PATTERNS IN SIZE DISTRIBUTION AND CATCH OF ROCKFISH (SEBASTES SPP.) FROM FISHERIES-DEPENDENT AND FISHERIES-INDEPENDENT HOOK-AND-LINE SURVEYS ON THE CENTRAL COAST OF CALIFORNIA

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ABSTRACT

Patterns in Size Distribution and Catch of Rockfish (*Sebastes* spp.) from Fisheries-Dependent and Fisheries-Independent Hook-and-Line Surveys on the Central Coast of California

Rose Elizabeth Dodgen

Stock assessments are statistical models which characterize the state of a population of fish. Data for stock assessment models of West Coast nearshore groundfish come largely from fisheries-dependent sources. Incorporating fisheries-independent data would increase data availability. A potential source of fisheries-independent data which is comparable to existing fisheries-dependent data is the California Collaborative Fisheries Research Program (CCFRP), a Marine Protected Area (MPA) monitoring study. We are interested in understanding the context in which CCFRP could be implemented into assessments of nearshore groundfish, specifically rockfish. To investigate this, we used management-relevant metrics to examine three questions concerning the implementation of CCFRP as a data source: whether the scope of the project captures the core depth distribution of a species, whether the methodology of the project affects assessment metrics, and how the presence of data from MPAs affects assessment metrics. Comparisons were made for three species with different life histories and desirability in the recreational groundfish fishery: Blue rockfish (*Sebastes mystinus*), Vermilion rockfish (*S. miniatus*), and Gopher rockfish (*S. carnatus*). Based on these metrics and comparisons, we found that the specific method of potential implementation of fisheries-independent data into stock assessments is highly species dependent, but all species could benefit. Implementing this data will lead to better-informed management, ensuring that these populations persist.

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1. INTRODUCTION

Within California and along the West Coast of the United States, groundfish support a substantial recreational and commercial fishery. Groundfish refers to a diverse group of species; the groundfish management plan for the West Coast of the United States includes rockfish, flatfish, several species of elasmobranchs, and roundfish, which includes greenling, lingcod, and cabezon (PFMC, 2016). Management strategies for these fishes, such as conservation areas, limits, and seasons, are established based on stock assessments. These assessments are statistical models that estimate the stock size and its surrounding uncertainty using the best available data and science. The National Marine Fisheries Service (NMFS), in collaboration with state fisheries and wildlife agencies, develops assessments for the Pacific Fisheries Management Council using a combination of both fisheries-dependent and fisheries-independent data (NMFS, 2001). Stock assessments for many rockfish in California are considered data-poor or data-moderate (Dick and MacCall 2010, Cope et al. 2015), meaning many species lack sufficient information to conduct a conventional stock assessment or are limited by poor data quality or lack of previous analysis (Bentley and Stokes 2009, Honey et al. 2010).

Data for stock assessment models of West Coast nearshore groundfish come largely from fisheries-dependent data, which are taken directly from commercial or recreational fishing operations. In California, one type of fisheries-dependent survey is conducted by fisheries observers (onboard observers) that accompany recreational hook-and-line anglers on Commercial Passenger Fishing Vessels (CPFVs). One onboard observer program collecting data on the central coast of California is the Cal Poly Observer Program (CPOP) based at California Polytechnic State University, San Luis

Obispo (Cal Poly). Data from this program have been incorporated into several rockfish stock assessments as an index of relative abundance with associated length compositions (He et al. 2015, Dick et al. 2016, He and Field 2018, Monk and He 2019), but it has limitations intrinsic to fisheries-dependent data. Fisheries-dependent data like CPOP can be impacted by angler behavior in several ways. Sampling locations are not objective, trips are of variable lengths and occur at variable times, fishing gear is unstandardized, and anglers and captains will target or avoid specific locations or species. Providing a data source to assessments that does not have these caveats, for example fisheries-independent data, would help improve data availability and objectivity. Fisheries-independent data typically come from sampling or monitoring surveys conducted by state or federal agencies or research institutions. These data provide more unbiased insight into the status of fish stocks because data are collected using standardized sampling methods. However, these data are typically less available than fisheries-dependent data (NMFS, 2001), as they are more costly and time consuming to collect. If possible, having both types of data for a given fishery allows a more complete picture of the fishery for assessment and management.

One fisheries-independent survey in California is the California Collaborative Fisheries Research Program (CCFRP), established in 2007 and designed to assess and monitor the performance of Marine Protected Areas (MPAs). The Marine Life Protection Act (1999) led to the creation of a network of MPAs across California. As of 2019, there are 124 MPAs in the state, which cover 16% of state waters (Avasthi 2005, Gleason et al. 2013, Kirlin et al. 2013, CDFW 2016). The main goal of CCFRP was to establish collaborative sampling efforts between fisheries scientists and fishers to monitor the

response of groundfish populations to some of these MPAs (Wendt and Starr, 2009), but CCFRP protocol was developed collaboratively with NMFS scientists such that it could be used in stock assessments. Despite this, until recently, CCFRP was only used in stock assessments in a limited capacity. Incorporating a fisheries-independent data source like CCFRP into these assessments in a broader scope would increase data availability and provide the assessment model with information not reliant on angler behavior (Melissa Monk, NMFS, personal communication, 2017). If assessors could determine how best to use the data, CCFRP could serve as a fisheries-independent data source for rockfish, a suite of species that are consistently data poor in their assessments.

Up to this point, CCFRP data have not been used in assessments for a variety of reasons. As it is a fisheries-independent survey established in 2007 for the specific purpose of MPA monitoring, it is in many ways constrained, especially in comparison to fisheries-dependent data for the long-established groundfish fishery. It was only recently that CCFRP established a time series long enough to be considered appropriate for assessments, and assessors are still determining the best methodology to model the data (Monk, personal communication, 2019, Monk and He 2019). There are also traits inherent to CCFRP as a data source which make it difficult to implement in assessments. CCFRP is limited in scope, most notably in its breadth of depths sampled, as it maintains a 36 m (120 ft) depth limit to reduce fish mortality from barotrauma, and many rockfish species have depth ranges that extend deeper. Furthermore, while CCFRP is a hook-and-line survey conducted on CPFVs and therefore in many ways similar to fishery-dependent onboard observer surveys such as CPOP, the sampling methodology does differ. For example, it is more limited in geography, as CPOP samples throughout the

county and CCFRP was designed to monitor a few more specific locations, and CCFRP avoids many caveats of fisheries-dependent data as outlined above. These differences have the potential to affect how a population of a species is represented in the data. Another key difference is that CCFRP data include information from protected areas, which fisheries-dependent hook-and-line data sources do not. Implementing CCFRP as a data source could therefore provide important additional information about these areas to the fishery. Despite the potentially informative nature of these data, most recent assessments do not include information from MPAs, and therefore the inclusion of this information presents an unknown. Depth constraints, methodology differences, and inclusion of MPA data all affect the potential use of CCFRP as fishery assessment data source.

In order to explore the potential implementation of fisheries-independent CCFRP data in stock assessments, we compared it to CPOP using two management-relevant time series metrics, length distribution comparisons and indices of abundance. These data sources are comparable as both surveys monitor groundfish using hook-and-line gear, operate on CPFVs, enumerate and measure all fishes encountered within a sample, and the studies overlap geographically to an extent within the Cal Poly CCFRP research sites (Piedras Blancas and Point Buchon). We assumed that both programs are sampling the same larger population, if not exactly the same groups of individuals. We drew a series of comparisons designed to address three questions regarding the use of CCFRP as a data source for stock assessments: 1) Whether the core depth distribution of a species is within the scope of the depth region sampled by CCFRP; 2) Whether differences in sampling methodology might cause the resulting data to reflect different trends for a species; and,

3) Whether a species shows different trends between open and protected areas within the same project. The first question was addressed by comparing CPOP data from depths inside and outside of the depth range of CCFRP. The second question was addressed by comparing CCFRP and CPOP data taken from areas which are geographically similar, shallow, and open to fishing. The third question was addressed by comparing CCFRP data from inside and outside of protected areas.

We compared three species: Blue rockfish (*S. mystinus*), Vermilion rockfish (*S. miniatus*) and Gopher rockfish (*S. carnatus*). We chose these species because they all have high catch rates in both projects, differing life histories, and varying degrees of desirability within the recreational hook-and-line fishery, allowing us to make these comparisons in different fishery contexts. Examining how assessment metrics of these species compare within and between fisheries-dependent CPOP data and fisheries-independent CCFRP data will allow us to better understand what information is available from each data source, and understand the context in which fisheries-independent data could be implemented into groundfish stock assessments, potentially providing an additional data source for future assessments. Examining these assessment metrics in open and protected areas within CCFRP will further improve our understanding of how these protected areas are functioning, which has important connotations for the status California’s MPA management strategy.

2. METHODS

2.1 FIELD METHODS

2.1.1 The California Collaborative Fisheries Research Project

CCFRP data were gathered following the methods detailed in Wendt and Starr 2009. Sampling sites, consisting of MPAs and associated reference areas, were sampled 3-4 times each year, and each sampling day consisted of twelve fifteen-minute periods of hook-and-line fishing divided between four randomly chosen cells. CCFRP maintained a depth limit of 36 m (120 ft, 36 m) within these sites to reduce barotrauma (Hannah and Matteson 2007). This study utilizes data from the 2007-2018 CCFRP sampling seasons. Most data were collected between July and September, though the sampling season occasionally extended to October. This study utilized data from the two MPAs sampled by Cal Poly CCFRP (Piedras Blancas and Point Buchon), which are in closest geographic proximity to the CPOP data (Fig.1). The Point Buchon sites were sampled each year of the project. The Piedras Blancas sites were not sampled in 2008 or 2015, but in the years when this area was sampled, it was sampled with equal frequency to the Point Buchon area.

2.1.2 The California Polytechnic State University Observer Program

CPOP data were gathered following the methods outlined in Stephens et al. 2006. Starting in 2003, onboard observers accompanied CPFVs approximately once a week throughout the rockfish season, March through September, each year and collected length and species data for all fish caught by a subset of anglers aboard. As the observers merely accompanied the trip rather than directing, captains determined trip lengths and fishing locations, and survey locations ranged across the coast of San Luis Obispo County. To

examine the longest possible time frame of abundance trends, we used data from the 2003-2018 seasons for indices of abundance. For length distributions, we drew direct two-way comparisons with CCFRP, and used data from only the 2007-2018 sampling seasons to match the time frame of CCFRP. We removed CPOP data with drift start locations deeper than 73 m (240 ft, 40 fm) for consistency across time; as the California Department of Fish and Wildlife (CDFW) implemented depth and area closures along the central California coast in the recreational groundfish fishery starting in 2002, but have relaxed those restrictions as of 2017 as a number of rockfish populations have rebuilt (14 CCR § 28.27, Fig. 1).

2.2 SPECIES OF INTEREST

Three species were chosen for this comparative study between the fishery-independent CCFRP and fishery-dependent CPOP surveys: Gopher rockfish, *S. carnatus*, Vermilion rockfish, *S. miniatus*, and Blue rockfish, *S. mystinus*. Gopher rockfish are territorial and maintain small benthic home ranges, as small as 15 m^2 (Larson 1980), and are found as deep as 86 m, but typically occur in 12-50 m (Butler et al. 2012, Love et al. 2002). Vermilion rockfish are typically found from 6 to 478 m deep, most commonly between 50 and 150 m (Butler et al. 2012). Vermilion rockfish have variable but typically low site fidelity, and have movement estimates as large as 5 km in a single day (Lowe et al. 2009). Blue rockfish are typically found at depths between 5 and 90 m, with young individuals sometimes found as shallow as tidepools, and adults found as deep as 549 m (Love et al. 2002). Blue rockfish home ranges have been estimated to be close to 9000 m^2, though they usually concentrate their activity in areas around 1350 m^2 (Jorgenson et al. 2006). None of these species have minimum size limits in the fishery. Vermilion

rockfish are one of the most popular species to catch recreationally (Kosaka et al. unpublished data), and while Gopher and Blue rockfish are less targeted in the fishery, they are two of the most common species caught in the recreational hook-and-line fishery and in CCFRP (CPOP, CCFRP, unpublished data).

2.3 ANALYTICAL METHODS

The analyses outlined below were designed to illustrate three comparisons. The first comparison was between shallow and deep CPOP data, so that differences inside and outside of CCFRP's 36 m depth restrictions could be examined within a single survey methodology. Shallow CPOP data was defined as any surveys starting in 46 m or shallower, deep CPOP data was defined as surveys starting between 46 m and our maximum depth of 73 m (Fig. 1). We used a cutoff of 46 m such that the depth range of the shallow data would be comparable to CCFRP, but also to maintain somewhat similar sample sizes between deep and shallow designated CPOP data. The second comparison was between shallow CPOP data, as defined above, and CCFRP data from areas open to fishing (CCFRP reference sites), to compare between different survey methodologies in similar areas. The third comparison between CCFRP open areas and protected areas was intended to examine differences between open and protected areas within a single survey methodology.

2.3.1 Length Distribution Comparisons

Length data were filtered by known minimum and maximum sizes for each species to remove outliers. A minimum size of 10 cm was used for all species, but the maximum size differed by species; 53 cm was used for Blue rockfish, 39.6 cm for Gopher rockfish, and 76 cm for Vermilion rockfish (Butler et al. 2012). Kolmogorov-

Smirnov (KS) tests were used to compare pairwise differences in length distributions. KS test comparisons were made between shallow and deep CPOP data, between shallow CPOP data and open area CCFRP data, and between open and protected CCFRP data, as described above. These tests were conducted both for the data overall, and for individual years between 2007 and 2018 to present a time series of differences. A total of 39 two-way comparisons were made for each species. Bonferroni corrections were used to adjust for multiple comparisons, an alpha value of 0.001 was used to establish significance for all size distribution comparisons.

2.3.2 Catch Per Unit Effort Modeling and Indices of Abundance

Data used in modeling were constructed such that each line of a data set corresponded to a single sampling period, or drop. Drops were defined as uninterrupted periods of fishing throughout the sampling day. For CCFRP, there were typically 12 drops per sampling day, each lasting 15 minutes. The range of drops was higher for CPOP, where there could be 20 or more in a day, ranging from five minutes to an hour or more. Each drop record included the number of individuals of the species being modeled caught in the drop, as well as all metadata associated with that drop to be used in modeling. Drops were considered "positive" if one or more individuals of the species was caught. We used information in individual drops as replicate measures of abundance. Prior to modeling, data were filtered to remove outliers and drops with missing or erroneous information (Table 1, Table 2). The CPOP dataset included 3438 sample drops, 1864 shallow drops and 1574 deep drops. The CCFRP dataset included 1939 drops, with 984 drops from protected areas and 955 drops from open areas.

Indices of abundance were calculated from models of catch or catch per unit effort at the drop level (CPUE; number of fishes per angler hour), which was modeled using generalized linear models. Catch was either modeled using a Bayesian negative binomial model, or CPUE was modeled using a delta-GLM approach. The delta-GLM approach allows development of an index for species with low catch rates, and high proportions of zeros in data. The delta-GLM is constructed by developing either a lognormal or gamma model of the positive values, and a binomial model for presence (Lo et al. 1992, code provided courtesy of E.J. Dick, NMFS SWFSC, personal communication, 2019). Previous habitat suitability models of eastern Pacific rockfish found depth, substrate type, and topographic complexity were strong predictors of preferred rockfish habitat (Matthews 1990b, Marliave and Challenger 2009, Young and Carr 2015, Pirtle et al. 2017). We included bottom type characteristics, rugosity and hard bottom cover, in our models to account for these potential environmental effects. For CCFRP models, variables tested included area of collection (Point Buchon or Piedras Blancas), depth (as a integer in Bayesian models and as a factor in delta GLMs using 5 m depth bins), and the bottom type variables were rugosity (three 0.005 bins labeled low, medium, and high) and percent hard bottom cover (three 33% bins labeled low, medium, and high). For CPOP models, variables tested were reef (area of collection, see appendix 1), depth (5 m bins for delta GLMs), and the bottom type variables were rugosity (five 0.0033 bins labeled low, medium low, medium, medium high, and high) and percent hard bottom cover (three 33% bins labeled low, medium, and high). Depth was calculated from a 2 by 2 m resolution raster using 40 m radius buffer around the start point, and bottom type variables were calculated from 2 by 2 m resolution rasters on the scale of a

500 by 500 m cell. Bin sizes were based on average variability of given bottom type factor within cells. For full description of how these characteristics were calculated, please see supplementary materials (Appendix 1). Any factor levels for which there were two or fewer positive records were removed from the model. The offset of log-scale angler hours was included in the Bayesian negative binomial models to account for changes in effort. The best model was selected by Bayesian information criterion (BIC). Best fit models used to construct indices can be found in Table 3, for full BIC selection process for all models and species please see supplementary materials (Appendix 2).

To construct the indices of relative abundance, we extracted the year effect from the best fit model. To better compare indices, we scaled each index to its mean value, such that the mean of the transformed index was one. To compare error, we calculated coefficients of variation for each year index value by dividing the standard error for the year by the index mean for that year. We calculated five indices for each species: one for each project overall, as well as one each for shallow CPOP, deep CPOP, open CCFRP sites, and protected CCFRP sites. All length distribution tests and catch per unit effort models and subsequent index of abundance calculations were completed in R v3.4.0.

3. RESULTS

3.1 DEPTH DIFFERENCES

The observed length distributions of Gopher rockfish did not differ between shallow CPOP and deep CPOP overall or in any individual year (Tables 3 and 4). The distribution shows a large percentage of individuals between 25 and 30 cm (Fig. 2). For catch, the best fit models for both deep and shallow CPOP included year, depth, and cell % hard bottom cover, and the shallow model also included reef (Table 5). The year 2003 was removed from the deep CPOP index due to low positive records. In the past five years both indices of abundance showed an increase, but shallow areas showed a more consistent increase in index values than deep areas (Fig. 6). The lowest point of both indices was 2013, but the deep index remained low in 2014 while the shallow index increased. The deep area index had larger average coefficients of variation (Table 6). A small percent of the CPOP deep samples used for sampling were positive for Gopher rockfish catch (24.92%), while a much higher percentage of the shallow CPOP samples (70.17%) were positive.

Vermilion rockfish did not show an overall difference in length distribution between shallow and deep areas (Table 3), but did have two individual years, 2010 and 2011, which had significant differences in length distributions; in both years the length distribution from deeper areas shows more individuals of shorter lengths, between 20-30 cm (Table 4, Fig. 4). In modeling Vermilion rockfish catch, the best fit model for both shallow and deep included year, and cell % hard bottom cover, and the shallow model also included depth (Table 5). Due to lack of positive records, 2003 was removed from deep CPOP and 2018 was removed from shallow CPOP. In the indices, shallow areas

showed a peak between 2004 and 2007, and deep areas showed a similar peak between 2010 and 2013 (Fig. 7). The overall project index, the model for which included year, depth, and cell % hard bottom cover, showed both of these peaks as well (Fig. 7). Neither index showed general trend of increase or decrease across the time span of the project. Average coefficient of variation estimates were similar between the two indices (Table 6). Almost half of samples from deep data were positive for vermilion rockfish presence (49.68%), while a smaller percentage of shallow samples were positive (40.83%).

Blue rockfish did not show a significant difference between overall length distribution comparisons between shallow and deep CPOP (Table 3), but in 2016 there was a significant difference between length distributions from CPOP data from shallow and deep areas, and the deeper area distribution showed a higher proportion of smaller individuals between 20-30 cm (Table 4, Fig. 5). For modeling catch, both the models for deep and shallow CPOP included year and cell % hard bottom cover. The model for overall CPOP included reef in addition to those two variables (Table 5). In the shallow and deep indices of abundance, there were similar overall trends in terms of years of increase and decrease between 2003 and 2014, but in more recent years there were a few key trend differences (Fig. 8), for example in 2015 and 2017, deep areas show an increase where shallow areas show a decline. Most notably, in 2018, deep areas showed a steep decrease where shallow areas continued to increase. The project-wide CPOP index did not reflect the decline seen in deeper data (Fig. 8). Coefficient of variation values were similar for the two indices (Table 6). More than half of samples used to model deep areas were positive for blue rockfish presence (53.94%), while a smaller percentage of shallow data was positive (43.83%).

3.2 METHODOLOGY DIFFERENCES

Gopher rockfish did not differ in their length distribution between shallow CPOP and open area CCFRP data overall or in any individual year (Tables 3 and 4). The distribution showed mostly adult individuals between 25-30 cm (Fig. 2). For modeling catch, the best fit catch model for Gopher rockfish for shallow CPOP included year, reef, depth, and cell % hard bottom, while the model for open area CCFRP included year, area, depth, and start point % hard bottom. In the resulting indices of abundance, both the shallow CPOP and open area CCFRP indices showed a general decline between 2007 and 2013, followed by an overall increase between 2013 and 2018, though there was a greater increase in the shallow CPOP data (Fig. 6). The lowest points of both indices occurred in 2013. Average coefficients of variation were higher for shallow CPOP than open area CCFRP (Table 6). A majority of samples used to model shallow CPOP data were positive for gopher rockfish (70.17%), and the percentage of positive samples form open area CPOP was even higher (85.55%).

Vermilion rockfish showed an overall significant difference between the length distributions of shallow CPOP data and open area CCFRP data (Table 3). Both distributions showed mostly individuals between 27-40 cm, open area CCFRP had a higher percentage of very small individuals, but shallow CPOP had a higher proportion of individuals in the 27-35 cm length range, which are likely small adults (Fig. 2). There were also significant differences between the length distributions of Vermilion rockfish between these two data sets specifically in 2009 and 2010 (Table 4), and the distribution of shallow CPOP data was shifted towards shorter lengths in these two years, with a higher proportion of smaller individuals between 20-30 cm (Fig. 4). In modeling catch,

the best fit model for Vermilion rockfish in shallow CPOP data included year, depth, and cell % hard bottom, while the open area CCFRP model included year, area, and depth (Table 5). The indices of abundance for these two groups showed inverse increases and decreases between 2007 and 2010 (Fig. 7), but between 2010 and 2018 they showed parallel trends of increase and decrease, though the magnitude of changes differed. Neither showed an overall trend of increase or decrease across the time span of either project. The average coefficient of variation for the open area CCFRP abundance index was notably larger than that for the shallow CPOP index (Table 6). A moderate percentage (40.83%) of samples used to model shallow CPOP were positive for Vermilion rockfish catch while a smaller percentage of samples used to model open area CCFRP were positive (36.86%).

Blue rockfish showed an overall significant difference between the length distributions of shallow CPOP data and open area CCFRP data (Table 3). Both distributions showed mostly individuals between 20-35 cm, and the open area CCFRP distribution was shifted towards shorter lengths (Fig. 2). Going year by year, Blue rockfish length distributions differed in 2007, 2009, 2014, 2016, and 2018 (Table 4). The open area CCFRP distribution was shifted towards longer lengths than shallow CPOP data in 2009 and 2018, but was shifted towards shorter lengths than shallow CPOP data in 2007, 2014, and 2016, in those years the CCFRP distributions showed more individuals between 15-25 cm (Fig. 5). For modeling catch, the best fit model for both data sources included year and cell % hard bottom cover, and the open area CCFRP model included area in addition to those variables (Table 5). The indices of abundance showed a similar overall decline between 2007 and 2012, followed by a parallel overall

increase between 2012 and 2018, though the shallow CPOP index showed declines in 2015 and 2017 which are absent from the open area CCFRP index (Fig. 8). Average coefficient of variation estimates were similar for the two models (Table 6). A moderate percentage (43.83%) of samples used to model shallow CPOP data were positive for Blue rockfish catch, while more than half (57.28%) of samples used to model open area CCFRP were positive for Blue rockfish catch.

3.3 PROTECTION DIFFERENCES

Gopher rockfish showed an overall significant difference between the length distributions of open area and protected area CCFRP data (Table 3). Both distributions showed mostly individuals between 24-30 cm, the protected area CCFRP distribution was shifted towards shorter lengths (Fig. 2). Year by year, length distributions differed significantly between the open area and protected area length distributions in 2008, 2009, 2010, and 2014 (Table 4), and the protected area length distribution was shifted towards shorter lengths in all those years (Fig. 3). For modeling abundance, the best fit models for both open and protected CCFRP included year, area, depth, and cell % hard bottom cover (Table 5). In the indices of abundance, the trends for the open and protected area were parallel. Both open and protected areas show a decline between 2007 and 2013, followed by an overall increase between 2013 and 2018, though there is a greater increase in the protected area data (Fig. 6). The lowest point of both indices occurred in 2013. The coefficient of variation is higher for the protected sites than the open sites (Table 6). The majority of samples used to model open area CCFRP were positive for Gopher rockfish catch (85.55%), and an even higher percentage of protected area samples were positive (93.29%).

Vermilion rockfish showed an overall significant difference between the length distributions from open area and protected area CCFRP data (Table 3). The protected area length distribution was shifted towards longer lengths with most of the distribution between 25-45 cm, while most of the protected area distribution lay between 20-40 cm (Fig. 2). Year by year, there were significant length distribution differences in 2008, 2009, 2011, 2012, 2014, and 2016 (Table 4). The length distribution was shifted towards longer lengths in the protected areas in all these years (Fig. 4). For modeling catch, the model for open area CCFRP data included year, area, and depth, while the protected area CCFRP model included year, depth, and cell rugosity (Table 5). In the indices of abundance, the open area index showed large fluctuations between 2011 and 2013, but no overall decrease or increase in index value between 2007 and 2018 (Fig. 7). On the other hand, the protected area index showed a steady rate of increase between 2007 and 2018. The overall project index for CCFRP, the model for which included year, area, site, and depth, reflected the same overall increase (Fig. 7). The protected area index had a higher coefficient of variation than the open area, but both CCFRP indices have notably larger coefficients of variation than any of the other average coefficient of variation estimates (Table 6). About a third (36.86%) of samples used to model open area CCFRP were positive for Vermilion rockfish catch, and more than half (55.89%) of samples used to model protected area CCFRP were positive for Vermilion rockfish catch.

Blue rockfish showed an overall significant difference in length distribution between open area and protected area CCFRP data (Table 3). Both distributions showed most individuals are between 20-35 cm, but the length distribution in the protected areas was shifted towards shorter lengths (Fig. 2). Year by year, there were significant

differences in 2008, 2016, and 2017 (Table 4). The protected area length distribution was shifted towards shorter lengths in years with differences (Fig. 5). For modeling catch, the best fit model for open area CCFRP included year, area, and cell % hard bottom group, while the model for protected areas included just year (Table 5). In the indices of abundance, the protected and open areas showed parallel trends across the entire span of the project, though the protected area index reached relatively higher levels in 2017 and 2018 (Fig. 8). The open area index had slightly larger average coefficients of variation (Table 6). Over half (57.28%) of samples used to model open area CCFRP were positive for Blue rockfish catch, an even higher percentage (72.97%) of samples used to model protected area CCFRP were positive for Blue rockfish catch.

4. DISCUSSION

In comparing these three species, the main point one can take away is that the potential utility of fisheries-independent data in assessment is highly species-dependent. Gopher rockfish, for example, show patterns across multiple comparisons and in multiple metrics which indicate that fisheries-independent data from CCFRP could be an effective data source for a stock assessment. Firstly, Gopher rockfish showed no differences in size distribution between shallow and deep CPOP. Looking at catch, the factors used in the models for these two indices overlapped, indicating factors important to predicting catch are common across depths. Additionally, the deep index for Gopher rockfish was in general uninformative, and had higher average error. This is likely due to fewer positive observations of Gopher rockfish in deeper areas leading to greater variability in the model. The fact that these metrics do not differ between shallow and deep data, and that there are small sample sizes and inconsistency in models of deeper data, support that the core depth distribution of this species is contained within the shallow data, which matches the depth limitations of CCFRP. Secondly, Gopher rockfish also showed no differences in size distribution between data from open area CCFRP and data from shallow CPOP. The models used to calculate the indices of abundance for shallow CPOP and open area CCFRP were the same (reef and area both refer to the area of collection), indicating that the factors predictive of catch within each project overlap. The patterns in the indices are quite similar across the span of both projects.

These metrics demonstrate that for Gopher rockfish the core depth distribution is within the limitations of CCFRP's depth restrictions, and that the species is represented in fisheries-independent hook-and-line data from shallow areas open to fishing similarly to

how it is represented in fisheries-dependent hook-and-line data from shallow areas open to fishing. The 2019 Gopher (*S. carnatus*) and Black-and-yellow rockfish (*S. chrysomelas*) complex stock assessment was able to use CCFRP data to calculate a relative index of the population and otoliths from CCFRP to estimate growth, demonstrating that these data could be used alongside fisheries-dependent data as an assessment data source (Monk and He 2019). Gopher rockfish are a small, benthic, nearshore species (Love et al. 2002, Butler et al. 2012) with a small home range (Larson 1980, Matthews 1985). Assessments for species with similar life histories, such as China rockfish (*S. nebulosus*), Brown rockfish (*S. auriculatus*), Grass rockfish (*S. rastrelliger*) or Kelp rockfish (*S. atrovirens*), and even species outside the Sebasetes complex, such as Kelp greenling (*Hexagrammos decagrammus*), might also be able to utilize CCFRP as a fisheries-independent data source for stock assessment modeling in the way it was used for the Gopher rockfish assessment.

Unfortunately, the patterns in size distribution and indices of abundance from CCFRP do not fit Vermilion and Blue rockfish in the same way as they do for Gopher rockfish, suggesting that CCFRP may not be appropriate fishery-independent data source for a stock assessment in the same way that it was used for Gopher rockfish. Both Vermilion and Blue rockfish demonstrate that the core of their depth distribution extends outside the bounds of CCFRP's depth limitations. For Vermilion rockfish, the models used to construct indices of abundance for shallow and deep areas were the same except that the shallow model included depth. This indicates that in shallow areas, depth is a significant predictor of Vermilion rockfish CPUE, but that in deeper areas Vermilion rockfish catch is consistent enough that depth is no longer an important predictive factor,

suggesting a depth threshold for catch. There is also an interesting pattern in the index values for this species between shallow and deep areas: there was a peak in abundance for the shallow areas in 2005-2007, and a subsequent nearly identical peak in deep areas in 2010-2012. The length distribution from deep areas had more small individuals in 2010 and 2011, which overlaps with that deep index peak. Vermilion rockfish are known to undergo an ontogenetic shift and move deeper as they age (Love et al. 2002, Butler et al. 2012). The increase observed in 2005-2007 in the shallow index may indicate a recruitment event around 2004, and those recruits may have moved to deeper areas around 2010, causing a temporary discrepancy in size distribution. Similarly, for Blue rockfish, the index for shallow areas has a sharp increase in 2016, followed by a peak in deep areas in 2017. In 2016, the deep size distribution was shifted towards shorter lengths. Blue rockfish also undergo an ontogenetic shift (Love et al. 2002, Butler et al. 2012), so this may indicate recruits moving deeper. These patterns in the data indicate that for both the species, the population moves outside of and extends beyond shallow areas, and therefore the core depth distribution of Vermilion rockfish and Blue rockfish populations is not contained within the shallow data and therefore the whole population cannot be assessed by CCFRP due to its depth restrictions.

Vermilion rockfish and Blue rockfish both further demonstrate that even in data that is taken in both projects from shallow areas open to fishing, CCFRP length frequency and indices of abundance differ from CPOP length frequency and indices of abundance, likely due to the methodology of the projects. Vermilion rockfish show differences in length distribution between shallow CPOP and open area CCFRP, with shallow CPOP showing a higher proportion of smaller adult size classes and shallow

CCFRP showing more very small individuals overall. The models used to construct the indices of abundance for Vermilion rockfish in shallow CPOP and open area CCFRP both include depth, which indicates that regardless of project, depth is an important in predicting CPUE in shallow areas, but none of the other model factors are analogous. It appears that what is important in predicting Vermilion rockfish CPUE in the resulting data differs based on project. The resulting indices are completely different in their values for most of the overlapping time span of these project, and the average error estimate for the open area CCFRP model is much larger. Blue rockfish also show differences between shallow CPOP and open area CCFRP, though the patterns of difference are different. Blue rockfish length distributions were shifted towards shorter lengths in open area CCFRP than shallow CPOP. The indices of abundance for Blue rockfish are mostly parallel, but the shallow CPOP data do not keep pace with the increases in open area CCFRP between 2012 and 2017.

There are two main method-based reasons that these differences between CCFRP and CPOP in shallow areas open to fishing might occur. The first is fishery selectivity. Vermilion rockfish are a desirable species in the recreational fishery, and captains are known to target Vermilion rockfish. As CCFRP is fisheries-independent, the same does not occur in CCFRP surveys. The same selectivity may be affecting Blue rockfish in the opposite direction. Rather than targeting this species, captains avoid large schools of small Blue rockfish. The 2017 assessment of Blue rockfish (Dick et al. 2017) shows that there was a spike in the pelagic juvenile index of Blue rockfish in 2013, suggesting a recruitment event. This recruitment captured in the indices here. The increase in the abundance indices between 2012 and 2018 was observed to be largely due to small recent

recruits, which may have been reflected differently in CCFRP data due to the fisheries-independent nature of the method of data collection. CCFRP does not and cannot avoid schools of small fish. The second reason for these differences could be geographic. In the case of the Gopher rockfish assessment, it was judged that despite spatial limitations, the core geographic distribution of Gopher rockfish was contained by CCFRP depths, and it was therefore possible to use the data to model the population (Melissa Monk, personal communication, 2019). However, unlike the solitary and sedentary Gopher rockfish, Blue and Vermilion rockfish are midwater species with higher mobility (Love et al. 2002, Jorgensen et al. 2006, Lowe et al. 2009, Butler et al. 2012). It could be that the life history of these species and the spatial limitations of CCFRP prevent it from capturing the same geographic breadth of population CPOP does.

Although these differences mean that CCFRP data cannot be utilized for all species in exactly the same way it was for the Gopher rockfish assessment, there is still information which could be useful in assessing Blue and Vermilion rockfish. For example, the abundance of Blue rockfish has undergone some extreme fluctuations, especially relative to the recruitment event around 2012 - 2013 and the subsequent steep increases seen in the index. Blue rockfish went from relatively rare in CCFRP to roughly 80% of total catch between 2016 and 2018 (CCFRP, unpublished data). The CPOP indices between 2003 and 2005, as well as some concurrent dive survey data (Wolfe and Pattengill-Semmens 2013), indicate that this species has gone through similar recruitment events and subsequent population booms before. An increase in the availability of nearshore data could help to provide more information about events like this. Furthermore, while the depth constraints of CCFRP prevent it from addressing the whole

breadth of the Vermilion rockfish population, certain age classes, especially younger, smaller age classes suggested by our size distributions, could be considered well-represented in CCFRP data and CCFRP data could be used to assess specifically these age classes of Vermilion rockfish. In addition to that, as discussed above, the shallow and deep CPOP metrics for Vermilion rockfish suggest the transition of a cohort from shallow to deep as they age. The peaks in the shallow and deep CPOP indices that suggested this were reflected in the overall CPOP index, but dividing the data in this way gave us the additional insight that these peaks were from different depth ranges. This demonstrates that there are trends in the population in shallow areas which are key to the status of the overall population. We could gain additional information about the population in shallow areas from CCFRP.

In short, one of the main limitations of CCFRP, its depth constraint, could also be considered one of CCFRP's strengths. The fishery-dependent hook-and-line data currently used in assessments may not have as much information about rockfish in shallow, nearshore areas as CCFRP does. Because CCFRP is fisheries-independent, the data it contributes about these areas could be considered to be more objective than some available fisheries-dependent data. Rockfish recruit to shallow, nearshore areas, and many species, like Vermilion and Blue rockfish, undergo an ontogenetic shift and move deeper as they age. Therefore, CCFRP provides objective data about newly recruited individuals of these species, and potentially provide the same information about species with similar life histories. For example, Copper rockfish (*S. caurinus*) have a similar life history to Vermilion rockfish and are similarly popular in the recreational fishery, and Yellowtail rockfish (*S. flavidus*) have a similar life history to Blue rockfish. Providing

fisheries-independent data for targeted species like Vermilion and Copper rockfish is a high priority, as their stocks are critical to the fishery. Further research, most importantly an assessment of CCFRP's geographic limitations in regard to these two species, would have to be conducted before data could necessarily be used in this way, but it does demonstrate interesting potential.

The other key strength of CCFRP is that it was designed as an MPA monitoring program and provides information from protected areas, which comparable fisheries-dependent hook-and-line data do not. The information drawn from protected area data is therefore novel and therefore examining the resulting assessment metrics is important, and all three species demonstrated some interesting patterns in this comparison. Of the three size distribution comparisons, this is the only one where Gopher rockfish show a significant difference in size distribution, both overall and in four of the twelve years of CCFRP. The Gopher rockfish length distribution was shifted toward smaller animals in the protected area, which was unexpected, as classically, protected areas are considered to generate larger sized individuals. The indices of abundance are parallel, but the protected areas have shown a greater rate of increase over the past five years, which could be the beginning of some type of impact of protection.

Vermilion rockfish show significant differences in the overall size distributions between open and protected areas, with the protected area distribution being shifted towards longer lengths than the open area distribution. This appears to be more in line with an expected MPA effect, but if the MPAs were causing increases in size, then we would expect to see continued divergence in size between the protected and open areas, and this is not the case. Size distribution differences appear throughout the timespan of

the project. These MPAs were designed to contain preferred rockfish habitat which already supported a sizable rockfish population, so these size distribution differences may be an artifact of protected area design. Further supporting this, the open area catch model for the index of abundance includes depth and rugosity, while the protected area model includes depth and area. This difference in important predictive factors may also be due to habitat differences between open and protected areas, as the higher proportion of good habitat inside of protected areas reduce its importance as a predictive factor for data from inside those areas. The Vermilion rockfish index values show a steady increase in catch in the protected areas across the span of CCFRP, which again may indicate the beginnings of some type of protection impact. However, the average relative error estimates for these index values are greater than those for the other species, which raises some concerns about the suitability of using CCFRP to model Vermilion rockfish in this way.

Blue rockfish, like Gopher rockfish, show the unexpected pattern of a length distribution shifted towards shorter lengths in protected areas. However, the model used to calculate the index of abundance for the open areas included year, area, and hard bottom cover, while the model for protected areas included only year, and the fewer predictive factors in the protected area model might indicate that once an area is protected, habitat and locational differences are no longer as important in predicting Blue rockfish CPUE. The indices of abundance for the protected area also show greater peaks than the open areas, also suggesting some impact of protection, though both indices show a decline in 2018. This could be due to individuals moving out of the depth range of CCFRP.

The exact cause of these differences between open and protected areas is beyond the scope of this paper. The fact that we wish to draw your attention to is that this information is from data which are not represented in existing hook-and-line sources. CCFRP could augment existing data by providing information about nearshore MPAs. As of 2019, California has 124 discrete MPAs which encompass 16% of state waters (Kirlin et al. 2013). Because MPAs are generally closed to recreational and commercial fishing, there is little to no fisheries-dependent information from MPAs to incorporate into stock assessments or fisheries management. Closing these areas, while a huge step for management, has spatially restricted rockfish data available from recreational and commercial fishers. CCFRP is the only long-term hook-and-line monitoring project collecting data from these previously fished but currently protected areas, which include quite a bit of key rockfish habitat. CCFRP could address data this gap if it were implemented as a data source. While the data presented in this project are too limited to address the gap alone, in 2017 and 2018, CCFRP was extended statewide, and data were gathered from 14 MPAs ranging from the South Cape Mendocino SMR, just south of Eureka in northern California, to the South La Jolla SMR, right off the coast of Mexico. If this statewide sampling effort is continued, a statewide time series of data concerning rockfish inside MPAs could be built. Statewide CCFRP has a large enough geographic scope that it could potentially address the lack of data for this considerable percentage of state waters. Continuing this statewide program is vital if assessors want to be able to include information about protected populations in their assessments of rockfish in California.

Rockfish populations declined drastically, in both number and size of fishes, through the latter half of the 20th century (Love et al., 1998a, Love et al., 1998b, Mason 1998). They have recovered due to careful and well-enforced management, but their recovery puts them back in the spotlight for fisheries exploitation. It is important that we understand the current status of rockfish populations as thoroughly as possible. This project is in collaboration with NMFS, and these results will help inform the scientists who perform the assessments of these stocks. These results demonstrate that the constraints of fisheries-independent data sources alter the method by which they can be utilized in assessment, but also show that fisheries-independent data could introduce important information which can be used to better understand specific aspects of stocks. Whether fisheries-independent data can be used to assess the whole stock, or as additional information to fill data gaps concerning nearshore age classes or population trends in protected areas, introducing it improves data availability in population assessments and stock projection. An increase in data availability will help inform future assessments and therefore assist in improving future management decisions for these species. California's nearshore rockfish fishery is both a fascinating biological system and an important social and economic resource to the central coast community. Our hope is that this project will improve the understanding of that resource and serve to perpetuate it. We further hope that other fishery managers will examine fishery-independent data sources in their own systems, as they have the potential to increase data availability to stock assessments in many fishery systems. Increasing data availability to improve assessment accuracy leads to improved management, which could have wide-reaching implications for the persistence of healthy fish stocks.

TABLES

Table 1. Fisheries-dependent data cleaning steps. Data cleaning steps for the fisheries-dependent Cal Poly Observer Program (CPOP) dataset. These steps were applied to catch samples before any catch or catch per unit effort (CPUE) sampling. GPS information refers to the coordinates taken at the start and end of a drop.

Removal Step	Number Removed	Resulting Number of Samples
Starting number of samples		7619
Removed any drop with absent, low resolution, or incorrect GPS data	127	7492
Removed all drops with missing information	183	7309
Removed all drops for which bottom type characteristics could not be assigned	375	6934
Removed drops with top and bottom 1% of observed fishers and minutes fished	220	6714
Removed drops deeper than 240ft depth	261	6453
Removed drops outside of June-September	3015	3438
Final number of samples		**3438**
Number of Shallow samples		1864
Number of Deep samples		1574

Table 2. Fisheries-independent data cleaning steps. Data cleaning steps for the Cal Poly portion of the fisheries-independent California Collaborative Fisheries Research Program (CCFRP) dataset. These steps were applied to catch samples before any catch or catch per unit effort (CPUE) sampling. GPS information refers to the coordinates taken at the start and end of a drop.

Removal Step	Number Removed	Number of Samples
Starting number of samples		2256
Removed anything outside of CCFRP protocol	238	2018
Removed anything from cells that were not consistently sampled over the project	76	1942
Removed anything with incorrect or missing GPS data	3	1939
Final Number of Samples		**1939**
Number of samples from Marine Protected Areas		984
Number of samples from open reference areas		955

Table 3. Summary of pairwise Kolmogorov-Smirnov tests. Significance values of pairwise Kolmogorov-Smirnov tests of length distribution of Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*) between deep and shallow CPOP data, shallow CPOP and open area CCFRP data, and open and protected CCFRP data. Highlighted cells are significant differences. A p-value of 0.001 was used to establish significance.

Species	**CPOP Shallow vs CPOP Deep**	**CPOP Shallow vs CCFRP Open**	**CCFRP Reference vs CCFRP Protected**
Gopher rockfish	0.0044	0.0166	1.721E-06
Vermilion rockfish	0.0543	8.374E-05	2.200E-16
Blue rockfish	0.0042	2.200E-16	2.200E-16

Table 4. Summary of time series pairwise Kolmogorov-Smirnov tests. Significance values of year by year pairwise Kolmogorov-Smirnov tests of length distribution of Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*), between deep and shallow CPOP data, shallow CPOP and open area CCFRP data, and open and protected CCFRP data. Highlighted cells are significant differences. A p-value of 0.001 was used to establish significance.

Species	**Year**	**CPOP Deep vs CPOP Shallow**	**CPOP Shallow vs CCFRP Open**	**CCFRP Open vs CCFRP Protected**
Gopher rockfish	2007	0.6876	0.0327	0.7814
	2008	0.7241	0.0213	5.865E-11
	2009	0.4667	0.0054	2.844E-05
	2010	0.1075	0.0239	3.873E-04
	2011	0.6747	0.8419	0.7249
	2012	0.9837	0.1610	0.1252
	2013	0.2354	0.0599	0.1385
	2014	0.8419	0.9163	7.625E-04
	2015	0.5280	0.9821	0.1357
	2016	0.8518	0.9830	0.0018
	2017	0.8631	0.7098	0.2968
	2018	0.4518	0.9027	0.4689
Vermilion rockfish	2007	0.2259	0.0651	0.0024
	2008	0.9360	0.5065	1.873E-05
	2009	0.0044	2.027E-07	2.955E-08
	2010	1.376E-06	0.0010	0.0184
	2011	8.407E-05	0.2497	3.568E-10
	2012	0.2740	0.1977	5.917E-05
	2013	0.0612	0.4235	0.5629
	2014	0.0063	0.0362	4.036E-08
	2015	0.8569	0.1109	0.1257
	2016	0.8266	0.0160	4.892E-07
	2017	0.3389	0.5874	0.0059
	2018	0.9999	0.9899	0.0062
Blue rockfish	2007	0.0025	1.433E-07	0.0341
	2008	0.1120	0.2008	5.982E-04
	2009	0.0130	5.697E-04	0.0155
	2010	0.1491	0.4354	0.1298
	2011	0.2287	0.0293	0.0478
	2012	0.0467	0.9596	0.8367
	2013	0.0931	0.0378	0.1253
	2014	0.0014	2.839E-05	0.0025
	2015	0.3976	0.0012	0.4804
	2016	1.692E-13	1.788E-08	2.776E-15
	2017	0.0059	0.1528	4.108E-15
	2018	0.0039	8.870E-04	0.0416

Table 5. BIC model fitting. BIC selected best fit models for Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*) abundance modeling for all data sources.For a full list of models tested an associated BIC scores used to select these models, please see supplemental materials (Appendix 1).

Species	**Data Source**	**Model Type**	**Model Sub-Type**	**Model**	**BIC**
Gopher rockfish	CPOP Deep	Delta GLM	Lognormal	*Year + Depth + Cell % Hard Bottom Cover Group*	886.6401
			Binomial	*Year + Depth*	1384.839
			Final	*Year + Depth + Cell % Hard Bottom Cover Group*	
	CPOP Shallow	Delta GLM	Lognormal	*Year + Reef + Depth*	3020.914
			Binomial	*Year + Cell % Hard Bottom Cover Group*	2319.111
			Final	*Year + Reef + Depth + Cell % Hard Bottom Cover Group*	
	All CPOP	Delta GLM	Lognormal	*Year + Reef + Depth*	3898.151
			Binomial	*Year + Depth + Cell % Hard Bottom Cover Group*	3733.249
			Final	*Year + Reef + Depth + Cell % Hard Bottom Cover Group*	
	CCFRP Open	NB Bayesian		*Year + Area + Depth + Cell % Hard Bottom Cover Group*	4744.638
	CCFRP Protected	NB Bayesian		*Year + Area + Depth + Cell % Hard Bottom Cover Group*	5564.084
	All CCFRP	NB Bayesian		*Year + Area + Site + Depth + Cell % Hard Bottom Cover Group*	10381.3
Vermilion rockfish	CPOP Deep	Delta GLM	Lognormal	*Year*	1770.996
			Binomial	*Year + Cell % Hard Bottom Cover Group*	2132.769
			Final	*Year + Cell % Hard Bottom Cover Group*	
	CPOP Shallow	Delta GLM	Lognormal	*Year*	1721.513
			Binomial	*Year + Depth + Cell % Hard Bottom Cover Group*	2458.243
			Final	*Year + Depth + Cell % Hard Bottom Cover Group*	
	All CPOP	Delta GLM	Lognormal	*Year*	3452.614
			Binomial	*Year + Depth + Cell % Hard Bottom Cover Group*	4543.803
			Final	*Year + Depth + Cell % Hard Bottom Cover Group*	
	CCFRP Open	NB Bayesian		*Year + Area + Depth*	2030.416
	CCFRP Protected	NB Bayesian		*Year + Depth + Cell VRM Class*	3049.334
	All CCFRP	NB Bayesian		*Year + Area + Site + Depth*	5061.309
Blue rockfish	CPOP Deep	Delta GLM	Lognormal	*Year + Cell % Hard Bottom Cover Group*	2171.066
			Binomial	*Year + Cell % Hard Bottom Cover Group*	1642.285
			Final	*Year + Cell % Hard Bottom Cover Group*	
	CPOP Shallow	Delta GLM	Lognormal	*Year*	2209.607
			Binomial	*Year + Cell % Hard Bottom Cover Group*	2076.948
			Final	*Year + Cell % Hard Bottom Cover Group*	
	All CPOP	Delta GLM	Lognormal	*Year + Reef + Cell % Hard Bottom Cover Group*	4299.189
			Binomial	*Year + Cell % Hard Bottom Cover Group*	3691.532
			Final	*Year + Reef + Cell % Hard Bottom Cover Group*	
	CCFRP Open	Delta GLM	Lognormal	*Year + Area*	1569.95
			Binomial	*Year + Area + Cell % Hard Bottom Cover Group*	1134.918
			Final	*Year + Area + Cell % Hard Bottom Cover Group*	
	CCFRP Protected	Delta GLM	Lognormal	*Year*	2119.73
			Binomial	*Year*	968.743
			Final	*Year*	
	All CCFRP	Delta GLM	Lognormal	*Year + Area + Site*	3673.47
			Binomial	*Year + Site*	2065.855
			Final	*Year + Area + Site*	

Table 6. Coefficients of variation. Mean coefficient of variation (CV) values for indices of abundance of Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*) from deep and shallow CPOP data and open and protected CCFRP data. CV was calculated by dividing the standard error of the index estimate by the mean of the index estimate for each year.

Species	**CPOP Deep**	**CPOP Shallow**	**All CPOP**	**CCFRP Open**	**CCFRP Protected**	**All CCFRP**
Gopher rockfish	0.3492	0.2364	0.4159	0.1899	0.1729	0.1325
Vermilion rockfish	0.2078	0.2102	0.1555	0.3266	0.2921	0.2086
Blue rockfish	0.2136	0.2332	0.2111	0.2000	0.1542	0.1208

FIGURES

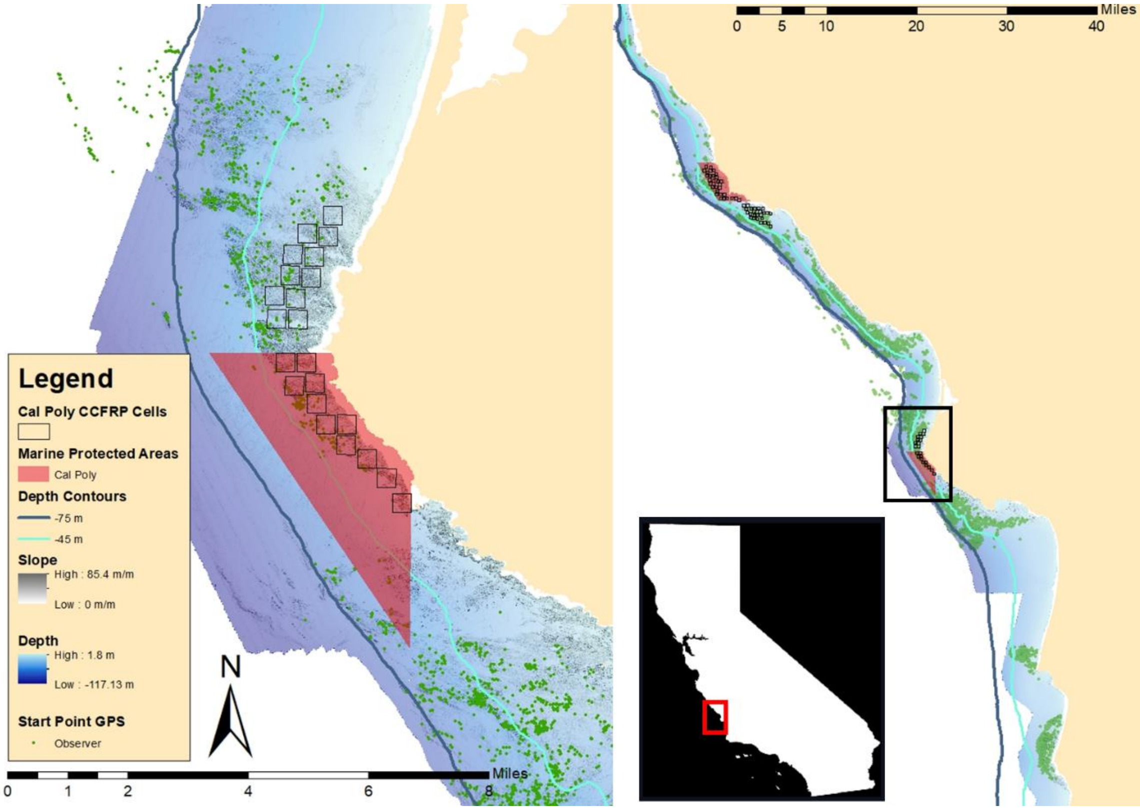

Figure 1. Maps of study area. Includes the study area for both the fisheries-independent (CCFRP) and fisheries-dependent (CPOP) projects, with bathymetric depth and slope demonstrating habitat. Right map is full extent, left map is Piedras Blancas area only to demonstrate detail. The Piedras Blancas (northern) and Point Buchon (southern) State Marine Reserves (SMRs) sampled by the California Collaborative Fisheries Research Program at Cal Poly are in red. Black boxes are 500 by 500 m CCFRP sampling cells. Green points show start points for CPOP surveys between 2003 and 2018. Contour lines show cutoffs for shallow and deep Cal Poly Observer Program data used in this study. Dark blue contour is 73 m (240 ft, 40 fm) and light blue contour is 46 m (150 ft, 25 fm). Larger inset state map shows extent of study area in red.

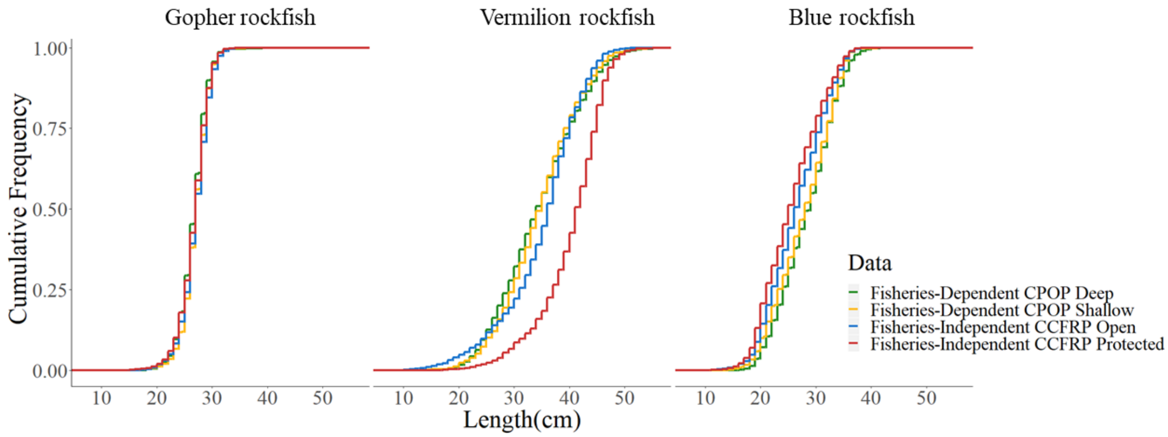

Figure 2. Cumulative distribution functions (CDFs) of lengths of species of interest. These functions show distribution of lengths of Gopher (*Sebastes carnatus*) Vermilion (*S. miniatus*), and Blue (*S. mystinus*) rockfish from shallow and deep CPOP surveys and CCFRP surveys from open and closed areas. Each step in the distribution represents the percent of the individuals caught of that size from each data source.

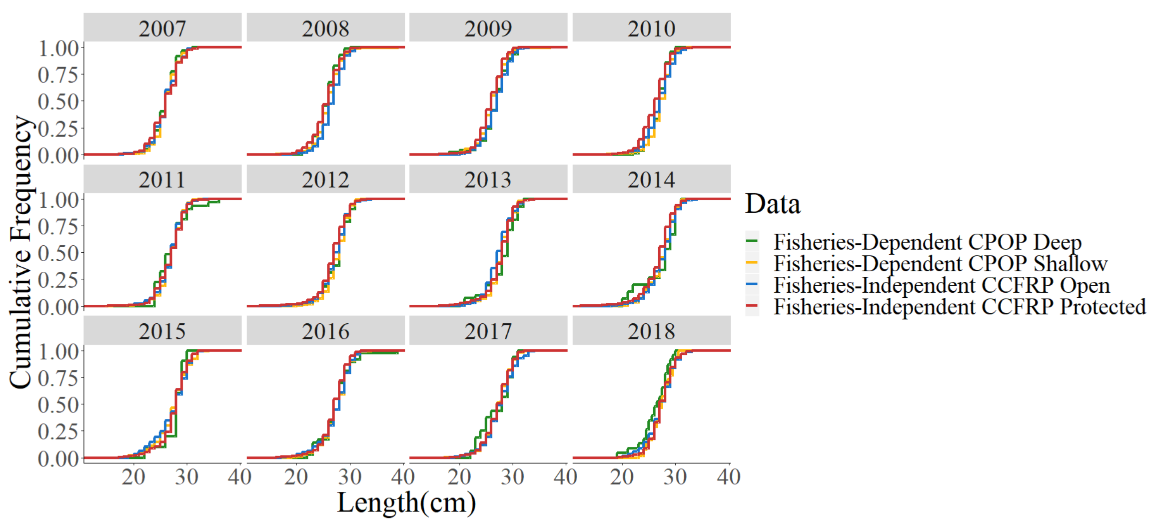

Figure 3. Yearly CDFs showing distribution of lengths of Gopher rockfish (*S. carnatus*). Functions show lengths from shallow and deep CPOP surveys and CCFRP surveys from open and closed areas. Each step in the distribution represents the percent of the individuals caught of that size from each data source.

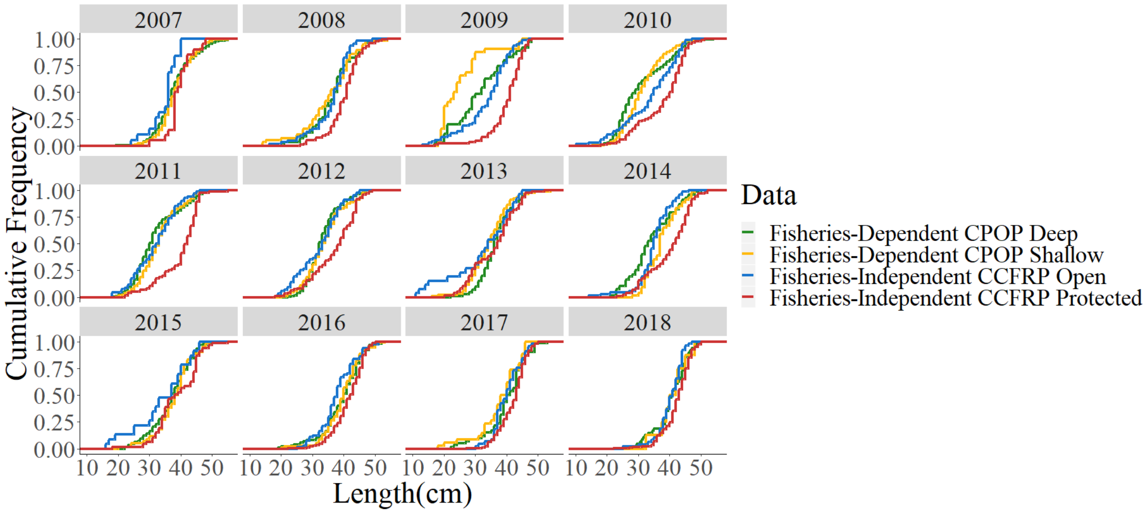

Figure 4. Yearly CDFs showing distribution of lengths of Vermilion rockfish (*S. miniatus*). Functions show lengths from shallow and deep CPOP surveys and CCFRP surveys from open and closed areas. Each step in the distribution represents the percent of the individuals caught of that size from each data source.

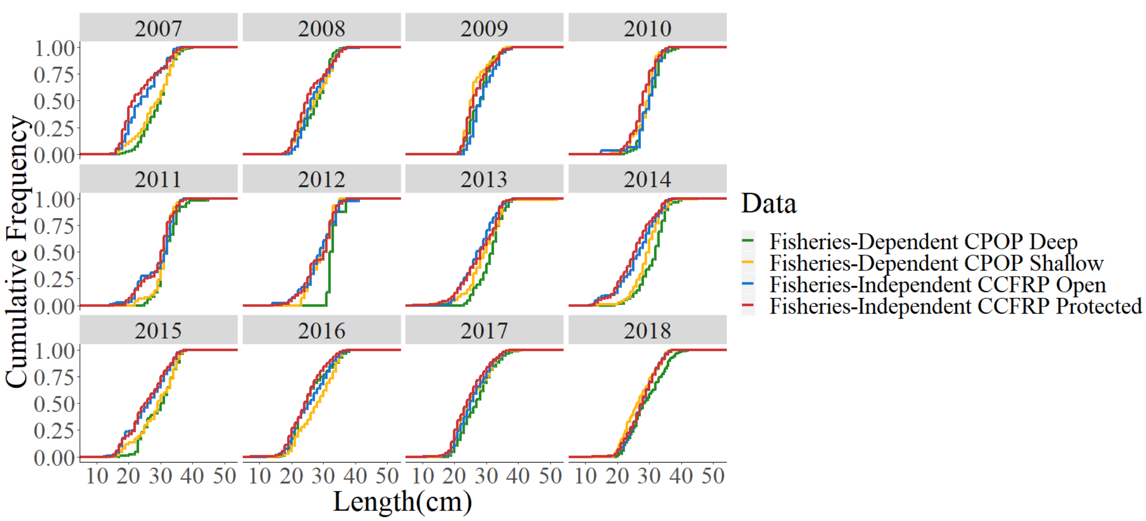

Figure 5. Yearly CDFs showing distribution of lengths of Blue rockfish (*S. mystinus*). Functions show lengths from shallow and deep CPOP surveys and CCFRP surveys from open and closed areas. Each step in the distribution represents the percent of the individuals caught of that size from each data source.

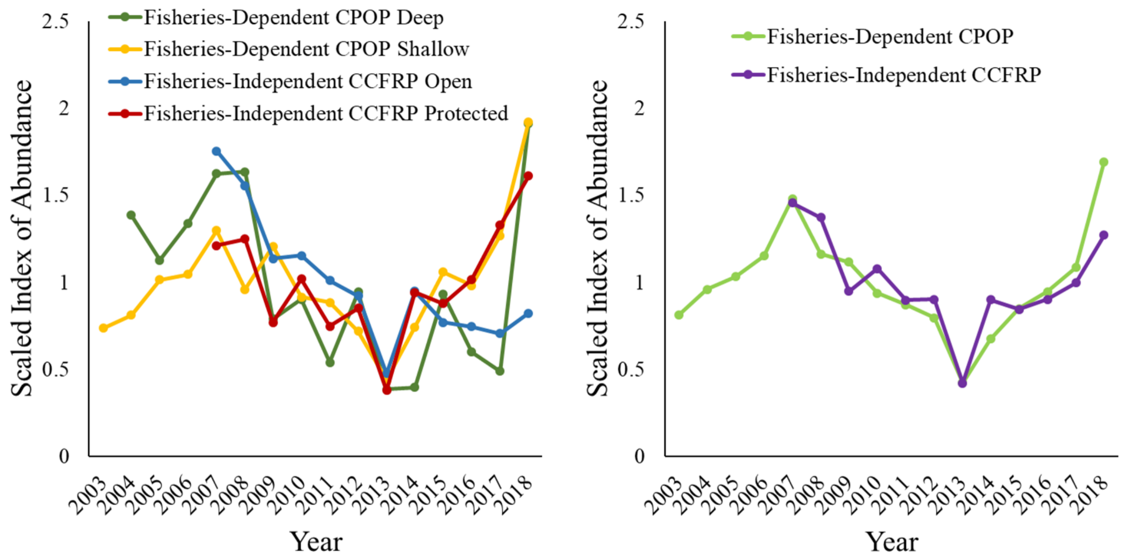

Figure 6. Time series indices of abundance of Gopher rockfish (*S. carnatus*). Left plot shows indices for CPOP split into shallow and deep areas and CCFRP split into open and protected areas, right plot shows indices for both projects overall.

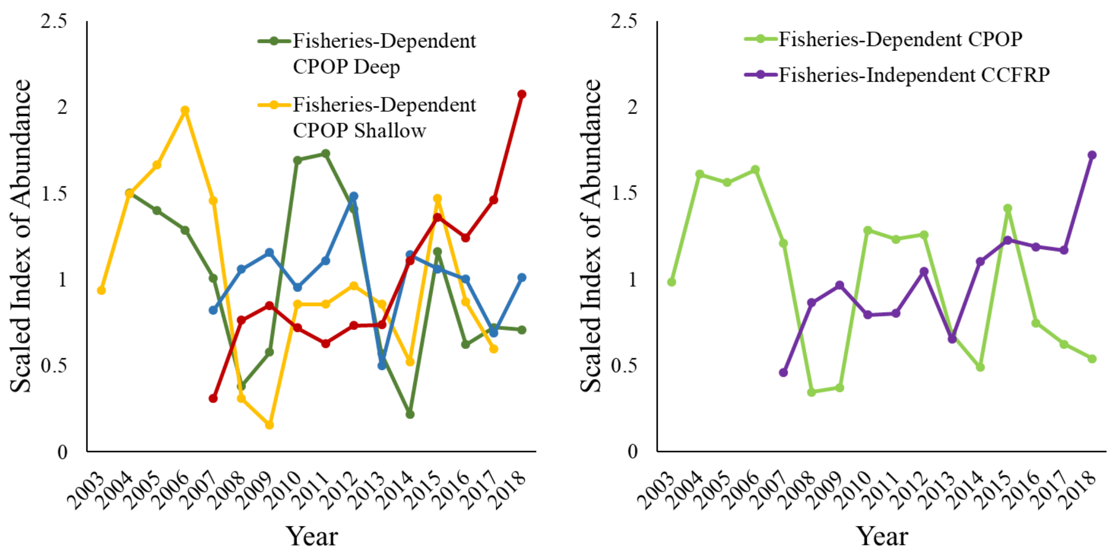

Figure 7. Time series indices of abundance of Vermilion rockfish (*S. miniatus*). Left plot shows indices for CPOP split into shallow and deep areas and CCFRP split into open and protected areas, right plot shows indices for both projects overall.

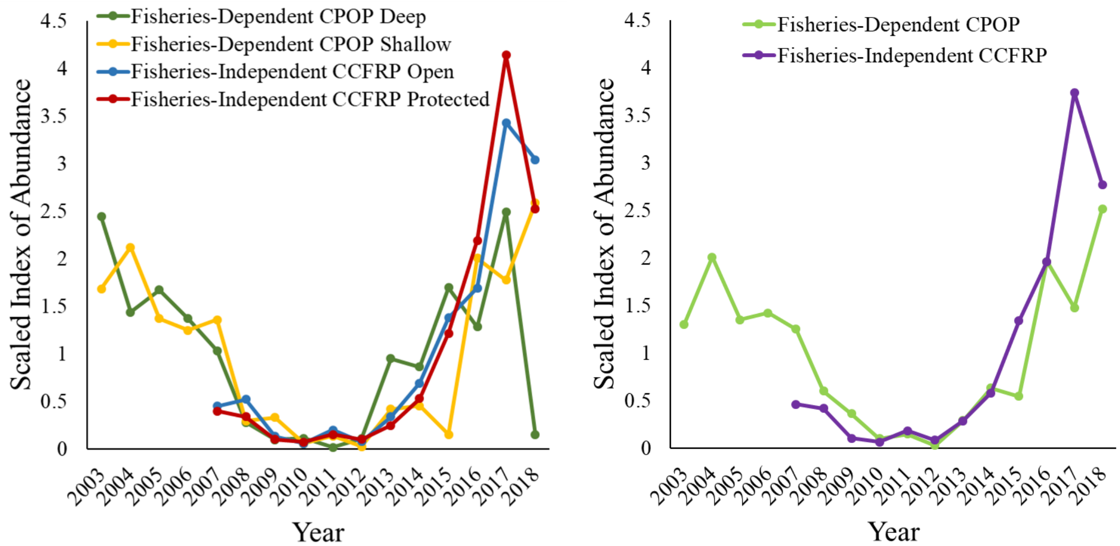

Figure 8. Time series indices of abundance of Blue rockfish (*S. mystinus*). Left plot shows indices for CPOP split into shallow and deep areas and CCFRP split into open and protected areas, right plot shows indices for both projects overall.

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APPENDIX A: BATHYMETRIC DATA PROCESSING

Bathymetry data used in this study were originally acquired, processed, archived, and distributed by the Seafloor Mapping Lab of California State University Monterey Bay, accessible through the California Seafloor Mapping Project (CSMP). Depth and percent hard bottom cover layers were at a resolution of 2 m by 2 m. Vector Ruggedness Measure (VRM) was used as the metric of rugosity, and was calculated from the slope layer at the same 2 by 2 m resolution using the Benthic Terrain Modeler Tool (Wright et al. 2006, Walbridge et al. 2018). These bottom type characteristics are considered second tier map products of the CSMP that are derived through semi/automated GIS processes from bathy soundings and backscatter intensity values. Bottom type variables were assigned based on location points taken at the start of CPOP and CCFRP surveys in Geographic Information Systems (GIS) using ArcMap v10.6.

For CCFRP, depth was calculated using a 40 m circular buffer around the start point of the drop. The ArcGIS zonal statistics tool was used to calculate the mean depth of this buffer area. Bottom type characteristics were calculated on the scale of a sampling cell, 500 by 500 meters. The zonal statistics tool was used to calculate mean VRM and percent hard bottom cover for each sampling cell, and each drop was assigned the VRM and percent hard bottom of the cell it was taken in. Due to the high rate of overlap of drifts throughout time, it was considered appropriate for samples within the same cells to be considered as sharing bottom type characteristics. The mean value of each characteristic was used to organized start points and cells into categorical groups such that these characteristics could be modeled as factors in delta-GLM models. Depth ranged from 10-45 m and was grouped into 5 m bins. Bottom type characteristics were

organized into large categorical groups. Cell VRM (rugosity) ranged from $8.7e^{-5}$-0.015, and was binned into three bins of 0.005, which was the average range of mean VRM of start points within a cell. These groups were labeled low, medium, and high. For percent hard cover, cells with <33% hard bottom were considered low, cells with 33-66% hard bottom were middle, and cells with >66% hard bottom were designated as high.

A similar methodology was applied for CPOP drops. To assign depth, we used the mean depth of a 40 m radius circular buffer around the start location of a drop. To calculate broader-scale metrics, a 500 by 500 m grid was drawn across the entire spatial span of the CPOP start points for all time. Each square within the grid was assigned a unique numeric ID, and each start point was designated a cell ID based on the grid square it fell within. This was intended to mimic the geographic characteristics of the sampling methodology of CCFRP, such that the broad-scale bottom type characteristics used were calculated on a similar scale. Once cells were established, the zonal statistics tool was used to calculate the mean VRM and percent hard bottom for the established 500 by 500 m cell within which each drop took place. Mean values were then used to organize start points and cells into categorical bins such that these characteristics could be used as factors in modeling. Depth ranged from 8-73 m and was grouped into 5 m bins. Cell-level metrics were grouped into larger bins. Cell VRM ranged from $1.9e^{-6}$-0.016 and was binned into five bins of 0.0033, which was the average range of VRM of start points within a cell. These groups were labeled low, mid-low, medium, mid-high, and high. Cell percent hard bottom was grouped into bins of high, medium, and low percent hard bottom, designated as low being <33% hard bottom, medium being 33-66% hard bottom, and high being >66% hard bottom.

In order to determine which reef a given drift was on, the spatial join tool in ArcMap ver. 10.6 was used to assign start point locations to either the reef they fell within, or the reef with closest geographic proximity. Reef designations were created by the Groundfish Analysis Team at NOAA Fisheries Southwest Fisheries Science Center. These reefs are derived from the 2 by 2 m resolution rough/smooth substrate dataset provided by CSMP described above, which were mosaiced together. A 5 m buffer was applied to this information to create the reefs. Reefs breaks were assigned based on a distance, all reef buffers located more than approximately 200 m away from each other were considered a different reef, in accordance to a spatial scale meaningful to rockfish with strong site fidelity, though there was some nuance to this designation based on professional judgement (see Dick et al. 2016).

APPENDIX B: BIC MODEL SELECTION

Gopher rockfish (*S. carnatus*)

Data Source	Model Type	Model Sub-Type	Model	BIC
CPOP Deep	NB Bayesian	Lognormal	Year	888.4172
			Year + Reef	922.1088
			Year + Depth	889.6954
			Year + Cell % Hard Bottom Cover Group	892.6746
			Year + Cell VRM Class	896.9827
			Year + Reef + Depth	915.8517
			Year + Reef + Cell % Hard Bottom Cover Group	932.9714
			Year + Reef + Cell VRM Class	933.9031
			Year + Depth + Cell % Hard Bottom Cover Group	886.6401
			Year + Depth + Cell VRM Class	895.033
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	923.6359
			Year + Reef + Depth + Cell VRM Class	926.905
		Final Lognormal	*Year + Depth + Cell % Hard Bottom Cover Group*	**886.6401**
		Binomial	Year	1761.614
			Year + Reef	1724.819
			Year + Depth	1384.839
			Year + Cell % Hard Bottom Cover Group	1740.166
			Year + Cell VRM Class	1713.609
			Year + Reef + Depth	1459.958
			Year + Reef + Cell % Hard Bottom Cover Group	1696.647
			Year + Reef + Cell VRM Class	1669.832
			Year + Depth + Cell % Hard Bottom Cover Group	1397.694
			Year + Depth + Cell VRM Class	1388.745
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	1472.81
			Year + Reef + Depth + Cell VRM Class	1459.555
		Final Binomial	*Year + Depth*	**1384.839**
		Final Model	*Year + Depth + Cell % Hard Bottom Cover Group*	
CPOP Shallow	Delta-GLM	Lognormal	Year	3082.218
			Year + Reef	3069.706
			Year + Depth	3047.491
			Year + Cell % Hard Bottom Cover Group	3085.479
			Year + Cell VRM Class	3095.821
			Year + Reef + Depth	3020.914
			Year + Reef + Cell % Hard Bottom Cover Group	3059.894
			Year + Reef + Cell VRM Class	3087.887
			Year + Depth + Cell % Hard Bottom Cover Group	3057.462
			Year + Depth + Cell VRM Class	3064.236
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	3027.409
			Year + Reef + Depth + Cell VRM Class	3044.199
		Final Lognormal	*Year + Reef + Depth*	**3020.914**
		Binomial	Year	2353.091
			Year + Reef	2383.510
			Year + Depth	2352.720
			Year + Cell % Hard Bottom Cover Group	2319.111
			Year + Cell VRM Class	2348.022
			Year + Reef + Depth	2378.648
			Year + Reef + Cell % Hard Bottom Cover Group	2358.000
			Year + Reef + Cell VRM Class	2390.043
			Year + Depth + Cell % Hard Bottom Cover Group	2331.857
			Year + Depth + Cell VRM Class	2349.603
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	2367.116
			Year + Reef + Depth + Cell VRM Class	2389.556
		Final Binomial	*Year + Cell % Hard Bottom Cover Group*	**2319.111**
		Final Delta GLM	*Year + Reef + Depth + Cell % Hard Bottom Cover Group*	

Data Source	Model Type	Model Sub-Type	Model	BIC
CCFRP Open	NB Bayesian		Year	4785.045
			Year + Area	4770.751
			Year + Depth	4763.181
			Year + Cell % Hard Bottom Cover Group	4771.877
			Year + Cell VRM Class	4795.736
			Year + Area + Depth	4757.873
			Year + Area + Cell % Hard Bottom Cover Group	4759.254
			Year + Area + Cell VRM Class	4782.333
			Year + Depth + Cell % Hard Bottom Cover Group	4768.742
			Year + Depth + Cell VRM Class	4775.948
			Year + Area + Depth + Cell % Hard Bottom Cover Group	4744.638
			Year + Area + Depth + Cell VRM Class	4756.522
		Final Model	*Year + Area + Depth + Cell % Hard Bottom Cover Group*	**4744.638**
CCFRP Protected	NB Bayesian		Year	5615.996
			Year + Area	5581.021
			Year + Depth	5615.323
			Year + Cell % Hard Bottom Cover Group	5628.314
			Year + Cell VRM Class	5616.274
			Year + Area + Depth	5567.101
			Year + Area + Cell % Hard Bottom Cover Group	5571.948
			Year + Area + Cell VRM Class	5581.877
			Year + Depth + Cell % Hard Bottom Cover Group	5628.379
			Year + Depth + Cell VRM Class	5605.988
			Year + Area + Depth + Cell % Hard Bottom Cover Group	5564.084
			Year + Area + Depth + Cell VRM Class	5572.564
		Final Model	*Year + Area + Depth + Cell % Hard Bottom Cover Group*	**5564.084**
CPOP All Data	Delta-GLM	Lognormal	Year	4121.967
			Year + Reef	4113.074
			Year + Depth	3919.827
			Year + Cell % Hard Bottom Cover Group	4130.596
			Year + Cell VRM Class	4141.400
			Year + Reef + Depth	3898.151
			Year + Reef + Cell % Hard Bottom Cover Group	4106.758
			Year + Reef + Cell VRM Class	4126.279
			Year + Depth + Cell % Hard Bottom Cover Group	3933.078
			Year + Depth + Cell VRM Class	3942.610
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	3911.298
			Year + Reef + Depth + Cell VRM Class	3923.815
		Final Lognormal	*Year + Reef + Depth*	**3898.151**
		Binomial	Year	4716.452
			Year + Reef	4359.344
			Year + Depth	3743.518
			Year + Cell % Hard Bottom Cover Group	4616.092
			Year + Cell VRM Class	4656.629
			Year + Reef + Depth	3810.273
			Year + Reef + Cell % Hard Bottom Cover Group	4264.132
			Year + Reef + Cell VRM Class	4297.485
			Year + Depth + Cell % Hard Bottom Cover Group	3733.249
			Year + Depth + Cell VRM Class	3733.643
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	3805.461
			Year + Reef + Depth + Cell VRM Class	3810.557
		Final Binomial	*Year + Depth + Cell % Hard Bottom Cover Group*	**3733.249**
		Final Delta GLM	*Year + Reef + Depth + Cell % Hard Bottom Cover Group*	

Data Source	Model Type	Model Sub-Type	Model	BIC
CCFRP All Data	NB Bayesian		Year	10520.390
			Year + Site	10411.030
			Year + Area	10524.680
			Year + Depth	10490.450
			Year + Cell % Hard Bottom Cover Group	10517.650
			Year + Cell VRM Class	10517.780
			Year + Area + Site	10417.660
			Year + Area + Depth	10486.340
			Year + Area + Cell % Hard Bottom Cover Group	10495.540
			Year + Area + Cell VRM Class	10523.330
			Year + Site + Depth	10387.790
			Year + Site + Cell % Hard Bottom Cover Group	10401.450
			Year + Site + Cell VRM Class	10424.62
			Year + Depth + Cell % Hard Bottom Cover Group	10500.03
			Year + Depth + Cell VRM Class	10460.66
			Year + Area + Site + Depth	10389.44
			Year + Area + Site + Cell % Hard Cover Group	10388.41
			Year + Area + Site + Cell VRM Class	10432.17
			Year + Area + Depth + Cell % Hard Bottom Cover Group	10478.77
			Year + Area + Depth + Cell VRM Class	10465.01
			Year + Site + Depth + Cell % Hard Bottom Cover Group	10393.49
			Year + Site + Depth + Cell VRM Class	10388.4
			Year + Area + Site + Depth + Cell % Hard Bottom Cover Group	10381.3
			Year + Area + Site + Depth + Cell VRM Class	10395.86
		Final Model	*Year + Area + Site + Depth + Cell % Hard Bottom Cover Group*	**10381.300**

Vermilion rockfish (*S. miniatus*)

Data Source	Model Type	Model Sub-Type	Model	BIC
CPOP Deep	Delta-GLM	Lognormal	Year	1770.996
			Year + Reef	1817.326
			Year + Depth	1798.070
			Year + Cell % Hard Bottom Cover Group	1776.240
			Year + Cell VRM Class	1771.359
			Year + Reef + Depth	1848.092
			Year + Reef + Cell % Hard Bottom Cover Group	1829.012
			Year + Reef + Cell VRM Class	1820.984
			Year + Depth + Cell % Hard Bottom Cover Group	1805.934
			Year + Depth + Cell VRM Class	1800.073
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	1860.547
			Year + Reef + Depth + Cell VRM Class	1852.687
		Final Lognormal	*Year*	**1770.996**
		Binomial	Year	2143.282
			Year + Reef	2225.338
			Year + Depth	2159.942
			Year + Cell % Hard Bottom Cover Group	2132.769
			Year + Cell VRM Class	2153.124
			Year + Reef + Depth	2251.898
			Year + Reef + Cell % Hard Bottom Cover Group	2224.722
			Year + Reef + Cell VRM Class	2237.519
			Year + Depth + Cell % Hard Bottom Cover Group	2158.262
			Year + Depth + Cell VRM Class	2172.508
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	2256.004
			Year + Reef + Depth + Cell VRM Class	2265.751
		Final Binomial	*Year + Cell % Hard Bottom Cover Group*	**2132.769**
		Final Delta GLM	*Year + Cell % Hard Bottom Cover Group*	
CPOP Shallow	Delta-GLM	Lognormal	Year	1721.513
			Year + Reef	1780.914
			Year + Depth	1733.211
			Year + Cell % Hard Bottom Cover Group	1733.585
			Year + Cell VRM Class	1745.536
			Year + Reef + Depth	1804.243
			Year + Reef + Cell % Hard Bottom Cover Group	1792.399
			Year + Reef + Cell VRM Class	1806.011
			Year + Depth + Cell % Hard Bottom Cover Group	1746.341
			Year + Depth + Cell VRM Class	1757.266
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	1817.445
			Year + Reef + Depth + Cell VRM Class	1828.570
		Final Lognormal	*Year*	**1721.513**
		Binomial	Year	2479.443
			Year + Reef	2553.821
			Year + Depth	2474.083
			Year + Cell % Hard Bottom Cover Group	2472.182
			Year + Cell VRM Class	2500.350
			Year + Reef + Depth	2553.007
			Year + Reef + Cell % Hard Bottom Cover Group	2554.811
			Year + Reef + Cell VRM Class	2575.464
			Year + Depth + Cell % Hard Bottom Cover Group	2458.243
			Year + Depth + Cell VRM Class	2493.179
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	2537.750
			Year + Reef + Depth + Cell VRM Class	2572.182
		Final Binomial	*Year + Depth + Cell % Hard Bottom Cover Group*	**2458.243**
		Final Delta GLM	*Year + Depth + Cell % Hard Bottom Cover Group*	

Data Source	**Model Type**	**Model Sub-Type**	**Model**	**BIC**
CCFRP Open	NB Bayesian		Year	2127.860
			Year + Area	2069.328
			Year + Depth	2073.416
			Year + Cell % Hard Bottom Cover Group	2074.788
			Year + Cell VRM Class	2087.885
			Year + Area + Depth	2030.416
			Year + Area + Cell % Hard Bottom Cover Group	2074.757
			Year + Area + Cell VRM Class	2072.861
			Year + Depth + Cell % Hard Bottom Cover Group	2057.650
			Year + Depth + Cell VRM Class	2067.277
			Year + Area + Depth + Cell % Hard Bottom Cover Group	2039.759
			Year + Area + Depth + Cell VRM Class	2043.802
		Final Model	*Year + Area + Depth*	**2030.416**
CCFRP Protected	NB Bayesian		Year	3146.703
			Year + Area	3086.452
			Year + Depth	3097.592
			Year + Cell % Hard Bottom Cover Group	3105.812
			Year + Cell VRM Class	3072.863
			Year + Area + Depth	3052.956
			Year + Area + Cell % Hard Bottom Cover Group	3079.104
			Year + Area + Cell VRM Class	3077.509
			Year + Depth + Cell % Hard Bottom Cover Group	3081.120
			Year + Depth + Cell VRM Class	3049.334
			Year + Area + Depth + Cell % Hard Bottom Cover Group	3057.201
			Year + Area + Depth + Cell VRM Class	3051.455
		Final Model	*Year + Depth + Cell VRM Class*	**3049.334**
CPOP All Data	Delta-GLM	Lognormal	Year	3452.614
			Year + Reef	3533.424
			Year + Depth	3492.366
			Year + Cell % Hard Bottom Cover Group	3458.400
			Year + Cell VRM Class	3469.313
			Year + Reef + Depth	3592.698
			Year + Reef + Cell % Hard Bottom Cover Group	3544.331
			Year + Reef + Cell VRM Class	3552.634
			Year + Depth + Cell % Hard Bottom Cover Group	3503.697
			Year + Depth + Cell VRM Class	3510.705
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	3606.454
			Year + Reef + Depth + Cell VRM Class	3612.834
		Final Lognormal	*Year*	**3452.614**
		Binomial	Year	4584.059
			Year + Reef	4695.670
			Year + Depth	4571.558
			Year + Cell % Hard Bottom Cover Group	4561.785
			Year + Cell VRM Class	4603.005
			Year + Reef + Depth	4707.288
			Year + Reef + Cell % Hard Bottom Cover Group	4690.918
			Year + Reef + Cell VRM Class	4716.909
			Year + Depth + Cell % Hard Bottom Cover Group	4543.803
			Year + Depth + Cell VRM Class	4591.923
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	4686.772
			Year + Reef + Depth + Cell VRM Class	4729.434
		Final Binomial	*Year + Depth + Cell % Hard Bottom Cover Group*	**4543.803**
		Final Delta GLM	*Year + Depth + Cell % Hard Bottom Cover Group*	

Data Source	**Model Type**	**Model Sub-Type**	**Model**	**BIC**
CCFRP All Data	NB Bayesian		Year	5359.739
			Year + Site	5256.191
			Year + Area	5250.625
			Year + Depth	5247.468
			Year + Cell % Hard Bottom Cover Group	5257.580
			Year + Cell VRM Class	5306.330
			Year + Area + Site	5138.902
			Year + Area + Depth	5167.843
			Year + Area + Cell % Hard Bottom Cover Group	5230.504
			Year + Area + Cell VRM Class	5264.871
			Year + Site + Depth	5148.163
			Year + Site + Cell % Hard Bottom Cover Group	5151.147
			Year + Site + Cell VRM Class	5142.454
			Year + Depth + Cell % Hard Bottom Cover Group	5205.723
			Year + Depth + Cell VRM Class	5236.151
			Year + Area + Site + Depth	5061.309
			Year + Area + Site + Cell % Hard Cover Group	5122.131
			Year + Area + Site + Cell VRM Class	5130.219
			Year + Area + Depth + Cell % Hard Bottom Cover Group	5167.204
			Year + Area + Depth + Cell VRM Class	5177.491
			Year + Site + Depth + Cell % Hard Bottom Cover Group	5111.356
			Year + Site + Depth + Cell VRM Class	5090.770
			Year + Area + Site + Depth + Cell % Hard Bottom Cover Group	5071.942
			Year + Area + Site + Depth + Cell VRM Class	5067.253
		Final Model	*Year + Area + Site + Depth*	**5061.309**

Blue rockfish (*S. mystinus*)

Data Source	Model Type	Model Sub-Type	Model	BIC
CPOP Deep	Delta-GLM	Lognormal	Year	2172.762
			Year + Reef	2177.126
			Year + Depth	2194.331
			Year + Cell % Hard Bottom Cover Group	2171.066
			Year + Cell VRM Class	2182.649
			Year + Reef + Depth	2199.656
			Year + Reef + Cell % Hard Bottom Cover Group	2178.010
			Year + Reef + Cell VRM Class	2174.348
			Year + Depth + Cell % Hard Bottom Cover Group	2196.281
			Year + Depth + Cell VRM Class	2204.227
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	2204.058
			Year + Reef + Depth + Cell VRM Class	2196.524
		Final Lognormal	*Year + Cell % Hard Bottom Cover Group*	**2171.066**
		Binomial	Year	1651.583
			Year + Reef	1735.938
			Year + Depth	1680.276
			Year + Cell % Hard Bottom Cover Group	1642.285
			Year + Cell VRM Class	1648.451
			Year + Reef + Depth	1765.344
			Year + Reef + Cell % Hard Bottom Cover Group	1736.999
			Year + Reef + Cell VRM Class	1737.874
			Year + Depth + Cell % Hard Bottom Cover Group	1673.728
			Year + Depth + Cell VRM Class	1680.753
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	1769.972
			Year + Reef + Depth + Cell VRM Class	1770.991
		Final Binomial	*Year + Cell % Hard Bottom Cover Group*	**1642.285**
		Final Delta GLM	*Year + Cell % Hard Bottom Cover Group*	
CPOP Shallow	Delta-GLM	Lognormal	Year	2209.607
			Year + Reef	2220.792
			Year + Depth	2231.440
			Year + Cell % Hard Bottom Cover Group	2216.007
			Year + Cell VRM Class	2226.937
			Year + Reef + Depth	2256.802
			Year + Reef + Cell % Hard Bottom Cover Group	2227.466
			Year + Reef + Cell VRM Class	2238.404
			Year + Depth + Cell % Hard Bottom Cover Group	2236.640
			Year + Depth + Cell VRM Class	2250.850
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	2262.657
			Year + Reef + Depth + Cell VRM Class	2275.850
		Final Lognormal	*Year*	**2209.607**
		Binomial	Year	2083.692
			Year + Reef	2140.451
			Year + Depth	2101.521
			Year + Cell % Hard Bottom Cover Group	2076.948
			Year + Cell VRM Class	2095.978
			Year + Reef + Depth	2166.212
			Year + Reef + Cell % Hard Bottom Cover Group	2138.452
			Year + Reef + Cell VRM Class	2152.860
			Year + Depth + Cell % Hard Bottom Cover Group	2096.365
			Year + Depth + Cell VRM Class	2117.058
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	2162.160
			Year + Reef + Depth + Cell VRM Class	2179.733
		Final Binomial	*Year + Cell % Hard Bottom Cover Group*	**2076.948**
		Final Delta GLM	*Year + Cell % Hard Bottom Cover Group*	

Data Source	Model Type	Model Sub-Type	Model	BIC
CCFRP Open	Delta-GLM	Lognormal	Year	1626.168
			Year + Area	1569.950
			Year + Depth	1646.437
			Year + Cell % Hard Bottom Cover Group	1612.699
			Year + Cell VRM Class	1620.474
			Year + Area + Depth	1597.270
			Year + Area + Cell % Hard Bottom Cover Group	1570.678
			Year + Area + Cell VRM Class	1574.337
			Year + Depth + Cell % Hard Bottom Cover Group	1632.121
			Year + Depth + Cell VRM Class	1642.190
			Year + Area + Depth + Cell % Hard Bottom Cover Group	1599.642
			Year + Area + Depth + Cell VRM Class	1602.581
		Final Lognormal	*Year + Area*	**1569.950**
		Binomial	Year	1142.498
			Year + Area	1148.021
			Year + Depth	1169.280
			Year + Cell % Hard Bottom Cover Group	1142.146
			Year + Cell VRM Class	1150.987
			Year + Area + Depth	1176.025
			Year + Area + Cell % Hard Bottom Cover Group	1134.918
			Year + Area + Cell VRM Class	1157.616
			Year + Depth + Cell % Hard Bottom Cover Group	1176.409
			Year + Depth + Cell VRM Class	1179.781
			Year + Area + Depth + Cell % Hard Bottom Cover Group	1172.291
			Year + Area + Depth + Cell VRM Class	1186.295
		Final Binomial	*Year + Area + Cell % Hard Bottom Cover Group*	**1134.918**
		Final Delta GLM	*Year + Area + Cell % Hard Bottom Cover Group*	
CCFRP Protected	Delta-GLM	Lognormal	Year	2119.730
			Year + Area	2122.161
			Year + Depth	2145.466
			Year + Cell % Hard Bottom Cover Group	2129.745
			Year + Cell VRM Class	2128.902
			Year + Area + Depth	2145.582
			Year + Area + Cell % Hard Bottom Cover Group	2132.753
			Year + Area + Cell VRM Class	2130.045
			Year + Depth + Cell % Hard Bottom Cover Group	2154.136
			Year + Depth + Cell VRM Class	2152.975
			Year + Area + Depth + Cell % Hard Bottom Cover Group	2156.752
			Year + Area + Depth + Cell VRM Class	2156.021
		Final Lognormal	*Year*	**2119.730**
		Binomial	Year	968.743
			Year + Area	973.853
			Year + Depth	1006.723
			Year + Cell % Hard Bottom Cover Group	980.530
			Year + Cell VRM Class	979.937
			Year + Area + Depth	1011.572
			Year + Area + Cell % Hard Bottom Cover Group	984.629
			Year + Area + Cell VRM Class	983.819
			Year + Depth + Cell % Hard Bottom Cover Group	1018.861
			Year + Depth + Cell VRM Class	1017.900
			Year + Area + Depth + Cell % Hard Bottom Cover Group	1022.836
			Year + Area + Depth + Cell VRM Class	1021.912
		Final Binomial	*Year*	**968.743**
		Final Delta GLM	*Year*	

Data Source	**Model Type**	**Model Sub-Type**	**Model**	**BIC**
CPOP All Data	Delta-GLM	Lognormal	Year	4321.651
			Year + Reef	4299.839
			Year + Depth	4359.633
			Year + Cell % Hard Bottom Cover Group	4318.860
			Year + Cell VRM Class	4343.468
			Year + Reef + Depth	4364.073
			Year + Reef + Cell % Hard Bottom Cover Group	4299.189
			Year + Reef + Cell VRM Class	4312.829
			Year + Depth + Cell % Hard Bottom Cover Group	4354.456
			Year + Depth + Cell VRM Class	4381.165
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	4364.036
			Year + Reef + Depth + Cell VRM Class	4376.353
		Final Lognormal	*Year + Reef + Cell % Hard Bottom Cover Group*	**4299.189**
		Binomial	Year	3709.543
			Year + Reef	3782.535
			Year + Depth	3735.326
			Year + Cell % Hard Bottom Cover Group	3691.532
			Year + Cell VRM Class	3714.162
			Year + Reef + Depth	3843.869
			Year + Reef + Cell % Hard Bottom Cover Group	3772.973
			Year + Reef + Cell VRM Class	3792.111
			Year + Depth + Cell % Hard Bottom Cover Group	3709.733
			Year + Depth + Cell VRM Class	3743.149
			Year + Reef + Depth + Cell % Hard Bottom Cover Group	3829.798
			Year + Reef + Depth + Cell VRM Class	3854.298
		Final Binomial	*Year + Cell % Hard Bottom Cover Group*	**3691.532**
		Final Delta GLM	*Year + Reef + Cell % Hard Bottom Cover Group*	

Data Source	Model Type	Model Sub-Type	Model	BIC
CCFRP All Data	Delta-GLM	Lognormal	Year	3779.269
			Year + Site	3707.115
			Year + Area	3743.602
			Year + Depth	3813.302
			Year + Cell % Hard Bottom Cover Group	3769.563
			Year + Cell VRM Class	3787.511
			Year + Area + Site	3673.470
			Year + Area + Depth	3777.831
			Year + Area + Cell % Hard Bottom Cover Group	3753.936
			Year + Area + Cell VRM Class	3726.333
			Year + Site + Depth	3738.086
			Year + Site + Cell % Hard Bottom Cover Group	3704.565
			Year + Site + Cell VRM Class	3714.266
			Year + Depth + Cell % Hard Bottom Cover Group	3797.941
			Year + Depth + Cell VRM Class	3818.498
			Year + Area + Site + Depth	3702.083
			Year + Area + Site + Cell % Hard Cover Group	3685.958
			Year + Area + Site + Cell VRM Class	3680.514
			Year + Area + Depth + Cell % Hard Bottom Cover Group	3786.552
			Year + Area + Depth + Cell VRM Class	3764.700
			Year + Site + Depth + Cell % Hard Bottom Cover Group	3723.123
			Year + Site + Depth + Cell VRM Class	3739.865
			Year + Area + Site + Depth + Cell % Hard Bottom Cover Group	3710.180
			Year + Area + Site + Depth + Cell VRM Class	3713.064
		Final Lognormal	*Year + Area + Site*	**3673.470**
	Delta-GLM	Binomial	Year	2124.621
			Year + Site	2065.855
			Year + Area	2132.178
			Year + Depth	2153.842
			Year + Cell % Hard Bottom Cover Group	2125.268
			Year + Cell VRM Class	2132.432
			Year + Area + Site	2073.418
			Year + Area + Depth	2161.058
			Year + Area + Cell % Hard Bottom Cover Group	2125.346
			Year + Area + Cell VRM Class	2133.297
			Year + Site + Depth	2097.435
			Year + Site + Cell % Hard Bottom Cover Group	2068.266
			Year + Site + Cell VRM Class	2079.619
			Year + Depth + Cell % Hard Bottom Cover Group	2161.290
			Year + Depth + Cell VRM Class	2164.264
			Year + Area + Site + Depth	2104.455
			Year + Area + Site + Cell % Hard Cover Group	2066.469
			Year + Area + Site + Cell VRM Class	2086.579
			Year + Area + Depth + Cell % Hard Bottom Cover Group	2161.535
			Year + Area + Depth + Cell VRM Class	2165.684
			Year + Site + Depth + Cell % Hard Bottom Cover Group	2106.576
			Year + Site + Depth + Cell VRM Class	2111.924
			Year + Area + Site + Depth + Cell % Hard Bottom Cover Group	2106.221
			Year + Area + Site + Depth + Cell VRM Class	2119.157
		Final Binomial	*Year + Site*	**2065.855**
		Final Delta GLM	*Year + Area + Site*	

APPENDIX C: CCFRP CELL ANALYSIS

In order to analyze the performance of CCFRP as a program, some additional analysis was performed of the CCFRP sampling sites to examine how they differed environmentally and how they performed in terms of catch. CCFRP samples four sites: the Point Buchon State Marine Reserve (SMR) and a corresponding non-protected reference site, and the Piedras Blancas SMR and an additional corresponding non-protected reference site, referred to in this appendix as marine protected area (MPA) and reference sites. Each of the four sites contains between 11 and 22 500 by 500 m cells, where CCFRP surveys are conducted. To compare each of these four areas, we calculated the mean depth, slope, rugosity, as well as the percent rough bottom cover and all time catch per unit effort (CPUE) for the pre-established sampling cells within a given area.

Bottom type characteristics were obtained in GIS using ArcMap v10.6. Spatial data used in this study were originally acquired, processed, archived, and distributed by the Seafloor Mapping Lab of California State University Monterey Bay, current access is available through the California Seafloor Mapping Project (CSMP). Bottom type characteristics were calculated using the borders of the established CCFRP cells as polygons, then extracting raster information with the zonal statistics tool. Rugosity was characterized as Vector Ruggedness Measure (VRM), calculated in GIS using the Benthic Terrain Modeler in GIS using 2x2 meter cells. VRM uses vector analysis where an orthagonal vector is used to analyze the 3-dimensional orientation of the cell, allowing for variation in local slope and aspect. VRM has no units, and varies from 0 (no variation) to 1 (complete variation) (Hobson 1972, Walbridge et al. 2018). All time CPUE was calculated using the sum of all fish caught in a given cell divided by the total

sum of angler hours fished in that cell in all years of the project. Once all these variables had been calculated, cells were grouped by area and compared using ANOVAs and post-hoc Tukey HSD two-way comparisons.

Depth did not differ significantly by area, but slope, VRM, percent rough bottom cover, and CPUE all differed significantly between areas (Table 7). The Point Buchon MPA and reference sites were not significantly different from each other in slope or VRM, but did differ from the Piedras Blancas MPA and reference sites, which did not differ from each other (Fig. 9, Fig. 10). Regarding percent rough cover, the two MPA sites did not differ significantly from each other, and the two MPA sites did not differ significantly from corresponding reference sites, but the reference sites did differ significantly from each other (Fig. 11). CPUE did not differ significantly between the Point Buchon MPA and the Piedras Blancas MPA, and CPUE did not differ significantly between the Point Buchon reference area and the Piedras Blancas reference area, but each MPA site differed significantly from its reference site. Interestingly, the Piedras Blancas reference site CPUE did not differ significantly from the Point Buchon MPA site (Fig. 12).

The paired MPA and reference sites are relatively similar in their bottom type parameters. However, the two areas differ significantly from each other in most bottom type metrics, which likely indicates different habitat complexity levels between these two areas. Despite these differences in bottom type, it is evident that CPUE is higher in the MPAs regardless. This shows that protection is having an effect regardless of the apparent relative quality of habitat in a protected area. However, it is notable that the Piedras Blancas reference area has higher CPUE than the Point Buchon reference area,

despite Point Buchon bottom type metrics indicating more complexity, which is preferred by rockfish (Matthews 1990b, Marliave and Challenger 2009, Young and Carr 2015, Pirtle et al. 2017). This may be due to a shift in the fishing effort of local sport fishermen and CPFVs, which was outlined by a previous thesis from this lab (Ivens-Duran, 2014). Following the establishment of the MPAs in this area in 2007, recreational fishing vessels traveled to the area near the Piedras Blancas reference site less often. The lowering of fishing effort in Piedras Blancas may have released the populations from fishing pressure and allowed them to grow, contributing to higher overall CPUE, despite lower habitat complexity.

APPENDIX D: LENGTH DISTRIBUTION COMPARISONS WITHIN CCFRP

In the interest of assessing the California Collaborative Fisheries Research Program (CCFRP), additional length comparisons were drawn using Kolmogorov-Smirnov (KS) tests within CCFRP data. The main body of this work reports results of comparisons between MPA and reference areas overall within the project. Comparisons were also drawn between the Piedras Blancas and Point Buchon areas overall, between MPA and reference areas within these discrete areas, and between the two MPA sites and the two reference sites. These comparisons were made both with data from all years combined and discretely year by year for 2007-2018. Three species were compared: Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*). A total of 57 supplementary KS tests were run for each species, so a p-value of 0.0009 was used to establish significance for these supplementary tests.

Overall, Gopher rockfish show different distributions between Piedras Blancas and Point Buchon (Table 8), and year by year Gopher rockfish have significantly different distributions between the two areas every year except for 2013 (Table 9). The size distribution of Gopher rockfish is shifted towards smaller sizes in Piedras Blancas both overall and in individual years with differences (Fig.13, Fig. 14). Overall, Vermilion rockfish distributions show significantly different distributions between the two areas (Table 8), though the only individual year to show a significant difference in size distribution is 2014 (Table 9). Point Buchon is shifted towards a smaller size distribution both overall and in 2014 (Fig. 13, Fig. 15). Blue rockfish show an overall difference in size distribution (Table 8), as well as size distribution differences in four individual years (Table 9): 2007, 2011 , 2017, and 2018. The overall mean length is larger in Piedras

Blancas, but the individual years with differences do not have a consistent pattern as to which area has a distribution shifted towards larger or smaller sizes (Fig. 13, Fig. 16).

Within the Point Buchon sampling area, only Vermilion rockfish differ significantly in their size distribution between MPA and reference areas (Table 8), and they are shifted towards longer lengths in the MPA (Fig. 17). Gopher rockfish do not show an overall difference in distribution but do show differences in distributions in 2008 and 2010, Vermilion rockfish show an additional difference in distribution in 2014, and Blue rockfish show distribution differences in 2016 and 2018 (Table 9). Gopher rockfish show a smaller-shifted distribution in the MPA in years with differences (Fig. 18), but Vermilion and Blue rockfish show distributions shifted towards larger sizes in the MPA in the years where there distributions are different (Fig. 19, Fig. 20).

Within the Piedras Blancas sampling area, all three species show significant differences in size distribution between the MPA and reference areas (Table 8). Vermilion rockfish are shifted towards larger sizes in the MPA, but Blue rockfish and Gopher rockfish are shifted towards smaller sizes (Fig. 17). Piedras Blancas has only been sampled ten out of the twelve years of the project, but of the years sampled, Gopher rockfish and Vermilion rockfish have more years where the distributions are different than not, whereas Blue rockfish distributions differ five out of the ten years. Gopher rockfish differ in 2008-2010, 2012, and 2014-2018. Vermilion rockfish differ in 2008-2009, 2011-2012, and 2014-2016, and Blue rockfish differ in 2008, 2014, and 2015-2018 (Table 9). Echoing the overall distribution differences, in years where they show differences, Gopher rockfish and Blue rockfish are shifted towards smaller sizes in the

MPA, whereas the size distribution of Vermilion rockfish is shifted towards larger sizes in the MPA (Fig. 18, Fig. 19, Fig. 20).

We can further draw comparisons between the Piedras Blancas MPA and the Point Buchon MPA sites and Piedras Blancas reference and Point Buchon reference sites. Overall, Gopher rockfish show a size distribution difference between the two MPAs (Table 8), and the size distribution in the Piedras Blancas MPA is shifted towards smaller sizes than the Point Buchon MPA (Fig. 17). Year by year, Gopher rockfish also show size distribution differences nine out of the ten years that Piedras Blancas was sampled, all years except in 2013, while reference site distributions differ only in 2010, 2011, and 2012 (Table 9). In these years, Piedras Blancas size distributions are shifted towards smaller sizes in both the MPA and reference comparisons (Fig. 18). Overall, Vermilion rockfish show a significant difference in size distribution between the two MPAs (Table 8), and the Piedras Blancas MPA is shifted towards longer lengths (Fig. 17), but do not show a significant difference between the size distributions of the reference sites. Year by year, Vermilion rockfish do not show any size distribution differences between the MPAs or between the two reference sites (Table 9). Blue rockfish show overall significant differences between both the MPAs and between the reference sites (Table 8), and the Point Buchon size distributions are shifted towards smaller sizes for both MPA and reference distributions (Fig. 17). Year by year, MPA to MPA and reference to reference comparisons both show significant differences in 2008, 2016, 2017, and 2018, while MPA to MPA shows an additional distribution difference in 2013 and reference to reference shows an additional difference in 2011 (Table 9). MPA comparisons do not consistently show one area to have a larger or smaller shifted distribution, but reference

comparisons show that the Point Buchon distribution is consistently shifted towards smaller sizes (Fig. 20).

There are several interesting conclusions we may draw from the CCFRP metrics. As we know from our initial overall MPA to reference site comparisons from earlier in this work, Gopher rockfish remain consistent in their size distribution whether an area is protected or not. Vermilion rockfish show some differences but there is not a consistent divergence in size distributions across as might be expected from an MPA effect. Blue rockfish are occasionally shifted towards smaller sizes in the MPA sites, though this is not consistent. However, when comparisons are drawn between the Point Buchon and Piedras Blancas areas separately, the patterns are different. The Point Buchon MPA and reference sites show very few significant size distribution differences in any species. Piedras Blancas, on the other hand, shows many size distribution differences between all three species. Based on the understanding that the community regards Point Buchon to be a more heavily fished area, we expected the Piedras Blancas areas to be more similar than the Point Buchon areas, as Point Buchon seemed more likely to have been impacted by fishing and subsequent protection. The Point Buchon area has more complex habitat in both the MPA and reference area, whereas Piedras Blancas has less complex habitat, especially in the reference area. This may be driving similar sizes in the Point Buchon area even with the impact of fishing pressure.

When comparing the two CCFRP sampling areas, Piedras Blancas and Point Buchon, the patterns differ by species. Overall, Vermilion rockfish do not show many differences between the two areas, and even between specifically the MPA sites and the reference sites, Vermilion rockfish do not differ in size distribution. Due to the

ontogenetic shift found in Vermilion rockfish, it is likely that this test is only capturing the smallest adult sizes, rather than the full range of the population. This makes it difficult to conclude anything about fishing pressure or habitat influences regarding these patterns, as fishing pressure and habitat selection are more likely to be experienced by mature adults. Blue rockfish differ, and while the patterns of these differences are somewhat sporadic, there are differences in all site-to-site comparisons in 2017 and 2018, when the population was increasing following a recruitment event. This shows that Blue rockfish size distribution is likely driven by events like recruitment rather than localized habitat or fishing pressure. Gopher rockfish are consistently shifted smaller in the Piedras Blancas site, especially in the Piedras Blancas MPA site as compared to the Point Buchon MPA site. Gopher rockfish are more habitat associated than the other two species considered in these comparisons, and it seems likely that the better habitat in Point Buchon (see Appendix 3) is driving the distribution towards larger sizes.

<u>**APPENDIX TABLES**</u>

Table 7. Summary of ANOVA comparisons of CCFRP bottom characteristics. Characteristics are calculated based on CCFRP sampling cells within the Piedras Blancas and Point Buchon MPA and reference sampling sites. Highlighted cells show the p-values of characteristics which have significant differences. A p-value of 0.05 was used to establish significance.

	F-value	**p-value**	**Piedras Blancas MPA Mean**	**Piedras Blancas Reference Mean**	**Point Buchon MPA Mean**	**Point Buchon Reference Mean**
Depth	0.976	0.411	-26.7	-25.5	-24.4	-23.1
Slope	34.11	7.74E-13	5.06	4.27	10.4	8.87
VRM	35.85	3.10E-13	0.00215	0.00222	0.00954	0.0062
Percent Cover	19.31	8.40E-09	0.501	0.381	0.682	0.831
CPUE	11.55	4.89E-06	13.3	9.17	12.6	5.1

Table 8. Summary of CCFRP pairwise Kolmogorov-Smirnov tests. Tests compared length distribution of Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*), between the Piedras Blancas and Point Buchon CCFRP sampling areas, and between the MPA and reference sites within those areas. Highlighted cells are significant differences. A p-value of 0.0009 was used to establish significance.

Species	**Piedras Blancas vs Point Buchon**	**Point Buchon MPA vs Reference**	**Piedras Blancas MPA vs Reference**	**Piedras Blancas MPA vs Point Buchon MPA**	**Point Buchon Reference vs Piedras Blancas Reference**
Gopher rockfish	2.20E-16	0.0601	2.20E-16	2.20E-16	6.24E-10
Vermilion rockfish	3.44E-15	4.33E-15	2.20E-16	1.55E-15	0.00512
Blue rockfish	2.20E-16	0.0691	2.20E-16	7.77E-16	2.20E-16

Table 9. Summary of CCFRP time series pairwise Kolmogorov-Smirnov tests. Tests compared length distribution year by year of Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*), between the Piedras Blancas and Point Buchon CCFRP sampling areas, and between the MPA and reference sites within those areas. Highlighted cells are significant differences. A p-value of 0.0009 was used to establish significance.

Species	Year	Piedras Blancas vs Point Buchon	Point Buchon MPA vs Reference	Piedras Blancas MPA vs Reference	Piedras Blancas MPA vs Point Buchon MPA	Point Buchon Reference vs Piedras Blancas Reference
Gopher rockfish	2007		0.7814			
	2008	7.27E-07	0.0002	5.10E-06	2.29E-05	0.0556
	2009	0.00029	0.0145	3.99E-05	0.0004	0.0106
	2010	2.20E-16	0.0004	1.06E-08	2.20E-16	9.50E-11
	2011	2.20E-16	0.7807	0.0054	2.96E-14	6.53E-07
	2012	2.20E-16	0.0210	0.0001	3.33E-16	1.14E-07
	2013	0.0011	0.1676	0.3247	0.0439	0.0025
	2014	9.62E-11	0.2169	7.85E-08	3.42E-14	0.0027
	2015		0.1357			
	2016	2.02E-09	0.0197	6.31E-06	2.91E-12	0.0415
	2017	2.20E-16	0.0038	4.52E-06	2.20E-16	0.2665
	2018	2.20E-16	0.0265	0.0003	2.20E-16	0.4057
Vermilion rockfish	2007		0.0024			
	2008	0.0065	0.1450	4.01E-05	0.0151	0.1527
	2009	0.0126	0.2755	3.72E-07	0.5084	0.0275
	2010	0.1475	0.1178	0.0573	0.3185	0.1899
	2011	0.9647	0.0554	2.46E-09	0.5929	0.9994
	2012	0.0031	0.6051	3.27E-05	0.0015	0.9333
	2013	0.1019	0.6510	0.6604	0.1001	0.5165
	2014	0.0003	0.0003	0.0002	0.0025	0.3215
	2015		0.1257			
	2016	0.1715	0.1320	3.69E-07	0.0073	0.9663
	2017	0.0256	0.1289	0.0318	0.0358	0.3742
	2018	0.0028	0.1757	0.0402	0.0032	0.5403
Blue rockfish	2007		0.0341			
	2008	2.44E-06	0.1842	6.66E-09	6.06E-07	2.48E-10
	2009	0.0010	0.6372	0.0499	0.0047	0.3428
	2010	0.0356	0.0402	0.4605	0.0150	0.6797
	2011	8.52E-06	0.3300	0.0006	0.0630	5.28E-05
	2012	0.0183	0.0361	0.9274	0.0055	0.9664
	2013	0.0016	0.8889	0.0013	1.80E-05	0.6516
	2014	0.0795	0.4408	1.43E-06	0.0014	0.0104
	2015		0.4804			
	2016	0.0021	2.20E-16	2.20E-16	1.72E-14	2.20E-16
	2017	2.20E-16	0.0277	2.22E-16	2.22E-16	2.20E-16
	2018	1.94E-07	1.14E-07	7.34E-06	2.20E-16	8.92E-05

APPENDIX FIGURES

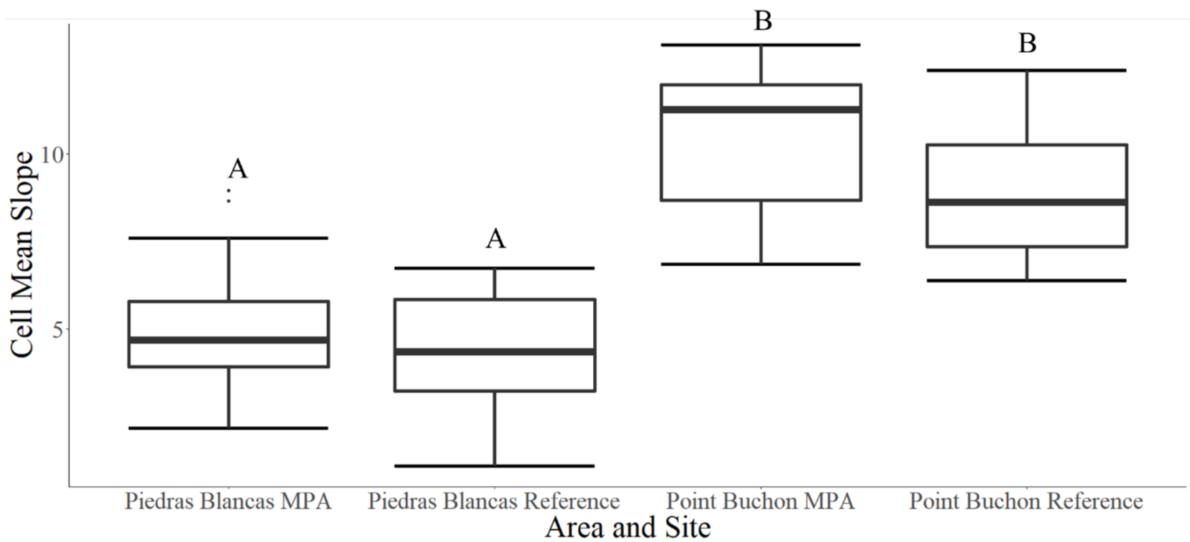

Figure 9. Box plots showing CCFRP cell slope ANOVA results. Slope values were calculated from CCFRP sampling cells in the Piedras Blancas and Point Buchon areas. Letters indicate post-hoc Tukey's HSD groupings. The extent of the box show the 25th and 75th percentile, and the dark line shows the median, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles).

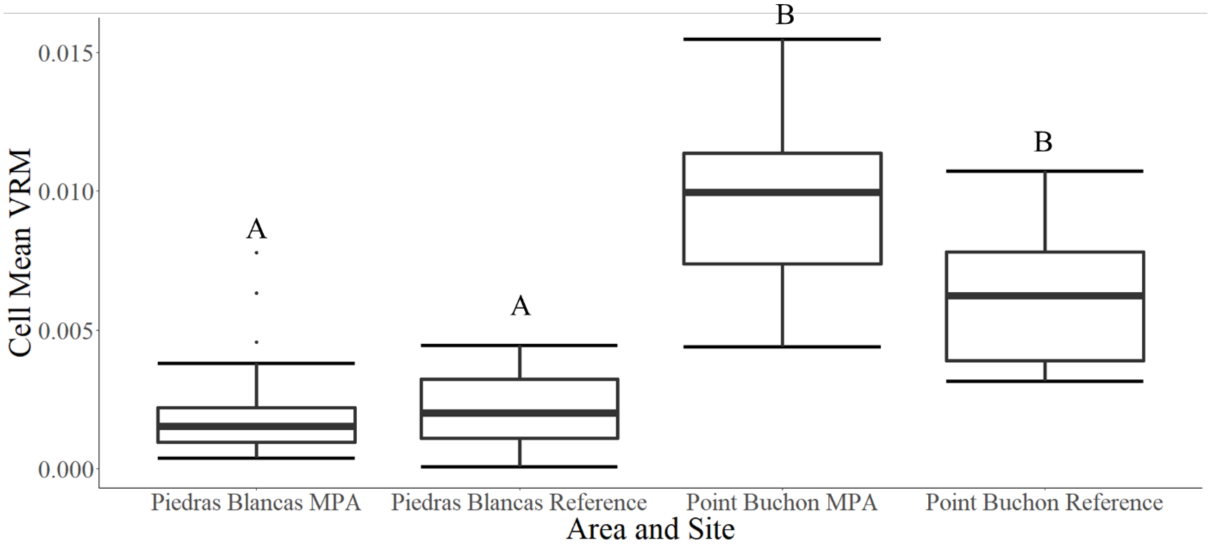

Figure 10. Box plots showing CCFRP cell VRM ANOVA results. VRM values were calculated from CCFRP sampling cells in the Piedras Blancas and Point Buchon areas. Letters indicate post-hoc Tukey's HSD groupings. The extent of the box show the 25th and 75th percentile, and the dark line shows the median, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles).

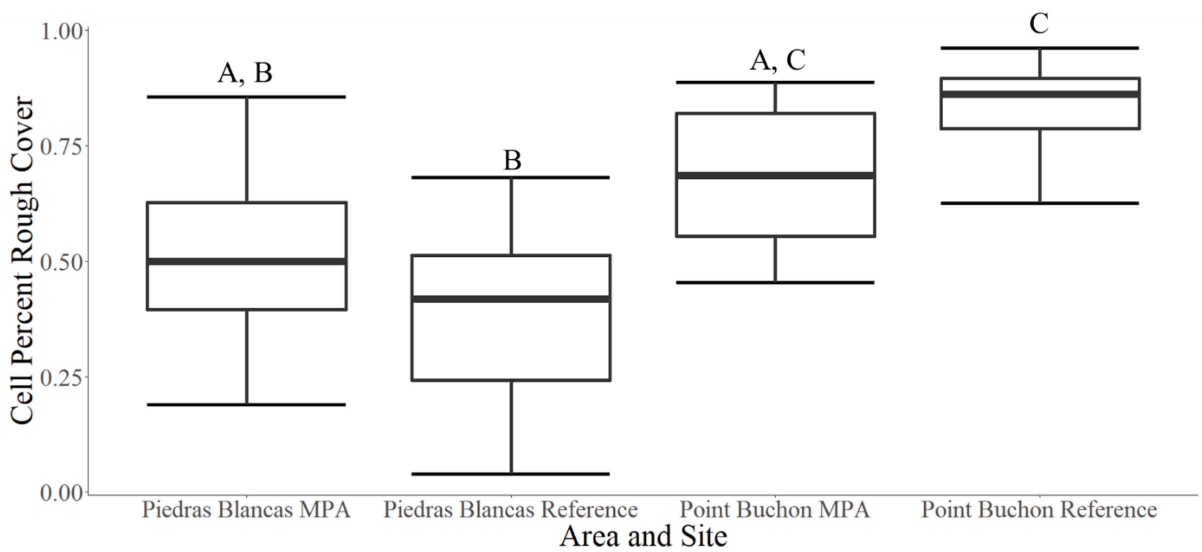

Figure 11. Box plots showing CCFRP cell percent rough cover ANOVA results. Percent rough cover values were calculated CCFRP sampling cells in the Piedras Blancas and Point Buchon areas. Letters indicate post-hoc Tukey's HSD groupings. The extent of the box show the 25th and 75th percentile, athe dark line shows the median, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles).

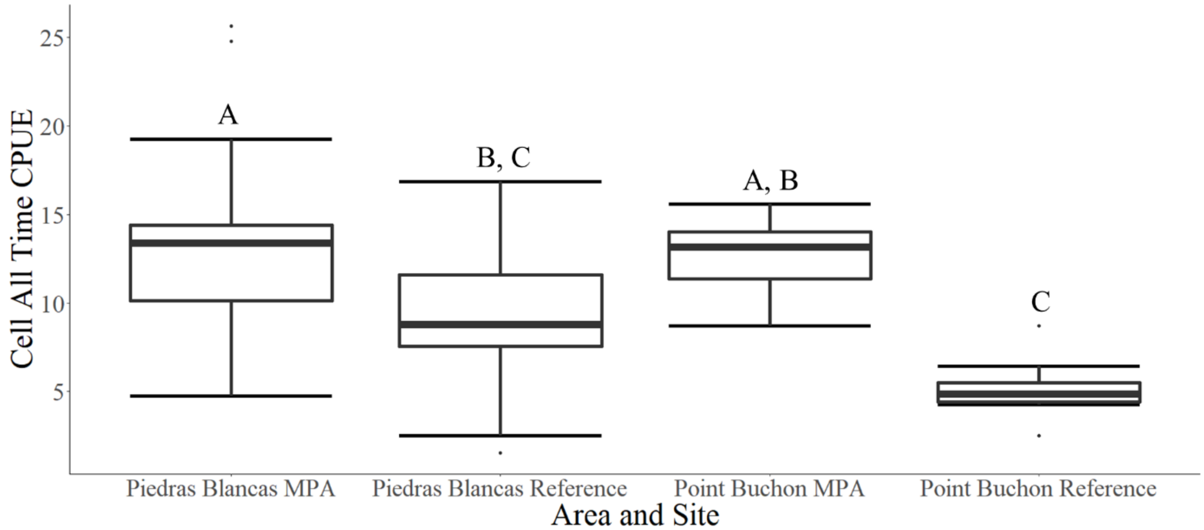

Figure 12. Box plots showing CCFRP cell catch per unit effort ANOVA results. Catch per unit effort (CPUE, measured in fish caught per angler per hour) was calculated from within CCFRP sampling cells in the Piedras Blancas and Point Buchon areas. Letters indicate post-hoc Tukey's HSD groupings. The extent of the box show the 25th and 75th percentile, and the dark line shows the median, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles).

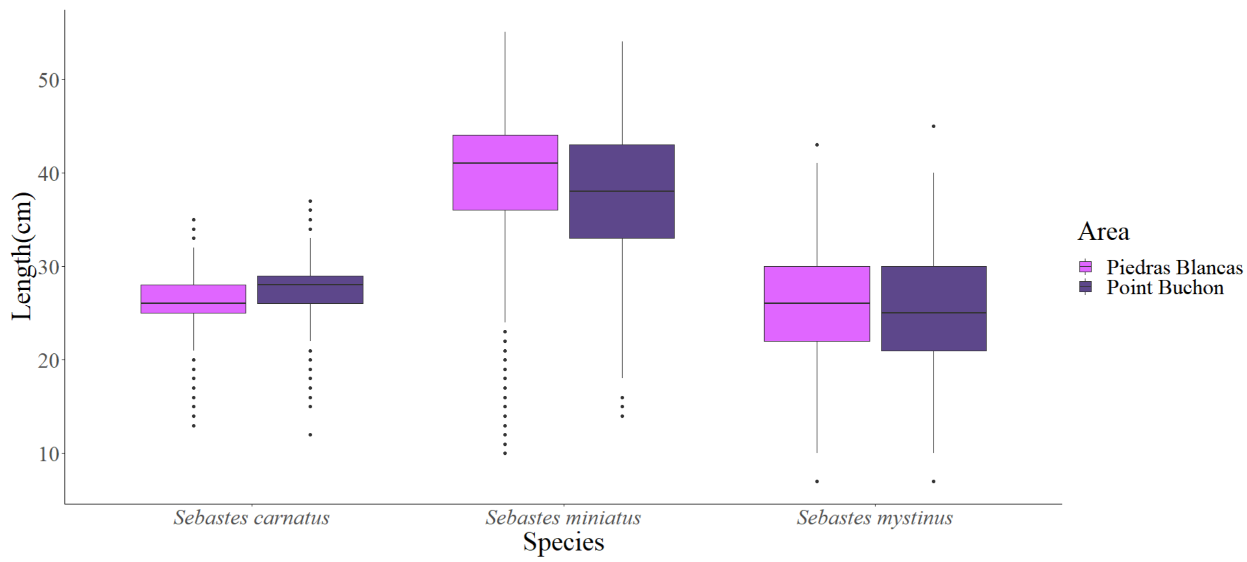

Figure 13. Box plots showing lengths of species of interest from CCFRP sampling areas. Lengths are of Gopher rockfish (*Sebastes carnatus*), Vermilion rockfish (*S. miniatus*), and Blue rockfish (*S. mystinus*) from CCFRP surveys from the Piedras Blancas and Point Buchon sampling areas. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

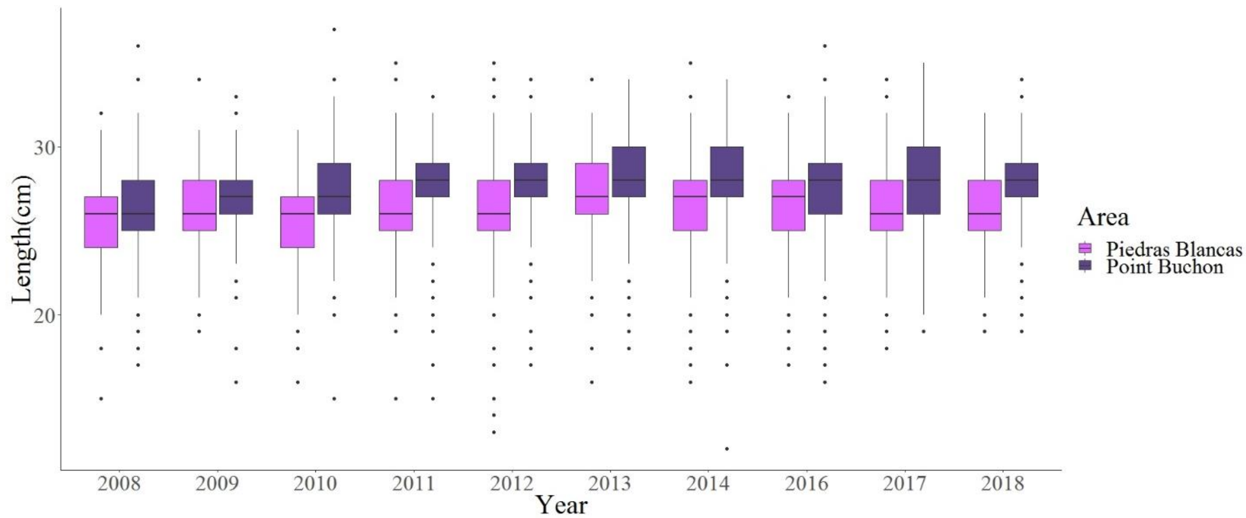

Figure 14. Time series of box plots of CCFRP Gopher rockfish (*S. carnatus*) lengths. Data are lengths of fish caught on CCFRP surveys in the Piedras Blancas and Point Buchon sampling areas. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

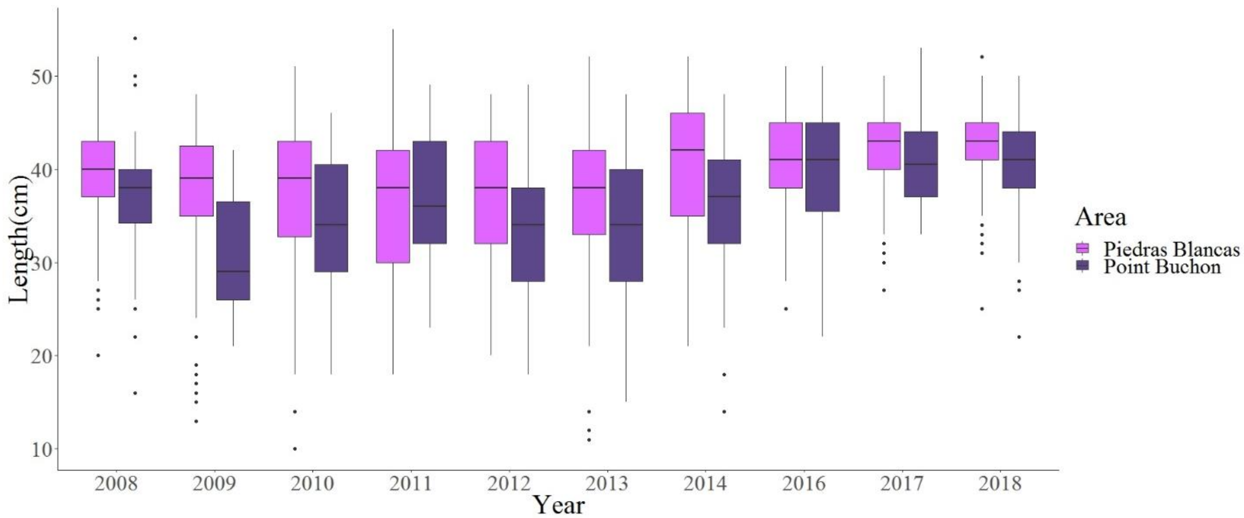

Figure 15. Time series of box plots of CCFRP Vermilion rockfish (*S. miniatus*) lengths. Lengths are of fish caught during CCFRP surveys in the Piedras Blancas and Point Buchon sampling areas. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

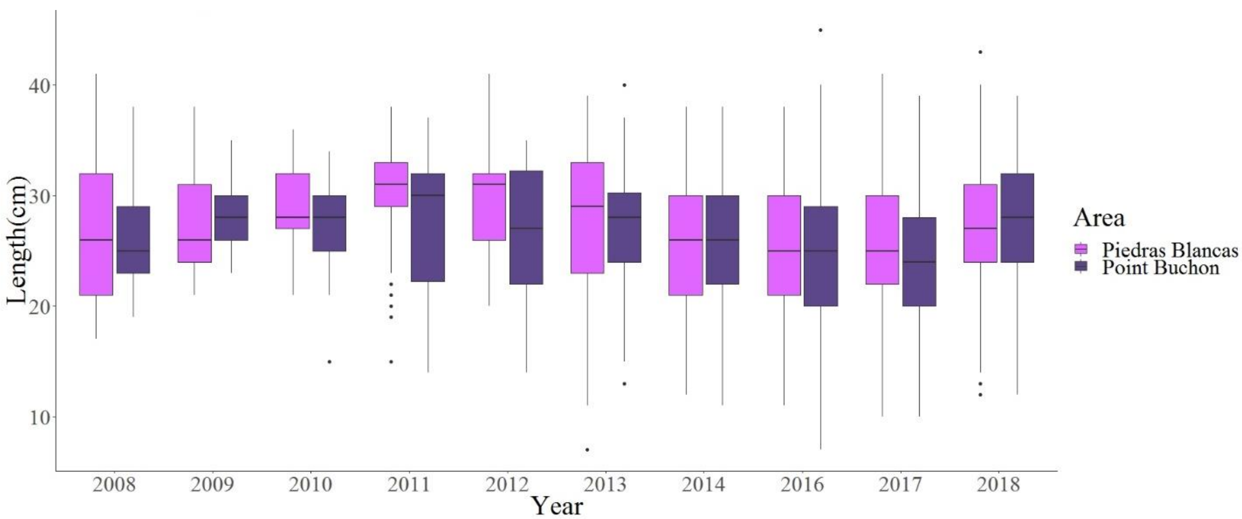

Figure 16. Time series of box plots of CCFRP Blue rockfish (*S. mystinus*) lengths. Lengths are of fish caught on CCFRP surveys in the Piedras Blancas and Point Buchon sampling areas. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

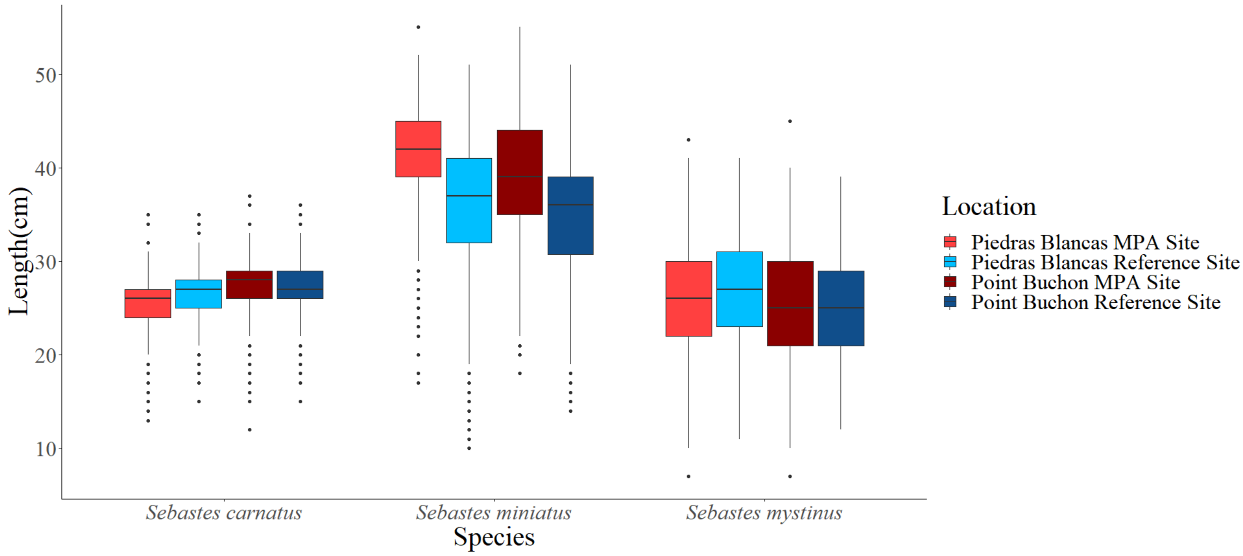

Figure 17. Box plots showing length of species of interest in protected and open areas. Lengths are of Gopher rockfish (*S. carnatus*), Vermilion rockfish (*S. miniatus*) and Blue rockfish (*S. mystinus*) from the Piedras Blancas and Point Buchon MPA and reference CCFRP sampling sites. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

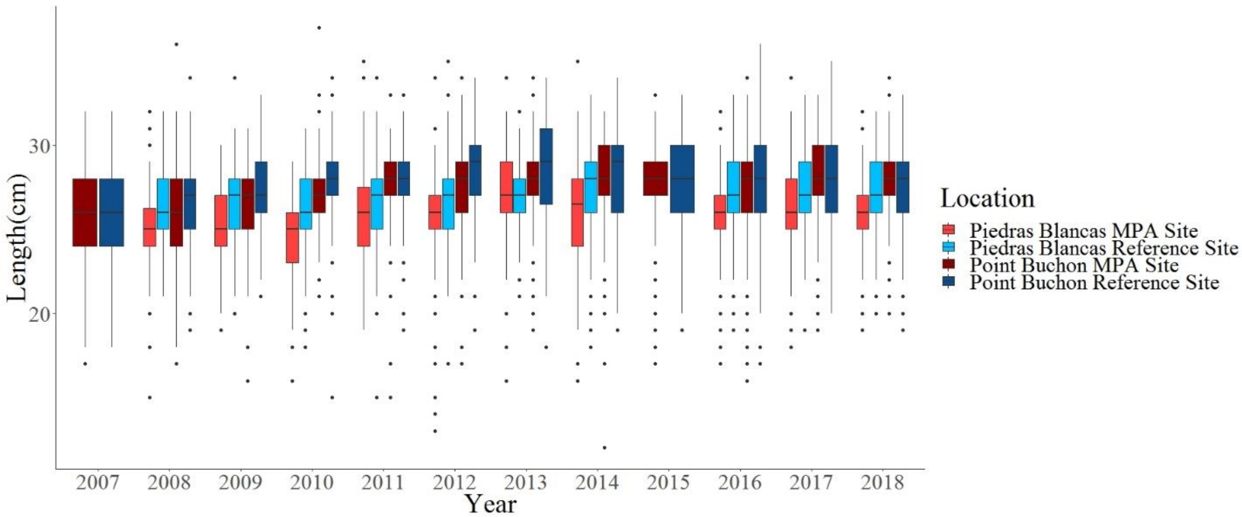

Figure 18. Time series of Gopher rockfish (*S. carnatus*) lengths from CCFRP sites. Box plots show time lengths of fish caught on CCFRP surveys in the Piedras Blancas and Point Buchon MPA and reference CCFRP sampling sites. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

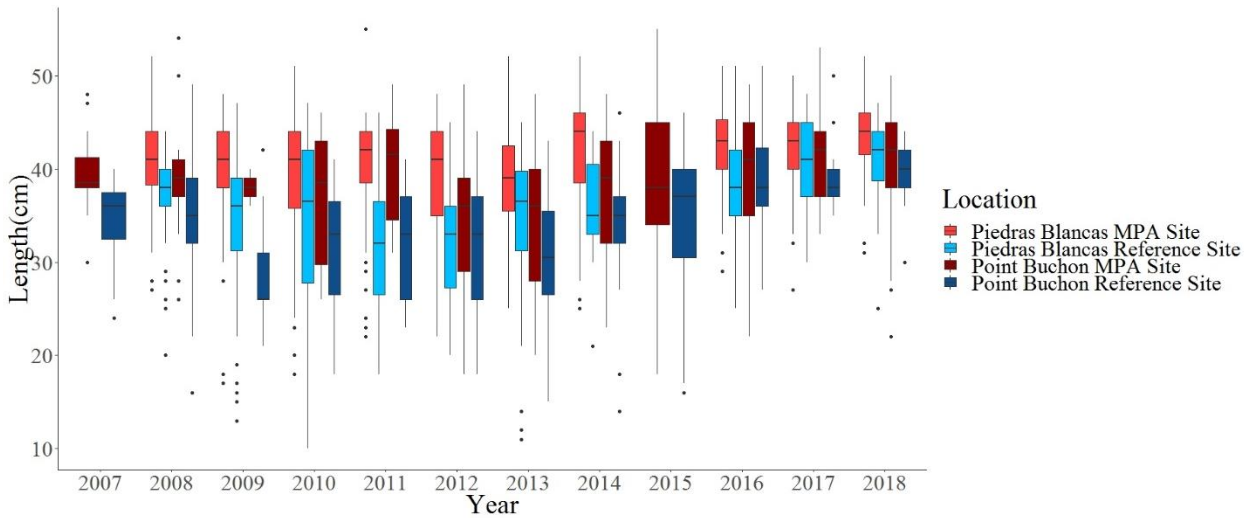

Figure 19. Time series of Vermilion rockfish (*S. miniatus*) lengths from CCFRP sites. Box plots show length of fish caught on CCFRP surveys in the Piedras Blancas and Point Buchon MPA and reference CCFRP sampling sites. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.

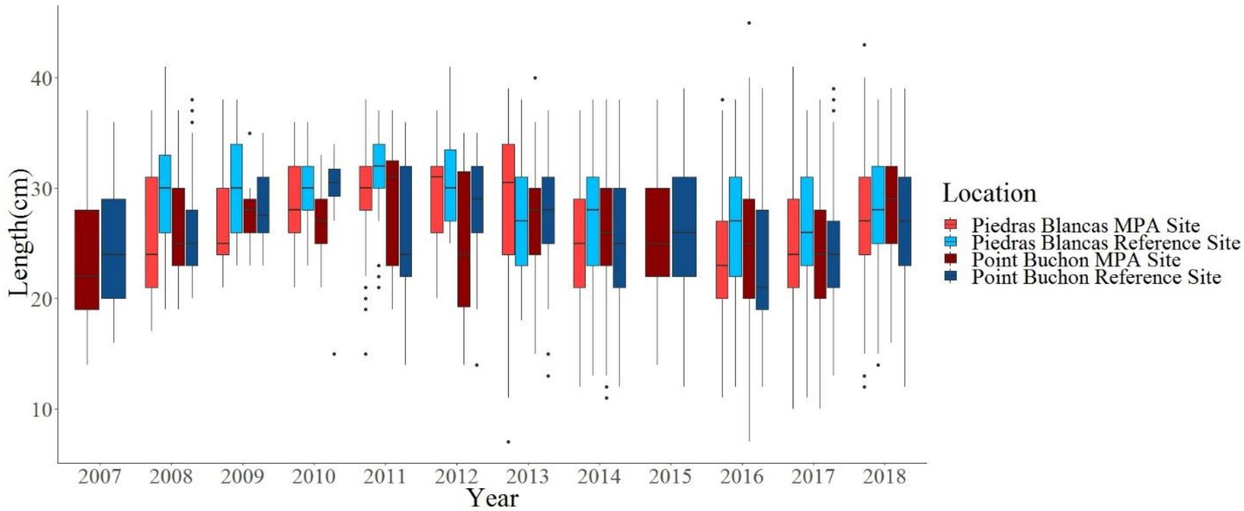

Figure 20. Time series of Blue rockfish (*S. mystinus*) lengths from CCFRP sites. Box plots show length of fish caught on CCFRP surveys in the Piedras Blancas and Point Buchon MPA and reference CCFRP sampling sites. Box shows first and third quartiles, central line shows mean, and whiskers extend to the smallest and largest values within the range of 1.5 times inter-quartile range (the difference between the first and third quartiles). Dots show outlying values.