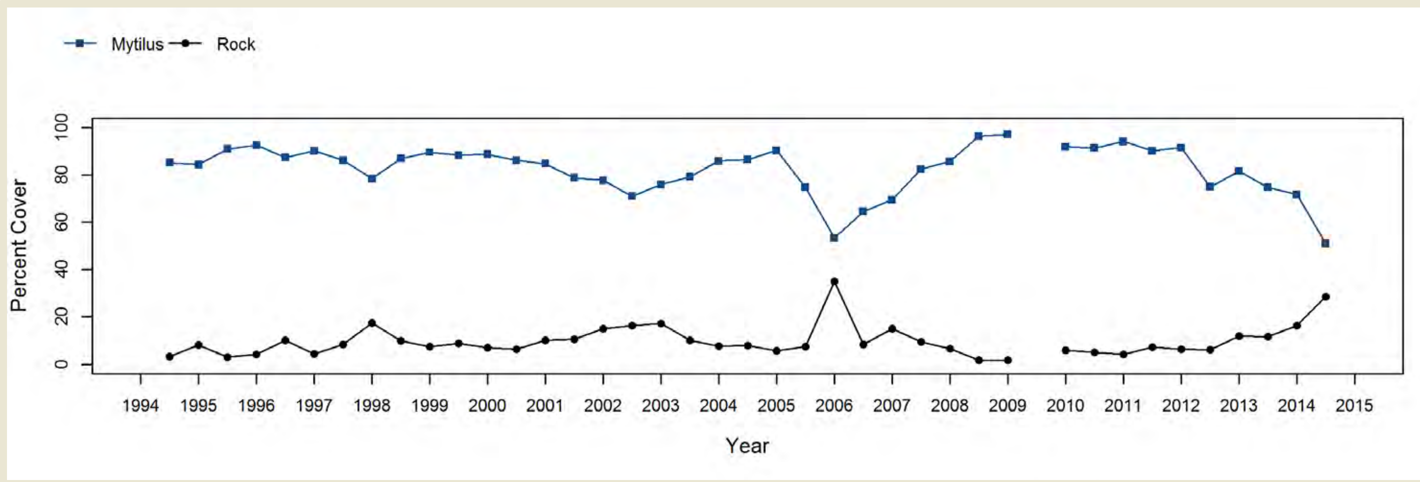
Chthamalus/Balanus (Acorn Barnacles) - percent cover



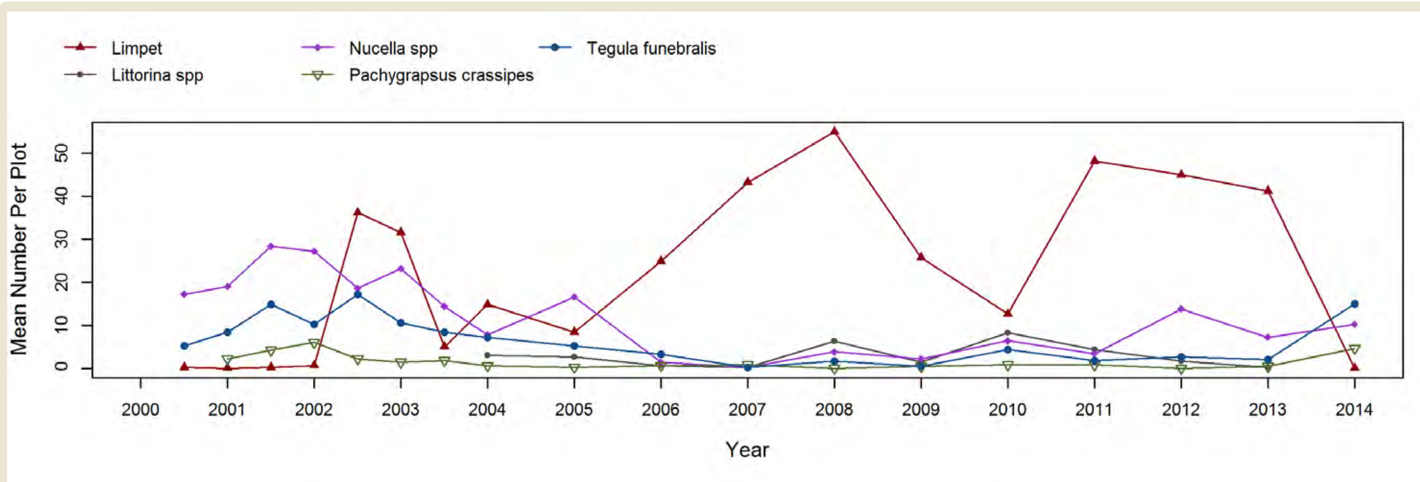
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



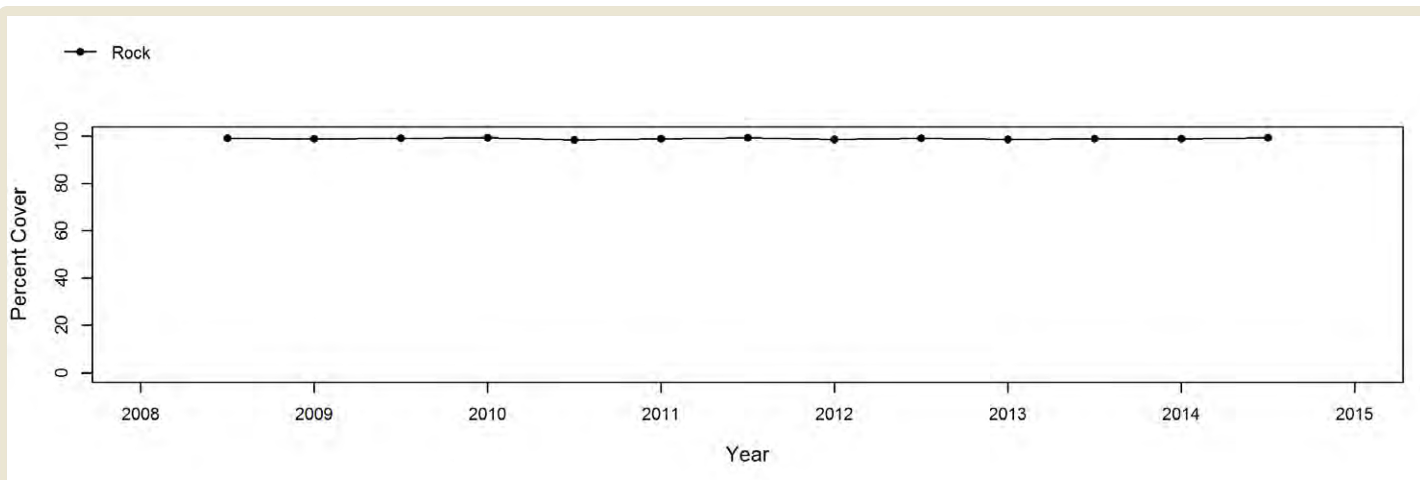
Mytilus (California Mussel) - percent cover



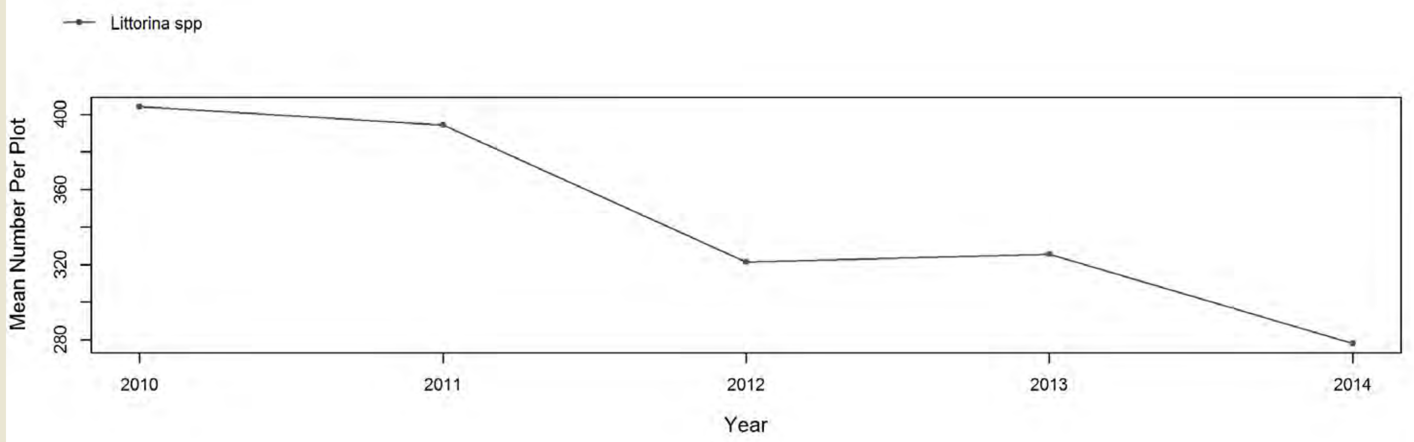
Mytilus (California Mussel) - motile invertebrate counts



Rock (Above Barnacles)



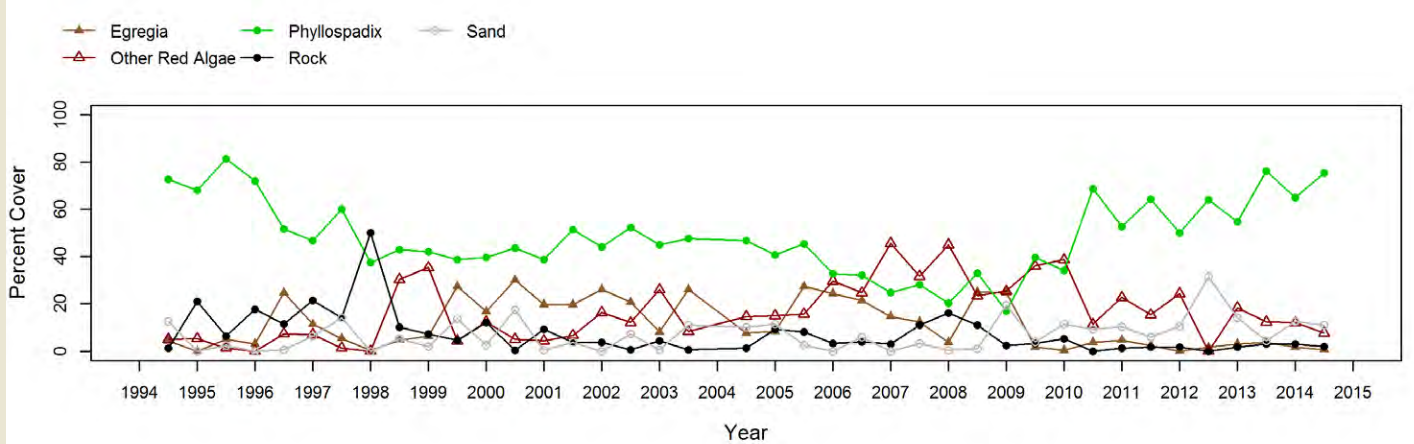
Rock (Above Barnacles) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

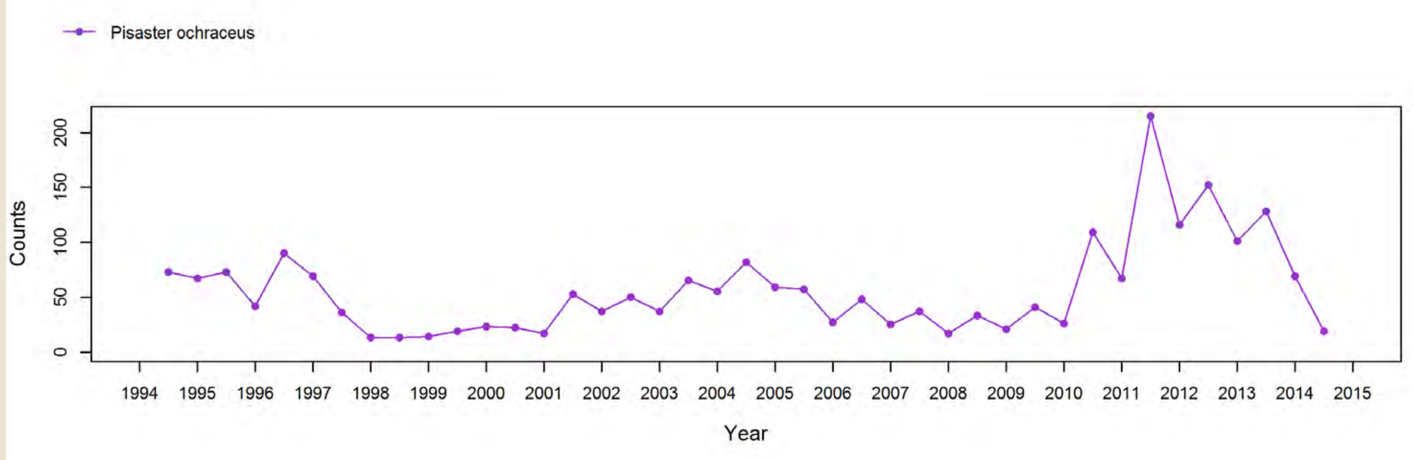
Phyllospadix (Surfgrass)



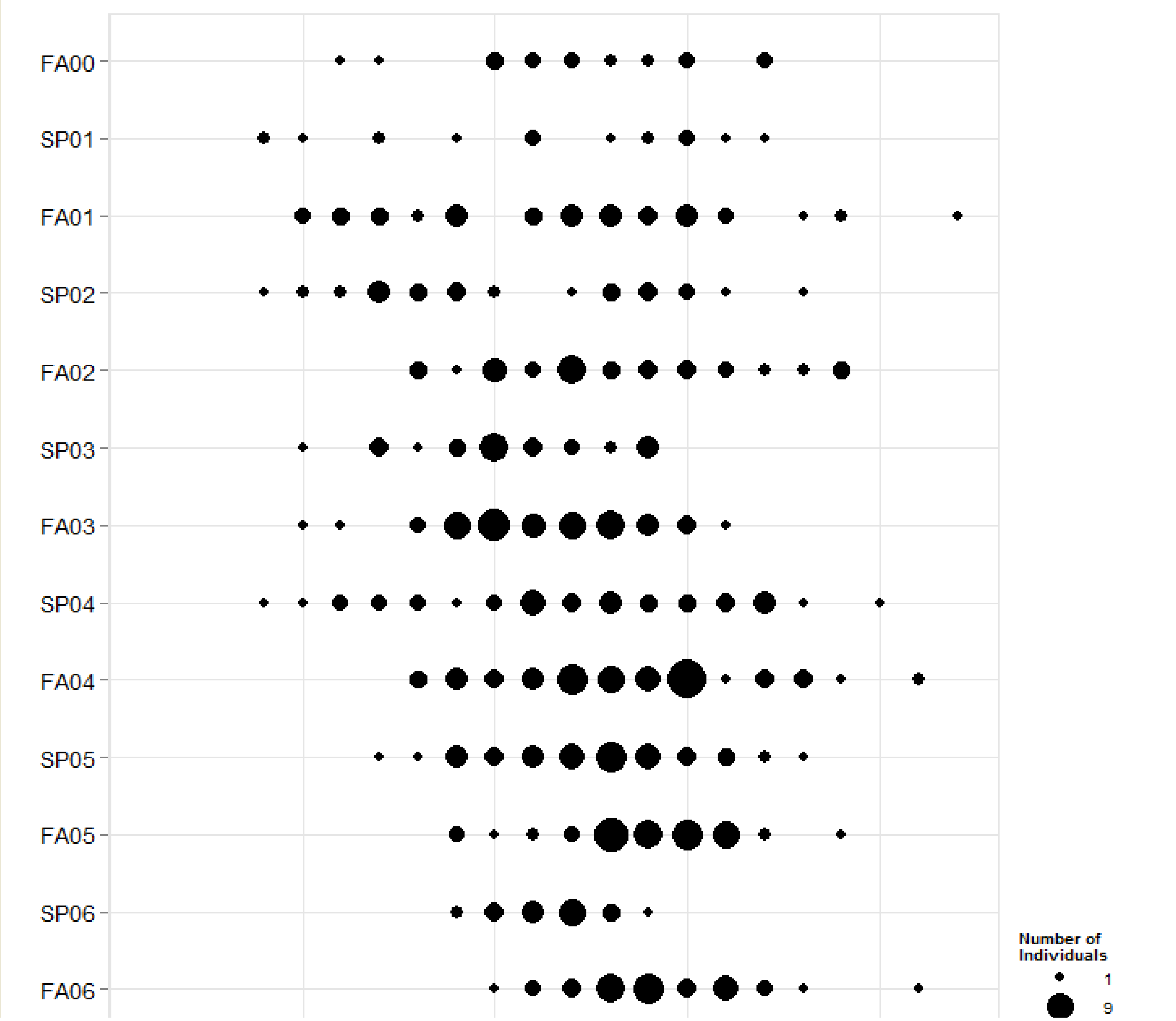
Species Counts and Sizes

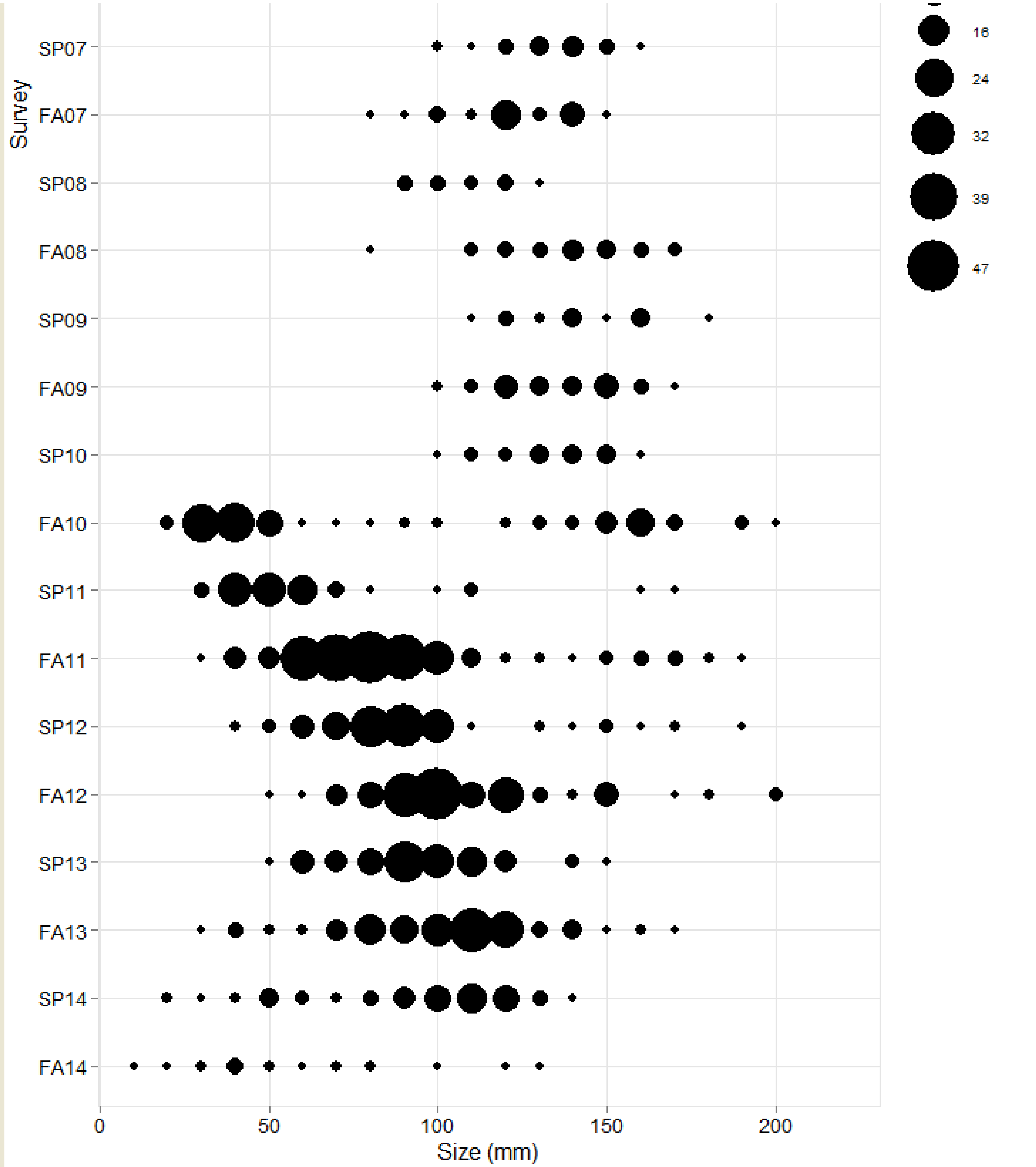
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Old Stairs Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The anemone plots at Old Stairs consist primarily of the colonial anemone, *Anthopleura elegantissima* rather than the solitary anemone *Anthopleura sola* (note that these were considered a single species prior to the past several years and they are not distinguished in our sampling methods). These plots showed greater variability due to sand inundation from their inception in 1994 through 2002, and more gradual change thereafter with cover ultimately declining from 70% to around 40% up to 2012. Anemone cover has increased a bit more recently. As anemones declined, invertebrate species (primarily *Phragmatopoma* and encrusting tunicates) and red algal species (namely *Chondracanthus* sp. and flamentous species) have taken their place, with each of these groups increasing to a mean cover of around 20%. Each of these plots has a unique ecological story to tell. One has a recurring colony of *Phragmatopoma* that grows for a period of time and then gets broken away, another has persistent colonies of both sponges and tunicates, along with recurring *Egregia* holdfasts which have periods of growth and senescence. Two others have persistent patches or red algae and mussels respectively, and the fnal plot has remained nearly covered by *Anthopleura* despite partial sand burial from time to time.

The barnacle plots at this site consist of a mixture of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula* with the former being the dominant component of all plots. Since their inception, barnacle cover declined from nearly 100% in 1994 to less than 20% in 2010. Barnacle cover rebounded a bit after that, but was back down to 25% as of fall 2014. In fact, a single plot, which has remained at nearly 100% barnacle cover throughout the years, is responsible for most of the remaining cover. The other four plots have become dominated by *Endocladia*, *Mytilus*, or a mixture of these two species along with bare rock. Motile invertebrate counts at this site began seasonally in the fall of 2000 and were changed to annual sampling in 2004. Littorines were added to the protocol in the fall of 2001. Within the barnacle plots, littorines and limpets are both highly abundant with the former varying in the neighborhood of 1000 individuals per plot and the latter steady at around 100 per plot. *Nucella* spp. snails are also common with around ten individuals per plot in most seasons, though these were absent during three sampling events.

Shortly after site establishment, the mussel plots exhibited a precipitous decline in mean *Mytilus* cover from around 80% in spring 1995 to near 30% the following fall. This decline was met by a corresponding increase in barnacle cover along with bare rock. After that, mussels began a gradual recovery interrupted by brief declines of varying degrees. One of these subsequent declines occurred in 2004-2005 the other in 2009, and both were the result of breakouts in the mussel beds, presumably due to heavy winter storms. A smaller decline was seen in fall 2014 with cover decreasing close to 50%, again due to storm-related mussel breakouts. Consistent recruitment of young mussels to this site has allowed these mussel beds to regenerate before other opportunistic species could become established in the plots. The data from the motile invertebrate sampling show consistent low levels of chitons (*Nuttalina* spp.) and littorines in these mussel plots, along with higher and more variable numbers of whelks (*Nucella* spp.). In addition, limpets have been quite abundant and highly variable in these plots since the spring of 2002.

The *Endocladia* plots at this site are a mixture of turfweed, barnacles, mussels, and bare rock with no clear patterns developing throughout the monitoring period. Mean *Endocladia* cover has varied between about 10 and 50%, barnacles have varied more dramatically between 20 and 60%, and mussels have remained steadier at around 10 to 30%. The data from the motile invertebrate sampling show consistent low levels of chitons (*Nuttalina* spp.) and whelks (*Nucella* spp.) in the *Endocladia* plots, along with higher and more variable numbers of limpets and littorines.

Rock ("Above Barnacles") plots were added to this site in the fall of 2008 to document any upward spread of intertidal species as a result of global climate change or other factors. These plots are expected to remain dominated by bare substrates unless barnacles or other species begin to encroach upon them. Barnacles have been observed within these plots since their inception, though their percent cover has remained low. Increased barnacle recruitment was observed in fall 2012 and barnacles have remained common in some plots since that time. Data were not collected in these plots during the spring of 2010. Littorines have been common in most of these plots since their inception.

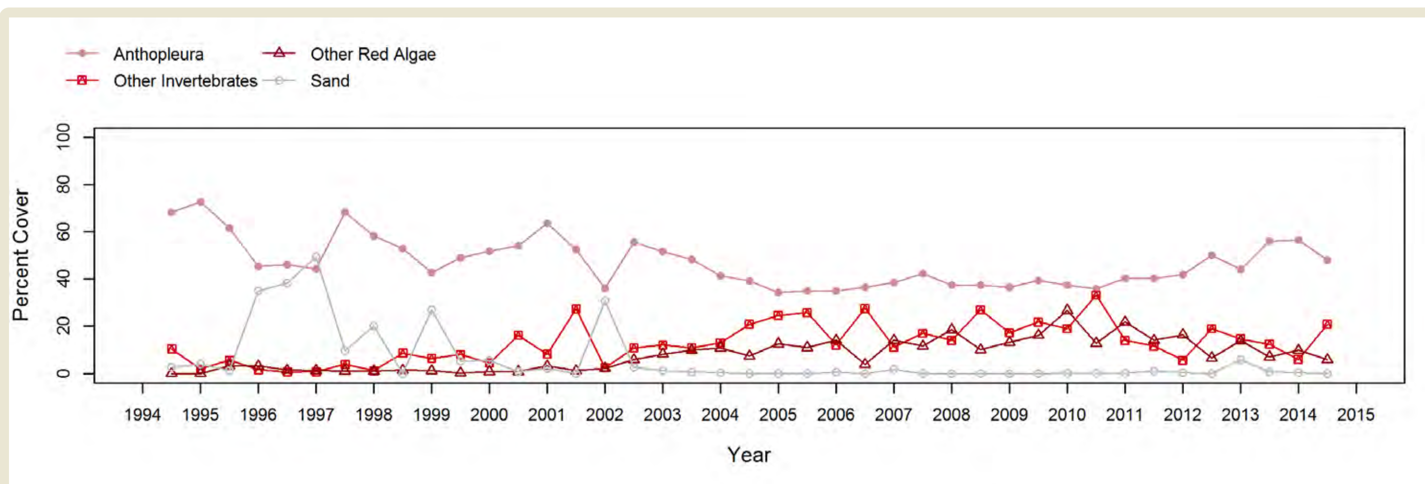
Sea star (*Pisaster ochraceus*) abundance within the original transect swaths began at around 30 total stars and remained below that level for the frst 5 years of sampling. After 2000, the numbers of stars began to increase and become more variable, both through time, and seasonally (with higher numbers in the spring compared to fall). In the spring of 2004, the push for methodological consistency among sites prompted the addition of a series of three large irregular plots to be sampled in addition to the transects. These data show a high number of stars (over 200) during their frst few seasons of sampling, and then declines to less than 50 stars by 2012. Seastars are often observed to be partially or completely buried in sand near the base of the reef structures at this site. While other sites in southern California were starting to become affected by the seastar wasting disease as early as the summer of 2013 and we had documented disease related declines at sites upcoast and downcoast of this one, we never confrmed the wasting disease at Old Stairs. This site was deemed the last holdout with respect to the wasting disease. In the fall of 2014, however, while a similarly large number of stars were counted in the fxed plots compared to recent seasons, most of the larger individuals were gone and a large number of young recruits made up the difference. It appears that the disease did fnally sweep through this part of the Malibu coast sometime between our Spring 2014 and Fall 2014 sampling events. A supplemental sitewide search for seastars was initiated during that latter sampling event. The size distribution fgure shows that the population of seastars at Old Stairs is comprised of mostly larger individuals but with a fair amount of consistent recruitment (presence of stars less than 50mm). There are no clear pulses of recruitment that have moved through the population. The seastar population at Old Stairs is likely maintained both through recruitment, and through migration to and from the subtidal.

Photo Plots

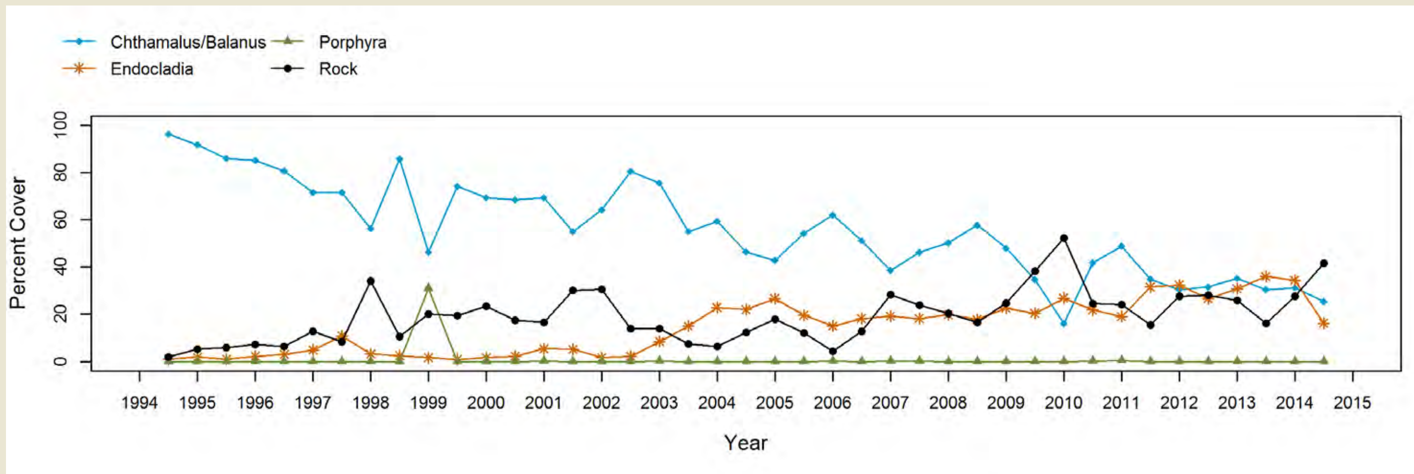
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

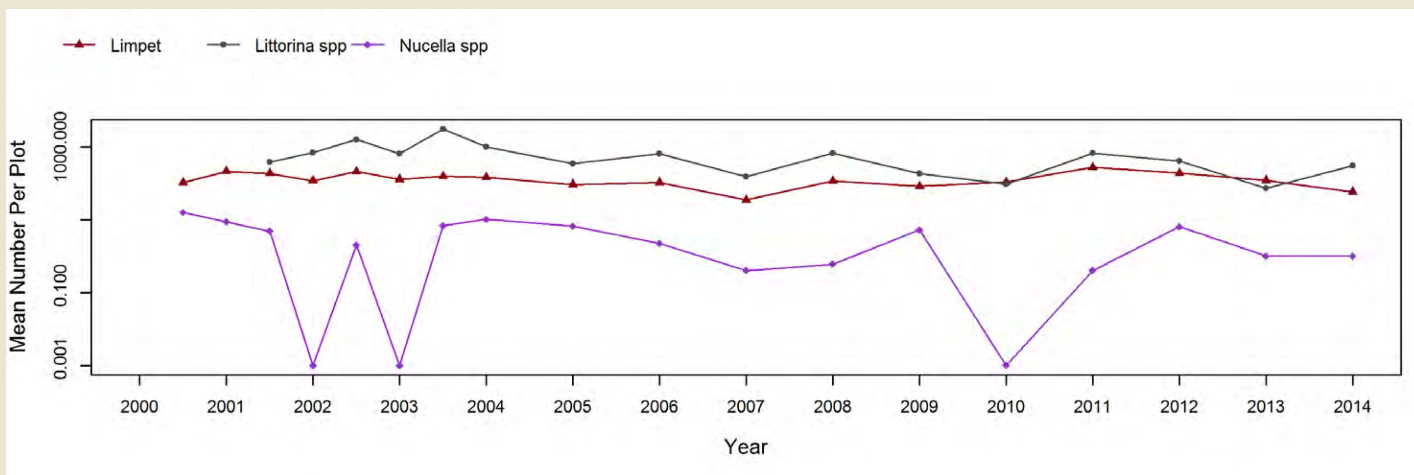
Anthopleura (Anemones)



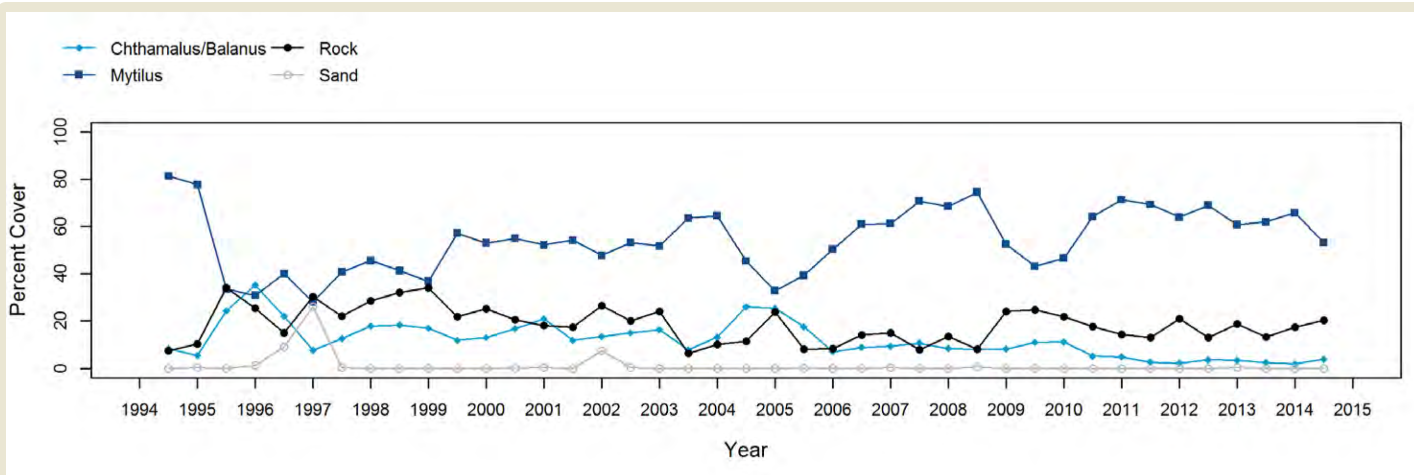
Chthamalus/Balanus (Acorn Barnacles) - percent cover



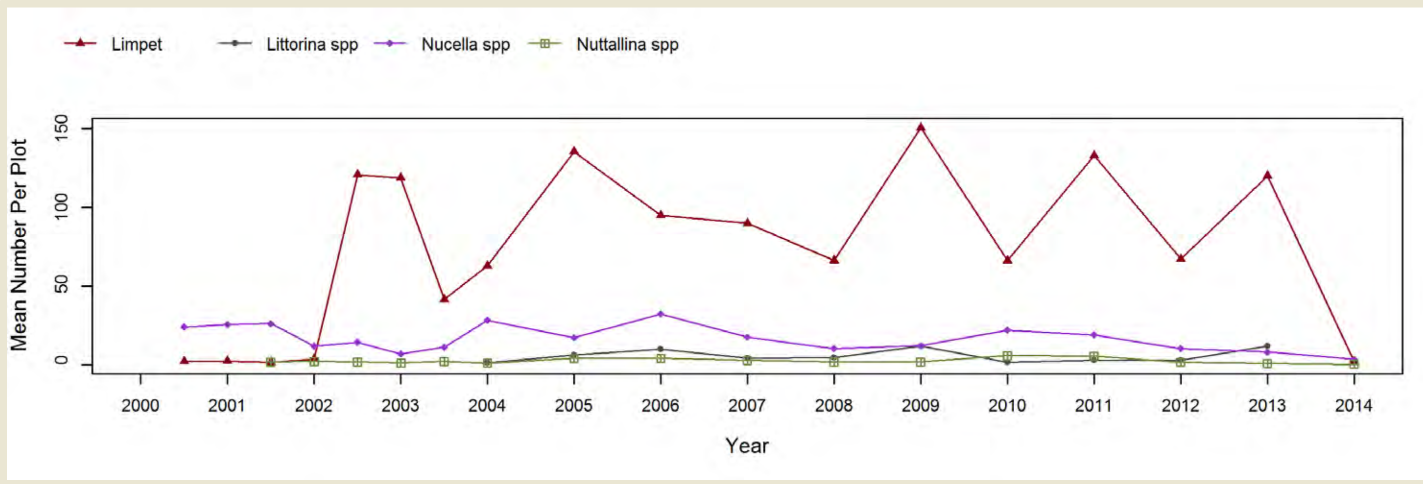
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



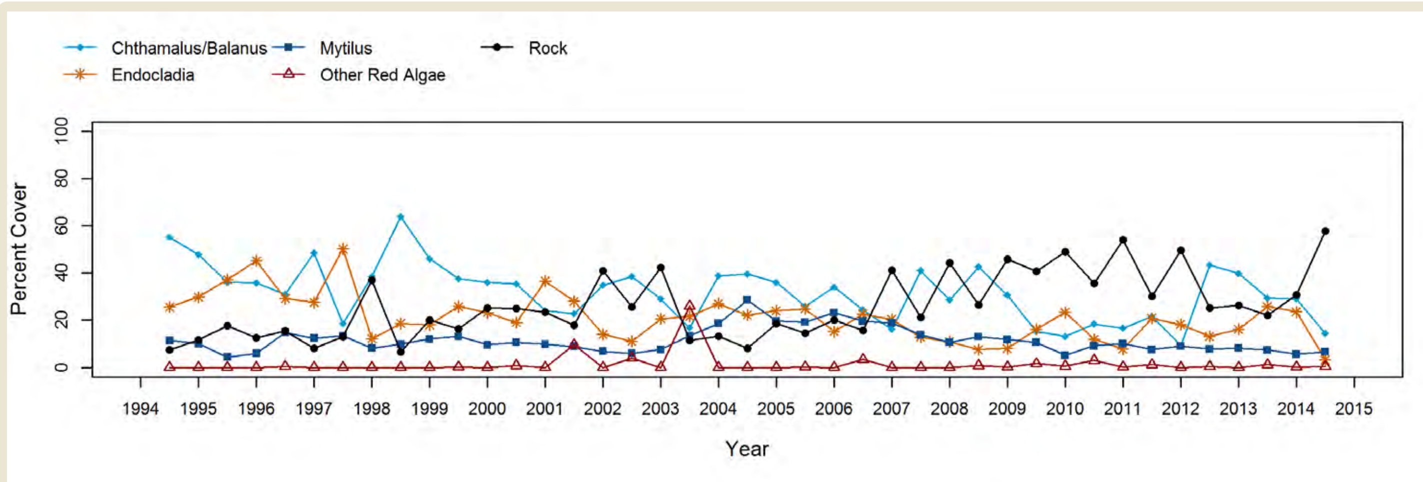
Mytilus (California Mussel) - percent cover



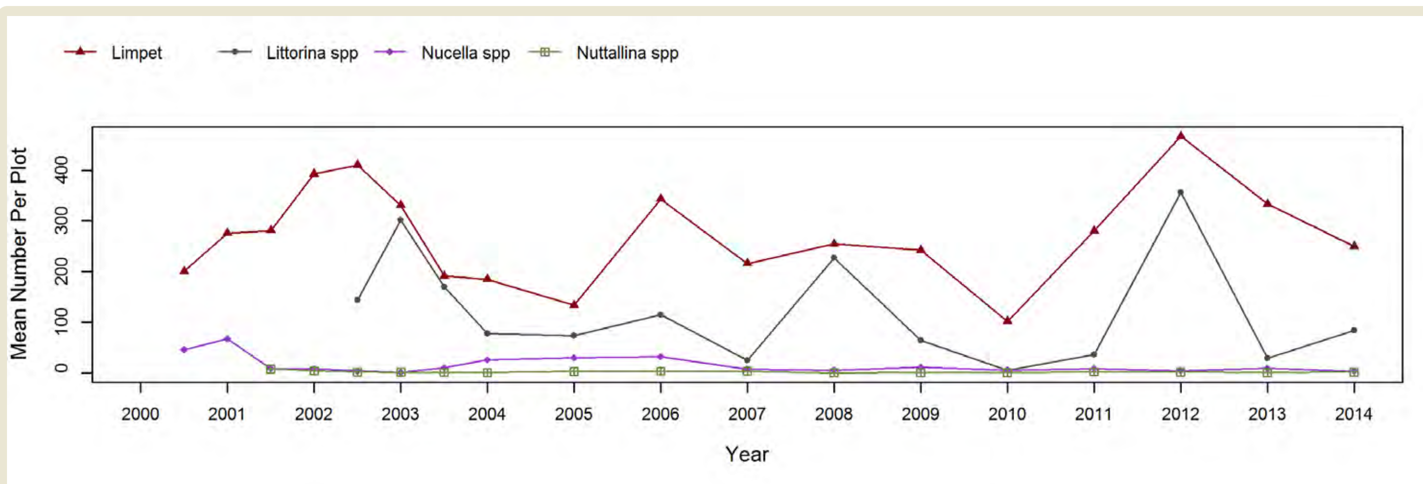
Mytilus (California Mussel) - motile invertebrate counts



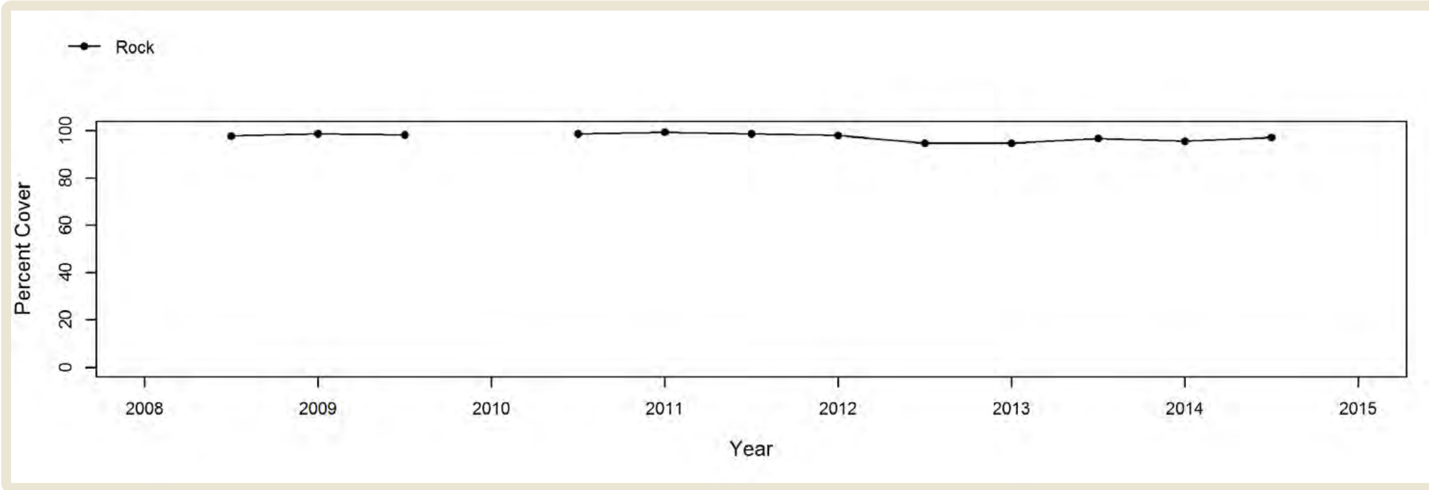
Endocladia (Turfweed) - percent cover



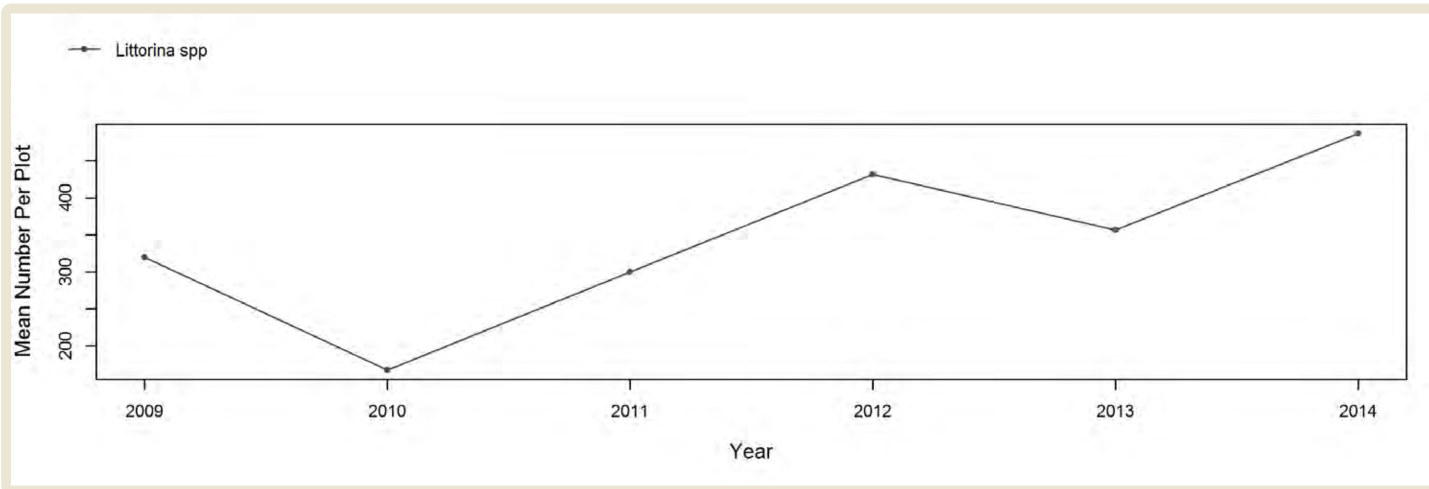
Endocladia (Turfweed) - motile invertebrate counts



Rock (Above Barnacles) - percent cover



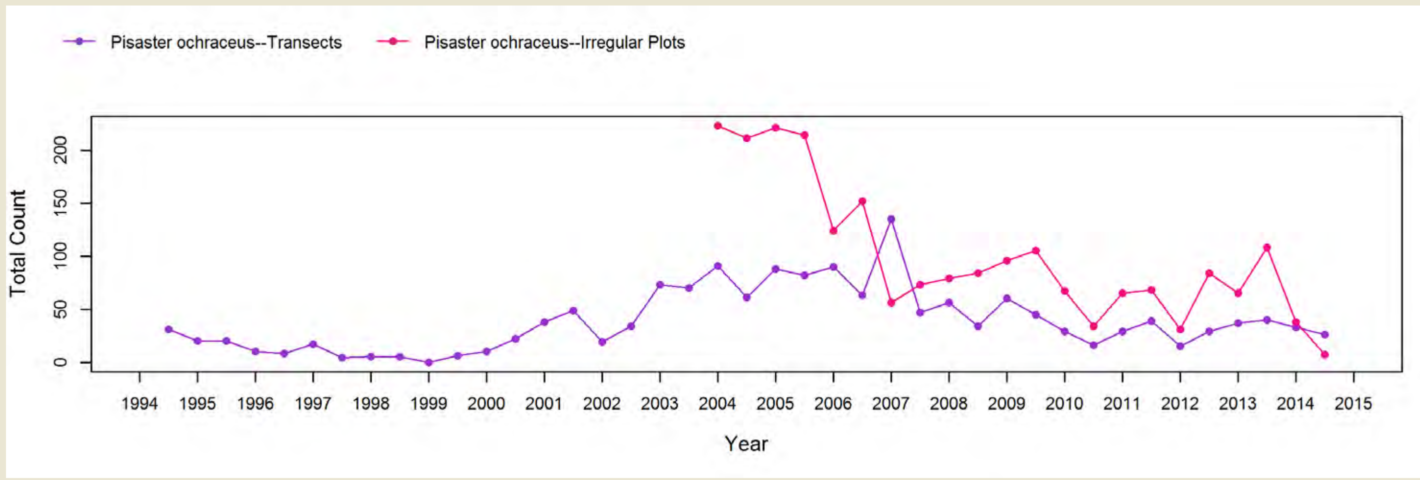
Rock (Above Barnacles) - motile invertebrate counts



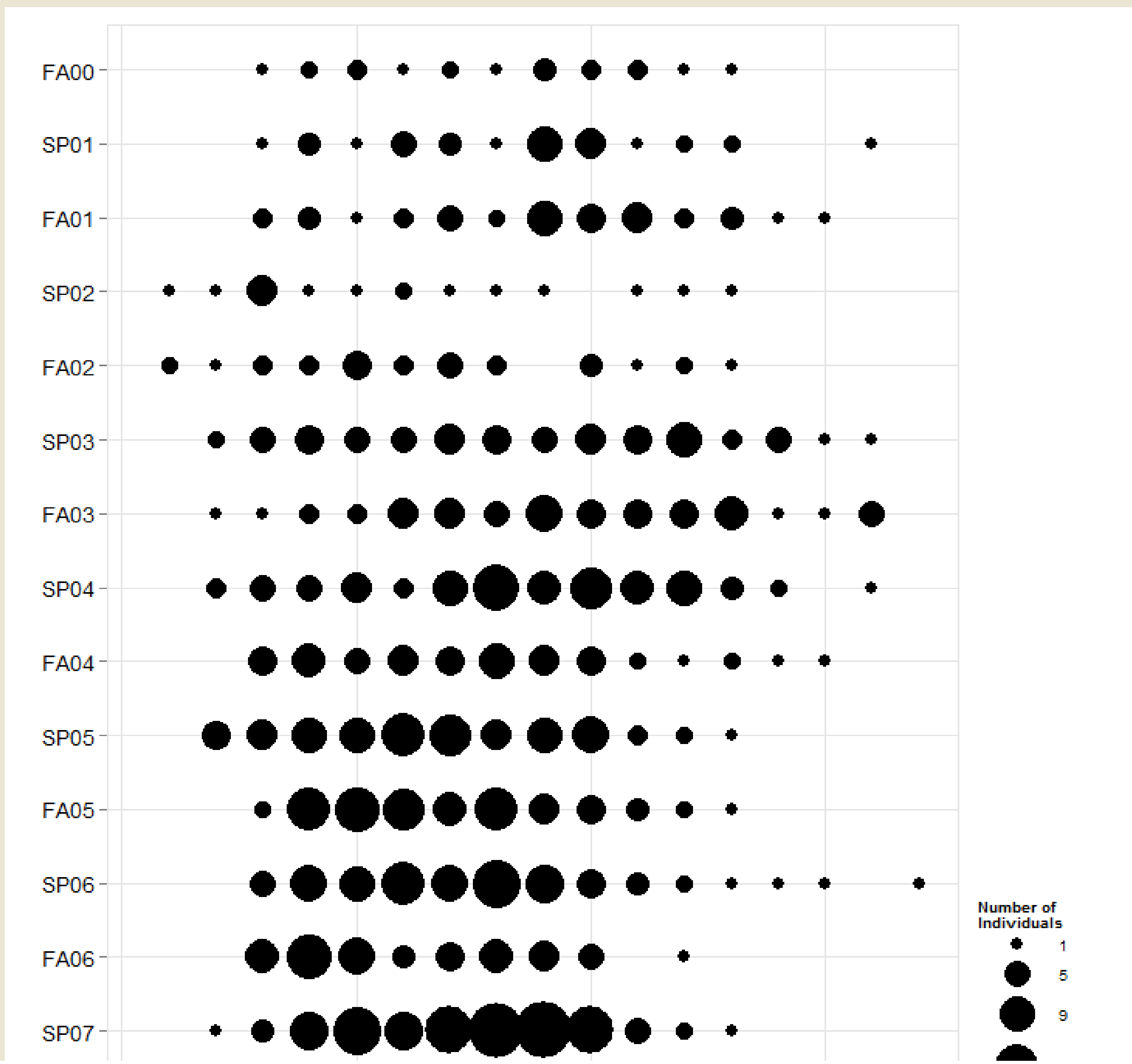
Species Counts and Sizes

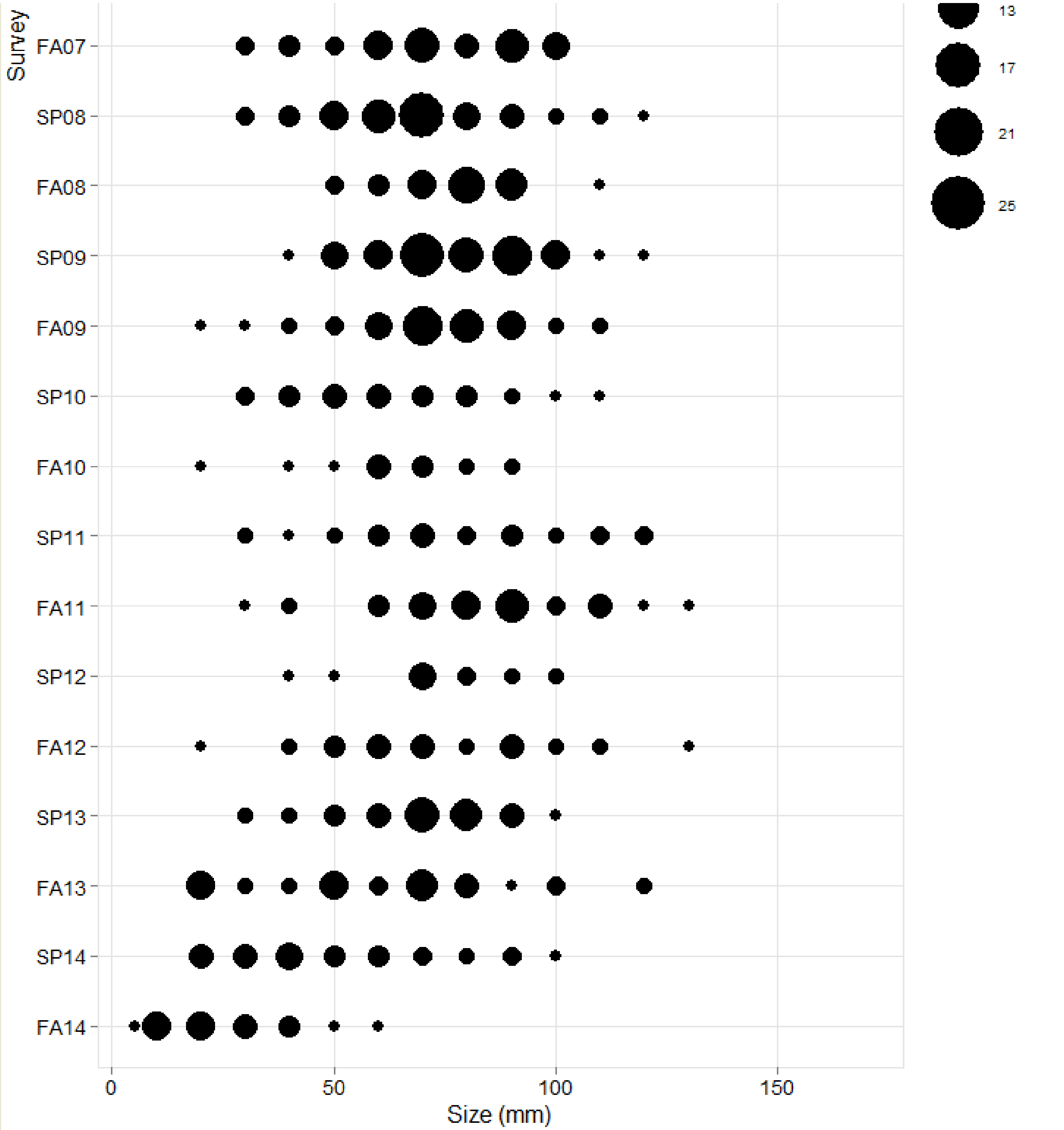
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes in Transects





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Paradise Cove Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The barnacle plots at Paradise Cove consist of a mixture of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula* with the former being the overwhelming dominant component of all plots. In general, barnacle cover has varied inversely with bare rock with current levels at about the lowest level since plots were established in 1994. For a time, these plots were invaded from below by *Endocladia* (mostly as epiphytes on barnacles), and this was suggestive of a possible ecological transition, but this *Endocladia* has all but disappeared as of several years ago. Motile invertebrate counts at this site began seasonally in the fall of 2000 and were changed to annual sampling in 2004. Littorines were added to the protocol in the fall of 2001. Within the barnacle plots, littorines were highly abundant and varied gradually in the neighborhood of 1000 to 2000 individuals per plot on average. Limpets were also common and varied gradually between 5 and 50 individuals per plot on average. Motile invertebrate data were not obtained for these plots in 2004.

The mussel plots at this site have been fairly stable throughout the years with mussel cover in the 80 to 90% range most of that time. A gradual decline in 1997-1998 and a more precipitous decline in 2005 were each followed by gradual recoveries. Another precipitous decline in 2011 has not been followed by a recovery; cover has remained at about 60% since that time. Not evident in this trend graph are changes in the size and depth of the mussel bed that have occurred throughout the years. For example, in 2006 a line of advancing seastars just below these photoplots caused the mussels to pile up atop one another, changing what had been a tight monolayer to a loose multilayered bed. In recent seasons, as seastar numbers have declined, the mussel bed has been tending back toward a dense monolayer. The data from the motile invertebrate sampling show consistent low levels of snails (*Tegula funebralis*), along with higher and more variable numbers of limpets. Peaks in limpet abundance occurred in 2003 and 2008 and 2012 with the latter two far exceeding the former.

Patterns of cover in the *Endocladia* plots have been dynamic with *Endocladia*, barnacles, mussels and rock all becoming dominant at one time or another. *Endocladia* started out with a low mean cover of around 20% in 1994 and it is was almost absent as of fall 2015. However, in the intervening years, turfweed rose to nearly 60% cover shortly after plot inception and remained there for 8 years before a precipitous crash in 2004. Barnacles had initially been at over 40% cover in 1994, but then declined to very low numbers by 1996 where they have largely remained ever since. On the other hand, mussel cover was negligible for the frst nine years of sampling, but then began increasing in 2003 and reached 60% cover by 2006. Subsequently, the mean mussel cover dropped back to 30% in the fall of 2008 and has dropped to almost 20% in the time since. And as mussels have declined, recordings of bare rock have become more common and are currently near the 60% level. The data from the motile invertebrate sampling show wide swings in both limpets and littorines in the Paradise Cove *Endocladia* plots. Limpets started out in the spring of 2000 with a mean abundance of 100 individuals per plot and dropped to half that amount on two different occasions. Around 60 limpets per plot were found in 2014. On the other hand, littorines started out at 140 limpets per plot in 2003, were almost completely gone by 2010, and were present but scarce in 2014.

The mean cover of Surfgrass (*Phyllospadix* spp.) has fuctuated widely throughout the years at this site with seasonal variation (lower in spring, higher in fall) along with intermittent periods of modest sand burial. Throughout the years, the cover of *Phyllospadix* hovered around 60% plus or minus 10 percent with one signifcant population decline in 1997 and 1998. This period was marked by an initial increase in sand through the frst two seasons of the decline, and then a sharp increase in rock during the spring 1998 sampling which is suggestive of true *Phyllospadix* dedlines. A subsequent drop in Phyllospadix in spring 2012 was due merely to sand burial without any actual loss of surfgrass. Red algae also showed seasonal increases that were the inverse of the seasonal *Phyllospadix* declines.

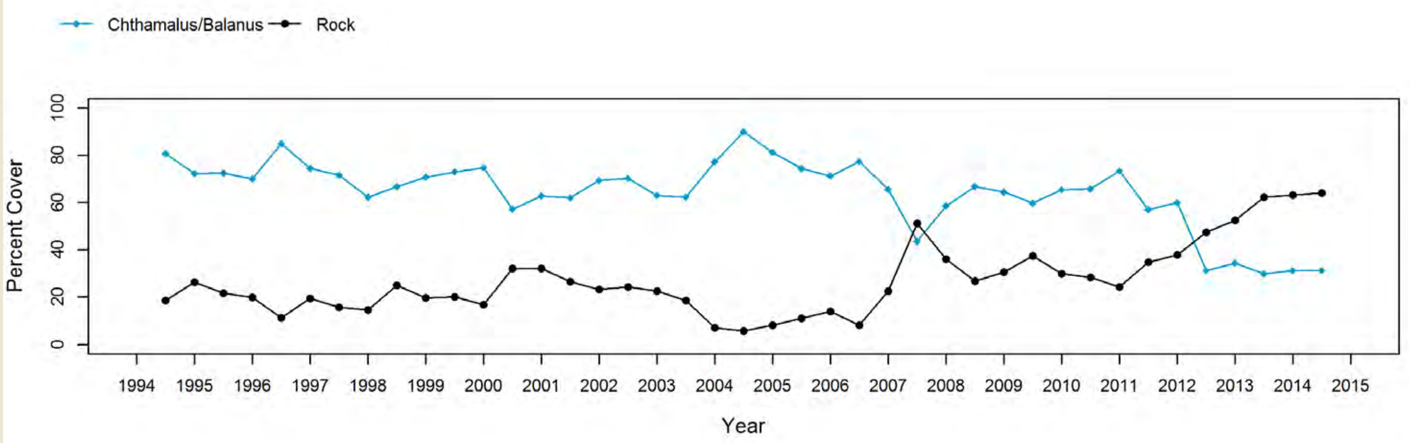
Seastar (*Pisaster ochraceus*) plots were added to this site in the spring of 2002 and consist of three large irregular plots surrounding an area of medium relief rock and shallow tidepools. At the frst sampling, the total number of seastars counted and measured was around 180. That number increased to nearly 300 by the following fall, but began to decline thereafter with some variation, but with numbers dropping to 50 stars or below by 2011. While the seastar wasting disease had devastated the star populations south of the Santa Monica Bay by the fall of 2013, this site in the northern bay had remained disease free until the spring of 2014. During our regular sampling early that March we found a similar to the number of stars to what was found in subsequent sampling events. But two clearly diseased stars were found, including one with missing rays. The decision was made to resample those plots later that month, and during that visit not a single star could be found, including sitewide. Stars were similarly absent in the fall 2014 sampling. While smaller (<50mm radius) stars have been common at this site throughout the years, those encountered tend to be larger (>70mm). General observations, along with the size distribution depicted in the trend graph, suggest that most seastars are moving in and out from the subtidal though some may be recruiting to the monitoring site as young stars.

Photo Plots

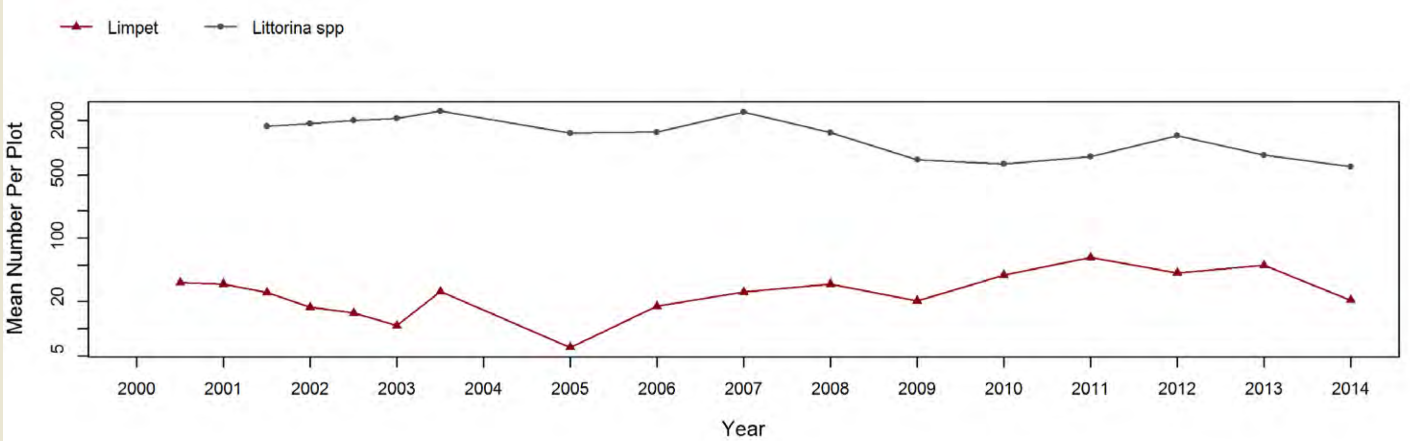
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

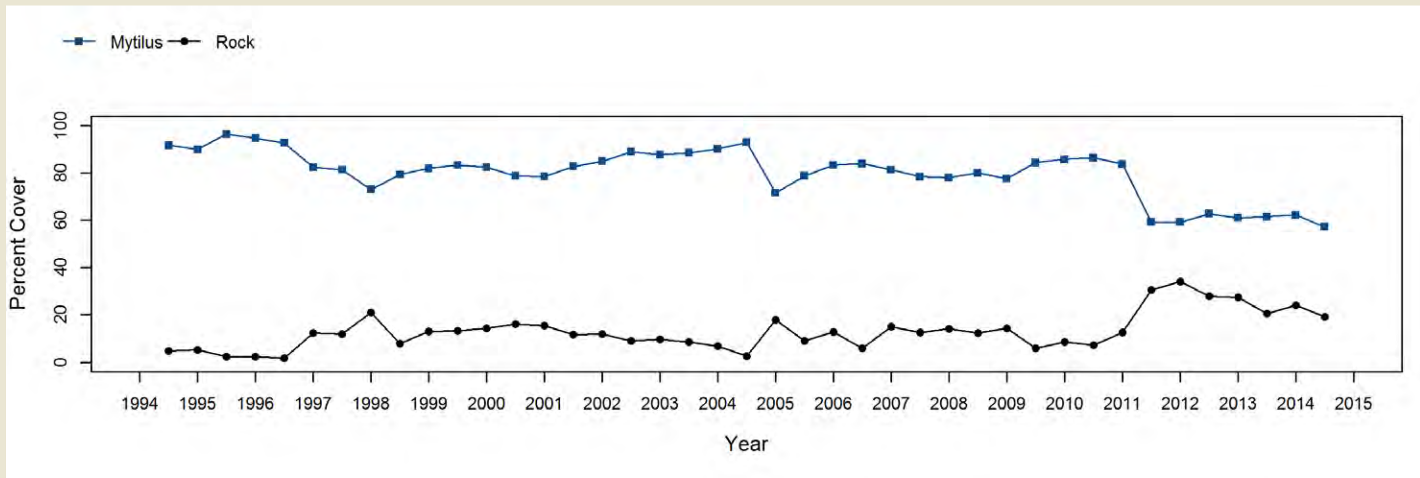
Chthamalus/Balanus (Acorn Barnacles) - percent cover



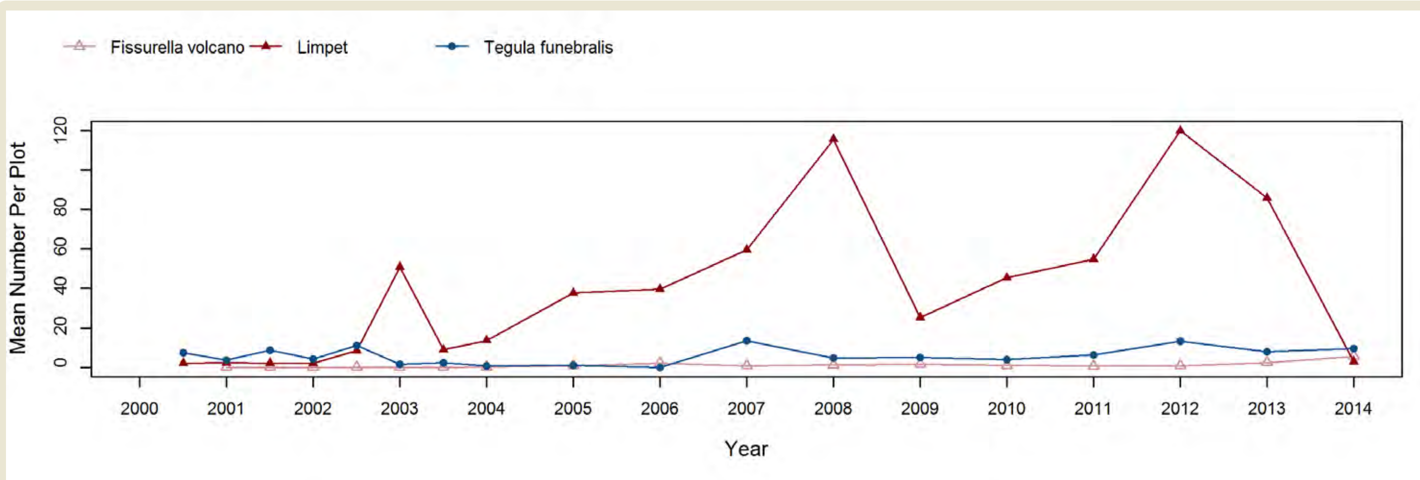
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



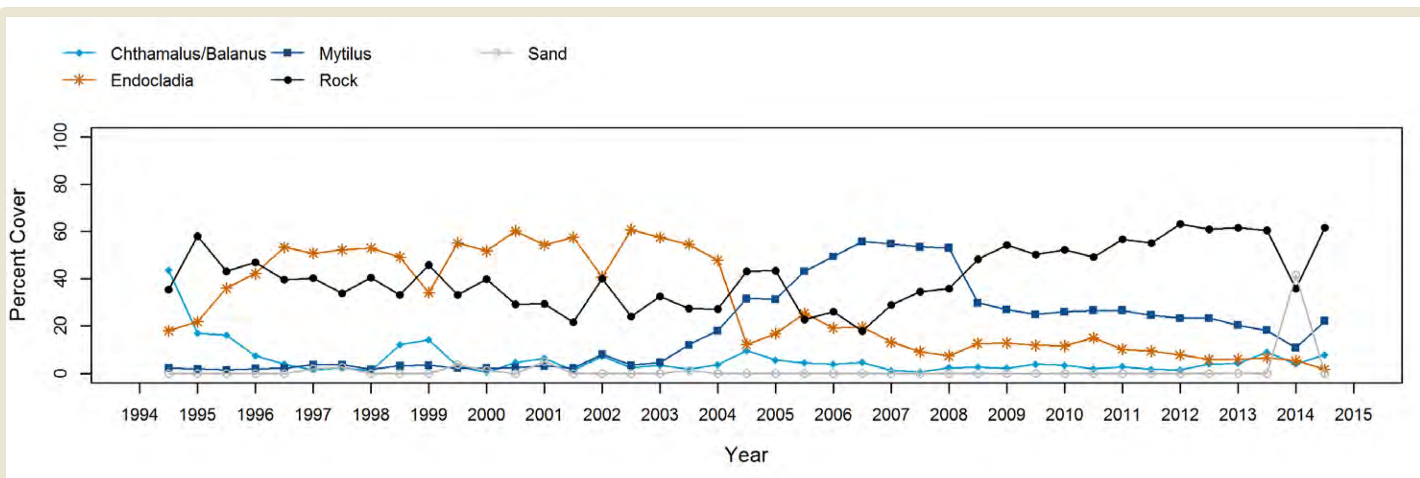
Mytilus (California Mussel) - percent cover



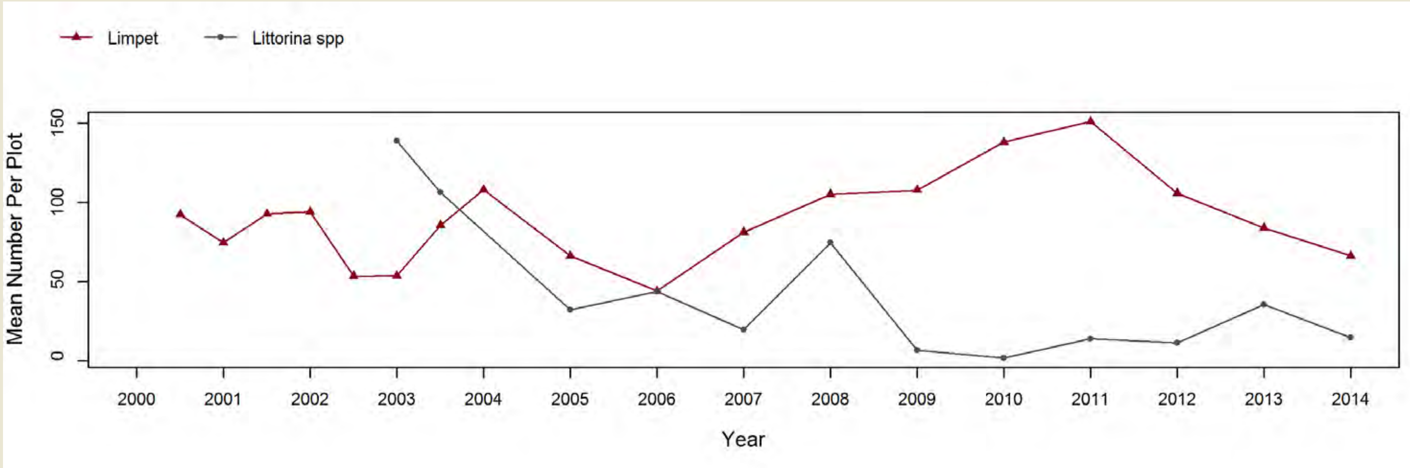
Mytilus (California Mussel) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



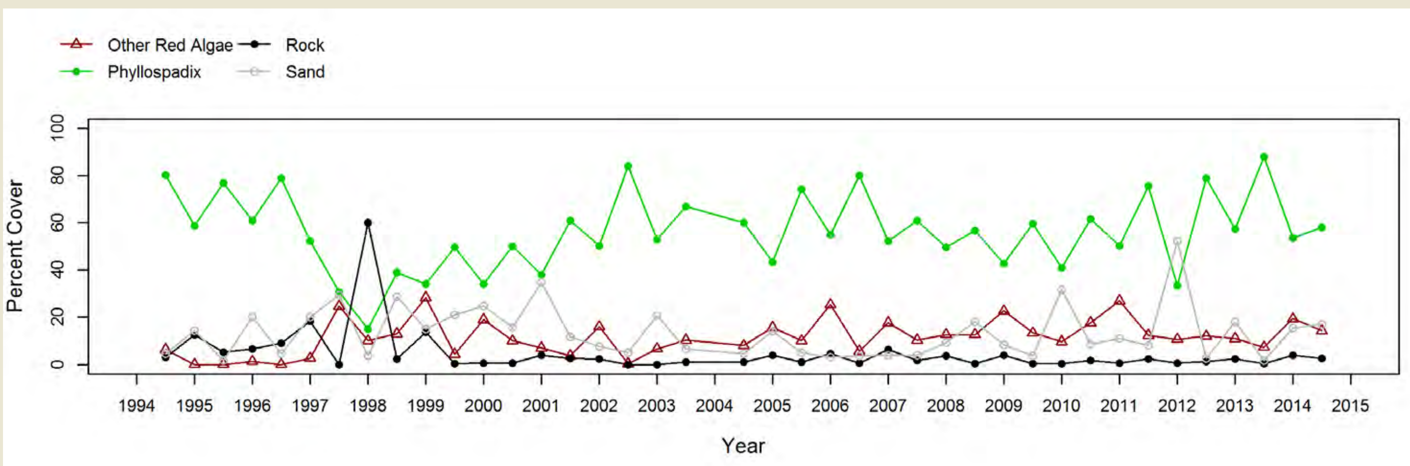
Endocladia (Turfweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

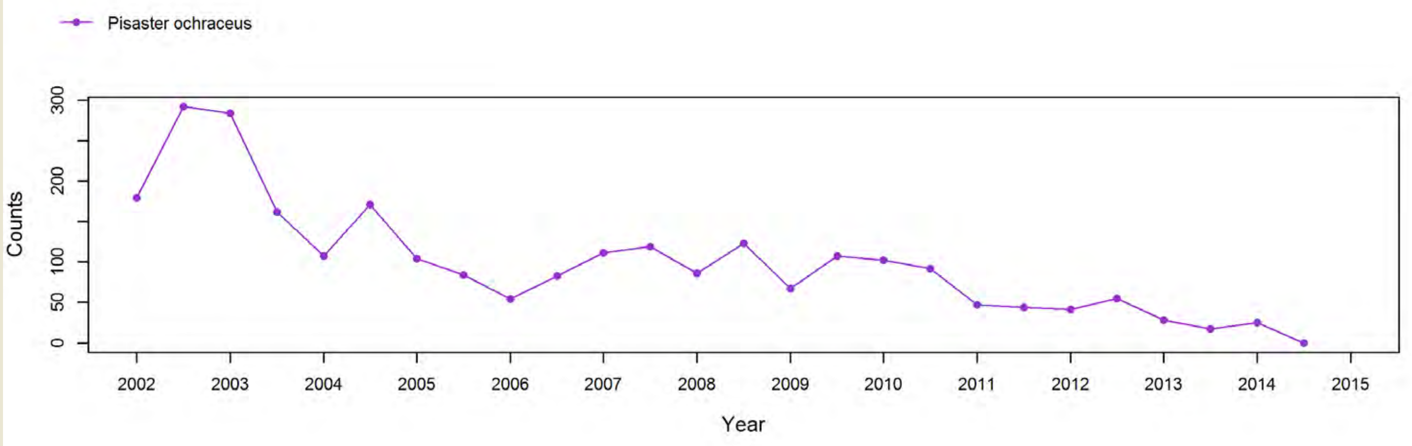
Phyllospadix (Surfgrass)



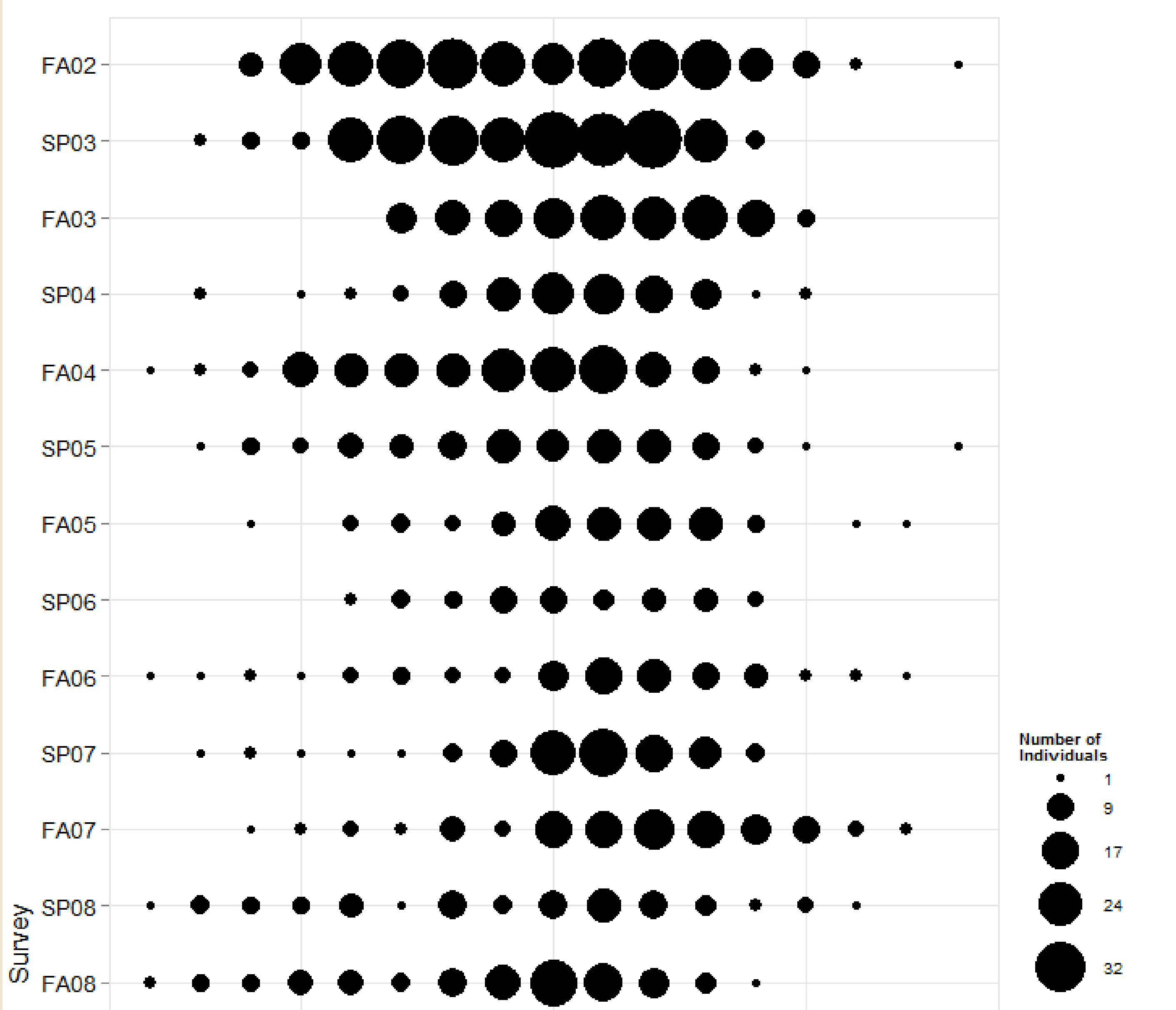
Species Counts and Sizes

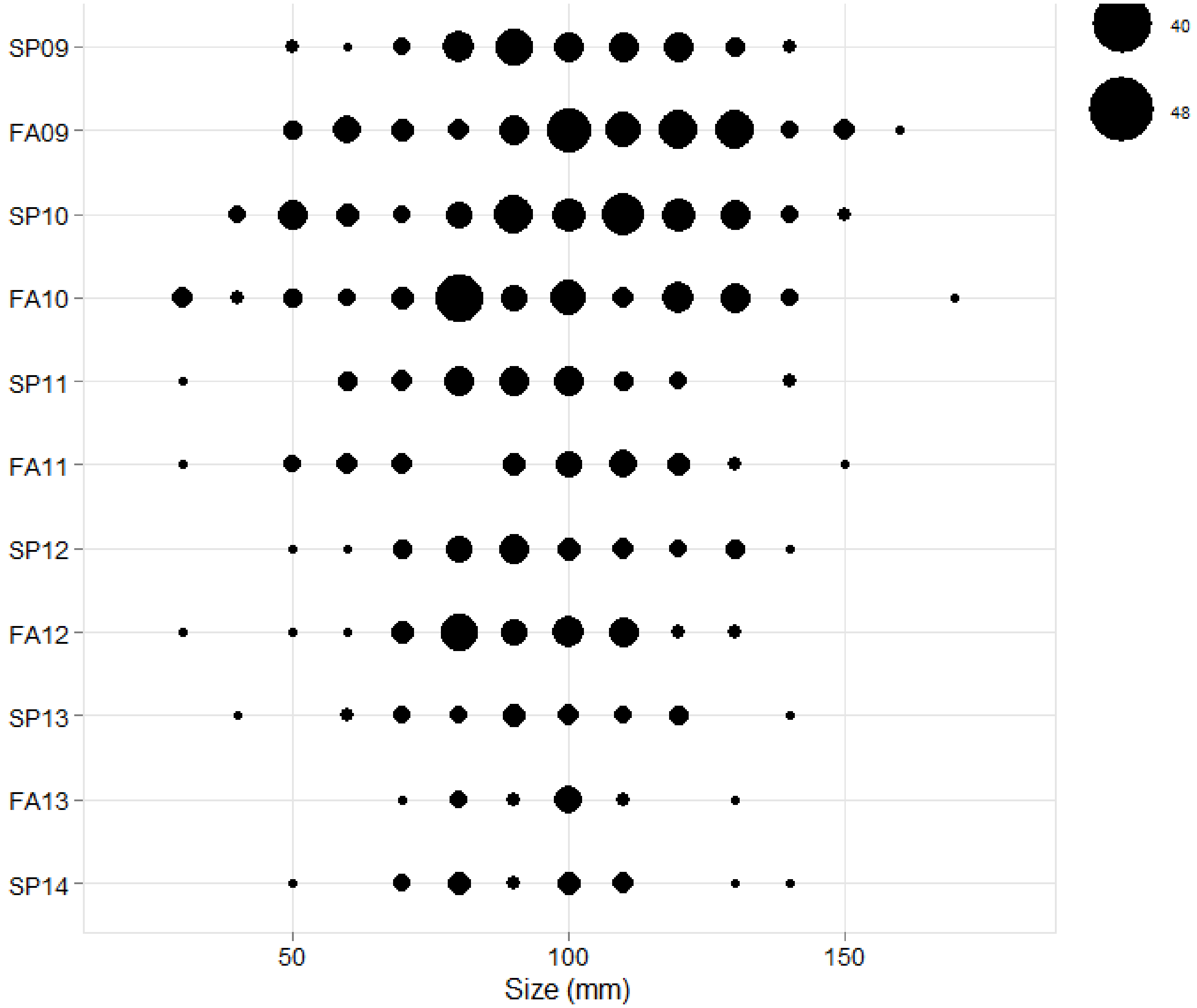
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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White Point Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The barnacle plots at White Point consist of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001) and *Balanus glandula* with separate plots (5 of each) designated at this site based on dominance of each genera at the time of setup. While the initial approach was to analyze these as separate assemblages, a latter decision was to treat all ten of these collectively as "barnacle plots" since the two genera were lumped during data collection. Thus, within these ten barnacle plots, barnacle cover has declined gradually throughout the monitoring period with one episode of precipitous decline and recovery in the late 1990's and another dip in cover in 2009-2010. Recordings of bare rock shot up during that former period and have remained high ever since. In addition, the cover of red algae have gradually increased throughout the years and have begun flling in the plots as barnacles declined. In the earlier years, a single red alga was responsible for this increase which has been loosely identifed as a very low growing form of *Mazzaella affnis* characterized by very small bladelets thickly emerging from a crustose base. Initially, this *M. affnis* carpet spread into the a signifcant portion of a single plot with a second plot impacted to a lesser extent. But in recent years those patches have grown and all plots have been invaded to some extent. And in 2002, the newly introduced and invasive alga, *Caulacanthus*, began spreading into these plots, initially growing atop the *M. affnis* carpet and then spreading further into the plots. These plots seem to be experiencing a slow transition toward an algae dominated state. Motile invertebrate counts at this site began seasonally in the Spring of 2001 (with littorines added the following fall) and were changed to annual sampling in 2004. Both limpets and littorines have been abundant in the barnacle plots with up to 500 or more individuals per plot in some sampling events and high variation generally. Neither species has shown variability tied to species cover in the photoplot sampling.

Mussels cover in the mussel plots remained high and largely stable in most years until 2006 when it dropped steeply from the 80% or greater range down to around 50% by 2008. After that a moderate rebound occurred with mussel cover leveling out in the 60 to 70% range through 2010 and then plateauing closer to 80% through 2013. In 2014, another precipitous decline was observed with mussel cover being halved to 40%. Two plots were largely responsible for this latter decline having undergone partial to complete mussel breakouts, presumably as a result of strong winter storms.

However, mussel bed contraction has also been a factor at this site, albeit less severe than at other sites in southern California such as Point Fermin and the Orange County sites. In general, the beds at this site are characterized by tightly packed monolayers of small to medium sized mussels interspersed with bare patches. In some plots, and in portions of mussel beds across the site, mussels are covered by a layer of epiphytic *Caulacanthus* that is thick enough to obscure the mussels completely in places. It is unknown wheter *Caulacanthus* might be contributing directly to mussel mortality, but the spread of this species could certainly be having an infuence on mussel recruitment and bed replenishment locally within this site. The data from the motile invertebrate sampling show that limpets are common in the mussel plots in the range of around 100 individuals per plot in most years. *Nuttalina* sp. chitons and littorines are also present in these plots in low numbers. The infrequency of snails in these plots is notable, though *Nucella* snails are occasionally found in low numbers. Sampling of limpets and littorines in mussel plots ceased in 2014.

Within the turfweed plots, *Endocladia* cover is seasonal (higher in spring, lower in fall) and has declined from the 70 to 80% range found in initial years of sampling to around 40 to 50% in most years since. Cover dropped below 20% in the spring of 2007 but rebounded soon thereafter. Barnacles and bare rock have generally, but imperfectly, trended inversely to *Endocladia* cover. And red algae cover, which in this case is almost entirely comprised of the exotic species *Caulacanthus ustulatus*, has been increasing in the turfweed plots since the early 2000's. This alga has invaded many of the available microtopographic lows within these plots while *Endocladia* has been more successful in retaining the higher ground. Motile intertebrate counts within the turfweed plots depict a high abundance and a high variability of both limpets and littorines.

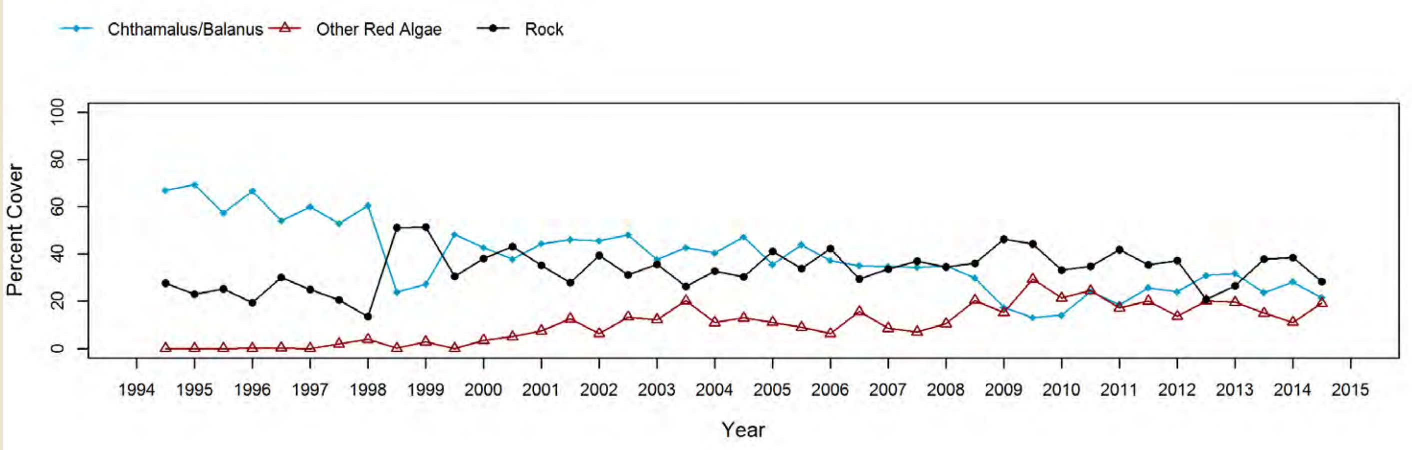
Sea star (*Pisaster ochraceus*) plots were added to this site in the fall of 2003 and consist of three large irregular plots surrounding an area of medium relief rock which includes several large cracks and ledges. The initial samples yielded just under 50 individuals each. Then abundance increased considerably in 2006 and 2007 to a high of around 200 seastars followed by a drop to basal levels in 2009. Subsequent peaks of around 100 stars each were observed in Spring 2010 and Fall 2012. The seastar wasting disease arrived at this site in the fall of 2013. During that sampling event, just a couple stars were observed and each of those was heaviliy lesioned or missing rays. Another solitiary ray was found with no associated seastar body. Following that season, no stars have been found at White Point, either in the fxed plots or sitewide. Recruitment has been common at this site with seastars in the 50mm or less range found in most seasons. It appears that a large recruitment event was at least partially responsible for the 2006-2007 increase. However, stars in the larger size classes are generally rare at White Point which may be the result of high, and largely unregulated, human visitation, species manipulation and harvesting at this site.

Photo Plots

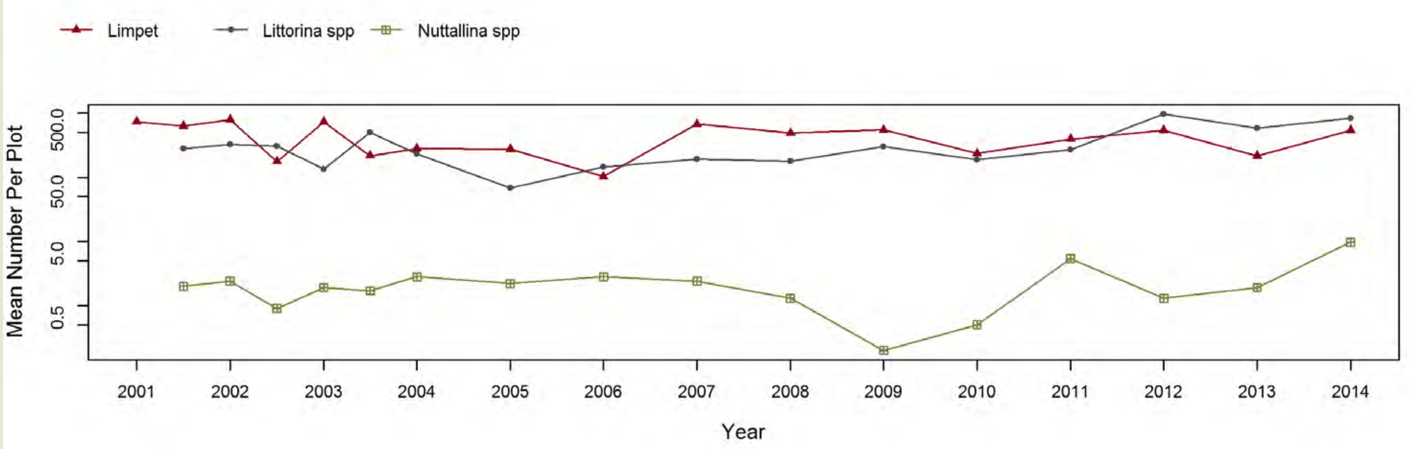
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

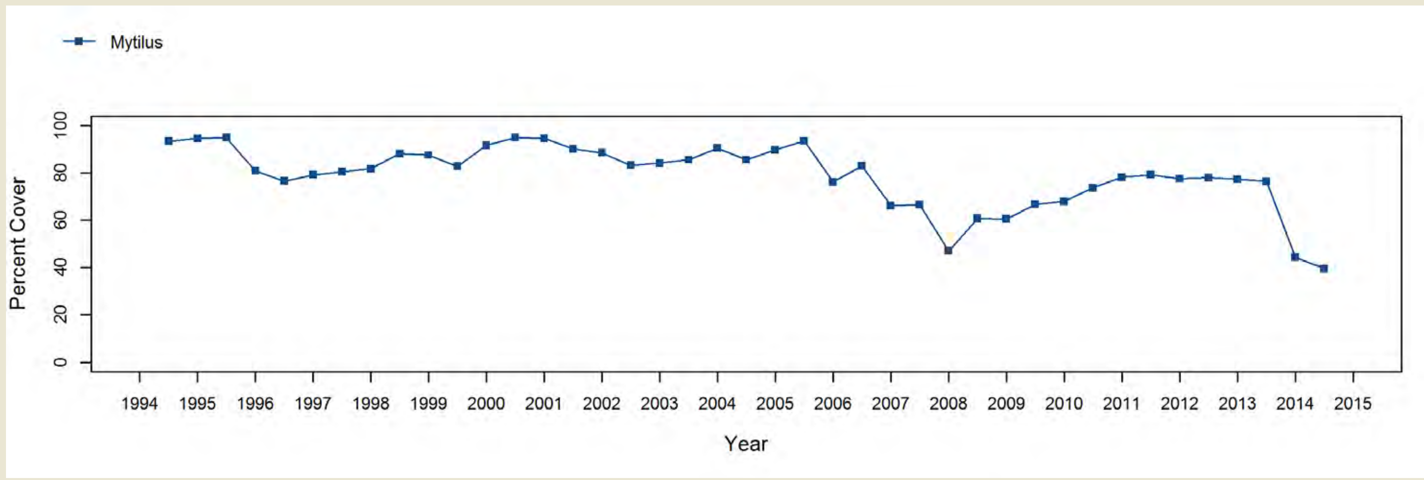
Chthamalus/Balanus (Acorn Barnacles) - percent cover



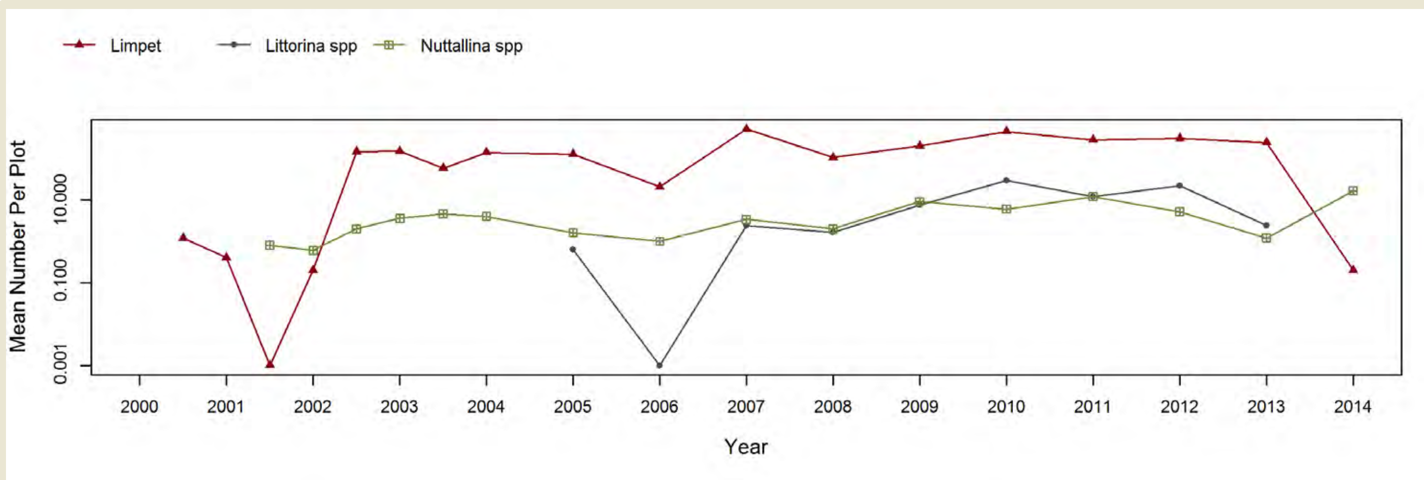
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



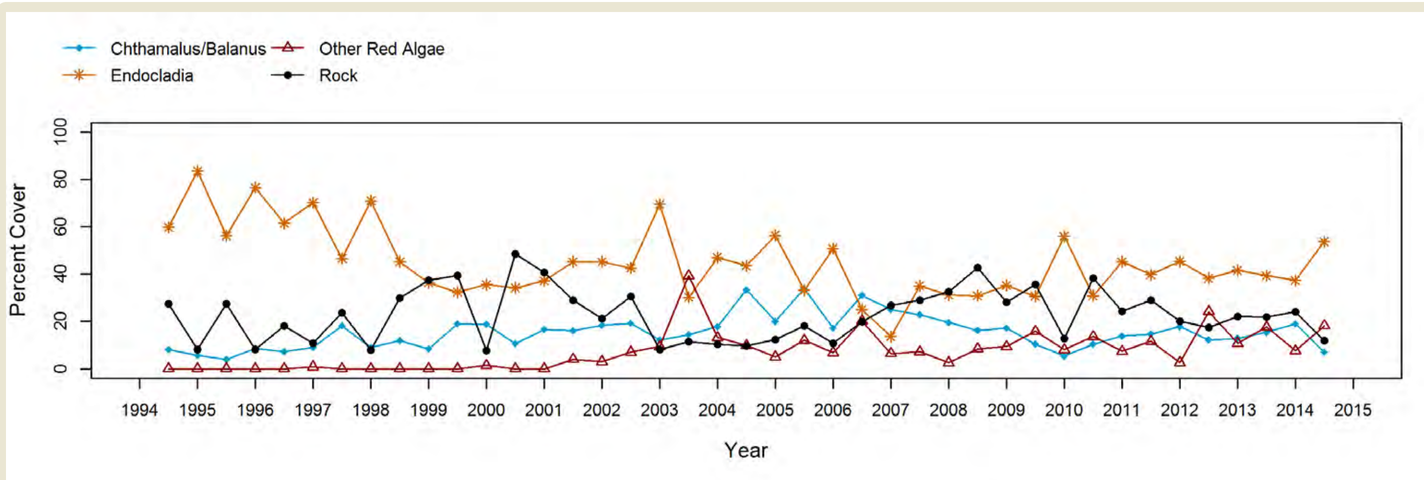
Mytilus (California Mussel) - percent cover



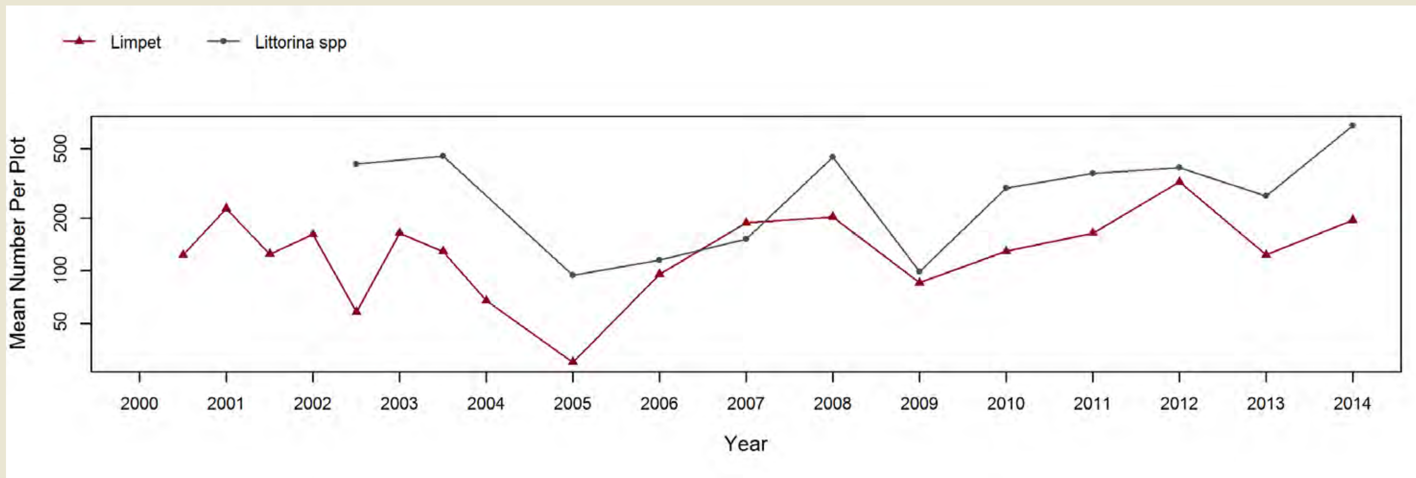
Mytilus (California Mussel) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



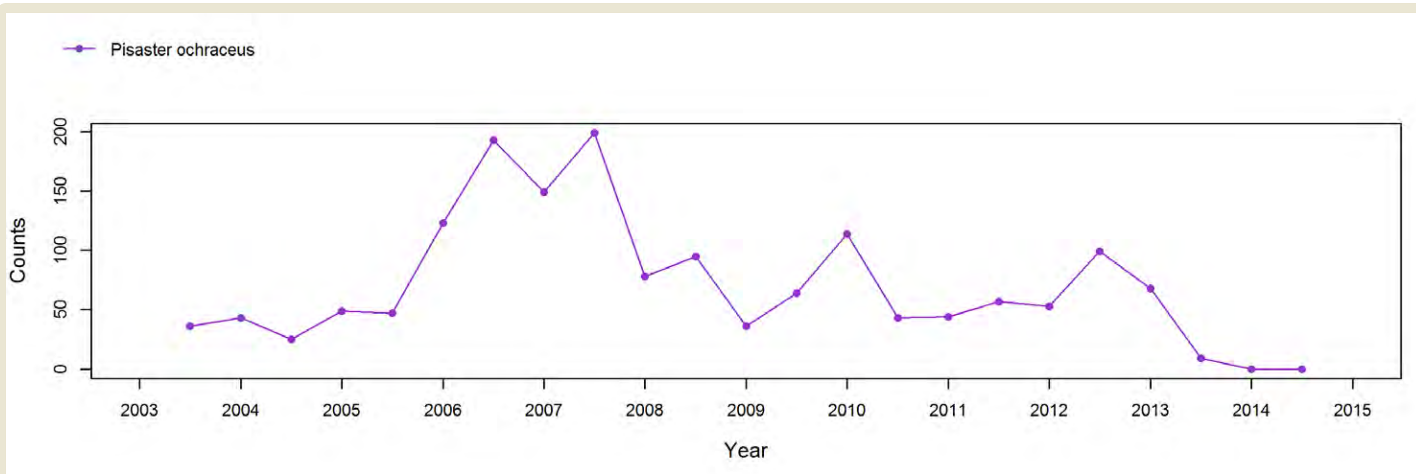
Endocladia (Turfweed) - motile invertebrate counts



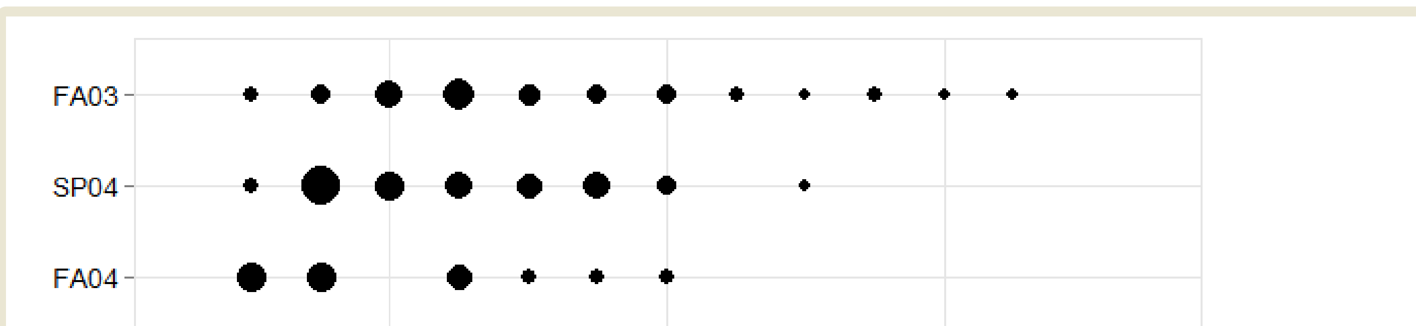
Species Counts and Sizes

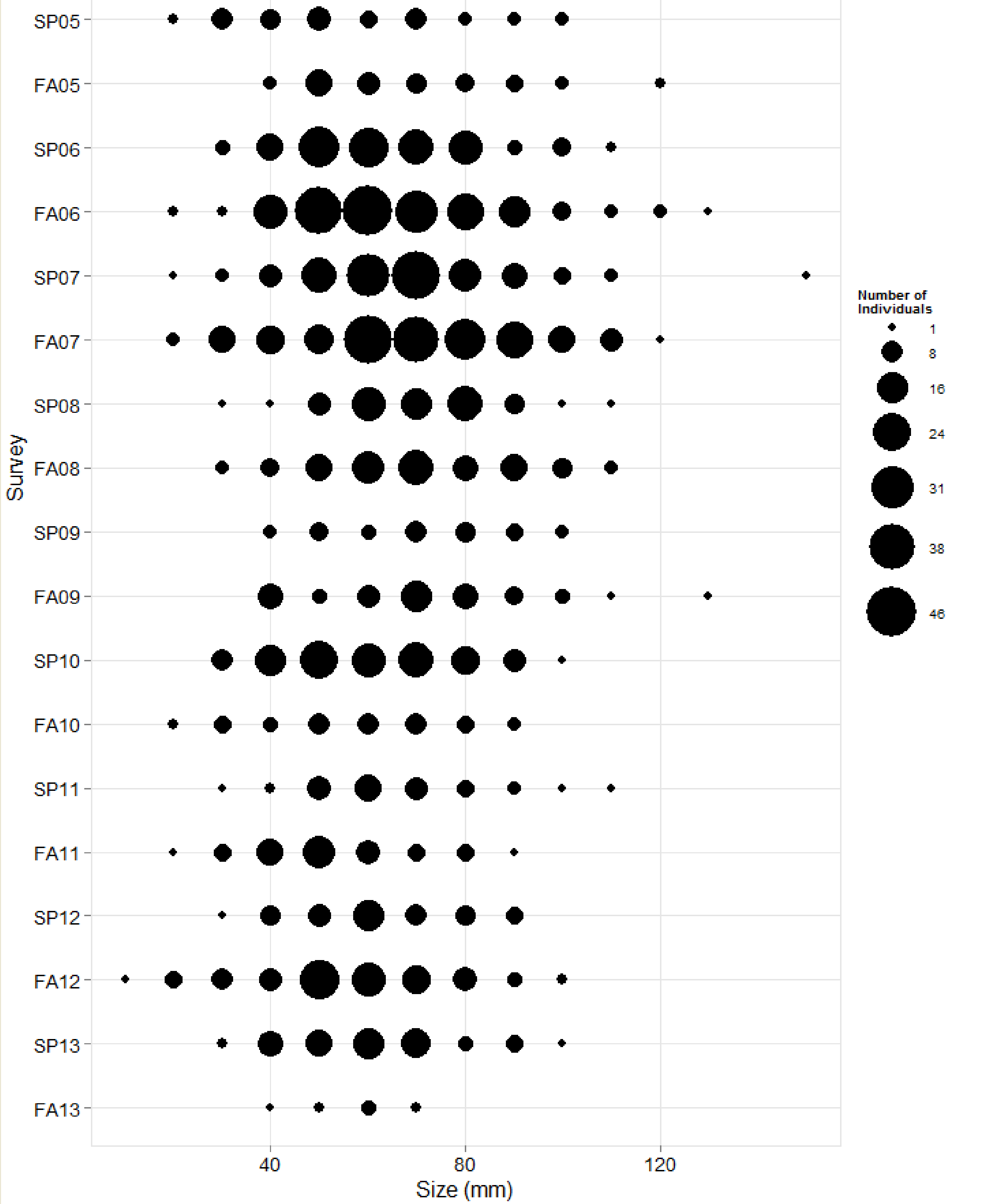
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Point Fermin Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

The barnacle plots at Point Fermin consist exclusively of *Chthamalus dalli/fssus* (note that species were not distinguished until 2001). Cover of *Chthamalus* typically varied inversely with rock cover, with relatively little else occurring in these plots. When this site was established in fall 2009, mean barnacle cover started out around 60%. Then it declined to around 40% by 2003, rose to nearly 80% by 2005, and declined again after 2006 to around 25% In recent years barnacle cover has evened out in the 30-40% range. Motile invertebrate counts at this site began seasonally in the fall of 2000 and were changed to annual sampling in 2004. Littorines were added to the protocol in the fall of 2001. Within the barnacle plots, littorines have been highly abundant, consistently in the neighborhood of 1000 individuals per plot. Limpets have also been common with up to 50 individuals per plot. Limpet abundance declined in 2010 but rebounded thereafter.

Mussels have declined substantially at the Point Fermin monitoring site. Mytilus cover in and around the mussel plots started close to 100% at site inception in 1999, but immediately began a steady decline leveling off at around 15% by 2003. The plots have remained largely unchanged since that time. Three plots became completely devoid of mussels (except for a few small isolated recruits), while one remained steady at around 70% cover and the last plot contains one small persistent patch of mussels. These plots are representative of the surrounding reefs as widespread mussel bed contractions have occurred at this site, a phenomenon that has been reported elsewhere in southern California. As the mussel bed contracted, bare rock and barnacles became more prevalent, as did the cover of species that do not appear in this graph (*Tetraclita*, *Lottia gigantea*, chitons (*Nuttalina* sp.), crustose algae, articulated coralline algae, and others). *Caulacanthus* also invaded the lower and wetter portions of these mussel plots as that introduced and invasive alga spread throughout this site several years ago. As indicated above, a small number of mussels have recruited into the plots since the decline, but these have never survived beyond a season or two. The data from the motile invertebrate sampling show that limpets, chitons (*Nuttalina* sp.) and shore crabs (*Pachygrapsus crassipes*) were all present in the mussel plots prior to the decline, each with an abundance of around 10 individuals per plot. As mussels declined, limpet abundance increased dramatically to around 1000 individuals per plot while shore crabs have declined on average, with sharper declines in 2010 and 2013. Chiton abundance has remained steady. The sampling of littorines began in 2006. Littorine abundance in these mussel plots has remained generally low with less than 10 individuals per plot on average. Sampling of limpets and littorines in these mussel plots ceased in 2014.

Within the rockweed plots, *Silvetia* has been seasonally variable (lower in spring and higher in fall) with the mean cover remaining steady near 100% (fall highs) for the frst 5 years of sampling. Starting in 2005, the cover started to decline gradually with fall highs dropping frst to around 90% and then to 80% by 2009. After that, cover continued to decline to about 50% by 2013, then to its lowest level (below 40%) in 2014 with no fall season rebound. Initially, much of this decline was due to a single plot which had dropped to less than 50% cover by fall 2010 and has declined further to less than 20% in subsequent years. The other four plots remained in the 70 to 90% cover range (fall highs) for most of these years; however, three of those plots dropped likewise to 20% cover in fall 2014. As *Silvetia* has declined, bare rock has become more prevalent in these plots, as have crustose algae and the invasive species *Caulacanthus*, none of which appear in this fgure. Motile intertebrate counts within these plots show that *Cyanoplax* spp. chitons are common under the rockweed canopy. In the early years, these chitons exhibited seasonal variation in synchrony with *Silvetia* cover. Following the switch to once-per-year sampling, the spring abundance has proven reasonably stable despite declines of *Silvetia*. Hermit crab (*Pagurus* spp.) numbers were high and variable during the early years but then dropped to zero by 2004. Meanwhile turban snails (*Tegula funebralis*) displayed an opposite trend with their numbers growing in recent years, and limpets have likewise become more abundant (and also more variable) in recent years.

Rock ("Above Barnacles") plots were added to this site in the fall of 2008 to document any upward spread of intertidal species as a result of global climate change or other factors. These plots are expected to remain dominated by bare substrates unless barnacles or other species begin to encroach upon them. From their inception, a few barnacles have been recorded within these fve plots, most of which were present inside cracks and fssures within these plots. While there have been a few recruits, barnacles have yet to spread out onto open surfaces. Littorines have been increasingly common in these rock plots.

The mean cover of Surfgrass (*Phyllospadix* spp.) at Point Fermin has shown seasonal variation (lower in spring, higher in fall) with moderate fuctuations in cover between about 60-80% (fall highs). Over these years the extreme range of cover documented has been between about 20% (Spring 2000) and over 80% (Fall 2013). Algal species have also shown seasonal variation with *Egregia* cover generally following *Phyllospadix* cover (though with lower seasonal swings), and red algae and articulated corallines displaying the inverse pattern (cover increasing when *Phyllospadix* is lower).

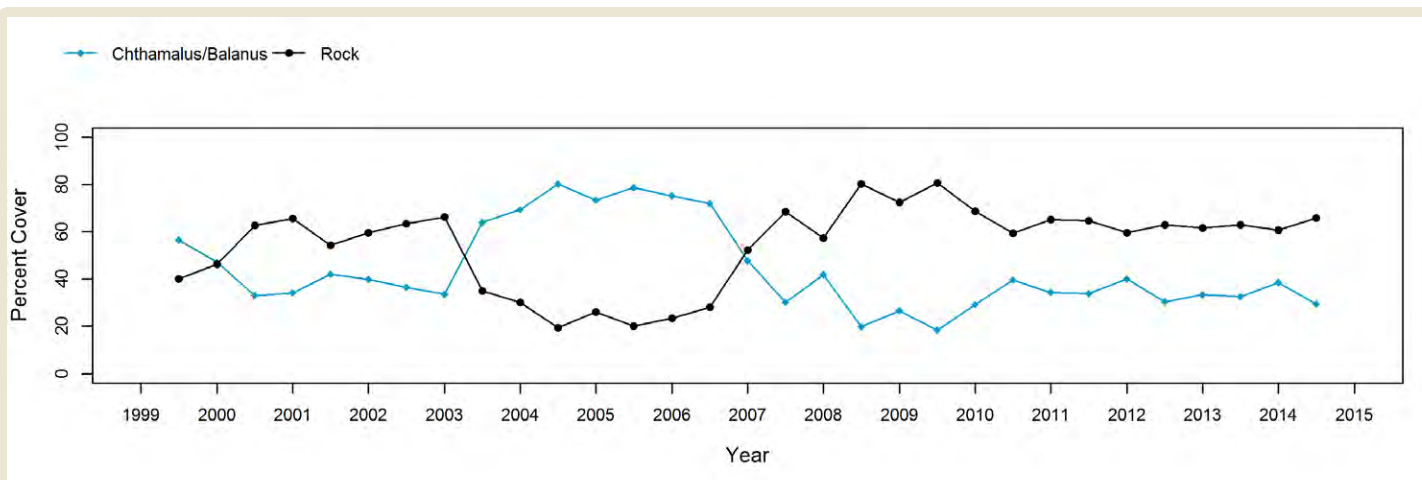
Sea star (*Pisaster ochraceus*) plots were added to this site in the spring of 2003 and consist of three large irregular plots surrounding an area of medium relief rock which includes several cracks and ledges. Seastars were common at this site when these plots were initiated, but declined steadily over the next two years such that just a few stars have been counted and measured each season since 2005. These plots are representative of the site as a whole. In recent seasons, sitewide searches turned up just a few additional seastars. The seastar wasting disease struck this site some time in advance of our fall 2013 sampling. There were local reports of diseased stars subtidally during that preceding summer, and the disease had struck the population of seastars at the Cabrillo Marine Aquarium. During our Fall 2013 sampling, no seastars could be found at the site, either in the fxed plots or in sitewide searches. Subsequent sampling events had yielded zero stars at the site through Fall 2014. The size frequency fgure indicates that the large number of seastars found during the frst sampling seasons, in part, may have been the result of a large recruitment pulse occurring sometime in the preceding years. Recruitment has been low since that point but has, along with potential migration in and out from the adjacent subtidal, helped to keep the numbers of seastars above zero at this site…up until the point where the seastar wasting disease arrived.

Photo Plots

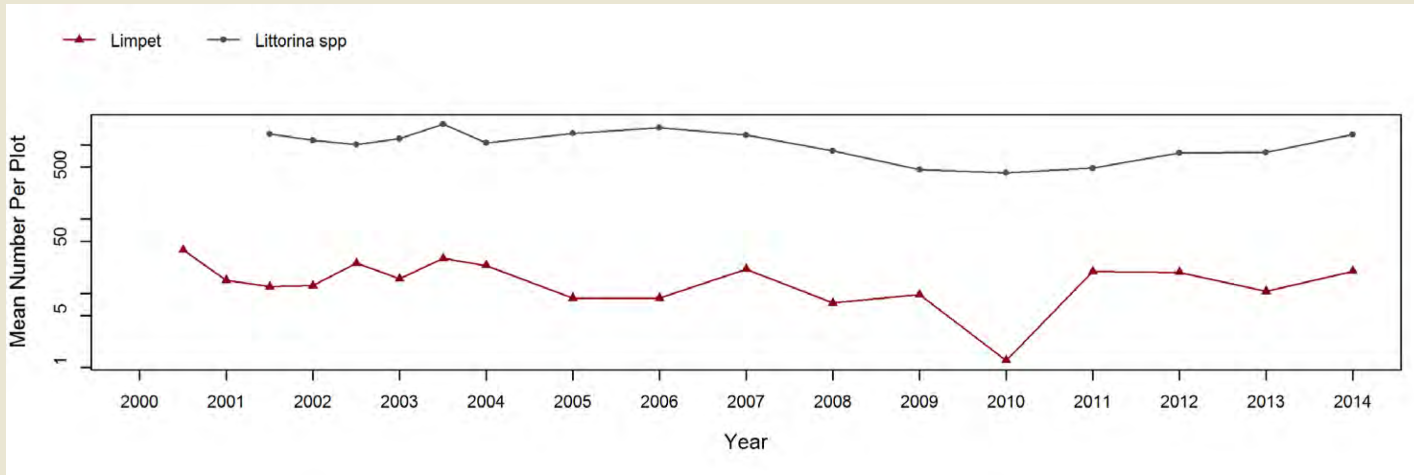
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

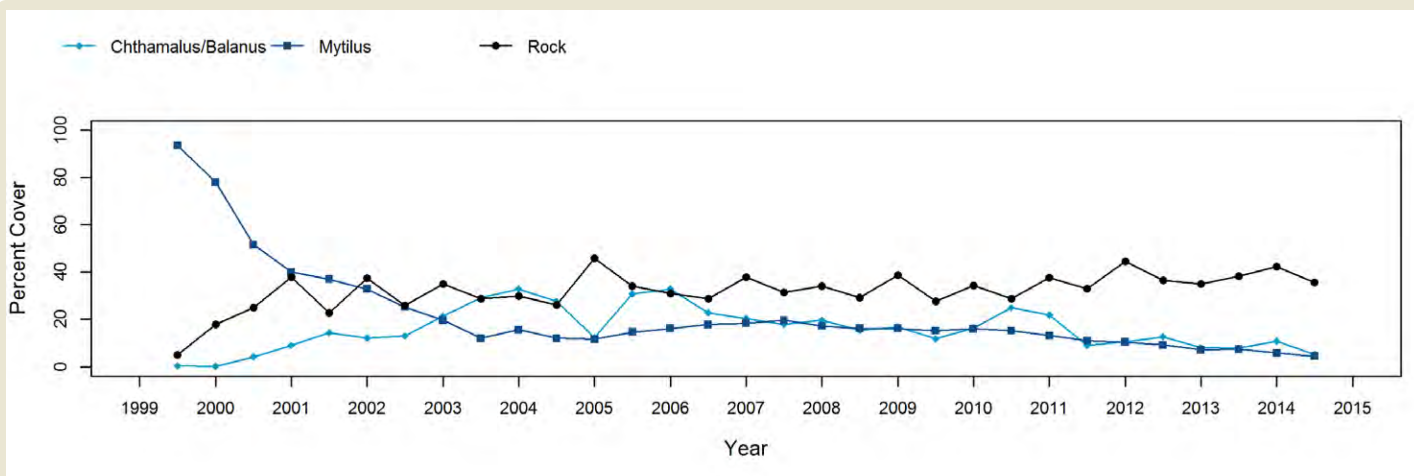
Chthamalus/Balanus (Acorn Barnacles) - percent cover



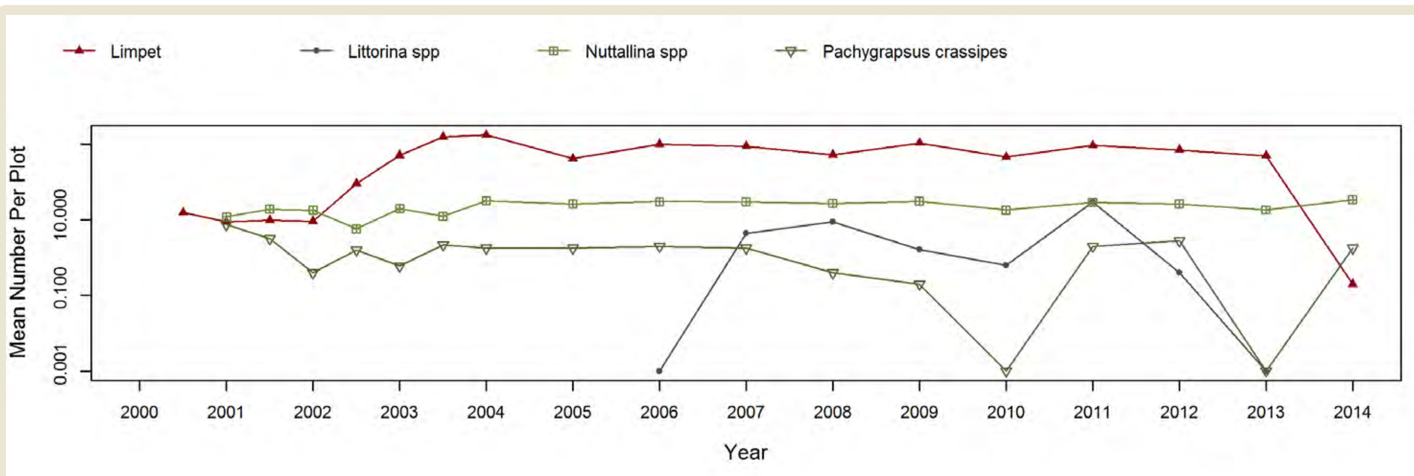
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



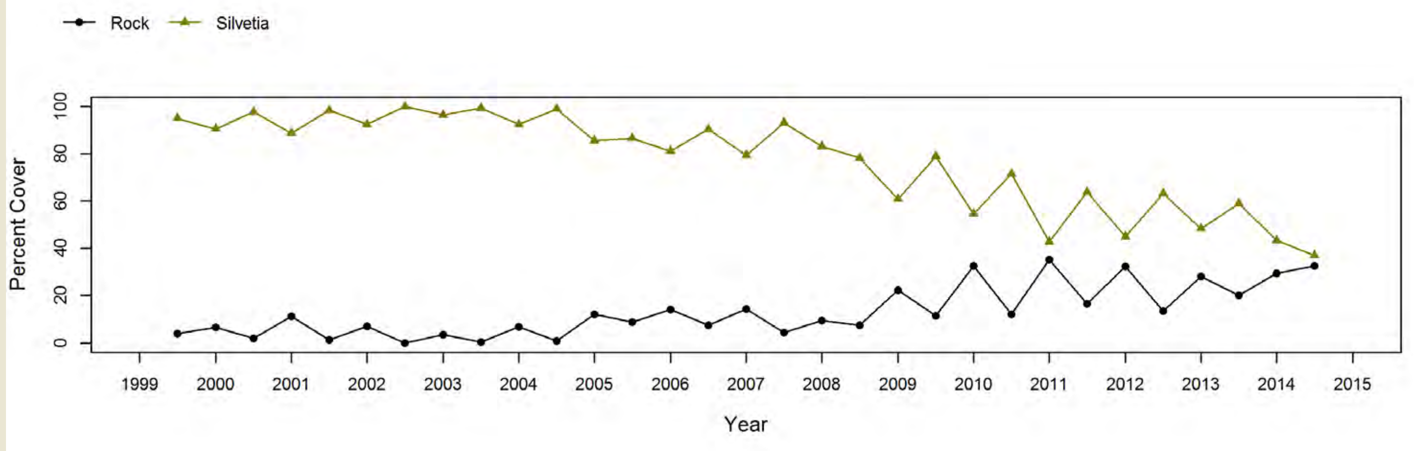
Mytilus (California Mussel) - percent cover



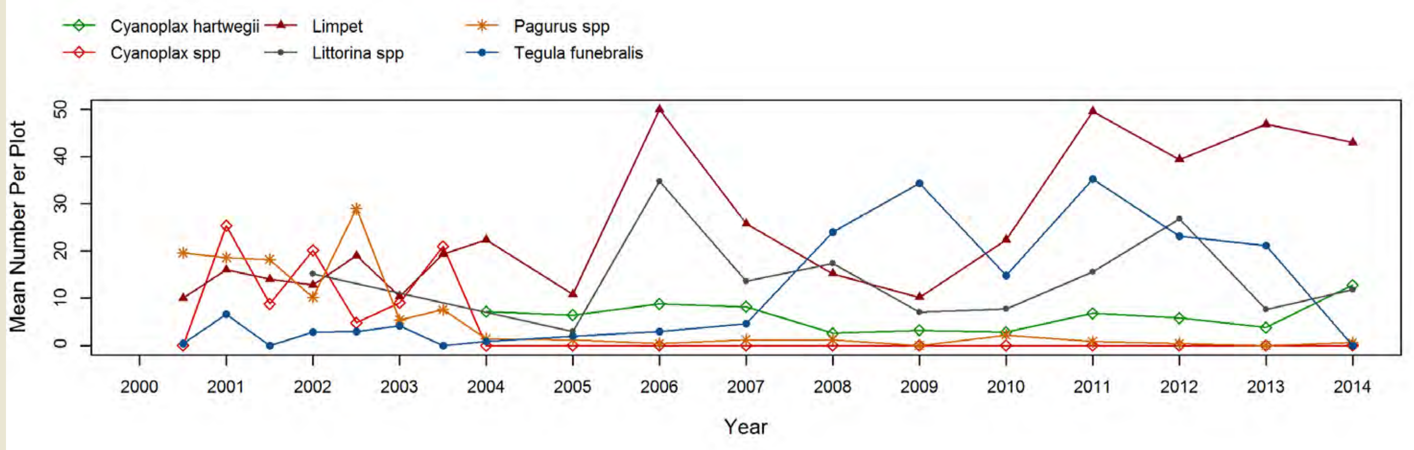
Mytilus (California Mussel) - motile invertebrate counts



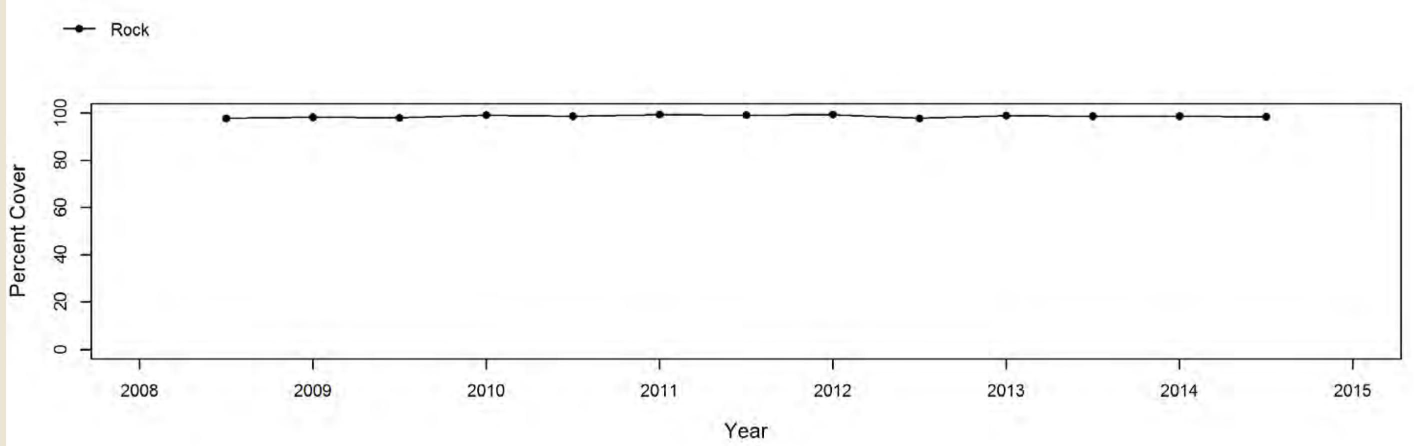
Silvetia (Golden Rockweed) - percent cover



Silvetia (Golden Rockweed) - motile invertebrate counts



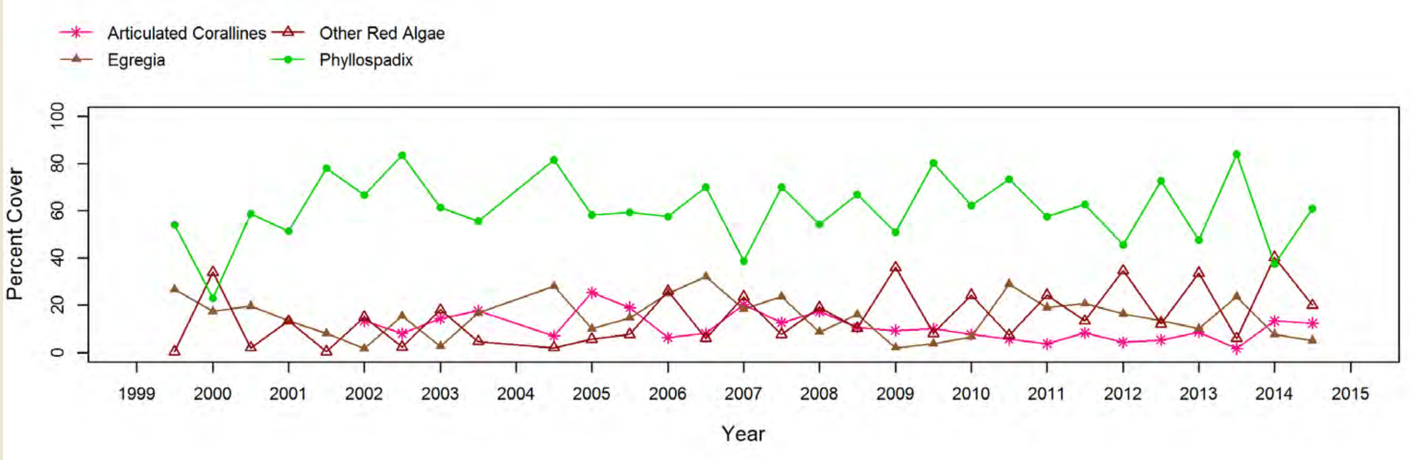
Rock (Above Barnacles)



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

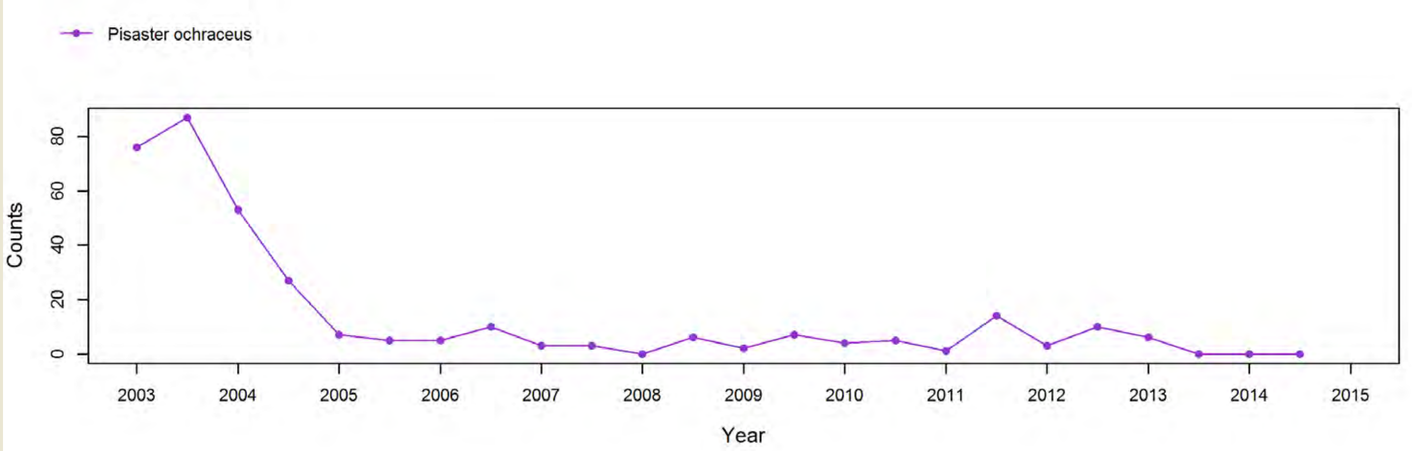
Phyllospadix (Surfgrass)



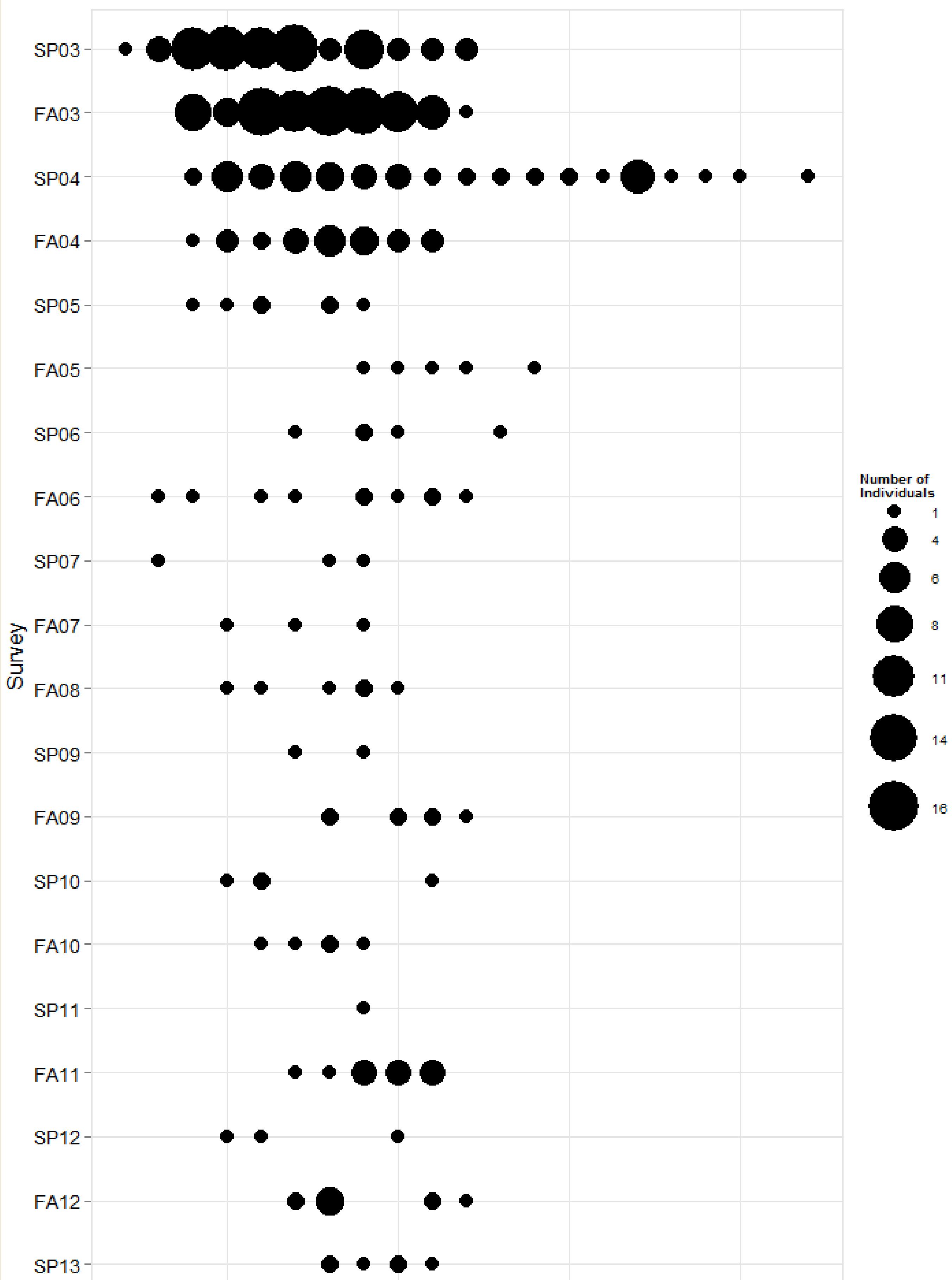
Species Counts and Sizes

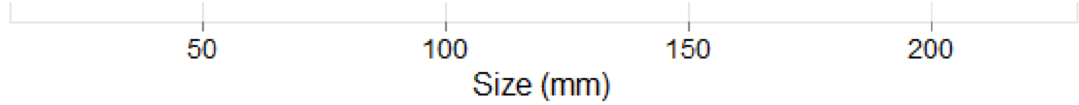
Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes





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Crystal Cove Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

From 1996-2006, average barnacle cover at Crystal Cove was generally high (50 to 80% cover) although abundance of barnacles fuctuated among sampling periods. For most plots, the majority of the area not covered by barnacles was simply bare (recorded as bare rock) aside from the occasional and short-lived appearance of small patches of algae such as the ephemeral sea lettuce *Ulva* and the red turf *Caulacanthus*. Mussels (*Mytilus* spp.) occasionally recruited into barnacle plots, but mussel abundance in these plots was generally low (less than 20% cover on average) and occurred mostly in a single plot. In 2006, barnacle cover dropped sharply across all plots, resulting in an increase in recorded coverage of bare rock. Since this drop, barnacle cover has increased slightly but remains variable. Barnacle plots have consistently contained extremely high numbers of limpets and periwinkles (*Littorina* spp.). Generally, higher numbers of *Littorina* are recorded in fall than in spring sampling periods.

From 1996 to 2006, mussel cover in Crystal Cove mussel plots remained relatively high (above 60%) with the notable exception of a large drop in cover associated with the 1997-1998 El Niño. During the El Niño, several different species moved in to fll the space opened up by this decline in mussel cover, including the annelid *Phragmatopoma*, the ephemeral alga *Ulva*, and articulated coralline algae; yet cover of these species declined over the next two years as mussels recovered to original cover levels. Following this recovery, mussel cover remained relatively high until 2007 when a moderate decline was observed following a storm with extraordinarily large waves. The effect of the storm was variable in space: some plots lost only a small amount of mussel cover but one plot was completely denuded of all mussels. Bare space created by the 2007 storm was flled quickly by a variety of algae including articulated corallines and non-calcifed red algae. From 2007-2011 overall mussel cover varied between approximately 40 and 60% cover, and cover in individual plots was dynamic. In the plot most heavily affected by the storm, mussel cover has remained low in subsequent years of monitoring; and in other plots, minor disturbances have caused smaller occasional reductions in mussel cover. Mussel cover began to increase in late 2011, reaching an average of ~80% cover in 2012. In Spring 2013, following stormy weather, mussel abundances were low in two plots, causing the average abundance to dip below 50%; and this overall decline continued into Fall 2013 when no mussels were recorded in any of the plots (although mussels do occur in low abundances elsewhere at the site). As with past drops in mussel cover, a variety of algae, including articulated corallines and non-coralline red algae (e.g *Centrocerus* and *Laurencia*) increased in abundance following mussel decline. Mobile animals in mussel plots consisted primarily of limpets in the genus *Lottia*, whose numbers were highly variable over time but have been low since Fall 2011.

Rockweeds show variation in cover within years with a pattern of higher cover in fall than in spring. Across years, there appeared to be a slight and slow decline in rockweed cover from 2004 – 2009, followed by a slight increase and relative stabilization with average cover exceeding 70% since Fall 2010. Space created by the reduction in *Silvetia* cover was flled by a variety of species including mussels and the red turf alga *Caulacanthus*, though in general these other species did not persist long in *Silvetia* plots. Several types of mobile invertebrates, including hermit crabs, chitons, and turban snails, were regularly found in low abundance in the rockweed plots. Limpets (*Lottia* spp) were the most abundant group of mobile animals in these plots; although numbers varied greatly over time, limpet counts were typically at least fve times higher than counts of any other taxon.

Surfgrass (*Phyllospadix*) cover varied within years (with higher cover in fall than in spring) and among years. Despite these temporal fuctuations, surfgrass cover remained generally high at this site (typically above 50% cover). While the feather boa kelp *Egregia* was the only other species with a notable contribution to cover in surfgrass habitat, several species of red algae (e.g. *Pterocladiella* and *Plocamium*) have been consistently present in this zone in low abundance. This habitat is also heavily infuenced by sand movement: sand cover typically fuctuated between 3 and 22 %.

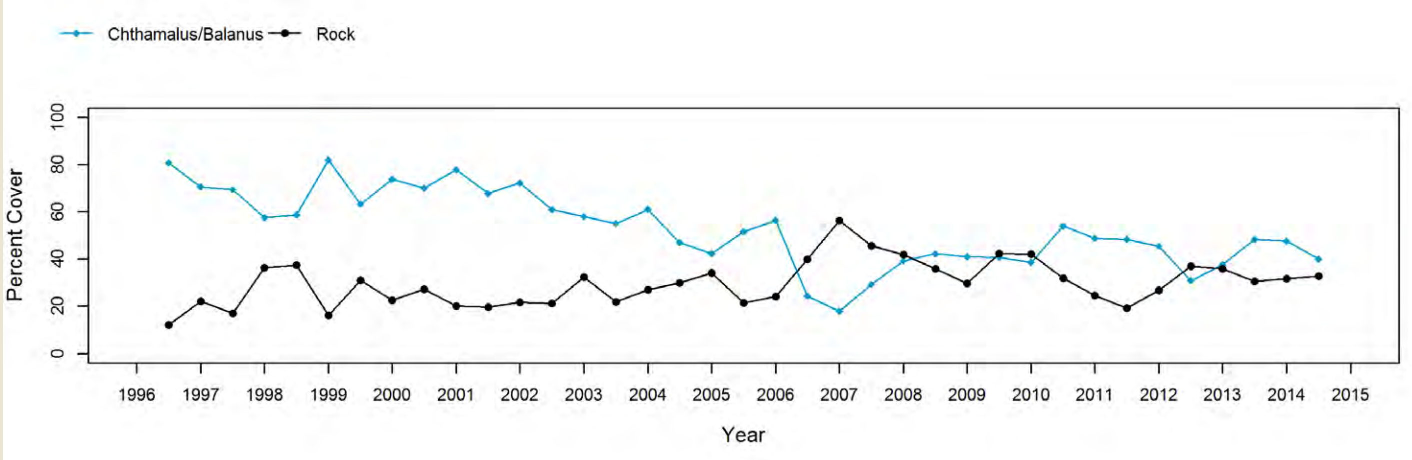
Sea star (*Pisaster*) counts at this site varied greatly over the sampling period. From 1997 to 2008, site-wide *Pisaster* counts were generally low (fewer than 50 individuals) with except for peaks in abundance in Fall 1999 and 2007. From 2008 to 2011, *Pisaster* counts were generally higher than in the previous decade, with more than 75 individuals per survey. Site-wide seastar counts were extremely high in 2013, exceeding 175 individuals in Fall of that year, before plummeting to a total of 11 observed individuals in Spring 2014. Sea Star Wasting Syndrome, which was frst observed at this site on November 4, 2013 (after the Fall 2013 survey), is a likely contributor to the sharp decline. *Pisaster* were still present at low abundance at the site in Fall 2014. Sea star size measurements were initiated in Spring 2012. Most individuals fall in the 100 to 150 mm size class. Larger individuals (>150 mm) were present in low numbers in 2012 but were less abundant towards the end of 2013.

Photo Plots

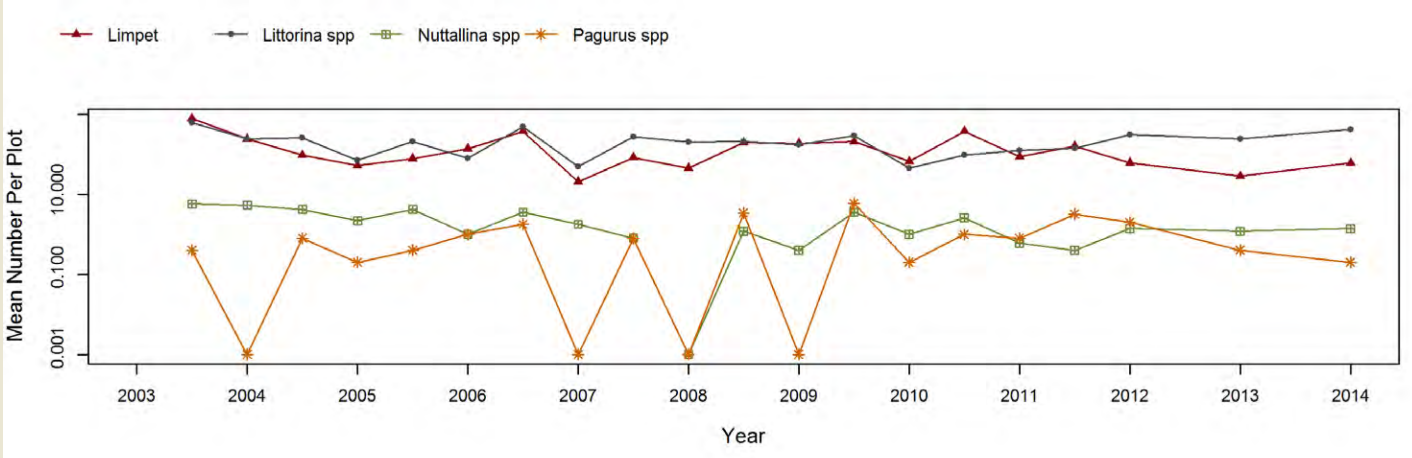
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

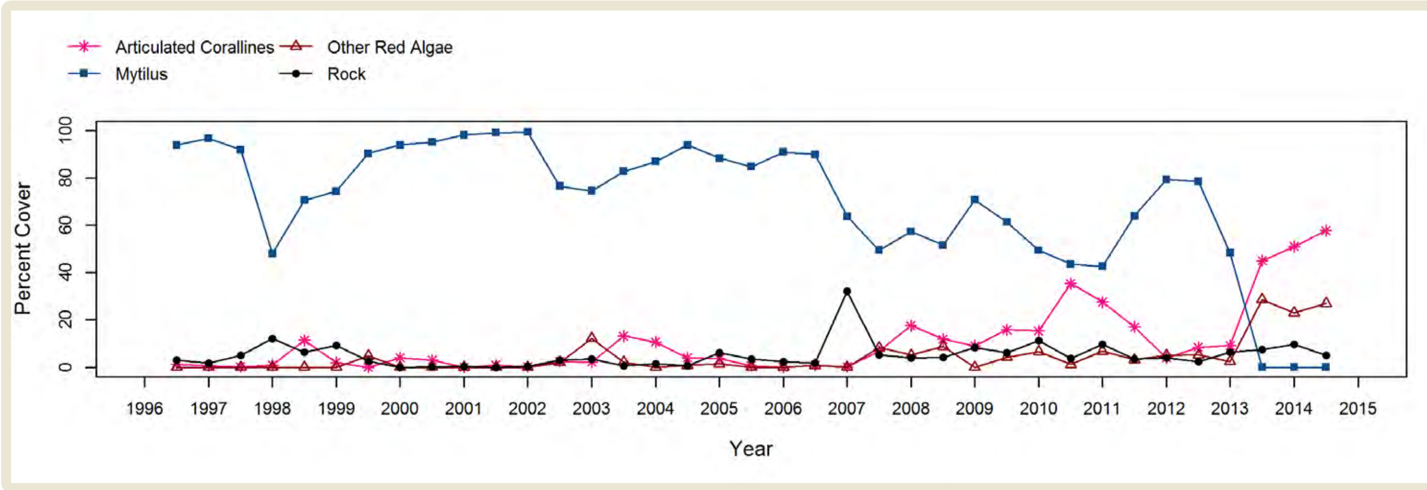
Chthamalus/Balanus (Acorn Barnacles) - percent cover



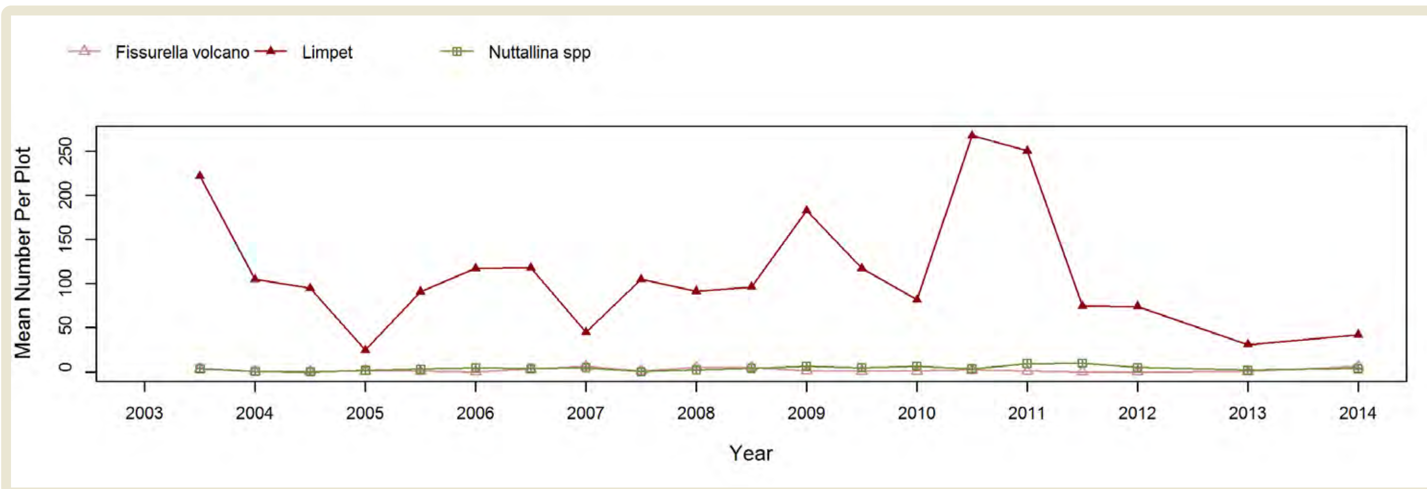
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



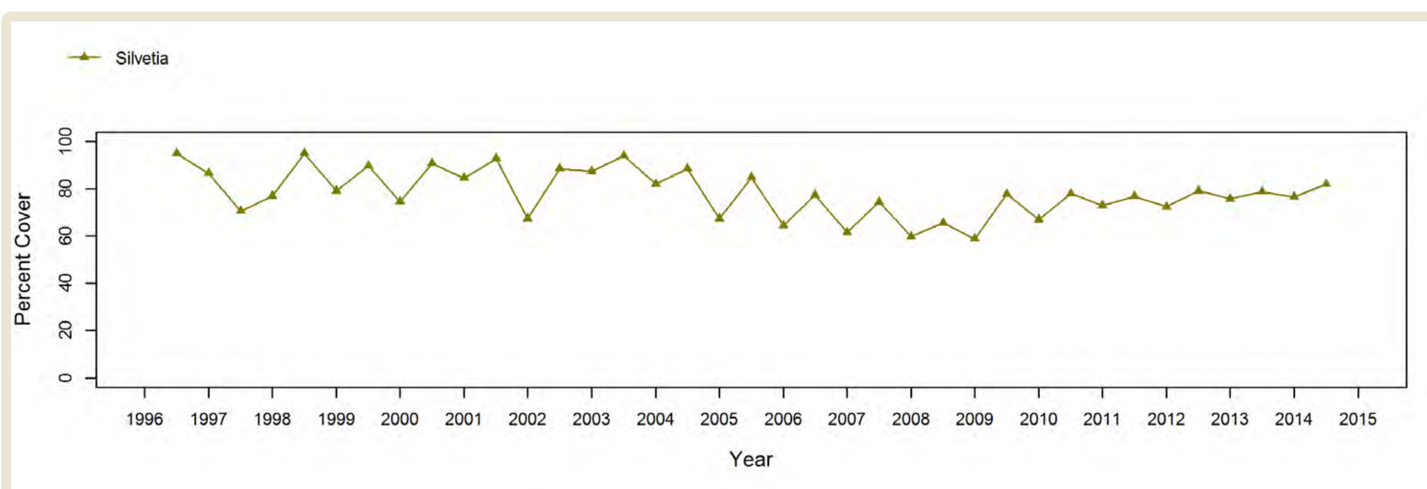
Mytilus (California Mussel) - percent cover



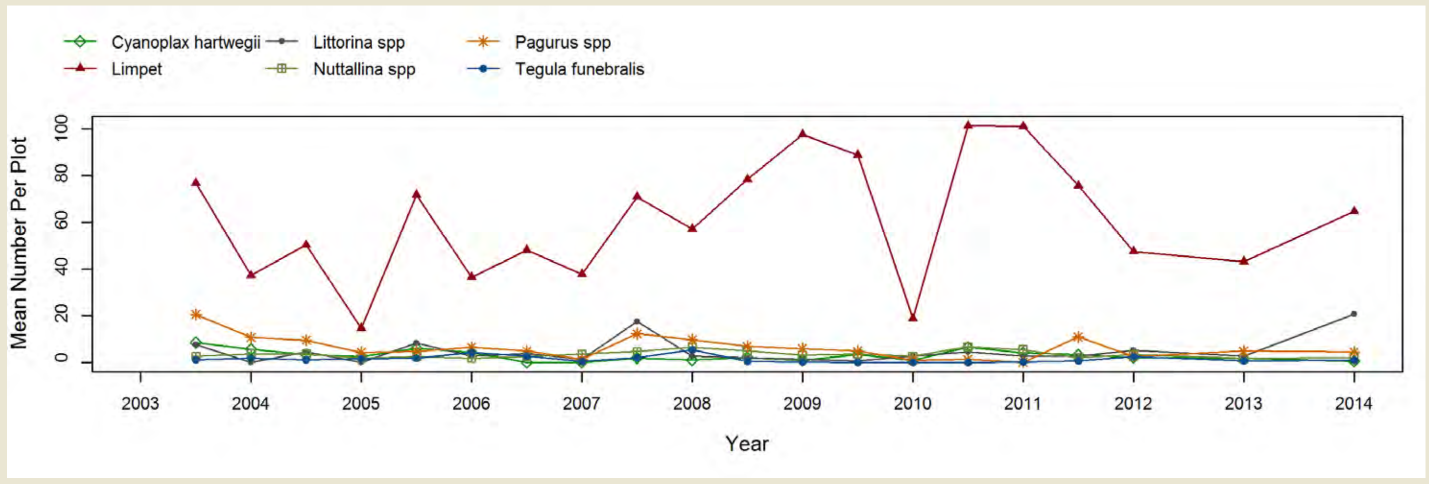
Mytilus (California Mussel) - motile invertebrate counts



Silvetia (Golden Rockweed) - percent cover



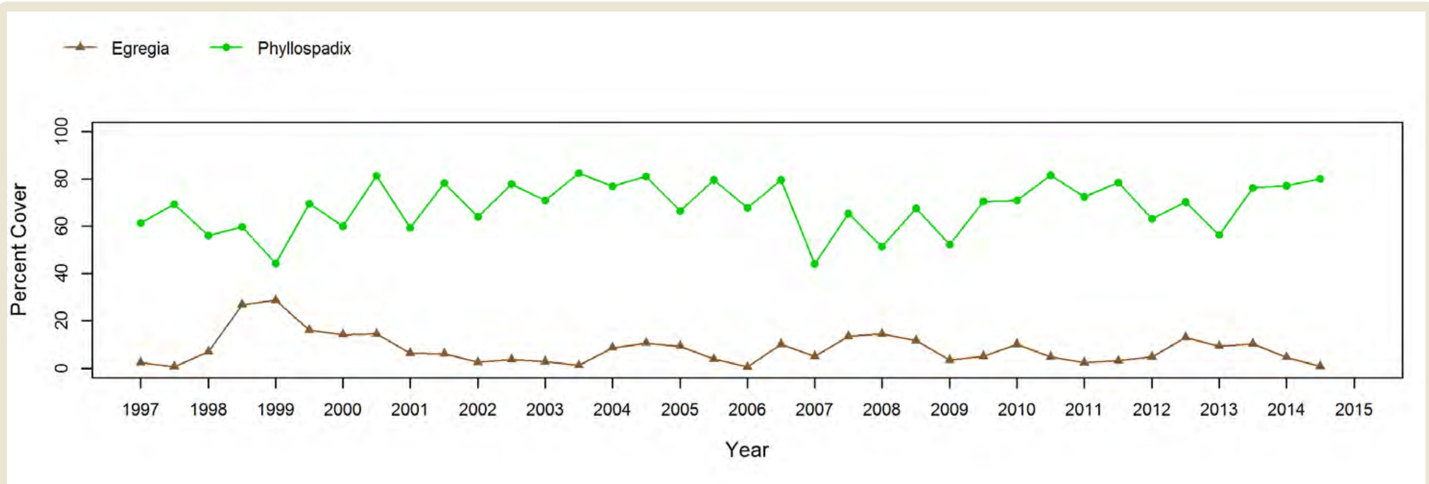
Silvetia (Golden Rockweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

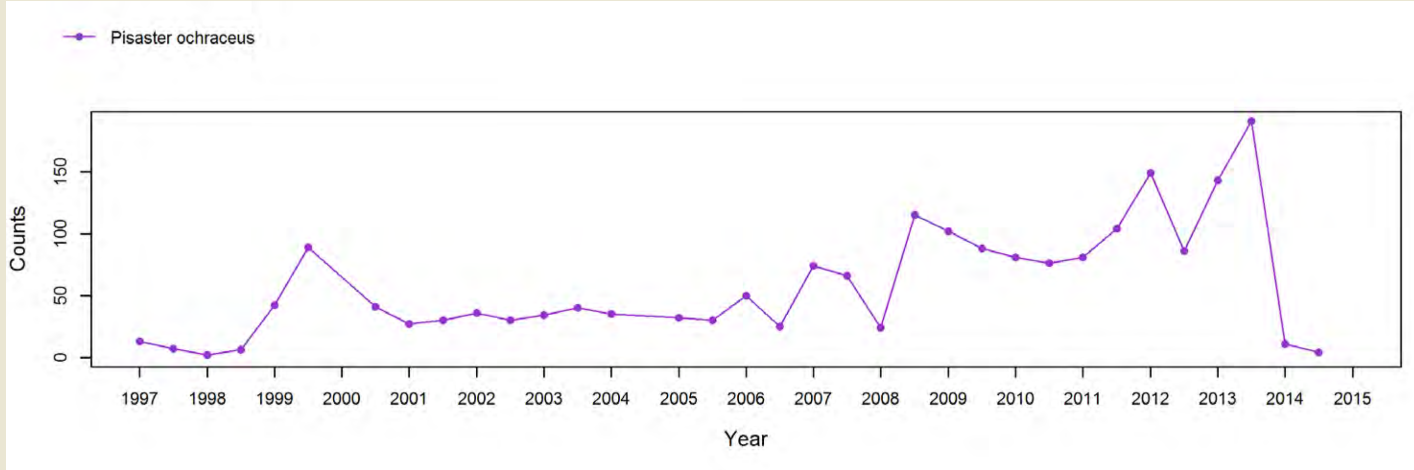
Phyllospadix (Surfgrass)



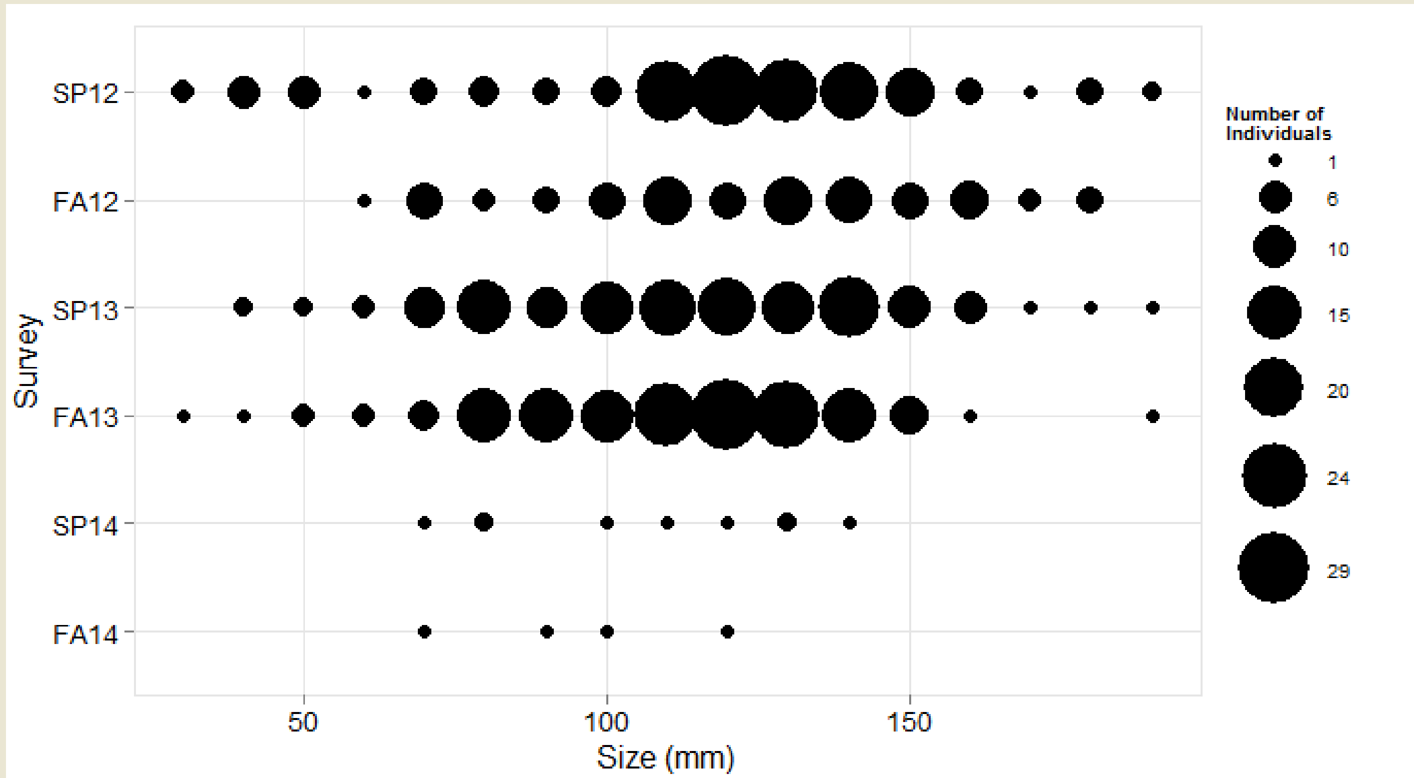
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster ochraceus (Ochre Star)



Pisaster ochraceus (Ochre Star) - sizes



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Shaws Cove Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle cover at Shaws Cove has exhibited a general decline since initiation of monitoring in 1996. From 1996 to 1999, barnacle cover was high (above 70% of plot area, on average). From 2000 – 2007, barnacle cover was slightly lower, with cover rarely exceeding 70% of plot area on average. From 2007 – 2014, cover in barnacle plots consisted of approximately half bare rock and half barnacles. In these plots, most of the area not covered by barnacles is bare rock. Other species do occur in the plots at low abundance; for example, non-coralline crusts typically average less than 2% cover in these plots with a maximum of close to 7% average cover in Fall 2009. In fall of 1998, the red alga *Endocladia* encroached into barnacle plots with an average cover of ~2.5%; in subsequent seasons this alga was occasionally noted in barnacle plots but average cover never exceeded 1% . On rare occasions, recruitment of the brown alga *Hesperophycus* was observed but individuals typically died off before the next sampling period. Motile invertebrate surveys in barnacle plots recorded high numbers of *Littorina* spp. and variable numbers of small limpets.

As in other sites in this region, mussel cover at Shaws Cove remained relatively static from Fall 1996 through Fall 1997, but cover declined during the 1997-1998 El Niño. During this period of lowered mussel cover, a moderate amount of bare rock cover was recorded in the plots, along with small abundances of barnacles, crustose corallines, articulated corallines, and non-coralline crusts. From 1998 to 2006, mussel cover steadily increased. The largest increase in cover was observed in fall 2003 (increase of 20% cover on average from the previous sampling period) as gaps within the mussel plots were flled with adult mussels (recruitment did not appear to play a role). In spring 2007, following a storm accompanied by large waves, we observed approximately 35% loss in average cover at the site, but the patchy nature of the disturbance resulted in 2 plots being almost completely denuded of mussels while other plots remained undisturbed. In disturbed plots, there was an increase in cover of the ephemeral alga *Ulva* in fall 2007 followed by a steady increase of barnacles which replaced *Ulva* in 2008 and 2009. After the drop in mussel cover in 2007, mean cover remained relatively constant for three years before increasing again in 2010. Since Fall 2012, mussel cover declined at the site, dropping below 50% average cover for the frst time since sampling was started at this location. Although the beginning of the mussel decline occurred during a period of increased sea star (*Pisaster*) abundance at the location, the decline in mussel cover continued following a drop in sea star numbers. The area previously occupied by mussels in this recent decline most commonly remained as bare rock, while low abundances of barnacles (*Chthamalus*, *Balanus*, and *Tetraclita*) and articulated corallines were found in some plots. Motile invertebrate counts were dominated by limpets, showing a seasonal pattern of higher counts in the fall sampling period. This pattern is not evident starting in 2012 after which sampling only occurred during the spring sampling periods.

Rockweeds at Shaws Cove exhibited typical variations in cover within and across years with a pattern of higher cover in the fall than in the spring sampling periods. Starting in 2004 there was a minor but steady decline in average rockweed cover, driven in part by a sharp decline in cover in a single plot in which rockweeds were completely absent by Fall 2008. Cover remained low in that plot through 2010, and as cover in that plot increased average abundance of *Silvetia* in the monitoring plots also increased to levels similar to those recorded pre-2004, exceeding 70% of plot area after Fall 2011. When *Silvetia* cover was low in the plots, most of the plot area was bare rock, although we also observed low cover of crustose algae, the red alga *Caulacanthus*, articulated corallines, and mussels Motile invertebrate counts were dominated by *Littorina* spp. and limpets that have remained mostly consistent over time. Chitons, turban snails, and hermit crabs are also consistently found in plots, with variable but low numbers over the years.

Abundance of the red alga *Endocladia* (turfweed) has varied greatly (from an average of 7 to 52% cover) at Shaws Cove since initiation of monitoring in 1996. The period with the highest cover occurred between spring 2001 and spring 2003 with cover values between 40 and 50%. Large losses (~20% cover) occurred in fall 2000, fall 2003, and fall 2007. Bleaching seems to have caused the largest loss of cover in 2003 as observers noted damaged thalli, and large portions of the turfweed were gone by the next sampling period. In fall 2007, cover reached a low of 7%, and after a moderate increase in cover from 2008 – 2012, cover declined again in Spring 2012 and remained low (under 20% of plot area on average) through 2014. In addition to *Endocladia*, bare rock and barnacles contributed to overall cover in these plots. Like *Endocladia*, recorded cover of bare rock and barnacles was highly variable over the years. Barnacle cover, on average, hovered around 30% with peaks above 50% cover in fall 1997, spring 2006, and Spring. Rockweed cover in *Endocladia* plots was relatively low from 1996 to spring 2003 but increased from fall 2003 to fall 2006, reaching a peak of 20% in fall 2004. Most of this change was driven by a dramatic increase in cover in two plots in 2004 (which were located adjacent to the rockweed bed). Rockweed cover dropped again and has not exceeded 3% of plot area on average since 2007. Motile invertebrate counts were dominated by *Littorina* spp. and limpets with numbers remaining relatively stable over the years.

Rock plots were established at this site in Fall 2011 in areas above the barnacle zone. In general cover of these plots consisted mostly of bare rock. Motile invertebrate counts within rock plots consisted primary of moderately high numbers of *Littorina* snails.

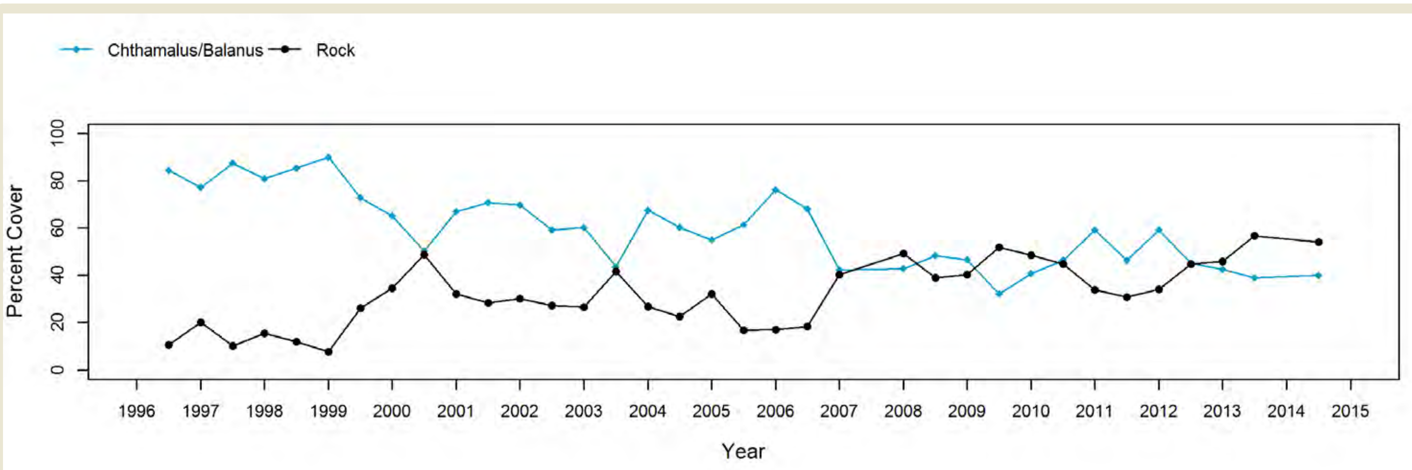
Sea Star (*Pisaster*) counts are taken over the entire site at Shaws Cove. Sea star numbers varied greatly over the sampling period. For most of the sampling period, fewer than 60 individuals were counted in each survey, with occasional peaks of high abundance (in 2004, 2006, and 2008-2009) of approximately 100 individuals per survey. Increasing numbers of sea stars were encountered at the site between 2010 and 2012, with more dramatic increases noted in late 2012 and early 2013. In Fall 2013, abundances peaked at approximately 400 individuals. In this Fall 2013 survey, no signs of sea star wasting syndrome were noted, although symptoms were observed in seastars at nearby Orange County sites a few days after the Shaws Cove survey had been completed. In Spring 2014, no *Pisaster* were observed at this site; Sea Star Wasting Syndrome is a likely contributor to this sharp decline. Sea star sizes were consistently measured starting in Spring 2012. Most individuals fell in the 80-130 mm size class.

Photo Plots

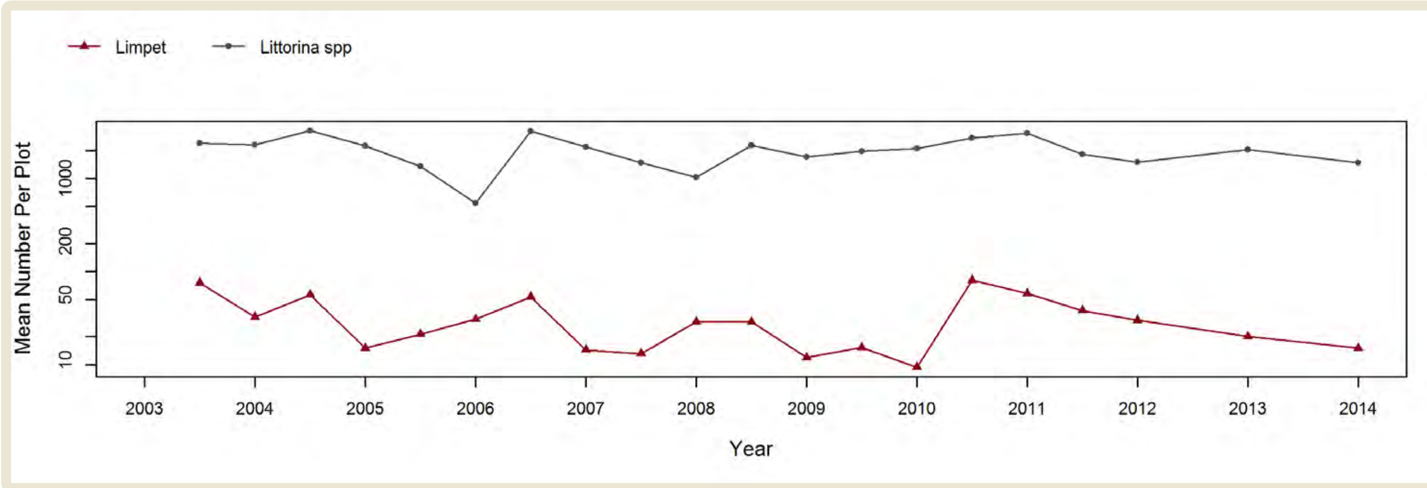
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

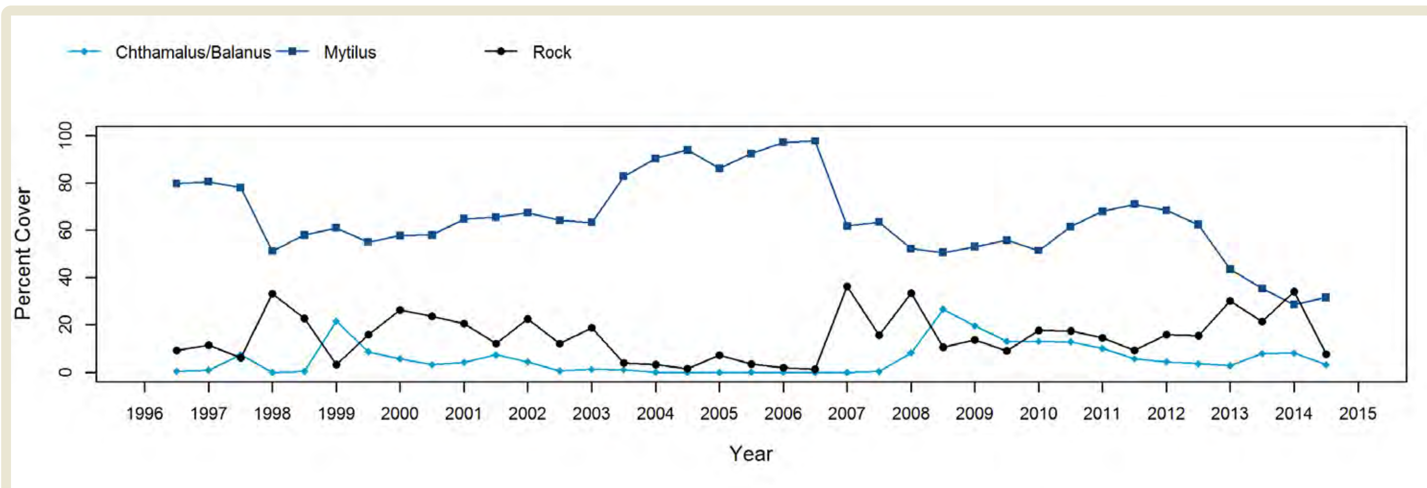
Chthamalus/Balanus (Acorn Barnacles) - percent cover



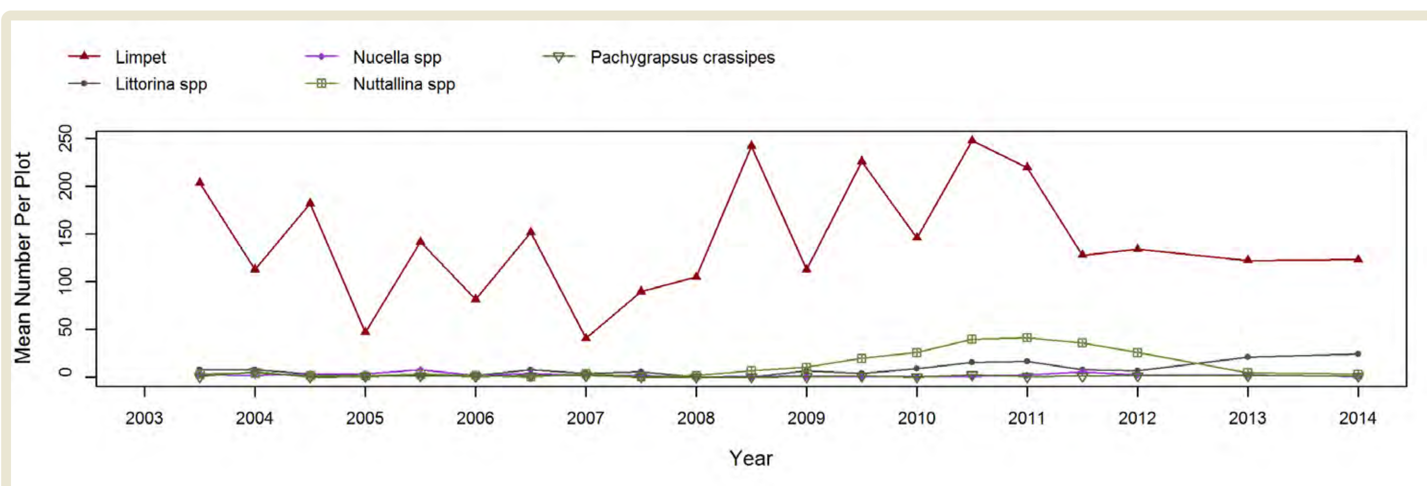
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



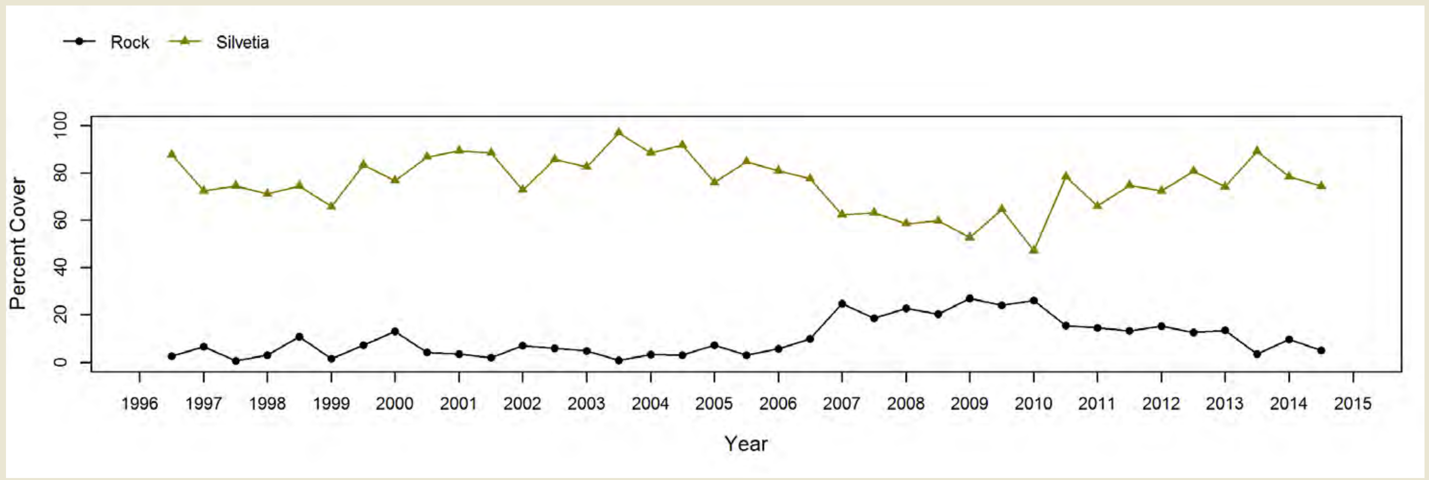
Mytilus (California Mussel) - percent cover



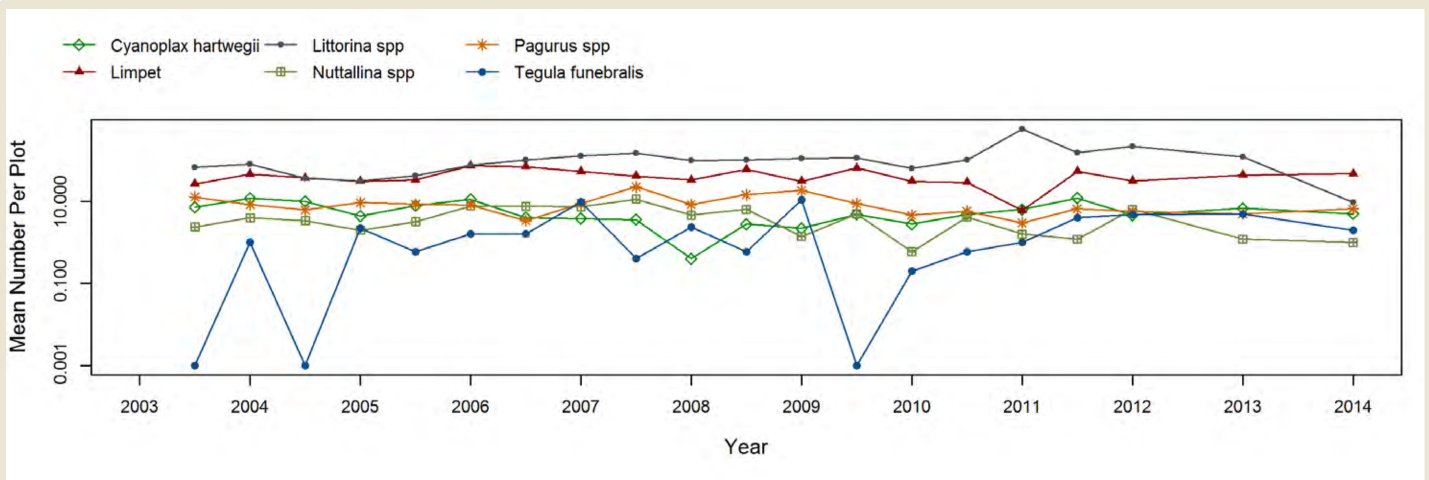
Mytilus (California Mussel) - motile invertebrate counts



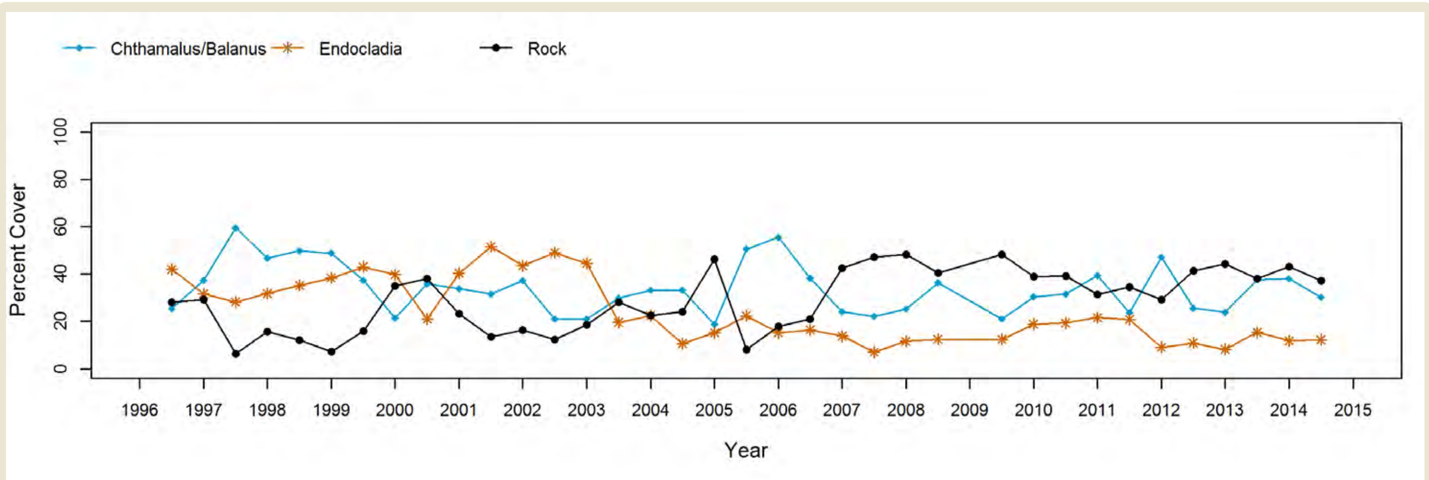
Silvetia (Golden Rockweed) - percent cover



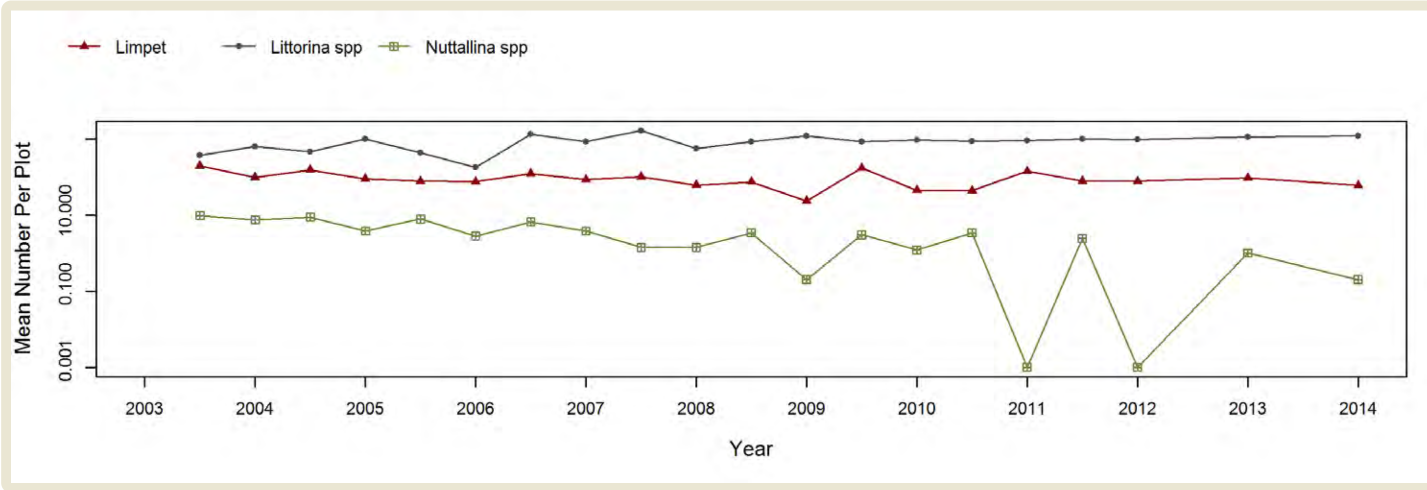
Silvetia (Golden Rockweed) - motile invertebrate counts



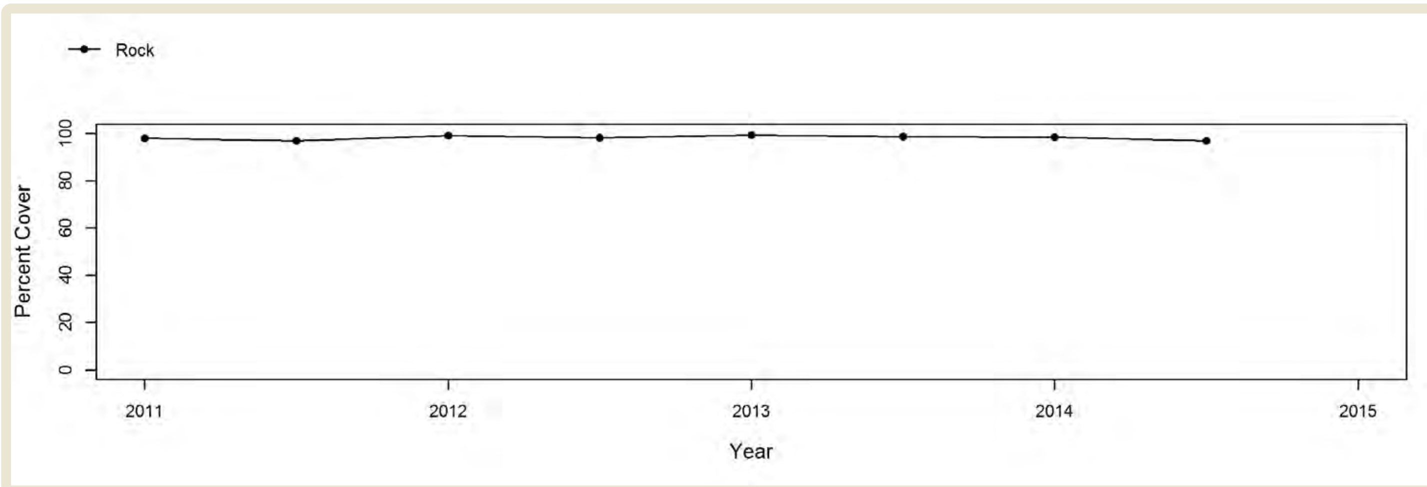
Endocladia (Turfweed) - percent cover



Endocladia (Turfweed) - motile invertebrate counts



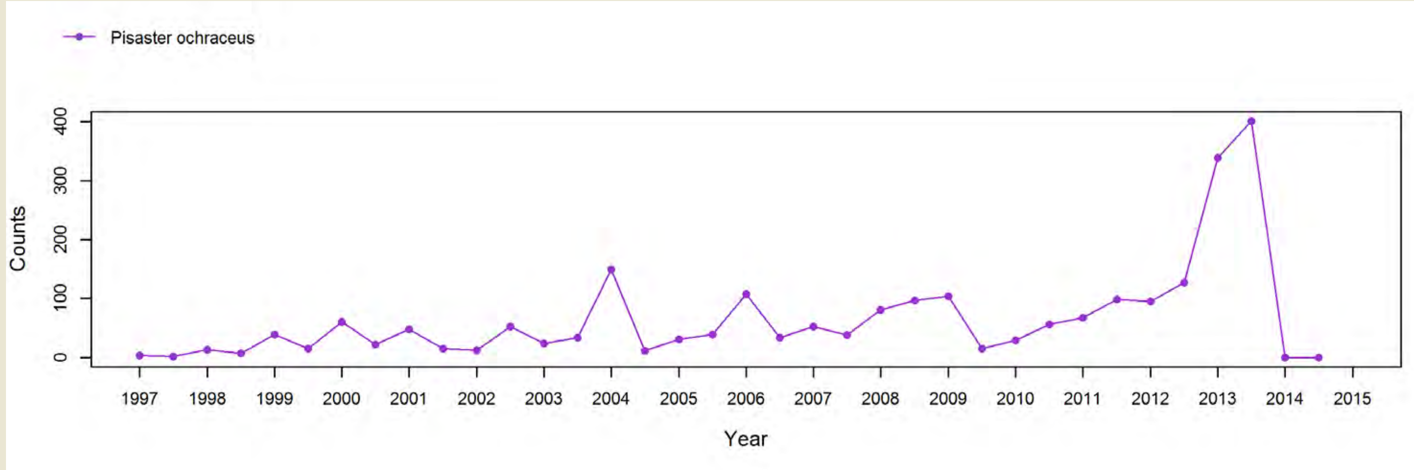
Rock (Above Barnacles)



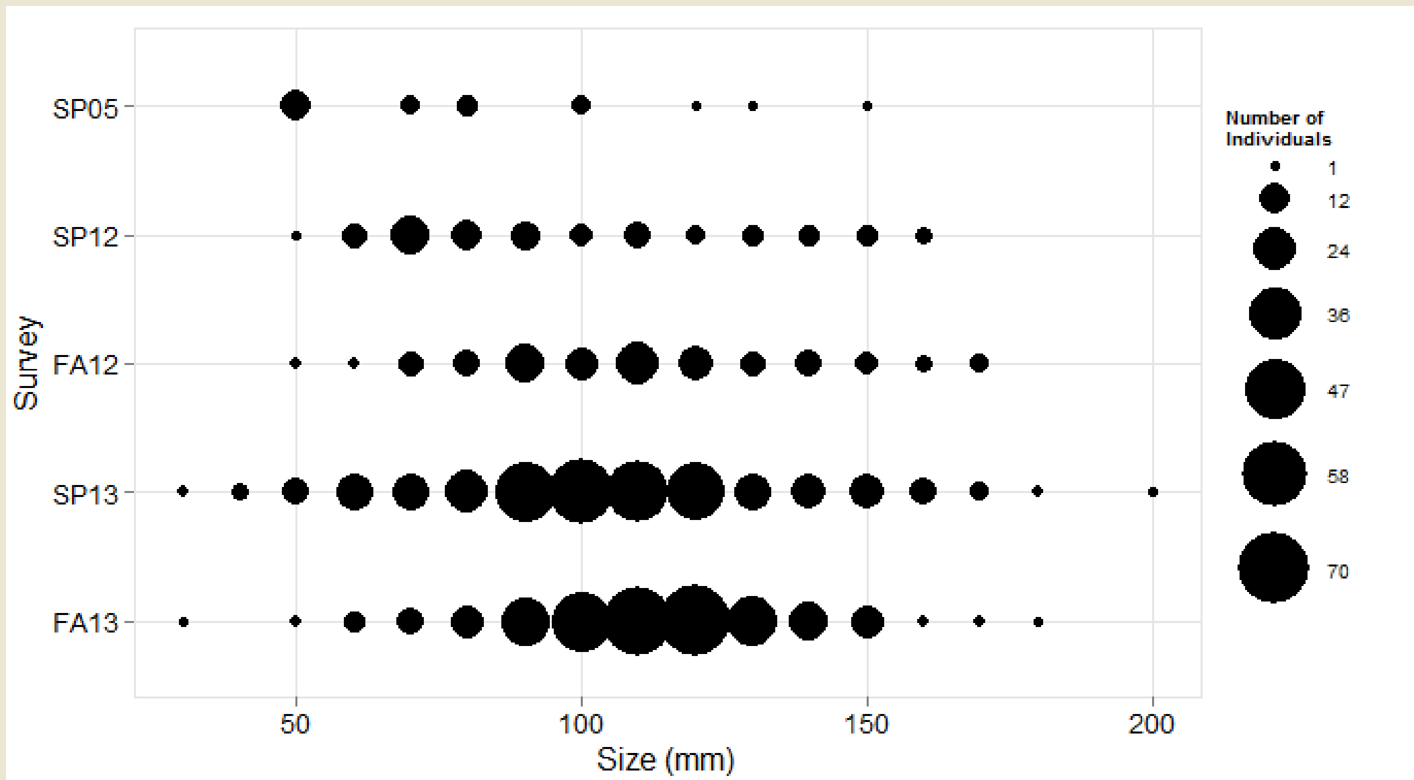
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster ochraceus (Ochre Star) - counts



Pisaster ochraceus (Ochre Star) - sizes



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Treasure Island Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle cover at Treasure Island was variable but exhibited a general decline over the course of the monitoring period, particularly between 1999 and 2003. Following low cover values of ~40% in 2003, there was a recovery period in which barnacles increased to ~80% cover on average, but subsequently abundance dropped below an average of 30% cover by Fall 2013. During periods of low barnacle cover, there were concurrent increases in the cover of bare rock. From 2009-2012, cover consisted of approximately half bare rock and half barnacles. Cover of the ephemeral alga *Ulva* was very low in all samples from 1996-2005. However, in two plots, there were large inundations of *Ulva* in fall 2005, spring 2006, and spring 2007 with additional increases in *Ulva* in one plot in spring 2008 and spring 2010. Non-coralline crusts exhibited two peaks in cover in spring 2003 (17%) and spring 2008 (9%), reducing bare rock cover during those periods. *Littorina* spp. counts in barnacle plots are extremely high with only occasional limpets found during certain sampling seasons.

Mussel cover at this site was relatively low at initiation of the monitoring in 1996 and decreased during subsequent sampling into the 1997-1998 El Niño. Cover remained low through 2002 but recovered to moderate levels in 2003 – 2004 with an increase of 40% during that year. Unlike the other sites in the region, the severe 2007 storm only resulted in a 10% loss of mussel cover in monitored plots, although mussel loss did occur at this site in the lower intertidal zone (below the area of the fxed photoplots). Mussel cover increased again in 2011 (exceeding 75% of plots on average) but since 2012, cover has declined to levels similar to the lowest levels observed since 1998. Bare rock cover was often high during periods of low mussel cover, with exception of seasons when barnacle cover increased, such as in fall 1999 and spring 2002. Other taxa found in the mussel plots included crustose corallines, *Tetraclita*, and non-coralline crusts but cover of these groups was highly temporally variable. Limpet counts in mussel plots varied greatly over time with peaks in 2004 and 2009, while other motile invertebrates were relatively low in numbers.

Rockweed cover showed seasonal fuctuations typical of this region with higher cover in the fall than in spring sampling periods. Rockweeds exhibited highly variable cover over time with a general pattern of low cover from 2005 - 2010. The lowest cover (~38%) occurred in spring 2006. At this time, barnacle cover reached its peak (~40%); aside from this high value, barnacles generally covered 5-10% of the surface in rockweed plots (on average). Cover of bare rock was highly variable, reaching peaks (20-25%) in 1999 and between 2007 and 2010. Mussel cover was very low in rockweed plots from 1996 to 2003 but increased to 4-9% cover after 2004. *Hesperophycus* was absent from 1996 to 2002, but abundance increased for a short period in 2003 with a peak of 8% cover in spring; this increase was short-lived, as it was followed by a die off in fall, and *Hesperphycus* cover has since remained low through 2014. Articulated corallines, crustose corallines, non-coralline crusts, other red algae, and *Ulva* were also common in *Silvetia* plots but highly variable in cover over time. Motile invertebrate counts were dominated by *Littorina* spp. and limpets that exhibited high variability over the years. *Littorina* abundances were low in 2012 and 2013. Chitons, the predatory snail *Nucella*, and hermit crabs have been consistently found in low numbers.

Rock plots were established at this site in Spring 2011 in areas above the barnacle zone. These plots are predominantly bare rock, and average cover of rock has remained high (above 80%) since their establishment. A heavy infux of sand covered one plot (100% cover of sand) on two occasions (Fall 2011 and Fall 2012), resulting in an overall lower average cover of rock in the sampling plots on these two sampling dates. Motile invertebrate counts within rock plots consisted primary of moderately high numbers of *Littorina* snails.

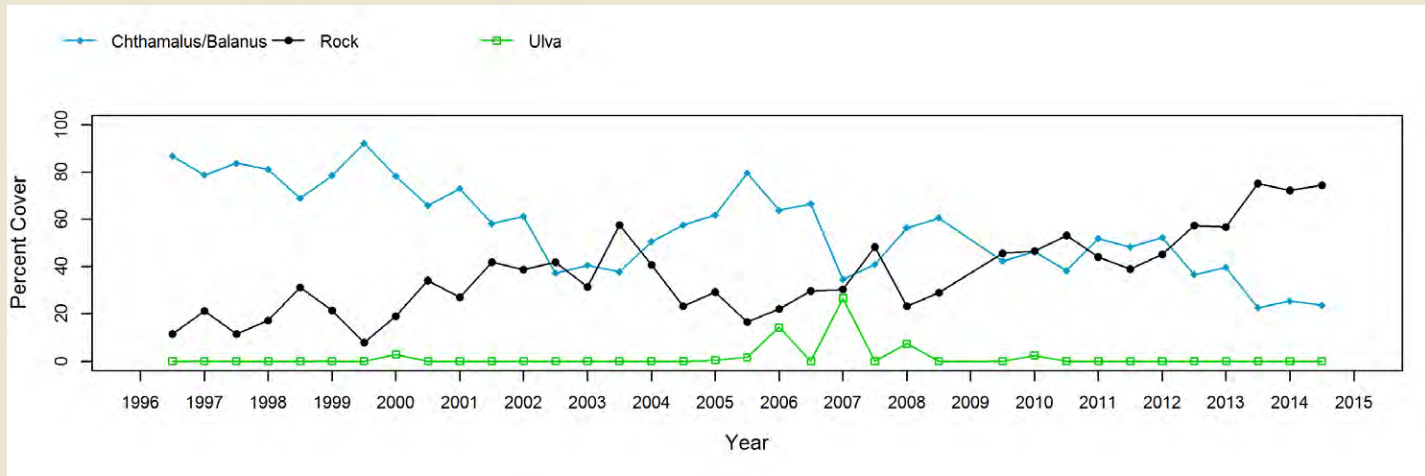
Site-wide sea star (*Pisaster*) counts, which were low from 1996 to 2004, increased dramatically in 2006 when over 150 individuals were observed at the site. After this 2006 peak, sea star abundance varied among sampling periods but did not exceed 100 individuals per survey again until Fall 2013. As with other Orange County sites, a large increase in sea star abundance was observed in Fall 2013. Signs of sea star wasting syndrome were noted in a few individuals at this site during the Fall 2013 *Pisaster* survey. In Spring 2014, no *Pisaster* were found at this location; Sea Star Wasting Syndrome is a likely factor in this decline. Sea star sizes were consistently measured starting in Spring 2012. Most individuals fell in the 100-150 mm size class.

Photo Plots

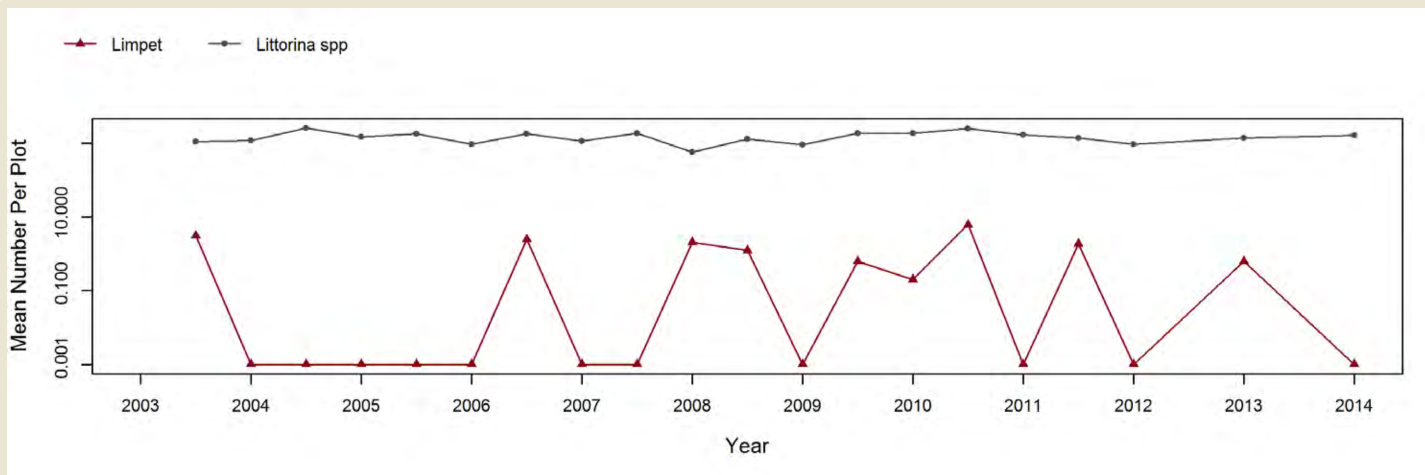
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

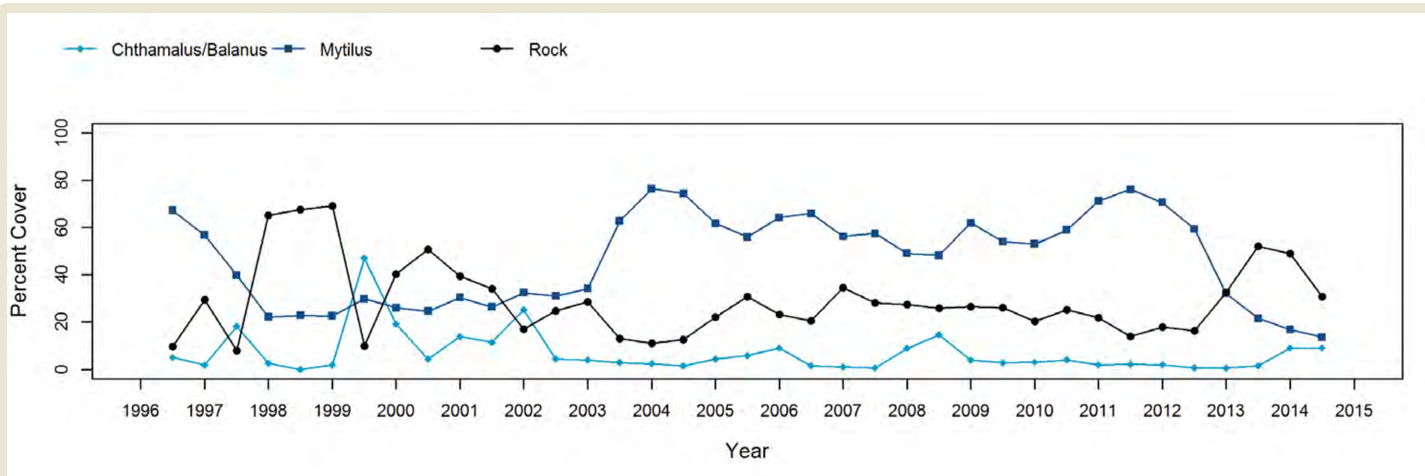
Chthamalus/Balanus (Acorn Barnacles) - percent cover



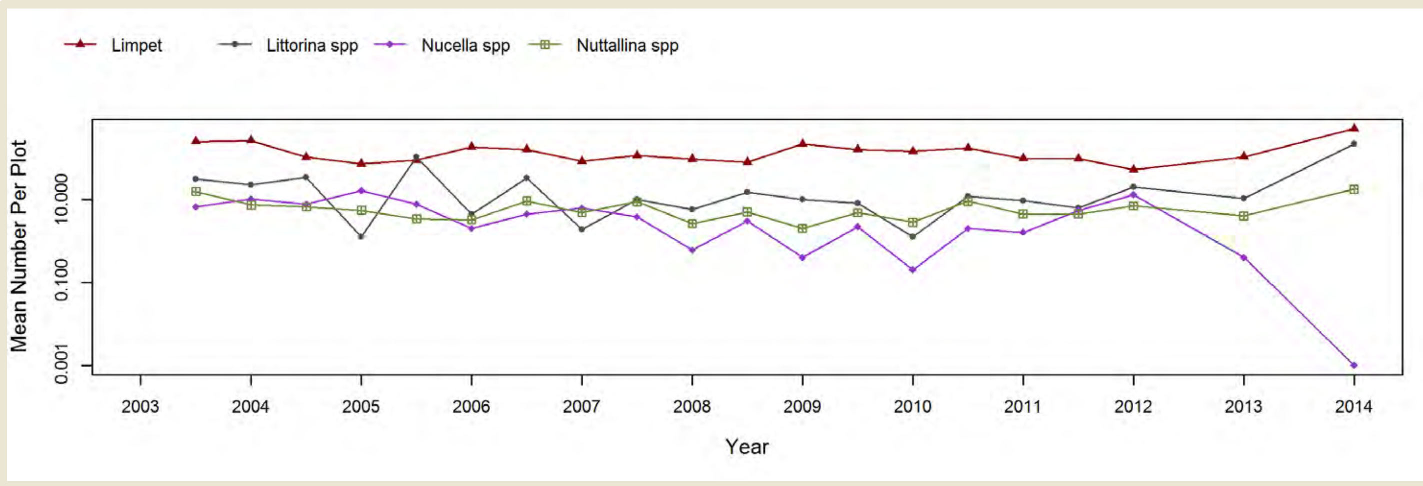
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



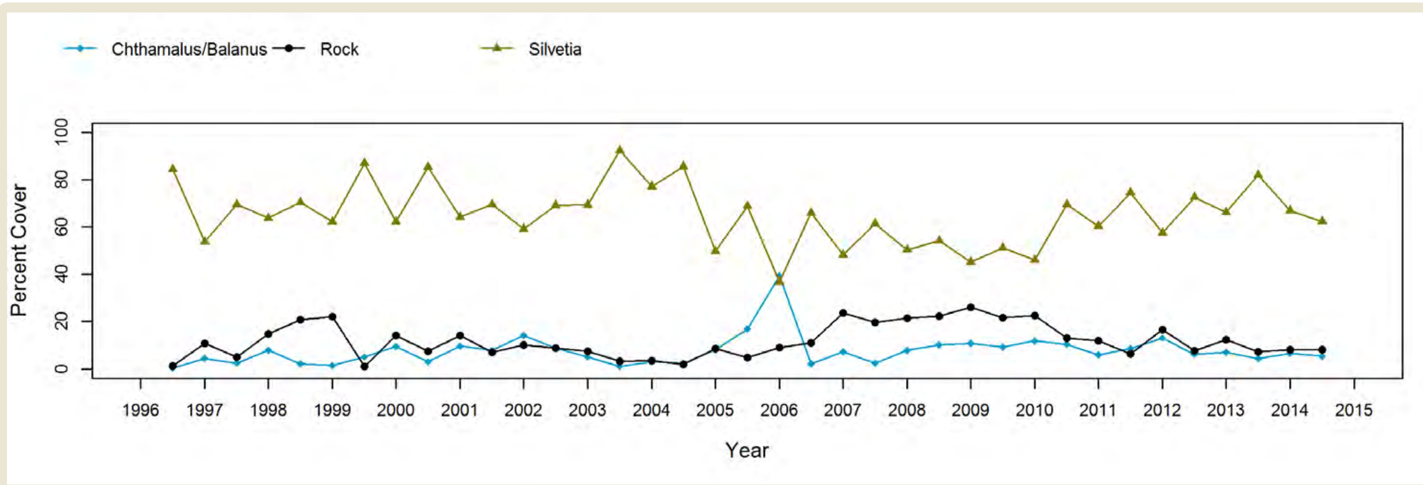
Mytilus (California Mussel) - percent cover



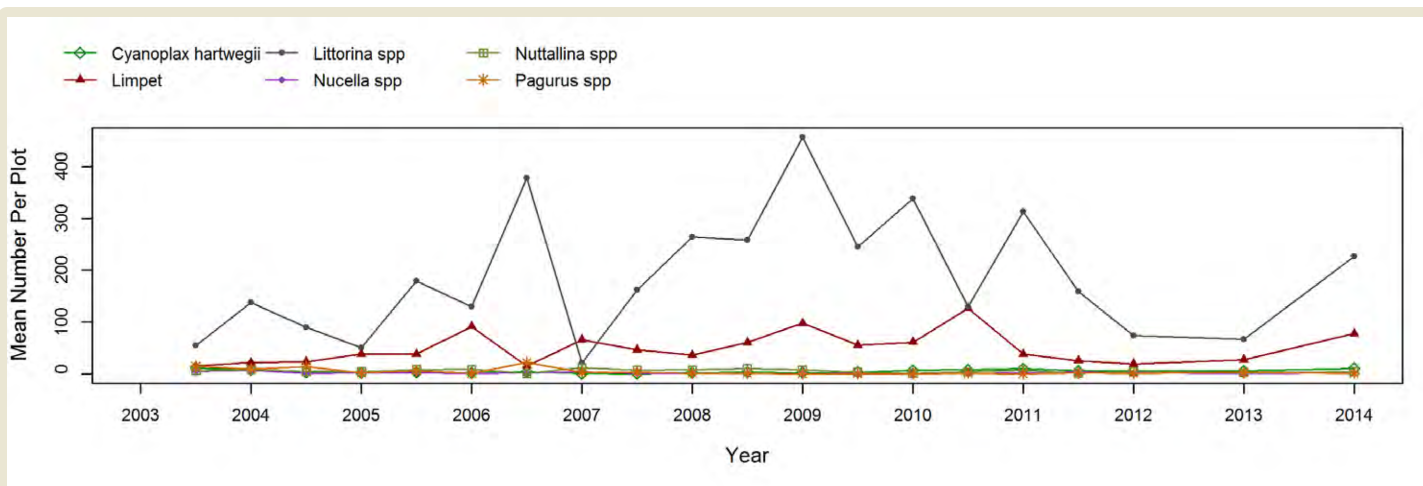
Mytilus (California Mussel) - motile invertebrate counts



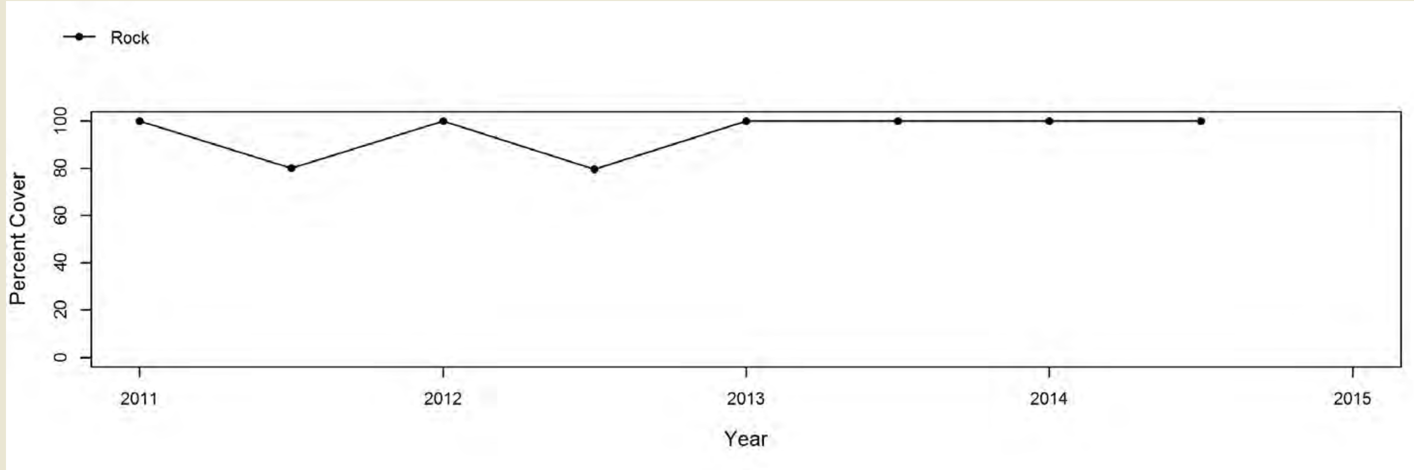
Silvetia (Golden Rockweed) - percent cover



Silvetia (Golden Rockweed) - motile invertebrate counts



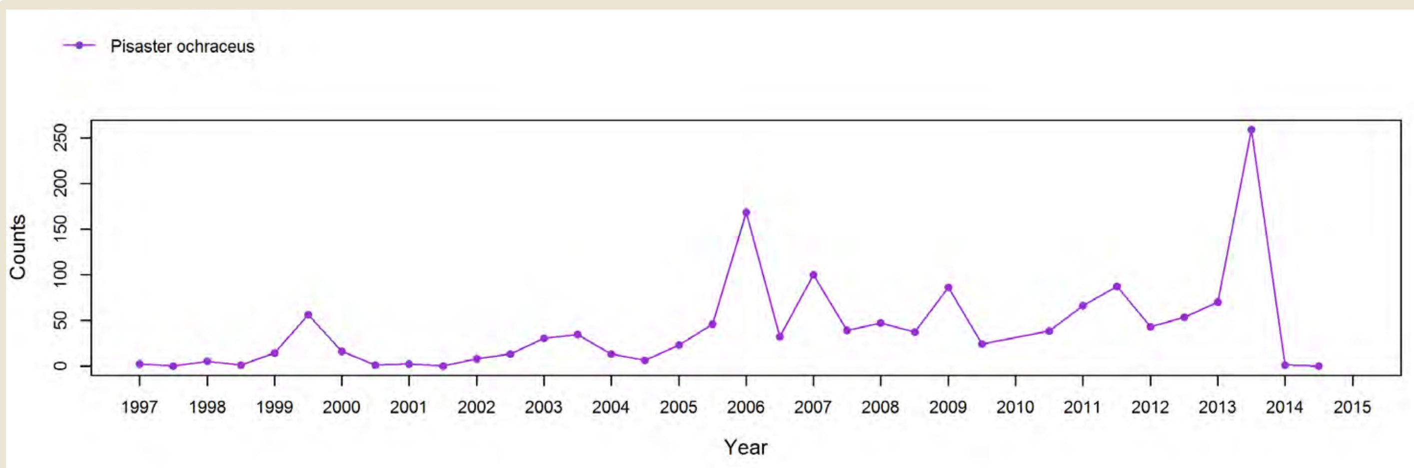
Rock (Above Barnacles)



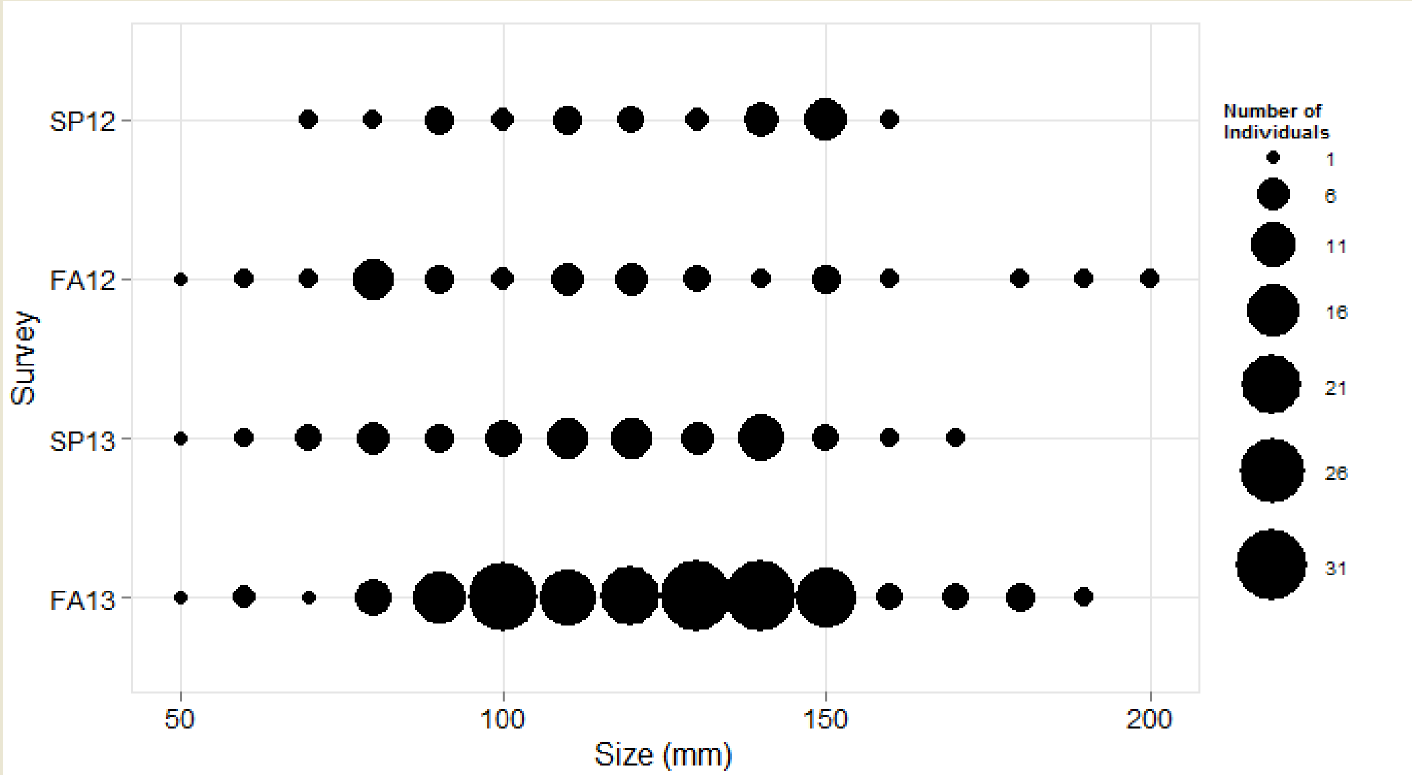
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster ochraceus (Ochre Star)



Pisaster ochraceus (Ochre Star) - sizes



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Dana Point Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle cover at Dana Point showed frequent small increases and decreases since initiation of sampling in 1996, with a trend of declining cover over time. On a few occasions, small amounts of algae (including the rockweed *Silvetia*, the ephemeral sea lettuce *Ulva*, the brown blade *Endarachne* and the red turf *Caulacanthus*) recruited into barnacle plots, but these algae did not persist. Instead, rock in barnacle plots that was not occupied by barnacles generally remained bare. Snails in the genus *Littorina* were consistently found in very high abundance in barnacle plots. Limpets (genus *Lottia*) were also consistently present but at much lower densities than *Littorina*.

Mussel cover at Dana Point also fuctuated over time. Mussel cover decreased during the 1997-1998 El Niño. After recovering following the El Niño, mussel cover dropped again in spring 2007 following a storm with extraordinarily large waves. As at other sites in the region (e.g. Crystal Cove) the effects of the storm were variable in space, with some plots losing more of their mussel cover than other plots. In general, following a drop in mussel cover, space on the rock not covered by mussels remained bare except for occasional recruitment of barnacles (acorn barnacles and *Tetraclita*). Low and fuctuating cover of the red turf alga *Caulacanthus* has been observed on top of mussels in several plots since the early 2000s. After the 2007 storm, plots that lost large numbers of mussels were slow to recover, and on average mussel cover remained lower than 75% of plot area until abundances began to increase at the end of 2010. Following several seasons of high cover, mussel abundance started to decline again in Fall 2013, and in 2014 average cover across all plots again remained lower than 75% of plot area. Several groups of molluscs are consistently found in low abundance in mussel plots (e.g. the chiton *Nuttallina*, the turban snail *Tegula funebralis*, and the periwinkle genus *Littorina*) but only limpets (genus *Lottia*) were found in very high abundance.

Rockweed cover at this site fuctuated within years (often with higher cover during fall sampling periods than spring sampling periods). Small amounts of sand were occasionally observed in a few of the rockweed plots during fall sampling, but overall sand infuence appeared to be low. Across all years, mean rockweed cover remained relatively high (above 60% of plot area, on average). When the cover of *Silvetia* dipped, the cover of bare rock typically increased: aside from the red turf alga *Caulacanthus* (which appeared at low levels in a few plots) and crustose algae, few other space-holding species were observed in rockweed plots. Limpets (*Lottia* sp) were very abundant in *Silvetia* plots, although limpet abundances fuctuated greatly over time (from a high average of 100 individuals per plot to a low average of approximately 20 individuals per plot). *Littorina* snails were somewhat common, while other taxa, such as chitons and turban snails were also regularly found in rockweed plots in low numbers.

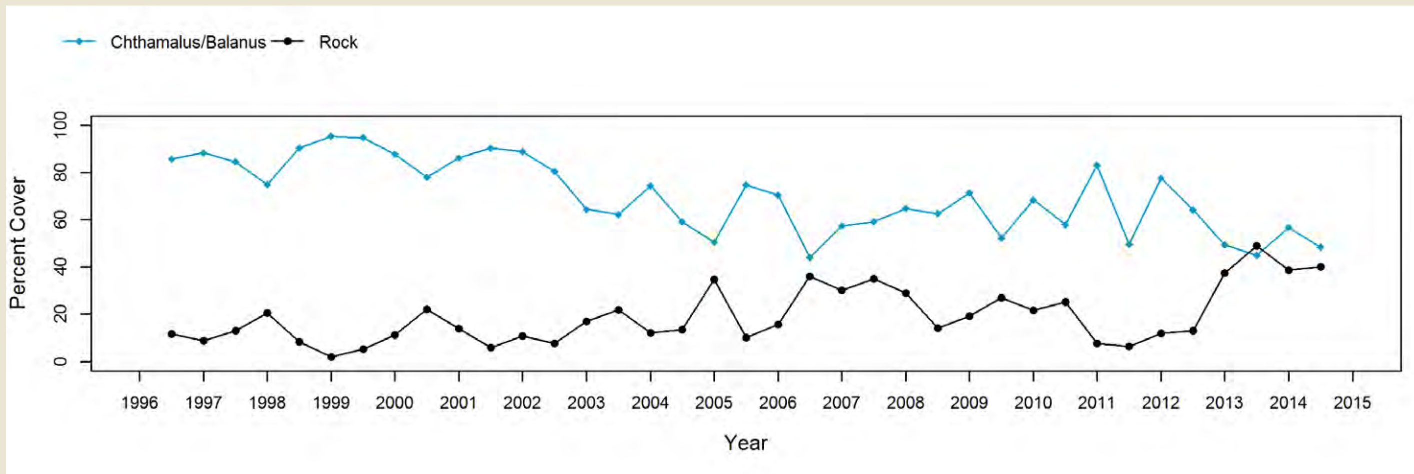
Sea star (*Pisaster*) counts varied greatly over the sampling period, but were generally lower than numbers observed at other Orange County Sites (see Crystal Cove, Shaws Cove, and Treasure Island for comparisons). From 1996 through 2002, the maximum number of *Pisaster* encountered in site-wide surveys at Dana Point was 10 individuals (in Fall 1999). From 2003 – 2012, counts fuctuated from a low of 1 individual to a high of 30 individuals encountered per survey . Measurements during this period (2004-2005 and 2012) indicated that most individuals fell into the 100 to 150 mm size class. As with other Orange County sites, *Pisaster* numbers increased sharply in 2013, with a count of 70 individuals in fall of that year. Measurements in Spring and Fall 2013 show that most individuals fell in the 100 to 150 mm size class, but individuals as small as 50mm and as large as 190 mm were present at the site. Consistent with other sites in the region, *Pisaster* counts dropped sharply following Fall 2013 surveys (no *Pisaster* were observed during surveys in Spring or Fall 2014). Sea Star Wasting Syndrome, which was observed at multiple sites in this region after our Fall 2013 survey, is a likely contributor to the sharp decline.

Photo Plots

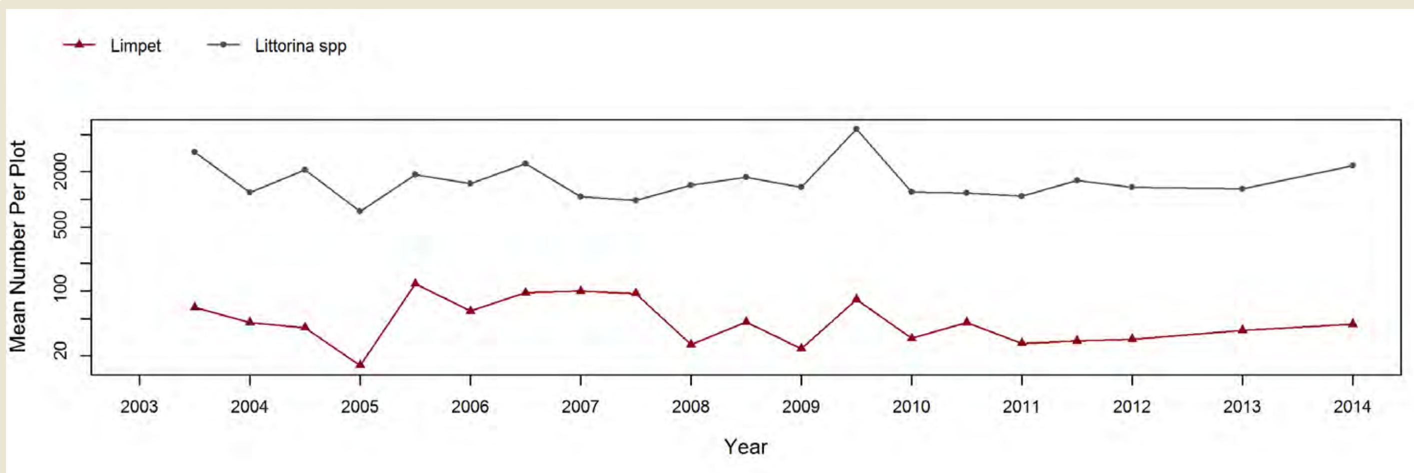
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. For motile invertebrate size trend graphs by site, please use the Interactive Map.

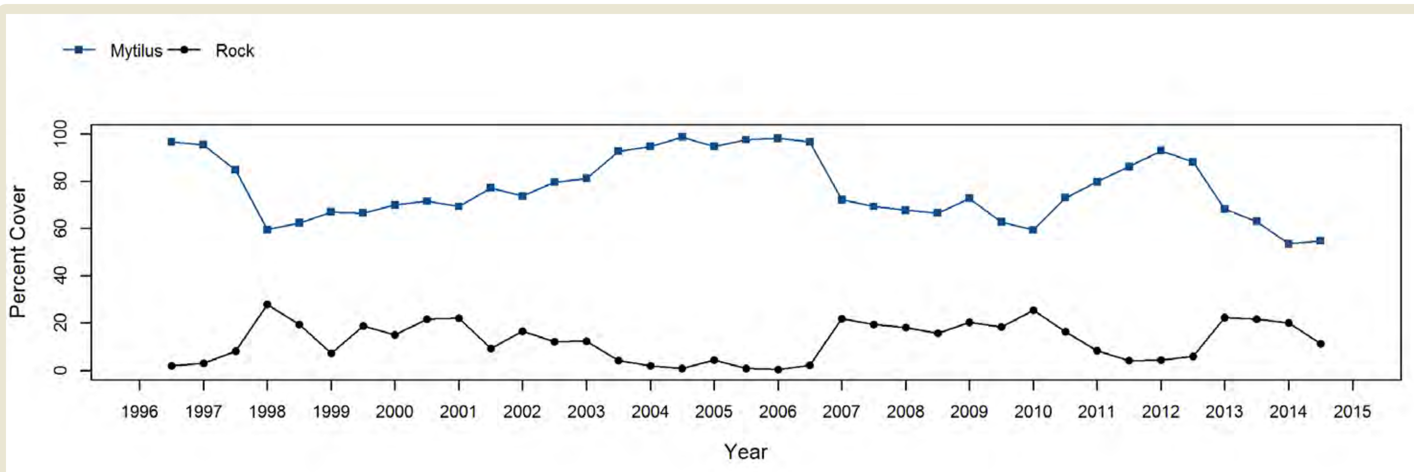
Chthamalus/Balanus (Acorn Barnacles) - percent cover



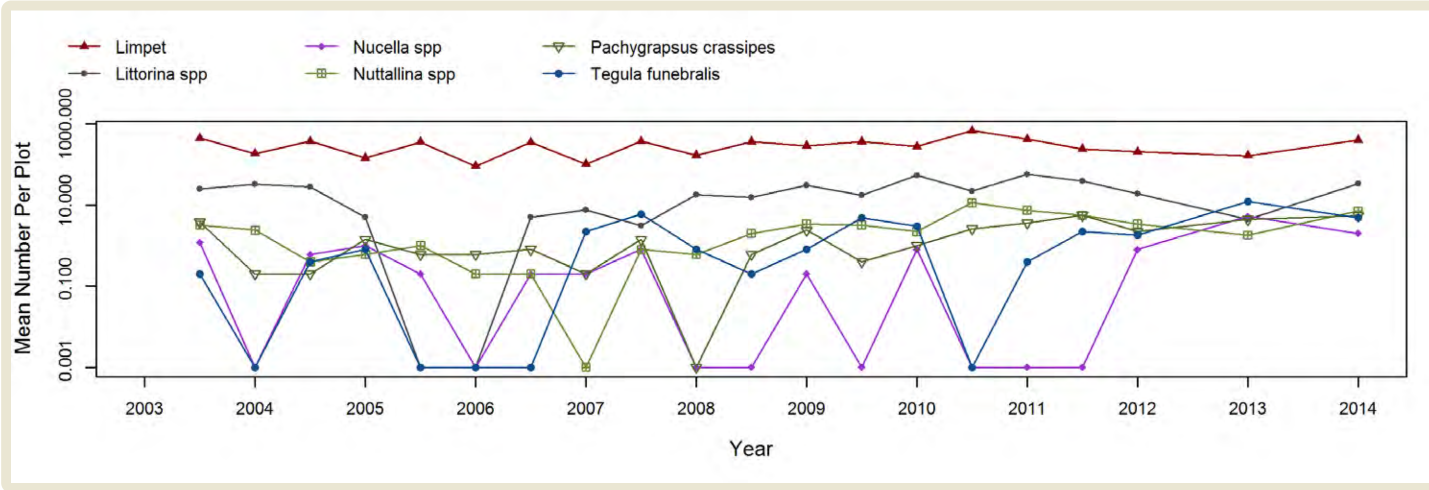
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



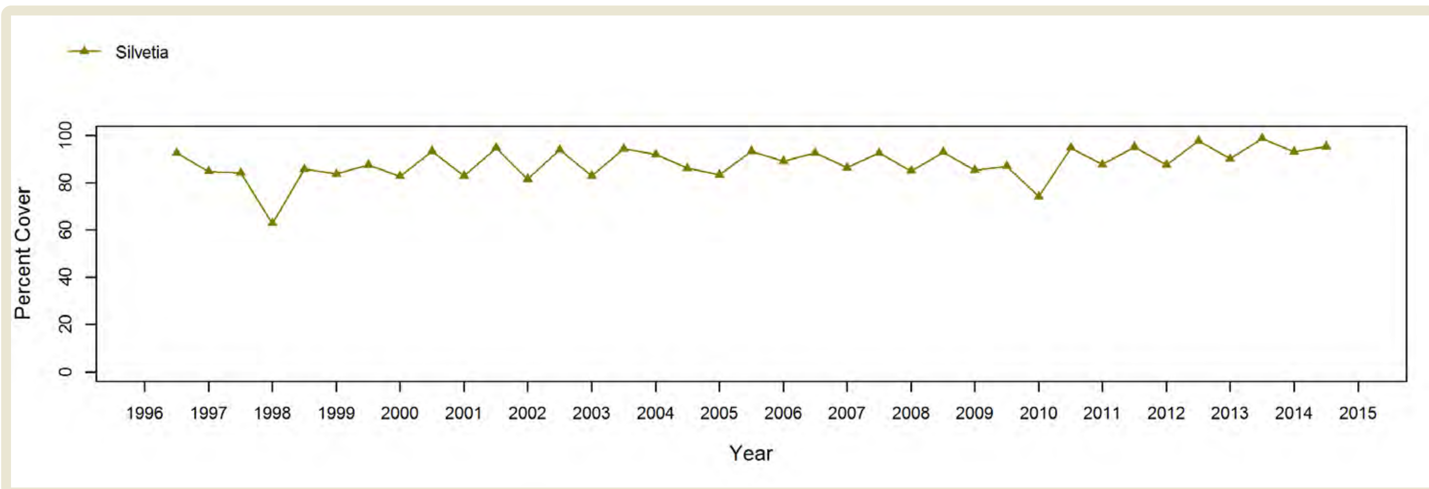
Mytilus (California Mussel) - percent cover



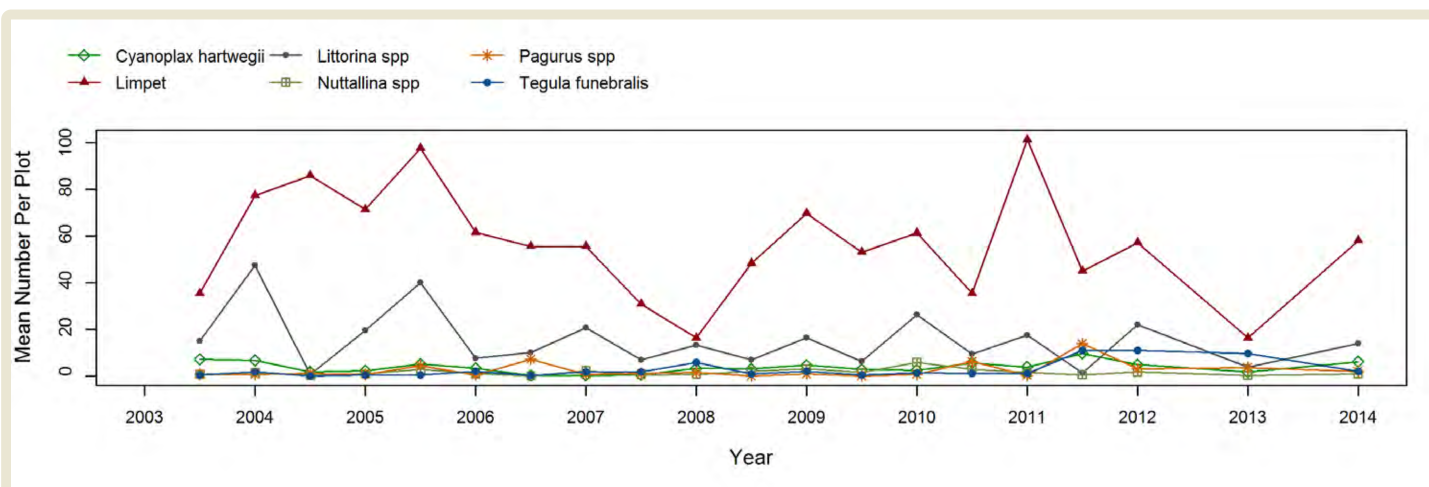
Mytilus (California Mussel) - motile invertebrate counts



Silvetia (Golden Rockweed) - percent cover



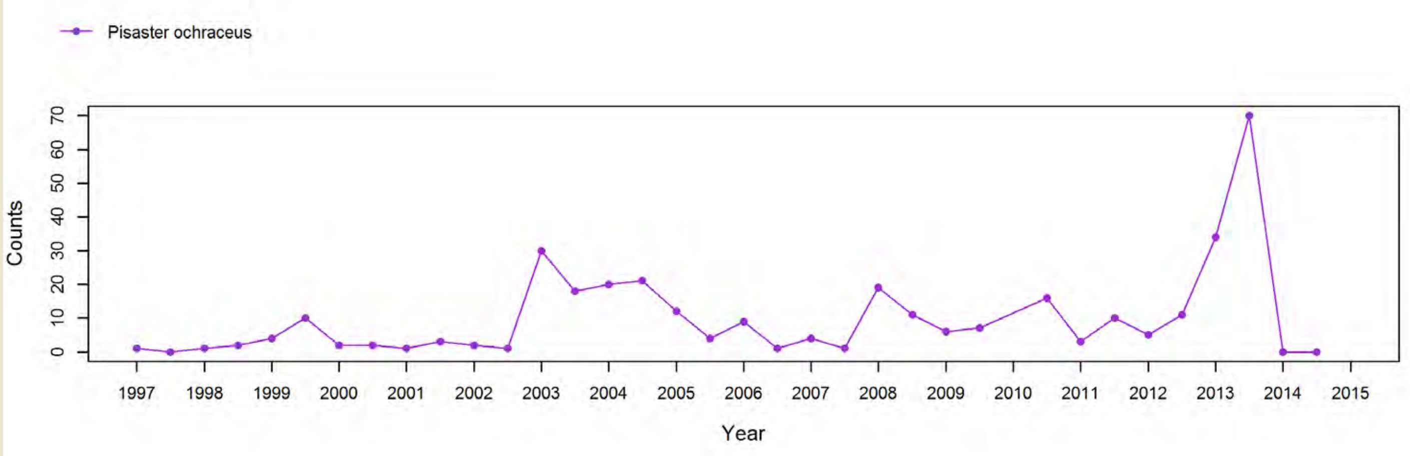
Silvetia (Golden Rockweed) - motile invertebrate counts



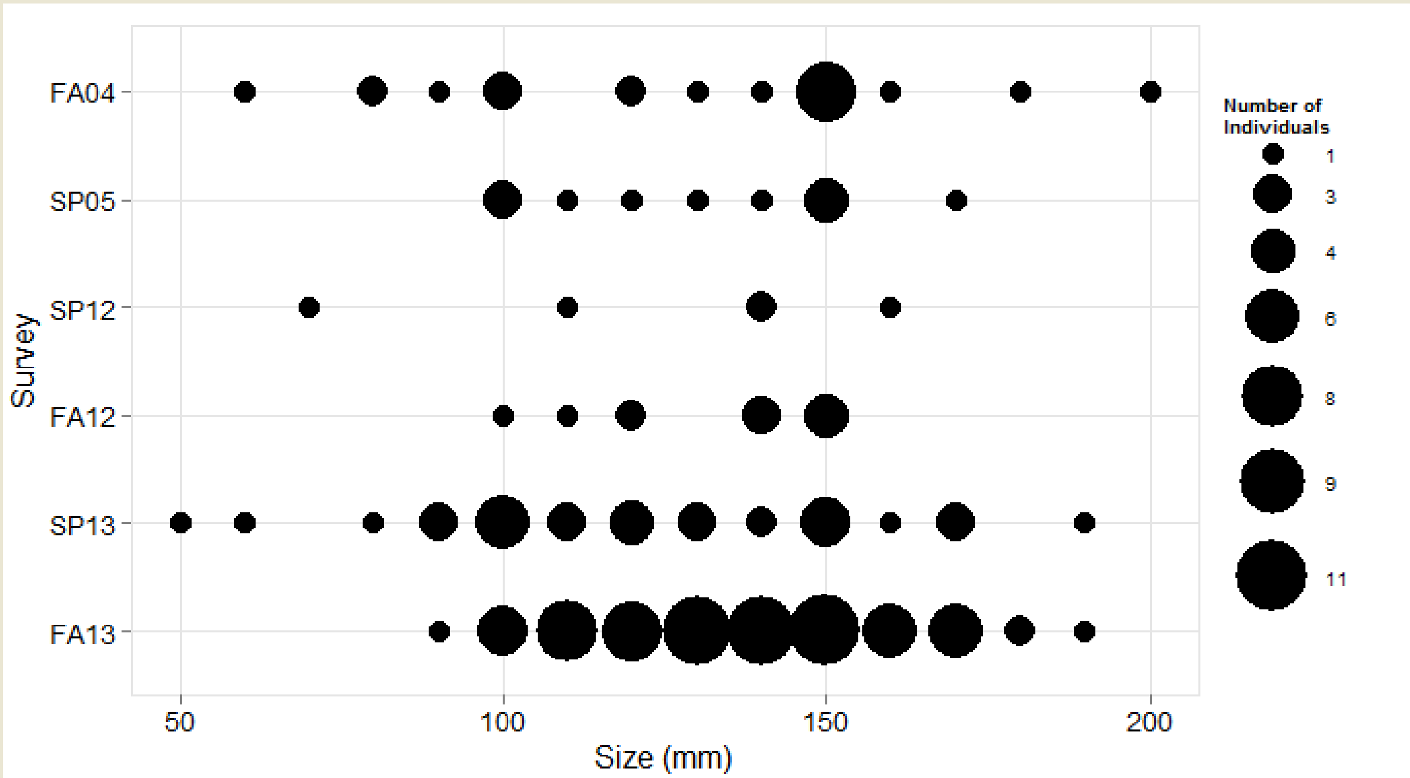
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster ochraceus (Ochre Star) - counts



Pisaster ochraceus (Ochre Star) - sizes



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Appendix 5: Sea Star Wasting Syndrome

Sea Star Wasting Syndrome

Ecological Consequences of SSWS

SSWS Updates

SSWS Articles

SSWS Observations

Sea Star Wasting Syndrome Map

Juvenile Observations Map

PDFs

seastarwasting.org

pacifcrockyintertidal.org

Sea Star Wasting Syndrome

Last updated April 16, 2015

SEA STAR WASTING MAP	JUVENILE OBSERVATION MAP	
SUBMIT OBSERVATIONS	COLLECT DATA	
UPDATES AND NEWS	EVENTS	SPECIES AFFECTED
ACKNOWLEDGEMENTS	IDENTIFICATION GUIDES	TIME LAPSE

Ecological Consequences and Juvenile Recruitment

Photo credits: Christy Bell (left), Rachael Williams (right).

Sea stars along much of the North American Pacifc coast are dying in great numbers from a mysterious wasting syndrome. 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. *Pisaster ochraceus* and many other species of sea stars have been affected by the current sea star wasting syndrome event. The following paper by Hewson et al. "Densovirus associated with sea-star wasting disease and mass mortality" provides evidence for a link between a densovirus (SSaDV) and sea star wasting syndrome (SSWS) but there is still much work to be done before this mysterious disease is fully understood.

The frst photograph in the below series of a sea star with wasting syndrome was taking on June 27th, 2014 on Guemes Island, Washington. The following picture was taken a day later, and the last picture, the day after that. These sequential photographs of a single individual demonstrate how quickly the disease can progress and the extent of damage that can be done in only three days.

Photo credit: Kit Harma

Over the past year, much of our effort has focused on documenting the progression of sea star wasting along the West Coast of North America and across a range of sea star species. That effort continues, however, we are now moving into a new phase in the assessment of sea star wasting: the ecological consequences from the loss of these species.

Sea star wasting syndrome 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 defated 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. The proximal cause of the disease, when pathological studies have been done, is typically a bacterium (vibrio), although a recent wasting event on the east coast of the United States has been attributed to a virus.

The current bout of this wasting syndrome was frst noted in ochre stars (*Pisaster ochraceus*) in June 2013 along the coast of Washington state during monitoring surveys conducted by MARINe researchers from Olympic National Park (ONP).

MARINe monitoring groups have since documented wasting in *Pisaster ochraceus* from Alaska through California (see wasting map for specifc 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 majority of early observations were made in intertidal (tidepool) 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 August 2013, divers investigating subtidal habitats reported massive die-offs of sunfower stars (*Pycnopodia helianthoides*) just north of Vancouver, British Columbia. Shortly afterwards, other subtidal sea star species in the region began showing signs of wasting. During October and November 2013, a similar mass death of sea stars occurred in Monterey, California, with another die-off of sunfower and ochre stars around Seattle, Washington, with the syndrome spreading throughout the Puget Sound.

In mid-December 2013, substantial numbers of wasting stars were spotted around southern California. By the turn of the year it had been reported in 45 of the 84 MARINe sites from Alaska to San Diego sampled since that summer, and in the summer of 2014 it has spread to Mexico and parts of Oregon, which had previously been unaffected. It is also intensifying, appearing at additional sites in those regions already affected.

Photo credit: Nate Fletcher

In subtidal habitats, the sunfower star is typically the frst 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 don't 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 sunfower 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.

From extensive samples collected researchers have begun to identify the agent behind the syndrome, and the environmental conditions that may have led to the outbreak. One of the top priorities is to confrm that an infectious agent is involved, and if so what it is. Molecular sequencing work of samples is underway at Cornell University to identify possible viruses and bacteria that could be causative agents. Current thinking is that there is an infectious agent involved, likely a pathogen. **Importantly there is no evidence at all that links the current wasting event to the ongoing disaster at the Fukushima nuclear facility in Japan.**

Ecologists consider both sunfower and ochre stars to be keystone species because they have a disproportionately large infuence on other species in their ecosystem. In fact *Pisaster ochraceus* was the basis of the Keystone species concept because of its potential to dramatically alter the rocky intertidal community in which it occurs. Our long-term monitoring data, including population estimates prior to the Wasting event, in combination with our biodiversity surveys, will allow us to interpret change to communities that might result from severe population declines of *P. ochraceus*. The collected information will also be used to document recovery of both sea star populations and the community affected by way of the loss of sea stars.

Long-term trends in *Pisaster ochraceus* numbers at our monitored sites can be viewed by location here or by using our Interactive Map & Graphing Tool. Under "Long Term Graph Type" select "species counts data" and under "plot type" select "pisaster".

For more information about Sea Star Wasting Disease, please click here:

Tracking and Documenting Observations

SUBMIT OBSERVATIONS HERE

Our research group is concentrating on:

1. Documenting the presence of sea star wasting symptoms by means of submitted reports, our own sampling as part of MARINe Long-Term Monitoring, and our newly established Rapid Assessment Surveys of the outbreak.

2. Developing a spatial/temporal map of the outbreak showing the location of affected populations and (when possible) the onset of symptoms for each location. This will allow for an evaluation of potential hypotheses concerning the cause of the disease. For example if the outbreak started from a single location its cause is likely to be different from a situation where there were multiple initiation points.

3. Assessing the impact of the outbreak on the biological community.

Other research groups are addressing the pathology and infectiousness of wasting. These groups include Cornell (Harvell & Hewson), University of Rhode Island (Gomez), Brown (Wessel), Western Washington University (Miner), and Seattle Aquarium.

If you are interested in adding information to our Sea Star Wasting Syndrome Map, please see the options below.

Fill out the Sea Star Disease Observation Log

Click here to submit observations through our web form. If you have any photos or spreadsheets to send, please send them here.

Please continue to submit observations after spending time diving or in the intertidal. We are constantly updating our website with the latest reports, and will update the map on a regular basis. Please remember to fll out a log even if you search and only fnd healthy sea stars, or no sea stars! This information is just as valuable as observations of diseased individuals.

Identifcation guides (PDF)

Pisaster ochraceus symptoms guide

Juvenile sea star identifcation

Evasterias symptoms guide

Examples of Mild vs. Severe symptoms

Collect additional sea star data:

Below are the different categories that we are using to document the stage of the disease. If you are interested in collecting additional information about sea star counts, sizes, and disease categories, please contact Melissa Miner and Rani Gaddam for details. We would like to increase the number of sites where long-term sea star data are collected, but in order to ensure data consistency, it is essential that a MARINe researcher is involved with initial site set-up and sampling.

Note that data submitted to us may be used by our research group for analyses, as well as by others who submit data requests to us. If you have any concerns about this, please contact us.

Download the intertidal sampling protocols (PDF).

Download the subtidal sampling protocols (PDF).

seastarwasting.org

pacifcrockyintertidal.org home

Ecological Consequences of SSWS

SEA STAR WASTING MAP JUVENILE OBSERVATION MAP

SUBMIT OBSERVATIONS COLLECT DATA

Juvenile sea star identifcation guide

Over the past year, much of our effort has focused on documenting the progression of sea star wasting syndrome (SSWS) along the West Coast of North America and across a range of sea star species. That effort continues, however, we are now moving into a new phase in the assessment of sea star wasting: the ecological consequences from the loss of these species. Because (1) many of the affected species are predators, (2) sea stars, generally, are not typical prey for other species and (3) prior to the wasting event sea stars were often abundant, there could be a population release for those species that were prey for sea stars. This could lead to signifcant changes in the ecological communities where sea stars have been affected. Such effects could intensify and persist until sea star populations are replenished.

Key to the assessment of the ecological consequences is an understanding of the potential for population replenishment of sea stars. Replenishment will most likely come from new individuals that recruit as larvae to sites along the coast. Very recently we have seen evidence of substantial recruitment of new sea stars (babies) in a few areas that have been severely affected by wasting. This could be a signal that replenishment of affected populations may be more rapid than expected. This will only be true if recruitment is geographically broad and intense and if the resulting juvenile sea stars are themselves relatively unaffected by wasting.

Our teams, along with those of our collaborators, are carefully monitoring recruitment at sites we study, but it is clear that citizen observations will be important (as they have been in the documentation of the progression of wasting) in documenting recruitment along the west coast. We encourage you to submit your observations of juvenile stars using our juvenile observation log. Your contributions will greatly assist the effort to fully understand the impact of and recovery from sea star wasting.

We have created a juvenile sea star identifcation guide to assist with proper identifcation; however submitting photos is also highly encouraged. Some things to note when making observations: (1) juveniles of different sea star species can look very similar to one another, particularly the ochre star, *Pisaster ochraceus* and the mottled star, *Evasterias troschelii*. The 6 armed star, *Leptasterias* spp., can also look similar to these species as an adult, so it is important to look carefully for the features described in our (forthcoming) identifcation guide. If you are not certain of a species' identifcation, please use the "unknown" category, rather than guessing.

seastarwasting.org home

Sea Star Wasting Syndrome Updates

SEA STAR WASTING MAP
JUVENILE OBSERVATION MAP
SUBMIT OBSERVATIONS
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Please continue to submit observations after spending time diving or tidepooling. We are constantly updating our website with the latest reports, and will update the map on a regular basis. Please remember to fll out a log even if you search and only fnd healthy sea stars, or no sea stars! This information is just as valuable as observations of diseased individuals.

In addition, we are considering the development of a mobile app that will provide educational information about sea stars and the wasting disease, as well as ID guides and survey protocols. This mobile app will be designed for Android and IOS platforms. We would greatly appreciate your input on the utility of this app and have put together a brief survey to gauge potential users' interest. The survey can be found here.

Mar 13, 2015 Nov 26, 2014 Nov 20, 2014 Sept 9, 2

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UPDATE – MAR 13, 2015

Sea stars with symptoms of wasting syndrome continue to be observed along the west coast of North America, and remain geographically patchy. Some sites monitored by citizen scientists in Washington, which had previously shown disease symptoms for many months, have recently been reported to have only healthy individuals, and in a few areas, substantial numbers of juveniles have been recorded. However, the opposite is true for other sites in Washington. Two of the long-term monitoring sites where SSWS was frst observed in low levels in June 2013 (Starfsh Point and Sokol Point), had disease prevalence ramp up in November 2014 to as high as 60%. While some sites were immediately highly impacted by the syndrome, these sites were not greatly impacted until nearly 1 1/2 years after the frst symptoms were seen. As for the sites that are currently free of diseased stars, continued sampling will determine whether these sites are indeed beginning to recover, or whether they are merely experiencing a pause in the progression of

SSWS.

The current status of SSWS is unknown for many MARINe monitoring sites because bi-annual sampling for most sites occurs in spring and fall. Beginning this month, many sites along the coast will be resampled and we will be able to assess the condition of sea star populations in those areas. Several sites sampled in December 2014 in Redwood National and State Parks showed relatively low rates of infection, 6% to 20%; however, ochre star abundances at these monitoring sites had dropped well below the long-term average, likely due to the impact of SSWS. Qualitative observations also continue to be reported from locations along the coast where sea stars are conspicuously absent from places people have observed them historically. While not quantitative, these observations provide important insight to the overall picture of the impact of SSWS.

As noted in the previous update, disease has also been seen in urchins in some locations along the coast. It is still unknown whether this is related to sea star wasting syndrome. Warmer than usual water temperatures may be playing a role, as has been the case in past events. In the last few months urchin disease symptoms have been reported in southern California and Baja California. MARINe researchers are currently developing protocols for monitoring urchins. These protocols were discussed recently at the MARINe consortium's annual meeting, along with information sharing and regional updates about the progression of SSWS along the entire west coast.

UPDATE – NOV 26, 2014

The northern-most observation of SSWS in the feld is now Sawmill Bay , east of Anchorage, Alaska. While it was hoped that Alaska's colder waters might provide reservoir populations of healthy sea stars, increased observations of disease in Alaska have made this unlikely. Affected mottled stars were seen this fall in Jakalof Bay, just west of Kenai Fjords National Park, as well as more observations of diseased stars around Juneau and Sitka, Alaska. Along the rest of the west coast, observations of disease continue throughout, but with varying levels of impact to sea star numbers.

In Central California fall long-term monitoring surveys are currently in progress, but for those sites sampled, 9 of 16 (56%) showed declines in *Pisaster ochraceus* numbers due to SSWS. Sites experiencing "lower" impact have all lost large numbers of adult stars, but higher population numbers are present due to a large infux of recruits, or healthy baby sea stars. While diseased juvenile sea stars have been observed, the majority appear healthy thus far. Only time will tell whether these juveniles live to replenish populations, or become diseased themselves. Please keep your eyes open for juvenile sea stars and report them on our juvenile observation log.

Another development since the last update is the recent observation in Southern California of wasting in other echinoderms, such as sea urchins. Urchin die-offs have occurred in the past during warm-water events, often associated with sea star wasting. It is unknown whether the current observations of urchin disease and die-offs are connected to SSWS, or are the result of another pathogen, potentially connected to the abnormally warm water temperatures that have been present in southern California. We encourage citizen observers as well as other researchers to monitor the condition of urchins and other echinoderms in addition to sea stars. Our updated disease observation log now includes a space to report observations of urchin disease.

UPDATE - NOV 20, 2014

The recently published paper by Hewson et al. “Densovirus associated with sea-star wasting disease and mass mortality” provides evidence for a link between a densovirus (SSaDV) and sea star wasting syndrome (SSWS). This is an important piece of the SSWS puzzle, but we want to stress that there is still much work to be done before this mysterious disease is fully understood. Importantly, Hewson’s testing of sea star tissue collected from as far back as 1942 indicates that the SSaDV has been around for a long time, yet has never resulted in mass mortality on the geographic or temporal scale we are currently witnessing. Thus, while a culprit may have been identifed, we still don’t fully understand the cause. The complete story is likely a complex interaction of multiple factors, and may involve different factors in different regions. For example, the emergence of SSWS in some areas appears to be correlated with increased water temperature, but this does not apply generally across the entire west coast. Finally, the discovery that the SSaDV is present in other echinoderms, such as urchins, which are not currently experiencing mass mortality, suggests that these species could serve as “reservoirs” for the virus that could continue to infect sea stars for many years to come. It may also be only a matter of time before we see broad-scale mortality of other echinoderm species, including urchins and sea cucumbers.

UPDATE - SEPT 9, 2014

Sea Star Wasting Syndrome (SSWS) continues to be observed along the West Coast of North America. The known current geographical range has not expanded much since the last update, though unfortunately some gaps within the range have now flled in as also being af fected. The Anchorage Museum continues to be the most northern known location at which SSWS has been observed, though the most recent northern observation in the feld was Peterson Bay , Alaska, southwest of Anchorage, in late July of this year. The current most southern known location for this event of SSWS was on North Coronado Island, in northern Baja California from early April this year.

Unfortunately, this past spring, sea star populations began crashing in some areas where disease presence had previously been minimal or absent, and high rates of disease were documented among the remaining individuals. The most noteworthy region was the Oregon coastline. At rocky intertidal sites along the Oregon coast in late April 2014, the percent of diseased ochre stars (*Pisaster ochraceus*) was less than 1% of those surveyed and abundances of ochre stars were within normal ranges, based on long-term monitoring. By late June 2014, those same sites had signifcantly lower abundances of ochre stars, and of those remaining, the percent showing disease ranged from 18-64%. It is unknown why that stretch of coast was not impacted until much later than most of the rest of the affected range.

During long-term monitoring of MARINe sites done in fall 2013, 39% of sites surveyed by the UCSC team in central and northern CA showed high levels of wasting. By summer 2014, 87% of sites sampled in spring and summer had high levels of wasting. One encouraging fnding was the presence of many juvenile sea stars at some sites where ochre star populations have been devastated by SSWS. During spring 2014 surveys of long-term rocky intertidal sea star plots, several sites in the Monterey Bay region had numbers of juvenile sea stars higher than ever recorded during the monitoring period (generally around 15 years). Almost universally, there has been a decline in abundance of large ochre stars; some of these sites had numbers of juveniles far above average, while others had only average or no recruitment. Long-term monitoring surveys this fall will allow us to see whether the juvenile sea stars seen this past spring have survived, and whether the infux of juveniles has extended to additional sites.

Only time will tell whether these juveniles will grow to replenish the populations at some sites, or whether they too will become affcted with the disease. Our monitoring continues to track the occurrence of SSWS along the coast and we encourage other researchers as well as the public to continue to submit observations to our database via our website. We are, however, beginning a new phase of monitoring, focusing on 1) the possible ecological consequences this disease may have on the communities in which sea stars live and 2) the potential for recovery of sea star populations, particularly in areas where we are seeing an infux of juvenile stars. For more information and to submit observations of juveniles, please see our page on Ecological Consequences of SSWS.

UPDATE - JUL 29, 2014

Over the past year, much of our effort has focused on documenting the progression of sea star wasting syndrome (SSWS) along the West Coast of North America and across a range of sea star species. That effort continues, however, we are now moving into a new phase in the assessment of sea star wasting: the ecological consequences from the loss of these species. For more information, please visit this page.

UPDATE - JAN 21, 2014

While the geographical range for which we have received reports of sea star wasting syndrome has expanded little since the last update (the southernmost observation is now San Diego County rather than Orange County, CA), we continue to fll in gaps in spatial coverage. Observations are coming from MARINe Long-Term Monitoring and citizen science groups such as LiMPETS (Long-Term Monitoring Program and Experiential Training for Students), colleagues at a number of universities and government agencies, as well as the general public. In addition, sea star assessment surveys are now being done by a team from UC Santa Cruz, with their entire focus being the assessment of sea star condition in areas with less frequent monitoring.

In Washington, rapid funding from WA Sea Grant and National Science Foundation (NSF) is being used to survey intertidal and near-shore areas of the coastline where we have little to no information about sea star populations. Recently surveyed areas include: 1) the north coast of the Olympic Peninsula, from Salt Creek to Port Townsend, 2) Whidbey Island, and 3) the mainland coast near Bellingham. Additional surveys are being done in the San Juan Islands by researchers at Friday Harbor

Labs. Rapid funding is also being used to train citizen science groups to implement sea star monitoring protocols. Thus far, citizen science monitoring sites have been established on Bainbridge Island and at Edmonds Underwater Park, with many more in the works. Results from recent surveys show that wasting syndrome has heavily impacted several species of sea stars at sites in the Puget Sound region, but the impact appears to be much lower farther to the north (along the northeast coast of Whidbey Island, in the San Juan Islands, and around Bellingham), and to the west along the Strait of Juan de Fuca.

In Oregon, wasting syndrome in sea stars has been observed at two sites. However, the populations have remained stable and the percent affected has been very low. The UC Santa Cruz survey team will visit several of our long-term monitoring sites at the end of January to help fll in some of the gaps in our knowledge about the presence of wasting along the OR coast.

Researchers at UC Santa Cruz have recently visited the northern coast of California and observed diseased individuals at 7 of 8 sites between Crescent City and Bodega Bay, though the percent affected was low at these sites. Reports from others in this region include sites with only apparently healthy individuals, so symptoms of wasting syndrome continue to be patchy, though widespread.

UC Santa Cruz is teaming up with divers from the Monterey Bay National Marine Sanctuary to re-survey PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) subtidal sites from Santa Cruz to Santa Barbara with historic sea star data. Wherever possible, these will be paired with our intertidal monitoring sites, which will allow for a more complete understanding of the impacts of wasting syndrome. Evidence from the few areas where we have both intertidal and subtidal survey data suggest that the effects of wasting syndrome may be more severe subtidally vs. intertidally.

These subtidal surveys are urgently needed because we are receiving numerous, new reports from the mainland Santa Barbara area about wasting sea stars. Thus far, the Channel Islands appear largely unaffected by wasting syndrome. A few ochre stars showing signs of the disease were found on San Clemente and Santa Rosa Islands, but no sick individuals have been reported from San Nicolas, Santa Cruz, Santa Barbara, Anacapa, or Catalina Islands. ROV surveys around oil platforms south of Santa Barbara also did not turn up diseased sea stars. However, a collection of apparently healthy sea stars from Catalina Island were brought to the California Science Center, and within a few days many were showing signs of wasting. Veterinarians at the center are currently experimenting with various treatments, which may aid in determining the cause of this wasting event.

One potentially positive fnding has been an apparent increase in the observation of sea stars re-growing lost arms. While arm-regrowth is not unusual in sea stars, the number of individuals recently observed with new arm "buds" has been higher than typically noted in some areas. In addition, we have noticed sea stars with what appear to be "scars" from healed lesions. Both of these observations suggest that sea stars can potentially recover from the effects of wasting syndrome.

The cause of the wasting event is still unknown. Researchers from universities including Cornell, University of Rhode Island, Brown, and Roger Williams continue to work to determine whether the root cause of the disease can be attributed to a pathogen, and many groups are looking for patterns in the geographic extent and spread of wasting syndrome, which might suggest certain environmental factors as possible causes. **There has been substantial speculation in the media that the disease could be a result of increased radiation from the nuclear power plant disaster in Fukushima, Japan. We have no evidence to suggest that radiation is a likely culprit.**

UPDATE - NOV 8, 2013

We continue to receive many reports of sea star wasting along the West Coast of the United States. To date, our most northern report comes from the Anchorage Museum in Alaska. There, mottled sea stars (*Evasterias* spp.) in the aquarium showed signs of wasting. These individuals were collected from Whittier, AK and Seward, AK, though it is unknown at what point they became sick.

During the last couple weeks, the UC Santa Cruz group sampled a number of our Long-Term Monitoring sites in central California. Most sites had at least a few affected individuals of the ochre star (*Pisaster ochraceus*). We were able to confrm presence of wasting in San Luis Obispo County, though diseased individuals were less prevalent overall than what we have observed in the Santa Cruz County area. Intertidal Long-Term Monitoring plots at Hopkins Marine Station were recently sampled with only approximately 2 ½ weeks in between surveys. When sampled on October 18, there were no signs of disease, and the abundances in the plots were within fuctuations documented since we established monitoring plots in 1999. We resampled the plots on Nov 5 and observed disease in about half of the ochre stars (*Pisaster ochraceus*). Overall abundance had dropped quite a bit, lower than recorded anytime during the previous 14 years of monitoring. We also received reports that in the subtidal off Hopkins Marine Station, sunfower stars (*Pycnopodia helianthoides*) had been abundant several weeks ago, but during a recent class dive trip, none were observed (Raimondi pers. com.). Observations such as these emphasize how quickly sea stars can go from appearing healthy to dying from whatever is causing this wasting event.

Currently, our most southern report along the West Coast comes from Laguna Beach in Orange County, CA. Based on our collected observations to date, it seems that while wasting syndrome is present in southern California, the percent of affected individuals is much lower than what has been documented farther north.

The cause of the wasting event is still unknown. Researchers from universities including Cornell, University of Rhode Island, Brown, and Roger Williams continue to work to determine the pathogen.

UPDATE - OCT 24, 2013

Signs of sea star wasting disease have been popping up on both the East and West Coasts of the United States, as well as reports globally. On the West Coast, sea star wasting has been observed as far north as Southeast Alaska, and as far south as Orange County, California. To date, we have received reports of at least 10 species of sea stars showing signs of infection. Reports of sea star disease and mortality on the East Coast began showing up in articles during July of this year. On the West Coast, sea star wasting was frst documented in June (although see Bates et al. for 2008 event), and by September observations were much more widespread, with accounts of diseased, dying and dead sea stars from numerous locations along the West Coast.

The frst evidence of a possible wasting event came in June when Long-Term Monitoring sites in Washington (monitored by Olympic National Park) recorded diseased stars with percent affected rates between 3-26%. Symptoms of wasting disease in a few *Pisaster ochraceus* were also noted in August at an intertidal Biodiversity site in Southeast Alaska. Articles from British Columbia, Canada report sightings of dozens of dead sea stars (notably *Pycnopodia helianthoides*) beginning in September, not far from Vancouver. One report from Vashon Island in Puget Sound indicates signs of wasting in *Pycnopodia helianthoides* from March of this year. This is the earliest account we have on the West Coast for 2013. From Friday Harbor Laboratories, we have received a report of diseased *Henricia* spp. and *Evasterias troschelii* at the southern tip of San Juan Island. In Oregon, we saw no obvious signs of wasting sea stars during Long-Term Monitoring surveys in May-August. Word-of-mouth accounts indicate that there may be wasting occurring at some sites in Oregon, and we hope to have more information from that section of coast soon.

In California, accounts of wasting in sea stars range from just north of Bodega Bay down to Orange County. In the Bodega Bay area there have been reports of wasting in sea stars both subtidally and intertidally. Researchers from UC Davis Bodega Marine Laboratory have observed wasting in *Pisaster ochraceus* in the intertidal at Schoolhouse Rock, just north of Bodega Bay, since spring 2013. In San Francisco, at the Gulf of the Farallones National Marine Sanctuary offce building, *Pisaster ochraceus* in the offce aquarium began "falling apart" in early October. Numerous observations of wasting in sea stars have recently been made in the region between San Francisco south to Big Sur. Accounts have come by way of Long-Term Monitoring from MARINe, LiMPETS, and PISCO, and from researchers from multiple institutions such as Long Marine Lab, Monterey Bay Aquarium Research Institute (MBARI), Monterey Bay Aquarium, and Moss Landing Marine Laboratories, as well as from recreational divers. In central California, species affected thus far include *Pisaster ochraceus*, *Pisaster brevispinus*, *Pisaster giganteus*, *Dermasterias imbricata*, *Asterina (Patiria) miniata*, *Orthasterias koehleri*, *Pycnopodia helianthoides*, and *Henricia* spp.

Interestingly, observations of wasting are patchy. For example, wasting sea stars have been seen subtidally off of Hopkins Marine Station in Monterey, but extensive searching in the intertidal nearby turned up only healthy looking individuals and abundances are within the natural fuctuation observed in Long-Term Monitoring plots at that site. Multiple other sites, however, have shown drastic declines in abundance below the fuctuation typically observed at those sites. In San Luis Obispo County, reports of wasting come from Corallina Cove in Montaña de Oro State Park. There, a CA State Parks scientist received information that sea stars were washing up on the beach; it has not yet been confrmed that this could be attributed to wasting.

The cause of this wasting event is still unknown, though researchers from various universities including Cornell, University of Rhode Island, Brown, and Roger Williams are currently working to identify the pathogen.

For more information about Sea Star Wasting Disease, please see visit our Articles, Publications, and News Broadcasts page.

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Sea Star Wasting Syndrome Articles

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For more information about Sea Star Wasting Disease, please see the links below:

Articles, Publications, and News Broadcasts

As Sea Stars Die, New Worries About Urchins (April 1, 2015)

Star search: Scientists watch for wasting (March 11, 2015)

What's killing millions of starfsh on the W est Coast (March 11, 2015)

Speak Up! Speak Out! Sea Stars with Melissa Miner (Feb 11, 2015)

Will the King of the Rock Fall? (Feb 4, 2015)

Signs of hope, and a prime suspect, in sea star wasting disease (Jan 23, 2015)

Sea stars may be on path to recovery; summer could provide answers (Jan 20, 2015)

Scientists Search for Cause of Sea Star Wasting Syndrome (Jan 16, 2015)

Zombie Starfsh - Nature's W eirdest Events (Jan 12, 2015)

Sea Star Wasting Disease (Dec, 2014)

Sea Star die-off Baffes Scientists (Dec 23, 2014)

Cause of Whidbey starfsh deaths discovered (Dec 12, 2014)

Ocean Currents Broadcast on KWMR (Dec 1, 2014)

In search of the starfsh killer: the quest to save the original keystone species (Nov 18, 2014)

Virus devastating sea stars on Pacifc Coast identifed (Nov 17, 2014)

Meet the Tiny Killer Causing Millions of Sea Stars to Waste Away (Nov 17, 2014)

Densovirus associated with sea-star wasting disease and mass mortality (Nov 17, 2014)

AK: Sea Star Mystery (Oct 24, 2014)

Is Alaska Safe For Sea Stars? (Oct 8, 2014)

Sea star Wasting Syndrome plagues shores of Camano Island (Sept 30, 2014)

Recovery Caucus proposes bill on sea star wasting syndrome (Sept 23, 2014)

Proposed Emergency Legislation Aims To Address Starfsh W asting Syndrome (Sept 18, 2014)

Program on sea star wasting disease kicks off series (Sept 13, 2014)

Scientists at Odds Over Sea Star Die-Off (Sept 12, 2014)

Sea stars wasting in local waters (Sept 7, 2014)

Sea stars making a comeback: Researchers study reason for die-off (Sept 1, 2014)

Plight of the Sea Stars: Wasting Disease in British Columbia (Aug 30, 2014)

Signs of sea-star recovery in California but not in NW (Aug 26, 2014)

Sea Star Deaths along the West Coast Elicit Close Study (Aug 14, 2014)

Scientists Investigate Outbreak Of Sea Star Wasting Syndrome (Aug 11, 2014)

Disease killing sea stars reaches local public aquariums (Aug 7, 2014)

Peninsula marine life centers losing sea stars to mysterious disease (July 28, 2014)

Warming Water Temperatures Could Be Driving Massive Sea Star Die Off (July 26, 2014)

Dying starfsh stump experts (July 26, 2014)

Scientists Look for Causes of Baffing Die-Of f of Sea Stars (July 17, 2014)

What's killing all the sea stars? (July 2, 2014)

Sunfower stars found in sound (July 2, 2014)

Starfsh are 'just melting': Disease killing 80 percent of them (June 28, 2014)

Peninsula volunteers pitching in on sea star wasting disease research (June 23, 2014)

Dissolving sea stars hit San Diego (June 20, 2014)

Scientists Close in on the Cause of Sea Star Wasting Syndrome (June 17, 2014)

Sea Star Video - "Falling Stars" (June 13, 2014)

Mystery Sea Stars 'Goo' Disease Spreads to Oregon (June 10, 2014)

Sea star wasting syndrome epidemic along the coast (June 7, 2014)

Sea Star Disease Hits Hard On Oregon Coast (June 6, 2014)

A plot to spot wasted stars (June 4, 2014)

Sea star disease epidemic surges in Oregon, local extinctions expected (June 4, 2014)

Die-Off Spawns New Sea Stars (May 24, 2014)

Scientists scurrying to determine what's killing starfsh (May 23, 2014)

Biologists investigate mysterious sun star beach stranding (May 14, 2014)

Mystery starfsh plague extends to Canada and Mexico, but the answer is within our grasp (May 8, 2014)

Scientists look for pathogen that's killing sea stars (May 7, 2014)

Sea Star Wasting Syndrome Arrives In Oregon (May 5, 2014)

Scientists narrow in on Sea Star Wasting Syndrome devastating the West Coast (May 4, 2014)

Death of the Stars (May 2, 2014)

Slideshow: Sea Stars Dying in Mysterious Plague (May 1, 2014)

Starfsh mysteriously disappearing along the Pacifc Coast (May 1, 2014)

Sea star population plummets at Shell Beach from mysterious wasting disease (Apr 5, 2014)

Mysterious sea star disease hitting San Diego (Apr 3, 2014)

Sea stars in Southern California are dying in droves from mysterious disease (Apr 3, 2014)

Professor Studies Disappearing Sea Stars (Mar 26, 2014)

Mass Sea Star Death Leaves Researchers Perplexed (Mar 11, 2014)

What's Killing the Starfsh - KQED broadcast (Mar 5, 2014)

Ocean Currents Broadcast on KWMR (Mar 3, 2014)

Sea Star Wasting Syndrome (Thank You Ocean Report) (Mar 3, 2014)

Sea star wasting devastates Pacifc Coast species (Feb 17, 2014)

Starfsh Disease, 'Sea Star W asting Syndrome,' Finds Way Into Anchorage Museum (Feb 10, 2014)

Cornell scientists race to understand devastating starfsh epidemic (Feb 4, 2014)

Mysterious epidemic devastates starfsh population of f the Pacifc Coast (Jan 30, 2014)

Devastating disease now found in Nanaimo starfsh (Jan 3, 2014)

The starfsh ar dying, and no one knows why (Dec 31, 2013)

Massive starfsh deaths baffing biologists (Dec 24, 2013)

Where are all the sea stars? Massive mortality raises questions and concerns (Dec 7, 2013)

Watch Underwater Video of Sea Stars Dying off West Seattle (Dec 3, 2013)

Divers search for clues to an epidemic killing millions of starfsh (Nov 30, 2013)

Sea stars stricken by mysterious wasting disease (Nov 26, 2013)

Sea stars are wasting away in larger numbers on a wider scale in two oceans (Nov 22, 2013)

Sea Star Wasting Disease Hits the West Coast (Nov 21, 2013)

Pisaster disaster: When starfsh wasting disease strikes, there's only one man to call (Nov 14, 2013)

What's wiping out the starfsh in California (Nov 12, 2013)

Sea Star Wasting Syndrome Reaches Santa Barbara County (Nov 7, 2013)

Starfsh wasting disease baffes US scientists (Nov 5, 2013)

Falling Stars: Starfsh Dying From "Disintegrating" Disease (Nov 5, 2013)

'Wasting' disease turning West Coast starfsh to mush; experts stumped (Nov 4, 2013)

Wasting disease devastating starfsh along Sonoma Coast (Nov 2, 2013)

Marine Scientists Investigate Massive Sea Star Die-Off (October 10, 2013)

Starfsh Deaths Alarm Vancouver Aquarium (October 7, 2013)

Dead starfsh in V ancouver waters puzzle scientists (September 12, 2013)

Why Are Sea Stars Dying from New Jersey to Maine? Divers Asked to Report Large Groupings of Starfsh (July 23, 2013)

Effects of temperature, season and locality on wasting disease in the keystone predatory sea star *Pisaster ochraceus* (Nov 9, 2009)

Blog Postings

Update on Sea Star Wasting Disease

West Seattle Blog

Sea Star Wasting Syndrome Updates

The Echinoblog

Notes from a California naturalist

Other Resources

Daily Planet (Discovery Channel) episode (Apr 10, 2014)

Virulent Disease Attacks Sea Stars on the West Coast of North America

(video courtesy Neil McDaniel)

California Academy of Sciences photo observation map

Vancouver Aquarium diver observation map

Sunfower star wasting video (courtesy Vancouver Aquarium)

Sea Star Wasting Disease (Seadoc Society)

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Sea Star Wasting Syndrome Observations

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CLICK HERE TO SUBMIT JUVENILE SEA STAR OBSERVATIONS

Please use the link above to submit observations of juvenile sea stars. For a guide to identifying juvenile sea stars, see our juvenile sea star identifcation guide . If you have disease observations as well as sightings of juveniles, please fll out both the juvenile observation log and the disease observation log. If you have **photos** to send along with your observations, please send them here.

Photo credits: Rani Gaddam (left) and Mark Nayer (right)

CLICK HERE TO SUBMIT DISEASE OBSERVATIONS

In addition to sea star disease observations, observations of disease in the purple sea urchin (*Strongylocentrotus purpuratus*) can now be reported (as of December, 2014). Note that prior to December 2014, there are no observations for *S. purpuratus* on the map. For species other than *S. purpuratus* observations should be recorded in the 'Additional Information' section of the disease observation log.

Photo credits: Melissa Miner (left) and Gus Van Vilet (right)

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Pacific Rocky Intertidal Monitoring: Trends and Synthesis

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Sea Star Wasting Syndrome Map: Last Updated: 2015-04-02

Please note that we do not know what is causing Sea Star Wasting Syndrome, and the cause may be different in different regions. The map below includes information from our regular intertidal monitoring surveys as well as information from logs submitted by other researchers, divers, and the general public (see acknowledgements below).

Long-term trends in Pisaster ochraceus numbers at our monitored sites can be viewed by location here or by using our Interactive Map & Graphing Tool. Under "Long Term Graph Type" select "species counts data" and under "plot type" select "pisaster".

Sea Star Disease Observation Logs.

Sea star disease presence category definitions

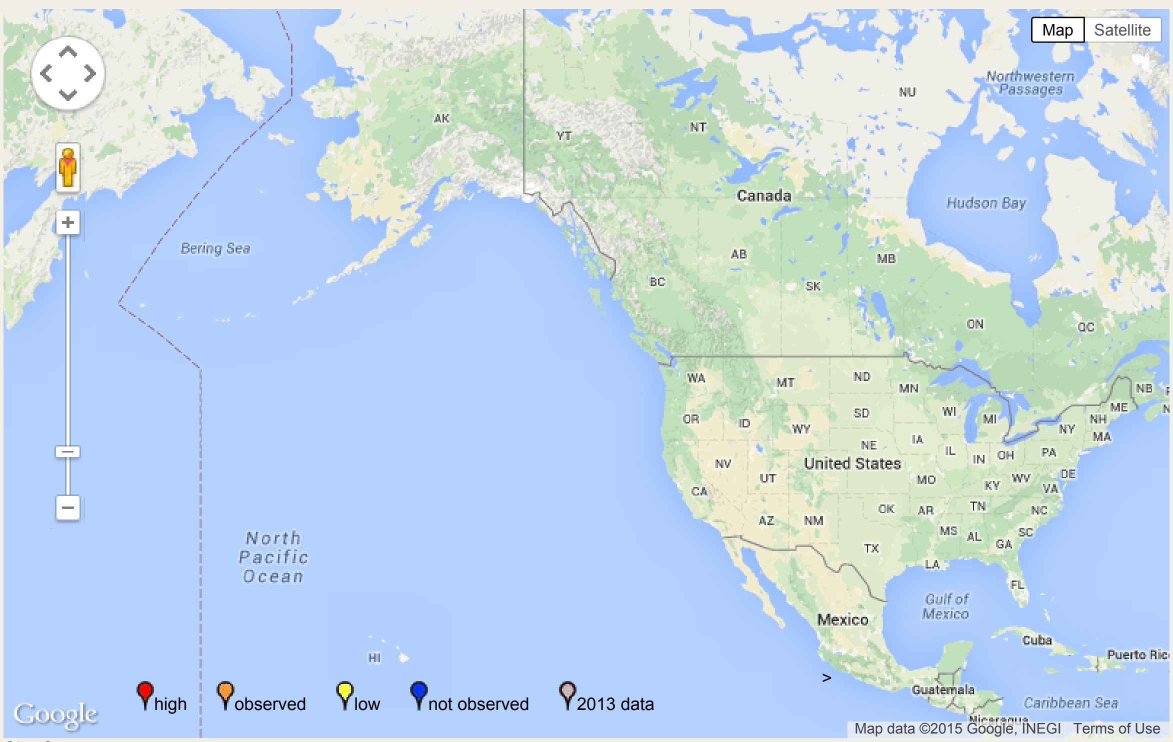
Site Observation History

Use the 'Map Display Options' to view sites on the map.

Map Display Options

select site:	All
OR select disease presence:	all
AND select location type:	Not Selected
AND select species:	Not Selected

Show All Sites | Clear | Draw Polygon | Show Sites by Last Sampled Dates: | 2013-01-01 | 2016-01-01



Site Summary:

Acknowledgements

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Pacific Rocky Intertidal Monitoring: Trends and Synthesis

pacificrockyintertidal.org
seastarwasting.org

Sea Star Wasting Syndrome Juvenile Observations Map: Last Updated: 2015-03-22

This map displays observations of "juvenile" sea stars (less than 1 inch or 25 millimeters) from our Long-Term Monitoring surveys and from the Juvenile Sea Star Observation Log. Please note that **we have only included observations where more than 10 juveniles were observed**. In addition, we have only included observations after June, 2014. For more information about juvenile recruitment, please click here.

Juvenile Sea Star Observation Log

Juveniles Observation History

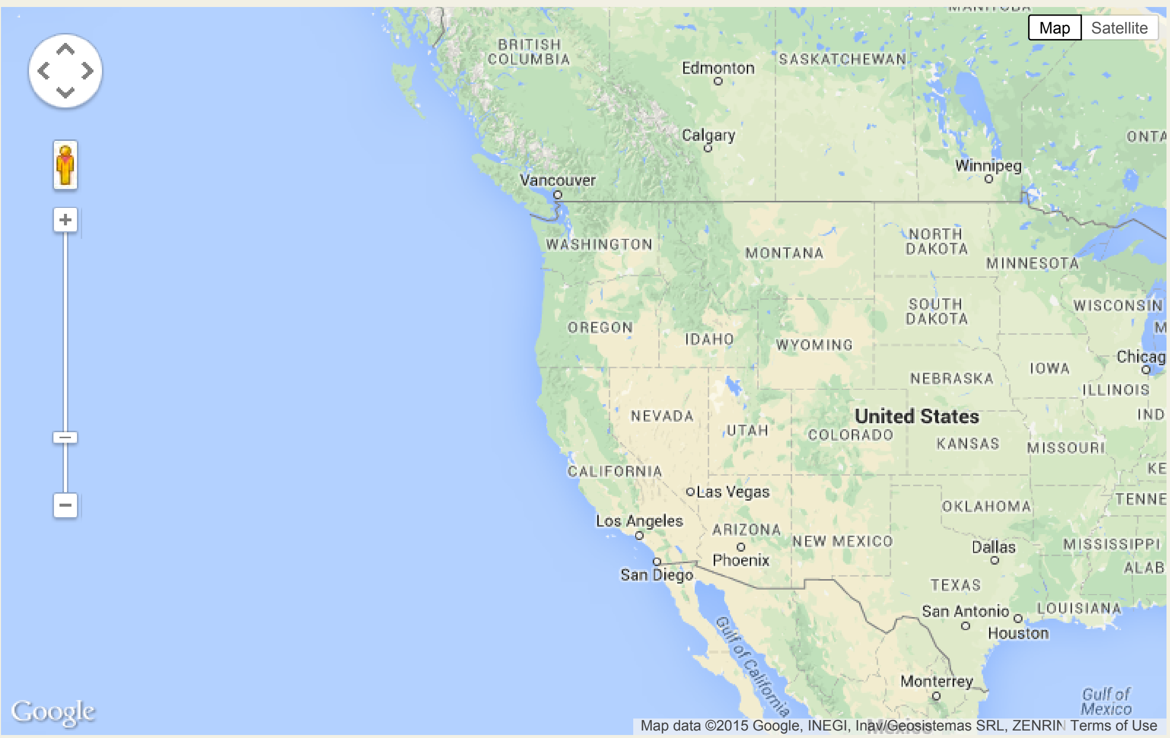
Use the 'Map Display Options' to view sites on the map.

Map Display Options

select site: All

OR select sea star species: Not Selected

Show All Sites | Clear | Draw Polygon | Show Sites by Last Sampled Dates: 2013-01-01 | 2016-01-01



Site Summary:

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COLDWATER MARINE AQUATICS

UC SANTA CRUZ

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Ben Miner, David Haley, Emily Tucker, Jan Kocian, Kelli Fisher, Mark Nayer, Melissa Miner, Stuart Wobbe, and many others. In addition, we would like to thank Melissa Redfield (UCSC) for consolidating this information for the map as well as for the Sea Star Wasting Syndrome Updates page.

Value of Citizen Science Monitoring

Involving citizen scientists in the sea star wasting disease survey effort has greatly expanded our spatial and temporal coverage. Citizen science groups can collect sea star population data using the MARINe sampling methods described below for counting and measuring sea stars and assessing condition in terms of wasting disease. In order to ensure repeatability of sampling effort within a group and standardize methods among groups, some initial training is required. A researcher from the MARINe group should accompany each citizen science group in the field to assist with appropriate site selection and set-up of permanent plots (if appropriate), and train participants in sea star species identification, proper measurement techniques and disease category designation. Scanned copies of data sheets should be sent to Rani Gaddam (gaddam@ucsc.edu) or Melissa Miner (cmminer@ucsc.edu) to be entered into the MARINe database. Data will be incorporated into the Sea Star Wasting Disease Map to enable groups to track the occurrence of wasting disease on a local and coast-wide scale.

Survey Methods:

Because the cause of sea star wasting syndrome is not fully understood, reasonable precautions against potential spread via sampling gear should be taken. Brush or spray gear (particularly boots) with freshwater to remove trapped material and spray with a dilute bleach solution between use at different sites. Also, avoid touching or marking sea stars showing symptoms of wasting disease with lumber crayons; instead, mark rock adjacent to these individuals (see methods below). If sick stars are touched (sometimes necessary to assess tissue softness/health), sterilize hands before touching additional animals.

Selection of survey sites should be based on appropriateness in terms of 1) habitat type and 2) location in order to ensure good geographical representation. For all areas, sea stars should be counted within clearly defined areas (using one of the approaches described below). The following information should be recorded for ochre stars (*Pisaster ochraceus),* and where appropriate, mottled stars (*Evasterias troschelii)***:** 1) species, 2) size to nearest 10 **mm** (**NOT cm**), 3) disease category (0-4, as defined by MARINe and adapted from those published by Bates et al. 2009). For all other sea star species, record 1) species, and 2) general disease category (healthy, mildly diseased, severely diseased). If diseased individuals are encountered, representative photos of all disease categories recorded should be taken for archival purposes. Special care should be taken to search for juveniles (<30 mm), as these are important for capturing new recruitment to sites.

The protocols below were designed for sampling in the intertidal zone. Subtidal protocols are also available on our website (seastarwasting.org).

Required Gear (for both survey types)
GPS
Flashlights/Headlamps
Rulers
Lumber crayons (yellow)
Camera
Data sheet
Pencils
Sanitizer gel/wipes

Optional Gear (for permanent plots only)
Meter tapes or line
Rock drill
Drill bit
Stainless steel bolts or screws
Z-spar marine epoxy or anchors for screws
Site map (if site already established)
Compass (to help locate bolts)
Site photos

Permanent Plots

Use datasheet labeled "SEA STARS —Disease Categories" for this approach when >1 plot is established. For sites with just one permanent plot, and one species to be measured use datasheet labeled with appropriate species' name ("*Pisaster ochraceus*" or "*Evasterias troschelii*"). For sites with one permanent plot, where both *Pisaster ochraceus* and *Evasterias troschelii* are common, use datasheet labeled "SEA STARS (*Pisaster ochraceus* and *Evasterias troschelii*) —Permanent Plot"

The number and sizes of ochre stars (and mottled stars if common) are recorded within the same well-defined areas (plots), repeatedly over time. Examples of appropriate "plots" include pier pilings, isolated boulders, or irregularly-shaped plots marked by four or more "corner" bolts (or screws or epoxy plugs), one of which is marked with notches indicating plot number. The most important feature of a plot is that it can be easily relocated, and sampled in the same way, over time. Typically, 3 separate plots are established (ideally with no shared sides) in areas of high sea star density (preferably >20 individuals/plot for a total of > 60-100 animals per site). Where plot markers are used, they should be placed on conspicuous (i.e., higher) rock features to ease relocation efforts, thus plot boundaries may include habitat unsuitable for sea stars. For this reason, **irregular plots are not intended to provide densities for comparison between sites**. Instead, they were designed to provide temporal comparisons within a site. After distinct "plots" have been chosen or permanent plot markers have been installed, a site map should be drawn showing prominent features of the area (e.g. large boulders, tide pools), with distances and compass bearings between plots or permanent markers clearly labeled. Plots should also be photographed from various angles.

To survey a plot, once the tide is low enough, a meter tape (or line) is laid out around the irregular plot perimeter (for plots with marker bolts), and the entire area encompassed by the boundary tape or within the defined plot boundaries (e.g. entire boulder or pier piling) is searched carefully. It is helpful to have a flashlight or headlamp to search within crevices. Size (radius) and disease category (0-4) are recorded for all *Pisaster ochraceus* (and *Evasterias troschelii*) present. A sea star is considered in the plot if any portion of the individual occurs within plot boundaries. **The "radius" of each sea star is measured with a ruler from the center of the disc to the tip of the longest ray to the nearest 5 mm for animals < 10 mm and the nearest 10 mm for larger individuals** (Note: sizes are in **mm, NOT cm**). Often sizes must be estimated because sea stars are wedged in tight spots with rays curved. Sea stars should never be "straightened" or removed from the rock.

Figure 1. Method used for measuring sea star "radius"

If stars have fewer than the normal number of arms (5 for most species), but otherwise appear healthy, they should be recorded as 0/healthy. Notes should be made about arm regrowth.

Special care should be taken to search for juveniles (<30 mm), as these are important for capturing new recruitment to sites. Juvenile stars typically occur in crevices, and can be difficult to see without a flashlight. Juveniles can be tricky to ID to species, and can be easily confused with the small, 6-armed star, *Leptasterias*. If juveniles cannot be identified with certainty, they should be recorded as "unidentified". See the photo guide and descriptions specific to juveniles for tips on how to distinguish species.

Species other than *Pisaster ochraceus* are counted, but not measured and general disease condition (healthy, mildly diseased, severely diseased) should be noted (*Evasterias troschelii* should also be measured where common). To avoid duplicate counting, it is helpful to use yellow lumber crayons to mark the rock adjacent to sea stars after they have been measured.

Unusual observations should be recorded in the notes section at the bottom of the datasheet. Unusual observations include "abnormal" sea star behavior such as "twisting", and falling off rocks. Signs of potential recovery from wasting should also be recorded, such as arm regrowth and lesion healing.

If diseased individuals are encountered, representative photos of all disease categories recorded should be taken for archival purposes. The following photo naming approach should be used:

genus_species_diseasecategory_site_year_monthday_photographer
Genus name can be abbreviated to the 1st letter so an example photo name would be:
p_brevispinus_cat1_hop_2013_1113_dsteller
For sea star photos where disease category is unknown, use "catu". For photos of unusual observations, include a brief descriptor in place of disease category (e.g. "p_giganteus_twisted_postpoint_2013_1228_miner").

Permanent Plots designated by GPS coordinates

Use datasheet labeled "SEA STARS—Non-Permanent Plots/Timed Searches" for this approach.

Where establishing permanent plots is not possible, or sea stars exist in too few numbers to monitor within replicated plots, large "plot" boundaries can be delineated by GPS coordinates, and timed searches can be done. To survey (around the time of low tide), mark plot boundaries by recording them as waypoints. It is helpful to use natural prominent features as boundaries, if possible, and photograph GPS waypoint locations to improve repeatability of surveys. Within the area delineated by GPS coordinates, search all appropriate sea star habitat (e.g., crevices and pools) along the mid-low intertidal zone. Count (all species) and measure (ochre stars and mottled stars only) all sea stars encountered (using methods described above for permanent plots), and designate appropriate disease category. Record search effort as # minutes spent searching by total number of samplers (e.g. 3 people for 20 min, for a total search effort of 60 min).

SEA STARS (*Pisaster ochraceus* and *Evasterias troschelii*)—Permanent Plot

Site:________________ Date:_______________ Recorder:__________________ Sampler:___________________

Disease Categories: 0=healthy, 1=lesion(s) on 1 arm or body, 2=lesions on 2 arms or 1 arm and body and/or deteriorating arm(s), 3=lesions on most of body and/or 1-2 missing arms, 4=severe tissue deterioration/death and/or >3 missing arms.

Size	***Pisaster ochraceus***					***Evasterias troschelii***				
Radius (mm)	0	1	2	3	4	0	1	2	3	4
5										
10										
20										
30										
40										
50										
60										
70										
80										
90										
100										
110										
120										
130										
140										
150										
160										
170										
180										
190										
200										

Other Sea Stars (total # and disease category only, no sizes; use 3 "general" disease categories for species other than *P. ochraceus* and *E. troschelii*)

Species	**Healthy**	**Mildly Diseased**	**Severely Diseased**

Other Observations (e.g. arm regrowth, lesion healing, "abnormal" twisting, etc.):

Evasterias troschelii

Site:____________________ Recorder:___________________

Date:____________________ Sampler:____________________

Disease Categories: 0=healthy, 1=lesion(s) on 1 arm or body, 2=lesions on 2 arms or 1 arm and body and/or deteriorating arm(s), 3=lesions on most of body and/or 1-2 missing arms, 4=severe tissue deterioration/death and/or ≥3 missing arms.

Size	**Disease Category**				
Radius (mm)	0	1	2	3	4
5					
10					
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					
130					
140					
150					
160					
170					
180					
190					
200					

Other Sea Stars [total # under appropriate general disease category only, no sizes]

Species	Healthy	Mildly Diseased	Severely Diseased

Other Observations (e.g. arm regrowth, lesion healing, “abnormal” twisting, etc.):

Pisaster ochraceus

Site:______________ Recorder:____________________________ Start Time:_________

Date:_____________ Sampler:_____________________________ End Time: _________

Disease Categories: 0=healthy, 1=lesion(s) on 1 arm or body, 2=lesions on 2 arms or 1 arm and body and/or deteriorating arm(s), 3=lesions on most of body and/or 1-2 missing arms, 4=severe tissue deterioration/death and/or ≥3 missing arms.

Size	**Disease Category**				
Radius (mm)	0	1	2	3	4
5					
10					
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					
130					
140					
150					
160					
170					
180					
190					
200					

Other Sea Stars [total # under appropriate general disease category only, no sizes]

Species	**Healthy**	**Mildly Diseased**	**Severely Diseased**

Other Observations (e.g. arm regrowth, lesion healing, “abnormal” twisting, etc.):

SEA STAR PLOTS—Disease Categories

Site:________________ Date:________________ Recorder:__________________ Sampler:___________________

Pisaster Disease Categories: 0=healthy, 1=lesion(s) on 1 arm or body, 2=lesions on 2 arms or 1 arm and body and/or deteriorating arm(s), 3=lesions on most of body and/or 1-2 missing arms, 4=severe tissue deterioration/death and/or ≥3 missing arms.

Size	Plot 1					Plot 2					Plot 3				
Radius (mm)	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
5															
10															
20															
30															
40															
50															
60															
70															
80															
90															
100															
110															
120															
130															
140															
150															
160															
170															
180															
190															
200															

Category 1

lesion(s) on 1 arm or body

Tissue degradation in some of these photos may be the result of multiple lesions merging, but it is restricted to a single arm, or single location on the oral disk.

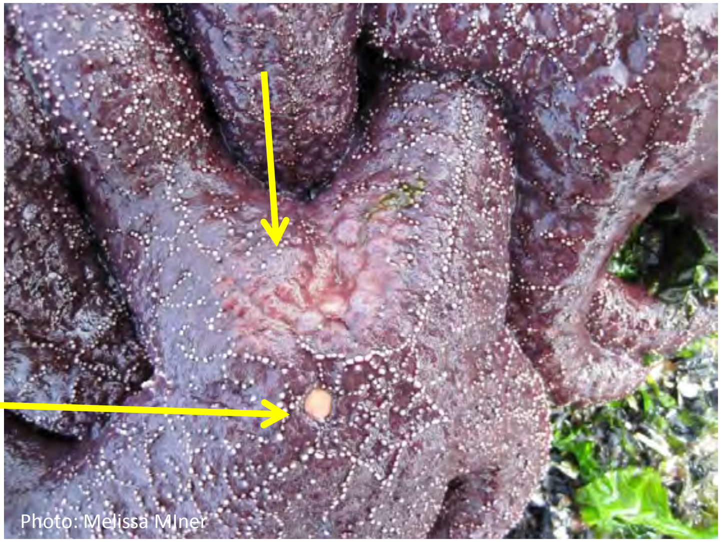

Photo: Melissa Miner


Photo: Melissa Miner


Photo: Melissa MIner

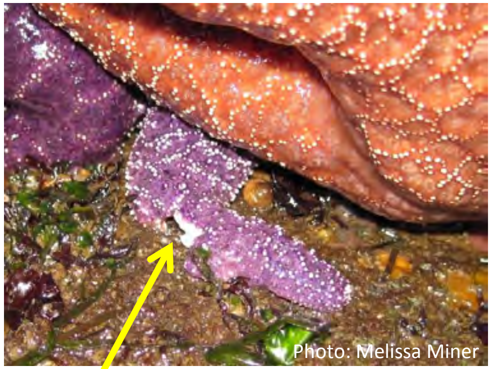
Category 1

NOT a lesion
(madreporite)



Category 2

lesions on 2 arms or 1 arm and body and/or deteriorating arm(s)



Arm starting to separate

Tissue deteriorating on 2 arms

Category 3

lesions on most of body and/or 1-2 missing arms

Category 3

Missing tips of 2 arms, lesion on 3rd

Category 4

severe tissue deterioration/death and/or ≥3 missing arms

Photo: Angela Johnson

Photo: Melissa Miner

Photo: Melissa Miner

Category 4


Photo: Dennis Paulson
Internal organs emerging from lesions


Photo: Melissa Miner


Photo: Melissa Miner

Spawning (all healthy/Category 0)

Spawning
(all healthy/Category 0)

Sea Star Wasting Syndrome Protocols for Subtidal Surveys

February 13, 2014

Value of Citizen Science Monitoring in the subtidal

Involving citizen scientists to survey the nearshore subtidal for evidence of sea star wasting syndrome will greatly improve our understanding of the spatial extent of the syndrome and track changes through time. Citizen science groups can collect subtidal sea star syndrome data using the standardized sampling methods described below, which have been modified from the approach used by the Multi-Agency Rocky Intertidal Network (MARINe) in the intertidal for counting and measuring sea stars and assessing condition in terms of wasting syndrome. In order to ensure repeatability of sampling effort within a group and standardize methods among groups, it is critical to collect data using the protocol described below. When possible, a researcher familiar with the protocol should accompany each citizen science group in the field to assist with site selection, data collection methods, and if appropriate, set-up of permanent transects/sampling areas. In addition, researchers can train citizen scientists in sea star species identification, proper measurement techniques and syndrome category designation.

Once the data have been collected, send scanned copies of data sheets to Rani Gaddam (gaddam@ucsc.edu, if in California) or Melissa Miner (cmminer@ucsc.edu, if in OR or WA) to be entered into the MARINe database. Data will be incorporated into the Sea Star Wasting Syndrome Map (http://data.piscoweb.org/marine1/seastardisease.html) to enable groups to track the occurrence of wasting syndrome on a local and coast-wide scale. We expect in mid-January to have an online data entry system, so please check the web site for updates (http://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting/index.html).

Survey Methods

Because the cause of sea star wasting syndrome is still unknown, reasonable precautions against potential spread via sampling gear should be taken. Rinse diving and sampling gear with freshwater between surveys at different sites. At all long-term survey sites, sea stars should be counted within clearly defined areas using one of the survey options described below. For all sea stars encountered, the following information should be recorded:
1) species (or "unknown" if ID not possible)
2) size category (optional)
3) health category
If unhealthy individuals are encountered, representative photos should be taken (if possible) to document the various stages of syndrome symptoms.

<u>Required Gear (for both survey options)</u>
Dive slate (something to write on)
Pencil
Compass
Measuring device (in cm)
Dive light

<u>Optional Gear (but VERY useful)</u>
Meter tape or marked line
Data Sheet printed on UW paper
GPS handheld (for site coordinates)
UW Camera


Dive slate


Dive light


Meter tape

Survey Option 1a and 1b: Fixed Permanent Transects and Fixed Sampling Areas

Ideally, the exact same areas should be sampled over time, in order to compare how numbers and the condition of sea stars change within a specific, fixed area. Some options for how to establish permanent surveys of a fixed area include:

1a) **Counts Along Fixed Permanent Transects**—A meter tape or marked line can be attached to a fixed structure (e.g., pier piling in a harbor or a particular rock at your favorite dive site) and then stretched out to a set length (e.g., most transect tapes are 30 m) along a fixed compass bearing that traverses sea star habitat. Divers can swim along the transect line, counting and assessing disease categories for all sea stars encountered within 1 m of either side of transect (for a 2 m x 30 m wide swath). The distance from the middle of your chest to the end of one outstretched arm is often a good proxy for 1 m (measure to check this!), or a 1 m bar (piece of pcv pipe) can be used as a guide. One diver can accomplish the same task by first swimming along 1 side of the transect, then returning along the other side. Ideally, at least 3 replicate transects would be established in the area, but ensuring they do not overlap one another. An even better way to sample is to set the transect line first, anchoring both the 0 m end and the 30 m end at fixed points (ones that you can easily return to in the future) and once it is in place, then sample along the transect. The idea is to sample this same piece of benthic habitat several times in the future, each time covering the same amount of area to determine how sea star numbers and condition change over time.

1b) **Counts Within Fixed Sampling Areas**—Sampling the same exact (i.e. fixed) area repeatedly can also be accomplished by counting all sea stars on permanent underwater features, such as distinct rock outcroppings surrounded by sand, submerged docks, or harbor jetties (or well defined sub-sections of jetties). The key to this method is defining an area that can be counted completely during each survey. For example, it may not be possible to count all sea stars along the entire length of a jetty, but small, well defined/described subsections could be accurately and completely counted during repeated surveys.

Survey Option 2: Non-Permanent Transects Repeated Within Defined Sampling Areas

For sites where permanent underwater features cannot be used as transect start/end markers, or well-defined underwater features do not exist, sea stars can be counted along non-permanent (i.e. random) transects within a defined sampling area. The boundaries of the sampling are should be defined by GPS coordinates, which can be accomplished using a boat's GPS system, a handheld GPS, or Google Earth. Within these sampling boundaries, divers can swim random, non-overlapping transects at a consistent depth or along a depth profile for a set amount of time (e.g., swim 10 min along compass heading, then shift over 5 m and return along the opposite compass bearing). The goal is to try to cover approximately the same area during all subsequent surveys within the defined sampling area.

Collecting data

For both survey options 1 and 2, the entire sampled area should be searched carefully for all sea stars. While it is important to do a careful search, cobble and boulders should not be moved to ensure that sampling is non-destructive. Crevices should be searched with a dive light for cryptic or small sea stars. Sea star size class and disease category are recorded for all sea stars present (see size and disease class definitions below). **The "radius" of each sea star is measured with a metric ruler from the center of the disc to the tip of the longest ray (see photo below).** Often sizes must be estimated because sea stars are wedged in tight spots or the rays are curved. Sea stars should never be "straightened" or removed from the rock to make a measurement; please measure them in place.

Unusual observations should be recorded in the notes section at the bottom of the datasheet. These include "abnormal" sea star behavior such as "twisting" of multiple rays, and drooping or hanging off vertical surfaces. Signs of potential healing from wasting should also be recorded.

If diseased individuals are encountered, representative photos of all disease categories recorded should be taken if possible; these images will be used in our archives. The following photo naming approach should be used:

genus_species_diseasecategory_site_year_monthday_photographer

Genus can be abbreviated to the 1st letter so an example photo name would be:
p_brevispinus_mild_breakwater_2013_1113_dsteller

For sea star photos where disease category is unknown, use "catU":
p_miniata_catU_lobos_2013_1223_jnichols

Size Classes (optional but VERY useful!)

Sea stars of all species encountered should be recorded under the size classes listed below, determined by measuring the radius (center of the disc to the tip of the longest ray). Note that the data sheet has 5 cm bins on the side, so if you print on UW paper, you can use that as a ruler. It is always good to double check that this scale bar matches up with an actual ruler, as the size could change during printing/photocopying.

- <5 cm
- 6-10 cm
- 11-15 cm
- >15 cm


Method used for measuring sea star "radius"

Disease Classes

Two tiers can be used for assigning disease class:

Tier 1: Two sea star condition categories

- "Healthy" = no symptoms of disease
- "Diseased" = symptoms of disease present (lesions, arm loss, deflated, etc.)

Tier 2: Three sea star condition categories. The separation of disease severity will help us understand whether sea star wasting syndrome can persist at a low level within a community. Sea stars with mild signs may be able to recover.

- "Healthy" = no symptoms of disease
- "Mild" Symptoms = few lesions, deflated appearance, extreme twisting of rays
- "Severe" Wasting/Death = many lesions, arm loss, disintegration

Species Identification

It is import to identify sea stars to species. However, if separating species is not possible, focus on the species that you can confidently identify, and record other species as unidentified. Incorrectly identifying species will jeopardize analyses and conclusions.

Common name	Scientific name
Ochre star	*Pisaster ochraceus*
Giant-spined star	*Pisaster giganteus*
Short-spined (or Pink) star	*Pisaster brevispinus*
Northern Rainbow star	*Orthasterias koehleri*
Sunflower star	*Pycnopodia helianthoides*
Sun stars	*Solaster* spp.
Mottled/False ochre	*Evasterias troschelii*
Bat star	*Patiria miniata*
Leather star	*Dermasterias imbricata*
Velcro star	*Stylasterias forreri*

Others not apparently impacted (yet):

Blood star	*Henricia* spp.
Red star	*Mediaster aequalis*

Subtidal Sea Star Protocol
Last updated Feb 13, 2014

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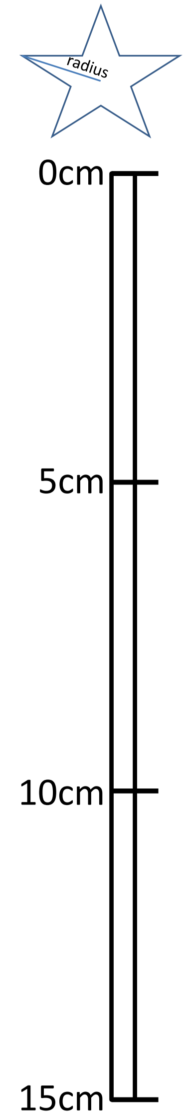
Site:______________________ Date:________________ Sampler Name:______________________

	Healthy (no signs of disease)				
Species	≤ 5cm	6-10cm	11-15cm	>15cm	not sized
Pycnopodia (sunflower)					
Evasterias (mottled)					
Pisaster ochraceus (ochre)					
Pisaster brevispinus (giant pink)					
Pisaster giganteus (giant star)					
Dermasterias (leather)					
Patiria miniata (bat)					
Solaster spp. (sun)					
Orthasterias (rainbow)					
Unknown					

	Diseased/Dead				
Species	≤ 5cm	6-10cm	11-15cm	>15cm	not sized
Pycnopodia (sunflower)					
Evasterias (mottled)					
Pisaster ochraceus (ochre)					
Pisaster brevispinus (giant pink)					
Pisaster giganteus (giant star)					
Dermasterias (leather)					
Patiria miniata (bat)					
Solaster spp. (sun)					
Orthasterias (rainbow)					
Unknown					

Notes:



Subtidal Sea Star Protocol
Last updated Feb 13, 2014

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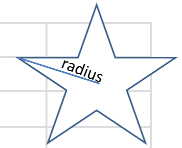
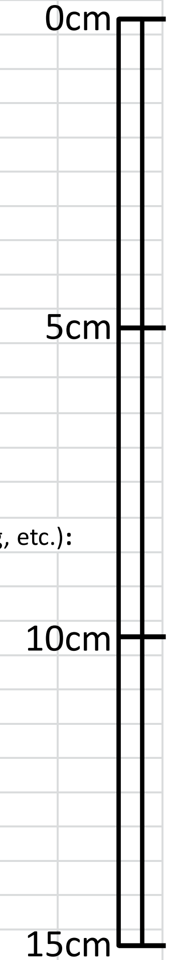
seastarwasting.org

Site:______________________ Date:________________ Sampler Name:_______________________



	Healthy (no signs of disease)				**Mild Signs of Disease**			
Species	≤ 5cm	6-10cm	11-15cm	>15cm	≤ 5cm	6-10cm	11-15cm	>15cm
Pycnopodia (sunflower)								
Evasterias (mottled)								
Pisaster ochraceus (ochre)								
Pisaster brevispinus (giant pink)								
Pisaster giganteus (giant star)								
Dermasterias (leather)								
Patiria miniata (bat)								
Solaster spp. (sun)								
Orthasterias (rainbow)								
Unknown								



	Severe Signs of Disease/Death			
Species	≤ 5cm	6-10cm	11-15cm	>15cm
Pycnopodia (sunflower)				
Evasterias (mottled)				
Pisaster ochraceus (ochre)				
Pisaster brevispinus (giant pink)				
Pisaster giganteus (giant star)				
Dermasterias (leather)				
Patiria miniata (bat)				
Solaster spp. (sun)				
Orthasterias (rainbow)				
Unknown				

Notes (e.g. arm regrowth, "abnormal" twisting, etc.):

Subtidal Sea Star Protocol
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0cm 5cm 10cm 15cm

Healthy (no signs of disease)

Species	$\leq$ 5cm	6-10cm	11-15cm	>15cm
Pycnopodia (sunflower)				
Evasterias (mottled)				
P. ochraceus (ochre)				
P. brevispinus (giant pink)				
P. giganteus (giant star)				
Dermasterias (leather)				
Patiria miniata (bat)				
Solaster spp. (sun)				
Orthasterias (rainbow)				
Unknown				

Site:____________________

Date:____________________

Sampler:__________________

Notes (e.g. arm regrowth, abnormal twisting, etc.):

Mild Signs of Disease

Species	$\leq$ 5cm	6-10cm	11-15cm	>15cm
Pycnopodia (sunflower)				
Evasterias (mottled)				
P. ochraceus (ochre)				
P. brevispinus (giant pink)				
P. giganteus (giant star)				
Dermasterias (leather)				
Patiria miniata (bat)				
Solaster spp. (sun)				
Orthasterias (rainbow)				
Unknown				

Severe Signs of Disease/Death

Species	$\leq$ 5cm	6-10cm	11-15cm	>15cm
Pycnopodia (sunflower)				
Evasterias (mottled)				
P. ochraceus (ochre)				
P. brevispinus (giant pink)				
P. giganteus (giant star)				
Dermasterias (leather)				
Patiria miniata (bat)				
Solaster spp. (sun)				
Orthasterias (rainbow)				
Unknown				

Pisaster Disease Examples
Last updated 2014-07-27

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seastarwasting.org

Category 1

lesion(s) on 1 arm or body
Tissue degradation in some of these photos may be the result of multiple lesions merging, but it is restricted to a single arm, or single location on the oral disk.

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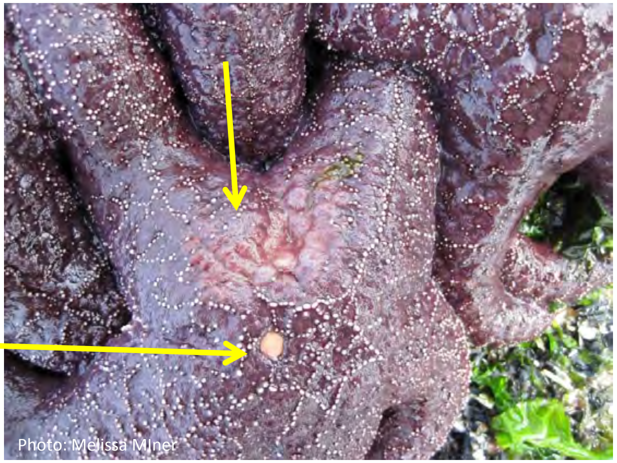
seastarwasting.org

Pisaster Disease Examples
Last updated 2014-07-27

Category 1

NOT a lesion (madreporite)



Pisaster Disease Examples
Last updated 2014-07-27

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Category 2

lesions on 2 arms or 1 arm and body and/or deteriorating arm(s)

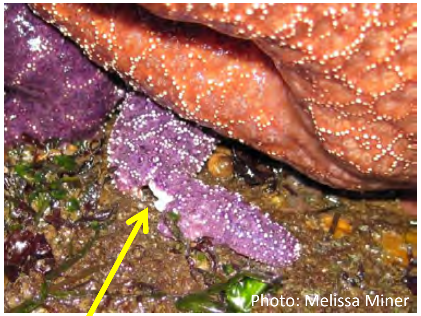
Photo: Melissa Miner

Arm starting to separate


Photo: Melissa Miner

Tissue deteriorating on 2 arms

Pisaster Disease Examples
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Category 3

lesions on most of body and/or 1-2 missing arms

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Category 3

Missing tips of 2 arms, lesion on 3rd

Pisaster Disease Examples
Last updated 2014-07-27

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seastarwasting.org

Category 4

severe tissue deterioration/death and/or >3 missing arms

Category 4

Internal organs emerging from lesions

Spawning (all healthy/Category 0)

Spawning
(all healthy/Category 0)

Juvenile Sea Star Identification Guide

Updated as of April 16, 2015:

- This guide is an accompaniment to the data form designed to capture evidence of recovery from Sea Star Wasting Syndrome in the form of recruitment (settlement and development of baby sea stars).
- “Juvenile" sea stars, with the exception of *Pycnopodia helianthoides*, are here defined as any individuals 25 mm / 1 inch or less in diameter (i.e. the size of a Quarter or Loonie coin). For smaller species such as *Henricia* and *Leptasterias*, individuals of this size are likely "adults" (of reproductive size), but because true juveniles are quite small and cryptic, they will commonly be over-looked. For *Pycnopodia helianthoides*, one of the larger species, juveniles will now be defined as individuals 50 mm / 2 inches or less in diameter.
- When small, sea stars can be hard to correctly identify. Please take and submit additional photos if ID is <100% certain.
- Thank you for your assistance in the continued Sea Star Wasting Syndrome tracking effort!


Photo: John Pearse

Pisaster ochraceus (ochre sea star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to Baja California

Appearance

Usually 5 arms that are widest where they meet the oral disk and taper at the ends, adult radius up to 250 mm; variable coloration (muted tones of gray, purple/blue, orange/tan, a mixture of the three) that provides more camouflage than the adults' more vivid pigmentation; often display a star shape in the center of their oral disk formed by a grouping of small white spines (lower right photo) (these can also be seen through the epidermis all over the star's aboral surface).

Habitat

Juveniles are much less conspicuous and they tend to occupy slightly different habitats (small cracks, under loose cobble, inside the mussel matrix, etc.) than the brightly-colored adults.

Can be confused with

Adults: *Evasterias troschelii*

Juveniles: *Leptasterias* spp. and juvenile *Evasterias troschelii*

Evasterias troschelii (false ochre / mottled star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Siberia/No. Alaska to Central California

Appearance (compared with *P. ochraceus* and *Leptasterias* spp.)

Generally 5 arms that are more slender than *P. ochraceus*' and have a constricted appearance where they meet a smaller oral disc, adult radius up to 300 mm; color ranges from orange-brown to blue-gray; star pattern (comprised of white spines) usually absent from the center of the disk's aboral surface. Spines on the side of the arm are in several rows (3 or more) and slant upwards toward aboral surface. If aboral surface is visible, the larger knobby spines of *Evasterias* are connected to each other by a net-like pattern of smaller, sharper spines. *Evasterias*, even when small, have proportionately much longer arms than does *Leptasterias* spp.

Habitat

Occurs primarily in protected or semi-protected waters, with preference for hard surfaces (pier pilings, docks, rip-rap, jetties, etc.); also found on sand. Juveniles often occur under cobble, within empty shells or in other cryptic habitat. Occasionally co-located with *P. ochraceus.*

Can be confused with

Adults: *Pisaster ochraceus*

Juveniles: *Leptasterias* spp. and juvenile *Pisaster ochraceus*

Pisaster giganteus

(giant-spined / knobby sea star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

British Columbia to Baja California

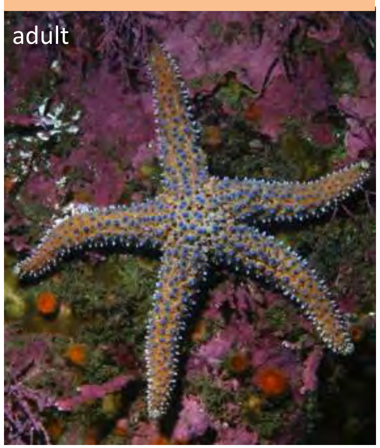
Appearance (compared with *P. ochraceus*)

Aboral spines are fewer and longer than those of *P. ochraceus*; they are also evenly spaced (never forming a star pattern), surrounded at their base by blue skin-like material, and are white in adults and pink, violet, or blue in juveniles. Adult radius up to 125 mm.

Habitat

Found on rocks/pier pilings in low intertidal zone or subtidal (to 88 m); occasionally on sand.

Photos: Dr. Steve Lonhart, NOAA MBNMS



Pisaster brevispinus

(short-spined / giant-pink sea star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

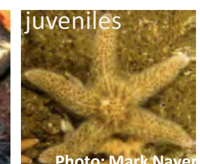
Alaska to San Diego, California

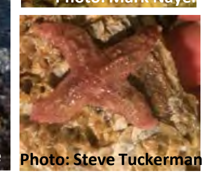
Appearance

Characteristic pink color in adults and uniform (un-mottled) off-white to light-pink color in juveniles (in juvenile photo, pink color is just starting to come through); usually 5, thick arms; short spines and two rows run parallel down center of each ray. Adult radius up to 250 mm.

Habitat

Occasionally found in the low intertidal zone but more common subtidally (0.5 m to 100 m) on soft bottoms, or on protected rocks/pier pilings.





Note: Often true juveniles of these 2 genera are closer to 10-15mm in diameter, however, they can be tricky to find and correctly ID at that size.

Henricia spp. (Pacific blood star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to Baja California

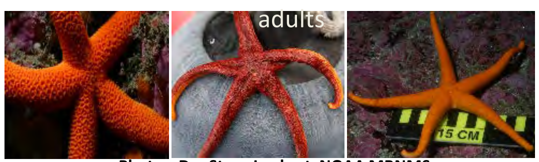
Appearance

Adults usually smaller than ~90 mm radius; small disk; usually 5, long arms that taper; body nearly smooth (not overtly spiny); colored tan to orange-red or purple, sometimes with darker colored banding; groups of short spines on aboral surface; huge variety in size and color morphology. Northern species can have white or tan patches on the central disk that can be confused with signs of wasting disease (lower right picture).

Habitat

Often found in sponge and bryozoan encrusted areas on or around rocks, caves, and pools in the low intertidal zone.

Photo: Natasha Meyers-Cherry



Photos: Dr. Steve Lonhart, NOAA MBNMS

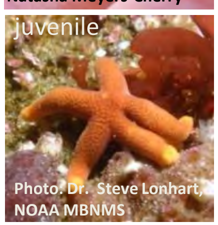


Photo: Dr. Steve Lonhart, NOAA MBNMS

Photo: Jan Kocian

← These white patches between Henricia arms are NOT symptoms of wasting.

Leptasterias spp. (six-rayed star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to the Channel Islands, California

Appearance

Brooding sea star; usually with 6 arms; adult radius up to 52 mm; coloration typically dark (mottled black or brown), sometimes brightly colored red or green. *Leptasterias* usually have 1-2 rows of spines on side of lower portion of arms and spines above this row are scattered. The mottling can take the form of a star pattern in center of aboral disk (see lower left picture) however this is distinct from the star pattern found in *P. ochraceus* where the central star pattern is formed by aboral spines.

Habitat

Intertidal species; typically found in cracks and crevices, to which its body conforms. Can be patchy in distribution, with individuals often occurring in clusters.

Can be confused with

Adults and juveniles: juvenile *Pisaster ochraceus* and juvenile *Evasterias troschelii*

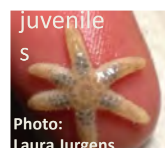


Photo: Laura Jurgens

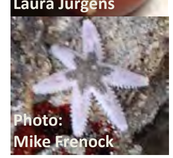


Photo: Mike Frenock

Photo: Dr. Steve Lonhart, NOAA MBNMS

Photo: Melissa Redfield

Patiria miniata (bat star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to Baja California

Appearance

Large disk with short, triangular arms (usually five), adult radius up to 120 mm; color variable, with orange and red (solid/mottled) variants most common—distinguishing features consistent in both juveniles and adults.

Habitat

Commonly found around rocks covered by surfgrass, algae, sponges, and bryozoans in the low intertidal; found subtidally to 290 m.

Dermasterias imbricata (leather star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to San Diego, California

Appearance

Adult radius to 120 mm; typically has 5 arms; epidermis is smooth, leathery, and slippery; color typically gray with red-orange mottling; individuals often smell of garlic or sulfur.

Habitat

Common to rocky shores in the low intertidal or shallow subtidal; can be found on pilings and harbor sea walls.

Photos: Dr. Steve Lonhart, NOAA MBNMS

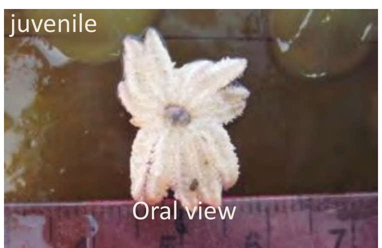
Pycnopodia helianthoides
(sunflower star)

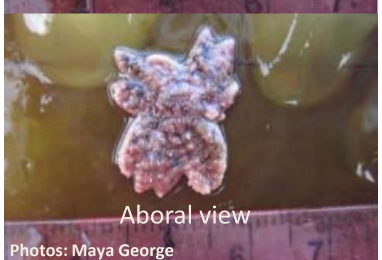
Size of juveniles
Up to 2 inches (50 mm) in diameter.

Range
Alaska to San Diego, CA (uncommon south of Monterey County, CA)

Appearance
Adult radius up to 400 mm+; soft, flexible, large oral disk; beginning with 5 arms, all but the smallest juveniles have 5+ arms and can acquire up to a total of 24 arms as adults—addition of arms is asymmetrical (see upper right photo); aboral surface pink, purple, or brown (uncommonly red, orange, or yellow)

Habitat
Low intertidal zone of rocky shores; found subtidally to 435 m on rock, sand, and mud.





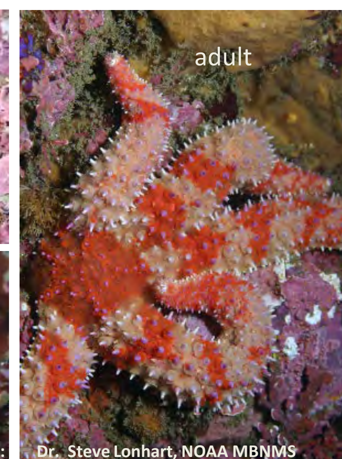
Orthasterias koehleri
(northern rainbow star)

Size of juveniles
Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range
Alaska to Santa Rosa Island (Channel Islands), California

Appearance
Small oral disk with sharp white-lilac spines on the aboral surface; 5 slim arms with adult radius up to 300 mm; coloration typically involves a dull orange/cream-colored body banded with red.

Habitat
Uncommonly found in very low intertidal on mud, sand, rock, and kelp; more common subtidally to 250 m.



Note: All *Solaster* species get combined to *Solaster spp.* due to difficulty differentiating between them.

Solaster stimpsoni (Stimpson's sun star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to Humboldt Co.

Appearance (compared with *Pycnopodia helianthoides*)

S. stimsponi's slender arms are tapered and can reach a radius of 250 mm; individuals typically have 10 arms; aboral disk color variable (red, orange, yellow, green, or blue), often with a blue-gray mark in central portion of disk that connects with similar colored lines radiating out along the aboral surface of each arm to the tips. *S. stimpsoni* has a smaller oral disk than the sunflower star (*Pycnopodia helianthoides*) and texture of it's aboral surface is also rougher due to presence of ossicles bearing spine clusters.

Habitat

This uncommon species is found primarily on rocks, less preferably on sand, from the very low intertidal to 60 m subtidally.

Can be confused with

Adults and juveniles: *Solaster dawsoni*, *Solaster paxillatus*, *Solaster endeca*, and *Pycnopodia helianthoides*

Solaster dawsoni (Dawson's sun star)

Size of juveniles

Up to 1 inch (25 mm) in diameter, or smaller than a Quarter or Loonie coin.

Range

Alaska to Monterey Co.

Appearance (compared with *S. stimpsoni*)

S. dawsoni can have from 8 to 13 arms (adults most commonly have 12-13) with radii of 250 mm; aboral coloration typically muted (gray, cream, yellow, brown) and infrequently bright (red or orange) with light patches in between the arms. Arms of *S. dawsoni* are typically less narrow than those found in *S. stimpsoni*.

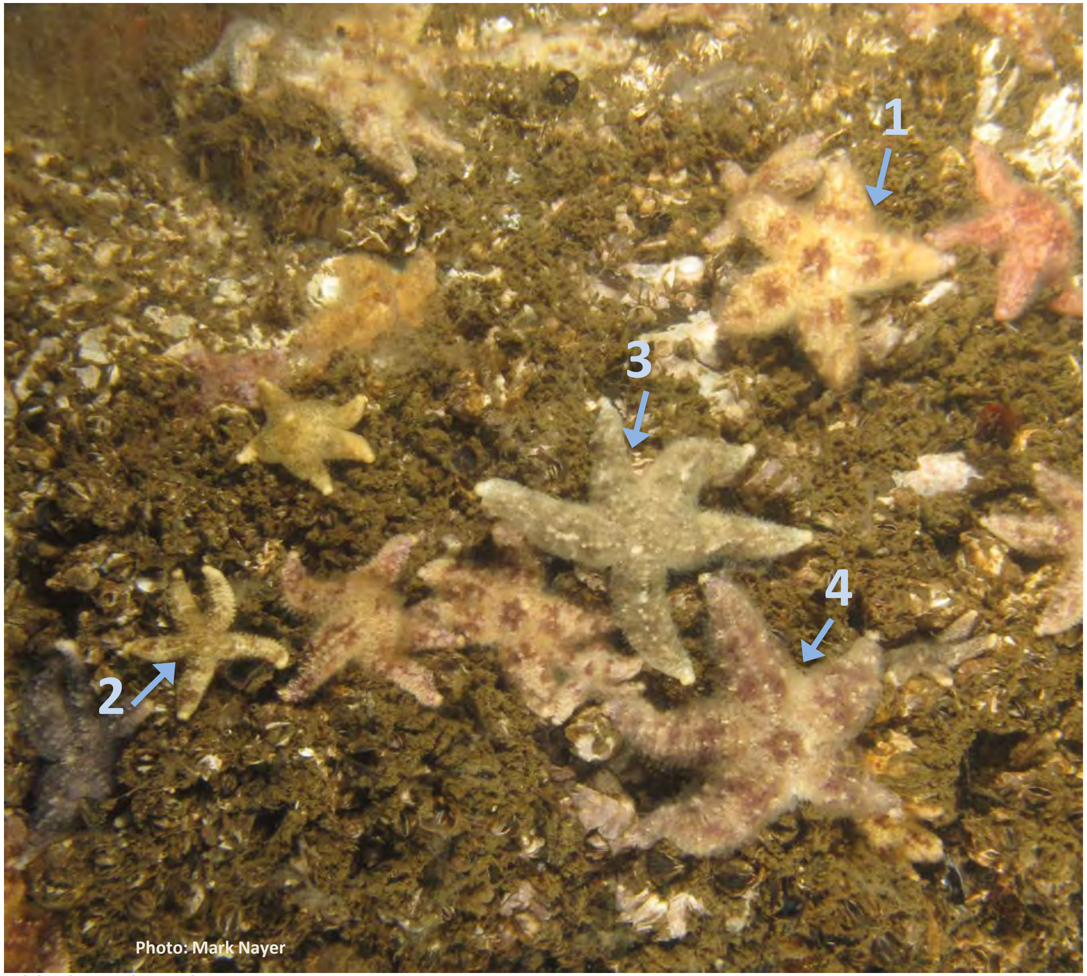
Habitat

Uncommonly encountered on mud, sand, gravel and rocks from the low intertidal zone to 420 m subtidally.

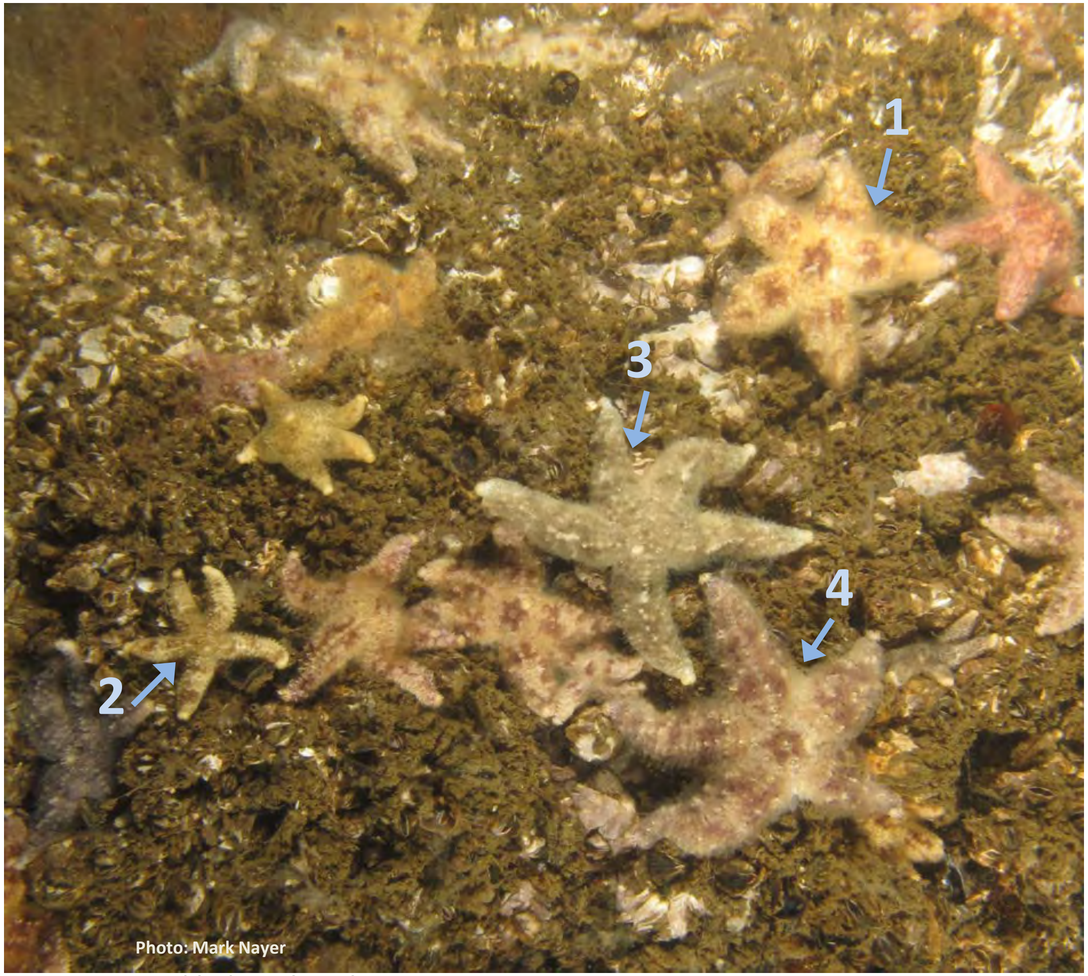
Can be confused with

Adults and juveniles: *Solaster stimpsoni*, *Solaster paxillatus*, *Solaster endeca*, and *Pycnopodia helianthoides*

Juvenile Sea Stars ID Game
Part 1

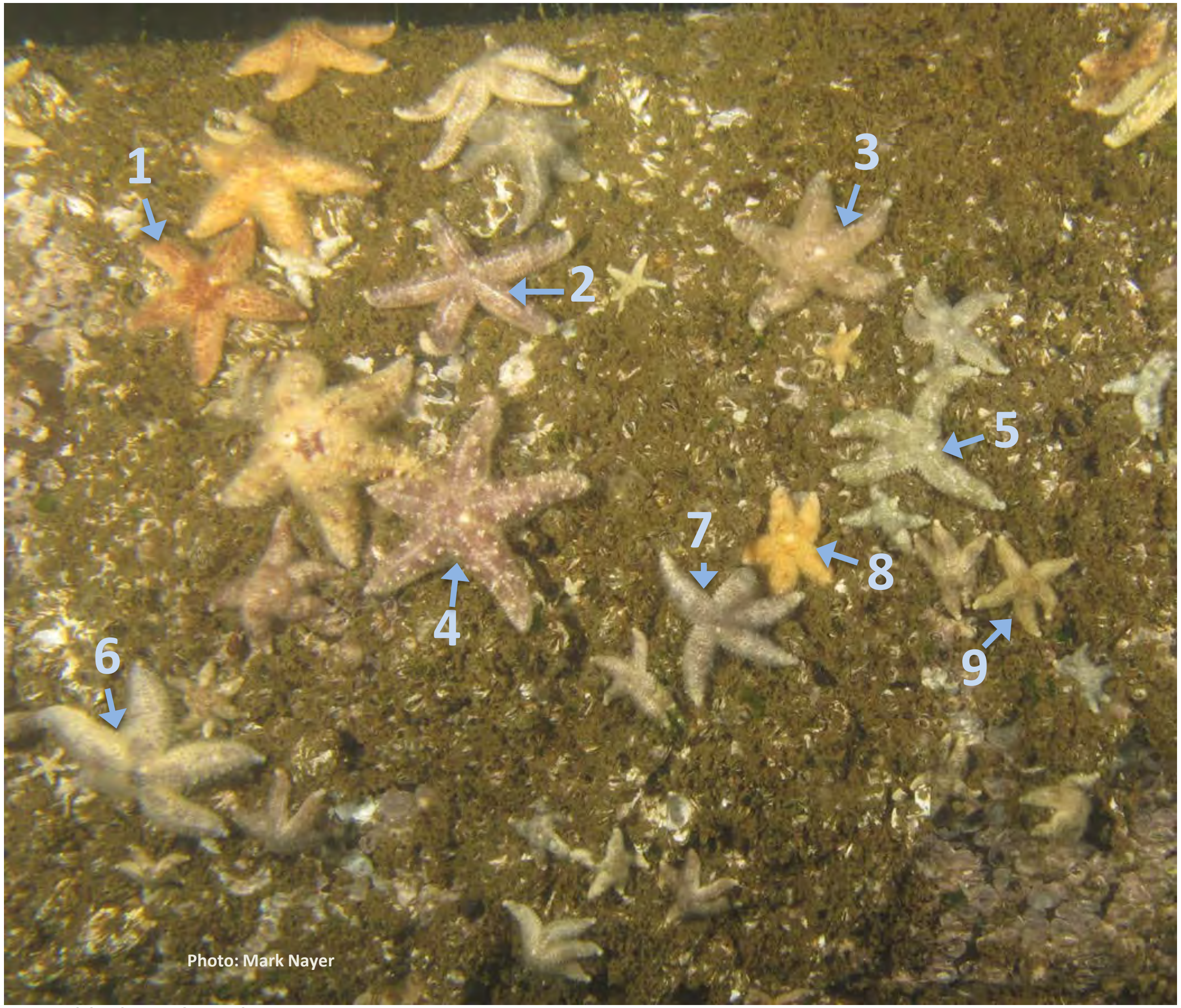


Juvenile Sea Stars ID Game
Part 1: key

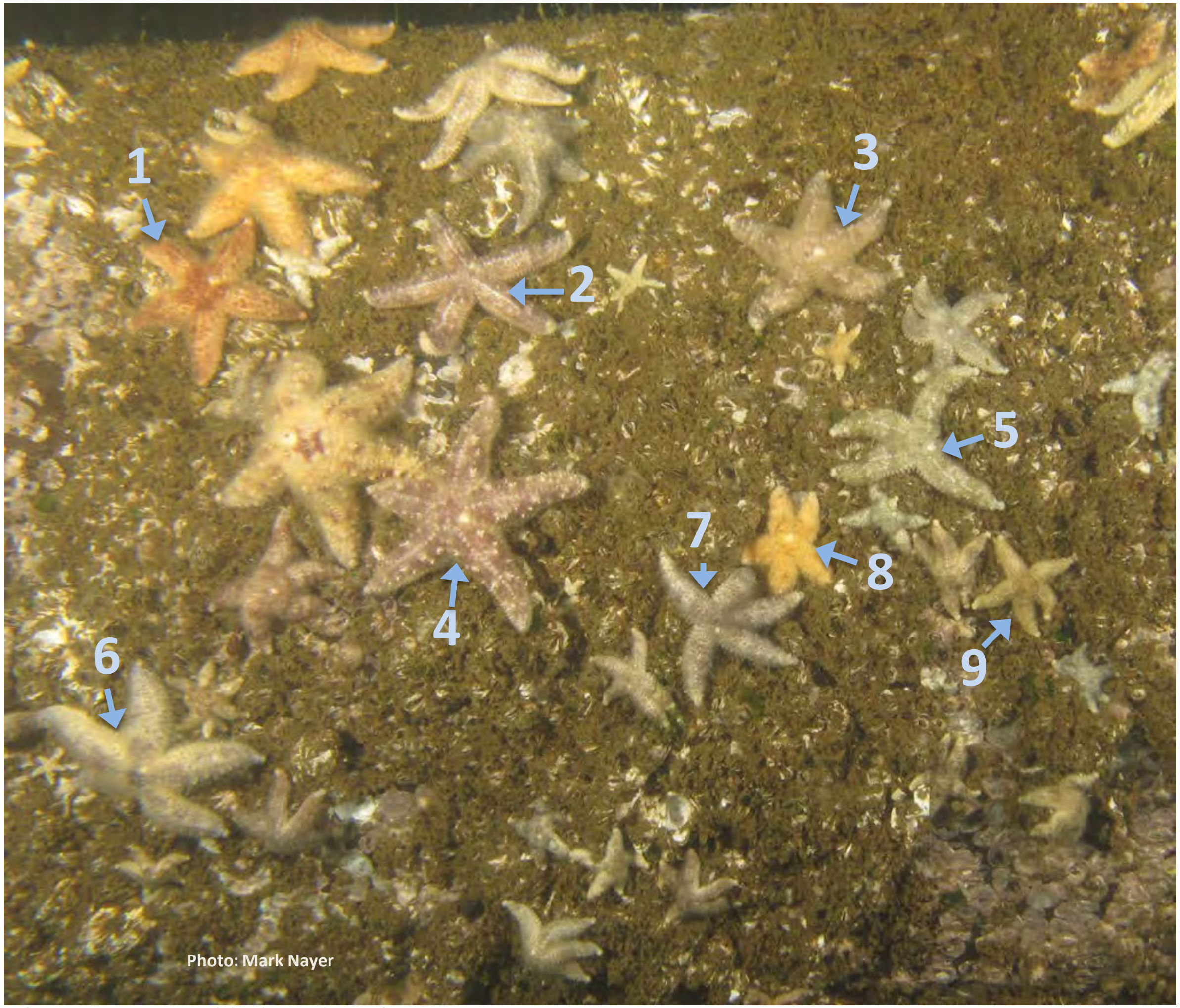


1. P. ochraceus
2. E. troschelii
3. E. troschelii
4. P. ochraceus

Juvenile Sea Stars ID Game
Part 2

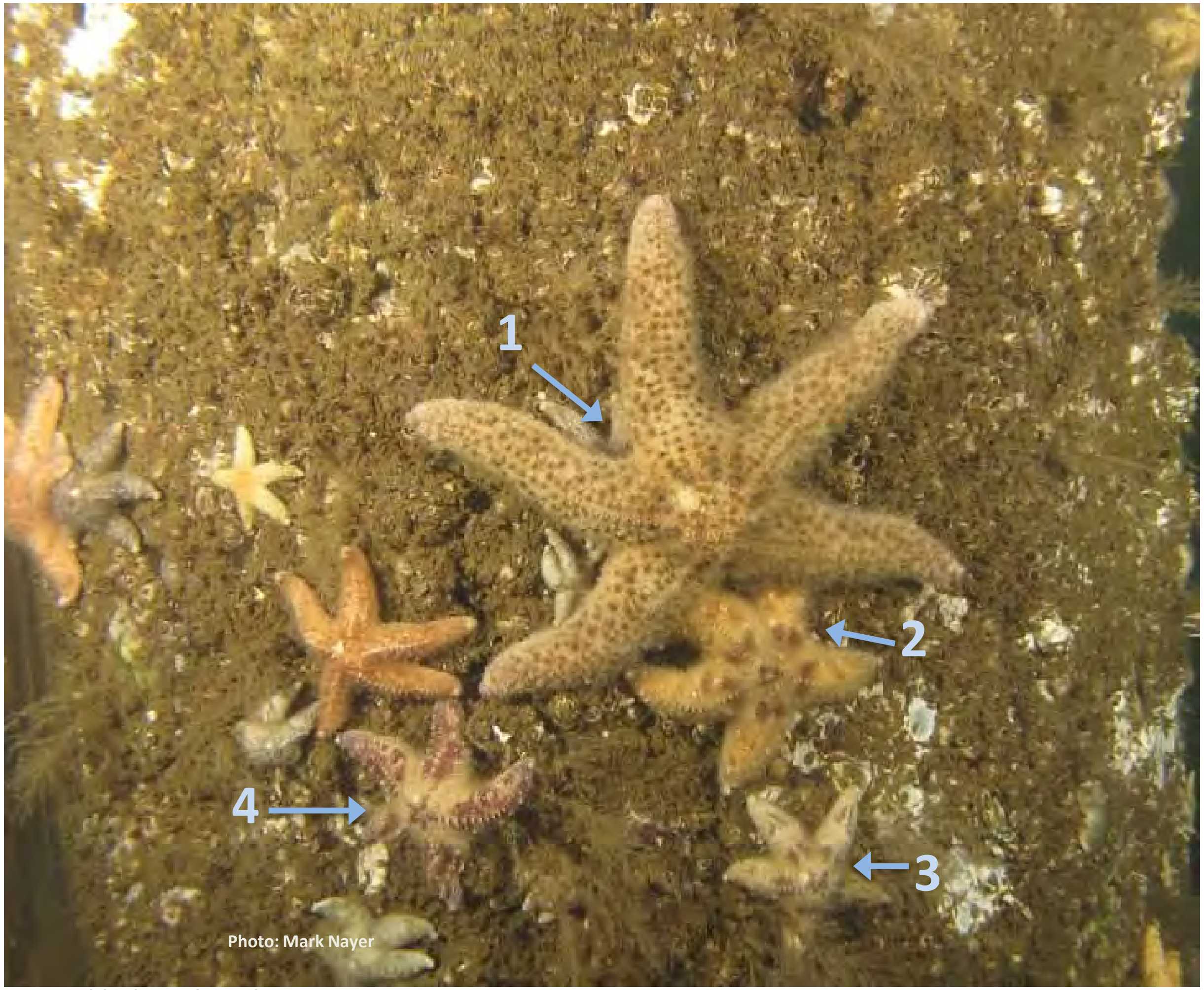


Juvenile Sea Stars ID Game
Part 2: key

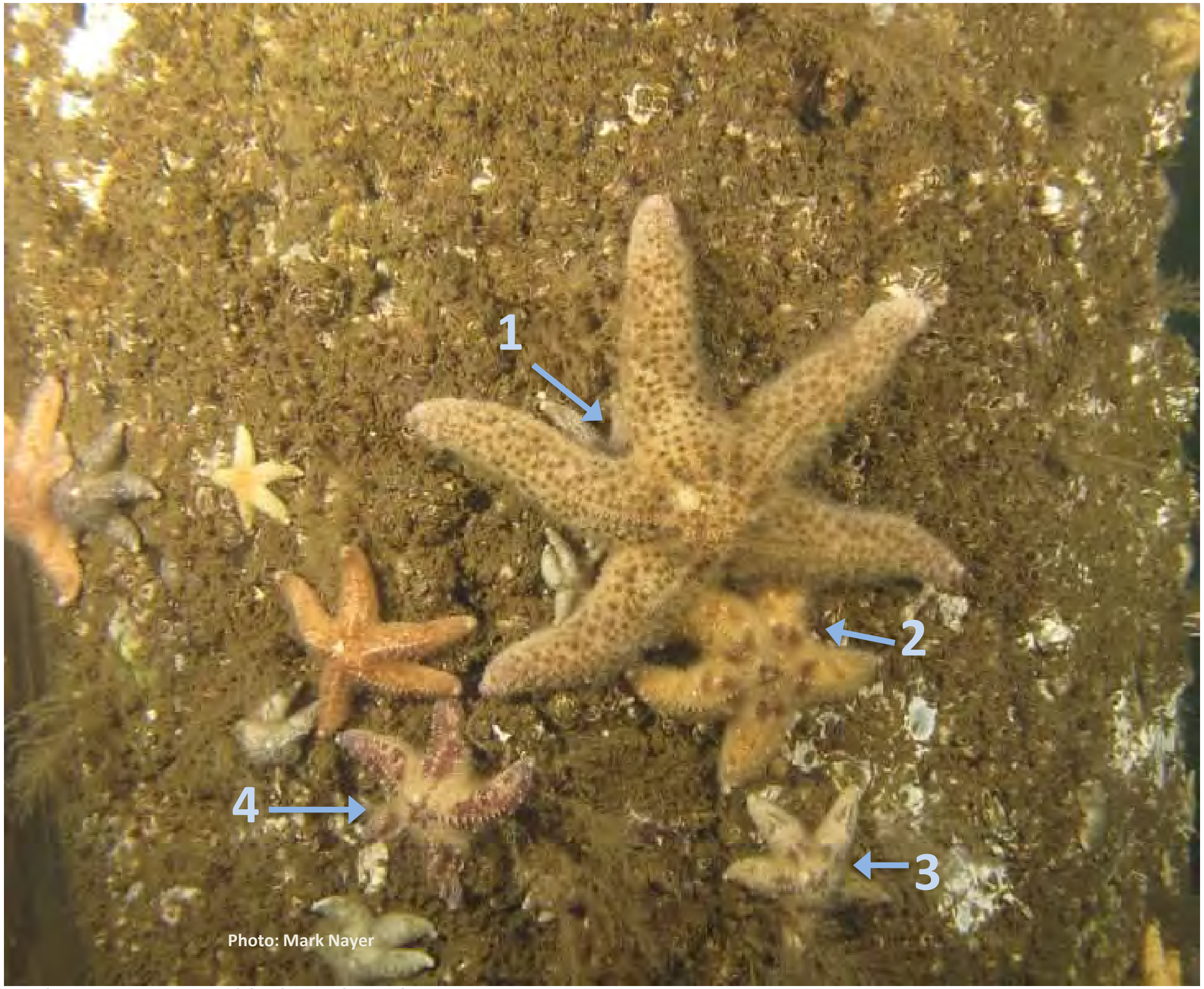


1. P. ochraceus
2. E. troschelii
3. P. ochraceus
4. P. ochraceus
5. E. troschelii
6. E. troschelii
7. E. troschelii
8. P. ochraceus
9. E. troschelii

Juvenile Sea Stars ID Game
Part 3



Juvenile Sea Stars ID Game
Part 3: key



1. P. brevispinus
2. P. ochraceus
3. P. ochraceus
4. P. ochraceus

Acknowledgments

•Majority of guide text from:

Morris, Robert H., Donald P. Abbott, and Eugene C. Haderlie. 1980. *Intertidal invertebrates of California*. Stanford, Calif.: Stanford University Press, 1980. Print.

&

Lamb, Andy and Bernard P. Hanby. 2005. *Marine Life of the Pacific Northwest: A Photographic Encyclopedia of Invertebrates, Seaweeds and Selected Fishes.* Madeira Park, BC.: Harbour Publishing, 2005. Print.

•Thanks to Aaron Baldwin for his descriptions of methods for differentiating *Leptasterias* from juvenile *Evasterias* and *Pisaster ochraceus*.

•Much appreciation to Steve Lonhart, John Pearse and Betsy Steele for their insightful edits and comments which have informed this guide.

•Many thanks to the photographers responsible for the photos included in this guide: Jeff Adams, Aaron Baldwin, Christy Bell, Mike Frenock, Maya George, David Haley, Laura Jurgens, Jan Kocian, Dave Lohse, Steve Lonhart (NOAA MBNMS), Natasha Leigh Meyers-Cherry, Mark Nayer (seastarwastingsyndrome.shutterfly.com), Abby Nickels, Melissa Redfield, Roxie Rochat, and Steve Tuckerman.

Category 0 (Healthy)

Evasterias troschelii **(mottled star) can look quite "unhealthy" at low tide. The water often drains out of part or all of the animal, leaving it looking "deflated". The stars' mottled appearance also makes detection of lesions more difficult, so check carefully when assessing potential disease in this species.**

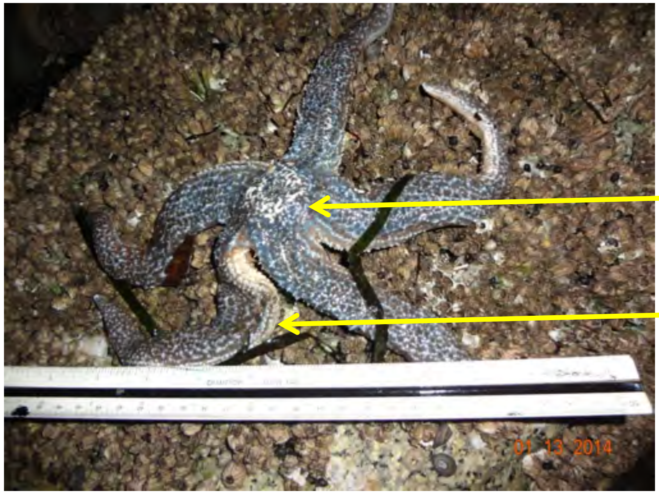
Photos: Jeff Harris

Category 1

lesion(s) on 1 arm or body
Tissue degradation restricted to a single arm, or the oral disk.

Lesion in 1 arm

Photo: Jeff Harris



Lesions on oral disk

"Deflated" appearance cannot be attributed to disease. Healthy animals often look "deflated" at low tide due to water loss.

Category 2

lesions on 2 arms or 1 arm and body, deteriorating arm(s)

Photos: Jackie Hildering;
www.themarinedetective.ca

Tissue deteriorating on 2 arms

Tissue deteriorating on oral disk and possibly also arms? Difficult to tell for sure in this photo.

Category 3

lesions on most of body, 1-2 missing arms

Healthy (hard to tell from photo)

Missing 2 arms

Missing 1 arm

Lesions on most of body

Photo: Jeff Harris

Guide to Wasting Symptoms in Evasterias troschelii

pacificrockyintertidal.org
seastarwasting.org

Category 4

severe tissue deterioration/death,
>3 missing arms

Photos: Jeff Harris

Severe tissue deterioration, arms beginning to separate

Lesions/tissue deterioration throughout body; borderline cat 3/4

Examples of “mild” and “severe” wasting/injury likely due to sea star wasting syndrome

Note: The following photos are intended to be used as a guide for identifying signs of wasting across many species of sea stars. Sea stars respond to many types of stress in a similar manner, so the tissue degradation and injuries shown in these photos may not be due to sea star wasting syndrome. However, all photos are from areas where SSWS was prevalent and thus likely responsible for the conditions shown.

Pisaster ochraceus

Mild Photo: Kayla Balmer

Severe Photo: John Ugerotz

Photos: Melissa Miner

Evasterias troschelii

Mild

Photo:
Mark Nayer

Photos:
Jan Kocian

Severe

Photos: Jeff Harris

Pycnopodia helianthoides

Mild

Note emaciated appearance

Photos: Mark Nayer

Severe

Pisaster giganteus

Mild

Severe

Photos: Leanne Foster

Pisaster brevispinus

Mild

Photos:
Mark Nayer

Severe

Photos:
Ken Bondy

Dermasterias imbricata

Mild

Photos:
Mark Nayer

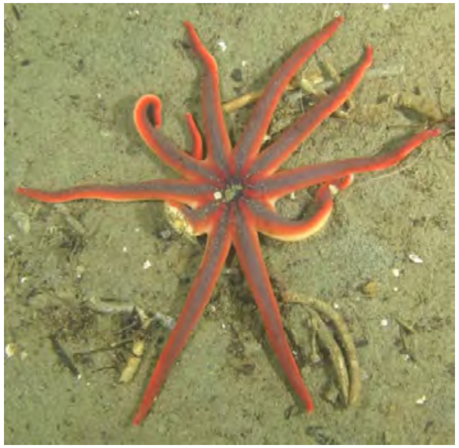
Severe

Photo:
Ethan Flanagan

Photo:
Nate Fletcher

Solaster spp.

Mild



Photos: Mark Nayer

Severe

Photo: Mark Nayer

Photo: Neil McDaniel

Orthasterias koehleri

Mild

Photos: Feiro Marine Life Center

Severe

No photo available

Leptasterias spp

Mild

Photo: Steve Fradkin

Severe

Photos: Melissa Miner

Patiria (Asterina) miniata

Mild

- No photo available

Severe

Photo: Ryan Berger

Pteraster spp.

Mild

Photo: Mark Nayer

Severe

Photo: Jackie Hildering

Crossaster papposus

mild

severe

Photos: Neil McDaniel

Henricia spp.

Mild

Photo: Linda Larsen

Note tissue degradation on single (uppermost) arm. Lighter patches on central disk are normal coloration pattern for this species of Henricia

Severe

Photo: Wendy Steffensen

Appendix 6: Assessment of BOEM-MARINe Long-Term Monitoring Program

Assessment of BOEM / MARINe monitoring program (Photoplots, *Phyllospadix*, *Lottia*, and *Pisaster*)

Pete Raimondi, July 23, 2014

The goal of this assessment was to assess the BOEM / MARINe long term monitoring program with a particular emphasis on two major goals: (1) estimation of effect size detectable under the current sampling design and (2) impact of changes to the current design on the detectable effect size. This phase of the assessment focuses on the following specific questions:

1. Given a 5%, 10%, 20% change in the community,
   a) What is the current statistical power to detect a change in the target species from an impact under the current biannual sampling plan?
   b) Is the statistical power to detect changes in a target species consistent across protocols and across the whole sampling region?
   c) What is the expected loss of statistical power to detect oil spills if sampling is reduced to annual?
   d) What is the loss of reducing the existing spatial BOEM sampling by 1-5 sites?
2. Recommend and justify a Temporal Strategy:
   a) Test the hypothesis that seasonal context is well established at BOEM-funded sites and that sampling could be done once a year with the appropriate level of power. Explain what has changed since 2002 when it was determined that biannual sampling should continue.
   b) If sampling was completed annually, how much does the time of year (month) of the sampling influence the statistical power to detect changes? Meaning, what is the best season for sampling?
   c) Can sampling be done irrespective of season, thereby taking advantage of multiple low-tide series throughout the year?

Statistical Approach

Answering these questions relies on the use of power analyses and the use of power analyses relies on an understanding of the statistical design that will be used to assess change. When the monitoring program was designed in 1991, we considered a design that made comparisons between two periods: pre vs post. Here, quadrats were considered replicates and there was no formal incorporation of time in the analysis. In the current assessment, we have up to 22 years of sampling enabling a different and much more robust and powerful approach to be used. This approach is formally called a Before After Control Impact Paired analysis (BACIP). The general idea of a BACIP approach is to use temporal samples as replicates and to then compare the average difference between impact and control sites prior to an impact to the difference after the impact. Here, spatial replicates within a site are used only to the extent that they allow more accurate estimation of the mean for the site at time t. The typical statistical test used for such assessments is either a 1 or 2 sample t-test (1 sample if you are evaluating the impact with only a single post-impact sample). For this assessment the key BACIP assumptions are:

1) Only focal species were assessed.
2) The impact to the focal species will be to reduce its abundance, hence a one tailed approach should be used.
3) Impacts may be limited to a single site, and the location of the site is unpredictable.
4) The set of potential control sites for any impact site includes all other sites having the focal species.
5) Only 21 samples were used (the most recent 10 years). This was done for a number of reasons including: (1) protocols were standardized during this period, (2) this gave the maximum span of years with no missing values for most sites, (3) ten years seemed like a long enough period to reasonably model differences among sites and sufficiently short enough not to include any long term trends in the region that could compromise the BACIP approach.

The other key assumptions in this assessment are based on the parameters that are used in the power analyses. These are the predicted effect size (5%, 10% or 20%), the value of Type 1 error (alpha: 0.05 or 0.20) and sample size (11 or 21 samples). All combinations of these values were assessed. The predicted effect sizes are absolute and not relative values (that is 10% change, not 10% of what was there). This was done in consideration of NRDA expectations, which focus on loss, not relative loss. Alpha values bracket values used for impact assessment. Sample size varied explicitly to assess the impact of reducing sampling from 2 times per year to one time.

Although power was estimated for all combinations of parameter values, I focus on a specific combination: Type 1 error (alpha) = 0.20, effect size = 10% (~20% relatively) and Type 2 error (beta) = 0.20 (note that this is power of 0.80). This particular combination is consistent with a 20, 20, 20 rule. That is, alpha = beta = effect size, which is based on the idea that there is no priority with respect to error type and that this value (0.2) should be about the same as effect size.

All calculations were based on an automated protocol I developed for BACIP assessment. Results were validated relative to Power approaches using SAS and SYSTAT statistical engines.

Results

Photoplot species

Figure 1 shows the overall power for all parameter combinations. As expected, average power increases with increasing effect size, increasing sample size, and increasing alpha. Note however, the range in values for power. These suggest that, for all parameter combinations, there are combinations of control and impact sites with high power.

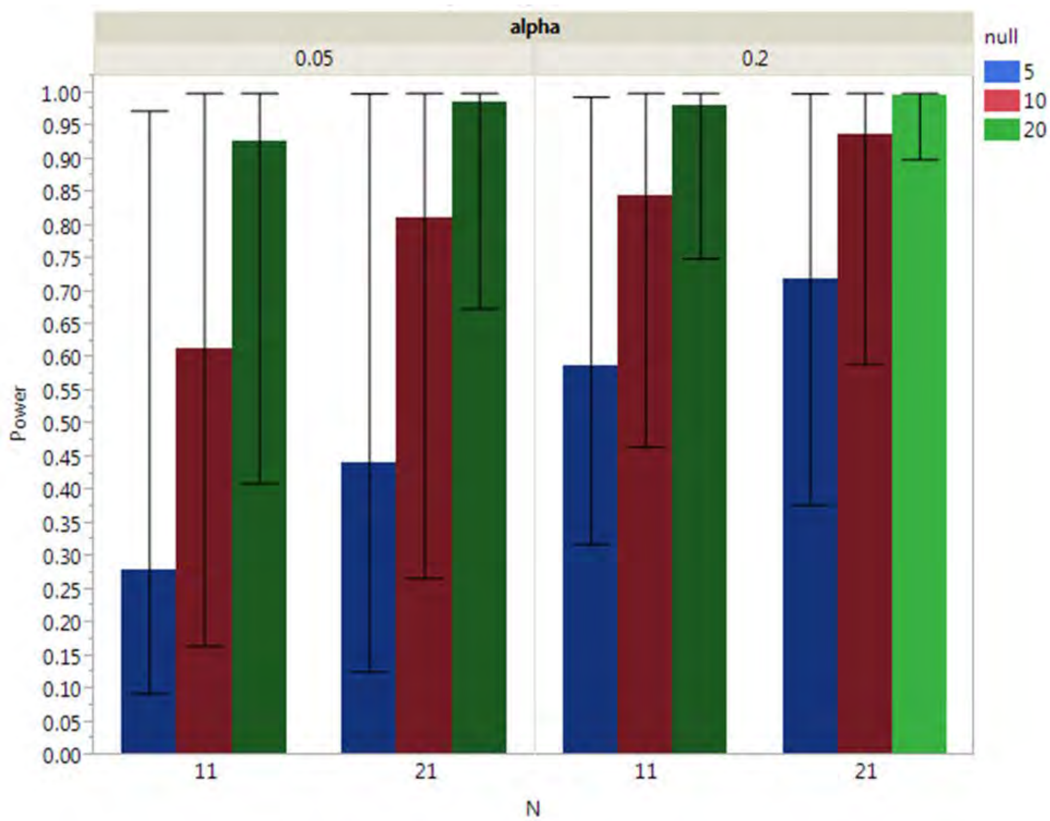


Figure 1: Mean and range of power for all parameter combinations (alpha, N, effect size). The top of each bar is the mean value. The ends of the brackets depict the range of values for that parameter combination.

More detail is given in Figure 2, which shows the same information broken out by focal species and site. For example, power at Whites Point to detect impacts to *Endocladia* ranges from about 20% to 100%, with a median of 90% depending on the control site and the values of power parameters (alpha, N, and effect size) at White's Point.

Figure 2: Median and range of power for all parameter combinations (alpha, N, effect size) for all sites and focal species. The top of each bar is the median value. The ends of the brackets depict the range of values for that parameter combination.

Even more detail is given in Figure 3, which shows the power associated with all combinations of power parameters. Each point on the graph is the power associated with a single pair of sites (one impact, one control).

Appendix 6: Assessment of BOEM-MARINe

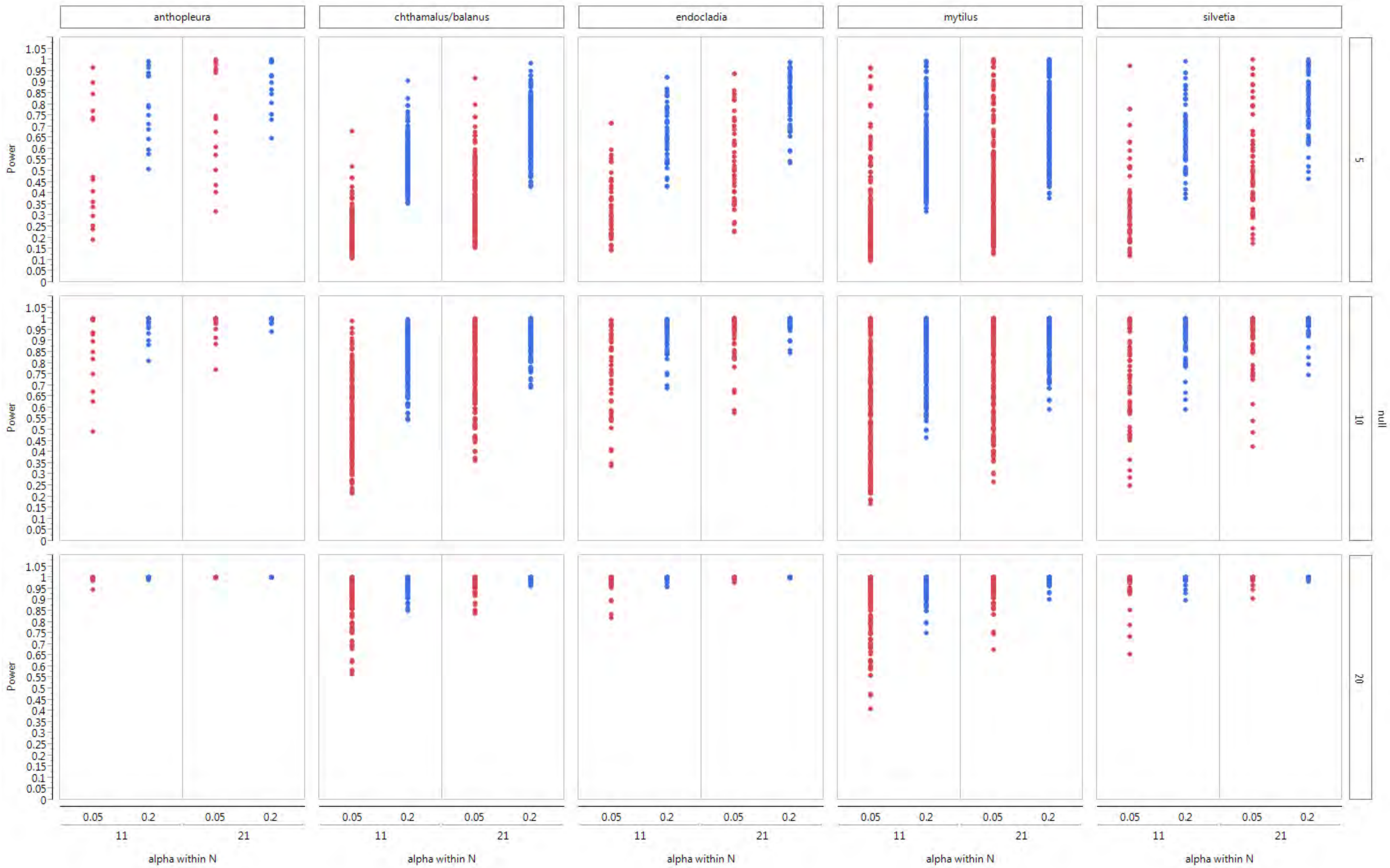


Figure 3: Power as a function of N, alpha, and effect size (null) for each focal species. Each point represents the power resulting from a BACIP analysis for a pair of sites (one impact, one control)

As noted above, I focused on a specific combination of power parameters that are consistent with the 20, 20, 20 rule. Figure 4 shows the results of an analysis to determine the utility of each site as a control under the 20, 20, 20 rule. Each cell represents a combination of sites (one control and one impact) for each focal species. Cells with pink fill depict combinations that have a power of at least 80%. The column labeled N shows the number of sites that could be used with 80% power for the impact site and focal species. Note that no combinations have an N of zero. Indeed, all are 5 or more. Also note that the maximum N varies based on the number of sites with the particular focal species. For this analysis I used a total number of samples = 11, which is ~ half of the total samples in the data set.

A summary of all results is given in Figure 5. The numbers in each cell are the number of control sites for a given impact site that yield at least 80% power under the given power parameters.

Species	Site	N	N(ALEG)	N(ARHO)	N(BOA)	N(CARP)	N(CAY)	N(COPT)	N(CRCO)	N(DAPT)	N(HAZ)	N(MUSH)	N(OCC)	N(OLDS)	N(PCOV)	N(PSN)	N(PTFM)	N(SHB)	N(SHCO)	N(STA)	N(TRIS)	N(WHPT)
anthopleura	ALEG	5	0	0	1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
anthopleura	BOA	5	1	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
anthopleura	CARP	5	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
anthopleura	COPT	5	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
anthopleura	MUSH	5	1	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
anthopleura	OLDS	5	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
chthamalus/balanus	ALEG	15	0	1	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	1	1	1
chthamalus/balanus	ARHO	7	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	1
chthamalus/balanus	BOA	10	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	1	1
chthamalus/balanus	CARP	12	1	1	0	0	0	0	1	1	0	0	0	1	1	0	1	1	1	1	1	1
chthamalus/balanus	CAY	12	1	0	1	0	0	0	0	1	1	0	1	1	0	1	0	1	1	1	1	1
chthamalus/balanus	CRCO	11	1	1	0	1	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1
chthamalus/balanus	DAPT	12	1	0	1	1	1	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1
chthamalus/balanus	HAZ	8	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	1	1
chthamalus/balanus	MUSH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
chthamalus/balanus	OCC	13	1	0	1	0	1	0	1	1	1	0	0	1	1	1	0	0	1	1	1	1
chthamalus/balanus	OLDS	13	1	1	0	1	1	0	1	1	0	0	1	0	1	0	0	1	1	1	1	1
chthamalus/balanus	PCOV	12	1	0	0	1	0	0	1	1	1	0	1	1	0	0	1	0	1	1	1	1
chthamalus/balanus	PSN	8	1	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1
chthamalus/balanus	PTFM	6	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1
chthamalus/balanus	SHB	7	0	0	1	1	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1
chthamalus/balanus	SHCO	17	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1
chthamalus/balanus	STA	14	1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	0	1	1
chthamalus/balanus	TRIS	16	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0	1
chthamalus/balanus	WHPT	17	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0
endocladia	BOA	9	0	0	0	0	1	0	0	0	1	0	1	1	1	0	0	1	1	1	0	1
endocladia	CAY	8	0	0	1	0	0	0	0	0	1	0	1	1	1	0	0	0	1	1	0	1
endocladia	HAZ	9	0	0	1	0	1	0	0	0	0	0	1	1	1	0	0	1	1	1	0	1
endocladia	OCC	9	0	0	1	0	1	0	0	0	1	0	0	1	1	0	0	1	1	1	0	1
endocladia	OLDS	9	0	0	1	0	1	0	0	0	1	0	1	0	1	0	0	1	1	1	0	1
endocladia	PCOV	8	0	0	1	0	1	0	0	0	1	0	1	1	0	0	0	0	1	1	0	1
endocladia	SHB	5	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0
endocladia	SHCO	8	0	0	1	0	1	0	0	0	1	0	1	1	1	0	0	0	0	1	0	1
endocladia	STA	9	0	0	1	0	1	0	0	0	1	0	1	1	1	0	0	1	1	0	0	1
endocladia	WHPT	8	0	0	1	0	1	0	0	0	1	0	1	1	1	0	0	0	1	1	0	0
mytilus	ALEG	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
mytilus	ARHO	16	0	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
mytilus	BOA	13	0	1	0	0	1	1	0	1	1	0	1	1	1	1	1	0	0	1	1	1
mytilus	CARP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
mytilus	CAY	12	0	1	1	0	0	0	1	1	1	0	1	0	1	1	1	0	1	1	1	0
mytilus	COPT	13	0	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	0	1	1	1
mytilus	CRCO	10	0	1	0	0	1	0	0	1	0	0	1	0	0	1	1	1	1	0	1	1
mytilus	DAPT	15	0	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1
mytilus	HAZ	13	0	1	1	0	1	1	0	1	0	0	1	1	1	1	1	0	0	1	1	1
mytilus	MUSH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
mytilus	OCC	16	0	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
mytilus	OLDS	10	0	1	1	0	0	1	0	0	1	0	1	0	1	1	1	0	0	1	1	0
mytilus	PCOV	15	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1
mytilus	PSN	16	0	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1
mytilus	PTFM	16	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1
mytilus	SHB	11	1	1	0	0	0	1	1	1	0	0	1	0	1	1	1	0	1	0	0	1
mytilus	SHCO	11	0	1	0	0	1	0	1	1	0	0	1	0	1	1	1	1	0	0	1	1
mytilus	STA	13	0	1	1	0	1	1	0	1	1	0	1	1	1	1	1	0	0	0	1	1
mytilus	TRIS	15	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1
mytilus	WHPT	14	0	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0
silvetia	BOA	9	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1	1	1	0
silvetia	CAY	5	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0
silvetia	CRCO	10	0	0	1	0	1	0	0	1	1	0	0	0	0	1	1	1	1	1	1	0
silvetia	DAPT	10	0	0	1	0	1	0	1	0	1	0	0	0	0	1	1	1	1	1	1	0
silvetia	HAZ	9	0	0	1	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	1	0
silvetia	PSN	9	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	0
silvetia	PTFM	7	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	1	1	0	1	0
silvetia	SHB	8	0	0	1	0	0	0	1	1	1	0	0	0	0	1	1	0	1	0	1	0
silvetia	SHCO	9	0	0	1	0	0	0	1	1	1	0	0	0	0	1	1	1	0	1	1	0
silvetia	STA	8	0	0	1	0	1	0	1	1	1	0	0	0	0	1	0	0	1	0	1	0
silvetia	TRIS	10	0	0	1	0	1	0	1	1	1	0	0	0	0	1	1	1	1	1	0	0

Figure 4: Sites that could serve as control sites for BACIP analyses for photoplot species. Each cell with pink fill is a site (column) that could serve as a control site should an impact occur to the site in the respective row. The table is divided by focal species. The results are based on alpha = 0.2, beta = 0.20 (power = 0.8), and effect size of 10% (relative effect of ~20%). Sample size for all comparisons = 11, which is half of the total samples.

Species	Site	N Rows	N(11, 0.05, 5)	N(11, 0.05, 10)	N(11, 0.05, 20)	N(11, 0.2, 5)	N(11, 0.2, 10)	N(11, 0.2, 20)	N(21, 0.05, 5)	N(21, 0.05, 10)	N(21, 0.05, 20)	N(21, 0.2, 5)	N(21, 0.2, 10)	N(21, 0.2, 20)
anthopleura	ALEG	37	0	1	5	0	5	5	0	4	5	2	5	5
anthopleura	BOA	53	3	4	5	3	5	5	3	5	5	5	5	5
anthopleura	CARP	52	1	5	5	3	5	5	3	5	5	5	5	5
anthopleura	COPT	50	1	4	5	3	5	5	3	5	5	4	5	5
anthopleura	MUSH	42	0	4	5	0	5	5	0	4	5	4	5	5
anthopleura	OLDS	50	1	4	5	3	5	5	3	5	5	4	5	5
chthamalus/balanus	ALEG	123	0	2	18	0	15	18	0	13	18	3	18	18
chthamalus/balanus	ARHO	102	0	2	16	0	7	18	0	4	18	2	17	18
chthamalus/balanus	BOA	112	0	1	17	0	10	18	0	9	18	4	17	18
chthamalus/balanus	CARP	112	0	1	16	0	12	18	0	9	18	2	18	18
chthamalus/balanus	CAY	119	0	3	17	2	12	18	1	10	18	3	17	18
chthamalus/balanus	CRCO	112	0	1	16	0	11	18	0	9	18	3	18	18
chthamalus/balanus	DAPT	117	0	1	17	0	12	18	0	12	18	3	18	18
chthamalus/balanus	HAZ	102	0	0	17	0	8	18	0	6	18	0	17	18
chthamalus/balanus	MUSH	62	0	0	1	0	0	18	0	0	18	0	7	18
chthamalus/balanus	OCC	115	0	2	15	0	13	18	0	10	18	3	18	18
chthamalus/balanus	OLDS	119	0	3	17	0	13	18	0	10	18	5	17	18
chthamalus/balanus	PCOV	116	0	2	17	0	12	18	0	11	18	2	18	18
chthamalus/balanus	PSN	105	0	2	13	1	8	18	1	6	18	3	17	18
chthamalus/balanus	PTFM	99	0	0	15	0	6	18	0	6	18	1	17	18
chthamalus/balanus	SHB	99	0	0	16	0	7	18	0	3	18	2	17	18
chthamalus/balanus	SHCO	132	0	4	17	0	17	18	0	16	18	7	17	18
chthamalus/balanus	STA	126	0	5	17	1	14	18	0	12	18	6	17	18
chthamalus/balanus	TRIS	126	0	3	17	0	16	18	0	15	18	4	17	18
chthamalus/balanus	WHPT	132	0	4	17	0	17	18	0	15	18	7	18	18
endocladia	BOA	83	0	7	9	3	9	9	3	9	9	7	9	9
endocladia	CAY	73	0	5	9	1	8	9	1	8	9	5	9	9
endocladia	HAZ	77	0	5	9	2	9	9	2	9	9	5	9	9
endocladia	OCC	82	0	6	9	3	9	9	2	9	9	8	9	9
endocladia	OLDS	82	0	5	9	4	9	9	4	8	9	7	9	9
endocladia	PCOV	64	0	1	9	0	8	9	0	8	9	2	9	9
endocladia	SHB	54	0	0	9	0	5	9	0	4	9	0	9	9
endocladia	SHCO	79	0	7	9	2	8	9	1	8	9	8	9	9
endocladia	STA	73	0	3	9	1	9	9	1	9	9	5	9	9
endocladia	WHPT	69	0	3	9	0	8	9	0	8	9	5	9	9
mytilus	ALEG	63	0	0	5	0	1	16	0	0	16	0	6	19
mytilus	ARHO	157	0	11	17	6	16	19	5	16	19	11	18	19
mytilus	BOA	150	2	10	17	5	13	19	5	13	19	10	18	19
mytilus	CARP	63	0	0	0	0	0	18	0	0	18	0	8	19
mytilus	CAY	113	0	1	16	0	12	19	0	10	19	1	16	19
mytilus	COPT	145	0	8	17	5	13	19	5	13	19	10	17	19
mytilus	CRCO	109	0	0	16	0	10	19	0	9	19	0	17	19
mytilus	DAPT	134	0	4	18	1	15	19	1	15	19	5	18	19
mytilus	HAZ	148	1	9	17	7	13	19	5	12	19	9	18	19
mytilus	MUSH	81	0	0	12	0	0	18	0	0	18	0	14	19
mytilus	OCC	150	0	9	17	5	16	19	4	16	19	9	17	19
mytilus	OLDS	115	0	4	14	0	10	18	0	10	18	5	17	19
mytilus	PCOV	137	0	7	16	1	15	19	1	15	19	8	17	19
mytilus	PSN	159	1	10	17	6	16	19	6	16	19	12	18	19
mytilus	PTFM	161	4	9	17	8	16	19	8	13	19	11	18	19
mytilus	SHB	112	0	1	16	0	11	19	0	9	19	1	17	19
mytilus	SHCO	113	0	1	16	0	11	19	0	10	19	1	17	19
mytilus	STA	146	2	8	17	4	13	19	4	13	19	10	18	19
mytilus	TRIS	128	0	2	17	0	15	19	0	14	19	5	18	19
mytilus	WHPT	136	0	4	18	2	14	19	2	14	19	6	19	19
silvetia	BOA	74	0	3	9	1	9	10	1	8	10	4	9	10
silvetia	CAY	56	0	0	7	0	5	10	0	5	10	1	8	10
silvetia	CRCO	93	0	7	10	5	10	10	4	10	10	7	10	10
silvetia	DAPT	87	1	6	10	3	10	10	2	9	10	6	10	10
silvetia	HAZ	89	0	7	10	4	9	10	1	9	10	9	10	10
silvetia	PSN	89	1	6	10	4	9	10	3	9	10	7	10	10
silvetia	PTFM	66	0	1	9	1	7	10	1	5	10	3	9	10
silvetia	SHB	75	0	4	9	1	8	10	0	8	10	5	10	10
silvetia	SHCO	84	0	6	10	2	9	10	1	9	10	7	10	10
silvetia	STA	76	0	3	10	2	8	10	2	7	10	4	10	10
silvetia	TRIS	81	0	5	10	1	10	10	1	9	10	5	10	10

Figure 5: Summary of sites that could serve as control sites for BACIP analyses for photoplot species. Each cell with pink fill shows the number of sites that could serve as a control site (with power = 80% or greater) should an impact occur to the site in the respective row. The table is divided by focal species. Columns to the right of N represent combinations of power parameters (N, alpha, and effect size).

Phyllospadix

The statistical approach taken for *Phyllospadix* was identical to that taken for photoplot species. The sampling approach is different in the field, and as a result, I am assessing this species separately. Figure 6, 7, and 8 depict the same information as in Figure 3, 4, and 5 for photoplot species.

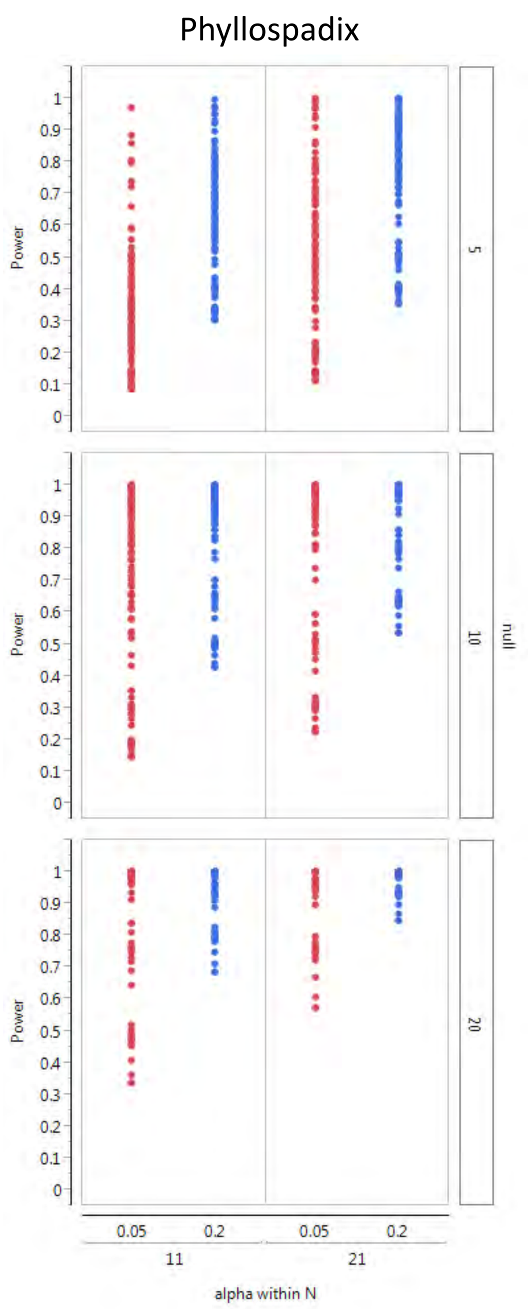


Figure 6: Power as a function of N, alpha, and effect size (null) for *Phyllospadix*. Each point represents the power resulting from a BACIP analysis for a pair of sites (one impact, one control).

Site	N	N(ALEG)	N(ARHO)	N(CARP)	N(CAY)	N(COPT)	N(CRCO)	N(DIA)	N(MUSH)	N(PCOV)	N(PSN)	N(PTFM)	N(SHB)	N(STA)
ALEG	11	0	1	1	1	0	1	1	1	1	1	1	1	1
ARHO	9	1	0	1	0	0	1	0	1	1	1	1	1	1
CARP	11	1	1	0	1	0	1	1	1	1	1	1	1	1
CAY	10	1	0	1	0	0	1	1	1	1	1	1	1	1
COPT	1	0	0	0	0	0	0	1	0	0	0	0	0	0
CRCO	11	1	1	1	1	0	0	1	1	1	1	1	1	1
DIA	11	1	0	1	1	1	1	0	1	1	1	1	1	1
HAZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUSH	11	1	1	1	1	0	1	1	0	1	1	1	1	1
PCOV	11	1	1	1	1	0	1	1	1	0	1	1	1	1
PSN	11	1	1	1	1	0	1	1	1	1	0	1	1	1
PTFM	11	1	1	1	1	0	1	1	1	1	1	0	1	1
SHB	11	1	1	1	1	0	1	1	1	1	1	1	0	1
STA	11	1	1	1	1	0	1	1	1	1	1	1	1	0

Figure 7: Sites that could serve as control sites for *Phyllospadix* in BACIP analyses. Each cell with pink fill is a site (column) that could serve as a control site should an impact occur to the site in the respective row. The table is divided by focal species. The results are based on alpha = 0.2, beta = 0.20 (power = 0.8), and effect size of 10 (relative effect of ~20%). Sample size for all comparisons = 11, which is half of the total samples.

Site	N	N(11, 0.05, 5)	N(11, 0.05, 10)	N(11, 0.05, 20)	N(11, 0.2, 5)	N(11, 0.2, 10)	N(11, 0.2, 20)	N(21, 0.05, 5)	N(21, 0.05, 10)	N(21, 0.05, 20)	N(21, 0.2, 5)	N(21, 0.2, 10)	N(21, 0.2, 20)
ALEG	109	1	9	12	5	11	12	2	11	12	9	12	13
ARHO	79	0	1	11	0	9	12	0	8	12	1	12	13
CARP	102	1	7	11	3	11	12	2	11	12	8	11	13
CAY	91	0	4	11	0	10	13	0	10	12	6	12	13
COPT	53	0	1	4	0	1	12	0	1	12	1	8	13
CRCO	105	0	8	12	3	11	13	1	11	12	9	12	13
DIA	117	3	9	12	7	11	12	6	11	12	9	12	13
HAZ	17	0	0	0	0	0	4	0	0	0	0	0	13
MUSH	89	0	4	11	0	11	12	0	11	12	4	11	13
PCOV	101	1	6	12	2	11	12	1	11	12	8	12	13
PSN	114	1	10	11	6	11	13	4	11	12	10	12	13
PTFM	97	0	6	11	2	11	12	1	10	12	8	11	13
SHB	111	1	9	11	5	11	12	5	11	12	9	12	13
STA	101	0	6	11	3	11	13	2	11	12	8	11	13

Figure 8: Summary of sites that could serve as control sites for BACIP analyses for *Phyllospadix*. Each cell with pink fill shows the number of sites that could serve as a control site (with power = 80% or greater) should an impact occur to the site in the respective row. The table is divided by focal species. Columns to the right of N represent combinations of power parameters (N, alpha, and effect size).

Lottia

The statistical approach taken for *Lottia* was identical to that taken for photoplot species. The sampling approach is different in the field and, as a result, I am assessing this species separately. Figure 9, 10, and 11 depict the same information as in Figure 3, 4, and 5 for photoplot species.

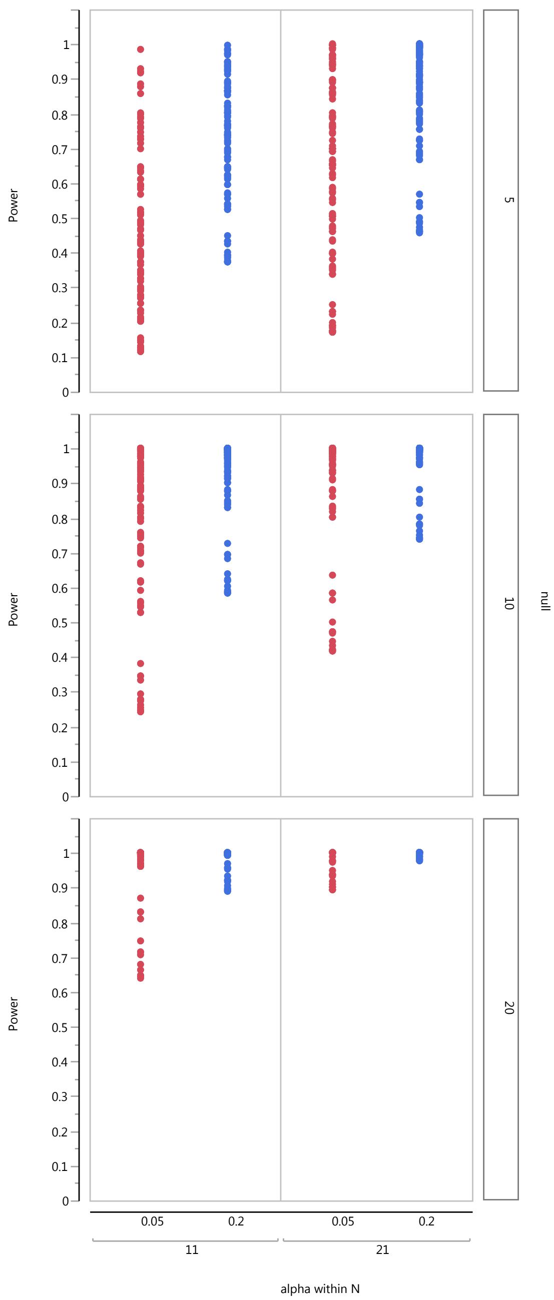


Figure 9: Power as a function of N, alpha, and effect size (null) for *Lottia* plots. Each point represents the power resulting from a BACIP analysis for a pair of sites (one impact, one control).

Effect Size	Site	N	N(ALEG)	N(BOA)	N(CARP)	N(CAY)	N(CRCO)	N(DAPT)	N(HAZ)	N(MUSH)	N(OLDS)	N(PCOV)	N(PTFM)	N(RMR)	N(SHCO)	N(STA)	N(WHPT)
10	ALEG	13	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1
10	BOA	13	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1
10	CARP	13	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1
10	CAY	13	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1
10	CRCO	13	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1
10	DAPT	13	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
10	HAZ	13	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1
10	MUSH	13	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
10	OLDS	13	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
10	PCOV	13	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1
10	PTFM	13	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
10	RMR	13	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1
10	SHCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	STA	13	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1
10	WHPT	13	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0
5	ALEG	10	0	1	1	1	1	1	1	1	0	1	1	0	0	1	0
5	BOA	9	1	0	0	1	1	1	1	1	0	1	1	0	0	1	0
5	CARP	4	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0
5	CAY	7	1	1	0	0	1	1	1	1	0	0	0	0	0	1	0
5	CRCO	6	1	1	0	1	0	1	0	1	0	1	0	0	0	0	0
5	DAPT	8	1	1	0	1	1	0	0	1	0	1	1	0	0	1	0
5	HAZ	6	1	1	0	1	0	0	0	1	0	0	0	1	0	1	0
5	MUSH	10	1	1	1	1	1	1	1	0	0	1	1	0	0	1	0
5	OLDS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	PCOV	7	1	1	0	0	1	1	0	1	0	0	1	0	0	1	0
5	PTFM	7	1	1	1	0	0	1	0	1	0	1	0	0	0	1	0
5	RMR	2	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
5	SHCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	STA	10	1	1	1	1	0	1	1	1	0	1	1	1	0	0	0
5	WHPT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 10: Sites that could serve as control sites for *Lottia* in BACIP analyses. Each cell with pink fill is a site (column) that could serve as a control site should an impact occur to the site in the respective row. The table is divided by focal species. The results are based on alpha = 0.2, beta = 0.20 (power = 0.8), and effect size of 5 and 10. Sample size for all comparisons = 11, which is half of the total samples.

Site	N	N(11, 0.05, 5)	N(11, 0.05, 10)	N(11, 0.05, 20)	N(11, 0.2, 5)	N(11, 0.2, 10)	N(11, 0.2, 20)	N(21, 0.05, 5)	N(21, 0.05, 10)	N(21, 0.05, 20)	N(21, 0.2, 5)	N(21, 0.2, 10)	N(21, 0.2, 20)
ALEG	142	3	12	13	10	13	14	10	13	14	12	14	14
BOA	136	3	11	13	9	13	14	8	13	14	11	13	14
CARP	126	0	11	14	4	13	14	2	13	14	13	14	14
CAY	128	2	9	13	7	13	14	5	13	14	11	13	14
CRCO	126	2	9	13	6	13	14	5	13	14	10	13	14
DAPT	127	0	11	13	8	13	14	3	13	14	11	13	14
HAZ	129	1	11	13	6	13	14	6	13	14	11	13	14
MUSH	138	2	11	13	10	13	14	9	13	14	12	13	14
OLDS	108	0	5	14	0	13	14	0	13	14	7	14	14
PCOV	129	0	10	13	7	13	14	6	13	14	12	13	14
PTFM	134	1	12	14	7	13	14	5	13	14	13	14	14
RMR	118	0	9	13	2	13	14	2	13	14	11	13	14
SHCO	51	0	0	4	0	0	14	0	0	14	0	5	14
STA	137	2	12	13	10	13	14	7	13	14	12	13	14
WHPT	99	0	1	14	0	13	14	0	13	14	2	14	14

Figure 11: Summary of sites that could serve as control sites for BACIP analyses for *Lottia*. Each cell with pink fill shows the number of sites that could serve as a control site (with power = 80% or greater) should an impact occur to the site in the respective row. The table is divided by focal species. Columns to the right of N represent combinations of power parameters (N, alpha, and effect size).

Pisaster

The statistical approach taken for *Pisaster* was identical to that taken for photoplot species. The sampling approach is different in the field, and as a result, I am assessing this species separately. Figures 12, 13, and 14 depict the same information as in Figure 3, 4, and 5 for photoplot species.

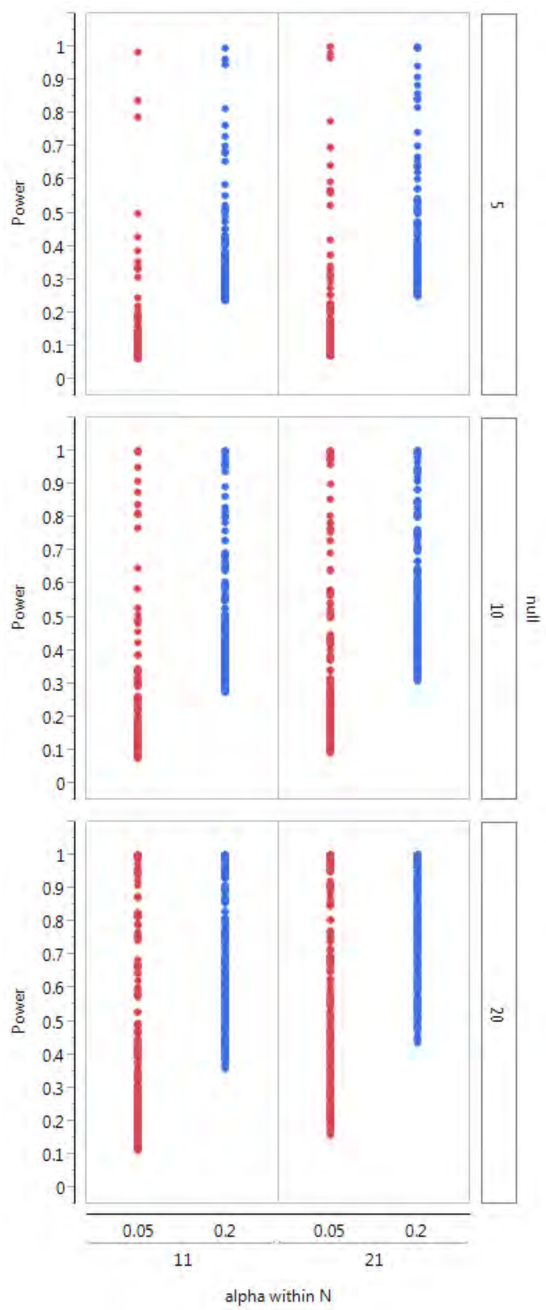


Figure 12: Power as a function of N, alpha, and effect size (null) for *Pisaster* plots. Each point represents the power resulting from a BACIP analysis for a pair of sites (one impact, one control).

Site	N	N(ALEG)	N(ARHO)	N(BOA)	N(CARP)	N(CAY)	N(COPT)	N(CRCO)	N(DAPT)	N(MUSH)	N(OLDS)	N(PCOV)	N(PSN)	N(PTFM)	N(SHB)	N(STA)	N(TRIS)	N(WHPT)
ALEG	8	0	1	0	0	0	1	0	1	0	1	1	1	1	1	0	0	0
ARHO	10	1	0	1	0	1	1	0	1	0	1	0	1	1	1	1	0	0
BOA	7	0	1	0	0	1	1	0	1	0	1	0	0	0	1	1	0	0
CARP	2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
CAY	9	0	1	1	0	0	1	0	1	0	1	0	1	1	1	1	0	0
COPT	15	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1
CRCO	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
DAPT	10	1	1	1	0	1	1	0	0	0	1	0	1	1	1	1	0	0
HAZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUSH	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
OCC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OLDS	10	1	1	1	0	1	1	0	1	0	0	0	1	1	1	1	0	0
PCOV	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
PSN	8	1	1	0	0	1	1	0	1	0	1	0	0	1	1	0	0	0
PTFM	8	1	1	0	0	1	1	0	1	0	1	0	1	0	1	0	0	0
SHB	10	1	1	1	0	1	1	0	1	0	1	0	1	1	0	1	0	0
SHCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STA	7	0	1	1	0	1	1	0	1	0	1	0	0	0	1	0	0	0
TRIS	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
WHPT	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Figure 13: Sites that could serve as control sites for *Pisaster* in BACIP analyses. Each cell with pink fill is a site (column) that could serve as a control site should an impact occur to the site in the respective row. The table is divided by focal species. The results are based on alpha = 0.2, beta = 0.20 (power = 0.8), and effect size of 20 (relative effect of ~20%). Sample size for all comparisons = 11, which is half of the total samples.

Site	N	N(11, 0.05, 5)	N(11, 0.05, 10)	N(11, 0.05, 20)	N(11, 0.2, 5)	N(11, 0.2, 10)	N(11, 0.2, 20)	N(21, 0.05, 5)	N(21, 0.05, 10)	N(21, 0.05, 20)	N(21, 0.2, 5)	N(21, 0.2, 10)	N(21, 0.2, 20)
ALEG	33	0	0	3	0	1	8	0	0	6	0	4	11
ARHO	65	0	2	6	1	5	10	1	4	10	3	8	15
BOA	34	0	0	2	0	2	7	0	1	6	0	3	13
CARP	12	0	0	0	0	0	2	0	0	1	0	0	9
CAY	48	0	1	4	0	2	9	0	2	9	1	5	15
COPT	113	2	8	11	4	11	15	3	8	15	8	12	16
CRCO	13	0	0	0	0	0	1	0	0	1	0	0	11
DAPT	58	0	3	6	0	3	10	0	3	10	3	6	14
HAZ	1	0	0	0	0	0	0	0	0	0	0	0	1
MUSH	6	0	0	0	0	0	1	0	0	0	0	0	5
OCC	0	0	0	0	0	0	0	0	0	0	0	0	0
OLDS	38	0	1	1	0	1	10	0	1	9	1	3	11
PCOV	9	0	0	0	0	0	2	0	0	1	0	0	6
PSN	48	0	1	6	1	2	8	0	1	8	1	7	13
PTFM	51	1	1	6	1	2	8	1	2	8	1	6	14
SHB	63	1	2	6	1	4	10	1	4	9	3	7	15
SHCO	0	0	0	0	0	0	0	0	0	0	0	0	0
STA	38	0	1	2	0	2	7	0	2	7	1	3	13
TRIS	16	0	0	1	0	1	1	0	0	1	0	1	11
WHPT	8	0	0	0	0	0	1	0	0	1	0	1	5

Figure 14: Summary of sites that could serve as control sites for BACIP analyses for *Pisaster*. Each cell with pink fill shows the number of sites that could serve as a control site (with power = 80% or greater) should an impact occur to the site in the respective row. The table is divided by focal species. Columns to the right of N represent combinations of power parameters (N, alpha, and effect size).

Draft conclusions

3. Given a 5%, 10%, 20% change in the community,
   a) What is the current statistical power to detect a change in the target species from an impact under the current biannual sampling plan?

   For all effect sizes greater than 10%, there are combinations of impact and control sites that produce power of at least 80%.

   b) Is the statistical power to detect changes in a target species consistent across protocols and across the whole sampling region?

   There are differences among sites and protocols, but 80% or greater power is achievable for all protocols and for almost all sites.

   c) What is the expected loss of statistical power to detect oil spills if sampling is reduced to annual?

   Assuming 80% power is the threshold, there is no obvious loss of power assuming all sites are maintained.

   d) What is the loss of reducing the existing spatial BOEM sampling by 1-5 sites?

   This very much depends on which sites are lost. There will be a clear and unmitigatable effect simply due to the direct loss of sites. These will be lost from the pool of sites for which an impact can be assessed. The other potential effect on power is due to the utility of the site as a reference site. Here, sites to be discontinued should be selected strategically to reduce the impact.

4. Recommend and justify a Temporal Strategy:
   a) Test the hypothesis that seasonal context is well established at BOEM-funded sites and that sampling could be done once a year with the appropriate level of power. Explain what has changed since 2002 when it was determined that biannual sampling should continue.

   This question is important under certain models but much less so using the BACIP approach taken here as the analysis is done on paired differences, which are not seasonal for focal species. What is important is that sites are sampled in the same season as this minimizes temporal variability in differences.

   b) If sampling was completed annually, how much does the time of year (month) of the sampling influence the statistical power to detect changes? Meaning, what is the best season for sampling?

   See above.

   c) Can sampling be done irrespective of season, thereby taking advantage of multiple low-tide series throughout the year?

Within a protocol, this should not be done as described above. Different protocols (e.g. photoplots vs Phyllospadix) could be done in different seasons.

Appendix 7: Justification for dropping motile invertebrate counts in photoplots

Appendix 7: Justification for Dropping Motile Invertebrate Counts in Photoplots

In 1999 the UCSC intertidal monitoring group began development and testing of protocols that could be used for counting and measuring (for a subset of species) motile invertebrate species that occurred within the existing, permanent photoplots. It was recognized that the method used for scoring photoplots ignored all “highly mobile” species, since the primary goal of this protocol was to capture percent cover of species attached to the rock (sessile species). By ignoring these sometimes abundant, highly mobile community members, it was hypothesized that we might be missing an important component of the dynamics within the communities targeted by the photoplots, and could potentially gain a better understanding of these dynamics by relating percent cover of sessile species to abundance of motile species. It should be stressed that accurately assessing the abundance of the motile invertebrate community for the site as a whole was never a goal for this protocol. Motile species can be highly patchy in distribution, and the placement of photoplots often did not align with the ideal habitat for many of the motile species targeted by this protocol. By early 2000, a revised, field-tested protocol had been developed, which captured both the abundance and size distribution (where appropriate) of motile invertebrates that could be found within photoplots without destructive sampling (i.e. no worms, amphipods, or other cryptic infauna were counted). Between 2000-2003, this revised motile invertebrate protocol was adopted by both UCLA and CSUF/CPP, and thus was being done at all 24 BOEM funded sites in southern/central California.

After collecting several years of data (10-14 years, depending on region), we wanted to know whether the motile community data helped to explain variability observed in the sessile community (percent cover) data. To explore this idea, we used a principal component analysis (PCA) to compare the amount of variability in the data that was explained by just the sessile community alone, to that explained by combining the sessile and motile community data. Principal components combine potentially correlated variables (here % cover of sessile species or counts of motile species) into new, uncorrelated variables (components) in such a way that PC1 explains the most variation in a data set, PC2 the next most, etc. Principal components were developed for the both the sessile and the motile communities. A primary PCA model was constructed that included only sessile data, to see how much variability was explained by the sessile community alone. This primary model included site, target assemblage (e.g. mussel), and survey as predictor variables. Survey was not significant, and therefore dropped. The response variables were principal component 1 (explained 47.8% of variation) or 2 (explained 29.7% of variation) for sessile species (Table 1). To examine the contribution of the motile community in explaining variation, a secondary PCA model was developed that was the same as the primary model, but also included principal components 1 (explained an additional 0.6% of variation), and 2 (explained an additional 0.1% of variation) for motile species. The additional variation explained by the inclusion of the motile species was significant ($p<0.0001$ for both), but quite small (<1% in both cases).

The motile invertebrate protocol is time consuming (it essentially doubles the time required to sample a site), and reduced funding in 2012 forced us to streamline our sampling efforts as much as possible in order to decrease the number of personnel required to survey a site. Given that only a tiny amount of additional information was gained by sampling the motile invertebrate communities within the photoplots, and the sampling required a substantial amount of effort in the field by someone with taxonomic expertise, the motile invertebrate protocol was an obvious one to drop.

	1° Model (sessile community only)	2° Model (sessile + motile community)	Additional variation explained by including motile community
PC1 Adjusted R^2	0.478	0.484	0.006 (0.6%)
PC2 Adjusted R^2	0.297	0.298	0.001 (0.1%)

Appendix 8: Oregon Site Descriptions

Ecola

Cape Meares

Fogarty Creek

Seal Rock

Bob Creek

Cape Arago

Coquille Point

Burnt Hill

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Ecola

Click here for Long-Term trends

Click here for Biodiversity Survey fndings

Ecola is located in Oregon, within Ecola State Park and Lewis and Clark National Historical Park. The site was established on a section of moderately sloping, consolidated bedrock that is part of a larger rocky point (Ecola Point). Access to the site is restricted by a surge channel that is only crossable during low tide, and involves either a a long beach walk, or a trek down a steep slippery trail, so human visitation is limited. However, a handful of people are typically seen on good low tides, beachcombing, harvesting algae, or fshing. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

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

Long-Term Monitoring Surveys at Ecola were established in 2001 and are done by University of California Santa Cruz. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Pelvetiopsis* (Dwarf Rockweed), *Neorhodomela* (Black Pine), *Saccharina* (Sea Cabbage), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). Click here

to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2005, and 2014. The Biodiversity Survey grid encompasses one section that is approximately 18.9 meters (along shore) x 33 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Ecola, please contact Pete Raimondi.

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Cape Meares

Click here for Biodiversity Survey fndings

Cape Meares is located in Oregon. This site is located approximately 40km north of Pacifc City and was established to monitor proposed wave energy devices along the Oregon Coast. This is a primary research site for Oregon State University (Bruce Menge's lab). A well-maintained trail leads to the beach adjacent to the reef, and there is high visitation during summer months. This steep site consists of moderately uneven terrain, containing few cracks and folds.

Cape Meares is dominated by a mixture of consolidated basalt and boulders, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and sandy beach. The primary coastal orientation of this site is west.

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 20 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Cape Meares, please contact Pete Raimondi.

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Fogarty Creek

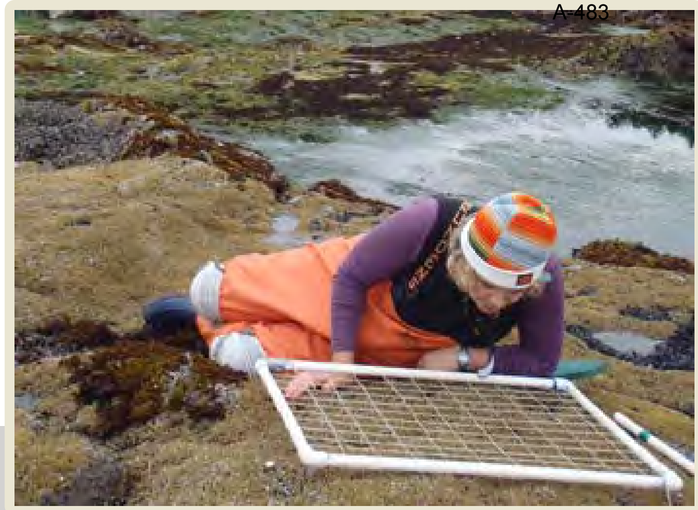
Click here for Long-Term trends

Click here for Biodiversity Survey fndings

Fogarty Creek is located in Oregon, within Fogarty Creek State Park. Access to Fogarty Creek is via private property, which eliminates visitation by the general public. However, this site has long been used by graduate students and researchers, particularly from Oregon State University, and thus it is normal to see a handful of people on the reef during most good low tides. It is also an important harbor seal haul-out. This gently sloping site consists of moderately uneven terrain, containing few cracks and folds.

Fogarty Creek 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 west.

Long-Term Monitoring Surveys at Fogarty Creek were established in 2000 and are done by University of California Santa Cruz. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Fucus* (Northern Rockweed), *Pelvetiopsis* (Dwarf Rockweed), *Neorhodomela* (Black Pine), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). Click here



to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2003, 2004, and 2013. The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 50 meters (seaward), and 15 meters (along shore) x 50 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Fogarty Creek, please contact Pete Raimondi.

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Seal Rock

Click here for Biodiversity Survey fndings

Seal Rock is located in Oregon. Located about 13km south of the wave energy facility proposed for Newport, this site consists of a long rock outcrop surrounded by an extensive sandy beach with frequent high wave energy. A well-maintained, short trail leads from the road to the beach. This is a site visited by researchers from Oregon State University. This steep site consists of moderately uneven terrain, containing few cracks and folds.

Seal Rock is dominated by consolidated basalt, 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.

Biodiversity Surveys were done by University of California Santa Cruz in 2013. The Biodiversity Survey grid encompasses two sections that are approximately 15 meters (along shore) x 10 meters (seaward), and 12 meters (along shore) x 10 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Seal Rock, please contact Pete Raimondi.

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Bob Creek

Click here for Long-Term trends

Click here for Biodiversity Survey fndings

Bob Creek is located in Oregon, within Neptune State Park and the Cape Perpetua Marine Reserve. This site is located on a collection of benches consisting mostly of consolidated bedrock, separated by surge channels. Sand levels vary greatly at this site, and the infuence of scouring and burial is evident in the community dynamics, particularly in plots closest to the beach. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Bob Creek is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and sandy beach. The primary coastal orientation of this site is west/southwest.

Long-Term Monitoring Surveys at Bob Creek were established in 2000 and are done by University of California Santa Cruz. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Semibalanus* (Thatched Barnacle), *Mytilus* (California Mussel), *Fucus* (Northern Rockweed), *Pelvetiopsis* (Dwarf Rockweed), *Endocladia* (Turfweed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). Click here to view Long-

Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2007, and 2013. The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 33 meters (seaward), and 15 meters (along shore) x 33 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Bob Creek, please contact Pete Raimondi.

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Cape Arago

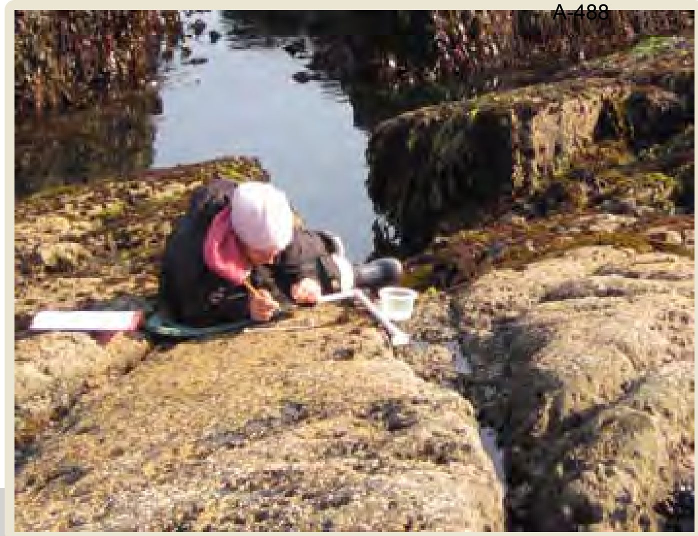
Click here for Long-Term trends

Click here for Biodiversity Survey fndings

Cape Arago is located in Oregon, within Cape Arago State Park. The site can be accessed via a trail from a parking lot above, and a handful of people are typically seen on the bench or surrounding areas. A portion of this site has also become an important sea lion haul-out in recent years, which has lead to substantial changes in the intertidal community. This moderately sloping site consists of moderately uneven terrain, containing few cracks and folds.

Cape Arago is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder felds, and sandy beach. The primary coastal orientation of this site is west/northwest.

Long-Term Monitoring Surveys at Cape Arago were established in 2000 and are done by University of California Santa Cruz. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Fucus* (Northern Rockweed), *Pelvetiopsis* (Dwarf Rockweed), *Endocladia* (Turfweed), *Phyllospadix* (Surfgrass), and *Pisaster* (Ochre Star). Click here to view Long-Term trends at this site.



Biodiversity Surveys were done by University of California Santa Cruz in 2001, 2005, and 2013.
The Biodiversity Survey grid encompasses two sections that are approximately 9 meters (along shore) x 10 meters (seaward), and 18 meters (along shore) x 20 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Cape Arago, please contact Pete Raimondi.

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Coquille Point

Click here for Biodiversity Survey fndings

Coquille Point is located in Oregon, within the Oregon Island National Wildlife Refuge. This site is very close to the proposed offshore wave energy facility in Bandon, Oregon, and is highly sand infuenced. There are a lot of birds at this site, including a large (>50,000 individuals) nesting colony of Common Murres. Some of other birds near this site include cormorants, gulls, pigeon guillemots, Canada geese, and kingfshers; many of these nest on the upper , very high sections of rock making up the reef. A stairway leads to the beach from the parking lot at Kronenburg County Park. This area has high visitation, especially during summer months. This steep site consists of moderately uneven terrain, containing few cracks and folds. The high level of steepness makes for clear zonation patterns at this site.

Coquille Point is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulders, and sandy beach. The primary coastal orientation of this site is north/northeast.

Biodiversity Surveys were done by University of California Santa Cruz in 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). Click here to view Biodiversity Survey fndings at this site.

For more information about Coquille Point, please contact Pete Raimondi.

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Burnt Hill

Click here for Long-Term trends

Click here for Biodiversity Survey fndings

Burnt Hill is located in Oregon. Access to the site is via an overgrown trail leading to a steep bluff that requires using a rope to descend, thus human visitation is nearly non-existent. This moderately sloping site consists of extremely uneven terrain, containing many deep cracks and folds.

Burnt Hill is dominated by consolidated bedrock, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulders, and sandy beach. The primary coastal orientation of this site is south/southwest.

Long-Term Monitoring Surveys at Burnt Hill were established in 2000 and are done by University of California Santa Cruz. Long-Term monitoring surveys currently target the following species: *Chthamalus/Balanus* (Acorn Barnacles), *Mytilus* (California Mussel), *Pelvetiopsis* (Dwarf Rockweed), *Endocladia* (Turfweed), *Phyllospadix* (Surfgrass) and *Pisaster* (Ochre Star). Click here to view Long-Term trends at this site.

Biodiversity Surveys were done by University of California Santa Cruz in 2002, 2006, and 2013.

The Biodiversity Survey grid encompasses two sections that are approximately 12 meters (along shore) x 25 meters (seaward), and 15 meters (along shore) x 25 meters (seaward). Click here to view Biodiversity Survey fndings at this site.

For more information about Burnt Hill, please contact Pete Raimondi.

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Appendix 9: Oregon Summary of Trends by Site

Ecola

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Ecola Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle cover in the barnacle plots at Ecola fuctuated between about 60%-90%, and plots were dominated by the acorn barnacle, *Balanus glandula*. Mussel cover in *Mytilus* plots was quite high (around 90%) and stable from 2001-2008, but then experienced a decline in 2009, largely due to a near-complete loss of mussels in one plot, and a loss of about 50% of the mussels in a second plot. As of 2014, mussel cover had recovered to original levels. *Pelvetiopsis* cover in its target plots was relatively low (typically below 50%), and varied inversely with cover of barnacles. Plots targeting *Neorhodomela* experienced a gradual decline in cover of the red alga over time as *Phyllospadix* abundance increased in these plots. Limpets and littorines are the most common motile invertebrates in most plot types. Other key motile invertebrates include *Nucella* in mussel and *Pelvetiopsis* plots, and *Tegula funebralis* in *Neorhodomela* plots.

Two transect types are present at Ecola, *Saccharina* (formerly *Hedophyllum*) and *Phyllospadix*. *Hedophyllum* was quite variable over time, with high cover between 2001-2004, followed by a near disappearance of the brown alga in 2005. 2006-2009 was a period of recovery, which in more recent years has been followed by a gradual decline. Cover of both surfgrass and the red alga, *Mazzaella*, has increased during periods of low *Saccharina* abundance. In the surfgrass transects, cover of *Phyllospadix* initially increased, but has been fairly stable since 2003.

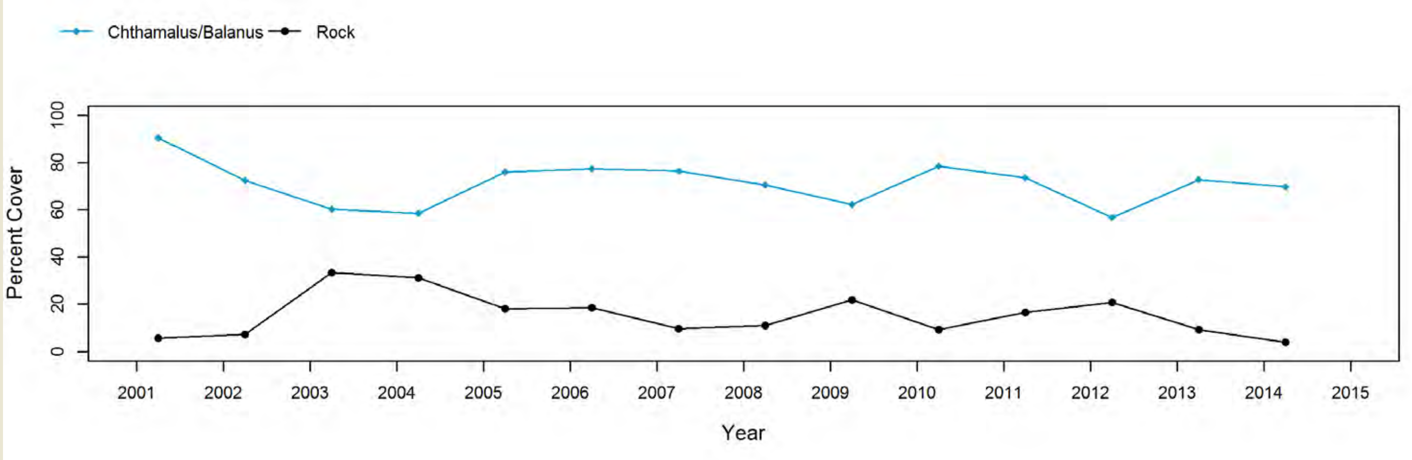
Ochre star counts fuctuated substantially over time, but as with several other Oregon sites, numbers were down in 2014, and we expect them to decline further in 2015 due to Sea Star Wasting Syndrome. Although a handful of small stars (<50 mm radius) were counted in most years, this site has not experienced any large recruitment events during the 13 years we have been monitoring it.

Photo Plots

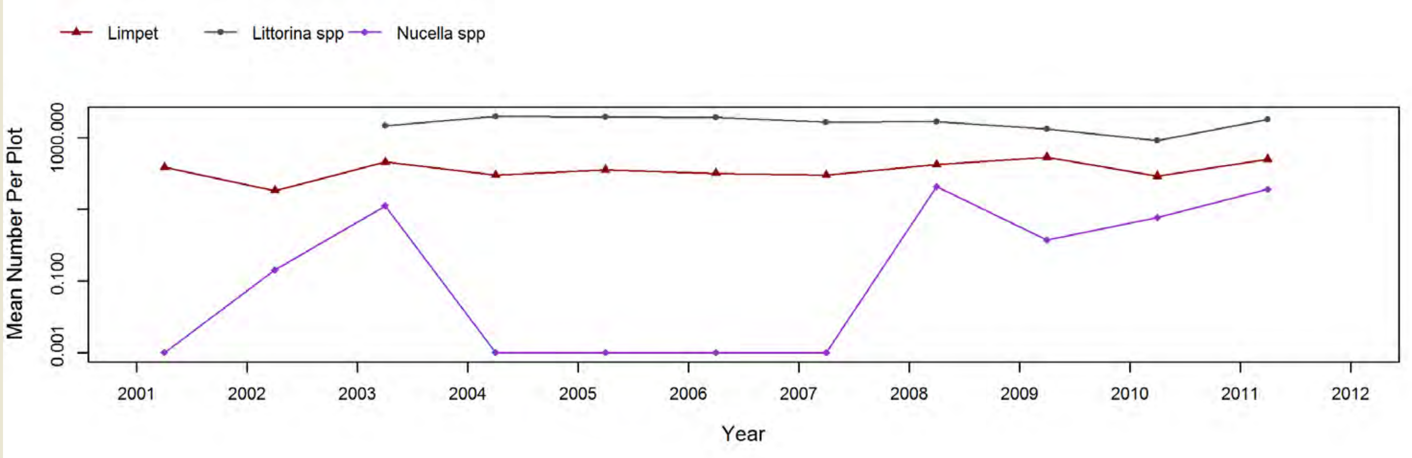
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since summer 2012. For motile invertebrate size trend graphs by site, please use the Interactive Map.

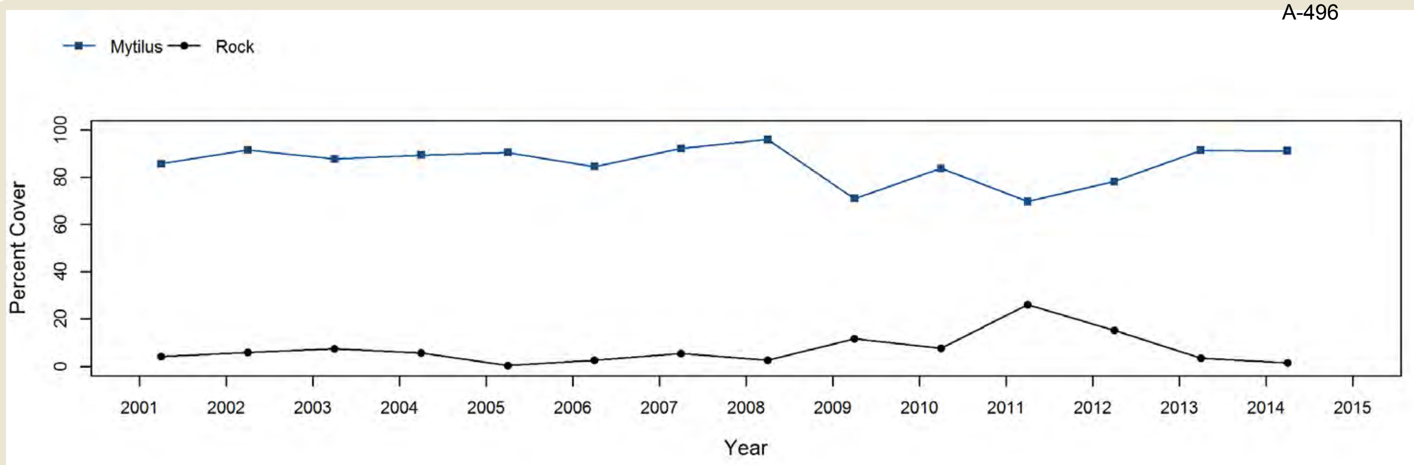
Chthamalus/Balanus (Acorn Barnacles) - percent cover



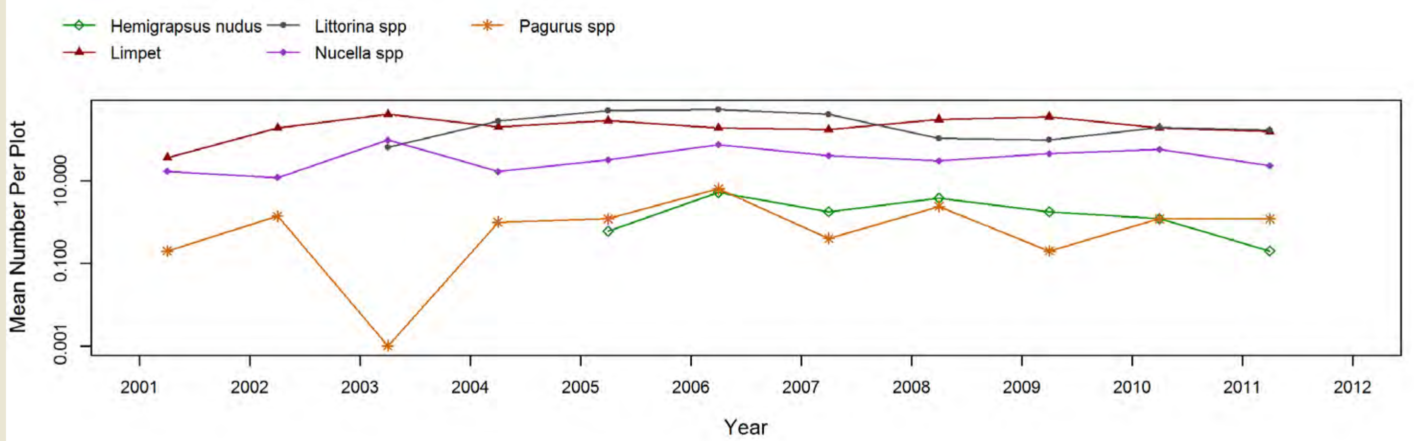
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



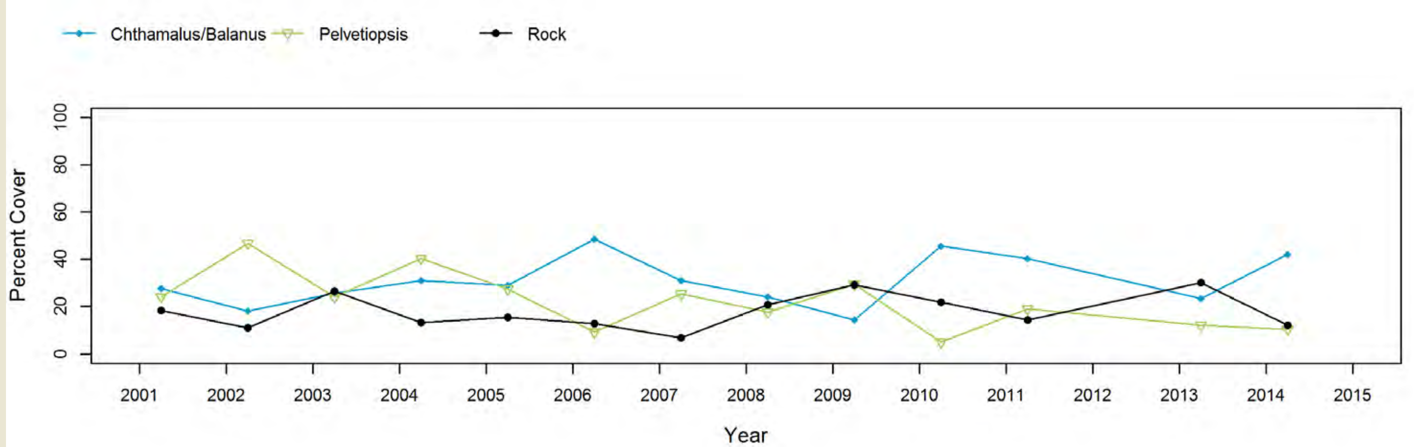
Mytilus (California Mussel) - percent cover



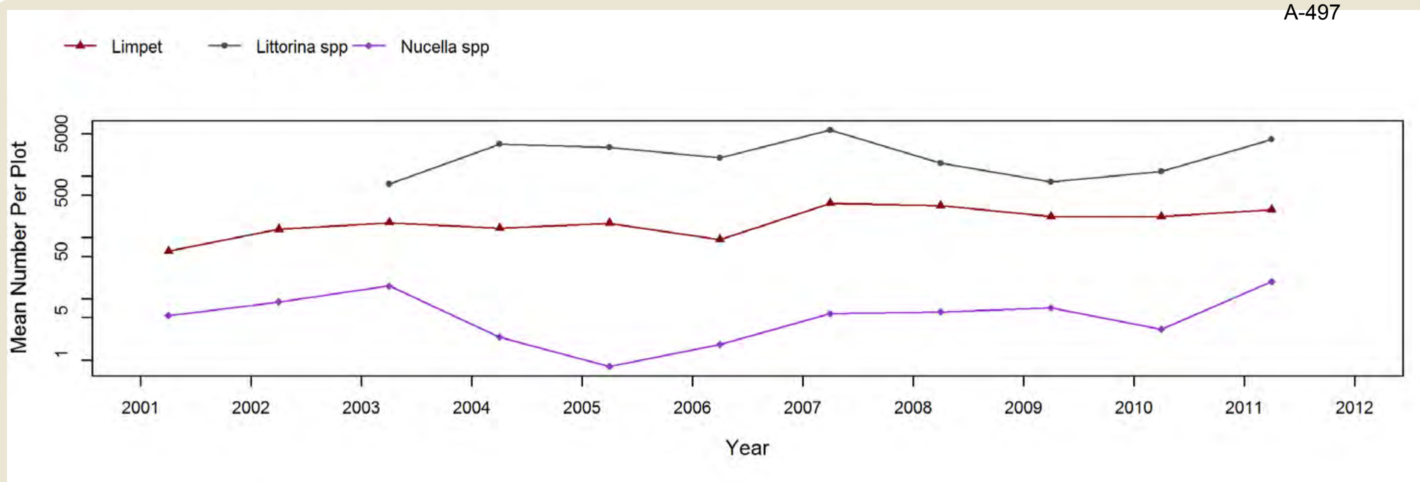
Mytilus (California Mussel) - motile invertebrate counts



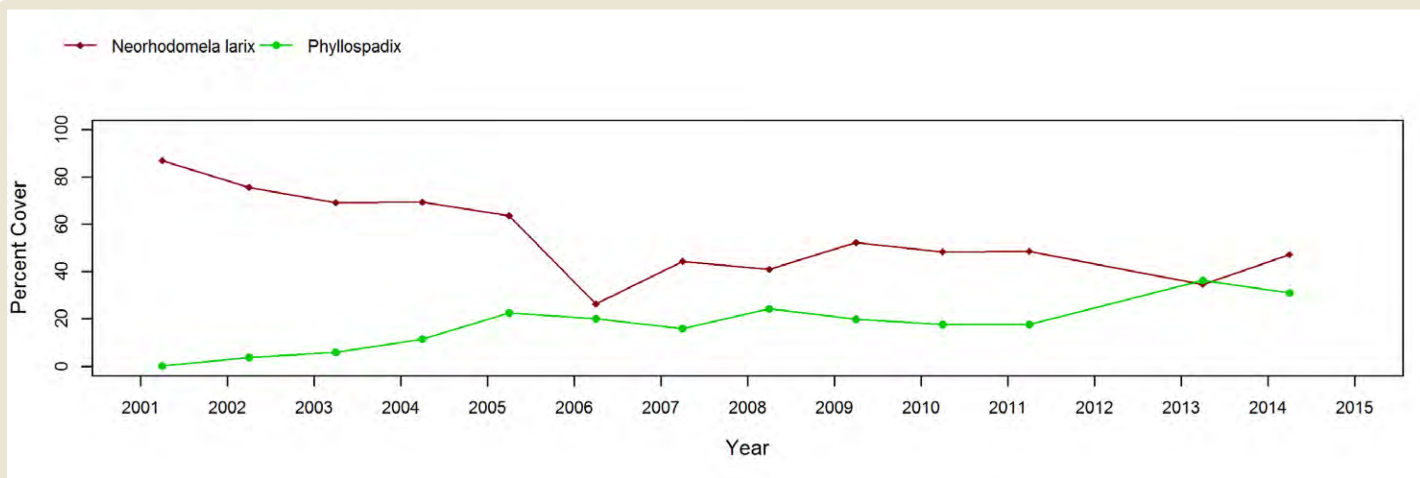
Pelvetiopsis (Dwarf Rockweed) - percent cover



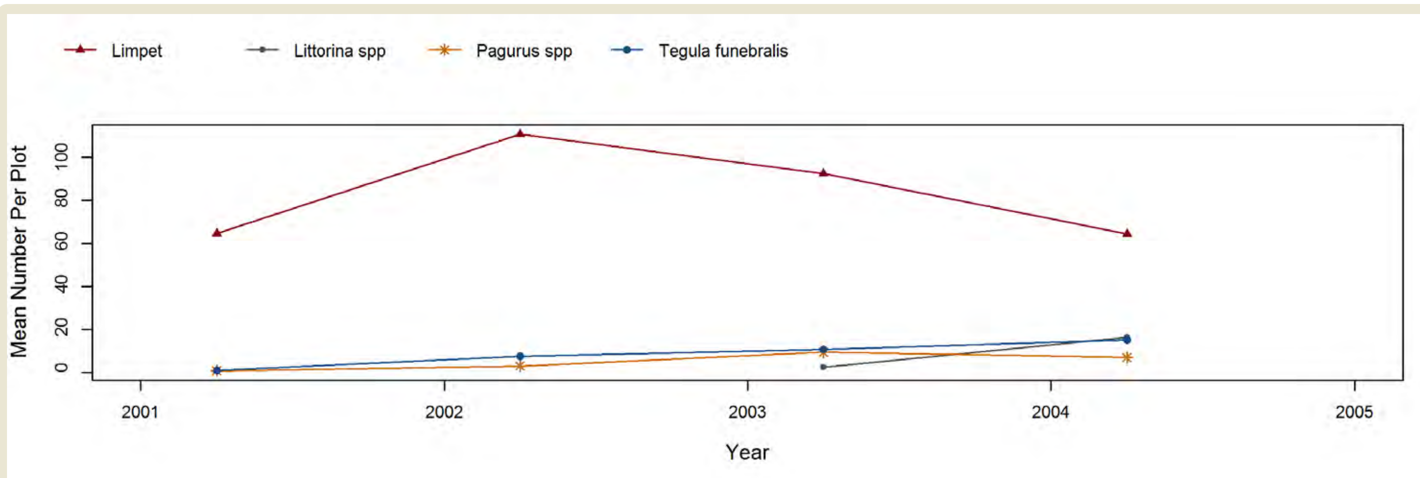
Pelvetiopsis (Dwarf Rockweed) - motile invertebrate counts



Neorhodomela (Black Pine) - percent cover



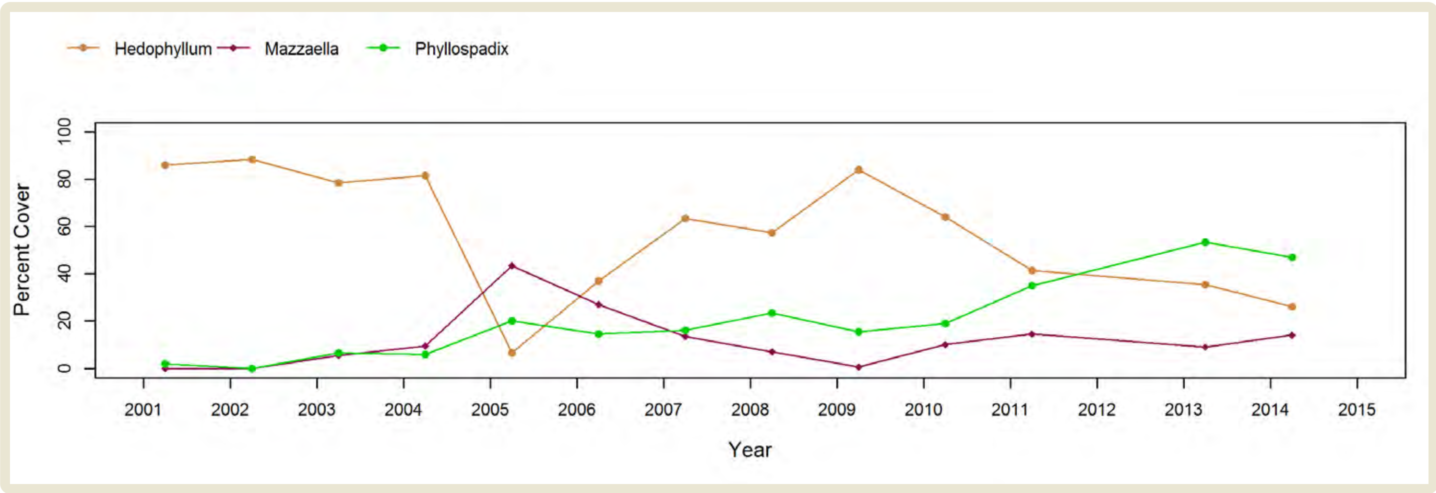
Neorhodomela (Black Pine) - motile invertebrate counts



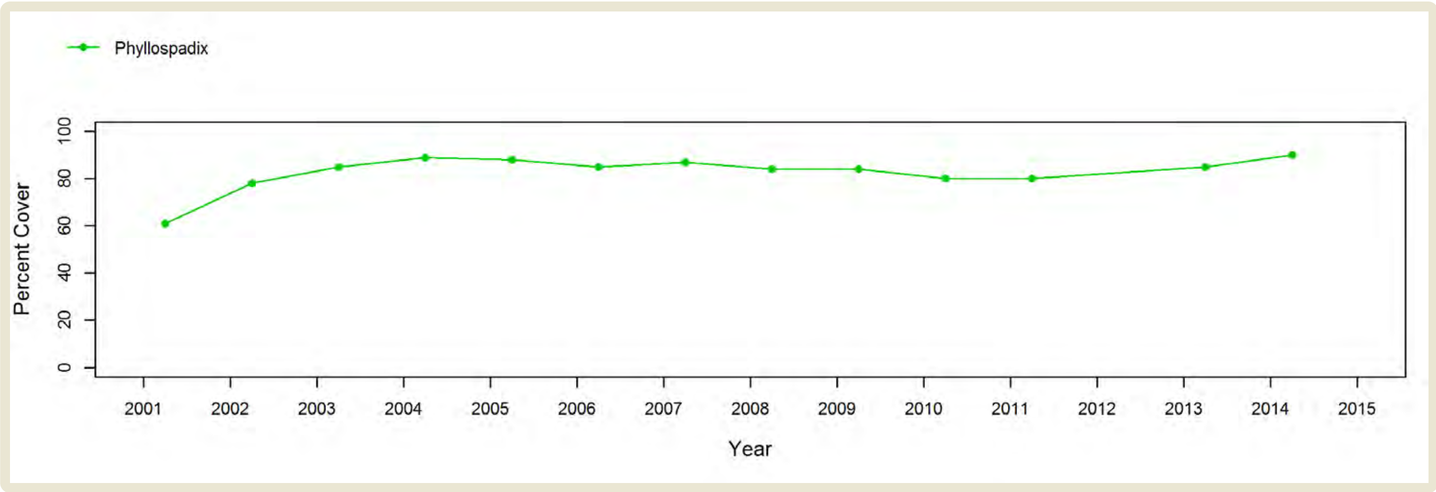
Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

Saccharina (Sea Cabbage)



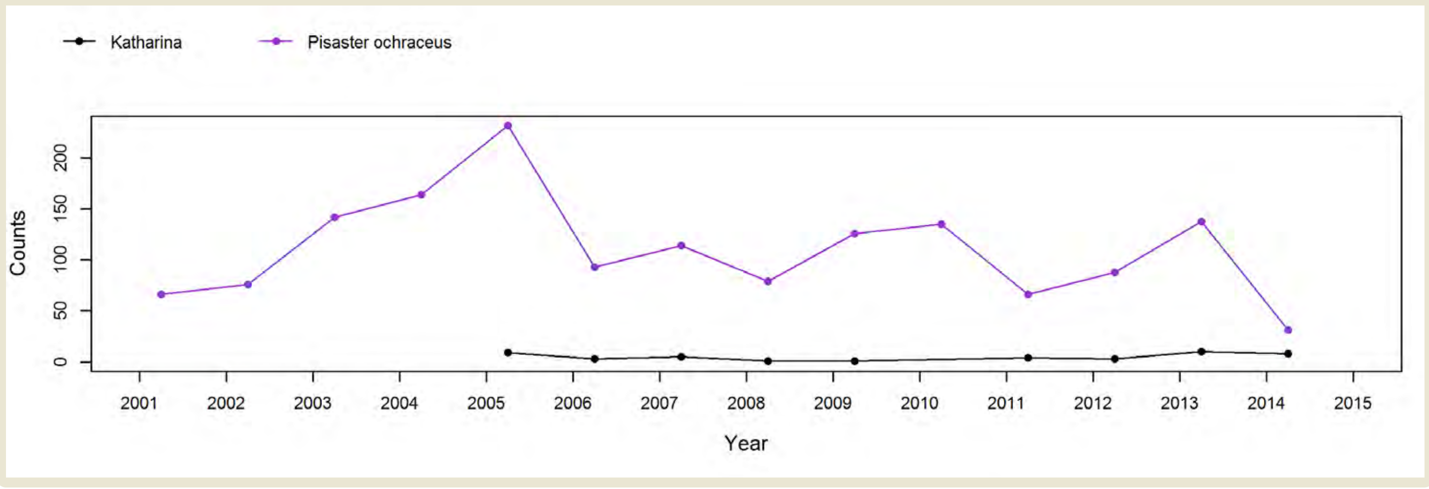
Phyllospadix (Surfgrass)



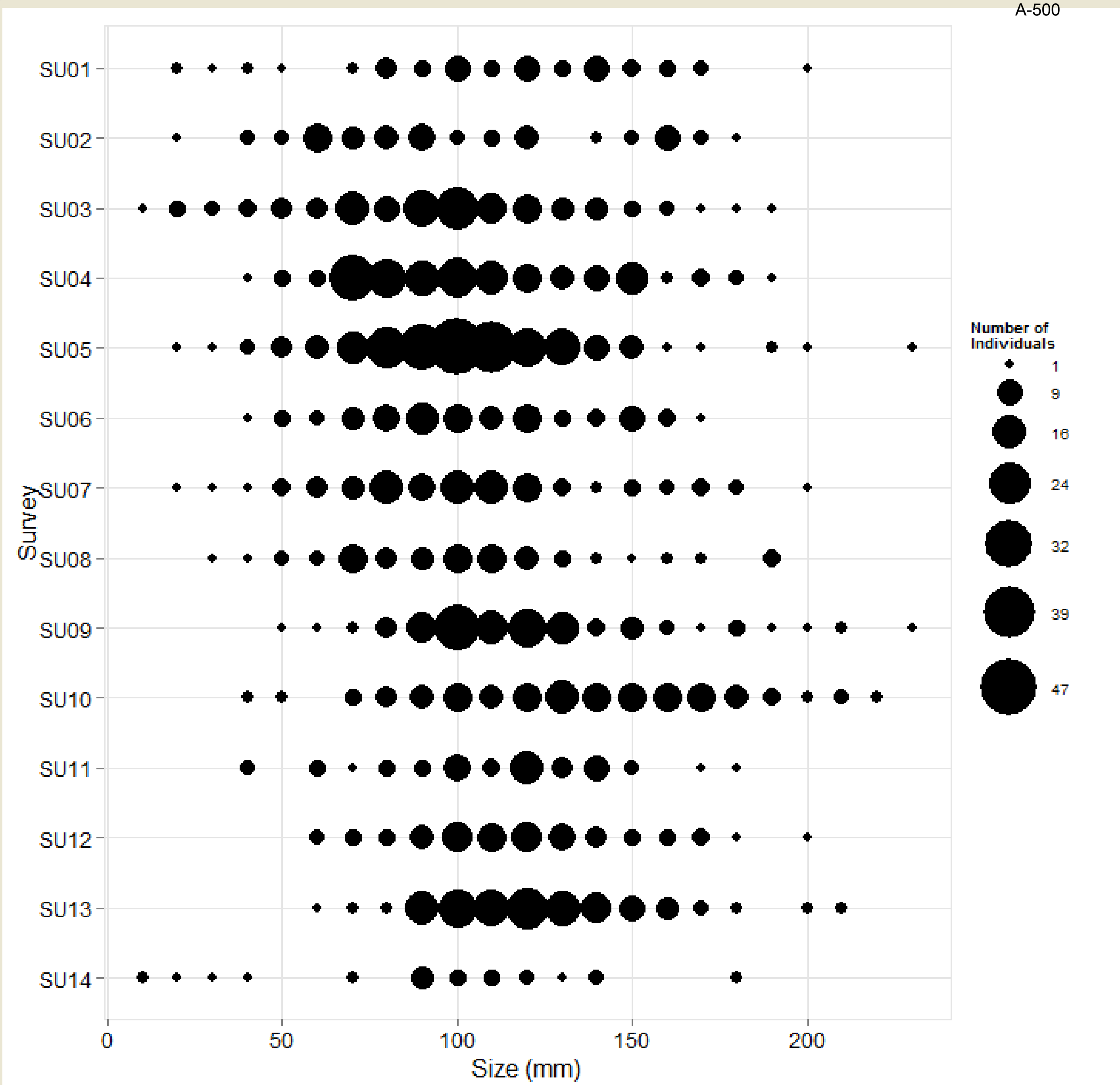
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes



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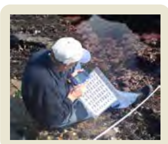
Ecola Biodiversity Survey fndings

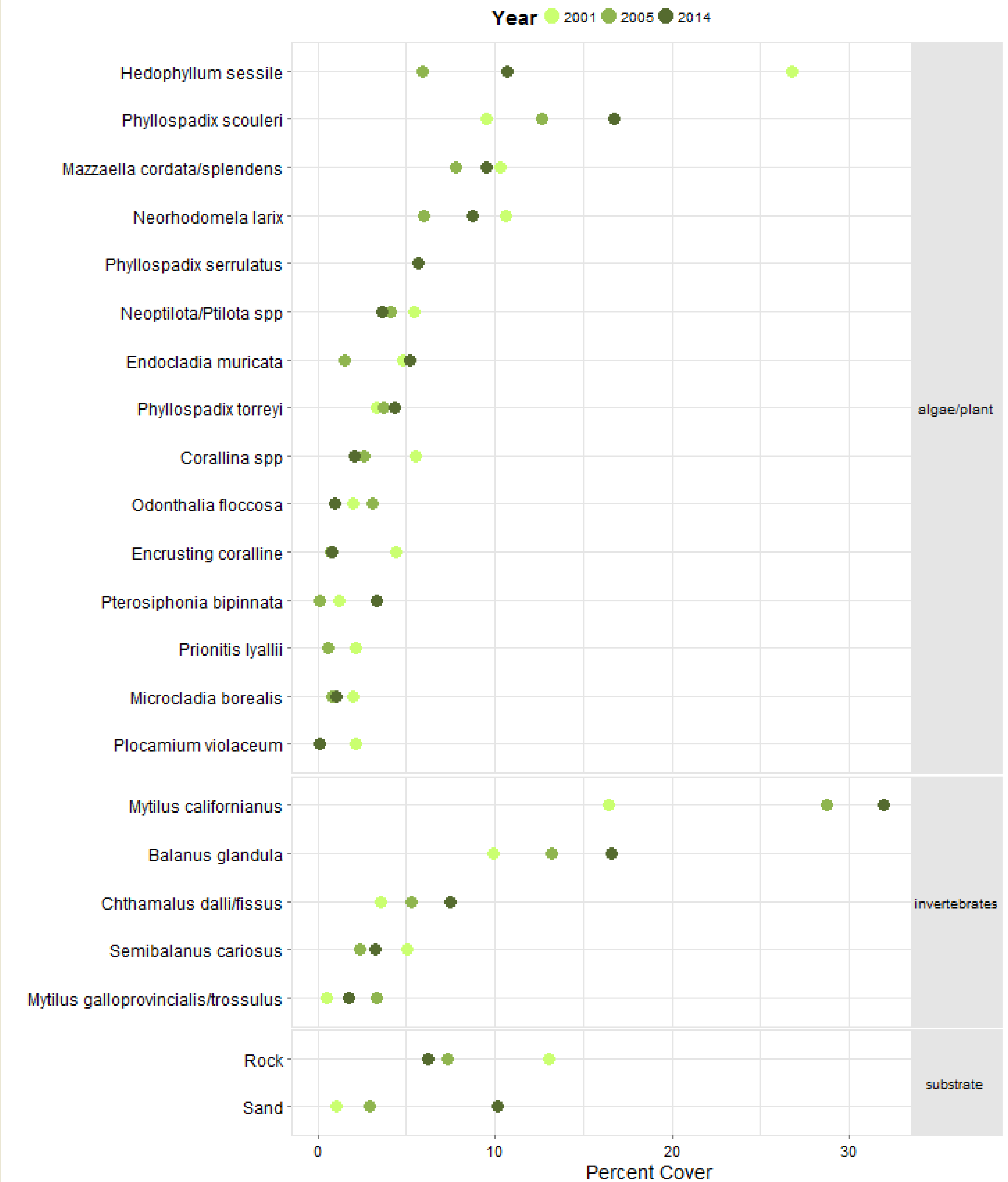
Click here (PDF link) for a list of species observed during the Biodiversity surveys at this site

For a complete species lookup table (including general taxonomic group name and common name, if available) of **ALL** species observed during the Biodiversity Surveys (at all sites), please click here (PDF link).

Point Contact Surveys

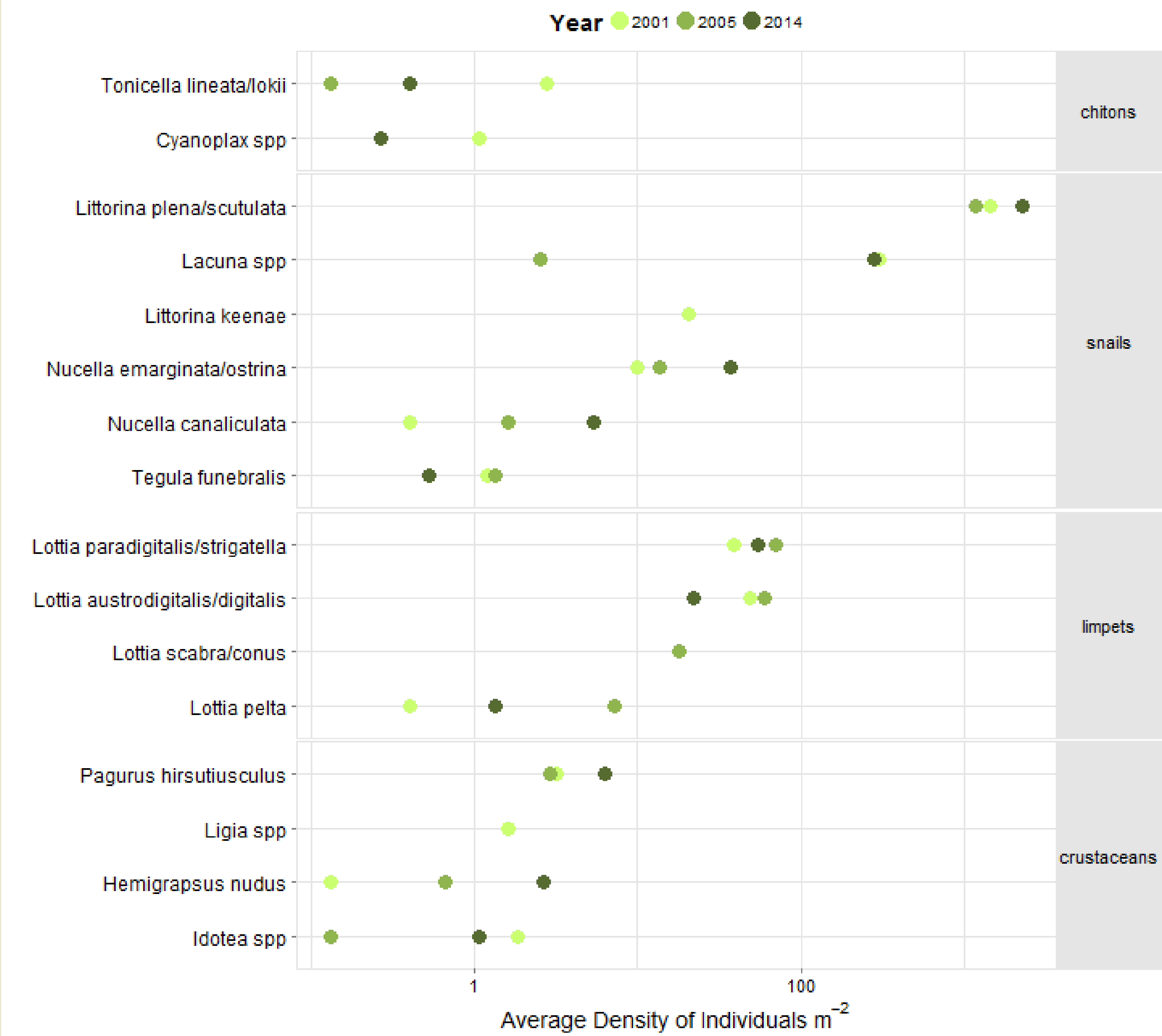


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.



Quadrat Surveys

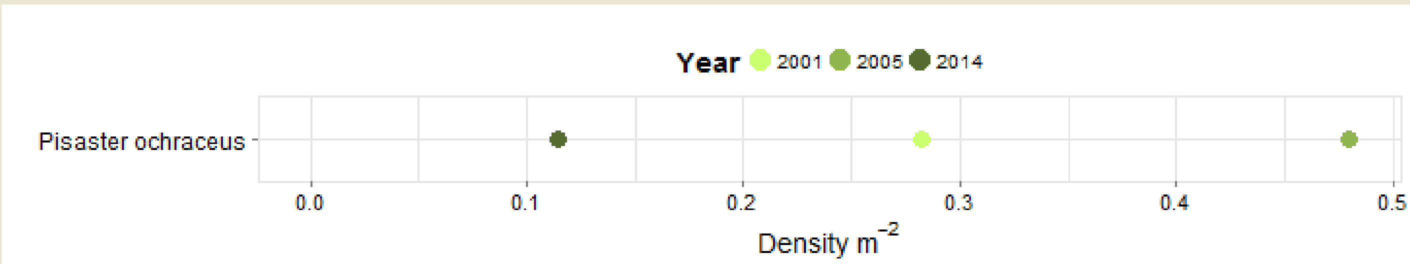
The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



Swath Surveys

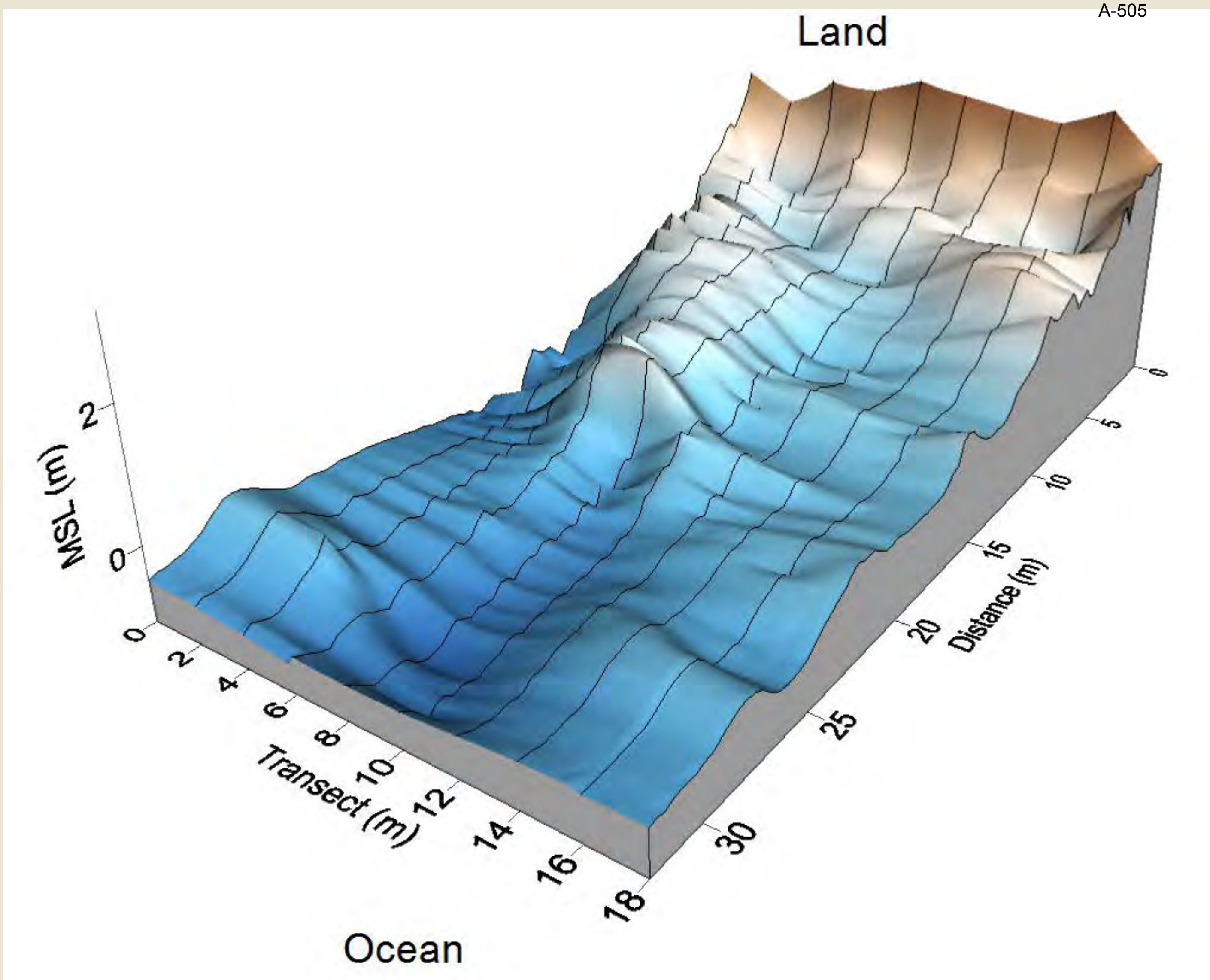
The graph below compares the density of seastar species observed per transect during the Swath

Surveys at this site.



Topography Surveys

The map below displays the topography of the site in meters above mean sea level (MSL). It was created from data collected during the Topography Surveys at this site.



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See Also

- Multi-Agency Rocky Intertidal Network

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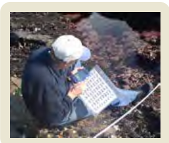
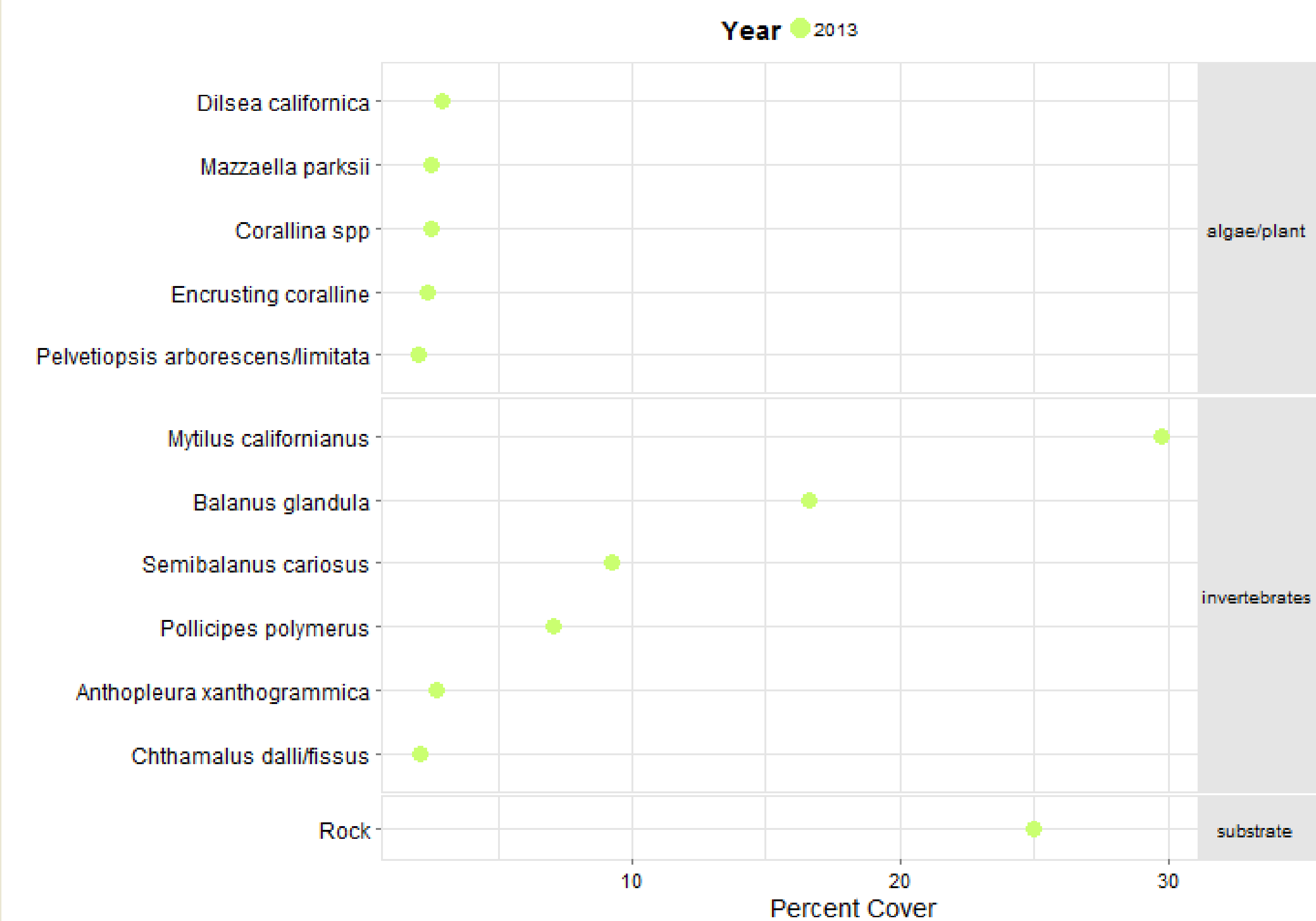
Cape Meares Biodiversity Survey fndings

For a complete species lookup table (including general taxonomic group name and common name, if available) of **ALL** species observed during the Biodiversity Surveys (at all sites), please click here (PDF link).

Point Contact Surveys

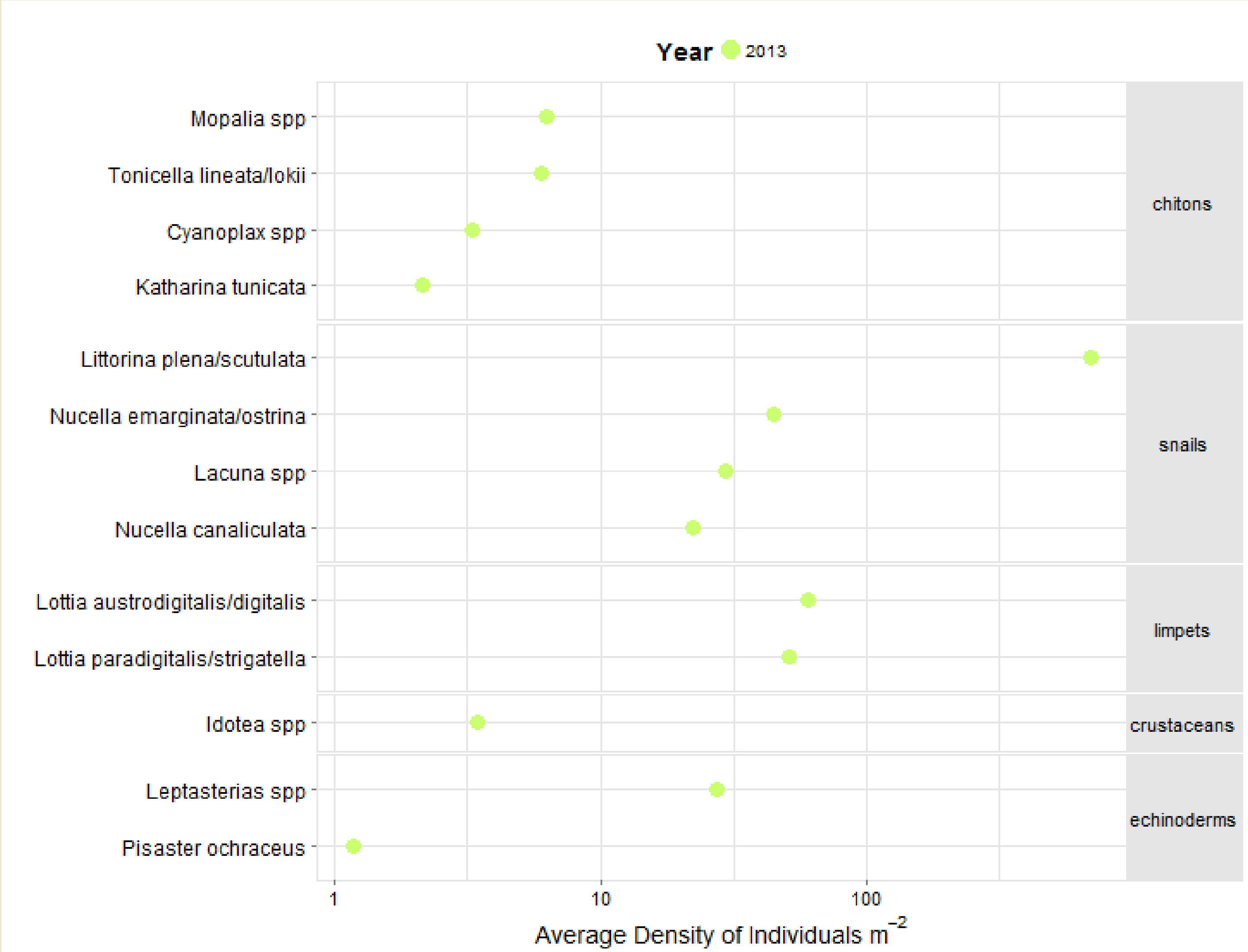


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.

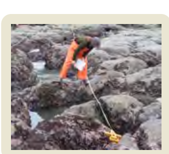


Quadrat Surveys

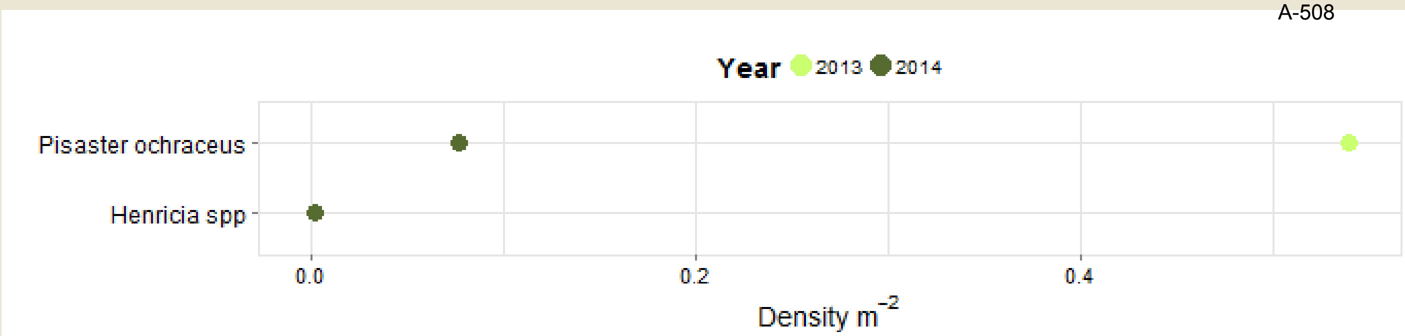
The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



Swath Surveys

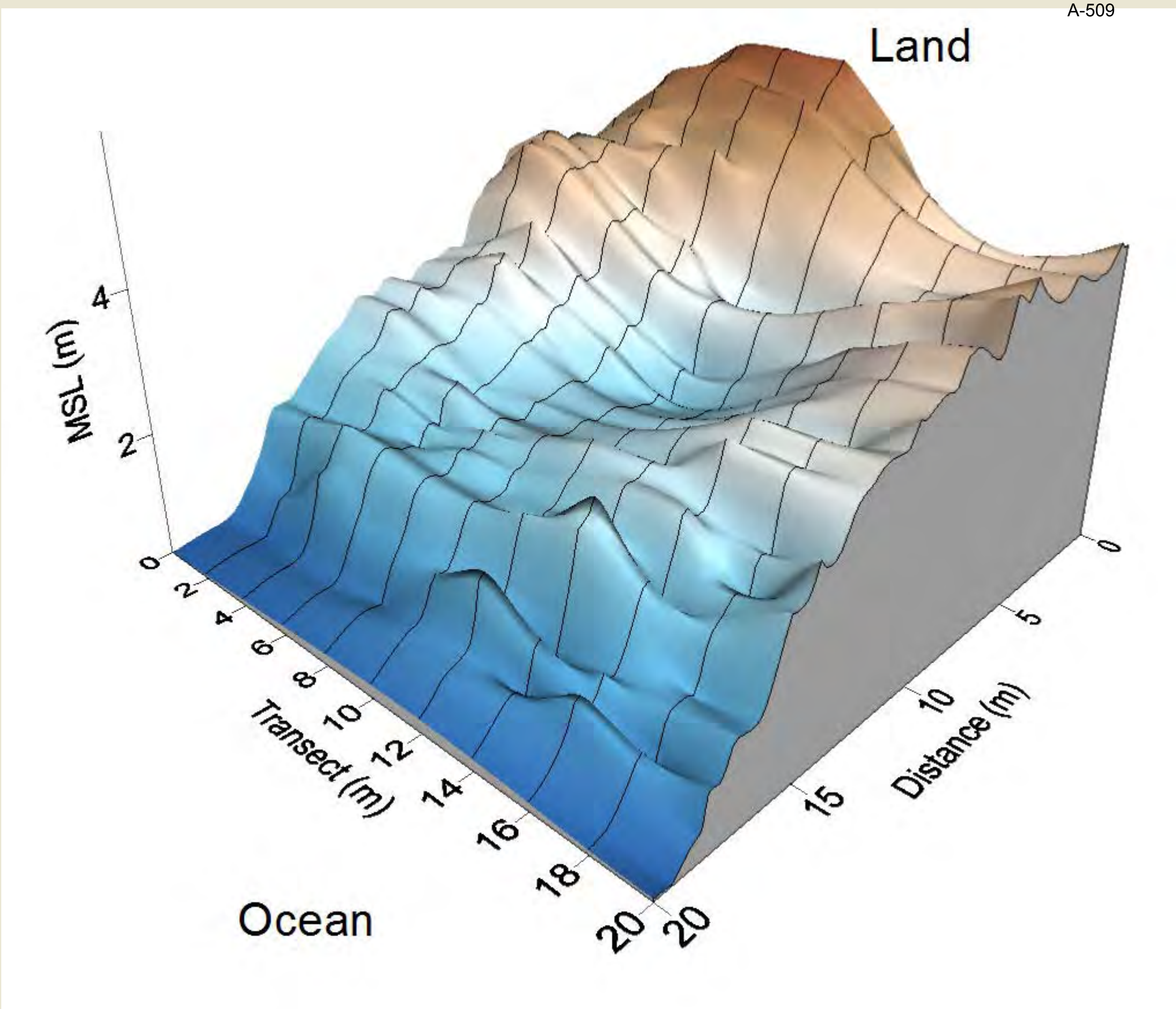


The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.



Topography Surveys

The map below displays the topography of the site in meters above mean sea level (MSL). It was created from data collected during the Topography Surveys at this site.



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Fogarty Creek Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle cover in the barnacle plots at Fogarty Creek was generally above 80%, which is surprising given that this area is a popular location for seals to haul out. *Balanus glandula* were much more abundant than *Chthamalus dalli/fssus* in these plots. Mussel cover in *Mytilus* plots was high and quite stable over time. The mussel bed at Fogarty Creek is so extensive and deep that we typically cannot fnd our bolts and need to rely on measurements and photos to locate the plots. *Fucus* cover in rockweed plots fuctuated somewhat over time, but was generally around 60% or higher. *Pelvetiopsis* cover in its target plots plummeted after the initial survey, and remained low in all successive years. Barnacles were typically the most common taxa in these plots. The target plots for *Neorhodomela* contained high cover of this red alga through 2006, after which a slight but gradual decline in cover occurred. Two "overstory" species—the boa kelp, *Egregia*, and the surfgrass, *Phyllospadix*, increased in cover during recent years, so it is possible that *Neorhodomela* was present under these species and had not declined substantially in cover. We have switched to a layering method for scoring photoplots, which will help to address these types of concerns. Limpets and littorines were the most abundant motile species in all plot types, but the whelk, *Nucella* spp was also common in *Mytilus* and *Fucus* plots and the turban snail, *Tegula funebralis* was sporadically common in barnacle, *Fucus*, and *Neorhodomela* plots. *Phyllospadix* cover was high throughout the duration of the study, and gradually increased in cover over time.

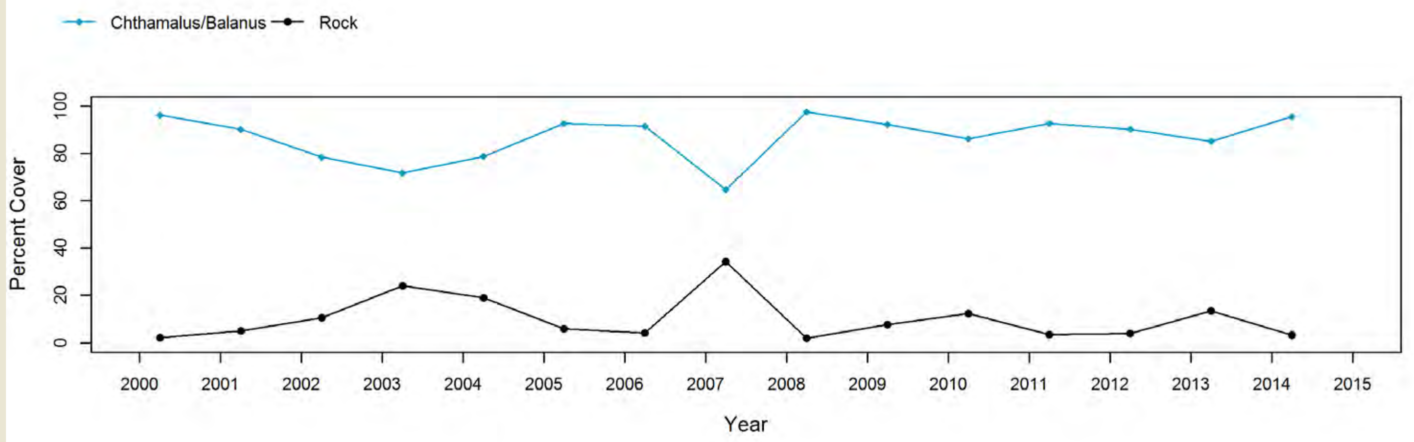
Ochre star counts within our 3 permanent plots generally hovered between 200-400 for most years, but spikes of over 700 stars were counted in 2004 and 2006. Size class data shows that these spikes in counts span the 40-120 range, so the increases were likely due to movement of stars into the plots from offshore habitat, rather than recruitment of new individuals to the site. Ochre star numbers were down in 2014, and we expect them to decline further in 2015 due to Sea Star Wasting Syndrome.

Photo Plots

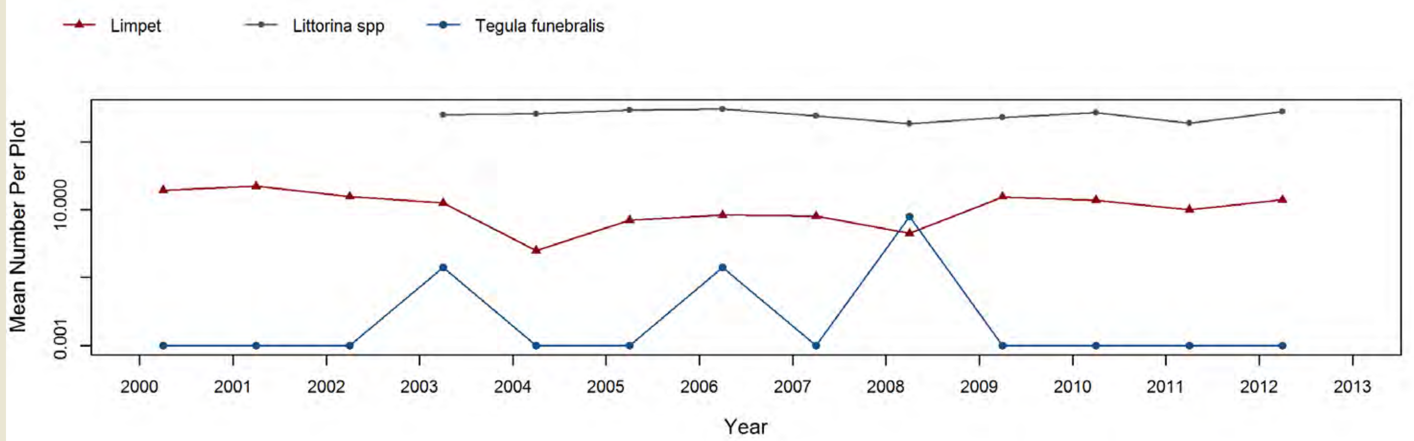
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since summer 2012. For motile invertebrate size trend graphs by site, please use the Interactive Map.

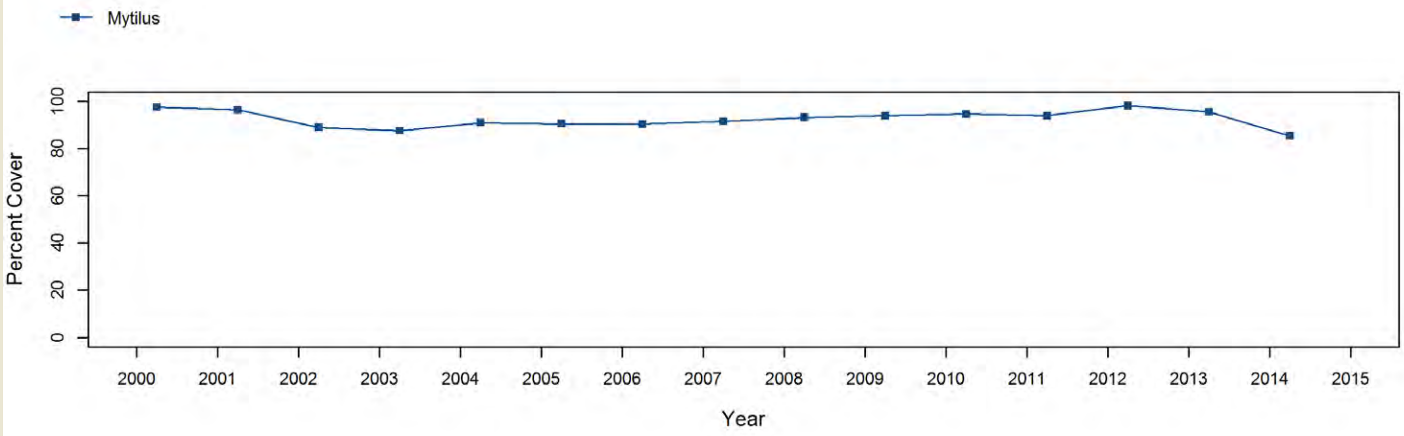
Chthamalus/Balanus (Acorn Barnacles) - percent cover



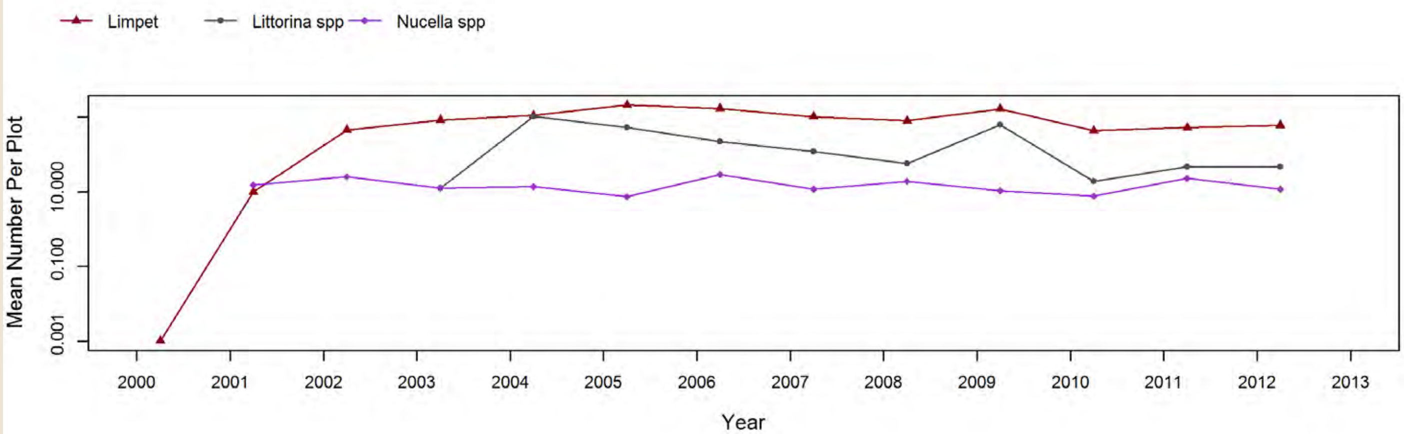
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



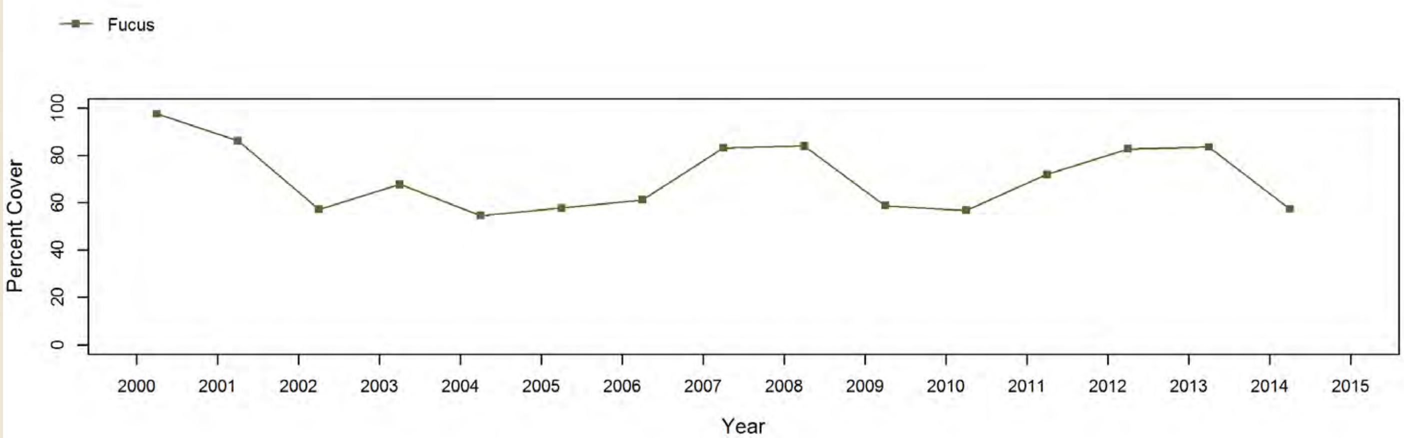
Mytilus (California Mussel) - percent cover



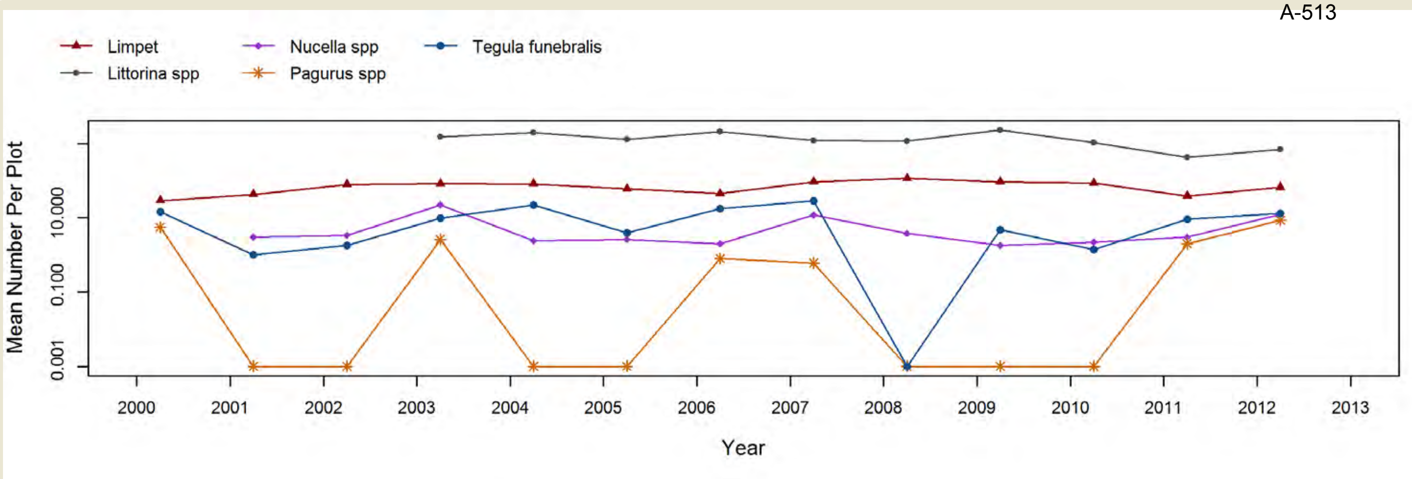
Mytilus (California Mussel) - motile invertebrate counts



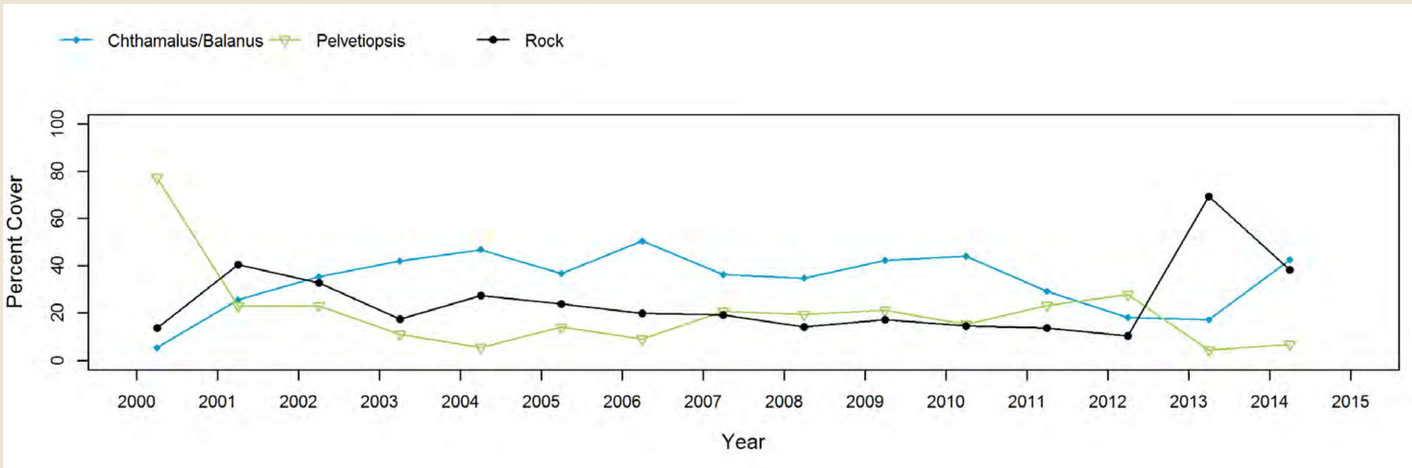
Fucus (Northern Rockweed) - percent cover



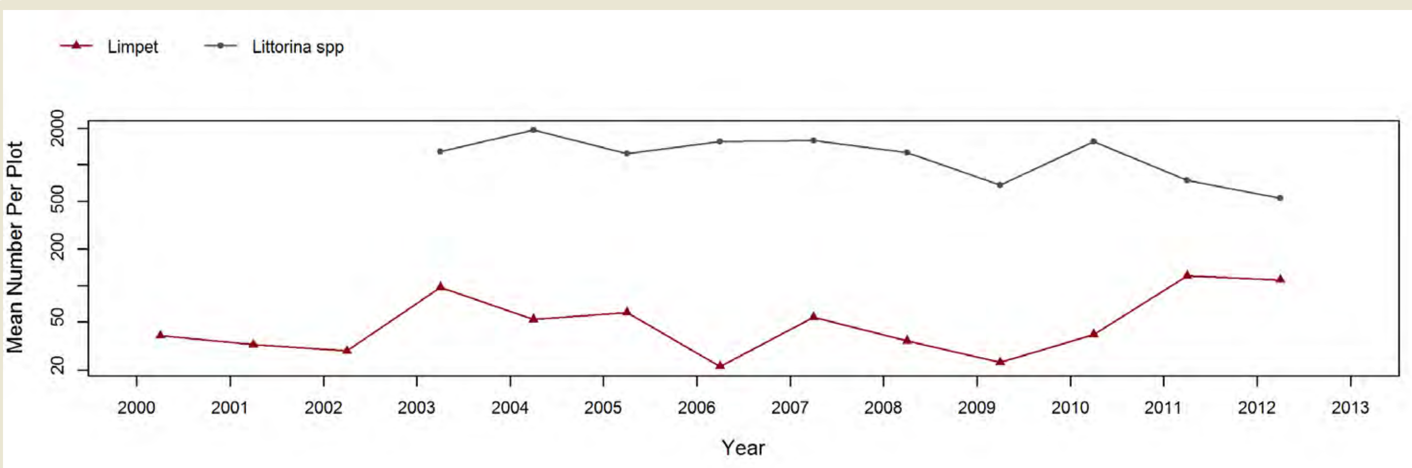
Fucus (Northern Rockweed) - motile invertebrate counts



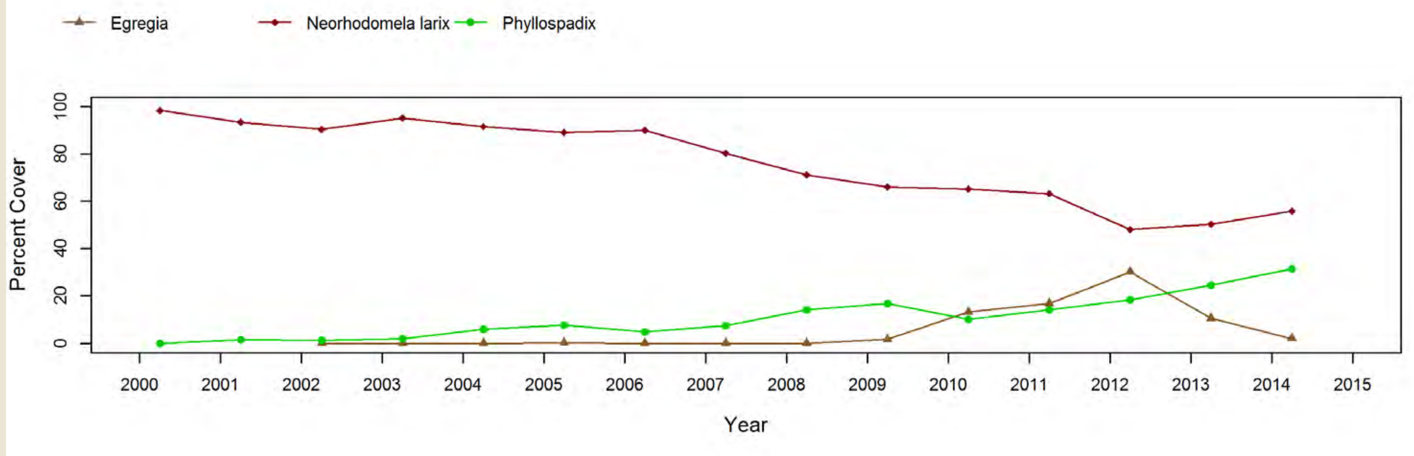
Pelvetiopsis (Dwarf Rockweed) - percent cover



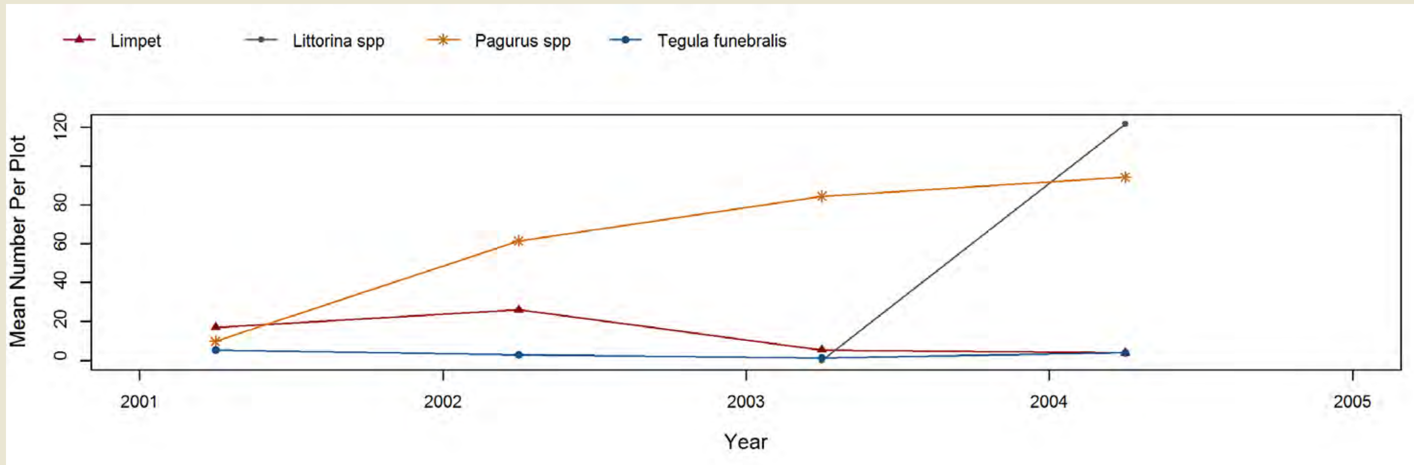
Pelvetiopsis (Dwarf Rockweed) - motile invertebrate counts



Neorhodomela (Black Pine) - percent cover



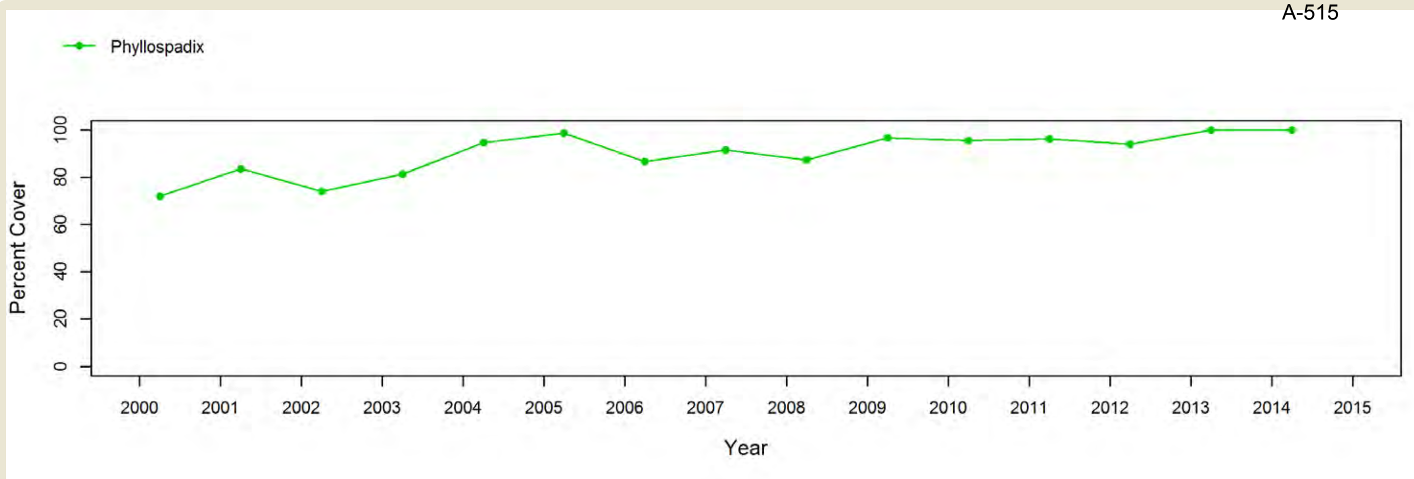
Neorhodomela (Black Pine) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

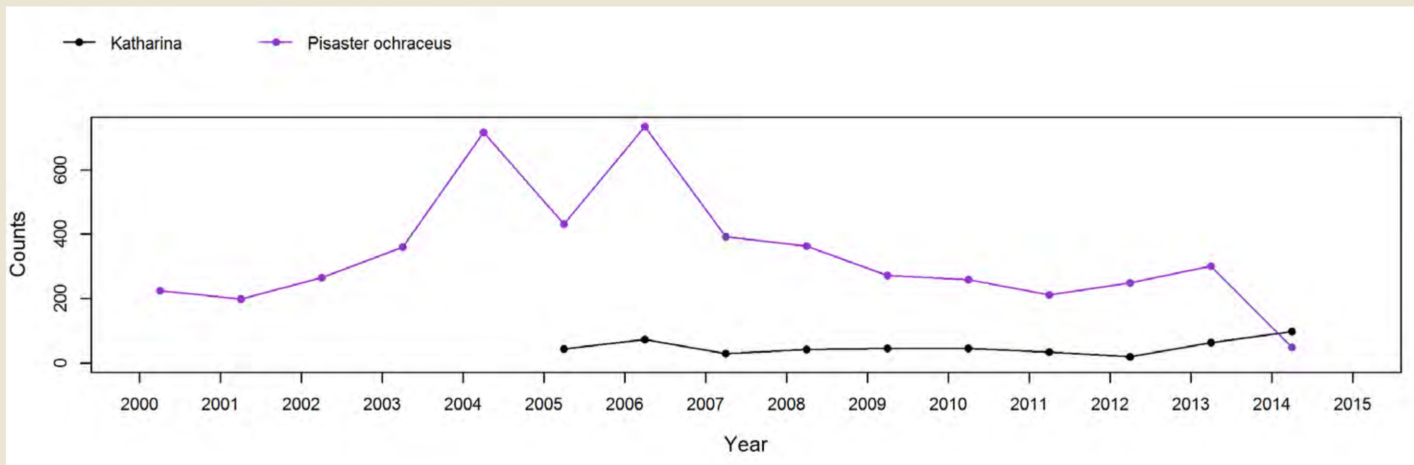
Phyllospadix (Surfgrass)



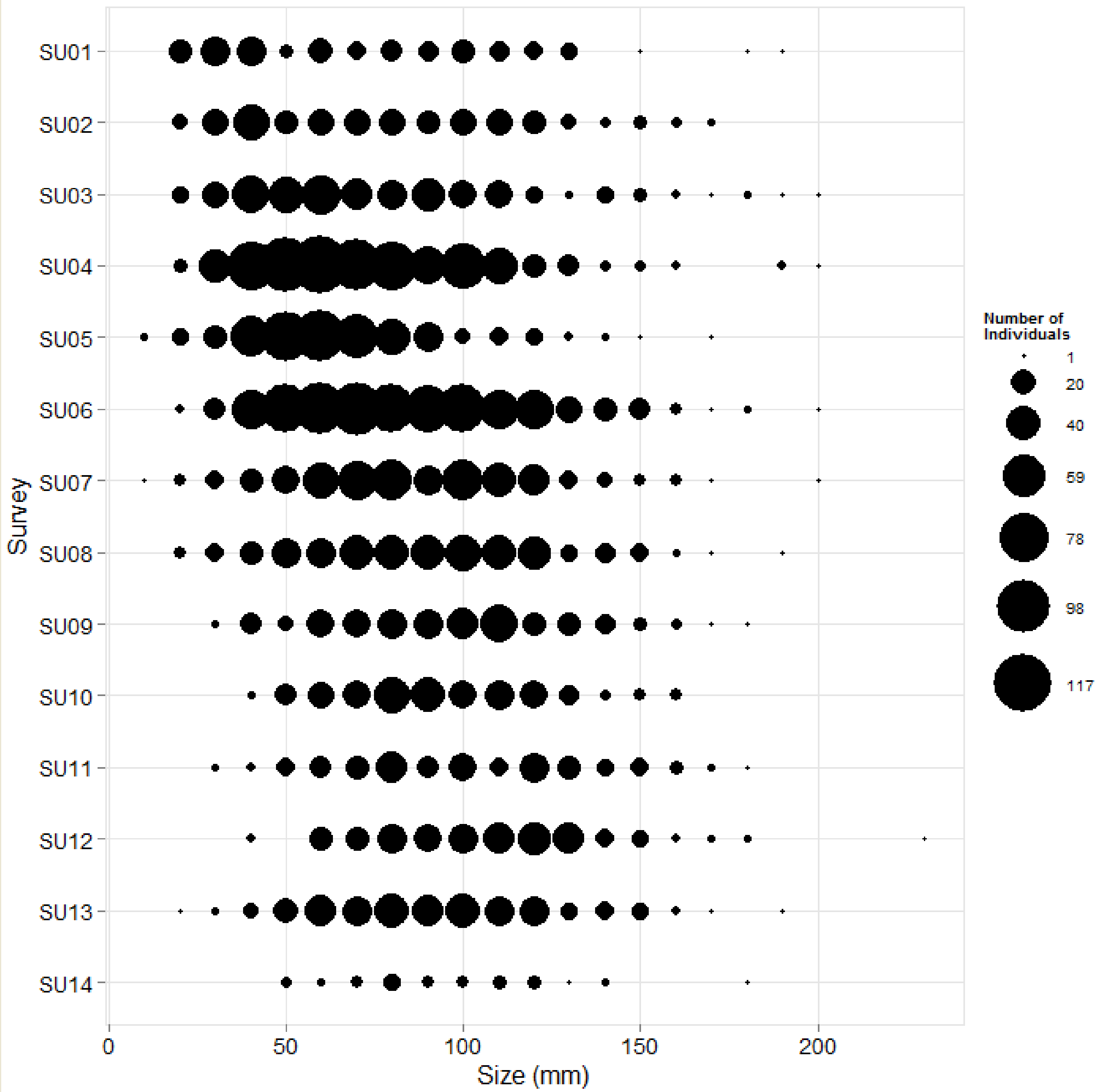
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes



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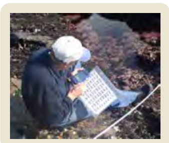
Fogarty Creek Biodiversity Survey fndings

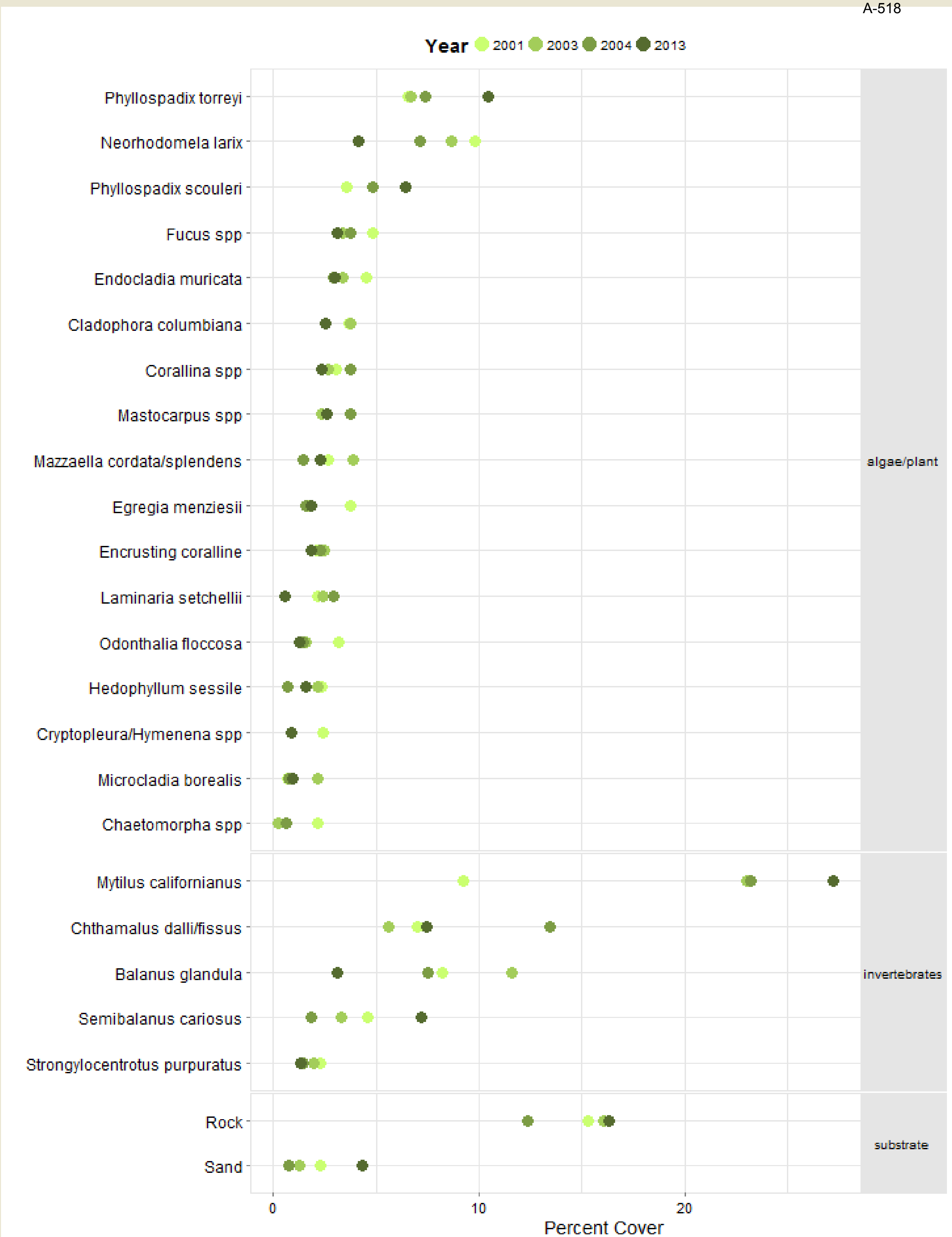
Click here (PDF link) for a list of species observed during the Biodiversity surveys at this site

For a complete species lookup table (including general taxonomic group name and common name, if available) of **ALL** species observed during the Biodiversity Surveys (at all sites), please click here (PDF link).

Point Contact Surveys

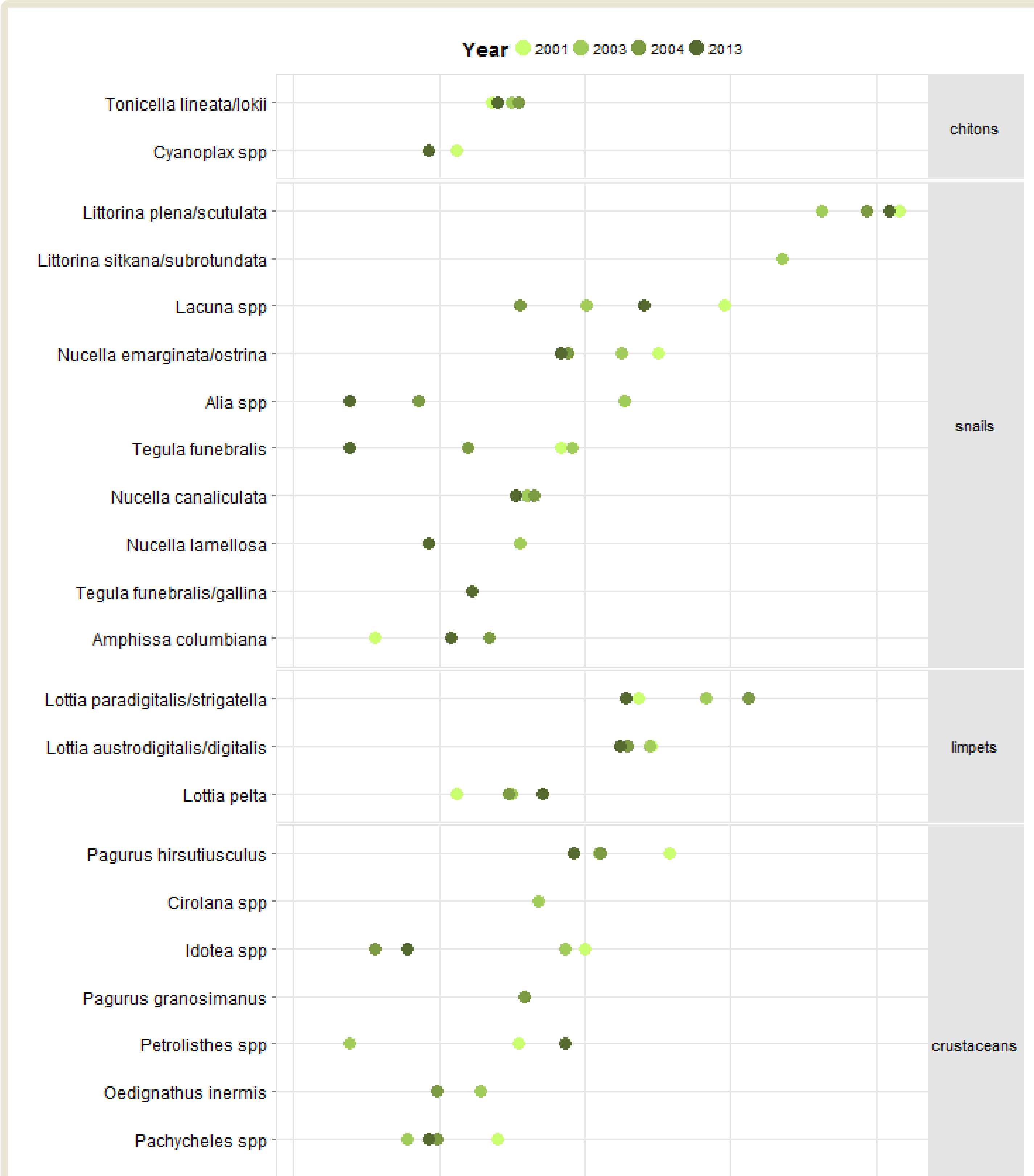


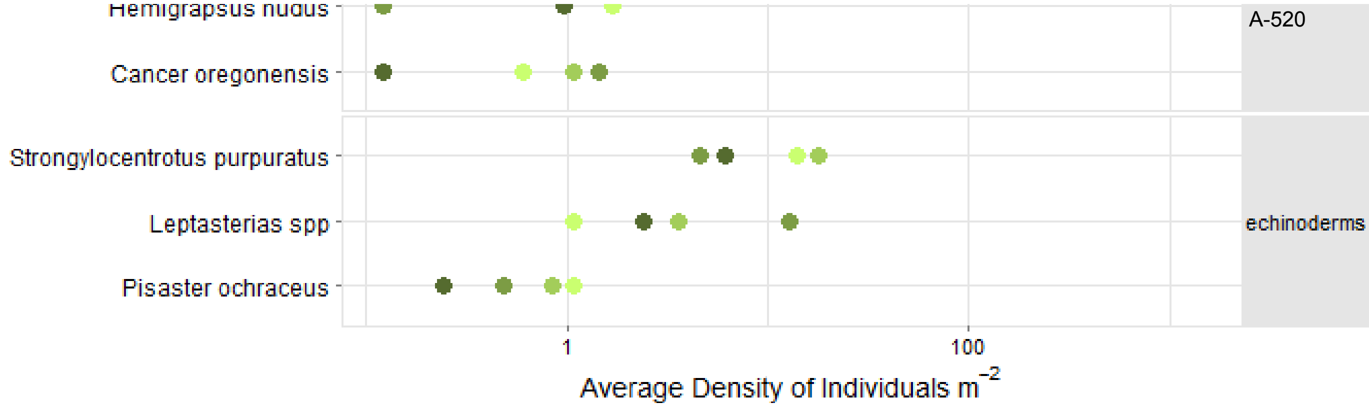
The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.



Quadrat Surveys

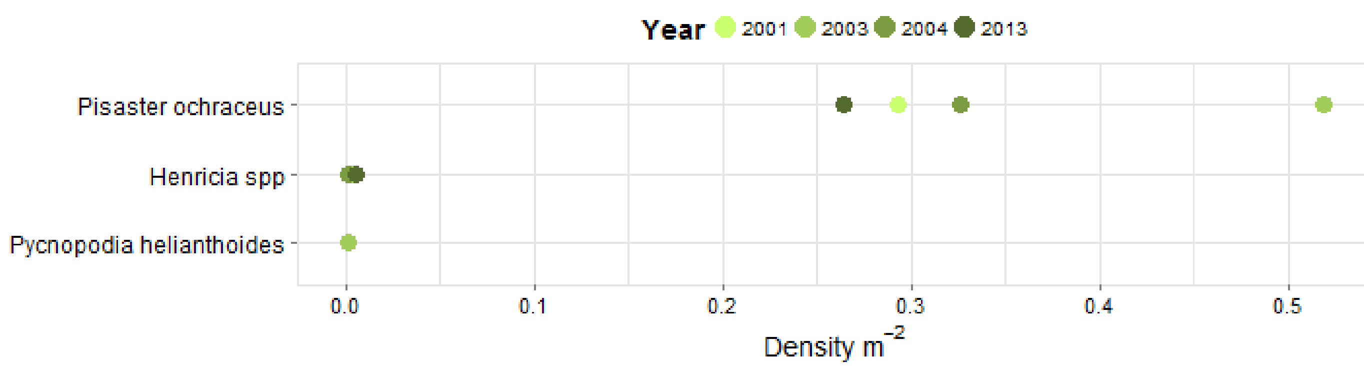
The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



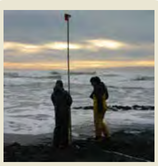


Swath Surveys

The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.

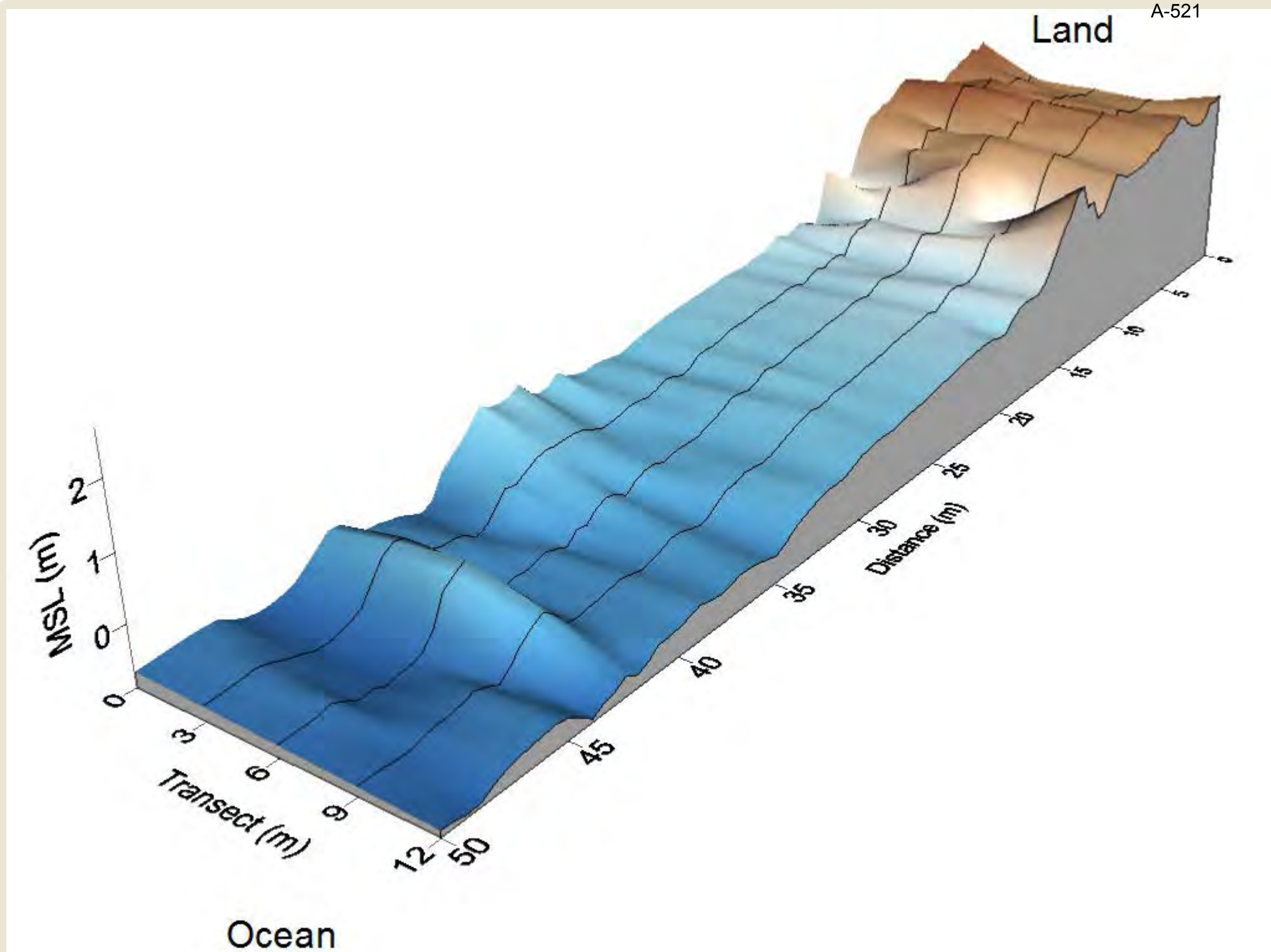


Topography Surveys

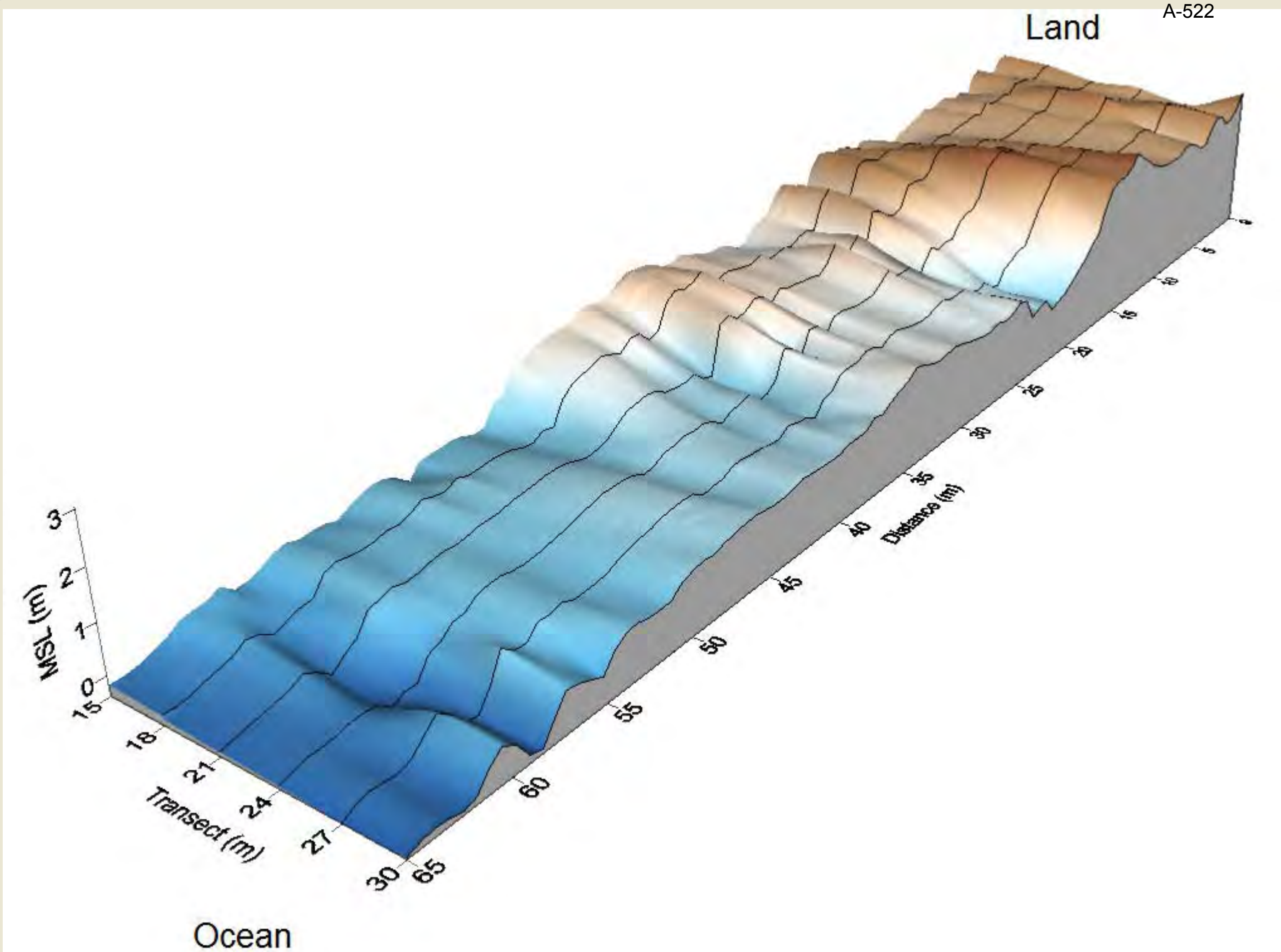


The map below displays the topography of the site in meters above mean sea level (MSL). It was created from data collected during the Topography Surveys at this site.

Section 1


A-521
Land
MSL (m)
2
1
0
0
3
6
9
12
Transect (m)
50
45
40
35
30
25
20
15
10
5
0
Distance (m)
Ocean

Section 2



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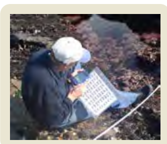
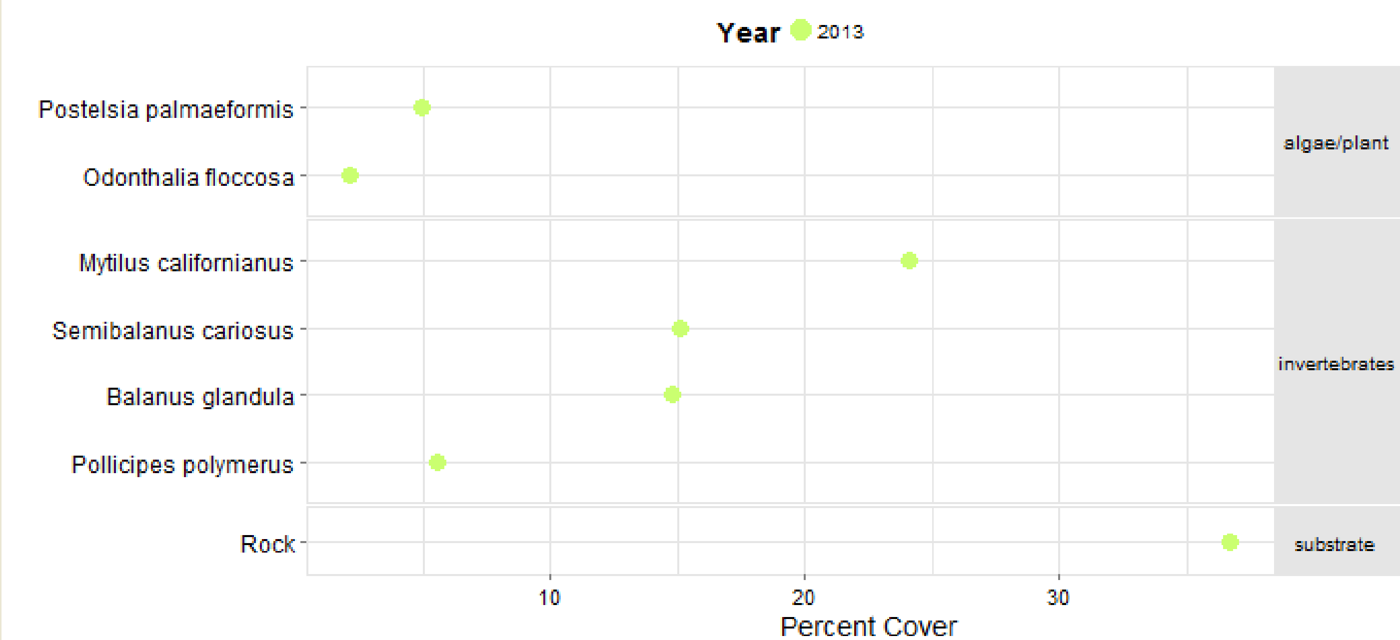
Seal Rock Biodiversity Survey fndings

For a complete species lookup table (including general taxonomic group name and common name, if available) of **ALL** species observed during the Biodiversity Surveys (at all sites), please click here (PDF link).

Point Contact Surveys

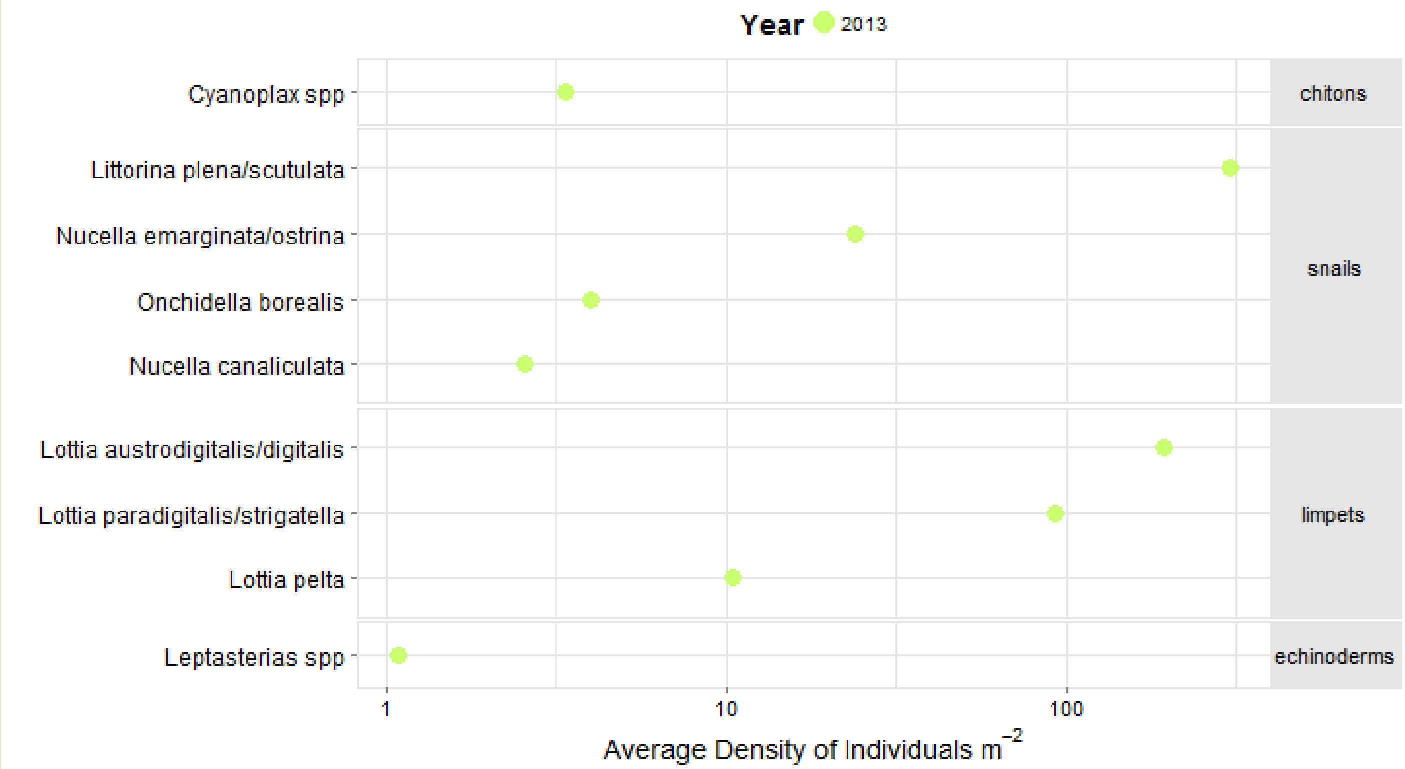


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.

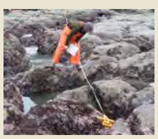


Quadrat Surveys

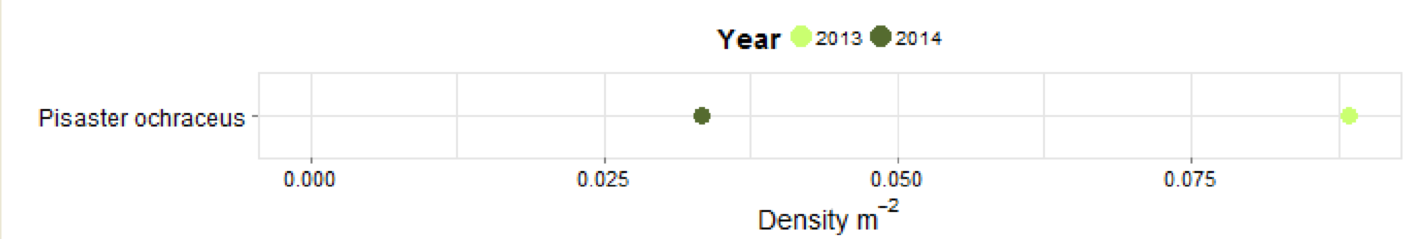
The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



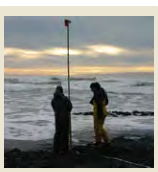
Swath Surveys



The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.



Topography Surveys



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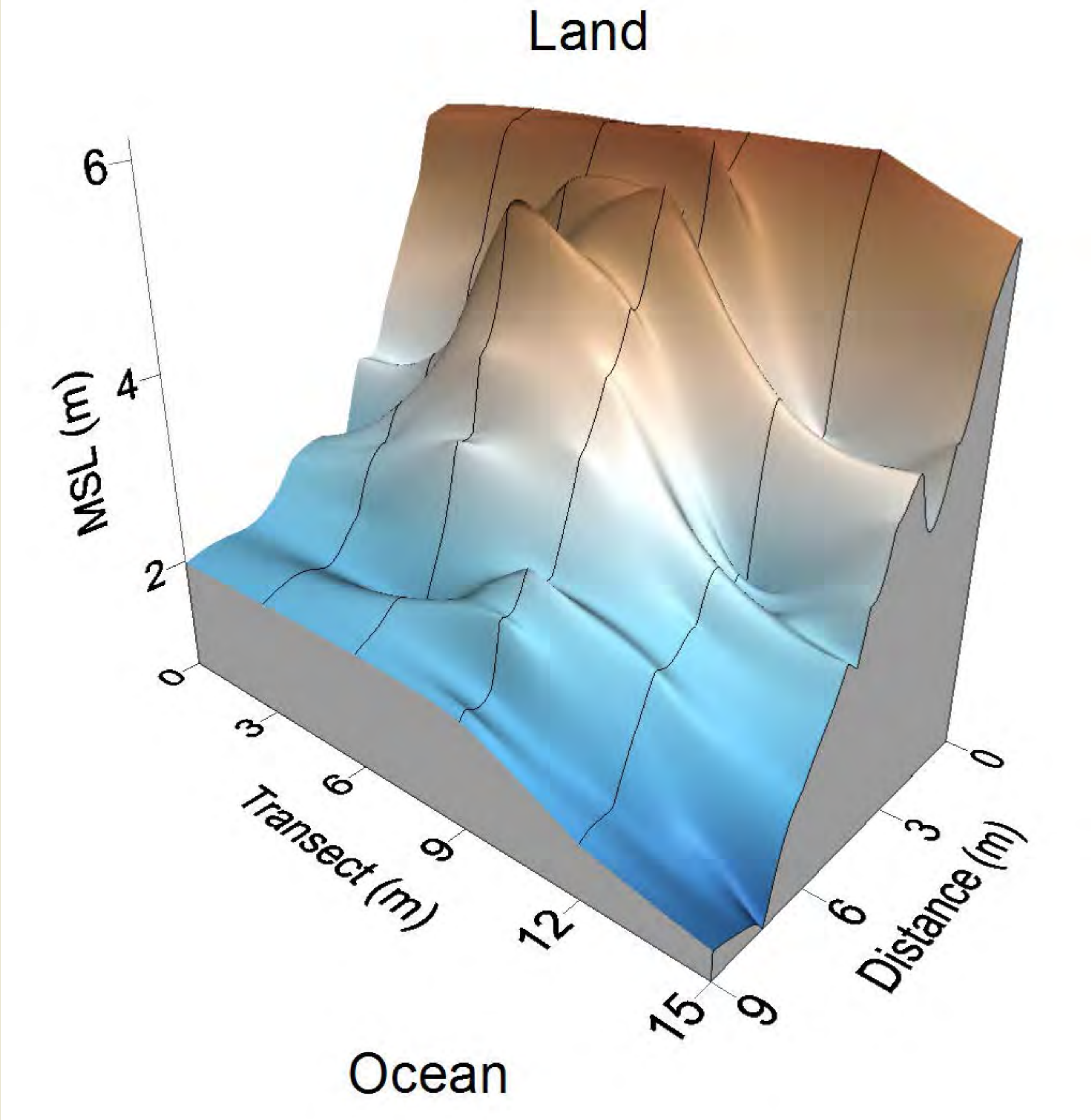
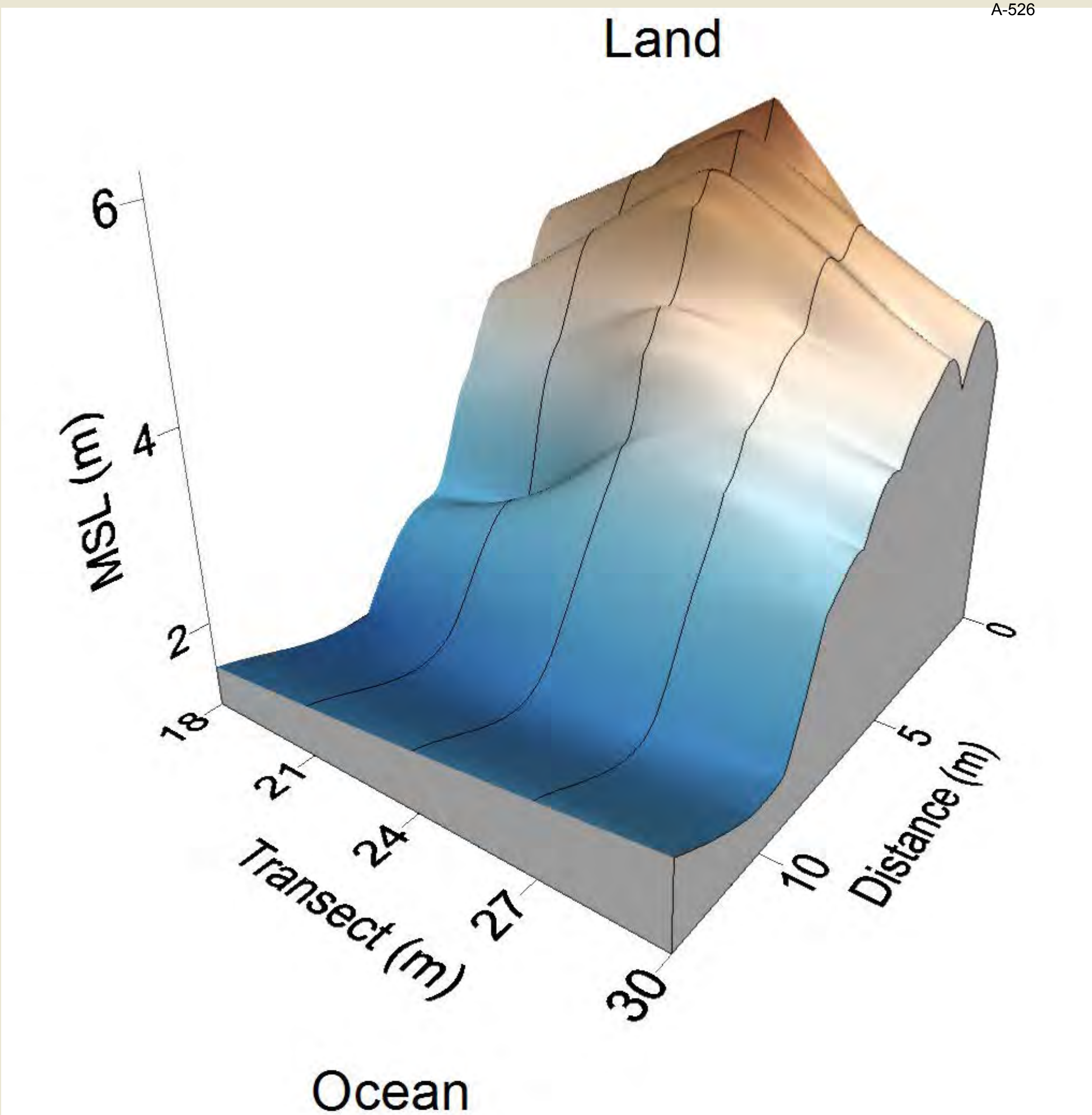
Section 1



Section 2



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Bob Creek Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacle cover was generally high in the barnacle plots at Bob Creek, and consisted almost exclusively of *Balanus glandula*. Barnacle plots at this site are subjected to a high level of scour from sand movement, and plot 5 is often buried when we survey in the summer. Because of this, we added a 6th barnacle plot in 2001 and excluded plot 5 from the trend graph summary data. *Pelvetiopsis* cover fuctuated substantially in 2 of the 5 barnacle plots, with high cover in 2011, 2012, and 2013. Cover of *Semibalanus* within its target plots was somewhat variable over time, beginning around 50%, then dropping to around 10% in 2004. A recruitment event in 2007 resulted in a spike in cover at around 70%, before stabilizing at about 40% over the past several years. This fuctuation in cover of thatched barnacles was surprising given their ability to be quite long-lived (10-15 years; Morris, Abbott, and Haderlie, 1980). Mussel cover was high in *Mytilus* plots in all years except 2003-2005 when a dip occurred, followed by recovery. *Fucus* cover in rockweed plots started out at nearly 100% but declined dramatically in 2002 and further in 2003. This decline was followed by a modest recovery in 2004/2005, but cover has since declined again and remained quite low. Barnacles were abundant in *Fucus* plots, but a fair amount of bare space was also present. *Pelvetiopsis* cover in its target plots fuctuated substantially over time, varying inversely with barnacle cover. *Endocladia* cover in turfweed plots began at just above 50%, but then declined and was generally quite low. Barnacles were commonly the most abundant taxa in these plots. Limpets and littorines were abundant in all photoplots. *Nucella* spp. were often quite numerous in *Semibalanus* plots, but were also present in *Mytilus*, *Endocladia*, and *Pelvetiopsis* plots.

Two of the surfgrass transects at Bob Creek had consistently high cover of *Phyllospadix* (nearly always close to 100%), but the third transect is located along the side of a surge channel and commonly contains signifcant cover of red algae such as *Prionitis* spp.

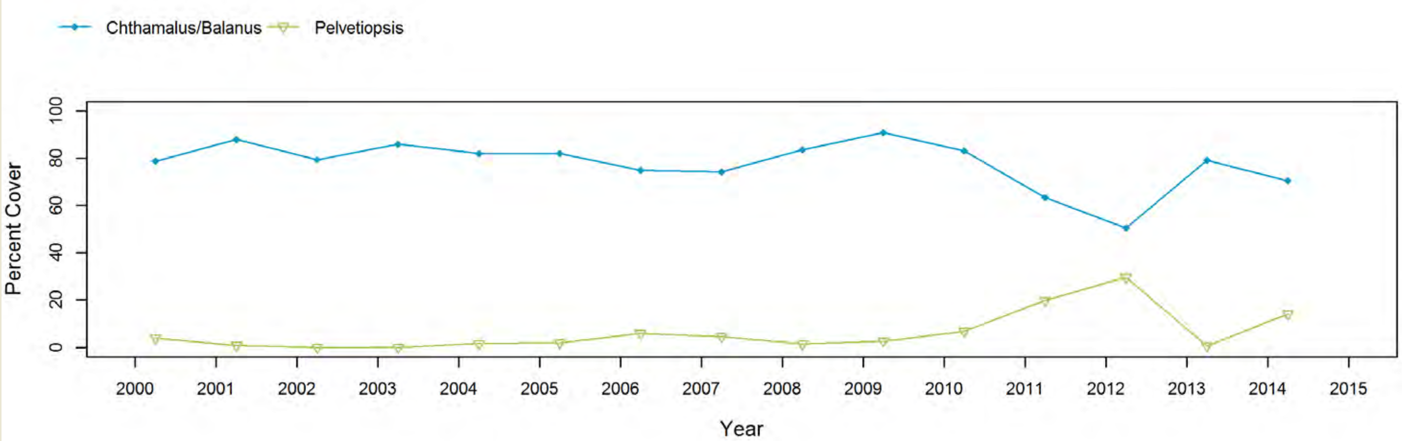
Ochre star numbers were relatively stable at Bob Creek until 2014. The “jump” in numbers between 2003 and 2004 was due to the enlargement of one plot that had low numbers of stars. Numbers declined in 2014, and it is likely that we will see further decline due to Sea Star Wasting Syndrome when the site is resampled in 2015. Occasional pulses in the number of juvenile ochre stars have occurred at Bob Creek, the most recent of which was in 2014. It is our hope that these juveniles survive and help to replenish the depressed sea star population.

Photo Plots

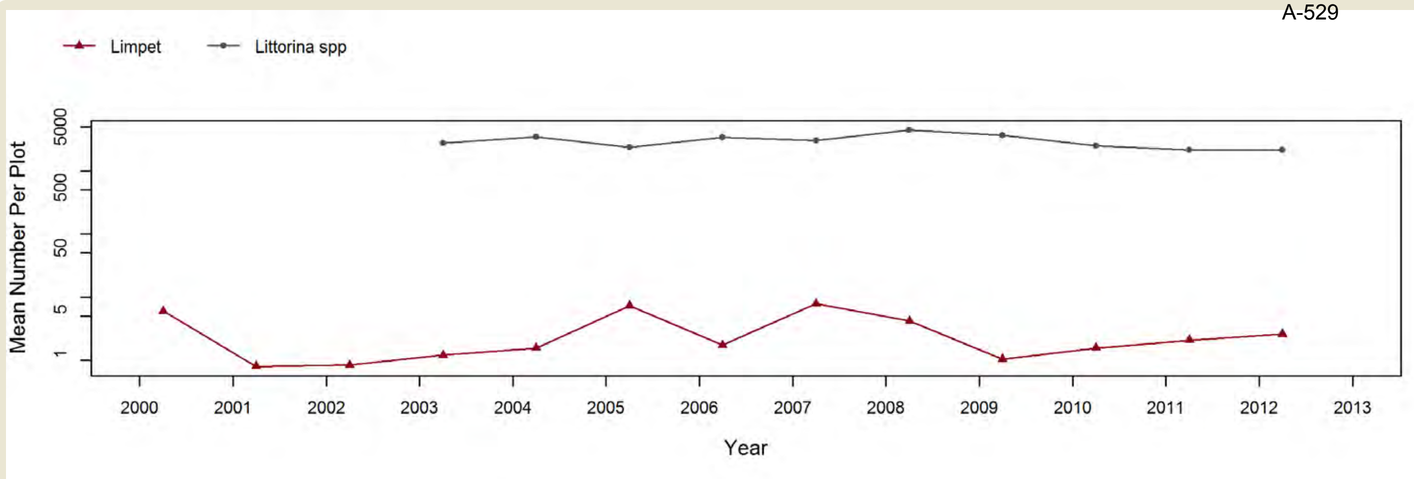
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since summer 2012. For motile invertebrate size trend graphs by site, please use the Interactive Map.

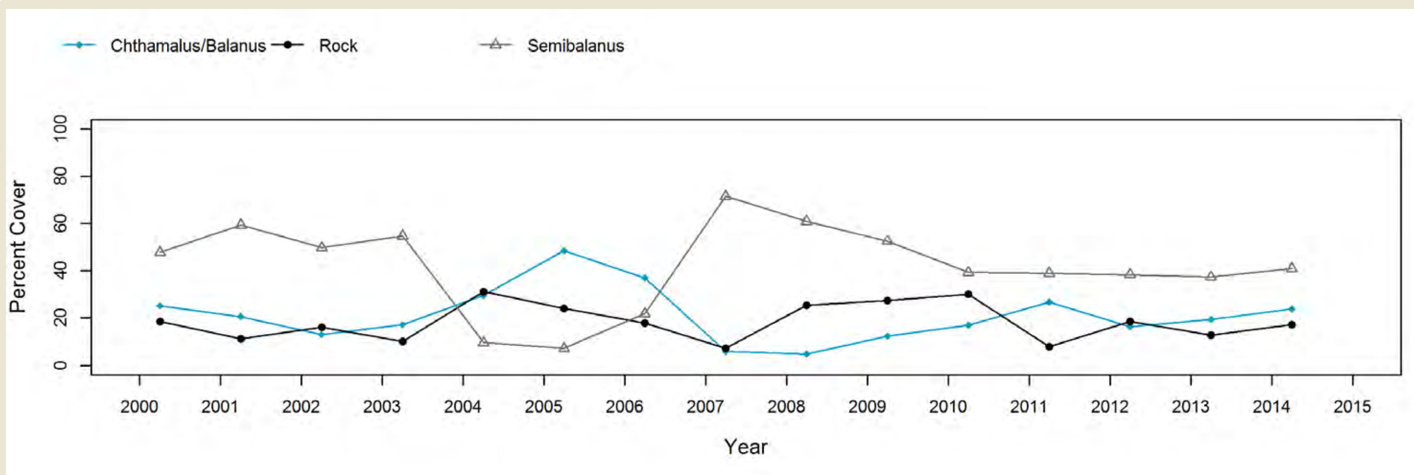
Chthamalus/Balanus (Acorn Barnacles) - percent cover



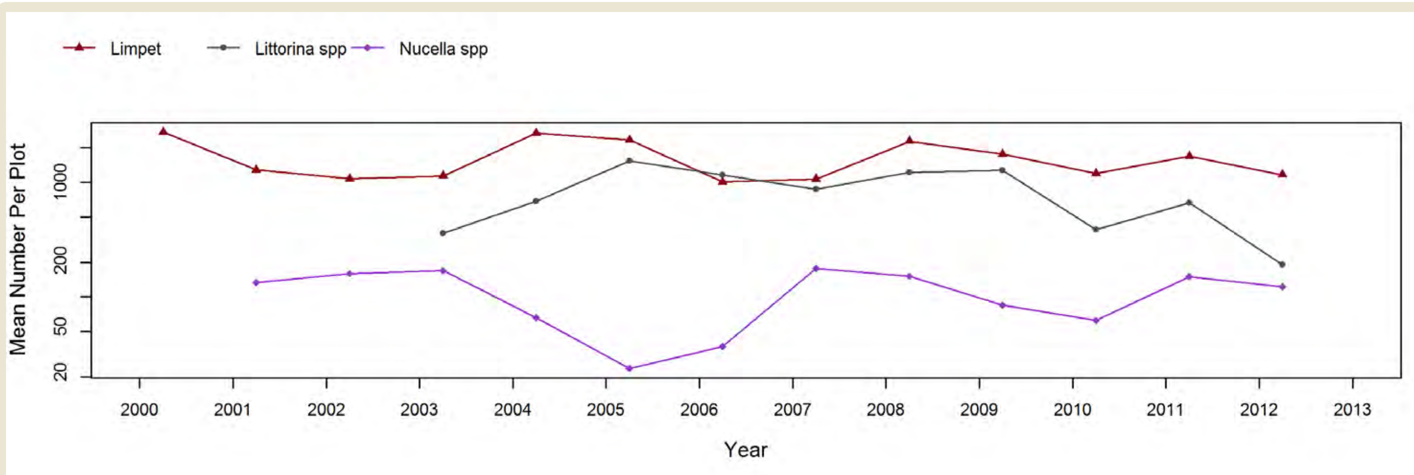
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



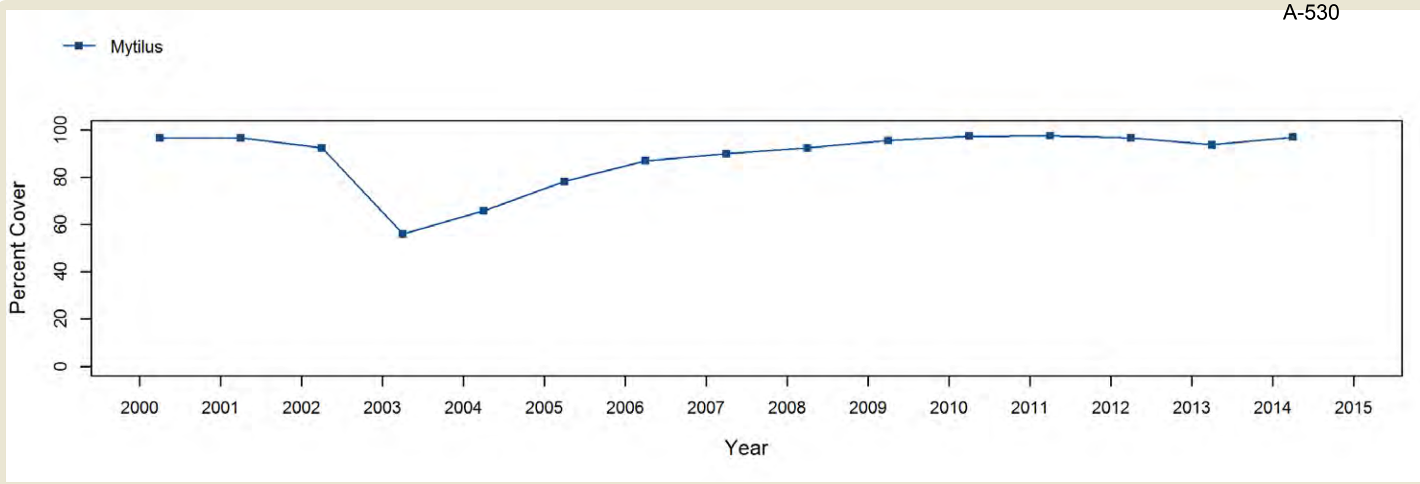
Semibalanus (Thatched Barnacle) - percent cover



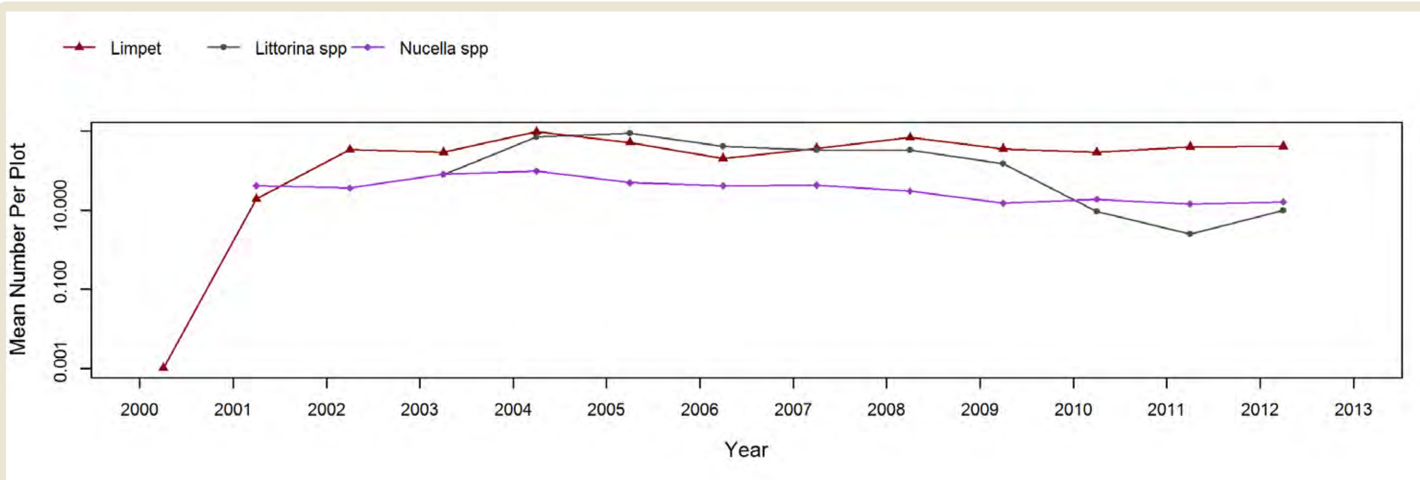
Semibalanus (Thatched Barnacle) - motile invertebrate counts



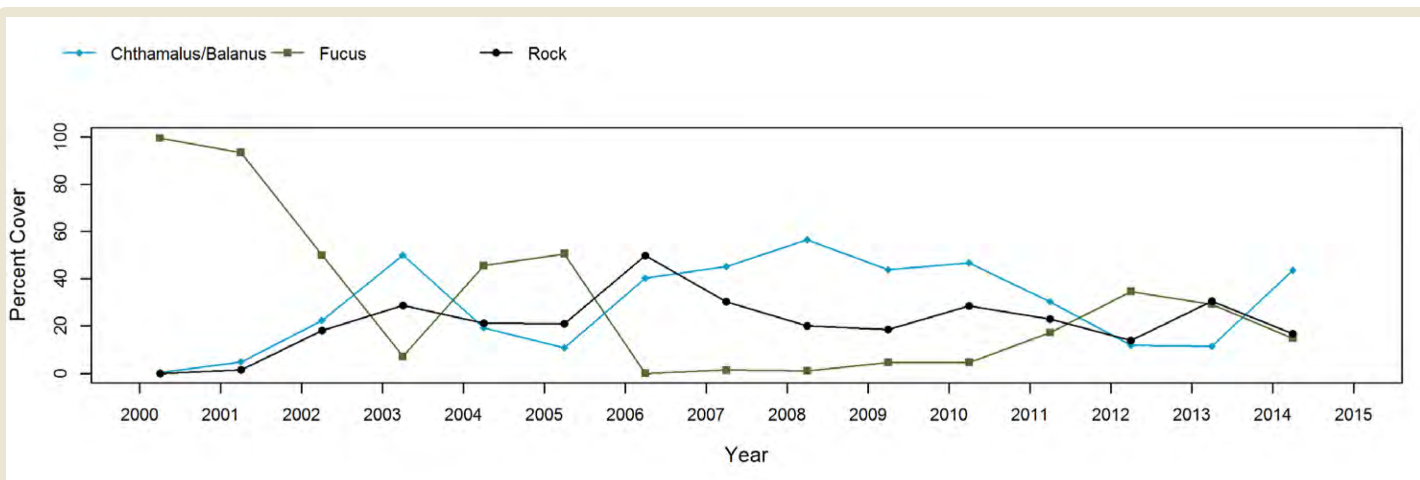
Mytilus (California Mussel) - percent cover



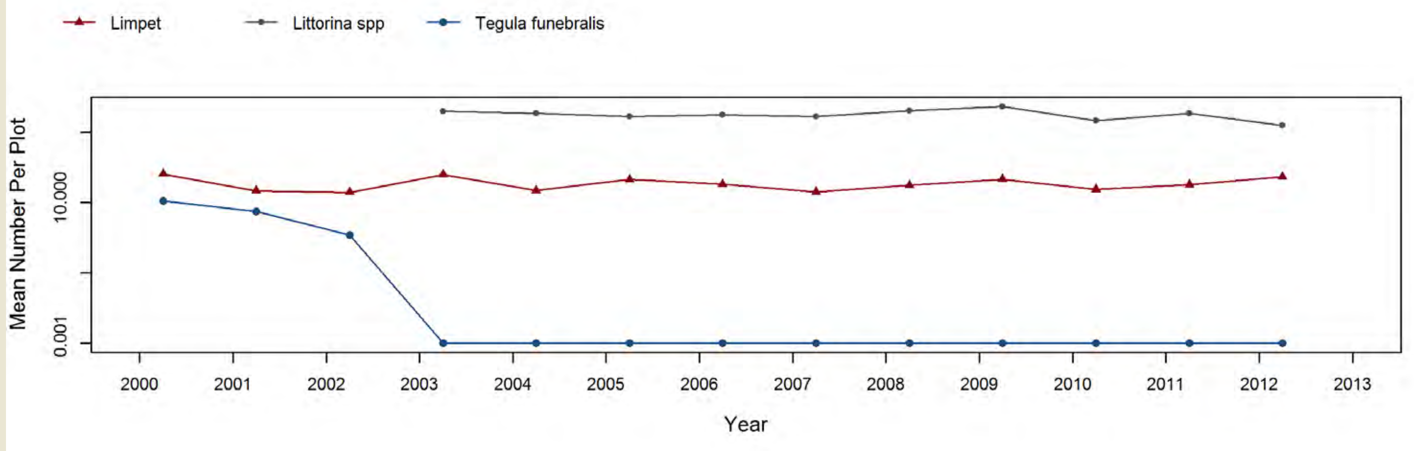
Mytilus (California Mussel) - motile invertebrate counts



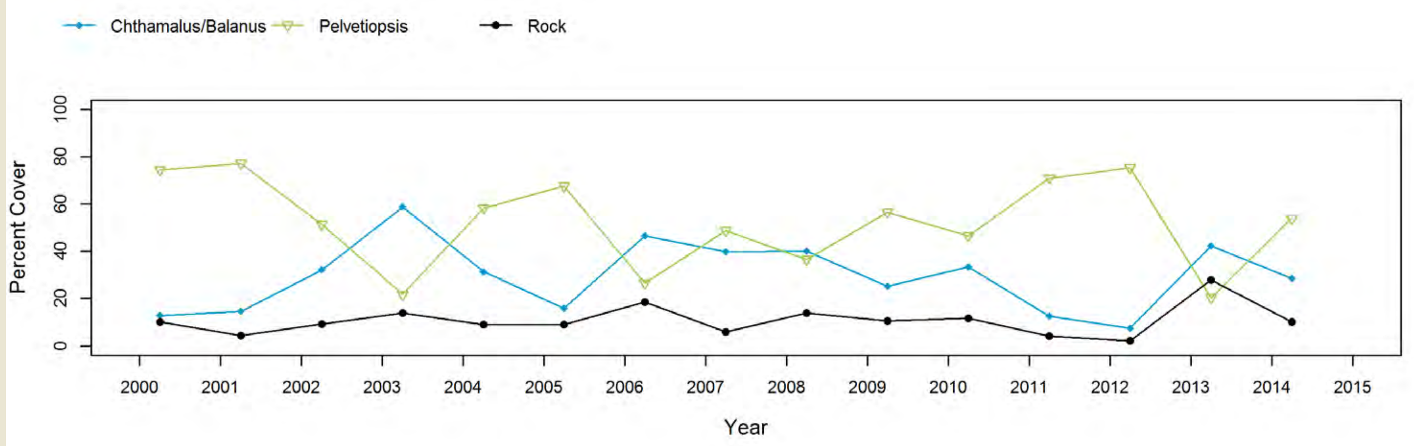
Fucus (Northern Rockweed) - percent cover



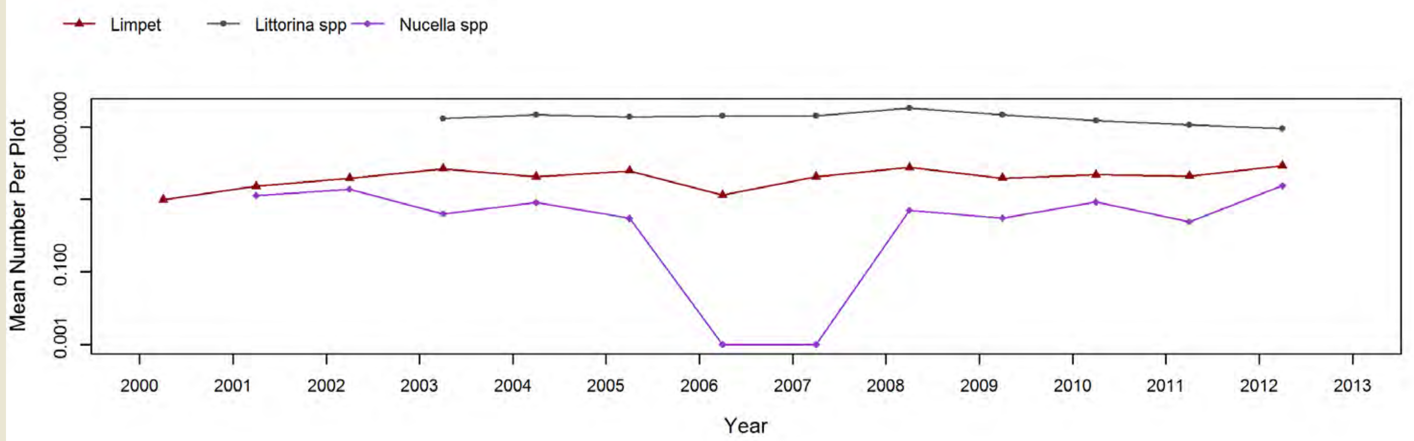
Fucus (Northern Rockweed) - motile invertebrate counts



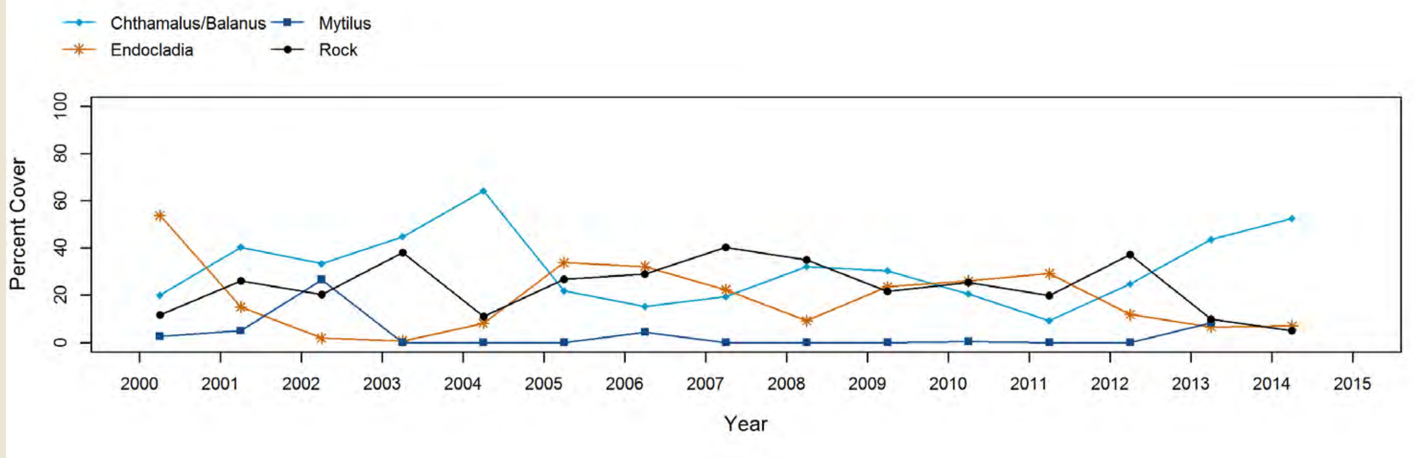
Pelvetiopsis (Dwarf Rockweed) - percent cover



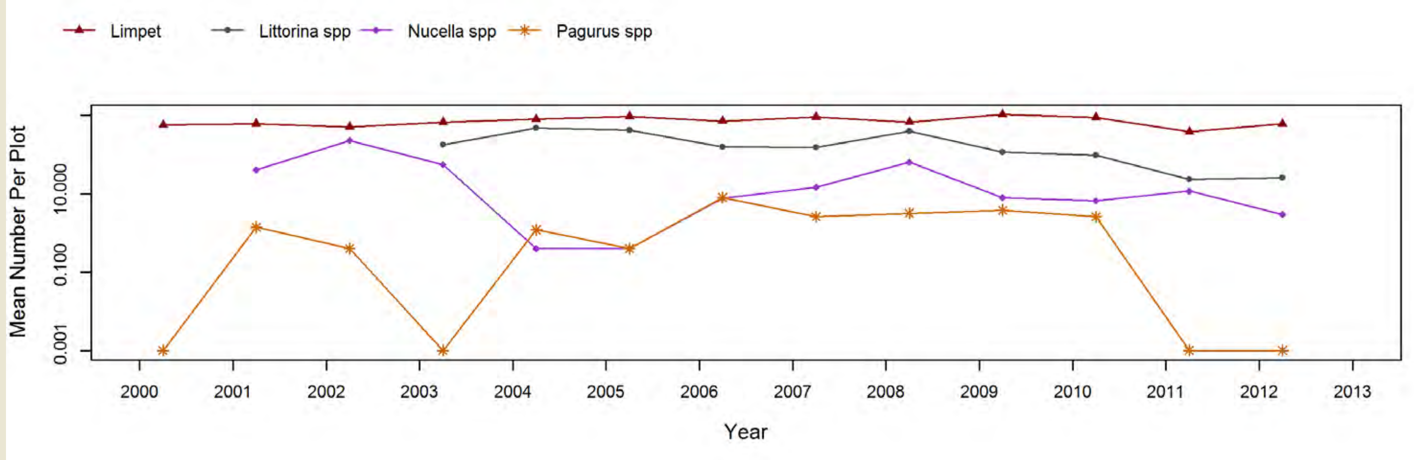
Pelvetiopsis (Dwarf Rockweed) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



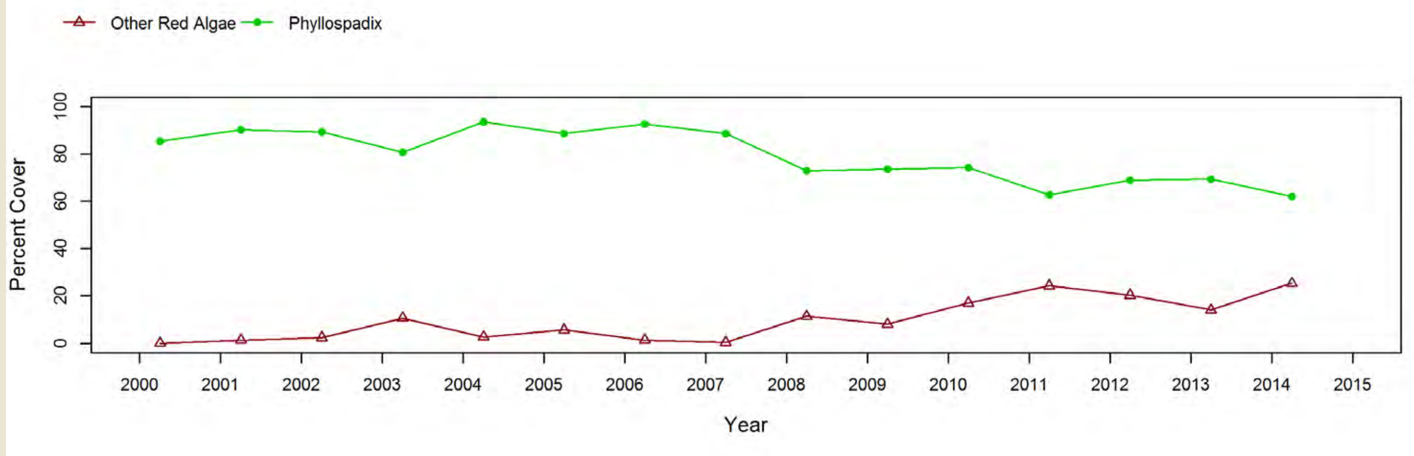
Endocladia (Turfweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

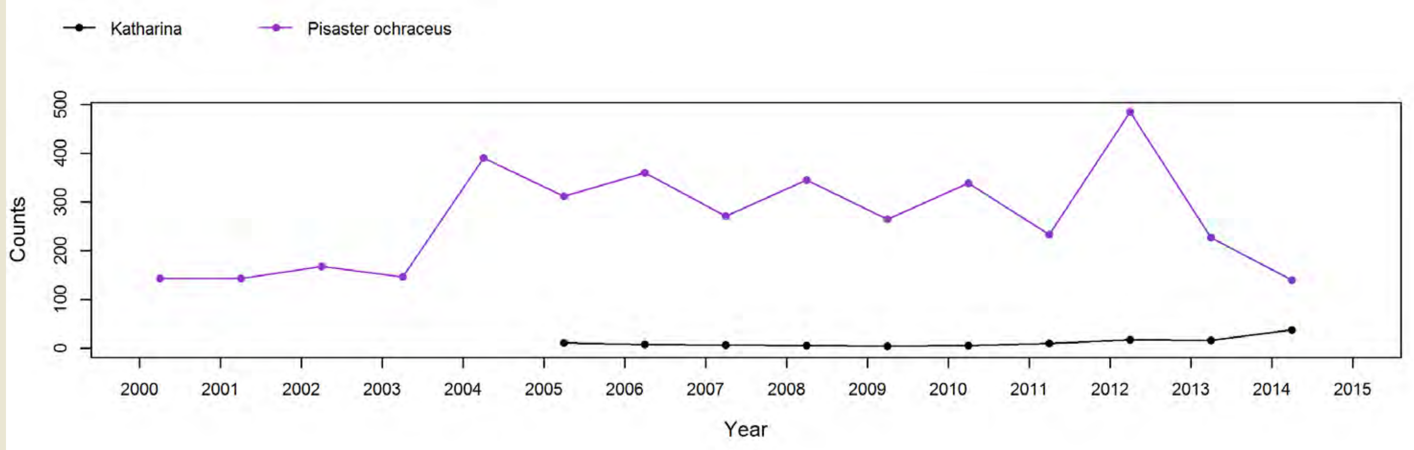
Phyllospadix (Surfgrass)



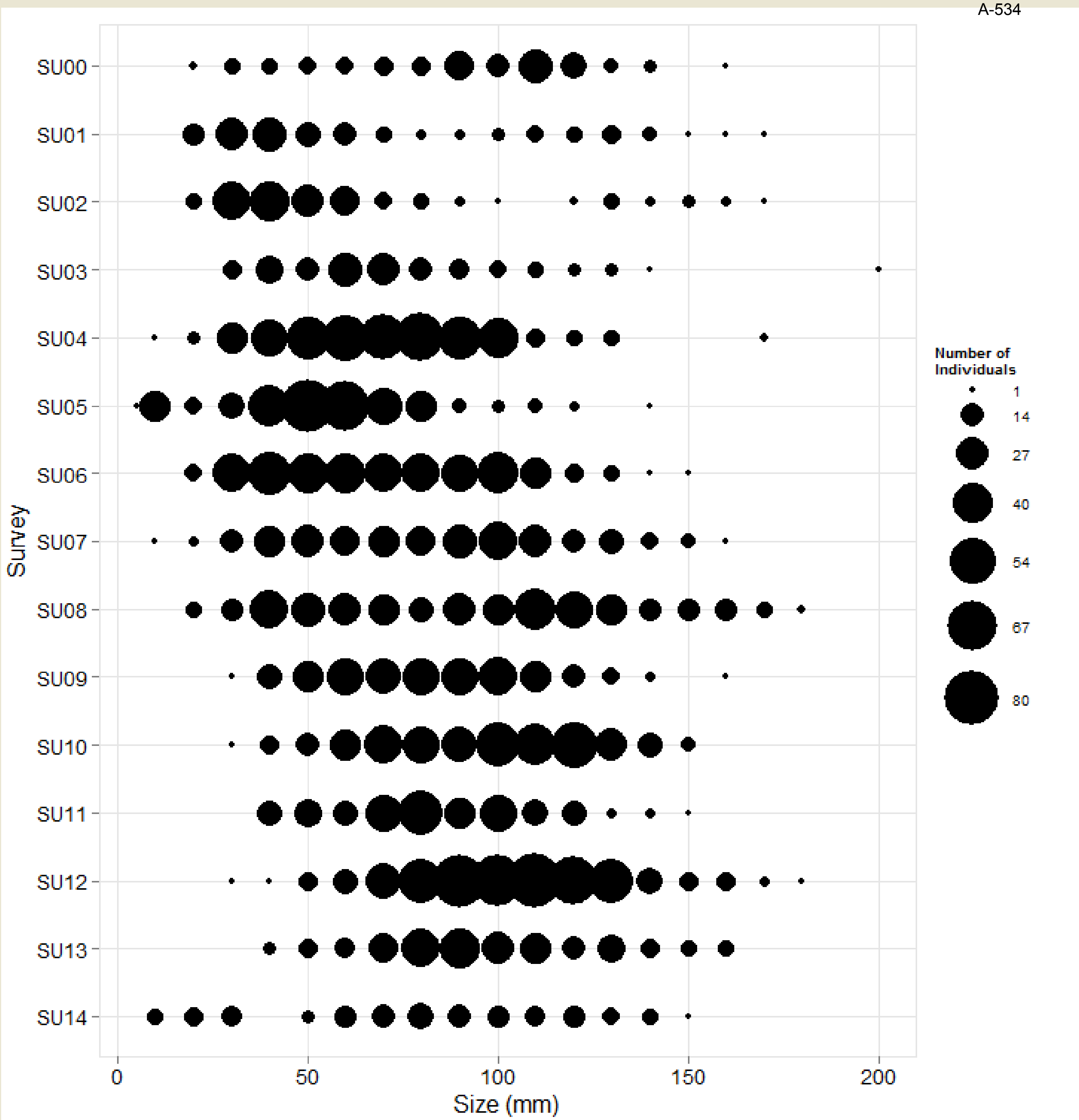
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes



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Bob Creek Biodiversity Survey fndings

Click here (PDF link) for a list of species observed during the Biodiversity surveys at this site

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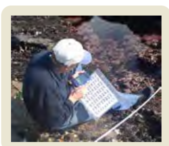
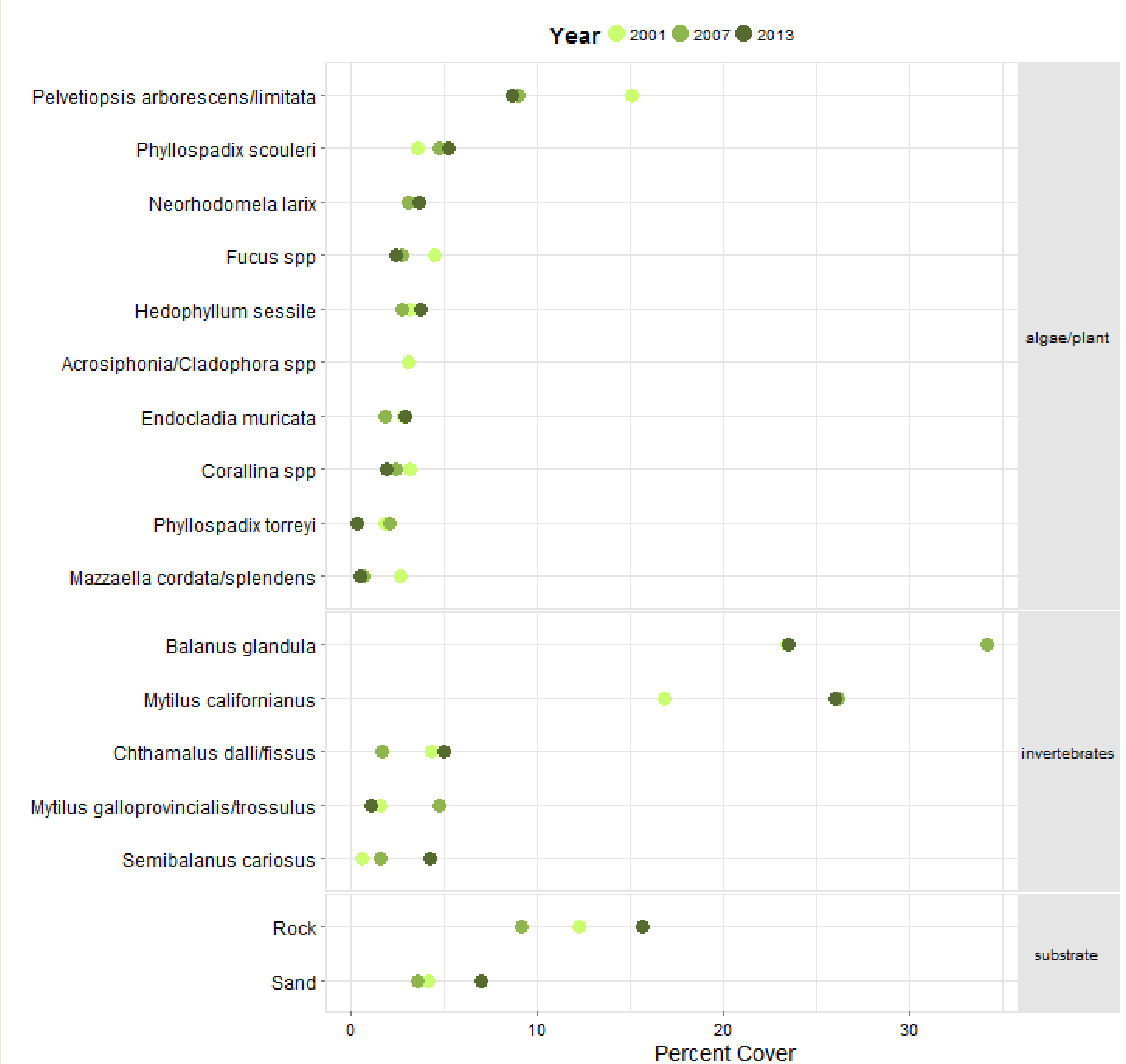
Point Contact Surveys

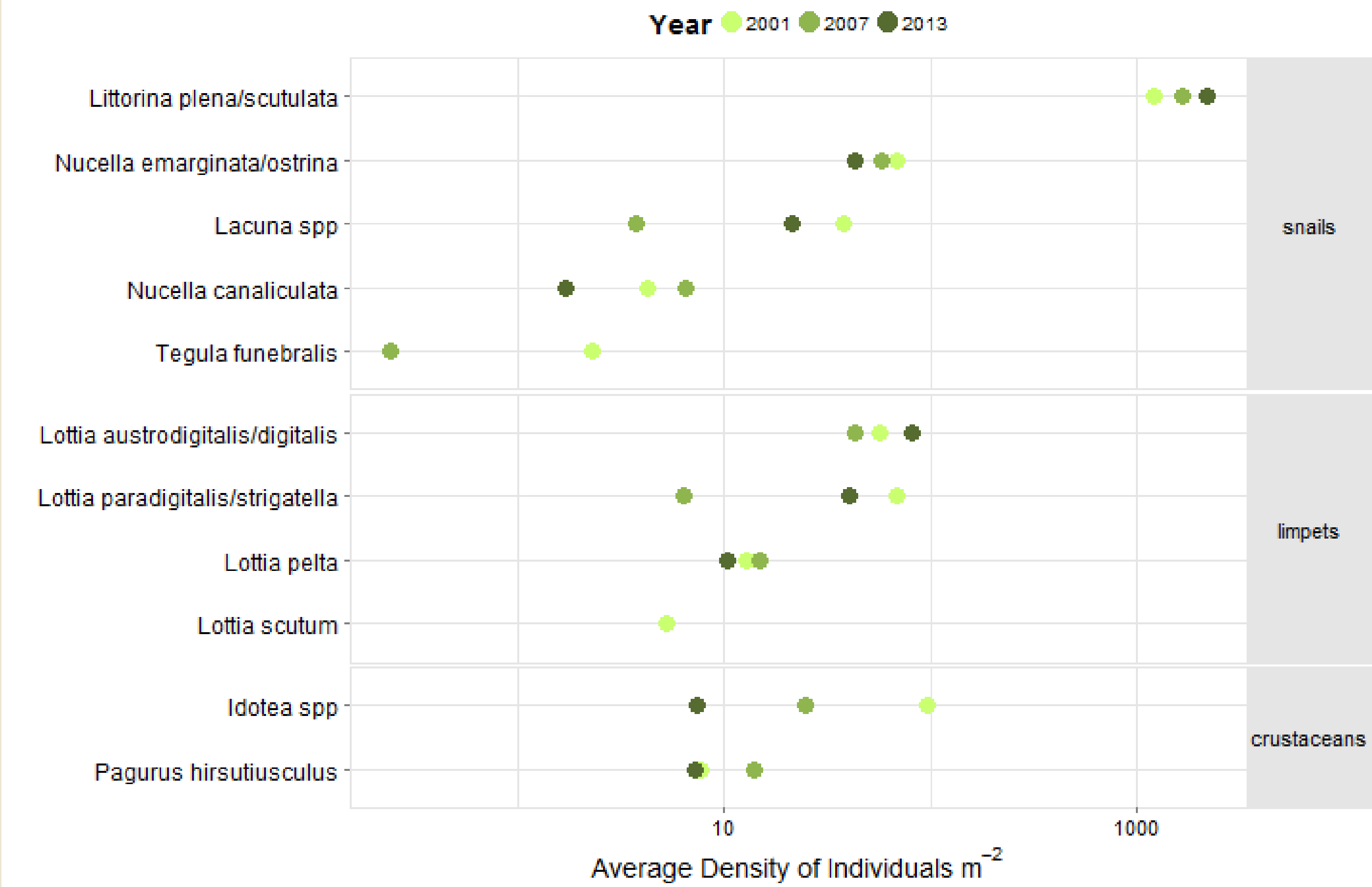


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.

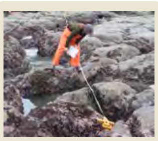


Quadrat Surveys

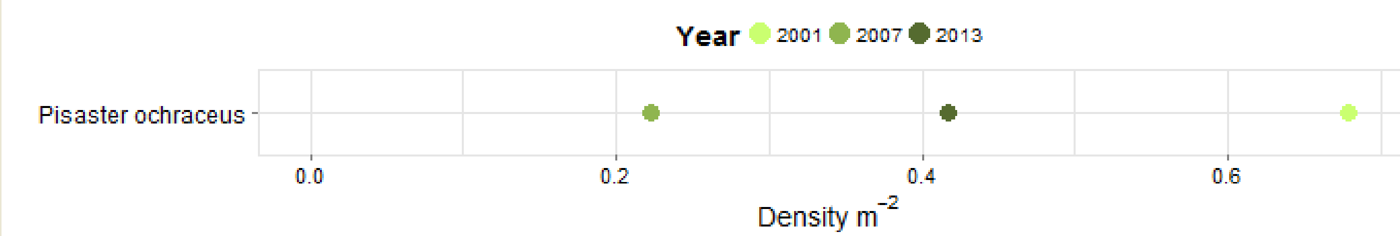
The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



Swath Surveys



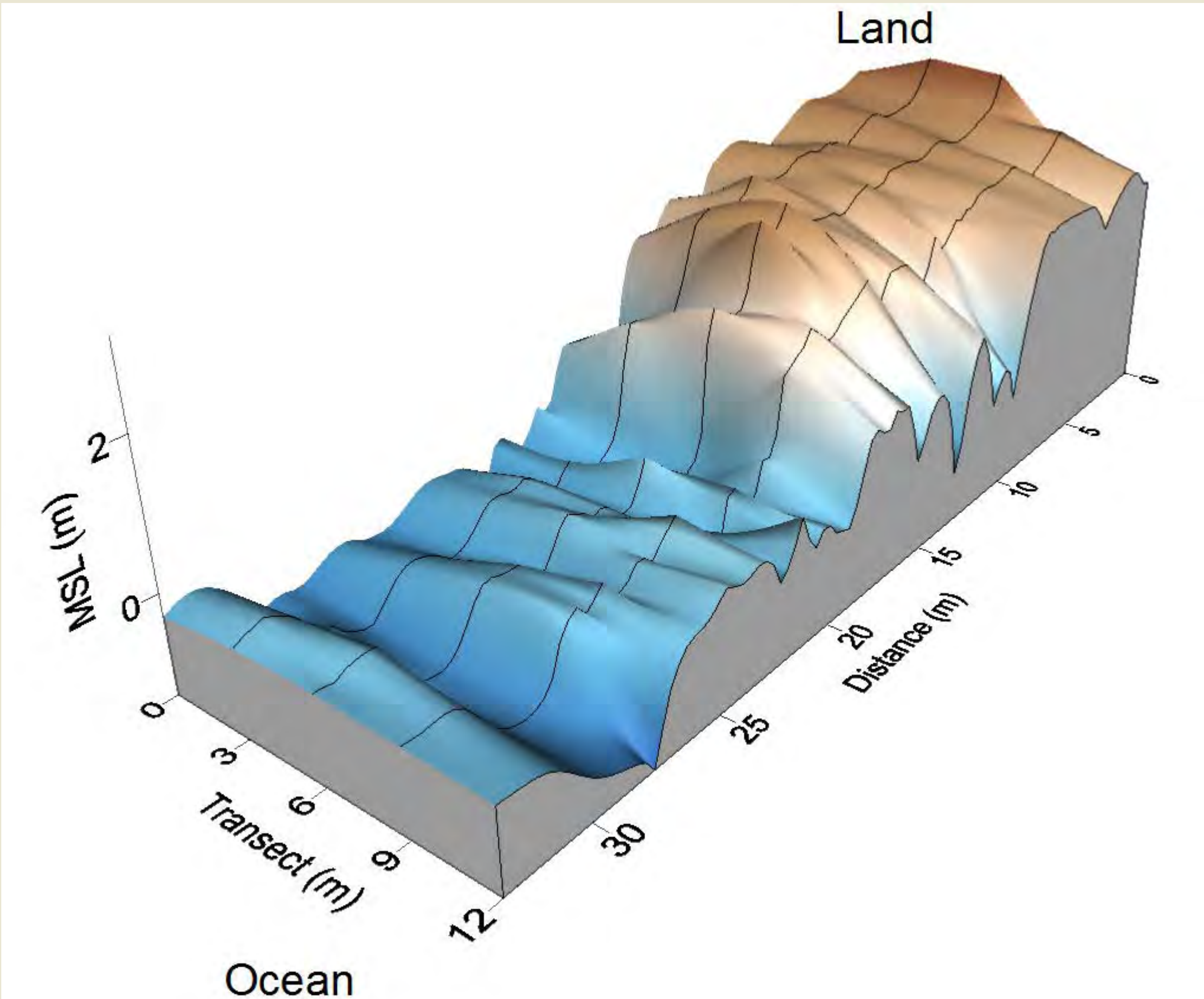
The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.



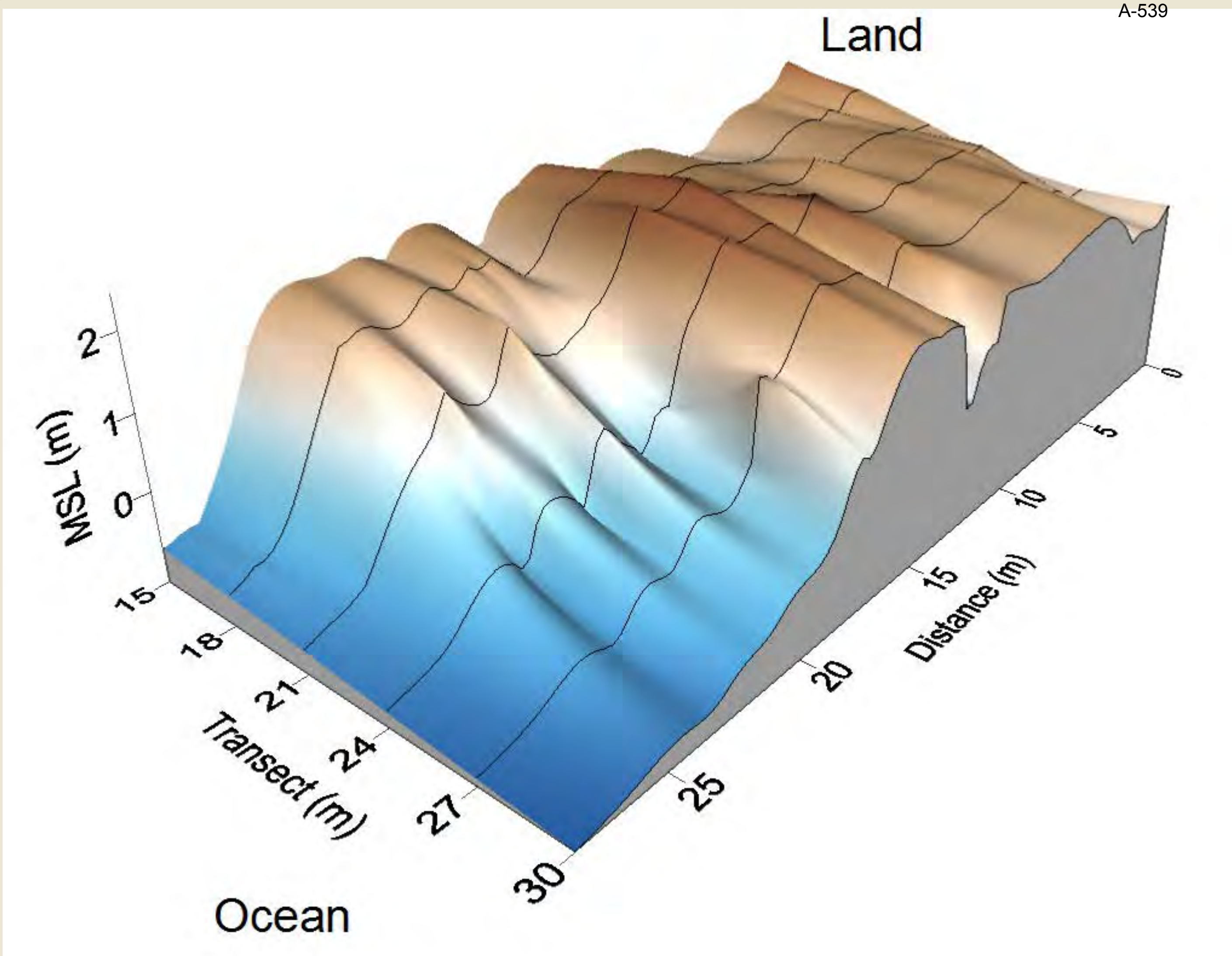
Topography Surveys

The map below displays the topography of the site in meters above mean sea level (MSL). It was created from data collected during the Topography Surveys at this site.

Section 1



Section 2



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Cape Arago Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

With the exception of the mussel plots, all photoplots at Cape Arago have had high cover of barnacles throughout much of the 15 year period they have been monitored. This site is an important pinniped haul-out, and the number of seals and sea lions using the site, as well as the duration of time spent at the site by seals and sea lions, appears to be increasing. We have had to re-schedule monitoring of this site several times during the past few years due to presence of seals and sea lions on the reef.

Barnacle plots at Cape Arago tended to be dominated by the acorn barnacle, *Balanus glandula*, but the little brown barnacle, *Chthamalus dalli/fssus* , was also consistently present, and occasionally in even higher abundance than *Balanus*. *Fucus* cover in rockweed plots plummeted from over 90% to nearly 0% between 2000-2001, and has never recovered. The decline of *Fucus* was almost certainly due to disturbance resulting from sea lions. Since 2001, these plots have been dominated by bare space and barnacles, a relatively short-lived group that can easily recruit to newly disturbed patches on a reef. Mussels have periodically recruited to the *Fucus* plots, and were particularly high in cover in 2006 and 2007, but they've since declined. In 2008 the spike in "Other Invertebrates" was driven by a recruitment event of *Mytilus trossulus* into the *Fucus* plots, although they did not persist into 2009.

As with *Fucus*, *Pelvetiopsis* and *Endocladia* cover in their respective target plots was generally low after the initial survey in 2000, and tended to be dominated by barnacles. Limpets and littorines were the primary motile invertebrates found in all above plot types.

Mussel plots are located in a different section of reef from the other photo plots, and were the only photo plot type not heavily impacted by sea lions. Mean cover of *Mytilus* in these plots remained near 100% from 2000-2011, then experienced a slight dip in 2012 to just under 80%, which has lasted through 2014. This dip was entirely due to a substantial loss of mussels from plot 1, which dropped from 83% cover in 2011 to 14% in 2012. Limpets and *Nucella* were common across all years in mussel plots.

The *Phyllospadix* transects at Cape Arago are located in a low-lying, calm bay just upcoast from the main site. It is an area rich in low intertidal/subtidal algae, and is unlike our surfgrass transect locations at most other sites in that it is not dominated by *Phyllospadix*. This difference is reflected in the long-term trend graph—surfgrass is high in cover at times, but low intertidal algae, particularly the boa kelp, *Egregia*, are also key players in the community.

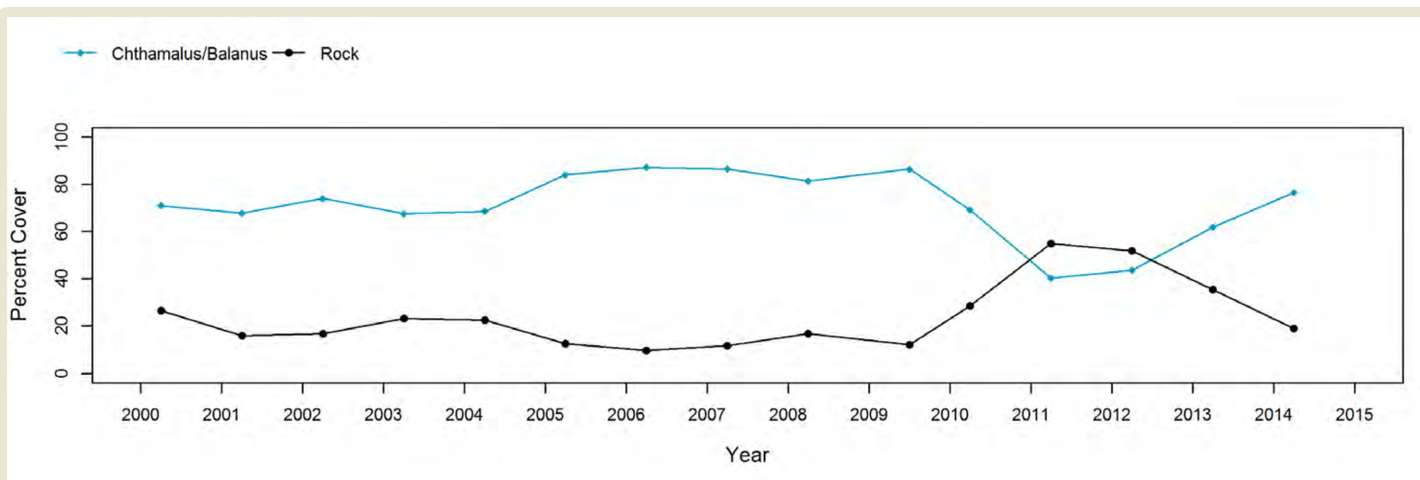
Ochre stars in the sea star plots were relatively common overall, but experienced a decline in numbers between 2008-2010 (Cape Arago could not be sampled in 2009 due to sea lions hauled out on the reef). We expect counts to be down further due to Sea Star Wasting Syndrome when we return in 2015. The katy chiton, *Katharina tunicata*, was extremely abundant in the sea star plots, particularly in 2014.

Photo Plots

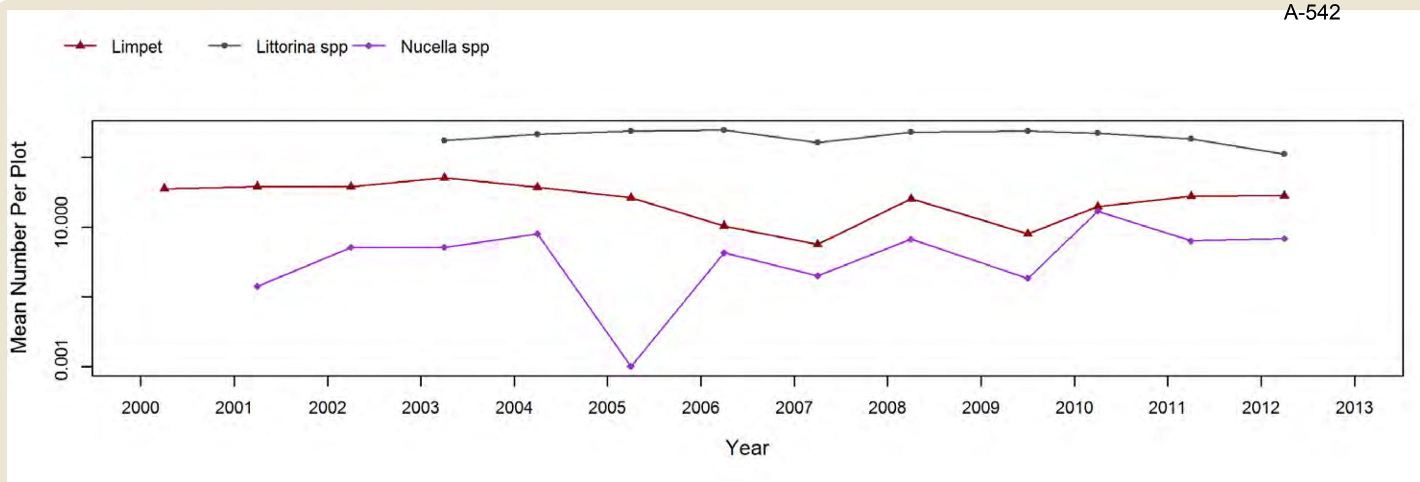
Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

For motile invertebrate Species Counts, a mean across all plots was calculated, and only those species with a value of at least 5 individuals for at least one sample are shown. Due to time constraints, motile invertebrate counts have not been done since summer 2012. For motile invertebrate size trend graphs by site, please use the Interactive Map.

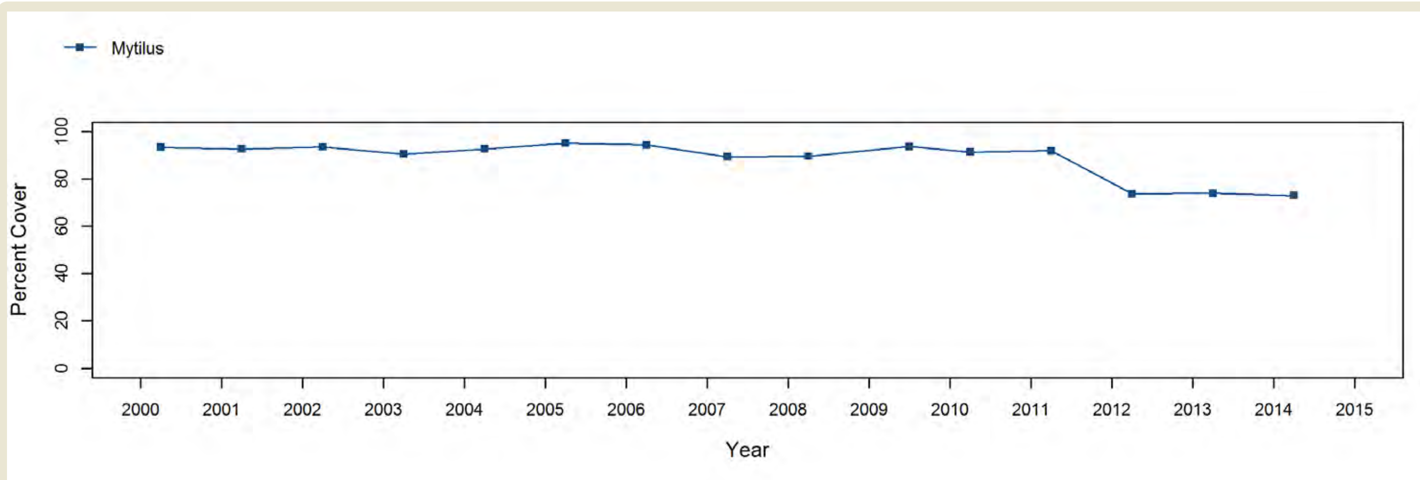
Chthamalus/Balanus (Acorn Barnacles) - percent cover



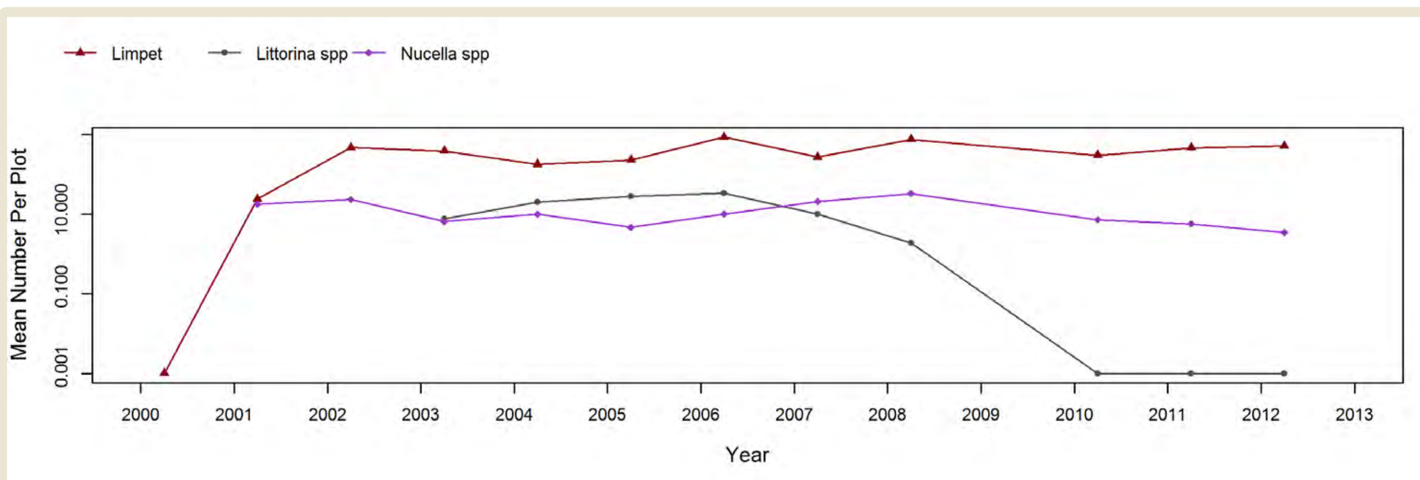
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



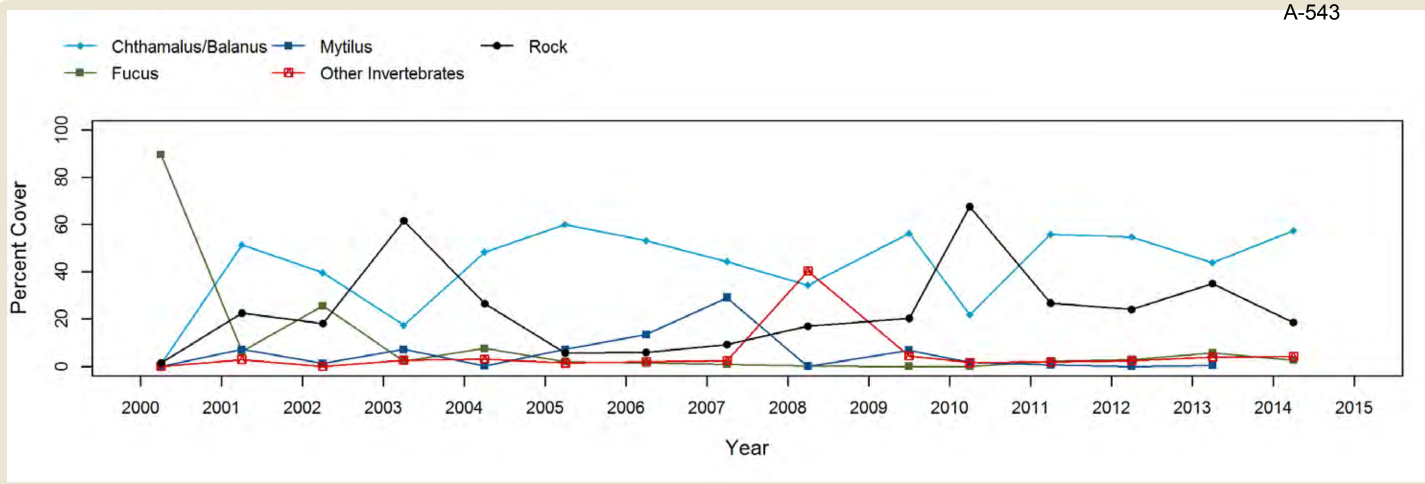
Mytilus (California Mussel) - percent cover



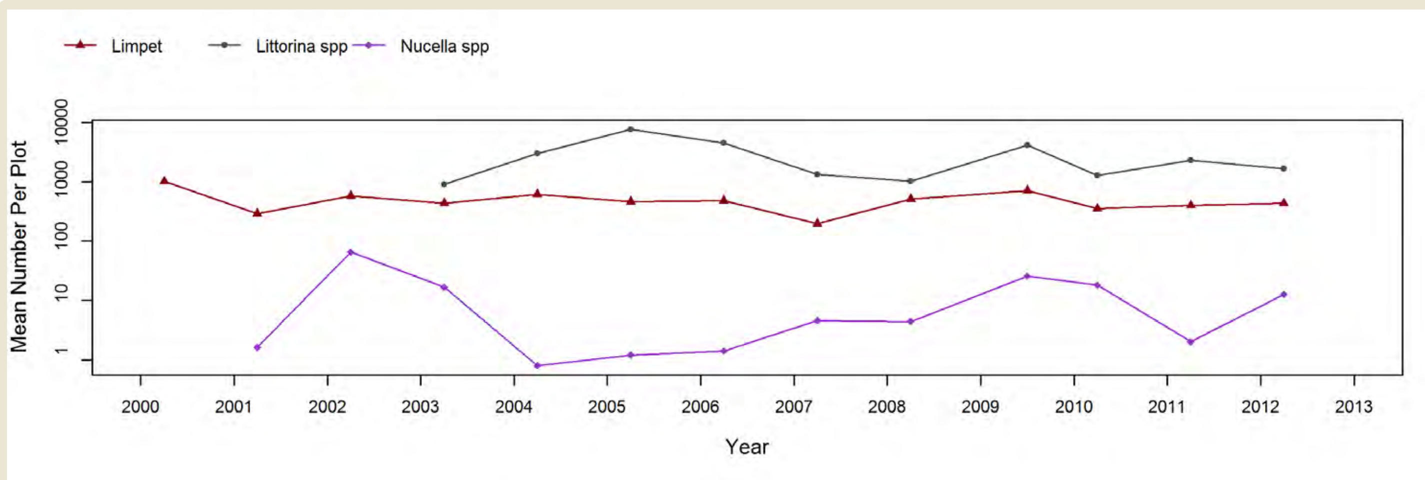
Mytilus (California Mussel) - motile invertebrate counts



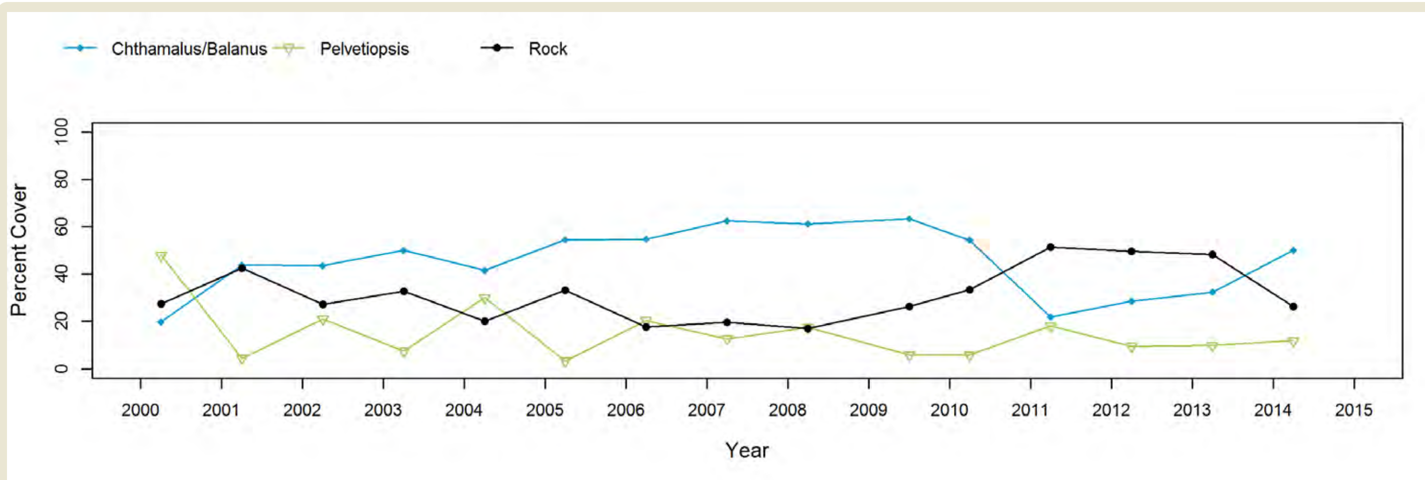
Fucus (Northern Rockweed) - percent cover



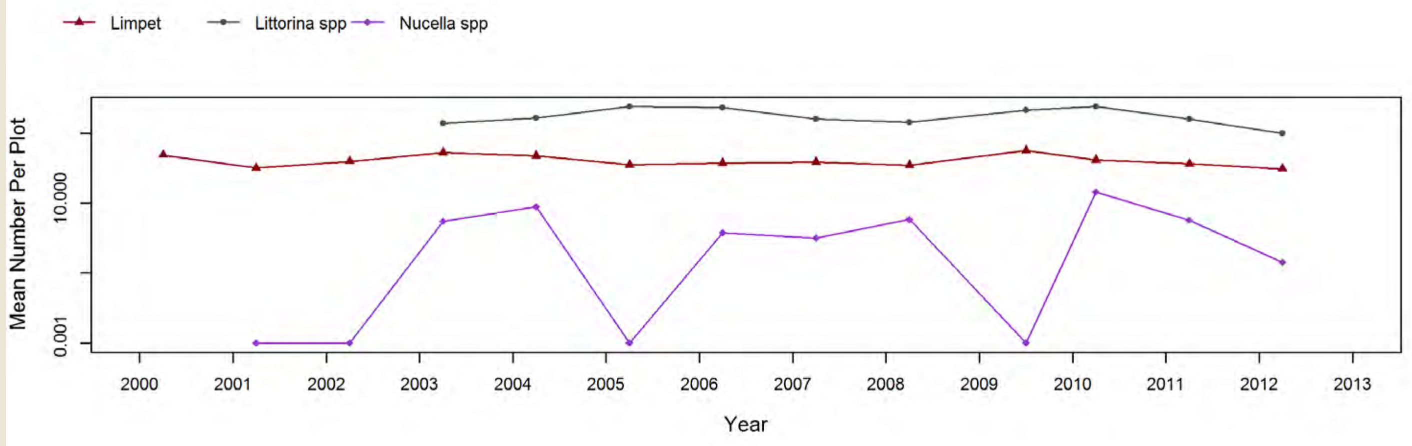
Fucus (Northern Rockweed) - motile invertebrate counts



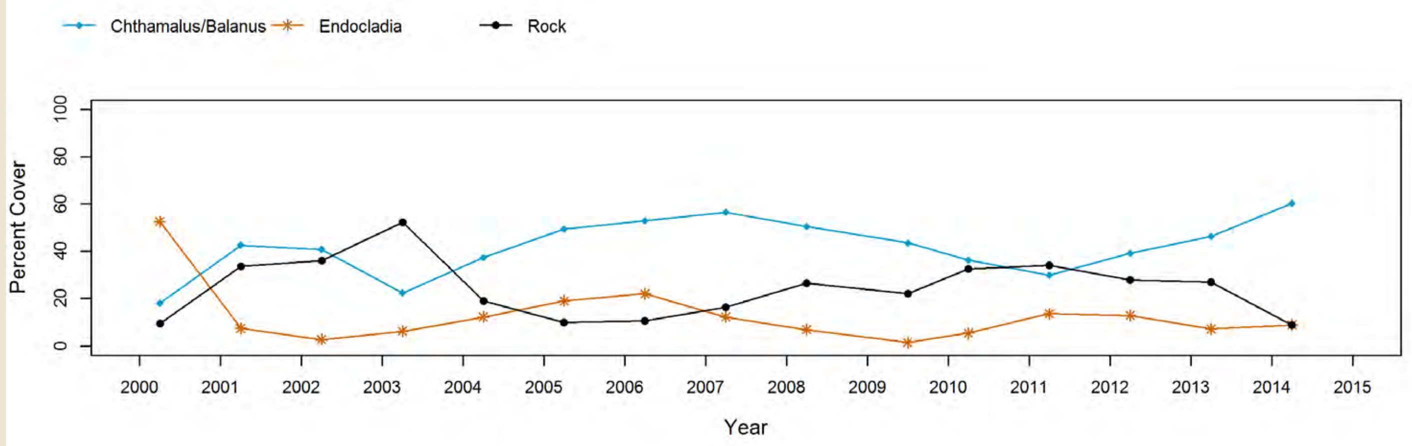
Pelvetiopsis (Dwarf Rockweed) - percent cover



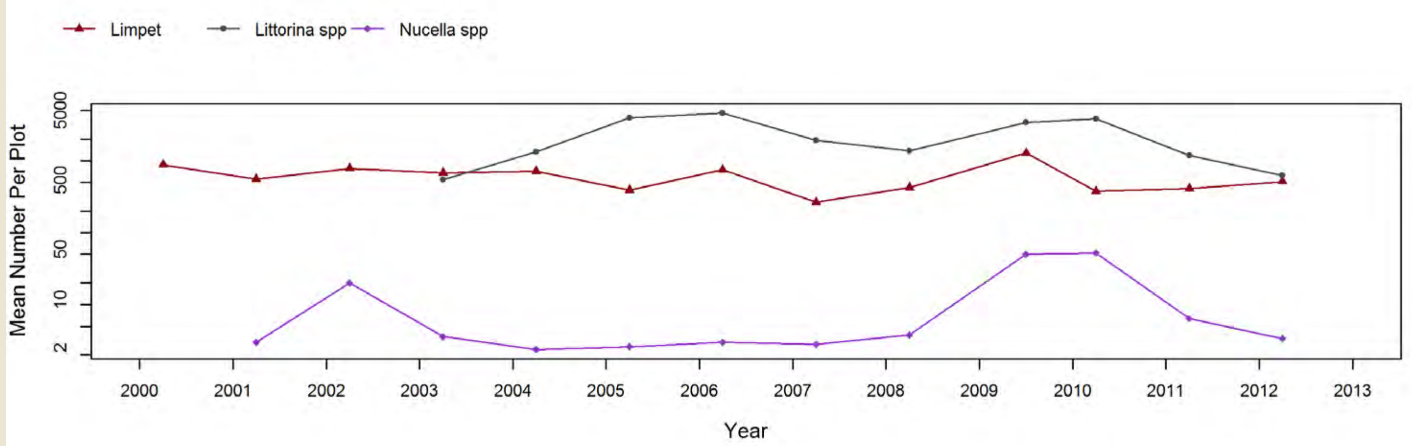
Pelvetiopsis (Dwarf Rockweed) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



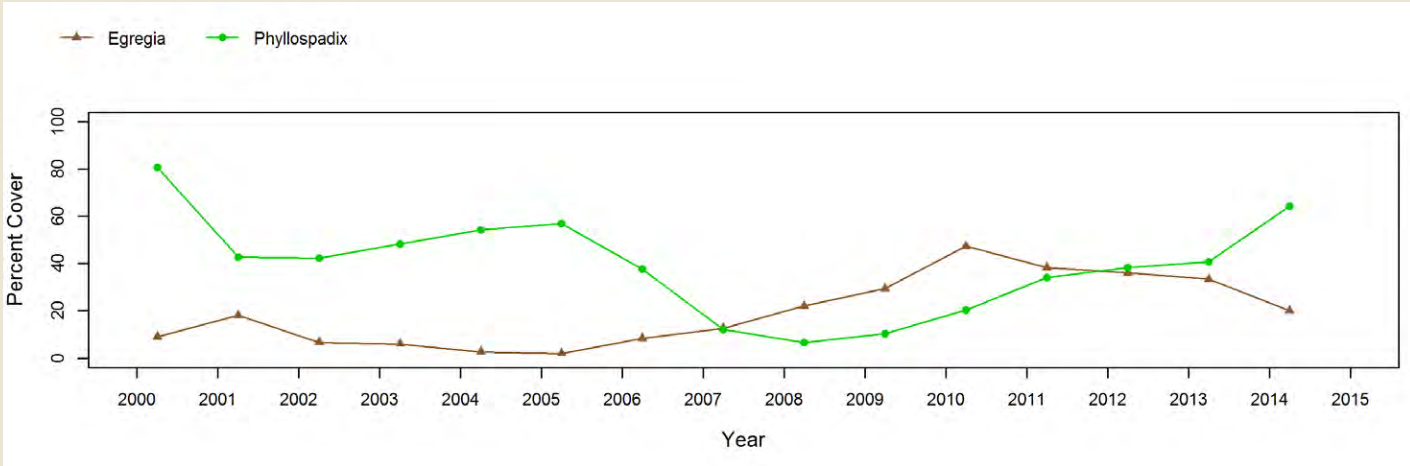
Endocladia (Turfweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

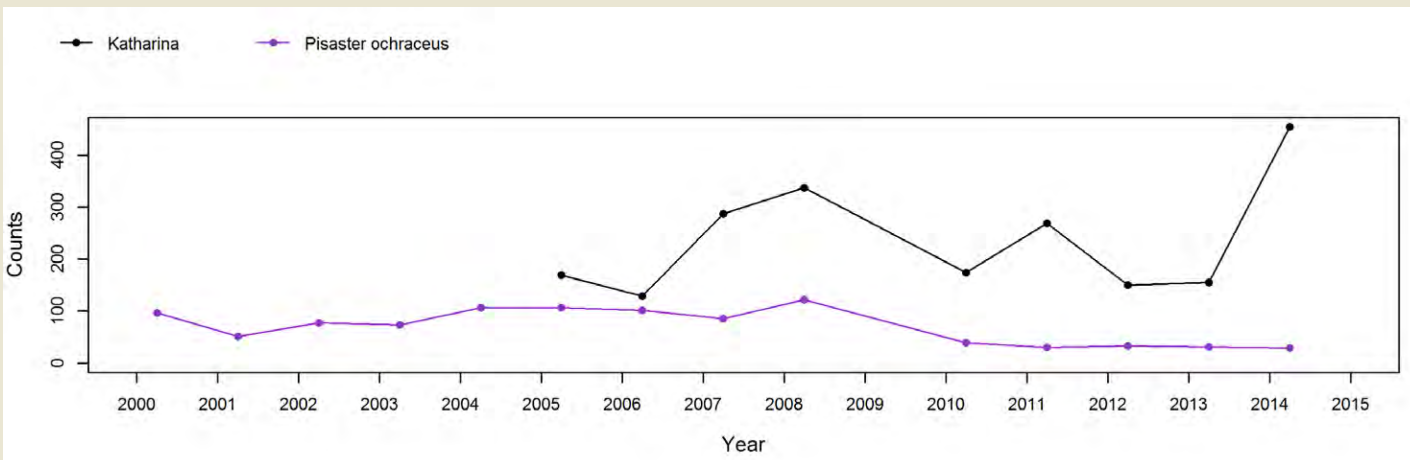
Phyllospadix (Surfgrass)



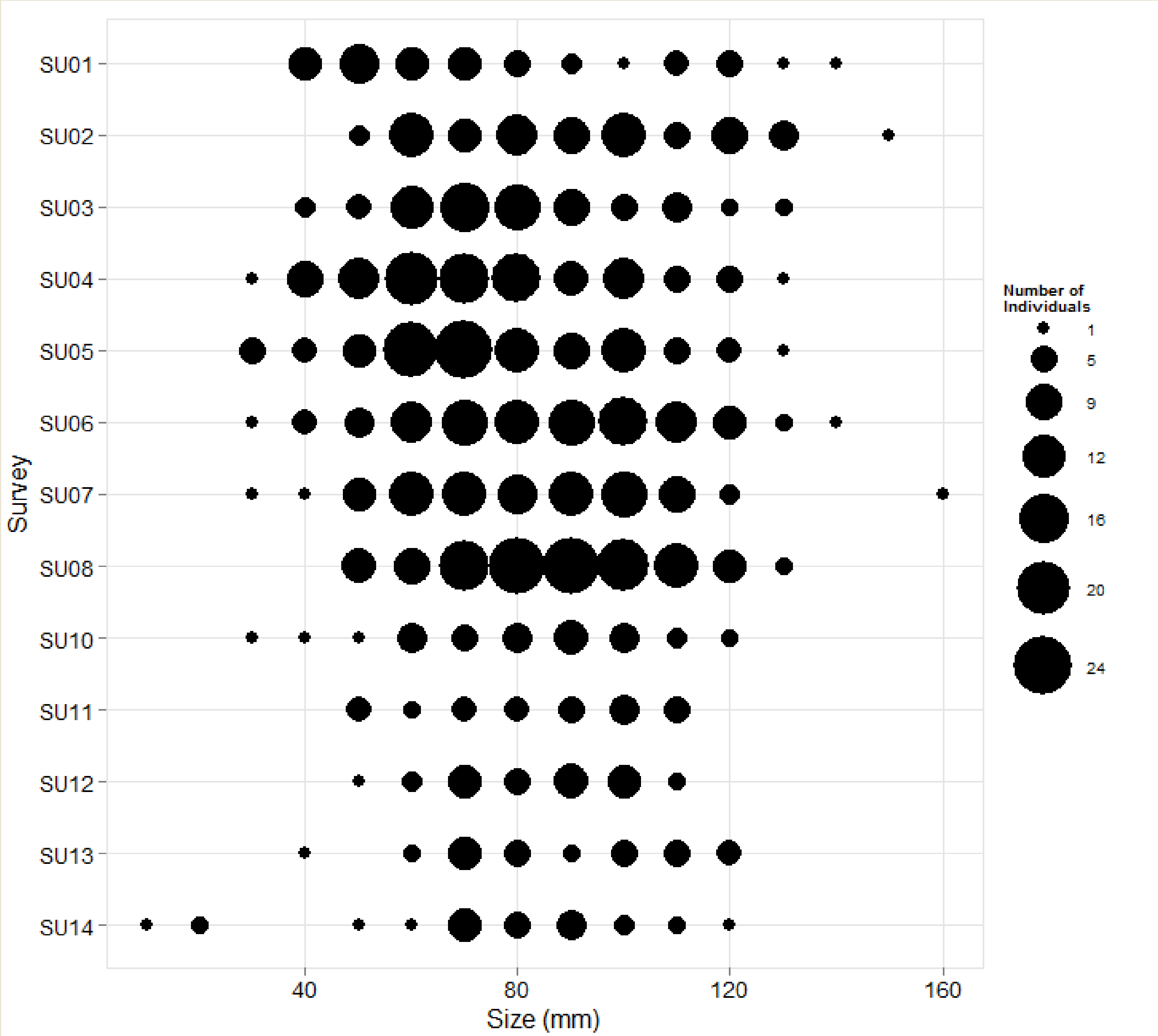
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes



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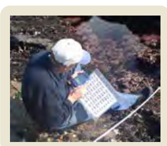
Cape Arago Biodiversity Survey fndings

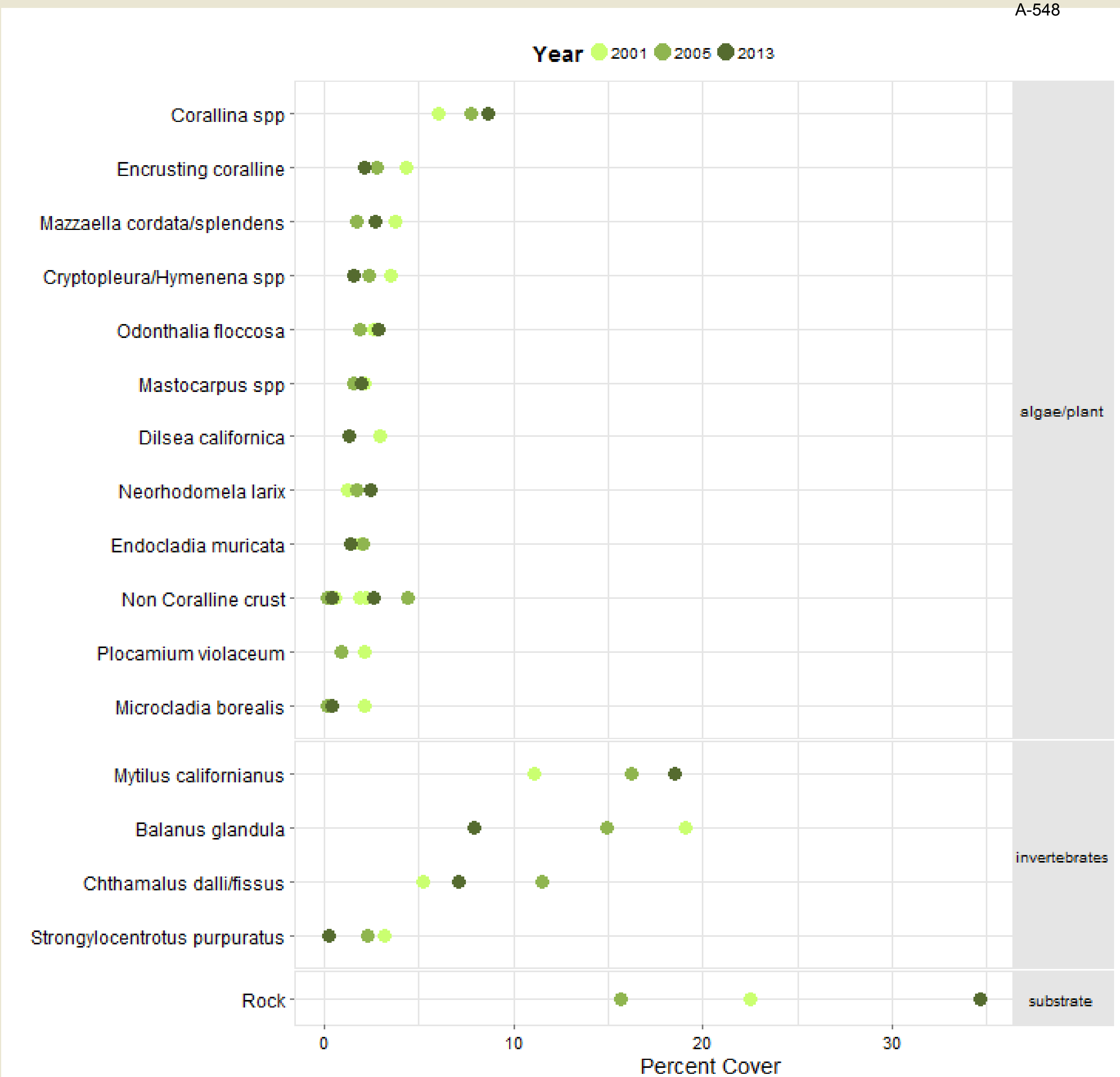
Click here (PDF link) for a list of species observed during the Biodiversity surveys at this site

For a complete species lookup table (including general taxonomic group name and common name, if available) of **ALL** species observed during the Biodiversity Surveys (at all sites), please click here (PDF link).

Point Contact Surveys

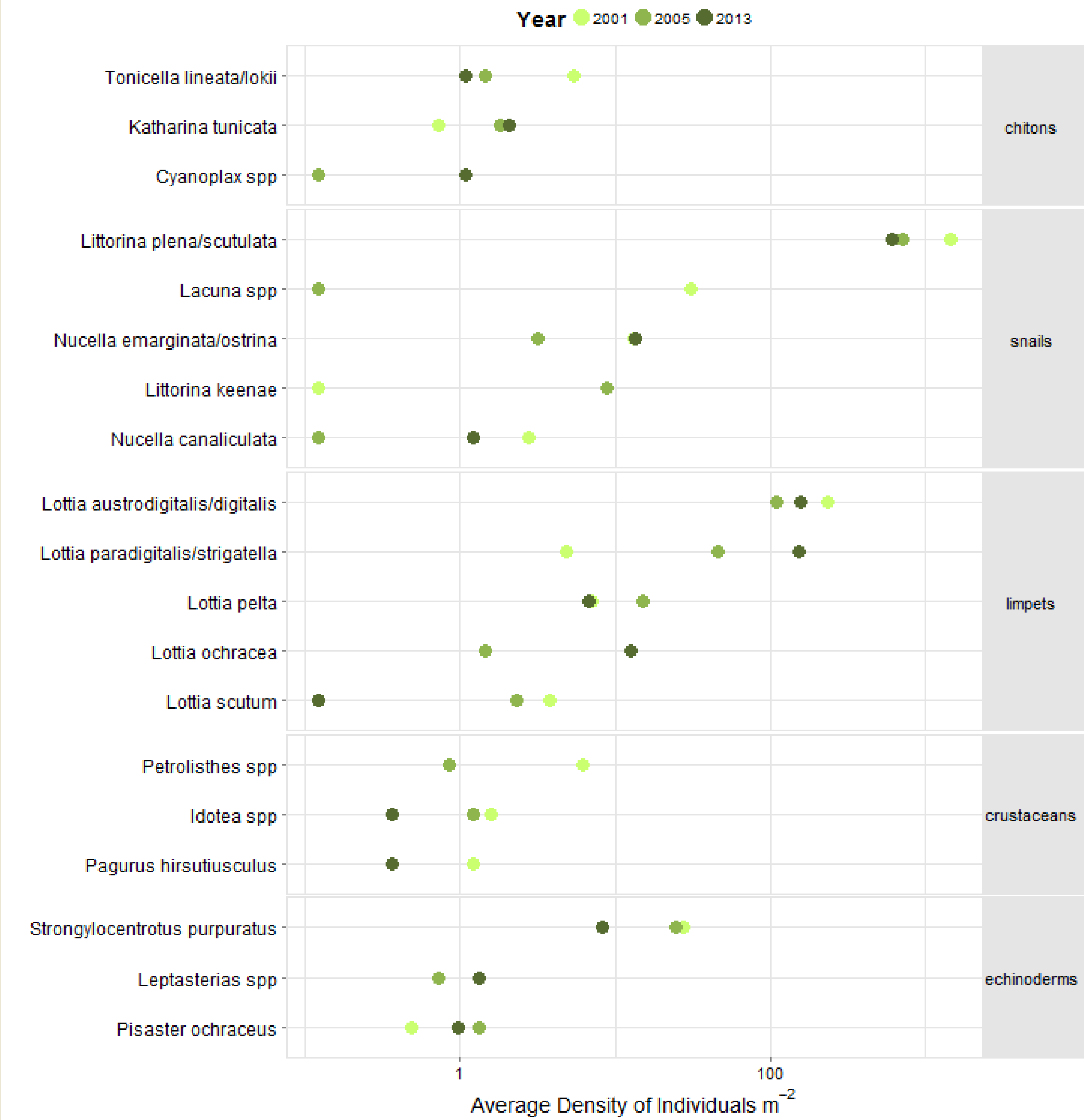


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.



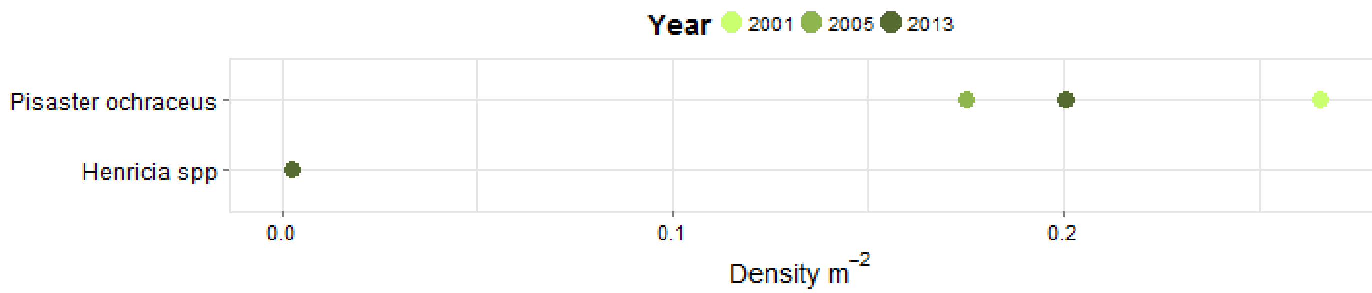
Quadrat Surveys

The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



Swath Surveys

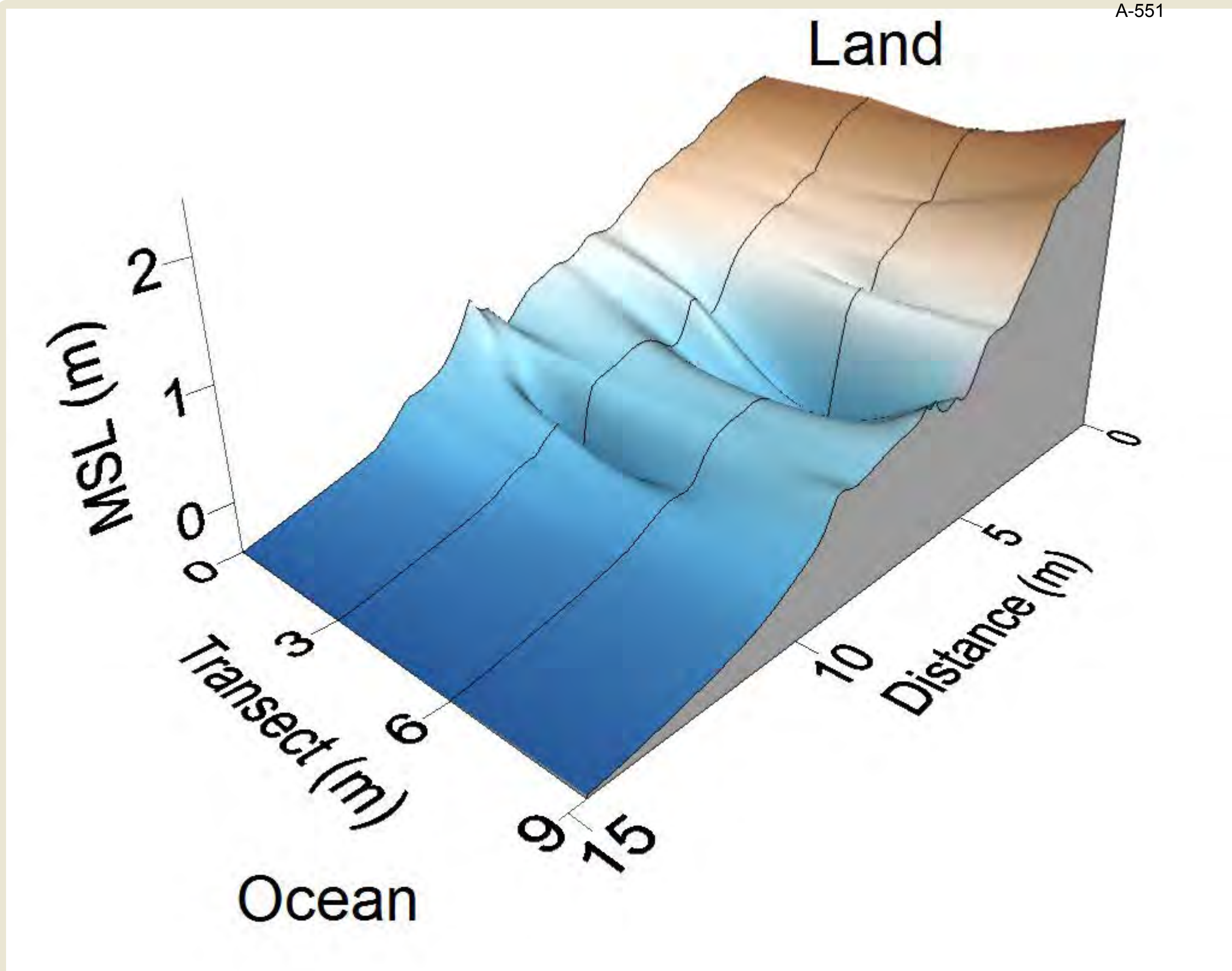
The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.



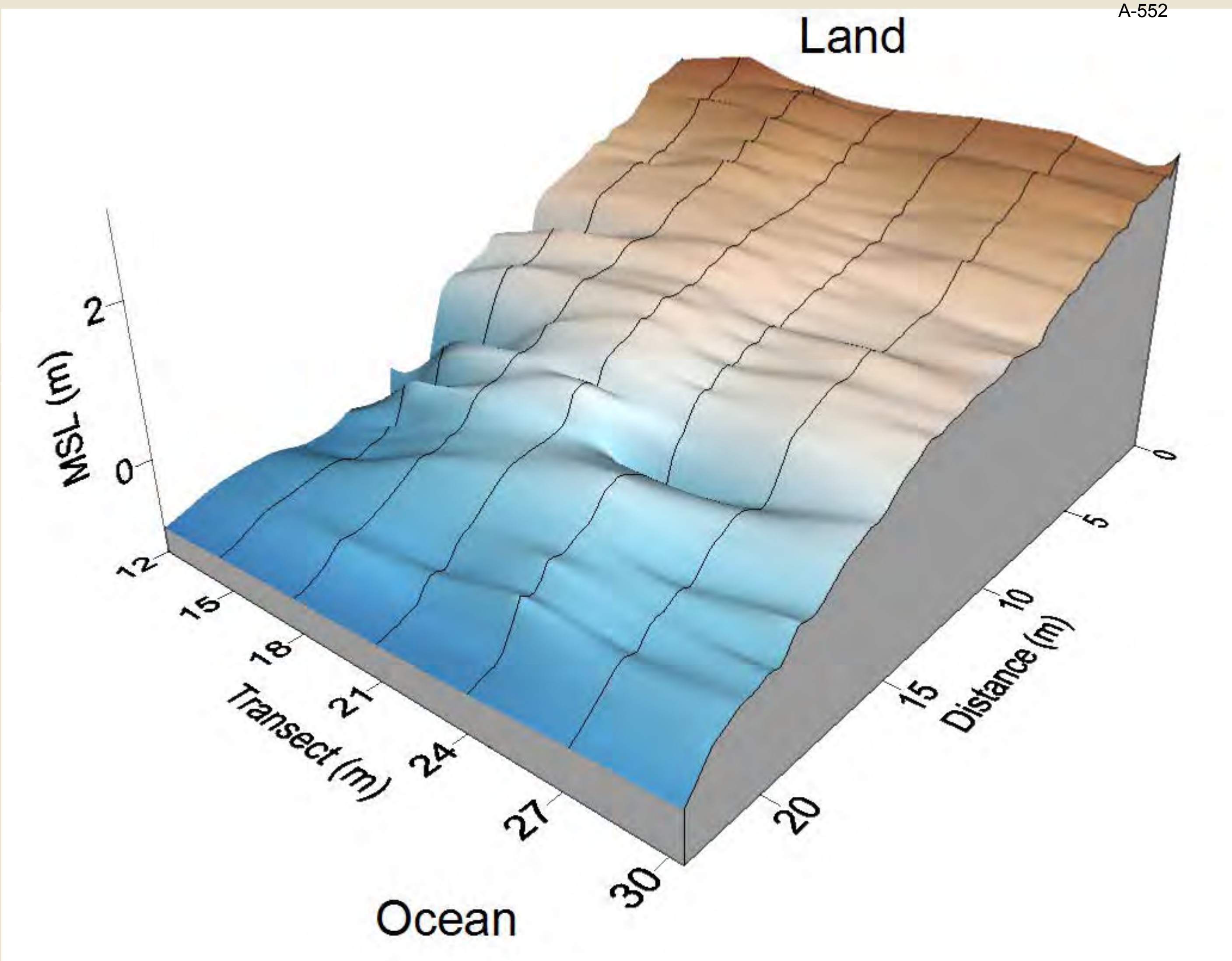
Topography Surveys

The map below displays the topography of the site in meters above mean sea level (MSL). It was created from data collected during the Topography Surveys at this site.

Section 1



Section 2



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Coquille Point Biodiversity Survey fndings

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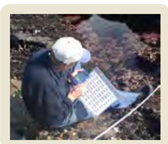
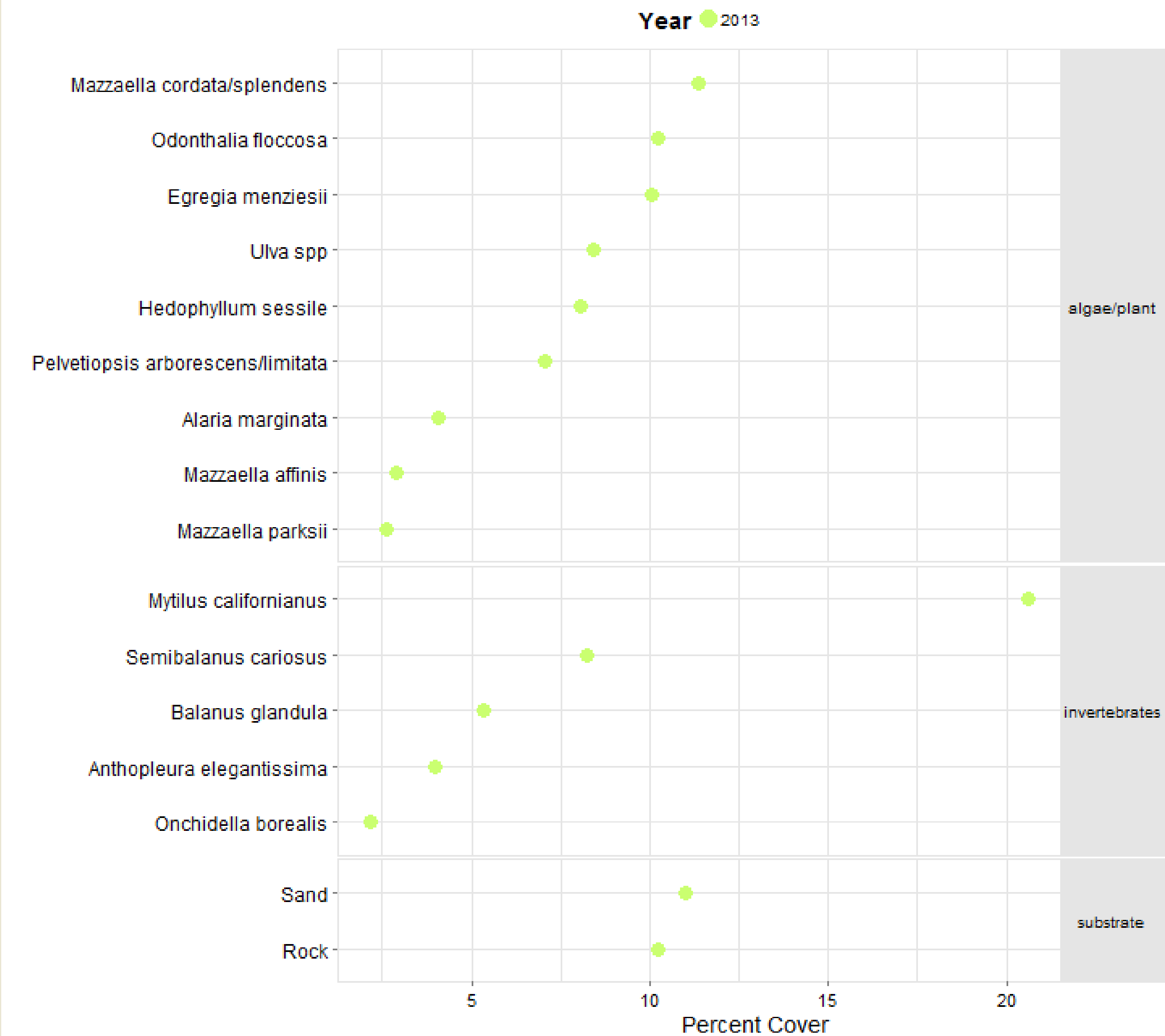
Point Contact Surveys

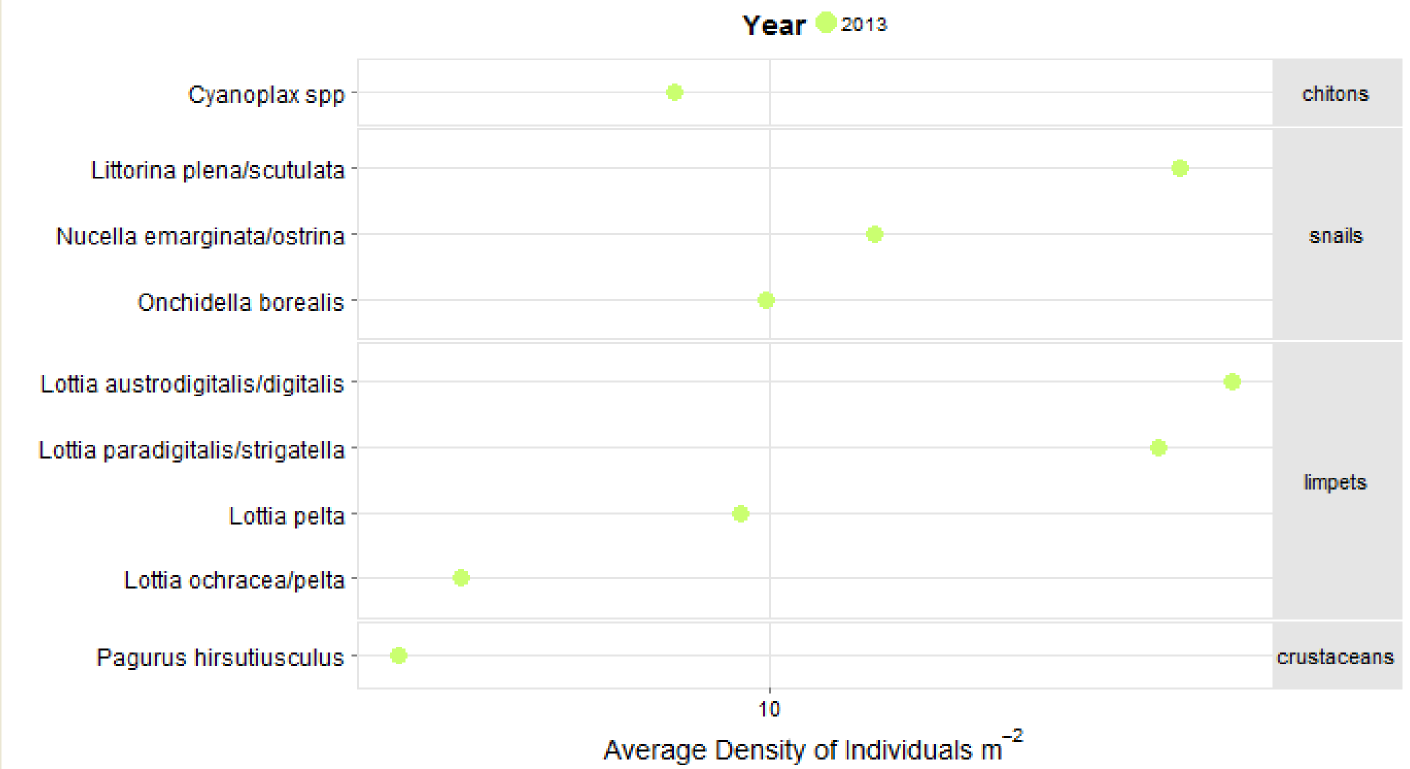


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.

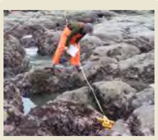


Quadrat Surveys

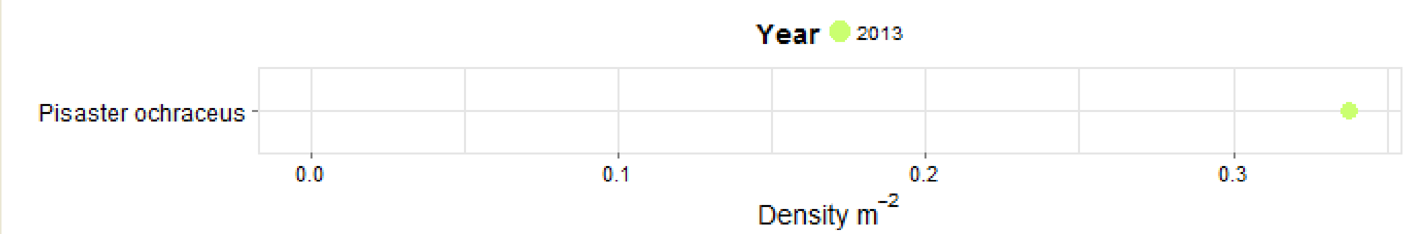
The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.



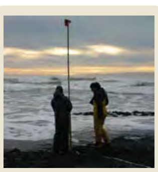
Swath Surveys



The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.



Topography Surveys



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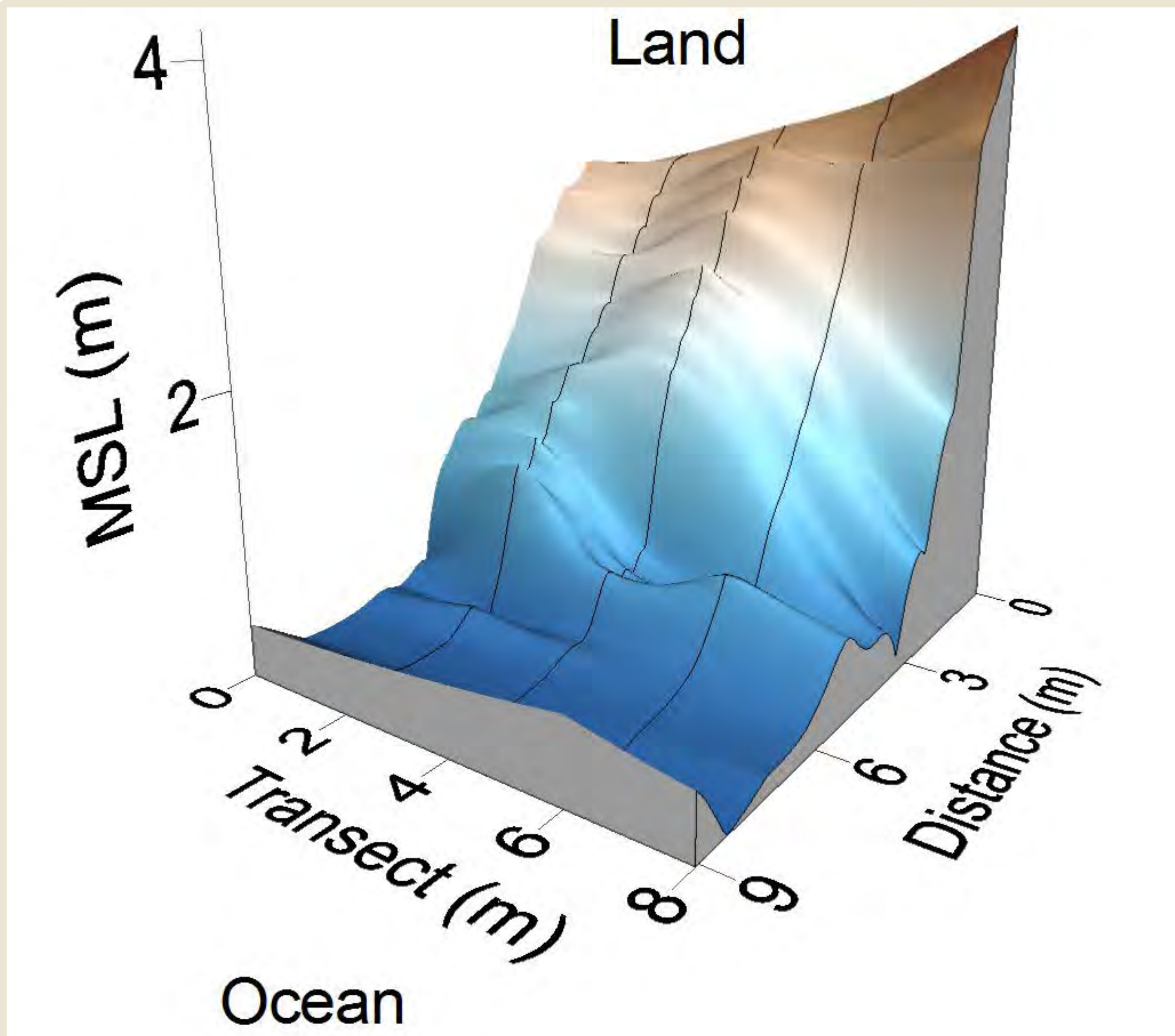
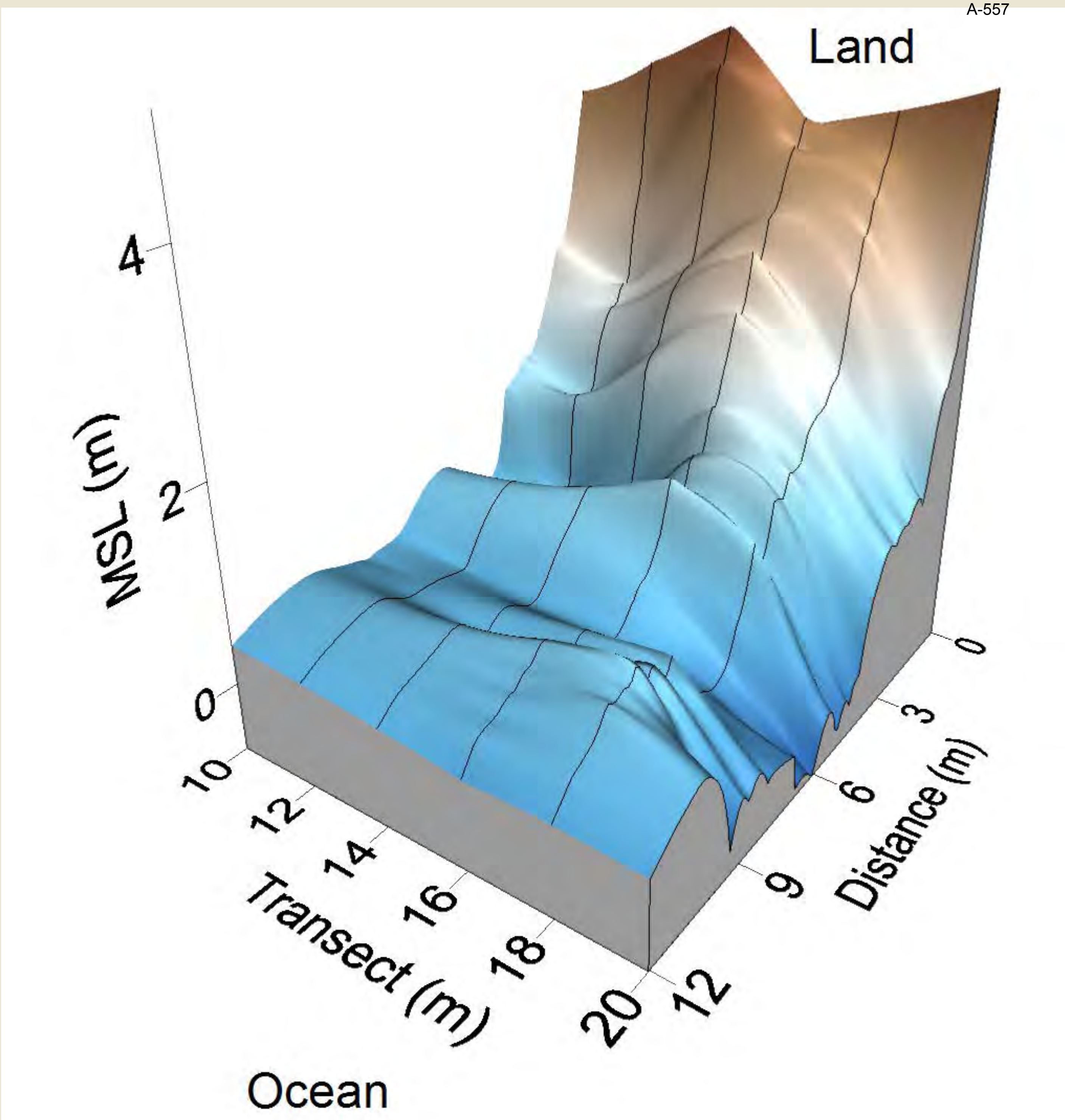
Section 1



Section 2



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Burnt Hill Long-Term trends

See below for trend graphs

In order to standardize species resolution across all MARINe groups, and over time, some species (typically rare) were lumped for graphical presentation of Long-Term monitoring data. See lumped categories for defnitions (some variation occurs between methods and over time).

Barnacles in the focal plots for this species group consisted of higher cover of *Balanus glandula* than *Chthamalus fssus/dalli* , but a mixture was present in all years. Total barnacle cover fuctuated between about 35%-85% in the 13 years they have been monitored, but in most years was relatively high. In the years when barnacle cover was lower, cover of the rockweed, *Pelvetiopsis*, increased. Barnacles, both live and dead, provide an excellent substrate upon which *Pelvetiopsis* can settle, so it is possible that during the years of “low” barnacle cover, barnacles were simply hidden below the rockweed. In 2014 we began keeping track of multiple layers under each point (previously only the top layer was typically scored), which will enable us to know whether species “declines” are real, or simply a result of one species overlaying another. Counts of littorines and limpets were consistently high in barnacle plots at Burnt Hill, and the whelk, *Nucella* was present in low numbers.

Cover of mussels in *Mytilus* plots was consistently high over time, fuctuating between 75-100%. Limpets, littorines and *Nucella* were all common in mussel plots.

Rockweed cover in *Pelvetiopsis* plots was high most years, but dipped below 50% in 2008-2010, and again in 2013-2014. These dips corresponded with increases in barnacle cover, and as described above, it is not clear whether these increases were real, or just a result of barnacles being exposed when epiphytic *Pelvetiopsis* cover declined. Limpets and littorines were consistently abundant in *Pelvetioptis* plots.

In general, *Endocladia* cover remained moderately high over time in the plots it is targeted in. Dips in cover were sometimes associated with an increase in *Mastocarpus*, but more often with increases in bare rock, suggesting that space is not a limited resource in these plots. Three groups of motile invertebrates, limpets, littorines and *Nucella*, were common in most years within *Endocladia* plots.

Phyllospadix transects are located within pools at Burnt Hill, which typically means that cover does not fuctuate as much as in areas where the surfgrass is exposed to air at low tide, and can become dry and bleached out during warm, mid-day low tide periods. Surfgrass cover was relatively stable, and while a few other species, such as *Odonthalia*, were commonly present along the transects, none exceeded 25% cover.

As with many sites, abundance of the sea star, *Pisaster ochraceus*, fuctuated substantially over time for this highly mobile animal. Surprisingly, ochre star numbers remained high in summer 2014, well after declines had occurred along much of the west coast due to Sea Star Wasting Syndrome. We expect that a signifcant decline will be evident after 2015 data are entered. Most of the ochre stars within our plots were fairly small (40-60 mm radius) when this site was established in 2002. This cohort has grown over time, as refected by the movement of the "bulge" up the size scale. Most stars in 2014 were between 80-120 mm in radius.

Photo Plots

Below are the trends observed for each Photo Plot target species at this site. Long-Term percent cover trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events. For additional species observed that did not meet this 25% threshold, please use the Interactive Map.

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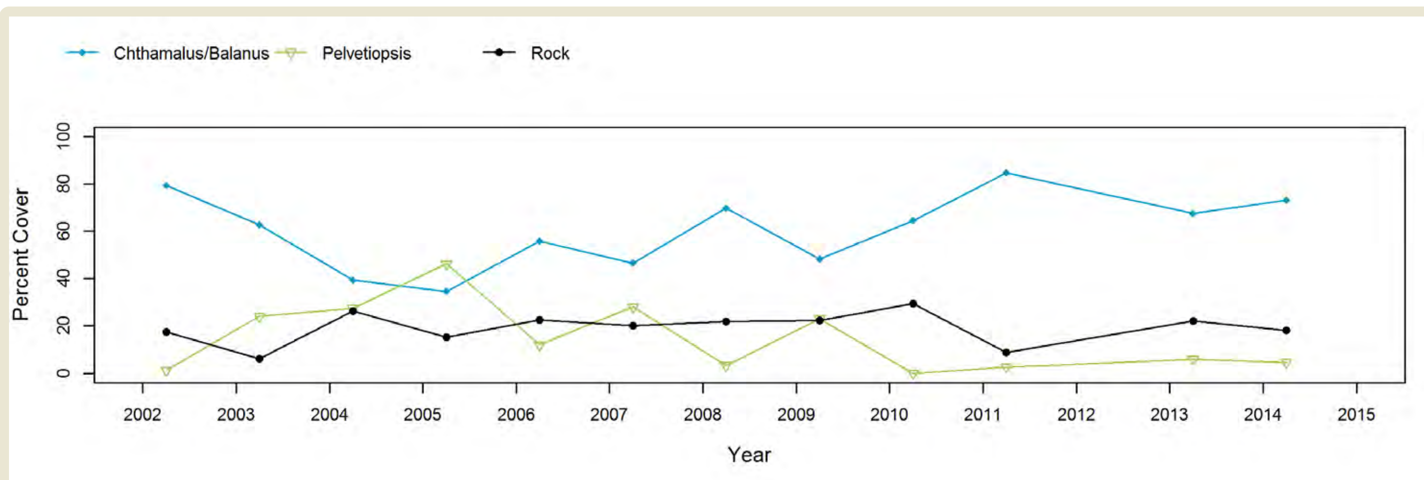
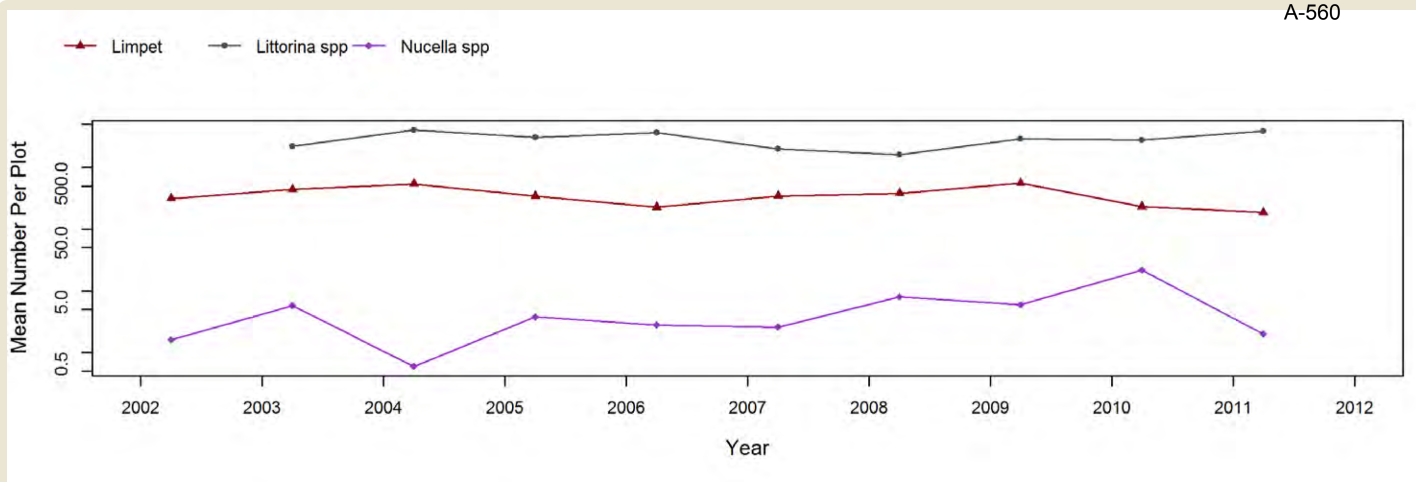
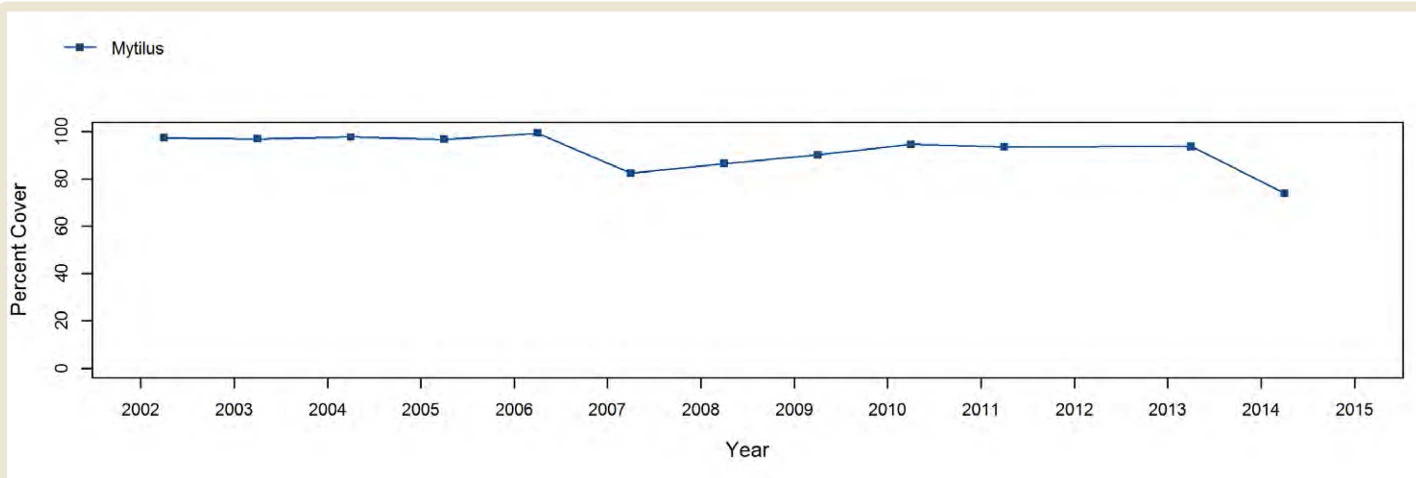
Chthamalus/Balanus (Acorn Barnacles) - percent cover



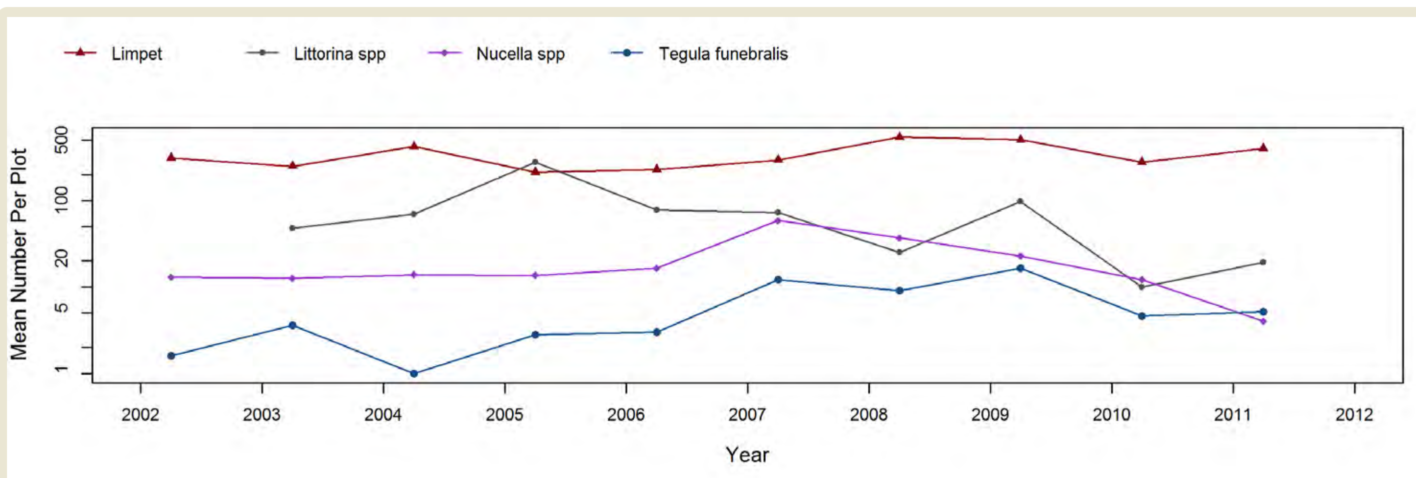
Chthamalus/Balanus (Acorn Barnacles) - motile invertebrate counts



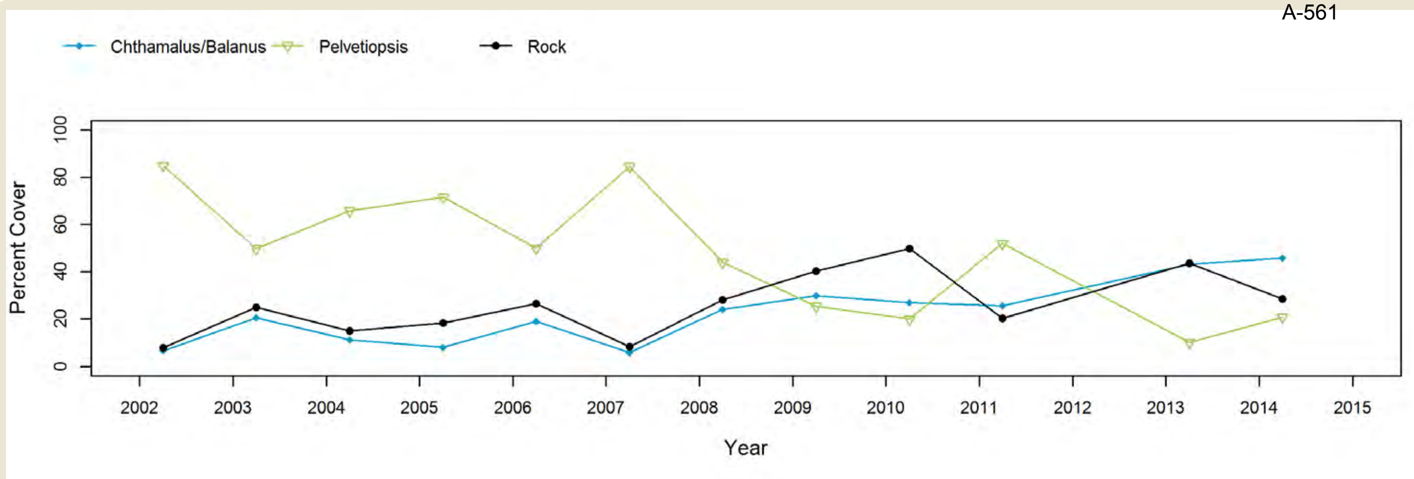
Mytilus (California Mussel) - percent cover



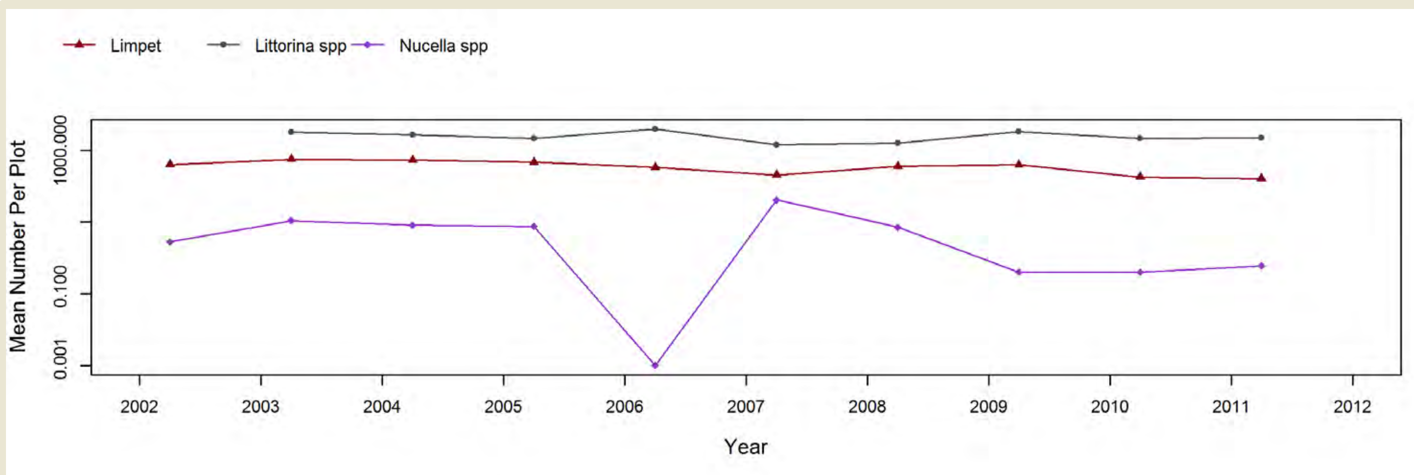
Mytilus (California Mussel) - motile invertebrate counts



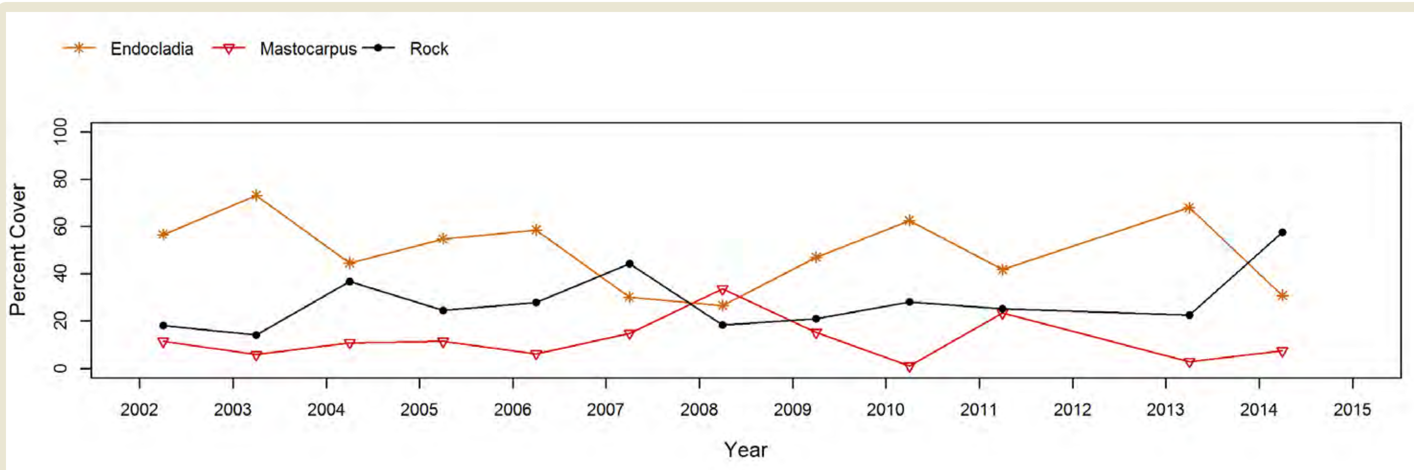
Pelvetiopsis (Dwarf Rockweed) - percent cover



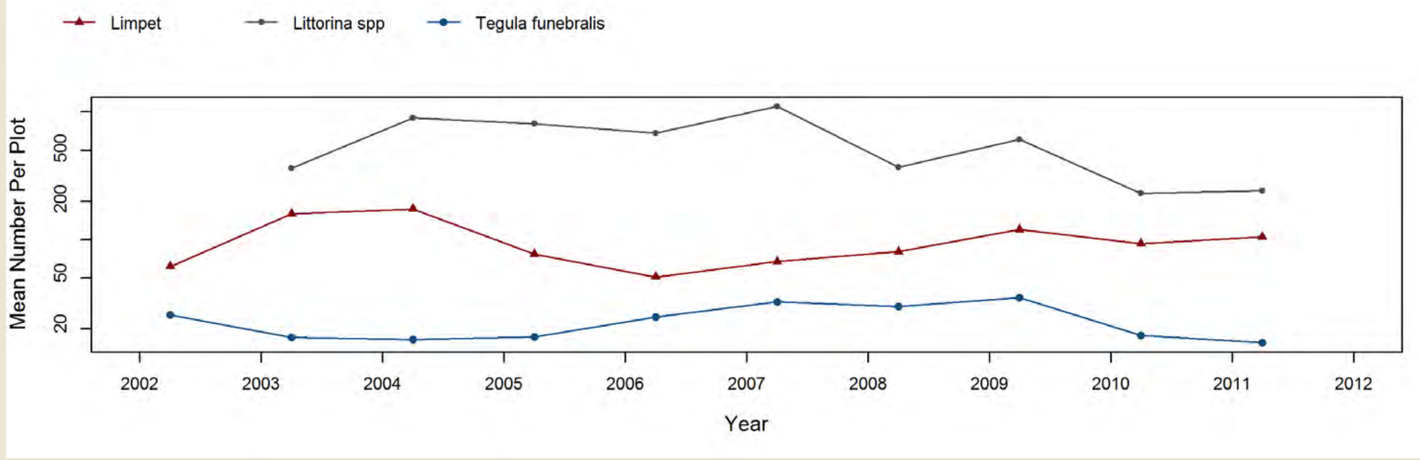
Pelvetiopsis (Dwarf Rockweed) - motile invertebrate counts



Endocladia (Turfweed) - percent cover



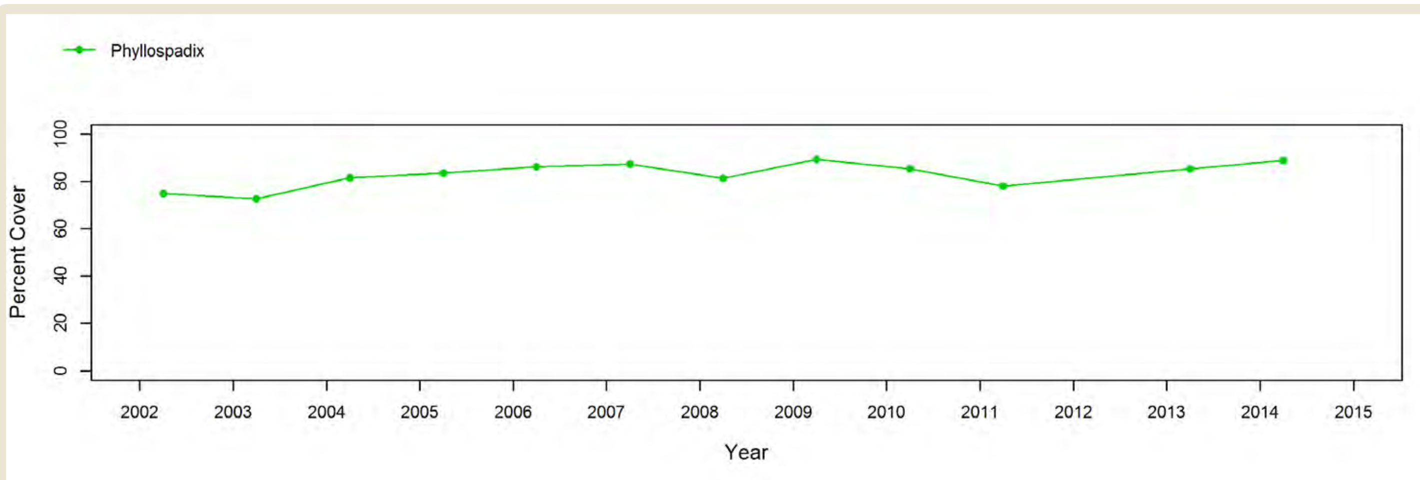
Endocladia (Turfweed) - motile invertebrate counts



Transects

Below are the trends observed for each Transect target species at this site. Long-Term trend graphs show all species that reached a minimum of 25% cover during any single point in time within a given target species assemblage. Breaks in trend lines represent missed sampling events.

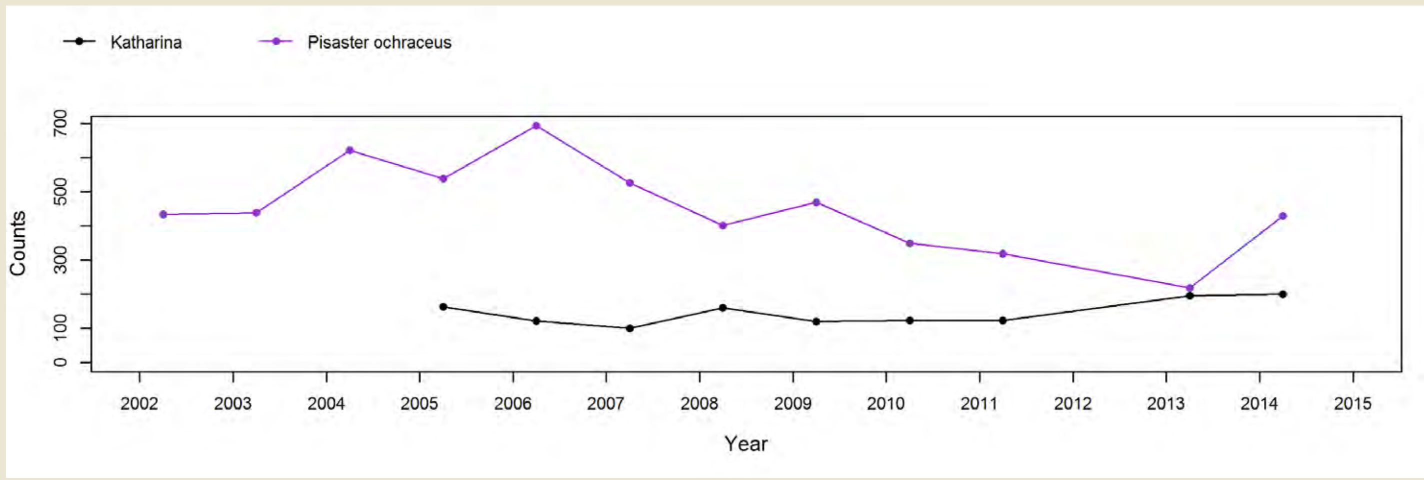
Phyllospadix (Surfgrass)



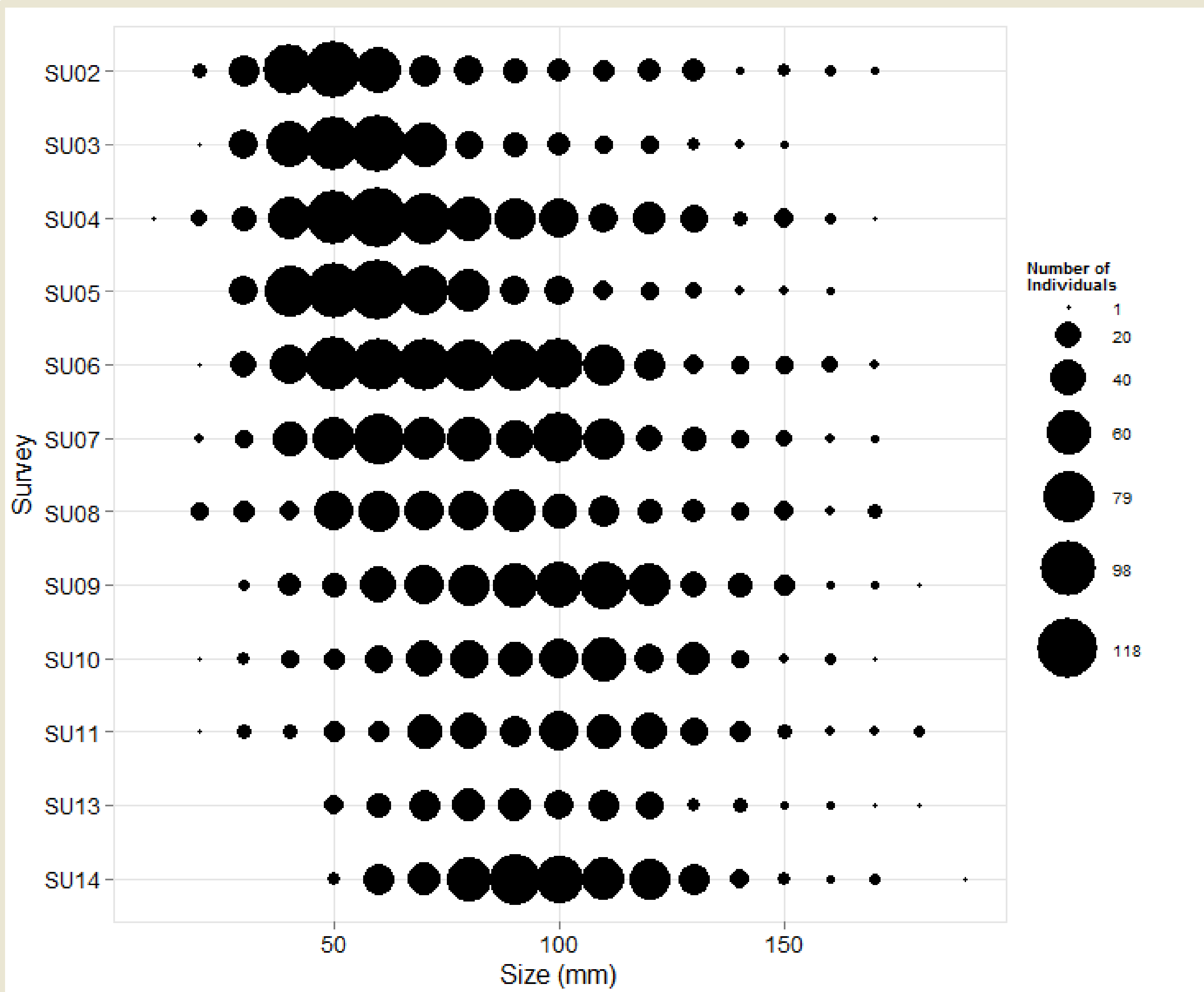
Species Counts and Sizes

Species Counts and Sizes (where recorded) for *Pisaster* are shown below for this site. The sum of all individuals across all plots is displayed.

Pisaster (Ochre Star) - counts



Pisaster (Ochre Star) - sizes



Burnt Hill Biodiversity Survey fndings

Click here (PDF link) for a list of species observed during the Biodiversity surveys at this site

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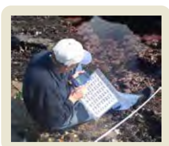
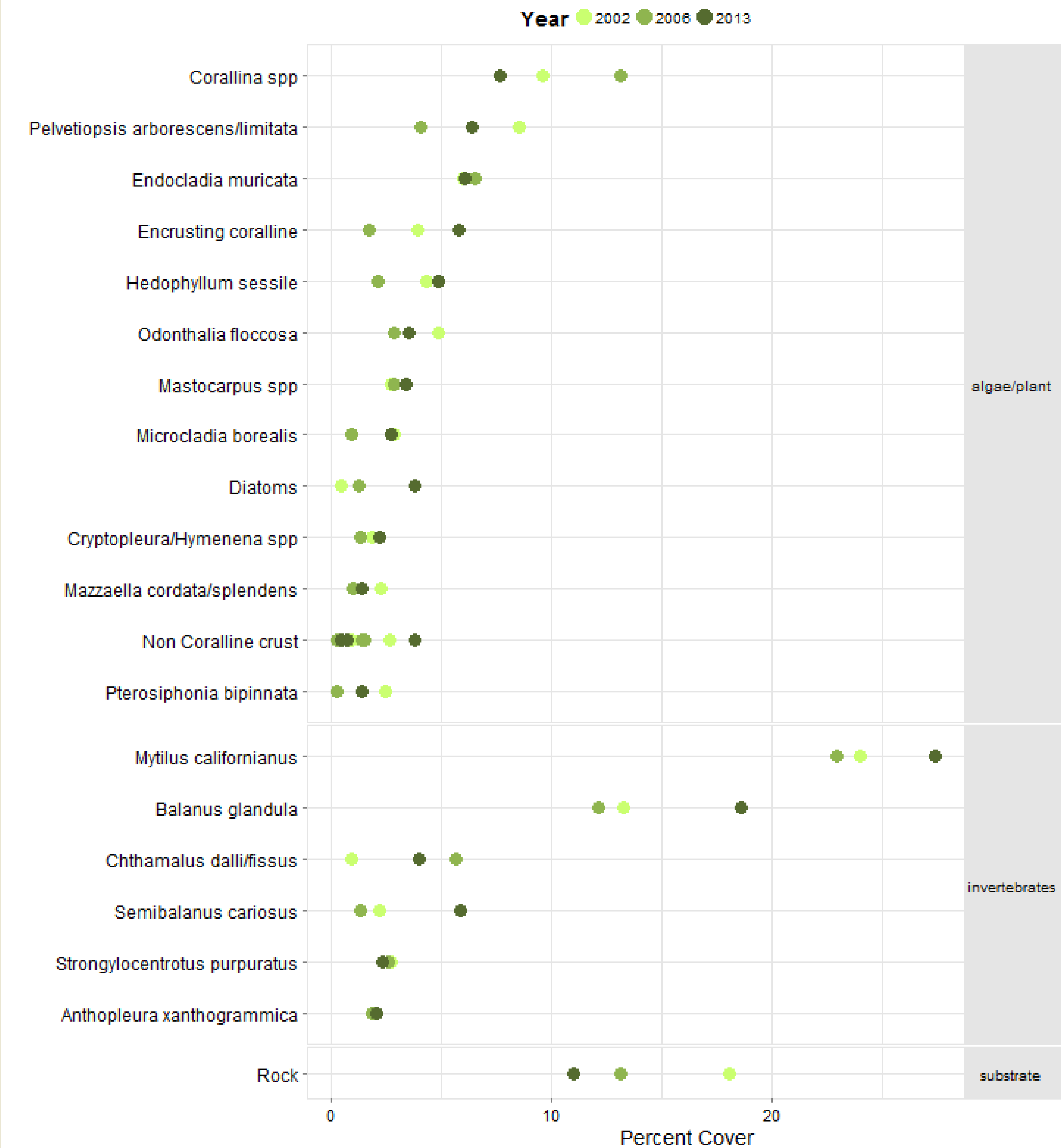
Point Contact Surveys

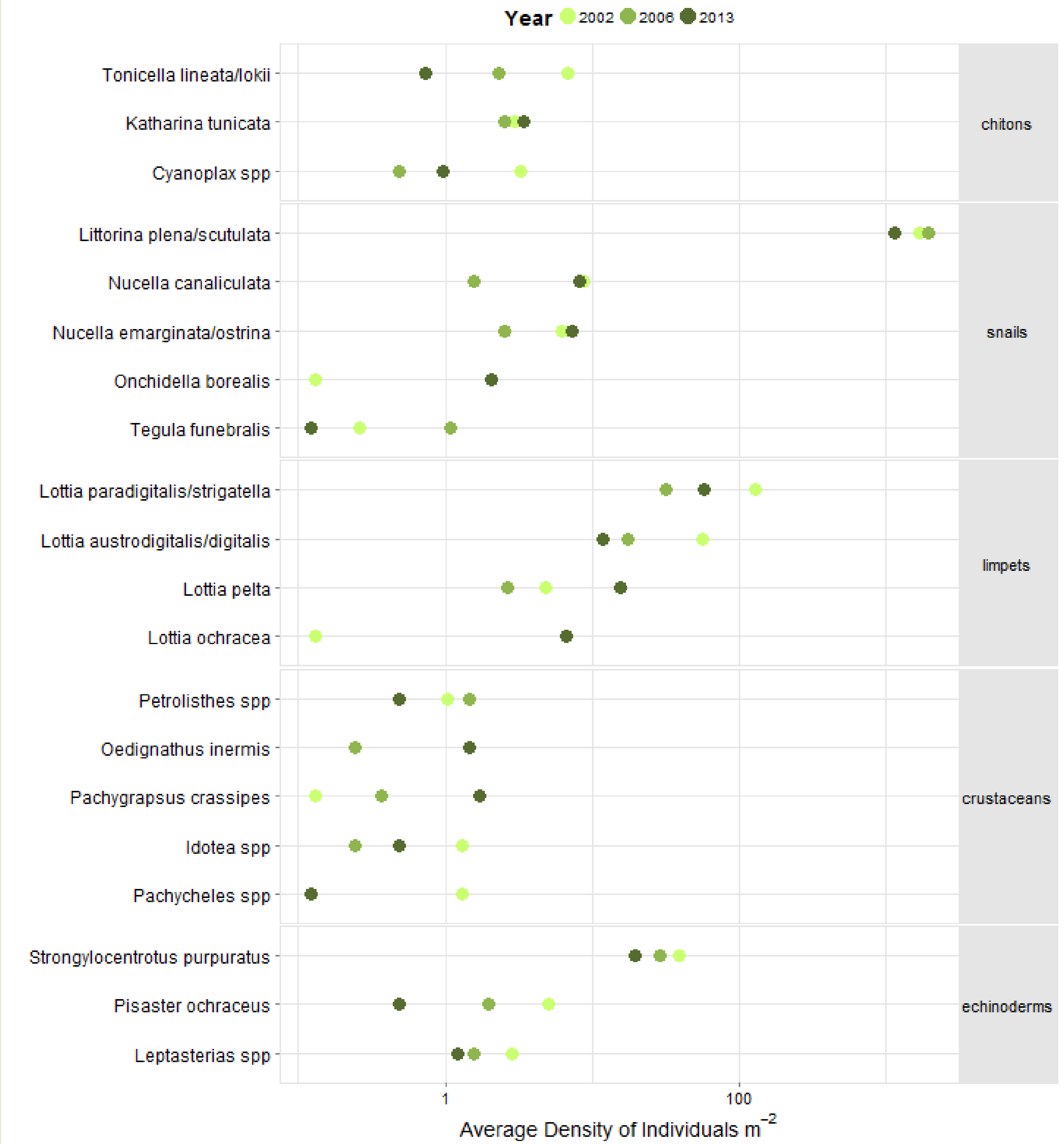


The graph below compares the percent cover of the most common species (>2% cover, frst points only, for at least one sample) observed during the Point Contact Surveys at this site.



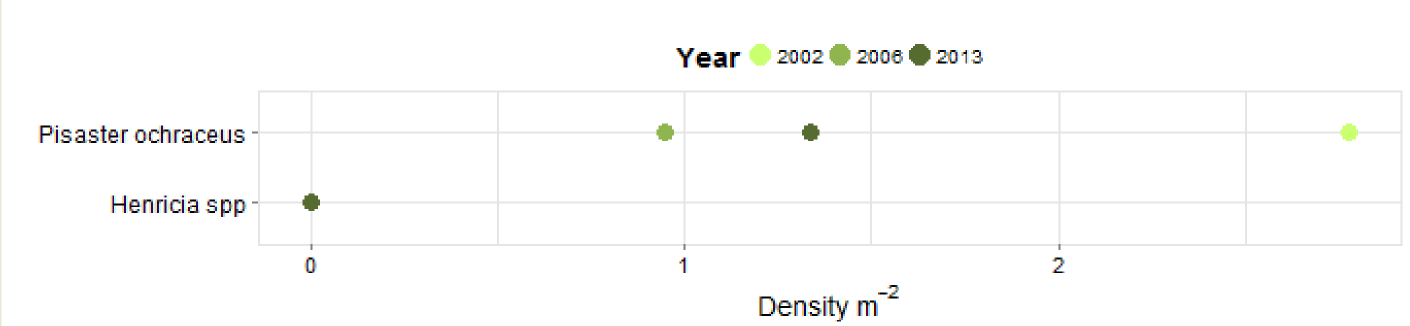
Quadrat Surveys

The graph below compares the density of the dominant species observed (>1 per m2 for at least one sample; note logarithmic scale) during the Quadrat Surveys at this site.

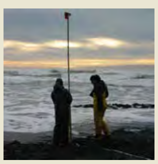


Swath Surveys

The graph below compares the density of seastar species observed per transect during the Swath Surveys at this site.

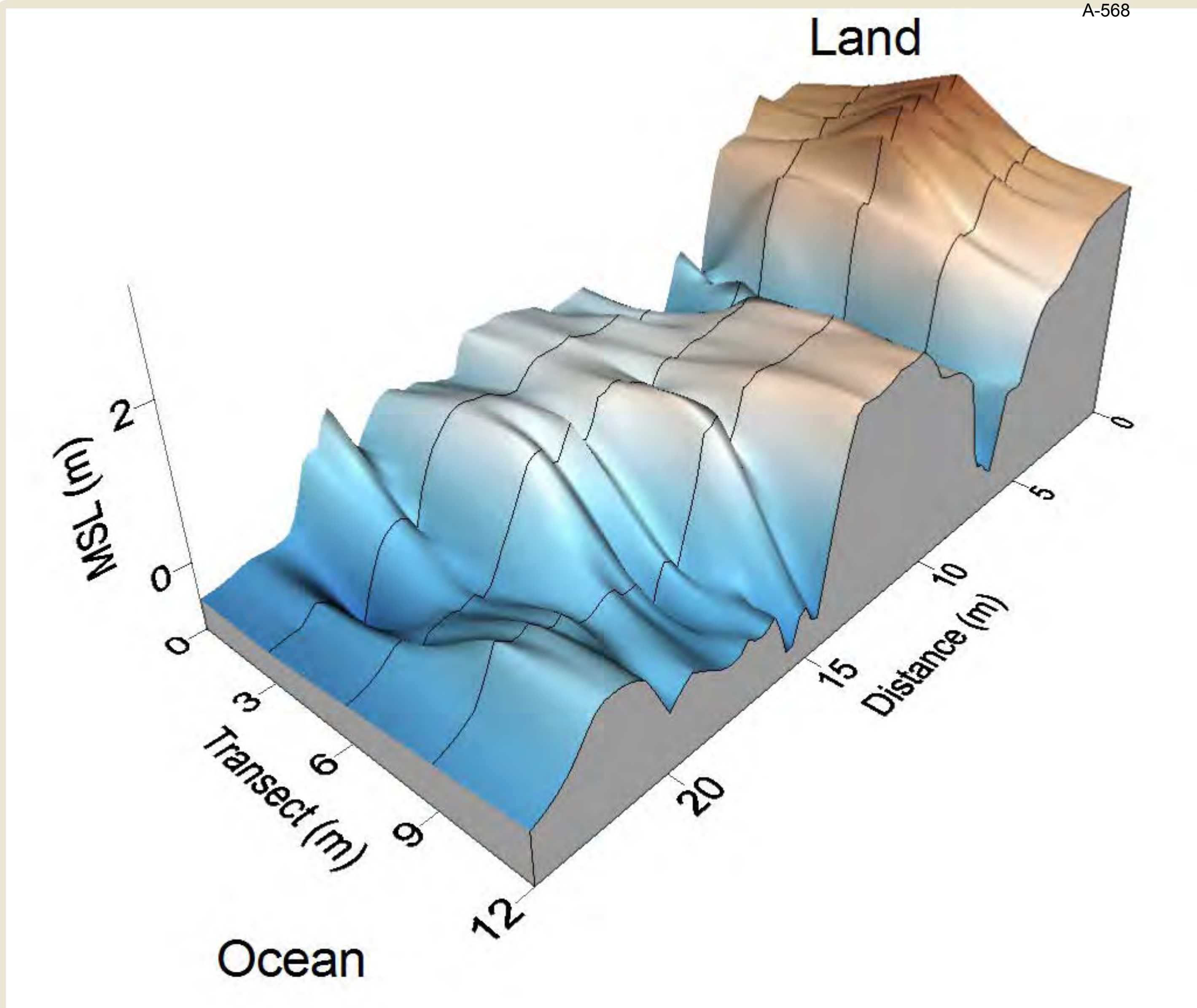


Topography Surveys

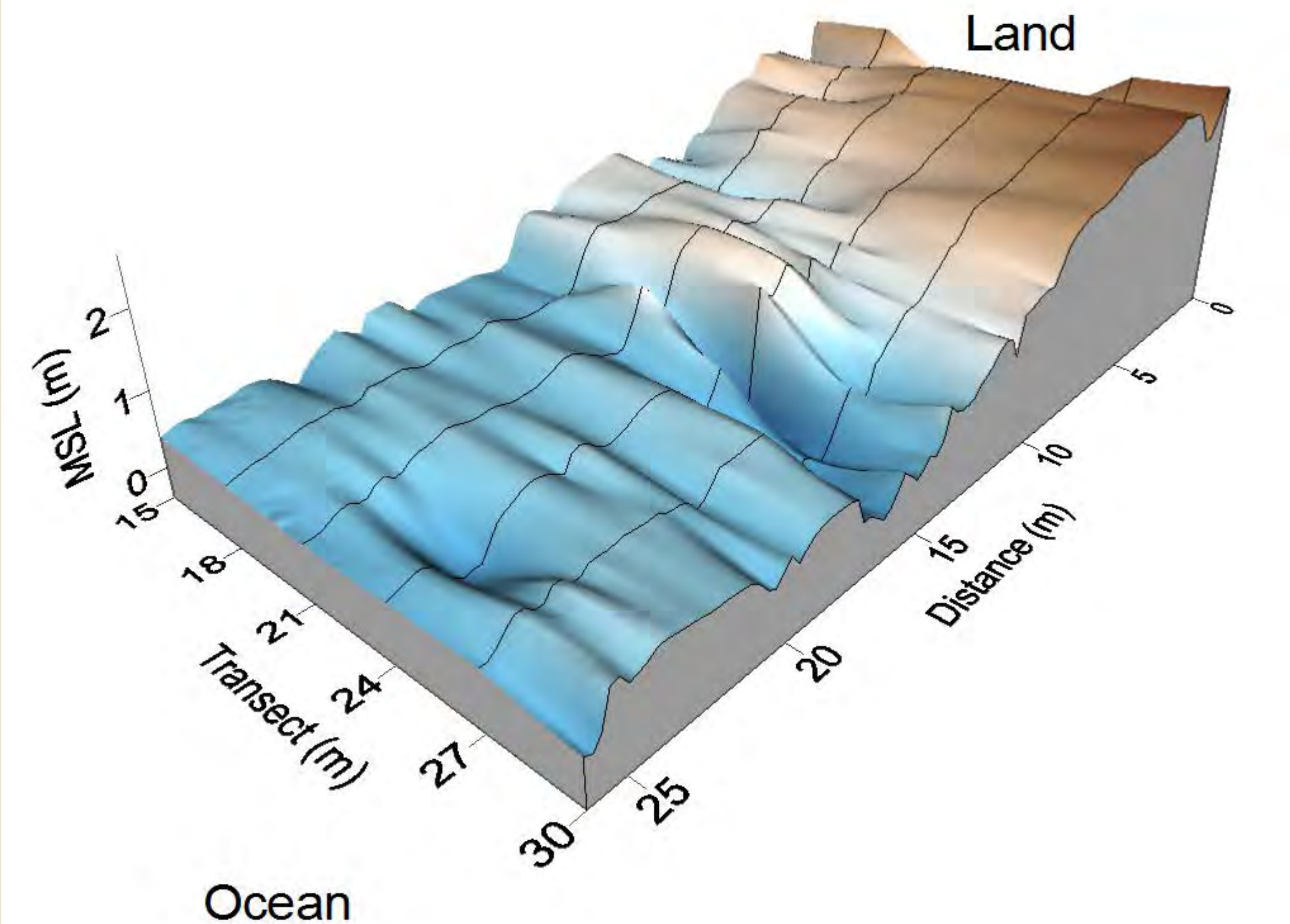


The map below displays the topography of the site in meters above mean sea level (MSL). It was created from data collected during the Topography Surveys at this site.

Section 1


A-568
Land
MSL (m)
2
0
0
3
6
9
12
Transect (m)
0
5
10
15
20
Distance (m)
Ocean

Section 2



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Interactive Map

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Appendix 11: Utility of Photos for Assessing Impacts of Oil Spills

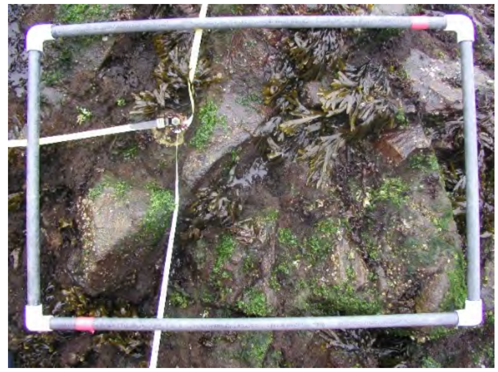
APPENDIX 11: UTILITY OF PHOTOS FOR ASSESSING IMPACTS OF OIL SPILLS

During the Cosco Busan oil spill, photos that were taken during the pre-spill phase were assessed to see if there were distinctive features within the plots that would help match up photos taken at a later time. For example, geographic features such as cracks or other distinctive markings on rocks could be used as a reference. During these initial assessments we determined that in many cases distinctive features were absent and it was unlikely that photos taken at a later date could be matched. The main reason for doing this was to see what sort of analysis would be useful – either paired differences or site averages. Another reason was to determine the likelihood of relocating the original plots. A subset of sites (Alcatraz, Marina Green, Berkeley Marina and Point Isabel) were chosen to compare photos taken at different times to determine the degree of actual overlap (Table 1). This varied by site, and we determined that it wasn't reliable for several reasons; 1) not all plots had distinctive features that could be easily identified in photos, 2) plots can change through substrate movement (i.e. influx of cobble or sand) or 3) communities can change in a way that may hide distinctive features (i.e. overstory algae). In addition, we determined that the additional time and effort required to match up photos in the lab was not justified because success rate was low. Limited field time, particularly during oil spill events that do not always coincide with good low tides, is not conducive to ensuring plots are located in exactly the same place. Overall, it was determined that the best approach is to attempt to revisit the original location (using photos, triangulation, measurements, and gps coordinates of transect locations), but to then use sites' averages (of the percent cover from the photos) for analysis. This approach was adopted for the Dubai Star oil spill.

Site	Number of photoplots taken	Numbers of Perfect matches	% Match
Alcatraz	147	27	18
Berkeley Marina	123	28	23
Marina Green	44	16	36
Point Isabel	41	12	29

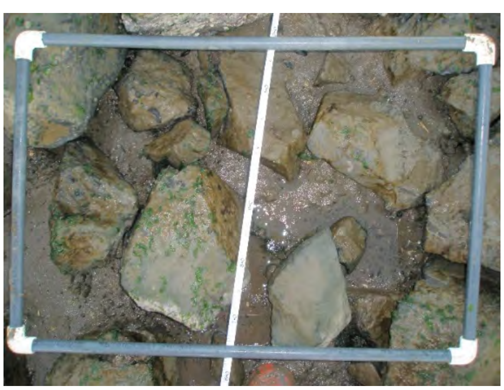
Table 1: Showing the % Match (or photos that we could discern were taken in the same place).

Examples of Matched Photos taken in 2007 and 2009

1. Representative photos from Alcatraz taken Dec 2007 (left) and Jan 2009 (right). In this case there was an existing bolt and some distinctive features that made matching the photos possible.


2. Representative photos from Alcatraz taken Dec 2007 (left) and Jan 2009 (right). In this case there was a distinctive boulder in the center of the plot, despite the cobble that moved around, that made matching the photos possible.




3. Representative photos from Berkeley Marina taken Dec 2007 (left) and Jan 2009 (right). In this case there were some distinctive rocks that we were able to match despite some of the cobble moving around.

4. Representative photos from Marina Green taken Nov 2007 (left) and Jan 2009 (right). In this case there were some distinctive rocks that made it possible to match up the photos.

5. Representative photos from Alcatraz taken Dec 2007 (left) and Jan 2009 (right). In this case there were some distinctive rocks that made it possible to match up the photos, despite the change in *Fucus* cover. In other cases, where *Fucus* cover made it difficult to discern if the photos matched or not.

6. Representative photos from Point Isabel taken Nov 2007 (left) and Jan 2009 (right). In this case there were some distinctive rocks that made it possible to match up the photos.

Appendix 12: Black Abalone Study for NOAA

APPENDIX 12: BLACK ABALONE STUDY FOR NOAA/NMFS

UCSC black abalone monitoring program carried out assessment of 5 intertidal locations in Santa Barbara and San Luis Obispo Counties for the for the years 2013-2014 using NOAA/NMFS supplementary funding. These sites were and are critically important to the ongoing studies of the effect of withering disease on black abalone populations and recovery probabilities. The results of this work are shown in appendix 4.

The Department of the Interior

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under US administration.

The Bureau of Ocean Energy Management

As a bureau of the Department of the Interior, the Bureau of Ocean Energy Management's (BOEM) primary responsibilities are to manage the mineral resources located on the National's Outer Continental Shelf (OCS) in an environmentally sound and safe manner.

The BOEM Environmental Studies Program

The mission of the Environmental Studies Program (ESP) is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments.