MARINE PROTECTED AREAS AND OCEANOGRAPHIC VARIABILITY: IMPACTS ON BLUE ROCKFISH (SEBASTES MYSTINUS) AND THE HUMAN DIMENSIONS OF COLLABORATIVE FISHERIES RESEARCH

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TITLE:	Marine Protected Areas and Oceanographic Variability: Impacts on Blue Rockfish (*Sebastes mystinus*) and the Human Dimensions of Collaborative Fisheries Research.
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ABSTRACT

Marine Protected Areas and Oceanographic Variability: Impacts on Blue Rockfish (*Sebastes mystinus*) and the Human Dimensions of Collaborative Fisheries Research.

Erin Margaret Johnston

Fishing pressure and environmental variability are two of the most impactful drivers of fish populations worldwide. It is critical to effective management to understand the intersection between the two and how each may affect fish population dynamics, especially for exploited nearshore species like rockfishes (*Sebastes spp.*). This is especially true as models indicate that global climate change will dramatically increase the frequency and severity of large-scale oceanographic perturbations. We were interested in whether we could detect changes in relative abundance of nearshore rockfishes relative to large-scale oceanographic events using a broad-scale index like the Multivariate Ocean Climate Indicator (MOCI), if detectable changes were different based on the life-stage of the fishes, and whether fishing pressure had an impact on the relationship between environmental variability and fish abundance. To investigate this, we calculated cross correlations between catch per unit effort (CPUE) of Blue Rockfish (*Sebastes mystinus*) and the MOCI. We used data collected by the California Collaborative Fisheries Research Program (CCFRP) inside of marine protected areas (MPAs) and in paired reference sites to account for fishing effort. We also incorporated data collected before, during, and after the North Pacific Marine Heatwave (NPMHW) into cross correlation analyses. Based on these cross correlations, our findings suggest that oceanographic variability impact juvenile *S. mystinus* population dynamics with a two-year time lag. Our findings also suggest that fishing pressure impacts adult *S. mystinus* population dynamics more strongly than juveniles, but that temporal shifts in regional oceanographic conditions appear to alter this relationship. These findings may help to inform groundfish management along the West Coast of the United States and has broader implication for predicting species responses to the combined effects of fishing pressure and oceanographic variability.

In addition to collecting necessary data on the status of fisheries populations, collaborative fisheries research programs engage stakeholders in data collection efforts, often with the benefit of increasing transparency about the status and management of natural resources. These programs are particularly important in marine systems, where management of recreational and commercial fisheries have historically been contentious. One such program is the CCFRP, which was designed in 2006 with two main goals: (1) to evaluate the efficacy of California's newly implemented network of MPAs while providing information for stock assessments, and (2) to engage anglers in all aspects of the research, including study design, data collection, analysis, and dissemination of scientifically robust data. CCFRP began on the Central Coast of California and expanded in 2017 to include six partner institutions spanning the entire state. To date, over 2,000 volunteer anglers have participated in the program, with many anglers volunteering for multiple years. A previous study that surveyed CCFRP anglers from the Central Coast demonstrated the importance of long-term participation in changing angler opinions of MPAs. Here, we extend that research four years after the expansion of CCFRP by surveying the statewide pool of volunteer anglers to assess the degree that participation in CCFRP has influenced their perceptions of MPAs, fisheries management, and conservation. We received 259 completed surveys, equating to an 18.7% response rate. Participation in CCFRP resulted in a significant, positive impact on the attitudes of anglers across all regions towards MPAs in

California. Anglers that participated in six or more CCFRP fishing trips had a more positive perception of MPAs than those that participated in fewer trips. Volunteer anglers across all regions perceived that they caught larger fishes, a higher abundance of fishes, and a greater diversity of species inside MPAs, consistent with the ecological findings of the program. These results highlight the benefits of involving community members in collaborative scientific research. Collaboration between researchers and the broader community increases transparency and trust between stakeholders, results in greater understanding of natural resources, and ultimately produces better management outcomes.

Keywords: Marine Protected Area, Marine Citizen Science, Rockfish, Oceanographic Variability, Fishing Pressure

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1.1. INTRODUCTION

Rockfishes (*Sebastes spp.*) are abundant along the U.S. West Coast (Love et al., 2002), among the most recreationally harvested fish species in California (Dick et al., 2017), and an important component of commercial groundfish harvest, generating $3-4 million annually (NOAA Fisheries, 2022). Despite their abundance and socioeconomic importance, most rockfish species are considered data-poor and are therefore subject to conservative management approaches (Dick and MacCall, 2011). The effects of fishing pressure on rockfish abundance and population assemblage sizes have been well documented (Harvey et al., 2006; Mangel and Levin, 2005; Musick, 1999). However, before federal fishing regulations were introduced in the early 2000s, excessive harvesting pressure resulted in the drastic decline of multiple rockfish species in California and along the entire U.S. West Coast (Hilborn et al., 2021; Love et al., 2002, 1998). With the implementation of extensive management actions designed to reduce fishing pressure such as harvest limits, seasonal closures, and spatial closures such as rockfish conservation areas (RCAs) and marine protected areas (MPAs), previously exploited rockfish stocks have started to recover (Barnett and Baskett, 2015; Micheli et al., 2004; Starr et al., 2015), but are still subject to oceanographic variability. Despite extensive research on rockfish populations and fishing pressure within the California Current Ecosystem (Dalton and Ralston, 2004; Field et al., 2010; Freeman et al., 2022; Wedding and Yoklavich, 2015), relatively little is known about the impact of oceanographic variability on rockfish populations in California's nearshore environment (but see Ziegler et al., 2023).

The coast of California is one of four major Eastern Boundary Upwelling Ecosystems (EBUS; Checkley and Barth, 2009), and experiences seasonal changes in environmental conditions (e.g., temperature, ocean chemistry, productivity), largely driven by variations in regional upwelling favorable winds (García-Reyes and Largier, 2012; Walter et al., 2018).

Upwelling is critical for supplying nutrients to the euphotic zone, fueling primary production, and contributing to the highly productive nature of these ecosystems (Chan, 2019; Pauly and Christensen, 1995; Thompson et al., 2012). However, spatial and temporal variation in regional oceanographic processes can have significant impacts on marine food webs (Menge et al., 1997), and may play a crucial role in shaping the structure and dynamics of nearshore rockfish populations. Therefore, characterizing the effects of both oceanographic variability and fishing pressure on rockfish population dynamics is critical for more holistic and effective management.

For many fish species, changes in oceanographic conditions can have profound effects on their ecology and populations dynamics. Oceanographic variability over a range of time scales has been linked to geographic range shifts (Lonhart et al., 2019; Nye et al., 2009; Perry et al., 2005) as well as variations in reproductive success (Pankhurst et al., 2011), biomass (Cheung and Frölicher, 2020), and relative abundance (Klyashtorin, 2001; Lonhart et al., 2019). Such oceanographic variability is also likely to affect juvenile and adult life stages in distinct ways. Fishes in their larval and pelagic stages may be particularly sensitive to changes in temperature and food availability (Pörtner and Peck, 2010), which can have significant impacts on survivorship during these life stages. Variation in nearshore circulation and transport processes can also influence larval retention and delivery to nearshore habitats (Phelan et al., 2018; Pineda et al., 2007; Taylor et al., 2004). In contrast, adult rockfishes are not directly impacted by ocean currents to the same degree as planktonic larvae. While adults of many species have specific rocky habitat preferences (Rooper et al., 2010) and small home ranges (Green et al., 2014; Jorgensen et al., 2006; Matthews, 1990; Tolimieri et al., 2009), they have been shown to move to avoid predators or respond to changes in prey location (Love et al., 2002). In addition, adults generally feed at a higher trophic level than the juveniles (Love et al., 2002), and therefore may be less vulnerable to short-term shifts in primary productivity and bottom-up ecological processes. Collectively, these factors can have profound impacts on rockfish population dynamics

(Caselle et al., 2010; Field and Ralston, 2011; Hollowed et al., 1987; Laidig et al., 2007; Markel and Shurin, 2020; Ralston and Howard, 1995; Wilson et al., 2008).

Since many rockfishes are targets of recreational and commercial fisheries (Love et al., 1998; Schroeder and Love, 2002), fishing mortality can further complicate the challenge of understanding the impact of oceanographic processes on population dynamics. In California, the Department of Fish and Wildlife implemented a series of no-take MPAs across the state from 2007-2012 in accordance with the Marine Life Protection Act (MLPA) of 1999. In addition to protecting, conserving, and rebuilding marine populations and ecosystems (among a range of other objectives; CDFG [California Department of Fish and Game], 2008), these MPAs also provide locations to examine the effects of oceanographic variability in the absence of fishing pressure. When paired with nearby locations that are open to fishing, researchers can explore the combined effects of these two major drivers on fish population dynamics.

The California Collaborative Fisheries Research Program (CCFRP) is a long-term, fishery-independent program designed to monitor the distribution, size, and abundance of nearshore fish populations in these MPAs and paired reference ('REF') sites (Wendt and Starr, 2009). Of all groundfish species caught by CCFRP along the central coast, Blue rockfish (*Sebastes mystinus*) are the ideal species for exploring the intersection between the impacts of fishing pressure and environmental variability. Rockfishes are generally slow-growing, long-lived, and recruit episodically following pelagic larval and pelagic juvenile stages (Love et al., 2002). However, *S. mystinus* are more abundant, relatively short-lived, and feed at lower trophic levels (i.e., zooplankton) compared with other rockfishes (Hallacher and Roberts, 1985; Love et al., 2002; Singer, 1985). *S. mystinus* also generally feed in the water column (along with Olive [*S. serranoides*], Yellowtail [*S. flavidus*], and Black rockfish [*S. melanops*]) more than many of their benthically associated congeners (e.g., Gopher [*S. carnatus*] and Vermilion rockfish [*S. miniatus*]). Additionally, while most rockfish species have a similar pelagic larval duration, juvenile *S. mystinus* recruit to nearshore habitats earlier in the year than most other species (Singer, 1985), which differentiates them from many other rockfishes.

Here, we examine a 14 year time-series from CCFRP (2007 to 2020) in central California, USA. The duration of this program and the high relative abundance of *S. mystinus* within this dataset enables a unique look into the role that oceanographic variability and differential fishing pressure play in shaping nearshore rockfish population dynamics. Over our study period, the CCE experienced a prolonged period of anomalously warm water (2014-2016), coinciding with a transition from a prolonged cold phase to a warm phase in the dominant climate mode affecting temperature in the North Pacific (Pacific Decadal Oscillation) and a strong El Niño event. This extended period of anomalously warm water has been termed the North Pacific Marine Heatwave (NPMHW; Hobday et al., 2016; Jacox et al., 2019). Using a broad regional index of oceanographic variability that synthesizes seasonal averages of oceanic and atmospheric variables (i.e., the Multivariate Ocean Climate Index [MOCI]; García-Reyes and Sydeman, 2017), we linked the population abundance of *S. mystinus* with fluctuations in ocean climate variability in this region. We also explored changes in specific oceanographic parameters within the Point Buchon study area to generate hypotheses about potential mechanisms for the observed patterns and to interpret the possible links between fisheries abundance data and changes in environmental conditions. Our observations are consistent with the ideas that 1) indices of large-scale oceanographic change can be used as a general predictor of *S. mystinus* abundance in the nearshore environment in central California, 2) adult and juvenile life-stages are affected by oceanographic conditions and fishing pressure in distinct ways, and 3) fishing pressure impacts the relationship between oceanographic conditions and *S. mystinus* abundance. Collectively, results from this study aim to elucidate how rockfish population dynamics may respond to climate change and future warming and begin to investigate the dynamic relationships between oceanographic variability and rockfish in California's nearshore environment.

1.2. METHODS

1.2.1. Study Design

CCFRP was established in 2006 as a collaboration between academic research groups, recreational anglers, commercial passenger fishing vessels (CPFVs), CPFV captains and crew, and management agencies (Wendt and Starr, 2009). CCFRP aims to collect rigorous, fishery-independent data on the status of nearshore fish assemblages and the effectiveness of the network of MPAs required by the MLPA, cooperatively among all partner groups. CCFRP began data collection in central California in 2007 and expanded statewide in 2017. We collected data for this study across four sampling areas in central California, USA spanning 2007-2020: Point Buchon (35.23°N, 120.89°W), Piedras Blancas (35.68°N, 121.30°W), Point Lobos (36.50°N, 121.95°W), and Año Nuevo (37.10°N, 122.31°W). Each area comprises two sites: a State Marine Reserve (SMR), which is a no-take MPA, and an adjacent reference ('REF') site of similar habitat where commercial and recreational fishing is allowed (Figure 1). We sampled each site on three trips between July and September for a total of 24 trips per sampling season each year. All sampling locations are divided into several fixed 0.5 km^2 fishing cells, designated based on the location of suitable groundfish habitat. We randomly selected four cells for sampling without replacement during a single trip but randomly selected cells with replacement for the duration of a season. During each trip, three 15-minute fishing drifts occurred in the four selected cells. Volunteer anglers caught groundfish using standardized fishing tackle (Wendt and Starr, 2009). For each fish caught, our science team recorded species, length, and condition. We released or descended all fishes depending on the species and degree of barotrauma (Starr et al., 2015). Because fishing methods and sampling effort are standardized, fishes caught on CCFRP are assumed to represent fish populations with respect to abundance, size, and species composition for the area in which they are caught. For more detailed CCFRP field methods see Wendt & Starr (2009) and Ziegler et al. (2022).

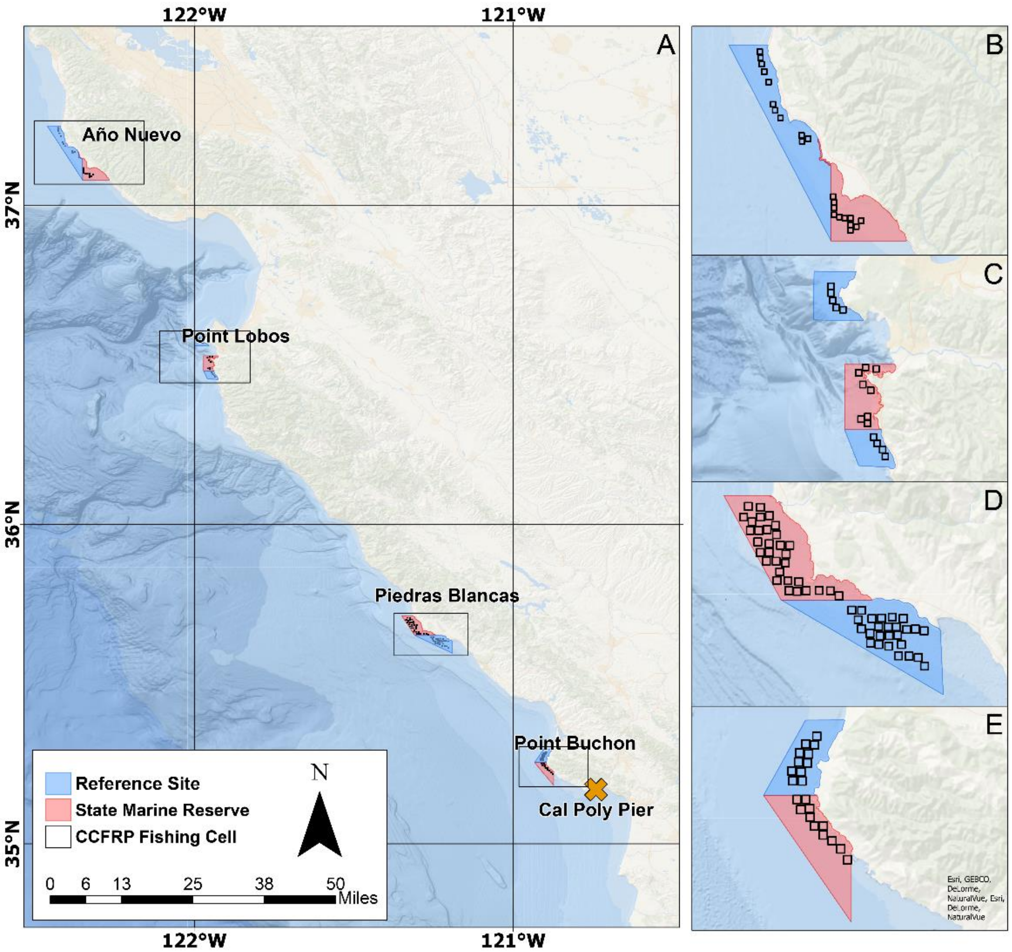


Figure 1. Map of (A) study areas in central California, including CCFRP fishing cells in both State Marine Reserves (pink shaded area) and areas open to fishing (i.e., 'Reference Sites'; blue shaded area) in (B) Año Nuevo, (C) Point Lobos, (D) Piedras Blancas, and (E) Point Buchon.

1.2.2. Data Preparation

We divided catch data into juvenile and adult rockfish categories based on their size at maturity (Love et al., 2002). To standardize catch across years and location, we calculated catch per unit effort (CPUE) as the number of fishes caught divided by the number of angler hours, where angler hours are the number of hours fished multiplied by the number of fishers (CPUE = number of fishes caught x angler hours^{-1}), minus the amount of time not spent fishing (e.g., lost gear, tangled lines, etc.), which we tracked for each drift. We calculated CPUE for each drift by dividing the number of fishes captured by the angler hours on that drift; we then computed the mean of this metric for each grid cell. The grid cell was used as the sampling unit to calculate means and variance at each level of protection within each sampling area. Because we randomly selected cells with replacement during the season, this calculation of CPUE accounts for any uneven sampling in years where cells were randomly selected more than one time in a season.

1.2.3. Study Species

Fishes caught by CCFRP are predominantly rockfishes; the most abundant species caught in central California is the Blue rockfish (*Sebastes mystinus*), the focus of this study. The size of *S. mystinus* caught by the CCFRP ranges from 6 cm to 48 cm. We categorized individual *S. mystinus* as juvenile, based on the size at 50% maturity (total length < 22cm; n = 86,864), and adults based on the size at 100% maturity (total length >31 cm; n = 76,006; Love et al., 2002). We did not analyze CPUE for sub-adult *S. mystinus* (n = 54,290). One study calculated Von Bertalanffy parameters such that *S. mystinus* less than 22cm were ages two to four (Female: Linf = 40.02, k = 0.15, t0 = -1.34; Male: Linf = 32.94, k = 0.20, t0 = -0.95; Laidig et al., 2003), whereas Hannah et al. (2015) calculated these parameters such that only two year old *S. mystinus* fell in this size range (Female: Linf = 40.79, k = 0.11, t0 = -6.36; Male: Linf = 31.21, k = 0.10, t0 = -12.00).

1.2.4. MPA vs REF

To evaluate the impact of MPAs on relative abundance of *S. mystinus*, we fit linear mixed effect models using the lmerTest R package (Kuznetsova et al., 2020) to determine the effect of site (MPA/REF) and year groups (before, during, and after warm water events) on cell-level *S. mystinus* CPUE. We considered juveniles and adults separately for this analysis. We examined the differences in catch rates between MPA and REF sites 10 years after MPA implementation by including year groupings before (2007-2013), during (2014-2016), and after (2017-2020) the NPMHW. We also included the interaction between site and year group, and treated area (i.e., the four sampling areas) as a random effect.

1.2.5. Oceanographic Parameters and Data Visualization

The Multivariate Ocean Climate Indicator (MOCI; http://www.faralloninstitute.org/moci) is a broad-scale measure of the state of the California coastal ocean (García-Reyes and Sydeman, 2017). MOCI combines a number of local and regional oceanographic parameters into a single value for every three-month season of the year starting in January of 1990 for Northern California (38-42°N), Central California (34.5-38°N), and Southern California (32-34.5°N). MOCI includes seasonal averages for upwelling index, sea level, alongshore wind, sea surface temperature, air temperature, and sea level pressure, as well as indices for the following climate modes: Multivariate ENSO Index (MEI), which measures El Niño Southern Oscillation intensity, the Pacific Decadal Oscillation (PDO), which is the first principal component of temperature anomalies in the North Pacific, and the Northern Oscillation Index, which measures sea level pressure anomalies in the North Pacific (NOI; Schwing et al., 2002). We included only information from the Central California region for this analysis; we also examined variations in the PDO and MEI individually because several other oceanographic studies examined these parameters (https://psl.noaa.gov/enso/mei/).

Monthly averages of sea surface temperature (SST) and phytoplankton abundance from the California Polytechnic State University, San Luis Obispo Research Pier (Figure 1; 35.1698, -120.7408; https://data.cencoos.org/?&sensor_version=v2#metadata/103544/station and https://erddap.sccoos.org/erddap/tabledap/HABs-CalPoly.html, respectively) provided a localized oceanographic dataset to explore insight into potential mechanisms for the observed variability in relative fish abundance at Point Buchon (35.23°N, 120.89°W), one of the four study sties. The SST data were measured at one meter below the surface using a profiling instrument package (see Walter et al., 2018 for details), while the phytoplankton abundance data were collected in surface waters as part of a state-wide Harmful Algal Blooms sampling program (see Barth et al., 2020 for details). Due to gaps in the pier data, we also obtained surface temperature data from the mouth of Morro Bay, located eight miles north of Pt. Buchon (https://data.caloos.org/?&sensor_version=v2cache#metadata/20679/station/data) and calculated monthly averages for both sites. We also examined changes in upwelling (via the coastal upwelling transport index; CUTI) and vertical nitrate flux (via the biologically effective upwelling transport index; BEUTI) at 35°N (https://oceanview.pfeg.noaa.gov/products/upwelling/cutibeuti) since these were the most spatially resolved datasets that were available to us to examine measures of upwelling and resultant nutrients.

We used weekly phytoplankton abundance data from the Cal Poly Pier to explore phenological shifts in the spring phytoplankton bloom. Using the threshold method (TH; Brody et al., 2013), we determined the dates of bloom initiation and peak for each year for diatoms, which dominate the spring bloom (Barth et al., 2020). In short, the median diatom concentration and the date of the maximum concentration were determined and then a threshold value for the year was calculated equal to 5% above the median concentration. Starting from the date of maximum concentration, we compared the previous measurements (e.g., earlier in the year) with the threshold until we reached two consecutive measurements smaller than the threshold value. We then set the initiation date as the first date with a measurement exceeding the threshold value after (e.g., closer to the diatom maximum) the two consecutive below-threshold dates. We examined both the raw abundance data as well as smoothed data (using Tukey's median smoothing method (Tukey, 1977)), which may better reflect the timing of shifts in oceanographic conditions that led to bloom initiation (Brody et al., 2013).

1.2.6. Lagged Correlation Analysis Between CPUE and Oceanographic Parameters.

We evaluated the relationship between Central California MOCI values and the calculated annual values of CPUE for each site from 2007 to 2020 by using a lagged cross correlation analysis. We calculated cross correlation values by first calculating the correlation between CPUE and MOCI values for each season from the same year, then recalculating correlations with MOCI values lagged by one year so that MOCI values from past years are evaluate against CPUE at present (e.g., MOCI values from 2012 were evaluated against CPUE in 2013). This process was iterated, increasing the lag by one year, up to a total lag of eight years. We limited the analysis to no more than eight years because of the length of the dataset. The same CPUE values were assigned to every season in a year even though CCFRP sampling only occurs between July and September. The Piedras Blancas study area was not sampled in 2007 or 2015; missing values were not replaced since there is no way to estimate the CPUE of a missing site or area in a given year. Initially, we kept missing CPUE values as placeholders for each lag iteration but omitted missing values before the correlation was calculated. We performed all analyses using R Statistical Software (version 3.6.2; R Core Team 2019).

1.3. RESULTS

1.3.1. Rockfish abundance in MPA vs REF sites

There were significantly more juvenile *S. mystinus* captured per unit effort during (i.e., 2014-2016; $p < 0.0001$) and after (i.e., 2017-2020; $p < 0.0001$) the NPMHW compared to before the event (Table 1; Figure 2a). The interaction between site type and year group revealed that there were significantly fewer juvenile *S. mystinus* captured in REF sites relative to MPAs during ($p = 0.009$) and after ($p = 0.029$) the NPMHW.

In general, there were marginally significantly fewer adult *S. mystinus* caught in REF sites relative to the MPAs during the full span (2007-2020) of the CCFRP dataset ($p = 0.053$) (Table 1; Figure 2b). There were significantly more adult *S. mystinus* captured per unit effort during ($p < 0.0001$) and after ($p < 0.0001$) the NPMHW than before regardless of site. Interestingly, while there were no significant differences between MPA and REF site catch rates of adult *S. mystinus* during the NPMHW, there were significantly fewer adults captured in REF sites relative to MPAs after the NPMHW ($p<0.0001$).

Table 1. Results of two linear mixed models for adult and juvenile *S. mystinus* to assess the effects of protection status and year groups before, during, and after the NPMHW as well as the interaction between protection status and year group.

MPA-REF Analysis

	Dependent variable:			
	Catch Per Unit Effort (CPUE): Cell Level			
	Adult		Juvenile	
Reference (REF)	-0.27*	(0.14)	-0.06	(0.17)
During	1.02***	(0.19)	2.03***	(0.23)
After	2.72***	(0.17)	2.05***	(0.21)
REF:During	-0.40	(0.27)	-0.85***	(0.33)
REF:After	-1.60***	(0.24)	-0.64**	(0.29)
Constant	0.51	(0.35)	0.27	(0.24)
Observations	1,010		1,010	
Log Likelihood	-1,917		-2,123	
Akaike Inf. Crit.	3,851		4,262	
Bayesian Inf. Crit.	3,890		4,301	
Note:	*p<0.06; **p<0.05; ***p<0.01			

1.3.2. Regional-Scale Oceanography

The MOCI largely captured the interannual variability of the individual climate indices and switched from a negative to positive value in 2014 (Figure 2c). This switch was concomitant with a shift in the PDO from a primarily cool phase to a primarily warm phase in 2014. The 2015-2016 El Niño event was reflected in the largest positive MEI values over the 14 years of this dataset as well as a peak in MOCI values.

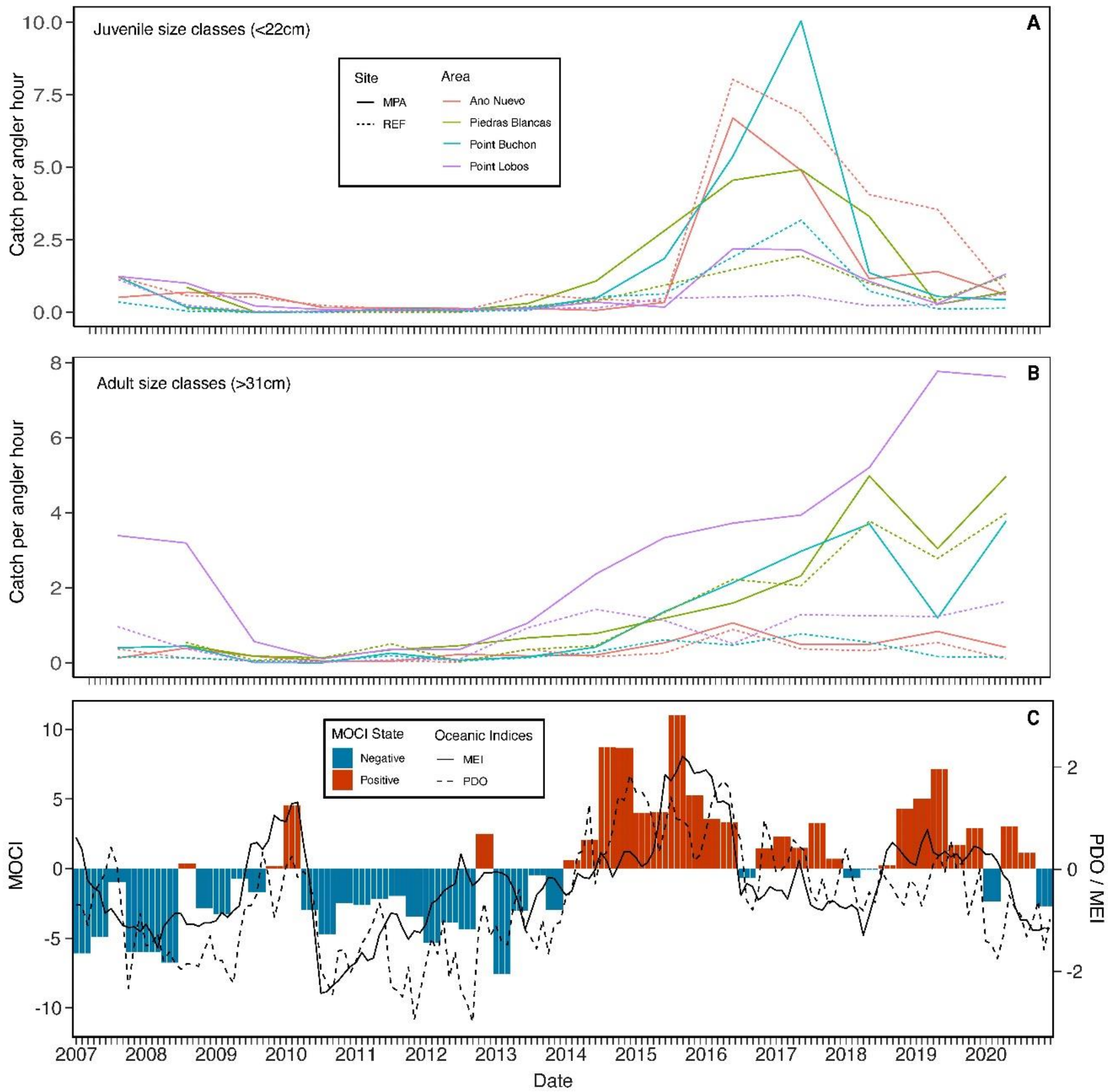


Figure 2. Time series during the study period from 2007-2020 of (A) juvenile (< 22cm) *S. mystinus* CPUE for four MPAs (solid lines) and associated reference sites (dashed lines), (B) the same parameters for adult (> 31 cm) *S. mystinus*, and (C) regional oceanographic indices, including PDO values (dashed line), MEI values (solid line), and positive (red) and negative (blue) MOCI values.

1.3.3. Regional-Scale Oceanography and Blue Rockfish Relative Abundance Cross Correlation Analysis

The cross correlation between MOCI values (e.g., regional-scale oceanographic conditions) and Blue rockfish (*Sebastes mystinus*) CPUE revealed differences between life-history stages. Juvenile *S. mystinus* had a consistent correlation with MOCI values in both MPA and REF sites in all sampling areas (Table 3; Figure 4). In three of four MPAs (Año Nuevo, Point Lobos, and Point Buchon) and two of four REF sites (Año Nuevo and Point Buchon), MOCI values in the summer two years previous had the strongest correlation with CPUE (r = 0.81-0.89). In the other two REF sites, Point Lobos and Piedras Blancas, MOCI values in the spring one year previously had the strongest correlation with CPUE (r = 0.57 and r = 0.66, respectively).

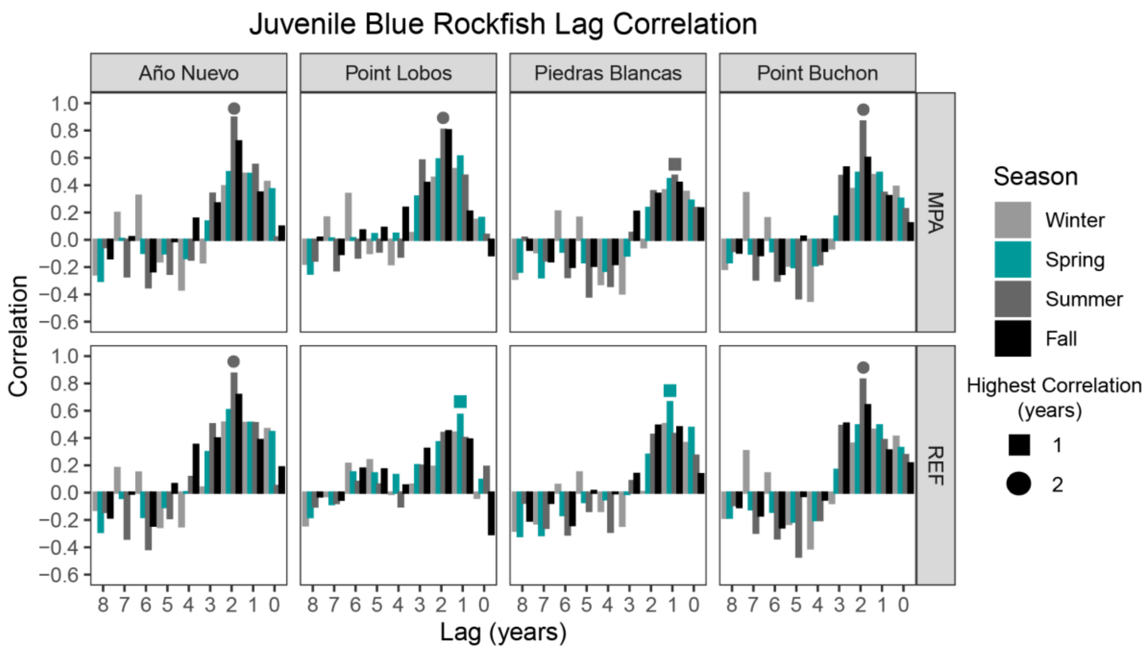


Figure 3. Correlation between lagged MOCI values and juvenile *S. mystinus* relative abundance. The height of bars represents the correlation value from 0-8 year lags. Each color represents a three-month season in the year starting in January and ending in December. Correlations for juvenile *S. mystinus* caught inside of MPAs are represented in the top row, correlations for those caught in REF sites are represented in the bottom row. The top right corner symbol shape and color represents the season (color) and lag (shape) with the highest correlation between MOCI values and juvenile *S. mystinus* CPUE.

Adult *S. mystinus* CPUE had a more consistent correlation with MOCI values within the MPAs than in the REF sites (Table 4; Figure 5). In the MPAs, MOCI values one year prior had the strongest correlation with CPUE in all four areas (r = 0.65 – 0.80), but the seasonality varied across these areas. In three out of four MPAs (Point Lobos, Piedras Blancas, and Point Buchon), CPUE had the highest correlation with MOCI values in spring of the previous year, whereas in Año Nuevo, the highest lag correlation between CPUE and MOCI values occurred in the summer.

The REF sites in the four areas had more variable results, with strong correlations between CPUE and MOCI values zero to three years prior. In Point Lobos, current MOCI values had the highest correlations with CPUE (r = 0.64), whereas Piedras Blancas, the highest correlation was between CPUE and MOCI values the previous spring (r = 0.70). In Año Nuevo, MOCI values in the summer two years prior had the strongest correlation with adult *S. mystinus* CPUE at present (r = 0.67) and in Point Buchon, the highest correlation between MOCI values and CPUE was three years prior in the fall (r = 0.60).

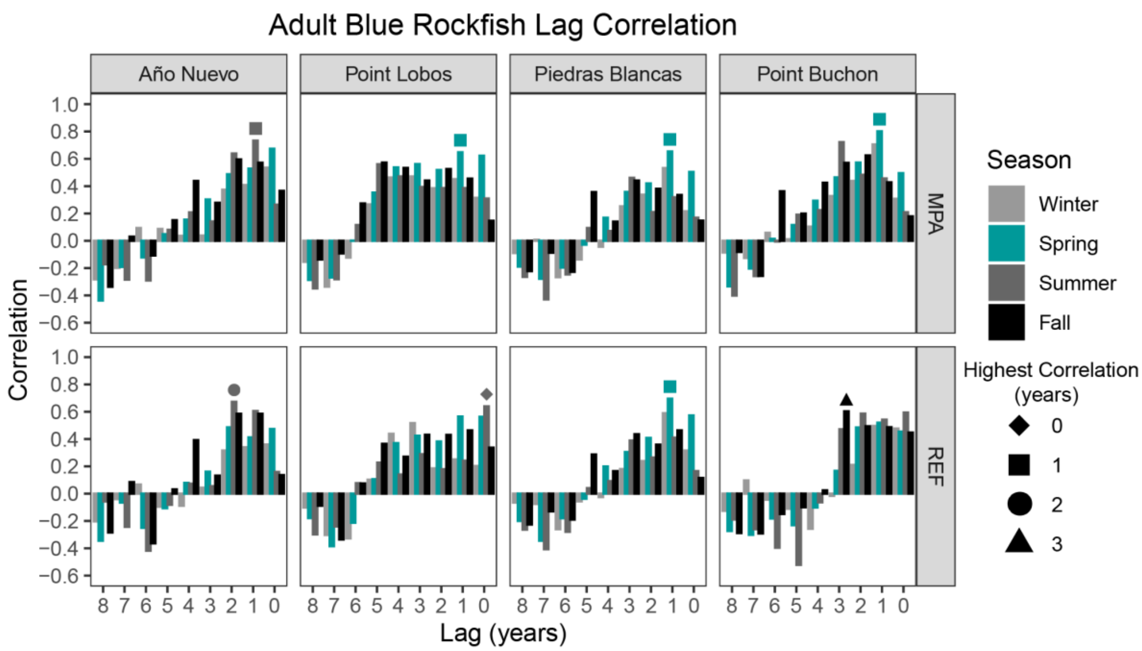


Figure 4. **Correlation between lagged MOCI values and adult *S. mystinus* relative abundance. The height of bars represents the correlation value from 0-8 year lags. Each color represents a three-month season in the year starting in January and ending in December. Correlations for adult *S. mystinus* caught inside of MPAs are represented in the top row, correlations for those caught in REF sites are represented in the bottom row. The top right corner symbol shape and color represents the season (color) and lag (shape) with the highest correlation between MOCI values and adult *S. mystinus* CPUE.**

1.3.4. Local-Scale Oceanography and Phytoplankton Phenology

Concomitant with regional changes in oceanography in the North Pacific (e.g., PDO and MEI state shifts and the arrival of the NPMHW), local sea surface temperatures (SSTs) adjacent to Point Buchon (see Section 2.5 for details) were elevated from 2014-2016 (Figure 5a). The warm water anomalies were particularly evident in the late summer and fall when wind-driven upwelling generally decreases in intensity (Figure 5a). The CUTI revealed consistent levels of upwelling (both in terms of magnitude and variability) over this same time period (Figure 5b). However, the BEUTI revealed a decrease in vertical nitrate flux starting in 2014 that did not return to pre-shift values through the end of 2020 (Figure 5c). Following the transition to warmer conditions (i.e., post 2014), the spring bloom was dampened and shifted timing (Figure 6, Table 2). Based on the TH analysis, spring bloom initiation occurred on average 60 days earlier in the warmer conditions (post-2014) relative to the cooler conditions (i.e., 2009-2013; Table 2). In addition, the peak of the bloom occurred on average 70-110 days earlier after 2014 relative to before 2014.

Table 2. Day of the year for spring phytoplankton bloom initiation and peak from 2009-2020. *Diatom concentration at the peak of the bloom was 99% of the total phytoplankton community for all years.

Year	Bloom Start Day	Bloom Peak Day	*Diatom Concentration at Peak (cells/mL)
2009	110	190	6.69E+06
2010	130	207	3.44E+06
2012	166	210	6.04E+05
2013	121	131	9.17E+05
2014	76	111	1.32E+06
2015	87	137	1.21E+06
2016	82	131	1.06E+06
2017	72	128	1.05E+06
2018	50	85	6.74E+05
2019	69	104	5.10E+05
2020	68	112	1.36E+06

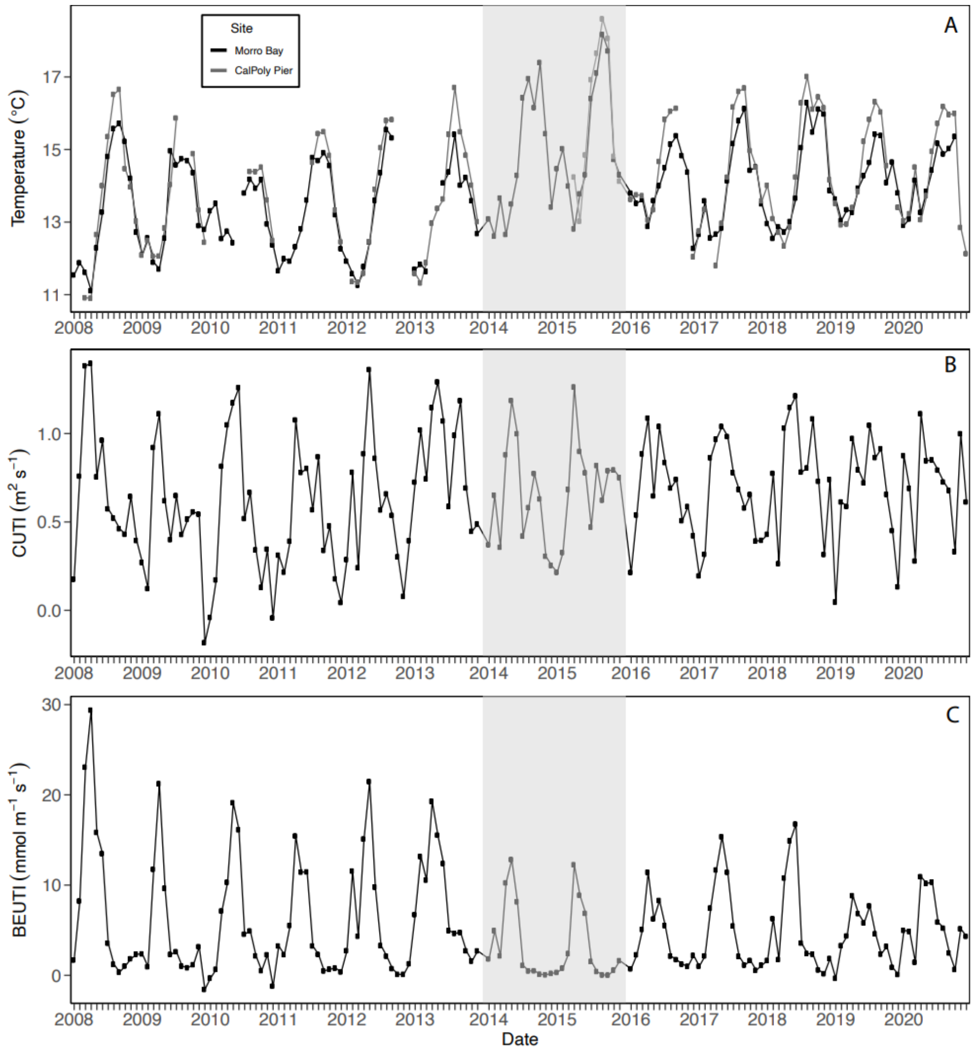


Figure 5. **Time series from 2008-2020 of (A) monthly mean surface temperatures in SLO Bay (black) and Morro Bay (grey), (B) coastal upwelling transport index (CUTI), and (C) biologically effective upwelling transport index (BEUTI). The light grey box denotes the North Pacific marine heatwave (NPMHW) from 2014-2016.**

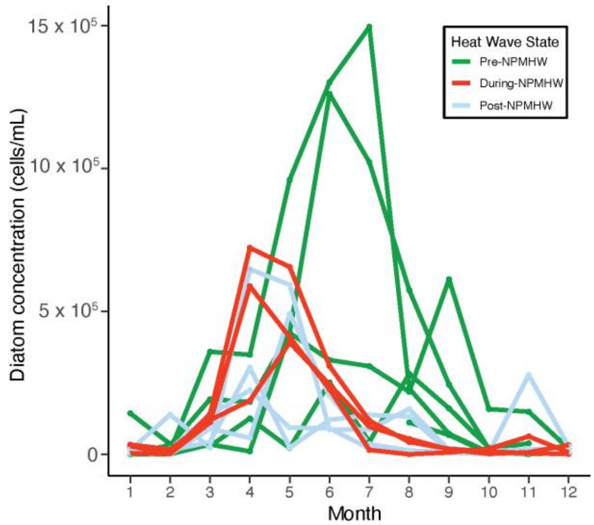


Figure 6. Seasonal variations in diatom abundance in different years. Each line represents a year (averaged within months) and the data have been superimposed over the sample 12-month period. The years are color coded by pre-NPMHW (green), during-NPMHW (red) and post-NPMHW (blue).

1.4. DISCUSSION

Long-term fisheries datasets like CCFRP provide a valuable lens through which to explore population dynamics of marine fishery species. However, changes in environmental conditions driven by variability in oceanographic processes occur at spatial and temporal scales that are independent of MPAs and other spatial management approaches. Therefore, by combining the long-term CCFRP data with a measure of broad-scale oceanographic variability (e.g., MOCI), we were able to assess how environmental conditions and fishing pressure impacted *S. mystinus* population dynamics across different life history stages. Though juvenile and adult rockfishes live in similar areas of the nearshore environment and display high homesite fidelity (Green et al., 2014; Jorgensen et al., 2006), environmental conditions and anthropogenic fishing pressure may affect these life stages differently. Our findings suggest that fishing pressure impacts adult rockfish population dynamics more strongly than juveniles, but that temporal shifts in regional oceanographic conditions appear to alter this relationship and impact adult and juvenile life stages in distinct ways.

1.4.1. Evidence for MPA Effects

MPA effects are well-documented for a range of nearshore species and trophic groups including many in the California Current system (e.g., Hamilton et al., 2021; Ziegler et al., 2022). Populations of Adult *S. mystinus* appear to respond strongly to MPAs. Not only was the CPUE for adult *S. mystinus* lower in REF sites relative to MPAs (Table 1; $p = 0.053$), the MPA effect was most significant 10 years after MPA implementation (i.e., 2017-2020; $p < 0.0001$). This finding is consistent with a large body of literature suggesting that MPA effects may take many years to appear, likely due in part to the life history of the species that may require many years for populations to recover following MPA implementation (Edgar et al., 2014; Hamilton et al., 2021; Micheli et al., 2004; Russ and Alcala, 2004; Ziegler et al., 2022). We hypothesize that this MPA effect is the result of fishing pressure targeting adult populations in REF sites and protection from harvest in MPAs, as has been seen in many other targeted fisheries species (Caselle et al., 2015; Hamilton et al., 2010).

We predicted that there might be notable variation in cross correlation values and lag years between the four MPAs because of differences in MPA size and length of protection (Friedlander et al., 2017; Starr et al., 2015). Contrary to that prediction, the lag year for the highest cross correlation value was highly consistent within MPAs for adult *S. mystinus*. On the other hand, there was more variation in the highest cross correlation values between the MOCI and CPUE for adult *S. mystinus* in REF sites across areas, possibly because of differences in fishing pressure and accessibility. For example, some areas are closer to fishing ports or are located between multiple ports, increasing accessibility and fishing pressure to those areas (Ivens-Duran, 2014; Rienecke et al., 2008), though we did not collect fishing pressure and accessibility information for this study. Overall, the consistent one-year lag with the highest cross correlation values in MPAs compared with REF sites supports the hypothesis that fishing pressure is a major driver of adult rockfish populations (Figure 5).

In contrast to adults, there was no overall effect of protection status on juvenile CPUE (Table 1), consistent with the hypothesis that juveniles benefit less from fishing protection than adults. This could be in part due to the fact that juveniles are generally not targeted and may be too small to be captured by the gear recreational fishers (and CCFRP) generally employ (Palomares et al., 2020). In fact, juvenile blue rockfish may be actively avoided; with few exceptions, captains often leave an area if anglers on their boats are catching juvenile fishes (Captain J. Gavin, personal communication). If juveniles experienced strong pressures in one site type, either from targeted fishing in REF sites or top-down predation in MPAs, we would have expected the relationship between juvenile abundance and oceanographic conditions (e.g., MOCI) to vary with protection status. While it is possible that a neutralizing effect is mitigating these two scenarios, it is more likely, considering the consistency of cross correlation results across protection status (Figure 2a), that changes in environmental conditions are the dominant factor influencing juvenile success.

1.4.2. Investigation of Oceanographic Influence

Changes in oceanographic conditions, like the NPMHW, play a significant role in shaping fish population dynamics (Cheung and Frölicher, 2020; Rogers et al., 2021; Thompson et al., 2022), though species are affected in disparate ways (Cavole et al., 2016). The increases in abundance for both life stages during and after the NPMHW (Figure 2) suggest that both juvenile and adult *S. mystinus* responded to changes in environmental conditions during this time. However, an increase in abundance was not observed in all rockfish species during and after the NPMHW (Hamilton et al., 2021). Rather, the decrease in abundance of many other rockfish species during this same time period resulted in an overall decrease in rockfish diversity inside and outside of the MPAs (Hamilton et al., 2021; Ziegler et al., 2023). While the MOCI provides an understanding of shifts in the broad-scale state of the coastal ocean, nearshore measurements of the physical (e.g., temperature, localized upwelling) and biological (e.g., phytoplankton) environment can provide more precise information about the interplay between oceanographic variability in nearshore ecosystems and *S. mystinus* populations.

The two-year lagged correlation between CPUE of juvenile *S. mystinus* and MOCI indicates that favorable environmental conditions during their pelagic larval stage may be linked to *S. mystinus* recruitment success in 2014 with the onset of oceanographic warming (Laidig et al., 2007; Love et al., 2002; Ralston et al., 2013). While there is variability in the age of juvenile *S. mystinus* less than 22 cm, a large proportion of fish in this size range are likely to be around two years of age (Hannah et al., 2015; Laidig et al., 2003). There is evidence for variability in recruitment events for *S. mystinus* prior to the marine heatwave (Dick et al., 2017); however, data did not extend past 2016, and there are no published datasets on larval recruitment in the region during the NPMHW of which we are aware. With the absence of larval data from the heatwave years, we are unable to directly compare larval success during the heatwave to pre-heatwave years. Our data show the highest CPUE for juvenile *S. mystinus* occurred two years after the onset of warming (e.g., 2016) and persisted for two years after the last warm year (e.g., through 2018, Figure 2a), suggesting that recruitment was strong during the NPMHW, possibly resulting from favorable oceanographic conditions with the onset of warming.

In coastal upwelling ecosystems, warming-induced shifts in the timing and magnitude of upwelling can alter nutrient supply and therefore food availability and food web dynamics (Barth et al., 2007; Brodeur et al., 2006). While adult *S. mystinus* are generally considered to be mid-trophic level predators, juveniles feed at a lower trophic level with preferred prey items such as larvae, pelagic tunicates, hydroids, and euphausiids (Hallacher and Roberts, 1985; Love et al., 2002; Pörtner and Peck, 2010). Therefore, *S. mystinus* populations, especially those of juveniles, may be influenced by changes in food availability, similar to other lower-trophic level fishes (e.g., Peruvian anchoveta [Ayón et al., 2008], Pacific sardine and northern anchovy [Rykaczewski and Checkley, 2008]). In addition, warming-driven changes in shorter time scale processes like upwelling-relaxation patterns, frontal features, and internal waves, can also influence larval dispersal and retention in the nearshore environments (Phelan et al., 2018; Trautman and Walter, 2021; Watson et al., 2010; Wing et al., 1998). Because *S. mystinus* are among the earlier rockfish species to spawn (Singer, 1985) and spawn during the winter when variability in upwelling is highest (García-Reyes and Largier, 2012), their population dynamics may be more strongly influenced by the timing of these physical events. Together, prey abundance and physical forcing both impact post-settlement survivorship and growth for juvenile rockfishes (Laidig et al., 2007; Ralston et al., 2013) and are important considerations at a local scale when exploring the mechanisms that may drive population dynamics.

We used oceanographic data from a nearshore monitoring site adjacent to Point Buchon as a case study to link regional oceanographic changes to local environmental variables and explore potential mechanisms for the observed *S. mystinus* abundance patterns. Consistent with regional warming, surface waters near Point Buchon were warmer during the NPMHW (2014-2016; Figure 5a) relative to the rest of the time-series. Warming generally increases water column stratification and decreases upwelling, which have significant impacts on the onshore and offshore transport of juvenile fish (Cury and Roy, 1989; Fennie et al., 2023). Unfortunately, investigating fluctuations in nearshore circulation patterns on the short time-scales relevant for *S. mystinus* fish spawning events is not feasible given the size range of fish caught within the CCFRP program and the short summertime period over which the fish are caught. However, the CUTI provides evidence for the lack of major changes in the timing and magnitude of seasonal upwelling in the region during the NPMHW (Figure 5b). On the other hand, even with regular seasonal upwelling in the region, the nitrate flux into the surface waters (as indicated by the BEUTI; Figure 5c) was notably lower during and after the NPMHW. This pattern is consistent with the hypothesis that surface warming increases upper-ocean stratification and deepens the nutricline (Behrenfeld et al., 2006; Doney, 2006; Lorenzo et al., 2005; Sarmiento et al., 2004; Zaba and Rudnick, 2016), thereby reducing nutrient flux to the euphotic zone.

Changes in nutrient supply can alter the timing and abundance of phytoplankton blooms and have far-reaching effects on marine food webs, including fish (Asch et al., 2019; Gittings et al., 2021; Platt et al., 2003; Yamaguchi et al., 2022). During the NPMHW, the magnitude of the phytoplankton bloom was lower and the bloom occurred ~ 70-110 days earlier in the season (Figure 6, Table 2). It is important to note that variations in bloom initiation calculated by the TH method can be challenging to interpret given the metric's dependence on the annual median phytoplankton concentration (Brody et al., 2013). On the other hand, peak bloom timing is less sensitive to interannual variations in phytoplankton abundance. Therefore, the TH metric can be appropriate for investigating the match or mismatch between phytoplankton and upper trophic levels because the match-mismatch hypothesis is based on the timing of the peak phytoplankton biomass period (Brosset et al., 2020; Cushing, 1990, 1971). Using this framework, we interpret the earlier spring bloom peaks as early declines of the bloom due to lower nutrient concentrations (Figure 6). In the absence of sufficient nutrients, the bloom may have been unable to persist into the early summer months as it had done prior to the NPMHW (Figure 5; Behrenfeld et al. 2006, Gittings et al. 2018). The lack of a sustained bloom could explain why populations of spring-spawning species such as Kelp and Gopher rockfishes declined during and after the NPMHW, whereas winter-spawning species like Blue and Olive rockfishes did not (Hamilton et al., 2021; Ziegler et al., 2023). Furthermore, winter-spawning species have relatively large embryonic reserves compared to spring-spawning species (Sogard et al., 2008) which may create more resistance to starvation when lower prey concentrations coincide with recruitment. The observed increases in juvenile CPUE from 2016-2018 is consistent with the hypothesis that the timing of the spring bloom during the NPMHW was favorable for *S. mystinus*. Reduced competition from and predation by species that declined during the NPMHW could also help to explain the observed increases in *S. mystinus* juvenile abundance, but this hypothesis would need to be explored further (Baskett et al., 2006). Following the marine heatwave, spring bloom dynamics were highly variable, and diatom concentrations during the spring bloom period continued to decline, with the apparent absence of any consistent spring bloom in post-heatwave years (Figure 6). The decline in juvenile CPUE two years after the final heatwave year (e.g., after 2018) is consistent with the hypothesis that post-heatwave years were no longer favorable for *S. mystinus* recruitment. Interestingly in 2020, the bloom pattern is more similar to the pattern during the heatwave pattern (Figure 6; Figure 8). Assessing this hypothesis using updated juvenile *S.* mystinus CPUE will be an important future direction for this work.

While *S. mystinus* do not feed directly on phytoplankton, changes in phytoplankton abundance are often used as a proxy for changes in overall ecosystem productivity and food availability (Chassot et al., 2010; Woodson and Litvin, 2015). This is an important consideration when interpreting changes in rockfish populations since food availability during the larval critical settlement window and post settlement may disproportionately impact juvenile rockfish survival. Despite lower overall concentrations of phytoplankton, the apparent earlier blooms may have benefited *S. mystinus*, one of the earliest species of rockfish to recruit (Love et al., 2002; Singer, 1985); conversely, many other rockfish species that recruit later may have been impacted negatively by the lack of phytoplankton bloom persistence into June and July (Hamilton et al., 2021). In this context, prey composition may also be an important consideration. Juvenile and adult *S. mystinus* diets have a low percent similarity overlap value compared with other juvenile rockfish species (Hallacher and Roberts, 1985; Singer, 1985), and therefore prey compositional changes can alter rockfish population dynamics. However, we are unable to assess these potential compositional changes with the current dataset.

The mechanism for the increase in adults following a shift to a warmer oceanographic state in 2014 is unlikely driven by changes in recruitment, since those recruit cohorts would have taken several years to appear in adult populations (Figure 2; Table 4). Instead, we hypothesize that adults may have moved into the nearshore environment to seek thermal refuge during this time period, though *S. mystinus* typically display high homesite fidelity (Green et al., 2014; Jorgensen et al., 2006). During the NPMHW, monthly mean temperatures at an offshore buoy near Point Buchon (NDBC buoy 46011; 34.936°N, 120.998°W) were consistently 1-2°C warmer than those from a temperature logger located in the nearshore at a Diablo Canyon Nuclear Power Plant control site outside the influence of the thermal outfall (35.22766°N, 120.87622°W) (Figure 7), particularly during the late spring to early fall upwelling season. This is consistent with prior work that showed upwelling in EBUS can moderate nearshore marine heatwave days compared with farther offshore (Varela et al., 2021). While offshore abundance data would be required to formally evaluate this hypothesis, prolonged warm water temperature anomalies in the offshore surface waters, and the resulting thermal stress, may have caused adult *S. mystinus* to move into the nearshore to seek thermal refuge in cooler upwelled waters. Changes in the timing of the spring bloom may have also affected food availability for adult *S. mystinus.* In general, as surface temperatures increase, productivity decreases, decreasing the preferred planktonic prey of *S. mystinus* further offshore (Fiedler et al., 1991; Love et al., 2002). This hypothesis is supported by lower nitrate flux and shifts in the spring phytoplankton bloom during the marine heatwave (Figure 5c; Figure 6). However, heating events can have other food web impacts. For example, anomalous and unprecedented numbers of Pyrosomes—potential prey for *S. mystinus*—were observed from California to Alaska from 2016-2017 (Brodeur et al., 2018) (Hallacher and Roberts, 1985). Ultimately, the spatial variability of prey may cause *S. mystinus* to seek areas with higher food availability and adds a layer of complexity to our understanding of rockfish population dynamics. More information about the food availability, food preferences, and movement of *S. mystinus*, especially during anomalous warm water events, would allow us to better understand the relative importance of these mechanisms.

Collectively, these findings demonstrate that life history may be a particularly important consideration when assessing the impact of climate variability because differences in life history strategies among different rockfish species may create differential responses, thereby producing a system with winners and losers, even among closely related congeners. It is important to note that our hypotheses for why blue rock populations fluctuated with changes in environmental conditions rely upon the assumption that all CCFRP areas had similar oceanographic patterns as Point Buchon in Central California. While we did not conduct a detailed comparison between these areas, the NPMHW was pervasive across the entire U.S. West Coast (Gentemann et al., 2017), and temperature trends and the sensitivity of seasonal shifts in the timing of major phytoplankton taxa (e.g., diatom vs. dinoflagellate dominance) as a result of warming were similar in both Monterey Bay and SLO Bay (Barth et al., 2020; Fischer et al., 2020). Moreover, climate change is predicted to modify the oceanographic variability in EBUS, with the potential for increased surface warming and stratification, intensified upwelling in poleward regions (and hence mitigated warming in the nearshore and increased offshore transport of phytoplankton in these regions), and shifts in the timing of the spring transition, among others (Bograd et al., 2023). However, there remain significant uncertainties about how these processes will change, and in particular how they might affect ecosystem structure and function (Bograd et al., 2023). Continued monitoring of rockfish in MPAs and co-located reference sites and contextualizing population patterns within a larger environmental context will be critical for testing these hypotheses and better predicting rockfish population dynamics in a changing climate.

1.5. CONCLUSION

Harvest effort and environmental variability are two of the most impactful drivers of fish population dynamics (Shelton and Mangel, 2011). Understanding the intersection between the two is critical to managing exploited species like rockfishes, yet it is difficult to disentangle specific oceanographic processes and their relation to fishing pressure given the complexity of the CCE and lack of spatially resolved environmental data. Using a broad-scale index like MOCI can provide a means to make inferences about rockfish population changes and the environmental conditions that might favor or disrupt recruitment events. Environmental conditions appear to be the dominant factor driving juvenile blue rockfish CPUE. In contrast, given the multiple age classes that comprise the adult population, as well as their status as a target species for both recreational and commercial fishing, fishing pressure may be a more important driver of adult abundance and subsequent CPUE. However, the relationship between environmental variability and adult *S. mystinus* was more variable across time and location.

Our findings have practical applications in fisheries science and stock assessments. Rockfishes are a slow-growing and long-lived species and are generally considered data poor. Considering that species with these life-history traits often experience a management lag (Williams et al., 2010), any predictive capabilities from using oceanographic tools, like MOCI, could potentially help sustainably manage populations. This study provides a framework to assess possible impacts of oceanographic variability on a range of targeted fisheries species on the West Coast. The standardized and consistent sampling design of the CCFRP enabled us to make relative comparisons across the 15-year dataset. In addition, continuing to link CCFRP data with other data sources, such as information on larval abundance, recruitment, and populations in deeper offshore waters will allow to develop and evaluate additional hypotheses to explain variability in *S. mystinus* and other rockfish populations. Most notably, information on the abundance of zooplankton in the region and the larval distribution of *S. mystinus* will be important for linking oceanographic variability with fish populations dynamics.

1.6. SUPPLEMENTAL MATERIAL

Table 3. Highest cross correlation coefficients for juvenile Blue rockfish for each of four areas and two sites.

area	*site*	*season*	*lag*	*correlation*
AN	MPA	JAS	-2	0.8935
BL	MPA	JAS	-1	0.4687
PB	MPA	JAS	-2	0.8654
PL	MPA	JAS	-2	0.8050
AN	REF	JAS	-2	0.8713
BL	REF	AMJ	-1	0.6622
PB	REF	JAS	-2	0.8275
PL	REF	AMJ	-1	0.5701

Table 4. Highest cross correlation coefficients for adult Blue rockfish for each of four areas and two sites.

area	*site*	*season*	*lag*	*correlation*
AN	MPA	JAS	-1	0.7335
BL	MPA	AMJ	-1	0.6534
PB	MPA	AMJ	-1	0.8016
PL	MPA	AMJ	-1	0.6478
AN	REF	JAS	-2	0.6721
BL	REF	AMJ	-1	0.6958
PB	REF	OND	-3	0.6028
PL	REF	JAS	0	0.6389

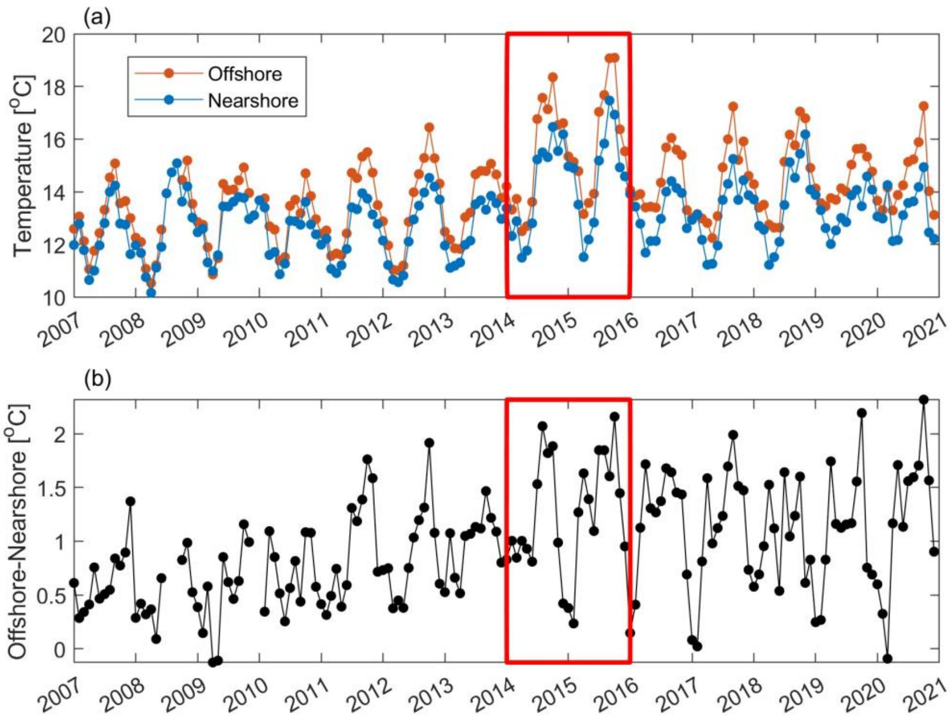


Figure 7. (a) Time series of monthly mean ocean temperatures from the nearshore (blue) and offshore (red). (b) Difference between monthly mean offshore and nearshore temperatures. The red box denotes the NPMHW from 2014-2016.

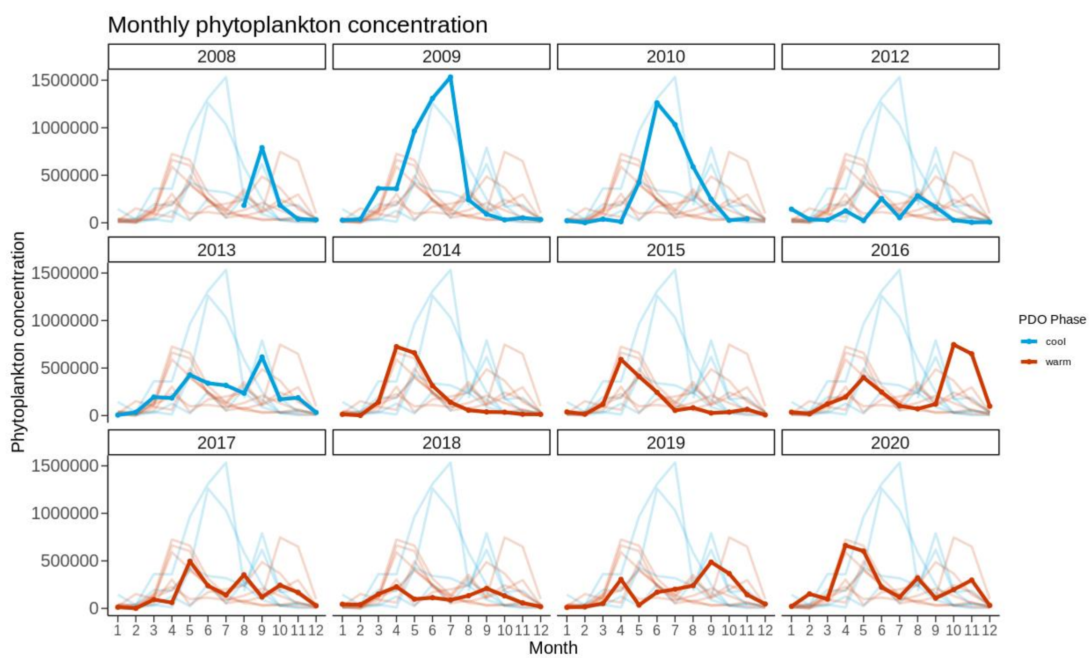


Figure 8. Phytoplankton abundance over the course of the time-series with each year highlighted sequentially (bold line).

Chapter 2. Participation in Collaborative Fisheries Research Improves the Perceptions of Recreational Anglers to Marine Protected Areas.

2.1. INTRODUCTION

Over the last several decades, it has become increasingly clear that effective management of natural resources requires participation and engagement of key stakeholder groups (Charles and Wilson, 2009). Stakeholders often span a diverse set of groups, including extractive users, recreation users, conservation groups, scientists, managers, and the general public. Developing approaches to engage these groups and understand their views is critical to the success of management strategies (Dimech et al., 2009). Engaging stakeholders throughout the management process is essential since it increases satisfaction with management in general while increasing compliance with regulations and decreasing disruptive activities (Ban et al., 2020).

In many cases, the management process relies on scientific information to guide effective decision making. However, especially in the current political climate, there may be mistrust of the science that feeds management decisions by some stakeholders, especially for those groups – such as resource users – whose activities may be restricted (Ordoñez-Gauger et al., 2018). Including potentially distrustful stakeholder groups in data collection through collaborative fisheries research can be an effective way to bring such people into the data collection process, increase their acceptance of scientific results that feed decisions, expand communication between scientists and stakeholders, and ultimately increase stakeholder support of the outcome of management processes (Saarman et al., 2013; Crandall et al., 2019). In addition, collaborative stakeholders can often provide first-hand insight into the resources and species they engage with regularly, which is invaluable information for effective study design (Beierle, 2002). Stakeholders are also more willing to support the conservation of species they engage with regularly (Sawchuk et al., 2015). Despite this, research that integrates the knowledge and expertise of stakeholders during planning and execution is lacking (Mackinson et al., 2011).

Engagement can be especially important in fisheries research where stakeholder groups include both commercial and recreational anglers, as well as conservation organizations (Mackinson et al., 2011). Over the last several decades, scientific data collection for fisheries has become more complex, and management actions and regulations have become more intense (Hilborn, 2012), often prompting strong dissatisfaction and resistance from stakeholder groups (Cowan et al., 2012). Perceptions of how a resource is managed are often more important than the results of scientific study when it comes to support and compliance, and perception is often a function of stakeholder participation (Crandall et al., 2019). Therefore, there is potentially great value in engaging stakeholders in the scientific process since this can improve their perceptions.

One particular area with both strong management actions and strong stakeholder opinions are the marine protected areas (MPAs) along the California coast. MPAs are a specific spatial management strategy used to regulate and restrict a range of human activities, including fishing (Rassweiler et al., 2012). In California, the Marine Life Protection Act of 1999 (MLPA) stipulated the redesign of MPAs to function as a comprehensive network with goals that included the protection of marine life and recovery of exploited species based on scientific guidelines (CDFG [California Department of Fish and Game], 2008). Despite ample research that shows the effectiveness of MPAs for species and community resilience (Lester et al., 2009; Starr et al., 2015; Ziegler et al., 2023), and that MPAs effectively increase abundance and size of target species (Micheli et al., 2004; Lester et al., 2009; Stobart et al., 2009), restriction of fishing activity in these areas has generated opposition to MPAs in the recreational and commercial fishing communities (Jones, 2009; Bennett and Dearden, 2014).

Stakeholder support of fisheries management decisions involving spatial closures might benefit from more thorough engagement of commercial and recreational fishing communities, particularly when those management decisions involve spatial closures (e.g., MPAs). Collaborative study designs of MPA monitoring and research are a potentially important way to build trust between the public and resource managers (Wendt and Starr, 2009; Yochum et al., 2012; Turner et al., 2016). This may not only increase support for MPAs, but also facilitate peer-to-peer communication of the benefits of MPAs to other stakeholders and reduce non-compliant activities such as poaching (Ban et al., 2020). However, data investigating the relationship between collaborative research design and support for management actions supporting these ideas are rare in monitoring programs originally designed to assess fisheries metrics for management decisions. Furthermore, there are few MPA monitoring studies designed to bridge the gap between resource users and resource managers.

The California Collaborative Fisheries Research Program (CCFRP) was designed in part to bridge this gap between scientists and the angling community by engaging these communities in data collection to monitor the MPAs along the coast of California (Wendt and Starr, 2009). The program was developed with input from California fishing communities, the commercial passenger fishing vessel industry (CPFV), commercial and recreational anglers as well as academic researchers and resource managers. The goals of this program were to provide scientifically robust data for stock assessments, engage stakeholders in research and education about marine conservation, and to give anglers a real voice in science and management through collaboration and communication (Wendt and Starr, 2009). In addition to providing high-quality information on the status of nearshore fish populations and communities (Monk and He, 2019; Monk et al., 2021; Taylor et al., 2021), CCFRP also provides an opportunity to gain insight into how participation impacts volunteer angler opinions about MPAs as well as evaluate the success of the statewide MLPA network in the fishing community.

To quantify the impacts of participation in CCFRP on angler opinions, we designed and distributed a survey to all volunteer anglers who participated in the program from 2007 to 2021. This study builds on two previous surveys: a pilot study conducted in collaboration with staff from the National Marine Fisheries Service (NMFS), which was developed and deployed in 2018 through Cal Poly San Luis Obispo (Kosaka, unpubl.), and a survey designed and distributed by CCFRP collaborators to CCFRP volunteer anglers in the Central Coast in 2018 (Mason et al., 2020). Both previous surveys were intended to assess volunteer angler opinions of MPAs, explore angler engagement with CCFRP, and gather information to improve angler retention and participation for individuals affiliated with central California CCFRP institutions. Mason et al. (2020) provided evidence that long-term angler engagement with CCFRP was correlated with more positive views of MPAs on the central California coast (Mason et al., 2020). The overarching goals of the current survey are two-fold: first, to build upon these previous surveys to query volunteer anglers statewide across all six CCFRP institutions which span the length of the California coast, and second, to assess whether CCFRP achieved the original program goals set out by Wendt and Starr (2009).

We included questions designed to assess angler opinions and knowledge of MPA implementation in California, the ecological effects of MPAs, and fisheries management as well as gauge how well CCFRP has met the dual goals of engaging stakeholders and education. We addressed four primary areas: 1) Are opinions about MPAs different after volunteering with CCFRP? Is there evidence of differential patterns in angler opinions related to geographic location or citizen science participation metrics? 2) Are effects of MPAs reflected accurately in CCFRP volunteer angler perceptions of fishery metrics? 3) Has CCFRP impacted angler views on the scientific process, marine conservation, and stewardship? 4) Are CCFRP anglers representative of the general California angling community?

Given their willingness to participate in fisheries research, we predicted that these anglers would have increased positive opinions about the implementation of California MPAs after volunteering with CCFRP, but that these changes in opinions would differ based on region and length of participation. Since research in other locations suggests that support of no-take MPAs increases with reserve age (Navarro et al., 2018), we predicted that there would be a greater percentage of positive opinion changes in the Central California region, where CCFRP has been sampling for 17 years and where MPAs are the oldest. We also predicted that increased participation would increase accurate perceptions of MPA effects on fishes and increase positive perceptions of fisheries management.

This is one of the first studies to explore the benefits of engaging stakeholders in long-term fisheries research, especially with programs that focus on management strategies like MPAs. Importantly, many of the themes in this study test the predictions of the original programmatic goals of engaging stakeholders in fisheries research and conservation education. Our results suggest that CCFRP may provide a framework for enhanced trust and communication between resource managers, scientists, and stakeholders.

2.2. METHODS

2.2.1. Survey Design

The survey was designed with a series of questions that could be answered in approximately 15 minutes (Appendix A). Respondents were asked about how their participation with the CCFRP impacted their opinion of MPAs and fisheries management. They were also asked about their experiences fishing with the CCFRP and their perceptions of fish population dynamics inside and outside of MPAs. These questions were designed to assess educational impacts and how participants in this program perceive the status of marine resources. In addition, we asked for a variety of demographic information and the length of time that respondents had participated in the CCFRP. These questions gave context for analyzing participant responses, helped us compare CCFRP citizen scientists to the broader angling community, and provided a number of additional analytical options.

We converted the survey to an online format using Qualtrics, a survey platform that allows the anonymous collection of survey responses. Respondents 18 years and older provided their consent by agreeing to participate in, filling out, and submitting the survey through Qualtrics. Qualtrics uses Transport Layer Security (TLS) which encrypts communications. Data collected in this format are secure and confidential because of TLS and the exclusion of any personally identifiable information. We also provided paper copies of the survey on a case-by-case basis to anglers who were unable to access or preferred not to use the online survey format. No personal identifying information was requested or recorded on the paper-based survey and therefore survey respondents remained anonymous. Our methods were approved by the Cal Poly Human Subjects Institutional Review Board under approval #2021-144.

2.2.2. Survey Distribution

We recruited survey participants via email inquiries as well as verbal recruitment during CCFRP summer research activities. We distributed surveys to 1,386 volunteer anglers via an outreach email (Appendix C) drafted by the CCFRP Statewide Coordinator. Recipients of the survey were past and present volunteer anglers on each institutions' email list. We did not send emails to volunteer anglers who had been asked to be removed from the list for several reasons (e.g., moved out of the area). Reminder emails were sent by each of the CCFRP institutions to their region's volunteer anglers at two, three, and four week intervals after the initial email was sent. We gave all survey participants a copy of the Informed Consent Form (Appendix B), which included the name and email addresses of project researchers, and invited survey participants to contact the project researchers for information on the results of the study upon completion.

2.2.3. Analyses

2.2.3.1. Volunteer Opinion Changes

To investigate changes in volunteer angler opinion, we asked survey participants their opinions about the creation of MPAs in California on an ordinal scale (positive to negative) before and after volunteering with the CCFRP. To obtain opinion change values from one respondent, we assigned numerical scores to their answers (positive= 1; somewhat positive = 2; neutral/no opinion = 3; somewhat negative = 4; negative = 5) and subtracted the 'after' score value from the 'before' score value to obtain a difference. A respondent with a negative difference was assigned to the category ‘negative change’, a positive difference was ‘positive change’, and if the difference was zero, the respondent was categorized as ‘no opinion change’.

We used a multinomial logistic regression from the nnet R package (Ripley and Venables, 2023) to test the effects of volunteer participation (measured in number of trips taken with CCFRP) and region on volunteer opinion change. All analyses were performed using R Statistical Software (version 3.6.2; R Core Team 2019).

2.2.3.2. Perceived vs Realized MPA Effects

We performed three separate chi-square tests of equal frequency to test whether statewide volunteer anglers perceived a difference in abundance, size, and species diversity inside or outside MPAs, which allowed us to determine whether the frequencies of each answer category are significantly different. We performed the same chi-square tests for each region to compare differences in perception across the state. We then made comparisons to ecological data collected over the last 15 years on the Central Coast and over the last five years in Southern and Northern California. We examined results from a report that utilized these data for overall fish abundance, size, and diversity for all paired MPA and reference sites sampled by CCFRP institutions (Hamilton et al., 2021).

2.2.3.3. CCFRP Educational Impacts

We analyzed several questions that gave insight into the education impacts of the CCFRP. For instance, we asked anglers what they had learned while volunteering with the CCFRP, what resources they used to learn about the data they helped to collect, and why they volunteered on their last CCFRP trip. When analyzing questions with an open ended ‘other’ option, we read each answer and determined whether it fell within the provided answer categories. If the written answer clearly aligned with an answer category, the written answer was reclassified into that category. If the open-ended answer did not clearly align with an answer category, it was left as ‘other’. Responses to questions where multiple answers were allowed but where selected answers contradicted one another were removed from the analysis. For example, we asked respondents if they had learned anything that they found useful while volunteering with the CCFRP. If a respondent indicated that they had not learned anything that they found useful while volunteering for CCFRP, but also selected a learning category, the entire response was removed.

2.2.3.4. CCFRP Anglers vs the Broad California Angling Community

Age, identity, education, and income were the main demographic characteristics asked of participants as well as the zip code of their primary residence. We characterized these categories and compared the distribution of answers against distributions of demographic data from a NOAA-NMFS California recreational fishing expenditure study in 2020 (Lovell et al. *in prep*) using a chi-square goodness of fit test for each demographic with a comparable answer category.

2.3. RESULTS

2.3.1. Survey Response Rate

We received 259 completed surveys of 1,386 distributed surveys. The overall response rate was 18.7%, though the response rate varied by institution and region (Table 5).

Table 5. Overall survey response rates, and response rates by region and CCFRP institution

Category	*Surveys distributed*	*Responses (n)*	*Response rate*
Overall Response Rate	1,386	259	18.7%
Region			
Northern California	246	71	28.9%
Central California	860	99	11.5%
Southern California	280	89	31.8%
CCFRP Institution			
Cal Poly Humboldt	86	21	24.4%
Bodega Marine Laboratory, UC Davis	160	50	31.3%
Moss Landing Marine Laboratories	626	63	10.1%
Cal Poly San Luis Obispo	234	36	15.4%
Marine Science Institute, UCSB	123	22	17.9%
Scripps Institution of Oceanography	157	67	42.7%

2.3.2. Volunteer Opinion Changes

Overall, statewide anglers predominantly had no self-reported change in opinion about the creation of MPAs in California after volunteering with CCFRP (58.2%), while 39.5% had a positive change in opinion and only 2.3% had a negative change in opinion. The log odds of having a positive change in opinion compared with no change in opinion decrease if participants are from the Northern region compared with the Central region and increase if participants are from the Southern region compared with the Central region (Table 6). Of those who had a change in opinion, 94.4% had a positive change in opinion and 5.6% had a negative change in opinion. Volunteer anglers who had a change in opinion in each region predominantly had a positive change in opinion that was statistically significant (91.3%, 93.3%, 97.4% in the North, Central, and South, respectively; Table 8). Volunteer anglers who did not have a change in opinion, predominantly started out with a positive view of the creation of MPAs in California (Figure 9).

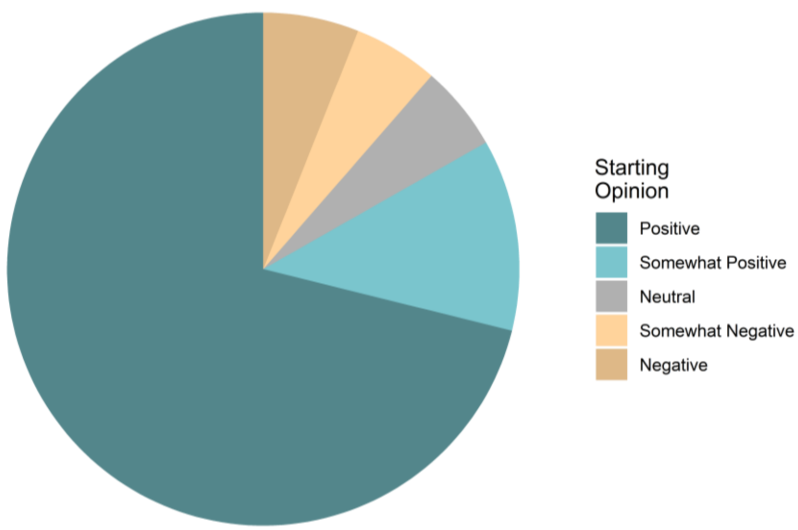


Figure 9. Opinions of CCFRP volunteer anglers about the creation of MPAs in California if there was no change in opinion.

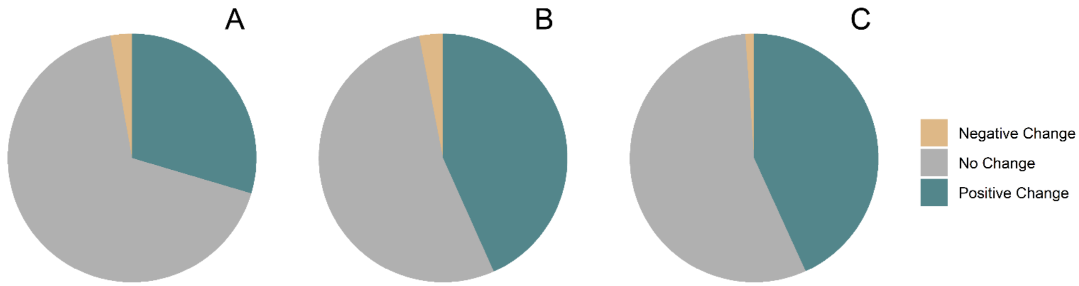


Figure 10. Opinion change percentage in the (A) Northern, (B) Central, and (C) Southern California region after taking at least one trip with CCFRP in the MPA.

Table 6. Log odds of having a positive or negative change in opinion by region and number of trips taken with CCFRP. Central California was the baseline against which Southern and Northern California were compared.

Category	*Positive Change*	*Negative Change*
Region		
Southern California	0.134	-0.854
Northern California	-0.270	0.030
Number of Trips		
2-5	0.099	0.181
6-10	1.116*	1.650
11-19	0.533	-8.190
20+	0.865	1.243

*p < 0.05

2.3.3. Perceived vs Realized MPA Effects

We compared empirical biological results inside and outside of MPAs with CCFRP volunteer angler perceptions of fish size, abundance, and diversity. Hamilton et al. (2021) analyzed statewide CCFRP data for a report that synthesized key biological findings from the program from 2007-2020 and found that 71% of species were more abundant inside MPAs and 79% of species were larger inside MPAs. Hamilton et al. (2021) and Ziegler et al. (2023) also found that diversity recovered more quickly inside of MPAs following large-scale oceanographic disturbances.

CCFRP anglers from all regions perceived that they caught more fishes inside of MPAs ($\chi^2 = 138.86$; $p < 0.0001$), bigger fishes inside of MPAs ($\chi^2 = 85.45$; $p < 0.0001$), and a greater diversity of fishes inside of MPAs ($\chi^2 = 99.53$; $p < 0.0001$). These results are consistent across all regions (Table 7; Figure 3) and across participation levels (Table 7; Figure 14).

Table 7. Chi-square values for participant responses when asked if they perceived catching more fishes, larger fishes, and a greater diversity of fishes within MPAs, in areas open to fishing, or no difference.

Category	*Abundance χ^2 value*	*Size χ^2 value*	*Diversity χ^2 value*
Region			
Southern California	46.571***	15.474***	21.806***
Central California	65.100***	53.525***	58.897***
Northern California	28.550***	23.081***	26.324***
Number of Trips			
1	23.545***	20.333***	23.412***
2-5	50.333***	34.083***	13.642 *
6-10	19.760***	13.130 **	17.360 **
11-19	22.889***	26.000***	30.769***
20+	26.373***	14.000***	18.471***

**p<0.01; **p<0.001; *** p<0.0001

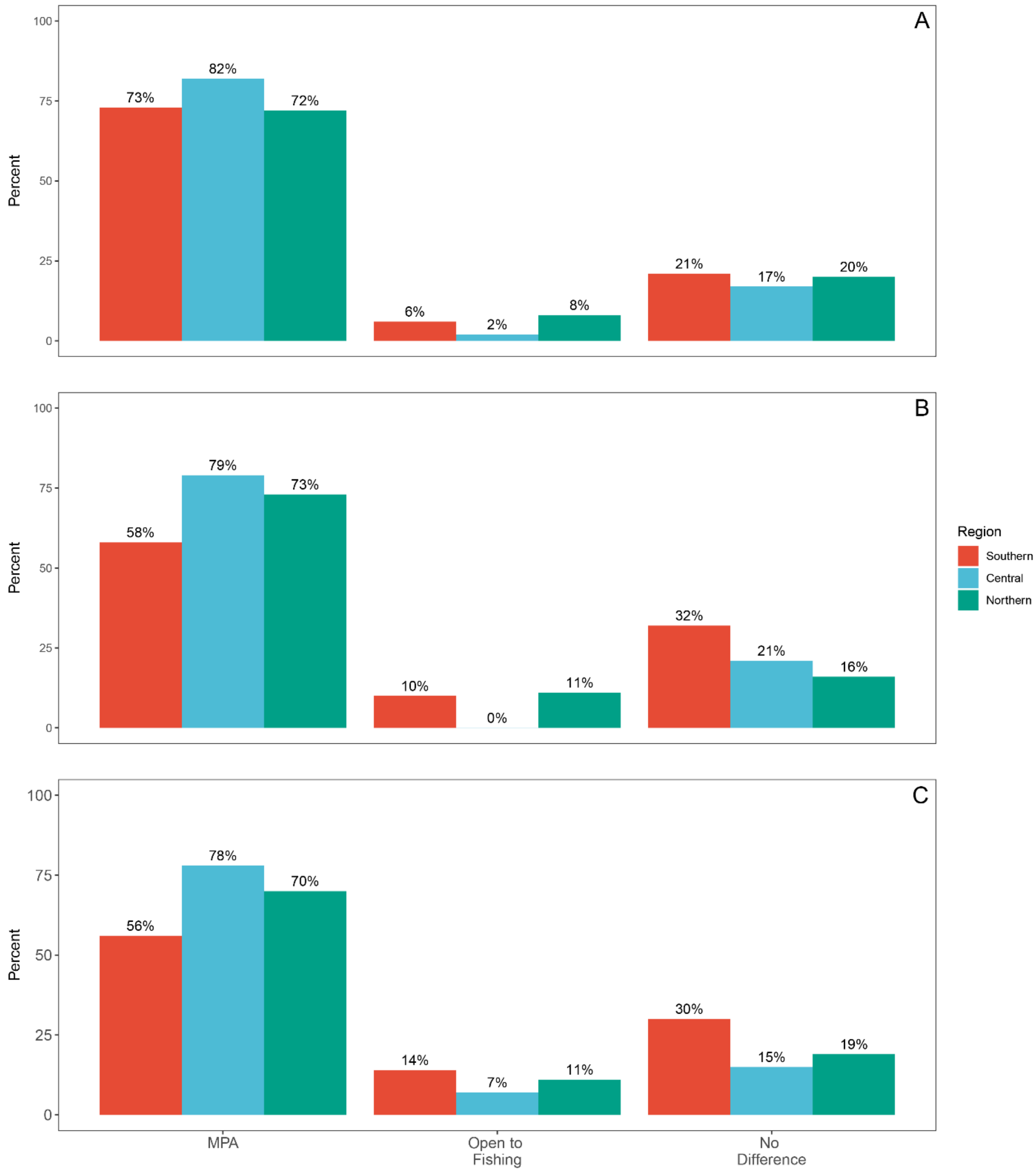


Figure 11. Percentages of respondents who selected that they perceived that they caught (A) a higher abundance of fishes, (B) larger fishes, and (C) a greater diversity of fishes within MPAs, areas open to fishing, or no difference in Southern (red), Central (blue), and Northern (green) California.

2.3.4. CCFRP Educational Impacts

When respondents were asked what they learned as a CCFRP volunteer that they found useful, 98.5% of respondents selected that they learned at least one thing from a list of responses (Appendix A) or wrote a response of something else that they had learned. Only four respondents

(1.5%) indicated that they had not learned anything that they found useful. The most selected answer category (67.5%) indicated that volunteer anglers learned how fishing data can be used in fisheries management. This answer category had more responses than all others except for the selection that volunteer anglers learned about techniques to descend groundfish back to depth while volunteering for CCFRP (54.1% response rate). Only 1.9% of respondents indicated that they were not interested in learning about the data that CCFRP collects (Figure 15)

When asked the primary reason they might enjoy fishing with CCFRP inside of an MPA, significantly more respondents answered that they enjoyed collecting scientific fishing data over catching larger fish, a greater quantity of fishes, multiple species, or no preference for fishing in an MPA ($\chi^2 = 299.66$; $p < 0.0001$; Figure S12). Lastly, the number of anglers that responded yes to whether they tell their friends about CCFRP was significantly higher than those that responded negatively ($\chi^2 = 211.59$; $p < 0.0001$; Figure 16)

2.3.5. CCFRP Anglers vs the Broad California Angling Community

CCFRP volunteer anglers are predominantly male (83%) and over the age of 55 (59%). The highest proportion of answers regarding education indicate that most CCFRP anglers hold a bachelor's degree (Table 9). A California fishing expenditure study from 2020 indicates that anglers from the broad California angling community are male (86%), over the age of 55 (58%), and have a bachelor’s degree (32.5%) (Lovell et al., *in prep*). Education was similar for CCFRP anglers across region (Figure 13). Interestingly, age was not the same between regions for CCFRP anglers (Figure 12), with a higher percentage of anglers over the age of 55 in Central California (73.5%) than in Southern California (55.7%) or Northern California (46.5%). In Central California, there was a much higher percentage of respondents over the age of 64 than in either other region, and in Northern California there was a higher percentage of respondents age 25-34 than in the other regions.

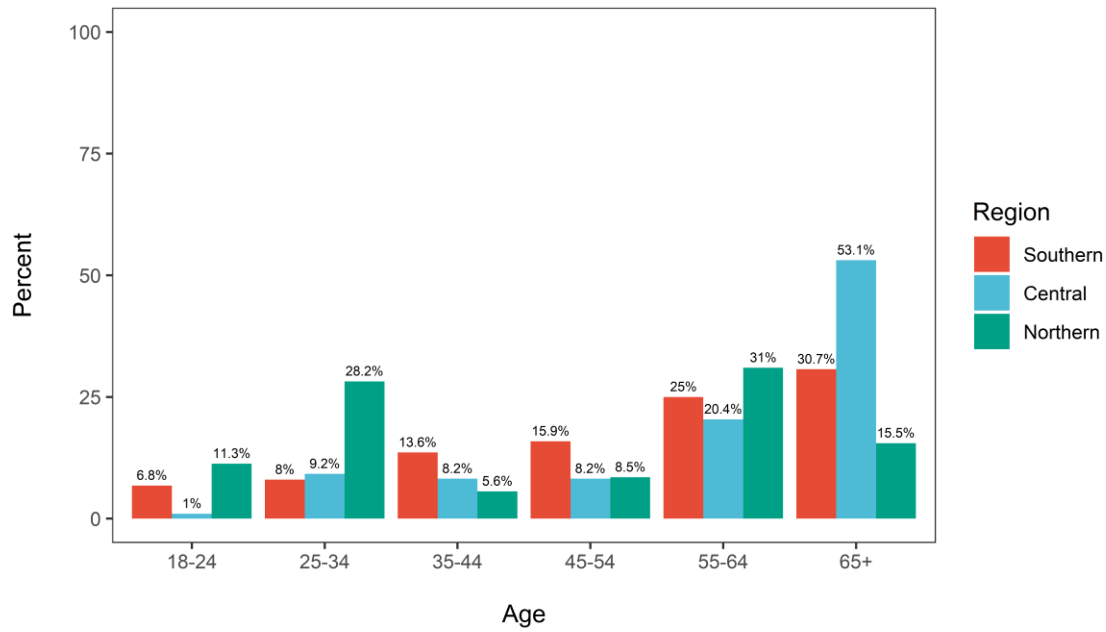


Figure 12. Percentages of respondents in each age category in Southern (red), Central (blue), and Northern (green) California.

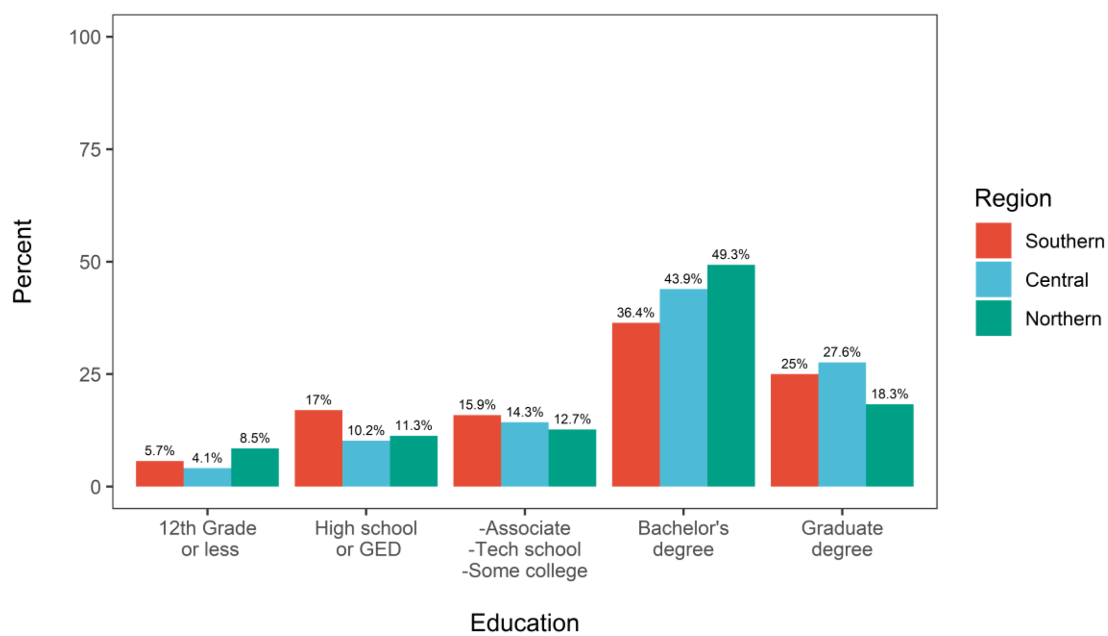


Figure 13. Percentages of respondents in each education category in Southern (red), Central (blue), and Northern (green) California.

2.4. DISCUSSION

Previous research indicated that long-term engagement with anglers can positively impact opinions about the creation of marine protected areas but was focused on one region of the California coast (Mason et al., 2020). Our research confirms these findings and provides evidence that these results are generally consistent statewide. In general, the anglers had positive opinions of MPAs before and after volunteering with the CCFRP. These changes in opinions did vary with length of participation, which we measured in the number of CCFRP trips that the anglers participated in. Anglers who volunteered for six or more CCFRP trips had a higher incidence of positive opinion change, indicating that long-term engagement with collaborative fisheries research programs has beneficial impacts, and more frequent interactions with stakeholders may improve opinions of MPAs. However, those who took part in fewer trips still had a high frequency of positive opinion change, suggesting that any amount of participation could help the CCFRP to engage stakeholders in an impactful way.

Interestingly, changes in opinion did not vary regionally as we originally predicted. Since MPA implementation varied temporally in each region and past research supports the idea that recreational anglers are more supportive of no-take MPAs when those areas have been established for longer (Navarro et al., 2018), we predicted regional variation with Central California showing the highest percentage of positive opinion changes. While the Central California region did have a high percentage of respondents whose opinion of MPAs improved after volunteering with the CCFRP, the proportion of positive opinion change was not statistically higher than the Southern or Northern California regions (Figure 10). Further, the highest proportion of responses indicated that angler opinions did not change after volunteering with the CCFRP in all regions. However, of those respondents, a significantly higher proportion of anglers had a positive opinion of MPAs before volunteering with CCFRP. This is encouraging since we interpret this to mean that CCFRP volunteer anglers who started with a positive opinion of MPAs do not change their minds, and those who started with less than a positive opinion had an increase in opinion statewide.

CCFRP volunteer anglers perceived that they caught fishes in greater quantities, of larger sizes, and with greater diversity inside of MPAs than outside of them statewide. Participants had fished inside of an MPA with CCFRP and were therefore qualified to give their opinion on fish population dynamics within and outside of protected waters. Perceptions of increased relative abundance and size in MPAs were consistent with ecological findings from the CCFRP program (Hamilton et al., 2021). Participants also noted a higher diversity of fishes inside of MPAs. While there are studies that show that protection increases or conserves diversity (Halpern and Warner, 2002), diversity indices indicate that MPA effects are nuanced, though recent research has shown that MPAs do help to maintain diversity (Ziegler et al., 2023). Detecting such nuance was beyond the scope of the angler survey, although perception of higher diversity within the MPA was encouraging.

Anglers' perception of higher fish abundance, size, and diversity remained consistent regardless of region, which shows that CCFRP anglers consistently noted differences within and outside of MPAs in all California regions, despite some regional differences in opinions of MPAs. These perceptions were also consistent across all levels of participation suggesting that anglers noticed differences in fish populations within MPAs after volunteering with CCFRP for any number of trips. These findings underscore the importance of engaging stakeholders in the data collection process. First-hand experiences, coupled with peer-to-peer communication from within the stakeholder group, may help to shift the perspective of the larger California angling community towards spatial management tools, like no-take MPAs.

Interestingly, despite their perceptions and knowledge of MPA effects on abundance, size, and diversity, a significantly higher proportion of anglers indicated their motivation for fishing with the CCFRP was to aid in collecting scientific data. These anglers have identified a motive to fish beyond the fish that they catch. Research on non-catch motivation for anglers showed that non-catch motives such as enjoying the natural environment and being social may be just as important, if not more so, than catch related motives (Fedler and Ditton, 1994). We stipulate that non-catch motives that are based in science are also important but may only occur if stakeholders feel engaged in data collection. Understanding angler motivations can help managers to target specific groups of stakeholders by designing outreach and educational programs to better fit the stakeholders' interests (Brinson and Wallmo, 2017).

Another goal identified at the outset of the program was to increase transparency of how science and the data obtained by stakeholders would be used to inform management decisions. Results from this survey show the CCFRP has met and exceeded this goal statewide. Most participants (98%) are interested in learning about the data they helped to collect and use CCFRP resources to do so. The resources available to volunteer anglers to learn about CCFRP data are post-trip data briefings after each trip, the annual newsletter, and attending annual data workshops. Additionally, most participants have discussed the CCFRP with their peers (95%), which may help to improve opinions of MPA research in the broader angling community. These results do not vary by region, indicating that in all areas where anglers participate with the CCFRP, they are more educated about the status of marine resources, more interested in learning about the information they collect, and more excited to help collect scientific data than the typical angler in California. Though this may be unsurprising given their willingness to participate in the angler survey.

There are some limitations to the scope of the survey considering that CCFRP volunteer anglers are a stakeholder group with unique qualities compared with other anglers. For instance, CCFRP volunteer anglers rated themselves as more conservation-minded than their peers, though this is unsurprising given their commitment to fishing with a scientifically robust, collaborative fisheries program like CCFRP. However, since CCFRP volunteer anglers are demographically similar to the broader California angling community, we believe that engaging other anglers in research may help to improve overall opinions about MPAs in California, particularly in communities where there has traditionally been some opposition to spatial management measures. Future programs could focus on attracting an ever more diverse set of volunteers (e.g., younger anglers, more women) in order to provide a better picture of the angling community as a whole.

2.5. CONCLUSION

Effective management is more likely to occur when there is widespread stakeholder buy-in with management strategies. Without community support, these strategies may be met with hostility and noncompliance and may require a significantly higher financial outlay for enforcement (Van Diggelen et al., 2022). All fisheries research involving spatial management approaches should include stakeholder groups who can provide peer-to-peer communication of the importance of management strategies and goals as well as enforcement of regulation from within the stakeholder group. Ideally, MPA research involves stakeholders through all phases of MPA implementation, from planning to monitoring, in order to develop awareness, support, trust, and transparency (Van Diggelen et al., 2022). Our research bolsters the idea that involving stakeholders in MPA research can increase positive opinions of protected areas (Mason et al., 2020).

The general public, including most stakeholders, may not read scientific literature. So, while there is a large body of literature showing that MPAs are effective tools for ecological restoration with regards to fish abundance, size, and diversity, especially for targeted fish populations (Caselle et al., 2015; Hamilton et al., 2021; Ziegler et al., 2023), public perception could remain antagonistic towards regulation without meaningful engagement. No matter how many studies show positive MPA effects, such as were shown with CCFRP data, management actions may continue to fall short of their goals without meaningful community engagement. While scientific results that show positive MPA effects are extremely encouraging from a conservation standpoint, stakeholder perceptions of fisheries resources may be just as important as the result of scientific study (Murphy et al., 2018). It is therefore incredibly important to have a shared understanding of these resources between fisheries scientists, managers, and stakeholder groups. One important and often underutilized way to reach this understanding is for scientists to communicate the results of their scientific studies, which is what makes the CCFRP so valuable. Wendt and Starr (2009) recognized the importance of this consensus, and one main goal of the CCFRP was reaching a shared understanding between stakeholders and policy makers of nearshore groundfish population dynamics through collaboration

The CCFRP has met its dual goals of generating scientifically robust information and engaging stakeholders (Wendt and Starr 2009). Since its inception, the CCFRP has collected data on 212,649 fishes from 101 species; these data have contributed to nine peer reviewed publications, three technical reports, 13 theses, and three stock assessments. The CCFRP has engaged 1,816 volunteer anglers, 31 vessels, 61 captains, and 175 crew members. Long-term participation in this program has improved volunteer angler opinions of marine protected areas statewide. Regularly collecting extensive data on the stakeholders who participate in collaborative fisheries research is a valuable tool to assess the success of management actions in the recreational angler community. Collecting these data on angler perceptions and demographics is a model that should be adopted by all collaborative fisheries monitoring programs. Doing so would allow for the assessment of ecological and societal outcomes.

2.6. SUPPLEMENTAL MATERIALS

Table 8. Percent change in opinion for multiple categories.

Category	*Negative Change*		*No Change*		*Positive Change*	
Overall	2.3%	(n = 6)	58.2%	(n = 149)	39.5%	(n = 101)
Region						
Northern California	2.8%	(n = 3)	67.6%	(n = 52)	29.6%	(n = 42)
Central California	3.1%	(n = 2)	53.6%	(n = 48)	43.3%	(n = 21)
Southern California	1.1%	(n = 1)	55.7%	(n = 49)	43.2%	(n = 38)
Number of Trips						
1	1.8%	(n = 1)	67.9%	(n = 38)	30.4%	(n = 17)
2-5	1.9%	(n = 2)	65.0%	(n = 67)	33.0%	(n = 34)
6-10	5.1%	(n = 2)	38.5%	(n = 15)	56.4%	(n = 22)
11-19	0.0%	(n = 0)	54.5%	(n = 18)	45.5%	(n = 15)
20+	4.0%	(n = 1)	44.0%	(n = 11)	52.0%	(n = 13)
Fishing Industry						
Yes	1.4%	(n = 1)	66.2%	(n = 47)	32.4%	(n = 23)
No	2.7%	(n = 5)	55.1%	(n = 102)	42.2%	(n = 78)
Resource Management						
Yes	1.4%	(n = 2)	66.0%	(n = 95)	32.6%	(n = 47)
No	3.6%	(n = 4)	48.2%	(n = 54)	48.2%	(n = 54)
Age						
18-24	0.0%	(n = 0)	73.3%	(n = 11)	26.7%	(n = 4)
25-34	2.8%	(n = 1)	80.6%	(n = 29)	16.7%	(n = 6)
35-44	4.2%	(n = 1)	62.5%	(n = 15)	33.3%	(n = 8)
45-54	0.0%	(n = 0)	57.1%	(n = 16)	42.9%	(n = 12)
55-64	62.5%	(n = 4)	54.7%	(n = 35)	39.1%	(n = 25)
65 +	0.0%	(n = 0)	48.3%	(n = 43)	51.7%	(n = 46)
Education						
High school or equivalent	0.0%	(n = 0)	73.3%	(n = 11)	26.7%	(n = 4)
Associate degree or tech school	1.5%	(n = 1)	50.7%	(n = 35)	47.8%	(n = 33)
Bachelor degree	3.6%	(n = 4)	56.4%	(n = 62)	40.0%	(n = 44)
Graduate degree	1.6%	(n = 1)	66.1%	(n = 41)	32.3%	(n = 20)

Table 9. Demographic information of CCFRP volunteer anglers for categories of age, identity, education, and income.

Demographic Category	*Number of respondents*	*Percent of respondents*
Age		
18 – 24	15	5.8%
25 – 34	36	13.8%
35 – 44	25	9.6%
45 – 54	29	11.2%
55 – 64	65	25.0%
65 +	90	34.6%
Identity		
Male	216	83.1%
Female	38	14.6%
Non-binary	1	0.4%
Prefer not to state	5	1.9%
Education		
Less than high school	0	0%
High school degree or equivalent	15	5.8%
Associate degree or technical or professional school	33	12.7%
Some college but no degree	38	14.7%
Bachelor degree	111	42.9%
Graduate degree	62	23.9%
Income		
< $25,000	10	3.9%
$25,000 – $34,999	14	5.5%
$35,000 – $49,999	18	7.0%
$50,000 – $74,999	29	11.3%
$75,000 – $99,999	43	16.8%
$100,000 – $149,999	50	19.5%
$150,000 – $199,999	30	11.7%
> $200,000	28	10.9%
Decline to state	34	13.3%

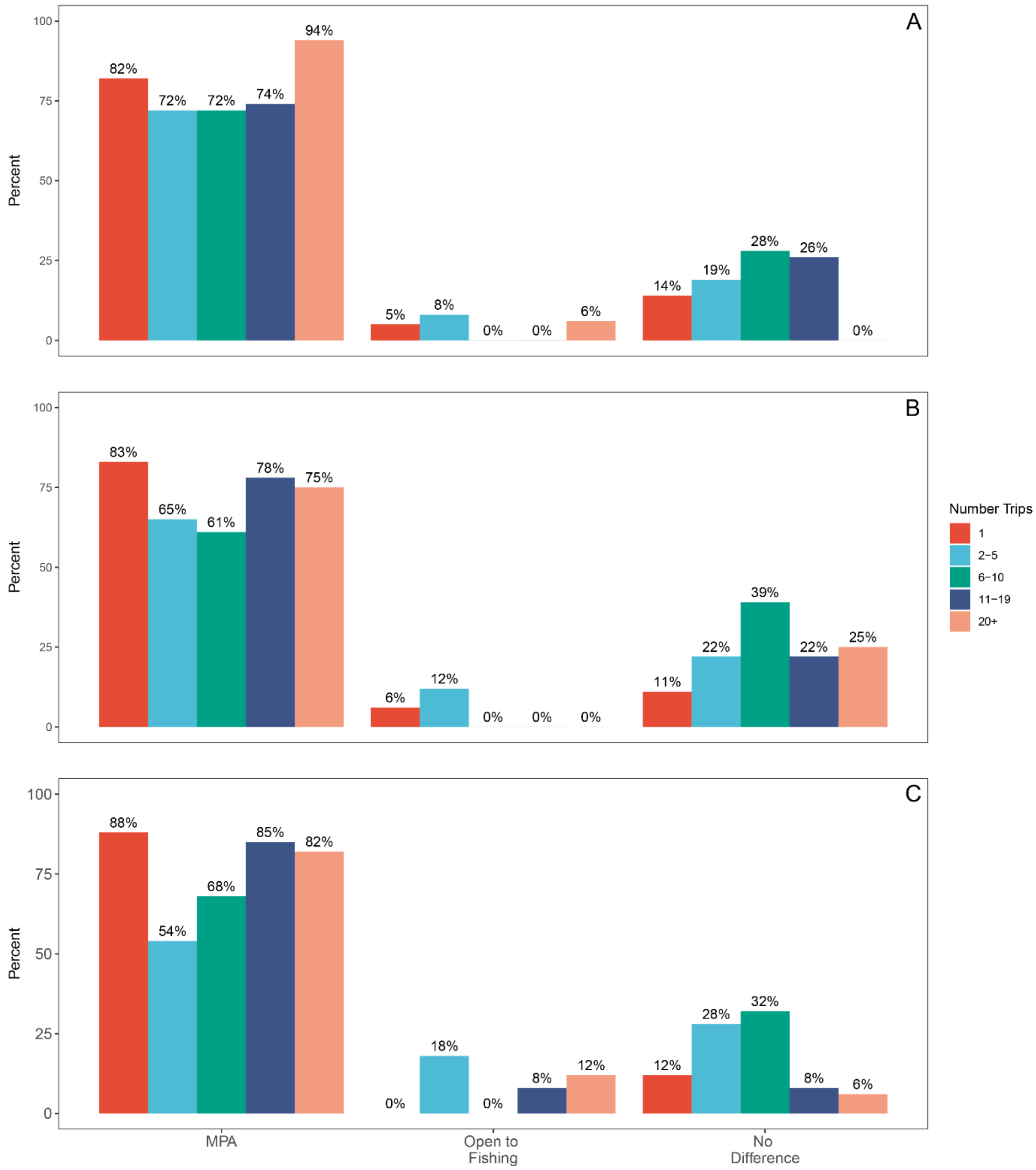


Figure 14. Percentages of respondents who selected that they perceived that they caught (A) a higher abundance of fishes, (B) larger fishes, and (C) a greater diversity of fishes within MPAs, areas open to fishing, or no difference using number of trips with CCFRP as a measure of participation.

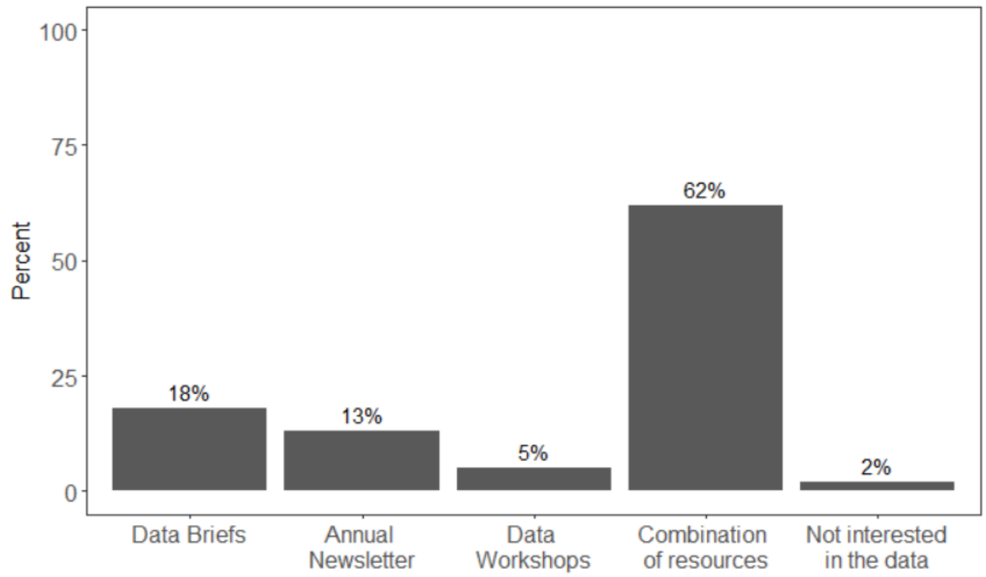


Figure 15. Percentages of respondents who used CCFRP resources to learn about the data that they helped to collect.

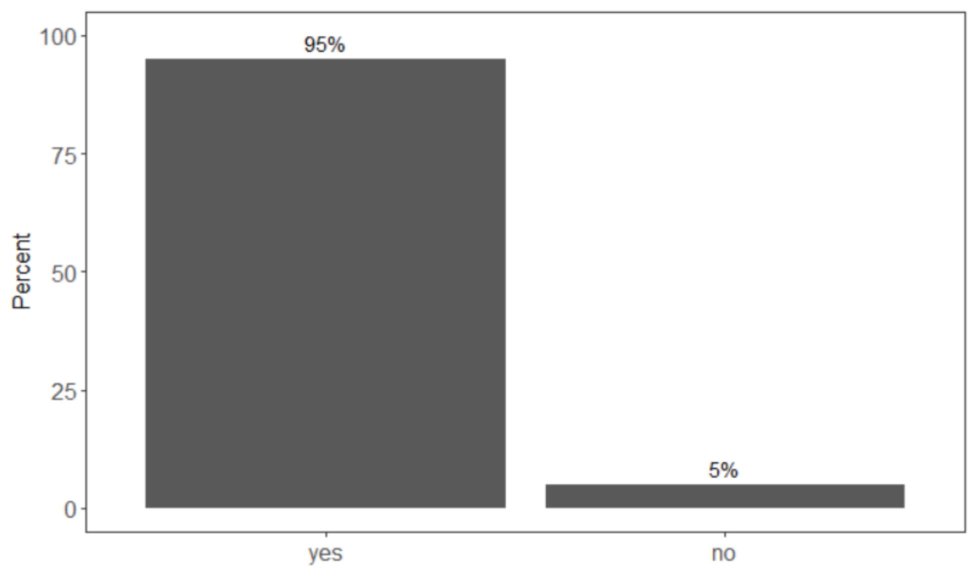


Figure 16. Percentages of respondents who communicated about CCFRP to their peers.

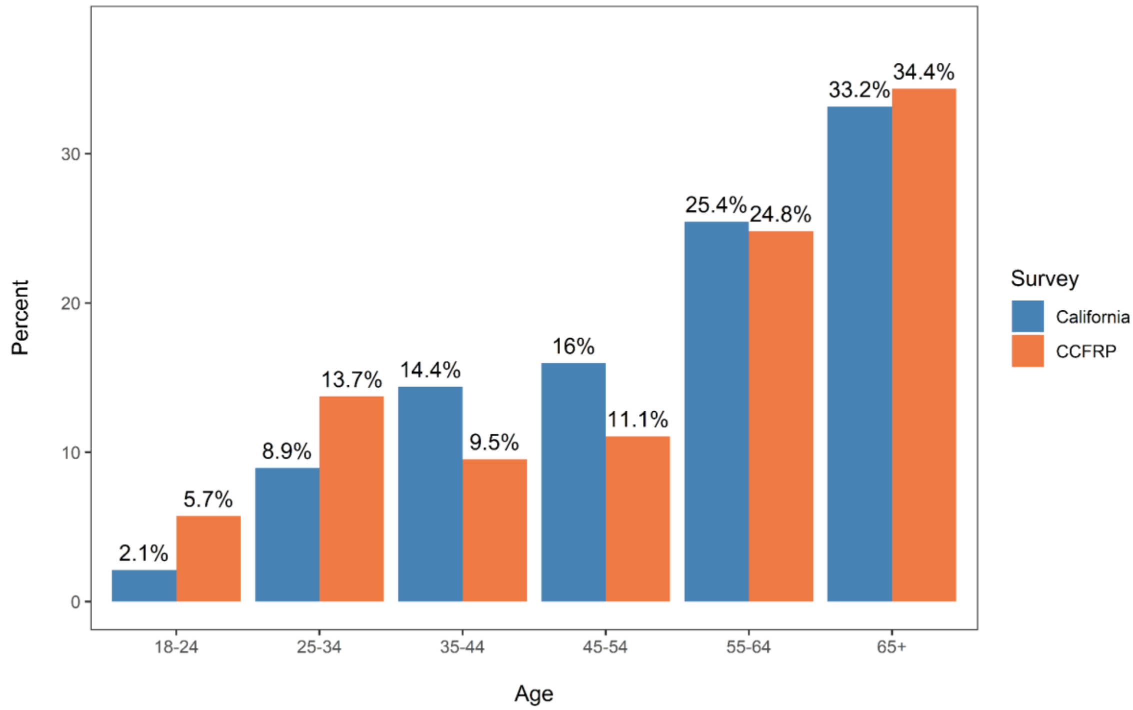


Figure 17. Distribution of ages for respondents to the CCFRP Angler Survey and to a California fishing survey (Lovell et al., personal communication).

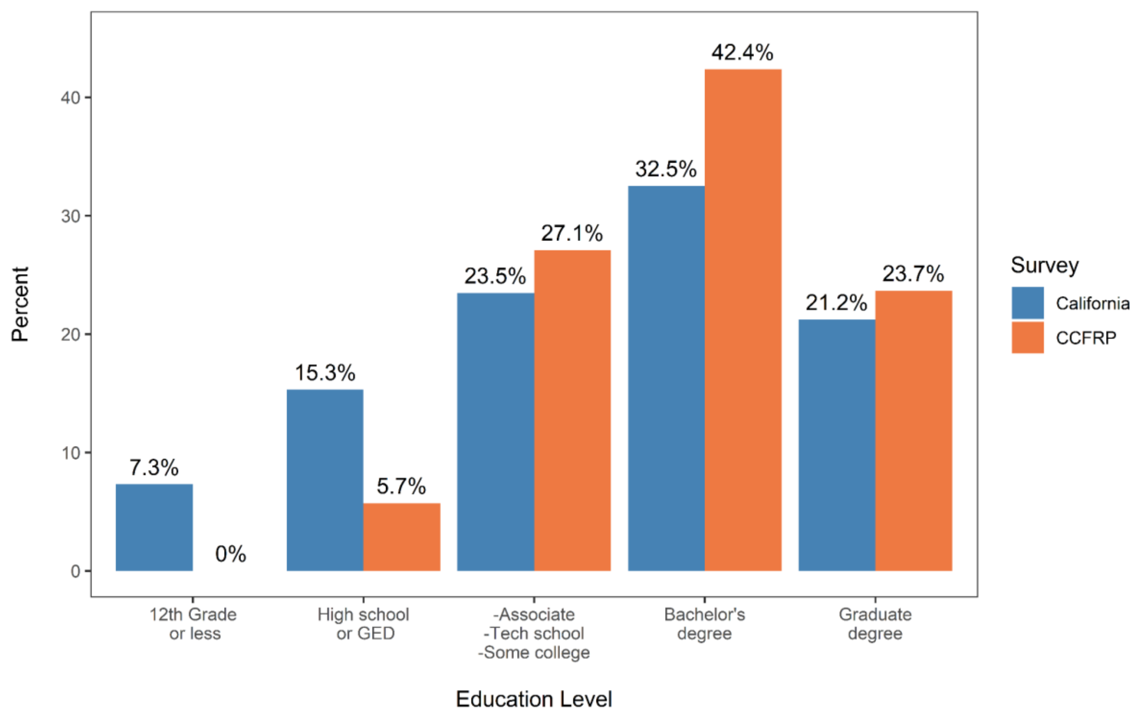


Figure 18. Distribution of education levels for respondents to the CCFRP Angler Survey and to a California fishing survey (Lovell et al., personal communication).

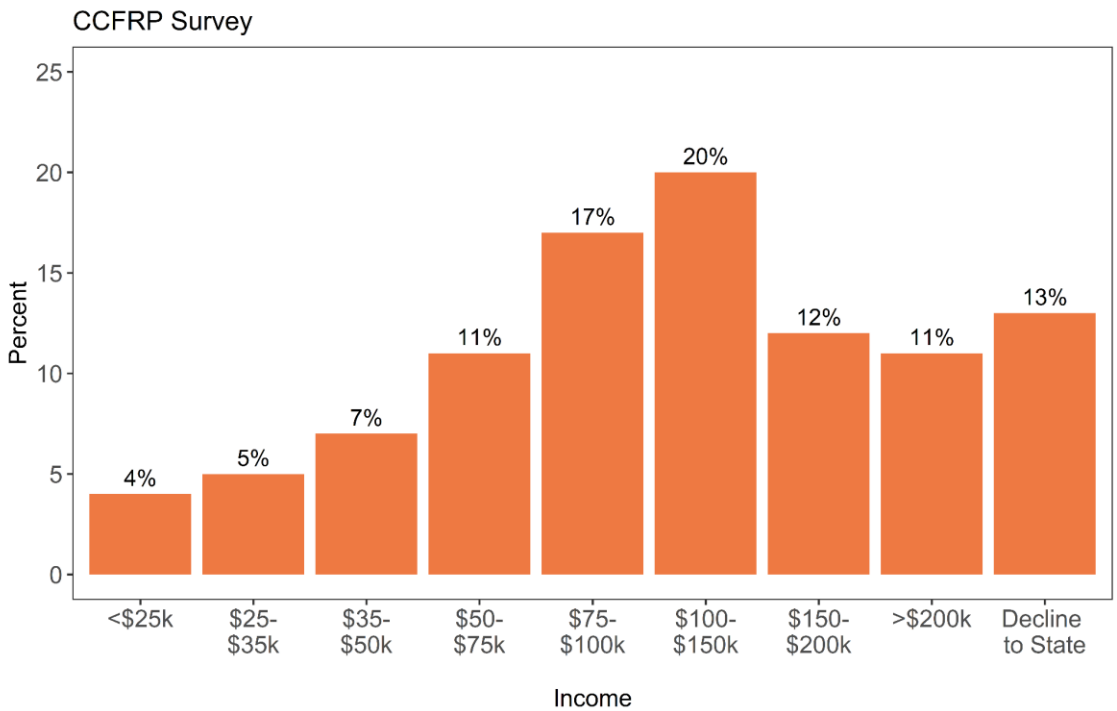


Figure 19. Distribution of income for respondents to the CCFRP Angler Survey.

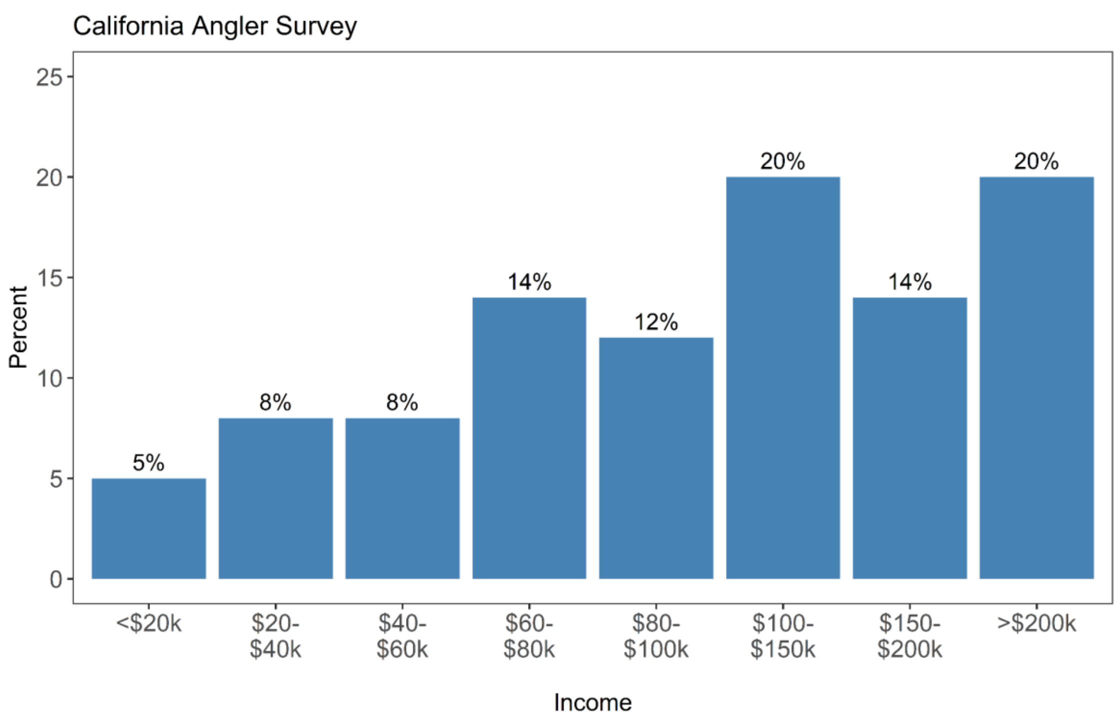


Figure 20. Distribution of income for respondents to a California fishing survey (Lovell et al., personal communication).

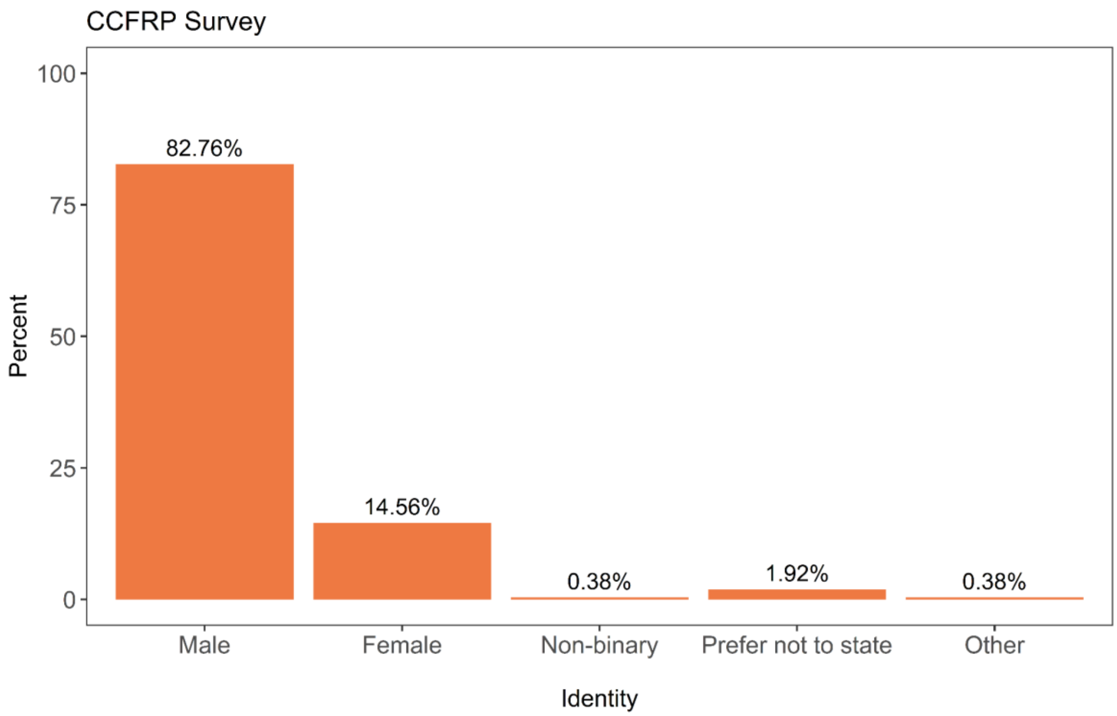


Figure 21. Distribution of identity for respondents to the CCFRP Angler Survey.

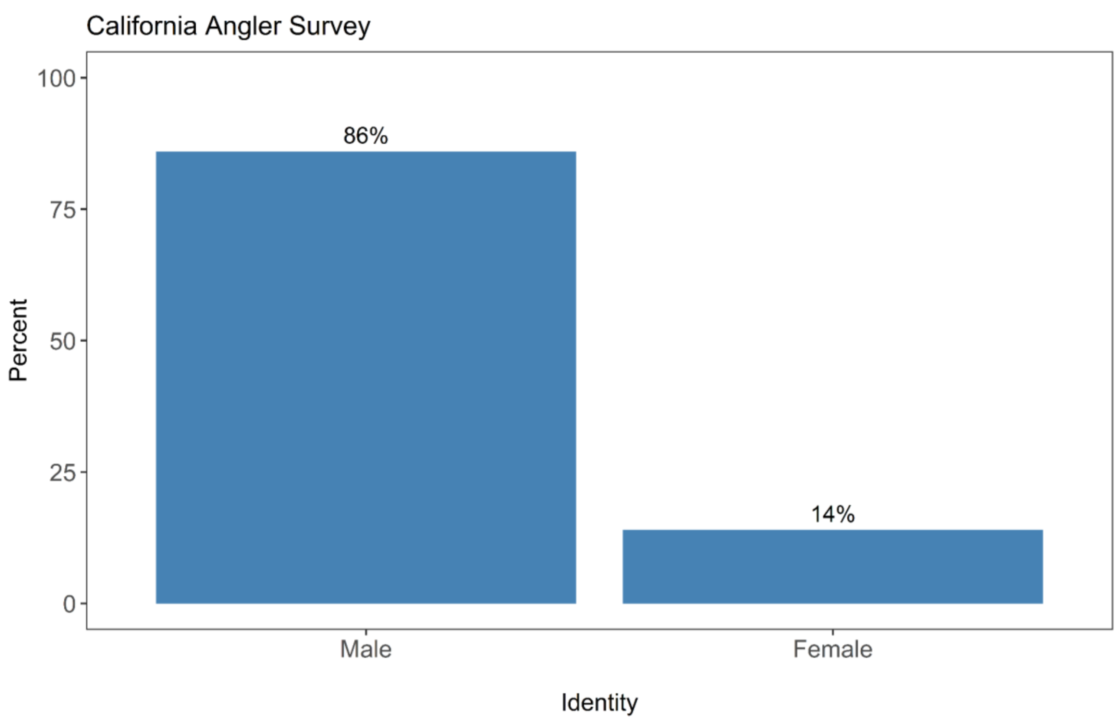


Figure 22. Distribution of identity for respondents to a California fishing survey (Lovell et al., personal communication).

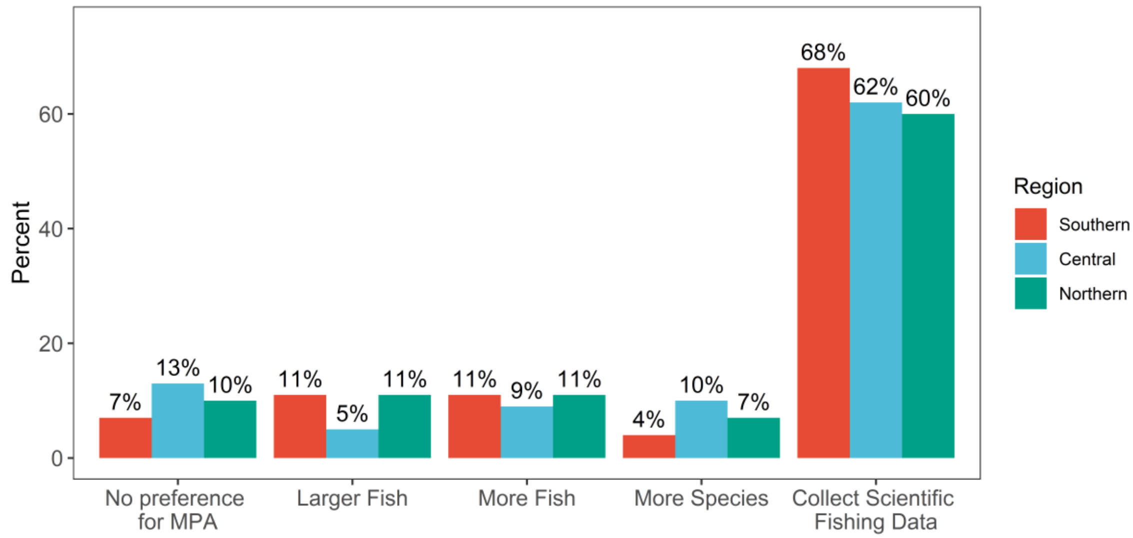


Figure 23. Percentage of responses given when asked the primary reason that anglers enjoy fishing with CCFRP in MPAs for the Southern (red), Central (blue), and Northern (green) California regions.

APPENDICES

A: CCFRP Angler Survey 2021

CCFRP Angler Survey 2021

This survey was designed to better understand CCFRP anglers' opinions and knowledge of ***ocean issues, conservation, and marine protected areas (MPAs)***. CCFRP science staff at Cal Poly, Moss Landing Marine Laboratories (MLML), Humboldt State, Bodega Marine Lab (UCD), the Marine Science Institute (UCSB), and Scripps Institution of Oceanography (UCSD) designed this survey; it builds on previous CCFRP-related surveys. The results generated from this survey will be used to inform CCFRP and the State of California about CCFRP anglers including their: experiences with MPAs, involvement with CCFRP, engagement in conservation, and basic demographic information. The survey is completely anonymous and voluntary.

This survey should take you ~15 minutes.

As a volunteer angler participating in this survey, we want to thank you for your time dedicated to our research! All of your time and input is very valuable to us – on and off the vessel!

Section 1) CCFRP Angler Involvement

The following are questions about your experience volunteering with CCFRP.

1. What year did you first volunteer with CCFRP?

   ____

2. How often do you volunteer with CCFRP?
   - Every year
   - Every few years
   - Infrequently (1 – 2 years only)
   - Never

3. How many trips have you gone on with CCFRP? *Select only one.*
   - 1
   - 2-5
   - 6-10
   - 11-19
   - 20+

4. What institution have you volunteered with most?
   - Humboldt State University
   - Bodega Marine Laboratory
   - Moss Landing Marine Laboratories

- Cal Poly SLO
- UC Santa Barbara
- Scripps Institution of Oceanography

5. Why did you volunteer to participate on your last CCFRP fishing trip? *Select all that apply.*
   - To enjoy fishing whenever I can
   - To fish inside the marine protected areas (MPAs)
   - To participate in citizen science
   - To give back to fisheries resources
   - To learn about rockfish, lingcod, and other species we catch on these trips
   - Other (specify) ____

6. Did you learn anything while volunteering with CCFRP that you found useful? *Select all that apply.*
   - I learned more about the wide range of fish species caught in this area
   - I learned what a marine protected area is
   - I learned where I am not allowed to go fishing
   - I learned how to identify nearshore fish species
   - I learned how fishing data can be used in fisheries management
   - I learned about techniques to descend groundfish
   - I learned how MPAs can be used to manage fisheries
   - I did not learn anything
   - Other (specify) ____

7. I use the following resources to learn about the data collected by CCFRP: *Select all that apply*.
   - CCFRP data briefings at the end of a trip
   - Reading the annual volunteer newsletter
   - Attending Volunteer Appreciation and Data Workshops if/when offered
   - am not interested in learning about the data that CCFRP collects

8. I have told my recreational fishing buddies about CCFRP.
   - Yes
   - No

Section 2) Marine Protected Areas

Marine protected areas (MPAs) are designated areas of the ocean where different types of activities such as fishing are monitored or prohibited. These marine protected areas are similar to designated areas on land such as national and state parks.

The following is split into three subsections: questions about your view of MPAs **before** volunteering with CCFRP, questions about your view of MPAs **after** volunteering with CCFRP, and then **general** questions about MPAs.

Before

9. **Before** volunteering with CCFRP, what was your general opinion of the creation of MPAs in California?

My general opinion of MPA creation was …

- Positive
- Somewhat positive
- Neither positive nor negative
- Somewhat negative
- Negative
- No Opinion

10. **Before** volunteering with CCFRP, did you believe the creation of MPAs would affect the size/abundance of groundfish inside MPAs? *Select all that apply.*

- Yes, I believed there would be an **increase** in the size of groundfish inside MPAs
- Yes, I believed there would be an **increase** in the abundance of groundfish inside MPAs
- Yes, I believed there would be a **decrease** in the size of groundfish inside MPAs
- Yes, I believed there would be a **decrease** in the abundance of groundfish inside MPAs
- No, I believed there would be **no effect** on size of groundfish inside MPAs
- No, I believed there would be **no effect** on the abundance of groundfish inside MPAs
- I don't know
- No opinion

After

11. **After** volunteering with CCFRP, what was your general opinion of the creation of MPAs in California?

My general opinion of MPA creation was…

- Positive
- Somewhat positive
- Neither positive nor negative
- Somewhat negative
- Negative
- No Opinion

12. **After** volunteering with CCFRP, did you believe the creation of MPAs would affect the size/abundance of groundfish inside MPAs? *Select all that apply.*
    - Yes, I believed there would be an **increase** in the size of groundfish inside MPAs
    - Yes, I believed there would be an **increase** in the abundance of groundfish inside MPAs
    - Yes, I believed there would be a **decrease** in the size of groundfish inside MPAs
    - Yes, I believed there would be a **decrease** in the abundance of groundfish inside MPAs
    - No, I believed there would be **no effect** on size of groundfish inside MPAs
    - No, I believed there would be **no effect** on the abundance of groundfish inside MPAs
    - I don't know
    - No opinion

<u>General</u>

13. If you believe that California MPA creation affected **groundfish abundance and/or size**, what aspect(s) of MPAs do you believe caused these changes? *Select all that apply.*
    - Location of MPAs
    - Size of MPAs
    - Enforcement of MPA restrictions
    - Planning of MPAs as a network
    - MPA protection of a portion of fish populations
    - Voluntary compliance with restrictions
    - Other
    - N/A, I do not believe there is an effect

14. In your **opinion**, what is the purpose of a Marine Protected Area? *Select all that apply*
    - To set aside areas of ocean to conserve, restore, and understand natural biodiversity and ecology of the area
    - To provide people the opportunity to experience these areas of the ocean now and into the future
    - To restrict industrial uses (seabed mining, oil and gas exploration or drilling, windmill or turbine construction, minerals extraction)
    - To prevent overfishing/ overuse/ degradation
    - MPAs do not have a purpose
    - I have no opinion on the purpose of MPAs

15. Have you ever fished in a Marine Protected Area before it was protected OR while volunteering with CCFRP? (If no, skip to section 3)
    - Yes
    - No

16. Think about this when answering a-c: Have you experienced a difference in fishing in an MPA versus outside of an MPA?

a. I catch more fish when fishing inside….
- MPAs
- Areas open to fishing
- I don't know
- No difference

b. I catch a greater diversity of fish species when fishing inside….
- MPAs
- Areas open to fishing
- I don't know
- No difference

c. I catch larger fish when I fish inside….
- MPAs
- Areas open to fishing
- I don't know
- No difference

17. What is the ***primary*** reason you enjoy fishing with CCFRP in an MPA (select one):
    - I have no preference for CCFRP fishing sites (MPA or reference)
    - To catch a large fish
    - To catch a lot of fish
    - To catch a lot of species
    - To collect scientific fishing data

18. Hypothetically, how much would you be willing to pay for one day of catch and release fishing inside an MPA while **NOT** participating on a CCFRP trip?
    - $0
    - $1 - $20
    - $21 - $50
    - $51 - $100
    - $101 - $500
    - >$500

Section 3) Natural Resource Conservation

Now we would like to query you on your opinions about **conservation**. The Merriam-Webster dictionary definition of **Conservation** is: the careful preservation and protection of something, especially the planned management of a natural resource to prevent exploitation, destruction, or neglect.

Additionally, this section asks a few questions about potential ocean issues in their relation to California's coastal waters.

19. In general, would you say you are more conservation-minded or less conservation-minded than others in the recreational angling community?

Compared to the rest of the angling community, I am …

- More conservation minded
- Similarly conservation minded
- Less conservation minded
- I don't know

20. Do you participate in activities with conservation-oriented groups (separate from CCFRP)?
    - Yes
    - No

21. How informed do you consider yourself to be concerning ocean issues in California?
    - Not well
    - Somewhat
    - Well
    - Very Well
    - Unsure

22. In what ways do you currently obtain information about ocean related issues? S*elect all that apply*.
    - CCFRP related events (Volunteer Appreciation/ Data Workshops)
    - Newspaper
    - Magazine
    - Family/Friends
    - Radio
    - Internet
    - Social Media
    - Television
    - Other ____
    - I have not sought out information on ocean related issues

23. In your opinion, how well are California groundfish stocks managed?

I believe California groundfish stocks are:

- Very well managed
- Well managed
- Adequately managed
- Poorly managed
- Very poorly managed
- I don't believe they are managed at all
- I don't know

24. Please rank the following types of fishing gear or fishing practices(from 1 to 8) as having the greatest impact on the degradation of the marine environment or reduction in fish stocks. (1 is least impact and 8 is greatest impact).

Traps or pots ___________
Hook and line, recreational ___________
Bottom trawling ___________
Longline ___________
Gill nets ___________
Midwater trawling ___________
Hook and line, commercial ___________
Spearfishing ___________

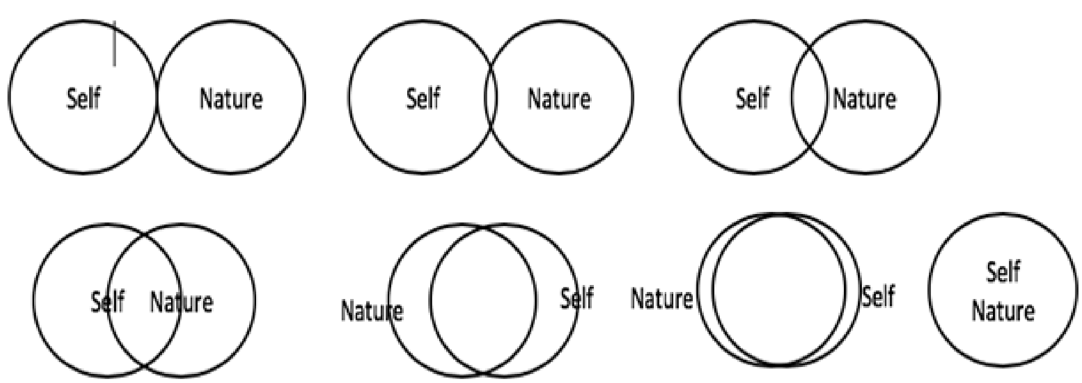
25. This question consists of a chart that queries you on your opinion of potential ocean issues. Statements are rated 1-7. An answer of '1' indicates that you strongly disagree, '4' indicates no opinion, and '7' indicates you strongly agree with the statement.

Please indicate whether you think any of the following is a threat to California's marine environment. Please circle ONE number for each.

Potential Ocean Issue	**Strongly Disagree**	**Somewhat Disagree**	**Disagree**	**No Opinion**	**Somewhat Agree**	**Agree**	**Strongly Agree**
Water Pollution	1	2	3	4	5	6	7
Marine Debris	1	2	3	4	5	6	7
Loss of Marine	1	2	3	4	5	6	7

Biodiversity							
Overfishing	1	2	3	4	5	6	7
Invasive/ Exotic Species	1	2	3	4	5	6	7
Rising Sea Temperatures	1	2	3	4	5	6	7
Ocean Acidification and Hypoxia	1	2	3	4	5	6	7
Wave energy/Power development	1	2	3	4	5	6	7
Oil/gas exploitation or transport	1	2	3	4	5	6	7

26. The following diagram labels a series of circles overlapping. They are labeled 'Self' and 'Nature'. Please circle the picture below that best describes your relationship with the natural environment. How interconnected are you with nature?



Section 4) Basic Demographics

27. What is the zip code of your primary residence?

____

28. I identify as
- Male
  - Female
  - Non-binary
  - Prefer not to state
  - Other:__________ (specify)

29. What is your age?
    - 18-24
    - 25-34
    - 35-44
    - 45-54
    - 55-64
    - 65 years and older

30. What is the highest level of education you have completed?
    - Less than high school degree
    - High school degree or equivalent (e.g., GED)
    - Associate degree or completion of technical or professional school
    - Some college but no degree
    - Bachelor degree
    - Graduate degree (e.g., Master degree. PhD, JD, MD, etc.)

31. Which of the following categories best describes your household's total annual income before taxes in 2020?
    - Less than $25,000
    - $25,000 - $34,999
    - $35,000 - $49,999
    - $50,000 - $74,999
    - $75,000 - $99,999
    - $100,000 - $149,999
    - $150,000 - $199,999
    - $200,000 or more
    - Decline to state
32. Have you or anyone you know ever worked in marine resource management at the local, state, federal, or academic level. *Select all that apply*. (e.g., CA Department of Fish and Wildlife or NOAA)
    - Yes, self
    - Yes, family
    - Yes, friend
    - No

33. Have you ever worked in the recreational fishing industry? (e.g., a captain, boat crew, bait or tackle salesperson, etc.)
    - Yes
    - No

34. Have you ever worked in the commercial fishing industry? (e.g., a fisherman, captain, boat crew, buyer, etc.)
    - Yes
    - No

35. Additional space is provided below for any additional comments or concerns regarding this survey.

Thank you for your time and participation!

B: Informed Consent Form

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT:

"2021 California Collaborative Fisheries Research Program (CCFRP) Volunteer Angler Survey"

This form asks for your agreement to participate in a research project involving a survey about anglers' opinions and knowledge of ocean issues, conservation, and marine protected areas (MPAs). Your participation involves completing and submitting a survey taken through an online survey tool or a paper/pen version. It is expected that your participation will take approximately 15 minutes. There are no risks anticipated with your participation. If you are interested in participating, please review the following information.

The purpose of the study is to assess CCFRP volunteer angler opinions and knowledge of ocean issues, conservation, and MPAs. Potential benefits associated with the study include increased understanding of local anglers' attitudes towards scientific data collection and MPAs, increased collaboration between fishers and scientists, and provide a forum for angler opinions to be recorded.

If you agree to participate, you will be asked to complete the 2021 CCFRP Volunteer Angler Survey and submit your answers anonymously through Qualtrics, an online survey tool or into a paper version. This survey contains questions about your experience with CCFRP, your opinions about MPAs, your opinions about natural resource conservation, and some questions regarding basic demographic information.

Please be aware that you are not required to participate in this research, refusal to participate will not involve any penalty or loss of benefits to which you are otherwise entitled, and you may discontinue your participation at any time. You may omit responses to any questions you choose not to answer. There are no risks anticipated with your participation in this study. Your responses will be provided anonymously to protect your privacy. We do not plan to destroy the data generated in this study and will store it on a Cal Poly server or other digital storage device secured through University firewalls. The data generated through this survey will be shared with our collaborators at the following CCFRP research institutions and be used to generate reports and manuscripts for publication: Humboldt State University, Bodega Marine Laboratories at UC Davis, Moss Landing Marine Laboratories, the Marine Science Institute at UCSB, and Scripps Institute of Oceanography at UCSD.

This research is being conducted by Grant Waltz (Senior Research Scientist) and Dean Wendt (Dean, College of Science and Mathematics) in the Biological Sciences Department at Cal Poly, San Luis Obispo. If you have questions regarding this study or would like to be informed of the results when the study is completed, please contact the researcher(s) at ccfrpslo@gmail.com or gwaltz@calpoly.edu.

If you have concerns regarding the manner in which the study is conducted, you may contact Dr. Michael Black, Chair of the Cal Poly Institutional Review Board, at (805) 756-2894, mblack@calpoly.edu, or Ms. Trish Brock, Director of Research Compliance, at (805) 756-1450, pbrock@calpoly.edu.

If you are 18 years of age or older and agree to voluntarily participate in this research project as described, please indicate your agreement by clicking the survey link sent to your email and completing the 2021 CCFRP Volunteer Angler Survey. Please retain a copy of this form for your reference, and thank you for your participation in this research.

C: Recruitment Outreach Email

This is a reminder for the "CCFRP Volunteer Angler Survey". If you have already submitted the survey, thank you! You do not need to re-submit.

Dear CCFRP volunteer angler,

The California Collaborative Fisheries Research Program (CCFRP) has been running for 15 years along the central coast and 5 years statewide. With the help of volunteers like you, we have been able to successfully complete over a decade of data collection regarding the species compositions, sizes, and catch rates of nearshore fishes in and around California MPAs. Building off two separate surveys conducted along the central coast in 2018, we're interested in learning from the program's current and former statewide volunteers about their awareness, attitudes, and knowledge of MPAs, marine resource issues, and how volunteering with CCFRP has influenced their support for marine conservation.

If you choose to participate in the study, click on the "Begin CCFRP Volunteer Angler Survey" link below. You will be provided a Letter of Consent (a copy of which is attached to this email) followed by a series of questions about your experience with CCFRP, your opinions of MPAs, your opinions of marine resource issues, and some demographic/miscellaneous questions. The entire survey should take 15 minutes to complete.

Participation in this study is completely voluntary and any answers you provide will be anonymous. Additionally, participation in this survey, or the answers you provide, will in no way impact your standing as a volunteer angler with CCFRP. The survey collection period will be open from July 12 to December 31, 2021, so please complete and submit the survey as soon as you are able.

Begin CCFRP Volunteer Angler Survey

Please contact Grant Waltz at gwaltz@calpoly.edu or ccfrpslo@gmail.com, or leave a voicemail at 805-756-2950 with any questions or concerns you may have regarding the study.

Thank you for your time and effort volunteering with CCFRP!

Sincerely,
California Collaborative Fisheries Research Program

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