BASELINE MONITORING OF ROCKY REEF AND KELP FOREST HABITATS OF THE NORTH COAST STUDY REGION

Final Report

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EXECUTIVE SUMMARY

The nearshore rocky reefs of the North Coast of California create complex structure that supports a wide array of benthic habitat from low lying fields of understory algae to crevices and boulders covered with large abalone and sea urchins to highly rugose rocky pinnacles and walls. This physical and biogenic structure also provides a variety of niches that are occupied by schools of nearshore fishes, particularly the ubiquitous rockfishes of the region. As such, these rocky reefs provide an outstanding array of goods and services, from commercial and recreational fishing for both fish and invertebrate species to SCUBA diving, boating, and wildlife viewing. These services provide the economic backbone of many of the small towns within the North Coast Study Region (NCSR) of the MLPA Monitoring Program. The rocky reefs of the North Coast are distinctly different from the central and southern regions of the state. The large, canopy forming kelp beds of *Macrocystis* are generally absent from the region, and the more sparse blades of *Nereocystis* dot the nearshore coastline. Sea surface temperatures are colder, the subsurface visibility is often reduced from rough ocean conditions and outflow from a multitude of river systems, and large predators (white sharks) are commonly sighted. Systematic surveys of these reefs are less common across the entire region, with most previous efforts centered around the southern end of the NCSR in the Fort Bragg / Mendocino headlands area.

Here we provide one of the first systematic, "snapshot" surveys of the entire NCSR, from the Oregon border to the headland at Point Arena. Our attempt was to characterize these subtidal rocky reefs both inside of the newly created MPAs throughout the region and at comparable and representative reference areas outside of MPAs. We utilized small (19 and 22 ft) vessels for these surveys since representative reef habitats in this region are often remote and inaccessible from shore. These habitats are better represented in this study relative to those often reported on from the limited beach access surveys confined to small areas by other monitoring efforts. We used SCUBA surveys to measure the physical characteristics of rocky reefs and the relative abundance and sizes of many of the fishes, mobile and sessile invertebrates, and algae at each site. Species abundances were estimated along 30 m long swath surveys that count individuals within a 60 m^2 area or at predetermined points along a transect using uniform point contact (UPC) methods to estimate the percent cover of colonial and encrusting organisms covering the reefs.

We used similar survey methods to those that have been utilized within the other MPA monitoring regions of the state of California with only slight modifications to account for the unique challenges of the NCSR. These include oceanographic conditions that are only intermittently amenable to SCUBA survey work for extended periods of time, subsurface visibility that is often reduced due to more extensive freshwater input from river basins along the North Coast, kelp forests that are more 'sparse' than those found at rocky reef locations to the south, and pinniped rookeries and haulout locations that dot the coastline leading to increased densities of apex predators (white sharks) that pose a threat to divers. We accounted for these challenges by assembling an experienced, well trained, safety conscious dive team and maintaining constant vigilance for amenable dive conditions- trips cannot be pre-planned on the North Coast. Due to the unpredictability of ocean conditions and subsurface visibility, it often required multiple visits to a single cell within a site to complete all survey objectives.

The baseline established by these surveys will be useful in detecting future changes in community structure that may be a consequence of MPA designation. Because these surveys were conducted immediately following the implementation of these MPAs, it is highly unlikely that any initial differences in community structure or species abundances would be detectable between MPA and non-MPA sites. No significant immediate community level reserve effect has been observed elsewhere in the state. As such we focus our analysis and results on the spatial variation in community structure at all monitored sites across the entirety of the NCSR. Because this monitoring project only consisted of two years of surveys, temporal variability cannot be attributed to long term changes in these reef communities, but may demonstrate annual variability in reef communities due to changes in oceanographic conditions and recruitment dynamics of many reef inhabitants.

We surveyed at four MPA sites (Pyramid Point SMCA, Double Cone SMCA, Ten Mile SMR, and Cabrillo SMR) and four reference sites (Trinidad, Abalone Point, Caspar Headlands, Elk Headlands) spread throughout the NCSR in both 2014 and 2015. Each site was divided into three locations or "cells", and within each cell a full array of all survey types along multiple depth strata were utilized. Previous monitoring programs have considered each separate cell an individual site, in which case we sampled 20 sites within the NCSR. At each cell we measured 1) the percent cover of habitat type and reef rugosity, 2) the percent cover of encrusting sessile and colonial invertebrates and algae on the reef surface, 3) the density of macroinvertebrates, algae, and fishes, and 4) the sizes of all fishes, red abalone, and sea urchins. The relative number of surveys completed within each site (and each cell within a site) varied between survey type, location, and year, based on ocean conditions, visibility, and accessibility.

The reefs surveyed throughout the region were comprised of 80-90 % bedrock and large boulder habitat and were primarily covered in crustose corallines and encrusting forms of red algae. The relative percentage of crustose coralline algal cover increased along a latitudinal gradient from north to south. Sea urchins, both purple and red, were the dominant macroinvertebrates on the reefs, and were found in extremely high densities at the southern end of the NCSR, particularly within the long standing (40 + years) Cabrillo SMR. We found low densities of the canopy forming algae *Nereocystis*, and most sites were dominated by the subcanopy kelps *Laminaria* and *Pterygophera*, although the relative density of each varied between sites. The lowest densities of macroalgae were observed within the long-standing Cabrillo SMR.

Fish assemblages were dominated by black and blue rockfishes, including both adult and newly recruited juveniles. Black rockfish were more abundant at the northern end of the study region while blue rockfish densities increased at the southern end of the NCSR. Young of the year rockfish recruits, often encountered in large, dense schools, accounted for a large number of the fishes observed. A large recruitment pulse of kelp-gopher-black and yellow rockfish, and a decrease in observed blue and black rockfish recruits in 2015, led to significant differences in fish assemblages between years, demonstrating the difficulty of describing a "baseline" of fish community structure on these nearshore reefs over a two year sampling period.

Spatial analysis of community structure revealed three relatively distinct regions that fall out along a latitudinal gradient across the NCSR. The two sites north of Cape Mendocino at Pyramid

Point (SMCA) and Trinidad, although sampled less rigorously than the other sites, had quite distinct overall community structure. This held true with spatial analysis of the percent benthic cover and both macroinvertebrate and fish assemblages. The second region included Double Cone SMCA, Abalone Point, and Ten Mile SMR, the three sites located immediately south of Cape Mendocino. These three sites represented an “intermediate” community structure on the reefs between the northern and southern sites. The three southern sites at Caspar Headlands, Cabrillo SMR, and Elk Headlands formed a final distinct community-level region with generally increased crustose coralline and algal cover, sea urchin densities, and blue rockfish abundances.

These observed geographic patterns of community structure suggest that the MPA and reference sites chosen for this monitoring program were well placed, and that sites closer to each other, rather than within or outside of MPAs, share increased similarities. Thus it is particularly informative to compare community structure at the reference site at Caspar Headlands to that observed at the directly adjacent long standing MPA at Cabrillo. This provides a possible glimpse of expectations of reserve designation, at least along the southern end of the NCSR. Within the Cabrillo MPA we observed increased densities of sea urchins, low densities of kelps, and low densities of red abalone when compared to the non-MPA site at Caspar. This is potentially a consequence of the lack of commercial urchin harvesting within the MPA, leading to increased grazing pressure on macroalgae and decreased drift algal availability for red abalone. Long term monitoring at this site by CDFW and observations by commercial urchin harvesters suggest this urchin dominated “barren” region has been maintained within the Cabrillo MPA over an extended time period. In contrast, the density of fishes observed with the Cabrillo SMR were almost double that observed at Caspar, again possibly a consequence of reduced commercial and recreational fishing pressure within the MPA.

In conclusion, this baseline monitoring program of nearshore rocky reefs of the NCSR surveyed structurally similar reefs across the region and found a latitudinal gradient of community structure that varies from north to south. We found little evidence of initial change in community structure due to MPA implementation, thus future changes may be the consequence of the results of reserve designation. The geographic variation in community structure observed suggests that future monitoring endeavors should match MPAs to nearby reference sites, and that results within a single MPA may not be applicable across the entire study region. Finally, the observed interannual variability in community structure, particularly that within the nearshore fish assemblages and purple sea urchins, demonstrates that short term changes are possible on these reefs, and caution against basing management decisions upon 1-2 year “snapshot” surveys.

NARRATIVE

Project Goals and Objectives

The overall goal of this monitoring program is to provide a summary description, assessment, and understanding of ecological conditions within nearshore rocky reef and kelp forest habitats both inside and outside of marine protected areas (MPAs) throughout the North Coast Study Region (NCSR). To meet this goal, the primary objectives were to (1) produce a quantitative baseline characterization and comparison of the structure of nearshore rocky reef and kelp forest ecosystems in MPAs and comparable reference areas of the NCSR, (2) assess spatial variation in community structure of nearshore fishes, macroinvertebrates, algae, and benthic cover across the entirety of the NCSR from the Oregon border to near Point Arena, CA, (3) provide a thorough baseline characterization of socioeconomically and ecologically important species found along North Coast rocky reefs, specifically describing current densities of two high priority species, red abalone (*Haliotis rufescens*) and red sea urchins (*Mesocentrotus franciscanus*), that are likely to be important metrics for assessing ecosystem health and change, and (4) establish benchmarks of species densities and community structure both inside newly created MPAs (Pyramid Point, Double Cone, Ten Mile) and those previously established (Cabrillo Point), as well as representative reference sites, that will inform future long-term monitoring of North Coast MPAs. Finally, we incorporated public involvement from representative stakeholders of the nearshore marine environment of the NCSR by working with commercial sea urchin harvesters who collected additional survey data on abalone and urchin abundance and sizes.

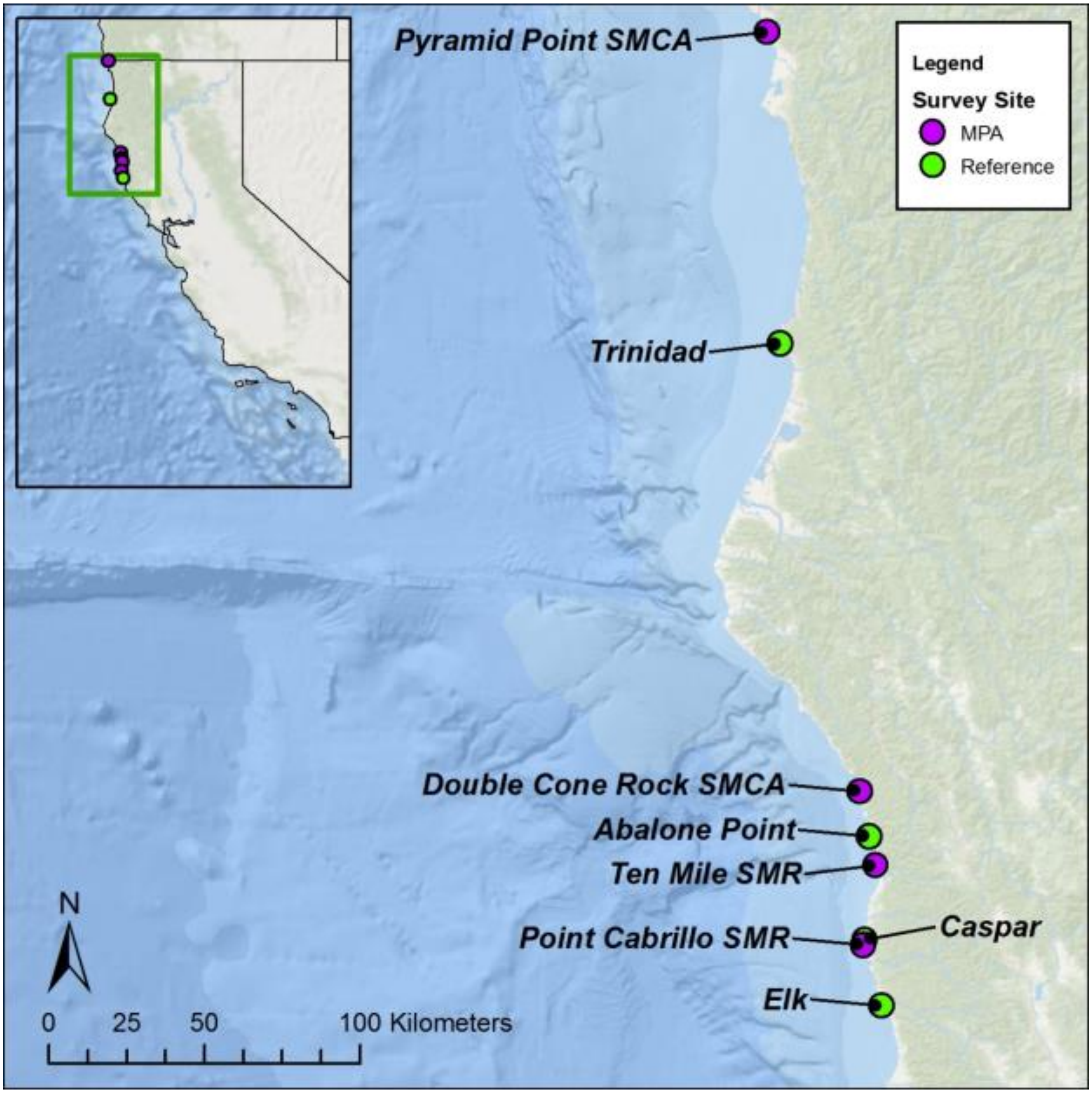

Figure 1. Locations of subtidal rocky reef baseline monitoring survey sites along the North Coast of California. Rocky reef habitat is limited north of Cape Mendocino, thus the non-uniform dispersal of sampling sites across the NCSR.

Description and Location of Sites

Baseline monitoring of subtidal rocky reefs of the NCSR provides unique logistical and in-situ sampling challenges rarely encountered at other locations along the California coast. Oceanographic conditions are only intermittently amenable to SCUBA survey work for extended periods of time, many MPAs are located farther from direct access points than any other mainland sites along the coast, subsurface visibility is often reduced due to more extensive freshwater input from river basins along the North Coast, kelp forests are more ‘sparse’ than those found at rocky reef locations to the south, and pinniped rookeries and haulout locations dot the coastline leading to increased densities of apex predators (white sharks) that pose a threat to divers. While MPAs and adjacent reference sites at the southern end of the NCSR, particularly surrounding the Mendocino Headlands area, are more dependable for survey work and have been sampled by multiple organizations (including HSU, CDFW and Reef Check California), little research has previously occurred at subtidal sites north of Fort Bragg, CA.

As with any sampling program, there is a tradeoff in sample allocation between temporal and spatial samples. For the purposes of a baseline characterization of an area as large as the NCSR, encompassing multiple MPAs and references sites, spatial coverage is far more informative in describing the distribution of key attributes of the ecosystem and was the primary focus of this monitoring project. Our initial proposed sampling regime included four additional sites throughout the NCSR, but allocated funding forced a reduction in survey effort. Nearshore rocky reef habitat is less abundant to the north of Cape Mendocino, with large sections of coast from the Klamath River mouth to Patrick’s Point and Trinidad Head to Cape Mendocino having only sandy bottom habitat. The time and effort to reach additional sites along the “Lost Coast” immediately south of Cape Mendocino required funding that was not provided, and resources were instead directed towards safer and more accessible sites further south. The consequence of the lack of rocky reef structure, coupled with both limitations in logistics and funding, left much of the “central” portion of the NCSR unsurveyed as part of this program.

Thus based on available funding, time and spatial logistics necessary to work at each site, as well as safety concerns, we sampled 4 MPAs and 4 references sites spread throughout the NCSR (Table 1, Figure 1). MPA survey sites were located at (1) Pyramid Point (SMCA), (2) Double Cone Rock (SMCA), (3) Ten Mile (SMR) and (4) Cabrillo Point (SMR). The SMR at Cabrillo Point was established in 1975, and later expanded to its current size and location. Reference sites were selected based upon (1) habitat characteristics as comparable as possible to sites sampled within MPAs, including reef rugosity and exposure to oceanic conditions, (2) a spatial distribution that allows sampling of nearshore rocky reefs outside of MPAs throughout the NCSR, and (3) project staff’s past experience diving and working in the immediate area of these sites. Reference survey locations were located at (from north to south) (1) Trinidad, (2) Abalone Point, (3) Caspar Headlands, and (4) Elk Headlands.

All survey sites were accessed utilizing HSU’s two small Boston Whalers (19’ and 22’) with outboard engines. This allowed for a more representative sample of nearshore reef habitats along the NCSR rather than the limited sampling at sandy nearshore habitats encountered via shore diving at the southern end of the study region (which is used by other monitoring programs). In addition, small vessel sampling allowed for better comparison of data between the primary dive team's results and those collected by commercial urchin divers. The three sites surveyed by commercial divers included: (1) Abalone Point, (2) Caspar Headlands, and (3) Cabrillo Point SMR.

Table 1. Subtidal rocky reef survey sites located within the NCSR. Positions given for the location of the outer (20 m) depth contour surveys- other surveys within each cell conducted on described depth strata directly inshore from these points (see Methods).

Site	**MPA Designation**	**Cell**	**Latitide**	**Longitude**
Pyramid Point	SMCA	1	41.5942	124.14209
Pyramid Point	SMCA	2	41.58486	124.13361
Trinidad	reference	1	41.05333	124.1014
Trinidad	reference	3	41.03071	124. 08628
Double Cone	SMCA	1	39.47617	123.50889

Double Cone	SMCA	2	39.45253	123.50678
Abalone Point	reference	1	39.41588	123.48732
Abalone Point	reference	2	39.39865	123.48732
Abalone Point	reference	3	39.37726	123.47795
Ten Mile	SMR	1	39.35387	123.47328
Ten Mile	SMR	2	39.34861	123.471
Ten Mile	SMR	3	39.34148	123.46907
Caspar	reference	1	39.22445	123.49607
Caspar	reference	2	39.2188	123.49417
Caspar	reference	3	39.21561	123.49662
Cabrillo	SMR	1	39.21337	123.49636
Cabrillo	SMR	2	39.20.518	123.49.592
Cabrillo	SMR	3	39.20667	123.4953
Elk	reference	2	39.10375	123.45644
Elk	reference	3	39.08369	123.4421

Methods

General sampling design

Our sampling design and protocols were a geographic extension of those that have been used to generate baseline characterizations of rocky reef and kelp forest ecosystems in the North Central Coast Study Region (NCCSR), Central Coast Study Region (CCSR) and the network of marine reserves in the Northern Channel Islands (NCI), with a few minor changes to address the unique logistical difficulties of sampling MPAs throughout the NCSR (as detailed below). These protocols were developed by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and used for long term monitoring of sites in central and southern California.

We utilized a stratified random permanent sampling design in which randomly located 30 m transects were sampled within fixed locations at each site. Each MPA and reference site was divided into three "cells", each of which contained contiguous rocky reef and possible *Nereocystis* forest habitat extending out to approximately 20m depth. The random transects were stratified within each of the three cells at each site across fixed depth zones. To reduce the likelihood of "edge effects" (i.e., "inside" samples collected near the boundary of an MPA being influenced by fishing effects in areas adjacent to the MPA), potential sampling sites did not lie within 100 m of an MPA boundary. We attempted to sample all cells at each site each year in both 2014 and 2015, although not all were surveyed due to access limited by oceanographic conditions, low subsurface visibility, or lack of contiguous reef habitat. Other statewide MPA Monitoring Programs refer to each "cell" as an individual "site" because all survey types at each depth contour occur within each cell (see below). Using this logic, we attempted to survey 10 MPA and 10 reference locations each year in 2014-15.

Within each cell of every MPA and reference site, four distinct diver surveys were completed: 1) Swath surveys to record densities of all conspicuous macroinvertebrates and macroalgae, 2) Swath surveys to record densities and size structure of fishes, 3) Uniform point contact (UPC) surveys to record physical habitat characteristics and percent cover of colonial and encrusting species, and 4) Swath surveys to record the size frequency and abundance of red abalone and red sea urchins. The unique requirements of each survey type lead to slight differences in sampling effort between the species being sampled. For example, variation in sampling effort between fish and benthic surveys is a product of the underwater time needed to complete each survey type- in the time two divers can complete two benthic transects two other divers may be able to complete six fish transects. Variation in the depth strata used for each survey type is born out of differences in natural history and distribution of fishes and the generally sessile invertebrates and algae monitored on benthic surveys. The depth contours used for sampling were based upon other MLPA rocky reef monitoring programs in California and have been adapted for the specific circumstances of the North Coast. For example, fish are much less abundant in shallow water along the NCSR due to increased wave energy, thus our shallowest fish surveys were conducted at 8 m depth. Conversely, much of the legal sport harvest of abalone occurs at depths less than 5 m, thus the shallowest benthic surveys occurred in the 3-4 m range to capture the impact of fished sites versus those protected within MPAs.

Fish survey methods

Swath surveys were used to quantify the composition of fish species assemblages while simultaneously estimating the density and total length of all conspicuous species. Because fishes are suspended within the water column, transects are stratified across depth zones within each cell as well as vertically within the water column. Due to the lack of a large surface canopy of kelp forests in the NCSR, which are found elsewhere in the state, we used two depth strata for fish surveys (the bottom 2 m of the water column and at mid-depth between the surface and the bottom), and did not include “canopy” counts. Fish counts in 2 m wide x 2 m tall x 30 m long transects along the bottom and approximately 2-3 m above the benthic diver generate density estimates per 240 m^3 volumes. If surface conditions allowed access to a particular site but the visibility was not adequate to visualize all fish within the sampling “box”, benthic surveys were instead completed and the site was revisited at a later date when at least 3 m of visibility was available. Although recorded and uploaded into the database separately (at OceanSpaces.org), counts of fishes in these two portions of the water column were combined for each 30 m transect for analysis.

A pair of divers sample each transect simultaneously, one on the bottom and one at mid-depth. Although modified slightly to match reef structure depth at each site (i.e. if there is no hard bottom substrate at 20m depth, the deepest survey would match the deepest part of the reef), an attempt was made to survey three random 30 m transects at 20, 16, 12, and 8 m depth isobaths, resulting in 12 fish surveys per cell, and 36 total fish transects at each site per year.

A large component of the nearshore fish assemblage throughout the NCSR were young of the year (YOY) rockfish recruits. These individuals, measured at less than 11 cm total length, often formed large, dense schools, and identifying, counting and sizing these fishes in the relatively poor visibility of the NCSR led to some possible biases in data interpretation. In particular, it was difficult to distinguish YOY black rockfish from the olive-yellowtail (OYT) rockfish complex. As very few adult sized OYT were observed during our surveys, many of the juvenile rockfish identified as OYT in the field were likely black rockfish. As such, these YOY were grouped into a black-OYT single complex for analysis purposes. Due to the patchy nature and high densities of these small fish, overall patterns can be obscured due to counts of over 500 fish in a single school. We thus analyzed the fish swath data separately for adults only, for YOY only, and as a single combined group.

Invertebrate and algae swath survey methods

Benthic swath surveys were used to quantify the density and community composition of large benthic invertebrates and specific macroalgae. Again, surveys were stratified across depth zones within each cell at each site. Two randomly placed 30m x 2 m swath transects were surveyed at each of three depth zones in each cell, generating 6 benthic surveys per cell, and 18 total benthic swath surveys at each site each year. In general, surveys were conducted at 20, 12.5, and 4 m depths, although variation in available hard bottom habitat and the location of the outer and inner edges of the reef at each site required slight modification of these depth contours. As such, survey depths were generally referred to as outer, middle, and shallow transects.

Benthic swath surveys are completed by a diver swimming in one direction of the transect counting conspicuous mobile and sessile invertebrate species within the 60m² swath area. All cracks and crevices of the substrate are searched, but no rocks or substrate are overturned or disturbed and no organisms were removed. The diver then returns along the transect counting all targeted macroalgal species.

In some cases, very high densities of invertebrates or macroalgal species were encountered on a transect, making completion of the survey difficult during the limited bottom time of SCUBA surveys. Thus within each 10 m segment of a transect, if 30 individuals of the same species were encountered, counting was completed and the distance covered to that point (to the nearest meter mark) was noted. A new count of the same species begins at each subsequent 10 m segment along the 30 m transect. This subsampling method still provides comparable density estimates (ind. / m²) to all other species, although all individuals along the full 30 m of transect were not counted for these more abundant species.

All invertebrate species larger than 2.5 cm at the largest width of their body were counted. For macroalgae, only *Nereocystis* taller than 1 m, *Pterogophera,* and *Laminaria* with stipes taller than 30 cm were counted. Only *Cystoseira osmundacea* plants greater than 6 cm diameter were counted. All *Alaria, Costaria, Pleurophycus*, and *Undaria pinnatifida* plants were counted.

Uniform Point Contact methods

Uniform point contact surveys were used to estimate benthic cover and general physical attributes of the rocky reefs. These surveys were conducted along the same transects as the benthic swath surveys, enumerated by the second member of the dive team at the same time. As such, the number of UPC and benthic swath surveys are identical within each cell and each site.

At each one meter mark along the 30 m transect line, the diver records the substratum type (sand, cobble, bedrock, boulder), the vertical relief in 4 categories (0 – 10 cm, 11 cm – 1m, 1 – 2 m, and > 2 m) measured within a 1 m x 0.5 m box around the point, and the species or functional group of invertebrates or algae covering the substrate at that point. Epiphytes and mobile invertebrates were not included in these surveys. In some instances, a layer of drift algae or the largest invertebrate species of the NSCR, the red abalone, was found at the sampling point. These were noted as a "superlayer" on the data sheet, drift algae was moved aside or the nearest point at the closest edge of the abalone was then sampled for benthic cover.

Abalone and Sea Urchin survey methods

While red abalone and both red and purple sea urchin species were recorded as part of all benthic swath surveys conducted during this monitoring program, we dedicated additional survey effort to these species due their enormous ecological and economic importance within the NCSR. Replicate 30m x 2 m swaths were surveyed at each depth contour within each cell, but at different random locations than the benthic swaths.

In addition to abundance counts, the first 30 individuals of each species encountered along each 10 m segment of the transect were measured to the nearest cm (test diameter for urchins, longest shell length for abalone). Thus these surveys allowed for analysis of size structure variation within these populations across the study area both within and outside of the newly created MPAs.

Additional abalone and sea urchin survey data were collected by commercial sea urchin harvesters based out of Noyo Harbor in Fort Bragg, California. Commercial divers were trained by the co-PI over a series of training sessions, provided with all necessary survey supplies (transect tapes, data sheets, slates, underwater lights, writing utensils), and asked to replicate the primary dive teams targeted abalone and sea urchin survey methods and data collection methods (above). Commercial divers were not accompanied by the primary dive team, but were in contact with PIs following all dives to review procedures and answer any questions. The only modifications to commercial diver surveys were that red abalone were sized to the nearest inch and converted to cm, and purple sea urchin test diameters were not recorded.

The commercial urchin collaboration included in this project was initially granted to a private consulting company (HT Harvey). After two years of the project, that company was unable to complete this collaboration due to insurance reasons. Thus the PI's at HSU asked for and received the small amount of funding allocated to this endeavor in 2016. This was the year after completion of data collection, thus the dive team and infrastructure was no longer available, nor were project member divers allowed to dive on board the commercial diver vessels (again, for insurance reasons). With such limitations in time and resources, our goal was to simply honor our commitment to have commercial dive interests involved in the monitoring program.

As these divers spend much of their lives underwater along the NCSR, there was no need to train them on how to dive, or where to find sites, or how to identify the species of interest. In fact, the primary comment from the commercial harvesters was that they did not want to be involved with or treated like training divers or college students, as used by Reef Check, hence we specifically avoided their training methodology for this project. The primary goal of the training, which was conducted by the PI, was to make clear the sequence of survey steps along the transect, to go over the simplified data sheets used by the commercial divers (they only were enumerating urchins and abalone), and to make sure the sites and depth zones surveyed were compatible with the primary dive team's work the previous two years. This training took place over approximately 14 hours between two days in Fort Bragg.

Commercial diver data was recorded both within the Abalone Point and Caspar reference areas as well as within the long standing Cabrillo Point SMR. Because this data was not collected until 2016 it was not included in our final analysis of abalone and sea urchin abundances and distribution but were compared to the data collected by the full HSU dive team to assess the possible efficacy of future commercial diver surveys that could be used in continued MPA monitoring.

Analysis

The primary objective of this preliminary assessment of nearshore subtidal rocky reef habitats was to provide a "snapshot" catalogue of species abundance and community structure at multiple sites (both within and outside of newly created MPAs) across the entirety of the NCSR. Thus our analysis is driven to 1) examine spatial differences in density and abundance of all monitored fish, benthic invertebrates, and algal species across all sites, 2) visually assess variation in community structure at each site, 3) look for impacts of MPA designation or "initial changes" in the first two years after establishment of the MPA network, and 4) describe temporal and spatial variability in the dominant species of each group with particular focus on red abalone and sea urchins.

To examine spatial and temporal variability in rocky reef community structure we constructed Bray-Curtis similarity matrices that were used to generate multi-dimensional scaling plots (MDS) using PRIMER (v.6). These plots illustrate the relative similarity of community structure at each site and between the two sampling years. We conducted separate analyses for 1) benthic cover of sessile and colonial invertebrates and encrusting algal species from UPC surveys, 2) macroinvertebrate and stipitate algae from benthic swath surveys, 3) fish assemblages from swath surveys, and 4) the entire community comprised of all these groups at each site. Dissimilarity matrices were generated to assess which species densities may have varied between years and contributed to clustering on MDS plots. We used a multivariate PERMANOVA to test for effects of MPA status and differences between years on community structure using UPC survey, benthic swath, and fish swath data. The mean densities and percent cover averaged over all transects at each site were used as replicates for this analysis.

Due to a variety of ecological factors- and results from other MLPA monitoring regions- we neither expected nor found any significant impact of MPA designation on changes in community structure over this initial two year period. However, the NCSR does contain the long standing SMR at Cabrillo Point, and this location *may* be indicative of the results of MPA designation for newly established MPAs in the future. Because of spatial differences in community structure across the NCSR and similarities in physical habitat characteristics, here we have used pairwise comparisons of the densities of the most abundant species between Cabrillo Point SMR and the adjacent reference site at Caspar Headlands to demonstrate possible outcomes of reserve designation for benthic cover, macroinvertebrates, and nearshore fishes.

We used a two factor ANOVA (year and site) to test for differences in densities of the most common species encountered during sampling. In particular we examined spatial and temporal variability in red abalone, red urchin, and purple urchin densities. Finally, we compared the results of commercial urchin diver surveys to the primary dive team's findings at the same- or nearby- sites using t-tests on the three above monitored species.

Baseline Characterization of NCSR Rocky Reefs

Spatial patterns in community structure

We found spatial and temporal variation in the overall community structure of subtidal rocky reefs across the entirety of the NCSR (Figure 2). Community structure at MPA sites was most similar to nearby reference sites, rather than other MPAs, demonstrating both the strong spatial component of community variation and the lack of "MPA effect" observable within the first few years of reserve designation. Similar patterns have been reported from the MLPA monitoring programs in the North Central Coast Study Region, Central Coast Study Region, and the northern Channel Islands. It appears there are three main regions of similar rocky reef community structure distributed across a latitudinal gradient within the NCSR.

The two sites north of Cape Mendocino- Pyramid Point SMR and the reference site at Trinidad, are quite distinct from a biotic perspective. We do caution oversimplification of this trend however, as these sites were sampled less frequently than all others during the study. Access to the site at Pyramid Point is difficult, and requires launching vessels across the border in Oregon. In addition, this site lies adjacent to the mouth of the Smith River, and discharge leads to frequent poor visibility at the rarely visited reefs at this site. To our knowledge, our transects at this site in 2015 were the first ever conducted. Increased effort here should provide a better snapshot of community structure in the future. The reference site, at Trinidad, while close to the hub of operations at Humboldt State University's Telonicher Marine Laboratory, also suffers from extended periods of low visibility diving conditions, making repeatable, consistent sampling outside of the protection of Trinidad Head difficult. Again, continued focus and increased sample size at this location will be important in future interpretation of spatial variability on community structure across the NCSR.

The three sites lying to the south of Cape Mendocino- Double Cone SMCA, the Abalone Point reference site, and Ten Mile SMR, tend to cluster together. Double Cone lies along the "Lost Coast" with no road access with the nearest ports at Noyo Harbor (over 25 miles to the south) and Shelter Cove (difficult vessel trailer access). Double Cone had less available rocky reef habitat than expected, and only two representative areas (cells) were sampled here. Again, it appears this was one of the first systematic surveys of the subtidal reefs in this area.

Finally, the sites in the Fort Bragg / Mendocino region tend to cluster together. In particular, the reference site at Caspar Headlands and the directly adjacent site in the long standing SMR at Cabrillo Point are quite similar in benthic topography and community structure, save differences in species abundances that are likely due to the reserve status at Cabrillo. We explore the relationship between these two sites in more detail below.

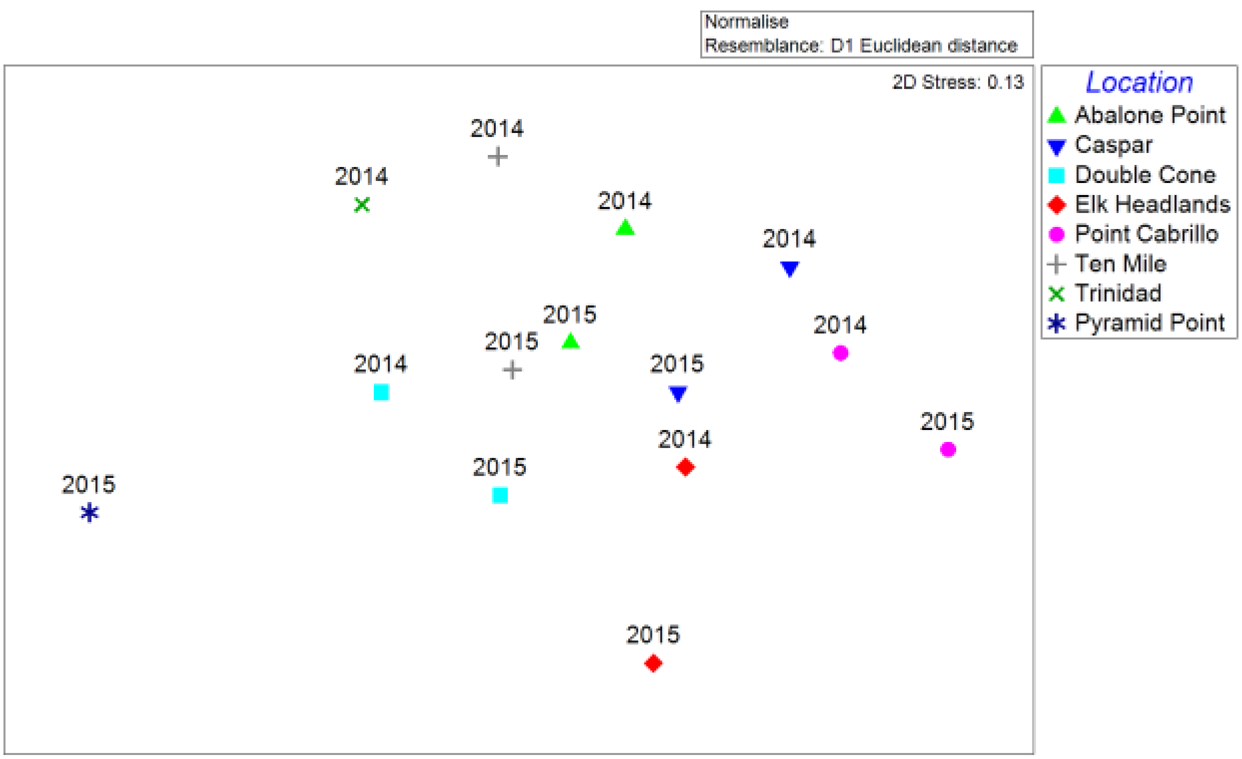

Figure 2. Multi-dimensional scaling plot (MDS) of community structure based on percentage of benthic cover, macroinvertebrates, macroalagae, and nearshore fish species combined. Each point represents the community sturcture at that site summed for each year. Points closer to eachother indicate closer similarity in community structure.

Spatial variation in physical characteristics

All survey locations were located on reef structure that were comprised of 80-90 % bedrock and large boulder habitat (Figure 3). None of the sites had reef structure with over 10% sand bottom within the survey cells. As such, it appears the selection of cells, and random transect locations within cells, was successful in allowing analysis of spatial and ecological variability across the region rather than being a function of geological variation. Reef rugosity was more variable between sites (Figure 4), with some locations at Double Cone, Ten Mile, and Elk Headlands containing more vertical structure because surveys were conducted along walls or offshore pinnacles. It is possible these high relief locations may harbor slightly different abundances of some species, but none of these sites contained all transect locations on vertical habitat, and thus were likely to skew interpretation of observed spatial patterns in community structure.

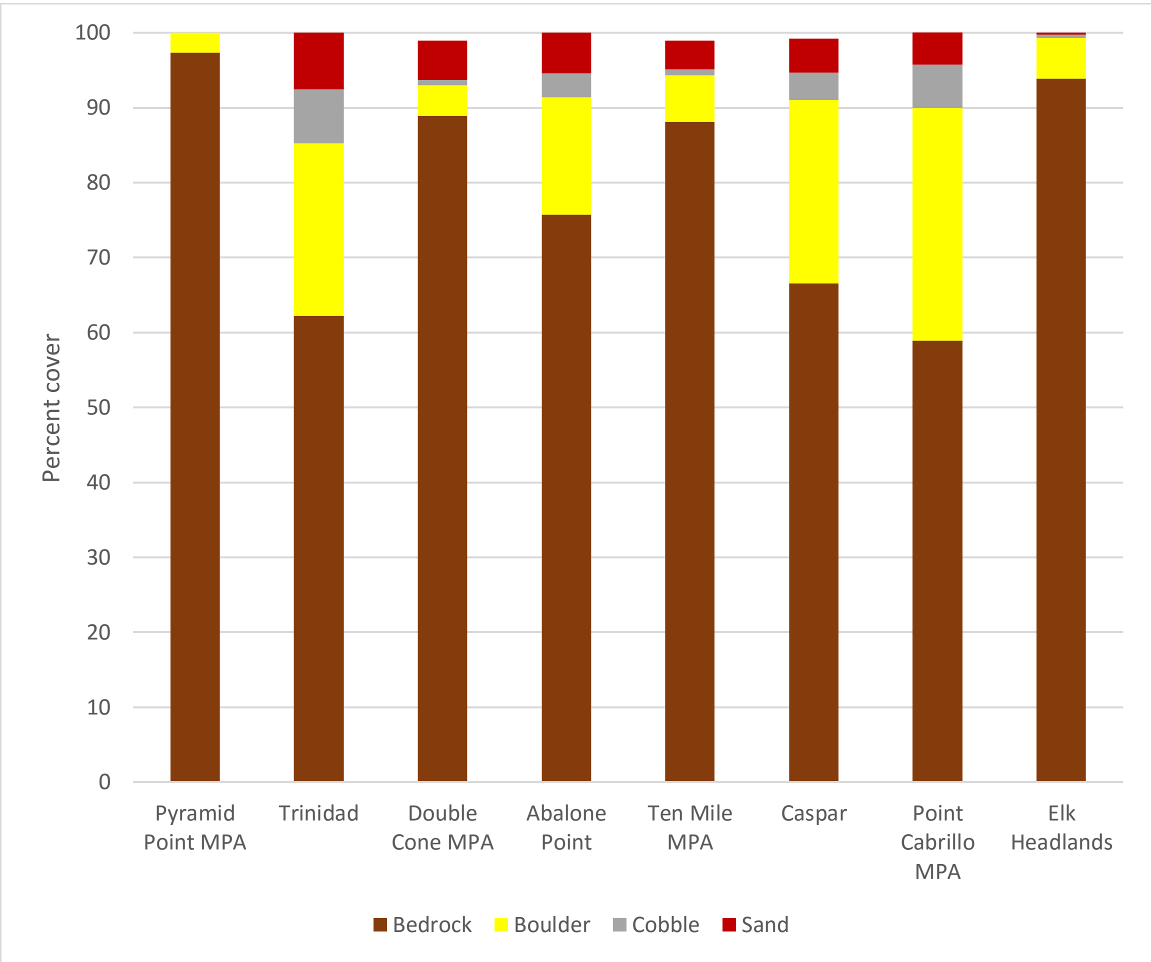

Figure 3. Mean percent cover of the four substrate types estimated during UPC diver surveys at all sites. Data represent means from all surveys within all cells at all depths at each site.

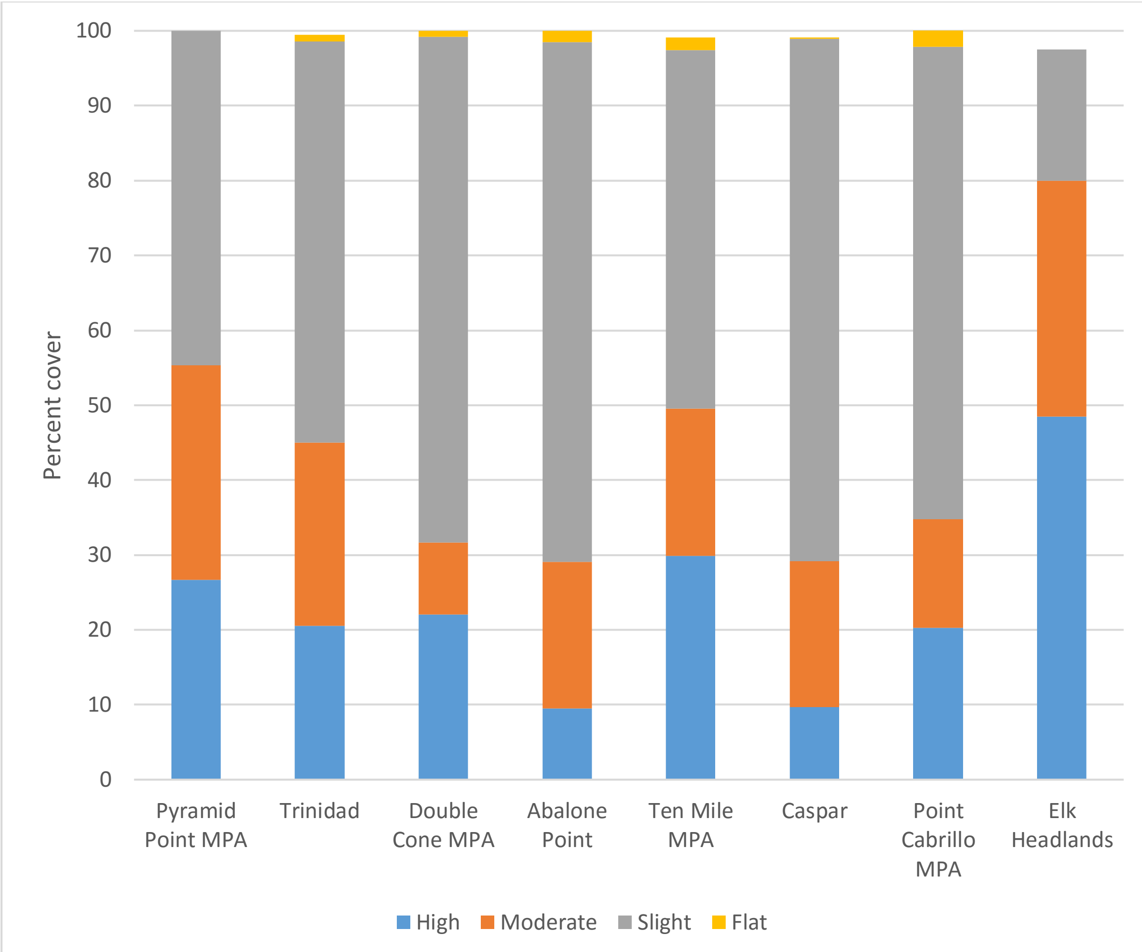

Figure 4. Mean percent of the four categories of vertical relief estimated during UPC diver surveys at all sites. Data represent means from all surveys within all cells at all depths at each site.

Spatial and temporal variation in benthic cover

Benthic cover of the nearshore rocky reefs was dominated by coralline and encrusting red algal species. However, this varied between sites and years. There is a strong latitudinal gradient in crustose coralline algal cover, with cover increasing from north to south across the NCSR (Figure 5). The two sites north of Cape Mendocino had increased variation in percent cover of benthic species when compared to sites to the south. In contrast, over 60% of benthic cover consisted of encrusting/erect coralline and encrusting red algal species at the three most southern sites.

From a benthic community perspective patterns of similarity match closely with the overall patterns which included all measured species, with sites within the three regions described above clustering closer to each other and further from other sites or between MPA and reference sites (Figure 6). Sites also clustered closer to each other between years although there was evidence of some variability in benthic percent cover between 2014 and 2015. However, these between year differences were not significant, nor was the difference in benthic community assemblages between MPA and reference sites (Table 2).

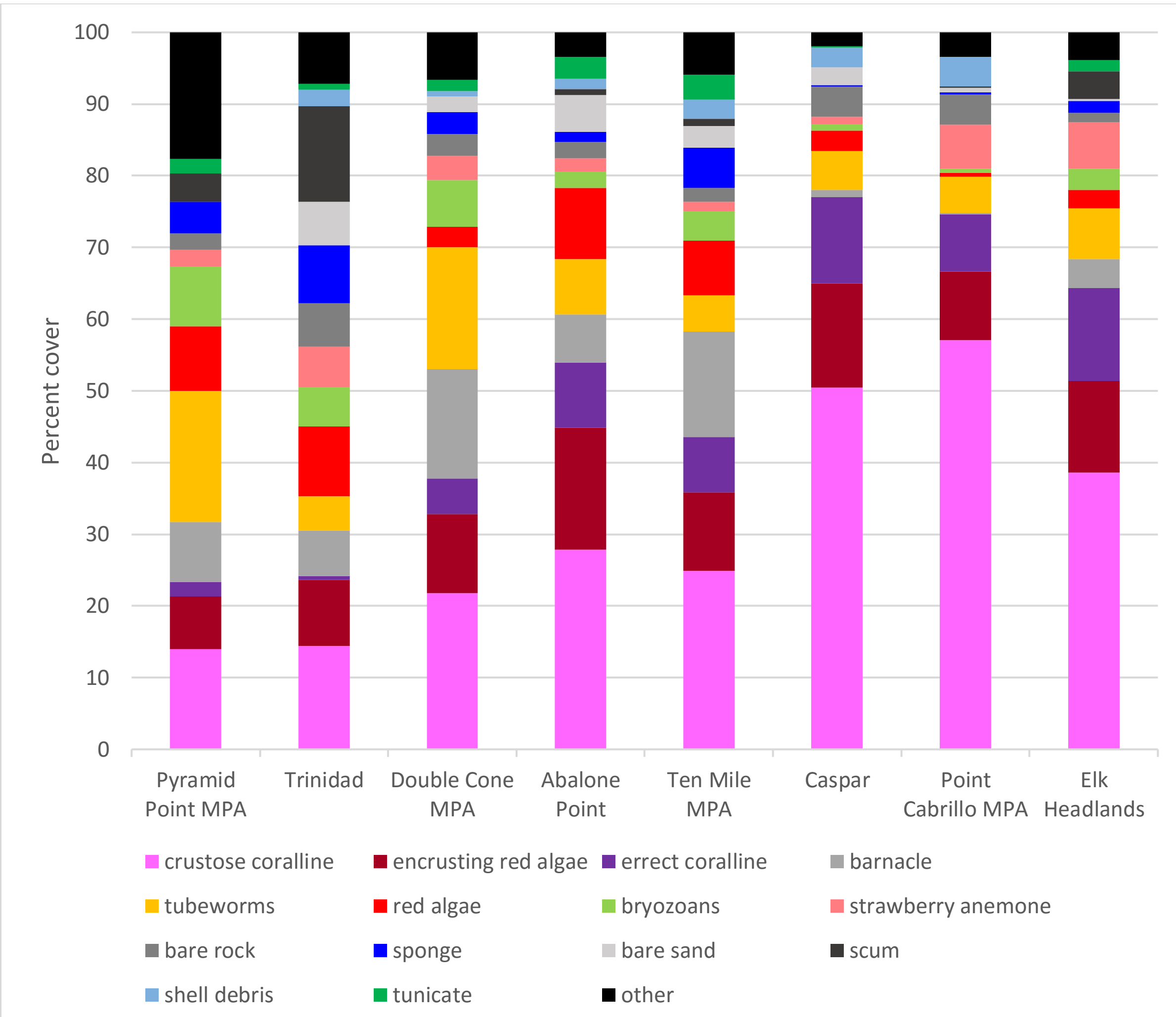

Figure 5. Mean percent cover of the 15 most abundant algal, sessile and colonial invertebrate, and non-living groups estimated during UPC diver surveys at all sites. Data represent means from all surveys within all cells at all depths at each site.

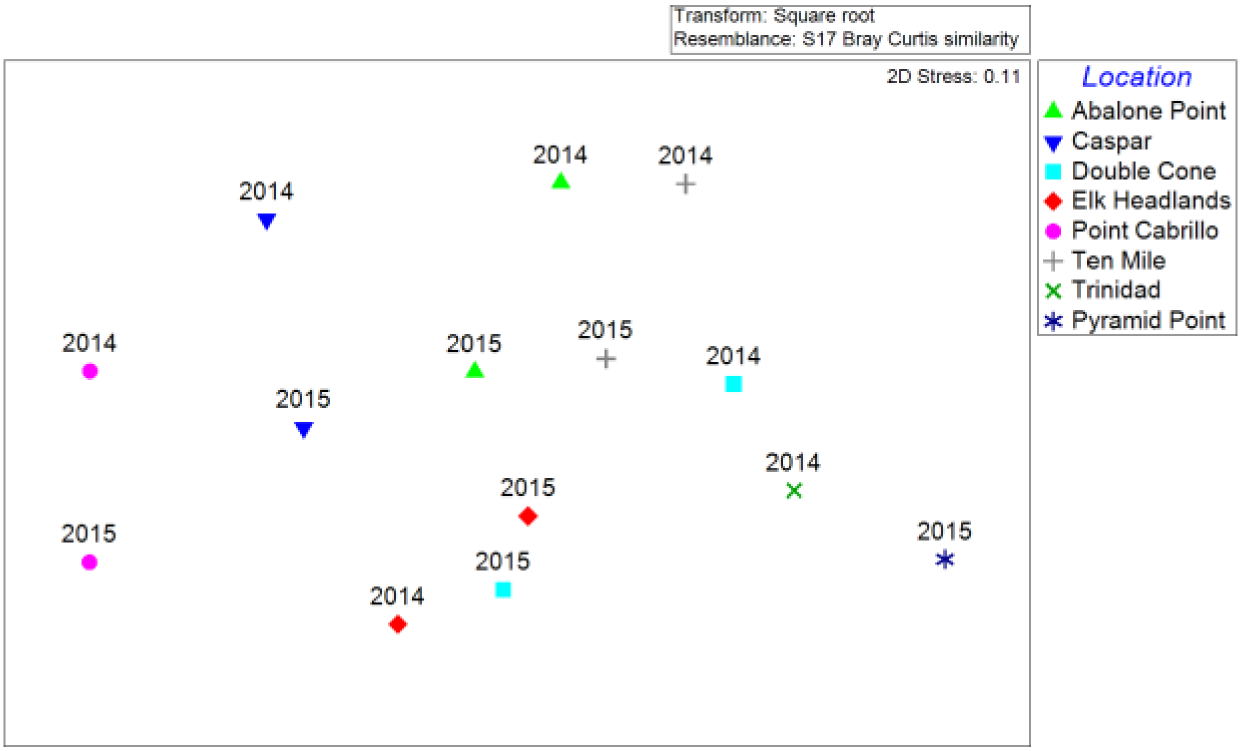

Figure 6. Multi-dimensional scaling plot (MDS) of community structure based on the percent cover of sessile and colonial invertebrates and turf algal species estimated on UPC surveys. Each point represents the community sturcture at that site summed for each year. Points closer to each other indicate closer similarity in community structure.

Spatial and temporal variation in macroinvertebrate and algal abundance and species composition

The most abundant macroinvertebrates of the NCSR subtidal rocky reefs were red and purple sea urchins (Figure 7), although this again varied across space, and to a lesser extent between years. The two northern sites at Pyramid Point and Trinidad were quite distinct in macroinvertebrate community structure, with low urchin abundances and greater densities of *Metridium* and giant green anemones (*Anthopleura xanthogrammica*). The three mid-region sites were quite similar in macroinvertebrate structure with increased stalked tunicate and acorn barnacle densities. The southern sites were dominated by both urchin species, and urchin densities were almost twice as high within the Cabrillo SMR when compared to all other sites.

The assemblage of stipitate algal species along the NCSR exhibited the most disparate spatial pattern of all measured groups (Figure 8). In general, algal communities were dominated by Laminaria and Pterygophera, although the relative density of each varied between sites. The lowest macroalgal abundances were observed at Cabrillo SMR, likely a consequences of the high sea urchin abundances observed here. The canopy forming kelp of the region, *Nereocystis* *leutkeana*, was not encountered in large numbers at any sites, and “kelps forests” were rare at all sampling sites.

Spatial analysis of these macroinvertebrate and algal communities again revealed three relatively distinct site groupings along a latitudinal gradient within the NCSR (Figure 9). The same sites generally clustered closer together between years and the direction of temporal change varied between sampling years, indicating no major changes in community structure between years. There was no significant differences in these communities at reference versus MPA sites or between the two sampling seasons (Table 2). However, of the changes measured, an increase in purple urchin abundance in 2015 accounted for 15% of the difference between community structure (Table 3). This trend has been observed by both CDFG (pers. comm.) and local commercial urchin harvesters.

It should be noted that Asteroid densities, particularly *Pisaster ochraceus* and *Pycnopodia helianthoides*, were significantly decreased within the NCSR during the sampling period due to a “wasting” disease (Sea Star Wasting Syndrome-SSWS) that lead to massive mortality of these species across the region- and the entire state. The ecological ramifications of this disease subtidally remain unknown from a community perspective. Although there is some evidence that *P. helianthoides* can alter small scale urchin distribution patterns due to predation pressure, there is no evidence that this interaction can lead to large scale variation in community structure.

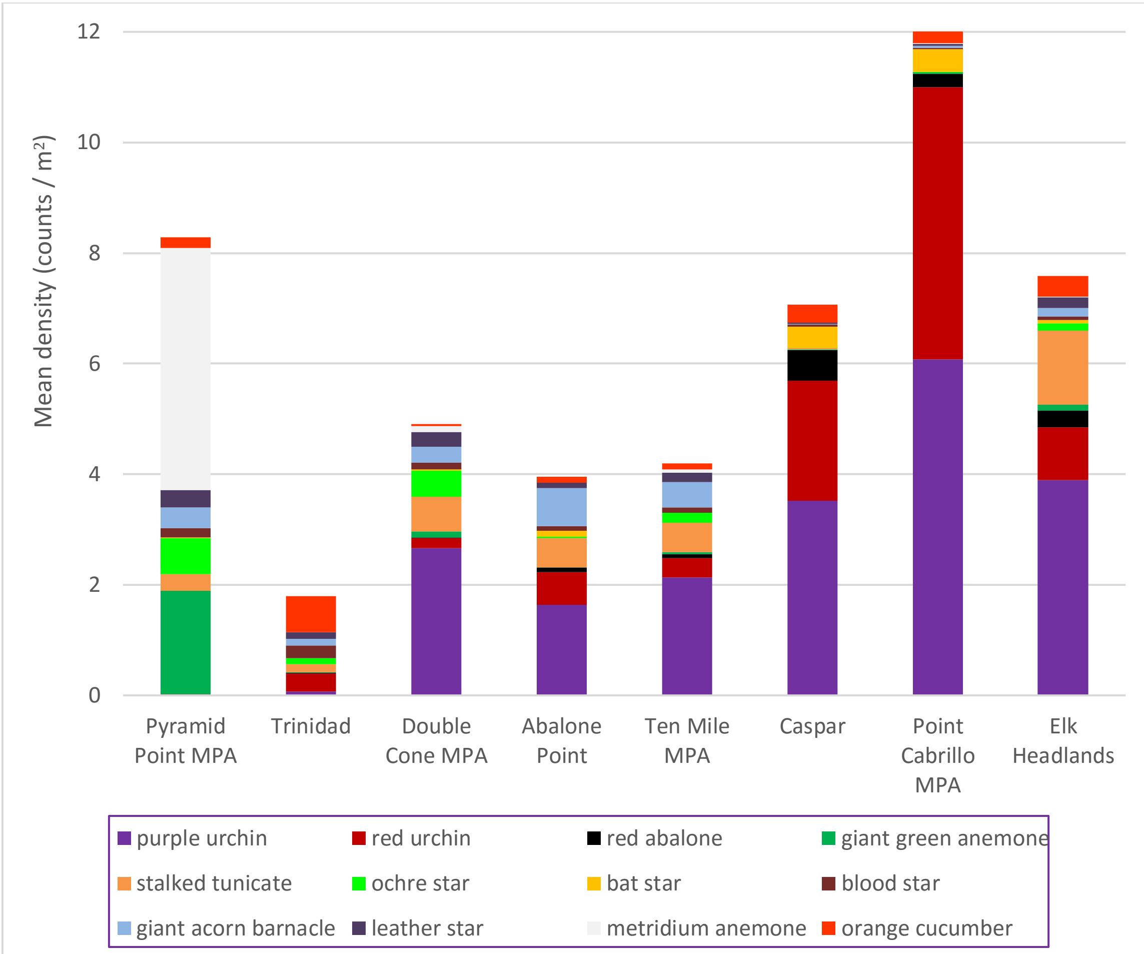

Figure 7. Mean densities of the 12 most abundant macroinvertebrate species enumerated during benthic swath surveys at all sites. Data represent means from all surveys within at cells at all depths at each site.

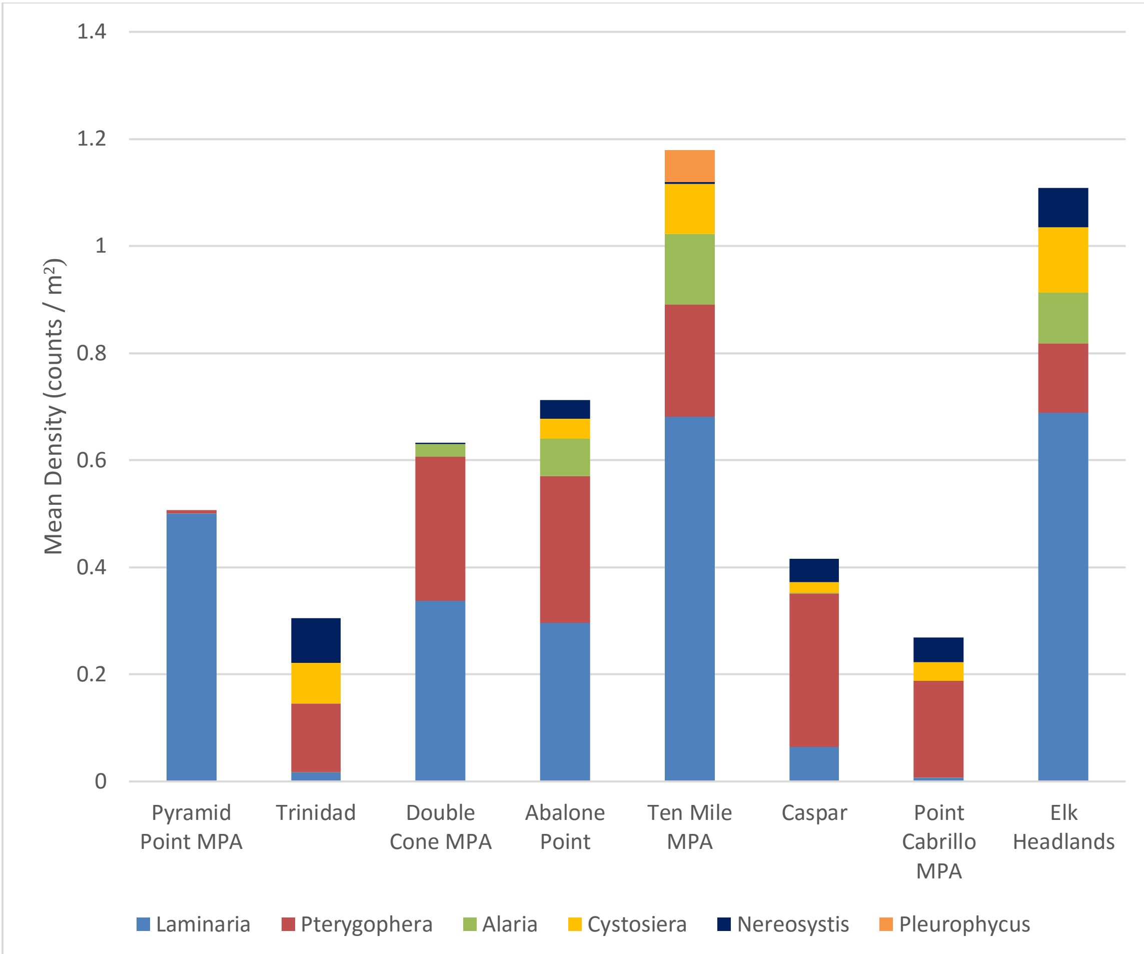

Figure 8. Mean densities of the six most abundant macroalgal species enumerated during benthic swath surveys at all sites. Data represent means from all surveys within at cells at all depths at each site.

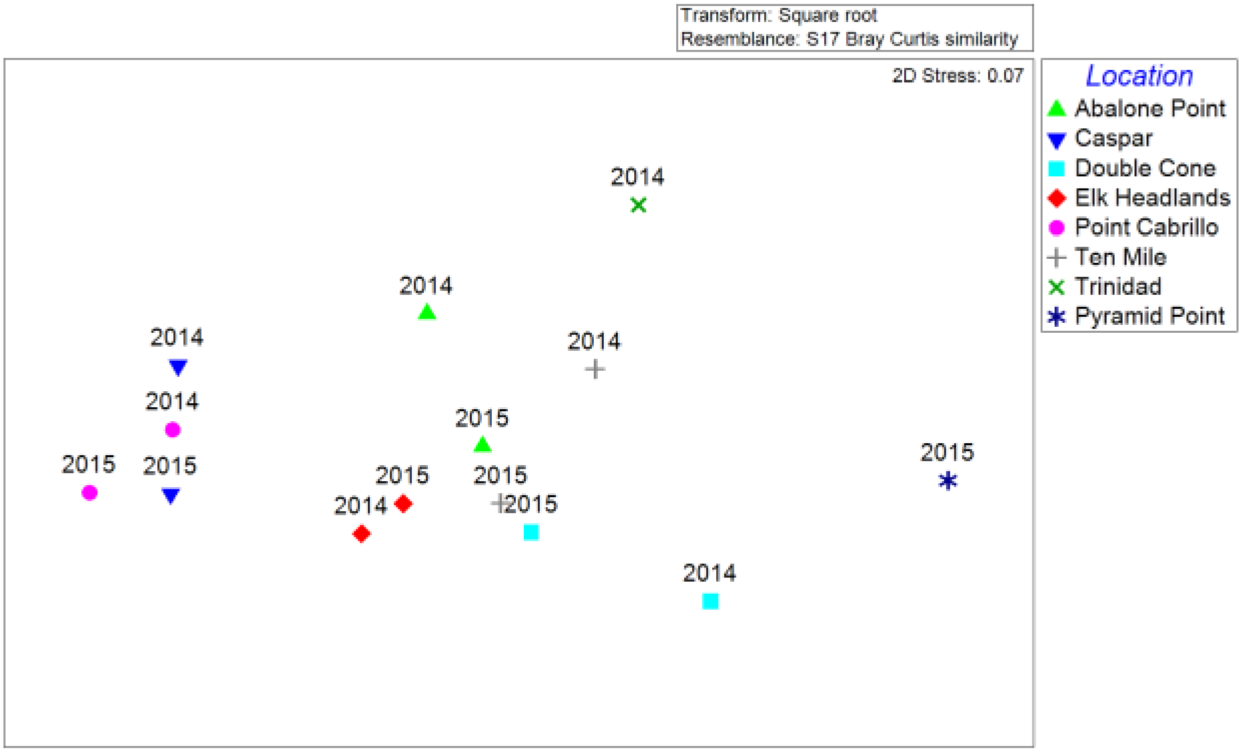

Figure 9. Multi-dimensional scaling plot (MDS) of community structure based on the abundance of macroinvertebrates and stipitate algal species recoreded on benthic swath surveys. Each point represents the community sturcture at that site summed for each year. Points closer to each other indicate closer similarity in community structure.

Spatial and temporal variation in fish abundance and species composition

There was a strong latitudinal gradient in the relative abundance of the two most common adult fish species observed (Figure 10). Black rockfish generally decreased in abundance from north to south, while blue rockfish exhibited the opposite pattern. At all sites these two species accounted for over half of the observed adult fish on swath surveys. Of particular interest is the high density of black rockfish at Pyramid Point SMR. This site was a well-known black rockfish "hotspot" for the live fish fishery out of Crescent City, CA prior to MPA designation. The densities of rockfishes at the long term SMR at Cabrillo Point are almost double those observed at other sites. Although this is a single location, it is possible this is a reflection of MPA designation and decreased fishing pressure at this site. The next most common nearshore reef fish species, the kelp greenling, was found in similar densities across the entire region.

The three groupings of sites observed within communities of benthic invertebrates and algae across the NCSR again emerge in MDS plots of adult fish assemblages (Figure 11). However, an interesting temporal pattern emerges with the addition of YOY rockfish to the MDS analysis (Figure 12). While the spatial site groupings remain similar, a significant year difference is detectible (Table 2). This is the result of two factors in 2015- 1) a large pulse of KGB (kelp, gopher, black and yellow rockfish) recruits were observed, which accounted for over 20% of the observed fish assemblage differences between years, and 2) a decrease from an average ca. 8 to 5 blue rockfish observed per survey, again accounting for about 20% of the variability between years (Table 3). In addition, black rockfish densities decreased between years, although whether this is a consequence of decreased adults or YOY is difficult to distinguish due to reasons discussed within the Methods.

We did not measure oceanographic characteristics of the nearshore rocky reefs as part of this monitoring program, but water temperatures were elevated in 2015 due to the presence of the warmer subtropical water pushing northward along the Pacific coast (a phenomenon termed the "warm blob"). How this variation in sea surface temperature impacted fish population dynamics is unknown.

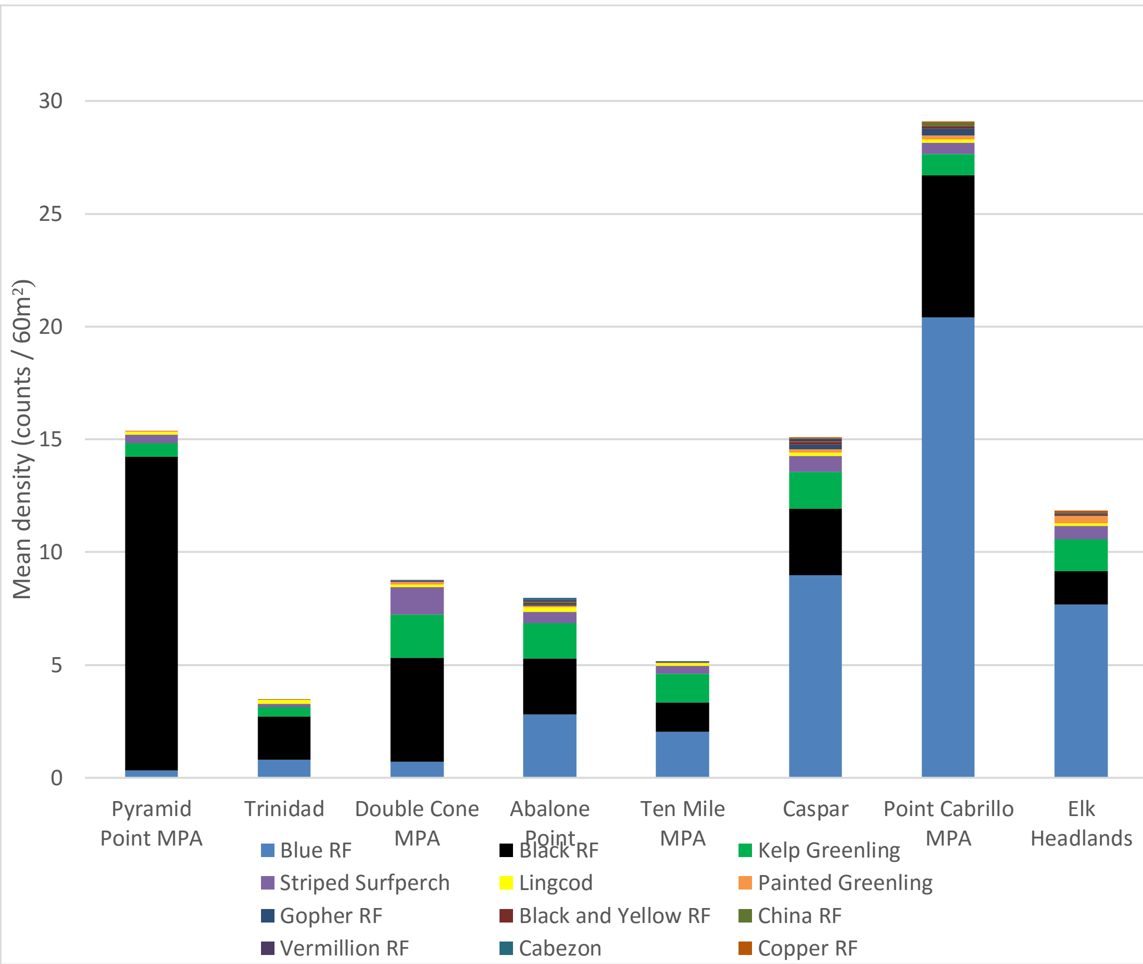

Figure 10. Mean densities of the 12 most abundant fish species enumerated during swath surveys at all sites. Data represent means from all surveys within all cells at all depths at each site. Young of the year rockfish are excluded from data presented here.

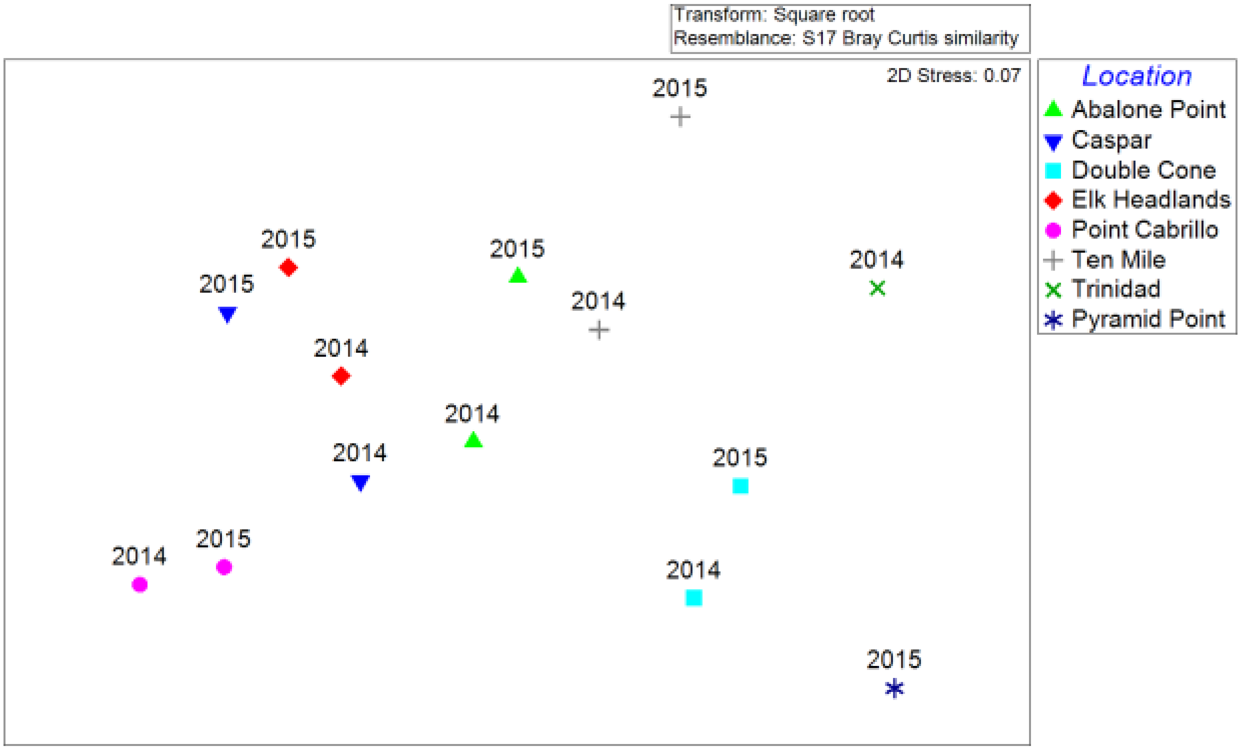

Figure 11. Multi-dimensional scaling plot (MDS) of community structure based on surveyed fish assembledges including only adult sized fish (excluding young of the year rockfish species). Each point represents the community sturcture at that site summed for each year. Points closer to each other indicate closer similarity in community structure.

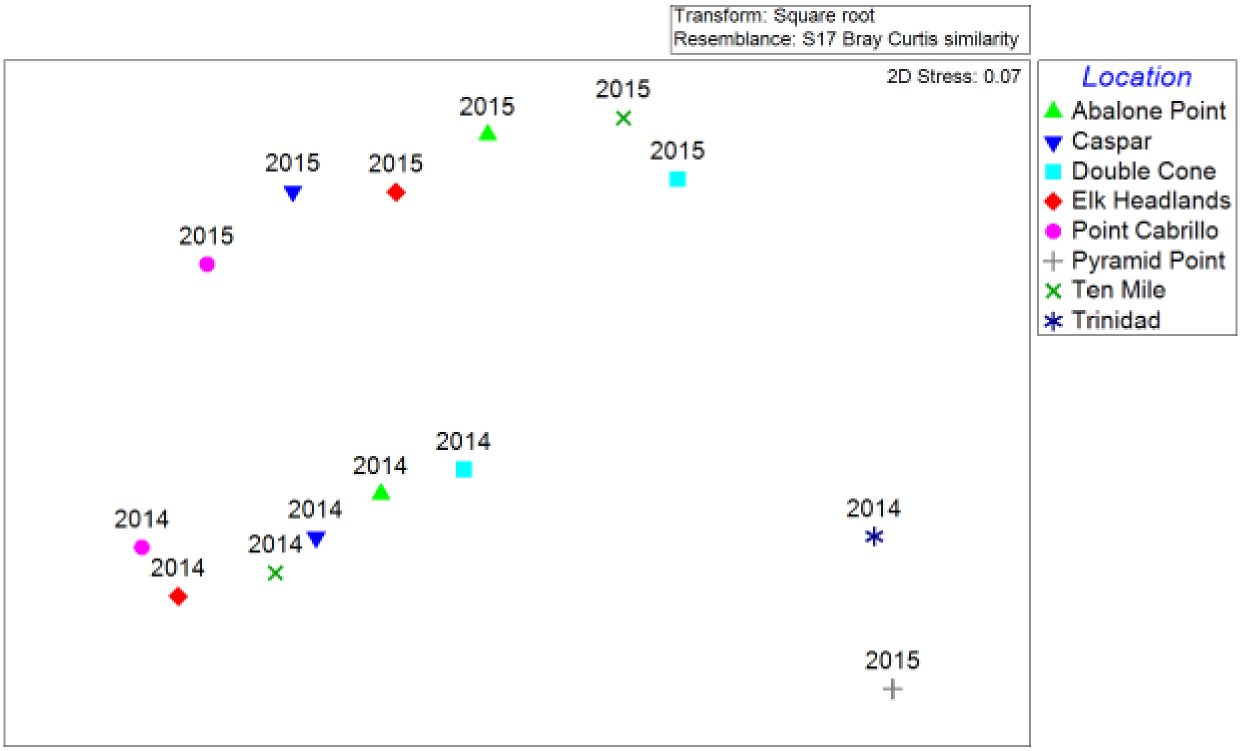

Figure 12. Multi-dimensional scaling plot (MDS) of community structure based on surveyed fish assembledges. Each point represents the community sturcture at that site summed for each year. Points closer to each other indicate closer similarity in community structure.

Spatial and temporal patterns of sea urchin and abalone abundance

The abundance of both sea urchins and red abalone tended to increase along a latitudinal gradient from north to south, with the highest densities of all three species measured in the southern cluster of sites. There was a significant difference between the sites for all three species (Table 4). The variance in abundance between individual surveys was large at many sites, and we used standard deviation to demonstrate this spread on Figures 13-15. For analysis purposes we included data collected during both benthic swath surveys and additional surveys targeting both urchin species and red abalone.

The highest purple sea urchin densities were measured within the SMR at Cabrillo Point (Figure 13). However, counts of over 1000 individual purple sea urchins per 30 m transect were recorded at all sites south of Cape Mendocino. The density of purple sea urchins was significantly higher in 2015 (Table 4), more than doubling across all sites from a mean of 0.89 / m^2 in 2014 to 1.85 / m^2 in 2015 (Table 3). This trend has been observed by both CDFG (pers. comm.) and local commercial urchin harvesters, and appears to have continued into 2016 (see below). There was a significantly higher density of purple urchins within the Cabrillo SMR compared to Caspar (Figure 16; $t_{89} = -2.644$, $p = 0.01$) when data was combined across all depths and between years.

Red sea urchin densities were highest at the two adjacent sites at Caspar and the Cabrillo Point SMR, and uniformly similar across all other sites (Figure 14). Within these two sites, red urchin densities were significantly higher within the Cabrillo SMR (Figure 16; $t_{89} = -2.991$, $p = 0.004$). The cause of increased red urchin densities within the SMR at Cabrillo is potentially the consequence of loss of harvesting pressure by commercial interests at this site. However, it is unclear why densities are also elevated at the adjacent reference site at Caspar. There was no measurable difference in red urchin abundance between the two survey years (Table 4).

Red abalone were most abundant at the three sites of the southern cluster (Figure 15). Of those three sites, the SMR at Cabrillo had the lowest densities. There was no measurable difference in red abalone abundance between the two survey years (Table 4). Although mean densities of red abalone were higher at Caspar ($0.44 \pm 0.563 / m^2$) compared to Cabrillo SMR ($0.248 \pm 0.126 / m^2$), this difference was only marginally significant (Figure 16; $t_{89} = 1.821$, $p = 0.072$).

There were significant, and interesting, differences in the data collected by the primary NCSR Monitoring Program team and commercial urchin harvesters as part of an effort to increase stakeholder and public participation in the overall MPA monitoring program. At all three of the sites surveyed by both groups purple urchin densities were over ten times higher, as measured by commercial urchin divers, in 2016 (Figure 17, Table 5). It is difficult to tease apart any differences or biases in these survey results between the groups, however, as there is a temporal trend of increasing purple urchin densities that begin in 2015 and continued in 2016. Conversely, red sea urchin counts were not significantly different between the groups at all three sites (Figure 18, Table 5). Finally, commercial diver estimated red abalone densities were significantly lower than those recorded by the primary dive team (Figure 19). This is likely a consequence of bias and lack of experience in scientific survey methods by the commercial divers.

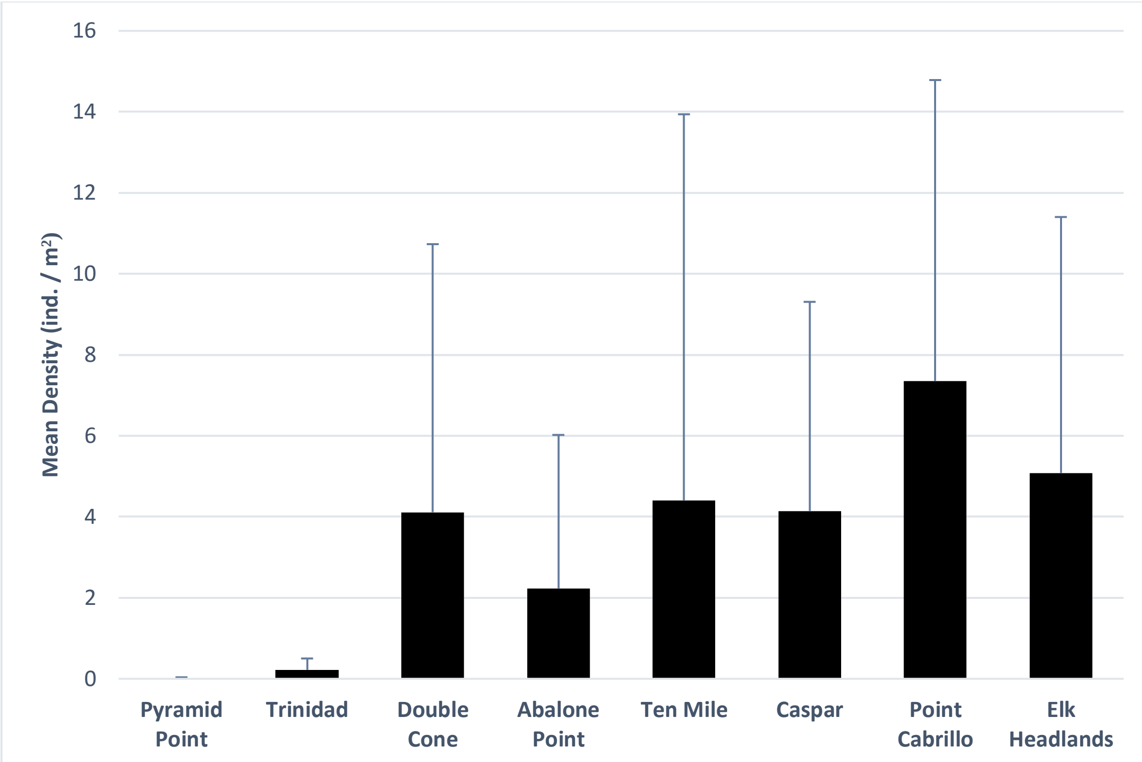

Figure 13. Mean density of **purple sea urchins** enumerated during both benthic swath and targeted urchin and abalone surveys. Densities represent means of all transects at all depths within each cell in 2014 and 2015. Error bars indicate a single standard deviation from the mean densities.

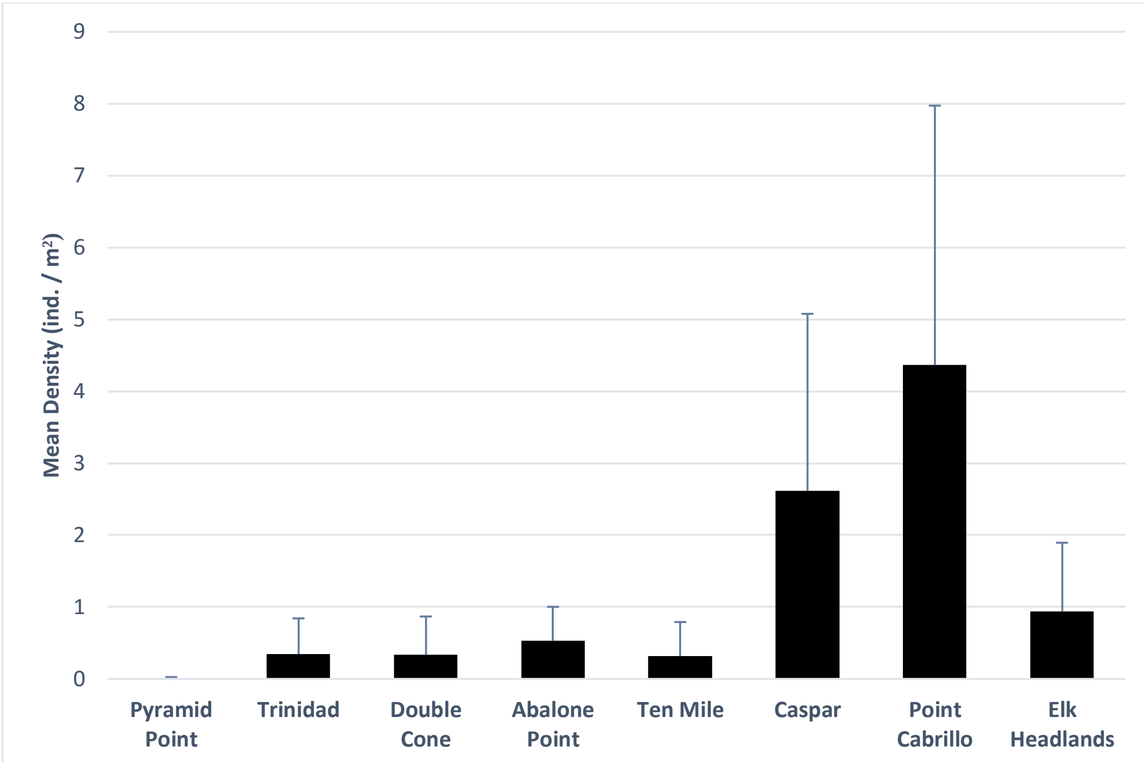

Figure 14. Mean density of **red sea urchins** enumerated during both benthic swath and targeted urchin and abalone surveys. Densities represent means of all transects at all depths within each cell in 2014 and 2015. Error bars indicate a single standard deviation from the mean densities.

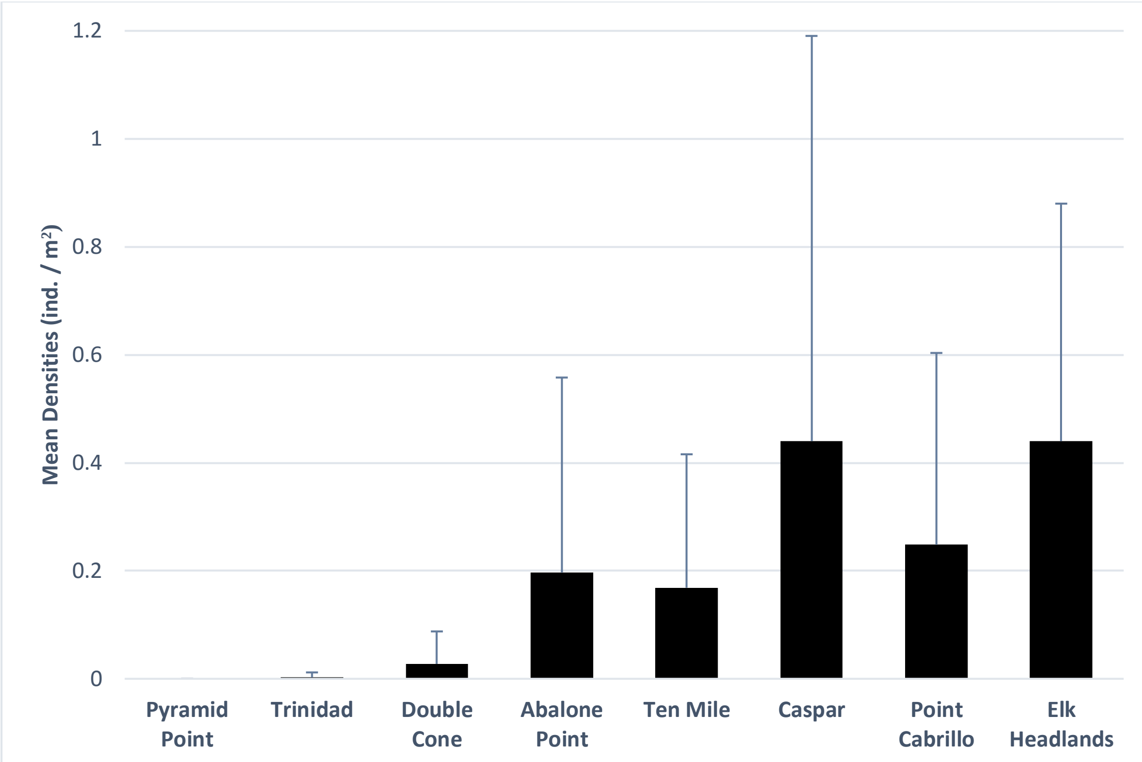

Figure 15. Mean density of **red abalone** enumerated during both benthic swath and targeted urchin and abalone surveys. Densities represent means of all transects at all depths within each cell in 2014 and 2015. Error bars indicate a single standard deviation from the mean densities.

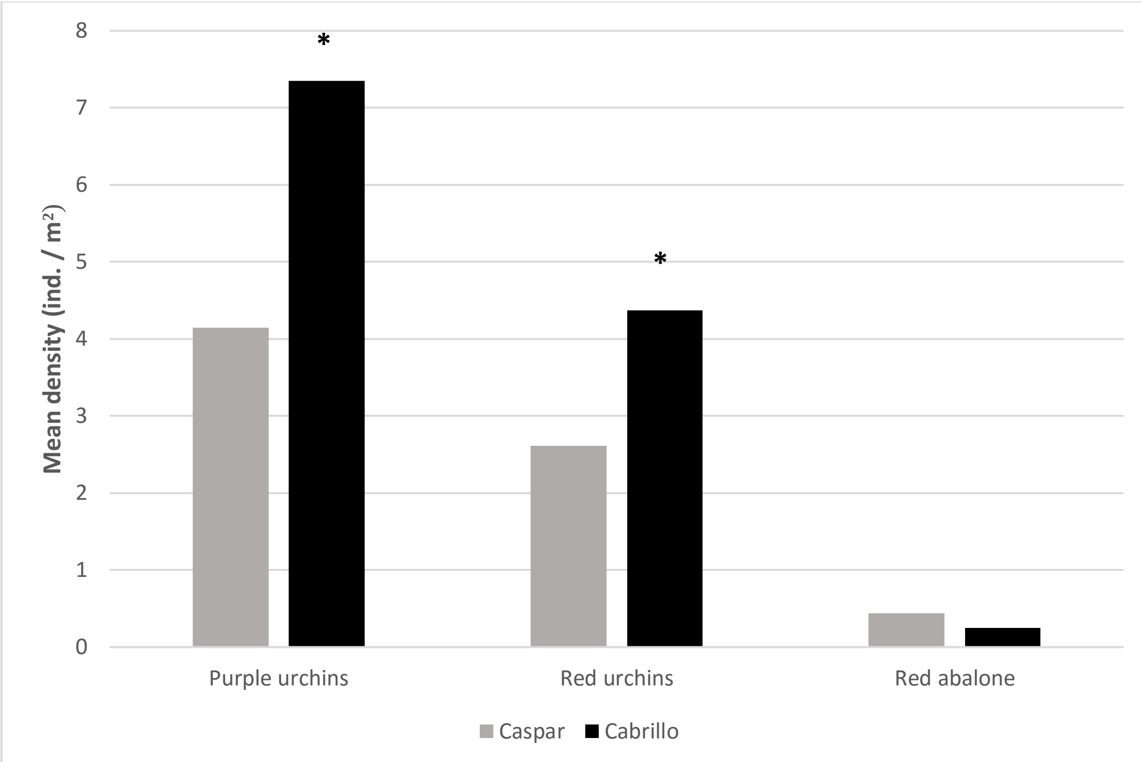

Figure 16. Comparison of purple sea urchins, red sea urchins, and red abalone densities at the adjacent Caspar reference site and the Point Cabrillo SMR site. Densities represent means of all transects at all depths within each cell in 2014 and 2015. See figures 13-15 for estimates of variance- SD bars removed from this figure so that mean differences were more apparent. * symbol denotes significant difference in density between the two survey types ($p < 0.05$).

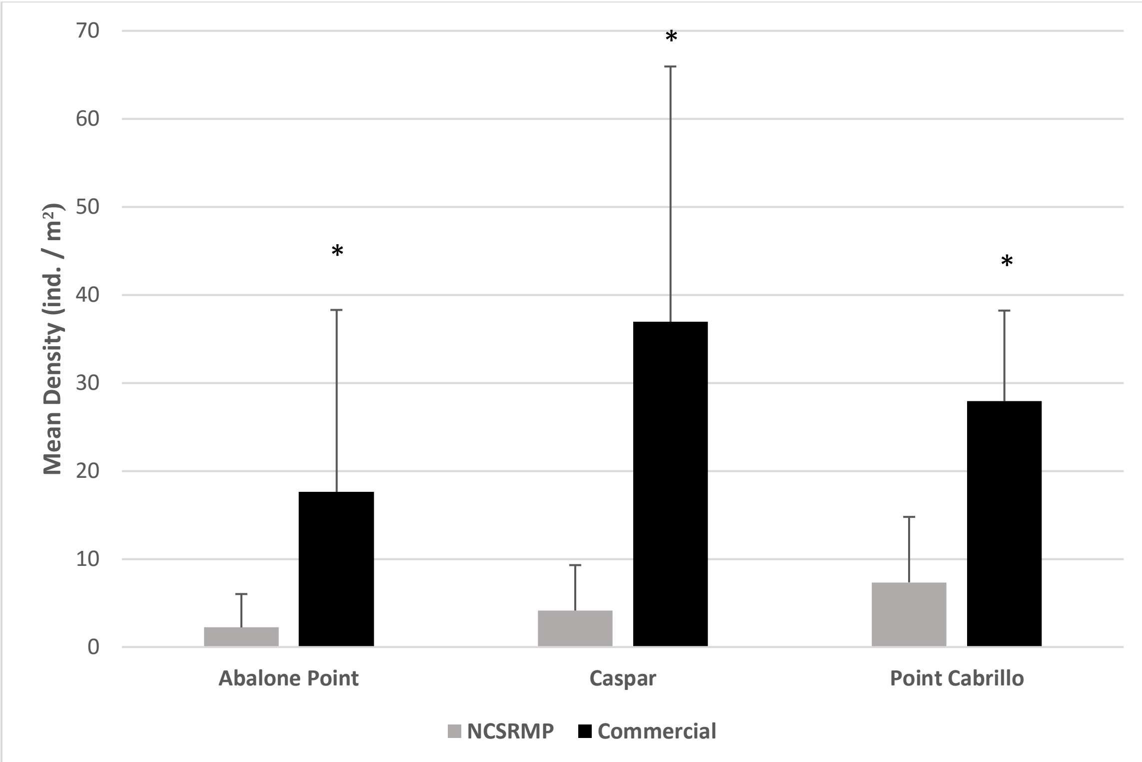

Figure 17. Comparison of mean purple sea urchin densities estimated at three sites by the North Coast Study Region Monitoring Program (NCSRMP) and commercial sea urchin divers. Sample size is not equal between survey groups. Error bars indicate a single standard deviation from the mean. * symbol denotes significant difference in density between the two survey types ($p < 0.05$).

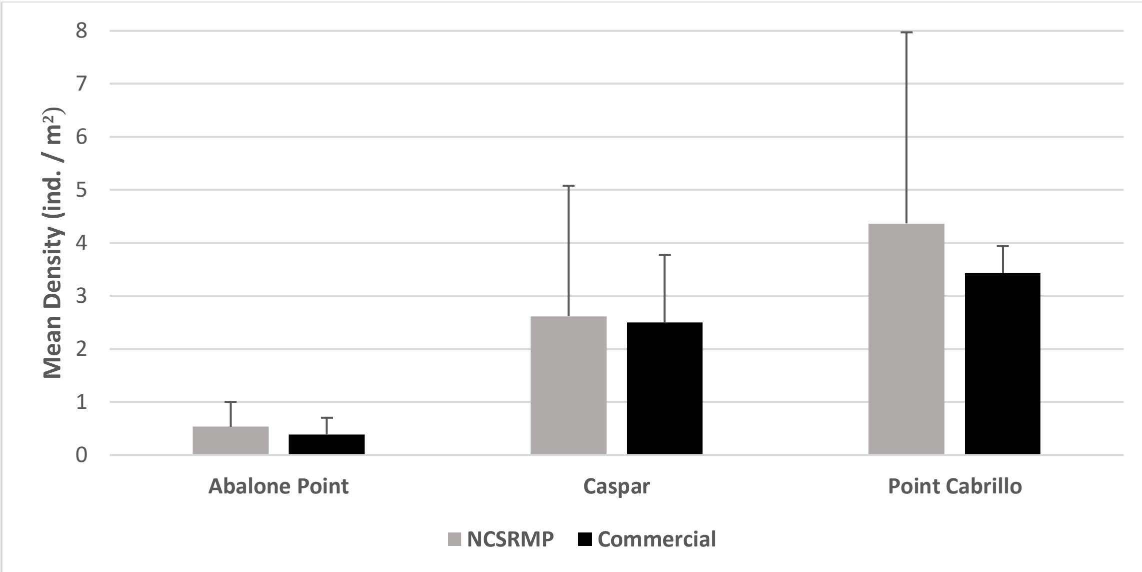

Figure 18. Comparison of mean red sea urchin densities estimated at three sites by the North Coast Study Region Monitoring Program (NCSRMP) and commercial sea urchin divers. Sample size is not equal between survey groups. Error bars indicate a single standard deviation from the mean. * symbol denotes significant difference in density between the two survey types ($p < 0.05$).

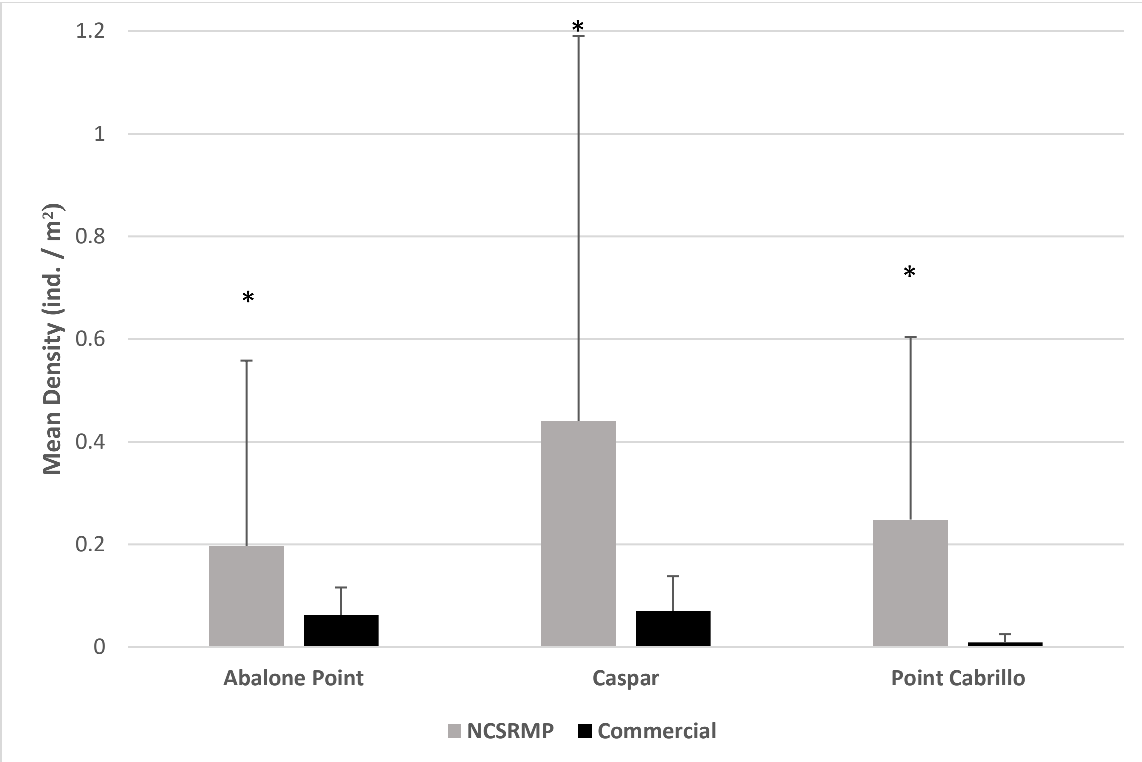

Figure 19. Comparison of mean red abalone densities estimated at three sites by the North Coast Study Region Monitoring Program (NCSRMP) and commercial sea urchin divers. Sample size is not equal between survey groups. Error bars indicate a single standard deviation from the mean. * symbol denotes significant difference in density between the two survey types ($p < 0.05$).

Conclusions and Recommendations for Long Term Monitoring

Conclusions

Conclusion 1: Community structure, taken as a whole and for each individual group (biotic benthic structure, macroinvertebrates and algae, and fish), varied at sites across the NCSR and along a latitudinal gradient from north to south. In general, the sites clustered into three geographic regions: sites north of Cape Mendocino, sites immediately south of Cape Mendocino, and sites in the Fort Bragg /Elk Headlands area.

Comments: These findings imply that future monitoring efforts within the NCSR should not be conducted at a few sites- particularly easy to access beach sites at the southern end of the region- with results extrapolated across the region. Instead long-term monitoring efforts should be distributed across all three geographic clusters, with MPA and reference sites monitored within each area.

Conclusion 2: The chosen reference sites were generally most similar to their associated MPA sites, rather than clustering among disparate sites across the region.

Comments: These reference sites seem appropriate for continued long term monitoring. We suggest the possible addition of a reference site in the Mendocino Headlands area, between the Cabrillo MPA and the reference site at Elk Headlands, as the Elk site has slightly higher relief within some cells than other sites, including Cabrillo. An additional reference site closer to the Pyramid Point SMCA, likely within the Point St. George reef complex off Crescent City, CA could also act as means to increase sample size in the difficult to survey northern region of the NCSR.

Conclusion 3: The ecology and life history of the majority of subtidal rocky reef species requires more than a few years to detect significant changes in density or community structure. As such, we did not expect nor did we find major differences between MPA and reference sites so soon following MPA implementation.

Comments: Using these findings as a baseline of species abundance and community structure, continued long term monitoring will be necessary to detect changes in the ecology of these rocky reefs as a consequence of MPA status.

Conclusion 4: Interannual variability is a common aspect of nearshore rocky reef population dynamics. While macroinvertebrate and algal densities remained relatively consistent between years (with the exception of a 15% increase in purple sea urchin densities in the south), rockfish assemblages varied significantly, primarily as a function of increases and decreases in recruitment of various species.

Comments: A two year baseline survey cannot be used to predict future variation in reef dynamics, and interannual variability is a common and well described aspect of temperate rocky reef communities. Long term temporal trends can be examined as part of a continued long-term monitoring program at the same locations surveyed here.

Conclusion 5: The long term SMR at Cabrillo provides a possible glimpse into the ecological ramifications of MPA designation within the NCSR, particularly at the southern end of the region. With little upper trophic level predation in these systems, it is possible that the commercial harvest of sea urchins decreases grazing on macroalgae, leading to increased drift algal availability and red abalone abundances. Within the Cabrillo SMR, extremely high densities of sea urchins have created large swaths of "urchin barren" habitat. However, the reserve designation does appear to have led to increased fish abundances, particularly the commercially and recreationally fished rockfish species.

Comments: These observations are informative for expectations of changes in community structure within NCSR MPAs. We interpret these results with a few caveats: as mentioned above, the results at this southern end of the NCSR may not be generalizable across all sites within the region, and this is a single site comparison, thus additional survey effort over time will provide increased resolution as to the persistence of this variation between MPA and reference sites in the area.

Conclusion 6: Purple sea urchin densities increased between surveys in 2014 and 2015, and based upon commercial urchin diver collected data and anecdotal observations, also increased in 2016. It thus appears this trend is continuing. The proximate cause of this increased abundance of purple urchins is unknown, and may be the consequence of a recent large scale recruitment event or the reduction of the only local scale predator, *Pycnopodia* sea stars, within the NCSR.

Comments: As mentioned above, these nearshore reef communities experience some level of change between years, and 2-3 years of surveys may not adequately capture longer term trends. However, the increase in purple urchins has the possibility of leading to drastic community level changes due to this species' ability to form large grazing fronts or urchin barrens, similar to those observed within the Cabrillo Point SMR. Additional focused long term monitoring of this species, and the possible ecological ramifications of increased abundances, is warranted.

Conclusion 7: The efficacy of utilizing commercial urchin divers to collect data on subtidal reefs cannot be determined by the limited sample size and time allocated to the effort as part of this project.

Comments: There was variability in the abundance estimates of sea urchins and red abalone between the primary dive team and the commercial urchin divers. This can be explained by both temporal changes in species abundances (surveys were not conducted during the same years) and a possible lack of experience in scientific data collection. The regional experience and detailed local knowledge of these urchin harvesters greatly exceeds that of other volunteer, "citizen science” groups whose data are utilized by the MLPA Monitoring Program, and we suggest future efforts to include commercial stakeholders in long term monitoring projects, with additional training.

Recommendations for Long Term Monitoring

Our primary recommendation for future monitoring of subtidal rocky reefs of the NCSR are stated in Conclusion 1 above. Namely, future monitoring efforts should not be conducted at a few sites- particularly easy to access beach sites at the southern end of the region- with results extrapolated across the region. Instead long-term monitoring efforts should be distributed across all three geographic clusters, with MPA and reference sites monitored within each area, because these clusters contain unique marine communities.

Conclusion 2 provides suggestions for future monitoring sites. We recommend attempting increased effort in the northern part of the NCSR, with the possible addition of a reference site closer to the Pyramid Point SMCA, likely within the Point St. George reef complex off Crescent City, CA. Logistically, it would be beneficial to base monitoring activities out of HSU’s Telonicher Marine Lab in Trinidad, CA.

We recommend maintaining the same sampling protocol utilized in this study and by the other monitoring programs elsewhere in the state. An attempt should be made to sample each site each year. Based upon funding allocated and time limitations, it may be advisable to attempt only two “cells” per site. Due to the nature of dive conditions on the North Coast, pre-planned dive trips are near impossible, and monitoring teams must be available and ready to survey when conditions become amenable.

We also strongly recommend that further monitoring be handled by a well experienced, safety-first dive team with adequate infrastructure to access representative dive sites along the North Coast. Shore access surveys by citizen science divers at the southern end of the study region do not provide representative data for the NCSR, as multiple depth strata are usually not reached from shore entry and sites utilized by both recreational and commercial fishers cannot be accessed in this manner. The spatial, physical, and safety conditions encountered across the entire North Coast necessitate a professional and well trained research group, such as that present at HSU, to complete further monitoring in a cost effective manner. In addition, including commercial dive operators in long term monitoring can be an effective means by which to increase public participation why also utilizing the vast experience of these citizens. In the future commercial divers should be able to work in tandem with the professional research divers, diving off different platforms to avoid the insurance issues that plagued this project.

Finally, we recommend continued thorough characterization of the socioeconomically and ecologically important species found along North Coast rocky reefs, specifically describing population dynamics of two high priority species, red abalone (*Haliotis rufescens*) and red sea urchins (*Mesocentrotus franciscanus*), that are likely to be important metrics for assessing ecosystem health and change within the NCSR.

Acknowledgements

We would like to sincerely thank all participants in this monitoring enterprise. This was the largest systematic dive survey of the entire NCSR ever attempted, and this multifaceted team of research divers, graduate students, instructors, collaborators, and commercial fisherman made it possible.

Mark Carr- collaborator

Brian Tissot- collaborator

Johnathan Centoni- primary research diver

Frankie Moitoza- primary research diver

Chris Teague- primary research diver

Doug Simpson- primary research diver

Brett Stacey-primary research diver

Rich Alvarez- HSU Diving Safety Officer

Steven Monk- HSU Boating Safety Officer

Jon Holcomb- commercial urchin fisherman

Lyle Davis- commercial urchin fisherman

Harry Barnard- commercial urchin fisherman

Tim Moxon- research diver

Jolene Evans- research diver

Allison Lui- research diver

Maia Grodin- research diver

Jeff Bernard- research diver

Johnny Roche- research diver

Billy Ray- research diver

Jack Heimburger- research diver

Results of Statistical Analysis

Table 2. PERMANOVA results for community structure derived from data recorded during UPC, benthic swath, and fish surveys as part of the NCSR Monitoring Project.

	Source	df	Sum of Squares	Mean Square Error	Psuedo-F	P(perm)	# unique permutations
Benthic community structure	MPA	1	539.21	539.21	0.66224	0.673	999
	Year	1	786.12	786.12	0.96459	0.433	998
	MPA*Year	1	430.56	430.56	0.52881	0.829	998
	Error	10	8142.1	814.21			
	Total	13	9939.3				
Macro invertebrates and algae	MPA	1	943.21	943.21	0.8807	0.394	998
	Year	1	1227.2	1227.2	1.01458	0.305	998
	MPA*Year	1	399.95	399.95	0.37345	0.852	997
	Error	10	10710	1071			
	Total	13	13354				
Fish assemblages	MPA	1	357.78	357.78	0.66807	0.62	996
	Year	1	1837.5	1837.5	3.4311	0.016	999
	MPA*Year	1	804.65	804.65	1.5025	0.241	998
	Error	10	5355.4	535.54			
	Total	13	8336.2				

Table 3. SIMPER dissimilarity values for benthic macroinvertebrates and algae and fish communities derived from Bray-Curtis matrices between sampling years in 2014-2015. Listed are all species from each community that contributed at least 4% of the change in community structure between years. Mean dissimilarity of invertebrate and algal communities between the two years was 43.86; mean dissimilarity for fish communities was 37.26. Abbreviations for fish groups: KGB – kelp, gopher, black and yellow rockfish; BOYT- black and olive-yellowtail rockfish. This BOYT group includes a high percentage of young of the year black rockfish.

Community	**Species**	**Mean density**		**Mean dissimilarity**	**% contribution**	**Cumulative contribution**
		2014	*2015*			
Benthic invertebrates and algae	Purple urchins	0.89	1.85	6.35	14.48	14.48
	Red urchins	0.98	0.97	3.86	8.8	23.29
	Acorn barnacles	0.34	0.54	2.16	4.92	28.2
	Stalked tunicates	0.61	0.47	2.12	4.83	33.03
	Metridium anemones	0.15	0.32	1.9	4.32	37.35
Fishes	KGB	0.66	5.07	7.78	20.87	20.87
	Blue rockfish	8.12	5.63	7.43	20.04	40.91
	Black rockfish	8.87	5.17	6.82	18.31	59.23
	BOYT	5.12	2.92	5.62	15.09	74.32

Table 4. Results of two-way ANOVA examining differences in densities of purple urchins, red urchins, and red abalone between the two sampling years (2014 – 2015) and sites. Because of sampling only conducted in a single year and generally low densities of these species, data from Pyramid Point SMCA and Trinidad were omitted from this analysis. Significant results in bold.

	SS	**df**	**F**	**P**
Purple urchins				
Site	428.38612	5	34.07	**<0.0001**
Year	254.84724	1	4.054	**0.0017**
*Site * Year*	36.38264	5	0.5787	0.7163
Red urchins				
Site	398.7557	5	0.0239	**<0.0001**
Year	0.10325	1	18.4536	0.8774
*Site * Year*	24.99629	5	1.1568	0.3327
Red abalone				
Site	3.22317	5	3.0715	**0.0112**
Year	0.0031649	1	0.0151	0.9024
*Site * Year*	0.4650071	5	0.4431	0.8178

Table 5. Results of two-sample t-tests comparing measured densities of purple urchins, red urchins, and red abalone between data collected by the primary HSU dive team and commercial urchin divers at three sites within the NCSR. Significant results in bold.

	df	**t-statistic**	**p-value**
Abalone Point			
purple urchins	11	-2.57131	**0.02599**
red urchins	21	1.0224	0.2344
red abalone	56	2.4639	**0.0168**
Caspar			
purple urchins	7	-3.19494	**0.01517**
red urchins	15	1.0338	0.3176
red abalone	70	3.7213	**0.0004**
Cabrillo SMR			
purple urchins	3	-3.91266	**0.0297**
red urchins	38	1.67479	0.1022
red abalone	53	4.798783	**<0.0001**

Financial Report

Budget Category	Budget Amount	Actual Expenditures	Variance
Salary & Wages	$ 137,493	$ 140,655	2.30%
Fringe	$ 21,986	$ 18,238	-17.05%
Supplies & Equipment	$ 16,351	$ 16,304	-0.29%
Travel	$ 21,986	$ 45,247	105.80%
Total other	$ 24,000	$ 27,000	12.50%
Total direct costs	$ 247,441	$ 247,444	0.00%
Total indirect costs	$ 57,360	$ 57,360	0.00%
TOTAL	$ 328,801	$ 331,804	-7.30%

Salary and benefits- Salary estimates closely matched expenditures, although fringe benefits were lower than expected due to the seasonal, short term employment of the field technicians on this project.

Travel- Travel expenditures were significantly higher than those originally expected. Due to the remote nature of many of the dive sites and the long distance to the primary access port at Fort Bragg, CA from the base of operations in Trinidad, CA, the project rented a house in the Caspar Headlands area for both summer sampling seasons. This allowed for quicker access to moored vessels, less dangerous towing of vessels, and quick response to short weather windows.

Other costs- Due to insurance and logistical reasons, the original budget for including commercial sea urchin divers as part of the project was subcontracted to a local consulting firm. However, the firm was unable to complete the project, and we re-acquired the funds on very short notice at the end of the project in 2016 to make sure we included these local stakeholders in the monitoring process.