# BASELINE CHARACTERIZATION OF FISH COMMUNITIES ASSOCIATED WITH NEARSHORE ROCKY REEFS IN THE NORTHERN CALIFORNIA MARINE PROTECTED AREA STUDY REGIONS

Final Report Submitted to the Ocean Protection Council
and
California Sea Grant

By


| | |
|---|---|
| Tim Mulligan | Humboldt State University |
| Joe Tyburczy | California Sea Grant |
| Jay Staton | Humboldt State University |
| Ian Kelmartin | Humboldt State University |
| Drew Barrett | Humboldt State University |


February 2017

## Table of Contents

## List of Tables

**List of Figures**

## Executive Summary

The North Coast Marine Protected Area (MPA) Study Region extends over 400 kilometers of coast from Alder Creek in Southern Mendocino County to the California-Oregon border; encompassing some of California's most rugged and rural coastline. The region contains three protected ports with full vessel services (Crescent City, Eureka, and Fort Bragg), plus two semi-protected mooring basins with small boat launching capabilities at Trinidad and Shelter Cove, and a marina that can berth small boats on the Albion River.

The nearshore rocky reef habitat along the North Coast supports a diverse assemblage of culturally, ecologically, and economically important fishes. These include the Rockfishes (*Sebastes spp.*), Lingcod (*Ophidion elongatus*), and Cabezon (*Scorpaenichthys marmoratus*) which support recreational and commercial fisheries (Figure 1). Many of these rocky reef associated fishes are slow growing, long lived, and mature late in life, making them particularly susceptible to overfishing and, if depleted may require prolonged recovery periods. Our objective was to establish a baseline dataset for nearshore rocky reef fish assemblages in order to facilitate future monitoring and assessment of the North Coast MPA network.

Figure 1. Commonly captured fishes from hook and line sampling, 2014-2015. Clockwise from top left; Yelloweye rockfish (*Sebastes ruberrimus*); Yellowtail rockfish (*Sebastes flavidus*); Cabezon (*Scorpaenichthys marmoratus*); Lingcod (*Ophidion elongatus*).

To characterize the fish communities associated with nearshore rocky reef habitat, we collaborated with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to conduct hook-and-line surveys in four pairs of MPA and reference sites. Sampling was conducted with scientific crews of six: four anglers, a sampler who handled, measured, and tagged fish, and a data recorder. Each of the four anglers used a different combination of baited or un-baited lures that represented gear frequently used by recreational anglers to catch the target species. Sites were sampled by fishing for 45 minutes in each of four, 500 meter by 500 meter sampling cells, which were randomly selected from a set of cells that covered bottom areas containing at least 20 percent rocky reef habitat, by area. Captains were directed to drift within the cells over areas of rocky habitat for a maximum of 15 minutes per drift, so that at least three areas of habitat within each cell would be sampled. Captured fish were identified to species, measured to the nearest millimeter in fork length, tagged with an external t-bar anchor tag, and returned to the water, using a descending device if needed. Each site was sampled five times, three from June-October 2014, and twice from May-August 2015.

In total, we captured and identified 4,235 fish of 23 different species (14 species of rockfish), representing six families. Of these, 3,491 were released with a tag. Catch was dominated by three species: Black rockfish (*S. melanops*), Blue rockfish (*S. mystinus*) and Lingcod (*Ophidion elongatus*), which comprised 39%, 19%, and 15% of the catch in numbers, respectively. The combined catch of all rockfish species accounted for 84% of the total catch.

The survey identified differences in relative abundance and diversity within and between some pairs of protected and non-protected sites (Figure 2). However, we believe the current patterns in relative abundance can be explained by the historic levels of fishing pressure, not by protected status. Though the difference was statistically significant only at Crescent City and Shelter Cove, for each MPA/reference site pair, the location closest to a fishing port had a lower relative abundance, in each case.

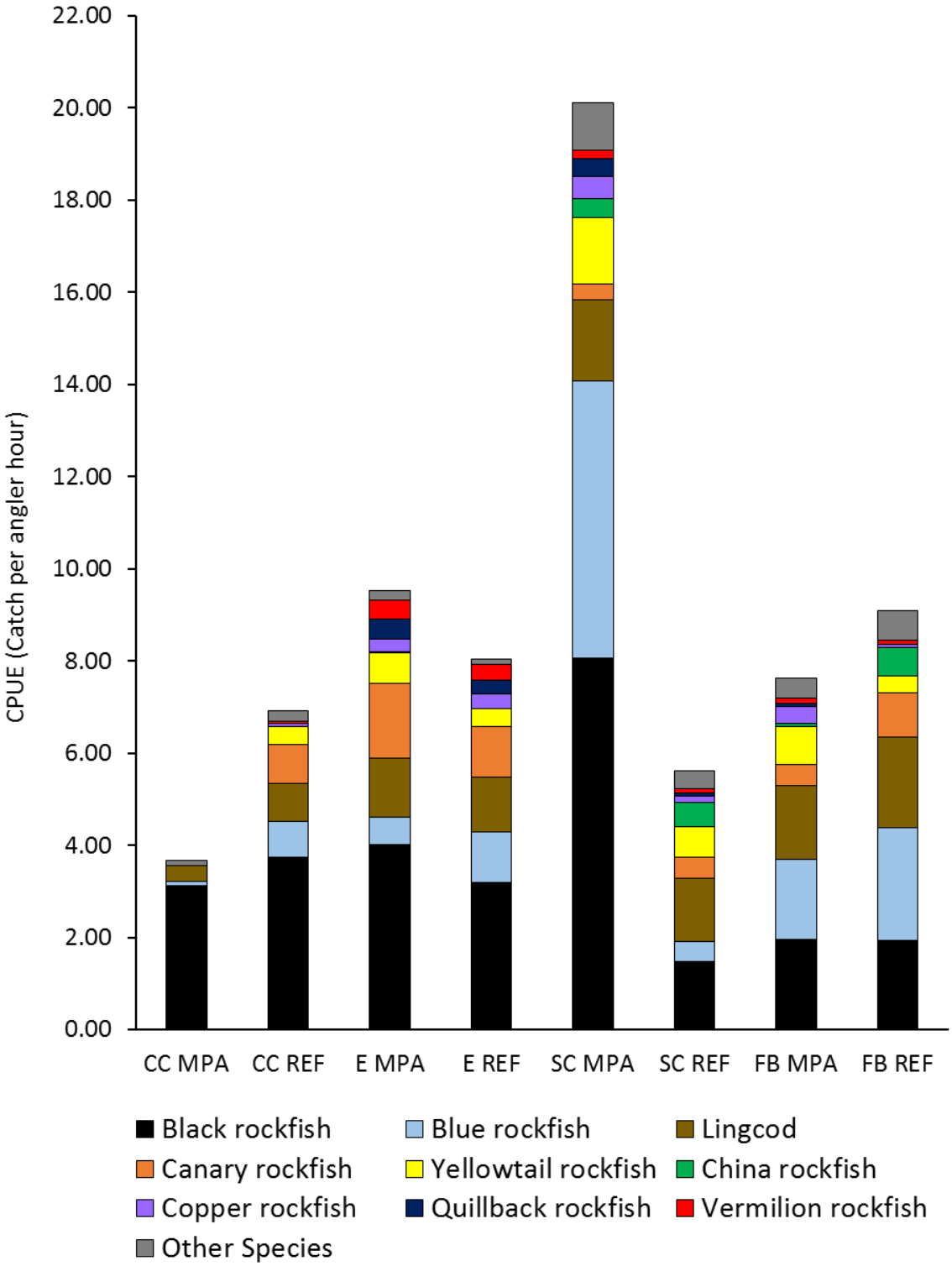



Figure 2. Comparison of relative abundance and species compositions at each Marine Protected Area (MPA) and reference (REF) site. Catch per angler hour (CPUE) averaged over the 2014 and 2015 sampling seasons shown for the top nine most abundant species and all other species combined. CC: Crescent City; E: Eureka; SC: Shelter Cove; FB: Fort Bragg.

We examined trends in CPUE, species richness, and Shannon diversity at two different depth categories, shallow (10-29 meters) and deep (30-50 meters), for MPA and REF sites combined, and years combined. Both Shannon diversity and species richness of all fish, and rockfish only, were found to be slightly higher in deep water cells compared to shallow cells. CPUE of all species combined, and all rockfish species combined, was also slightly higher in deep water cells. Eight of the nine most abundant species sampled in this survey had a higher CPUE in deep cells, with the exception of Black rockfish (Figure 3).

Of the 3,491 fish released with a tag, 18 were recaptured: nine Black rockfish, seven Lingcod, one Yelloweye rockfish (*S. ruberrimus*), and one Pacific halibut (*Hippoglossus stenolepis*). With the exception of five Black rockfish that were recaptured 300-680 kilometers north of their release location, tagged fish either showed no detectable net movement, or small displacements of less than 10 kilometers.

The project engaged 12 professional captains and deckhands working out of four ports and 40 volunteer fishers representing 80 volunteer-days of effort, or half the sampling effort for the entire project.

Long-term monitoring of rocky-reef associated fish communities will be critical for assessing the performance of North Coast MPAs, and the strength of the entire California Marine Protected Area Network. Although these communities are relatively slow to respond to protection (Starr et al. 2015), frequent monitoring would allow environmental and MPA effects to be parsed more easily than occasional monitoring similar to this baseline assessment, even if it was more limited in scope.

Data from continued study would provide information about rocky reef associated nearshore fishes along the North Coast, where a scarcity of published data exists (Steinberg, 2008). This information includes length distributions, community composition and relative abundance of these fishes, all of which can aid in the management of these commercially and recreationally important species. This is particularly important for long-lived rockfish species that are especially vulnerable to overfishing, such as Canary and Yelloweye rockfish. Additionally, hook and line sampling in rocky reef habitat has been identified as an important data source for assessment of Canary rockfish stocks (Thorson and Wetzel, 2016).

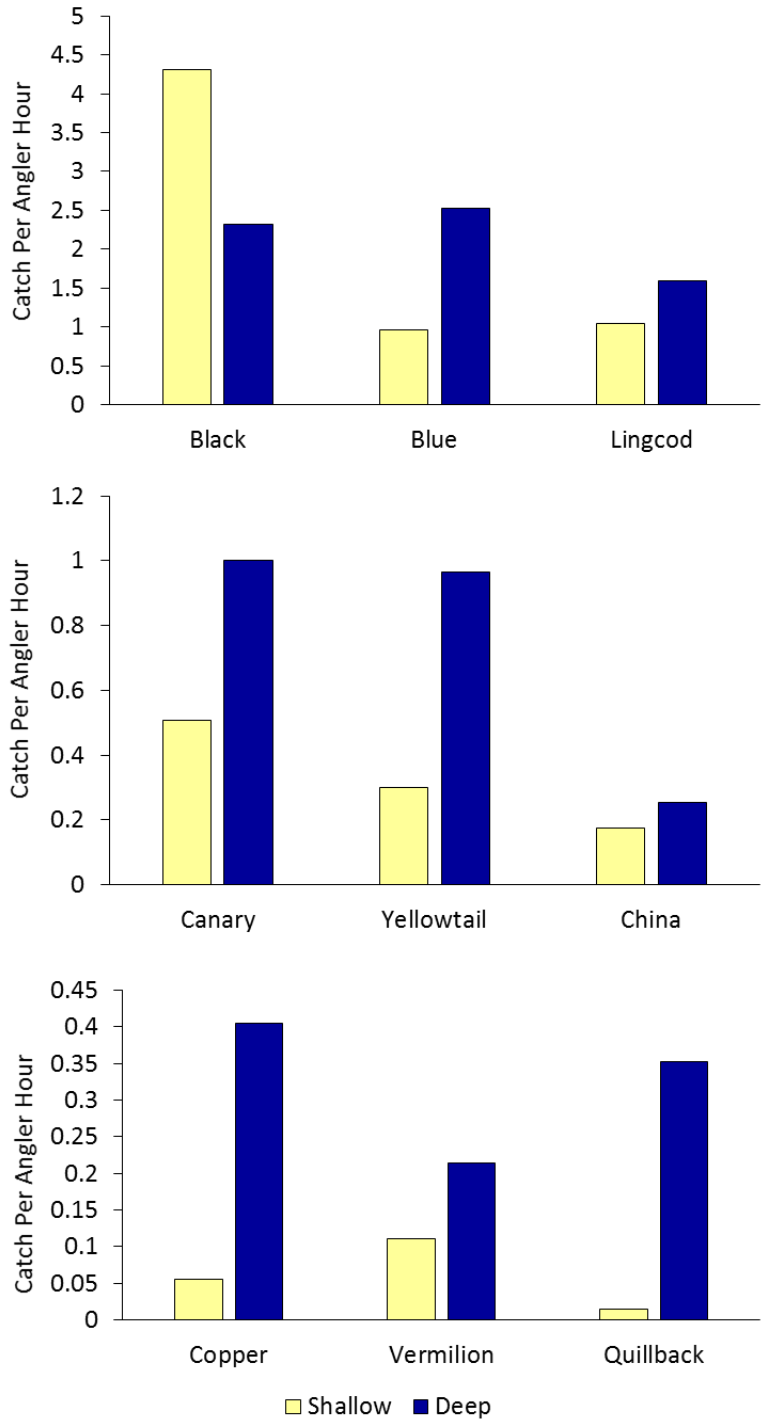



Figure 3. Mean catch per angler hour of the top nine most abundant fish species captured in shallow (10-29 meters) and deep (30-50 meters) sampling cells for all Marine Protected Area and reference sites for 2014 and 2015 sampling seasons combined.

## Introduction

Nearshore rocky reef habitat in Northern California supports a rich diversity of culturally and economically important fish species including Rockfishes, Lingcod, Cabezon, and Greenling (Lenarz 1987, Parker et al. 2000). However, these fish communities are poorly understood. This is because the distance much of this habitat is from fishing ports, frequent unfavorable weather conditions, and the scarcity of marine laboratories/research completed along this stretch of coast. We quantified the relative abundance of common species, size distribution, and species diversity in these communities at the time of MPA implementation through a collaborative hook-and-line survey. Additionally, we examined the impact of depth on those parameters.

In December 2012, regulations providing for 19 coastal Marine Protected Areas (MPAs) were enacted along the Northern California coast, from Alder Creek in Southern Mendocino County to the California-Oregon border. These MPAs completed California's statewide MPA network, which was authorized by the California Marine Life Protection Act of 1999. We surveyed four MPAs, including three state marine reserves (SMRs) and one state marine conservation area (SMCA). Four unprotected reference sites, one in close proximity to each protected area, were surveyed to control for local and regional differences in ocean conditions that could affect the abundance and species composition of rocky reef-associated fish communities.

To survey the fish communities, we adapted protocols developed by the California Collaborative Fisheries Research Program (CCFRP; Starr et al. 2015) to suit the challenges posed by the North Coast's unique environment. Hook-and-line surveys using standardized gear were conducted from small commercial passenger fishing vessels (CPFVs, or colloquially, six-pack charter vessels), with the aid of volunteer anglers. We surveyed each site three times from June to October 2014 and twice from May to August 2015.

Collaborative fisheries research involves diverse stakeholders including commercial and recreational fishers, academic scientists, management agencies, as well as other interests in developing and executing a sampling program. Collaborative research may increase the fishing communities' confidence in the findings of such studies, and in any levels of management derived from the collaboratively collected data (Guidetti and Claudet 2010). Additionally, the work produces fisheries independent data which can be used to inform stock assessments (Starr et al. 2015).

There has been increasing interest in using collaborative hook and line surveys to study nearshore rocky reef associated fish communities along the West Coast. The CCFRP has studied these communities along the Central California Coast since 2007. The Oregon Department of Fish and Wildlife (ODFW) has conducted both collaborative hook and line, and long line studies to monitor some of their MPAs since they were established in 2012. A previous study funded by

the Resource Legacy Fund Foundation conducted collaborative fisheries research on the North Coast in 2010 and 2011.

Hook and line surveys can sample highly complex habitat that is difficult to access using other methodologies. The ODFW project included visual surveys by SCUBA, video landers, and remotely operated vehicles (ROVs), which are all more expensive to conduct, in the same spatial extent, and provide less precise estimates of fish length than hook and line surveys, an important metric in evaluating MPA performance (Claudet et al. 2010, Huntington et al. 2015).

The primary goals of this study were to:
1) Produce a quantitative baseline characterization of relative abundance, size composition, and species diversity of fishes associated with nearshore rocky reef habitats inside and outside of MPAs in the North Coast Region for use as a benchmark against which to evaluate future MPA performance.

2) Engage local fishing communities in the MPA monitoring process, thereby providing a foundation for long-term monitoring of North Coast MPAs using collaborative fisheries research techniques and fostering community support for MPA-related management.

3) Continue to develop and strengthen collaborative working relationships among fishermen, academic scientists, and management agencies to facilitate effective and efficient marine fisheries research.

4) Assist future long-term North Coast MPA monitoring programs by identifying and recommending useful monitoring metrics for describing the state of nearshore fish communities.

5) Integrate this assessment with other related baseline survey components (rocky intertidal, shallow water SCUBA, and deeper water ROV surveys) to provide greater insight and cross-validation and to guide future MPA monitoring.

6) Evaluate site fidelity and movements of fishes across MPA boundaries.

# Methods

## Site Selection

Initially, we proposed surveying all nine MPAs in the Northern California MPA study region that contained rocky reef habitat (Figure 4). However, due to funding constraints, we were restricted to studying four MPA sites: Pyramid Point SMCA (Figure 5), South Cape Mendocino SMR (Figure 6), Sea Lion Gulch SMR (Figure 7), and Ten Mile SMR (Figure 8). These MPAs contained significant rocky reef habitat, and were distributed across the study region. We then selected a nearby reference (REF) site for each MPA with similar habitat characteristics and environmental conditions, so that the effects of MPA status could be evaluated in the future (Table 1). Paired MPA and REF sites are referenced in this document by the port from which they were fished. Criteria used to select reference sites were the presence of rocky habitat at similar depths and proximity to the paired MPA site. In some cases, lack of suitable habitat and/or logistical concerns resulted in REF sites being relativity distant from their paired MPA site.

In the case of the Crescent City MPA/REF pair, the nearest suitable habitat in California was approximately 40 km to the south. Although habitat that is physically similar to the Crescent City MPA exists more proximately in Oregon, the desire to engage exclusively California-based charter captains led us to select Damnation Creek as our REF site. For the Shelter Cove MPA/REF pair, the nearest suitable habitat is protected by the Mattole Canyon SMR to the north. While other suitable rock habitat exists closer to the Shelter Cove MPA, than the selected reference site, it falls north of Cape Mendocino, which is a known oceanographic and biogeographic boundary (Williams and Ralston 2002, Sakuma et al. 2006). With these considerations, the best candidate for a reference site was Point Delgada, located approximately 30 km to the south.

Each site was divided into 500m x 500m cells, and overlaid with high resolution bathymetric data obtained from the California Seafloor Mapping Project (2010). Using GIS software, mean depth and percentage rough substrate were calculated for each cell. From a pool of cells with a mean depth of 10-50 meters, and with bottom composed of greater than 20% rough substrate, four cells were randomly selected for sampling within each MPA and reference site. Unlike the CCFRP project, the cells selected at each site were held constant through the course of the study. We visited each site five times, three in Summer 2014 and twice in Summer 2015.

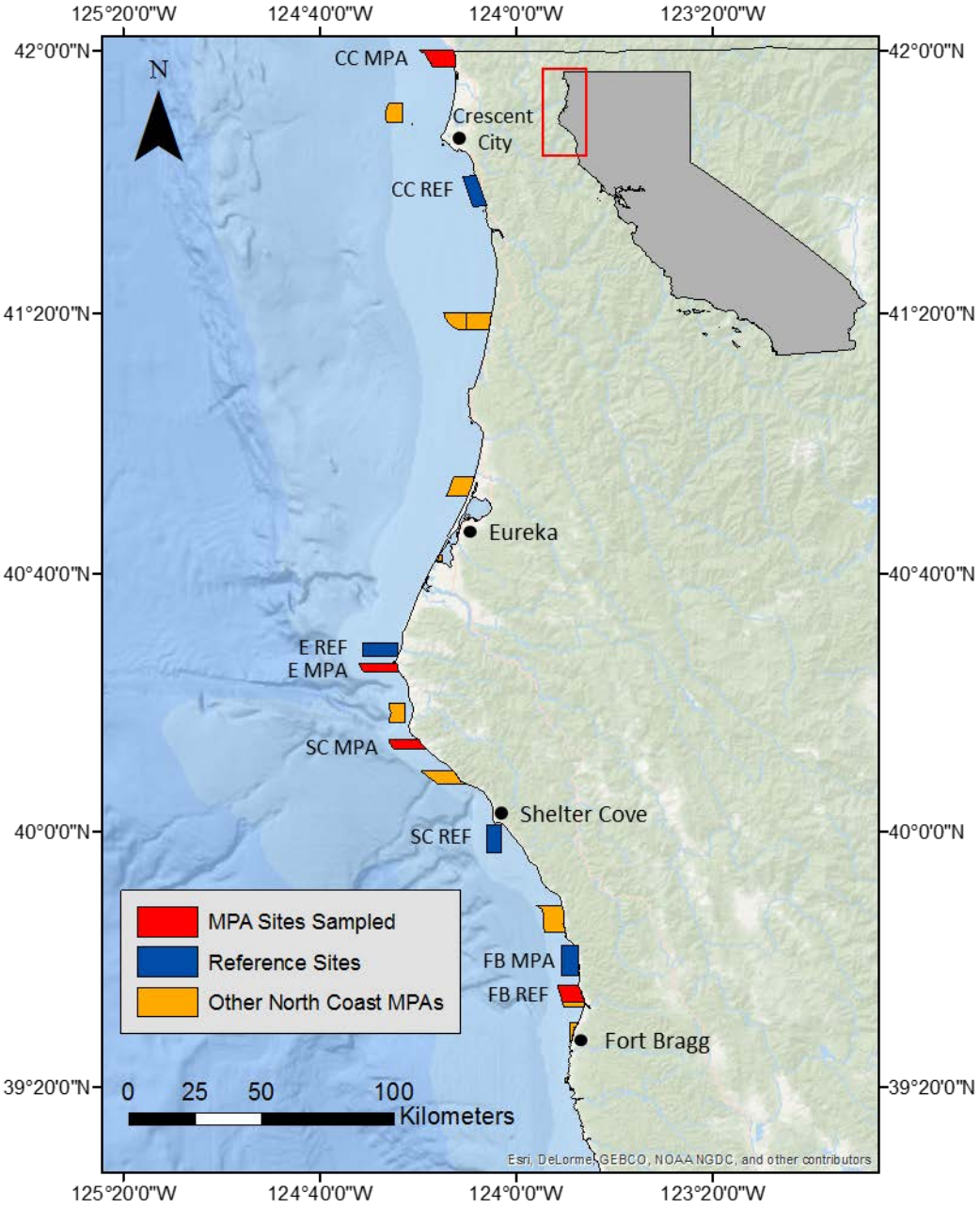



Figure 4. Map of The North Coast Marine Protected Area (MPA) Study Region showing all North Coast MPAs. Highlighted are the four paired MPA/reference (REF) study sites along with the four ports used to access these sites during the baseline characterization hook-and-line surveys. CC: Crescent City; E: Eureka; SC: Shelter Cove; FB: Fort Bragg.

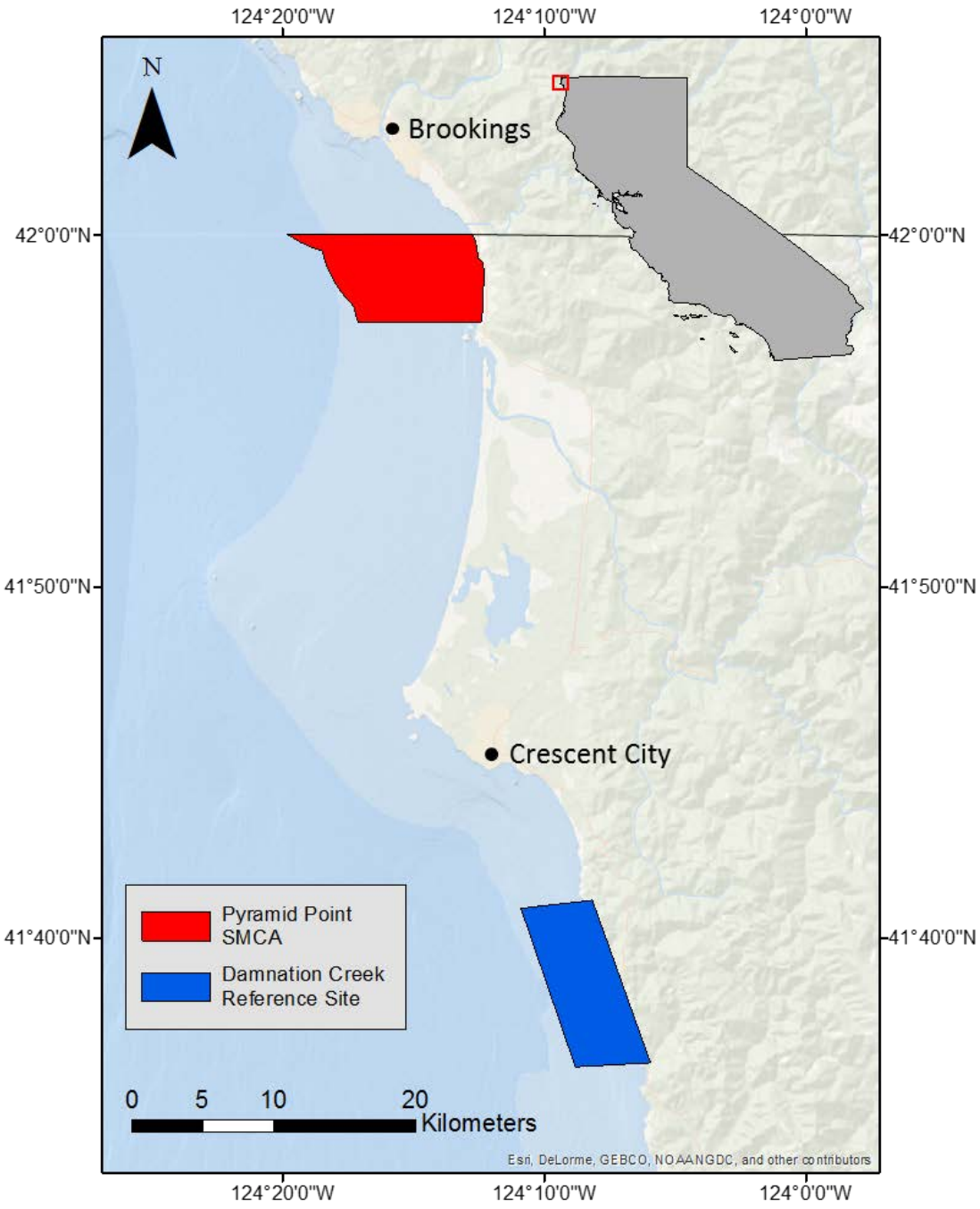



Figure 5. Map of the Crescent City Marine Protected Area (Pyramid Point SMCA) and reference site (Damnation Creek).

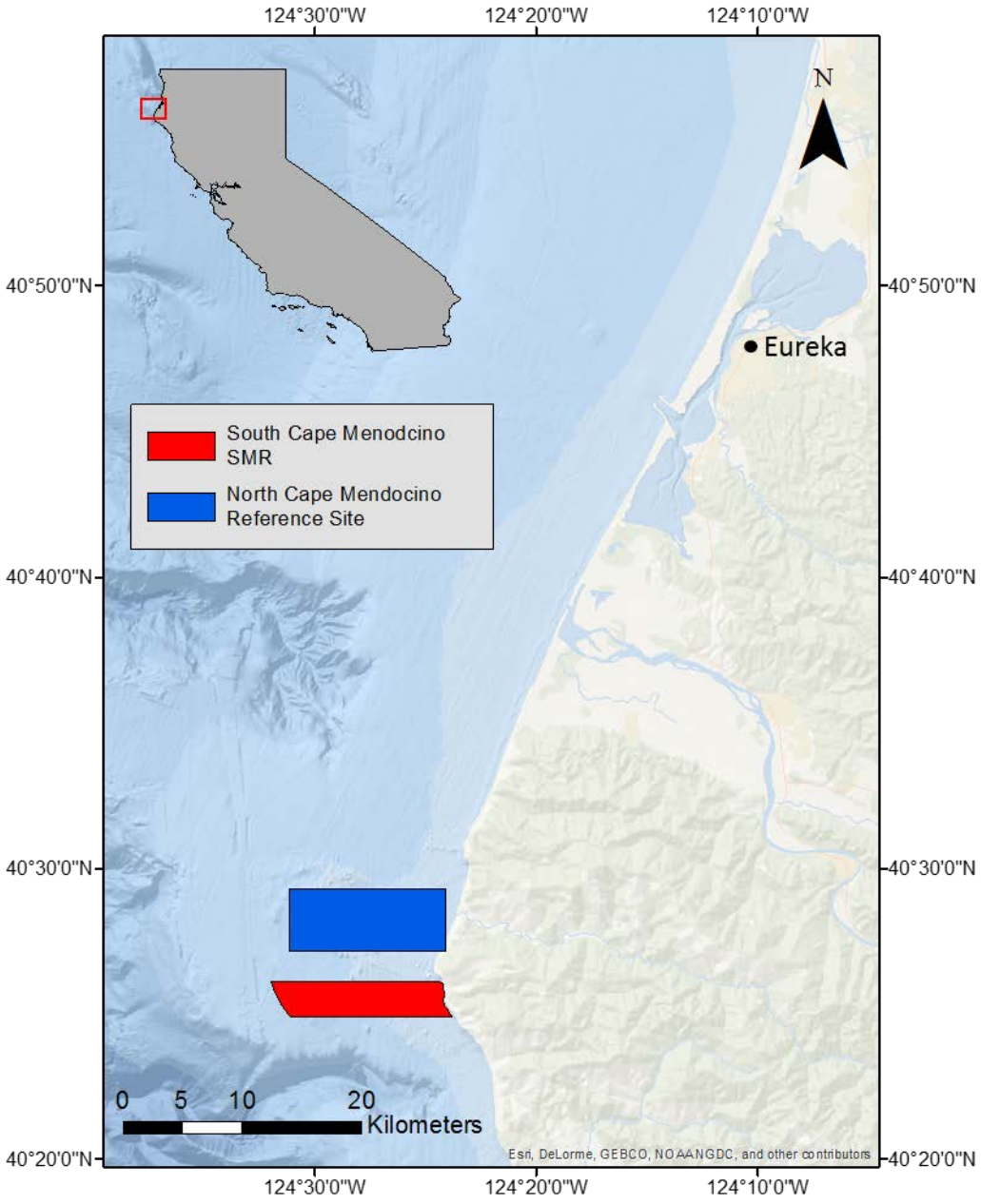



Figure 6. Map of the Eureka Marine Protected Area (South Cape Mendocino SMR) and reference site (North Cape Mendocino).

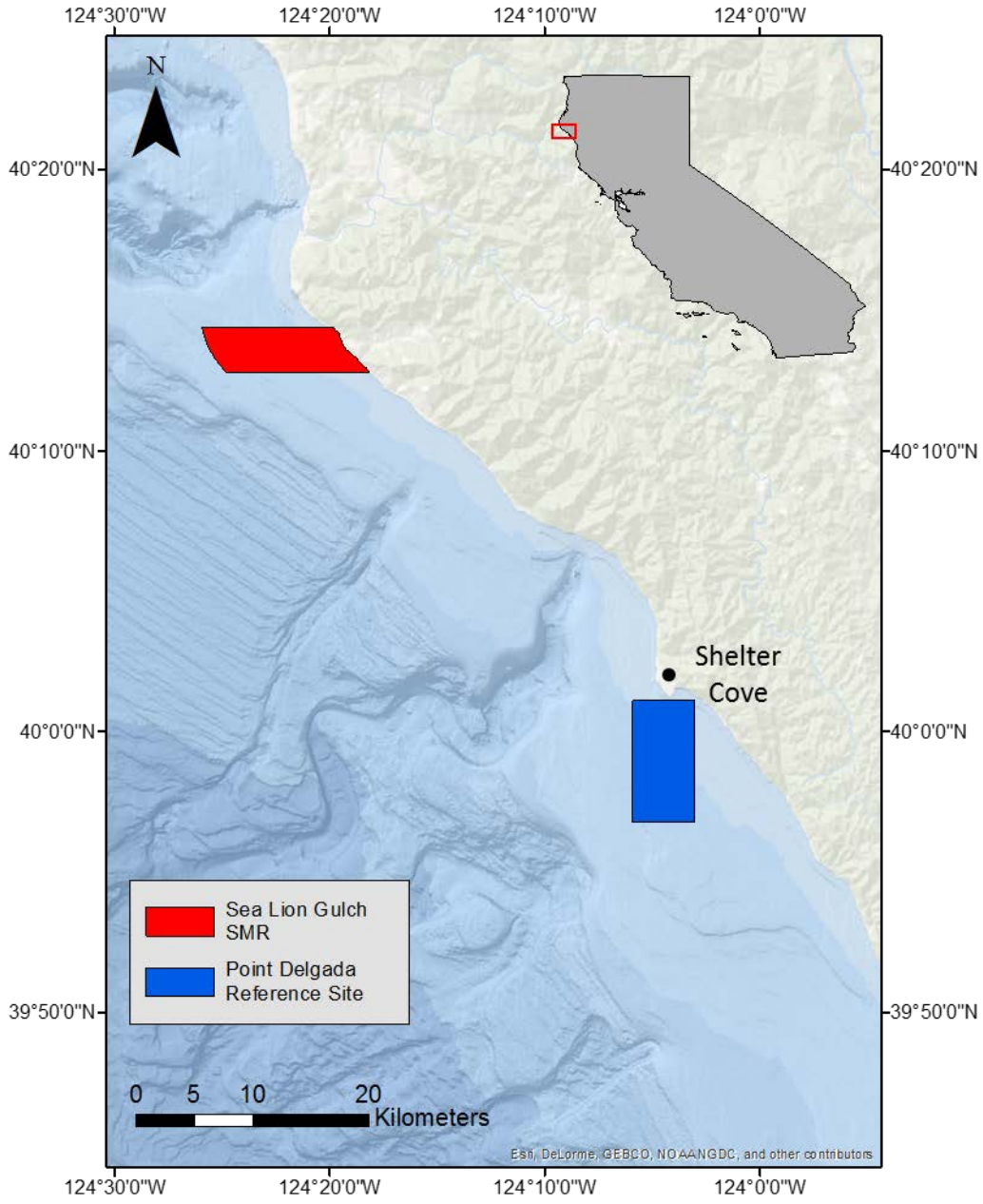



Figure 7. Map of the Shelter Cove Marine Protected Area (Sea Lion Gulch SMR) and reference site (Point Delgada).

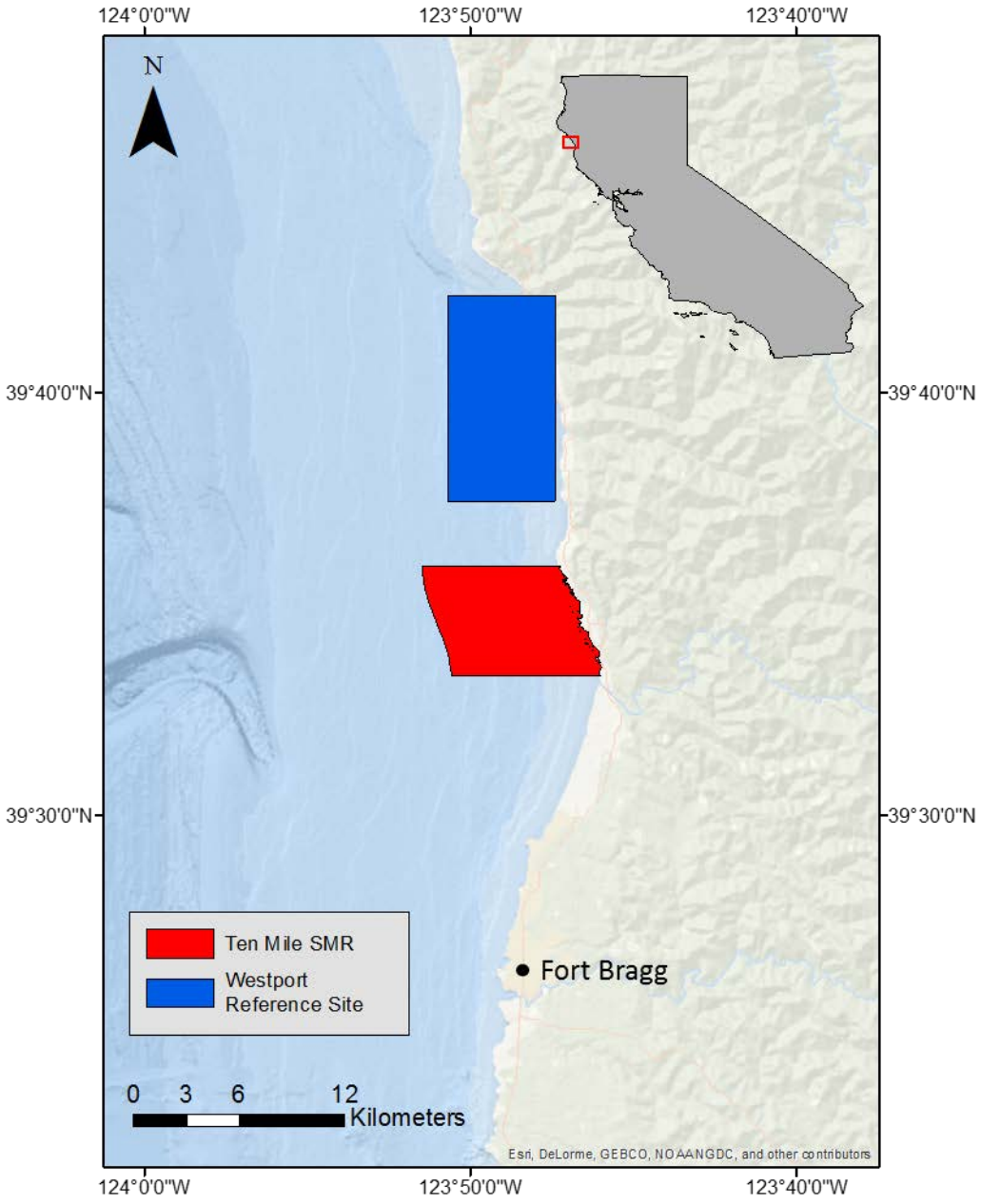



Figure 8. Map of the Fort Bragg Marine Protected Area (Ten Mile SMR) and reference site (Westport).

Table 1. Sampling port and associated pair of Marine Protected Area (MPA) and reference (REF) sites.

| Port | MPA | REF |
|---|---|---|
| Crescent City | Pyramid Point SMCA | Damnation Creek |
| Eureka | South Cape Mendocino SMR | North Cape Mendocino |
| Shelter Cove | Sea Lion Gulch SMR | Point Delgada |
| Fort Bragg | Ten Mile SMR | Westport |

## Sampling Protocol

Because the captains of the fishing vessels available to us were only licensed to carry six passengers, our sampling crews were significantly smaller than those used in the other MPA regions. Each sampling trip had a scientific crew of six: four anglers and two science team members that identified, measured, and tagged fish, and recorded data. Anglers were either volunteers from a pool of local fishers, undergraduate research technicians, or deckhands. Volunteer anglers were recruited from local fishing clubs, online fishing websites, previous collaborative fisheries projects, Humboldt State University marine science programs (e.g. Fisheries Biology, Oceanography, Marine Biology), as well as from public outreach events conducted as part of the project. Efforts were made to include as many different volunteer anglers from the community as possible over the entire course of the project.

Fishes were collected using hook-and-line gear designed to mimic methods used by local recreational fishers. Each of the four cells in a site was sampled by four anglers, each using a different category of standardized hook-and-line fishing gear. Each cell was actively fished for a total of 45 minutes during each sampling event. The four categories of standardized sampling gear used were: 1) two red or white size 4/0 shrimp-flies baited with a 3-6 cm strip of squid, 2) two un-baited red or white size 4/0 shrimp-flies, 3) a diamond or bar style metal jig paired with a single un-baited red or white size 4/0 shrimp-fly tied 60-120 cm above the jig, 4) a lead jig-head fitted with a scampi or swimbait style soft plastic jig paired with a single size 4/0 red or white un-baited shrimp-fly tied 60-120 cm above the jig (Figure 9).


Figure 9. Photos of fishing gear used during hook-and-line sampling. Left: red and white size 4/0 shrimp-flies; Top right: Bar style metal jig; Bottom right: swimbait style soft plastic jig.

Charter captains positioned the vessels to drift over as much rocky reef habitat as possible during the 45-minute sampling period within each grid cell. Specific drift locations within a grid cell were selected by the captain with the intent of targeting suitable habitat and dictated by the weather/ocean conditions of the day. Captains were directed to target at least three separate areas of suitable habitat within each cell for 15 minutes per area. If a single 15-minute drift was not possible due to strong currents or wind, the captain could choose to make several drifts in the same location for a combined total of 15 minutes.

Gear type, species, fork length (mm), and location of capture (sampling cell) was recorded for every fish landed. With few exceptions, all captured fish with a fork length over 240 millimeters were tagged with an external t-bar anchor tag implanted through the dorsal pterygiophores and released at depth at the location of capture using a descending device (weighted inverted hook or customized weighted milk crate) if needed. The condition of all captured fish was evaluated, and those that were significantly injured (e.g. barotrauma, significant mouth injury, injuries from marine mammals or other predators while being reeled in) were assigned a condition code and released without a tag (Table 2). In order to reduce incidental mortality, care was taken when handling fishes and the duration of time that fish were aboard the vessel was minimized. If a high catch rate prevented rapid processing of the captured fishes, anglers were instructed to stop fishing so that the fish aboard could be processed before angling resumed.

Anglers that submitted information, from recovered tagged fish, received information about their fish (including distance traveled and time since previous capture), and were entered into a drawing for a $500 prize, and sent a t-shirt for every tag recovered.

Table 2. Condition code descriptions used to evaluate the condition of fish landed and released.

| Condition Code | Description of Condition |
|---|---|
| 1 | Released with descending device |
| 2 | Vented |
| 3 | Crystalized eyes |
| 4 | Mammal or fish predation (no mortality) |
| 5 | Remained on surface |
| 6 | Mortality from mammal or fish |
| 7 | Other mortality |
| 8 | Lost at rail |

**Analysis**

Data were analyzed using R statistical computing software (R Core Team 2016). Catch per unit effort (CPUE), defined as the number of fish captured per hour of angler effort, was calculated for each species of fish at each site. CPUE of MPA and REF sites were compared using a Welch's unequal variance t-test for each year of sampling, and for both years combined. A Welch's t-test was chosen to allow for the comparison of data that violates the equal variance assumption required by the more common Student's t-test (Ruxton 2006). CPUE and mean lengths for each of the five most commonly caught fishes were compiled and compared similarly. These fishes were Black rockfish (*S. melanops*), Blue rockfish (*S. mystinus*), Canary rockfish (*S. pinniger*), Yellowtail rockfish (*S. flavidus*), and Lingcod (*Ophidion elongatus*). The percentage of the total number of fish captured at each site was calculated for each species, for each year of sampling and both years combined.

The total number of species was tallied for all sampling trips combined and summarized by year. Shannon diversity values were calculated for each sampling trip and averaged for each year. These values were compared using Welch's unequal variance t-tests.

The effect of depth was examined categorically at the sampling cell level. Cells with a mean depth between 10 and 29 meters were classified as shallow (n = 18); cells with a mean depth between 30 and 50 meters were classified as deep (n = 14). For shallow and deep cells, we calculated mean CPUE, Shannon diversity, and species richness. We calculated these values for all species combined, and for rockfish species only. CPUE for the nine most abundant fishes sampled during this study was also compared across depth categories.

# Results

## Catch Composition

Over the two sampling seasons combined (2014, 2015), we captured and identified 4,235 fish representing 23 different species from six families, including 14 species of Rockfish (*Sebastes spp.*; Table 3). Of these, 3,491 were tagged and released. Catch was dominated by three species: Black rockfish, Blue rockfish and Lingcod, which comprised 39%, 19%, and 15% of the catch, respectively (Table 4; Table 5). Deacon rockfish (*S. diaconus*), described in 2015, were captured over the course of the study, but were identified as Blue rockfish (Frable et al. 2015). All species of rockfish combined accounted for 84% of the catch.

Over both years combined the Crescent City MPA yielded 220 total fish of six different species, the lowest total of any site sampled. Black rockfish (86%) made up the overwhelming majority of the catch at this site. At the Crescent City REF site, 10 species were captured, the most abundant were Black rockfish (54.3%), Canary rockfish (12.3%), Lingcod (11.8%), and Blue rockfish (11.1%; Figure 10; Table 6). In the Eureka paired sites, 13 species were caught in the MPA and 11 in the REF site (Table 7). Species composition at the Eureka paired sites were similar; Black rockfish, Canary rockfish, Lingcod, and Blue rockfish dominated the catch. The Shelter Cove MPA site contained the highest fish total (1,207); Black rockfish and Blue rockfish combined made up 70% of the total catch (Table 8). The Shelter Cove REF site was dominated by Black rockfish (26.4%) and Lingcod (24.3%). Species richness at the Shelter Cove paired sites was similar, 17 species in the MPA and 16 species in the REF site. At the Fort Bragg paired sites, 18 species were captured in the MPA, dominated by Black rockfish (25.8%), Blue rockfish (22.8%) and Lingcod (21.0%; Table 9). Eleven species were captured in the REF site, the most abundant were Blue rockfish (26.9%), Lingcod (21.6%), and Black rockfish (21.2%).

Catch composition was similar for both years of sampling, with the notable exception of changes in percent catch of Black rockfish and Blue rockfish in three of the four sites south of Cape Mendocino (Figure 11; Figure 12). The largest discrepancy occurred at the Shelter Cove MPA site, where in 2014, Black Rockfish comprised 49.6% of the catch and decreased to 23.2% in 2015, while Blue rockfish increased in percent catch from 21.6% to 44.6% over the two years. A similar pattern was observed at the Fort Bragg sites, where the percent catch of Black rockfish decreased from 34.9% in the MPA site and 28.7% in the REF site to 14.1% and 7.3% in the MPA and REF sites, respectively, from 2014 to 2015. In contrast, Blue rockfish increased from 19.8% in the MPA and 26.6% in the REF site to 22.0% (MPA) and 36.1% (REF) over the same period. These changes occurred despite similar combined species CPUE at those sites between years (Figure 13; Figure 14).

Table 3. Summary of years sampled, days fished, number of fish, and species richness in each Marine Protected Area (MPA) and reference (REF) site during hook-and-line surveys conducted in summer 2014 and 2015.

| Ports | Year Sampled | Days Fished | Fish Caught MPA/REF | Species Richness MPA/REF |
|---|---|---|---|---|
| Crescent City | 2014 | 3 | 137/222 | 5/10 |
| | 2015 | 2 | 83/192 | 5/8 |
| | Total | 5 | 220/414 | 6/10 |
| Eureka | 2014 | 3 | 390/310 | 13/10 |
| | 2015 | 2 | 182/172 | 9/10 |
| | Total | 5 | 572/482 | 13/11 |
| Shelter Cove | 2014 | 3 | 768/221 | 14/16 |
| | 2015 | 2 | 439/116 | 17/13 |
| | Total | 5 | 1207/337 | 17/16 |
| Fort Bragg | 2014 | 3 | 258/355 | 16/14 |
| | 2015 | 2 | 199/191 | 14/12 |
| | Total | 5 | 457/546 | 18/15 |
| **Site Total** | MPA/REF | 20/20 | 2456/1779 | 21/18 |
| **Grand Total** | All Areas | 40 | 4235 | 23 |

Table 4. Total number and percent catch for all species in Marine Protected Areas and associated reference sites, 2014, 2015.

| Common Name | Scientific Name | Number Caught | Total Catch (%) |
|---|---|---|---|
| Black rockfish | *Sebastes melanops* | 1652 | 39.0 |
| Blue rockfish | *Sebastes mystinus* | 791 | 18.7 |
| Lingcod | *Ophiodon elongatus* | 618 | 14.6 |
| Canary rockfish | *Sebastes pinniger* | 347 | 8.2 |
| Yellowtail rockfish | *Sebastes flavidus* | 284 | 6.7 |
| China rockfish | *Sebastes nebulosus* | 100 | 2.4 |
| Copper rockfish | *Sebastes caurinus* | 100 | 2.4 |
| Quillback rockfish | *Sebastes maliger* | 78 | 1.8 |
| Vermilion rockfish | *Sebastes miniatus* | 75 | 1.8 |
| Olive rockfish | *Sebastes serranoides* | 43 | 1.0 |
| Yelloweye rockfish | *Sebastes ruberrimus* | 37 | 0.9 |
| Kelp greenling | *Hexagrammos decagrammus* | 34 | 0.8 |
| Rosy rockfish | *Sebastes rosaceus* | 24 | 0.6 |
| Cabezon | *Scorpaenichthys marmoratus* | 22 | 0.5 |
| Gopher rockfish | *Sebastes carnatus* | 13 | 0.3 |
| Buffalo sculpin | *Enophrys bison* | 4 | 0.1 |
| Chinook salmon | *Oncorhynchus tshawytscha* | 4 | 0.1 |
| Brown rockfish | *Sebastes auriculatus* | 3 | 0.1 |
| Pacific halibut | *Hippoglossus stenolepis* | 2 | < 0.1 |
| Pacific sanddab | *Citharichthys sordidus* | 2 | < 0.1 |
| Widow rockfish | *Sebastes entomelas* | 2 | < 0.1 |
| Petrale sole | *Eopsetta jordani* | 1 | < 0.1 |
| Red Irish lord | *Hemilepidotus hemilepidotus* | 1 | < 0.1 |

Table 5. Count of all species caught during the two sampling seasons (2014, 2015) using hook-and-line surveys in paired Marine Protected Areas (MPA) and reference (REF) sites.

| | Crescent City | | | Eureka | | | Shelter Cove | | | Fort Bragg | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **MPA** | **REF** | ***Total*** | **MPA** | **REF** | ***Total*** | **MPA** | **REF** | ***Total*** | **MPA** | **REF** | ***Total*** |
| Black rockfish | 188 | 225 | 413 | 241 | 192 | 433 | 483 | 89 | 572 | 118 | 116 | 234 |
| Blue rockfish | 5 | 46 | 51 | 35 | 66 | 101 | 362 | 26 | 388 | 104 | 147 | 251 |
| Lingcod | 20 | 49 | 69 | 77 | 71 | 148 | 105 | 82 | 187 | 96 | 118 | 214 |
| Canary rockfish | 0 | 51 | 51 | 98 | 66 | 164 | 21 | 27 | 48 | 27 | 57 | 84 |
| Yellowtail rockfish | 0 | 24 | 24 | 40 | 23 | 63 | 86 | 40 | 126 | 49 | 22 | 71 |
| China rockfish | 0 | 0 | 0 | 1 | 0 | 1 | 24 | 32 | 56 | 5 | 38 | 43 |
| Copper rockfish | 0 | 4 | 4 | 16 | 19 | 35 | 29 | 8 | 37 | 21 | 3 | 24 |
| Quillback rockfish | 0 | 0 | 0 | 27 | 18 | 45 | 24 | 4 | 28 | 4 | 1 | 5 |
| Vermilion rockfish | 0 | 2 | 2 | 24 | 20 | 44 | 11 | 5 | 16 | 7 | 5 | 12 |
| Olive rockfish | 0 | 0 | 0 | 1 | 0 | 1 | 20 | 6 | 26 | 0 | 16 | 16 |
| Yelloweye rockfish | 0 | 0 | 0 | 10 | 3 | 13 | 17 | 5 | 22 | 1 | 1 | 2 |
| Kelp greenling | 1 | 9 | 10 | 0 | 3 | 3 | 4 | 1 | 5 | 8 | 8 | 16 |
| Rosy rockfish | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 7 | 23 | 1 | 0 | 1 |
| Cabezon | 5 | 3 | 8 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 8 | 11 |
| Gopher rockfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 6 | 5 | 11 |
| Chinook salmon | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 2 |
| Brown Rockfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| Buffalo sculpin | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| Pacific halibut | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Pacific sanddab | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| Widow rockfish | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| Petrale sole | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Red Irish lord | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

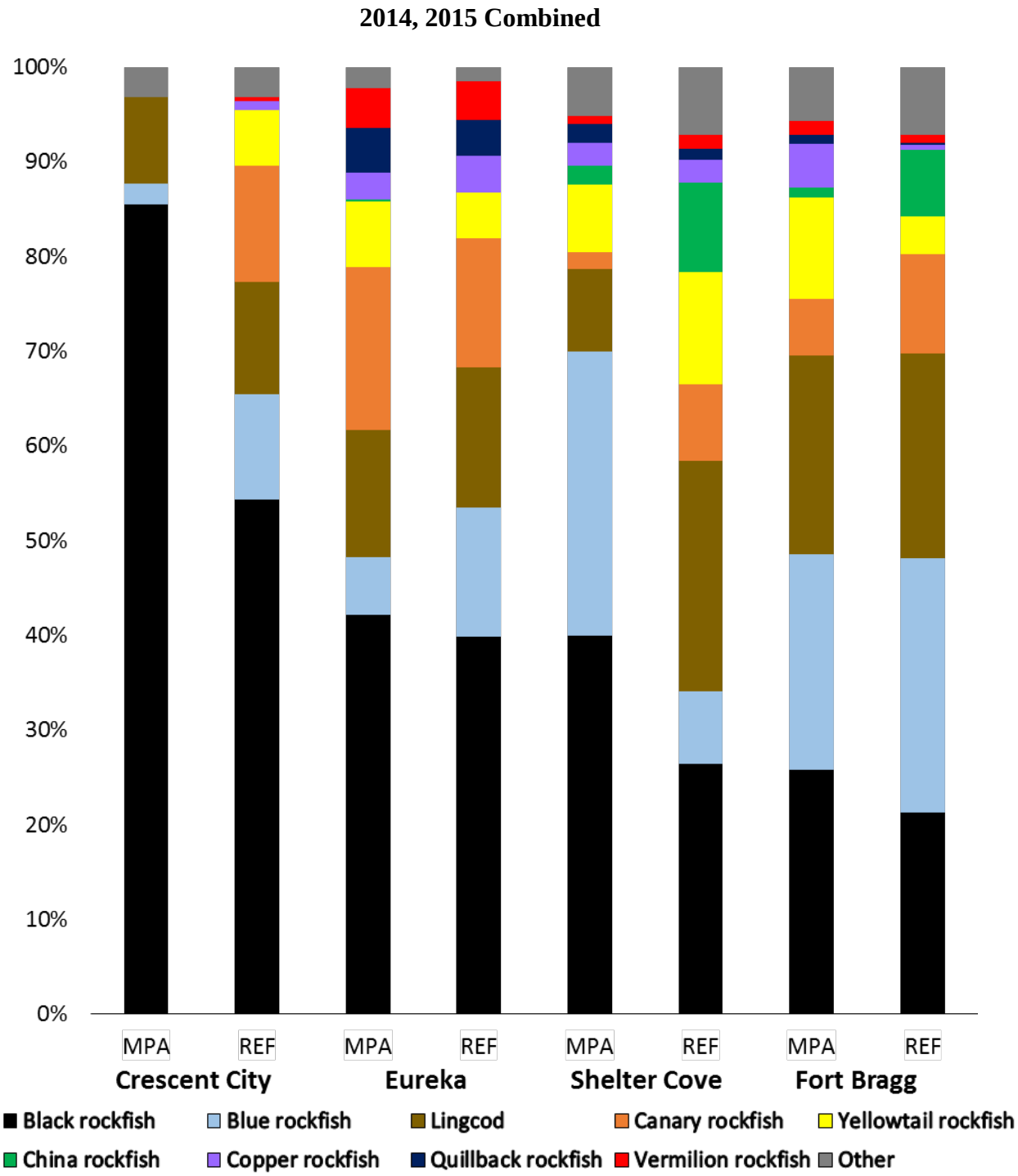



Figure 10. Species composition by site, Marine Protected Area (MPA) and reference (REF) of the top nine most commonly captured species for 2014 and 2015 sampling seasons combined. All other species are grouped into "Other" category.

Table 6. Species composition observed during hook-and-line surveys at the Crescent City Marine Protected Area (MPA) and reference (REF) sites; 2014, 2015, both years combined. Values are percentage of total catch (total number in parentheses). An asterisk (*) indicates a value less than 0.1%.

| | **Crescent City 2014** | | **Crescent City 2015** | | **Crescent City Both Years** | |
|---|---|---|---|---|---|---|
| **Species** | MPA (137) | REF (222) | MPA (83) | REF (192) | MPA (220) | REF (414) |
| Black rockfish | 87.6 | 58.6 | 81.9 | 49.5 | 85.5 | 54.3 |
| Blue rockfish | 2.9 | 4.5 | 1.2 | 18.8 | 2.3 | 11.1 |
| Buffalo sculpin | | | 1.2 | | * | |
| Cabezon | 1.5 | 0.9 | 3.6 | 0.5 | 2.3 | 0.7 |
| Canary rockfish | | 9.5 | | 15.6 | | 12.3 |
| Copper rockfish | | 0.9 | | 1.0 | | 1.0 |
| Kelp greenling | 0.7 | 3.6 | | 0.5 | 0.5 | 2.2 |
| Lingcod | 7.3 | 15.3 | 12.0 | 7.8 | 9.1 | 11.8 |
| Red Irish lord | | 0.5 | | | | * |
| Rosy rockfish | | | | | | |
| Vermilion rockfish | | 0.9 | | | | * |
| Yellowtail rockfish | | 5.4 | | 6.3 | | 5.8 |
| Total Number Species | 5 | 10 | 5 | 8 | 6 | 10 |
| Total Rockfish Species | 2 | 6 | 2 | 5 | 2 | 5 |

Table 7. Species composition observed during hook-and-line surveys at the Eureka Marine Protected Area (MPA) and reference (REF) sites; 2014, 2015, both years combined. Values are percentage of total catch (total number in parentheses). An asterisk (*) indicates a value less than 0.1%.

| | **Eureka 2014** | | **Eureka 2015** | | **Eureka Both Years** | |
|---|---|---|---|---|---|---|
| **Species** | MPA (390) | REF (310) | MPA (182) | REF (172) | MPA (572) | REF (482) |
| Black rockfish | 48.7 | 38.1 | 28.0 | 43.0 | 42.1 | 39.8 |
| Blue rockfish | 7.9 | 11.9 | 2.2 | 16.9 | 6.1 | 13.7 |
| Canary rockfish | 11.3 | 14.5 | 29.7 | 12.2 | 17.1 | 13.7 |
| China rockfish | 0.3 | | | | * | |
| Chinook salmon | 0.3 | | | | * | |
| Copper rockfish | 2.8 | 5.2 | 2.7 | 1.7 | 2.8 | 3.9 |
| Kelp greenling | | 0.6 | | 0.6 | | 0.6 |
| Lingcod | 10.5 | 14.2 | 19.8 | 15.7 | 13.5 | 14.7 |
| Olive rockfish | 0.3 | | | | * | |
| Pacific halibut | | | | 0.6 | | 0.2 |
| Petrale sole | 0.3 | | | | * | |
| Quillback rockfish | 4.4 | 4.5 | 5.5 | 2.3 | 4.7 | 3.7 |
| Vermilion rockfish | 3.1 | 5.2 | 6.6 | 2.3 | 4.2 | 4.1 |
| Yelloweye rockfish | 1.0 | 1.0 | 3.3 | | 1.7 | 0.6 |
| Yellowtail rockfish | 9.2 | 4.8 | 2.2 | 4.7 | 7.0 | 4.8 |
| Total Number Species | 13 | 10 | 9 | 10 | 13 | 11 |
| Total Rockfish Species | 10 | 8 | 8 | 7 | 10 | 8 |

Table 8. Species composition observed during hook-and-line surveys at the Shelter Cove Marine Protected Area (MPA) and reference (REF) sites; 2014, 2015, both years combined. Values are percentage of total catch (total number in parentheses). An asterisk (*) indicates a value less than 0.1%.

| | **Shelter Cove 2014** | | **Shelter Cove 2015** | | **Shelter Cove Both Years** | |
|---|---|---|---|---|---|---|
| Species | MPA (768) | REF (221) | MPA (439) | REF (116) | MPA (1207) | REF (337) |
| Black rockfish | 49.6 | 26.7 | 23.2 | 25.9 | 40.0 | 26.4 |
| Blue rockfish | 21.6 | 10.9 | 44.6 | 1.7 | 30.0 | 7.7 |
| Cabezon | | 0.5 | 0.2 | 0.9 | * | 0.6 |
| Canary rockfish | 1.4 | 5.9 | 2.3 | 12.1 | 1.7 | 8.0 |
| China rockfish | 2.1 | 11.3 | 1.8 | 6.0 | 2.0 | 9.5 |
| Chinook salmon | | | 0.2 | | * | |
| Copper rockfish | 2.1 | 2.3 | 3.0 | 2.6 | 2.4 | 2.4 |
| Gopher rockfish | | 0.9 | | | | 0.6 |
| Kelp greenling | 0.3 | 0.5 | 0.5 | | * | * |
| Lingcod | 6.9 | 25.8 | 11.8 | 21.6 | 8.7 | 24.3 |
| Olive rockfish | 2.5 | 0.5 | 0.2 | 4.3 | 1.7 | 1.8 |
| Pacific halibut | | 0.5 | | | | * |
| Pacific sanddab | | | 0.2 | | * | |
| Quillback rockfish | 1.8 | 1.4 | 2.3 | 0.9 | 2.0 | 1.2 |
| Rosy rockfish | 1.2 | 1.8 | 1.6 | 2.6 | 1.3 | 2.1 |
| Vermilion rockfish | 1.0 | 0.5 | 0.7 | 3.4 | 0.9 | 1.5 |
| Widow rockfish | 0.1 | | 0.2 | | * | |
| Yelloweye rockfish | 1.3 | 1.4 | 1.6 | 1.7 | 1.4 | 1.5 |
| Yellowtail rockfish | 8.1 | 9.5 | 5.5 | 16.4 | 7.1 | 11.9 |
| Total Number Species | 14 | 16 | 17 | 13 | 17 | 16 |
| Total Rockfish Species | 12 | 12 | 12 | 11 | 12 | 12 |

Table 9. Species composition observed during hook-and-line surveys at the Fort Bragg Marine Protected Area (MPA) and reference (REF) sites; 2014, 2015, both years combined. Values are percentage of total catch (total number in parentheses). An asterisk (*) indicates a value less than 0.1%.

| | **Fort Bragg 2014** | | **Fort Bragg 2015** | | **Fort Bragg Both Years** | |
|---|---|---|---|---|---|---|
| **Species** | MPA (258) | REF (355) | MPA (199) | REF (191) | MPA (457) | REF (546) |
| Black rockfish | 34.9 | 28.7 | 14.1 | 7.3 | 25.8 | 21.2 |
| Blue rockfish | 19.8 | 22.0 | 26.6 | 36.1 | 22.8 | 26.9 |
| Brown Rockfish | 0.4 | | 1.0 | | 0.7 | |
| Buffalo sculpin | 0.4 | | | 0.5 | * | * |
| Cabezon | 0.4 | 0.3 | 1.0 | 3.7 | 0.7 | 1.5 |
| Canary rockfish | 3.5 | 11.5 | 9.0 | 8.4 | 5.9 | 10.4 |
| China rockfish | 1.6 | 7.0 | 0.5 | 6.8 | 1.1 | 7.0 |
| Chinook salmon | 0.8 | | | | * | |
| Copper rockfish | 2.3 | 0.8 | 7.5 | | 4.6 | 0.5 |
| Gopher rockfish | 0.8 | 1.1 | 2.0 | 0.5 | 1.3 | 0.9 |
| Kelp greenling | 0.8 | 1.4 | 3.0 | 1.6 | 1.8 | 1.5 |
| Lingcod | 17.4 | 20.0 | 25.6 | 24.6 | 21.0 | 21.6 |
| Olive rockfish | | 2.5 | | 3.7 | | 2.9 |
| Pacific sanddab | 0.4 | | | | * | |
| Quillback rockfish | | 0.3 | 2.0 | | 0.9 | * |
| Rosy rockfish | | | 0.5 | | * | |
| Vermilion rockfish | 0.8 | 0.6 | 2.5 | 1.6 | 1.5 | 0.9 |
| Yelloweye rockfish | 0.4 | 0.3 | | | * | * |
| Yellowtail rockfish | 15.5 | 3.4 | 4.5 | 5.2 | 10.7 | 4.0 |
| Total Number Species | 16 | 14 | 14 | 12 | 18 | 15 |
| Total Rockfish Species | 10 | 11 | 11 | 8 | 12 | 11 |

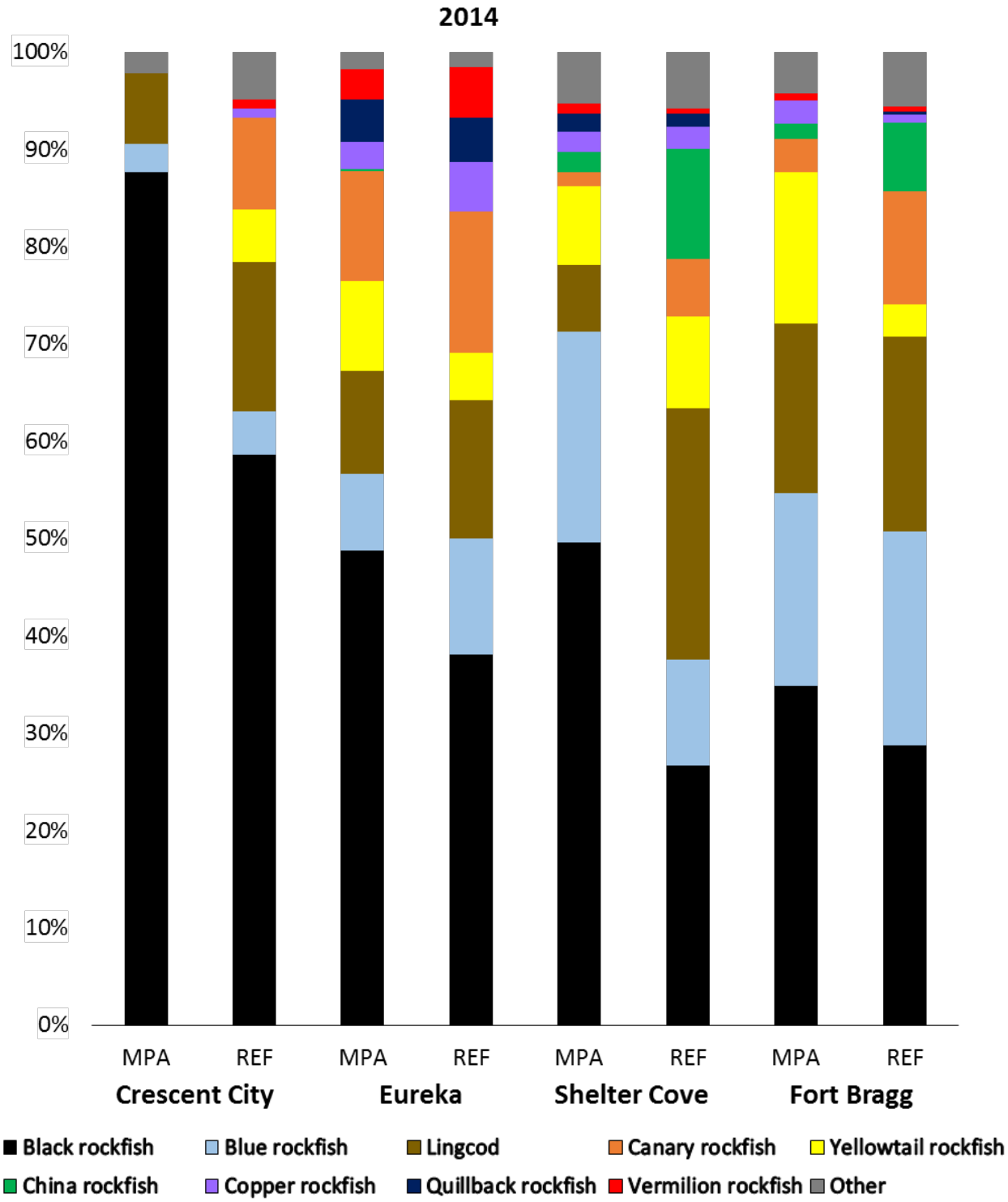



Figure 11. Species composition by site, Marine Protected Area (MPA) and reference (REF) of the top 9 most commonly captured species in the 2014 sampling season. All other species are grouped into "Other" category.

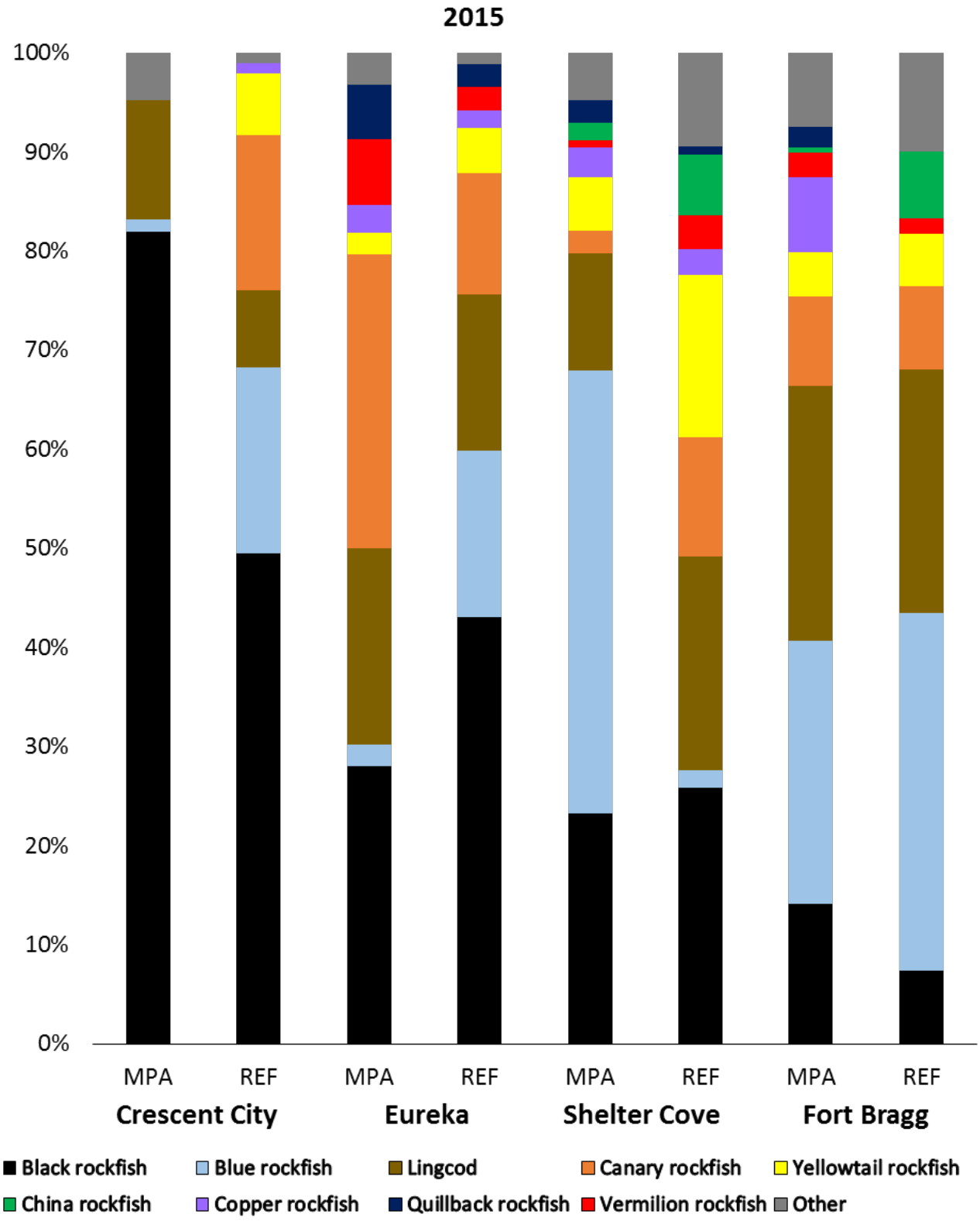



Figure 12. Species composition by site, Marine Protected Area (MPA) and reference (REF) of the top 9 most commonly captured species in the 2015 sampling season. All other species are grouped into "Other" category.

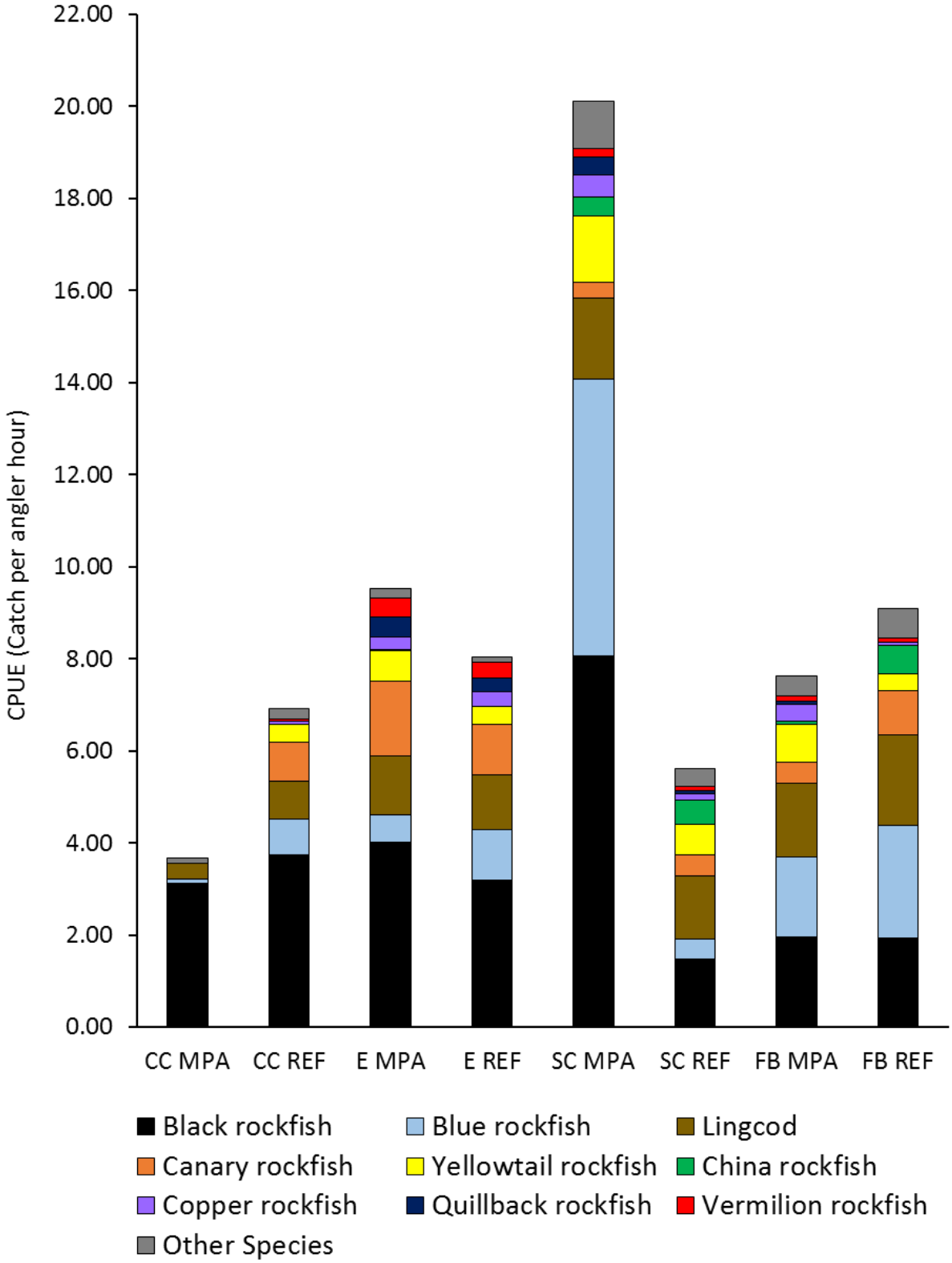



Figure 13. Comparison of relative abundance and species compositions at each Marine Protected Area (MPA) and reference (REF) site. Catch per angler hour (CPUE) during 2014 and 2015 sampling seasons shown for the top nine most abundant species and all other species combined. CC: Crescent City; E: Eureka; SC: Shelter Cove; FB: Fort Bragg.

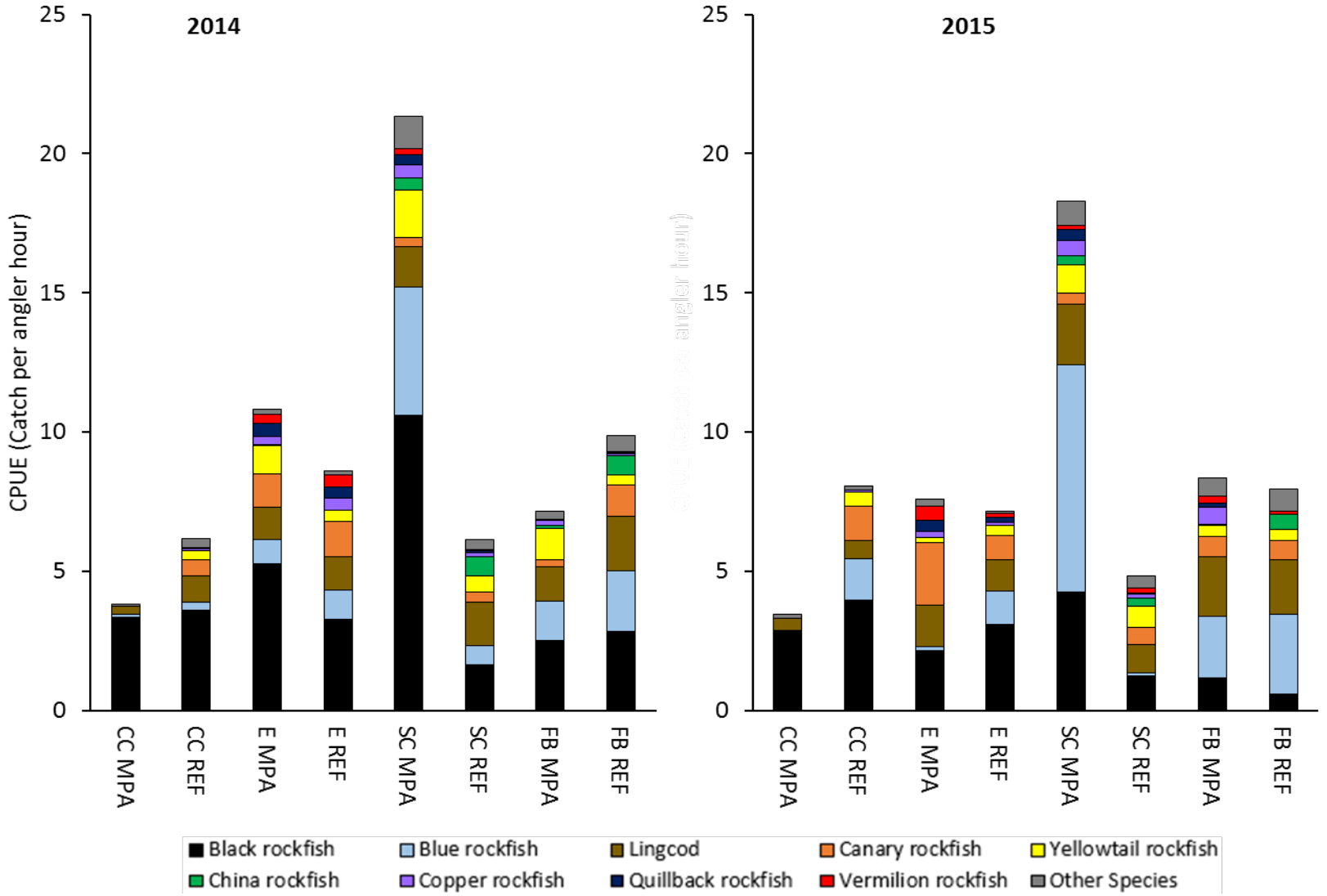
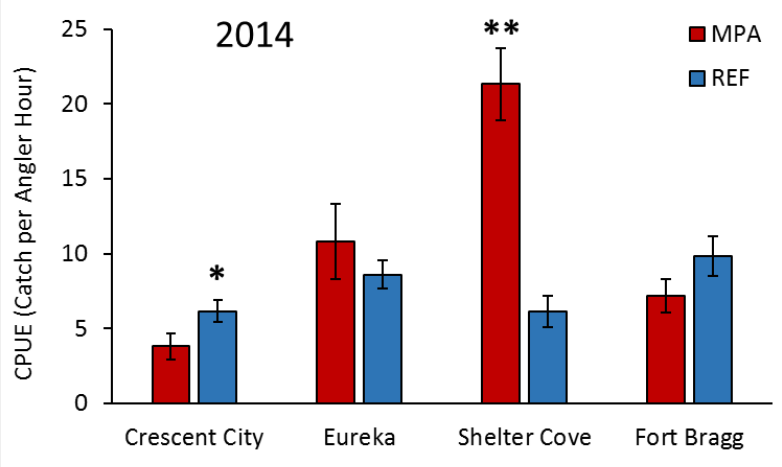


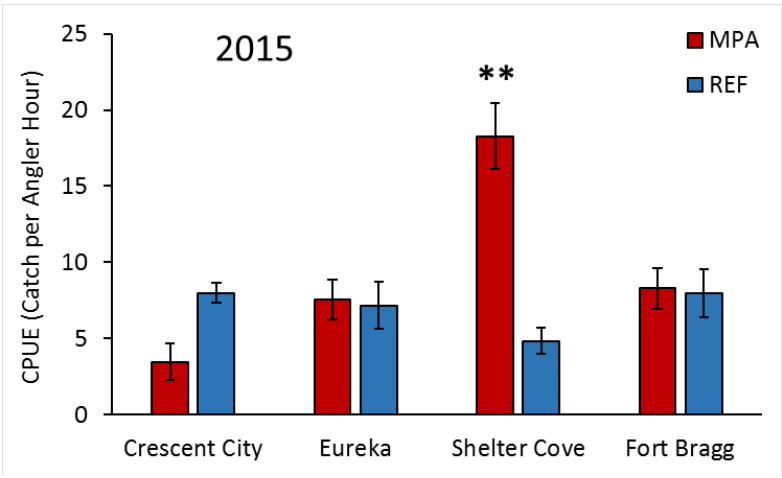

Figure 14. Comparison of relative abundance and species compositions at each Marine Protected Area (MPA) and reference (REF) site. Catch per angler hour (CPUE) during 2014 (left) and 2015 (right) sampling seasons shown for the top nine most abundant species and all other species combined. CC: Crescent City; E: Eureka; SC: Shelter Cove; FB: Fort Bragg.

**Relative Abundance**

Average CPUE for all sites and years combined was 8.8 fish per angler hour, while the average CPUE at individual sites ranged from 3.7 (Crescent City MPA) to 20.1 (Shelter Cove MPA; Figure 15; Table 10). Between MPA and REF sites, significant differences in all species CPUE over both years combined were detected at the Shelter Cove sites and Crescent City sites. In Shelter Cove, combined species CPUE for both years averaged 20.12 +/- 1.67 (standard error) at the MPA site, and 5.62 +/- 0.70 at the REF site. A t-test showed the mean CPUE at the Shelter Cove MPA site was significantly higher than the REF site (p-value < 0.001). In Crescent City, the 2-year average for combined species CPUE was 3.67 +/- 0.57 for the MPA site and 6.90 +/- 0.94 for the REF site. The t-test indicated that mean CPUE at the Crescent City MPA was significantly lower than the MPA site (p-value = 0.007; Table 11). No significant difference in combined species CPUE was detected between the Eureka and Fort Bragg pairs of MPA and REF sites. No significant interannual differences in combined species CPUE were detected for any site between 2014 and 2015.

Species-specific differences in CPUE for the five most commonly captured species during both sampling years combined were found at both the Crescent City and Shelter Cove sites (Figure 16; Table 12). Lingcod (p-value = 0.02), Canary rockfish (p-value < 0.0001), and Yellowtail rockfish (p-value = 0.008) were all caught in significantly higher numbers at the Crescent City REF site compared to its paired MPA site (Table 13). At the Shelter Cove MPA site, Black rockfish (p-value = 0.009) and Blue rockfish (p-value < 0.0001) had significantly higher CPUEs than at the REF site. Comparing years, significant changes in CPUE were observed in Black and Blue rockfish at the Shelter Cove MPA; CPUE of Black rockfish decreased from 10.6 in 2014 to 4.3 in 2015 (Figure 17; Figure 18; Table 14; Table 15). In contrast, CPUE of Blue rockfish increased from 4.6 to 8.2 over the same period. A similar but more modest trend was observed in the Fort Bragg MPA and REF sites, where Black rockfish CPUE decreased from 2.5 to 1.2 in the MPA, and 2.8 to 0.6 in the REF site, while Blue rockfish CPUE increased from 1.4 to 2.2 in the MPA site and 2.2 to 2.9 in the REF site (Table 16; Table 17).



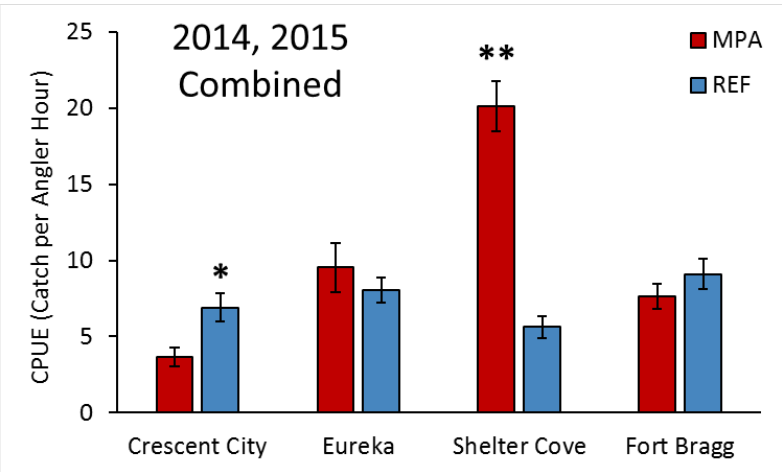




Figure 15. Catch per angler hour in all paired Marine Protected Area (MPA) and reference (REF) sites for 2014, 2015, and both years combined. Error bars represent standard error. One asterisk (*) indicates the paired sites are significantly different (p-value < 0.05). Two asterisks (**) indicates the paired sites are significantly different (p-value < 0.001). Asterisks are placed over the site that is significantly higher.

Table 10. Average catch per angler hour and corresponding standard error (SE) for all species combined by port, Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB) and site, Marine Protected Area (MPA), reference (REF), for 2014, 2015, and both years combined.

| | | **Catch per Angler Hour (SE)** | | |
|---|---|---|---|---|
| | | 2014 | 2015 | Both Years |
| CC | | 4.99 (0.60) | 5.73 (1.21) | 5.28 (0.60) |
| | CC MPA | 3.81 (0.87) | 3.46 (0.62) | 3.67 (0.57) |
| | CC REF | 6.17 (0.72) | 8.00 (2.10) | 6.90 (0.94) |
| E | | 9.72 (1.33) | 7.38 (0.98) | 8.78 (0.90) |
| | E MPA | 10.83 (2.52) | 7.58 (1.30) | 9.53 (1.61) |
| | E REF | 8.61 (0.93) | 7.17 (1.56) | 8.03 (0.83) |
| SC | | 13.74 (2.03) | 11.56 (2.07) | 12.87 (1.47) |
| | SC MPA | 21.33 (2.39) | 18.29 (2.15) | 20.12 (1.67) |
| | SC REF | 6.14 (1.02) | 4.83 (0.86) | 5.62 (0.70) |
| FB | | 8.51 (0.89) | 8.13 (0.99) | 8.36 (0.66) |
| | FB MPA | 7.17 (1.12) | 8.29 (1.33) | 7.62 (0.84) |
| | FB REF | 9.86 (1.32) | 7.96 (1.57) | 9.10 (1.01) |

Table 11. Results from a Welch's two-sample t-test conducted on mean CPUE (catch per angler hour) of paired Marine Protected Area (MPA) and reference (REF) sites Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB), for 2014, 2015, and both years combined.

| | | Mean CPUE | | | | |
|---|---|---|---|---|---|---|
| 2014 | | MPA | REF | t | df | p-val |
| | CC | 3.81 | 6.17 | -2.09 | 21 | 0.049 |
| | E | 10.83 | 8.61 | 0.83 | 14 | 0.421 |
| | SC | 21.33 | 6.14 | 5.84 | 15 | <0.001 |
| | FB | 7.17 | 9.86 | -1.55 | 21 | 0.135 |
| 2015 | | | | | | |
| | | MPA | REF | t | df | p-val |
| | CC | 3.46 | 8.00 | -2.07 | 21 | 0.071 |
| | E | 7.58 | 7.17 | 0.21 | 14 | 0.840 |
| | SC | 18.29 | 4.83 | 5.80 | 9 | <0.001 |
| | FB | 8.29 | 7.96 | 0.16 | 14 | 0.873 |
| Both Years | | MPA | REF | t | df | p-val |
| | CC | 3.67 | 6.90 | -2.96 | 31 | 0.006 |
| | E | 9.53 | 8.03 | 0.83 | 28 | 0.413 |
| | SC | 20.12 | 5.62 | 8.01 | 25 | <0.001 |
| | FB | 7.62 | 9.10 | -1.13 | 37 | 0.266 |

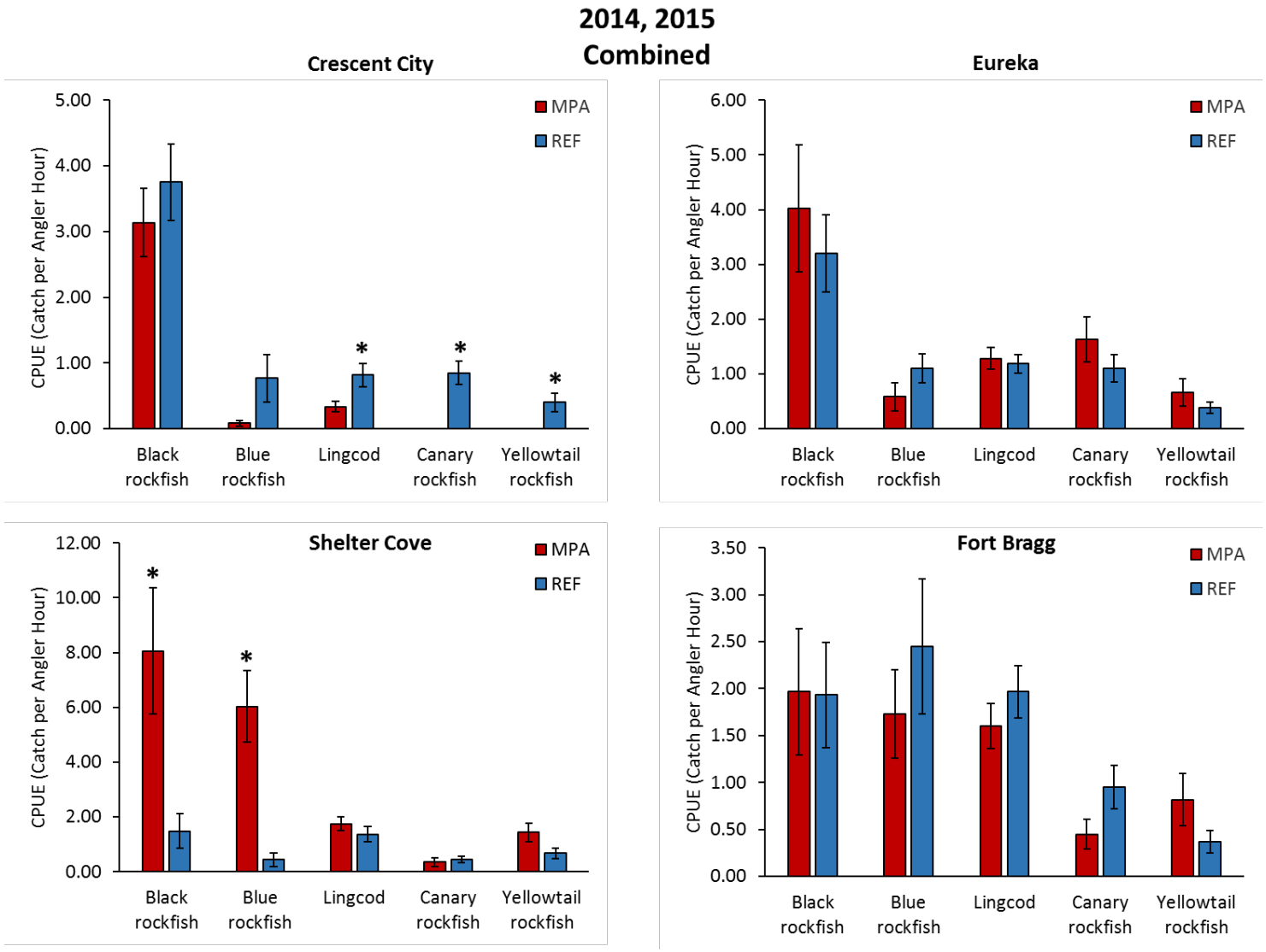



Figure 16. Catch per angler hour for the five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites at Crescent City (CC), Eureka (E), Shelter Cove (SC), and Fort Bragg (FB) for both sampling seasons combined, 2014, 2015. Error bars represent standard error. Asterisk (*) indicates the paired sites are significantly different (p-value < 0.05).

Table 12. Mean catch per angler hour, with standard error in parenthesis, of five most commonly caught species at all sites, Marine Protected Area (MPA) and reference (REF) during hook-and-line surveys in 2014 and 2015 sampling seasons combined.

| Both Years | **Crescent City** | | **Eureka** | | **Shelter Cove** | | **Fort Bragg** | |
|---|---|---|---|---|---|---|---|---|
| Species | MPA | REF | MPA | REF | MPA | REF | MPA | REF |
| Black rockfish | 3.13 (0.52) | 3.75 (0.58) | 4.02 (1.16) | 3.2 (0.7) | 8.05 (2.20) | 1.48 (0.63) | 1.97 (0.67) | 1.93 (0.56) |
| Blue rockfish | 0.08 (0.04) | 0.77 (0.36) | 0.58 (0.26) | 1.1 (0.26) | 6.03 (1.30) | 0.43 (0.25) | 1.73 (0.47) | 2.45 (0.72) |
| Lingcod | 0.33 (0.08) | 0.82 (0.18) | 1.28 (0.2) | 1.18 (0.17) | 1.75 (0.26) | 1.37 (0.27) | 1.6 (0.24) | 1.97 (0.28) |
| Canary rockfish | 0 (0) | 0.85 (0.18) | 1.63 (0.41) | 1.1 (0.25) | 0.35 (0.16) | 0.45 (0.11) | 0.45 (0.16) | 0.95 (0.23) |
| Yellowtail rockfish | 0 (0) | 0.4 (0.14) | 0.67 (0.25) | 0.38 (0.10) | 1.43 (0.34) | 0.67 (0.18) | 0.82 (0.28) | 0.37 (0.12) |

Table 13. Results from a Welch's two-sample t-test conducted on mean CPUE (catch per angler hour) of the five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites for Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB), for both sampling seasons combined (2014, 2015).

| Both Years | | | | | | |
|---|---|---|---|---|---|---|
| Crescent City | Species | MPA | REF | t | df | p-val |
| | Black rockfish | 3.13 | 3.75 | -0.79 | 38 | 0.433 |
| | Blue rockfish | 0.08 | 0.77 | -1.90 | 20 | 0.072 |
| | Lingcod | 0.33 | 0.82 | -2.43 | 27 | 0.022 |
| | Canary rockfish | 0.00 | 0.85 | -4.60 | 19 | <0.001 |
| | Yellowtail rockfish | 0.00 | 0.40 | -2.94 | 19 | 0.008 |
| Eureka | | | | | | |
| | Black rockfish | 4.02 | 3.20 | 0.60 | 31 | 0.551 |
| | Blue rockfish | 0.58 | 1.10 | -1.39 | 38 | 0.172 |
| | Lingcod | 1.28 | 1.18 | 0.38 | 37 | 0.706 |
| | Canary rockfish | 1.63 | 1.10 | 1.12 | 32 | 0.273 |
| | Yellowtail rockfish | 0.67 | 0.38 | 1.06 | 25 | 0.301 |
| Shelter Cove | | | | | | |
| | Black rockfish | 8.05 | 1.48 | 2.87 | 22 | 0.009 |
| | Blue rockfish | 6.03 | 0.43 | 4.24 | 20 | <0.001 |
| | Lingcod | 1.75 | 1.37 | 1.02 | 38 | 0.312 |
| | Canary rockfish | 0.35 | 0.45 | -0.51 | 33 | 0.611 |
| | Yellowtail rockfish | 1.43 | 0.67 | 2.01 | 29 | 0.054 |
| Fort Bragg | | | | | | |
| | Black rockfish | 1.97 | 1.93 | 0.04 | 37 | 0.970 |
| | Blue rockfish | 1.73 | 2.45 | -0.83 | 33 | 0.410 |
| | Lingcod | 1.60 | 1.97 | -1.01 | 37 | 0.320 |
| | Canary rockfish | 0.45 | 0.95 | -1.77 | 34 | 0.086 |
| | Yellowtail rockfish | 0.82 | 0.37 | 1.50 | 25 | 0.147 |

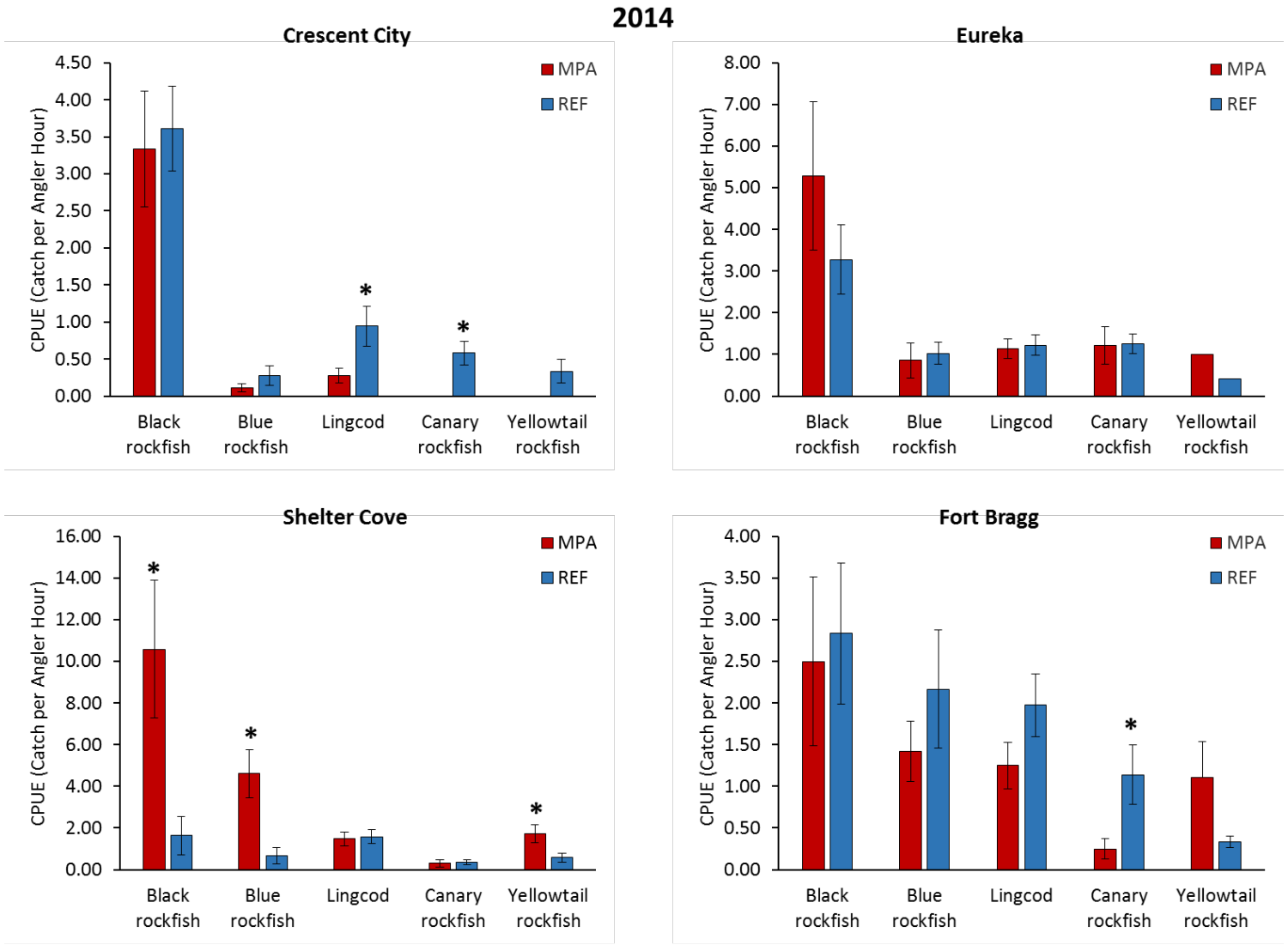



Figure 17. Catch per angler hour (CPUE) for the top five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites for Crescent City (CC), Eureka (E), Shelter Cove (SC), and Fort Bragg (FB) in 2014. Error bars represent standard error. Asterisk (*) indicates the paired sites are significantly different (p-value < 0.05).

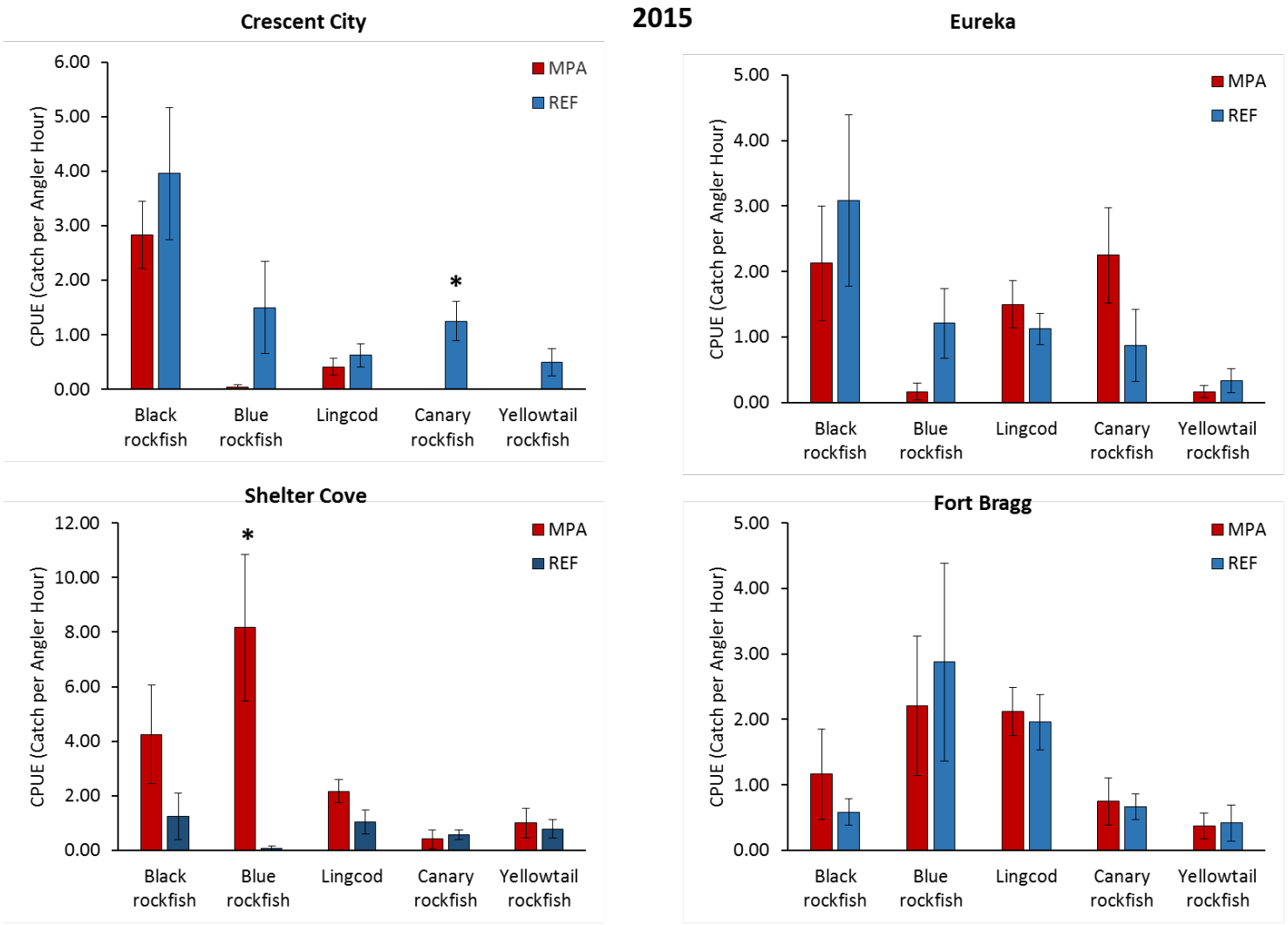



Figure 18. Catch per angler hour (CPUE) for the five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites for Crescent City (CC), Eureka (E), Shelter Cove (SC), and Fort Bragg (FB) in 2015. Error bars represent standard error. Asterisk (*) indicates the paired sites are significantly different (p-value < 0.05).

Table 14. Mean catch per angler hour, with standard error in parenthesis, of five most commonly caught species at all sites, Marine Protected Area (MPA) and reference (REF) during hook-and-line surveys in 2014.

| 2014 | **Crescent City** | | **Eureka** | | **Shelter Cove** | | **Fort Bragg** | |
|---|---|---|---|---|---|---|---|---|
| Species | MPA | REF | MPA | REF | MPA | REF | MPA | REF |
| Black rockfish | 3.33 (0.78) | 3.61 (0.57) | 5.28 (1.78) | 3.28 (0.83) | 10.58(3.32) | 1.64 (0.92) | 2.50 (1.01) | 2.83 (0.85) |
| Blue rockfish | 0.11 (0.06) | 0.28 (0.13) | 0.86 (0.42) | 1.03 (0.27) | 4.61(1.15) | 0.67 (0.4) | 1.42(0.36) | 2.17 (0.71) |
| Lingcod | 0.28 (0.1) | 0.94 (0.27) | 1.14 (0.23) | 1.22 (0.25) | 1.47(0.32) | 1.58 (0.33) | 1.25 (0.28) | 1.97 (0.38) |
| Yellowtail rockfish | 0 (0) | 0.33 (0.16) | 1.00 (0.38) | 0.42 (0.13) | 1.72(0.43) | 0.58 (0.21) | 1.11 (0.43) | 0.33 (0.07) |
| Canary rockfish | 0 (0) | 0.58 (0.16) | 1.22 (0.45) | 1.25 (0.23) | 0.31(0.18) | 0.36 (0.13) | 0.25 (0.12) | 1.14 (0.36) |

Table 15. Mean catch per angler hour, with standard error in parenthesis, of the five most commonly caught species at all sites, Marine Protected Area (MPA) and reference (REF) during hook-and-line surveys in 2015.

| 2015 | **Crescent City** | | **Eureka** | | **Shelter Cove** | | **Fort Bragg** | |
|---|---|---|---|---|---|---|---|---|
| Species | MPA | REF | MPA | REF | MPA | REF | MPA | REF |
| Black rockfish | 2.83 (0.62) | 3.96 (1.21) | 2.13 (0.88) | 3.08 (1.31) | 4.25 (1.81) | 1.25 (0.84) | 1.17 (0.69) | 0.58 (0.2) |
| Blue rockfish | 0.04 (0.04) | 1.50 (0.84) | 0.17 (0.13) | 1.21 (0.53) | 8.17 (2.68) | 0.08 (0.08) | 2.21 (1.06) | 2.88 (1.51) |
| Lingcod | 0.42 (0.15) | 0.63 (0.21) | 1.5 (0.36) | 1.13 (0.24) | 2.17 (0.43) | 1.04 (0.44) | 2.13 (0.37) | 1.96 (0.42) |
| Canary rockfish | 0 (0) | 1.25 (0.36) | 2.25 (0.73) | 0.88 (0.55) | 0.42 (0.33) | 0.58 (0.18) | 0.75 (0.36) | 0.67 (0.19) |
| Yellowtail rockfish | 0 (0) | 0.50 (0.25) | 0.17 (0.09) | 0.33 (0.18) | 1.00 (0.54) | 0.79 (0.33) | 0.38 (0.2) | 0.42 (0.28) |

Table 16. Results from a Welch's two-sample t-test conducted on mean CPUE (catch per angler hour) of the five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites, Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB) for the 2014 sampling season.

| 2014 | | | | | | |
|---|---|---|---|---|---|---|
| Crescent City | | MPA | REF | t | df | p-val |
| | Black rockfish | 3.33 | 3.61 | -0.29 | 20 | 0.777 |
| | Blue rockfish | 0.11 | 0.28 | -1.16 | 16 | 0.261 |
| | Lingcod | 0.28 | 0.94 | -2.35 | 14 | 0.034 |
| | Canary rockfish | 0.00 | 0.58 | -3.54 | 11 | 0.005 |
| | Yellowtail rockfish | 0.00 | 0.33 | -2.10 | 11 | 0.060 |
| Eureka | | | | | | |
| | Black rockfish | 5.28 | 3.28 | 1.02 | 16 | 0.325 |
| | Blue rockfish | 0.86 | 1.03 | -0.33 | 19 | 0.744 |
| | Lingcod | 1.14 | 1.22 | -0.25 | 22 | 0.807 |
| | Canary rockfish | 1.22 | 1.25 | -0.05 | 16 | 0.957 |
| | Yellowtail rockfish | 1.00 | 0.42 | 1.44 | 13 | 0.174 |
| Shelter Cove | | | | | | |
| | Black rockfish | 10.58 | 1.64 | 2.59 | 13 | 0.023 |
| | Blue rockfish | 4.61 | 0.67 | 3.23 | 14 | 0.006 |
| | Lingcod | 1.47 | 1.58 | -0.24 | 22 | 0.813 |
| | Canary rockfish | 0.31 | 0.36 | -0.25 | 20 | 0.804 |
| | Yellowtail rockfish | 1.72 | 0.58 | 2.39 | 16 | 0.030 |
| Fort Bragg | | | | | | |
| | Black rockfish | 2.50 | 2.83 | -0.25 | 21 | 0.803 |
| | Blue rockfish | 1.42 | 2.17 | -0.94 | 16 | 0.361 |
| | Lingcod | 1.25 | 1.97 | -1.53 | 20 | 0.142 |
| | Canary rockfish | 0.25 | 1.14 | -2.36 | 13 | 0.034 |
| | Yellowtail rockfish | 1.11 | 0.33 | 1.79 | 12 | 0.100 |

Table 17. Results from a Welch's two-sample t-test conducted on mean CPUE (catch per angler hour) of the five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites, Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB) for the 2015 sampling season.

| 2015 | | | | | | |
|---|---|---|---|---|---|---|
| Crescent City | | MPA | REF | t | df | p-val |
| | Black rockfish | 2.83 | 3.96 | -0.82 | 10 | 0.428 |
| | Blue rockfish | 0.04 | 1.50 | -1.74 | 7 | 0.125 |
| | Lingcod | 0.42 | 0.63 | -0.80 | 13 | 0.440 |
| | Canary rockfish | 0.00 | 1.25 | -3.47 | 7 | 0.010 |
| | Yellowtail rockfish | 0.00 | 0.50 | -1.98 | 7 | 0.088 |
| Eureka | | | | | | |
| | Black rockfish | 2.13 | 3.08 | -0.61 | 12 | 0.555 |
| | Blue rockfish | 0.17 | 1.21 | -1.91 | 8 | 0.094 |
| | Lingcod | 1.50 | 1.13 | 0.86 | 12 | 0.406 |
| | Canary rockfish | 2.25 | 0.88 | 1.50 | 13 | 0.158 |
| | Yellowtail rockfish | 0.17 | 0.33 | -0.84 | 10 | 0.422 |
| Shelter Cove | | | | | | |
| | Black rockfish | 4.25 | 1.25 | 1.50 | 10 | 0.164 |
| | Blue rockfish | 8.17 | 0.08 | 3.01 | 7 | 0.020 |
| | Lingcod | 2.17 | 1.04 | 1.83 | 14 | 0.089 |
| | Canary rockfish | 0.42 | 0.58 | -0.45 | 11 | 0.661 |
| | Yellowtail rockfish | 1.00 | 0.79 | 0.33 | 11 | 0.748 |
| Fort Bragg | | | | | | |
| | Black rockfish | 1.17 | 0.58 | 0.81 | 8 | 0.439 |
| | Blue rockfish | 2.21 | 2.88 | -0.36 | 13 | 0.724 |
| | Lingcod | 2.13 | 1.96 | 0.30 | 14 | 0.768 |
| | Canary rockfish | 0.75 | 0.67 | 0.20 | 11 | 0.842 |
| | Yellowtail rockfish | 0.38 | 0.42 | -0.12 | 13 | 0.906 |

**Species Mean Lengths**

Mean lengths between MPAs and reference sites were significantly different (p-value < 0.05) in four of the five most abundant species when data from both the 2014 and 2015 sampling seasons were pooled (Figure 19; Table 18). Blue rockfish and Yellowtail rockfish were significantly larger in both the Shelter Cove and Fort Bragg MPA sites compared to their REF sites. At the Eureka sites, Canary rockfish and Black rockfish were significantly larger in the MPA compared to the REF site. Blue rockfish at Crescent City were the only species found to be significantly longer in any REF site compared to their paired MPA site. However, these results may be due to low sample size of Blue rockfish at the Crescent City MPA (n = 5). Additionally, because no Canary rockfish or Yellowtail rockfish were caught in the Crescent City MPA, size comparison could not be conducted with its reference site. A year to year comparison of length data was not conducted due to small sample sizes in some sites and species.

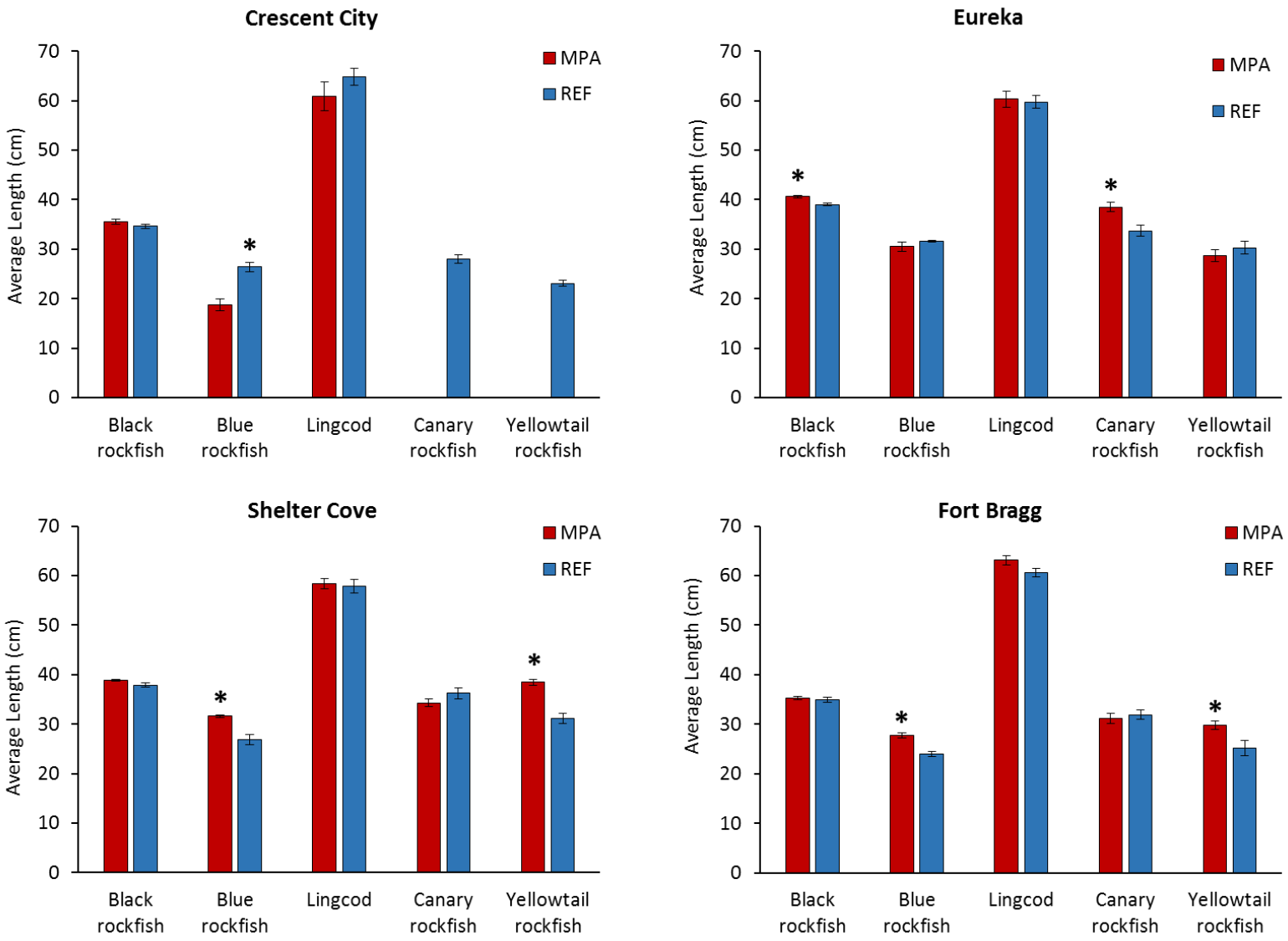


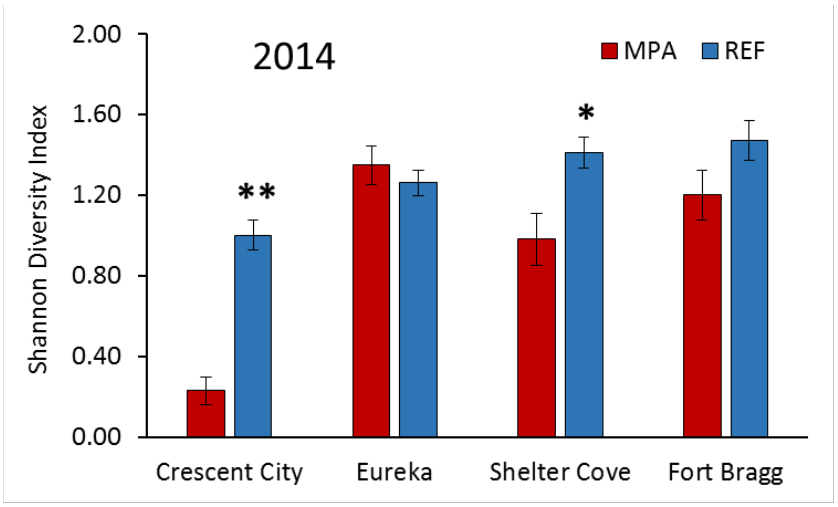

Figure 19. Average length (cm) of the five most commonly caught species in paired Marine Protected Area (MPA) and reference (REF) sites at Crescent City (CC), Eureka (E), Shelter Cove (SC), and Fort Bragg (FB) with both sampling seasons combined (2014, 2015). Error bars represent standard error. Asterisk (*) indicates the paired sites are significantly different (p-value < 0.05).

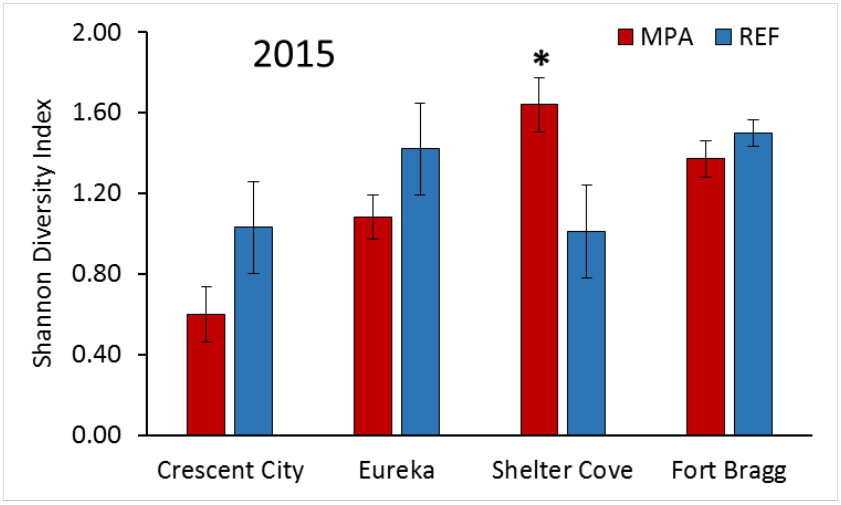
Table 18. Mean length (cm), with standard error in parenthesis, of the five most commonly caught species for each site, Marine Protected Area (MPA) and reference (REF), combining both sampling season (2014, 2015). One asterisk (*) indicates the paired sites are significantly different (p-value < 0.05). Two asterisks (**) indicates the paired sites are significantly different (p-value < 0.001).

| | **Crescent City** | | **Eureka** | | **Shelter Cove** | | **Fort Bragg** | |
|---|---|---|---|---|---|---|---|---|
| | MPA | REF | MPA | REF | MPA | REF | MPA | REF |
| | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) |
| Species | Number | Number | Number | Number | Number | Number | Number | Number |
| Black rockfish | 35.5 (0.5) | 34.6 (0.5) | 40.6 (0.3)** | 39.0 (0.3) | 38.8 (0.2) | 37.9 (0.5) | 35.3 (0.4) | 35.0 (0.5) |
| | 185 | 215 | 229 | 187 | 468 | 86 | 115 | 111 |
| Blue rockfish | 18.7 (1.2) | 26.4 (0.9)** | 30.5 (0.9) | 31.6 (0.2) | 31.6 (0.2)** | 26.9 (1.0) | 27.7 (0.5)** | 24.0 (0.5) |
| | 5 | 43 | 35 | 66 | 340 | 25 | 101 | 145 |
| Lingcod | 60.8 (2.9) | 64.8 (1.7) | 60.3 (1.6) | 59.7 (1.3) | 58.4 (1.0) | 57.8 (1.4) | 63.1 (1.0) | 60.6 (0.9) |
| | 18 | 43 | 69 | 65 | 94 | 72 | 90 | 111 |
| Canary rockfish | - (-) | 28.0 (0.9) | 38.5 (0.9)** | 33.7 (1.1) | 34.3 (0.7) | 36.2 (1.1) | 31.2 (1.0) | 31.9 (0.9) |
| | 0 | 51 | 96 | 62 | 21 | 25 | 26 | 56 |
| Yellowtail | - (-) | 23.1 (0.6) | 28.7 (1.2) | 30.3 (1.3) | 38.5 (0.6)** | 31.2 (1.0) | 29.8 (0.9)* | 25.2 (1.6) |
| rockfish | 0 | 24 | 38 | 23 | 82 | 39 | 48 | 20 |

**Species Diversity**

The Shannon diversity index for all sites and years combined was 1.90. Values for individual sites ranged from 0.38 (Crescent City MPA) to 1.48 (Fort Bragg REF; Figure 20; Table 19). When pooling both sampling seasons, the Crescent City sites were the only pair where a statistically significant difference in Shannon diversity between MPA (0.38) and REF (1.01; p-value < 0.001) sites was observed. In 2014 the Shelter Cove REF site had a significantly higher Shannon diversity index (1.41) than the MPA site (0.98; p-value = 0.019). In 2015, this was reversed and the MPA (1.64) had a significantly higher index than the REF (1.01; p-value = 0.007). No other significant interannual difference in Shannon diversity index was detected (Table 20).



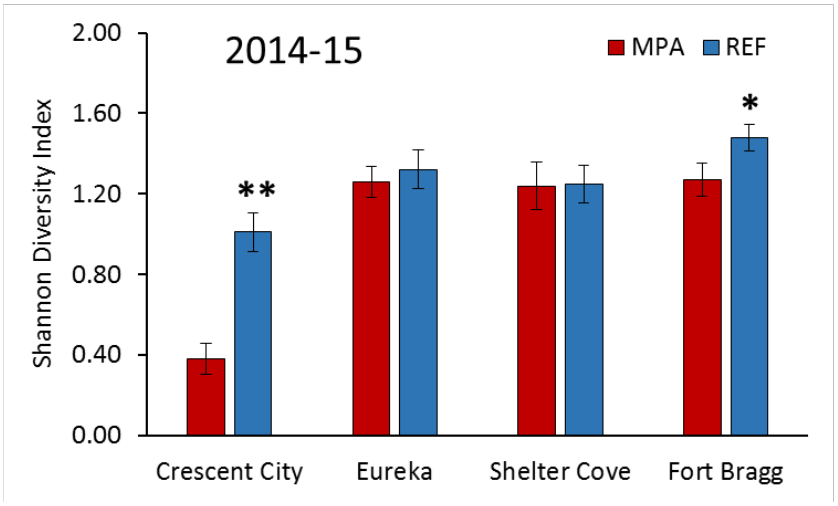




Figure 20. Shannon diversity index in all paired Marine Protected Area (MPA) and reference (REF) sites for 2014, 2015, and both years combined. Error bars represent standard error. One asterisk (*) indicates the paired sites are significantly different (p-value < 0.05). Two asterisks (**) indicates the paired sites are significantly different (p-value < 0.001). Asterisks are placed over the site that is significantly higher.

Table 19. Mean Shannon diversity index with corresponding standard error (SE) for all species combined by port, Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB) and site, Marine Protected Area (MPA) and reference (REF) site, for 2014, 2015, and both years combined.

| | | **Shannon Diversity Index (SE)** | | |
|---|---|---|---|---|
| | | 2014 | 2015 | Both Years |
| CC | | 0.62 (0.09) | 0.81 (0.14) | 0.69 (0.08) |
| | CC MPA | 0.23 (0.07) | 0.60 (0.14) | 0.38 (0.08) |
| | CC REF | 1.00 (0.07) | 1.03 (0.23) | 1.01 (0.10) |
| E | | 1.31 (0.06) | 1.25 (0.13) | 1.28 (0.06) |
| | E MPA | 1.35 (0.10) | 1.08 (0.11) | 1.25 (0.08) |
| | E REF | 1.26 (0.06) | 1.42 (0.23) | 1.32 (0.10) |
| SC | | 1.20 (0.09) | 1.32 (0.12) | 1.25 (0.07) |
| | SC MPA | 0.98 (0.13) | 1.64 (0.13) | 1.24 (0.12) |
| | SC REF | 1.41 (0.11) | 1.01 (0.14) | 1.25 (0.09) |
| FB | | 1.34 (0.08) | 1.43 (0.06) | 1.38 (0.05) |
| | FB MPA | 1.20 (0.13) | 1.37 (0.09) | 1.27 (0.08) |
| | FB REF | 1.47 (0.10) | 1.50 (0.06) | 1.48 (0.06) |

Table 20. Results from a Welch's two-sample t-test conducted on mean Shannon diversity of paired Marine Protected Area (MPA) and reference (REF) sites for Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB), for 2014, 2015, and both years combined.

| | | Mean Shannon Diversity | | | | |
|---|---|---|---|---|---|---|
| 2014 | | MPA | REF | t | df | p-val |
| | CC | 0.23 | 1.00 | -7.64 | 22 | <0.001 |
| | E | 1.35 | 1.26 | 0.790 | 19 | 0.440 |
| | SC | 0.98 | 1.41 | -2.53 | 21 | 0.019 |
| | FB | 1.20 | 1.47 | -1.68 | 21 | 0.107 |
| 2015 | | | | | | |
| | CC | 0.60 | 1.03 | -1.61 | 11 | 0.134 |
| | E | 1.08 | 1.42 | -1.31 | 10 | 0.219 |
| | SC | 1.64 | 1.01 | 3.17 | 14 | 0.007 |
| | FB | 1.37 | 1.50 | -1.20 | 13 | 0.254 |
| Both Years | | | | | | |
| | CC | 0.38 | 1.01 | -5.08 | 36 | <0.001 |
| | E | 1.26 | 1.32 | -0.64 | 36 | 0.525 |
| | SC | 1.24 | 1.25 | -0.05 | 36 | 0.959 |
| | FB | 1.27 | 1.48 | -2.04 | 36 | 0.049 |

**Depth Analysis**

We examined trends in CPUE, species richness, and Shannon diversity at two different depth categories, shallow (10-29 meters) and deep (30-50 meters), for all sites and years combined. Both Shannon diversity and species richness of all fish and rockfish only were found to be slightly higher in deep cells compared to shallow cells (Figure 21; Table 21). Similarly, CPUE of all species combined and rockfish species only was slightly higher in deep cells. Eight of the nine most abundant species had a higher CPUE in deep cells (Figure 22; Table 22). Copper rockfish (*S. caurinus*) and Quillback rockfish (*S. maliger*) showed an especially large disparity in CPUE at different depth categories; CPUE was nearly 10 times higher for Copper rockfish and over 20 times higher for Quillback rockfish in deep cells compared to shallow cells. Black rockfish was the only species in the top nine that had a higher CPUE in shallow cells (4.3) than deep cells (2.3).

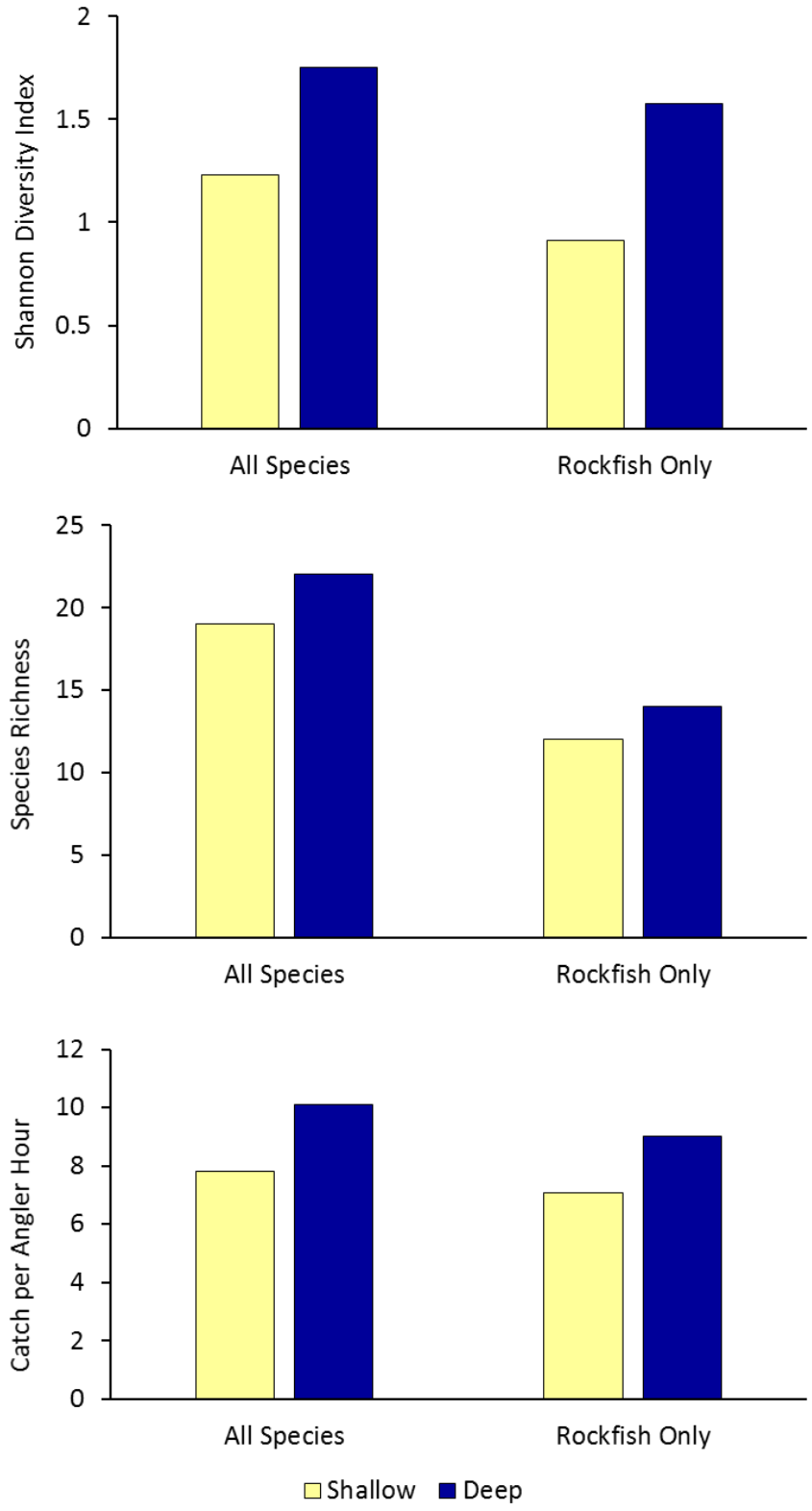



Figure 21. Mean Shannon diversity index, species richness, and catch per angler hour for all species combined and rockfish species only in shallow (10-29 meters average depth) and deep (30-50 meters average depth) cells caught in Marine Protected Area and reference sites in 2014 and 2015 combined.

Table 21. Mean Shannon diversity index, species richness, and catch per angler hour for all species combined and rockfish species only in shallow (10-29 meters average depth) and deep (30-50 meters average depth) cells caught in Marine Protected Area and reference sites in 2014 and 2015 combined.

| | Shannon Diversity Index | | Species Richness | | Catch Per Angler Hour | |
|---|---|---|---|---|---|---|
| Depth | All Species | Rockfish Only | All Species | Rockfish Only | All Species | Rockfish Only |
| Shallow | 1.23 | 0.91 | 8.06 | 5.50 | 7.82 | 7.07 |
| Deep | 1.75 | 1.58 | 11.07 | 8.86 | 10.11 | 9.02 |

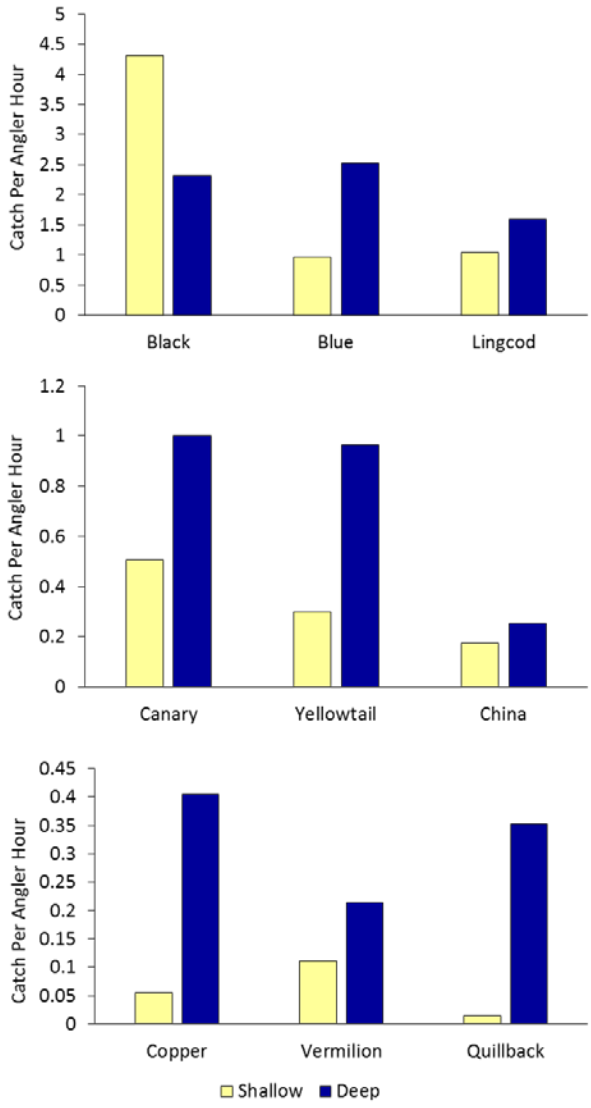



Figure 22. Mean catch per angler hour of the nine most abundant species captured in shallow (10-29 meters average depth) and deep (30-50 meters average depth) sampling cells for all Marine Protected Area and reference sites for 2014 and 2015 sampling seasons combined.

Table 22. Mean catch per angler hour of the nine most abundant species captured in shallow (10-29 meters average depth) and deep (30-50 meters average depth) sampling cells for all Marine Protected Area and reference sites for 2014 and 2015 sampling seasons combined.

| | Catch Per Angler Hour | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth | Black rockfish | Blue rockfish | Lingcod | Canary rockfish | Yellowtail rockfish | China rockfish | Copper rockfish | Vermilion rockfish | Quillback rockfish |
| Shallow | 4.31 | 0.96 | 1.04 | 0.51 | 0.30 | 0.17 | 0.06 | 0.11 | 0.01 |
| Deep | 2.32 | 2.53 | 1.60 | 1.00 | 0.97 | 0.25 | 0.40 | 0.21 | 0.35 |

**Tag Returns**

As of January 2017, we have received 18 tag returns (0.5%) of the 3,491 fish tagged. Returns were dominated by Black Rockfish (n = 9) and Lingcod (n = 7), with one return each for Yelloweye rockfish (*S. ruberrimus*), and Pacific halibut (*Hippoglossus stenolepis*; Table 23). Fish recaptured in the same sample site as their release were assigned a net movement of zero; calculated displacement distances are approximate and dependent on the precision of the reported recapture location. Among recaptured Black rockfish, no displacement was detected in four cases, one was recaptured approximately seven kilometers north of its original capture location, and four had displacements of greater than 300 kilometers, all to the north. The largest displacement was an individual tagged in the South Cape Mendocino SMR and recaptured 586 days later off of Willapa Bay, WA, a net movement of 680 kilometers. Lingcod either showed no detectable displacement (n = 5), or small displacements of less than 10 kilometers (n = 2). The Yelloweye rockfish and Pacific halibut showed no detectable displacement.

Table 23. Tag return data as of January 2017, including species, tag number, tagging date and site, Crescent City (CC), Eureka (E), Shelter Cove (SC), Fort Bragg (FB), Marine Protected Area (MPA), and reference site (REF), date and location recaptured, days at liberty, and net movement (km). Recapture location is either a study site, reported coordinates outside of a study site, or an estimated location.

| Species | Tag # | Date Tagged | Site Tagged | Date Recaptured | Recapture Location | Days at Liberty | Net Movement (km) |
|---|---|---|---|---|---|---|---|
| Black rockfish | 2261 | 10/5/2014 | CC REF | 7/6/2015 | CC REF | 274 | 0 |
| Black rockfish | 0488 | 7/16/2014 | SC MPA | 8/11/2014 | SC MPA | 26 | 0 |
| Black rockfish | 0192 | 6/26/2014 | E MPA | 7/24/2015 | E MPA | 393 | 0 |
| Black rockfish | 0087 | 6/19/2014 | CC REF | 8/9/2015 | CC REF | 416 | 0 |
| Black rockfish | 0229 | 6/26/2014 | E MPA | 8/30/2015 | 40º 29.5'N 124º 29.5'W | 430 | 6.7 |
| Black rockfish | 0782 | 7/25/2014 | FB MPA | 3/26/2016 | 42º 06.977'N 124º 22.124'W | 610 | 300 |
| Black rockfish | 0157 | 6/23/2014 | CC MPA | 4/16/2016 | Off Government Pt, OR | 663 | 330 |
| Black rockfish | 2284 | 10/9/2014 | CC MPA | 8/28/2016 | 45º 12.614'N 123º 59.371'W | 689 | 370 |
| Black rockfish | 1707 | 8/28/2014 | E MPA | 4/5/2016 | 46º 30.7'N 124º 16.9'W | 586 | 680 |
| Lingcod | 0116 | 6/19/2014 | CC REF | 5/22/2015 | CC REF | 337 | 0 |
| Lingcod | 1811 | 8/29/2014 | FB REF | 7/25/2015 | FB REF | 330 | 0 |
| Lingcod | 1467 | 8/13/2014 | FB REF | 7/29/2016 | FB REF | 716 | 0 |
| Lingcod | 1503 | 8/13/2014 | FB REF | 9/10/2016 | FB REF | 759 | 0 |
| Lingcod | 2174 | 10/3/2014 | E REF | 9/17/2016 | E REF | 715 | 0 |
| Lingcod | 2033 | 9/15/2014 | E MPA | 8/28/2016 | 40º 26.7'N 124º 26.4'W | 713 | 4.4 |
| Lingcod | 1914 | 8/30/2014 | FB MPA | 8/12/2016 | 39° 38.732'N 123° 47.502'W | 713 | 6.0 |
| Pacific halibut | 2343 | 5/31/2015 | E REF | 7/6/2016 | E REF | 402 | 0 |
| Yelloweye rockfish | 0024 | 6/12/2014 | SC REF | 8/2/2014 | SC REF | 51 | 0 |

**Collaboration with the Fishing Community**

We engaged 40 individual volunteers in 80 volunteer-days of fishing effort. This accounted for half of the 160 angler-days of effort completed during the project. The pool of volunteers included experienced recreational anglers, students, and community members that were relatively new to fishing. Volunteers were drawn from all sampling ports and, in several cases, from out of state. Enthusiasm among volunteer anglers was high, 18 volunteered more than once, and 10 participated in at least three trips. Our most dedicated volunteer, a respected member of the local recreational fishing community, volunteered on eight trips and fished with us out of all four ports. Collaborating with us were six charter captains and six deckhands (Table 24). Initial reaction to the project by the captains and deckhands was mixed, but by the end of the study they expressed mostly positive views about the project, if not enthusiasm about the need for and efficacy of Marine Protected Areas. Many anglers that we interacted with held similar views.

Table 24. Commercial Passenger Fishing Vessel (CPFV) captains who participated in collaborative hook-and-line surveys of Northern California Marine Protected Areas, 2014-2015.

| Port | Captain | Vessel |
|---|---|---|
| Crescent City | Craig Strickhouser | CPFV Tally Ho II |
| Eureka | Matt Dallam | CPFV Fishy Business |
| | Tim Klassen | CPFV Reel Steel |
| Shelter Cove | Jared Morris | CPFV C'mon |
| | Kevin Riley | CPFV Outcast & |
| | | CPFV Squirrel |
| Fort Bragg | Kurt Akin | CPFV Fish on & |
| | | CPFV Bella Bleu |

# Discussion

## Relative Abundance

Because many of the fish species associated with nearshore rocky reefs are slow growing and long lived (Love et al. 1990), we did not expect to detect any significant effects of protection in this baseline survey. This expectation is further supported by similar research on the Central California coast that found significant biological response to protection only in the one MPA that had been created more than 20 years prior, but little or no effect for the MPAs that had been designated only seven years prior (Starr et al. 2015). We believe much of the difference in CPUE among sites in this study can be attributed to the effect of historical fishing pressure, which can be approximated by the distance from a fishing port to each sampling site (Barrett et al. 2012; Table 25).

The North Coast has three ports with full vessel services and over 400 km of shoreline, resulting in large areas of remote nearshore fishing grounds. There are several factors that prevent fishers from accessing these areas: 1) the time required to reach remote fishing grounds 2) the cost of fuel consumed in transit to and from these areas, and 3) the risks associated with traveling to grounds far from refuge. Without exception, among each set of paired sites, a higher catch rate was observed at the site farthest from the nearest fishing port, regardless of protected status (Table 25). This is an important relationship that was only fully realized after analysis of the data was completed, and should be considered when selecting reference sites for other North Coast MPAs.

This effect was especially pronounced at the Shelter Cove sites. Shelter Cove is the only harbor located along the Lost Coast, an area spanning roughly from Ferndale in Humboldt County to Westport in Mendocino County; it offers no dockage, only seasonal mooring and craft must be trailer-launched, limiting the size of vessels. However, Shelter Cove is a popular destination for fishing, which accounts for the catch rates and diversity index of the reference site located just offshore (Point Delgada) being similar to that of other more accessible fishing sites in the North Coast Study Region. Sea Lion Gulch SMR, Shelter Cove's MPA site, is located approximately 35 kilometers north of Shelter Cove. Magnifying the limitations listed above, fishers launching from Shelter Cove are restricted to smaller craft, and the site is located offshore of Punta Gorda, which is infamous among the fishers we worked with for its especially unpredictable and rapidly changing sea conditions. CPUE at the Sea Lion Gulch SMR (20.1 fish per angler hour) are comparable to those documented at the "Old" Point Lobos MPA (24.4 fish per angler hour) in the central California, established in 1973 (Starr et al. 2008, Starr et al. 2015). Because of this, we suggest Sea Lion Gulch has been serving as a de facto MPA for many years. If other current or future MPAs along the North Coast turn out to be strategically located and effectively enforced, we may observe similar CPUEs in them after an extended period of time.

Table 25. Distance from nearest port (km) and combined species catch per unit effort (CPUE) for each Marine Protected Area (MPA) and reference (REF) site for sampling years 2014 and 2015 combined.

| Port | Site | Dist. from Port (km) | CPUE |
|---|---|---|---|
| Crescent City | MPA | 6.5 | 3.67 |
| | REF | 9.7 | 6.9 |
| Eureka | MPA | 53 | 9.53 |
| | REF | 49 | 8.03 |
| Shelter Cove | MPA | 32 | 20.12 |
| | REF | 3.4 | 5.62 |
| Fort Bragg | MPA | 18 | 7.62 |
| | REF | 25 | 9.1 |

At the outset of this study (2014), Canary rockfish were classified as overfished and the subject of an intensive rebuilding effort. Although there is little previous data on nearshore Canary rockfish populations, along the North Coast, it is nonetheless encouraging that they ranked fourth in overall CPUE for the project. The Canary rockfish stock was declared rebuilt in 2015 (Thorson and Wetzel, 2016). Three of the sites we sampled were also sampled five times per year in 2010 and 2011 by Barrett et al. (2011) in a previous collaborative fisheries research project (Table 26, Figure 23). CPUE for Canary rockfish shows no detectable trends at any of these sites across these years (2010-2011, 2014-2015). We also compared CPUE for Black rockfish, the most commonly captured fish in both studies, and similarly found no trends. Yelloweye rockfish, another species of concern, were sampled by this study and by Barret et al. (2011). However, they were caught in numbers too low for meaningful comparison.

Table 26. Mean catch per angler hour for Black rockfish and Canary rockfish during a previous collaborative fisheries research project (2010 and 2011) and during baseline sampling (2014 and 2015). Damnation Creek was not sampled in 2011.

| Black rockfish | Site | 2010 | 2011 | 2014 | 2015 |
|---|---|---|---|---|---|
| | Damnation Creek | 4.15 | - | 3.61 | 3.96 |
| | Ten Mile | 0.32 | 1.49 | 2.50 | 1.17 |
| | Westport | 0.65 | 0.89 | 2.83 | 0.58 |
| **Canary rockfish** | | | | | |
| | Damnation Creek | 0.83 | - | 0.58 | 1.25 |
| | Ten Mile | 0.48 | 0.85 | 0.25 | 0.75 |
| | Westport | 0.71 | 0.45 | 1.14 | 0.67 |

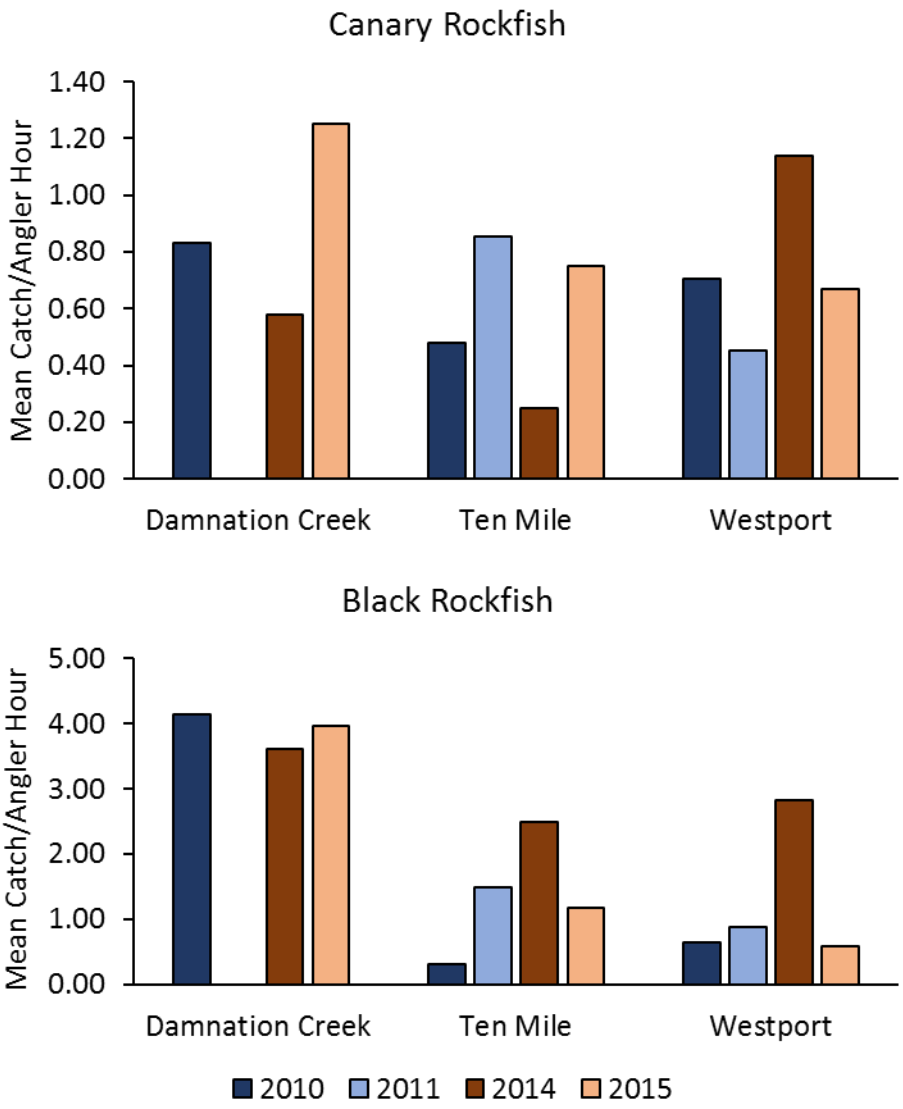



Figure 23. Mean catch per angler hour for Black rockfish and Canary rockfish during a previous collaborative fisheries research project (2010 and 2011) and during baseline sampling (2014 and 2015). Damnation Creek was not sampled in 2011.

## Tag Returns

Although formal analysis was not possible due to the low rate of recapture, there is an emerging pattern of a large northward movement (greater than 300 kilometers) occurring in about half (four out of nine) the Black rockfish recaptured (Figure 24). This pattern was also observed in the Central Coast MPA Study Region, where a similar ratio (21 out of 45) of Black rockfish recaptures occurred greater than 350 kilometers to the north of the point of release (Starr et al. 2015).

Figure 24. Left: A project technician inserts an external t-bar anchor tag into a captured fish. Right: A Black rockfish (*Sebastes melanops*) after tagging.

## Challenges

During sampling of MPAs located near more populated areas (i.e. Pyramid Point SMCA and Ten Mile SMR), we frequently observed illegal fishing within MPA boundaries. Many of the vessels we observed fishing within the bounds of Pyramid Point SMCA appeared to be from the port of Brookings, OR, which lies about 5 kilometers to the north. We did not notice these incursions at Sea Lion Gulch SMR or at South Cape Mendocino SMR. Since the area surrounding Sea Lion Gulch SMR is rarely fished, there may not be a benefit to be gained in terms of increased yield or quality of fish by violating the MPA. Although South Cape Mendocino SMR is farther from its nearest port (Eureka, about 50 kilometers to the North) than Sea Lion Gulch SMR, the area surrounding it is more frequently fished because it is the nearest suitable rockfish grounds accessible from Eureka and the other ports on Humboldt Bay. The South Cape Mendocino SMR is located on a large reef complex, so despite the higher fishing pressure in the area, there may still be little incentive to fish inside the MPA. Both Ten Mile SMR and Pyramid Point SMCA protect smaller patch reefs, with relatively few desirable fishing grounds nearby, which may lead to increased illegal fishing inside the protected areas.

While we modeled our protocols after those of the CCFRP, we encountered challenges adapting them to the North Coast. The biggest logistical challenge we faced was scheduling sampling trips. We found scheduling sampling trips more than 3-5 days in advance to be infeasible because of highly variable and frequently poor sea conditions. In 2014, 12 of our first 15 sampling trips were cancelled due to unfavorable weather conditions. As we developed

relationships with the captains, we were able to work closely with them to plan sampling within the window of the 5-day marine weather forecast and in a manner that had minimal impact on their regular clients. Several captains began contacting us when they were available and good sea conditions were expected.

Because of the unpredictable sampling schedule, long drive times to ports, long vessel transit times to sites, challenging fishing conditions, and use of small boats frequently without comfortable facilities, our pool of willing and able volunteers was insufficient to provide four anglers for each trip. For that reason, we typically employed one or two undergraduate research assistants as anglers, samplers, or data recorders on each sampling trip. This allowed us to collect more consistent data, as well as schedule our trips on short notice, often less than 24 hours, and complete our entire sampling schedule.

As part of one of the master's thesis associated with the project, we conducted a pilot study that allowed the small scientific crew to collect data on where individual fish were caught. To do this, we used a handheld GPS unit in conjunction with a GoPro camera. The GoPro was set up to capture a clear view of the deck with all anglers. The GPS was set to record position every 30 seconds during sampling and was briefly held up to the camera at the beginning of each sampling period with the time displayed to allow synchronization of the footage and GPS data during processing. The technician processing the video footage could then associate the time of capture for each fish with the location of the vessel at that time. This process minimized the burden of recording fish positions during sampling at sea, but required substantial effort afterward to extract the location where each fish was caught.

The project engaged a significant portion of the fishing community on the North Coast through direct participation in sampling, outreach events, and word of mouth. Most community members we engaged were enthusiastic about the project itself, but remained skeptical of the need for and benefits of MPAs – especially in our region. Outreach efforts on the North Coast have been modest; it is possible that MPAs will gain more support as the fishing community becomes more knowledgeable about the MPA network and more invested in scientific monitoring through participatory projects including collaborative fisheries research. Such outreach on MPAs could foster greater interest in community stewardship of the North Coast's marine resources, and decrease the rate of fishing incursions that we observed.

**Anticipated Products and Student Outcomes**

Data from this study has been, and will continue to be, presented at professional meetings. It will also be incorporated into two master's theses and several subsequent journal articles, including synthesis articles incorporating data from other North Coast baseline projects.

The two graduate students who assisted with this study have presented findings at venues including professional and community meetings, and an invited poster session showcasing student research at the California State University Chancellor's office in Long Beach, CA. They are actively pursuing careers or further education in the marine fisheries field.

In addition to the two graduate students, this project involved many undergraduate students as volunteer anglers, and five as undergraduate research technicians. A survey was distributed to the undergraduate research technicians asking if working on the project influenced their career choices, and if they benefitted from participating in the MPA process as a whole. A common thread in the responses was that they felt they benefitted tremendously from getting hands-on experience sampling fishes and working with a collaborative research team, and that they've been encouraged to continue careers in fisheries. A few of the technicians worked on multiple MPA projects, and reported gaining experience in a range of sampling techniques. Of the five undergraduate research technicians, two are now in fisheries graduate programs, one has recently graduated and is seeking employment in the fisheries field, and two are nearing completion of Fisheries Biology degrees at Humboldt State University.

## Long-term Monitoring Recommendations

Long-term monitoring of rocky-reef associated fish communities will be critical for assessing the performance of North Coast MPAs, and the strength of the entire California Marine Protected Area Network. Although these communities are relatively slow to respond to protection (Starr et al. 2015), frequent monitoring would allow environmental and MPA effects to be parsed more easily than occasional monitoring similar to this baseline assessment, even if it was more limited in scope. This is especially important because the baseline monitoring occurred during atypically warm and nutrient-poor ocean conditions (Bond et al. 2015, Jacox et al. 2016).

Data from these studies would provide information about rocky reef associated nearshore fishes along the North Coast, where a scarcity of published data exists (Steinberg, 2008). This information includes length distributions, community composition, and relative abundance of these fishes, all of which can aid in the management of these commercially and recreationally important species. This is particularly important for long-lived rockfish species that are especially vulnerable to overfishing, such as Canary rockfish. Additionally, hook and line sampling in rocky reef habitat has been identified as an important data source for assessment of Canary rockfish stocks (Thorson and Wetzel, 2016).

More frequent monitoring will also help to maintain relationships and collaboration with the local fishing community. Angler outreach events such as data workshops and raffles similar to those conducted by the Central California Collaborative Fisheries Research Program would contribute to the development of a robust network of collaborating captains and volunteer anglers, and would be most effective at maintaining that network if monitoring were undertaken annually.

Further, a continuous program will provide higher quality, more consistent, and more cost-effective data collection by facilitating recruitment and retention of key technicians and graduate students. We propose annual monitoring of two MPA/reference site pairs, and a rotating schedule of sampling the remaining seven MPAs, along the North Coast, that contain rocky reef habitat. This would maintain a continuous dataset for several sites allowing detection of short-term or episodic temporal trends (e.g. environmental variation such as El Niño events), while continuing to provide occasional abundance and diversity estimates for all MPAs in the North Coast Study Region, which should be sufficient to quantify longer-term trends.

We recommend annual monitoring of the South Cape Mendocino SMR, Ten Mile SMR and their associated reference sites. These reference sites that are proximate to the MPAs, relative to the distance from port, minimize the confounding effect of disparate historical fishing pressure. Both reference sites are similar in habitat, species composition, and relative abundance to their associated MPA. The locations of each pair represent conditions in more northern and southern

areas of the North Coast Study Region, and are accessible by two of the most popular fishing ports on the North Coast, Eureka (South Cape Mendocino SMR) and Fort Bragg (Ten Mile SMR). Continued monitoring of Sea Lion Gulch SMR and its reference site (Point Delgada), perhaps on less frequent basis (every 2-4 years) would provide valuable data on the abundance of fish at a site that appears to have been minimally impacted by fishing pressure even prior to MPA designation. Lastly, periodic monitoring (perhaps alternating years with Sea Lion Gulch SMR and Point Delgada) at Pyramid Point SMCA and its reference site (Damnation Creek) would provide insight into the impact of enforcement (or lack thereof) on the efficacy of that MPA.

## Literature Cited

Barrett D., J. Abrams, A. Wagschal, D. Berman, (2011). Data from Resource Legacy Fund Foundation collaborative fisheries research 2010-2011. Unpublished dataset, used with permission.

Barrett D., J. Abrams, A. Wagschal, D. Berman, (2012). An evaluation of community structure, age/length distribution, and relative abundance of nearshore fishes associated with rocky reef habitats along historic fishing pressure gradients in Northern California. Final Report for the Resource Legacy Foundation.

Bond, N.A., M.F. Cronin, H. Freeland, and N. Mantua (2015). Causes and impacts of the 2014 warm anomaly in the NE Pacific, (2015). Geophys. Res. Lett., 42, 3414–3420. doi: 10.1002/2015GL063306.

California Seafloor Mapping Project, 2010. “California seafloor mapping project: a collaborative effort”. Last accessed October 10, 2016. http://seafloor.csumb.edu/csmp/csmp.html.

Claudet, J., C.W. Osenberg, P. Domenici, F. Badalamenti, M. Milazzo, J.M. Falcon, I. Bertocci, L. Benedetti-Ceccchi, J.A. Garcia-Charton, R. Goni, J.A. Borg, A. Forcada, G.A. De Lucia, A. Perez_Ruzafa, P. Afonso, A. Brito, I. Guala, L. Le Direach, P. Sanchez-Jerez, P.J. Somerfield, and S. Planes, (2010). Marine reserves: Fish life history and ecological traits matter. Ecological Society of America, 20(3), 830-839.

Frable, B.W., D.W. Wagman, T.N. Frierson, A. Aguilar, and B.L. Sidlauskasi, (2015). A new species of Sebastes (Scorpaeniformes: Sebastidae) from the northeastern Pacific, with a redescription of the blue rockfish, S. mystinus (Jordan and Gilbert, 1881). Fisheries Bulletin, 113, 355-377.

Guidetti, P., J. Claudet, (2010). Comanagement practices enhance fisheries in marine protected areas. Conservation Biology, 24(1), 312-318.

Huntington, B., J. Watson, K. Matteson, N. McIntosh, D. Wolfe Wagman, K. Pierson, C. Don, D. Fox, S. Marion, and S. Groth (2015). Ecological Monitoring Report 2012-2013. Oregon Department of Fish and Wildlife.

Jacox, M.G., E.L. Hazen, K.D. Zaba, D.L. Rudnick, C.A. Edwards, A.M. Moore, and S.J. Bograd, (2016). Impacts of the 2015–2016 El Niño on the California Current System: Early assessment and comparison to past events, Geophys. Res. Lett., 43, 7072–7080, doi:10.1002/2016GL069716.

Lenarz, W. H., (1987). A history of California rockfish fisheries. In *Proceeding of the International Rockfish Symposium.* Anchorage, Alaska, Univ. of Alaska.

Love, M. S., P. Morris, M. McCrae, and R. Collins, (1990). Life history aspects of 19 rockfish species (Scorpaenidae: Sebastes) from the Southern California Bight (p. 38).

Parker, S.J., S.A. Berkeley, J.T. Golden, D.R. Gunderson, J. Heifetz, M.A. Hixon, R. Larson, B.M. Leaman, M.S. Love, J.A. Musick, and V.M. O'Connell, (2000). Management of Pacific rockfish. Fisheries, 25(3), 22-30.

R Core Team, (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Ruxton, G.D., (2006). The unequal variance t-test is an underused alternative to the Student's t-test and the Mann-Whitney U test. Behavioral Ecology, 17(4), 688-690.

Sakuma, K. M., S. Ralston, and V.G. Wespestad, (2006). Interannual and spatial variation in the distribution of young-of-the-year rockfish (Sebastes spp.): expanding and coordinating a survey sampling frame. California Cooperative Oceanic Fisheries Investigations Report, 47, 127.

Steinberg, S. J. 2008. North Coast Marine Information System. Report to the Resource Legacy Fund Foundation, Arcata, CA.

Starr, R.M., D.E. Wendt, N. Yochum, K. Green, L. Longabach (2008). *Surveys of Nearshore Fishes in and Near Central California Marine Protected Areas*. Final Report Submitted to the Ocean Protection Council and California Sea Grant College Program. Retrieved from: http://oceanspaces.org/data/collaborative-fisheries-surveys-nearshore-fishes-central-coast-final-report-data-metadata

Starr, R.M., D.E. Wendt, C.L. Barns, C.I. Marks, D. Malone, G. Waltz, K.T. Schmidt, J. Chiu, A.L. Launder, N.C. Hall, and N. Yochum, (2015). Variation in responses of fishes across multiple reserves within a network of Marine Protected Areas in temperate waters. PLoS ONE 10(3): e0118502. doi:10.1371/journal.pone.011850

Thorson, J.T., and C. Wetzel, (2016). The status of canary rockfish (Sebastes pinniger) in the California Current in 2015. Pacific Fishery Management Council 7700 (2015): 97200-1384.

Williams, E. H., and S. Ralston, (2002). Distribution and co-occurrence of rockfishes (family: Sebastidae) over trawlable shelf and slope habitats of California and southern Oregon. Fishery Bulletin, 100(4), 836-855.

## Appendix 1: List of publications and description of outreach effort

*Presenting Author(s)

Ian Kelmartin*, Jay Staton, Drew Barrett, Tim Mulligan, and Joe Tyburczy. 15 October 2015. *Collaborative Research to Characterize Nearshore Rocky Reef Fish Communities on the Northern California Coast*. Talk presented at HSU Sponsored Programs Foundation PI Celebration, Arcata, CA.

Rocky reefs are iconic features of the California coast that support both recreational and commercial fisheries and provide habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys in partner with commercial passenger fishing vessel (CPFV) captains and volunteer fishers to characterize baseline status of nearshore rocky reef fish assemblages in 4 pairs of MPAs and reference areas along the coast of Northern California. The project sampled 4248 individuals of 22 species, including 14 species of Rockfish (*Sebastes spp.*). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39%), Blue Rockfish (*Sebastes mystinus*, 19%) and Lingcod (*Ophidion elongatus*, 15%) across all sites. The sampling effort was successful, but hampered by the remote nature of some ports and sites, frequent unfavorable sea conditions, mechanical problems, and scheduling around the captain's regular business--challenges that led to the cancellation of 12 of the first 15 sampling trips. Though requiring greater coordination among the collaborators, scheduling trips within the 5 day coastal waters forecast window resulted in a far lower cancellation rate, and benefited captains by allowing them to fill days when no other charter was booked.

Jay Staton*, Ian Kelmartin, Drew Barrett, Tim Mulligan, and Joe Tyburczy. 7 November 2015. *Distance from Port as a Proxy for Historical Fishing Pressure on Nearshore Rocky Reefs in Northern California*. Poster presented at the Western Society of Naturalists Annual Meeting, Sacramento, CA.

Rocky reefs are iconic features of the California coast that support both recreational and commercial fisheries and provide habitat for a rich diversity of fishes. Monitoring the response of nearshore rocky reef fish communities to Marine Protected Area (MPA) establishment is critical to understanding the effectiveness of the newly formed network of MPAs on California's North Coast. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys in partner with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to characterize baseline status of nearshore rocky reef fish assemblages in 4 pairs of MPAs and reference areas along the coast of Northern California. We used linear models to compare relative fish abundance, diversity, and size structure with distance from the nearest fishing port, a proxy for historical fishing pressure. We found higher relative fish abundances (p-value = 0.001) and diversity (p-value = 0.022) as distance from port increased. We also saw significant increases in fork length of the two most commonly captured fishes, Black rockfish (*Sebastes melanops*) and Blue rockfish (*Sebastes mystinus*) as distance from nearest fishing port increased (p-value < 0.0001).

Ian Kelmartin*, Jay Staton, Drew Barrett, Tim Mulligan, and Joe Tyburczy, 7 November 2015. *Collaborative Research Methods for Surveying Fish Communities Associated with Nearshore Rocky Reefs in Northern California MPAs.* Talk presented at the Western Society of Naturalists Annual Meeting, Sacramento, CA.

Rocky reefs are iconic features of the California coast that support both recreational and commercial fisheries and provide habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys in partner with commercial passenger fishing vessel (CPFV) captains and volunteer fishers to characterize baseline status of nearshore rocky reef fish assemblages in 4 pairs of MPAs and reference areas along the coast of Northern California. The project sampled 4248 individuals of 22 species, including 14 species of Rockfish (*Sebastes spp.*). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39%), Blue Rockfish (*Sebastes mystinus*, 19%) and Lingcod (*Ophidion elongatus*, 15%) across all sites. The sampling effort was successful, but hampered by the remote nature of some ports and sites, frequent unfavorable sea conditions, mechanical problems, and scheduling around the captain's regular business--challenges that led to the cancellation of 12 of the first 15 sampling trips. Though requiring greater coordination among the collaborators, scheduling trips within the 5 day coastal waters forecast window resulted in a far lower cancellation rate, and benefited captains by allowing them to fill days when no other charter was booked.

Ian Kelmartin*, Jay Staton, Drew Barrett, Tim Mulligan, and Joe Tyburczy, 17 November 2015. *Baseline Characterization of Fish Communities Associated with Nearshore Rocky Reefs*. Talk presented at the North Coast Collaborative Forum, Fortuna, CA.

Rocky reefs are iconic features of the California coast that support both recreational and commercial fisheries and provide habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys in partner with commercial passenger fishing vessel (CPFV) captains and volunteer fishers to characterize baseline status of nearshore rocky reef fish assemblages in 4 pairs of MPAs and reference areas along the coast of Northern California. The project sampled 4248 individuals of 22 species, including 14 species of Rockfish (*Sebastes spp.*). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39%), Blue Rockfish (*Sebastes mystinus*, 19%) and Lingcod (*Ophidion elongatus*, 15%) across all sites. The sampling effort was successful, but hampered by the remote nature of some ports and sites, frequent unfavorable sea conditions, mechanical problems, and scheduling around the captain's regular business--challenges that led to the cancellation of 12 of the first 15 sampling trips. Though requiring greater coordination among the collaborators, scheduling trips within the 5 day coastal waters forecast window resulted in a far lower cancellation rate, and benefited captains by allowing them to fill days when no other charter was booked.

Jay Staton*, Ian Kelmartin*, Drew Barrett, Tim Mulligan, Joe Tyburczy, and Tim Bean. 8 March 2016. *Characterizing Diversity, Abundance, and Habitat of Fish Communities Associated with Nearshore Rocky Reefs in Northern California Through Collaborative Research*.

Poster presented at CSU Council on Ocean Affairs, Science & Technology Annual Student Research Poster Reception, Office of the Chancellor, Long Beach, CA.

Rocky reefs are iconic features of the California coast. They support important recreational and commercial fisheries while providing habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys, partnering with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to characterize the baseline status of fish assemblages in four MPAs, along with four reference sites, off the north coast. Over two sampling years, 4248 individuals were captured, representing 22 species, including 14 species of Rockfish (*Sebastes spp.*). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39%), Blue Rockfish (*Sebastes mystinus*, 19%) and Lingcod (*Ophidion elongatus*, 15%) across all sites. Linear models were used to compare relative fish abundance, diversity, and size structure to distance from the nearest fishing port, a proxy for historical fishing pressure. We found higher relative fish abundances (p-value = 0.001) and diversity (p-value = 0.022) as distance from port increased. We also saw significant increases in fork length of the two most commonly captured fishes, Black rockfish (*Sebastes melanops*) and Blue rockfish (*Sebastes mystinus*) as the distance from nearest fishing port increased (p-value < 0.0001).

Ian Kelmartin*, Jay Staton, Drew Barrett, Tim Mulligan, Joe Tyburczy, and Tim Bean. 23 March 2016. *Collaborative research methods for surveying fish communities associated with nearshore rocky reefs in the northern California Marine Protected Area (MPA) study region.* Talk presented at Western Division of the American Fisheries Society Annual Meeting, Reno, NV.

Rocky reefs are iconic features of the California coast. They support important recreational and commercial fisheries while providing habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys, partnering with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to characterize the baseline status of fish assemblages in four MPAs, along with four reference sites, off the north coast. Over two sampling years, 4,248 individuals were captured, representing 22 species, including 14 species of rockfish (*Sebastes* spp.). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39 percent), Blue Rockfish (*Sebastes mystinus*, 19 percent) and Lingcod (*Ophidion elongatus*, 15 percent) across all sites. Linear models were used to compare relative fish abundance, diversity, and size structure to distance from the nearest fishing port, a proxy for historical fishing pressure. We found higher relative fish abundances (p-value = 0.001) and diversity (p-value = 0.022) as distance from port increased. We also saw significant increases in fork length of the two most commonly captured fishes, Black Rockfish (*Sebastes melanops*) and Blue Rockfish (*Sebastes mystinus*) as the distance from nearest fishing port increased (p-value < 0.0001).

Jay Staton*, Ian Kelmartin*, Drew Barrett, Tim Mulligan, Joe Tyburczy, and Tim Bean. 30 April 2016. *Characterizing Diversity, Abundance, and Habitat of Fish Communities Associated with Nearshore Rocky Reefs in Northern California Through Collaborative Research*.

Poster presented at Humboldt Area Saltwater Anglers Annual Fundraiser Dinner, Arcata, CA.

Rocky reefs are iconic features of the California coast. They support important recreational and commercial fisheries while providing habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys, partnering with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to characterize the baseline status of fish assemblages in four MPAs, along with four reference sites, off the north coast. Over two sampling years, 4248 individuals were captured, representing 22 species, including 14 species of Rockfish (*Sebastes spp.*). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39%), Blue Rockfish (*Sebastes mystinus*, 19%) and Lingcod (*Ophidion elongatus*, 15%) across all sites. Linear models were used to compare relative fish abundance, diversity, and size structure to distance from the nearest fishing port, a proxy for historical fishing pressure. We found higher relative fish abundances (p-value = 0.001) and diversity (p-value = 0.022) as distance from port increased. We also saw significant increases in fork length of the two most commonly captured fishes, Black rockfish (*Sebastes melanops*) and Blue rockfish (*Sebastes mystinus*) as the distance from nearest fishing port increased (p-value < 0.0001).

Ian Kelmartin, Jay Staton*, Drew Barrett, Tim Mulligan, Joe Tyburczy, and Tim Bean. 7 May 2016. *Collaborative research methods for surveying fish communities associated with nearshore rocky reefs in the Northern California Marine Protected Area (MPA) study region.* Talk presented at Humboldt Marine Science Student Associate Annual Student Research Symposium, Eureka, CA.

Rocky reefs are iconic features of the California coast. They support important recreational and commercial fisheries while providing habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys, partnering with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to characterize the baseline status of fish assemblages in four MPAs, along with four reference sites, off the north coast. Over two sampling years, 4,248 individuals were captured, representing 22 species, including 14 species of rockfish (*Sebastes* spp.). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39 percent), Blue Rockfish (*Sebastes mystinus*, 19 percent) and Lingcod (*Ophidion elongatus*, 15 percent) across all sites. Linear models were used to compare relative fish abundance, diversity, and size structure to distance from the nearest fishing port, a proxy for historical fishing pressure. We found higher relative fish abundances (p-value = 0.001) and diversity (p-value = 0.022) as distance from port increased. We also saw significant increases in fork length of the two most commonly captured fishes, Black Rockfish (*Sebastes melanops*) and Blue Rockfish (*Sebastes mystinus*) as the distance from nearest fishing port increased (p-value < 0.0001).

Jay Staton*, Ian Kelmartin*, Drew Barrett, Tim Mulligan, Joe Tyburczy, and Tim Bean. 22 October 2016. *Characterizing Diversity, Abundance, and Habitat of Fish Communities Associated with Nearshore Rocky Reefs in Northern California Through Collaborative Research*. Poster presented at Humboldt Bay Symposium, Eureka, CA.

Rocky reefs are iconic features of the California coast. They support important recreational and commercial fisheries while providing habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys, partnering with commercial passenger fishing vessel (CPFV) captains and volunteer anglers to characterize the baseline status of fish assemblages in four MPAs, along with four reference sites, off the north coast. Over two sampling years, 4248 individuals were captured, representing 22 species, including 14 species of Rockfish (*Sebastes spp.*). Catch composition was dominated by Black Rockfish (*Sebastes melanops*, 39%), Blue Rockfish (*Sebastes mystinus*, 19%) and Lingcod (*Ophidion elongatus*, 15%) across all sites. Linear models were used to compare relative fish abundance, diversity, and size structure to distance from the nearest fishing port, a proxy for historical fishing pressure. We found higher relative fish abundances (p-value = 0.001) and diversity (p-value = 0.022) as distance from port increased. We also saw significant increases in fork length of the two most commonly captured fishes, Black rockfish (*Sebastes melanops*) and Blue rockfish (*Sebastes mystinus*) as the distance from nearest fishing port increased (p-value < 0.0001).

Jay Staton*, Ian Kelmartin, Tim Mulligan, Joe Tyburczy, and Tim Bean. 11 November 2016. *Habitat and Spatial Drivers of Rocky Reef Associated Fish Abundance and Diversity in the North Coast MPA Region*. Talk presented at the Western Society of Naturalists Annual Meeting, Monterey, CA.

Rocky reefs are iconic features of the California coast. They support a rich diversity of fishes targeted by both recreational and commercial fishers. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys to characterize the baseline status of fish assemblages in four MPAs, along with four reference sites, in the North Coast MPA region. Differences in fish abundance and diversity, between MPA and reference sites, are not considered direct effects of the recently established MPAs, but rather an indication of different habitat conditions or less historical fishing pressure prior to MPA establishment. We applied a suite of habitat and spatial variables as predictors in generalized linear models to explain what is driving differences in relative abundance and diversity of rocky reef fishes. Results varied across the most commonly captured species. However, distance from port, a proxy for historical fishing pressure, and mean depth were included in the best model, and were therefore important descriptors for almost every species analyzed.

Ian Kelmartin*, Jay Staton, Tim Mulligan, Joe Tyburczy, and Tim Bean. 11 November 2016. Using *Maxent And Collaborative Research To Model Habitat Suitability For Nearshore Reef Fishes In Northern California.* Talk presented at the Western Society of Naturalists Annual Meeting, Sacramento, CA.

Rocky reefs are iconic features of the California coast. They support important recreational and commercial fisheries while providing habitat for a rich diversity of fishes. Using methods developed by the California Collaborative Fisheries Research program, we conducted hook-and-line surveys, partnering with commercial passenger fishing vessel (CPFV) captains and volunteer

anglers to characterize the baseline status of fish assemblages in four marine protected areas, along with four unfished reference sites, off the Northern California Coast. Data from this survey and high-resolution bathymetric imagery available from the California Seafloor Mapping Program was used to populate Maxent habitat suitability models for several commonly captured fish species, including Black Rockfish (*Sebastes melanops*), Blue Rockfish (*S. mystinus*), Canary Rockfish (*S. pinniger*), and Lingcod (*Ophidion elongatus*).