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September 2, 2015
Ms. Dorothy Lowman, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220

Dear Chair Lowman and Council members:

On behalf of the many partners and collaborators on this project, I am pleased to submit to the Pacific Fisheries Management Council a final report entitled "*Supporting a Spatial Analysis of the Distribution and Size of Rebuilding Stocks in the Rockfish Conservation Areas through Directed Surveys*" conducted, in part, under an Exempted Fishing Permit (EFP #13-14-TNC-01).

Our observations of rebuilding species from this study show they are widely distributed along the Central California coast; however, some areas we studied had higher densities of many rebuilding species and could be considered "hotspots" for these species. Results of our visual surveys suggest that the abundance of Yelloweye Rockfish and Cowcod appear to be much greater in Central California than what might be predicted based on catches and/or bottom trawl surveys alone; these two species tend to be associated with rocky habitat and structural relief. With our fishermen partners, we landed 8,827 lbs. of fish under this EFP, while limiting the catch of the most constraining rebuilding species (only 23 lbs. of Cowcod and 23 lbs. of Yelloweye Rockfish were caught). Comparison of fishing and video surveys indicated that fishermen could fish with modified hook and line gear to catch semi-pelagic species, without frequently catching rebuilding species that may spatially co-occur.

The Nature Conservancy supports the Council's efforts to rebuild depleted stocks and protect the important and sensitive habitats, such as along the shelf-slope break and areas of topographic relief, that help maintain healthy adult populations in order to sustain spawning biomass levels at or above management targets. Information on the distribution of rebuilding species (especially the more vulnerable species), the density and size structure of their populations, and species-habitat associations should be factored in when considering changes to management measures in this complex multi-species fishery.

We hope that the results of this study can help inform management decisions, and we encourage the Council to carefully consider any changes to spatial management measures such as Essential Fish Habitat (EFH) and the Rockfish Conservation Areas (RCAs) to ensure that the rebuilding process is not unduly delayed or hindered.

Sincerely,

Mary Gleason

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Supporting a Spatial Analysis of the Distribution and Size of Rebuilding Stocks In the Rockfish Conservation Areas Through Directed Surveys

Final Report

to the

Pacific Fishery Management Council

2 September 2015

EFP 13-14-TNC-01

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Executive Summary

In 2002, the Pacific Fishery Management Council and the National Marine Fisheries Service established coast-wide, depth-based closures known as Rockfish Conservation Areas (RCAs) to support rebuilding efforts for several West Coast groundfish species that were declared overfished. Although some of these species have subsequently been declared rebuilt, others are not and the RCAs constrain fishing opportunities for more productive stocks. In 2012, the Central California Seafood Marketing Association received approval for an Exempted Fishing Permit (EFP) to conduct research fishing using vertical hook and line gear in the RCAs off Central California. This EFP was part of a broad collaboration to study the distribution and abundance of rebuilding species in the RCAs to inform both fishing and management decisions.

Project partners first worked with the Environmental Defense Fund and NOAA Biogeographic team to develop predictive groundfish models (maps) using fishery-independent trawl survey data collected as part of the annual West Coast Groundfish Bottom Trawl Surveys. We then developed a research plan that included test fishing and visual surveys to ground-truth the maps and provide more information about the distribution of rebuilding species. We conducted fishing surveys across a broad range of depths, habitat types, and localities in central California, using vertical hook and line gear in September and October of 2013 and 2014. Fishermen used snapper reel fishing gear to target healthy stocks of fish while trying to avoid rebuilding species. We retained all rebuilding rockfish species (Bocaccio, Canary Rockfish, Cowcod, and Yelloweye Rockfish), as well as selected samples from target species, for biological analyses. Also, we designed a stereo-video camera system ("video lander") to make visual observations on size and abundance of fish and we deployed it at the same places in which we fished.

Over the 2-year period, we fished a total of 58 days and completed 741 sets with the snapper reel fishing gear. A total of 8,827 lb of fish were landed. Combined catches of Vermillion Rockfish, Yellowtail Rockfish, Chilipepper, Bocaccio, and Widow Rockfish comprised 98% of total landings by weight. The overall ratio of the weight of target species caught to that of rebuilding species caught was 10.1 lb target to 1 lb rebuilding species. Only two Cowcod and four Yelloweye Rockfish were caught in two years, representing ~ 0.5% of the total weight of all fish landed. Biological data from the retained fishes have helped to fill in important data gaps for many species, and have been used to update the size-dependent fecundity relationship in the Bocaccio stock assessment. We conducted 299 visual surveys that occurred in the same locations as fishing occurred. On those surveys, we observed a total of 10,873 fishes, representing 60 different species or species groups. Bocaccio and Canary Rockfish were commonly observed, and Yelloweye and Cowcod were widely distributed. We observed relatively few Cowcod, but Yelloweye Rockfish occurred in more than 20% of our visual surveys. In our study, Yelloweye Rockfish were six times more likely to be encountered on high relief rocky areas than low-relief softer substrates. Results of our visual surveys suggest that the abundance of Yelloweye Rockfish and Cowcod is much greater in Central California than might be predicted based on catches and/or bottom trawl surveys alone. Comparison of fishing and video surveys indicated that fishermen could fish with modified hook and line gear to catch semi-pelagic species without frequently catching rebuilding species. This suggests that as populations of Yelloweye Rockfish and Cowcod start to recover, there might be a way to fish for abundant species while limiting bycatch of the two most constraining species.

I. Introduction

In 2002, the Pacific Fishery Management Council (Council) and the National Marine Fisheries Service (NMFS) established a set of coast-wide, depth-based closures known as Rockfish Conservation Areas (RCAs) to support rebuilding efforts for several West Coast groundfish species that were declared overfished under federal guidelines. Although some of these species have subsequently been declared rebuilt (Widow Rockfish, Lingcod, and soon Canary Rockfish), others, have not (Yelloweye Rockfish, Cowcod) and the RCAs continue to protect their populations and constrain fishing opportunities for more productive stocks. In 2012, the Central California Seafood Marketing Association (CCSMA) received approval for an Exempted Fishing Permit (EFP) to conduct research fishing using vertical hook and line gear in the RCAs off Central California in 2013 and 2014. This was part of a broader study ("RCA Study") led by The Nature Conservancy (TNC), Moss Landing Marine Laboratories (MLML) / California Sea Grant (CSG), and the National Marine Fisheries Service (NMFS) / Southwest Fisheries Science Center (SWFSC) in partnership with the California Groundfish Collective (CGC, formerly known as the CA Risk Pool) and Environmental Defense Fund (EDF). The goal of the RCA Study was to advance understanding of the distribution and abundance of rebuilding species in the RCAs to inform both fishing and management decisions. The RCA Study included predictive modeling of species distributions based on existing survey data, new visual surveys paired with fishing surveys inside the RCAs, and biological analyses of selected species. This final report to the Pacific Fisheries Management Council documents the results of the directed fishing under the EFP, and includes analyses completed to date from the visual surveys and biological analyses.

Background

The West Coast groundfish fishery is comprised of more than 90 species of fish including flatfishes, rockfishes, and roundfishes. Some groundfish species are inherently vulnerable to overfishing, with long lifespans and late maturity (Love et al 2002; Cope et al. 2011; Patrick et al. 2010). Management of multi-species fisheries that include stocks of various resiliencies to overfishing has proven challenging throughout the U.S. (Muraswki 1991; Essington et al. 2006; Cope et al. 2011). The species-rich California Current ecosystem situated off of the U.S. West Coast is a classic example of this challenge. Starting in the late 1990s, a total of ten West Coast groundfish species have been declared overfished, including seven rockfishes [Bocaccio (*Sebastes paucispinus*), Canary Rockfish (*S. pinniger*), Cowcod (*S. levis*), Darkblotched Rockfish (*S. crameri*), Pacific Ocean Perch (*S. alutus*), Widow Rockfish (*S. entomelas*), and Yelloweye Rockfish (*S. ruberrimus*)], as well as Lingcod (*Ophiodon elongatus*), Pacific hake (*Merluccius productus*) and Petrale sole (*Eopsetta jordani*). Whereas some of these species were declared rebuilt in a relatively short period of time (i.e., Pacific hake and Lingcod), others have only recently been (or are in the process of being) declared rebuilt (Widow Rockfish, Canary Rockfish, Petrale Sole), or are expected to be rebuilt within the next 1-2 years (Bocaccio and Darkblotched Rockfish). The other three species (Cowcod, Pacific Ocean Perch, and Yelloweye Rockfish) require longer rebuilding timeframes, and the allowable catch may never reach historical catch levels.

Mandatory rebuilding plans for the more vulnerable stocks have resulted in catch reductions, gear restrictions, and implementation of the depth-based, coast-wide fishing closures (RCAs) to reduce bycatch and support rebuilding efforts. The RCAs include an area closed to bottom trawling (the "trawl RCA") that, in

Central California, generally follows the 100-150 fathom isobaths on the continental shelf-slope break and upper slope, an area closed to commercial fixed gear (the “non-trawl RCA”) that approximately follows the 30-150 fathom isobaths on the shelf, as well as a shallower area that was closed to recreational fishing (the “recreational RCA”).

The RCAs have been successful at reducing mortality of rebuilding species by protecting important habitats for the rebuilding species and reducing bycatch; however, they have also closed some of the most highly productive areas along the continental shelf and shelf-slope break to various gear types. This has forced fishermen to concentrate their efforts on either shallow-water flatfish species (e.g., Petrale Sole, Rex Sole, and English Sole) or deep-water species (primarily Dover Sole, Shortspine Thornyhead, Longspine Thornyhead, and Sablefish), leaving healthy stocks of other mid-depth species such as Lingcod, Yellowtail Rockfish, and Chilipepper underutilized.

In 2011 an Individual Fishing Quota (IFQ) program was implemented for the West Coast groundfish trawl sector that included hard caps on catch and 100% human observers for accountability. The limited quota for rebuilding species provided a strong incentive to avoid them, and discards dramatically decreased in the first few years of the IFQ program, along with bycatch of rebuilding rockfish species. While the biological benefits are clear, there is still a lack of good information on the distribution, abundance and size structure of rebuilding species. This has created significant costs and limitations associated with the IFQ program. Principal among these are, 1) very low quota levels for rebuilding species that constrain the catch of “healthy” target stocks, and 2) limited access to fishing grounds due to area closures that pre-date the IFQ program. These problems have translated to catch levels that are lower than before the catch share program, with attainment levels ranging between 29-35% of annual catch limits (ACLs) for 2012-2014. As a result, both revenue and product supply have not yet reached their full potential.

To manage the risk of encountering rebuilding species with low quota allocations, some fishermen have formed risk pools, such as the California Groundfish Collective (a partner in this project), that provide a degree of insurance against quota deficits (Holland and Jannot 2012). Essentially, fishermen contribute their quota for rebuilding species to a pool that is then distributed as needed to cover quota deficits. In exchange, fishermen agree to fish according to spatially-explicit fishing plans that prohibit risky fishing that is likely to lead to encounters with rebuilding species. Fishermen in the CGC also use electronic logbooks (TNC’s e-Catch https://www.ecatch.org/) to share information on locations where rebuilding species are caught; spatial fishing plans are adapted frequently based on local catch and research data to further reduce the risk of constraining species catch. Thus, information on location of these rebuilding species is critical to fishing operations in the risk pool.

There has been little research, however, on the finer scale demographic and distributional patterns of rebuilding species that could help fishermen target healthy populations while avoiding depleted ones. For instance, there are strong populations of some species, such as Chilipepper, Yellowtail Rockfish, and Lingcod that are difficult to access due to their proximity to the RCA and the risk of encountering rebuilding species. A confounding problem is that the primary method of monitoring groundfish stocks is the annual West Coast Groundfish Bottom Trawl Survey (Keller et al. 2012), which is conducted almost exclusively on low-relief habitats. As such, the survey often provides little information about species that inhabit high-relief, untrawlable habitats, including most of the more vulnerable species of rockfish. Without directed sampling of habitats used by rebuilding species, we continue to run the risk of misunderstanding the rebuilding trajectory and may unnecessarily reduce the harvest of robust stocks.

Project Goals and Objectives

The purpose of our project was to examine species distributions and size structures of rebuilding species within the RCAs in Central California with the aim of informing bycatch avoidance plans and potential reconfiguration of the RCA. This was a collaborative effort that brought together the fishing industry, NGOs, state and federal agencies, and academia to use both scientific data and local knowledge, and fill critical gaps to increase our understanding of rebuilding species and their habitat associations. The goals of the project, as proposed in the EFP, were to:

1. Compile existing data about the distribution of rebuilding species collected from NMFS trawl surveys, underwater visual surveys, and historical catches;
2. Use the combination of existing fisheries independent and dependent data and local knowledge to develop predictive maps of the distribution, abundance, and size of rebuilding groundfish stocks along the entire West Coast;
3. Ground-truth the predictive maps by performing scientific sampling (visual surveys and directed fishing) to assess encounter rates with rebuilding species in a subset of locations inside the RCA in Central California with predicted high, medium, and low density (“hotspots”, “warm spots”, and “cold spots” respectively) for these species; and
4. Characterize the abundance, length, and habitat associations of rebuilding species in those same locations, as well as collect biological samples for growth and maturity studies.

The study was originally designed to address the following research questions:

1) Can predictive maps of the distribution and abundance of target and overfished species be used to describe the realized catch-per-unit-effort (CPUE) of these species during commercial fishing operations?
2) What is the relative abundance of target and rebuilding species in predicted “cold spots”, “warm spots”, and “hotspots” of rebuilding species based on directed fishing effort methods and visual surveys?
3) How does the abundance and size distribution of rebuilding species inside the RCA differ among nine different sites in Central California, based on directed fishing effort and visual survey methods?

Deviations from proposed plans

The research was conducted to address those key research questions; however, some deviations to proposed plans were necessary for a variety of reasons:

- Due to the coarse scale of the predictive maps, we had difficulty in distinguishing potential “cold spots”, “warm spots”, and “hot spots” from the maps alone. Instead we used a combination of predictive maps, local fishermen knowledge gathered in focal group discussions, and existing data on habitats and fish presence from prior research to identify 28 study blocks that had potential habitat for rebuilding species in three sub-regions (North, Central, and South) in Central California and stratified our sampling among those study blocks.
- Based on a recommendation from the Groundfish Management Team and due to limited areas of rocky habitat in the trawl RCA in Central California, we expanded the surveys to include areas in the non-trawl RCA.
- To better understand seasonal patterns, we expanded the visual surveys to include additional cruises in May and June/July of 2013 and 2014; however, we did not expand the fishing surveys to other seasons as per the terms of the EFP.

Project Timeline

This has been a four-year project from initial application for the EFP to the completion of a final report to the Council. We are still completing some of the video and data analyses, and also anticipating the development of several peer-review publications from this work.

Project Activity	Timeline
Exempted Fishing Permit process	Initial application: November 2011 PFMC meeting Presented study design to SSC, GMT: June 2012 Final approval: July 2012 PFMC meeting EFP Terms and Conditions finalized with NMFS: September 3, 2013
Predictive mapping by NCCOS	2011-2013
Meetings with fishermen to select study sites and discuss fishing gear	Spring - Fall 2012 and Winter 2013
Securing federal observers	April 2013
Selecting participating fishermen	July 2013
Conducting fishing surveys	September-October in 2013 and 2014
Conducting visual surveys	April, July, September, October 2013; April, July, September, October 2014; April, June 2015
Video review and data analysis	April 2013 - present
Biological analysis of fish samples	Fall 2013, Fall and Winter 2014, Winter 2015
Reporting	Interim report for November 2013 PFMC meeting; Final report for September 2015 PFMC meeting

II. Methods

Site selection and study design

Project partners worked with the EDF and the NOAA Biogeographic team from the National Center for Coastal and Ocean Science (NCCOS) to develop predictive groundfish models (maps) using fishery-independent trawl survey data collected as part of the annual West Coast Groundfish Bottom Trawl Survey and provided by the NWFSC-Fisheries Resource Analysis and Monitoring Division (FRAM, see Appendix A for details). We then met with fishermen to share information about the EFP project and solicit feedback on the study design and logistics. We shared results from the predictive modeling work by the NOAA Biogeographic team and the fishermen shared their local knowledge to identify areas of high risk for bycatch of rebuilding species. The predictive mapping alone was too coarse in detail for some species to inform our sampling design for the fishing surveys, so a combination of both predictive modeling and local fishermen knowledge was used to inform the design for the fishing surveys.

From these efforts, prior visual surveys, and substrate maps complied by the California Seafloor Mapping Project (http://seafloor.otterlabs.org/csmp/csmp.html), we identified a range of predicted areas for rebuilding species in Central California between Pt. Reyes and Morro Bay. We chose to sample areas where the predicted abundance from NOAA's spatial analyses and modeling correlated well with observational information and local knowledge. We then stratified the study area into three subregions (North, Central, South) to account for regional variability, as well as improve study logistics by minimizing travel time from ports (Fig. 1). We identified a total of 28 potential study blocks in which to concentrate both directed fishing and visual surveys and aimed to distribute effort as broadly as possible over our study area but in targeted hard bottom habitats. These study blocks were located within or adjacent to the trawl RCA (100-150 fathoms) and extended into the non-trawl RCA (30-100 fathoms).

Fishermen selection process

We worked with representatives from the Morro Bay Commercial Fishermen's Organization (MBCFO) to develop an application form to guide the selection of fishermen for the fishing surveys. We distributed the application form to harbor masters, city representatives, commercial fishermen organizations, fish processors, and fishermen between Port San Luis and Half Moon Bay in mid-April 2013. Once we received applications, a five-person review committee comprised of fishermen and project leaders independently scored and ranked each of the candidates. The committee scored applicants based on several eligibility requirements and their level of experience in groundfish fisheries, with a strong preference for fishermen that had prior experience fishing rockfish in RCA depths with hook and line gear prior to establishment of the closures. Four candidates were selected (Roger Cullen of the F/V *Dorado*, Mike Ricketts of the F/V *Sea Hawk*, Brad Leage of the F/V *Princess*, and Tom Mattusch of the F/V *Huli Cat*). These candidates were then subjected to background checks conducted by NMFS Office of Law Enforcement to ensure the selected fishermen had no violations. Also, using an open bid process on the federal business opportunities website (https://www.fbo.gov/) under solicitation numbers WAD-NFFR7500-13-02316 (2013) and RA-133F-14-RQ-0664DR (2014), we selected the F/V *Donna Kathleen*, operated by Tim Maricich, to conduct the visual surveys.

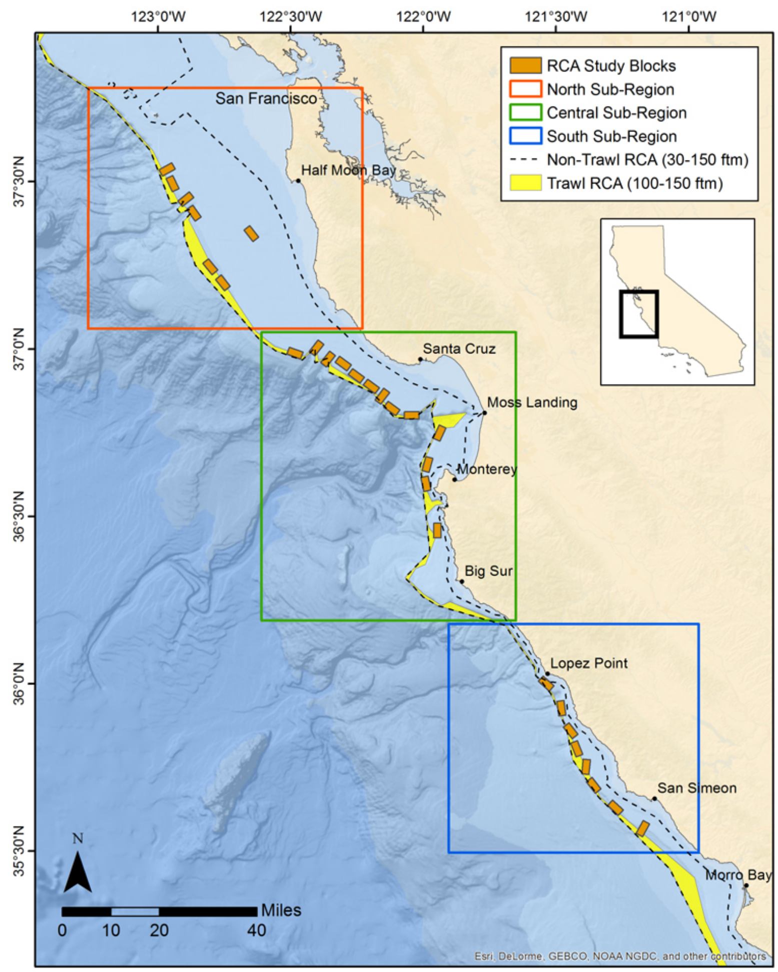


Figure 1. Central California study region divided into three sub-regions for logistical efficiency and to account for potential ecological variation. Each sub-region included targeted sampling blocks to ensure that data collection was distributed throughout the area selected and within either the trawl or non-trawl RCA.

Observer coverage and permits

Through a competitive bid process we selected Alaskan Observers Inc. (AOI) to provide federal observers. Two observers were chosen based on their qualifications. The selected candidates became certified federal at-sea observers and shore-side monitors in May 2013. In addition to securing observers for the EFP, we also secured approval and the required permits to carry out the fishing and visual surveys inside the RCA from the Council, NMFS, the California Department of Fish and Wildlife, and the Monterey Bay National Marine Sanctuary. We received initial approval for the EFP by the Council at their June 2012 meeting, incorporated recommended revisions by the Council and the Science and Statistical Committee (SSC), and then submitted the revised EFP to NMFS in November 2012. We received the finalized terms and conditions from NMFS in September 2013. TNC, as a partner and holder of the trawl permits and quota, assumed the lead role for issuing and managing the EFP, including setting up vessel quota accounts.

Experimental fishing surveys

We used snapper reel fishing gear on the directed fishing surveys. This is a hook and line gear type that is fished vertically within the water column and is actively lowered and hauled up using a powered reel set at a desired speed (Fig. 2). The mainline was made up of Dacron line (300 lb test) attached to the reel and included a section of 200 lb test monofilament attached below the Dacron line by a swivel. A 25 ft section of 180 lb test nylon line, tied to a 10 lb weight, was placed below the 200 lb monofilament to serve as a breakaway section to minimize loss of hooks. Hooks were spaced approximately one foot apart along the 200 lb test monofilament portion of the mainline with a 6-inch gangion (100 lb test line) containing a 10/0 easybaiter shrimpfly hook baited with a strip of squid. The hook nearest to the bottom was kept more than 25 feet above the 10 lb weight so as to minimize contact of fishing gear with the bottom and to target species in the water column and well above the bottom. All fishing trips carried both a researcher and an AOI fishery observer.

We conducted fishing surveys in September and October of 2013 and 2014 across a broad range of depths, habitat types, and localities in our sampling blocks (Fig. 3). We distributed fishing effort across two depth ranges: shallower than 100 ftm and greater than or equal to 100 ftm (corresponding to the depth boundary between the trawl and non-trawl RCA). We conducted a minimum of five fishing sets in each sampling block per year, realizing that some areas are potentially more productive than others and have more suitable habitat for fishing. Fishermen were also allowed to occasionally fish outside of the study blocks if they wanted to try a new area or they saw a school of fish on their echosounders. Fishermen metered over the fishing location prior to setting gear and deployed 3-5 fishing sets, each 15-20 minutes long, before moving to another location. Soak time varied for each location depending on the depth fished and whether or not fish were biting. We tried to avoid gear saturation (fish on all hooks). Also, we aimed to have the lead weight positioned slightly off the bottom to avoid hang ups or gear loss.

At each fishing location, we recorded start and end depth, start and end geographic coordinates, time the gear reached the bottom, time the gear was retrieved, bottom rugosity (on a scale of 1 to 3 with 1 being low relief and 3 being high relief, based on the vessel's echosounder), location, vessel, day, disposition (whether each fish was retained and by whom or if it was discarded for market or size reasons), and sex (when it was possible to determine). As the gear was retrieved, we recorded the species caught on each hook to determine if there were patterns in catch by depth. We then measured each fish to the nearest 0.5 cm (total length) and weighed individual or species groups in pounds.

Figure 2. A string of Vermilion Rockfish caught on hydraulic snapper reel gear.

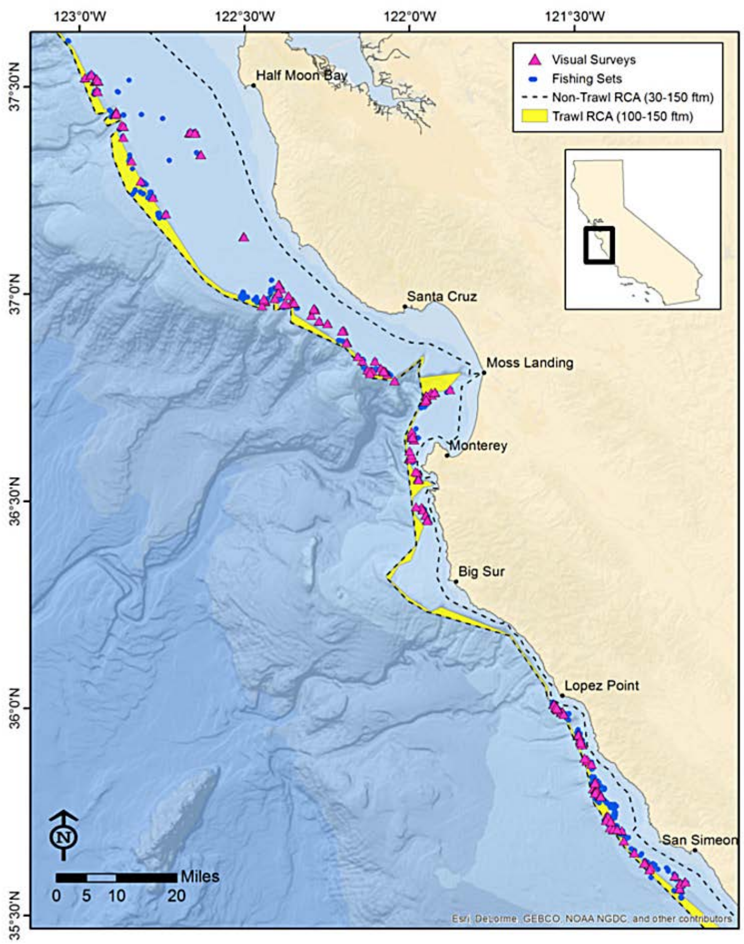


Figure 3. Locations of co-located visual surveys (n=299) and fishing sets (n=741) conducted in September and October of 2013 and 2014 on the central coast of California.

We used 15-hook sets to fish new areas. If large numbers of target species were landed after retrieving one or two 15-hook fishing sets, with little or no catch of constraining species, then the fisherman could switch to 30-hook sets. The decision to allow a fisherman to switch from 15-hooks to 30-hooks was based primarily on the catch of Chilipepper, the target species for which the largest amount of quota was dedicated for this study. Fishermen were allowed to sell target species as an incentive to become a partner and target desirable species in their fishing efforts.

We retained all rebuilding rockfish species (Bocaccio, Canary Rockfish, Cowcod, and Yelloweye Rockfish), as well as selected samples from target species. Each fish retained for biological analyses was tagged and transferred to the NMFS Santa Cruz lab for processing. Fishermen retained and sold the majority of target species to fish buyers. Fish weights were obtained from landings data recorded by first receivers and shoreside monitors. Some fish were recorded as discards due to market or regulatory limits and when fish fell off of hooks prior to being brought on board the vessel. Discards brought onboard were weighed and measured; fish lost before landing were simply logged with estimated weights by fisheries observers. We classified discards into 4 categories: drop-off prior to reaching the vessel, market reasons/small size, predation, and regulation for under-sized fishes. We summarized the number and overall weight of discards by species. No rebuilding species were observed or recorded as discards during the project.

We summarized the fishing survey data by year, sub-region, and depth range to examine patterns in catch, catch per unit effort (CPUE), and discards. We generated length frequency plots for key species from the two years of pooled data collected by onboard researchers to determine what proportion of fish were at or above the size at 50% maturity reported for rockfishes in Central California (Love et al. 2002, Keller et al. 2012, He et al. In Review). We summarized the number of fishing sets that yielded rebuilding species and calculated the ratio of target to rebuilding species caught by year, sub-region, and overall using the number and weights summed for these species (target vs. rebuilding). We did not use the small volume (~1.1% by weight of the overall catch) of discards for calculating target to rebuilding species ratios.

Visual surveys

In 2012 we worked with engineers from Marine Applied Research and Exploration (MARE) to design a video camera system to survey demersal fishes. The tool we designed (“stereo-video lander”) consisted of a stereo-video camera system mounted on a tethered lander vehicle capable of deployment to depths of 300 m. We designed the tool to enable us to use “Point Count” visual survey protocols that were developed by Bohnsack and Bannerot (1986) and continue to be used in quantitative assessment of fishery resources (Smith et al. 2011, Ault et al. 2013). The camera system contained a pair of color, wide-angle standard-definition video cameras mounted obliquely on a rotating tray that enabled us to obtain stereo-video imagery of fishes and habitats in a 360-degree arc on and just above the seafloor around the stereo-video lander (Fig. 4). The speed of the rotation was set so that each complete rotation took approximately one minute. The stereo-video lander was equipped with three Deep Sea Power and Light, Multi-Sealite Matrix dimmable LED lights, each providing 2600 lumens. One light was positioned downward looking, with a downward looking video camera to aid in Lander placement in rugged habitat A timecode (UTC) was overlaid on both video recordings using a global position system (GPS) feed to aid in stereo synchronization and data collection. A GoPRO camera (high-definition) was mounted above the main starboard camera during the second year to aid in species identification in the lab. Video from the two stereo cameras was stored on hard drives at depth and also transmitted up an umbilical for real-time viewing and metadata collection onboard the support vessel. Prior to each cruise, we calibrated the stereo video system in a test tank, measured the field of view, and conducted experiments to calculate error associated with stereo measurements. During test and calibration deployments, we collected video data to develop species accumulation curves to determine appropriate soak times, location of lights to reduce backscatter, optimum rotation speeds, and when to start and stop video collection.

Figure 4. Rotating stereo-video lander system designed for conducting visual surveys for this project.

The stereo-video lander was used to estimate species composition and relative abundance of fishes in the same locations in which our fishing collaborators set vertical fishing gear as part of the EFP. Visual surveys were completed within one to two days of the fishing surveys in each site when weather permitted. On each sampling day we used a Simrad ES-60 echosounder installed on the 57 ft long F/V *Donna Kathleen* to locate the area associated with the acoustic returns that the fishers had targeted to fish and to verify that the location we chose to sample contained rocky habitat. The video lander was deployed using the ship's boom and winch. The winch operator used the live video feed from the downward facing camera to place the lander so that it would rest upright on the seafloor. As our aim was to compare visual surveys to baited fishing surveys, we attached two plastic bait jars containing chopped squid to the lander frame below the camera field of view.

After deploying the video lander and allowing it to settle to the bottom, we waited 1-2 minutes for suspended sediment caused by the deployment to settle. We then recorded video of the fishes seen during the 360° rotation of the cameras for eight full rotations, which we defined as one "drop". Depending on the extent of rocky habitat and number of fishes observed, we conducted up to seven drops of the lander per deployment. When we conducted multiple drops in a single deployment, the lander was raised at least 10 m off the bottom, rotation and lights were turned off, and the boat transited at least 100 m from the previous drop location before lowering the lander to the bottom. Deployment data (coordinates, starting and ending times, preliminary fish counts and species observed) were recorded directly into a relational database, as well as onto datasheets.

Species composition, sizes, and habitat associations from visual surveys

Paired video files were reviewed at Moss Landing Marine Laboratories. Data collected from video included fine-scale habitat type, species and number of individual fishes observed, as well as sizes of individual fishes. We used SeaGIS EventMeasure software (www.seagis.com.au/) to obtain distances, lengths, and counts of fishes recorded in the video. Only drops with eight complete 360° sweeps of the cameras were used for analyses within the EventMeasure software. All fish were identified to the lowest possible taxonomic level. To prevent double counting, relative abundance estimates for all species was defined as the maximum number of individuals of each species (MaxN: Cappo et al. 2003, 2004) present in the field of view for a single rotation during each drop. Similarly, we only measured the lengths of fish occurring in the single sweep with the greatest number of observations for that species. Individuals that could not be identified to species level were grouped into higher taxonomic levels and counted in sweeps where the highest number of that taxon was observed.

All fishes identified to species level and whose head and tail were clearly visible in both stereo-cameras were measured using the EventMeasure software. Preliminary analyses revealed that measurement errors were lowest when fishes were positioned perpendicular to at least one of the cameras. Frame-stepping was used to position the fish optimally in both video frames and then magnified by 4X to aid in identifying the exact point of the head and tail in each video. Fishes that could not be positioned in video feeds so that both head and tail were visible, or only appeared in one of the two cameras, were not measured. Summary data files containing all data for each individual fish were exported to a relational database for subsequent analyses.

Habitat characteristics within a single 360° sweep from each drop were described and recorded by one individual for consistency. Habitat classifications included sediment grain size, relief, rugosity (Table 1) and biogenic cover of common macro-invertebrates. Sediment grain size was classified using a two-character code modified from Greene et al. (1999) and Tissot et al. (2007). The first character of each code described the primary habitat classification, i.e., the one that described the grain size that comprised at least 50% or more of the area visible in one camera sweep. The secondary code described the habitat that comprised at least 20% of the habitat in the visible area. Relief was defined as height of the dominant feature(s) visible in the field of view. Rugosity was a qualitative assessment of the functional size of holes and crevices based on the ability of a fish to use them as shelter. Finally, biogenic cover was categorically determined by counting the number of either the anemone *Metridium farcimen* or the crinoid *Florometra serratissima* present in a single sweep, defined as 0-3, 4-10, 11-24, or greater than 25 individuals. Fish-habitat associations were determined from the frequency of occurrence in each habitat category.

Table 1. Levels of classification for each of three characteristics used to classify fish habitat in each stereo-video lander drop based on laboratory post-processing of video files.

Sediment Grain Size	Relief	Rugosity
S = Sand/mud	L = Low – 0-250 mm	L = Low – Cracks and crevices too small for fishes to use as refuge
P = Pebble (<65 mm)	M = Medium – 250-1500 mm	
C = Cobble (65-250 mm)	H = High – > 1500 mm	M = Medium – Small rockfishes can use as refuge (<250 mm at largest point of diameter).
B = Boulder (250-3000 mm)		
R = Rock Ridge (continuous rock)		H = High – Large rockfishes can use as refuge (>250 mm at largest point of diameter)

Calculating fish density from visual surveys

The SeaGIS Event Measure software enabled us to measure the distance that fish targets were observed from the center of the stereo cameras. For each species, we used a frequency distribution of measured distances to observed fishes to determine the distance within which 95% of all individuals were observed. These distances were deemed to be the maximum distances at which a video analyst could identify each species across a variety of seafloor conditions and only observations within that distance were used for density calculations. The minimum distance any fish could be observed (the closest point of the seafloor visible by the cameras) was 0.81 m away from the center of the lander. We used this minimum distance and species-specific maximum distances from the cameras to calculate the area observed in each sweep, thus enabling us to calculate densities of each species in each drop (Fig. 5).

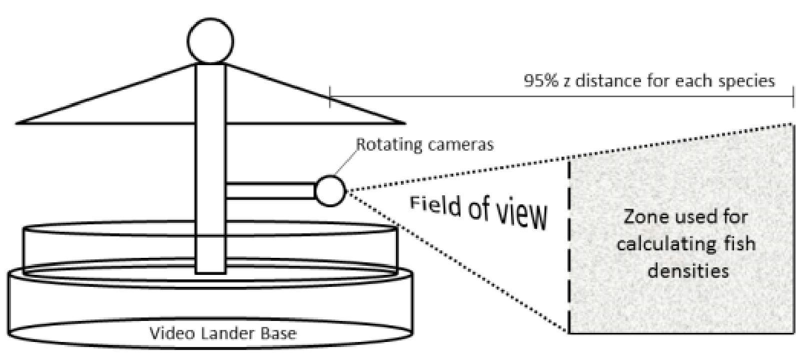


Figure 5. Geometry of the field of view and area used for density calculations for the stereo-video lander.

Biological sampling and processing

All overfished species, as well as a number of target species, were transferred to the Fisheries Ecology Division of the Southwest Fisheries Science Center in Santa Cruz to support life history research. From the collected samples, we are able to estimate fecundity (females only), age (from otoliths), and hepatosomatic indices (from liver weights). We measured each fish and collected tissue samples for genetic analyses (Fig. 6).

Figure 6. Processing rockfish caught on experimental fishing sets to collect samples for fecundity and life history analyses at NOAA/NMFS Fisheries Ecology Division, Southwest Fisheries Science Center.

Comparison of visual and fishing surveys

Fishing sets were mapped using the start and end coordinates recorded onboard during fishing operations. These coordinates were converted into vectors in ArcGIS and a 500 m buffer was drawn around each fishing set. If a video lander drop was within a 500 m buffer of a fishing set it was designated as ‘near fishing’ and the fishing set was designated as ‘near lander’. Areas of comparison were defined by merging any overlapping boundaries of fishing buffers. Fishing set landings and visual observations of species were then compared within each sampling area. To determine if there was a relationship between what was caught and what was observed, we used a regression analysis of the number of fish per fishing set (CPUE) and the number of fish per video lander drop within each area. The strength of the relationship was inferred from the R^2 value and a significant relationship was a detected when the slope was $\neq 0$ and $p < 0.01$.

Lengths of each fish measured, by species, either collected by snapper-reel fishing surveys or visual surveys, were pooled across the two years to produce length frequency distributions for each sampling technique.

A Kolmogorov-Smirnov (KS) two-sample test was used to compare the length frequency distributions for each species and sampling technique (Langolis et al. 2012; Sokal and Rohlf, 2012). Also, we calculated average lengths from the visual and fishing surveys for just those fish that were above the length at 50% maturity. We conducted a Welch's t-test to compare mean lengths of fish in a similar (reproductive) size range.

III. Results

Experimental Fishing Surveys

We conducted a total of 741 fishing sets over the 2-year period. In 2013, we fished 30 days and completed 416 sets with the snapper reel fishing gear. In 2014, we fished 28 days and completed 325 sets. More fishing sets occurred in the southern sub-region (Table 2) because there were 2 vessels operating there and only one each for the northern and central sub-regions. Few sets were made in ≥100 ftm because rocky habitat was not readily located at those depths and vessels were often unable to find suitable habitat on which to set the gear.

Table 2. Number of completed experimental fishing sets by sub-region and depth range where shallow depths correspond to the non-trawl RCA (< 100 ftm) and deeper depths to the trawl RCA (≥ 100 ftm).

Depth range	Northern sub-region	Central sub-region	Southern sub-region	Total
<100 ftm	112	174	285	570
≥100 ftm	29	26	115	170
Total	141	200	400	741

Vessels conducted an average of 185 fishing sets per vessel (range 162–231 sets). A total of 8,922 lb of fish were caught in this project; 8,827 pounds of fish were landed (Table 3). Overall, five out of 22 species caught comprised 98% of total landings by weight (Fig. 7). These five species included Vermillion Rockfish (62.7%), Yellowtail Rockfish (12.3%), Chilipepper (11.3%), Bocaccio (8.3%), and Widow Rockfish (4.2%). Relative catches of these species varied by year. In 2013 Vermilion, Bocaccio, Chilipepper, and Yellowtail Rockfishes made up about 95% of the total catch. In 2014, fewer Bocaccio and Vermilion were caught and there was a higher catch of Yellowtail, Chilipepper, and Widow Rockfishes. Discards were very low overall in comparison to the volume of fish landed. A total of 61 fishes, with an estimated weight of 95 lb, was discarded during the entire time period (<1% overall discard; Appendix B, Table B1). Most fishes classified as discards either dropped off of hooks prior to being brought onboard the vessels (25 fishes) or were discarded due to no market or small size (25 fish). One Widow Rockfish was lost to predation, and several undersized Lingcod were thrown back.

The most abundant species in the catch varied by sub-region (Appendix B, Table B1). Landings in the south were dominated by Vermilion Rockfish (over 5,200 lb and about 79% of the catch for this sub-region) followed by Bocaccio, Yellowtail Rockfish, and Chilipepper. The northern and central sub-regions were similar in terms of catch of the most commonly caught species. Chilipepper, Yellowtail, and Widow Rockfishes were the top three species landed although catch rates were higher in the northern sub-region compared to the central sub-region. Vermilion Rockfish were a minor portion of overall catch in the northern and central sub-regions. While the number of fishes caught in the northern sub-region had similar patterns to that of landed weight, the landed Bocaccio were smaller in size (2.5 lb per fish) compared to other sub-regions.

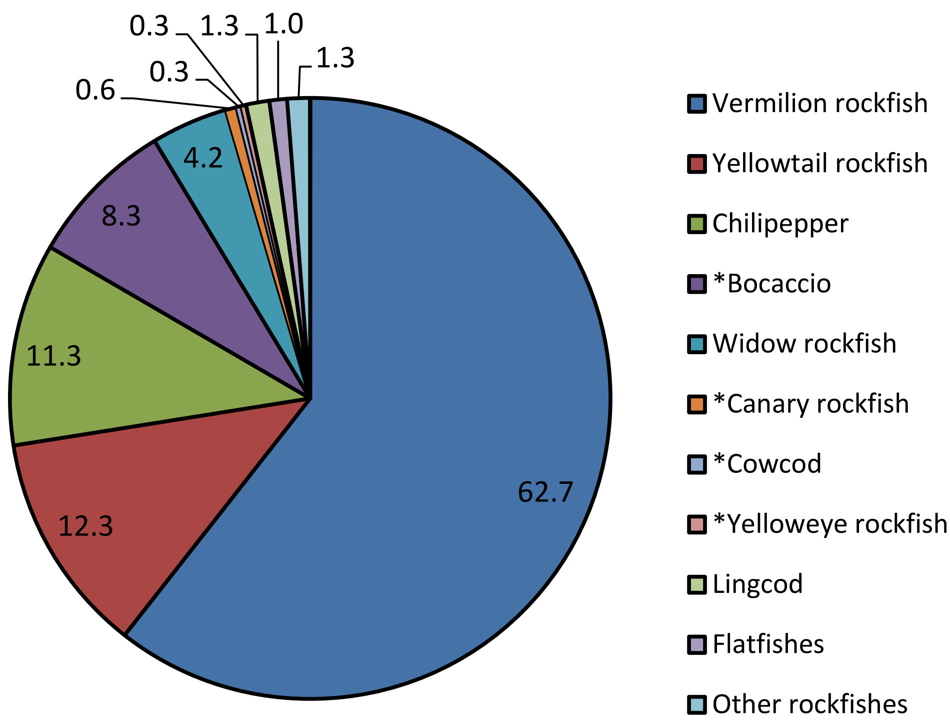


Figure 7. Proportion of catch by species represented as a percentage of total weight landed during fishing surveys. Species in labeled with asterisks (*) are rebuilding species.

Table 3. Weight (lb) of individual species and IFQ species groups landed by year in the fishing surveys. Weights are species landings as recorded by first receivers/processors except discards, which were weighed, or weights estimated onboard. Species labeled with asterisks (*) are rebuilding species.

Species/IFQ Species Group	2013 Landings	2014 Landings	Project Total
*Bocaccio	420	278	698
*Canary Rockfish	19	33	52
*Cowcod	-	23	23
*Yelloweye Rockfish	-	23	23
Chilipepper	248	704	952
Lingcod	51	58	109
Pacific Whiting (hake)	-	1	1
Sablefish N of 36°	-	3	3
Widow Rockfish	49	310	359
Southern shelf rockfish			
Greenspotted Rockfish	5	50	55
Greenstriped Rockfish	1	1	2
Redstripe Rockfish	-	1	1
Speckled Rockfish	8	24	32
Stripetail Rockfish	4	1	5
Vermilion Rockfish	2,936	2,367	5,303
Yellowtail Rockfish	236	808	1,044
Southern slope rockfish			
Bank Rockfish	-	14	14
Sharpchin Rockfish	3	-	3
Nearshore rockfish			
Blue Rockfish	-	57	57
Copper Rockfish	-	5	5
Quillback Rockfish	-	2	2
Other flatfishes			
Pacific Sanddab	23	61	84
Discards			
Drop-off			62
Market smalls			9
Predated			2
Regulation (undersized)			22
Total	4,002	4,825	8,922

Fish were caught on 294 of the 741 total fishing sets (39.7%). Rebuilding species were caught in 80 of the 294 sets (27%) that caught fish (Table 4); Bocaccio was the only rebuilding species caught in 63 of the 80 sets (Appendix B, Table B2). Only 17 of the 294 sets that caught fish (5.8%) contained rebuilding species other than Bocaccio. Yelloweye Rockfish were encountered in 3 of the 294 sets that caught fish, and two sets contained Cowcod. The overall ratio of the weight of target species to rebuilding species caught was 10.1 lb target to 1 lb rebuilding (Table 5). This varied both by sub-region and year, with the northern sub-region displaying the highest target to rebuilding species ratio (20.4:1).

Table 4. Number of fishing sets that caught rebuilding species, caught no rebuilding species, and those with no catch by sub-region for the fishing surveys.

Fishing Set Type	Northern subregion	Central subregion	Southern subregion	Total
Rebuilding species landed	18	8	54	80
No rebuilding species	70	38	106	214
Nothing landed	53	154	240	447
Total	141	200	400	741

Table 5. Total catch (landed weight) and target/rebuilding weight ratio by year and sub-region for all fishing sets. Rebuilding species landed included Bocaccio (n=130), Canary Rockfish (n=22), Yelloweye Rockfish (n=4), and Cowcod (n=2).

	Target species weight (lb)	Rebuilding species weight (lb)	Target:Rebuilding weight ratio
Year			
2013	3,564	438	8.1
2014	4,468	357	12.5
Subregion			
South	5,978	672	8.9
Central	235	39	6.0
North	1,818	89	20.4
Project total	8,031	795	10.1

We deployed a total of 617 sets that contained 15-hooks; 250 of these sets caught fish. There were few patterns as to where fish were caught along the main fishing line (bottom vs. top hooks) for most target species, other than that fewer fish were caught in the top five hooks. Some rebuilding species were caught primarily by hooks nearest the bottom (Table 6). Canary and Yelloweye Rockfishes were caught more frequently on the bottom five hooks, although a few Canary Rockfish were caught on both middle and top hooks and one Yelloweye was caught on the top five hooks. There were no apparent trends for Bocaccio as they were caught relatively evenly throughout the entire 15 hook setup, and the two Cowcod were caught in middle and top layer hooks.

Table 6. Species catch (numbers of fishes) by hook location within the water column for 15-hook fishing sets. Bottom hooks were hooks 1-5, middle 6-10, and top 11-15. Species labeled with asterisks (*) are rebuilding species.

Species/IFQ species group	Bottom hooks	Middle hooks	Top hooks
*Bocaccio	28	34	33
*Canary rockfish	10	4	3
*Cowcod	-	1	1
*Yelloweye rockfish	3	-	1
Chilipepper	127	120	113
Lingcod	6	6	5
Southern shelf rockfish			
Vermilion rockfish	332	308	277
Yellowtail rockfish	119	118	100
Other flatfish			
Pacific sanddab	68	60	58
Widow rockfish	42	38	44
Total	735	689	635

Visual surveys

We completed a total of 485 stereo-video lander survey drops in September and October of 2013 and 2014. Of the 485 drops, 299 co-occurred within 500 m of experimental fishing sets (Table 7). Of those 299 co-located visual surveys, 124 drops occurred in the central sub-region, 110 in the south sub-region, and 65 in the northern sub-region. The majority of surveys were conducted in depths shallower than 100 ftm due to difficulty encountering rocky habitat in the deeper areas we surveyed.

Table 7. Number of visual survey video-lander drops completed within 500 m of experimental fishing sets by year, depth strata (< 100 ftm or ≥ 100 ftm) and sub-region.

	North		Central		South		Depth class		Total
Year	<100	≥100	<100	≥100	<100	≥100	<100	≥100	
2013	18	3	50	4	43	11	111	18	129
2014	42	2	64	6	46	10	152	18	170
Total	60	5	114	10	89	21	263	36	299

In the 299 co-located visual surveys, we observed a total of 10,873 fishes, representing 60 different species or species groups (Fig. 8). A complete list of species observed in those 299 drops, by sub-region and depth category, is included in Appendix C, Table C1. Shortbelly Rockfish (*Sebastes jordani*) was the most abundant species observed, but they occurred in only 6% of visual surveys. Many unidentified *Sebastes* spp. were observed at distances from the stereo-video lander cameras that allowed general identification to family but not to species. Overall, 44% of visual survey drops contained at least one rebuilding species (Table 8). Observations of rebuilding species occurred less frequently in depths greater than 100 fathoms, but overall sampling was much lower in that depth range. Lingcod was the species with the highest frequency of occurrence; that species was recorded in more than 50% of survey drops. Vermilion and Canary Rockfishes each were observed in 27% of drops, and Yelloweye Rockfish occurred in 21% of drops. Cowcod were relatively rare in the visual surveys with a total of 23 cowcod, occurring in only 4% of drops. Both Yelloweye and Cowcod were observed more frequently in the south sub-region and less frequently in the north.

When analyzed by habitat type, rebuilding species were almost three times as likely to be observed on hard substrates than on soft bottom seafloor habitats (Table 9a). The hard substrate category includes rock ridge, boulder, cobble, and mixed substrates. When analyzed by specific habitat types, rebuilding species were observed in more than 70% of the visual surveys that occurred on rock ridge and boulder habitats, and in 49% of visual surveys in mixed rock and soft habitats (Table 9b). The frequency of occurrence (percentage of lander drops) for each of the four rebuilding species was 1.6 – 6.2 times greater in rock habitat than in soft sediment habitats (Fig. 9).

Fish density

Average fish density in visual surveys, for all species combined, was approximately 1 fish/m^2 (Appendix C, Table C2). Average density of rebuilding species was 0.13 ± 0.02 (Standard error, SE) fish/m^2 in depths shallower than 100 fathoms and 0.01 ± 0.00 SE fish/m^2 in depths greater than 100 fathoms. Densities of three rebuilding species observed in visual surveys varied by substrate, relief, sub-region, and depth strata (Fig. 10). Rebuilding species were commonly observed (Fig. 11, Fig. 12).

Table 8. Total number of observations and the frequency of occurrence (percentage of drops in which they occurred) for ten species of interest from the 299 co-located visual survey drops in 2013 and 2014. All ten species were also caught in fishing sets. Species labeled with an asterisk (*) are rebuilding species.

	Number Observed				Depth (ftm)		Freq. of
Common Name	North	Central	South	Total	<100	≥100	occurrence
Vermilion Rockfish	11	33	1238	1282	1255	27	27%
Canary Rockfish*	171	386	121	678	678	0	27%
Yellowtail Rockfish	178	273	90	541	541	0	23%
Lingcod	62	203	224	489	478	11	56%
Pacific Sanddab	12	273	86	371	346	25	12%
Bocaccio*	185	95	61	341	338	3	14%
Widow Rockfish	143	160	5	308	308	0	8%
Chilipepper	56	51	3	110	62	48	6%
Yelloweye Rockfish*	21	30	47	98	94	4	21%
Cowcod*	1	7	15	23	23	0	4%

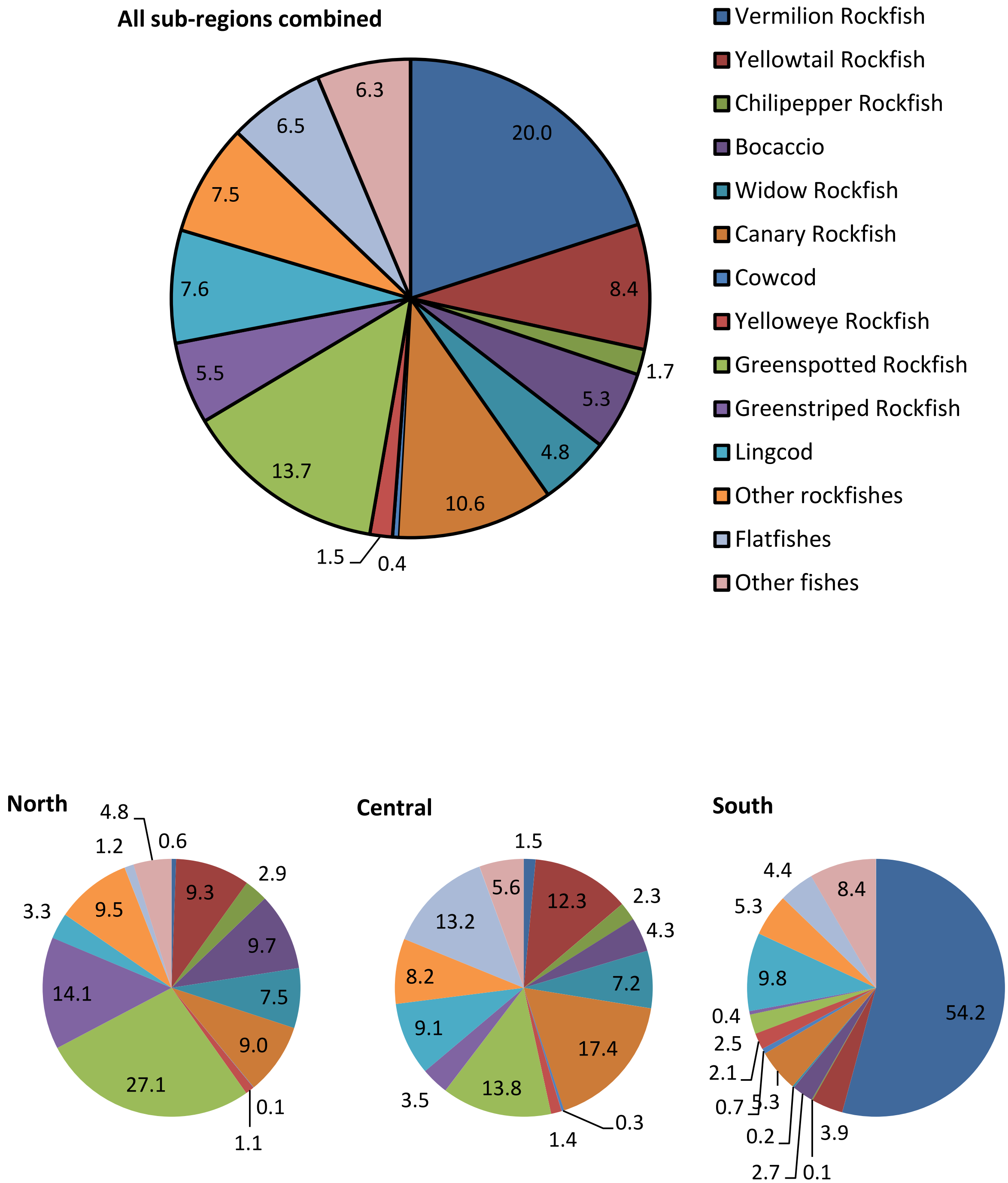


Figure 8. Species composition based on the total number of individuals observed in 299 visual surveys for all observations combined and by sub-region. The 12 most abundant species (groups), each representing at least 5% of observations, made up 96% of all fishes identified to species. An additional 28 species were seen in low numbers and made up the remaining 4% of observations.

Table 9. (a) The number of visual surveys occurring on hard and soft bottom types that contained observations of rebuilding species (Bocaccio, Cowcod, Canary Rockfish, Yelloweye Rockfish, or Darkblotched Rockfish). (b) The number of visual surveys, divided by habitat types that contained rebuilding species.

(a) Substrate	No. of Drops with rebuilding spp.	No. Drops w/out rebuilding spp.	Total Drops	Percentage of Drops with rebuilding spp.
Hard	102	61	163	63%
Soft	31	105	136	23%
Total	133	166	299	44%

(b) Habitat category				
Rock Ridge	50	20	70	71%
Boulder	26	11	37	70%
Mixed	19	20	39	49%
Cobble	7	10	17	41%
Sand	31	105	136	23%
	133	166	299	

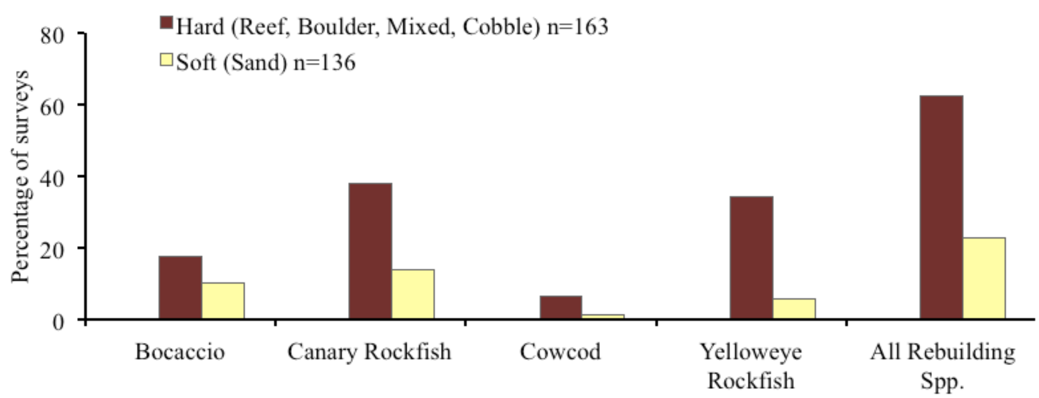


Figure 9. Frequency of occurrence (percentage of visual survey drops in which they occurred) for four rebuilding species and all rebuilding species combined in hard and soft substrates.

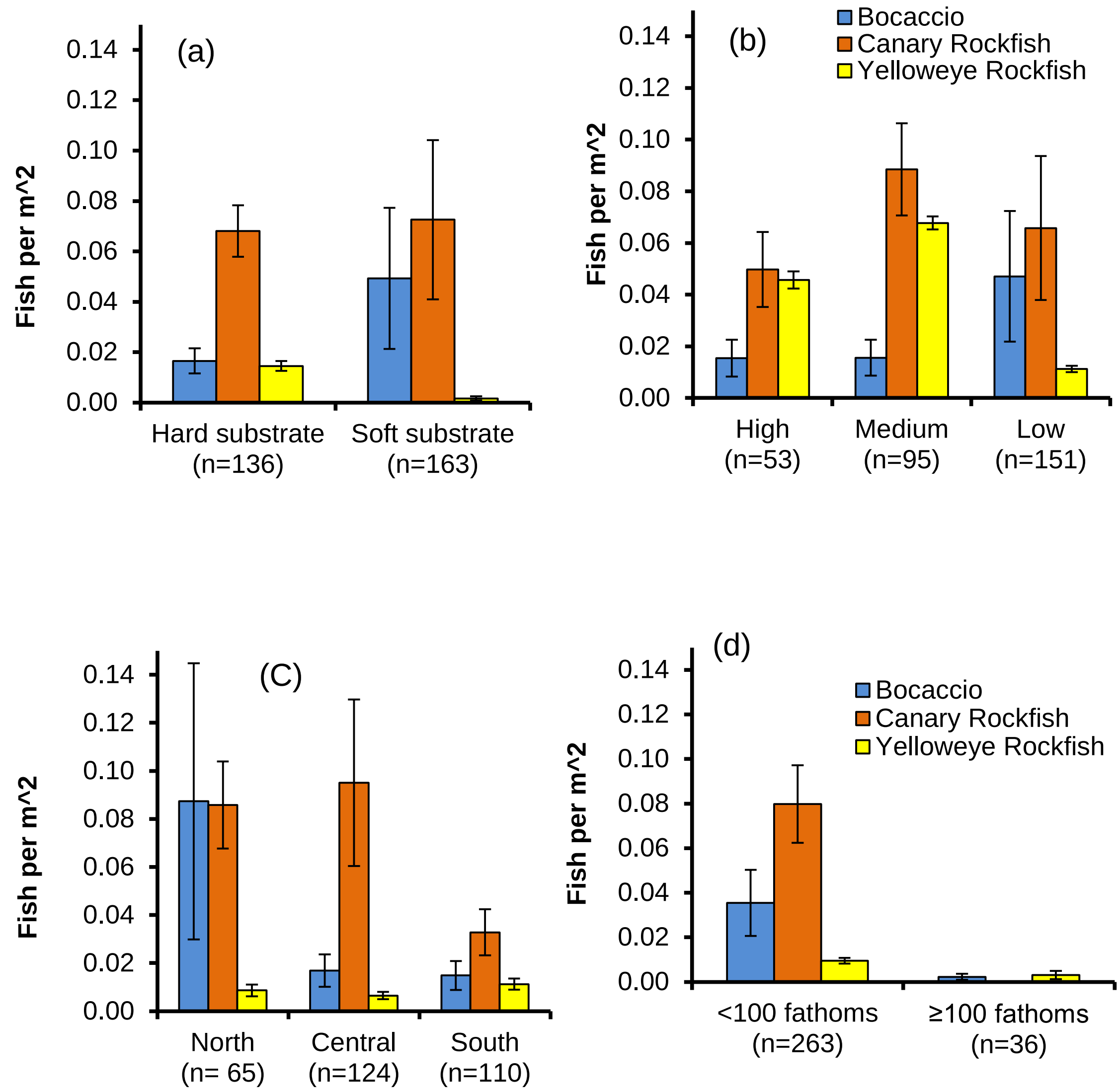


Figure 10. Densities of three rebuilding species, Bocaccio, Canary Rockfish, and Yelloweye Rockfish observed in visual surveys by (a) substrate, (b) seafloor relief, (c) sub-region, and (d) depth range. Error bars depict $\pm$1 standard error. N is the number of visual survey drops completed within each category.

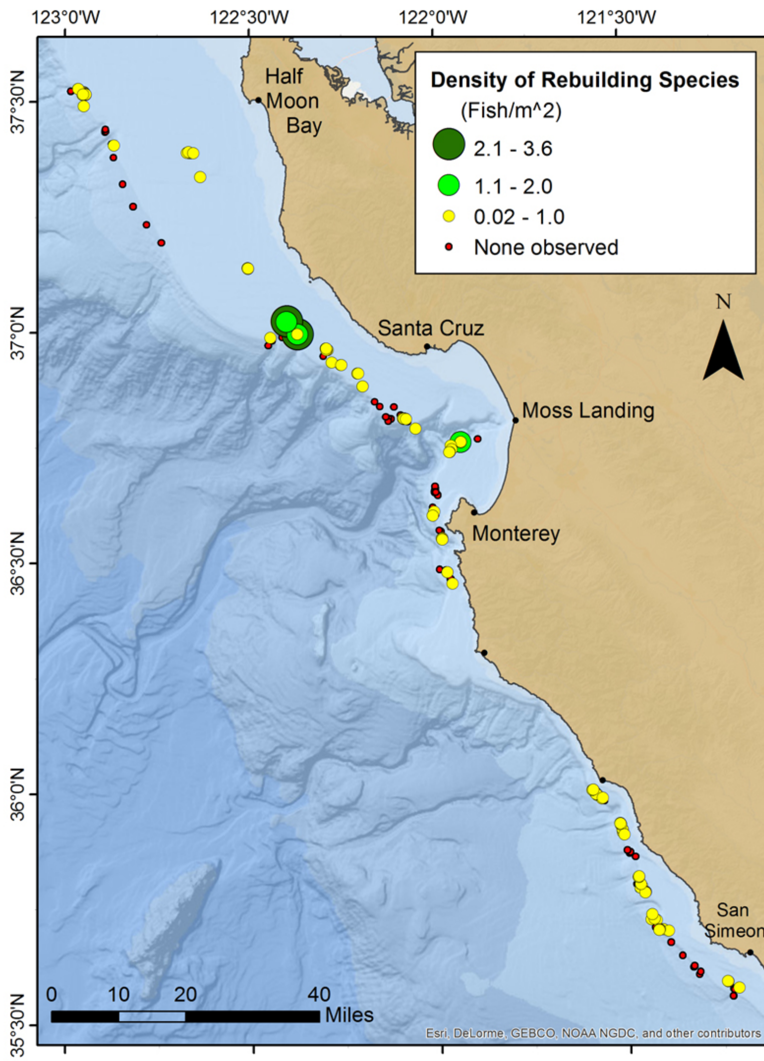


Figure 11. Density (number of fish/ m^2) of all rebuilding species combined estimated from visual surveys.

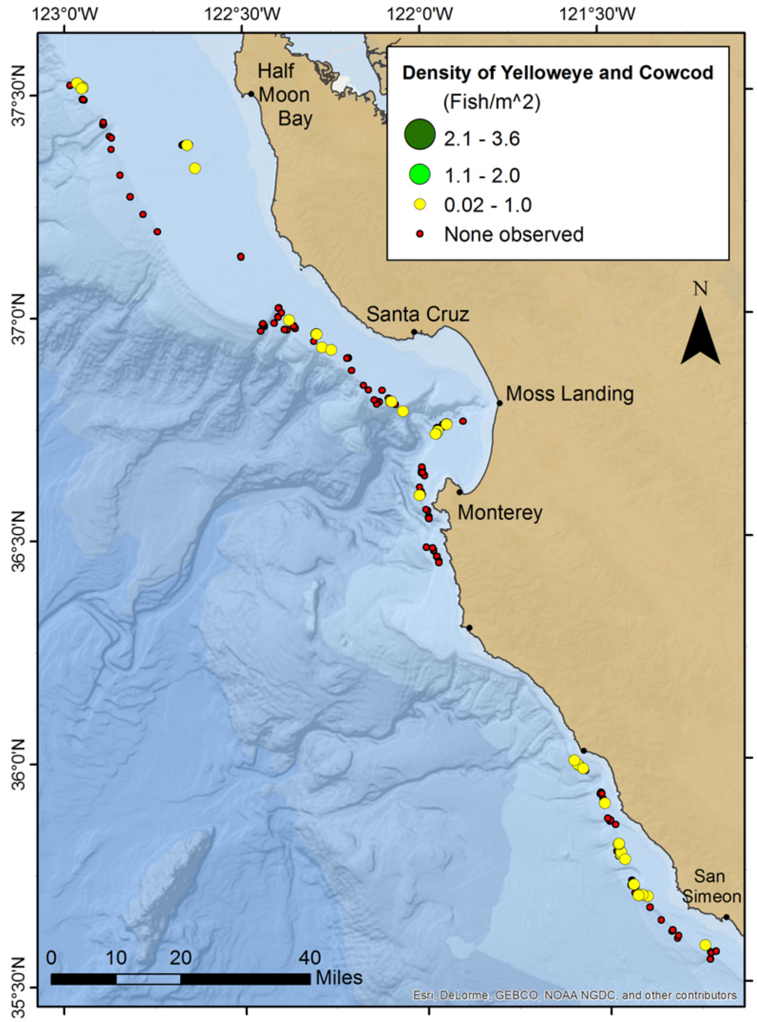


Figure 12. Densities (number of fish/ m^2) of Yelloweye Rockfish and Cowcod (combined) estimated from visual surveys.

Comparisons of Visual and Fishing Surveys

We identified 96 discrete sampling areas in which fishing and lander surveys were co-located : 57 areas in 2013 and 39 areas in 2014. The number of fishing sets co-occurring with visual surveys in those areas averaged 5 fishing sets and 3 visual surveys per area. We caught rebuilding species in 46% of the fishing surveys that co-occurred with visual surveys (Table 10). Most of the rebuilding species encountered in fishing sets, however, were Bocaccio and Canary Rockfish, which tend to be mobile. Yelloweye Rockfish were observed in 37 areas but caught in only two of those areas (Table 10). Although two Cowcod were caught in fishing operations, no Cowcod were caught in areas in which fishing and lander surveys co-occurred. There was no significant relationship between the number of rebuilding species observed near fishing sets and the number of rebuilding species caught during fishing operations (Fig. 13). There was, however, a significant correlation between the number of target species caught (e.g., Vermilion Rockfish and Yellowtail Rockfish) and the number of target species observed in visual surveys (Fig. 14).

Table. 10. Comparison of where rebuilding species were observed in visual surveys and caught in experimental fishing sets. The data are based on 96 areas where fishing and video-lander surveys co-occurred.

	No. of areas with visual observation of rebuilding spp.	No. of areas where rebuilding spp. were both caught & observed	Percentage of areas where rebuilding spp. were caught and observed
All rebuilding species	50	23	46%
Bocaccio	28	15	54%
Canary Rockfish	26	9	35%
Cowcod	10	0	0%
Yelloweye Rockfish	37	2	5%

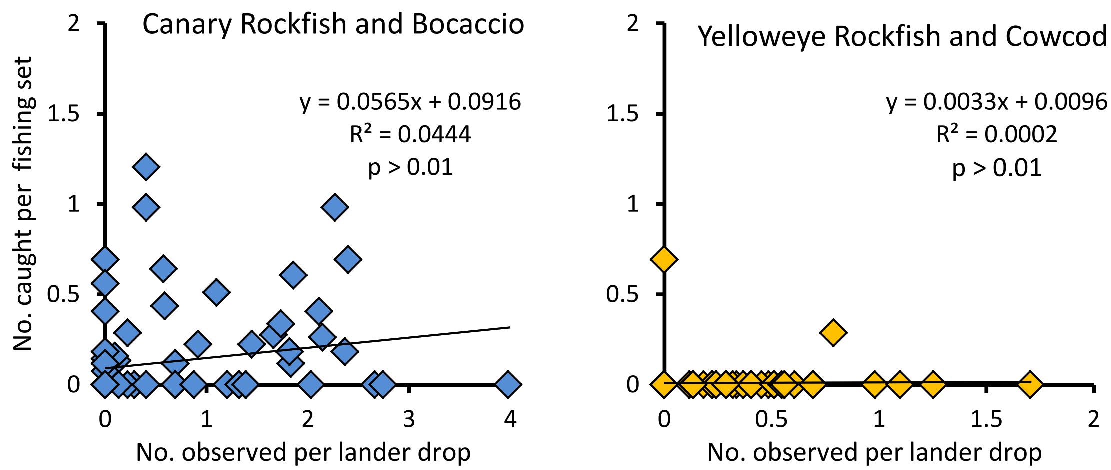


Figure 13. Regression analyses of rebuilding species caught in fishing sets and observed in visual surveys. Data are shown as ln (x+1) transformations of catch and observations.

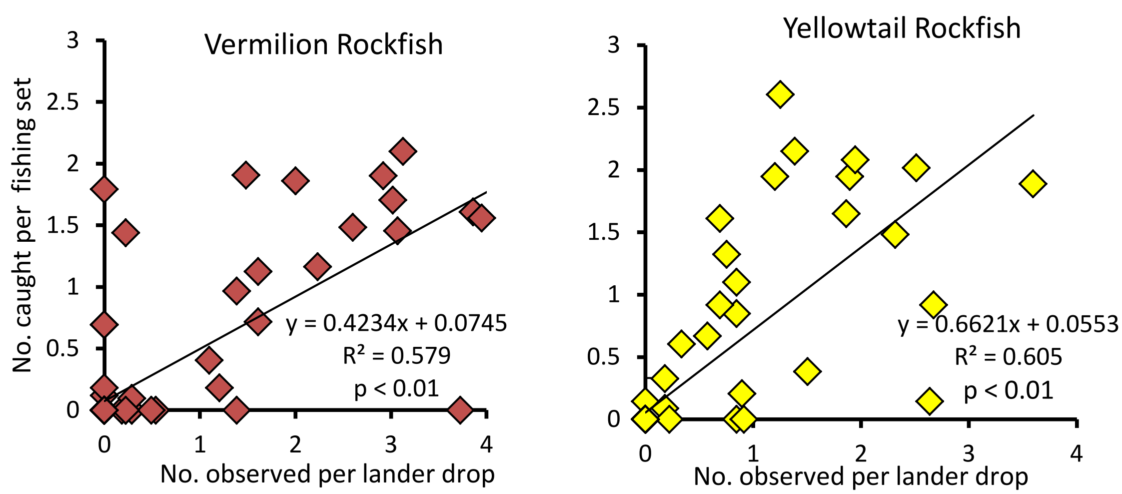
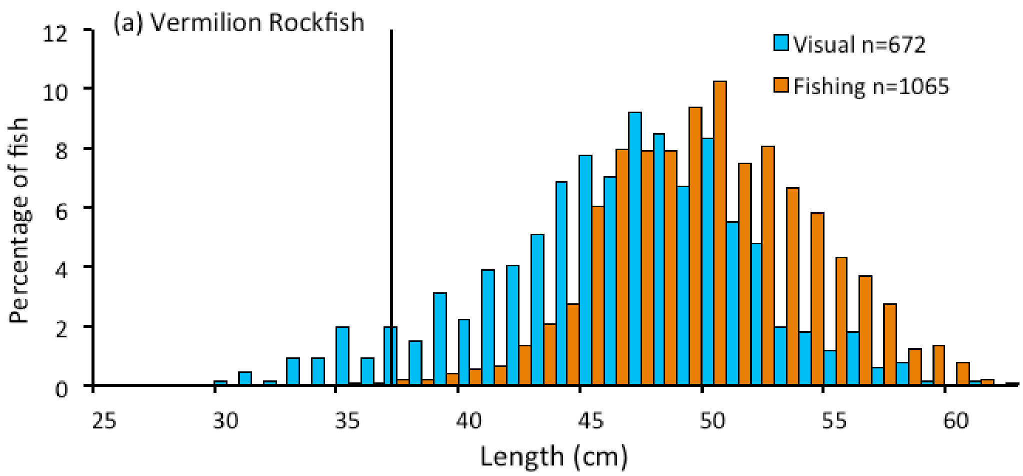


Figure 14. Regression analyses of two target species caught and observed in visual surveys. Data are shown as ln (x+1) transformations of catch and observations.

Length frequency distributions developed from stereo-video observations and fish catches (Fig. 15) showed a broad size range for Vermilion Rockfish, Yellowtail Rockfish, Chilipepper, Widow Rockfish, and Bocaccio. Except for Widow Rockfish, the majority of fish caught were either at or above the size of 50% maturity reported in the literature for Central California rockfishes (Love et al. 2002, Keller et al. 2012, He et al.

In Review). Vermilion Rockfish observed or caught were nearly all larger than the size at 50% maturity. This reflects the ontogenetic movement of Vermilion Rockfish as juveniles reside in shallower water. For a similar reason, most Yellowtail Rockfish and Bocaccio observed and caught were larger than the size at 50% maturity. Sub-adult (<35 cm long) Widow Rockfish were well represented in catches and often observed in relatively large schools of smaller individuals. Few mature Widow Rockfish were observed in visual surveys. For all species that were both caught in fishing sets and observed in visual surveys, we saw smaller individuals in the visual surveys than were caught in the fishing sets.



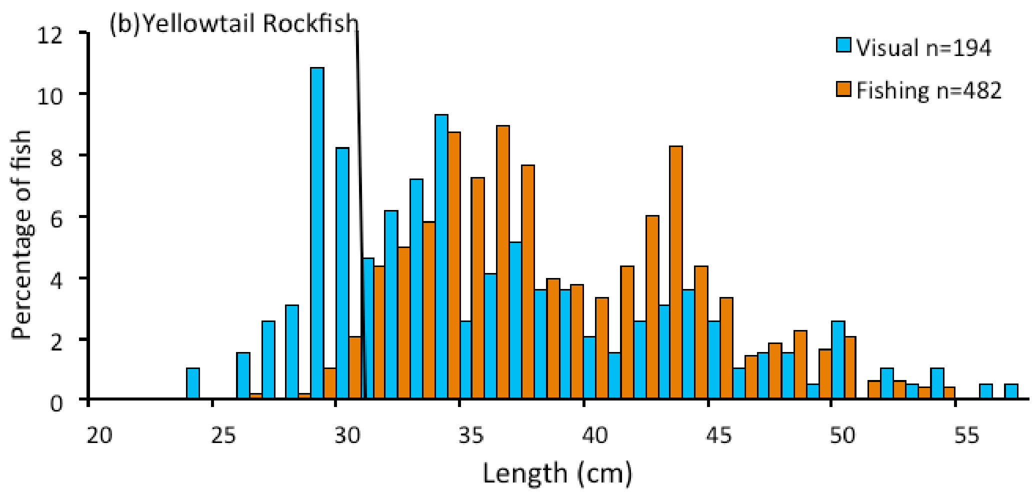


Figure 15. Length frequency distributions as percentages of all fish landed or observed in visual surveys for the five most frequently landed species: (a) Vermilion Rockfish, (b) Yellowtail Rockfish. The solid black line represents length at 50% maturity for females.

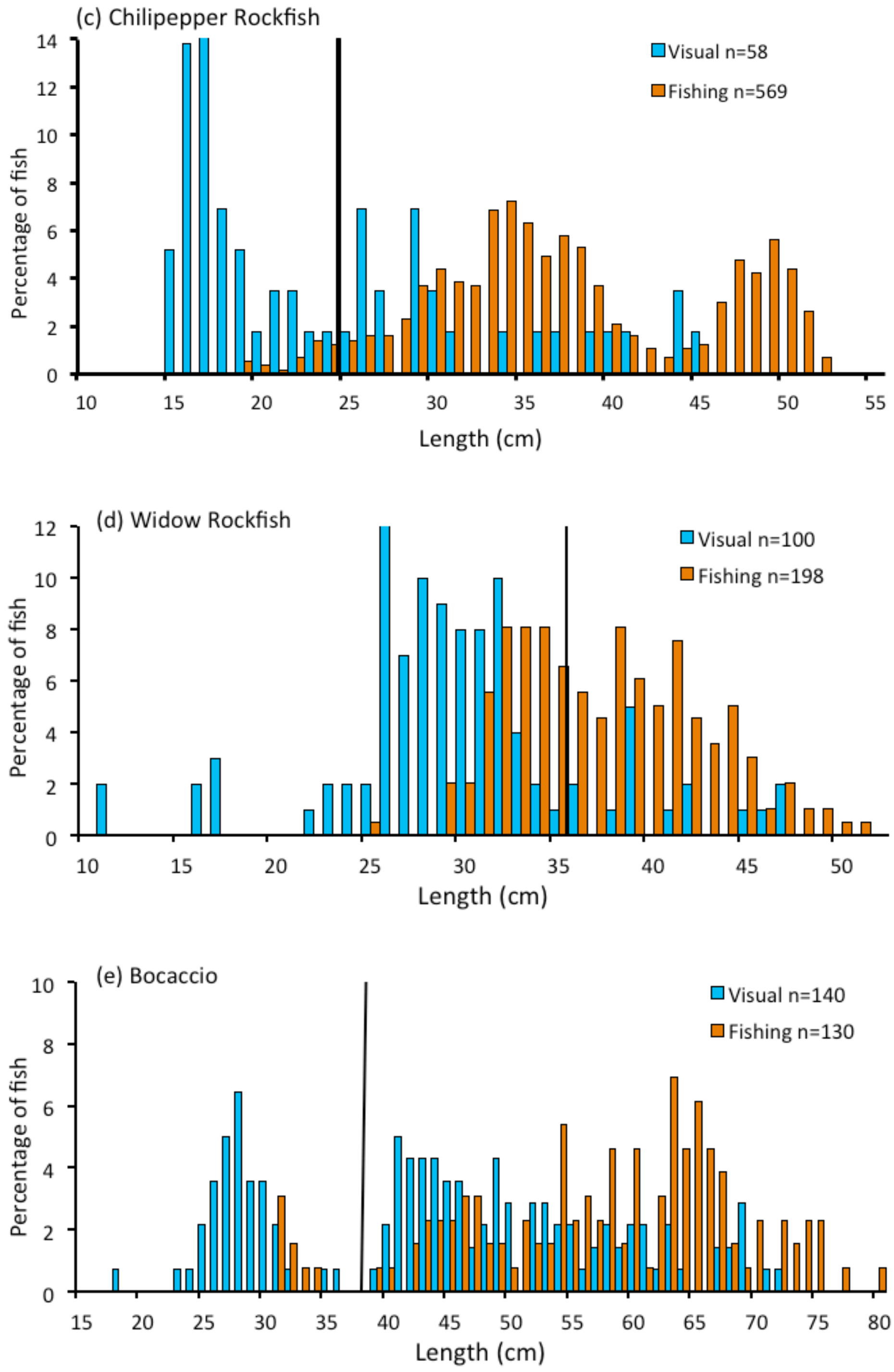


Figure 15 continued. Length frequency distributions as percentages of all fish landed or observed in visual surveys for the five most frequently landed species: (c) Chilipepper, (d) Widow Rockfish, and (e) Bocaccio. The solid black line represents length at 50% maturity for females.

We used a two-sample Kolmogorov-Smirnov test to compare frequency distributions of fishes caught and fishes observed. For Bocaccio, Yellowtail Rockfish, Widow Rockfish, Vermilion Rockfish, and Chilipepper, Kolmogorov-Smirnov tests indicated that length frequency distributions were significantly different between visual surveys and fishing surveys ($p<0.05$), primarily because many small fish were observed on visual surveys. Additionally, length frequency distributions were also significantly different when visual data were truncated to omit the fishes that were smaller than the minimum size of the fishes caught ($p<0.05$). Only when limiting the analysis to fish longer than the female length of 50% maturity did we find a similar length frequency distribution between catches and observations for Widow Rockfish.

We also compared mean lengths of fishes caught and fishes observed. We limited comparisons to only those fish observed or caught that were larger than the length at 50% maturity. In four of the five species evaluated, mean lengths of fishes caught were significantly larger than fishes observed in visual surveys (Table 11).

Table 11. Results of Welch's t-test comparing mean lengths above the 50% maturity estimation for species in both visual and fishing surveys. Significant differences are identified by bolded p-values.

	Fishing Surveys			Visual Surveys			
Common Name	n	mean	SE	n	mean	SE	p-value
Bocaccio	122	59.0	0.9	148	51.1	0.7	**<0.05**
Chilipepper	536	38.2	0.3	33	34.7	1.3	**<0.05**
Vermilion Rockfish	1061	49.9	0.1	826	47.3	0.2	**<0.05**
Widow Rockfish	117	40.9	0.3	40	41.0	0.5	0.844
Yellowtail Rockfish	444	39.3	0.2	203	37.8	0.4	**<0.05**

Biological sampling of selected species

A total of 408 fish were retained to support life history studies at the Fisheries Ecology Division, Southwest Fisheries Science Center, 158 of which were rebuilding species. Retained fishes were primarily Bocaccio, but included Canary Rockfish, Yelloweye Rockfish and Cowcod (Table 12).

Table 12. Number of fish caught in fishing surveys that were transferred to the NOAA/NMFS Fisheries Ecology Division of the Southwest Fisheries Science Center to support fecundity and life history research. Rebuilding species denoted by an *.

Year/Species	Number of Fish processed	Fecundity subsamples collected	Fecundity Estimated (as of June 2015)	Histology samples collected
2013				
Bank	2			
Bocaccio*	75	34	5	
Canary*	7			
Chilipepper	40	32	15	
Widow	31	8		
Yellowtail	29	5		
Total 2013	**184**	**79**	**20**	
2014				
Bank	4	4		4
Bocaccio*	55	24	5	49
Canary*	15	1	1	6
Chilipepper	30	24	2	29
Cowcod*	2	1	1	1
Greenspotted	7	1	1	6
Speckled	9	9	4	9
Vermilion	19	19	5	19
Widow	36	16		35
Yelloweye*	4			3
Yellowtail	40	23		32
Total 2014	**221**	**122**	**19**	**193**
Grand Total (2013 and 2014)	405	201	39	193

IV. Discussion

The scarcity of information on the distribution and population status of rebuilding and target species, especially those associated with rocky or high relief habitats, has limited both management options and fishing opportunities. Our study demonstrated some tangible benefits of combining experimental fishing surveys with visual surveys to more fully document the distribution, abundance, and size of rebuilding and selected target species within the RCAs. We were able to document that rebuilding species, including the most constraining species such as Yelloweye and Cowcod, are distributed along the Central California region and occur primarily in rocky or high-relief habitat. We also documented broad size ranges within their populations, with a large proportion of individuals observed or caught being above the size of maturity.

The primary tool used by NMFS to assess groundfish stocks is the West Coast Groundfish Bottom Trawl Survey (Keller et al. 2008). This survey (a combined Shelf/Slope survey time series) was designed specifically to provide fishery-independent data for statistical assessments required by the fisheries management process. The survey targets the commercial groundfish resources inhabiting depths of 55 to 1,280 meters depth and from Cape Flattery, Washington (lat. 48°10'N) to the U.S.-Mexican border (lat. 32°30'N). Approximately 750 trawl tows are sampled annually, offering an extensive fishery-independent dataset (Keller et al. 2012). However, the trawl tows are successful primarily on low-relief habitats, and provide only limited density information about rebuilding species, although relative abundance over time is obtained. This scarcity of data on species primarily associated with rocky or high relief habitats is further compounded by the fact that areas with high abundances of rebuilding species are also closed to fishing, and fishery dependent data streams are therefore limited. The inability to fully sample the appropriate habitat areas for many rockfish species contributes to uncertainty in both abundance and trend information, in the data that are used in stock assessments.

In the absence of information about the density of rebuilding species in all habitats, the current assumption with respect to the use of data and indices of abundance from the existing trawl surveys is that the trawl tows prosecuted in low-relief habitats near untrawlable areas will catch some proportion of rebuilding species that move off the rocky habitats and into trawlable areas. Importantly, the associated assumption is that the proportion of rebuilding species caught will be representative of the overall relative abundance in survey blocks that contain untrawlable habitats, and that such areas will accurately reflect the distribution and relative abundance of rebuilding species. This assumption may not be true if there are density-dependent processes driving the relative abundance of a given species across optimal (e.g., high relief) versus suboptimal (e.g., low relief or soft-bottom) habitats (MacCall 1990, Thorson et al. 2014). We are currently, and hope to continue, working with NMFS to test the use of visual survey tools (such as the stereo-video lander) in rocky and high relief habitats to complement the annual bottom trawl surveys.

Distributions of rebuilding species

The NMFS Northwest Fisheries Science Center (NWFSC) tried to address the lack of information about untrawlable habitats when they were identifying Essential Fish Habitat by gathering information from trawl surveys and visual surveys (http://www.pcouncil.org/wp-content/uploads/Groundfish_EFH_Synthesis_Report_to_PFMC_FINAL.pdf). They lumped data in to 2 km x 2 km blocks and provided maps that were slightly different than the maps created by the NCCOS modeling work

(Appendix A). Based on our fishing and visual surveys, both the NWFSC and NCCOS maps are useful for broad-scale (i.e., coast-wide) evaluations of fish distributions, but are too coarse for regional-scale management, such as needed for modifications of the RCA. For example, the NCCOS modeling predicted that there would be a 0-5% probability of encountering a Yelloweye Rockfish in almost all areas in Central California. This value closely matches the encounter rate from both our experimental fishing and visual surveys in waters deeper than 100 ftm. The 0-5% range also encompasses the historical average percentage of Yelloweye Rockfish landed from all commercial rockfish fisheries (1.7%) from 1987-2000 in Central California (Starr et al. 2002), and from 1990–1999 hook and line fisheries only (2.1–3.7% by weight, reported in NMFS CalCOM data). The visual surveys we conducted in waters shallower than 100 ftm, however, provided a different view of the relative abundance of Yelloweye Rockfish as we encountered Yelloweye Rockfish in more than 20% of our visual surveys. In our study, Yelloweye Rockfish were six times more likely to be encountered on high relief rocky areas than low-relief softer substrates. From this information, the map made from NWFSC modeling, which shows more Yelloweye in the Monterey Canyon area (because of incorporation of previous submersible surveys), is more accurate than the NCCOS map. Neither the NCCOS nor the NWFSC modeling results, however, describe the wide distributional occurrence of Yelloweye Rockfish that we observed. This is probably due to the fact that we targeted higher relief, rocky substrates that more commonly contain Yelloweye Rockfish than lower relief habitats. Results of our visual surveys suggest that the abundance of Yelloweye Rockfish and Cowcod is much greater in Central California than might be predicted based on catches and/or bottom trawl surveys alone. The observations of rebuilding species show they are widely distributed along the Central California coast.

Experimental gear performance

The RCAs have been successful at reducing mortality of rebuilding species; however, they have also closed some of the most highly productive areas along the continental shelf and shelf-slope break to various gear types. As part of our EFP, we worked with commercial fishermen to develop gear that might be more selective for the relatively abundant species, such as Chilipepper, Vermilion Rockfish, Widow Rockfish, and Yellowtail Rockfish. In discussions with our fishing collaborators, we decided to use a hydraulic snapper reel fishing gear that provides instant notice of a fish biting a hook. Based on the work of Hannah et al. (2008), we designed the gear so there was a 25 ft space between the bottom weight and the first hook. Skippers attempted to fish the gear so that it remained vertical, so that demersal species would have to come off the bottom to be caught. Hannah et al. (2008) described success at catching semi-pelagic rockfishes while limiting catches of demersal rebuilding species. They reported that catch rates for Yelloweye Rockfish and Canary Rockfish were reduced 84% and 41%, respectively, when fishing gear with a 3 m (9.8 ft) or 4.6 m (15 ft) “long leader” compared to gear with no long leader between the bottom weight and first hook.

We had success avoiding demersal species while catching semi-pelagic species, as evidenced by the high target/rebuilding species catch ratios. Bocaccio was the one rebuilding species we did catch in moderate numbers, but the stock assessment for Bocaccio have shown an increase in biomass over the past decade (Field 2013). The regression analyses we conducted between catches in an area and observations in co-occurring video surveys showed that when schooling fishes were abundant, our experimental fishing sets resulted in high catches of fish. The interesting part of the fishing/video comparison is that we discovered no relationship between catches and occurrence of Yelloweye Rockfish and Cowcod, the two most constraining of the rebuilding species. This suggests that as populations of those two species start to recover, there might be a way to fish for abundant species while limiting bycatch of Yelloweye Rockfish and Cowcod. The success of the fishing gear in avoiding Yelloweye Rockfish and Cowcod is even more impressive, considering that rebuilding species were at their historical lows in the 1990s and stock assessments indicated that all are at somewhat to considerably higher levels now.

The fishing we conducted was designed to be limited in scope, yet large enough to let fishermen evaluate whether or not the snapper reel gear with a long leader could provide them enough catch to make that fishing technique economically viable. Our fishing collaborators indicated that at current market prices, they would need an allocation or quota of about 1500 lb/day, along with a bycatch quota for limited catch of rebuilding species, for this type of targeted fishing to be economically viable. One of the limitations of this type of fishing is that it requires locations in which fishes aggregate; it is less practical for sparsely distributed fishes. Unless a fisherman searches for a school, it is likely to take much longer soak times to fill a quota with this gear type. Fishing on aggregations may be an indication that a given stock or population is more vulnerable to overfishing if effective management measures are not in place. Species that form large schools or aggregations also tend to be more vulnerable to localized depletion. A greater understanding of fish aggregations and fish movements would help address this potential concern. However, our results also demonstrate that snapper reel gear that includes a long leader appears to be a highly effective means of allowing fishermen to target healthy stocks in highly structured shelf habitat while avoiding rebuilding species.

Lengths of fishes

When comparing estimated lengths of fishes from visual and fishing surveys for the abundant species, the mean lengths of Bocaccio, Chilipepper, Vermilion Rockfish, and Yellowtail Rockfish caught were 2-8 cm larger than those observed in visual surveys. For fish greater than the length at 50% maturity, Widow Rockfish mean lengths were similar between visual and fishing surveys. We expected these results because, based on published comparisons of visual surveys and fishing surveys, fishing selects for the larger individuals in a population. Combined, however, the length frequency distributions developed from stereo-video observations and fish catches provided an estimate of the existing size classes of fishes in central California. These kinds of data can be used to augment the length frequencies of species that are under-sampled by the annual trawl surveys. Also, we note the good news that many of the size frequency distributions contained a large proportion of fishes above the length at 50% maturity.

Biological analyses

As the timing of the fishing effort was aligned with the beginning of the reproductive season for many species we were targeting, the retained fishes supported several ongoing size-dependent reproductive output (fecundity) studies (e.g., Beyer et al. 2015). The biological samples enabled additional histological analyses to confirm maturity stages of retained fishes. This helped us evaluate the frequency and demographic predictors of multiple brooding in a number of species known to produce multiple broods (including Bocaccio, Chilipepper, Cowcod, and Speckled Rockfish). Thus, the retained fishes have helped to fill in important data gaps for many of these species. The fecundity data from many of the Bocaccio that were collected have already been used to update the size-dependent fecundity relationship in that stock assessment, and to better understand how the phenomena of multiple brooding may alter our view of the productivity of that stock (He et al. In Review).

Conclusions

The purpose of our project was to examine species distributions and size structures of rebuilding species within the RCAs in Central California with the aim of informing bycatch avoidance plans and potential reconfiguration of the RCA. The visual survey techniques we used enabled us to successfully identify locations, densities, and habitat associations of rebuilding species across a 200-mile section of the central California coast.

In a separate effort, our observations from this study were incorporated into a geodatabase on the occurrence of rebuilding species. The geodatabase includes observational data from over 30 sources including fishing and visual surveys (e.g. using Remotely-Operated Vehicles, submersibles, or other tools) that document presence of rebuilding species (Appendix D). Compilation of these types of observational data from a variety of sources is very critical for supporting the development of spatially-explicit bycatch avoidance plans (such as those used by the California Groundfish Collective) and in the design and evaluation of proposed changes to Essential Fish Habitat or RCA areas.

The experimental fishing gear enabled fishermen to target abundant stocks while avoiding Cowcod and Yelloweye, the two species that most constrain rockfish fisheries. The success of this project suggests that these fishing techniques could be used along other parts of the U.S. West Coast to allow limited fishing activities to occur. The results of our research will be important to California groundfish fishermen, “risk pools” that have formed in the West Coast groundfish fishery, managers and stock assessors from NMFS and CDFW, and conservation organizations interested in protecting important habitats and promoting rebuilding of depleted stocks. Specifically, an outcome of our effort has been the advancement of the understanding of finer-scale distributions, habitat associations, and demographic patterns of rebuilding species inside and adjacent to the RCA. This information will help:

- Reduce the bycatch of overfished species by informing bycatch avoidance plans.
- Help increase attainment levels by increasing fishing opportunities for underutilized species, especially near the RCA.
- Evaluate the contribution of the RCAs and high relief habitats to rebuilding depleted species to help inform assessments and management.
- Inform research strategies by comparing directed fishing and visual surveys with trawl surveys for future assessment and modeling studies.
- Inform the potential reconfiguration of RCAs and EFH to better protect rebuilding species and allow selective fishing in areas that can be fished cleanly.
- Create a geodatabase of spatial information on rebuilding species that can grow into the future as new information becomes available.

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Appendix A - Predictive modeling of groundfish abundance

The Environmental Defense Fund (EDF) funded the National Centers for Coastal Ocean Science (NCCOS) to interpret groundfish survey data sets and map the predicted distribution of key target and rebuilding species along the West Coast. The primary goal of this research was to provide a finer scale prediction of groundfish distributions than currently exists for the region, and use this information to support fishery management. The effort was focused on helping to answer the following questions:

- What are important environmental drivers of groundfish distributions?
- Where are groundfish species hotspots and coldspots and how do these relate to federally managed areas?
- Where are we most and least certain of groundfish distributions?
- How have groundfish distributions changed over time?
- What are useful indicators of groundfish population distribution?
- How have long-term closures affected the distribution and abundance of fish populations in closed areas?

To answer these questions, NCCOS compiled a range of fish observations and environmental data sets (e.g., depth, bottom temperature), and used innovative spatial predictive models to develop new predictive groundfish distribution maps. The new maps show continuous predictions of occurrence, relative abundance and uncertainty in those predictions at relatively high spatial resolution (1 km) for the entire West Coast. The 15 species for which predictive maps were developed are listed below.

Table A1: Rebuilding and commercial target species modeled. Species labeled with asterisks (*) are rebuilding species.

Common name	Scientific name
*Bocaccio	*Sebastes paucispinis*
*Canary Rockfish	*Sebastes pinniger*
*Cowcod	*Sebastes levis*
*Darkblotched Rockfish	*Sebastes crameri*
*Pacific Ocean Perch	*Sebastes alutus*
Widow Rockfish	*Sebastes entomelas*
*Yelloweye Rockfish	*Sebastes ruberrimus*
Petrale Sole	*Eopsetta jordani*
Sablefish	*Anoplopoma fimbria*
Longspine Thornyhead	*Sebastolobus altivelis*
Shortspine Thornyhead	*Sebastolobus alascanus*
Blackgill Rockfish	*Sebastes melanostomus*
Chilipepper	*Sebastes goodei*
Dover Sole	*Microstomus pacificus*
Lingcod	*Ophiodon elongates*

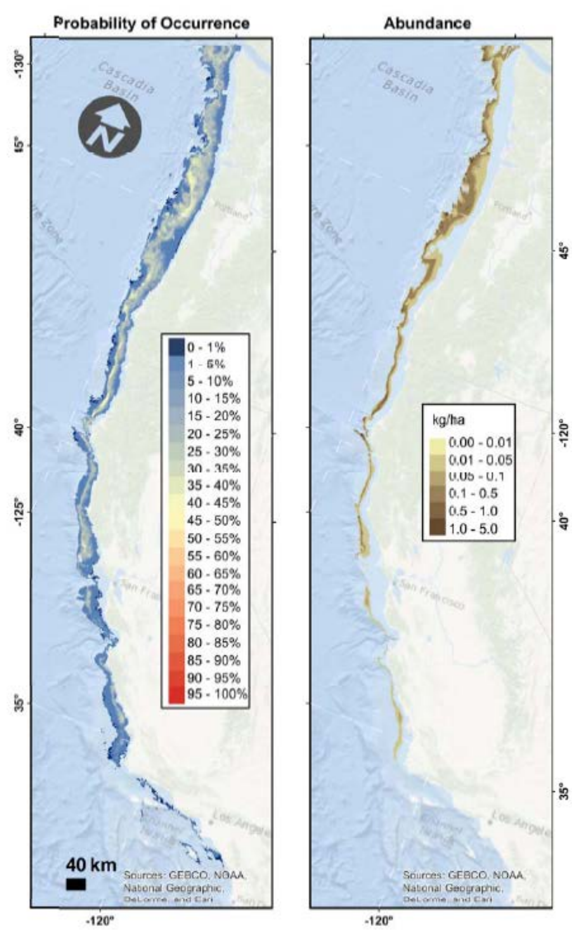
The modeling efforts were focused on waters off of California, Oregon, and Washington, where sufficient data were present to conduct analyses. We used the fishery-independent annual bottom trawl survey data collected by the Northwest Fisheries Science Center (NWFSC) Fishery Resource Monitoring Division (FRAM) from 2003-2010 and the fishery-independent tri-annual trawl data collected by the Alaska Fisheries Science Center from 1985-2004. The models have two distinct components ("stages"), one for predicting the probability of occurrence, and another for predicting relative abundance given presence. The predicted probability of occurrence (Stage I) is multiplied by the predicted abundance conditional on occurrence (Stage II) to produce the final estimate of relative abundance, which is the expected long-term average catch per unit effort (CPUE). The long-term average can be considered the estimated mean from repeated bottom trawls scattered between 2003 and 2010. Within each stage of the model, relationships among groundfishes and their environment were used to predict a trend surface using transformed Generalized Linear Models (GLMs), and spatial autocorrelation in GLM residuals was modeled using geostatistical modeling (kriging). For each species and each stage a model selection routine was used to select which environmental variables would be used in generalized linear models and which ones would be omitted. Final models were selected based on a statistic that balanced model fit to the training dataset with model complexity, and tested on a cross-validation set not included in model fitting. The modeling process can be summarized as follows:

1. Transform dependent variables and potential predictor variables for linearity.
2. Divide data into training and validation ("holdout") subsets for cross-validation purposes.
3. Stage I trend model: Use a GLM (binomial distribution, logit link) to generate a predictive map of the mean probability of species occurrence.
4. Stage I residual model: Use ordinary indicator kriging (OIK) to predict the "residual" probability map, where "residual" is defined as the probability that the regression model leads to an incorrect classification of the presence state ($Pi(x,y)$) of a given location.
5. Final Stage I model: Adjust the trend-predicted probability map using the kriged residual probability map from step 4. The trend from step 3 and residual from step 4 are combined using probability laws.
6. Stage II trend model: Use a GLM (normal distribution, Box-Cox link) to generate a predictive map of the mean abundance of a species when it is present. The Box-Cox link indicates that data were transformed for normality for this part of the analysis using a Box-Cox type transformation (Box and Cox 1964), described further below, and back-transformed for final maps.
7. Stage II residual model: Use Simple Kriging (SK) to predict residual map of the regression model of abundance.
8. Final Stage II model: Add the trend map from step 6 and the residual map from step 7.
9. Final Stage I x II model prediction: Multiply the predicted probability of occurrence at each location by the predicted abundance if present to produce the final prediction of the expected value (long-term average) of abundance at each location.
10. Relative uncertainty calculation: scaled relative uncertainty values were calculated for the trend, residual, and final models for Stage I and Stage II, and for the final Stage IxII prediction.
11. Model evaluation, cross-validation, and relative uncertainty calibration.
12. Post-processing

For details on the modeling process please refer to the Appendix of the EFH Synthesis Report at http://www.pcouncil.org/wp-content/uploads/Appendix_to_Groundfish_EFH_Synthesis_Report_to_PFMC_FINAL.pdf

This work built off of existing data and regional modeling efforts, and relied on expertise found in NOAA's Northwest, Southwest and Alaska Fisheries Science Centers, The Nature Conservancy, the Seafloor Mapping Lab at California State University Monterey Bay (CSUMB), the Sustainable Fisheries Group (SFG) at University of California Santa Barbara (UCSB), and Moss Landing Marine Laboratories (MLML). During the course of this project different groupings of the individuals from the institutions identified above came together to identify analytical objectives, compile fishery and environmental data sets, provide guidance on groundfish ecology and ecological modeling approaches, or conduct reviews of models and results. This work was later complemented by similar efforts at the Northwest Science Center (NWFSC) and maps from both groups were incorporated into the Essential Fish Habitat (EFH) Synthesis Report, which can be viewed at http://www.pcouncil.org/wp-content/uploads/Groundfish_EFH_Synthesis_Report_to_PFMC_FINAL.pdf. The map below is from the Synthesis Report and shows the predicted abundance and probability of occurrence for Darkblotched Rockfish

Darkblotched (*Sebastes crameri*)



Appendix B - Additional experimental fishing data

Table B1. Weight (lb) of individual species and IFQ species groups landed in experimental fishing sets by sub-region. Species in labeled with asterisks (*) are rebuilding species.

Species / IFQ species group	Northern sub-region landings	Central sub-region landings	Southern sub-region landings
*Bocaccio	81	26	591
*Canary Rockfish	8	9	35
*Cowcod	-	-	23
*Yelloweye Rockfish	-	5	18
Chilipepper	700	81	171
Lingcod	16	10	83
<u>Southern shelf rockfish</u>			
Greenspotted Rockfish	52	3	-
Greenstriped Rockfish	2	-	-
Redstripe Rockfish	1	-	-
Speckled Rockfish	4	2	26
Stripetail Rockfish	5	-	-
Vermilion Rockfish	56	17	5,230
Yellowtail Rockfish	529	96	419
<u>Southern slope rockfish</u>			
Bank Rockfish	-	-	14
Sharpchin Rockfish	3	-	-
<u>Nearshore rockfish</u>			
Blue Rockfish	57	-	-
Copper Rockfish	-	5	-
Quillback Rockfish	2	-	-
<u>Other flatfishes</u>			
Pacific Sanddab	82	2	-
Pacific Whiting (hake)	1	-	-
Sablefish N of 36°	3	-	-
Widow Rockfish	305	19	35
Totals	1,907	275	6,645

Table B2. Discarded fishes from all experimental fishing sets in 2013-2014 summarized by the reason they were logged as discard. Weights are onboard measurements for caught discards or estimated by onboard observers when not brought onboard the vessel.

Discard reason	Species	Number of fish	Weight
Drop-off	Chilipepper	2	2
	Lingcod	2	17
	Pacific Sanddab	2	1
	Vermilion Rockfish	2	10
	Widow Rockfish	3	6
	Yellowtail Rockfish	14	26
Market-smalls	Halfbanded Rockfish	7	2
	Pacific Sanddab	1	0.4
	Sablefish	12	6
	Shortbelly Rockfish	5	1
Predated	Widow Rockfish	1	2
Regulation (undersized)	Lingcod	10	22
Total		61	95

Table B3. Mean lengths (cm) and standard error of fishes caught in fishing surveys by subregion.

	North			**Central**			**South**			**Total**		
Common Name	**n**	**Avg.**	**SE**	**n**	**Avg.**	**SE**	**n**	**Avg.**	**SE**	**n**	**Avg.**	**SE**
Bocaccio	32	44.8	1.7	8	49.3	3.7	90	62.4	0.8	130	57.3	1.0
Canary RF	6	35.5	0.7	4	39.0	1.1	12	42.7	1.1	22	40.1	0.9
Chilipepper	449	36.4	0.3	71	35.3	1.0	49	48.9	0.2	569	37.3	0.3
Lingcod	8	48.0	5.5	1	76.5	-	12	68.8	3.5	21	61.2	3.7
Pac. Sanddab	66	26.3	0.2	120	26.2	0.2	0	-	-	186	26.2	0.1
Vermilion RF	8	54.1	1.3	5	49.9	3.0	1052	49.8	0.1	1065	49.8	0.1
Widow RF	173	37.3	0.4	14	33.9	0.8	11	43.8	1.2	198	37.4	0.4
Yelloweye RF	0	-	-	1	50.0	-	3	52.8	1.9	4	52.1	1.5
Yellowtail RF	262	38.5	0.3	55	35.9	0.6	165	39.6	0.5	482	38.6	0.3

Appendix C – Additional Visual Survey Data

Table C1. Complete list of fish species observed in visual surveys using the stereo-video lander co-located within 500 m of fishing sets (n = 299 lander drops) by sub-region and depth category. Frequency of occurrence is calculated from the number of drops out of 299 in which the species was observed. Rebuilding species denoted by an *.

Genus	Species	Common Name	North	Cent.	South	Total	<100	≥100	Freq. of occur.
Sebastes	*jordani*	Shortbelly Rockfish	54	508	1066	**1628**	581	1047	6%
Sebastes	spp.	Genus- Rockfishes	408	490	630	**1528**	1500	28	58%
Sebastes	*miniatus*	Vermilion Rockfish	11	33	1238	**1282**	1255	27	27%
Sebastes	*chlorostictus*	Greenspotted Rockfish	517	306	56	**879**	873	6	36%
Sebastes	*pinniger*	Canary Rockfish*	171	386	121	**678**	678	0	27%
Sebastes	*wilsoni*	Pygmy Rockfish	10	262	275	**547**	547	0	27%
Sebastes	*flavidus*	Yellowtail Rockfish	178	273	90	**541**	541	0	23%
Ophiodon	*elongatus*	Lingcod	62	203	224	**489**	478	11	56%
Citharichthys	*sordidus*	Pacific Sanddab	12	273	86	**371**	346	25	12%
Sebastes	*elongatus*	Greenstriped Rockfish	268	77	10	**355**	344	11	26%
Sebastes	*paucispinis*	Bocaccio*	185	95	61	**341**	338	3	14%
Sebastes	*entomelas*	Widow Rockfish	143	160	5	**308**	308	0	8%
Sebastes	*sebastomus*	Subgenus - Sebastomus	62	90	99	**251**	243	8	39%
Sebastes	*semicinctus*	Halfbanded Rockfish	12	152	63	**227**	227	0	7%
Eptatretus	*stoutii*	Pacific Hagfish	51	68	82	**201**	126	75	23%
Sebastes	*rosaceus*	Rosy Rockfish	66	56	53	**175**	175	0	25%
Sebastes	*goodei*	Chilipepper	56	51	3	**110**	62	48	6%
Sebastes	*constellatus*	Starry Rockfish	34	44	27	**105**	105	0	20%
Sebastes	*ruberrimus*	Yelloweye Rockfish*	21	30	47	**98**	94	4	21%
Hydrolagus	*colliei*	Spotted Ratfish	4	12	72	**88**	62	26	10%
Sebastes	*caurinus*	Copper Rockfish	27	44	9	**80**	80	0	13%
Sebastes	*hopkinsi*	Squarespot Rockfish	8	27	39	**74**	74	0	11%
Anoplopoma	*fimbria*	Sablefish	15	20	1	**36**	22	14	6%
Sebastes	*rubrivinctus*	Flag Rockfish	7	21	6	**34**	34	0	7%
Sebastes	*saxicola*	Stripetail Rockfish	17	3	6	**26**	18	8	3%
Merluccius	*productus*	North Pacific Hake	11	5	9	**25**	21	4	4%
Sebastes	*levis*	Cowcod*	1	7	15	**23**	23	0	4%
Sebastes	*mystinus*	Blue Rockfish	19	0	0	**19**	19	0	1%

Pleuronectidae	spp.	Righteye Flounders	4	9	3	**16**	11	5	4%
Bothidae	spp.	Lefteye Flounders	0	0	11	**11**	11	0	1%
Sebastes	*melanostomus*	Blackgill Rockfish	0	10	0	**10**	10	0	<1%
Hexagrammos	*decagrammus*	Kelp Greenling	5	4	0	**9**	9	0	2%
Sebastes	*rufus*	Bank Rockfish	2	1	6	**9**	3	6	2%
Zaniolepis	spp.	Combfishes	1	5	2	**8**	8	0	2%
Argentina	*sialis*	North-Pacific Argentine	0	0	7	**7**	7	0	<1%
Microstomus	*pacificus*	Dover Sole	2	4	1	**7**	7	0	2%
Sebastes	*ensifer*	Swordspine Rockfish	0	0	7	**7**	7	0	1%
Sebastes	*helvomaculatus*	Rosethorn Rockfish	4	0	3	**7**	6	1	2%
Parophrys	*vetulus*	English Sole	2	4	0	**6**	4	2	2%
		Family - Smelts	0	0	6	**6**	2	4	1%
Sebastes	*ovalis*	Speckled Rockfish	0	3	2	**5**	5	0	1%
		Family- Poachers	0	3	2	**5**	3	2	1%
		Family- Sculpins	0	3	2	**5**	5	0	1%
Eopsetta	*jordani*	Petrale Sole	2	2	0	**4**	1	3	1%
Lycodes	*cortezianus*	Bigfin Eelpout	0	2	2	**4**	0	4	1%
Rhinogobiops	*nicholsii*	Blackeye Goby	1	0	2	**3**	3	0	1%
Sebastes	*zacentrus*	Sharpchin Rockfish	3	0	0	**3**	3	0	<1%
Anarrhichthys	*ocellatus*	Wolf-eel	0	1	1	**2**	2	0	<1%
Sebastolobus	spp.	Genus- Thornyheads	0	0	2	**2**	2	0	<1%
		Family- Pricklebacks	2	0	0	**2**	2	0	<1%
Glyptocephalus	*zachirus*	Rex Sole	0	1	0	**1**	0	1	<1%
Lepidopsetta	*bilineata*	Rock Sole	0	1	0	**1**	1	0	<1%
Bathymasteridae	spp.	Ronquils	1	0	0	**1**	1	0	<1%
Porichthys	*notatus*	Plainfin Midshipman	0	1	0	**1**	1	0	<1%
Raja	*rhina*	Longnose Skate	0	0	1	**1**	1	0	<1%
Sebastes	*aurora*	Aurora Rockfish	0	0	1	**1**	0	1	<1%
Sebastes	*crameri*	Darkblotched Rockfish*	0	0	1	**1**	1	0	<1%
Sebastes	*maliger*	Quillback Rockfish	1	0	0	**1**	1	0	<1%
Sebastes	*nigrocinctus*	Tiger Rockfish	1	0	0	**1**	1	0	<1%
Unknown fishes			41	121	45	**207**	192	15	26%

Table C2. Calculated fish densities (fish/m^2) of the top 20 species observed in 299 visual surveys by depth category. Rebuilding species denoted by an *.

	<100 fathoms (n=263)		≥100 fathoms (n=36)	
	Mean Density	SE	Mean Density	SE
All Fishes	0.97	0.06	1.08	0.64
All rebuilding species	0.13	0.02	0.01	0.00
Vermilion Rockfish	0.14	0.03	0.02	0.02
Shortbelly Rockfish	0.12	0.07	1.49	1.15
Greenspotted Rockfish	0.11	0.02	<0.01	<0.01
Pacific Sanddab	0.10	0.02	0.05	0.02
Pygmy Rockfish	0.10	0.02	<0.01	<0.01
Canary Rockfish*	0.08	0.02	<0.01	<0.01
Bocaccio*	0.04	0.01	<0.01	<0.01
Greenstriped Rockfish	0.04	0.01	0.01	<0.01
Lingcod	0.04	<0.01	0.01	<0.01
Yellowtail Rockfish	0.04	0.01	<0.01	<0.01
Halfbanded Rockfish	0.03	0.01	<0.01	<0.01
Pacific Hagfish	0.03	0.01	0.13	0.04
Rosy Rockfish	0.03	<0.01	<0.01	<0.01
Widow Rockfish	0.03	0.01	<0.01	<0.01
Starry Rockfish	0.02	<0.01	<0.01	<0.01
Chilipepper	0.01	0.01	0.08	0.08
Copper Rockfish	0.01	<0.01	<0.01	<0.01
Spotted Ratfish	0.01	<0.01	0.02	0.01
Squarespot Rockfish	0.01	<0.01	<0.01	<0.01
Yelloweye Rockfish*	0.01	<0.01	<0.01	<0.01
Cowcod*	<0.01	<0.01	<0.01	<0.01

Table C3. Calculated fish densities (fish/m^2) of the top 20 species observed in 299 visual surveys by hard and soft substrates. Rebuilding species denoted by an *

	Hard Substrate (n=136)		Soft Substrate (n=163)	
	Mean Density	SE	Mean Density	SE
All Fishes	1.11	0.07	0.84	0.19
All rebuilding species	0.10	0.01	0.12	0.04
Bocaccio*	0.02	<0.01	0.05	0.03
Vermilion Rockfish	0.22	0.04	0.01	0.01
Pygmy Rockfish	0.16	0.03	<0.01	<0.01
Greenspotted Rockfish	0.15	0.03	0.04	0.01
Canary Rockfish*	0.07	0.01	0.07	0.03
Yellowtail Rockfish	0.06	0.01	<0.01	<0.01
Rosy Rockfish	0.05	0.01	<0.01	<0.01
Lingcod	0.05	<0.01	0.02	<0.01
Pacific Hagfish	0.04	0.01	0.04	0.01
Halfbanded Rockfish	0.03	0.01	0.01	0.01
Greenstriped Rockfish	0.03	0.01	0.04	0.01
Starry Rockfish	0.03	<0.01	<0.01	<0.01
Widow Rockfish	0.02	0.01	0.02	0.01
Squarespot Rockfish	0.02	<0.01	<0.01	<0.01
Shortbelly Rockfish	0.02	0.02	0.60	0.33
Copper Rockfish	0.02	<0.01	<0.01	<0.01
Yelloweye Rockfish*	0.01	<0.01	<0.01	<0.01
Spotted Ratfish	0.01	<0.01	<0.01	<0.01
Cowcod*	<0.00	<0.01	<0.01	<0.01
Chilipepper	<0.00	<0.01	0.04	0.02
Pacific Sanddab	<0.00	<0.01	0.20	0.05

Table C4. Mean lengths (cm) and standard error of some species of fishes observed in visual surveys by sub-region. Rebuilding species denoted by an *.

	North			Central			South			Total		
Common Name	**n**	**Avg.**	**SE**	**n**	**Avg.**	**SE**	**n**	**Avg.**	**SE**	**n**	**Avg.**	**SE**
Bocaccio*	42	28.8	0.8	63	46.9	1.0	35	57.8	1.4	140	44.2	1.1
Canary Rockfish*	112	33.3	0.3	226	37.5	0.3	72	41.0	0.8	410	37.0	0.2
Chilipepper	25	23.5	2.0	30	24.2	1.4	3	20.0	1.5	58	23.7	1.1
Cowcod*	1	44.0	-	7	47.9	3.3	11	61.1	2.5	19	55.3	2.4
Lingcod	37	42.4	2.1	145	49.6	1.6	135	63.3	1.4	317	54.6	1.1
Pacific Sanddab	2	15.0	2.0	208	24.2	0.4	30	18.7	0.8	240	23.4	0.4
Vermilion Rockfish	9	40.7	2.4	32	40.3	0.9	631	46.5	0.2	672	46.1	0.2
Widow Rockfish	35	32.0	1.0	61	29.2	0.8	4	16.5	0.3	100	29.7	0.7
Yelloweye Rockfish*	16	34.2	3.3	28	30.1	2.5	42	49.2	1.9	86	40.2	1.7
Yellowtail Rockfish	70	34.7	0.6	90	34.3	0.6	34	42.7	1.6	194	35.9	0.5

Appendix D. A pilot rebuilding species geodatabase to support bycatch avoidance and groundfish management

To better understand the distribution and abundance of rebuilding species to support fishing and management decisions, The Nature Conservancy (TNC) worked with key partners in Central California on a pilot project to develop a repository of available spatially-referenced observations and catch data for rebuilding species. The repository consists of a rebuilding species geodatabase and map products of positive sightings or catch of rebuilding species in Central California (roughly the region between Point Reyes and Morro Bay, California).

We compiled observational and catch data on rebuilding species from a broad array of data sources from willing research and agency partners in Central California. The repository combines information collected at a variety of different spatial scales, with different survey and fishing tools, and for different purposes. Spatial resolution for each observation is dependent on data source and confidentiality requirements, as requested by the data owner. Data from these sources has been used, with permission, in aggregate form to create a "best available map" of rebuilding species locational information to inform fishing and management decisions (Figs. D1-2).

Data sources include:

Moss Landing Marine Labs (MLML) – Submersible, remotely-operated vehicle (ROV), and Video Lander observational data; and research fishing surveys

Marine Applied Research and Exploration (MARE) – ROV observational data

Monterey Bay Aquarium Research Institute (MBARI) – ROV observational data

National Marine Fisheries Service (NMFS) – Groundfish Ecology trawl and hook and line survey, Fisheries Research Assessment and Monitoring Division (FRAM) Coastwide Groundfish Bottom Trawl Survey (presence data)

California Department of Fish and Wildlife (CDFW) – ROV observational data

California Ocean Science Trust (CalOST) – Submersible and ROV observational data

Monterey Bay National Marine Sanctuary (MBNMS) – Submersible and ROV observational data

California State University, Monterey Bay (CSUMB) – Camera sled and ROV observational data

The Nature Conservancy (TNC) – ROV and Video Lander observational data

Cordell Bank National Marine Sanctuary (CBNMS) – Submersible observational data

Greater Farallones National Marine Sanctuary (GFNMS) – Submersible and ROV observational data

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) – SCUBA surveys

REEFCHECK – SCUBA surveys

Reef Environmental Education Foundation (REEF) – SCUBA survey

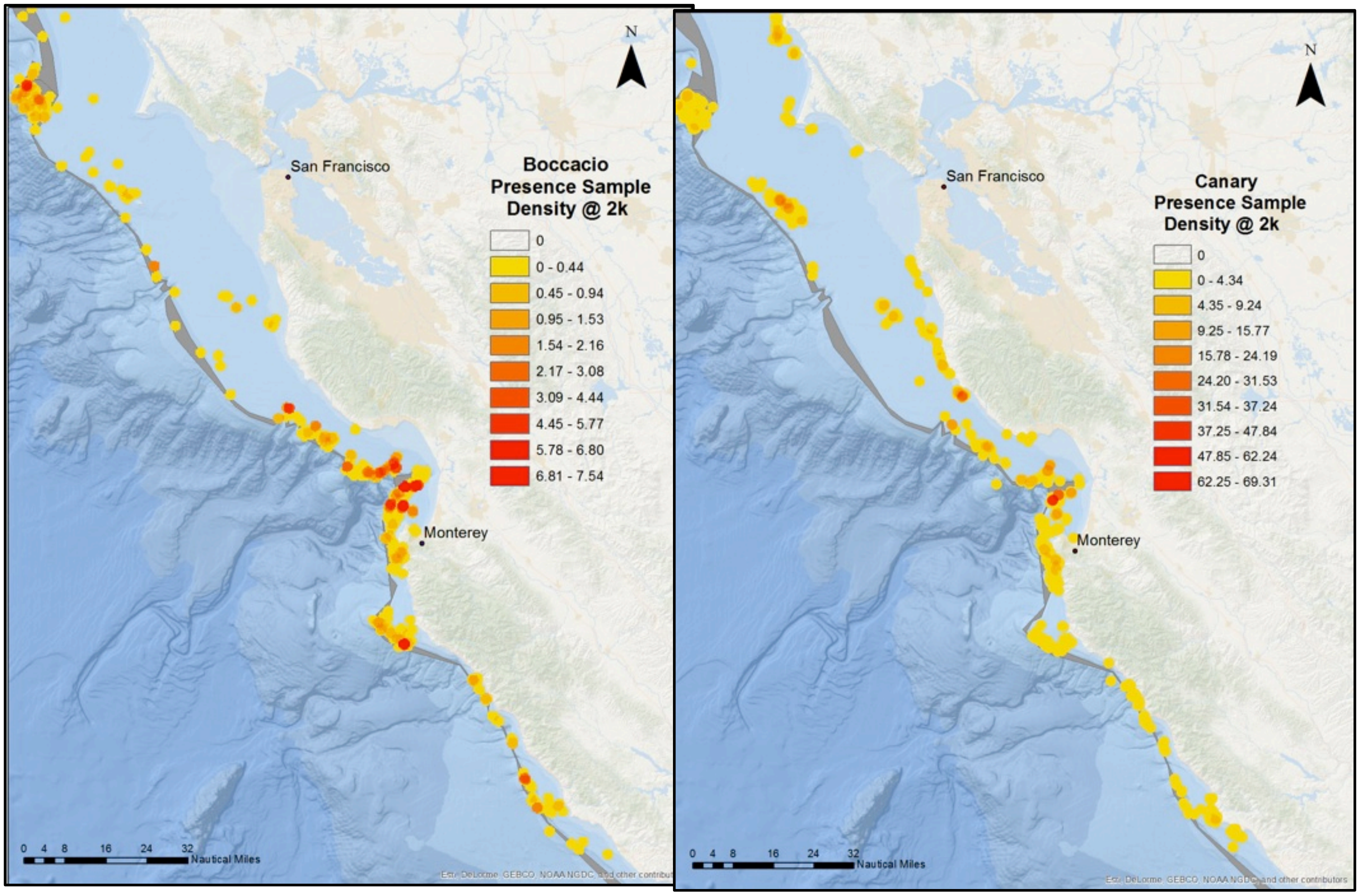


Figure D1. Documented presence, compiled from 31 datasets assembled from 14 organizational sources, for Bocaccio (n=1934 observations) and Canary Rockfish (N=5262 observations) along the central coast of California between 2000 – 2015, from nine different data collection modes including trawl, visual, and fishing surveys. Densities represent the number of observations in a 2 km radius buffer around observations based on ArcGIS analyses. The grey contour lines represent the Trawl Rockfish Conservation Area (RCA).

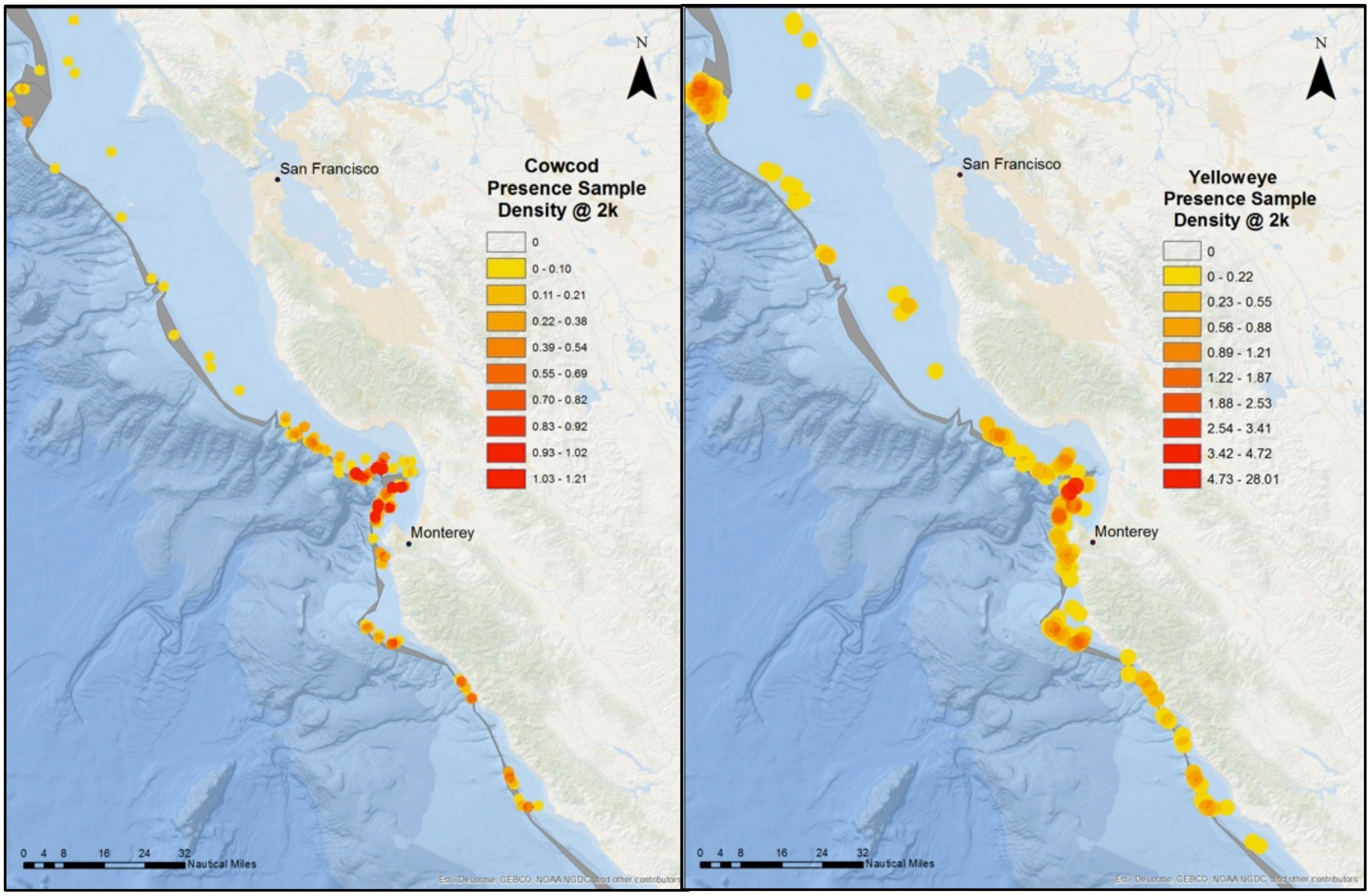


Figure D2. Documented presence, compiled from 31 datasets assembled from 14 organizational sources, for Cowcod (N=396 observations) and Yelloweye Rockfish (N=799 observations) along the central coast of California between 2000 – 2015, from nine different data collection modes including trawl, visual, and fishing surveys. Densities represent the number of observations in a 2 km radius buffer around observations based on ArcGIS analyses. The grey contour lines represent the Trawl Rockfish Conservation Area (RCA).