Monitoring California's rocky marine ecosystems across a network of MPAs: methodological comparison of multiple monitoring techniques

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List of Acronyms in the Report

ANOVA – Analysis of Variance
CA – California
Cal Poly SLO - California Polytechnic State University, San Luis Obispo
CCFRP – California Collaborative Fisheries Research Program
CDFW – California Department of Fish and Wildlife
CINP – Channel Islands National Park
CPFV – Commercial passenger fishing vessel
CRANE - Cooperative Research and Assessment of Nearshore Ecosystems
LSV – Least significant value
MARE – Marine Applied Research and Exploration
MLML – Moss Landing Marine Laboratories
MLPA – Marine Life Protection Act
MPA – Marine protected area
NCI- Northern Channel Islands
NPS KFM – National Park Service Kelp Forest Monitoring
OPC – California Ocean Protection Council
PISCO – Partnership for Interdisciplinary Studies of Coastal Oceans
RCCA – ReefCheck California
ROV – Remotely operated vehicle
SBC – Santa Barbara Channel
SBC-LTER – Santa Barbara Coastal Long Term Ecological Research
SCB – Southern California bight
SMCA – State Marine Conservation Area
SMR – State Marine Reserve
UCSB – University of California, Santa Barbara
UCSC – University of California, Santa Cruz

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Executive Summary

California recently completed the implementation of a large network of Marine Protected Areas (MPAs) across the state via legislation called the Marine Life Protection Act (MLPA). Following implementation of MPAs in each region, the state instigated and funded Phase 1 of a Statewide MPA Monitoring Program which allowed for 2-3 years of baseline ecological monitoring in each region around the time of MPA implementation. Baseline monitoring was intended to provide a benchmark against which future change in MPAs could be evaluated. Importantly, baseline monitoring for many habitats built on existing programs, several of which already had long time-series of monitoring data in and around the MPAs. Building on Phase 1, the California Department of Fish and Wildlife (CDFW) and California Ocean Protection Council (OPC) are developing priorities and strategies for Phase 2, statewide long-term monitoring. This study seeks to inform aspects of this long-term monitoring plan by evaluating existing time series and techniques currently being deployed in rocky nearshore ecosystems throughout California.

Specifically, we present two studies meant to inform long-term monitoring of MPAs in California:

1) A comparison of two long-term monitoring programs utilizing SCUBA surveys on nearshore rocky reefs and kelp forests, one composed of professional, academic scientists (PISCO - Partnership for Interdisciplinary Studies of Coastal Oceans) and the other a citizen-science program utilizing a combination of paid staff and volunteers (RCCA - ReefCheck California).
2) An evaluation of data from multiple monitoring techniques across a large depth gradient to provide information on the latitudinal and depth profile of species likely to be protected by MPAs.

Part I. Reef Check CA and PISCO surveys of nearshore rocky reefs and kelp forests.
California's network of MPAs was designed to encompass a variety of habitats including shallow kelp and rocky reef (defined by the state as 0-30m of depth). Nearshore rocky reefs are one of the most well sampled habitats in California's MPAs, due primarily to the existence of several long-term monitoring programs and the accessibility of most nearshore areas to SCUBA diving. Of these programs, two operate at the statewide scale and have focused efforts on monitoring MPAs. The kelp forest monitoring program of PISCO is run out of academic institutions (UCSB and UCSC) since 1999 and relies on a mix of paid professional scientists and volunteer students. RCCA is a citizen science program, monitoring California's kelp forests since 2006 with a mix of paid staff and volunteer divers.

Citizen science has an important role in natural resource management and in some cases, may be a cost-effective solution to limitations in academic or government-sponsored monitoring but impediments to broader use of citizen science data include data quality, sampling bias and lack of tools or resources for management and analysis of data. Overcoming concerns about data quality requires quantitative examinations of monitoring data from multiple types of monitoring programs. Previous comparative studies have tended to focus on observer quality,

or the abilities of different types of observers to gather accurate data in the field. This study assumes similar observer quality and instead, tests aspects of programmatic sampling bias in space and time, specifically evaluating site and transect replication as well as duration and consistency of time series against a single, very specific question – are there MPA effects on fish biomass in paired inside-outside comparisons and what is the statistical power of the programs to detect change over time?

We approached this question by running two sets of simple Analysis of Variance Models (ANOVA) testing for effects of MPA status and year on fish biomass for all targeted species (summed) and for individual, abundant species. We located MPAs where both programs had lengthy time series (5 MPAs from southern and central California) and then created two datasets: one where the sets were truncated in time to only contain matching years and the second using the full time series for each program. The first approach measures the inherent variability in the time series for each program while controlling for year to year environmental variation while the second approach utilizes the full data assets of each program as of 2016. We then conducted power analyses on all models to compare and contrast statistical power between the programs.

The results showed that both programs are capable of detecting effects of MPA status when such effects were relatively large (primarily southern CA MPAs). Both programs largely fail to detect strong MPA effects in central CA MPAs. The two programs were not perfectly congruent in their ability to detect MPA effects, with some variation among sites and species groupings and cases where only PISCO detected an MPA effect and other cases where only RCCA detected an effect. Given the intrinsic temporal variability in these dynamic kelp forest systems, power to detect MPA effects over the stochastic noise in the system is an important trait of any monitoring program. While both programs detected MPA effects, assessments of the statistical power of the programs to detect effects of varying sizes differed. We found that the PISCO program has more power to detect smaller effect sizes and inherent in that, the ability to detect changes on shorter time scales than the RCCA program. This result is likely due to higher site and transect replication in the PISCO program within and outside of MPAs.

Visualization of the geographic distribution of monitoring sites showed some regions with high overlap between the two programs, other regions with low overlap (one program present) and many regions with little monitoring. Despite a difference in statistical power, the findings indicate that there may be opportunity to strategically coordinate the two monitoring groups to maximize geographic coverage of California's MPAs. In relation to MPA assessment, there may not be justification for extensive spatial overlap between the two programs. Though there are a number of considerations that could contribute to a decision strategy for adding/discontinuing sites within each group, length of time-series and existing spatial coverage within and outside of an MPA should be primary considerations.

This report contributes to the ongoing discussion of relative benefits of citizen science and academic (professional) science programs for kelp forest monitoring. While advancing our understanding of a relatively specific question posed by the state, it is important to

acknowledge the limitations of this study. Ultimately, the role for citizen science programs will need to be evaluated on a number of criteria, including cost-effectiveness relative to ability of data to answer multiple questions of interest. We presented one specific aspect of the 'effectiveness' side of the equation here but there are many other considerations for monitoring marine ecosystems in CA including but not limited to understanding the effects of climate change and contributing data to fisheries management. In addition, a thorough analysis of the 'cost' side of the equation should be undertaken when evaluating any monitoring program (not just citizen science programs).

Part II. Methodological comparison of multiple monitoring techniques for California's rocky marine ecosystems.

The Marine Life Protection Act (MLPA) resulted in a coordinated system of MPAs throughout the state that encompasses the diversity of marine and estuarine habitats within state waters. The design process recognized both the importance of connectivity within and between habitats as well as the need for adequate representation of these habitats across the network. Regional baseline monitoring plans recognized 8 key habitats across the network. Of these, several habitats are defined on the basis of hard substrate (i.e. rocky intertidal, kelp and shallow rock (0-30m), mid-depth rock (30-100m) and deep ecosystems and canyons (>100m). As Phase 1 baseline monitoring transitions to statewide long-term monitoring of the MPA network, and recognizing potential connectivity among habitats and depth zones, it will be important to assess existing monitoring tools and techniques as well as existing data assets across multiple habitats for California's MPA network.

The **goal of this study** is to perform a methodological comparison of existing data collected in rocky ecosystems across depths to inform long-term statewide MPA and fisheries monitoring strategies. We analyzed existing data from surveys utilizing hook-and-line on commercial passenger fishing vessels (CPFV) through the California Collaborative Fisheries Research Program (CCFRP), remotely operated vehicles (ROV), manned submersibles, and SCUBA surveys both by PISCO and RCCA programs. In this study, we provide information on the fish species commonly captured by these techniques, species dynamics such as ontogenetic habitat shifts, as well as the depth and latitudinal range of particular species. This data, brought together for the first time in a single database, will help to identify a suite of techniques that can be used to monitor certain indicator species and/or identify synergies among different monitoring techniques to collectively inform the status of indicator species.

We recorded 193 unique fish species for the combined data from five monitoring techniques analyzed in this study. Of these species, 15 were common to all the monitoring techniques including blue rockfish (*Sebastes mystinus*), lingcod (*Ophiodon elongatus*), and kelp greenling (*Hexagrammos decagrammus*), and many of the 15 are targeted by fishing. Identification of shared species across methods will aid future network level monitoring coordination efforts.

In total, data from the various monitoring techniques were distributed across the state but not every technique has been used in every region, nor is the monitoring consistent over time. Hook-and-line, ROV, and SCUBA (both RCCA and PISCO) methods were well distributed

latitudinally but each program had uneven sampling over time. Manned submersible surveys were limited to central California. We note that our data compilation efforts likely did not include the full range of data that exist in CA. However, the dataset we developed can be added to as additional data are located or collected.

The statewide extent and wide depth range of the surveys allowed us to derive information on species depth and latitudinal distribution and potential ontogenetic movements. We found some species (e.g. blacksmith [*Chromis punctipinnis*], California sheephead [*Semicossyphus pulcher*], senorita [*Oxyjulis californica*], and treefish [*Sebastes serriceps*]) to be restricted to the southern part California, other species were only observed in the northern part of the state (e.g. china and quillback rockfishes [*Sebastes nebulosus* and *S. maliger]*) and several species are distributed across the entire state (e.g. lingcod and blue rockfish [*O. elongatus* and *S. mystinus]*). For the most part, the distributional patterns we observe corroborate our knowledge and published accounts of the distributional ranges of these fishes. Patterns of size structure over latitude and depth were more interesting. For example, we observed potential ontogenetic latitudinal patterns for some species, such as vermilion rockfish and copper rockfish. The small-sized individuals of these two species can be found at lower latitude of California while no fish less than 20cm length was recorded at higher latitudes. We also observed clear cases of depth related, size structuring in species such as canary rockfish (*S. pinniger*), lingcod (*O. elongatus)*, vermilion rockfish (*S. miniatus*), yellowtail rockfish (*S. flavidus*) and bocaccio (*S. paucispinis*) with larger and presumably older individuals recorded in deeper areas while smaller, presumably juvenile fishes were recorded in shallow to mid-depth areas. This study adds to a body of knowledge of ontogenetic patterns in depth for California fish species.

Our results have several applications. We provide a species-method table to aid in choosing the most effective monitoring technique, combination of techniques, or alternative (or new) technique to capture the indicator species from monitoring plans.

Second, our results can inform the choices of appropriate techniques to be used to detect MPA effects across habitats and importantly, identify cases where we might be missing important segments of the population of a given species by using a particular technique. For example, we found some species of rockfishes were restricted to nearshore, shallow areas. Therefore, the full geographic and demographic distribution of these species can be captured by SCUBA surveys in nearshore MPA areas or by any of the other monitoring tools that can access those shallow depths. However, we found other rockfish species that, while present in nearshore SCUBA surveys, have maximal biomass (e.g. more and bigger fish) at much greater depths. Nearshore shallow monitoring would not fully capture the entire depth range or demographic structure of these species and could be misleading in analyses of MPA performance.

Future work can build on the datasets created for this study by including more existing data, especially from mid-depth and deep rock ecosystems. We could not assess MPA effects, per se, as many of the methods we assessed do not have lengthy time series or are arrayed across

MPAs at present. Eventual evaluation of the power of the various methods to detect change over time (as in Part I of this study) will be required.

General Introduction

Marine protected areas (MPAs) are increasingly being used as a fisheries management and conservation tool to enhance species biomass, improve catches for adjacent fisheries, protect populations from decline, and conserve and restore natural ecosystems (Dugan and Davis 1993; Allison et al. 1998; Roberts et al. 2001; Alcala and Russ 2006; Worm et al. 2006; Gaines et al. 2010; Caselle et al. 2015). Despite their potential to provide considerable benefits, the designing of effective MPAs comes with significant challenges considering the dynamic nature of the biological resources that the MPAs are protecting and the variable responses in fishing behavior of resource users in areas adjacent to MPAs. A crucial element in ensuring that MPAs meet their intended objectives is the creation of effective monitoring programs.

Effective monitoring provides managers with the tools to implement adaptive management in cases where MPAs may not perform as intended. Monitoring should be tuned to the stated goals of the MPA or network of MPAs. For many MPAs, monitoring addresses the biological or ecological questions regarding changes in populations. For monitoring to be effective, the method must capture the state and dynamics of the populations being examined. Furthermore, the timing and frequency of monitoring must be sufficient and consistent to allow for timely and accurate management responses. Although a single monitoring method may be able to provide insights into the performance of MPAs, more often than not, multiple methods will be required to adequately monitor across different habitats, spatio-temporal scales, and species. Using multiple monitoring techniques can also lead to greater inclusion of scientists and stakeholders (e.g. citizen science), ultimately increasing engagement and providing a more holistic look at the ecosystems within an MPA network.

California recently completed the implementation of a large network of MPAs across the state via legislation called the Marine Life Protection Act (MLPA). Spanning the entire coastline of California, 124 MPAs were located, placing 16% of the coastline under some form of protection (9.4% was designated as no-take). The goals of the MLPA were quite general, and even though the law was the enabling legislation for the MPAs, it contained few specific operational metrics (Botsford et al. 2014). The network goals are concerned with protection at the ecosystem level, but they also require the state to help ‘sustain, conserve and protect marine life populations’ (Goal 2). The MLPA had two other important requirements: (1) that it makes use of the best readily available science and (2) that after implementation, the MPAs be monitored and subject to adaptive management (MLPA, Chapter 10.5 of the California Fish and Game Code, §2850-2863).

Following implementation of MPAs in each region, the state instigated and funded Phase 1 of a Statewide MPA Monitoring Program (2007-2018, across the regions) which allowed for 2-3 years of baseline ecological monitoring in each region around the time of MPA implementation. Baseline monitoring was intended to provide a benchmark against which future change in MPAs could be evaluated. Importantly, baseline monitoring for many habitats built on existing programs and techniques, several of which already had long time-series of monitoring data in and around the MPAs. Building on Phase 1, the California Department of Fish and Wildlife

(CDFW) and California Ocean Protection Council (OPC) are developing priorities and strategies for Phase 2, statewide long-term monitoring. This study seeks to inform aspects of this long-term monitoring plan by evaluating existing time series and techniques currently being deployed in rocky nearshore ecosystems throughout California.

Here, we perform two studies meant to inform long-term monitoring of MPAs in California:

1) A comparison of two long-term monitoring programs utilizing SCUBA surveys on nearshore rocky reefs and kelp forests, one composed of professional, academic scientists (PISCO: Partnership for Interdisciplinary Studies of Coastal Oceans) and the other a citizen-science program utilizing a combination of paid staff and volunteers (RCCA: ReefCheck California).
2) An evaluation of data from multiple monitoring techniques across a large depth gradient to provide information on the latitudinal and depth profile of species likely to be protected by MPAs.

For both analyses, we restrict the scope to fishes. The analyses presented here could be adapted for invertebrates and algae in the future.

Part I. Nearshore rocky reefs: a comparison of academic and citizen science programs for MPA evaluation in California

Background

Kelp forest and nearshore rocky reef ecosystems are among the most productive in the world and provide numerous important services to humans in the form of recreational and commercial fisheries, shoreline protection, non-consumptive recreational opportunities and maintenance of biodiversity (Smale et al. 2013). Kelps are considered to be a key biogenic habitat, providing habitat and food to a large number of associated species (Graham 2004). In California, kelp beds and rocky reefs support valuable commercial and recreational fisheries that target a diversity of fishes and invertebrates.

California's network of MPAs was designed to encompass a variety of habitats including shallow kelp and rocky reef (defined by the state as 0-30m of depth). Nearshore rocky reefs are one of the most well sampled habitats in California's MPAs, due primarily to the existence of several long-term monitoring programs and the accessibility of most nearshore areas to SCUBA diving. Rocky reef monitoring programs in California include both academic ('professional') programs (e.g. PISCO, SBC-LTER), federal agency programs (e.g. CINP) and citizen science programs (e.g. RCCA). Of these programs, two operate at the statewide scale and have recently focused efforts on monitoring MPAs. The kelp forest monitoring program of PISCO is run out of academic institutions (UCSB and UCSC) since 1999 and relies on a mix of paid professional scientists and volunteer students. RCCA is a citizen science program, monitoring California's kelp forests since 2006 with a mix of paid staff and volunteer divers.

Citizen science programs have increased dramatically over the past decades and once primarily limited to terrestrial observations, data collection in marine environments is increasing in prevalence and scope (Thiel et al. 2014). Citizen science has an important role in natural resource management and in some cases, may be a cost-effective solution to limitations in academic or government-sponsored monitoring (Sharpe and Conrad 2006; Delaney et al. 2008; Schmeller et al. 2009). Other benefits of citizen-based monitoring programs include increased interactions between the public and the scientific community, education about ecosystems and resource management, fostering of local stewardship, and increased scientific literacy of the general public (Conrad and Hilchey 2011, Gillett et al. 2012). Citizen science programs vary across a spectrum in the degree of involvement from citizens; ranging from contributory, which are generally designed by scientists and for which members of the public primarily contribute data, to 'co-created' programs which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process (Bonney et al. 2009). Research has shown that citizen science can play a role in adaptive management of natural resources (Aceves-Bueno et al. 2015) but limitations such as data quality, sampling bias and lack of tools or resources for management and analysis of data within citizen science programs can lead to less use of citizen collected data (Crall et al. 2010).

One of the impediments to broader use of citizen science-produced data include concerns about data quality. Overcoming these concerns requires side by side, quantitative examinations of monitoring data from multiple types of monitoring programs. Previous comparative studies have tended to focus on the abilities of different types of observers to gather accurate data in the field, that is, observer quality (Dickinson et al. 2010, Finn et al. 2010, Crall et al. 2011). For CA kelp forest monitoring, that would include the ability of volunteer divers to recognize various species and record data in unbiased ways. For example, as a precursor to report, Gillette et al. 2012 compared professionally collected data (from PISCO) with citizen science data (RCCA). Note that this study was not concerned with MPA evaluation, as the time series were not long enough to allow this at the time. Instead, the analysis focused on a single year of data (2008) and 13 overlapping reef locations. The approach was to create the most similar datasets possible from the two programs. This was accomplished by a) finding matching site locations, b) creating identical time series (by truncating where necessary), c) using a matched set of species or species groupings (by reducing taxonomic resolution where necessary) and d) matching size classes (by reducing resolution in sizing where necessary). Results from that study indicated that all things being equal, broad scale biogeographic patterns in species assemblages and abundances were congruent between the two programs across southern California. These results were not surprising, given the high levels of training and testing that RCCA divers must undertake, prior to collecting data and, importantly, that the datasets were harmonized to be as similar as possible.

Few studies have focused on the underlying statistical models on which citizen science programs are based, including inherent variance in time series data and the patterns of data collection in space and time. The next step in comparing among monitoring programs for California's MPAs is to evaluate the underlying time series with respect to statistical power to

answer question posed by resource managers. Indeed, all environmental monitoring programs should undergo periodic evaluations to assess effectiveness in meeting goals and allowing for adaptive management (Douvere and Ehler 2011). Here we expand the previous comparisons of PISCO and RCCA rocky reef monitoring in the following ways.

1) Evaluation of aspects of the two programs independently of one another and relative to statewide MPAs:
    - Spatial placement of sites
    - Length of time series
    - Consistency in time series (e.g. presence of and patterns in gaps)
    - Seasonality of surveys

2) For MPAs in which both PISCO and RCCA conduct surveys, evaluation of MPA effects and program power. We ask:
    - Are the trends in key fish species and species groups similar over time between the two programs?
    - Is the power to detect MPA effects similar between the two programs?

Methods

Shallow rocky reefs and kelp forests (<20m depth) are among the most well-monitored marine ecosystems in California, with several monitoring programs that have well over a decade of data at particular sites. SCUBA survey techniques are well developed for this relatively easy-to-access habitat. In this study, we used data on fish biomass density from PISCO and RCCA for our analyses. Both programs have well developed protocols and intensive training programs. Detailed information on the protocols including training methods, datasheets and learning resources can be found here for PISCO (http://www.piscoweb.org/kelp-forest-sampling-protocols) and here for RCCA (http://www.reefcheck.org/california/monitoring-protocol/). Further methodological comparisons of these two programs can be found in Gillett et al. 2012. Brief summaries are provided below.

PISCO protocol summary

PISCO's kelp forest monitoring has been running continuously since 1999 in shallow (5-20m depth) nearshore sites located on rocky bottom habitat. Sites are situated across a range of oceanographic and anthropogenic conditions, including different levels of coastal upwelling and inside and outside of MPAs. PISCO's monitoring approach is based primarily on SCUBA diver surveys that quantify the density and abundance of the macroalgae, invertebrates and fishes that constitute kelp forest communities. This approach allows characterization and quantification of ecosystem attributes such as biodiversity, community structure, and population abundance and size structure of ecologically and economically important species.

Site layout for fish surveys consists of 2 or 4 strata from inshore shallow to offshore deep (depending on reef width and steepness). At each site, 8 to 12 transects measuring 30m × 2m × 2m are conducted at multiple levels in the water column: benthic, midwater, and kelp canopy

(when present). Transects are laid out in a stratified random design, with multiple nonpermanent transects located in fixed strata (i.e. outer, middle and inner edges of the reef). At each level in the water column, a SCUBA diver counts and estimates the sizes of all fish species to the nearest centimeter (total length), excluding small cryptic fishes.

RCCA protocol summary

The RCCA sampling program was designed to mimic the PISCO protocols as closely as possible, with spatial and taxonomic modifications intended to make the program accessible to trained volunteers. In fact, PISCO principal investigators advised on the original development of the RCCA protocols and PISCO scientists and staff continue to advise and actively participate in RCCA surveys. RCCA has monitored kelp forests and rocky reefs since 2006. Site layout for RCCA surveys consists of 2 core strata, inshore and offshore with three transects in each for fish and benthos. Additional fish-only transects are surveyed inshore and offshore of each of the two core strata, resulting in ~6 different depth zones for fish transects. At each site, a total of 18 transects measuring 30m× 2m × 2m are conducted on the bottom only. Like PISCO, transects are laid out in a stratified random design, with multiple nonpermanent transects located in semi-fixed depth strata. RCCA divers are trained to record the presence of a constrained list of fish (35 potential species) in an effort to simplify the amount of required taxonomic skill and to focus on taxa that are most commonly observed, protected, actively fished, or of ecological importance (Dawson and Shuman 2009). The sizes of most fish were visually estimated into small (<15cm), medium (15–30cm), and large (>30cm) size classes, until 2013, when RCCA divers began to estimate the size of all fishes to the nearest 1cm. This change came with a change in the number and qualifications of divers to conduct fish surveys. The majority of fish counting for RCCA is now performed by paid RCCA staff and long-time volunteers (many of whom are past or current PISCO divers), while newer volunteers are tasked with surveying invertebrates and algae.

Key methodological differences between programs:

- *Taxonomic resolution.* RCCA uses a closed species list (35 species) for fishes, PISCO is open - meaning any fish observed is sized and counted (with the exception of small, cryptic species). For a list of fish species surveyed by both programs see Appendix Table 1.1.
- *Taxonomic resolution.* PISCO endeavors to identify all juveniles to species, RCCA uses YOY for rockfish.
- *Fish Sizing.* PISCO sizes all fish to the nearest centimeter, RCCA used size bins (<15cm, 15-30cm, >30cm) prior to 2013 and 1cm resolution from 2013 onwards, as much as possible.
- *Survey strata.* PISCO surveys three strata throughout the water column: bottom, midwater and canopy. RCCA survey bottom only.

Key methodological similarities between programs:

- *Sampling Approach*. Both programs employ a stratified random sampling approach, with non-permanent transects in fixed depth strata.

- *Transect dimension*. Both programs have identical transect dimensions (30m x 2m x 2m).
- *Training*. Both programs conduct training programs and testing with divers prior to taking data. Training occurs annually for both programs although the duration of training may differ.
- *Georeferencing*: Both programs use fixed georeferenced anchor points for site relocation.

Biomass calculations

Prior to year 2013, RCCA binned fish observations of total length into small (<15cm), medium (15-30cm), and large (>30cm) categories. Starting in 2013, most of the RCCA divers sized fish to 1 cm resolution, similar to the PISCO surveys. To calculate biomass for the RCCA data where the categorical sizing has been used, we transformed the data by assigning 10 cm as the average size for small, 20cm for medium, and 35cm for large. This method will certainly introduce biases into the RCCA biomass data but it is difficult to predict whether the method will underestimate, overestimate or not change the biomass totals. Moving into the future, this will become less of an issue because of changes in sizing protocols.

Analyses

We first visually inspected the existing time series from both programs inside and outside of MPAs across the state and chose a subset of MPAs for which both programs appeared to have long time series and similarly placed MPA and reference locations. These were: Anacapa Island SMR and SMCA, Scorpion SMR (Santa Cruz Island), Pt. Dume SMR and SMCA, Pt. Lobos SMR, and Carmel Bay SMCA. The precise locations of sites were different for each program but were selected to represent the MPA and reference areas for each MPA. For the Pt Lobos SMR we did two comparisons, one using a set of northern non-MPA sites as a reference and one using the Carmel Bay SMCA sites as a reference for the Pt. Lobos SMR. For a table of all MPA and reference sites for these models see Appendix Table 1.2. Note that many other MPAs exist for which one or the other program has a long time-series (see Figures 1.1 – 1.7); for this analysis, we choose only those MPAs where both programs had sufficient data to perform statistical analysis.

We focused our analyses on biomass and on fish species that are targeted by fishing because these metrics are most likely to show early effects of MPAs. Densities are notoriously variable and depend on recruitment (also highly variable) and as such, are less useful for detecting patterns in annual changes. However, estimating biomass for RCCA data prior to 2013 required using midpoints of size bins and may be biased (see above) in unknown ways.

We modeled the change in time for 'targeted' (i.e. fished) species biomass and for select individual species biomass at the selected MPA and reference sites using Analysis of Variance (ANOVA). Models were created separately for each program in order to compare effect sizes, variance and power. We tested the effects of MPA status (inside vs. outside), Year, and the interaction between Year and MPA status. Year was considered a continuous variable because

we are interested in detecting trends over time. Biomass for all species and species groupings was square root transformed to meet the assumptions of ANOVA.

For each model, we calculated power statistics including effect size (δ), power, least significant value (LSV) and relative LSV (LSV/ δ). Calculation of statistical power, which is the probability of rejecting the null hypothesis of "no effect" when it is false, requires description of the number of replicates and the ratio between the size of an effect and the variability among the replicates (Cohen 1977). Thus, the power of any test of a management action (e.g. MPA implementation) is simultaneously constrained by (1) the variability of the data, (2) the magnitude of the impact or action and (3) the number of independent sampling events (Osenberg and Schmitt 1994). Power increases as: sample size increases; error variance decreases; the difference between the true parameter value and the hypothesized value increases.

BOX 1. Description of power analysis output

Effect Size (δ)
The effect size, denoted by δ, is a measure of the difference between the null hypothesis and the true values of the parameters involved. The null hypothesis might be formulated in terms of a single linear contrast that is set equal to zero, or of several such contrasts. The value of δ reflects the difference between the true values of the contrasts and their hypothesized values of 0.

Power
The power of a test is the probability that the test gives a significant result. The power is a function of the effect size δ, the significance level α, the error standard deviation σ, and the sample size *n*. The power is the probability that you will detect a specified effect size at a given significance level.

Least Significant Value (LSV)
The LSV, or *least significant value*, is computed for single-degree-of-freedom hypothesis tests. The LSV is the smallest effect size, in absolute value, that would be significant at the specified level alpha and sample size. The LSV gives a measure of the sensitivity of the test on the scale of the parameter, rather than on a probability scale (such as power).

Relative LSV
Relative LSV is the LSV relative to the effect size, δ. It is calculated by dividing LSV by δ. It represents the observed effect size relative to the smallest detectable effects size that could be observed given a specified alpha. In effect, relative LSV measures how 'close' to the limits of power a model is. The smaller the value, the more 'scope' for detection of smaller effect sizes is present.

Any particular assessment design will have different assumptions about the meaning of "effect," "variability," and "replicate" (Green 1989, Eberhardt and Thomas 1991, Underwood 1991, 1994, Osenberg et al. 1992, Stewart-Oaten 1996), and must be specified before power can be assessed unambiguously. Description of the power statistics is in Box 1. For our analyses, alpha (α) was set to 0.05. All analyses were done with JMP 13 Pro (SAS institute).

We ran identical ANOVA models on two different datasets. In the first set of models, the time series were truncated to include the most overlap in years possible between the two programs. (hereafter called 'Matched Years Analysis'). This set of models allow us to investigate the intrinsic variance structure of the programs, testable only if one is comparing similar datasets in terms of time series. No other aspects of the data were matched; taxonomic resolution remained unchanged for each program, as did sample size and number of locations. For the Matched Years analysis, the following years were included:

- Anacapa island - 2008-2016
- Pt. Dume - 2010-2013
- Scorpion (Santa Cruz island) - 2008-2013
- Carmel Bay 2007-2016
- Pt. Lobos - 2006-2016
- Pt. Lobos using Carmel Bay as Reference - 2006-2016

For the second set of models, we used the 'best' time series for each program. 'Best' refers to the longest time series for each program where both inside and outside MPAs were monitored (hereafter called 'Best Time Series Analysis'). This set of models takes into account the current data assets of each programs as of 2016. In most cases, the time series analyzed are longer for both programs than in the previous analysis. These models provide a current assessment of MPA performance (for the subset of MPAs chosen) and allow a side by side evaluation of statistical power given the current status of the datasets from each program. For the Best Time Series analysis, the following years were included:

PISCO:

- Anacapa island - 2004-2016
- Pt. Dume - 2010-2013
- Scorpion (Santa Cruz island) - 2004-2016
- Carmel Bay - 2001-2016
- Pt. Lobos - 2001-2016
- Pt. Lobos using Carmel Bay as Reference - 2001-2016

RCCA:

- Anacapa island - 2008-2014
- Pt. Dume - 2007-2015 (missing 2011)
- Scorpion (Santa Cruz island) - 2008-2013
- Carmel Bay - 2007-2016
- Pt. Lobos - 2006-2016
- Pt. Lobos using Carmel Bay as Reference - 2006-2016

Results and Discussion

Spatial and temporal distribution of sampling

We found that the distribution of sites is not uniform across the state for the two programs (Figures 1.1 - 1.7). PISCO has historically focused on southern (Santa Barbara channel and northern Channel Islands (SBC-NCI) and central California (from Santa Cruz to Pt. Conception) with fewer sites in the Southern California bight (SCB) and Northern California. RCCA also has non-uniformly (clustered) distributed sites (Figures 1.1 - 1.7) along the coast. Several of these clusters of sites do not overlap with current or long-term PISCO sites. RCCA was originally envisioned to fill spatial gaps in PISCO monitoring and some of these clusters of sites reflect this. Especially notable is the presence of RCCA surveys in Northern California and the southern part of the SCB where PISCO has traditionally not surveyed. In other cases, RCCA sites directly overlap with PISCO sites. Perhaps this co-location was envisioned to allow direct comparisons such as that presented in this report, or due to the desirability of some dive sites for volunteer divers, the result is that several locations on our coast are extremely well sampled.

Both programs have time series that range in duration, including some sites that have been monitored consistently for the life of the respective program. As of 2016, PISCO time series extend as long as 18 years (20 years as of 2018-not included in this report) while for RCCA, consistently monitored sites have time series up to 11 years (13 years as of 2018-not included in this report) (Figure 1.8).

Figures 1.9 and 1.10 show the time series for PISCO (Figure 1.9) and RCCA (Figure 1.10) by site and MPA designation. Visualizing the time series in this way shows an interesting pattern of gaps and consecutive blocks of multi-year surveys, which differ between the two programs and likely indicate differences in funding models and other programmatic considerations. PISCO, with more sites overall and a longer program duration, has a number of 'core' sites that extend for the entire time series, a group of sites that were surveyed as a result of shorter-term funding opportunities (e.g. 2-5 year datasets) and some sites that are opportunistic (Figure 1.9). For example, extensive PISCO surveys between 2005-2008 were due to augmentation of PISCO funding by the CI NPS and Montrose settlement funds. Similarly, an increase in sites in the central mainland coast during 2007-2008 was the result of baseline funds for MLPA in that region. RCCA, with fewer sites and a shorter program timespan, has a pattern of gaps in sampling that is different than PISCO (Figure 1.9). Missing years of surveys appear more randomly distributed and are likely consequences of weather or volunteer availability.

Future monitoring plans should attempt to reduce direct spatial overlap between the two programs, especially if re-allocation of assets could result in greater spatial coverage along the coast (e.g. to locations that are not being currently monitored). When evaluating the possibility of discontinuing (or moving) a monitoring site, any program will need to assess criteria such as length of existing time series, cost to monitor the site and 'importance' of site to stakeholders. RCCA may have an additional factor that relates to the availability and interest in diving that

site by volunteers. Another possibility that will require further analysis would be to consider combining data in order to increase replication and potential added ability to detect effects of MPAs. Combining datasets would require reduction in taxonomic scope of the PISCO surveys to match the smaller species list of RCCA, but this is possible in that RCCA species lists were specifically designed as nested subsets of the PISCO lists. That is, each more specific species or category for PISCO can be summed to directly match a broader category for RCCA.

It is important to note that this analysis does not account for many other programs and existing datasets that use similar (or identical) protocols to PISCO. These include CRANE and BIGHT surveys of 2004 and 2008, respectively, and MLPA baseline surveys in 2010-13, throughout southern CA. North coast and North central coast Baseline monitoring datasets (using PISCO methods) are also not presented here. Many of these datasets were limited in duration (2-4 years) but were situated with the intent to provide information for eventual long-term monitoring.

We plotted the number of fish surveys conducted each month of the year by site for both programs (Figures 1.11 and 1.12). In general, PISCO surveys are more constrained to the months of August, September and October with the majority of fish surveys taking place in September (Figure 1.13). RCCA survey encompassed a broader range of months, likely due to constraints in finding volunteers but also possibly due to inclusion of sites in difficult regions to sample such as the North coast. PISCO teams complete two rounds of surveys at each location, starting with benthic surveys in June-August and then revisiting sites for fish surveys in August-November. RCCA strives to complete both benthic and fish surveys in a single visit.

The seasonality of sampling times in California will likely affect the results and the variance across surveys of highly variable rocky reefs and kelp forests. Surveys conducted over the course of a year can detect different species and different size classes due to recruitment and ontogenetic movements. Giant kelp (*Macrocystis pyrifera*) abundance changes dramatically over the course of a year (Bell et al. 2015) so quantification of this important foundational species will largely depend on survey timing. This is particularly important because giant kelp abundance is often used as an indicator of ecosystem health and is an important primary habitat for many fish species. Seasonal variability in kelp abundance may impact surveys for fishes and invertebrates that associate with this biotic habitat. Other algae species with annual lifecycles (e.g. the invasive *Sargassum horneri*) also vary strongly throughout the year and abundance estimates will be similarly influenced by survey seasonality. PISCO times their annual fish surveys in order to follow and capture the full season of fish recruitment (usually spring and summer). This consideration might be less important for RCCA that places less emphasis on documenting annual recruitment (i.e. no kelp canopy surveys, less taxonomic resolution for young of year). The effects of seasonal survey timing will require further analysis. Most rocky reef survey programs in CA conduct annual surveys (e.g. PISCO, RCCA, NPS KFM) but there may be opportunities for understanding the effects of seasonality in survey timing by locating and analyzing existing data sets with multiple surveys per year (e.g. SBC LTER), even if those data come from one or a few locations. We recommend that these types of analyses be

done in the future but until that time, efforts should be made to constrain the sampling to the extent possible within seasons.

MPA Analysis and Power

Temporal patterns in the biomass of targeted and non-targeted species are shown in Figures 1.14 – 1.19. Figures are presented by MPA (Carmel Bay SMCA, Pt. Lobos SMR, Pt. Lobos SMR vs. Carmel Bay SMCA, Scorpion SMR, Anacapa SMR/SMCA and Pt. Dume SMR/SMCA) and arranged by program (PISCO and RCCA). Note that the Y-axis scales differ among plots as the focus of this analysis was to assess differences over time. Methodological differences in fish surveys between PISCO and RCCA (specifically closed versus open species lists) will result in differences in absolute biomass for larger species groupings. Corresponding ANOVA models are presented in Tables 1.1 – 2.1.

Matched Years – The first set of ANOVA models used the 'Matched Years' datasets in order to compare detectable effect sizes and inherent variability between the two programs, allowing for protocol differences (e.g. transect and site replication, site location, taxonomic resolution) but not confounding duration of time series (i.e. environmental variation) (Table 1.1A-C, Figures 1.14 – 1.19). Overall, all models were significant (Table 1.1A). In terms of MPA effects, we found a significant positive effect of MPA (higher biomass inside relative to outside) for both programs at almost all locations (Table 1.1B). There were no significant MPA effect at Carmel Bay for RCCA (Figure 1.14) and Pt. Lobos for PISCO (Figure 1.15). In addition, for Carmel Bay, the effect of MPA was negative, that is, biomass of targeted species was greater outside than inside the MPA for both programs (Figure 1.14). At Scorpion, for RCCA there was a significant MPA*Year effect which makes interpreting the significant MPA effect difficult. This was also the case for the Pt. Lobos vs. Carmel Bay comparison for both programs.

Power analyses on the Matched Years ANOVA models (Table 1.1C) revealed that the power to detect differences between MPA and reference areas varied among locations and programs - no single program had more power than the other across all the sites. In the southern California MPAs, the PISCO program had lower LSV (Least Significant Value) values than RCCA at Anacapa and Scorpion and a higher value at Pt. Dume. However, the relative LSV value was lower for the PISCO program at all three MPAs, with RCCA values ranging from 1.03 to 1.62 times that of PISCO. These results indicate that the PISCO program is capable of detecting smaller effect sizes (smaller differences between MPA and reference sites) and could do so in fewer years and potentially with lower sample replication. In central CA MPAs, power was highly variable. At Carmel Bay, relative LSV was dramatically lower for PISCO (0.255 versus 1.215) while at Pt. Lobos, the opposite was found (PISCO LSV=3.209 vs. RCCA LSV=0.475). For the comparison of Pt. Lobos SMR with Carmel Bay SMCA, relative LSV was similar (PISCO=0.256; RCCA=0.236).

Best Time Series – While constraining the datasets to matching years helps to evaluate inherent variability, the reality of designing long-term monitoring for CA must account for the, sometimes extensive, data assets that programs are currently holding (i.e. the existing time series). Thus, we ran ANOVA models with the same structure on the datasets that contained the 'best' time series for each program. Again, all of the models were significant with the

exception of Pt. Lobos for PISCO (Table 1.2A). In terms of MPA effects, we found very similar results to the 'Matched Years' analysis, in that most sites and programs showed significant MPA effects (Table 1.2B). Again, there was no significant MPA effect at Carmel Bay for RCCA (Figure 1.14) and Pt. Lobos for PISCO (Figure 1.15) and for Carmel Bay the MPA effect was negative (Figure 1.14). In addition, at Pt. Dume, the previously significant MPA effect for RCCA became non-significant, despite a longer time series at that site for that program (Figure 1.19). This result demonstrates that longer time series will not always lead to MPA effects and that over time MPA and reference areas can become more similar. At Anacapa, Pt. Dume, Pt. Lobos vs. Carmel Bay for RCCA and Scorpion for both programs, there was a significant MPA*Year effect which makes interpreting the significant MPA effect difficult.

Power analyses on the 'Best Time Series' ANOVA models (Table 1.2C) also showed some variation among sites in the strength of a program to detect effects of MPAs but in general, and likely due to longer time series, PISCO models had higher power and lower relative LSV. Only at Pt. Lobos did RCCA have a relative LSV 11.9 times lower than that of PISCO. At the remaining sites, relative LSV ranged from 1.26 to 6.51 times lower for PISCO. The interpretation is that relative to the effect sizes detected, PISCO monitoring can detect much lower effect sizes should they exist. A lower relative LSV also implies that small effect size can be detected more quickly.

Single Species – We chose several representative species from each region to conduct similar MPA and power analyses. Species selection was based on high total biomass in the region and inclusion on the species (indicators) lists presented in the Draft Action Plan for MPA Monitoring (http://www.opc.ca.gov/2018/07/draft-mpa-monitoring-action-plan-now-available-for-public-comment/). For Pt. Lobos and Carmel Bay comparisons we chose Kelp rockfish (*Sebastes atrovirens*), Lingcod (*Ophiodon elongatus*) and Blue rockfish (*Sebastes mystinus*). For Scorpion, Anacapa and Pt Dume MPAs, we chose CA Sheephead (*Semicossyphus pulcher*) and Kelp Bass (*Paralabrax clathratus*). For single species analyses we used the "best time series" datasets. Time series plots for selected single species biomasses are shown in Figures 1.20 – 1.25. For each species-site combination, biomass data are plotted on the same scale. For identical species, we can assess not only the pattern of change in biomass over time, but absolute biomass differences. Corresponding ANOVA models are presented in Table 1.3.

Results of the single species analyses were not very different from the targeted species analyses, likely because all of the selected single species are fished and contribute heavily to the targeted species biomass (Table 1.3). Power analyses on the MPA effects from the ANOVA models of these single species showed similar variation among sites in the strength of each program to detect effects of MPAs as in the Targeted Species models above. Again, in general, and likely due to longer time series, PISCO models had higher power and lower relative LSV.

Interestingly, on average, absolute biomass was greater for almost all species and sites for PISCO compared to RCCA. Reasons for this are almost certainly methodological. For example, biomass of blue rockfish was greater in PISCO surveys, likely because PISCO includes midwater and kelp canopy strata in fish counts. PISCO's midwater and canopy surveys may also explain

slightly higher biomass for kelp rockfish and kelp bass. Benthic species such as lingcod or CA sheephead do not show strong absolute biomass differences between programs.

Conclusions

For our limited comparison (5 MPAs, 6 comparisons) and targeting the species grouping and metric most likely to show MPA responses (i.e. fished species biomass, most abundant species) we found that both PISCO and RCCA were able to detect significant MPA effects when the effects were relatively large, but with varying degrees of power. We stress that these ANOVA models were very simple and do not take into account any aspects of habitat or other environmental correlates. Using targeted species is an attempt to control for these variable and isolate the fishing effect but makes the assumptions that a) targeted species are actually fished outside of these MPAs, and b) the responses of targeted species to habitat and environment is the same inside and outside of the MPAs. Implicit in our analyses (albeit, all MPA analyses of this type) is that reference areas are similar in benthic habitat and oceanographic conditions to MPA areas. Obviously, it is not possible to control for all variables when selecting paired MPA and reference sites in the natural environment, but the differences that we saw in the models of Pt. Lobos SMR using Northern Santa Cruz sites as references (little or no effect) versus those using Carmel Bay SMCA sites as references (strong MPA effect) make it clear that choice of reference areas is critical and can influence detection of MPA effects. One way to help mitigate undue influence of single sites (either positive or negative) is to survey more locations within and outside of any focal MPA. Stratifying sites in the alongshore direction across larger areas in MPAs and reference sites might be equally or more important for assessing MPA performance than stratifying across depth zones (within the limited 20m limit to SCUBA surveys).

While both programs were able to detect some MPA effects, there were a few interesting results worth discussing. First, central coast sites showed more variable temporal patterns in fish biomass and tended to show fewer differences in sites inside and outside MPAs. Carmel Bay SMCA, in particular, has on average greater biomass of fished species outside than inside. Carmel Bay SMCA allows recreational take of finfish and it is possible that fishing effort in this area is greater than the reference sites to the North (Pescadero, Cypress Pt., Lone Tree, Lingcod; Appendix Table 1.2). If true, this also explains the lack of a large effect when comparing Pt. Lobos to northern reference areas (for PISCO only) and the large effect of the Pt. Lobos SMR when compared to Carmel Bay SMCA (for both programs). As found during the five-year review of the central CA MPAs, we also found mixed and somewhat weak effects of protection in this region. For the MPAs in the Santa Barbara channel area and NCI, we found more consistent, positive effects of protection. We attribute the more visible effects of protection to generally higher levels of fishing adjacent to the south coast MPAs and potentially to the faster growth rates of a warmer, more sub-tropical fish fauna in southern CA.

Given the intrinsic temporal variability in these dynamic kelp forest systems, power to detect MPA effects over the stochastic noise in the system is an important trait of any monitoring program. While both programs detected MPA effects, assessments of the statistical power of the programs to detect effects of varying sizes differed. In southern CA, the PISCO program has

more power to detect smaller effect sizes and inherent in that, the ability to detect changes on faster time scales than the RCCA program. There could be many reasons for this finding. First, the PISCO surveys, especially in the Channel Islands region occur at many sites within and outside of individual MPAs. Reefs in this region tend to be narrow and steep in the onshore-offshore direction and PISCO adds stratification in the alongshore direction – the result is fewer transects per site but more sites. While this might lead to more variation, it also leads to a higher sample size (number of transects) per MPA-Reference pair. In total, despite fewer transects per site, PISCO surveys more transects per MPA and reference area. This survey design has added advantages of capturing more variation in micro-habitat (which can vary on small spatial scales in Southern CA rocky reefs), as well as increasing probability of detecting rare or invasive species.

Despite this variability in detection power, in general both programs were able to detect similar differences in fish biomass metrics between MPA sites and appropriate reference sites. This promising result indicates that there may be opportunity to strategically coordinate the two monitoring groups to maximize geographic coverage of California's MPAs. Outside of studies similar to the current analysis, there may not be justification for extensive spatial overlap between the two programs. Though there are a number of considerations that could contribute to a decision strategy for adding/discontinuing sites within each group, length of time-series and existing spatial coverage within and outside of an MPA should be primary considerations. Currently there are some fairly clear geographic patterns in regional coverage that could guide large-scale partitioning of the state between the two groups. For example, the PISCO group has broad coverage and long time series across the Northern Channel islands while RCCA's coverage is spottier with shorter time series. In contrast, RCCA covers the south coast (LA, Orange, and San Diego Counties, and Catalina Island) while PISCO does not currently survey south of Malibu. There are other such examples along the coast. Future coordination and allocation of resources between the groups may provide opportunities to enhance spatial coverage and limit redundancy in survey efforts.

This report contributes to the ongoing discussion of relative benefits of citizen science and academic science programs for kelp forest monitoring. We started with the assumption that observer quality is similar, that is, individual divers in the two programs have equal abilities to identify and size organisms, and generally conduct a survey in a similar manner underwater. Given that starting point, we test aspects of programmatic sampling bias in space and time, specifically evaluating site and transect replication as well as duration and consistency of time series against a single, very specific question – are there MPA effects on fish biomass in paired inside-outside comparisons and what is the statistical power of the programs to detect change over time? While important, what this study does not do is equally important. Ultimately, the role for citizen science programs will need to be evaluated on a number of criteria, including cost-effectiveness relative to ability of data to answer multiple questions of interest. We presented one specific aspect of the 'effectiveness' side of the equation here but there are many other considerations for monitoring marine ecosystems in CA including but not limited to understanding the effects of climate change and contributing data to fisheries management. In

addition, a thorough analysis of the 'cost' side of the equation should be undertaken when evaluating any monitoring program (not just citizen science programs).

Part II. Methodological comparison of multiple monitoring techniques for California's rocky marine ecosystems

Background

The Marine Life Protection Act (MLPA) recognized the value of California's marine diversity and ecosystems by requiring the state to redesign its fragmented system of existing Marine Protected areas to function as a network (MLPA, Chapter 10.5 of the California Fish and Game Code, §2850-2863). Marine protected areas (MPAs) are a form of whole ecosystem management and protect and conserve habitats and biodiversity within them. The MLPA resulted in a coordinated system of MPAs throughout the state that encompasses the diversity of marine and estuarine habitats within state waters. The design process recognized both the importance of connectivity within and between habitats as well as the need for adequate representation of these habitats across the network (Botsford et al. 2014). Regional baseline monitoring plans recognized 8 key habitats (and 2 types of human usage) across the network. Of these, several habitats are defined on the basis of hard substrate (i.e. rocky intertidal, kelp and shallow rock (0-30m), mid-depth rock (30-100m) and deep ecosystems and canyons (>100m). As Phase 1 baseline monitoring transitions to statewide long-term monitoring of the MPA network, and recognizing potential connectivity among habitats and depth zones, it will be important to assess existing monitoring tools and techniques as well as existing data assets across multiple habitats for California's MPA network.

In California, various techniques are being used for monitoring nearshore marine ecosystems and MPAs. For example, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), an academic consortium that conducts research to advance understanding of the coastal ocean within the California Current Large Marine Ecosystem and inform management and policy, has been conducting SCUBA surveys of MPAs throughout the state for the past two decades. SCUBA surveys are limited to relatively shallow depths. Other monitoring methods that are being used by other institutions and programs in California include SCUBA surveys by citizen scientists (e.g. ReefCheck CA [RCCA]), collaborative fisheries science using scientific fishing aboard sport fishing vessels, remotely operated vehicles (ROV), manned submersibles, and drop cameras/landers. These monitoring techniques tend to be utilized at different depths and geographic locations and may capture species or particular life history stages of species, that are unique to one or a few techniques or common across multiple techniques.

The **goal of this project** is to perform a methodological comparison of existing data collected in rocky ecosystems across depths to inform long-term statewide MPA and fisheries monitoring strategies. We analyze existing data from surveys utilizing hook-and-line, remotely operated vehicles (ROV), manned submersibles, and SCUBA surveys (both by PISCO and RCCA) programs. In this study, we focus on fishes and provide information regarding the species commonly

captured by these techniques, potential species dynamics such as ontogenetic habitat shifts where individuals spend their early life in shallow areas then move to deeper areas as they grow bigger, as well as the potential depth and latitudinal range of particular species. This information will be useful to ensure that any particular monitoring technique is effective for selected indicator species as long-term monitoring plans become established. Ideally, methodological comparisons will enable managers to identify a suite of techniques that can be used to monitor certain indicator species or identify synergies among different monitoring techniques to collectively inform statuses of indicator species. Combining complementary data from different monitoring techniques that often operate at different time periods, geographic regions, and depths may enhance monitoring frequency and extent in cost-effective ways while potentially providing more meaningful information for assessment and management of the network.

Methods

We performed a methodological comparison of existing data collected in rocky ecosystems to inform long-term statewide MPA and fisheries monitoring. We analyzed existing data from surveys utilizing hook-and-line on commercial passenger fishing vessels (CPFV), remotely operated vehicles (ROV), manned submersibles, and SCUBA surveys both by PISCO and RCCA programs. Description of data sources follows. We determined the species of fishes observed by these monitoring techniques and synthesized ecological information derived from these techniques. In particular, we visualized the latitudinal ranges of different species and the demographic profile (i.e. fish size) of species in relation to depth and latitudes. The later aimed to reveal potential ontogenetic latitudinal and depth patterns exhibit by different species. Finally, we discuss the strengths and limitations of different monitoring techniques and how these techniques can complement each other.

For each monitoring dataset, we extracted geographic location associated with the samples (latitude and longitude), sampling depth, fish species identification, number of individuals, and fish size. We applied the following data filters to make the datasets from different monitoring techniques comparable:

a) RCCA began sampling in 2006 and categorically sized fishes into the following bins: small (<15cm), medium (15-30cm), and large (>30cm). In 2013, the protocols were changed and RCCA divers began to estimate the size of all fishes at 1cm resolution, although some categorical sizing still exists in the dataset after 2013. In order to derive the relationships of fish sizes with depths and latitudinal locations, we required high resolution sizing and thus we removed all categorical entries in our methodological comparison analysis.

b) For all datasets, we binned the size classes into the 5cm intervals to allow us to better visualize latitudinal and depth patterns of fish size. For example, fish of size 0 to 5cm are assigned a length of 5cm. We cap the size representation to 75cm, i.e. all fish with size >70cm are assigned length 75cm.

c) For all datasets, we only retained organism entries that are identified at the species level. For example, entries such as “Young of year (<10cm Sebastes sp.)”, “Schooling (10-15cm Sebastes sp.)”, “Sebastes spp”, “Unidentified fish”, “Unidentified Sebastes sp.”, and “Unidentified Pleuronectidae” were excluded from our analysis.

We derived the normalized distribution of individual species sampled per monitoring techniques in relation to depths and latitudes. We used geom_density_ridges from the ggridges package in R to calculate the density estimates from the provided data.

The following are short descriptions of the datasets from different monitoring techniques used in the analysis:

1. Remotely Operated Vehicle (ROV)
The California Department of Fish and Wildlife (CDFW) and MARE (Marine Applied Research and Exploration), together with partners, developed the use of ROV for monitoring deep subtidal environment in California. We received the state-wide ROV data for years 2014 to 2016 (courtesy of Mike Prall, CDFW). The ROV can operate to depths beyond 300m but most of the surveys in the dataset were performed in depths <100m.

ROV surveys employ a rigorous three-step process to enumerate fishes along six parallel 500m long transects placed in a systematic random fashion within a predetermined section of rocky habitat. First, the ROV uses forward facing video transects to record fishes present and the size and number of fishes are documented using this method. Lasers mounted in ROVs aid in sizing fishes. All fishes are identified to the species level when possible. In the second step, the fish identification is verified using videos from down-facing camera and still photographs. Lastly, an observer not involved in the first two processes reviews the fish identification.

2. Manned submersible
We used a two-year manned submersible dataset (2007 and 2008) from the California IMPACT project, which was part of the Central Coast Baseline Program in deep portions of eight newly-established (at the time) MPAs and associated reference sites (Starr and Yoklavich 2008). This dataset was downloaded from the OceanSpaces website (a project of the CA Ocean Science Trust; http://oceanspaces.org/). The eight MPAs are: Soquel Canyon State Marine Conservation Area (SMCA), Portuguese Ledge SMCA, Point Lobos State Marine Reserve (SMR), Point Lobos SMCA, Point Sur SMR, Point Sur SMCA, Big Creek SMR, and Big Creek SMCA. Although this dataset is limited in latitudinal range compared to other monitoring techniques, this data can provide us with important insights on the fish composition in the deeper areas as the surveys extend beyond 300m deep.

The IMPACT project performed their monitoring on September 10 to November 5 2007 and September 6 to November 3 2008, encompassing ~170,000m^2 of seafloor habitats in depths from 24m to 365m. A pilot operates the submersible while an experienced scientist identifies, measures, and counts all fish species within a 2-m-wide strip transect. Fish total length in cm is

estimated using mounted paired lasers as a guide. An external video camera documents each survey and used for post-survey review to verify the accuracy of fish identification and sizing.

3. Hook-and-line

We used the data from the California Collaborative Fisheries Research Program (CCFRP), a partnership of scientists and community members interested in fisheries sustainability. CCFRP is a citizen science program designed to evaluate effectiveness of California's MPA network. This dataset was provided by Dr. Rick Starr, Moss Landing Marine Laboratories (MLML). The CCFRP program, let by MLML and California Polytechnic State University San Luis Obispo (CalPoly SLO), initially performed experimental fishing by volunteer anglers in four MPAs and nearby reference sites in Central California (years 2007-2016). Since 2017, the program has expanded statewide to include 10 additional MPAs in southern, north central and northern California. The experimental fishing surveys were performed in nearshore rock habitats at depths less than 40m, in order to limit fish mortality from barotrauma.

In conducting the hook-and-line surveys, rock habitat is first identified from benthic habitat maps and then stratified into 500m x 500m grid cells within MPAs and associated reference areas. Sampling locations are selected randomly among these cells with a goal of sampling four cells per day. Caught fishes are identified to the species level, measured to the nearest cm total length, fishing location and depth is recorded, and the fish are tagged before being released at the point of capture.

4. ReefCheck California (RCCA)

RCCA is a citizen science program, monitoring California's kelp forests since 2006 with a mix of paid staff and volunteer divers. RCCA's program is designed to facilitate trained volunteer divers to participate in monitoring fish communities and reef health. RCCA assesses populations of a set of target fish species (35 species), including those that are easily identified by volunteer divers and are of interest for MPA evaluations. A total of 18 transects are surveyed per monitoring site across depths with a maximum depth of approximately 20m. Survey transect area is 30m × 2m × 2m along the benthos. These transect dimensions are consistent with the PISCO monitoring protocol. Prior to year 2013, RCCA sized fish into small (<15cm), medium (15-30cm), and large (>30cm) categories. Numerical sizing of fishes to the nearest cm resolution started at year 2013 although just under 50% of the surveys from year 2013 onwards still size fish categorically. RCCA data are publicly available although we obtained the full raw dataset directly from Dr. Jan Freiwald, Director of RCCA.

5. Partnership for the Interdisciplinary Studies of Coastal Oceans (PISCO)

The kelp forest monitoring program of PISCO is run out of academic institutions (UCSB and UCSC) since 1999 and relies on a mix of paid professional scientists and volunteer students. PISCO's monitoring approach is based on SCUBA diver surveys that quantify the density and abundance of the fishes as well as macroalgae and invertebrates that constitute kelp forest communities. The approach allows characterization and quantification of ecosystem attributes such as biodiversity, community structure, and population abundance and size structure of ecologically and economically important species.

At each site, 8 to 12 fish transects measuring 30m × 2m × 2m are conducted at multiple levels in the water column: benthic, midwater, and kelp canopy (when present). Transects are laid out in a stratified random design, with multiple nonpermanent transects located in fixed strata (i.e. outer, middle, and inner edges of the reef). At each level in the water column, a SCUBA diver counts and estimates the sizes of all fish species to the nearest centimeter (total length), excluding small cryptic fishes. PISCO also makes data publicly accessible but the raw datasets used here were provided by the author (Caselle) for this analysis.

Results and Discussion

We recorded 193 unique fish species for the combined data from five monitoring techniques analyzed in this study (Table 2.1). Of these species, 15 were common to all the monitoring techniques including blue rockfish, lingcod, kelp greenling and senorita (Table 2.2). Most, but not all (e.g. senorita) of these 15 common species are targeted by fishing. Manned submersible and ROV tallied the highest number of species among the monitoring techniques analyzed (106 and 107, respectively). This is due to the fact that these monitoring methods surveyed a wider range of depths (manned submersible from ~27m to 300m and ROV from ~20m to 100m). On the other hand, RCCA tallied the lowest number of species being monitored (31 species). This is due to the design of RCCA monitoring, i.e., to focus on few, easily identified indicator species that a trained volunteer diver can record. We summarize the most commonly surveyed species for each technique in Tables 2.3 – 2.7. The top species recorded in ROV dataset is halfbanded rockfish that accounted for 62% of all the recorded fish individuals (Table 2.3), pygmy rockfish (27%) for manned submersible (Table 2.4), blue rockfish (39%) for hook-and-line (Table 2.5), and blacksmith for both PISCO and RCCA at 21% and 34%, respectively (Tables 2.6 and 2.7).

In total, data from the various monitoring techniques were distributed across the state but not every technique has been used in every region (Figure. 2-1). Survey sites utilizing hook-and-line, ROV, and SCUBA (both RCCA and PISCO) methods were well distributed latitudinally (Table 2-8, Figure 2-1). However, the manned submersible surveys were limited to central California, making it likely that the species composition recorded for this method was biased towards central California species. Although the hook-and-line data from CCFRP was geographically well represented for 2017, the majority of the data (from 2007 to 2016) was solely from central California. Therefore, the results for the species composition for the hook and line data may also be biased towards central California species. We note that our data compilation efforts likely did not include the full range of data that exist in CA. However, the dataset we developed can be added to as additional data are located or collected.

The surveys from five fish monitoring methods targeted different depths but still showed some amount of overlap (Figure 2.2). Both RCCA and PISCO SCUBA surveys were performed at depths <20m, hook-and-line at depths <50m, ROV predominantly from 20-100m, and manned submersible at depths up to 300m (Figure 2.2). We note that ROVs can operate at much greater depths but the current dataset focused at 20-100m depth was likely designed to monitor mid-depth fish populations, a focal 'ecosystem feature' for the MLPA baseline monitoring programs. The differences in primary survey depths at which these five monitoring techniques operate as

well as their inherent methodological differences (i.e. four visual systems - one using cameras and three using humans and one non-visual system) resulted in a different set of species observed per monitoring technique.

The differences in survey depths as well as the statewide extent of the surveys allowed us to: 1) derive information on species depth and latitudinal distribution and potential ontogenetic movements, and 2) assess the potential suitability and complementarity of monitoring techniques in assessing different fish populations. For example, blacksmith, California sheephead, senorita, and treefish are some species we found to be restricted to lower latitudes of California (i.e. south of Pt. Conception) (Figure 2-3). Other species were only observed in the northern part of the state, such as china and quillback rockfishes, while several species are well distributed across the state such as lingcod and blue rockfish. As explained above, there could be biases since every technique was not performed at every latitude but the patterns we observe corroborate our knowledge and published accounts of the distributional ranges of these fishes (Miller and Lea 1972). Interestingly, we observed potential ontogenetic latitudinal patterns for some species, particularly vermilion rockfish and copper rockfish (Figure 2-3). The small-sized individuals of these two species can be found at lower latitude of California while no fish less than 20cm length was recorded at higher latitudes. Even the smaller bodied Rosy rockfish appears to show a similar pattern with larger individuals in the north. This could represent true ontogenetic movements, as some of these species are capable of large migrations over their lifetime (Haldorson et al. 1994, Lea et al. 1999, Hanan and Curry 2012) but the pattern may also be explained by differences in growth rates within species across the state with higher productivity in the colder, upwelling influenced north coast (Black et al. 2005, Gertseva et al. 2010) and fish spending less time in smaller size classes. Geographic differences in recruitment could also result in the observed spatial patterns.

We also observed clear cases of depth related, size structuring in species such as canary rockfish, lingcod, vermilion rockfish, yellowtail rockfish and bocaccio (Figure 2-4). Larger and presumably older individuals of these species were recorded in deeper areas while smaller, presumably juvenile fishes were recorded in shallow to mid-depth areas. Ontogenetic patterns in depth have been documented for many rockfish species as well as lingcod in California (Hartman 1987, Lea et al. 1999, Miller and Geibel 1973, Greenley et al. 2016). Although the observed latitudinal and depth-related patterns were likely natural patterns as other fished species do not show those patterns (i.e. using those other species as 'controls'), it is also possible that those patterns are confounded or driven by harvesting of some species (Frank et al. 2018).

Conclusions

We show that different monitoring techniques tend to be confined to distinct and sometimes somewhat narrow depth zones but that overlap in many species distributions across depth zones and sampling techniques enabled us to detect some interesting depth- and latitude-dependent patterns (e.g. bigger individuals found in deeper areas and at higher latitudes). Matching the monitoring method to the spatial extent of the species of interest or adjusting the method to account for the ecology of the species of interest can enhance future monitoring

effectiveness. The results of this study will not only serve to inform decisions on habitat-specific indicators for future MPA monitoring but will also enhance our ability to conduct cross-habitat analyses for MPA performance evaluations.

Our results have several applications. First, indicator species have been identified for long-term statewide monitoring (Draft Action Plan for MPA Monitoring; (http://www.opc.ca.gov/2018/07/draft-mpa-monitoring-action-plan-now-available-for-public-comment/) and here we provide a species-method table to aid in choosing the most effective monitoring technique, combination of techniques, or alternative techniques (in cases where logistical constraints prevent any particular monitoring technique from being employed) to capture these indicators. In some cases, we may discover that we have not currently employed any monitoring techniques to capture a particular indicator or set of indictors. In this case, we can evaluate the indicator itself and/or develop new monitoring techniques. This report assessed five programs currently employed in CA but that does not encompass the full extent of techniques, especially for mid-depth and deep rock areas. In particular, new developments in drop camera technology are occurring throughout CA and show promise for monitoring a variety of depths (Starr pers. comm.).

Second, our results can inform the choices of appropriate techniques to be used to detect MPA effects across habitats and importantly, identify where we might be missing important segments of the population of a given species by using a particular technique. For example, kelp rockfish, gopher rockfish, and blue rockfish are examples of species for which the majority of the sampled individuals were found in nearshore, relatively shallow areas (<100m depth). Therefore, the full geographic and demographic distribution of these species can be captured by SCUBA surveys combined with any of the other monitoring tools that can access those shallow depths. However, species such as vermilion and canary rockfish, while present in nearshore SCUBA surveys, have maximal biomass (e.g. more and bigger fish) at much greater depths. Nearshore shallow monitoring would not fully capture the entire depth range or demographic structure of these species and could be misleading in analyses of MPA performance. These are simply a few examples of species with different depth ranges. In addition, it is envisioned that data from the MPA long-term monitoring programs be used to inform fisheries management in CA. Careful attention will need to be paid to data from methods that might only capture part of a stock. A combination of techniques may be required for a full assessment of populations of species that occur over large depth ranges and/or show ontogenetic movements across depths.

As a next step to this study, it will important to quantify the ability of particular techniques to detecting changes in populations as a result of MPA protection (such as done for the first section of this report). Longer time series will be required for that analysis. Assessing the detection of power of different monitoring techniques for different species, particularly those that exhibit ontogenetic latitudinal and depth patterns can better inform MPA evaluation and fisheries management actions. It may require some time before the length of time series from deep water habitats approach those of more easily accessible shallow water habitats but

understanding species distributions across MPAs as we have shown here will guide rational and cost effective monitoring.

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Figures and Tables Part I.

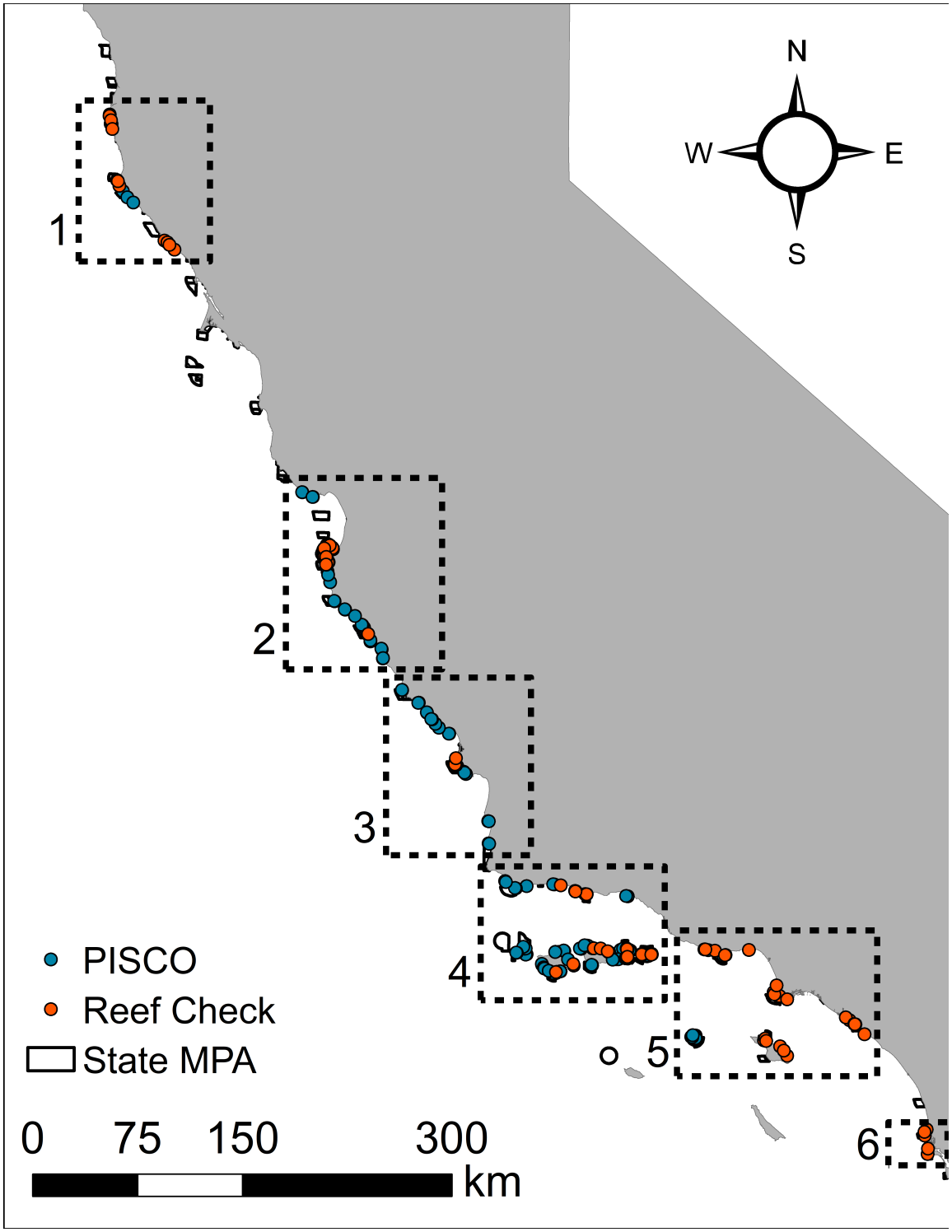


Figure 1.1. Map of PISCO and RCCA monitoring sites in California. Only sites with > 2 years of monitoring are shown. Hatched numbered boxes mark zones shown in more detail in following maps. In these detailed maps, bubbles are scaled to the number years of data and that scale is identical in all maps. MPAs are shown in red shading.

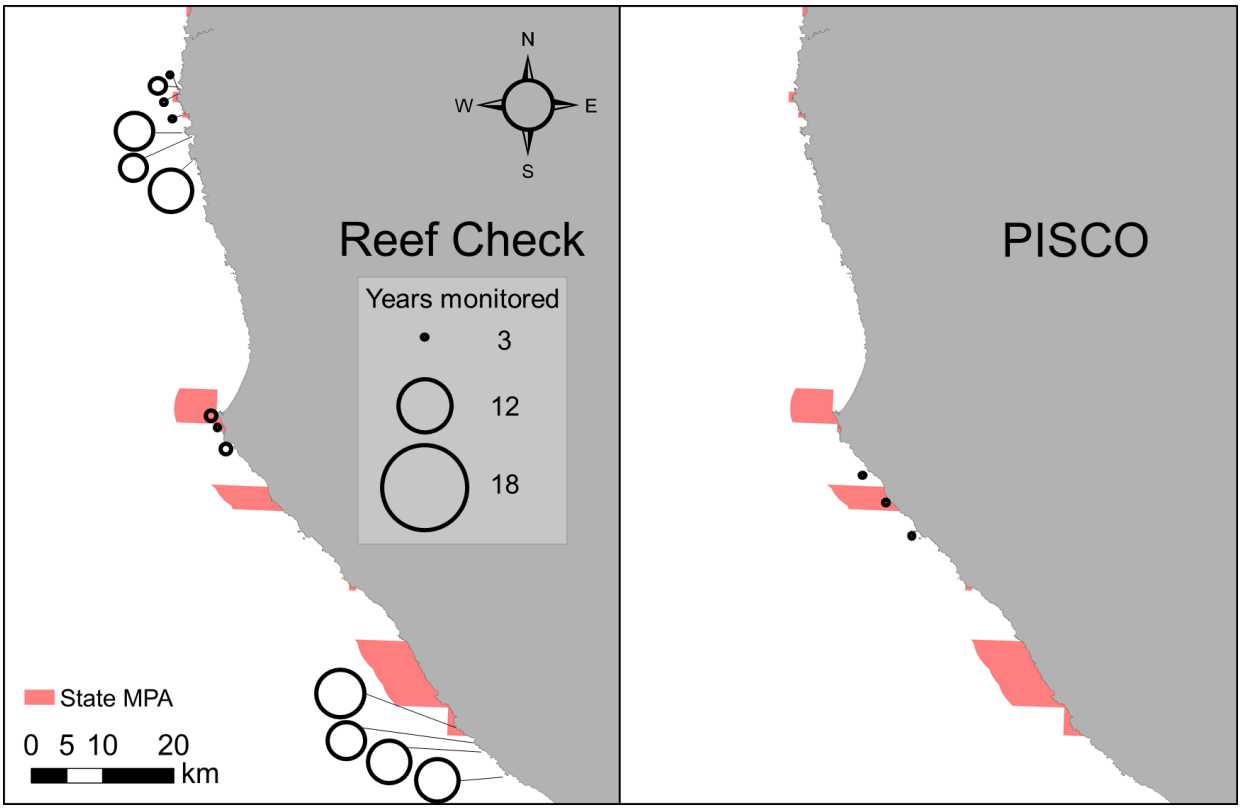


Figure 1.2. Zone 1 Northern California.

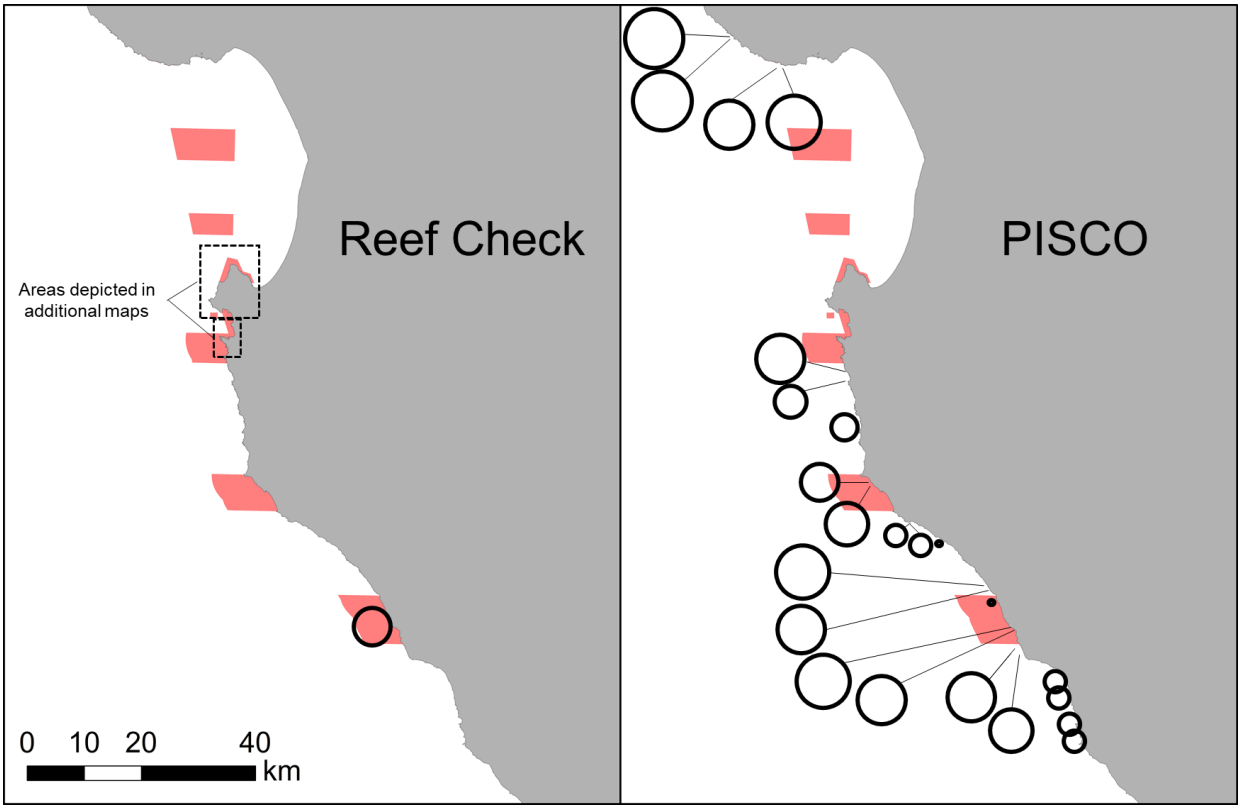


Figure 1.3. Zone 2 North central California. Hatched boxes mark areas shown in further detail in Figures 1.3a and 1.3b below

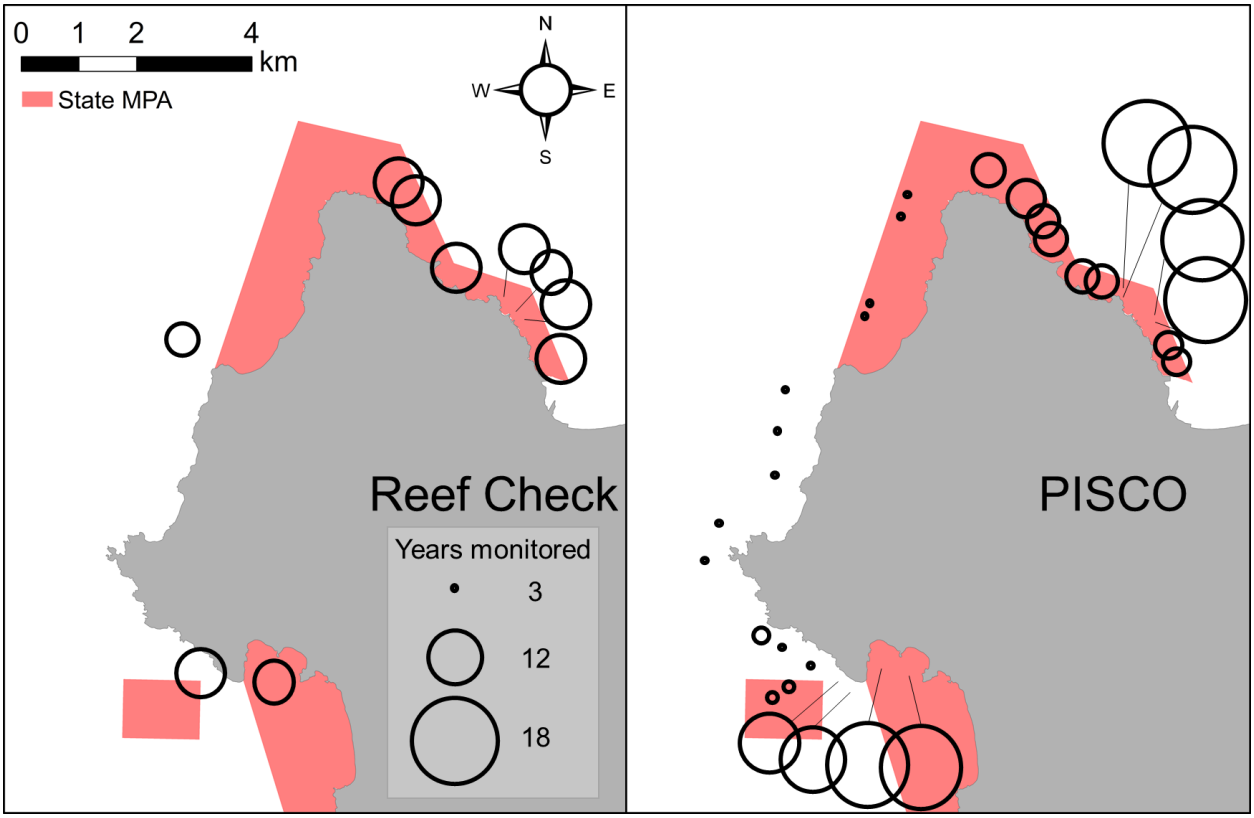


Figure 1.3a. Detail of Monterey Peninsula (hatched box in Figure 1.3)

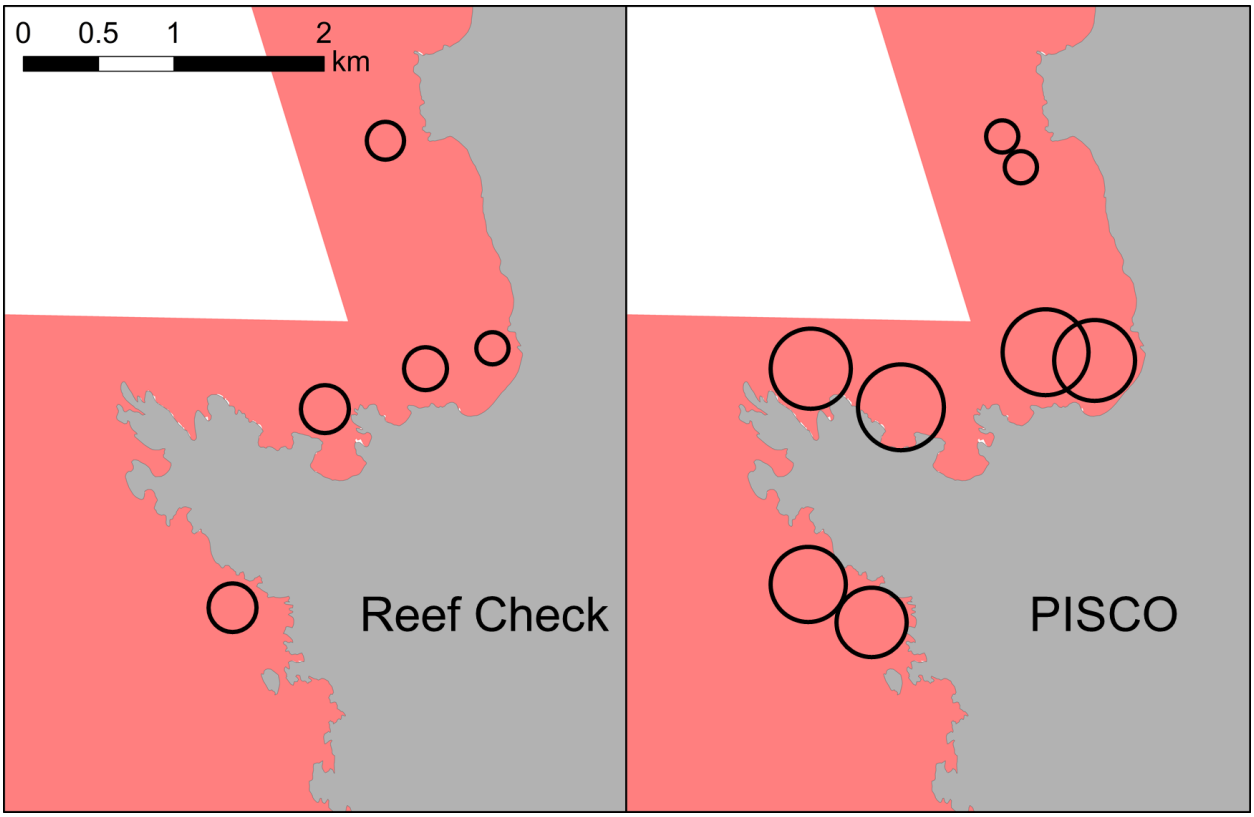


Figure 1.3b. Detail of southern Monterey and northern Big Sur coast (hatched box in Figure 1.3)

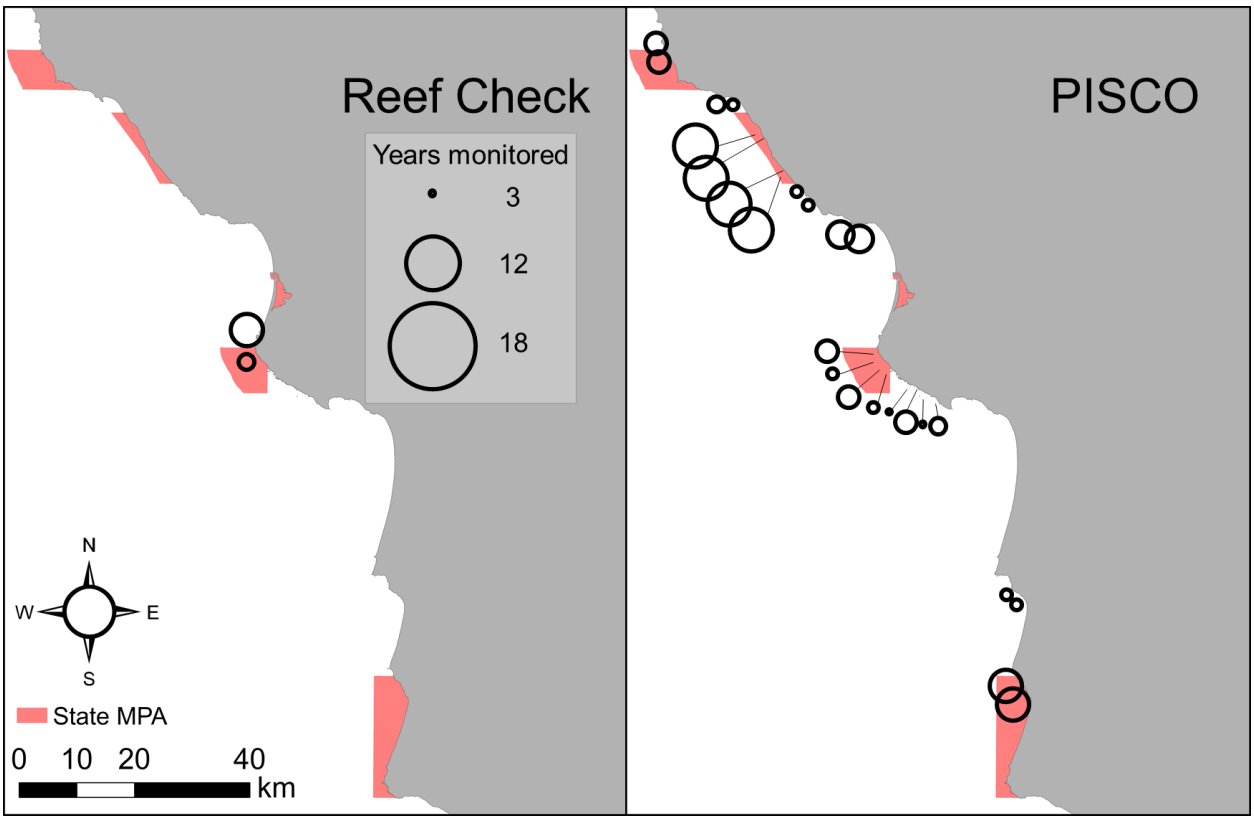


Figure 1.4. Zone 3 South central California

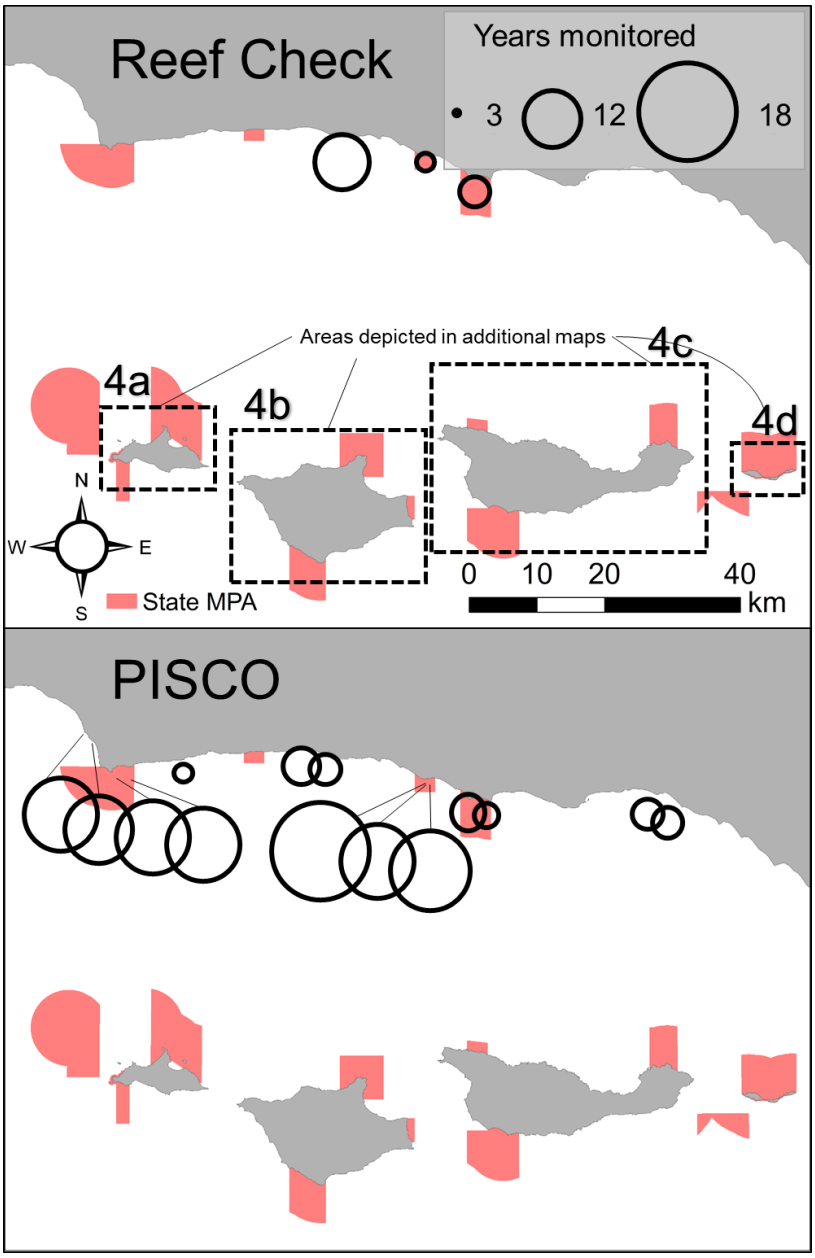


Figure 1.5. Zone 4 Santa Barbara Channel. Hatched boxes mark areas shown in further detail in Figures 5a-d below.

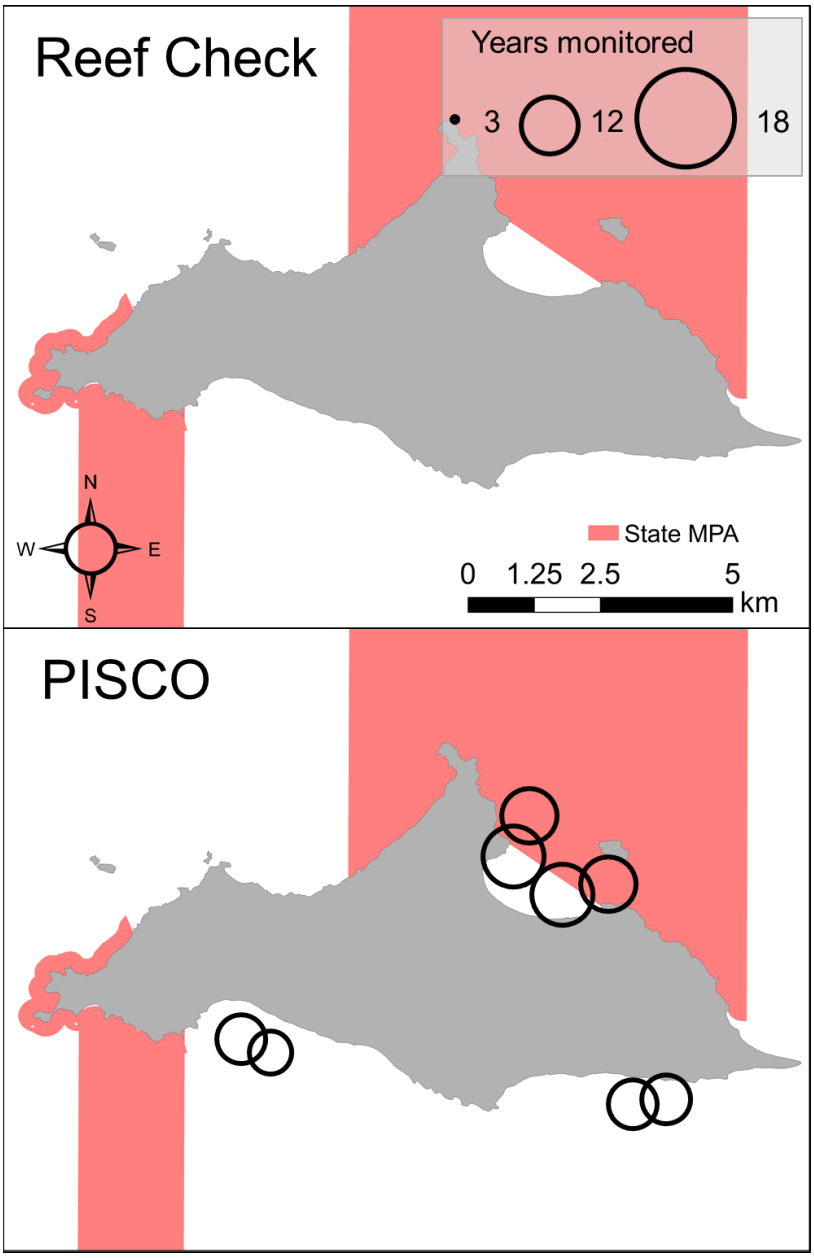


Figure 1.5a. Detail of San Miguel island (hatched box 4a in Figure 1.5)

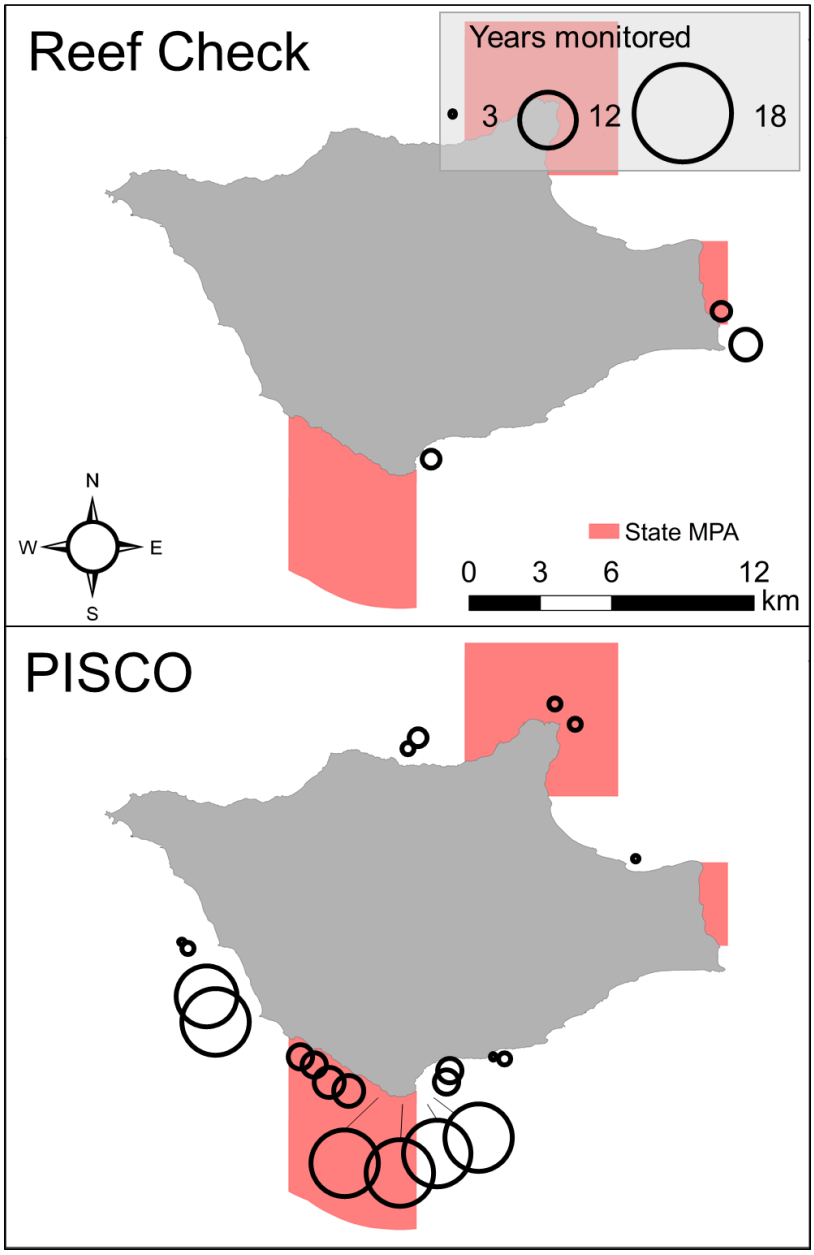


Figure 1.5b. Detail of Santa Rosa Island (hatched box 4b in Figure 1.5)

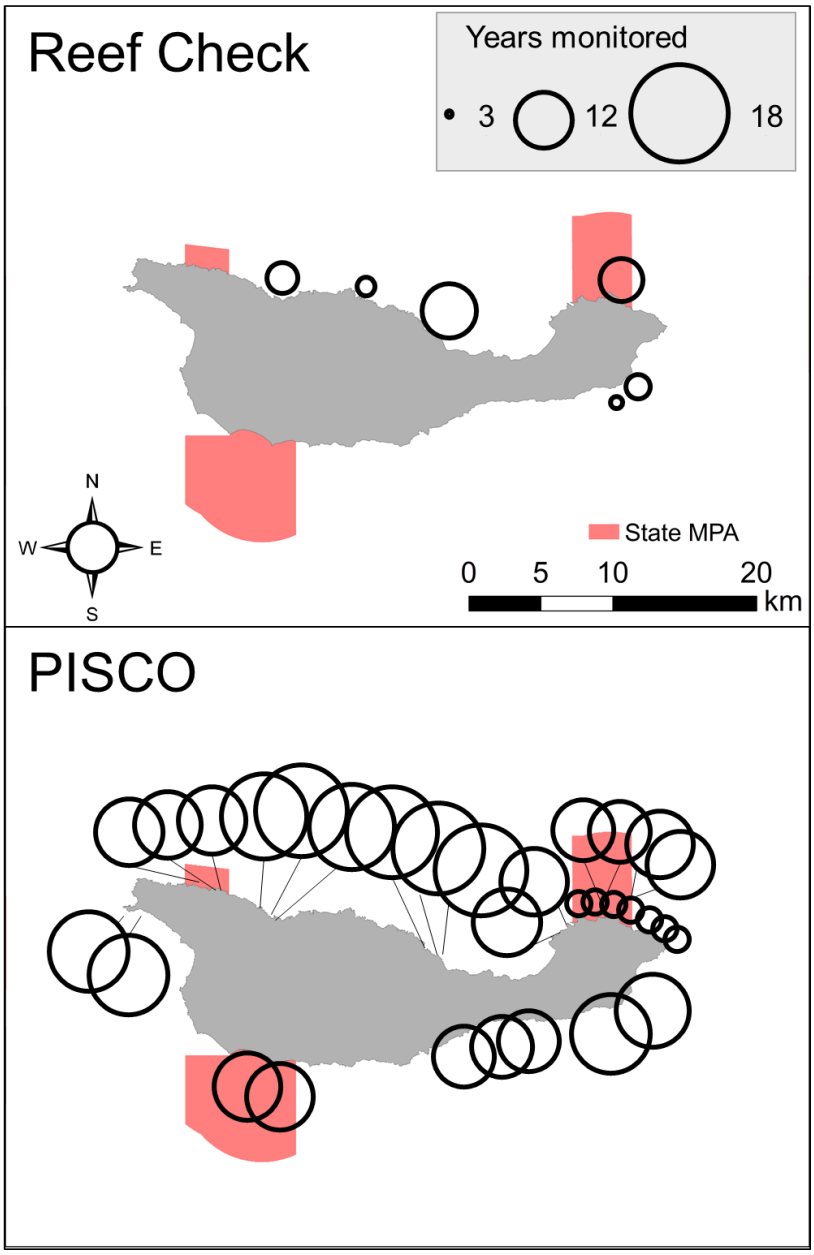


Figure 1.5c. Detail of Santa Cruz island (hatched box 4c in Figure 1.5).

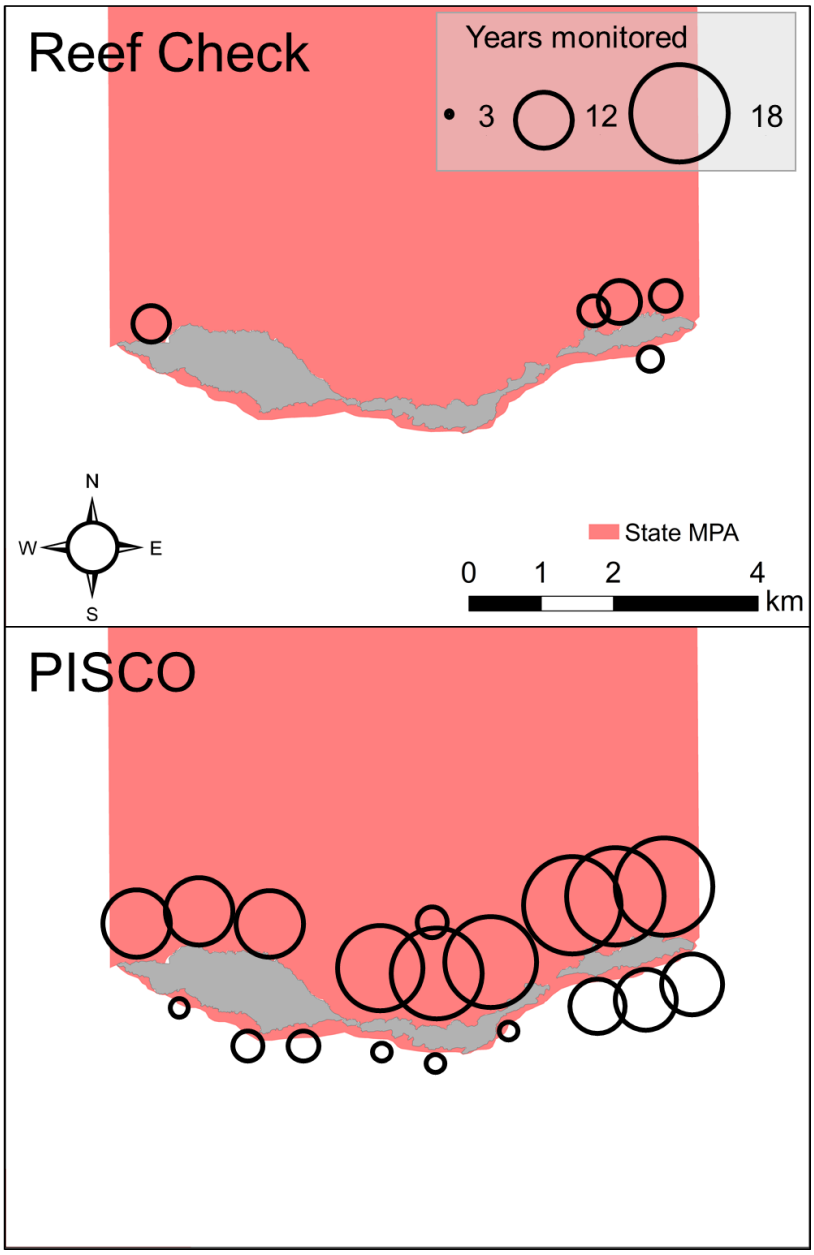


Figure 1.5d. Detail of Anacapa island (hatched box 4d in Figure 1.5).

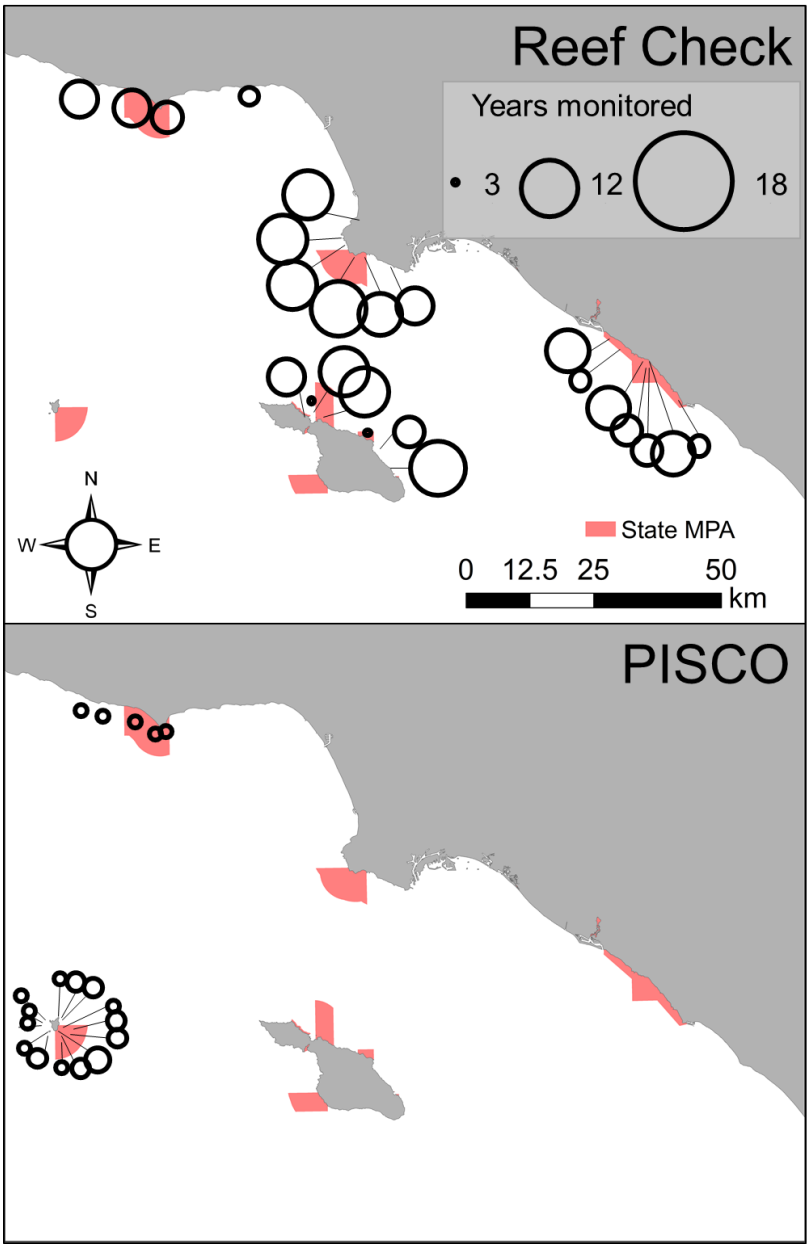


Figure 1.6. Zone 5 Los Angeles and Orange counties including Santa Catalina and Santa Barbara islands.

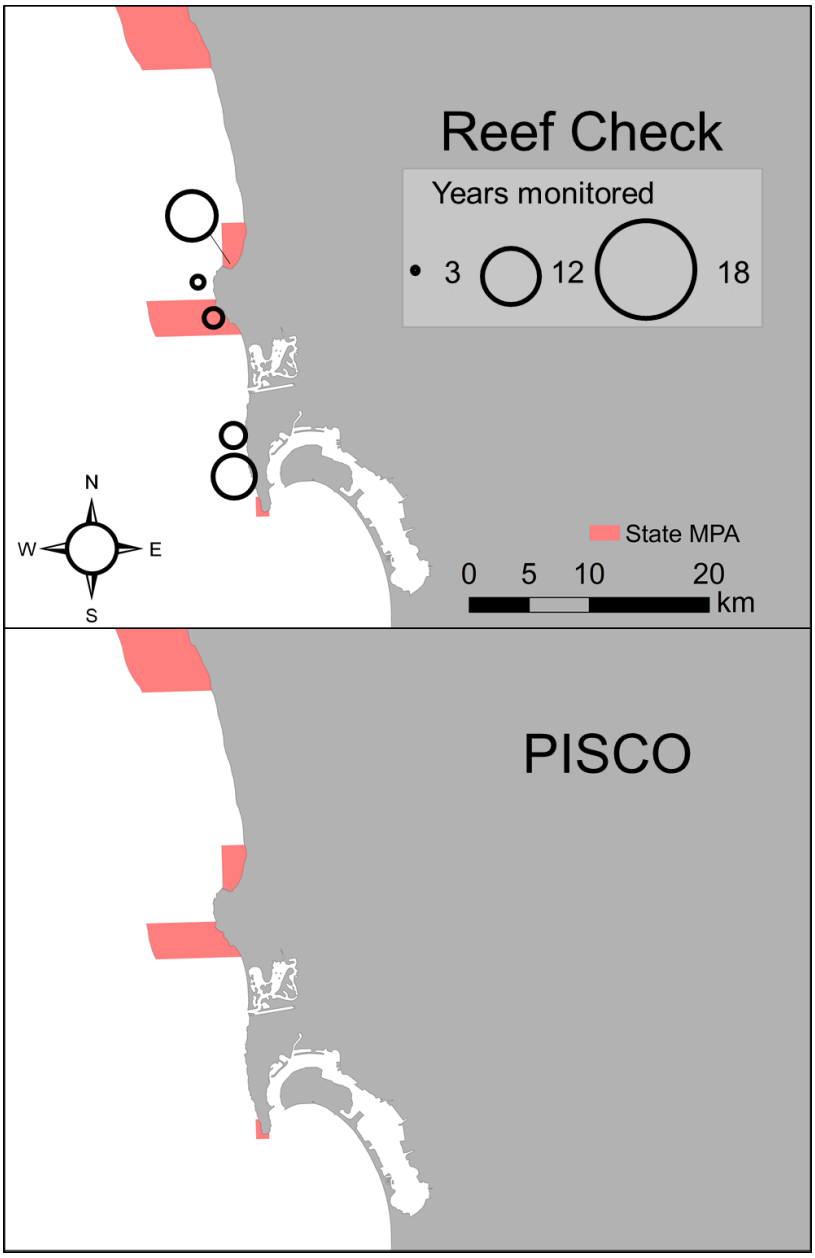


Figure 1.7. Zone 6 San Diego area.

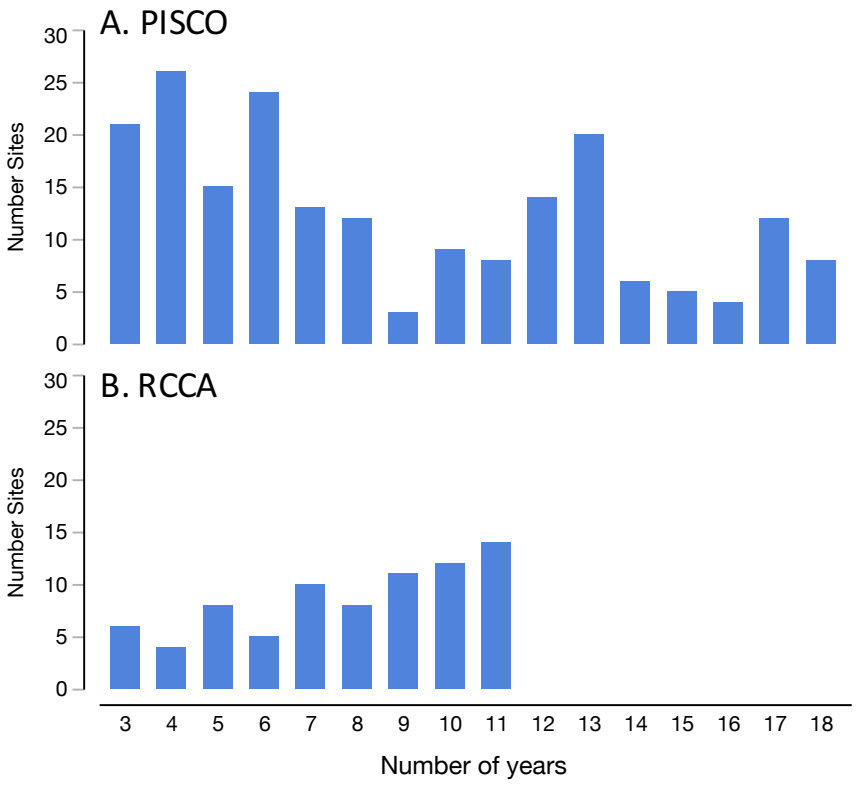


Figure 1.8. Frequency distribution showing the number of sites with time series of various durations (years).

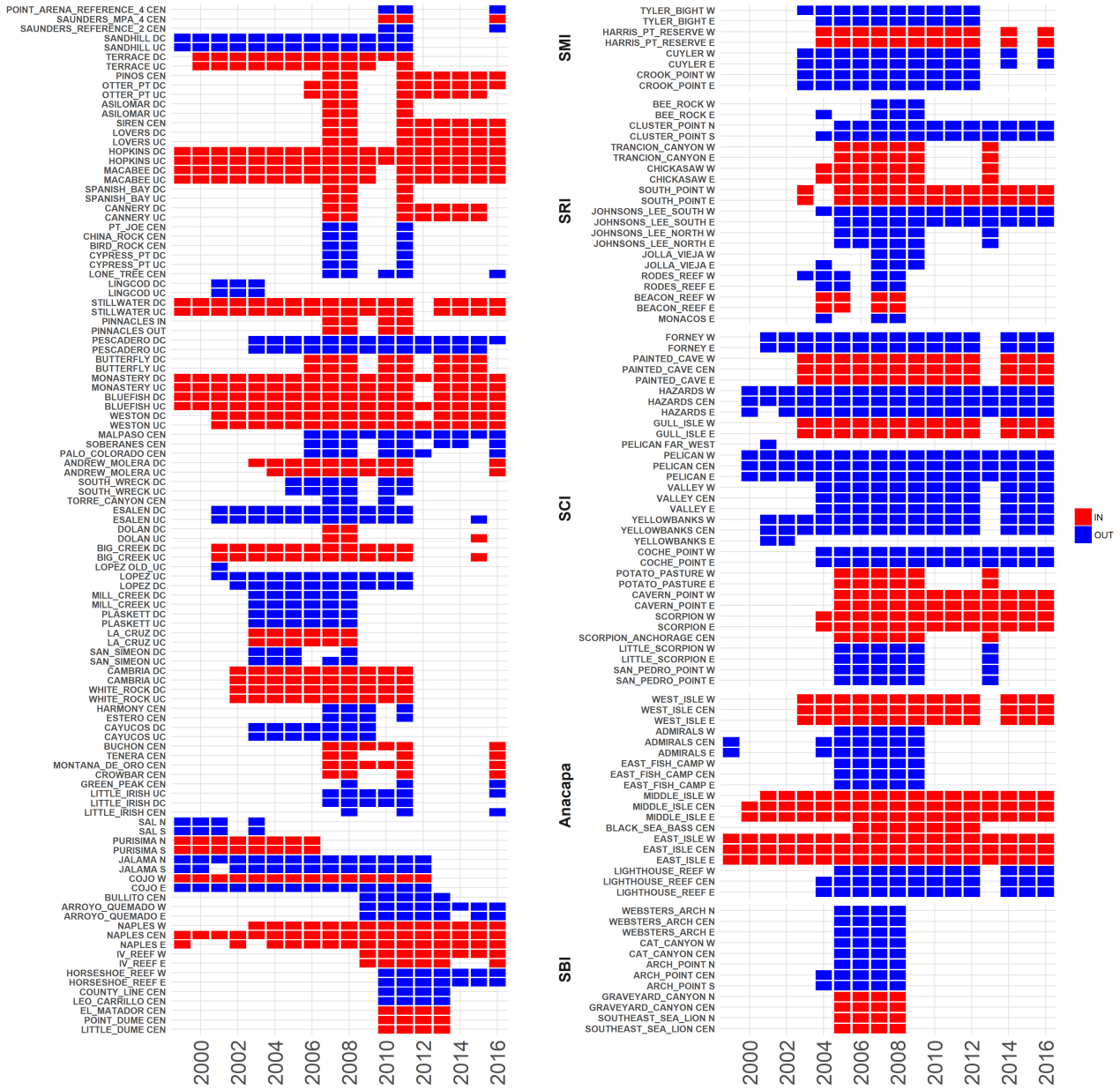


Figure 1.9. Time series for PISCO monitoring. Blocks show annual survey by site. Sites ordered North to South on the mainland coast (left panel) and roughly NW to SE on the islands (right panel). Only sites with greater than 2 years of monitoring are shown. Red indicates sites inside MPAs, blue indicate sites outside of MPAs. SMI= San Miguel island, SRI=Santa Rosa island, SCI = Santa Cruz island, SBI=Santa Barbara island.

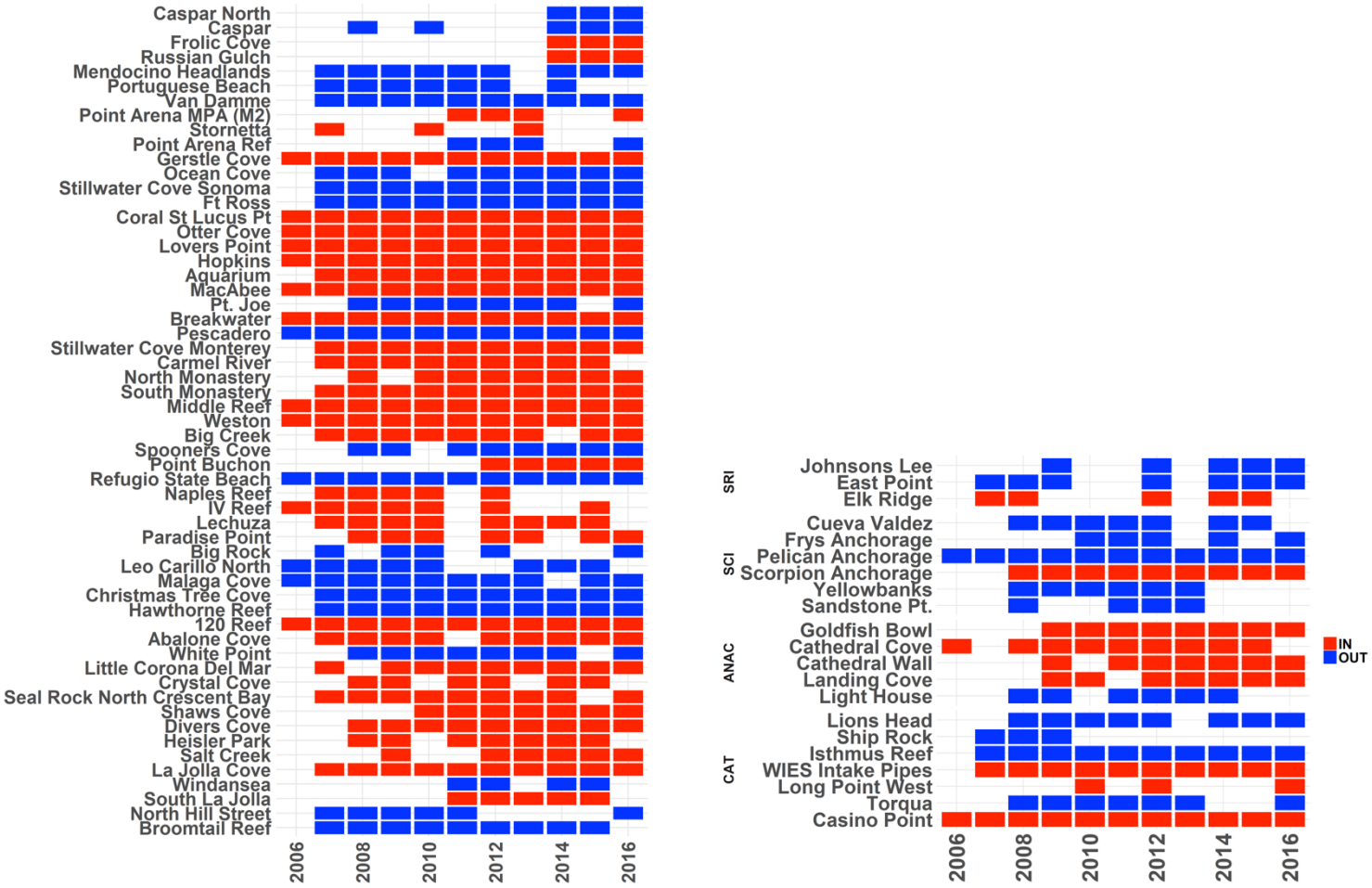


Figure 1.10. Time series for RCCA monitoring. Blocks show annual survey by site. Sites ordered North to South on the mainland coast (left panel) and roughly NW to SE on the islands (right panel). Only sites with greater than 2 years of monitoring are shown. Red indicates sites inside MPAs, blue indicates sites outside of MPAs. SRI=Santa Rosa island, SCI = Santa Cruz island, ANAC = Anacapa island, CAT=Catalina island.

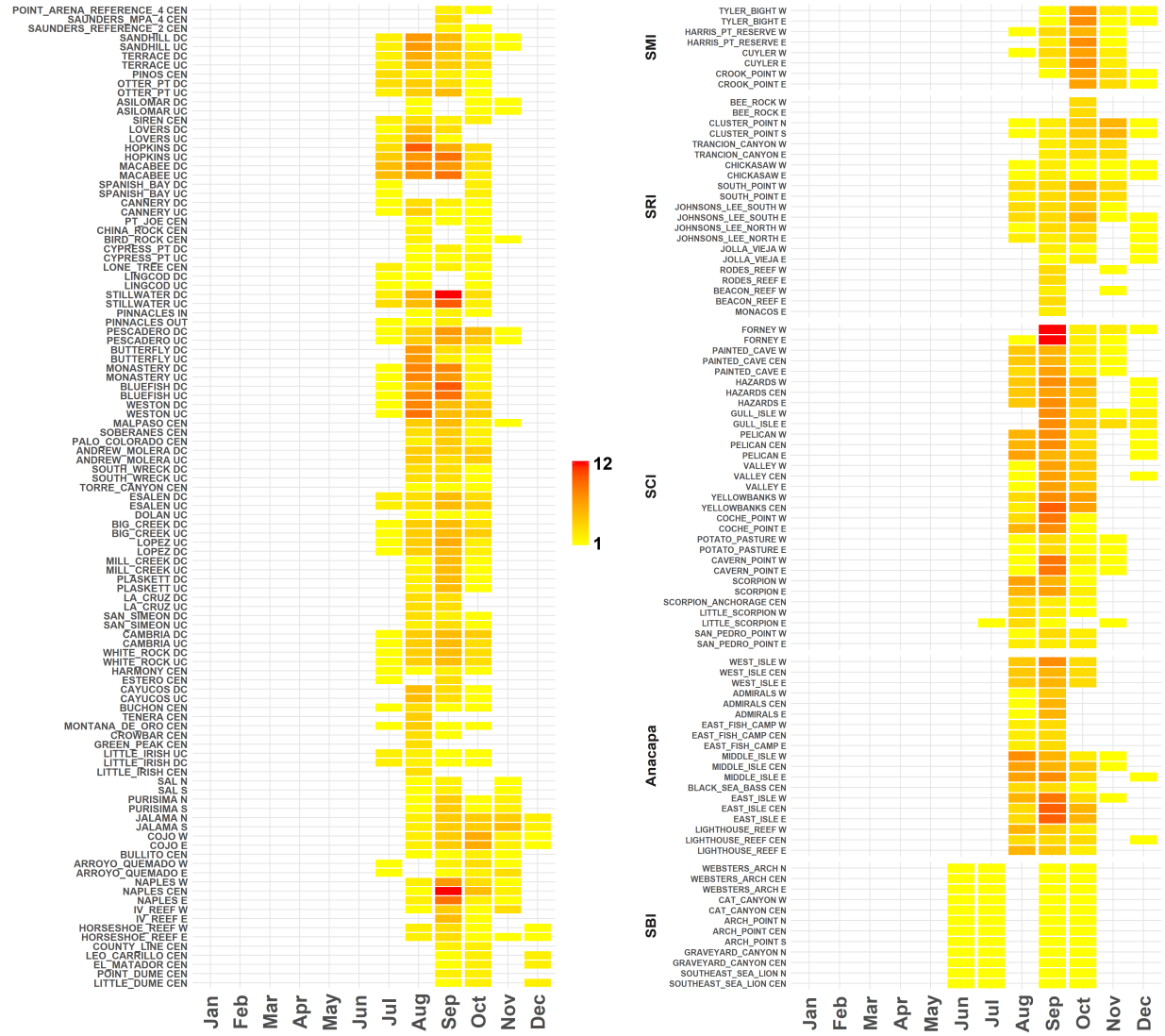


Figure 1.11. Seasonality of fish sampling for PISCO. Sites ordered North to South on the mainland coast (left panel) and roughly NW to SE on the islands (right panel). Only sites with greater than 2 years of monitoring are shown. Color scale indicates number of annual surveys. SMI= San Miguel island, SRI=Santa Rosa island, SCI = Santa Cruz island, SBI=Santa Barbara island.

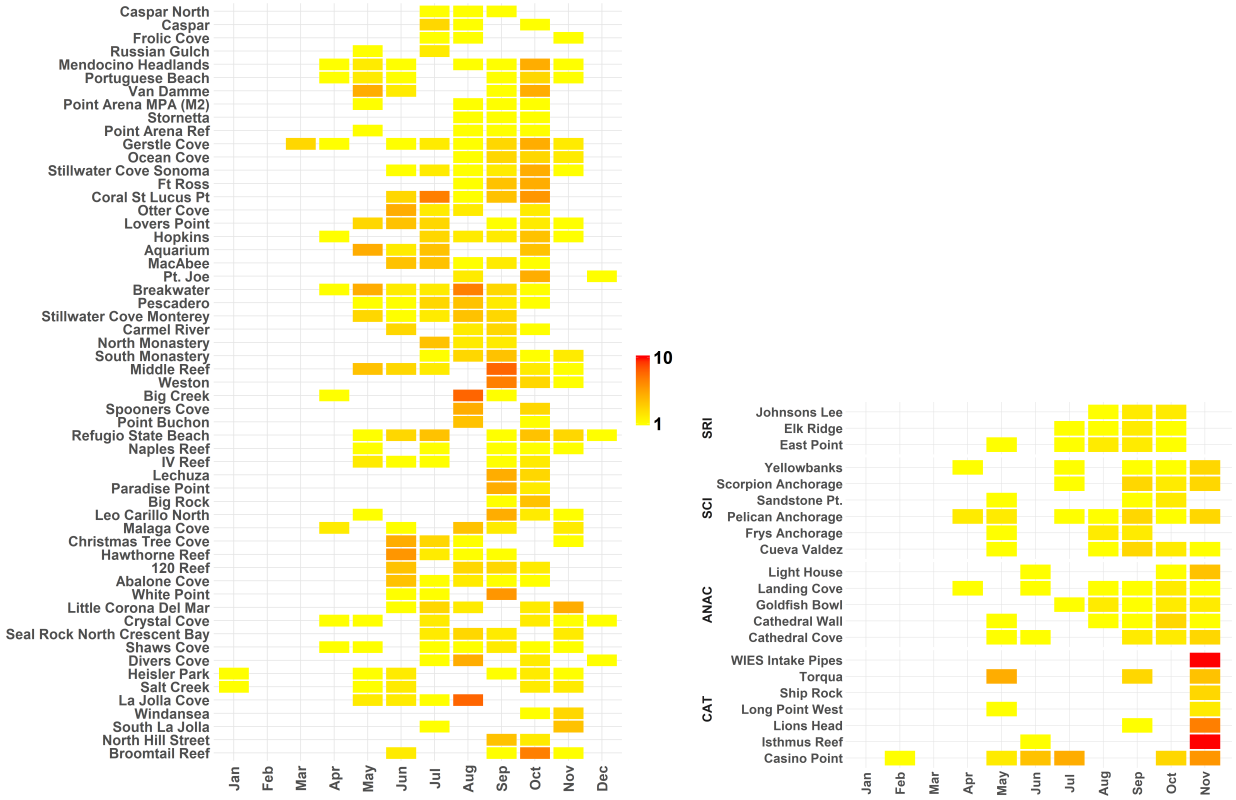


Figure 1.12. Seasonality of fish sampling for RCCA. Sites ordered North to South on the mainland coast (left panel) and roughly NW to SE on the islands (right panel). Only sites with greater than 2 years of monitoring are shown. Color scale indicates number of annual surveys. SRI=Santa Rosa island, SCI = Santa Cruz island, ANAC = Anacapa island, CAT=Catalina island.

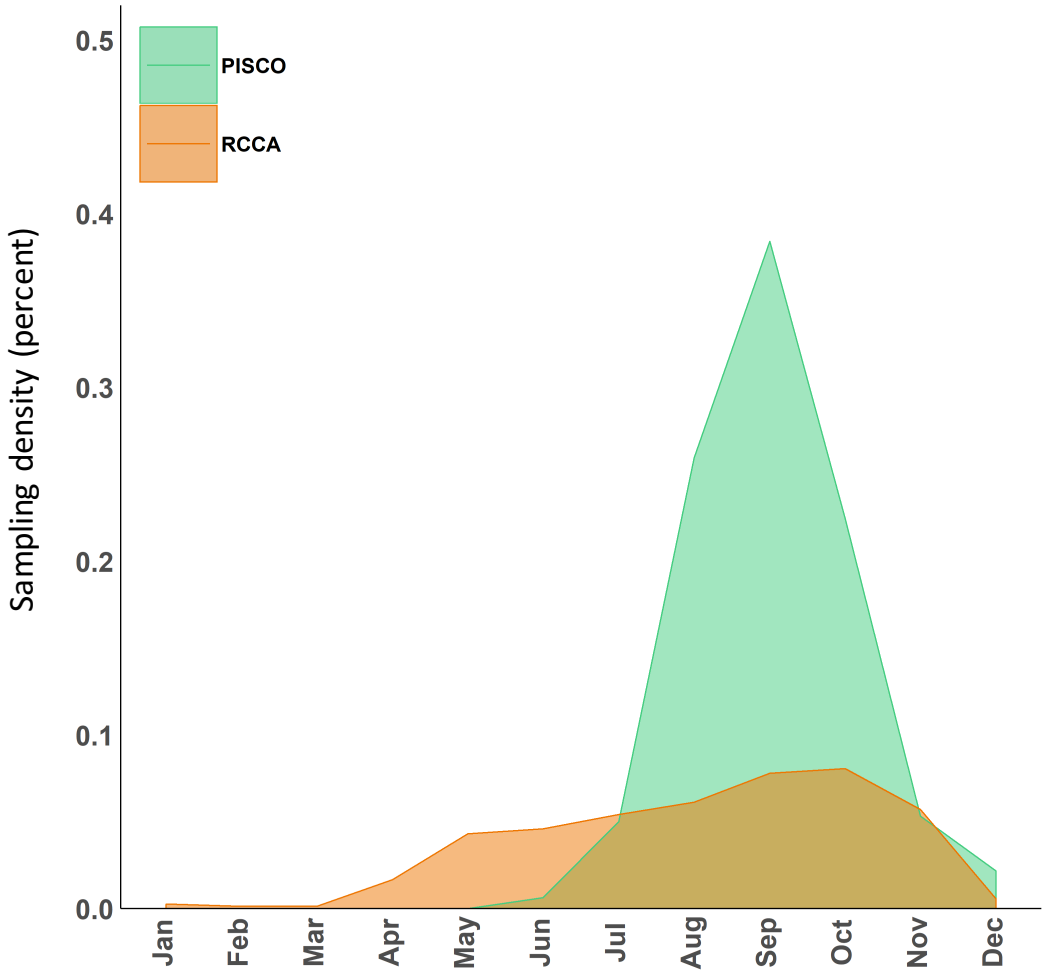


Figure 1.13. Sampling density (percent of all surveys per program) across months for PISCO (green) and RCCA (tan).

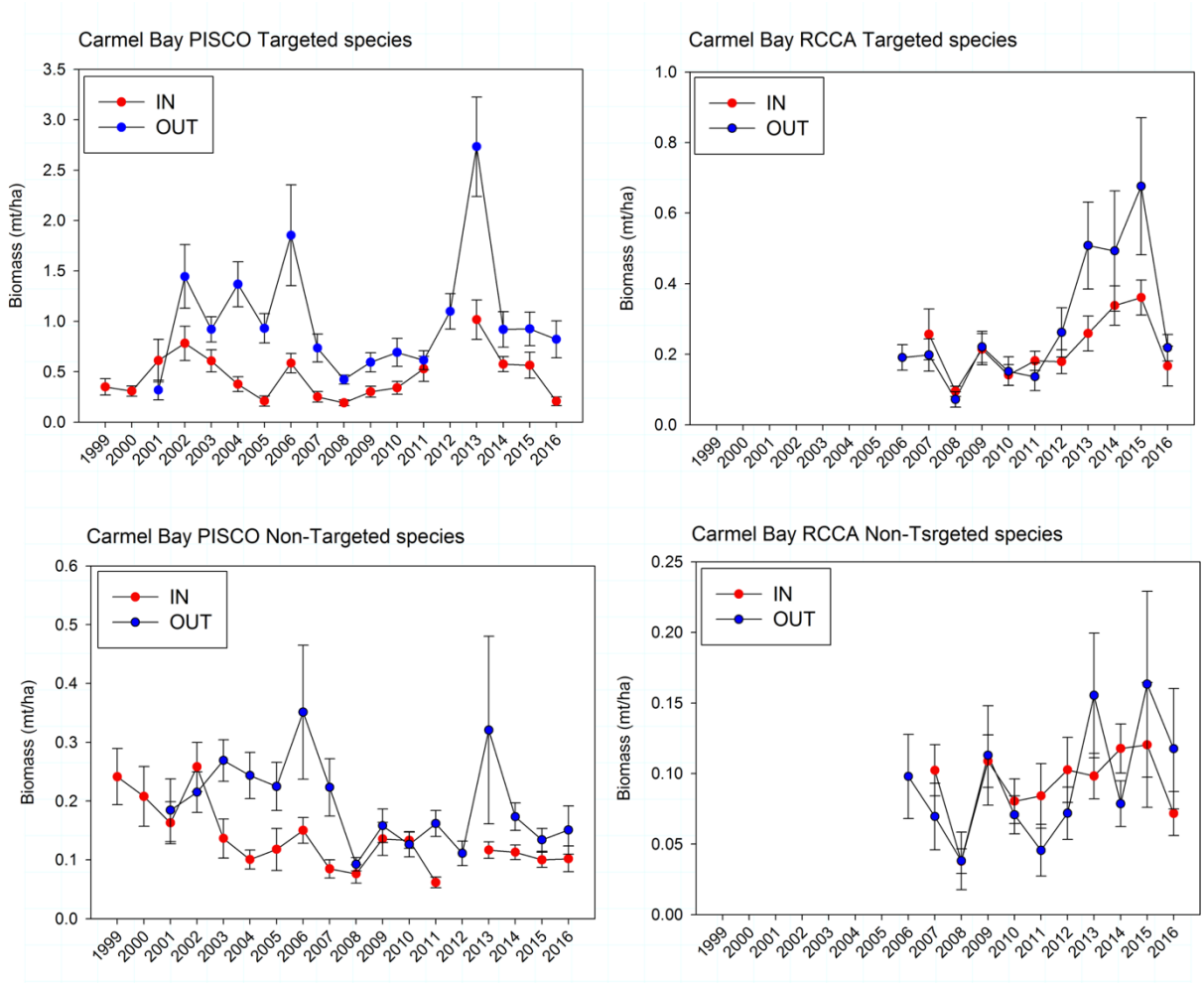


Figure 1.14. Time series plots for Carmel Bay SMCA showing biomass (mt/ha) for targeted species (top row) and non-targeted species (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales differ among the plots.

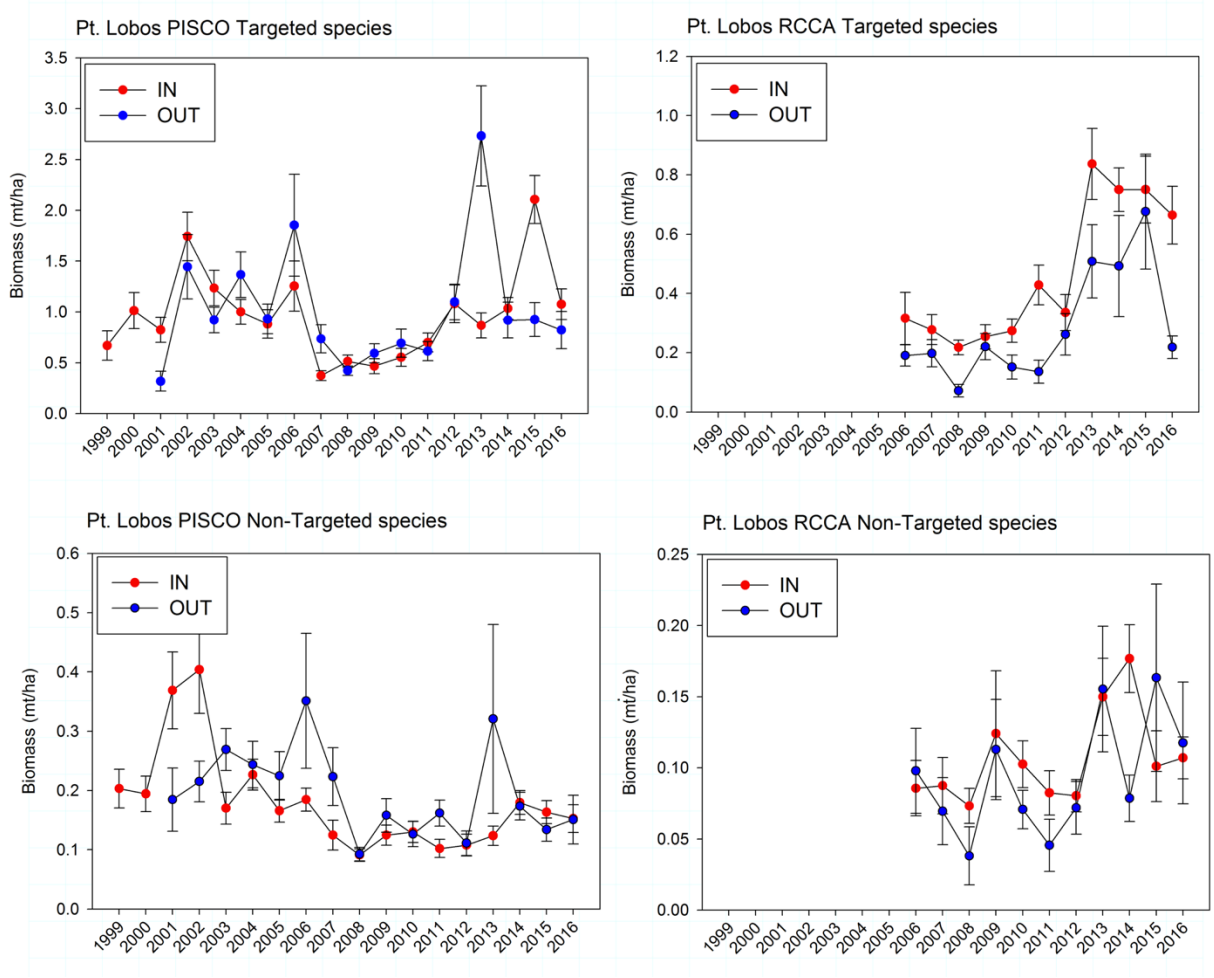


Figure 1.15. Time series plots for Pt. Lobos SMR showing biomass (mt/ha) for targeted species (top row) and non-targeted species (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales differ among the plots.

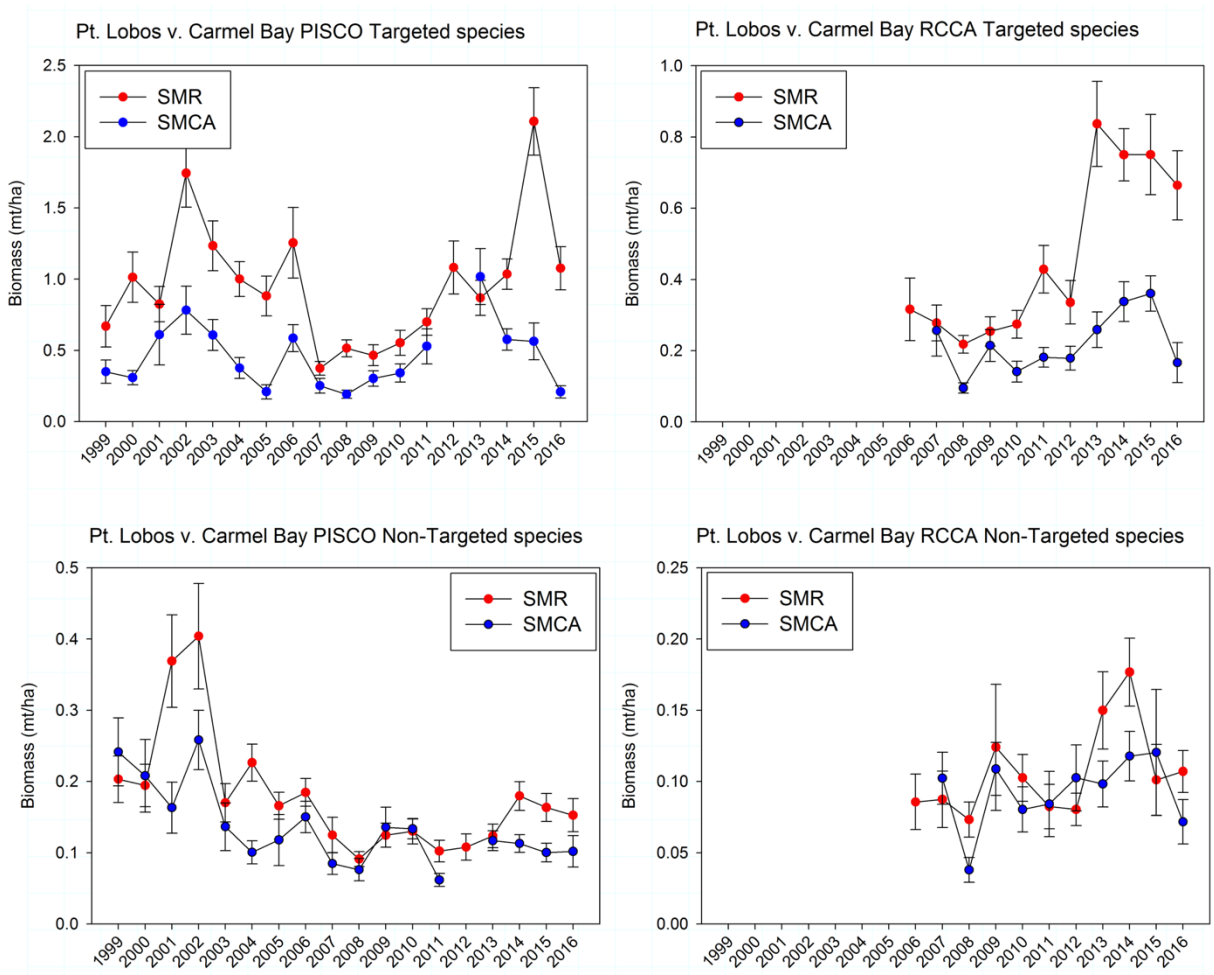


Figure 1.16. Time series plots for Pt. Lobos SMR and Carmel Bay SMCA showing biomass (mt/ha) for targeted species (top row) and non-targeted species (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are Pt. Lobos SMR sites, blues lines are Carmel Bay SMCA sites. Symbols are means +/- 1 standard error. Y-axis scales differ among the plots.

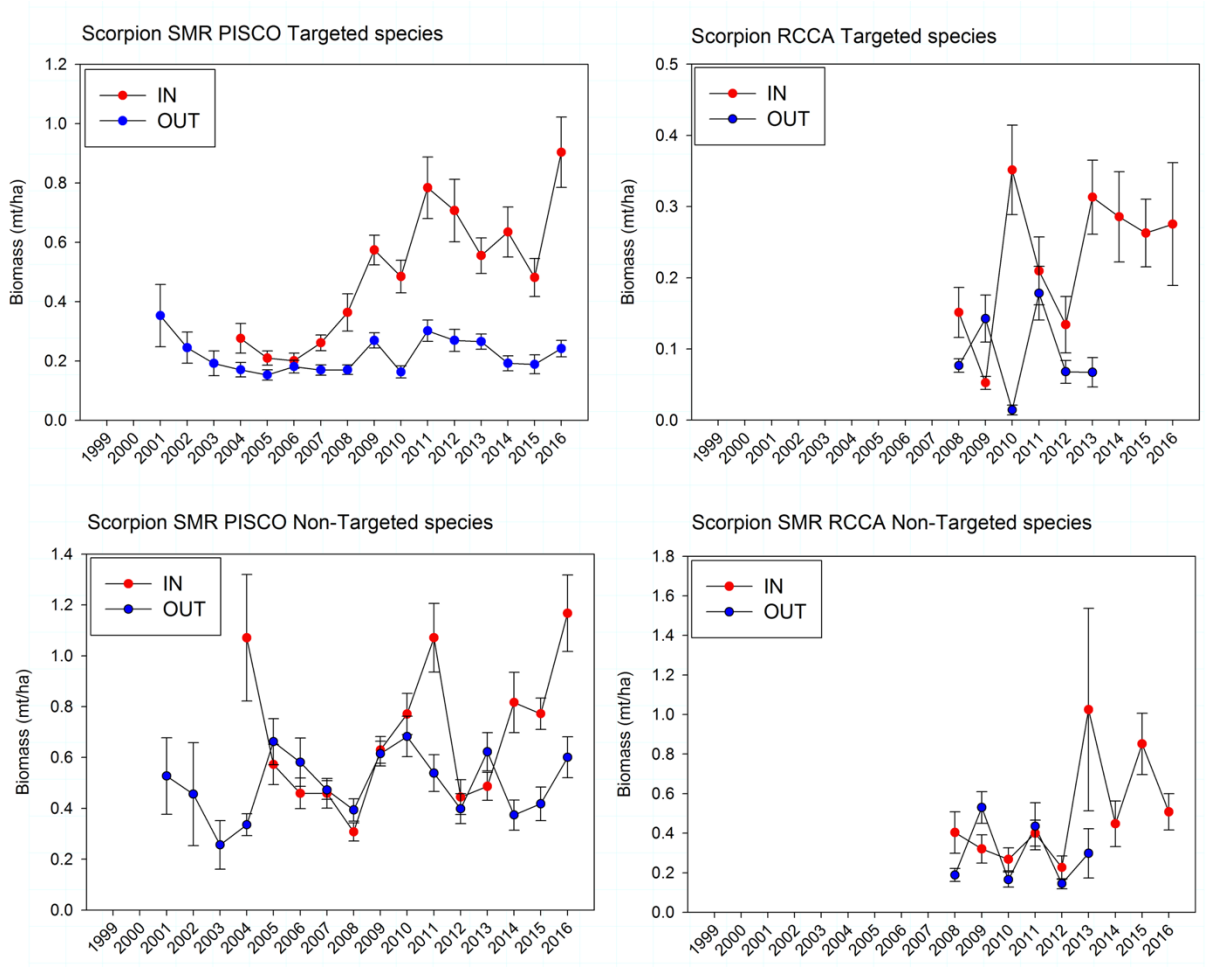


Figure 1.17. Time series plots for Scorpion SMR showing biomass (mt/ha) for targeted species (top row) and non-targeted species (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales differ among the plots.

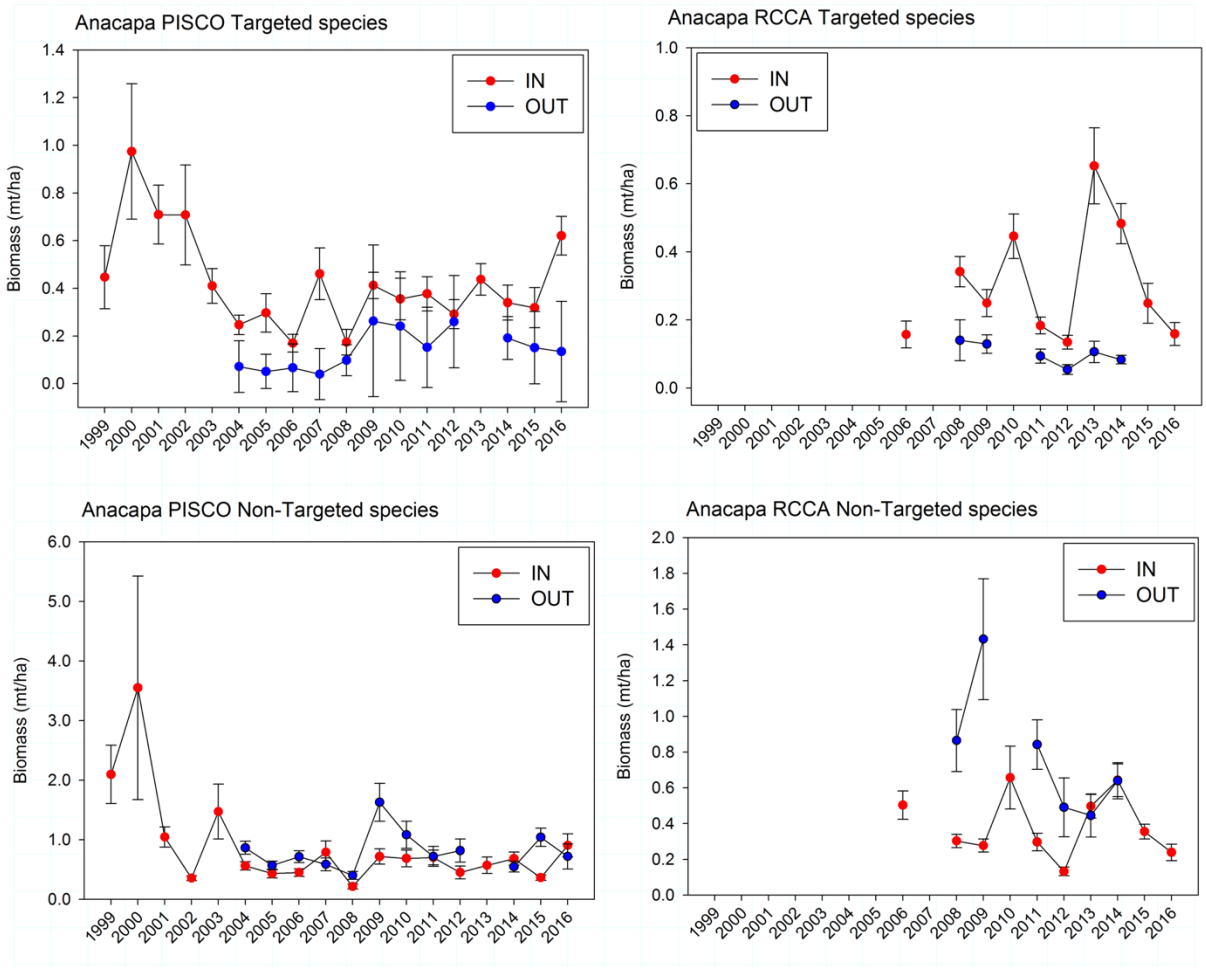


Figure 1.18. Time series plots for Anacapa SMR/SMCA showing biomass (mt/ha) for targeted species (top row) and non-targeted species (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales differ among the plots.

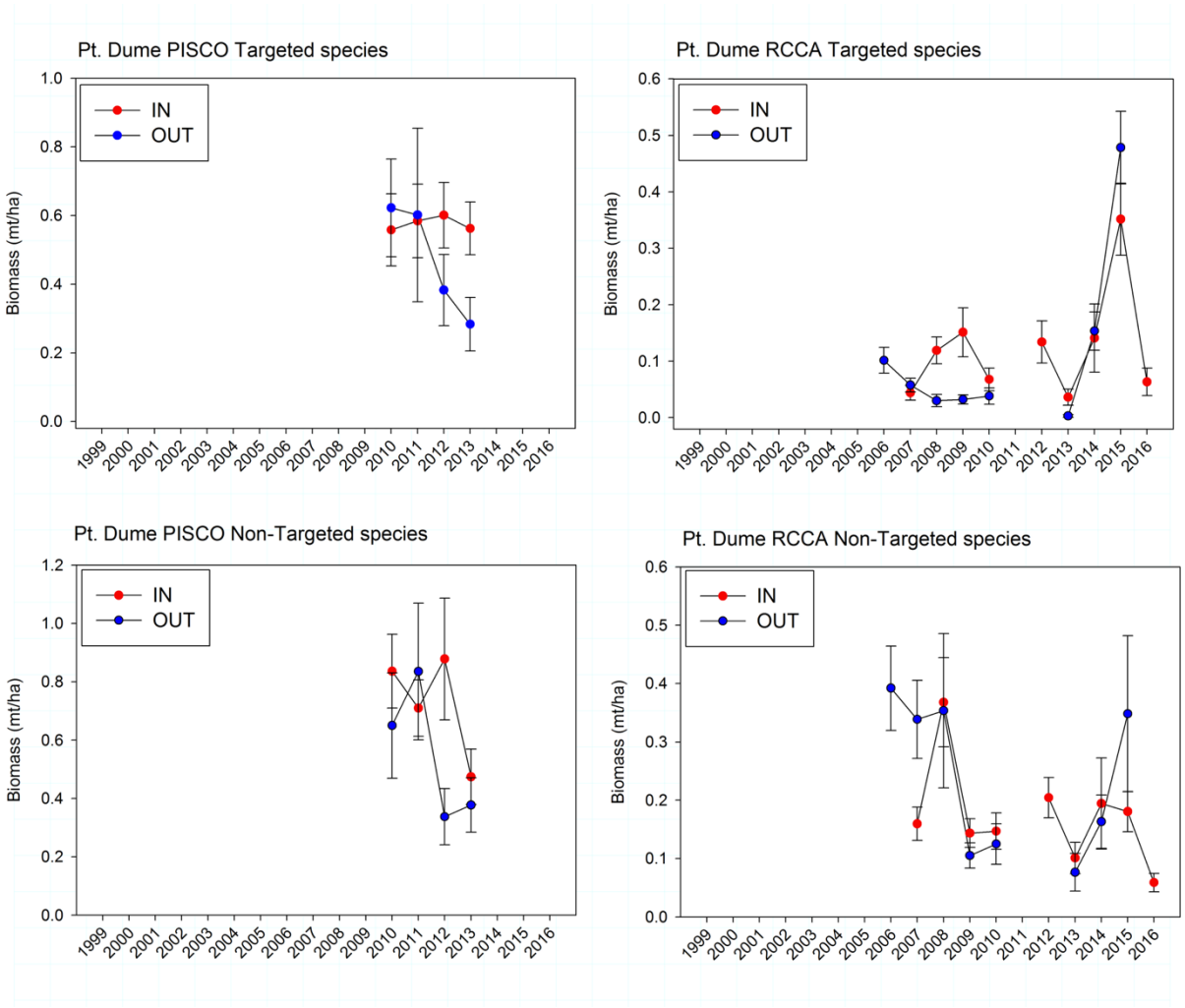


Figure 1.19. Time series plots for Pt. Dume SMR/SMCA showing biomass (mt/ha) for targeted species (top row) and non-targeted species (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales differ among the plots.

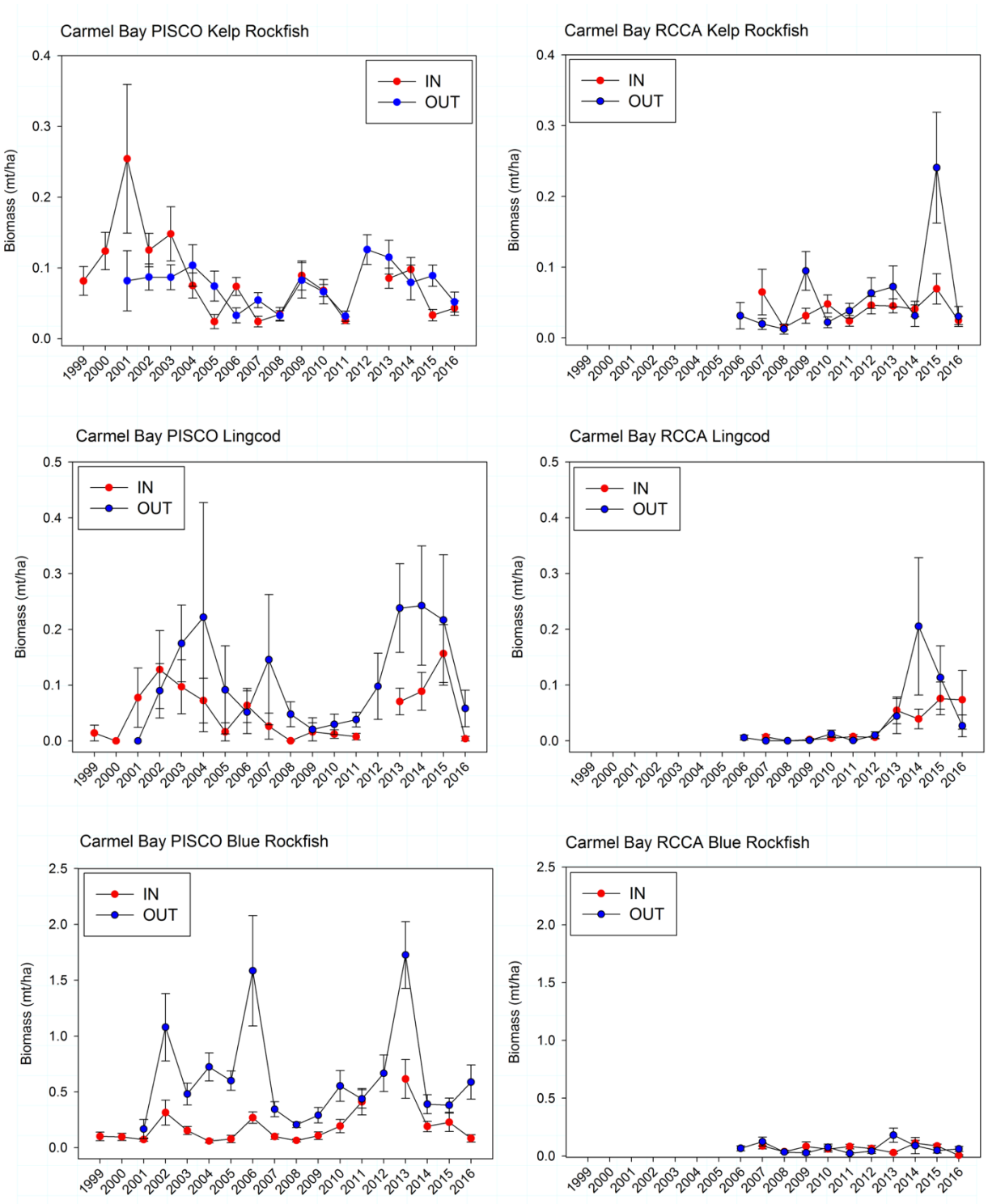


Figure 1.20. Time series plots for Carmel Bay SMCA showing biomass (mt/ha) for kelp rockfish, lingcod and blue rockfish (top to bottom rows) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales for each species are the identical.

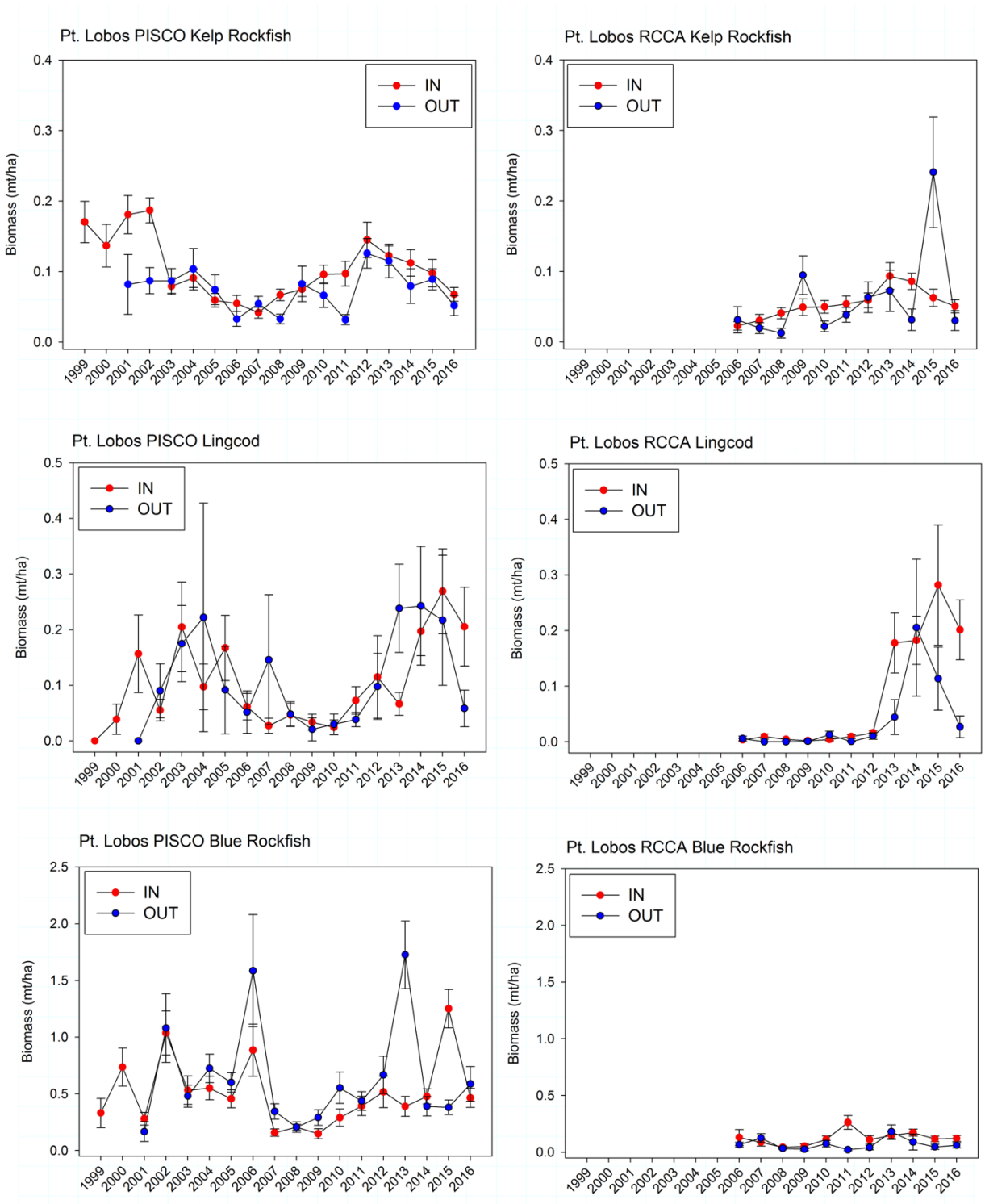


Figure 1.21. Time series plots for Pt. Lobos SMR showing biomass (mt/ha) for kelp rockfish, lingcod and blue rockfish (top to bottom rows) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales for each species are the identical.

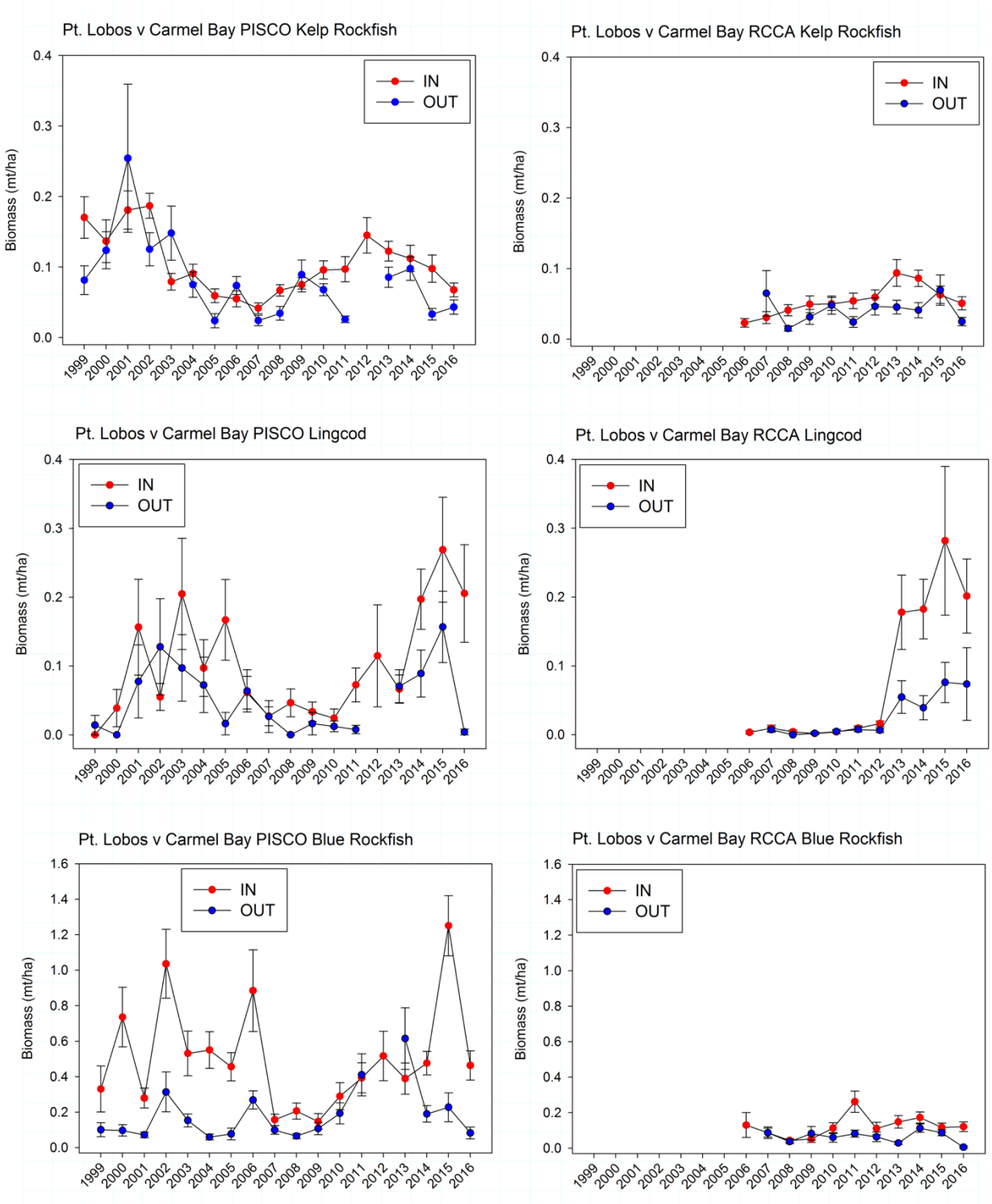


Figure 1.22. Time series plots for Pt. Lobos SMR (IN) and Carmel bay SMCA (OUT) showing biomass (mt/ha) for kelp rockfish, lingcod and blue rockfish (top to bottom rows) for PISCO (left panels) and RCCA (right panels). Red lines are Pt. Lobos sites, blues lines are Carmel Bay sites. Symbols are means +/- 1 standard error. Y-axis scales for each species are the identical.

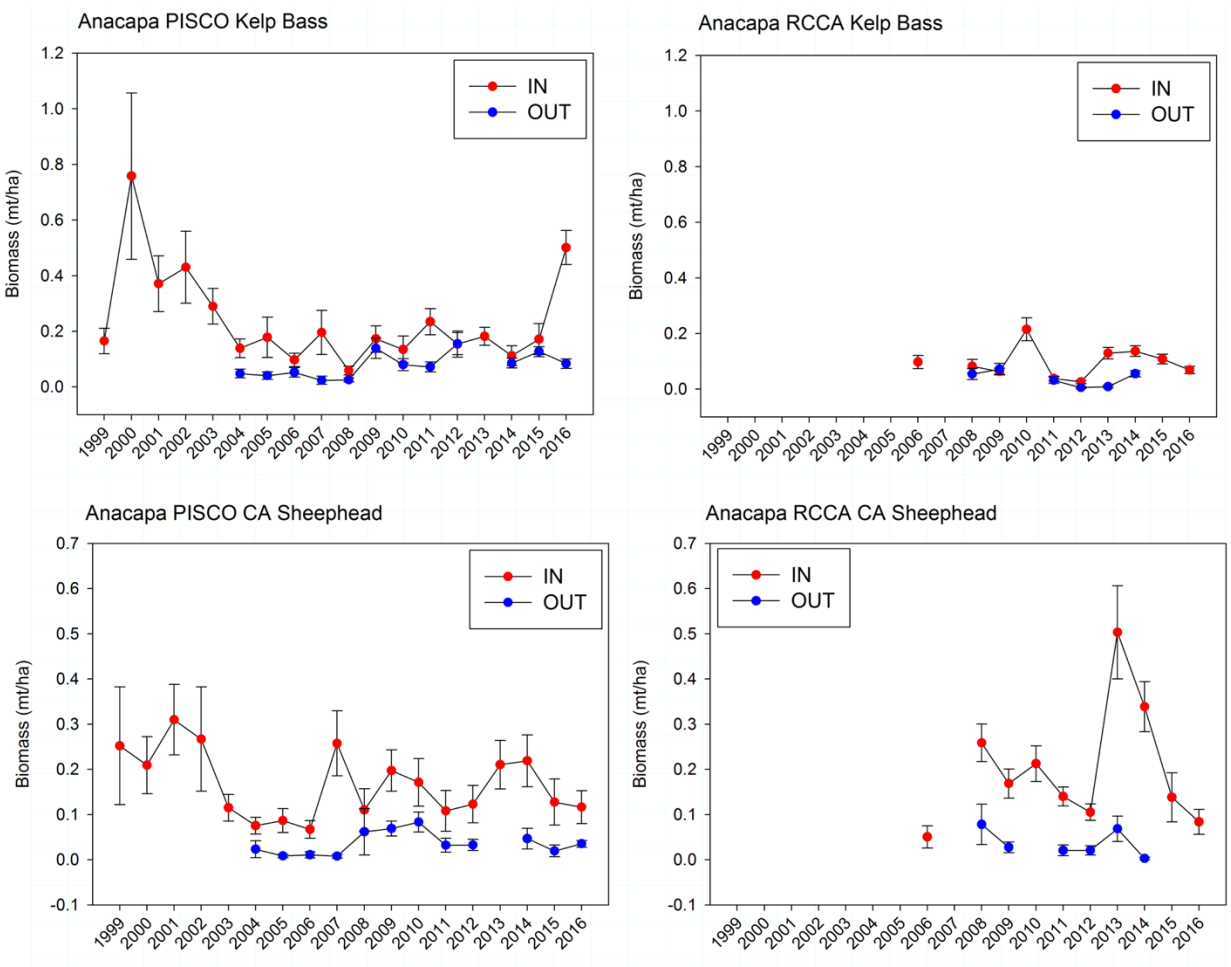


Figure 1.23. Time series plots for Anacapa SMR/SMCA showing biomass (mt/ha) for kelp bass (top row) and CA Sheephead (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales for each species are the identical.

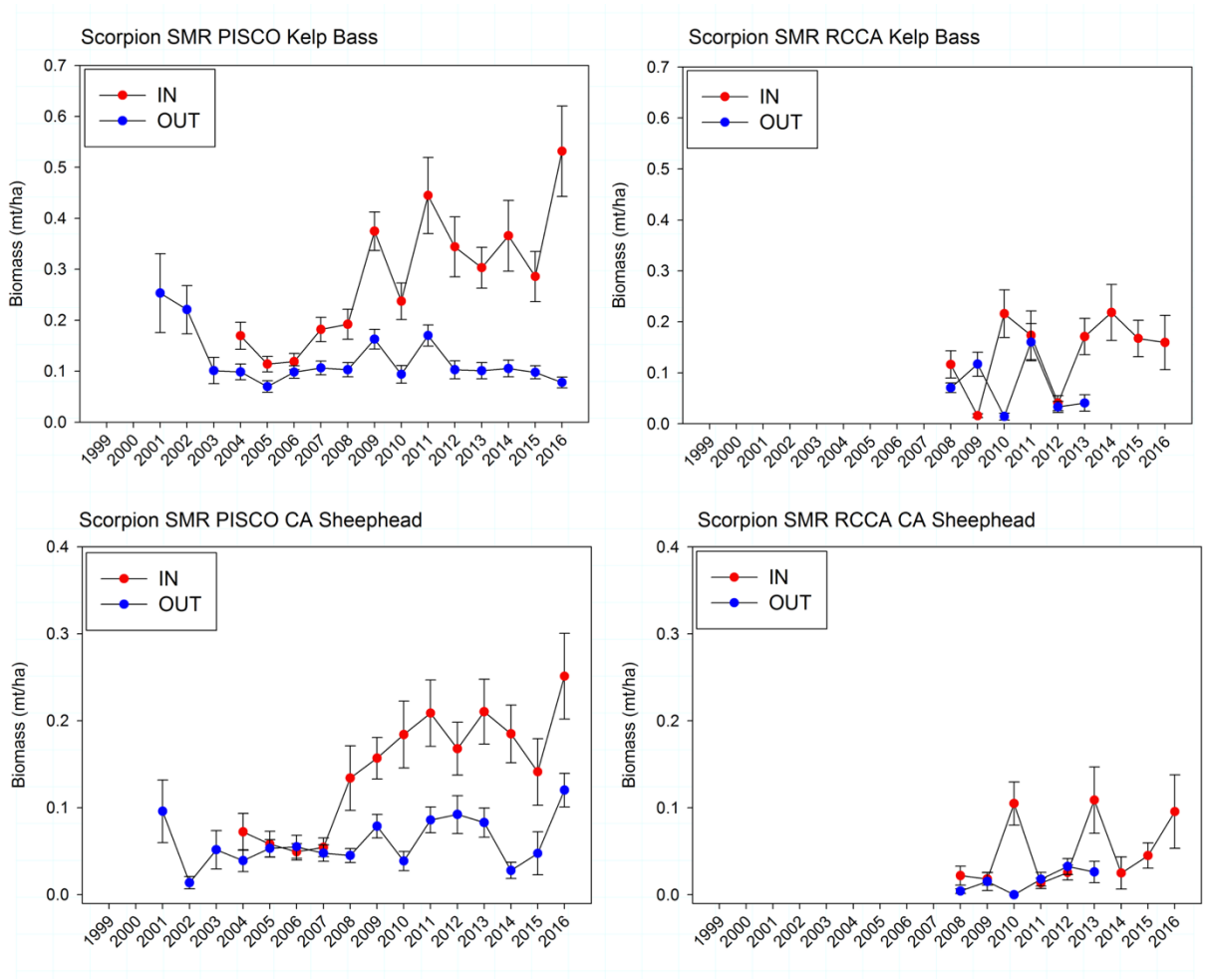


Figure 1.24. Time series plots for Scorpion SMR showing biomass (mt/ha) for kelp bass (top row) and CA Sheephead (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 standard error. Y-axis scales for each species are the identical.

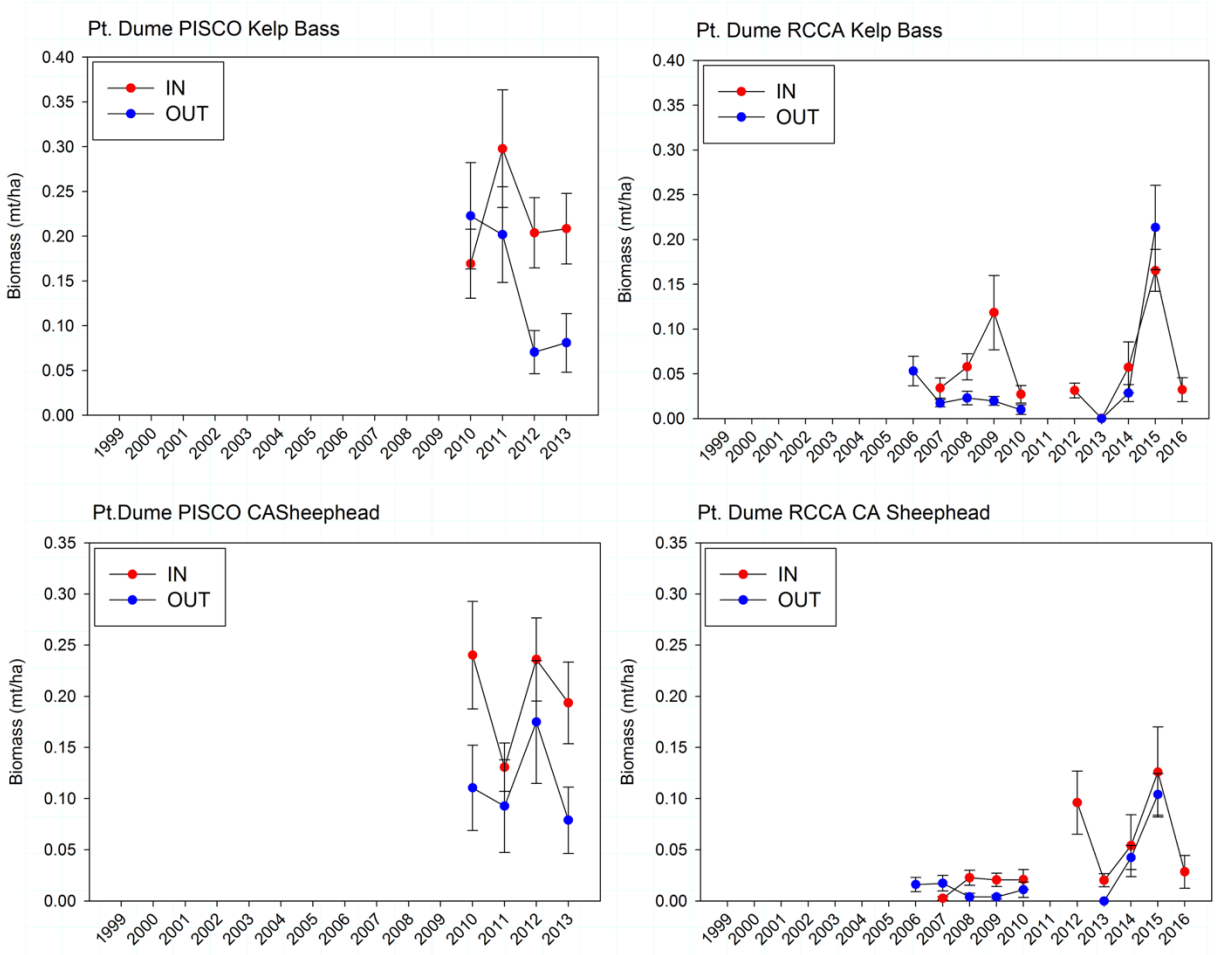


Figure 1.25. Time series plots for Pt. Dume SMR/SMCA showing biomass (mt/ha) for kelp bass (top row) and CA Sheephead (bottom row) for PISCO (left panels) and RCCA (right panels). Red lines are MPA sites, blues lines are outside reference sites. Symbols are means +/- 1 Standard error. Y-axis scales for each species are the identical.

Table 1.1. Results of analysis of variance using the "Matched Years" datasets (see text for sites and years used). Dependent variable in all models is Biomass of targeted species (squareroot transformed). MPA is categorical with two levels (inside or outside) while year is continuous. A) Model statistics, B) Effects tests, C) Power analyses. SS=Sums of squares. MS=Mean square.

A. Model Statistics

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
A. Anacapa	PISCO	Model	3	3.47	1.16	17.28	<.**0001**
		Error	376	25.18	0.07		
		C. Total	379	28.66			
	RCCA	Model	3	4.08	1.36	15.05	<.**0001**
		Error	495	44.70	0.09		
		C. Total	498	48.78			
B. Carmel Bay	PISCO	Model	3	16.27	5.42	28.99	<.**0001**
		Error	730	136.52	0.19		
		C. Total	733	152.79			
	RCCA	Model	3	2.72	0.91	13.21	<.**0001**
		Error	512	35.16	0.07		
		C. Total	515	37.88			
C. Pt. Dume	PISCO	Model	3	1.70	0.57	3.31	0.**0208**
		Error	234	40.09	0.17		
		C. Total	237	41.79			
	RCCA	Model	3	0.35	0.12	3.02	0.**0323**
		Error	128	4.89	0.04		
		C. Total	131	5.23			
D. Pt. Lobos	PISCO	Model	3	13.02	4.34	17.16	<.**0001**
		Error	1126	284.68	0.25		
		C. Total	1129	297.70			
	RCCA	Model	3	15.22	5.07	47.71	<.**0001**
		Error	815	86.68	0.11		
		C. Total	818	101.90			
E. Pt. Lobos v Carmel Bay	PISCO	Model	3	37.74	12.58	64.15	<.**0001**
		Error	1063	208.48	0.20		
		C. Total	1066	246.23			
	RCCA	Model	3	19.37	6.46	68.87	<.**0001**
		Error	926	86.82	0.09		
		C. Total	929	106.19			
F. Scorpion	PISCO	Model	3	12.19	4.06	47.90	<.**0001**
		Error	791	67.10	0.08		
		C. Total	794	79.29			
	RCCA	Model	3	2.45	0.82	19.35	<.**0001**
		Error	271	11.43	0.04		
		C. Total	274	13.88			

B. Effects tests

Location	Program	Source	DF	SS	F Ratio	Prob > F
A. Anacapa	PISCO	MPA	1	3.16	47.21	**<.0001**
		year	1	0.10	1.54	0.2153
		MPA*year	1	0.06	0.85	0.3574
	RCCA	MPA	1	3.68	40.71	**<.0001**
		year	1	0.02	0.26	0.6084
		MPA*year	1	0.00	0.01	0.9041
B. Carmel Bay	PISCO	MPA	1	11.26	60.18	**<.0001**
		year	1	6.89	36.84	**<.0001**
		MPA*year	1	0.04	0.22	0.6372
	RCCA	MPA	1	0.20	2.92	0.0880
		year	1	2.43	35.33	**<.0001**
		MPA*year	1	0.23	3.36	0.0675
C. Pt. Dume	PISCO	MPA	1	0.93	5.44	**0.0206**
		year	1	0.34	2.01	0.1572
		MPA*year	1	0.59	3.46	0.0641
	RCCA	MPA	1	0.29	7.59	**0.0067**
		year	1	0.11	2.99	0.0863
		MPA*year	1	0.02	0.59	0.4422
D. Pt. Lobos	PISCO	MPA	1	0.11	0.43	0.5132
		year	1	7.87	31.15	**<.0001**
		MPA*year	1	0.90	3.55	0.0599
	RCCA	MPA	1	2.51	23.60	**<.0001**
		year	1	7.33	68.92	**<.0001**
		MPA*year	1	0.37	3.52	0.0610
E. Pt. Lobos v Carmel Bay	PISCO	MPA	1	12.49	63.69	**<.0001**
		year	1	17.51	89.26	**<.0001**
		MPA*year	1	1.80	9.15	**0.0025**
	RCCA	MPA	1	6.99	74.57	**<.0001**
		year	1	7.16	76.39	**<.0001**
		MPA*year	1	1.49	15.91	**<.0001**
F. Scorpion	PISCO	MPA	1	10.15	119.64	**<.0001**
		year	1	1.42	16.70	**<.0001**
		MPA*year	1	0.14	1.68	0.1957
	RCCA	MPA	1	2.02	47.96	**<.0001**
		year	1	0.04	0.95	0.3300
		MPA*year	1	0.47	11.07	**0.0010**

C. Power analyses (α =0.05 for all models)

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/ δ
A. Anacapa	PISCO	MPA	0.259	0.091	380	1.000	0.026	0.288
		MPA*year	0.259	0.012	380	0.151		
	RCCA	MPA	0.301	0.086	499	1.000	0.035	0.404
		MPA*year	0.301	0.002	499	0.052		
B. Carmel Bay	PISCO	MPA	0.432	0.124	734	1.000	0.032	0.255
		MPA*year	0.432	0.008	734	0.076		
	RCCA	MPA	0.262	0.020	516	0.400	0.024	1.215
		MPA*year	0.262	0.021	516	0.448		
C. Pt. Dume	PISCO	MPA	0.414	0.063	238	0.641	0.054	0.863
		MPA*year	0.414	0.050	238	0.457		
	RCCA	MPA	0.195	0.047	132	0.781	0.042	0.889
		MPA*year	0.195	0.013	132	0.119		
D. Pt. Lobos	PISCO	MPA	0.503	0.010	1130	0.100	0.031	3.209
		MPA*year	0.503	0.028	1130	0.469		
	RCCA	MPA	0.326	0.055	819	0.998	0.026	0.475
		MPA*year	0.326	0.021	819	0.466		
E. Pt. Lobos v Carmel Bay	PISCO	MPA	0.443	0.108	1067	1.000	0.028	0.256
		MPA*year	0.443	0.041	1067	0.856		
	RCCA	MPA	0.306	0.087	930	1.000	0.020	0.236
		MPA*year	0.306	0.040	930	0.979		
F. Scorpion	PISCO	MPA	0.291	0.113	795	1.000	0.020	0.180
		MPA*year	0.291	0.013	795	0.253		
	RCCA	MPA	0.205	0.086	275	1.000	0.025	0.291
		MPA*year	0.205	0.041	275	0.912		

Table 1.2. Results of analysis of variance using the "Best time series" datasets (see text for sites and years used). Dependent variable in all models is Biomass of targeted species (squareroot transformed). MPA is categorical with two levels (inside or outside) while year is continuous. A) Model statistics, B) Effects tests, C) Power analyses. SS=Sums of squares. MS=Mean square.

A. Model Statistics

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
A. Anacapa	PISCO	Model	3	8.37	2.79	41.77	<.0001
		Error	565	37.73	0.07		
		C. Total	568	46.09			
	RCCA	Model	3	5.59	1.86	21.42	<.0001
		Error	369	32.11	0.09		
		C. Total	372	37.70			
B. Carmel Bay	PISCO	Model	3	18.30	6.10	29.88	<.0001
		Error	1046	213.61	0.20		
		C. Total	1049	231.92			
	RCCA	Model	3	2.72	0.91	13.21	<.0001
		Error	512	35.16	0.07		
		C. Total	515	37.88			
C. Pt. Dume	PISCO	Model	3	1.70	0.57	3.31	0.0208
		Error	234	40.09	0.17		
		C. Total	237	41.79			
	RCCA	Model	3	2.67	0.89	16.15	<.0001
		Error	324	17.88	0.06		
		C. Total	327	20.55			
D. Pt. Lobos	PISCO	Model	3	0.07	0.02	0.09	0.9663
		Error	1591	422.82	0.27		
		C. Total	1594	422.90			
	RCCA	Model	3	15.22	5.07	47.71	<.0001
		Error	815	86.68	0.11		
		C. Total	818	101.90			
E. Pt. Lobos v Carmel Bay	PISCO	Model	3	28.90	9.63	41.57	<.0001
		Error	1721	398.80	0.23		
		C. Total	1724	427.70			
	RCCA	Model	3	19.37	6.46	68.87	<.0001
		Error	926	86.82	0.09		
		C. Total	929	106.19			
F. Scorpion	PISCO	Model	3	29.56	9.85	136.09	<.0001
		Error	1603	116.04	0.07		
		C. Total	1606	145.60			
	RCCA	Model	3	2.45	0.82	19.35	<.0001
		Error	271	11.43	0.04		
		C. Total	274	13.88			

B. Effects Tests

Location	Program	Source	DF	SS	F Ratio	Prob > F
A. Anacapa	PISCO	MPA	1	5.71	85.58	**<.0001**
		year	1	2.64	39.56	**<.0001**
		MPA*year	1	0.08	1.13	0.2874
	RCCA	MPA	1	4.11	47.21	**<.0001**
		year	1	0.30	3.50	0.0622
		MPA*year	1	0.53	6.04	**0.0144**
B. Carmel Bay	PISCO	MPA	1	18.20	89.13	**<.0001**
		year	1	0.09	0.46	0.4992
		MPA*year	1	0.08	0.39	0.5325
	RCCA	MPA	1	0.20	2.92	0.0880
		year	1	2.43	35.33	**<.0001**
		MPA*year	1	0.23	3.36	0.0675
C. Pt. Dume	PISCO	MPA	1	0.93	5.44	**0.0206**
		year	1	0.34	2.01	0.1572
		MPA*year	1	0.59	3.46	0.0641
	RCCA	MPA	1	0.04	0.71	0.3997
		year	1	2.55	46.16	**<.0001**
		MPA*year	1	0.39	7.11	**0.0080**
D. Pt. Lobos	PISCO	MPA	1	0.04	0.14	0.7102
		year	1	0.01	0.05	0.8318
		MPA*year	1	0.01	0.03	0.8732
	RCCA	MPA	1	2.51	23.60	**<.0001**
		year	1	7.33	68.92	**<.0001**
		MPA*year	1	0.37	3.52	0.0610
E. Pt. Lobos v Carmel Bay	PISCO	MPA	1	28.85	124.50	**<.0001**
		year	1	0.32	1.38	0.2402
		MPA*year	1	0.05	0.21	0.6482
	RCCA	MPA	1	6.99	74.57	**<.0001**
		year	1	7.16	76.39	**<.0001**
		MPA*year	1	1.49	15.91	**<.0001**
F. Scorpion	PISCO	MPA	1	15.48	213.81	**<.0001**
		year	1	9.46	130.71	**<.0001**
		MPA*year	1	3.14	43.37	**<.0001**
	RCCA	MPA	1	2.02	47.96	**<.0001**
		year	1	0.04	0.95	0.3300
		MPA*year	1	0.47	11.07	**0.0010**

C. Power analyses (α =0.05 for all models)

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/ δ
A. Anacapa	PISCO	MPA	0.258	0.100	569	1.000	0.021	0.212
		MPA*year	0.258	0.012	569	0.186		
	RCCA	MPA	0.295	0.105	373	1.000	0.033	0.320
		MPA*year	0.295	0.038	373	0.689		
B. Carmel Bay	PISCO	MPA	0.452	0.132	1050	1.000	0.027	0.208
		MPA*year	0.452	0.009	1050	0.096		
	RCCA	MPA	0.262	0.020	516	0.400	0.023	1.214
		MPA*year	0.262	0.021	516	0.448		
C. Pt. Dume	PISCO	MPA	0.414	0.063	238	0.641	0.054	0.862
		MPA*year	0.414	0.050	238	0.457		
	RCCA	MPA	0.235	0.011	328	0.134	0.026	2.426
		MPA*year	0.235	0.035	328	0.758		
D. Pt. Lobos	PISCO	MPA	0.516	0.005	1595	0.066	0.027	5.664
		MPA*year	0.516	0.002	1595	0.053		
	RCCA	MPA	0.326	0.055	819	0.998	0.026	0.475
		MPA*year	0.326	0.021	819	0.466		
E. Pt. Lobos v Carmel Bay	PISCO	MPA	0.481	0.129	1725	1.000	0.024	0.187
		MPA*year	0.481	0.005	1725	0.074		
	RCCA	MPA	0.306	0.087	930	1.000	0.020	0.236
		MPA*year	0.306	0.040	930	0.979		
F. Scorpion	PISCO	MPA	0.269	0.098	1607	1.000	0.013	0.134
		MPA*year	0.269	0.044	1607	1.000		
	RCCA	MPA	0.205	0.086	275	1.000	0.025	0.291
		MPA*year	0.205	0.041	275	0.912		

Table 1.3. Results of analysis of variance using the "Best time series" datasets (see text for sites and years used). Dependent variable in each model is biomass of specific indicator species (squareroot transformed). We chose the three of the most abundant species in the central California datasets (Lingcod, Kelp Rockfish and Blue Rockfish) for analysis of those MPAs. Similarly, we chose two of the most abundant species in the southern California datasets (Kelp bass and CA Sheephead) for analyses of those MPAs. MPA is categorical with two levels (inside or outside) while year is continuous. Tables are presented by species for ease of comparison between sites and programs. A (i-v) Model statistics, B (i-v) Effects tests, C (i-v) Power analyses. SS=Sums of squares. MS=Mean square.

A. Model Statistics

i. Lingcod

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
Carmel Bay	PISCO	Model	3	0.65	0.22	3.00	**0.0298**
		Error	1046	75.01	0.07		
		C. Total	1049	75.66			
	RCCA	Model	3	0.98	0.33	12.60	**<.0001**
		Error	512	13.28	0.03		
		C. Total	515	14.25			
Pt. Lobos	PISCO	Model	3	1.27	0.42	4.42	**0.0042**
		Error	1591	152.05	0.10		
		C. Total	1594	153.32			
	RCCA	Model	3	6.10	2.03	35.71	**<.0001**
		Error	815	46.43	0.06		
		C. Total	818	52.54			
Pt. Lobos v	PISCO	Model	3	2.36	0.79	10.27	**<.0001**
Carmel Bay		Error	1721	131.82	0.08		
		C. Total	1724	134.18			
	RCCA	Model	3	6.59	2.20	43.43	**<.0001**
		Error	926	46.87	0.05		
		C. Total	929	53.46			

ii. Kelp Rockfish

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
Carmel Bay	PISCO	Model	3	0.24	0.08	2.29	0.0773
		Error	1046	36.09	0.03		
		C. Total	1049	36.33			
	RCCA	Model	3	0.31	0.10	3.43	**0.0169**
		Error	512	15.25	0.03		
		C. Total	515	15.55			
Pt. Lobos	PISCO	Model	3	1.05	0.35	9.15	**<.0001**
		Error	1591	60.61	0.04		
		C. Total	1594	61.65			
	RCCA	Model	3	0.75	0.25	8.30	**<.0001**
		Error	815	24.61	0.03		
		C. Total	818	25.37			
Pt. Lobos v Carmel Bay	PISCO	Model	3	1.90	0.63	16.49	**<.0001**
		Error	1721	66.17	0.04		
		C. Total	1724	68.08			
	RCCA	Model	3	0.71	0.24	8.50	**<.0001**
		Error	926	25.64	0.03		
		C. Total	929	26.35			

iii. Blue Rockfish

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
Carmel Bay	PISCO	Model	3	21.05	7.02	41.94	**<.0001**
		Error	1046	174.97	0.17		
		C. Total	1049	196.01			
	RCCA	Model	3	0.02	0.01	0.13	0.9421
		Error	512	20.53	0.04		
		C. Total	515	20.54			
Pt. Lobos	PISCO	Model	3	1.78	0.59	2.61	**0.0500**
		Error	1591	361.07	0.23		
		C. Total	1594	362.85			
	RCCA	Model	3	1.53	0.51	8.05	**<.0001**
		Error	815	51.58	0.06		
		C. Total	818	53.11			
Pt. Lobos v Carmel Bay	PISCO	Model	3	18.02	6.01	31.15	**<.0001**
		Error	1721	331.89	0.19		
		C. Total	1724	349.91			
	RCCA	Model	3	1.85	0.62	10.65	**<.0001**
		Error	926	53.73	0.06		
		C. Total	929	55.58			

iv. Kelp Bass

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
Anacapa	PISCO	Model	3	4.29	1.43	27.65	**<.0001**
		Error	565	29.19	0.05		
		C. Total	568	33.48			
	RCCA	Model	3	1.18	0.39	12.02	**<.0001**
		Error	369	12.02	0.03		
		C. Total	372	13.20			
Scorpion	PISCO	Model	3	16.51	5.50	96.09	**<.0001**
		Error	1603	91.79	0.06		
		C. Total	1606	108.30			
	RCCA	Model	3	1.08	0.36	9.57	**<.0001**
		Error	271	10.21	0.04		
		C. Total	274	11.29			
Pt. Dume	PISCO	Model	3	1.36	0.45	5.68	0.0009
		Error	234	18.63	0.08		
		C. Total	237	19.98			
	RCCA	Model	3	0.74	0.25	7.45	<.0001
		Error	324	10.73	0.03		
		C. Total	327	11.47			

v. CA Sheephead

Location	Program	Source	DF	SS	MS	F Ratio	Prob > F
Anacapa	PISCO	Model	3	3.66	1.22	24.56	**<.0001**
		Error	565	28.07	0.05		
		C. Total	568	31.73			
	RCCA	Model	3	7.16	2.39	26.43	**<.0001**
		Error	369	33.32	0.09		
		C. Total	372	40.48			
Scorpion	PISCO	Model	3	8.47	2.82	54.49	**<.0001**
		Error	1603	83.11	0.05		
		C. Total	1606	91.58			
	RCCA	Model	3	0.65	0.22	10.68	**<.0001**
		Error	271	5.46	0.02		
		C. Total	274	6.11			
Pt. Dume	PISCO	Model	3	1.33	0.44	5.36	**0.0014**
		Error	234	19.37	0.08		
		C. Total	237	20.70			
	RCCA	Model	3	1.01	0.34	14.09	**<.0001**
		Error	324	7.72	0.02		
		C. Total	327	8.72			

B. Effects tests

i. Lingcod

Location	Program	Source	DF	SS	F Ratio	Prob > F
Carmel Bay	PISCO	MPA	1	0.38	5.25	**0.0221**
		year	1	0.28	3.90	**0.0484**
		MPA*year	1	0.06	0.78	0.3786
	RCCA	MPA	1	0.02	0.66	0.4169
		year	1	0.93	35.76	**<.0001**
		MPA*year	1	0.02	0.78	0.3774
Pt. Lobos	PISCO	MPA	1	0.05	0.50	0.4793
		year	1	0.91	9.55	**0.0020**
		MPA*year	1	0.00	0.04	0.8380
	RCCA	MPA	1	0.25	4.32	**0.0379**
		year	1	3.03	53.11	**<.0001**
		MPA*year	1	0.33	5.76	**0.0167**
Pt. Lobos v Carmel Bay	PISCO	MPA	1	0.88	11.51	**0.0007**
		year	1	0.92	11.96	**0.0006**
		MPA*year	1	0.15	2.00	0.1571
	RCCA	MPA	1	0.71	14.05	**0.0002**
		year	1	3.63	71.69	**<.0001**
		MPA*year	1	0.63	12.54	**0.0004**

ii. Kelp Rockfish

Location	Program	Source	DF	SS	F Ratio	Prob > F
Carmel Bay	PISCO	MPA	1	0.00	0.00	0.9493
		year	1	0.06	1.74	0.1869
		MPA*year	1	0.16	4.72	**0.0300**
	RCCA	MPA	1	0.07	2.39	0.1229
		year	1	0.21	7.10	**0.0080**
		MPA*year	1	0.05	1.55	0.2133
Pt. Lobos	PISCO	MPA	1	0.89	23.25	**<.0001**
		year	1	0.01	0.32	0.5721
		MPA*year	1	0.09	2.28	0.1310
	RCCA	MPA	1	0.02	0.77	0.3807
		year	1	0.61	20.04	**<.0001**
		MPA*year	1	0.01	0.30	0.5866
Pt. Lobos v Carmel Bay	PISCO	MPA	1	0.90	23.37	**<.0001**
		year	1	0.85	22.02	**<.0001**
		MPA*year	1	0.02	0.64	0.4225
	RCCA	MPA	1	0.30	10.98	**0.0010**
		year	1	0.26	9.25	**0.0024**
		MPA*year	1	0.03	1.12	0.2909

iii. Blue Rockfish

Location	Program	Source	DF	SS	F Ratio	Prob > F
Carmel Bay	PISCO	MPA	1	20.69	123.71	**<.0001**
		year	1	0.26	1.57	0.2106
		MPA*year	1	0.29	1.74	0.1880
	RCCA	MPA	1	0.00	0.01	0.9139
		year	1	0.01	0.31	0.5772
		MPA*year	1	0.01	0.18	0.6753
Pt. Lobos	PISCO	MPA	1	1.78	7.82	**0.0052**
		year	1	0.00	0.00	0.9960
		MPA*year	1	0.00	0.00	0.9522
	RCCA	MPA	1	0.38	5.93	**0.0151**
		year	1	0.16	2.51	0.1132
		MPA*year	1	0.44	6.90	**0.0088**
Pt. Lobos v Carmel Bay	PISCO	MPA	1	17.65	91.53	**<.0001**
		year	1	0.57	2.96	0.0853
		MPA*year	1	0.50	2.57	0.1092
	RCCA	MPA	1	0.63	10.88	**0.0010**
		year	1	0.39	6.67	**0.0100**
		MPA*year	1	0.44	7.50	**0.0063**

iv. Kelp Bass

Location	Program	Source	DF	SS	F Ratio	Prob > F
Anacapa	PISCO	MPA	1	2.237	43.302	**<.0001**
		year	1	2.079	40.231	**<.0001**
		MPA*year	1	0.001	0.023	0.8790
	RCCA	MPA	1	0.512	15.712	**<.0001**
		year	1	0.098	3.007	0.0837
		MPA*year	1	0.326	10.019	**0.0017**
Scorpion	PISCO	MPA	1	10.968	191.538	**<.0001**
		year	1	2.798	48.854	**<.0001**
		MPA*year	1	2.022	35.314	**<.0001**
	RCCA	MPA	1	0.597	15.848	**<.0001**
		year	1	0.043	1.148	0.2850
		MPA*year	1	0.323	8.576	**0.0037**
Pt. Dume	PISCO	MPA	1	0.706	8.873	**0.0032**
		year	1	0.390	4.903	**0.0278**
		MPA*year	1	0.409	5.136	**0.0244**
	RCCA	MPA	1	0.116	3.490	0.0627
		year	1	0.596	18.007	**<.0001**
		MPA*year	1	0.706	8.873	**0.0032**

v. CA Sheephead

Location	Program	Source	DF	SS	F Ratio	Prob > F
Anacapa	PISCO	MPA	1	3.432	69.073	**<.0001**
		year	1	0.237	4.774	**0.0293**
		MPA*year	1	0.006	0.123	0.7255
	RCCA	MPA	1	6.454	71.485	**<.0001**
		year	1	0.071	0.782	0.3770
		MPA*year	1	0.317	3.506	0.0619
Scorpion	PISCO	MPA	1	3.409	65.756	**<.0001**
		year	1	3.780	72.901	**<.0001**
		MPA*year	1	0.881	16.986	**<.0001**
	RCCA	MPA	1	0.473	23.454	**<.0001**
		year	1	0.197	9.771	**0.0020**
		MPA*year	1	0.004	0.203	0.6527
Pt. Dume	PISCO	MPA	1	1.329	16.054	**<.0001**
		year	1	0.000	0.002	0.9677
		MPA*year	1	0.001	0.013	0.9096
	RCCA	MPA	1	0.003	0.122	0.7271
		year	1	0.999	41.948	**<.0001**
		MPA*year	1	0.033	1.406	0.2366

C. Power analyses (α =0.05 for all models)

i. Lingcod

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/δ
Carmel Bay	PISCO	MPA	0.268	0.019	1050	0.629	0.016	0.860
		MPA*year	0.268	0.007	1050	0.142		
	RCCA	MPA	0.161	0.006	516	0.128	0.015	2.555
		MPA*year	0.161	0.006	516	0.142		
Pt. Lobos	PISCO	MPA	0.309	0.005	1595	0.109	0.016	2.975
		MPA*year	0.309	0.002	1595	0.054		
	RCCA	MPA	0.239	0.017	819	0.546	0.019	1.111
		MPA*year	0.239	0.020	819	0.668		
Pt. Lobos v Carmel Bay	PISCO	MPA	0.277	0.023	1725	0.9237	0.0140	0.615
		MPA*year	0.277	0.009	1725	0.293		
	RCCA	MPA	0.225	0.028	930	0.962	0.015	0.544
		MPA*year	0.225	0.026	930	0.942		

ii. Kelp Rockfish

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/δ
Carmel Bay	PISCO	MPA	0.186	0.000	1050	0.050	0.011	30.959
		MPA*year	0.186	0.012	1050	0.583		
	RCCA	MPA	0.173	0.012	516	0.338	0.016	1.343
		MPA*year	0.173	0.009	516	0.237		
Pt. Lobos	PISCO	MPA	0.195	0.024	1595	0.997	0.010	0.437
		MPA*year	0.195	0.007	1595	0.326		
	RCCA	MPA	0.174	0.005	819	0.141	0.014	2.634
		MPA*year	0.174	0.003	819	0.084		
Pt. Lobos v Carmel Bay	PISCO	MPA	0.196	0.023	1725	0.998	0.009	0.432
		MPA*year	0.196	0.004	1725	0.126		
	RCCA	MPA	0.166	0.018	930	0.911	0.011	0.616
		MPA*year	0.166	0.006	930	0.184		

iii. Blue Rockfish

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/δ
Carmel Bay	PISCO	MPA	0.409	0.140	1050	1.000	0.025	0.177
		MPA*year	0.409	0.017	1050	0.260		
	RCCA	MPA	0.200	0.001	516	0.051	0.018	19.186
		MPA*year	0.200	0.004	516	0.070		
Pt. Lobos	PISCO	MPA	0.476	0.033	1595	0.798	0.025	0.753
		MPA*year	0.476	0.001	1595	0.050		
	RCCA	MPA	0.252	0.021	819	0.681	0.020	0.948
		MPA*year	0.252	0.023	819	0.746		
Pt. Lobos v Carmel Bay	PISCO	MPA	0.439	0.101	1725	1.000	0.022	0.218
		MPA*year	0.439	0.017	1725	0.360		
	RCCA	MPA	0.241	0.026	930	0.909	0.016	0.619
		MPA*year	0.241	0.022	930	0.781		

iv. Kelp Bass

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/δ
Anacapa	PISCO	MPA	0.227	0.063	569	1.000	0.019	0.296
		MPA*year	0.227	0.001	569	0.053		
	RCCA	MPA	0.181	0.037	373	0.977	0.021	0.555
		MPA*year	0.181	0.030	373	0.884		
Scorpion	PISCO	MPA	0.239	0.083	1607	1.000	0.012	0.142
		MPA*year	0.239	0.035	1607	1.000		
	RCCA	MPA	0.194	0.047	275	0.978	0.024	0.507
		MPA*year	0.194	0.034	275	0.831		
Pt. Dume	PISCO	MPA	0.282	0.054	238	0.843	0.037	0.675
		MPA*year	0.282	0.041	238	0.617		
	RCCA	MPA	0.182	0.019	328	0.461	0.021	1.095
		MPA*year	0.182	0.017	328	0.386		

v. CA Sheephead

Location	Program	Effect	σ	δ	Number	Power	LSV	LSV/δ
Anacapa	PISCO	MPA	0.223	0.078	569	1.000	0.018	0.236
		MPA*year	0.223	0.003	569	0.064		
	RCCA	MPA	0.300	0.132	373	1.000	0.034	0.260
		MPA*year	0.300	0.029	373	0.463		
Scorpion	PISCO	MPA	0.228	0.046	1607	1.000	0.011	0.243
		MPA*year	0.228	0.023	1607	0.985		
	RCCA	MPA	0.142	0.041	275	0.998	0.017	0.417
		MPA*year	0.142	0.004	275	0.073		
Pt. Dume	PISCO	MPA	0.288	0.075	238	0.979	0.038	0.502
		MPA*year	0.288	0.002	238	0.051		
	RCCA	MPA	0.154	0.003	328	0.064	0.017	5.858
		MPA*year	0.154	0.010	328	0.219		

Figures and Tables Part II.

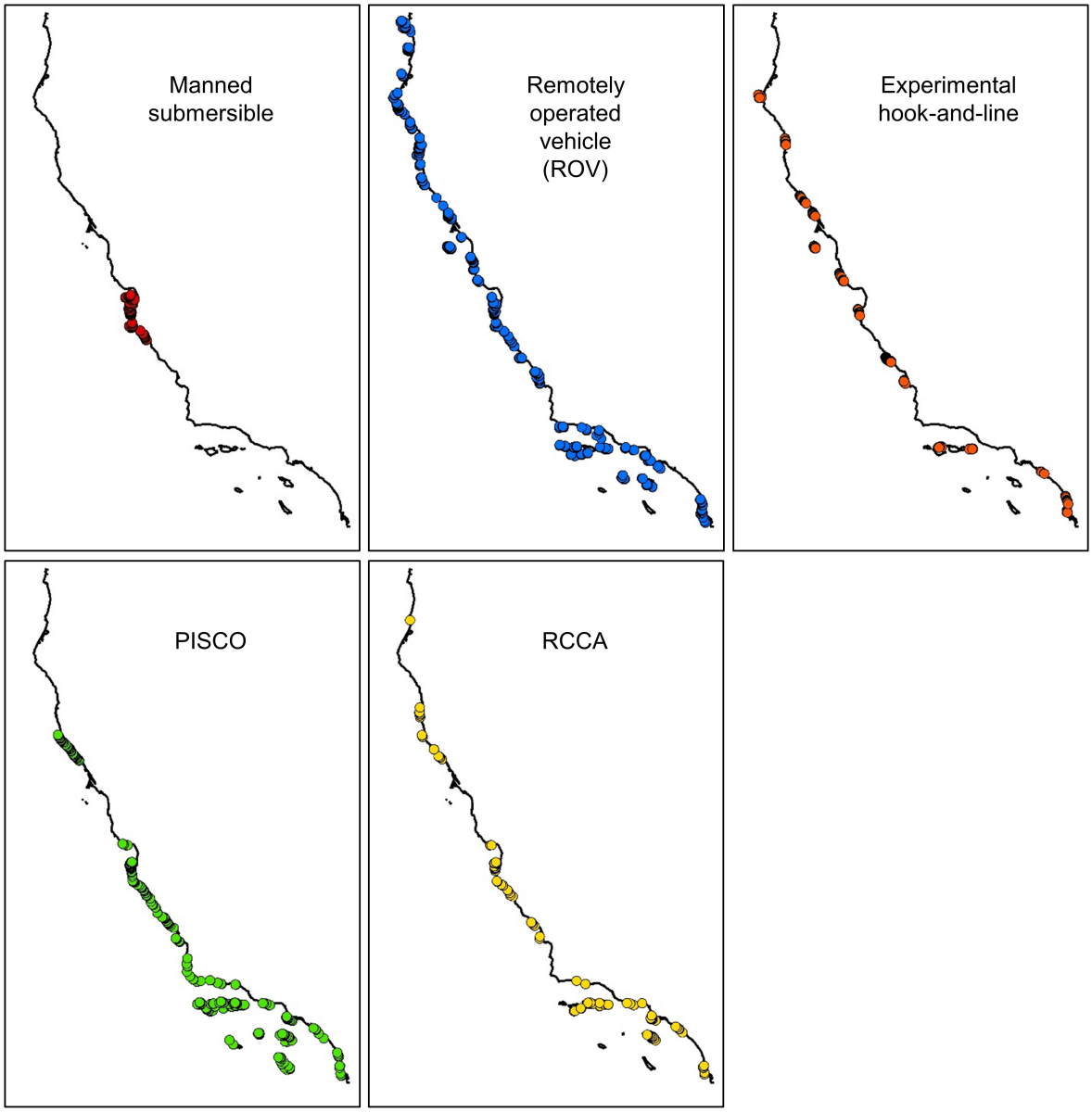


Figure 2.1. Survey locations for various techniques used in CA fish monitoring. The colors indicate the type of monitoring methods: red - manned submersible, blue – remotely operated vehicle (ROV), orange - experimental hook-and-line, green – PISCO and yellow - RCCA. See methods for description of the programs and datasets.

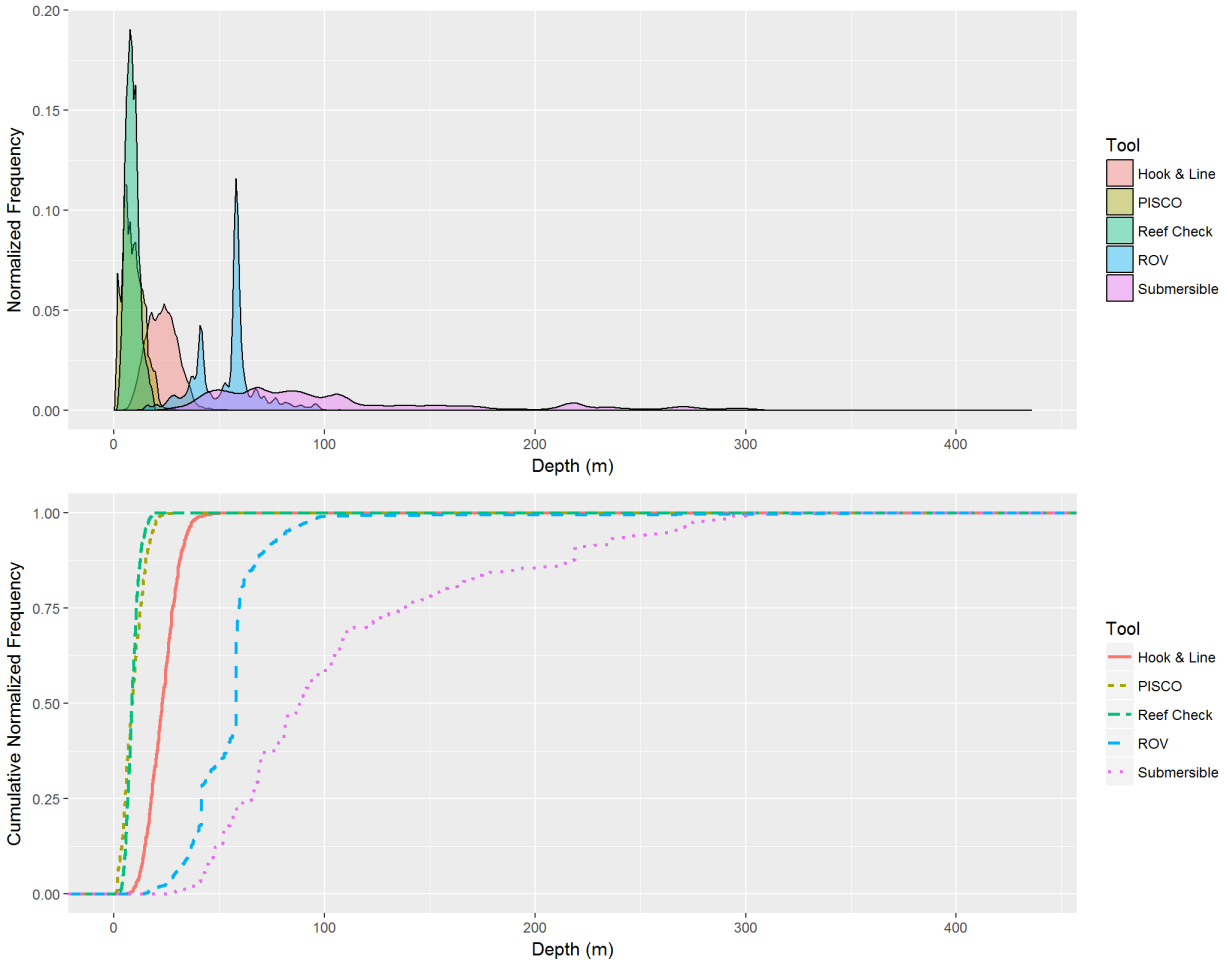


Figure 2.2. Sampled fish frequency distribution. Top: Frequency of recorded fish individuals for different types of monitoring techniques. Bottom: Corresponding cumulative frequency function of the frequency plots at the top panel.

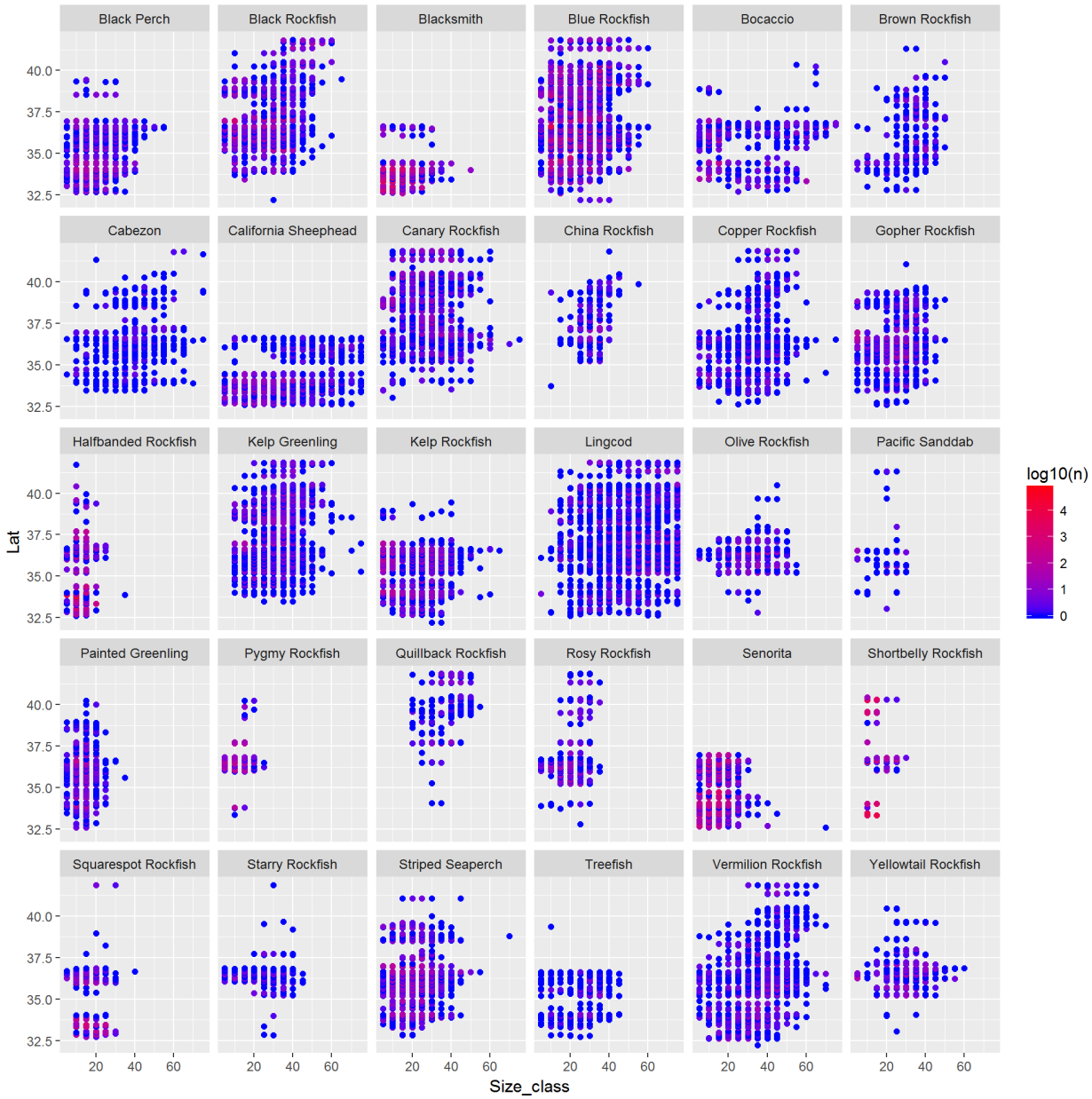


Figure 2.3. Latitude vs. size classes of top fish species (in terms of number of samples) using ROVs. Color indicates the number of samples in $\log_{10}$ scale.

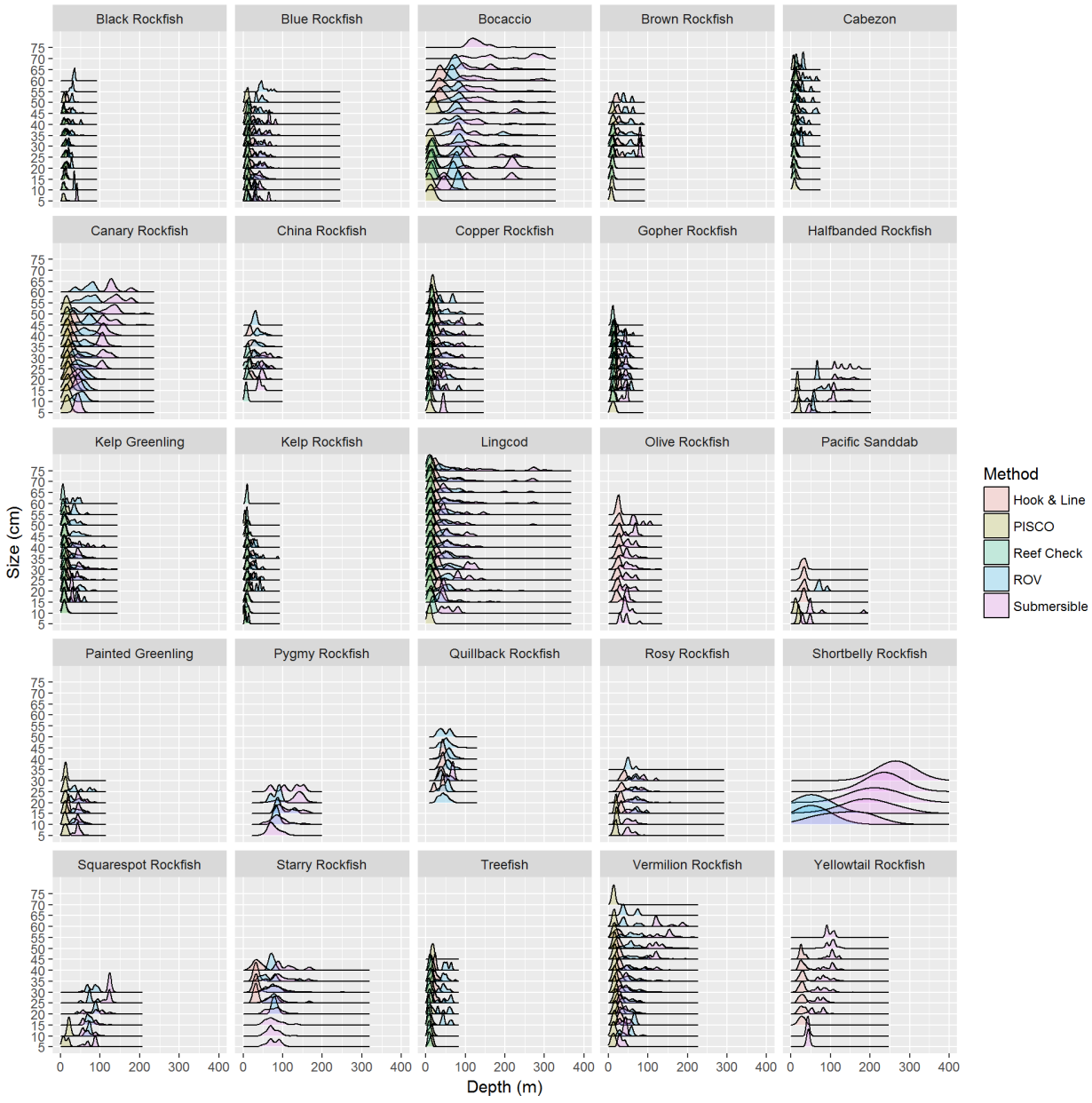


Figure 2.4. Size class (fish total length [cm]) vs. depth (m) for selected species. Colors show different monitoring techniques.

Table 2.1. Number of individual fish and number of species recorded.

	ROV	Manned Submersible	Hook and Line	RCCA	PISCO
Years of dataset	2014-2016	2007-2008	2007-2017	2006-2016	1999-2016
Num. of fish records	270,155	85,078	107,624	169,407	1,203,564
Num. of species	107	106	75	31	90

Table 2.2. The 15 most common fish species present in all of the five monitoring techniques used in this report. Values indicate percentage of individuals of each species observed or caught for all study sites combined.

Common Name	Species Name	Remotely Operated Vehicle	Hook and Line	Manned Submersible	RCCA	PISCO
Blue Rockfish	*Sebastes mystinus*	8.265	39.007	2.453	6.198	18.391
Lingcod	*Ophiodon elongatus*	1.274	3.917	0.478	0.290	0.114
Kelp Greenling	*Hexagrammos decagrammus*	0.701	0.547	0.146	0.983	0.457
Senorita	*Oxyjulis californica*	0.496	0.002	0.049	22.634	17.280
Copper Rockfish	*Sebastes caurinus*	0.417	1.685	0.207	0.135	0.297
Gopher Rockfish	*Sebastes carnatus*	0.267	18.859	0.596	0.498	0.722
Black Rockfish	*Sebastes melanops*	0.217	13.054	0.005	0.744	1.608
California Sheephead	*Semicossyphus pulcher*	0.192	0.105	0.012	4.067	1.317
Bocaccio	*Sebastes paucispinis*	0.128	0.020	1.013	0.015	0.516
Striped Seaperch	*Embiotoca lateralis*	0.097	0.008	0.048	1.923	1.901
Brown Rockfish	*Sebastes auriculatus*	0.094	0.751	0.013	0.034	0.043
Kelp Rockfish	*Sebastes atrovirens*	0.026	2.338	0.004	1.443	2.990
Treefish	*Sebastes serriceps*	0.026	0.186	0.008	0.072	0.088
Cabezon	*Scorpaenichthys marmoratus*	0.015	0.295	0.002	0.115	0.081
Black Perch	*Embiotoca jacksoni*	0.001	0.001	0.035	3.343	1.903

Table 2.3. Top 10 species recorded in terms of percent of fish individuals in the remotely operated vehicle dataset.

Common Name	Species Name	Percent
Halfbanded Rockfish	*Sebastes semicinctus*	61.56
Shortbelly Rockfish	*Sebastes jordani*	10.90
Blue Rockfish	*Sebastes mystinus*	8.26
California Scorpionfish	*Scorpaena guttata*	3.35
Blacksmith	*Chromis punctipinnis*	2.88
Squarespot Rockfish	*Sebastes hopkinsi*	2.46
Lingcod	*Ophiodon elongatus*	1.27
Vermilion Rockfish	*Sebastes miniatus*	1.10
Canary Rockfish	*Sebastes pinniger*	1.05
Kelp Greenling	*Hexagrammos decagrammus*	0.70

Table 2.4. Top 10 species recorded in terms of percent of fish individuals in the manned submersible dataset.

Common Name	Species Name	Percent
Pygmy Rockfish	*Sebastes wilsoni*	26.94
Blackeye Goby	*Coryphopterus nicholsii*	11.83
Squarespot Rockfish	*Sebastes hopkinsi*	8.48
Rosy Rockfish	*Sebastes rosaceus*	6.00
Halfbanded Rockfish	*Sebastes semicinctus*	4.99
Rosethorn Rockfish	*Sebastes helvomaculatus*	3.85
Pacific Hake	*Merluccius productus*	3.25
Bank Rockfish	*Sebastes rufus*	3.05
Splitnose Rockfish	*Sebastes diploproa*	2.61
Blue Rockfish	*Sebastes mystinus*	2.45

Table 2.5. Top 10 species recorded in terms of percent of fish individuals in the hook and line dataset.

Common Name	***Species Name***	Percent
Blue Rockfish	*Sebastes mystinus*	39.01
Gopher Rockfish	*Sebastes carnatus*	18.86
Black Rockfish	*Sebastes melanops*	13.05
Olive Rockfish	*Sebastes serranoides*	5.35
Lingcod	*Ophiodon elongatus*	3.92
Vermilion Rockfish	*Sebastes miniatus*	2.95
Deacon rockfish	*Sebastes diaconus*	2.67
Yellowtail Rockfish	*Sebastes flavidus*	2.40
Kelp Rockfish	*Sebastes atrovirens*	2.34
Copper Rockfish	*Sebastes caurinus*	1.68

Table 2.6. Top 10 species recorded in terms of percent of fish individuals in the PISCO dataset.

Common Name	Species Name	Percent
Blacksmith	*Chromis punctipinnis*	21.09
Blue Rockfish	*Sebastes mystinus*	18.39
Senorita	*Oxyjulis californica*	17.28
Kelp Perch	*Brachyistius frenatus*	6.30
Halfblind goby	*Lethops connectens*	5.31
Tubesnout	*Aulorhynchus flavidus*	4.23
Kelp Rockfish	*Sebastes atrovirens*	2.99
Kelp Bass	*Paralabrax clathratus*	2.81
Jack Mackerel	*Trachurus symmetricus*	2.61
Black Perch	*Embiotoca jacksoni*	1.90

Table 2.7. Top 10 species recorded in terms of percent of fish individuals in the RCCA dataset.

Common Name	Species Name	Percent
Blacksmith	*Chromis punctipinnis*	33.71
Senorita	*Oxyjulis californica*	22.63
Kelp Bass	*Paralabrax clathratus*	7.99
Blue Rockfish	*Sebastes mystinus*	6.20
Rock Wrasse	*Halichoeres semicinctus*	5.68
Garibaldi	*Hypsypops rubicundus*	5.63
California Sheephead	*Semicossyphus pulcher*	4.07
Black Perch	*Embiotoca jacksoni*	3.34
Striped Seaperch	*Embiotoca lateralis*	1.92
Kelp Rockfish	*Sebastes atrovirens*	1.44

Table 2.8. Latitudinal range of the dataset (in decimal degrees).

	ROV	Manned Submersible	Hook and Line	RCCA	PISCO
Min.	32.61000	36.0123	32.22000	32.69423	32.66371
Max.	41.86000	36.8503	40.49000	41.05500	38.95117

Appendix Table 1-1. Species observed by PISCO and RCCA ordered alphabetically by species name.

Species Name	Common Name	PISCO	RCCA
Alloclinus holderi	Island Kelpfish	X	
Alopias vulpinus	Thresher Shark	X	
Amphistichus argenteus	Barred Surfperch	X	
Anarrhichthys ocellatus	Wolf Eel	X	
Anisotremus davidsonii	Sargo	X	X
Anoplagonus inermis	Smooth Alligatorfish	X	
Apodichthys flavidus	Penpiont Gunnel	X	
Apodichthys sanctaerosae	Kelp Gunnel	X	
Apogon guadalupensis	Guadalupe Cardinalfish	X	
Artedius corallinus	Coralline Sculpin	X	
Atherinidae/Atherinopsidae spp	Grunion, Topsmelt Or Jacksmelt	X	
Atherinops affinis	Topsmelt	X	
Atherinopsis californiensis	Jacksmelt	X	
Atractoscion nobilis	White Seabass	X	
Aulorhynchus flavidus	Tubesnout	X	
Balistes polylepis	Finescale Triggerfish	X	
Bathymasteridae spp	Ronquils	X	
Blenniidae spp	Blennies	X	
Bothidae spp	Lefteyed Flounders	X	
Bothidae/Paralichthyidae spp	Lefteyed /Large Toothed Flounders	X	
Brachyistius frenatus	Kelp Surfperch	X	
Caulolatilus princeps	Ocean Whitefish	X	
Cebidichthys violaceus	Monkeyface Eel	X	
Cephaloscyllium ventriosum	Swell Shark	X	
Chaetodon falcifer	Scythemarked Butterflyfish	X	
Cheilotrema saturnum	Black Croaker	X	
Chirolophis nugator	Mosshead Warbonnet	X	
Chitonotus pugetensis	Roughback Sculpin	X	
Chromis punctipinnis	Blacksmith	X	X

Citharichthys sordidus	Pacific Sanddab	X	
Citharichthys spp	Sanddabs	X	
Citharichthys stigmaeus	Speckled Sanddab	X	
Clinidae spp	Kelpfishes And Fringeheads	X	
Clinocottus analis	Wooly Sculpin	X	
Clupeidae spp	Sardines And Anchovies	X	
Cottidae spp	Sculpins	X	
Cymatogaster aggregata	Shiner Surfperch	X	
Embiotoca jacksoni	Black Surfperch	X	X
Embiotoca lateralis	Striped Surfperch	X	X
Embiotocidae spp	Surfperches	X	
Engraulis mordax	Northern Anchovy	X	
Enophrys bison	Buffalo Sculpin	X	
Ernogrammus walkeri	Masked Prickleback	X	
Galeorhinus galeus	Tope Shark	X	
Gibbonsia spp	Kelpfish	X	
Girella nigricans	Opaleye	X	X
Gobiesox maeandricus	Northern Clingfish	X	
Gobiidae spp	Gobies	X	
Gymnothorax mordax	California Moray	X	
Halicoeres semicinctus	Rock Wrasse	X	X
Hemilepidotus hemilepidotus	Red Irish Lord	X	
Hermosilla azurea	Zebra-Perch Sea Chub	X	
Heterodontus francisci	Horn Shark	X	X
Heterostichus rostratus	Giant Kelpfish	X	
Hexagrammos decagrammus	Kelp Greenling	X	X
Hexagrammos lagocephalus	Rock Greenling	X	X
Hexagrammos stelleri	Whitespotted Greenling	X	
Hexanchus griseus	Sixgill Shark	X	
Hyperprosopon analis	Spotfin Surfperch	X	
Hyperprosopon argenteum	Walleye Surfperch	X	
Hyperprosopon ellipticum	Silver Surfperch	X	
Hypsurus caryi	Rainbow Surfperch	X	X
Hypsypops rubicundus	Garibaldi	X	X

Jordania zonope	Longfin Sculpin	X	
Kasatkia seigeli	Six-Spot Prickleback	X	
Leiocottus hirundo	Lavender Sculpin	X	
Lepidogobius lepidus	Bay Goby	X	
Lethops connectens	Kelp Goby, Halfblind Goby	X	
Liparis mucosus	Slimy Snailfish	X	
Lythrypnus dalli	Bluebanded Goby	X	
Lythrypnus zebra	Zebra Goby	X	
Medialuna californiensis	Halfmoon	X	
Micropetrus minimus	Dwarf Surfperch	X	
Mola mola	Ocean Sunfish	X	
Mugil cephalus	Mullet	X	
Mycteroperca xenarcha	Broomtail Grouper	X	
Myliobatis californica	Bat Ray	X	
Neoclinus blanchardi	Sarcastic Fringehead	X	
Neoclinus stephensae	Yellowfin Fringehead	X	
Neoclinus uninotatus	Onespot Fringehead	X	
Notorynchus cepedianus	Broadnose Sevengill Shark	X	
Ophiodon elongatus	Lingcod	X	X
Orthonopias triacis	Snubnose Sculpin	X	
Oxyjulis californica	Senorita	X	X
Oxylebius pictus	Painted Greenling	X	
Paralabrax clathratus	Kelp Bass, Calico Bass	X	X
Paralabrax maculatofasciatus	Spotted Sandbass	X	
Paralabrax nebulifer	Barred Sandbass	X	X
Paralichthys californicus	California Halibut	X	
Phanerodon atripes	Sharpnose Surfperch	X	
Phanerodon furcatus	White Surfperch	X	
Pholididae spp	Gunnels	X	
Platyrhinoides triseriata	Thornback	X	
Pleuronectidae spp	Righteyed Flounders	X	
Plueronichthys coenosus	C-O Turbot	X	
Porichthys notatus	Plainfin Midshipman	X	
Prionace glauca	Blue Shark	X	
Raja binoculata	Big Skate	X	

Raja stellulata	Starry Skate	X	
Rathbunella alleni	Stripefin Ronquil	X	
Rathbunella hypoplecta	Smooth Ronquil	X	
Rhacochilus toxotes	Rubberlip Surfperch	X	X
Rhacochilus vacca	Pile Surfperch	X	X
Rhamphocottus richardsoni	Grunt Sculpin	X	
Rhinobatos productus	Shovelnose Guitarfish	X	
Ronquilus jordani	Northern Ronquil	X	
Sarda chiliensis	Eastern Pacific Bonito	X	
Sardinops sagax	Pacific Sardine	X	
Scomber japonicus	Pacific / Greenback Mackerel	X	
Scorpaena guttata	California Scorpionfish, Sculpin	X	
Scorpaenichthys marmoratus	Cabezon	X	X
Sebastes atrovirens	Kelp Rockfish	X	X
Sebastes auriculatus	Brown Rockfish	X	X
Sebastes carnatus	Gopher Rockfish	X	X
Sebastes caurinus	Copper Rockfish	X	X
Sebastes chrysomelas	Black And Yellow Rockfish	X	X
Sebastes dallii	Calico Rockfish	X	
Sebastes diploproa	Spitnose Rockfish	X	
Sebastes entomelas	Widow Rockfish	X	
Sebastes hopkinsi	Squarespot Rockfish	X	
Sebastes maliger	Quillback Rockfish	X	
Sebastes melanops	Black Rockfish	X	X
Sebastes miniatus	Vermilion Rockfish	X	X
Sebastes mystinus	Blue Rockfish	X	X
Sebastes nebulosus	China Rockfish	X	X
Sebastes paucispinis	Bocaccio	X	X
Sebastes pinniger	Canary Rockfish	X	X
Sebastes rastrelliger	Grass Rockfish	X	X
Sebastes rosaceus	Rosy Rockfish	X	
Sebastes rubrivinctus	Flag Rockfish	X	
Sebastes saxicola	Stripetail Rockfish	X	
Sebastes semicinctus	Halfbanded Rockfish	X	

Sebastes serranoides/flavidus	Olive Rockfish/Yellowtail Rockfish	X	X
Sebastes serriceps	Treefish	X	X
Sebastes umbrosus	Honeycomb Rockfish	X	
Sebastes spp	Rockfish Young Of Year (YOY)		X
Semicossyphus pulcher	California Sheephead	X	X
Seriola lalandi	Yellowtail	X	
Sphyraena argentea	California Barracuda	X	
Squalus acanthias	Spiny Dogfish	X	
Squatina californica	Pacific Angel Shark	X	
Stereolepis gigas	Giant Sea Bass	X	X
Stichaeidae spp	Pricklebacks	X	
Synchirus / Rimicola spp	Manacled Sculpin/Kelp Clingfish	X	
Syngnathus spp	Pipefish	X	
Synodus lucioceps	California Lizardfish	X	
Torpedo californica	Pacific Electric Ray	X	
Trachurus symmetricus	Jack Mackerel	X	
Triakis semifasciata	Leopard Shark	X	
Urobatis halleri	Haller's Round Ray	X	
Xenistius californiensis	Californian Salema	X	
Zalembius rosaceus	Pink Surfperch	X	
Zapteryx exasperata	Banded Guitarfish	X	

APPENDIX Table 1.2. List of sites included in the ANOVA and power analyses in Tables 1.1 – 1.3. Note that for the Pt. Lobos v. Carmel Bay comparison, we used Carmel Bay SMCA sites as the "reference' sites for Pt. Lobos.

MPA	Program	MPA	Site
Anacapa Island SMR and SMCA	PISCO	IN	Anacapa East Isle CEN
	PISCO	IN	Anacapa East Isle E
	PISCO	IN	Anacapa East Isle W
	RCCA	IN	Cathedral Cove
	RCCA	IN	Cathedral Wall
	RCCA	IN	Landing Cove
	PISCO	REF	Anacapa Lighthouse Reef CEN
	PISCO	REF	Anacapa Lighthouse Reef E
	PISCO	REF	Anacapa Lighthouse Reef W
	RCCA	REF	Light House
Carmel Bay SMCA	PISCO	IN	Butterfly DC
	PISCO	IN	Butterfly UC
	PISCO	IN	Stillwater DC
	PISCO	IN	Stillwater UC
	RCCA	IN	Carmel River
	RCCA	IN	Stillwater Cove Monterey
	PISCO	REF	Cypress Pt DC
	PISCO	REF	Cypress Pt UC
	PISCO	REF	Lingcod DC
	PISCO	REF	Lingcod UC
	PISCO	REF	Lone Tree CEN
	PISCO	REF	Pescadero DC
	PISCO	REF	Pescadero UC
	RCCA	REF	Pescadero
Pt. Dume SMR and SMCA	PISCO	IN	El Matador CEN
	PISCO	IN	Little Dume CEN
	PISCO	IN	Point Dume CEN
	RCCA	IN	Lechuza
	RCCA	IN	Paradise Point
	PISCO	REF	County Line CEN
	PISCO	REF	Leo Carrillo CEN
	RCCA	REF	Leo Carrillo North
Pt. Lobos SMR	PISCO	IN	Bluefish DC
	PISCO	IN	Bluefish UC
	PISCO	IN	Monastery DC
	PISCO	IN	Monastery UC
	PISCO	IN	Weston DC
	PISCO	IN	Weston UC
	RCCA	IN	Middle Reef
	RCCA	IN	North Monastery

	RCCA	IN	South Monastery
	RCCA	IN	Weston
	PISCO	REF	Cypress Pt DC
	PISCO	REF	Cypress Pt UC
	PISCO	REF	Lingcod DC
	PISCO	REF	Lingcod UC
	PISCO	REF	Lone Tree CEN
	PISCO	REF	Pescadero DC
	PISCO	REF	Pescadero UC
	RCCA	REF	Pescadero
Scorpion SMR	PISCO	IN	SCI Cavern Point E
	PISCO	IN	SCI Cavern Point W
	PISCO	IN	SCI Potato Pasture E
	PISCO	IN	SCI Potato Pasture W
	PISCO	IN	SCI Scorpion E
	PISCO	IN	SCI Scorpion W
	PISCO	IN	SCI Scorpion Anchorage CEN
	RCCA	IN	Scorpion Anchorage
	PISCO	REF	SCI Coche Point E
	PISCO	REF	SCI Coche Point W
	PISCO	REF	SCI Little Scorpion E
	PISCO	REF	SCI Little Scorpion W
	PISCO	REF	SCI San Pedro Point E
	PISCO	REF	SCI San Pedro Point W
	PISCO	REF	SCI Yellowbanks CEN
	PISCO	REF	SCI Yellowbanks E
	PISCO	REF	SCI Yellowbanks W
	RCCA	REF	Sandstone Pt.
	RCCA	REF	Yellowbanks
Pt. Lobos SMR v Carmel Bay SMCA	PISCO	SMR	Bluefish DC
	PISCO	SMR	Bluefish UC
	PISCO	SMR	Monastery DC
	PISCO	SMR	Monastery UC
	PISCO	SMR	Weston DC
	PISCO	SMR	Weston UC
	RCCA	SMR	Middle Reef
	RCCA	SMR	North Monastery
	RCCA	SMR	South Monastery
	RCCA	SMR	Weston
	PISCO	SMCA	Butterfly DC
	PISCO	SMCA	Butterfly UC
	PISCO	SMCA	Stillwater DC
	PISCO	SMCA	Stillwater UC
	RCCA	SMCA	Carmel River
	RCCA	SMCA	Stillwater Cove Monterey

Appendix Table 2.1. List of species and percent composition recorded per monitoring technique. Ordered by percent in ROV surveys. NA = not present in surveys.

Common Name	Species Name	ROV	Hook & Line	Manned Submersible	RCCA	PISCO
Halfbanded Rockfish	*Sebastes semicinctus*	61.559	NA	4.994	NA	0.126
Shortbelly Rockfish	*Sebastes jordani*	10.905	NA	0.742	NA	NA
Blue Rockfish	*Sebastes mystinus*	8.265	39.007	2.453	6.198	18.425
California Scorpionfish	*Scorpaena guttata*	3.345	0.042	0.001	NA	0.004
Blacksmith	*Chromis punctipinnis*	2.881	0.006	NA	33.708	21.080
Squarespot Rockfish	*Sebastes hopkinsi*	2.463	0.003	8.478	NA	0.019
Lingcod	*Ophiodon elongatus*	1.274	3.917	0.478	0.290	0.114
Vermilion Rockfish	*Sebastes miniatus*	1.101	2.947	1.111	NA	0.173
Canary Rockfish	*Sebastes pinniger*	1.049	1.426	0.863	NA	0.212
Kelp Greenling	*Hexagrammos decagrammus*	0.701	0.547	0.146	0.983	0.458
Senorita	*Oxyjulis californica*	0.496	0.002	0.049	22.634	17.305
Speckled Rockfish	*Sebastes ovalis*	0.444	NA	0.235	NA	NA
Copper Rockfish	*Sebastes caurinus*	0.417	1.685	0.207	0.135	0.297
Painted Greenling	*Oxylebius pictus*	0.373	0.004	1.154	NA	1.816
Pink Seaperch	*Zalembius rosaceus*	0.361	NA	0.272	NA	NA
Widow Rockfish	*Sebastes entomelas*	0.334	0.004	2.367	NA	0.027
Pile Perch	*Rhacochilus vacca*	0.324	0.001	NA	1.442	1.103
Rosy Rockfish	*Sebastes rosaceus*	0.314	0.539	5.996	NA	0.001
California Lizardfish	*Synodus lucioceps*	0.295	0.064	NA	NA	0.001
Gopher Rockfish	*Sebastes carnatus*	0.267	18.859	0.596	0.498	0.723
Pygmy Rockfish	*Sebastes wilsoni*	0.232	NA	26.940	NA	NA
Black Rockfish	*Sebastes melanops*	0.217	13.054	0.005	0.744	1.611
California Sheephead	*Semicossyphus pulcher*	0.192	0.105	0.012	4.067	1.318
Calico Rockfish	*Sebastes dallii*	0.190	0.035	0.006	NA	0.008
Slender Snipefish	*Macroramphosus gracilis*	0.148	NA	NA	NA	NA
Quillback Rockfish	*Sebastes maliger*	0.135	0.215	0.008	NA	NA
Bocaccio	*Sebastes paucispinis*	0.128	0.020	1.013	0.015	0.517
Brown Cat Shark	*Apristurus brunneus*	0.120	NA	NA	NA	NA
Splitnose Rockfish	*Sebastes diploproa*	0.107	NA	2.613	NA	NA
Yelloweye Rockfish	*Sebastes ruberrimus*	0.101	0.013	0.200	NA	NA
Striped Seaperch	*Embiotoca lateralis*	0.097	0.008	0.048	1.923	1.904
Greenspotted Rockfish	*Sebastes chlorostictus*	0.094	NA	2.122	NA	NA
Brown Rockfish	*Sebastes auriculatus*	0.094	0.751	0.013	0.034	0.043
Greenstriped	*Sebastes elongatus*	0.091	NA	1.201	NA	NA

Rockfish						
Shortspine Thornyhead	*Sebastolobus alascanus*	0.086	NA	0.347	NA	NA
Flag Rockfish	*Sebastes rubrivinctus*	0.079	NA	0.056	NA	0.000
Pacific Hake	*Merluccius productus*	0.067	NA	3.252	NA	NA
Pacific Sand Lance	*Ammodytes hexapterus*	0.047	NA	NA	NA	NA
China Rockfish	*Sebastes nebulosus*	0.043	1.021	0.075	0.012	NA
Pacific Hagfish	*Eptatretus stoutii*	0.037	NA	NA	NA	NA
Dover Sole	*Microstomus pacificus*	0.036	NA	1.775	NA	NA
Tubesnout	*Aulorhynchus flavidus*	0.036	0.001	NA	NA	4.219
White Seaperch	*Phanerodon furcatus*	0.036	NA	0.043	NA	0.311
Stripetail Rockfish	*Sebastes saxicola*	0.035	NA	1.571	NA	0.046
Spotted Ratfish	*Hydrolagus colliei*	0.029	NA	0.293	NA	NA
Kelp Rockfish	*Sebastes atrovirens*	0.026	2.338	0.004	1.443	2.995
Treefish	*Sebastes serriceps*	0.026	0.186	0.008	0.072	0.088
Kelp Bass	*Paralabrax clathratus*	0.023	0.423	NA	7.993	2.812
Ocean Whitefish	*Caulolatilus princeps*	0.023	1.246	NA	NA	0.115
Starry Rockfish	*Sebastes constellatus*	0.021	0.081	1.302	NA	NA
Rex Sole	*Glyptocephalus zachirus*	0.020	NA	NA	NA	NA
Blackgill Rockfish	*Sebastes melanostomus*	0.019	NA	0.022	NA	NA
Opaleye	*Girella nigricans*	0.018	0.004	NA	1.108	1.149
Bluebanded Ronquil	*Rathbunella hypoplecta*	0.015	NA	0.025	NA	0.001
Cabezon	*Scorpaenichthys marmoratus*	0.015	0.295	0.002	0.115	0.081
Longnose Skate	*Raja rhina*	0.014	NA	0.108	NA	NA
Wolf-eel	*Anarrhichthys ocellatus*	0.012	0.003	0.002	NA	0.002
Yellowtail Jack	*Seriola lalandi*	0.009	0.001	NA	NA	0.001
Cowcod	*Sebastes levis*	0.007	NA	0.195	NA	NA
English Sole	*Parophrys vetulus*	0.007	NA	NA	NA	NA
Tiger Rockfish	*Sebastes nigrocinctus*	0.007	0.001	NA	NA	NA
Aurora Rockfish	*Sebastes aurora*	0.006	NA	0.226	NA	NA
Slender Sole	*Lyopsetta exilis*	0.006	NA	0.626	NA	NA
Bank Rockfish	*Sebastes rufus*	0.006	NA	3.054	NA	NA
Redbanded Rockfish	*Sebastes babcocki*	0.006	NA	0.085	NA	NA
Rubberlip Seaperch	*Rhacochilus toxotes*	0.005	0.002	0.004	0.227	0.239
Petrale Sole	*Eopsetta jordani*	0.004	0.003	0.015	NA	NA
Pinkrose Rockfish	*Sebastes simulator*	0.004	NA	0.233	NA	NA
Giant Sea Bass	*Stereolepis gigas*	0.004	NA	NA	0.009	0.001
California Halibut	*Paralichthys californicus*	0.004	0.012	0.002	NA	0.003
Darkblotched Rockfish	*Sebastes crameri*	0.004	NA	0.262	NA	NA
Sablefish	*Anoplopoma fimbria*	0.004	NA	0.002	NA	NA
Starry Skate	*Raja stellulata*	0.004	NA	0.002	NA	NA
Shiner Perch	*Cymatogaster*	0.003	NA	NA	NA	0.604

	aggregata					
Big Skate	*Raja binoculata*	0.003	NA	0.008	NA	NA
Halfmoon	*Medialuna californiensis*	0.003	0.011	NA	NA	0.548
Threadfin Bass	*Pronotogrammus multifasciatus*	0.003	NA	NA	NA	NA
Chilipepper	*Sebastes goodei*	0.002	0.001	0.026	NA	NA
Pacific Electric Ray	*Torpedo californica*	0.002	NA	NA	NA	0.017
Pacific Sanddab	*Citharichthys sordidus*	0.002	0.203	0.018	NA	0.002
Rock Sole	*Lepidopsetta bilineata*	0.002	0.038	0.005	NA	NA
Rosethorn Rockfish	*Sebastes helvomaculatus*	0.002	NA	3.851	NA	NA
Swell Shark	*Cephaloscyllium ventriosum*	0.002	NA	NA	NA	0.006
Pacific Angel Shark	*Squatina californica*	0.001	NA	NA	NA	0.001
Barred Sand Bass	*Paralabrax nebulifer*	0.001	0.048	NA	0.492	0.066
Bat Ray	*Myliobatis californica*	0.001	NA	NA	NA	<0.001
Greenblotched Rockfish	*Sebastes rosenblatti*	0.001	NA	0.442	NA	NA
Sunset Rockfish	*Sebastes crocotulus*	0.001	NA	NA	NA	NA
Black Perch	*Embiotoca jacksoni*	0.001	0.001	0.035	3.343	1.906
Buffalo Sculpin	*Enophrys bison*	0.001	0.007	NA	NA	NA
Kelp Perch	*Brachyistius frenatus*	0.001	NA	NA	NA	6.311
Longspine Thornyhead	*Sebastolobus altivelis*	0.001	NA	0.015	NA	NA
Ocean Sunfish	*Mola mola*	0.001	NA	NA	NA	NA
Pacific Staghorn Sculpin	*Leptocottus armatus*	0.001	NA	NA	NA	NA
Yellowtail Rockfish	*Sebastes flavidus*	0.001	2.401	1.358	NA	NA
Bluntnose Sixgill Shark	*Hexanchus griseus*	<0.001	NA	NA	NA	NA
Horn Shark	*Heterodontus francisci*	<0.001	NA	NA	0.040	0.009
Pacific Halibut	*Hippoglossus stenolepis*	<0.001	NA	0.002	NA	NA
Pacific Lamprey	*Entosphenus tridentatus*	<0.001	NA	NA	NA	NA
Pacific Tomcod	*Microgadus proximus*	<0.001	NA	NA	NA	NA
Rock Greenling	*Hexagrammos lagocephalus*	<0.001	0.007	NA	0.004	NA
Rock Wrasse	*Halichoeres semicinctus*	<0.001	0.001	NA	5.675	0.721
Sharpchin Rockfish	*Sebastes zacentrus*	<0.001	NA	0.170	NA	NA
Shortraker Rockfish	*Sebastes borealis*	<0.001	NA	NA	NA	NA
Speckled Sanddab	*Citharichthys stigmaeus*	<0.001	0.006	0.012	NA	0.002
Striped Kelpfish	*Gibbonsia metzi*	<0.001	NA	NA	NA	NA
Swordspine Rockfish	*Sebastes ensifer*	<0.001	NA	0.276	NA	NA
Black-and-Yellow Rockfish	*Sebastes chrysomelas*	NA	0.183	NA	0.556	0.442
Bull Sculpin	*Enophrys taurina*	NA	0.002	NA	NA	NA

Grass Rockfish	*Sebastes rastrelliger*	NA	0.016	NA	0.035	0.018
Jack Smelt	*Atherinopsis californiensis*	NA	0.004	NA	NA	NA
King Salmon	*Oncorhynchus tshawytscha*	NA	NA	NA	NA	NA
Pacific Bonito	*Sarda chiliensis*	NA	0.007	NA	NA	0.001
Rainbow Seaperch	*Hypsurus caryi*	NA	NA	NA	0.372	0.883
Pacific Sardine	*Sardinops sagax*	NA	0.005	NA	NA	0.001
Sand Sole	*Psettichthys melanostictus*	NA	0.003	NA	NA	NA
Top smelt	*Atherinops affinis*	NA	0.003	NA	NA	NA
White Croaker	*Genyonemus lineatus*	NA	0.010	NA	NA	NA
Blackeye Goby	*Coryphopterus nicholsii*	NA	NA	11.827	NA	NA
Olive Rockfish	*Sebastes serranoides*	NA	5.352	1.205	NA	NA
Jack Mackerel	*Trachurus symmetricus*	NA	0.051	0.552	NA	2.618
Rex Sole	*Errex zachirus*	NA	NA	0.504	NA	NA
Bluebarred Prickleback	*Plectobranchus evides*	NA	NA	0.337	NA	NA
Shortspine Combfish	*Zaniolepis frenata*	NA	NA	0.300	NA	NA
Northern Anchovy	*Engraulis mordax*	NA	0.006	0.284	NA	0.001
Pacific Mackerel	*Scomber japonicus*	NA	0.033	0.163	NA	0.001
Bigfin Eelpout	*Lycodes cortezianus*	NA	NA	0.121	NA	NA
Longspine Combfish	*Zaniolepis latipinnis*	NA	NA	0.095	NA	NA
English Sole	*Pleuronectes vetulus*	NA	NA	0.079	NA	NA
Chameleon Rockfish	*Sebastes phillipsi*	NA	NA	0.072	NA	NA
Pile Perch	*Damalichthys vacca*	NA	NA	0.063	NA	NA
Pacific Argentine	*Argentina sialis*	NA	NA	0.051	NA	NA
Stripefin Ronquil	*Rathbunella alleni*	NA	NA	0.041	NA	0.001
Spotfin Sculpin	*Icelinus tenuis*	NA	NA	0.040	NA	NA
Threadfin Sculpin	*Icelinus filamentosus*	NA	NA	0.032	NA	NA
Puget Sound Rockfish	*Sebastes emphaeus*	NA	NA	0.022	NA	NA
Red Brotula	*Brosmophycis marginata*	NA	NA	0.011	NA	NA
Sharpnose Surfperch	*Phanerodon atripes*	NA	0.008	0.011	NA	NA
Roughback Sculpin	*Chitonotus pugetensis*	NA	NA	0.008	NA	NA
Bronzespotted Rockfish	*Sebastes gilli*	NA	NA	0.007	NA	NA
Spotted Cusk-eel	*Chilara taylori*	NA	NA	0.007	NA	NA
Plainfin Midshipman	*Porichthys notatus*	NA	NA	0.006	NA	NA
Pacific Electric Ray	*Torpedo Californica*	NA	NA	0.004	NA	NA

Moser's Rockfish	*Sebastes moseri*	NA	NA	0.002	NA	NA
Bearded Eelpout	*Lyconema barbatum*	NA	NA	0.001	NA	NA
Blacktail Snailfish	*Careproctus melanurus*	NA	NA	0.001	NA	NA
Blacktip Poacher	*Xeneretmus latifrons*	NA	NA	0.001	NA	NA
Blue Spotted Poacher	*Xeneretmus triacanthus*	NA	NA	0.001	NA	NA
California Skate	*Raja inornata*	NA	NA	0.001	NA	NA
Deepsea Sole	*Embassichthys bathybius*	NA	NA	0.001	NA	NA
Hornyhead Turbot	*Pleuronichthys verticalis*	NA	NA	0.001	NA	NA
Pacific Lamprey	*Lampetra tridentata*	NA	NA	0.001	NA	NA
Pygmy Poacher	*Odontopyxis trispinosa*	NA	NA	0.001	NA	NA
Ratfish Egg Case	*Hydrolagus colliei egg*	NA	NA	0.001	NA	NA
Garibaldi	*Hypsypops rubicundus*	NA	0.001	NA	5.632	0.779
Deacon Rockfish	*Sebastes diaconus*	NA	2.667	NA	NA	NA
Sargo	*Anisotremus davidsonii*	NA	NA	NA	0.203	0.041
Honeycomb Rockfish	*Sebastes umbrosus*	NA	0.025	NA	NA	0.001
White Seabass	*Atractoscion nobilis*	NA	0.017	NA	NA	0.005
CA barracuda	*Sphyraena argentea*	NA	0.004	NA	NA	0.001
Fantail Flounder	*Xystreurys liolepis*	NA	0.003	NA	NA	NA
Scalyhead sculpin	*Artedius harringtoni*	NA	0.002	NA	NA	NA
Spiny Dogfish	*Squalus acanthias*	NA	0.002	NA	NA	NA
Sarcastic Fringehead	*Neoclinus blanchardi*	NA	0.001	NA	NA	0.001
Coho salmon	*Oncorhynchus kisutch*	NA	0.001	NA	NA	NA
Salema	*Xenistius californiensis*	NA	0.001	NA	NA	0.054
Walleye Surfperch	*Hyperprosopon argenteum*	NA	NA	NA	NA	0.046
Giant Kelpfish	*Heterostichus rostratus*	NA	NA	NA	NA	0.243
Spotfin Surfperch	*Hyperprosopon anale*	NA	NA	NA	NA	0.033
Sliver Surfperch	*Hyperprosopon ellipticum*	NA	NA	NA	NA	0.012
Finescale Triggerfish	*Balistes polylepis*	NA	NA	NA	NA	0.001
Black Croaker	*Cheilotrema saturnum*	NA	NA	NA	NA	0.002
Leopard shark	*Triakis semifasciata*	NA	NA	NA	NA	0.024
C-O Sole	*Pleuronichthys coenosus*	NA	NA	NA	NA	0.002
CA Moray	*Gymnothorax mordax*	NA	NA	NA	NA	0.004
Lavender Sculpin	*Leiocottus hirundo*	NA	NA	NA	NA	0.005
Yellowfin Fringehead	*Neoclinus stephensae*	NA	NA	NA	NA	0.001
Halfblind Goby	*Lethops connectens*	NA	NA	NA	NA	5.233
Dwarf Surfperch	*Micrometrus minimus*	NA	NA	NA	NA	0.003
Monkeyface prickleback	*Cebidichthys violaceus*	NA	NA	NA	NA	0.004

Zebra Perch	*Hermosilla azurea*	NA	NA	NA	NA	0.002
Shovelnose guitarfish	*Rhinobatos productus*	NA	NA	NA	NA	0.001
Tope shark	*Galeorhinus galeus*	NA	NA	NA	NA	0.000
Guadalupe Cardinalfish	*Apogon guadalupensis*	NA	NA	NA	NA	0.001
Thornback ray	*Platyrhinoidis triseriata*	NA	NA	NA	NA	0.001
Round Stingray	*Urobatis halleri*	NA	NA	NA	NA	<0.001
Banded Guitarfish	*Zapteryx exasperata*	NA	NA	NA	NA	<0.001
Barred Surfperch	*Amphistichus argenteus*	NA	NA	NA	NA	<0.001
Broadnose Sevengill Shark	*Notorynchus cepedianus*	NA	NA	NA	NA	<0.001