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Article

Comparing fishery-independent and fishery-dependent data to characterize West Coast groundfish populations

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ABSTRACT

Objective: Fisheries-independent data from the California Collaborative Fisheries Research Program (CCFRP), a long-term marine protected area (MPA) and fishery monitoring study, have been incorporated as a data source into stock assessments of U.S. West Coast rockfish *Sebastes* spp. conducted in the past 5 years. We investigate the specific population information that is being gained from this fisheries-independent data source as compared to fisheries-dependent onboard observer data for three representative rockfish species.

Methods: We used length distributions and abundance indices for Blue Rockfish *S. mystinus*, Vermilion Rockfish *S. miniatus*, and Gopher Rockfish *S. carnatus* to characterize the differences in the information provided by each data source. We evaluated what new population information was being gained by using data from inside MPAs, whether an objectively designed fisheries-independent sampling method gathered different information about a population than a fisheries-dependent method, and whether the data could be applied to the population across the breadth of the species' depth distribution.

Results: We found that the information to be gained from fisheries-independent data is species dependent. Gopher Rockfish exhibited similar size structure and trends in abundance, showing high congruency between CCFRP (fisheries-independent) and Observer Program (fisheries-dependent) data. In contrast, Vermilion and Blue rockfishes demonstrated differing trends between MPAs and areas open to recreational fishing and between sampling methods, indicating that CCFRP data are introducing information about juveniles and small adults of both species in nearshore waters and large adult Vermilion Rockfish from inside MPAs.

Conclusions: Our results demonstrate that the information gained from fisheries-independent data sources and data from inside MPAs is species specific and may augment fisheries-dependent data sets. Understanding the specific information that different data sources bring to analyses for different species assists with the development of uses and best practices for data in management analyses, leading to better informed management and thus conservation of nearshore rockfish populations.

KEYWORDS: fisheries-independent data, management, marine nearshore, Pacific coast groundfish, stock assessment, survey methods

LAY SUMMARY

Fisheries managers often rely upon limited data in their analysis and decision-making processes. We compare the information available between fisheries-independent and fisheries-dependent data sources to examine what new information the different sources of data can provide. The comparisons provide managers with information about two data sources from the same region and illustrate what each source contributes to stock assessment, fisheries management, and marine protected area management.

INTRODUCTION

Long-term fisheries-independent surveys are often considered the gold standard for monitoring fish populations. Fisheries-independent surveys are typically developed with a consistent survey design and are considered less likely to be biased by factors inherent to fisheries-dependent surveys, such as angler selectivity, changing regulations, and the locations fished. However, long-term fisheries-independent survey data are

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typically less available than fisheries-dependent data (National Marine Fisheries Service, 2001), as they can be more costly and time consuming to collect. If fisheries-independent data become available, this can benefit the fishery in many ways, such as increasing the certainty associated with models generated in stock assessments (Honey et al., 2010). There is a significant amount of literature weighing the costs and benefits of fisheries-independent and fisheries-dependent surveys to fisheries stock assessments and management, with the consensus that assessment models benefit from integrating multiple sources and kinds of data (e.g., Alglave et al., 2022; Gruss et al., 2023; Rufener et al., 2021).

In California, approximately 60 species of rockfish (genus *Sebastes*) support substantial recreational and commercial fisheries (Love et al., 2002). Management decisions for this fishery are based on forecasts from stock assessments. In recent years, the number of full benchmark stock assessments for rockfish off the U.S. West Coast has increased, but many rockfish species in California remain categorized as data poor or data moderate (Cope et al., 2015; Dick & MacCall, 2010) and lack sufficient information for conducting full age-structured stock assessments (Bentley & Stokes, 2009; Honey et al., 2010). Even when sufficient data for a full benchmark stock assessment are available, the data are often sparse or lacking in spatial and temporal coverage. Increased availability of high-quality data is a key step in improving assessments of data-limited stocks (Honey et al., 2010). This includes collecting data to estimate biological parameters, such as growth, maturity, and fecundity (Pacific Fishery Management Council, 2018).

During the past decade, two data sources became available for managers and stock assessments of the rockfish complex along the California coast: a fisheries-dependent survey and, subsequently, a fisheries-independent survey. The fisheries-independent survey is the California Collaborative Fisheries Research Program (CCFRP). The CCFRP was established in 2007 to monitor the response of groundfish populations to the establishment of California's Marine Protected Area (MPA) network (Starr et al., 2015; Wendt & Starr, 2009; Yochum et al., 2011; Ziegler et al., 2023). The CCFRP is a collaborative hook-and-line survey program that partners with recreational charter boats, volunteer anglers, and project researchers to collect fisheries data both inside and adjacent to the MPAs, where fishing still occurs. It is currently the only hook-and-line survey for rockfish that samples inside of California's MPAs along the entire coast. The CCFRP sampling design was developed collaboratively with academic scientists, National Marine Fisheries Service (NMFS) fishery scientists, resource managers from the California Department of Fish and Wildlife, and members of the commercial and recreational fishing communities. One of the guiding intents of this approach was to ensure that NMFS scientists could utilize the data for stock assessments (Wendt & Starr, 2009). These data were first used in the 2015 stock assessment of China Rockfish *S. nebulosus* (Dick et al., 2016). They have since been incorporated into at least 10 other stock assessment models (e.g., Dick et al., 2023; Monk et al., 2021, 2024; Wetzel et al., 2023).

The recreational fisheries-dependent data are from onboard observer surveys of recreational hook-and-line charter boat trips, commonly known as party boats or charter boats (Monk & He 2019; Monk et al., 2014, 2016). These kinds of surveys have been operated by state agencies for many decades, but the specific onboard observer program (hereafter, referred to as the "Observer Program") referenced herein is operated by California Polytechnic State University, San Luis Obispo (Cal Poly), one of the same institutions that has been conducting the CCFRP since its inception in 2007. Data from the Observer Program are now commonly used to develop an index of relative abundance for rockfish assessments in California and Oregon. However, they have limitations typical to fisheries-dependent data: Fishing locations are not randomized, trips are of variable lengths and occur only when the fishery is open, fishing gear is unstandardized, and charter boat captains may target or avoid specific locations and species depending on regulations or angler preference.

Although the limitations of fisheries-dependent data are generally well understood, the limitations and benefits of CCFRP data have not been explored as extensively. The constraints and advantages of these data stem from the CCFRP's inception as an MPA monitoring program. The CCFRP only samples a subset of the depths and areas that are inhabited by West Coast rockfish species. Depth is an important component of rockfish habitat: Some species are found at specific depths, and some undergo ontogenetic shifts, inhabiting different depth strata as they age (Love et al., 2002). The CCFRP may not sample a truly representative portion of the population for species that occupy areas deeper than the CCFRP samples. Additionally, the CCFRP only samples MPAs and adjacent reference areas. California's statewide network of 124 MPAs covers approximately 16% of coastal waters. Even between MPAs and associated reference sites, the CCFRP's spatial coverage will likely include a small fraction of most rockfish populations. Conversely, the CCFRP is able to survey the portion of the rockfish metapopulation that was closed to fishing, thereby excluding fisheries-dependent sampling, when California's MPAs were established. Furthermore, California's MPAs were designed to protect key habitats, including rocky reef habitat, the preferred habitat of many rockfish (California Department of Fish and Wildlife, 2016; Love et al., 2002). Due to the lack of sampling by other sources and the likely presence of preferred rockfish habitat in MPAs, we assume that data from inside of MPAs will add valuable information to our understanding of any given population as a whole. We are interested in what that information is and how it relates to historically available onboard observer data in the context of CCFRP depth and spatial sampling limitations.

We characterized and compared fisheries-independent CCFRP data and fisheries-dependent onboard observer data. The CCFRP's sampling design closely resembles California's onboard observer programs in methodology (Stephens et al., 2006). Both are hook-and-line surveys conducted aboard charter boats, with spatial overlap on the central coast of California. This similarity allowed us to compare a fisheries-independent data set (CCFRP) and a fisheries-dependent data set (Observer Program) that incorporate similar sampling gear and have substantial spatiotemporal overlap. These data provide a unique opportunity to examine the ways in which the CCFRP data may introduce specific information into assessments of rockfish populations that is absent or insufficient from onboard observer data or the ways in which the CCFRP data may be insufficient compared to fisheries-dependent data.

Our evaluation of the CCFRP data and the Observer Program data was structured around three questions: (1) “What new information do we gain from sampling MPAs?”; (2) “What, if any, new information do we gain by using a standardized, fisheries-independent sampling method?”; and (3) “Do the fisheries-independent data represent the breadth of the population as a whole?” To answer these questions, we conducted a series of comparisons between length distributions and indices of abundance taken from fisheries-independent data and fisheries-dependent data for three rockfish species. Our analyses will provide an understanding of the limitations of and value to be gained from different sources of data and how those sources may work in concert to augment our understanding of a population.

METHODS

Study species

We chose three species for this study: Gopher Rockfish *S. carnatus*, Vermilion Rockfish *S. miniatus*, and Blue Rockfish *S. mystinus*. These species were chosen due to high encounter rates in both projects, differing life histories, and varying degrees of desirability within the recreational hook-and-line fishery (Love et al., 2002). None of these species has a minimum size limit in the fishery, but for the purposes of this project we considered an individual to be a sexually mature adult at a length of 10 cm. All three species are long-lived and slow growing (Love et al., 2002). Vermilion Rockfish are one of the most desirable species to catch recreationally due to their bright coloration and large size (R. Kosaka, NMFS, Southwest Fisheries Science Center, unpublished data). Gopher and Blue rockfishes are both encountered extremely frequently in the central California coast recreational fishery (Dick et al., 2017; Monk & He, 2019) but are less desirable to anglers and therefore less likely to be specifically targeted. For more details on study species life history, see Supplement 1 (see online Supplementary Material).

Field methods

To maximize similarity between the data sources under comparison, we chose to use data from Cal Poly, which hosts the Observer Program. Data from this program have been incorporated into several rockfish stock assessments as an index of relative abundance with associated lengths and as a source of age composition data (Dick et al., 2016; He & Field, 2018; He et al., 2015; Monk & He, 2019; Monk et al., 2021). Cal Poly also conducts annual CCFRP sampling at two of the project’s sites on California’s central coast. These two projects operate from the same suite of charter boats and overlap spatially off the central coast of California.

The CCFRP

All CCFRP sampling was conducted in accordance with standardized methodology as detailed by Wendt and Starr (2009). Our study utilized data from the two MPAs sampled by the CCFRP operating out of Cal Poly—the Piedras Blancas and Point Buchon State Marine Reserves—from 2007 to 2018 (Figure 1). Sampling occurred at locations inside the two MPAs, which prohibit commercial or recreational take of all marine resources (California Department of Fish and Wildlife, 2016), and at reference locations in adjacent areas that contain similar habitat and are open to take. Each MPA and associated reference area was sampled 3–4 d each year, with each sampling day consisting of 12 separate 15-min periods of hook-and-line fishing divided among four randomly chosen cells. Fishing locations within the cells were chosen by the captains of charter boats hired for the project. The CCFRP maintained a depth limit of 36 m within these sites to reduce barotrauma for all caught-and-released fish (Hannah & Matteson, 2007). All fish were measured to the nearest centimeter fork length and then released; for more details, see Wendt and Starr (2009) and Yochum et al. (2011). Most data were collected between July and September, although the sampling season occasionally extended to October. The Point Buchon sites were sampled during 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, the sampling frequency was equal to that of the Point Buchon sites.

The Cal Poly Observer Program

The Observer Program data were gathered following the methods outlined by Stephens et al. (2006). Starting in 2003, onboard observers accompanied charter boats approximately once per week throughout the rockfish season (April–December) each year and collected length and species data for all fish caught by a subset of approximately 4–10 anglers during a fishing “drop” (the period in which lines were in the water). Anglers were limited to two hooks and a single line. Charter boat captains determined the trip lengths and fishing locations. Vessels departed from either Morro Bay or Port San Luis, and fishing locations ranged across the coast of San Luis Obispo County and northern Santa Barbara County. We used data from the 2003–2018 seasons to develop indices of relative abundance for the Observer Program. For length distributions, where we drew direct two-way comparisons with the CCFRP, we used data from only the 2007–2018 sampling seasons to match the time frame of the CCFRP. We removed Observer Program data with drift start locations deeper than 73 m for consistency; maximum depth cutoffs for recreational groundfish fishing have changed several times since they were first enacted in 2002, and 73 m (equal to 40 fathoms) is the shallowest depth limit used during the period of data collection (Central Groundfish Management Area, 2024; Figure 1).

Analytical methods

Length distribution comparisons, CPUE models, and index of abundance calculations were conducted in R version 3.4.0 (R Core Team, 2017; Venables & Ripley, 2002). Analyses of variance, Tukey honestly significant difference (HSD) post hoc analyses of length, and creation of figures were conducted in R version 4.2.3 (R Core Team, 2022; Wickham, 2016; Wickham et al., 2019).

To answer the first of our three questions (i.e., regarding what new information we gain from data collected inside of MPAs), we compared data from the CCFRP open areas (i.e., reference sites) to the CCFRP data from closed areas (i.e., MPAs), which allowed us to examine the effects of protection without having

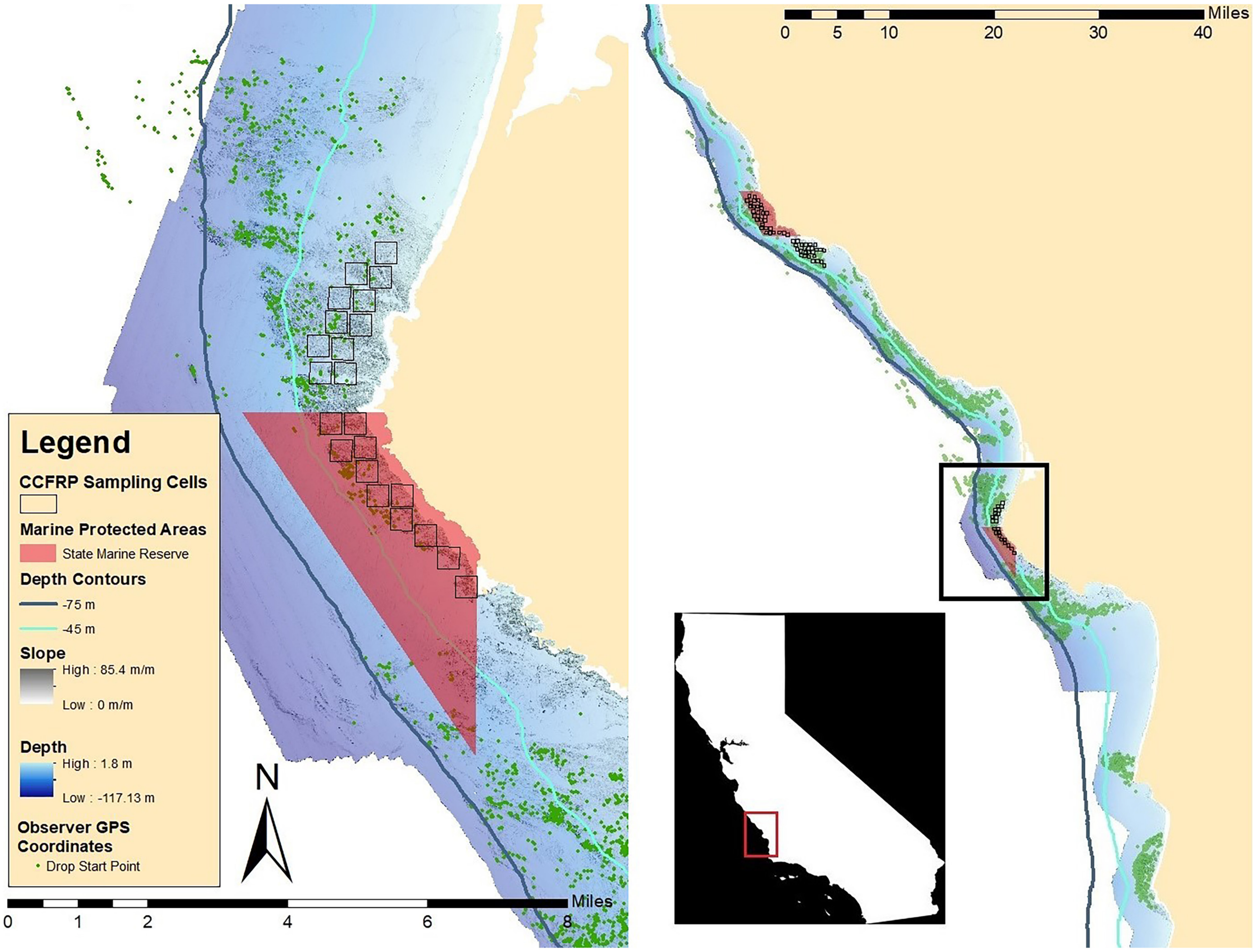

Figure 1. Maps of the study areas, indicating the portion of the California Collaborative Fisheries Research Program (CCFRP) conducted by California Polytechnic State University, San Luis Obispo (Cal Poly), and the Observer Program conducted by Cal Poly. The right panel shows the full extent of the study areas, the left panel shows the Point Buchon area only to demonstrate fine-scale detail, and the inset map of California shows the entire extent of the study area outlined. The Piedras Blancas (northern) and Point Buchon (southern) State Marine Reserves are shaded. Boxes are 500- × 500-m CCFRP sampling cells. Points show the starting points for Observer Program surveys between 2003 and 2018. Contour lines show the cutoffs for shallow and deep Observer Program data used in this study. The dark contour represents 73 m, and the light contour represents 46 m. Bathymetric depth and slope layers are included to demonstrate habitat.

to account for methodology differences. To answer question 2 (i.e., whether we are gaining new information and what new information we are gaining from a standardized method), we compared "shallow" Observer Program data with CCFRP data from areas open to fishing (CCFRP reference sites). Shallow Observer Program data were defined as any surveys starting in a depth of 46 m or less. We used a cutoff of 46 m such that the depth range of the shallow data would be comparable to that of the CCFRP but also to maintain similar sample sizes between Observer Program data designated as "deep" and those designated as "shallow." Comparing shallow Observer Program data to CCFRP reference site data allowed us to examine differences in data from a standardized and nonstandardized methodology in areas that overlap spatially and in depth and where recreational fishing is occurring. To answer question 3 (i.e., whether the fisheries-independent data represent the breadth of the population as a whole), we compared shallow and deep Observer Program data to examine differences inside and outside of the CCFRP's 36-m depth restriction within a single survey methodology. Deep Observer Program data were defined as surveys starting at a depth between 46 m and our maximum of 73 m (Figure 1).

Length distribution comparisons

Length data were filtered by minimum and maximum sizes for each species to remove outliers and restrict our samples to individuals that have recruited to the nearshore environment. A minimum size of 10 cm was used for all species, as most species of rockfish at that size are no longer considered to be pelagic juveniles but are considered recruited to the nearshore environment (Love et al., 2002). The maximum length differed by species based on the literature-reported maximum size of adults of each species. We used maximum lengths of 53 cm for Blue Rockfish, 39.6 cm for Gopher Rockfish, and 76 cm for Vermilion Rockfish (Butler et al., 2012). Analyses of variance and Tukey HSD post hoc analyses were used to compare mean lengths between data types within a single species using data combined from all years. An α value of 0.05 was used to establish significance for mean length comparisons. Two-way Kolmogorov–Smirnov tests were used to compare differences in length distributions between open and protected area CCFRP data, between shallow Observer Program data and open area CCFRP data, and between shallow and deep Observer Program data as defined above. Length distribution comparisons were conducted on the data for each species combined across all years and for individual years between 2007 and 2018 to present a time series of differences. In total, 39 two-way comparisons of length distribution were made for each species. Bonferroni corrections were used to correct for multiple comparisons of the length distribution data, resulting in an α value of 0.001 used to establish significance in the Kolmogorov–Smirnov test results.

Catch per unit effort modeling and indices of abundance

We constructed models of CPUE (number of fish per angler-hour) at the level of a "drop." A drop was defined as an uninterrupted period of fishing within a sampling day, and a single drop represented a single sample. Under the CCFRP sampling protocol, there were typically 12 drops per sampling day, with each drop lasting 15 min. The number of drops per trip was higher for the Observer Program, in which there could be 20 or more drops in a day, ranging from 5 min to over 1 h. Each drop record included counts of each species encountered as well as all metadata associated with that drop, including latitude/longitude, depth, start time, and end time. If an angler took a brief break from fishing, that was not factored into time fished for calculating CPUE. If an angler completely stopped fishing, a new "drop" data sheet was begun with the new reduced number of anglers. Data were collapsed such that individual fish caught were not tracked to specific anglers.

Prior to modeling, data were filtered to remove drops with missing or obviously erroneous information and to account for outliers. For Observer Program data, we filtered out any drops with missing information; with absent, low-resolution, or clearly incorrect GPS data; for which bottom type characteristics could not be assigned; that occurred deeper than 73 m; and that took place outside of the typical CCFRP sampling period (June–September). We also removed the top and bottom 1% of observed fishers and minutes fished to account for outliers. For the CCFRP data, we filtered out any drops that did not comply with the CCFRP protocol, that took place in sampling cells that were not consistently sampled over the project, or that had obviously incorrect or missing GPS data. See Supplement 2 for specifics on data filtering.

The CPUE at the drop level was modeled using generalized linear models (GLMs) via a delta-GLM approach (Lo et al., 1992), which is typically used to model relative abundance for species with high proportions of zeros in data. The delta-GLM is composed of either a lognormal or gamma model for the positive values and a binomial model for presence/absence (Lo et al., 1992; Stefánsson, 1996 ; E. J. Dick, National Marine Fisheries Service, Southwest Fisheries Science Center, personal communication).

We constructed a total of 12 models, one for each species (Gopher, Blue, and Vermilion rockfish) from each type of data used to draw our comparisons (protected area CCFRP, open area CCFRP, shallow Observer Program, and deep Observer Program data). Certain years were filtered from the model for few positive samples; this included filtering 2003 from all deep Observer Program data for all species. Previous habitat suitability models of eastern Pacific rockfish found that depth, substrate type, and topographic complexity were strong predictors of preferred rockfish habitat (Pirtle et al., 2017; Marliave & Challenger, 2009; Matthews, 1990a, 1990b; Young & Carr, 2015). We included two bottom type characteristics—rugosity and percent hard bottom cover—as covariates in our models to account for potential environmental effects (see Supplement 3). Rugosity was represented as the vector ruggedness measure, which is a unitless calculated metric that varies from 0 (indicating no terrain variation) to 1 (indicating complete terrain variation; Hobson, 1972; Sappington et al., 2007).

For the CCFRP, variables tested included area of collection (Point Buchon or Piedras Blancas), depth (as a categorical covariate using 5-m depth bins), and the bottom type variables of rugosity (three 0.005 bins labeled low, medium, and high) and percent hard bottom cover (three 33% bins labeled low, medium, and high). See Supplement 3 for a complete explanation of spatial variables. For Observer Program models, variables tested included the reef where a given fish was caught (reef), depth (5-m bins for delta-GLMs), and the bottom type variables of 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- × 2-m resolution raster using a 40-m radius buffer around the starting point. Bottom type variables were calculated from a 2- × 2-m resolution raster using a 500- × 500-m square. Because the CCFRP already samples within set 500- × 500-m cells, we drew a grid of 500- × 500-m squares over the study area sampled by the Observer Program and assigned each Observer Program drop a "cell" based on its location in the grid to mimic the CCFRP protocol such that locational variables would be assigned on a similar scale. Bin sizes were based on average variability of the given bottom type factor within cells. For full descriptions of how these characteristics were calculated, see Supplement 3. Any factor levels for which there were two or fewer positive records were removed from the delta-GLM model. The best model was selected based on the Bayesian information criterion (Brewer et al., 2016). Best fit models can be found in Table 1. The full Bayesian information criterion selection process for all models and species is described in Supplement 4.

Time series of the index of relative abundance were estimated from the models of CPUE. To construct the indices of relative abundance, we extracted the year effects from the final best fit models for each species and data type. We created an index of annual relative abundance from each of our 12 models. For visual comparison of indices, we scaled each index to the mean value across years. The 25% and 95% CIs were also scaled to the mean of the index to put them on the appropriate scale.

RESULTS

After filtering, the Observer Program data set used for CPUE modeling included 3,438 sample drops consisting of 1,864 shallow drops and 1,574 deep drops. The CCFRP data set used for

Table 1. Best fit models (selected based on the Bayesian information criterion) for Gopher, Vermilion, and Blue Rockfish catch or CPUE modeling for all data sources. For a full list of models tested and associated Bayesian information criterion scores used to select these models, please see Supplement 4. Abbreviations: CCFRP = California Collaborative Fisheries Research Program; VRM = vector ruggedness measure.

Data source	Species	Model
CCFRP protected areas	Gopher Rockfish	Year + Area + Cell % hard bottom cover group
	Vermilion Rockfish	Year + Cell VRM class
	Blue Rockfish	Year
CCFRP open areas	Gopher Rockfish	Year + Area + Depth + Cell % hard bottom cover group
	Vermilion Rockfish	Year + Area + Depth
	Blue Rockfish	Year + Area + Cell % hard bottom cover group
Observer Program shallow	Gopher Rockfish	Year + Reef + Depth + Cell % hard bottom cover group
	Vermilion Rockfish	Year + Depth + Cell % hard bottom cover group
	Blue Rockfish	Year + Cell % hard bottom cover group
Observer Program deep	Gopher Rockfish	Year + Depth + Cell % hard bottom cover group
	Vermilion Rockfish	Year + Cell % hard bottom cover group
	Blue Rockfish	Year + Cell % hard bottom cover group

Table 2. Significance values of pairwise Kolmogorov–Smirnov tests of length distribution for Gopher, Vermilion, and Blue rockfish (1) between California Collaborative Fisheries Research Program (CCFRP) data from open and protected areas, (2) between CCFRP open areas and Observer Program shallow data, and (3) between Observer Program shallow and deep data. Significant differences are marked with the letter *z*. A *P*-value of 0.001 was used to establish significance.

Question	Gopher Rockfish	Vermilion Rockfish	Blue Rockfish
1. CCFRP protected areas vs. open areas	2.049×10^{-6} z	2.220×10^{-16} z	2.200×10^{-16} z
2. CCFRP open areas vs. Observer Program shallow	0.0191	4.384×10^{-5} z	2.200×10^{-16} z
3. Observer Program shallow vs. deep	0.0049	0.0574	0.0021

CPUE modeling included 1,939 drops, with 984 drops from MPAs and 955 drops from reference areas open to fishing. See Supplement 2 for more details.

Question 1: What new information do we gain from data gathered inside MPAs? Comparing data from MPAs to data from areas open to recreational fishing within the CCFRP methodology

Gopher Rockfish exhibited differences in length distribution between CCFRP open areas and MPAs, both overall and during the individual years 2008, 2009, 2010, and 2014 (Tables 2, 3). The length distribution from the MPAs was shifted toward smaller fish both overall and in those years, although the material difference in size of individuals encountered was small (Figure 2; Table 4). The average length of Gopher Rockfish in samples from open areas and protected areas was significantly different (Tukey HSD: $P = 0.000$, 95% CI = −0.4313, −0.1779), but the size of the difference was less than 0.5 cm (Table 4). The factors in the best fit CPUE models used to calculate the indices of abundance for CCFRP protected and open areas both included year, area of collection, and percent hard bottom, and the model for the open areas also included depth (Table 1).

Vermilion Rockfish had significantly different mean length and length distributions between open and protected areas overall, and the length distribution also differed in each of the 6 years tested (Tukey HSD: $P = 0.000$, 95% CI = 4.363, 6.051; Figure 2; Tables 2, 3). The protected areas showed a distribution that was shifted toward larger fish (Figure 2). The average length of Vermilion Rockfish from open areas sampled by the CCFRP was 35.1 cm and the average length of Vermilion Rockfish from protected areas was 40.3 cm, representing the largest difference between two means for any groups that we compared (Table 4). The model for CPUE for open area CCFRP data included year, area, and depth, while the protected area CCFRP model included year and cell rugosity (Table 1). The protected area scaled index of abundance for Vermilion Rockfish showed a steady rate of increase between 2007 and 2018, but the open area index of abundance showed no overall decrease or increase between 2007 and 2018 (Figure 3).

Blue Rockfish showed significant differences in overall mean length and length distribution between the protected areas and open areas sampled by the CCFRP as well as in three of the annual length distribution comparisons (Tukey HSD: $P = 0.000$, 95% CI = −1.094, −0.7165; Figure 2; Tables 2, 3). Both distributions showed that most individuals were between 20 and 35 cm, but the distribution for the protected areas was shifted toward smaller fish (Figure 2); however, the mean lengths of fish from open areas and protected areas were similar (Table 4). The best fit CPUE model for open area CCFRP data included year, area, and cell percent hard bottom group, while the best model for protected areas included just year (Table 1). Visually, the indices of abundance for the protected and open areas showed parallel trends across the entire span of the project, although the protected area index reached relatively high levels in 2017 and 2018 (Figure 3). The average nominal CPUE of Blue Rockfish CCFRP samples from protected areas was by far the highest of any data type and reached a peak in 2017 (Figure 4).

Table 3. Significance values of year-by-year pairwise Kolmogorov–Smirnov tests of length distribution for Gopher, Vermilion, and Blue rockfish (1) between California Collaborative Fisheries Research Program (CCFRP) data from open and protected areas, (2) between CCFRP open areas and Observer Program shallow data, and (3) between Observer Program shallow and deep data. Significant differences are marked with the letter *z*. A *P*-value of 0.001 was used to establish significance.

Question	Year	Gopher Rockfish	Vermilion Rockfish	Blue Rockfish
1. CCFRP protected areas vs. open areas	2007	0.7247	0.0068	0.0497
	2008	5.865×10^{-11} z	1.873×10^{-5} z	5.982×10^{-4} z
	2009	2.844×10^{-5} z	2.955×10^{-8} z	0.0155
	2010	3.873×10^{-4} z	0.0238	0.1298
	2011	0.7249	3.568×10^{-10} z	0.0478
	2012	0.1252	5.917×10^{-5} z	0.8367
	2013	0.1385	0.5629	0.1186
	2014	7.625×10^{-4} z	4.036×10^{-8} z	0.0025
	2015	0.1357	0.1257	0.4804
	2016	0.0018	4.892×10^{-7} z	2.887×10^{-15} z
	2017	0.2968	0.0059	5.218×10^{-15} z
	2018	0.4689	0.0062	0.0416
2. CCFRP open areas vs. Observer Program shallow	2007	0.04566	0.1016	1.433×10^{-7} z
	2008	0.0213	0.4787	0.0426
	2009	0.0065	4.530×10^{-8} z	7.160×10^{-4} z
	2010	0.0354	0.0003 z	0.4172
	2011	0.7454	0.2497	0.0293
	2012	0.1698	0.1648	0.9596
	2013	0.0599	0.4235	0.0378
	2014	0.9163	0.0362	2.839×10^{-5} z
	2015	0.9821	0.1109	0.0012
	2016	0.9830	0.0160	1.788×10^{-8} z
	2017	0.7098	0.5874	0.1528
	2018	0.9027	0.9899	8.870×10^{-4} z
3. Observer Program shallow vs. deep	2007	0.6876	0.2259	0.0025
	2008	0.7241	0.9006	0.0249
	2009	0.4870	0.0008 z	0.0157
	2010	0.1016	2.581×10^{-6} z	0.1557
	2011	0.6374	8.407×10^{-5} z	0.2287
	2012	0.9843	0.2463	0.0467
	2013	0.2354	0.0612	0.0931
	2014	0.8419	0.0063	0.0014
	2015	0.5280	0.8569	0.3976
	2016	0.8518	0.8266	1.692×10^{-13} z
	2017	0.8631	0.3389	0.0059
	2018	0.4518	0.9999	0.0039

Question 2: What, if any, new information are we gaining by using a standardized, fisheries-independent sampling method? Comparing data from a fisheries-independent project (CCFRP) to a fisheries-dependent project (Observer Program) where the projects overlap spatially and recreational fishing is occurring

Gopher Rockfish showed no significant differences in length distribution between the CCFRP open area samples and the shallow Observer Program samples in any individual year or overall (Figure 5; Tables 2, 3). The average length of Gopher Rockfish in both shallow Observer Program samples and in CCFRP open area samples was the same (Tukey HSD: $P = 0.9933$, 95% CI $= -0.152$, 0.1233; Table 4). The factors in the best fit CPUE models used to calculate the indices of abundance for shallow Observer Program and open area CCFRP data were the same; both included year, area of collection (reef in the Observer Program and area in the CCFRP), depth bin, and percent hard bottom (Table 1). The scaled indices showed similar patterns of decreasing relative abundance starting in 2007 until a minimum was reached in 2013, with an increasing trend observed for the remainder of the time series (Figure 6).

Vermilion Rockfish showed significant differences in length distribution between shallow Observer Program samples and open area CCFRP samples both overall and in 2009 and 2010 (Tables 3, 4). Although the differences in distribution were statistically significant, the actual size differences were not large (Table 4). The mean length of Vermilion Rockfish over all years did not differ significantly between shallow Observer Program samples and CCFRP open area samples (Tukey HSD: $P = 0.4271$, 95% CI $= -0.3393$, 1.318; Figure 5). The difference in mean lengths between the two data sets across all years was 0.5 cm, with larger fish occurring in the open area CCFRP samples (Table 4). In 2009 and 2010, the shallow Observer Program samples showed a distribution shifted toward smaller fish than the open area CCFRP distribution (Figure 5). The models used to construct the indices of abundance for Vermilion Rockfish in shallow Observer Program and open area CCFRP data both

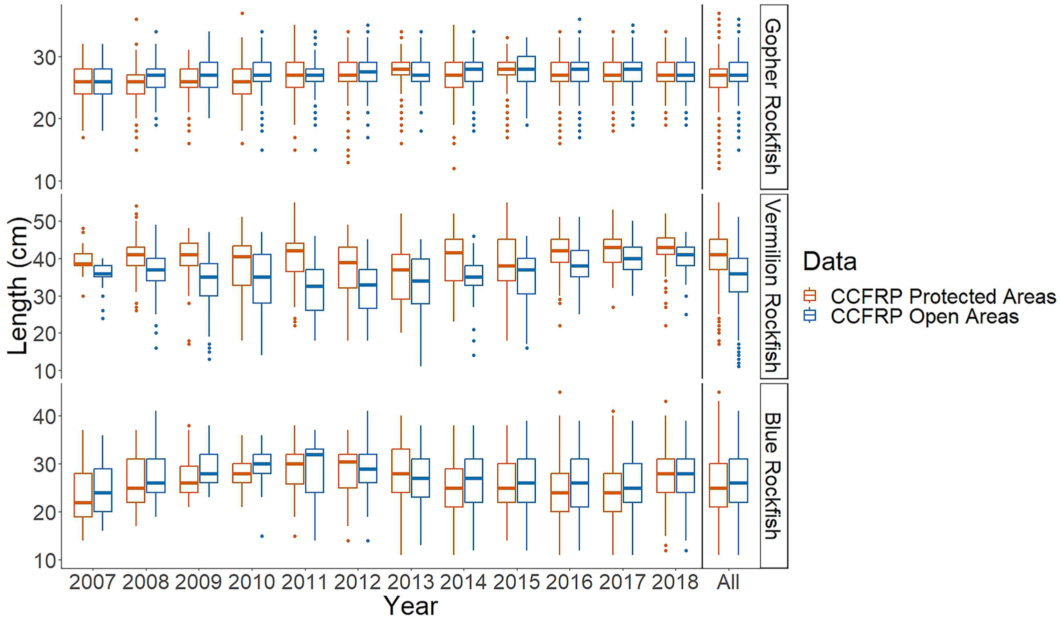

Figure 2. Box-and-whisker plots showing the fork lengths (cm) of study species from California Collaborative Fisheries Research Program (CCFRP) data collected in open and protected areas for each year between 2007 and 2018 and for data combined across all years (far right). The central line shows the median length, the box shows upper and lower quartiles, the whiskers represent the range, and dots indicate outliers. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

Table 4. Mean fork lengths (cm) and SDs of rockfish. Abbreviation: CCFRP = California Collaborative Fisheries Research Program. *N* refers to the number of fish. Averages are calculated based on data combined across all years (2003–2018 for the Observer Program; 2007–2018 for the CCFRP).

Data source	Species	*N*	Mean length (cm)	SD
CCFRP protected areas	Gopher Rockfish	4,609	26.7	2.59
	Vermilion Rockfish	667	40.3	6.01
	Blue Rockfish	16,648	25.6	5.32
CCFRP open areas	Gopher Rockfish	2,873	27	2.58
	Vermilion Rockfish	4,247	35.1	7.19
	Blue Rockfish	1,387	26.5	5.27
Observer Program shallow	Gopher Rockfish	2,279	27	2.36
	Vermilion Rockfish	2,274	34.6	6.92
	Blue Rockfish	6,754	27.7	5.27
Observer Program deep	Gopher Rockfish	645	26.7	2.45
	Vermilion Rockfish	1,563	34.5	7.47
	Blue Rockfish	7,454	28.3	5.08

included year and depth, but the Observer Program model also included cell percent hard bottom cover, while the open area CCFRP model included area (Table 1). The scaled indices of abundance calculated from the shallow Observer Program data and the open area CCFRP data showed inverse increases and decreases between 2007 and 2010 and then parallel trends of increase and decrease between 2010 and 2018 (Figure 6). Neither the index from shallow Observer Program data nor the index from the open area CCFRP data showed an overall trend of increase or decrease across the time span of either project.

Blue Rockfish had a significant difference in mean length overall between shallow Observer Program data and open area CCFRP data (Tukey HSD: $P = 0.000$, 95% CI $= -1.515$, -0.8654; Figure 5). Length distributions of Blue Rockfish from these two groups were significantly different both overall and in five of the years tested: 2007, 2009, 2014, 2016, and 2018 (Tables 2, 3). In the overall comparison, both distributions showed mostly individuals between 20 and 35 cm, but the open area CCFRP distribution was shifted toward slightly smaller fish (Figure 5). The mean length of Blue Rockfish was similar between shallow Observer Program and open area CCFRP samples (Table 4). In individual years, the distribution for open area CCFRP data showed a higher proportion of smaller fish than the distribution for the shallow Observer Program data, except in 2009, for which the reverse was observed (Figure 5). The best fit CPUE model for both data sources included year and cell percent hard bottom cover, and the open area CCFRP model also included area (Table 1). The scaled indices of abundance showed a similar overall decline between 2007 and 2012, followed by a parallel overall increase between 2012 and 2018 (Figure 6).

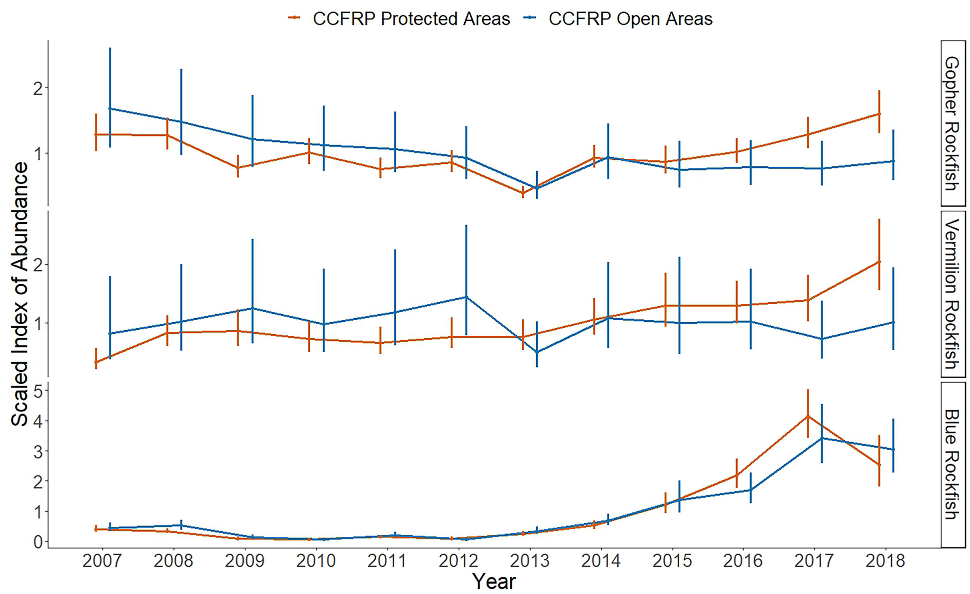

Figure 3. Scaled indices of abundance of Gopher, Vermilion, and Blue rockfish calculated from California Collaborative Fisheries Research Program (CCFRP) data collected in open and protected areas between 2007 and 2018. Error bars show the 25% and 95% CIs. Index values and CIs were scaled to the mean of the index. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

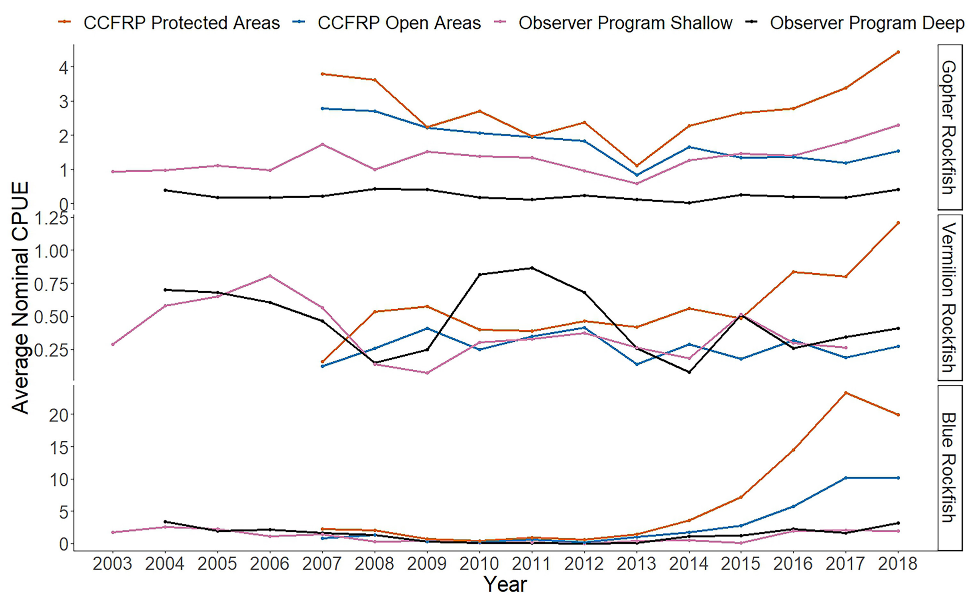

Figure 4. Average CPUE of Gopher, Vermilion, and Blue rockfish from California Collaborative Fisheries Research Program (CCFRP) data between 2007 and 2018 and from Observer Program data between 2003 and 2018. The CCFRP data were collected in open and protected areas, and Observer Program data were collected in shallow and deep areas. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

Question 3: Do the fisheries-independent data represent the breadth of the population as a whole? Comparing data from shallow and deep areas within the Observer Program methodology

Gopher Rockfish were present in 70.217% of samples from shallow areas, while this species was encountered in only 24.92% of samples from areas deeper than 46 m (Table 5). There were no differences in the length distributions between shallow and deep Observer Program data (Tables 2, 3). The mean lengths of Gopher Rockfish from deep and shallow Observer Program samples did differ significantly (Tukey HSD: $P=0.0014$, 95% CI $=0.1154$, 0.6595; Figure 7), but the difference was less than 0.5 cm (Table 4). The factors in the best fit CPUE models for the two Observer Program indices of abundance both included year, depth bin, and percent hard bottom cover, and the model for the shallow areas also included the area of collection (reef; Table 1). The scaled indices showed overall parallel trends of increase and decrease (Figure 8). However, despite trends of

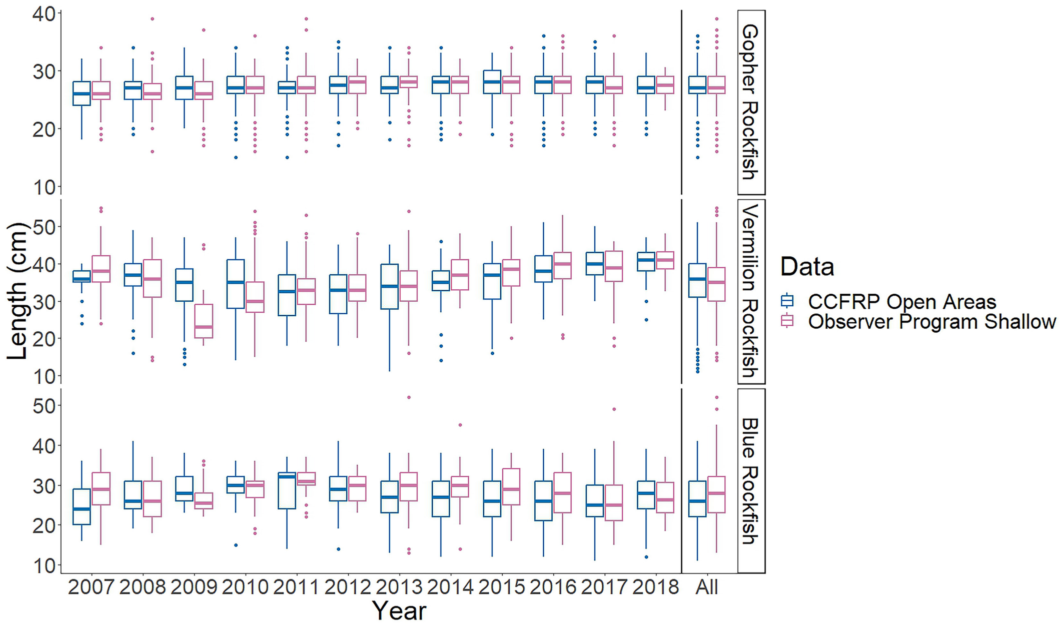

Figure 5. Box-and-whisker plots showing the fork lengths (cm) of study species from California Collaborative Fisheries Research Program (CCFRP) data collected in areas open to recreational fishing and from Observer Program data collected in shallow areas for each year between 2007 and 2018 and for data combined across all years. The central line shows the median length, the box shows upper and lower quartiles, the whiskers represent the range, and dots indicate outliers. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

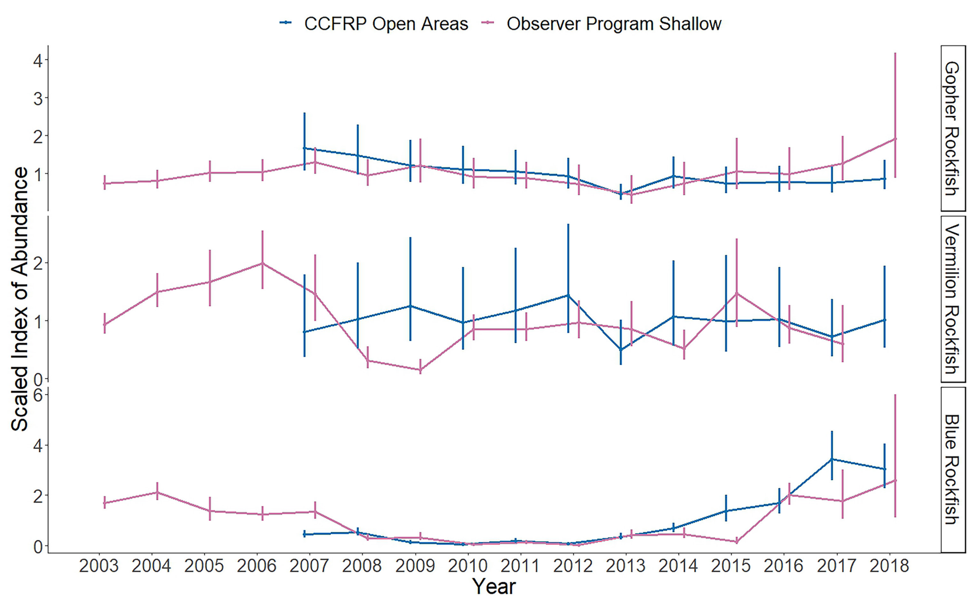

Figure 6. Scaled indices of abundance of Gopher, Vermilion, and Blue rockfish calculated from California Collaborative Fisheries Research Program (CCFRP) data collected in areas open to recreational fishing (2007–2018) and from Observer Program data collected in shallow areas (2003–2018). Error bars show the 25% and 95% CIs. Index values and CIs were scaled to the mean of the index. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

similar shape, the average nominal CPUE of Gopher Rockfish was much lower in deep Observer Program samples than in shallow Observer Program samples or in either open or protected areas sampled by the CCFRP (Figure 4).

Vermilion Rockfish were found in 43.8% of samples from shallow areas and 49.8% of samples from deep areas (Table 5). Deep and shallow Observer Program samples did not differ significantly in mean length overall (Tukey HSD: $P = 0.9612$, 95% $CI = -0.476, 0.7006$; Figure 7). The length distributions of Vermilion Rockfish were significantly different between the shallow and deep Observer Program samples from 2009 to 2011 (Table 3). In 2009, the deep samples showed a distribution shifted toward larger fish, whereas in 2010 and 2011 the deep samples showed a distribution shifted toward smaller

Table 5. Sample sizes for data used to construct models. Abbreviation: CCFRP = California Collaborative Fisheries Research Program. *N* is the number of samples (drops) used for modeling. "Positive samples" refers to the number of samples for which at least one fish of that species was caught during the drop. "Percent positive" is the percentage of positive samples for that species from that data source. Records are summarized across all years (2003–2018 for the Observer Program; 2007–2018 for the CCFRP).

Data source	Species	Positive samples	Percent positive
CCFRP protected areas ($N = 984$)	Gopher Rockfish	918	93.3
	Vermilion Rockfish	550	55.9
	Blue Rockfish	718	73.0
CCFRP open areas ($N = 955$)	Gopher Rockfish	817	85.5
	Vermilion Rockfish	352	36.9
	Blue Rockfish	547	57.3
Observer Program shallow ($N = 1,864$)	Gopher Rockfish	1,308	70.2
	Vermilion Rockfish	817	43.8
	Blue Rockfish	761	40.8
Observer Program deep ($N = 1,574$)	Gopher Rockfish	392	24.9
	Vermilion Rockfish	782	49.7
	Blue Rockfish	849	53.9

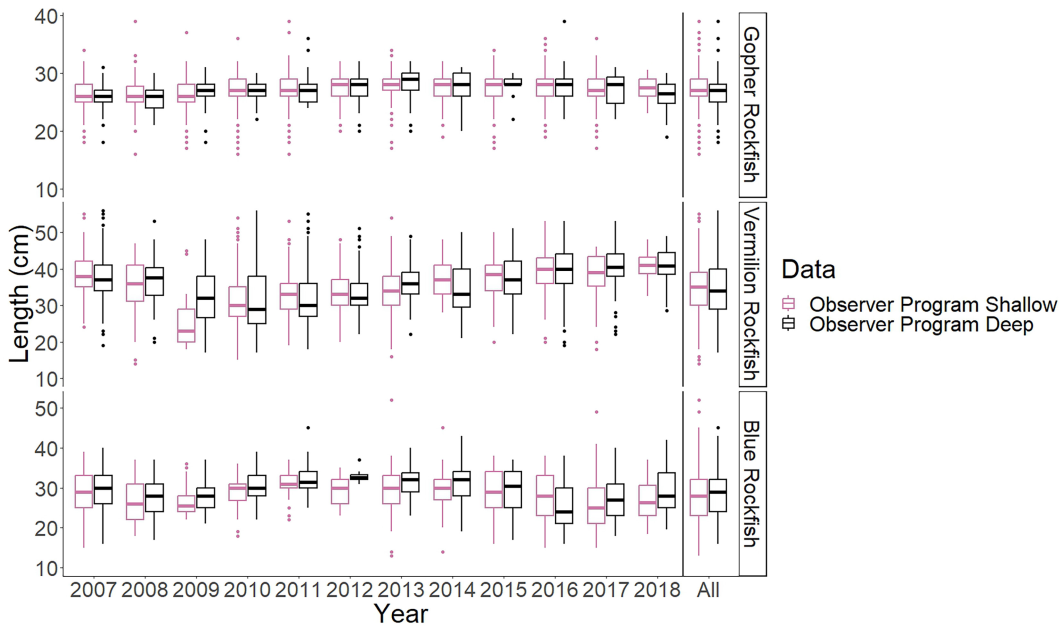

Figure 7. Box-and-whisker plots showing fork lengths (cm) of study species from Observer Program data collected in shallow and deep areas for each year between 2007 and 2018 and for data combined across all years. The central line shows the median length, the box shows upper and lower quartiles, the whiskers represent the range, and dots indicate outliers. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

fish (Figure 7). However, length distributions did not differ in comparisons of data from all years combined (Table 2), and the overall average lengths of Vermilion Rockfish from deep and shallow Observer Program samples were almost identical, differing only by 0.1 cm (Table 4). The models used to construct indices of abundance for Vermilion Rockfish in shallow and deep areas were the same, except that the model for shallow CPUE included a significant depth effect (Table 1). The scaled indices of abundance broadly overlapped, but there was a peak in abundance for the shallow Observer Program samples in 2005–2007 and a subsequent peak in abundance for deep samples in 2010–2012 (Figure 8). The average nominal CPUE was higher in deep Observer Program samples than in shallow Observer Program samples or in either open or protected areas sampled by the CCFRP (Figure 4).

Blue Rockfish were present in 40.8% of shallow Observer Program samples and 53.9% of deep Observer Program samples (Table 5). They showed no significant difference in length distribution between deep and shallow Observer Program data overall (Table 2). The mean lengths between deep and shallow samples were significantly different (Tukey HSD: $P = 0.0002$, 95% CI $= -1.004, -0.243$; Figure 7) but only by 0.6 cm (Table 4). The length distributions of Blue Rockfish in deep and shallow Observer Program data were significantly different only in 2016 (Table 3). In that year, the distribution from the deeper areas was shifted toward smaller individuals (Figure 7). The best fit CPUE models for shallow and deep areas both included year and percent hard bottom cover (Table 1). The resulting scaled indices of abundance for Blue Rockfish in both the shallow and deep areas showed an overall pattern of decrease

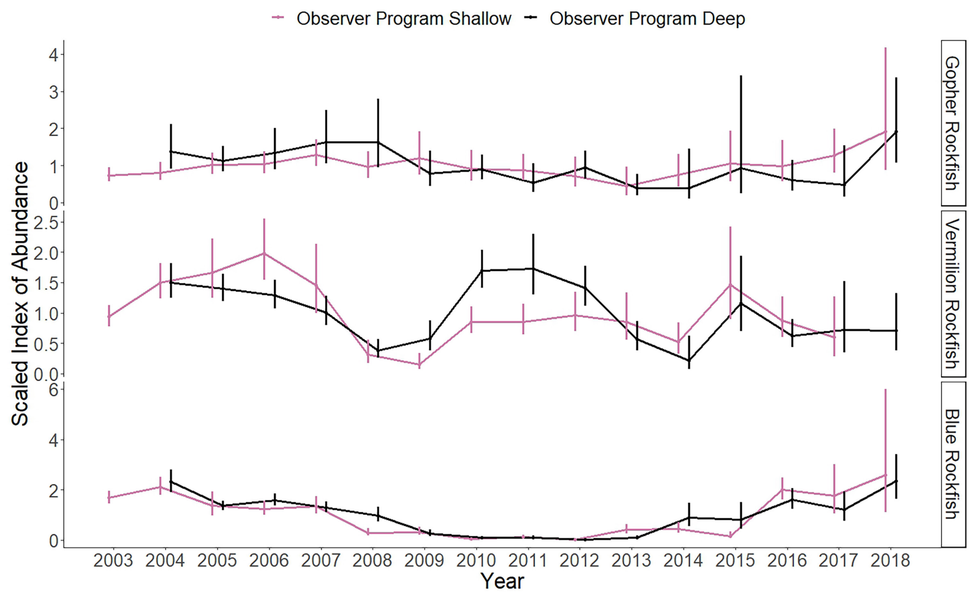

Figure 8. Scaled indices of abundance of Gopher, Vermilion, and Blue rockfish calculated from Observer Program data collected in shallow and deep areas between 2003 and 2018. Error bars show the 25% and 95% CIs. Index values and CIs were scaled to the mean of the index. Note that for maximum visual clarity of comparisons, the *y*-axis scale varies by species.

between 2003 and 2011 and then an overall pattern of increase between 2011 and 2017 (Figure 8).

DISCUSSION

We found that the information to be gained from each data source and the applicability of that information to a broader population were highly variable among the three rockfish species. Although we gained insight about portions of the population that had not recently been sampled due to the presence of MPAs for some species, MPA effects were not universal. The degree to which information differed between data taken with a standardized, fisheries-independent methodology and fisheries-dependent data was not consistent. Across depth, some populations appeared split in trends between shallow and deep areas while others had common trends regardless of depth. Although maximizing available data for management assessments is considered universally beneficial, the impact on our understanding of any given population of a species by introducing one type of information or the other appears to be heavily influenced by the life history of that species.

Question 1: What new information are we gaining from data gathered inside MPAs?

At the time of this work, it appears that the population indices and length structure of Gopher Rockfish populations from inside and outside of MPAs overlap considerably. Although there was a statistically significant difference in mean lengths and size distributions of Gopher Rockfish between open areas and protected areas sampled by the CCFRP, the differences were small enough that they are unlikely to be biologically significant. Gopher Rockfish population trends appear very similar between open and protected areas, indicating that there is not a strong effect of protection on this species. The population information to be gained from sampling inside MPAs appears to be the same as information that is already available from sampling areas that are open to fishing. This could be driven by life history; Gopher Rockfish are territorial and have small home ranges that may cause them to distribute themselves differently than the other species examined in this study. Furthermore, we examined only 11 years of data from MPA sites, which is a relatively short period with respect to the life span of many rockfishes (Love et al., 2002). It is possible that, over time, this population could see impacts due to fishing pressure or a lack thereof. Marine protected areas can lend population resilience to disruptions like climate perturbations (Hoffman et al., 2021). California has been subject to extreme climate perturbation in the last decade (Di Lorenzo & Mantua, 2016; Gentemann et al., 2017; Jacox et al., 2016).

The Vermilion Rockfish appears to be the species for which we gain the most information from data collected inside MPAs. In terms of population size structure, Vermilion Rockfish differed in size distribution and mean length between open and protected areas within the CCFRP data, with larger fish consistently found in MPAs. The difference in mean lengths of Vermilion Rockfish from open and protected CCFRP samples was not only significant but was also the largest difference in mean length between two groups in this study. The difference in size does not appear to be an effect of MPA protection. Firstly, the MPAs had only been in place for 11 years at the time this project was conducted, which is a relatively small fraction of the life span of a Vermilion Rockfish. The MPAs likely would not have had time to generate a significant divergence in size. Furthermore, if the presence of MPAs had been able to impact Vermilion Rockfish size, we would expect to see the sizes diverge over time, as the implemented protections allowed fish to grow larger. However, this difference in size distributions appears throughout the time span of the data. It is more likely that larger fish would be present in this area regardless of whether it is protected or not, perhaps due to California's MPAs being established in areas that were already known to contain certain kinds of habitat preferred by species like Vermilion Rockfish (California Department of Fish and Wildlife, 2016). On the other hand, Vermilion Rockfish abundance showed a steady increase in protected areas across the time span studied, whereas the same increase was not seen in areas open to fishing. This suggests an MPA effect. Analyses incorporating data only from areas open to recreational fishing are likely excluding a growing sector of the population and a portion of the population that includes the larger adults present in the MPAs. The exclusion of large sizes is important because this portion of the population could be significantly contributing to the population as a whole. Female rockfish of many species produce an exponentially greater number of larvae and more robust larvae as they grow larger and can outlive unfavorable environmental periods to reproduce prolifically when conditions become favorable again (Barneche et al., 2018; Hixon et al., 2014; Love et al., 2002), and California's MPAs contribute more to larval propagation than unprotected areas (Yeager et al., 2023).

Blue Rockfish also showed some differences between protected and open areas. The indices of abundance for CCFRP open and protected areas showed similar peaks, but the size structure of the individuals making up that abundance appeared to differ. There was a higher proportion of smaller Blue Rockfish in protected areas than in open areas, and the overall mean length was smaller in protected areas. Data only from areas open to fishing may not accurately reflect the proportion of small individuals in the population. Furthermore, the predictive factors for modeling CPUE also differed between open and protected areas, possibly indicating that protection is the strongest factor in predicting Blue Rockfish CPUE, more so than any variance in habitat and location.

Question 2: What new information might we be gaining from a standardized, fisheries-independent sampling method?

There does not appear to be new information to be gained about Gopher Rockfish populations from a standardized sampling design. Gopher Rockfish showed the same population trends between the two projects where the projects overlapped spatially and where recreational fishing was occurring.

In contrast, it appears that information can be gained about Vermilion Rockfish from a standardized sampling method for certain population trends. The differences in size between fisheries-dependent and fisheries-independent data are unlikely to be biologically significant; the size distributions broadly overlapped, and fish were only 0.5 cm larger on average in the CCFRP data than in the Observer Program data. This is somewhat unexpected, as Vermilion Rockfish are highly desirable to recreational anglers and we expected that they might be subject to size selectivity. Apart from size structure, indices of abundance calculated from the two data sources showed different trends across the overlapping time span of the two projects. Furthermore, the factors that were important in predicting Vermilion Rockfish CPUE differed depending on the project. Vermilion Rockfish were predicted by hard bottom in the fisheries-dependent data but not in the fisheries-independent data. It is difficult to know the cause of these differences, but they do indicate an impact of sampling methodology. Fisheries-independent or fisheries-dependent data alone may be inadequate to determine Vermilion Rockfish population size over time.

Our results for Blue Rockfish also show that there is information to be gained from a standardized, fisheries-independent methodology. Although the indices of abundance for Blue Rockfish showed similar trends between the two projects, the size distributions and mean lengths of fish differed. The higher proportion of smaller fish in CCFRP samples could be due to an issue of size selectivity. The 2017 assessment of the Blue Rockfish and Deacon Rockfish *S. diaconus* stock complex (Dick et al., 2017) reported a strong year-class based on the pelagic juvenile index of Blue Rockfish in 2013, suggesting a possible recruitment event. Recruitment events can result in very large, concentrated schools of very small fish. The overall upward trend in abundance seen in all indices from 2012 to 2018 was observed in the field to primarily encompass large schools of small recent recruits. Captains and anglers involved in Observer Program sampling may be avoiding these very small individuals. While Observer Program captains can choose to move their vessels when the catch is mostly small or less desirable fish, captains following the CCFRP sampling design cannot actively avoid schools of small fish that may appear during a fishing drift (nor do they want to, as capturing fish objectively is part of the goal of the CCFRP). When the CCFRP began in 2007, Blue Rockfish were relatively rare to catch, but between 2016 and 2018, they constituted roughly 80% of the total catch in CCFRP surveys. Observer Program data taken prior to the beginning of the CCFRP and concurrent dive survey data (Wolfe & Pattengill-Semmens, 2013) indicated that this species has gone through similar recruitment events and rapid population increases before, notably between 2003 and 2005. Our results show an even higher proportion of recruit-sized Blue Rockfish in protected areas. Recruits occur near shore, meaning that they are likely to be captured within the CCFRP's sampling depth, and fisheries-dependent data may select against new recruits, as charter boat captains have been observed to move their vessels to avoid large schools of small fish. Therefore, nearshore fisheries-independent data could provide more information about Blue Rockfish recruitment events while avoiding sampling pitfalls, such as fishery selectivity against small individuals.

Question 3: Can these data be applied to the breadth of a population?

A very small number of Gopher Rockfish was found in waters deeper than 46 m. Where there were fish to be found in deeper water, the population trends paralleled those in shallow areas. It appears that data taken from shallow waters, such as CCFRP data, could apply to the breadth of the population of Gopher Rockfish. In fact, Gopher Rockfish are far more likely to be encountered inside the CCFRP's depth range than outside. It is because of this potential breadth of representation that the first stock assessment to use the CCFRP data as a relative index of abundance was the 2019 stock assessment for the Gopher Rockfish and Black-and-yellow Rockfish *S. chrysomelas* complex (Monk & He, 2019).

Data with a shallow depth restriction, such as data from the CCFRP, do not fully represent the breadth of the Vermilion

Rockfish population. It is well established in the literature that Vermilion Rockfish habitat extends deeper than even our deepest Observer Program samples. This is supported by the fact that Vermilion Rockfish were equally present in both shallow and deep Observer Program samples. Furthermore, depth was an important factor for modeling CPUE in shallow areas but not deep areas, suggesting that while depth is a significant predictor of Vermilion Rockfish CPUE in depths sampled by the CCFRP, past the CCFRP depth bounds the CPUE is consistent enough that depth is no longer predictive. This indicates that there is a threshold of depth past which the species is more evenly distributed and that this threshold is deeper than the CCFRP sampling depth constraints. The differences between the shallow and deep Observer Program samples suggest that a cohort of Vermilion Rockfish may have transitioned from shallow to deep habitat during the years in which these data were collected. Vermilion Rockfish undergo an ontogenetic shift, a life history characteristic whereby fish spawned in shallow waters move deeper as they age (Butler et al., 2012; Love et al., 2002). The peak in the index of abundance calculated for the shallow area samples in 2005–2007 was followed by a peak in the abundance index calculated from deep samples in 2010–2012, which may indicate a recruitment event around 2004, followed by an ontogenetic shift around 2010. This is further supported by the size distributions; there were more small individuals in deep areas in 2010 and 2011, at the time of that peak in the deep area index, which may represent a cohort of young adults newly present in deep areas. More in-depth analysis would be required to further support this population event definitively, but our data suggest that we could be capturing this species during early life stages in shallow areas. Although our results show that the CCFRP could not apply to the breadth of the Vermilion Rockfish population due to its depth constraints, it could be the case that smaller adults are well represented in data sources from shallower waters.

Blue Rockfish are also known to occupy a broader depth range than what is sampled by both the CCFRP and the Observer Program (Love et al., 2002). They were equally present in shallow and deep areas in our samples. However, it appears that shallow-water data might show trends that are indicative of trends in the breadth of the Blue Rockfish population, despite only sampling part of it. In the Observer Program data, size differed significantly between samples from deep and shallow areas in only 1 year and the factors predictive of CPUE were the same across depths. Essentially, it may be appropriate to draw conclusions about Blue Rockfish populations at large based on Blue Rockfish populations in shallow water because the samples in shallow water alone showed the same population trends as the samples collected in deep water.

Conclusions

The data from our fisheries-independent CCFRP survey provide species-specific insight into populations. For species that are found mostly in shallow water, have a strong benthic association, and have a small home range, like Gopher Rockfish (Butler et al., 2012; Larson, 1980; Love et al., 2002; Matthews, 1985), population trends drawn from CCFRP data appear to overlap considerably with those from fisheries-dependent data. For use in management and assessment, CCFRP data serve the valuable purpose of increasing data volume for the breadth of the population and providing a data source from areas that are closed to fishing. This lends more certainty to tools like assessment models, but it is unlikely to capture any population trends not already described by fisheries-dependent Observer Program data. The similarity between the two data sets for Gopher Rockfish could change if California undergoes unforeseen perturbations, such as increased fishing pressure or changes in ocean climate, which might increase the importance of MPAs in providing resilience to the population (e.g., Hoffman et al., 2021). Fisheries-independent data from the CCFRP could potentially provide additional information for species with life histories similar to that of Gopher Rockfish, such as other members of the *Sebastes* complex (e.g., China Rockfish *S. nebulosus*, Brown Rockfish *S. auriculatus*, Grass Rockfish *S. rastrelliger*, and Kelp Rockfish *S. atrovirens*) and other groundfish (e.g., Kelp Greenling *Hexagrammos decagrammus*), all of which are encountered by CCFRP sampling.

The Vermilion and Blue Rockfish data indicate that there is additional information to be gained from a fisheries-independent nearshore data source with a standardized sampling method, such as the CCFRP. These data appear to provide information about recruitment events and specifically the status of juveniles and young adults in these species' populations. Another factor that distinguishes the CCFRP is that it is the only long-term fisheries-independent hook-and-line survey of MPAs in California. By nature, the data sources historically used for assessments of these species do not include information from MPAs. We have seen that for both Vermilion and Blue rockfish, there is information to be gained about the population from inside the MPAs, which is necessarily absent from fisheries-dependent data. The large number of small Blue Rockfish demonstrated that the MPAs house new recruits. If assessors exclude data from MPAs, the size of these recruitment events could be inaccurately reflected as smaller than they are. The large Vermilion Rockfish inside the MPAs are likely to be disproportionately contributing to the greater metapopulation of Vermilion Rockfish. Larger Vermilion Rockfish contribute disproportionately more to larval production than small Vermilion Rockfish relative to their body mass (Barneche et al., 2018; Hixon et al., 2014; Love et al., 2002), and MPAs contribute more to particle distribution and interarea connectivity than nonprotected areas in California (Yeager et al., 2023). Rockfishes are broadcast spawners. An increased spread of a disproportionate number of larvae potentially produced by individual Vermilion Rockfish in MPAs would magnify their impact on the metapopulation. Information of this type is valuable in assessing rockfish populations using methods like those employed by NMFS in rockfish stock assessment, and a lack of such information could represent a significant data gap in other sources of information about this population. These data could extend beyond the specific species analyzed within this study. For example, our understanding of Copper Rockfish *S. caurinus* populations could benefit from CCFRP data, as they have a life history similar to that of Vermilion Rockfish and are similarly popular in the recreational fishery.

Although this study focuses on the CCFRP and onboard Observer Program data from San Luis Obispo County, the CCFRP has been a statewide program since 2017.

Fisheries-independent data are gathered from 14 MPAs ranging from just south of Oregon (South Cape Mendocino State Marine Reserve) to near the coast of Mexico (South La Jolla State Marine Reserve). Some of these sampling areas are new to the program, so trends over time cannot be fully addressed across the entire state at present. However, over time, the CCFRP could be used to build a robust statewide time series of rockfish population data inside MPAs. The geographic scope of the statewide CCFRP can address the lack of data for this considerable percentage of state waters.

Rockfish populations declined substantially in size and number through the latter half of the 20th century (Love, Caselle, & Herbison, 1998; Love, Caselle, & Van Buskirk, 1998; Mason, 1998). These populations have recovered due to careful and well-enforced management (Warlick et al., 2018). For these populations to continue to be effectively managed, it is important that we have the most complete picture of rockfish population status, including information from MPAs and nearshore areas. Our results demonstrate that different data sources introduce new information about populations on a species-specific basis. This further supports the longstanding view that fisheries-independent data can help to increase our understanding of the status of fish populations and therefore potentially lead to more robust management.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Marine and Coastal Fisheries* online.

DATA AVAILABILITY

Data are available upon request to the corresponding author, R. E. Dodgen.

ETHICS STATEMENT

All research meets the ethical guidelines and legal requirements of the State of California and the United States of America as well as the guidelines for the use of fishes in research set by the American Fisheries Society (Use of Fishes in Research Committee, 2014).

FUNDING

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CONFLICTS OF INTEREST

The authors certify that they have no conflicts of interest to disclose.

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