NMFS Southwest Fisheries Science Center

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Agency Report to the Technical Subcommittee of the Canada-U.S. Groundfish Committee

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With contributions from John Field, Tom Laidig, Aaron Mamula, Nick Wegner, and William Watson

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A. AGENCY OVERVIEW

The Southwest Fisheries Science Center (SWFSC) conducts fisheries and marine mammal research at three laboratories in California. Activities are primarily in support of the Pacific Fishery Management Council, the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), as well as a number of international fisheries commissions and conventions. The Science and Research Director is Kristen Koch and the Acting Deputy Director is Dr. Toby Garfield. All SWFSC divisions have supported the essential needs of the NMFS and the Pacific Fishery Management Council (PFMC) for groundfish, including as active members of the PFMC's Scientific and Statistical Committee (SSC), the Groundfish Management Team, and other management teams and advisory bodies.

The Center is headquartered in La Jolla, which hosts three divisions that conduct research on a wide range of Pacific and Antarctic fish, marine mammals, sea turtles, and marine habitats; the Antarctic Ecosystem Research Division (led by Dr. George Watters), the Marine Mammal and Turtle Division (led by Dr. Lisa Ballance), and the Fisheries Resources Division (led by Dr. Gerard DiNardo). The Fisheries Resources Division (FRD) conducts research on groundfish, large pelagic fishes (tunas, billfish and sharks), and small coastal pelagic fishes (anchovy, sardine and mackerel), and is the only source of groundfish research at the La Jolla facility. The Fisheries Research Division is also the primary source of federal support for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys that have taken place along much of the California coast since 1951. Researchers at FRD have primary responsibility for ichthyoplankton collections, studies of species abundance and distribution (including responses to climate variability), systematics, and the application of early life history information to stock assessments.

The Fisheries Ecology Division (FED) in Santa Cruz is directed by Dr. Steve Lindley, and four of the six research branches conduct studies focused on groundfish. Dr. Steve Lindley is currently the acting supervisor of the Early Life History and Habitat Ecology teams. The Early Life History team (led by Dr. Susan Sogard through March 2018) focuses on early life history of fishes, salmonid ocean and estuarine ecology, habitat ecology, and the molecular ecology of fishes. The Habitat Ecology team (led by Dr. Mary Yoklavich through December 2017) utilizes a number of survey tools, e.g., visual surveys conducted with remotely operated vehicles (ROV), human-occupied submersibles, autonomous underwater vehicles (AUV), scuba, etc., to study deep-water demersal communities. The Molecular Ecology team (led by Dr. Carlos Garza) studies the molecular ecology and phylogeny salmonids and groundfish. The Fisheries Assessment group (led by Michael Mohr) conducts research and stock assessments in salmon population analysis, economics, groundfish, and fishery oceanography of salmonids and groundfish. Dr. John Field leads the Groundfish Analysis team within the Fisheries Assessment group, which supports the needs of NMFS and the Pacific Fishery Management Council, one of which is groundfish stock assessment. The Groundfish Analysis team also conducts the annual pelagic juvenile rockfish recruitment and ecosystem assessment survey along the West Coast. Specific objectives of the FED groundfish programs include: (1) collecting and developing

information useful in assessing and managing groundfish stocks; (2) conducting stock assessments and improving upon stock assessment methods to provide a basis for harvest management decisions at the PFMC; (3) characterizing and mapping biotic and abiotic components of groundfish habitats, including structure-forming invertebrates; (4) disseminating information, research findings and advice to the fishery management and scientific communities; and (5) providing professional services (many of which fall into the above categories) at all levels, including inter-agency, state, national and international working groups. A scientist from the Ichthyoplankton Lab in La Jolla currently represents the SWFSC on the Pacific Council's Groundfish Management Team.

The Environmental Research Division (ERD) is led by Dr. Toby Garfield and has researchers located in both Monterey and Santa Cruz. The ERD is a primary source of environmental information to fisheries researchers and managers along the west coast, and provides science-based analyses, products, and information on environmental variability to meet the agency's research and management needs. The objectives of ERD are to: (1) provide appropriate science-based environmental analyses, products, and knowledge to the SWFSC and its fishery scientists and managers; (2) enhance the stewardship of marine populations in the California Current ecosystem, and other relevant marine ecosystems, by understanding and describing environmental variability, the processes driving this variability, and its effects on the production of living marine resources, ecosystem structure, and ecosystem function; and (3) provide science-based environmental data and products for fisheries research and management to a diverse customer base of researchers, decision-makers, and the public. The ERD also contributes oceanographic expertise to the groundfish programs within the SWFSC, including planning surveys and sampling strategies, conducting analyses of oceanographic data, and cooperating in the development and testing of environmental and biological indices that can be useful in preparing stock assessments.

B. MULTISPECIES STUDIES

B1. Research on larval rockfish at the SWFSC

Contact: William Watson (william.watson@noaa.gov)

Over the past year (2017-2018) the Ichthyoplankton Ecology and Molecular Ecology labs within the Fisheries Resources Division in La Jolla completed a project that used molecular methods to identify larval rockfishes collected from winter core CalCOFI stations between 1998 and 2013. The overall aim of this research was to develop a species-specific larval rockfish time-series and then use this data to evaluate how spawning patterns of different rockfishes responded to environmental factors and the presence of rockfish conservation areas in Southern California between 1997 and the present. We found that the mean abundances of 6 of 8 rockfishes targeted by fishers and 3 of 7 non-targeted species increased significantly between 1998 and 2013 throughout southern California. We also found that 75% of targeted species increased at a greater rate within the CCA than at locations with similar environmental conditions outside of

the reserves. By contrast, there was no difference in rate of change for the untargeted species within or outside the CCA. Results from this research were published in a University of San Diego MS thesis (Chen 2017) and in an article in the Royal Society Open Science (Thompson et al. 2017)

We began a project to extract otoliths from the genetically-identified rockfish larva and measure otolith band widths and core size. We will then test the hypothesis that higher maternal investment (larger core) and recent growth (wide outer bands) correlate positively with recruitment success between 1998 and 2013 in southern California. This project is being led by Noah Ben-Aderet, a FATE-funded postdoctal fellow.

We continued a project that is using next generation sequencing to bulk-identify rockfish (and other fish) species presence/absence from plankton samples. We collected plankton samples for this research from CalCOFI stations, in the Santa Barbara Channel, in Santa Monica Bay and along transects spanning northern California, Oregon and Washington. We first manually identified fish eggs and larvae under the microscope and by sequencing small amounts of tissue from individuals. We then returned the ichthyoplankton into the appropriate plankton sample and masticated contents of several samples. After extracting DNA from each sample we conducted Mi-seq metabarcoding runs to sequence part of the mitochrondrial 12S gene. Comparison of metabarcoding sequence to reference sequences available on GenBank indicated that metabarcoding was able to identify with high precision which fish species, including rockfishes, which were present in each sample. However, reference sequences were not available for some species and these were only capable of being identified to the genus or family level. We are currently preparing additional samples for Mi-seq runs and building up a 12S reference library using tissue from fishes of known identity. This research is being led by Dovi Kacev, a NRC postdoctoral researcher.

Finally, we have continued updating larval fish identifications from historic CalCOFI surveys to current taxonomic standards. We currently have completed all surveys from July 1962 through 2014, and by the end of this year expect to have completed analysis of samples collected in winter and spring of 2015 and 2016. This will provide a 52-year time series of larval abundances of the rockfish species visually identifiable as larvae (*Sebastes aurora*, *S. diploproa*, *S. goodei*, *S. jordani*, *S. levis*, *S. paucispinis*).

B2. Pelagic Juvenile Rockfish Studies

Several studies have been published or are in press related to ongoing studies of both the role of pelagic juvenile rockfish in the ecosystem as forage, particularly relative to other pelagic juvenile and forage species (Wells et al. 2017, Ainley et al. 2017, Friedman et al. in press). Other studies have focused on the high abundance levels, and trends in the diversity of pelagic juvenile rockfish and other groundfish, as well as other components of the forage assemblages over time, specifically with respect to the unusual diversity observed during the marine heatwave of 2014-

2016 (Sakuma et al. 2016, Santora et al. 2017). Several of these studies (and others that are in preparation or review) have focused The Wells et al. (2017) manuscript in particular highlights the complex role of climate as a forcing mechanism of trophic interactions in the Central California region (particularly the Gulf of the Farallons). That analysis demonstrated that variable ocean conditions (such as reduced upwelling) can lead to poor survival and abundance of pelagic juvenile rockfish, which in turn leads common murres (*Uria aalge*) who rely on pelagic juvenile rockfish during the breeding season in most years to switch feeding instead on adult northern anchovies, which are found closer to shore. This in turn leads to an increase in predation of outmigrating juvenile salmon, which co-occur with anchovies, which has the potential to result in substantive increases in early ocean survival of commercially and ecologically important salmon populations, particularly as the seabird colonies recover from historical population impacts (Figure 1).

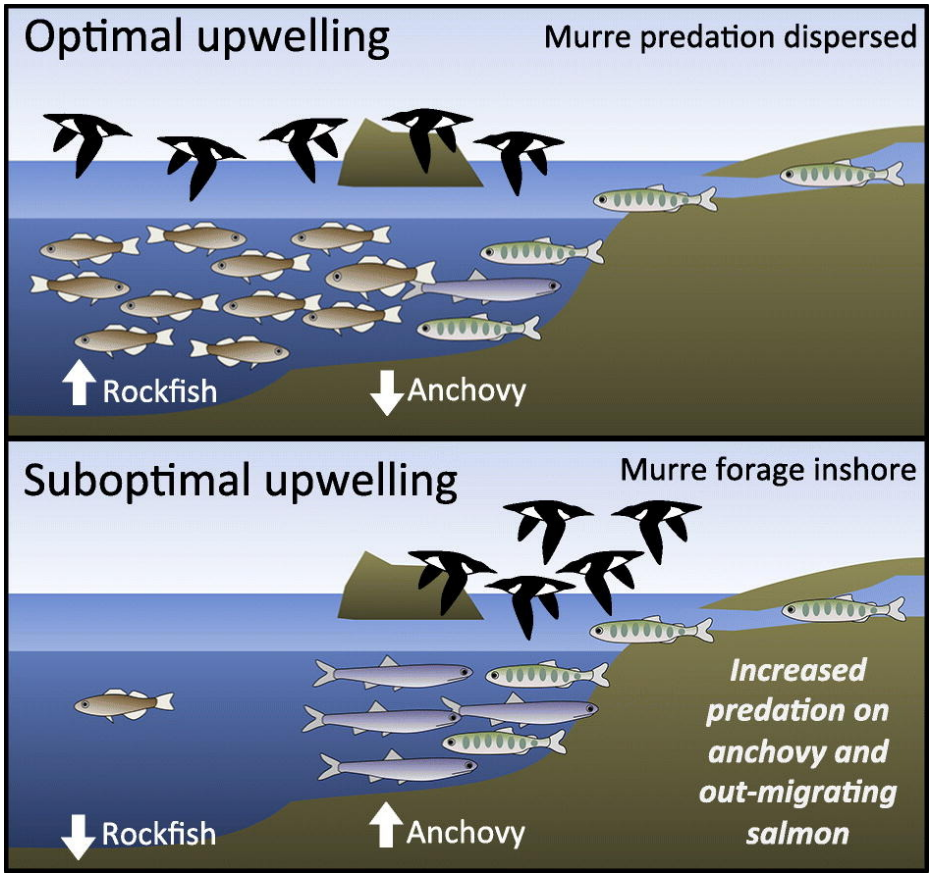


Figure 1: Conceptual figure of the complex interactions among pelagic juvenile rockfish, northern anchovy, outmigrating ocean entry salmon and common murres in the Gulf of the Farallons ecosystem (Central California).

C. BY SPECIES, BY AGENCY

C.1.Rockfish barotrauma and release device research at SWFSC La Jolla Lab

Contact: Nick Wegner (nick.wegner@noaa.gov)

The Genetics, Physiology, and Aquaculture program at the SWFSC continues to evaluate post release survival of rockfishes (*Sebastes* spp.) suffering from barotrauma. Over the past few years we have used commercially available descending devices to release rockfishes tagged with acoustic transmitters containing depth and accelerometer sensors in order to monitor long-term survival and recovery from barotrauma. This work reveals relatively high survival rates, although there are differences between the five species studied (Bank Rockfish, *S. rufus*, Bocaccio, *S. paucipinis*, Cowcod, *S. levis*, Starry Rockfish, *S. constellatus*, Sunset Rockfish, *S. crocotulus*). Over the two years we have focused efforts on examining post-release survival of juvenile Cowcod, the species that dictates many groundfish management decisions in southern California. Because of a rebounding population, juvenile Cowcod are becoming more frequently encountered by recreational fishers. To date, we have acoustically tagged 15 juvenile Cowcod in coastal areas (100-120m depth) off San Diego, and preliminary data suggest high post-release survival for these smaller size classes.

In addition to tagging juvenile Cowcod, we have implemented a cooperative program with the recreational fishing community in San Diego to measure the effectiveness and angler preference for five different types of commercially available devices. While descending devices are now being more commonly used by the recreational fisheries to release fish at depth, quantitative estimates of device effectiveness are limited. This work is showing that all descending devices are effective in recompressing rockfish experiencing barotrauma and that if fish are caught in 75-100m of water, descending fish to a depth of 50 m results in successful release approximately 92% of the time. Although all descending devices work, at-sea conditions, vessel type, and fish size tend to influence effectiveness and user preference of different device types. This work currently being prepared for publication.

C.2. Reproductive Ecology Studies

Several studies related to the reproductive ecology of rockfishes were published over the past year. Dick et al. (2017) completed a meta-analysis of fecundity in the genus *Sebastes*, in which a hierarchical modeling framework was developed to produce robust estimates for data informed species as well as predictive distributions for unobserved species and subgenera. Importantly,

the result documents that weight-specific fecundity increases with size in nearly all observed Sebastes species, confirming that the assumption of proportionality between mature female biomass and total egg production is inappropriate for most *Sebastes* stock assessments. The results are now considered to be the most appropriate fecundity values for use in West Coast stock assessments. Lefebvre et al. (2018) followed on the theme with a manuscript documenting both multiple brooding and abortive maturation in chilipepper rockfish (*S. goodei*) using macroscopic and histological methods. That analysis also provides a revised fecundity function for use in stock assessments that accounts for the both greater fecundity and increased probability of producing multiple broods with size. A closely related laboratory study in preparation by Susan Sogard and Sabrina Beyer (FED/SWFSC) has also found that in rosy rockfish (*S. rosaceus*), larger females also produced disproportionately more larvae, as well as more overall broods, with up to five broods per year documented I some individuals. Moreover, females in a low ration treatment produced 60% fewer larvae a year compared with well-fed females in a high ration treatment. These studies highlight the importance of continued studies in reproductive ecology to better inform stock assessment models, and data collected during continued research sampling of relative fecundity of chilipepper and yellowtail rockfish continued in the 2017-2018 spawning season, with analysis and publication of the time series expected in late 2018 or early 2019.

C3. Stock Assessments

In 2017, SWFSC staff led benchmark stock assessments on Blue/Deacon rockfish (Dick et al. 2017) and California Scorpionfish (Monk et al. 2017), as well as update assessments on Bocaccio (Xi and Field 2017) and Blackgill rockfish (Field and Xi 2017). All were done using the Stock Synthesis 3 assessment framework.

Blue and Deacon Rockfishes (*Sebastes mystinus* and *Sebastes diaconus*, respectively) are two genetically distinct species, with the Blue Rockfish dominant in the species composition from Monterey Bay, CA and south and Deacon Rockfish prominent from Monterey Bay, CA and north through Oregon. Catches of Blue and Deacon Rockfishes cannot be separated in either the commercial or recreational catches and it is not possible to disentangle the landings of the two species. Two independent stock assessments were conducted to approximate spatial variations in species composition, exploitation history, and other factors affecting the dynamics.

Spawning output of Blue/Deacon Rockfish in California was estimated to be 37% of unfished spawning output. In California, spawning output declined rapidly in the 1970s and early 1980s, falling below the minimum stock size threshold in the early 1980s, followed by a steady recovery since the late 2000s. In Oregon, spawning output was estimated to be 296 million eggs in 2017, which when compared to unfished spawning output equates to a depletion level of 69% in 2017. In general, spawning output has been trending slightly downwards, with the exception of an increase in the 1990s due to several high recruitment years. Stock size is estimated to be at the

lowest level throughout the historic time series in 2017, but the stock is estimated to be well above the management target of B40%.

The stock of California Scorpionfish (*Scorpaena guttata*) was assessed in 2017 in in U.S. waters off the coast of southern California (south of Pt. Conception) to the U.S./Mexico border. California Scorpionfish was previously assessed in 2005 with not age and growth data. The 2017 assessment incorporated age data from the NWFSC bottom trawl survey, and a number of fishery-independent sources of data including all of the southern California Publicly Owned Treatment Works monitoring trawl surveys. The predicted spawning biomass from the base model generally showed a slight decline prior to 1965, when information on recruitment variability became available. A short, but sharp decline occurred between 1965 and 1985, followed by a period cyclical variation in spawning biomass, and then a decline from 2000 to 2015. The stock showed increases in stock size in 2015 due to a combination of strong recruitment and smaller catches in 2015 and 2016. The 2016 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass at 54.3%.

The southern stock of Bocaccio (*Sebastes paucispinis*), from the U.S./Mexico Border ot Cape Blanco, OR) was declared rebuilt in 2017, as the stock assessment update indicated a 2017 spawning output of 48.6% of the estimated unfished level. The stock had been increasingly steadily since the early 2000s, driven initially by a very strong 1999 year class, and most recently with a very strong 2013 year-class, estimated to be the largest since 1980. Since being declared overfished in 1999 a total of six benchmark assessments and three assessment updates have been conducted to determine bocaccio status and trends and evaluate rebuilding progress. In addition to limited age composition data and considerable length composition data from commercial and recreational indices, the assessment used a number of relative abundance indices, including CalCOFI larval abundance estimates from 1951 through 2016, the SWFSC pelagic juvenile abundance survey, the NWFSC bottom trawl survey, the NWFSC hook and line survey, and several recreational CPUE indices.

For Blackgill Rockfish (*Sebastes melanostomus*), the stock assessment update was consistent with the previous full assessment, which indicated that the spawning output was at relatively high levels in the mid-1970s; began to decline steeply in the late 1970s through the 1980s (consistent with the rapid development and growth of the targeted fishery); and reached a low point of approximately 20% of the unfished level in the mid-1990s. Since that time, catches have declined sharply and spawning output has increased, such that the 2017 estimated larval production is nearly to the target level of 40% of the unfished larval output. Recruitment in the assessment is assumed to be deterministic, and the assessment is primarily informed by fishery age and length compositional data from commercial fisheries, as well as a relative abundance index and age and length data from the NWFSC Bottom Trawl Survey.

C4. Flatfish

The Groundfish Analysis Team at FED is currently concluding a study of fecundity of Petrale sole, for which the assessment is currently informed by a single study with data collected in the 1950s. We have processed and examined histology slides from 153 female petrale, primarily to support fecundity work but also to examine the seasonality of ovarian development, confirm homogenous development throughout the ovary, and confirm the fecundity type of the species. Based on histology, Petrale appear to be determinate batch spawners, with potential annual fecundity (maximum number of eggs to be spawned in the entire season; doesn't account for down regulation) set prior to the onset of spawning and eggs being released in several spawning events throughout the reproductive season. To date 93 fecundity subsamples from 20 females have been counted for potential annual fecundity, including samples used to verify development throughout the ovary is homogenous. Estimates range from approximately 1 million to 2.5 million eggs being released in an unknown number of spawning events throughout the season. Additionally, 43 fecundity subsamples from 14 females have been counted for estimating batch fecundity (the number of eggs released in a single spawning event). Variability is higher in batch fecundity samples, resulting in more estimates from individual females being thrown out due to high coefficients of variations between subsamples. Batch fecundity estimates range from 72,000 to 180,000 and appears to be weakly related to maternal size. Due to the variability and as batch fecundity only tells us how many eggs are released in a single event, efforts are being focused on quantifying potential annual fecundity.

D. OTHER RELATED STUDIES

D1. Demersal Communities

Contact: Tom Laidig (tom.laidig@noaa.gov)
FED HET Investigators: Joe Bizzarro, Tom Laidig, Diana Watters

The SWFSC/FED Habitat Ecology Team (HET) conducts research focused on deep-water California demersal communities. Our goal is to provide sound scientific information to ensure the sustainability of marine fisheries and the effective management of marine ecosystems, with objectives to: (1) improve stock assessments, especially of rockfish species in untrawlable habitats; (2) characterize fish and habitat associations to improve EFH identification and conservation; (3) contribute to MPA design & monitoring; and (4) understand the significance of deep-sea coral (DSC) as groundfish habitat. The HET uses a variety of underwater vehicles to survey demersal fishes, macro-invertebrates (including members of DSC communities), and associated seafloor habitats off northern, central, and southern California. These surveys have resulted in habitat-specific assemblage analyses on multiple spatial scales; fishery-independent stock assessments; baseline monitoring of MPAs; documentation of marine debris on the seafloor; and predictive models of the distribution and abundance of groundfishes and deep sea corals. The following are a few examples of recent projects conducted by the HET and

collaborators.

D2. Mapping and Visual Surveys of Seafloor Habitats and Fishes, 9-26 October 2017
Contact: Diana Watters (diana.watters@noaa.gov)

Aboard the NOAA R/V *Bell M. Shimada*, scientists used the vessel's ME70 multibeam echosounder to collect high-resolution bathymetric and backscatter (seafloor scattering strength) data at depths 30-350 meters in three areas (Figure 2) off Santa Cruz and Anacapa Islands in the vicinity of Channel Islands National Marine Sanctuary in Southern California. Approximately 96 km2 of seafloor were mapped during 13 nights of surveying. Thirty-two expendable bathythermograph (XBT) probes were deployed during the ME70 survey to obtain water column sound velocity profiles for improved accuracy of depth measurements. NMFS's SeaBED autonomous underwater vehicle (AUV), equipped with 3 cameras and strobe light, was deployed from the *Shimada* and used to survey seafloor communities and groundtruth habitat interpretations of mapped areas. Four AUV groundtruthing dives were completed during daytime, with a typical AUV deployment of 4-5 hrs. The AUV typically surveys benthic communities from 2.5-3 m above the seafloor. CTD casts were made in association with the AUV dives to obtain water column sound velocity profiles for optimal communications with the AUV during dives.

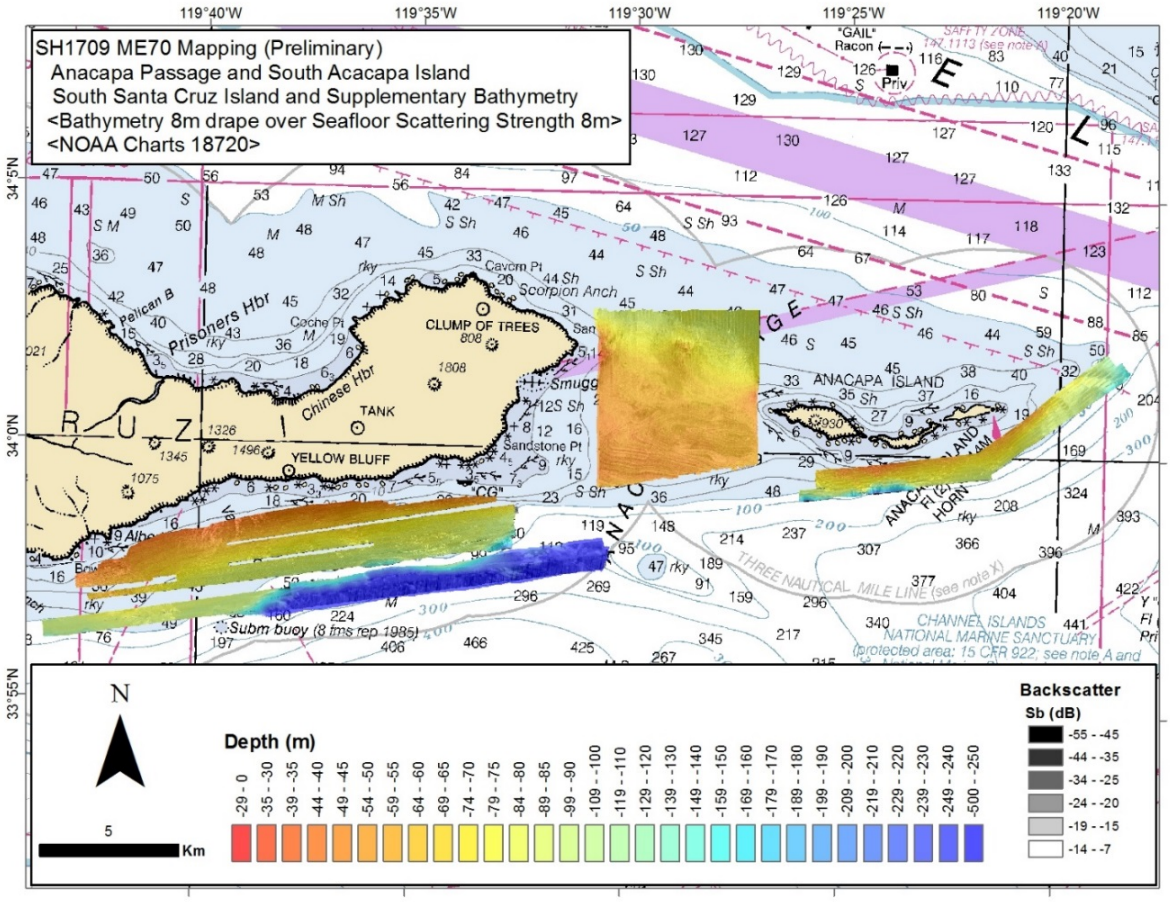


Figure 2. Study sites off Santa Cruz and Anacapa Islands in Southern California, indicating areas of bathymetric and backscatter (seafloor scattering strength) surveys using the ME70 multibeam echosounder from NOAA R/V *Bell M. Shimada* 13-25 October 2017.

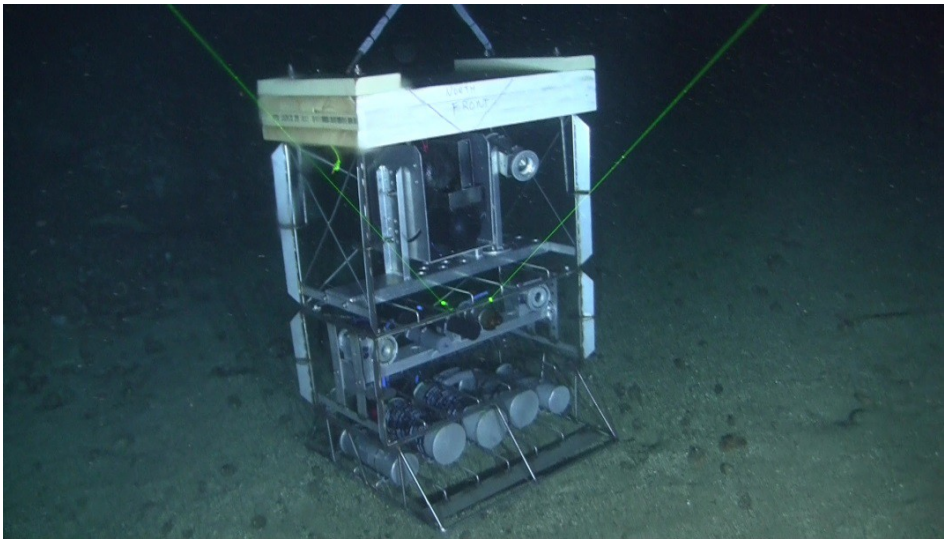
The bathymetry and backscatter data collected during this mission and a descriptive summary of these data will be submitted to NOAA Office of Coast Survey and, with OCS approval, to National Centers for Environmental Information (NCEI) for archiving and access. We currently are analyzing the visual fish and habitat data from the AUV dives (Figure 3).

Figure 3. An AUV image of the seafloor with a large golden gorgonian (*Acanthogorgia* spp.) west of Footprint Bank in 285 m of water.

D3. FY17-18 NMFS Untrawlable Habitat Strategic Initiative: Southern California Bight Test Bed, 7-26 October 2017

Contact: Tom Laidig (tom.laidig@noaa.gov)

NMFS Untrawlable Habitat Strategic Initiative (UHSI) Team completed the second year of field research in the Southern California Bight. This team is made up of researchers from the Southwest, Northwest, Alaska, and Southeast Fisheries Science Centers along with academic partners. The goal of this project is to further our understanding of the effects of mobile survey vehicles on the behavior of rockfish species living in deep rocky habitats. Surveillance platforms with paired visual and acoustic (DIDSON) cameras were launched from the F/V *Velero IV* and positioned on the seafloor by the DeepWorker manned submersible (Figure 4). Data collected from these platforms will be used to determine rockfish movement and behavior in response to a SeaBED AUV (launched from NOAA R/V *Bell Shimada*), an MLML drop camera (launched from the NOAA R/V *Shearwater*), and a manned submersible (launched from the *Velero*) in order to estimate the efficiency of these survey tools to count and measure demersal rockfish species.



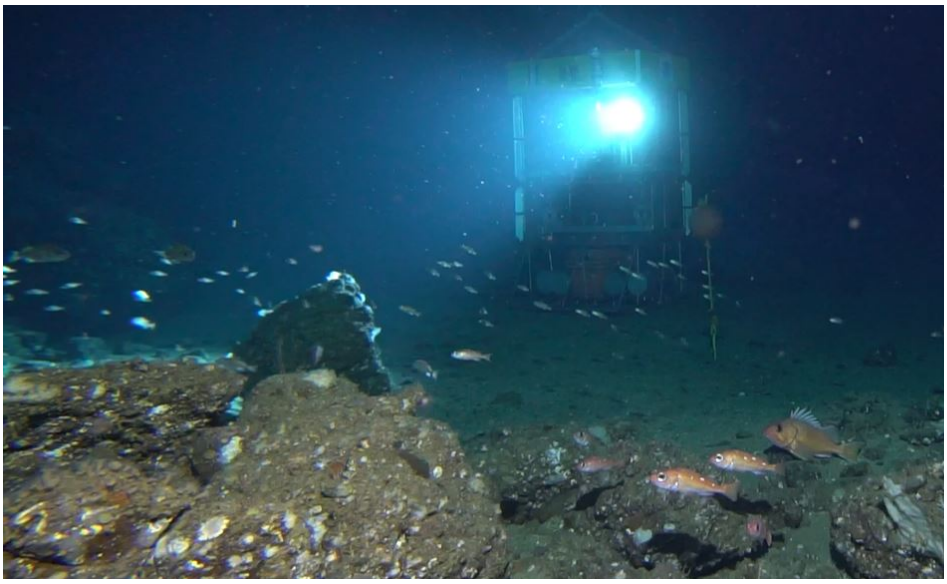


Figure 4. Top image: A surveillance platform resting on the seafloor. Lower level contains the computers and batteries, middle level contains the stereo cameras and other instrumentation, and upper level houses the DIDSON sonars and the strobe for the cameras. Image was taken from the manned submersible. For reference, the green lasers are 20 cm apart. Bottom image: The surveillance platform (with strobe flashing) as viewed from the MLML drop camera.

Three surveillance platforms were deployed each day during daylight hours on the top of Footprint Bank at depths of 120 - 130 m. To test the fish reactions, the AUV and submersible were flown past the surveillance platforms at a similar speed and height above the seafloor used during visual rockfish surveys and the MLML drop camera was deployed within 10m of the front of the platforms. During the study, we successfully completed 20 drop camera deployments, 33 passes near the platforms with the AUV, and 43 passes with the manned submersible. Over 450,000 paired images (one color and one black & white) were shot from the platform cameras and 100 hours of DIDSON readings were taken during the study.

For each vehicle pass, we will count the number of fishes of each species, determine their height above the sea floor, and measure the total length for all individuals >15 cm for all fishes within 5 m of the platforms. Counts will begin 4 min before and continue until 4 min after a vehicle pass. An example of the change in fish counts is shown in Figure 5. This represents the number of fish observed for 4 min before the drop camera reached the sea floor. A large increase in the number of fishes present is observed starting 30 sec before the drop camera reached the sea floor. Finally, we will ascertain the fish's reaction (using the DIDSON sonars) by measuring the distances and directions travelled by individual fishes in response to the presence of survey vehicles.

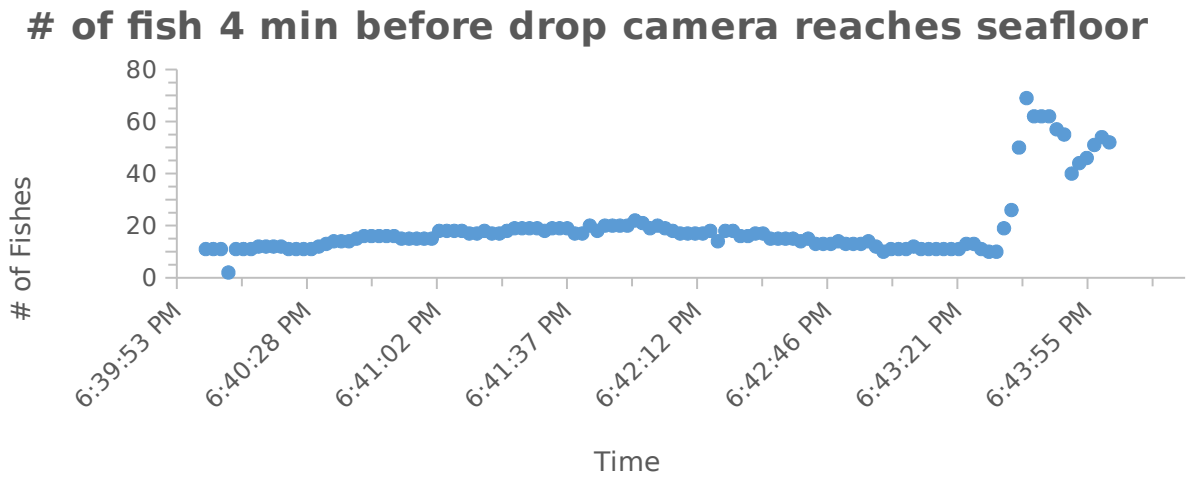


Figure 5. The number for fish over time counted from images taken from surveillance platforms before the drop camera reaches the sea floor. There is a large uptick in the number of fish observed starting about 30 second before the drop camera touches down on the sea floor.

This is the second year of a two-year field season study by the UHSI team in southern California. During the remainder of FY18, we will continue to collect fish count data from the stereo camera images and movement data from the DIDSON sonars. Once all the data is collected, we will analyze trends and produce a report with recommendations and possible biases for each vehicle.

In a related study, members of the AFSC and the UHSI team aboard the Shimada deployed stereo camera systems (developed at AFSC) across Footprint Bank. These camera systems recorded an image every 30 seconds and were left on the sea floor for up to 24 hours. Over the course of the cruise, there were 32 deployments of the camera systems. Using this data, the researchers will develop an independent density of rockfishes across the bank and compare these densities to ones previously estimated for certain rockfish species on Footprint Bank. This is a trial of their camera system to determine if it can be used to make detailed density estimates in a localized area using this relatively simple and inexpensive method.

D4. Anthropogenic noise generated by mobile survey vehicles

Contact: Tom Laidig (tom.laidig@noaa.gov)

During our UHSI cruise in southern California, HET members and researchers at Moss Landing Marine Laboratories placed acoustic devices on each surveillance platform to record ambient

sound. The sounds created by each survey vehicle and support vessel were distinct and could be identified from the acoustic sonogram. This data will be examined in conjunction with the DIDSON and imagery data to determine how sound may influence rockfish behavior. These data also help to corroborate vehicle position and when each vehicle made its nearest pass to the surveillance platforms. Three times the platforms were left overnight due to poor sea conditions for retrieval. Interestingly, during these overnight times, the hydrophones picked up rockfish calls.

D5. Complete Habitat Use Database (HUD) Upgrade

Contact: Joseph Bizzarro (joe.bizzarro@noaa.gov)

During 2017, data entry was completed for all 117 species of groundfish identified in the current PFMC Groundfish Fishery Management Plan (FMP). Dr. Bizzarro will begin working with Todd Hay (NWFSC) during May 2018 to finalize the HUD, link it to a mapping program, and make it publically available through the NWFSC/FRAM Data Warehouse (https://www.nwfsc.noaa.gov/data/map).

D6. Update California Substratum Map for Cross-Shelf Benthic Habitat Suitability Modeling

Contact: Joseph Bizzarro (joe.bizzarro@noaa.gov)

A collaborative effort between NOS, NMFS, and BOEM personnel was initiated in 2016 to create habitat suitability models for corals and infaunal invertebrates and will continue until through 2018. A substratum map of the region offshore of California was initially created for the 2005 PFMC review of EFH for West Coast groundfishes and merged with a companion map that was produced for the Pacific Northwest; however, the California portion of this coast-wide map has not been updated since. The region off Washington and Oregon, however, has been substantially updated with new information, and contains a more detailed estimation of seafloor induration (soft, mixed, hard categories) than the California portion (soft, hard). During 2017, the entire coast-wide substratum map (25 m x 25 m raster) was updated to include all newly acquired seafloor induration collected since the last such effort during the 2012 EFH synthesis, and to include hard, mixed, and soft habitat types in California waters. A data quality layer is now being compiled to improve the utility of the map for modeling purposes by weighing the reliability of various seafloor induration data. This update was a necessary precursor to coral and infauna modeling efforts, which are currently being conducted, but the new West Coast Substratum Map has widespread utility for any similar spatial study that incorporates induration data off the U.S. West Coast.

D7. Create Diet Composition Database

Contact: Joseph Bizzarro (joe.bizzarro@noaa.gov)

In its current format, the HUD documents spatial information for FMP groundfish species.

Predator and prey information is contained in a very generalized manner. The incorporation of quantitative diet composition data, using the 47 prey categories that were established during the recent 5-year EFH review, would add considerable utility to the database and make it a complete ecological repository for all FMP groundfishes. A queriable database that contains all documented information on the spatial associations and trophic relationships of FMP groundfishes would be of great value for the consideration of ecological approaches to fisheries management. It also could be used to identify data gaps and focus future research efforts, including hypothesis testing and meta-analyses, and to inform data collection priorities during the West Coast Groundfish Bottom Trawl Survey. Quantitative diet composition information already has been collected and synthesized for 18 FMP groundfish species. The goal during 2017-18 is to locate, synthesize, and enter diet composition data for the remaining 99 species, resulting in the creation of a complete ecological database for all FMP groundfishes. This work is ongoing with an expected completion date by the end of the calendar year.

D8. Investigate Ecological Relationships among U.S. Pacific Coast Groundfishes
Contact: Joseph Bizzarro (joe.bizzarro@noaa.gov)
During 2015-2016, a study of the diet composition and foraging ecology of 18 FMP groundfish species was completed and is available online at Environmental Biology of Fishes (Bizzarro et al 2017). Building on the findings and limitations of this study and the progression of studies D5 and D7, an expanded ecological study will be initiated to incorporate several additional species and to investigate both aspects of the ecological niche – spatial associations and trophic relationships. This project also will enable the investigation of spatio-temporal dietary variation, which is believed to be a major driver of dietary differences but was beyond the scope of the original study. A better understanding of the major prey taxa of groundfishes, identification of important foraging habitats, and the determination of ecological guilds have major implications for the development of ecosystem-based management approaches to groundfishes. This work is ongoing, and the findings of this research will be submitted to a leading, peer-reviewed journal for publication during late 2018 or early 2019.

D9. Catch estimation methods in sparsely sampled mixed stock fisheries
Contact: E.J. Dick (Edward.Dick@noaa.gov)
An ongoing project led by Nick Grunloh (UCSC/Center for Stock Assessment Research) and E.J. Dick (FED), with participation by Don Pearson (FED), John Field (FED) and Marc Mangel (UCSC/CSTAR) is focusing on the development of Bayesian hierarchical modeling approaches to be applied to historical and recent rockfish catch data and species composition samples in California fisheries, in order to improve estimates and quantify uncertainty in those estimates. Furthermore, the team has developed a Bayesian model averaging approach for inferring spatial pooling strategies across the over-stratified port sampling system. This modeling approach, along with a computationally robust system of inference and model exploration, will allow for

objectively comparing alternative models for estimation of species compositions in landed catch, quantification of uncertainty in historical landings, and an improved understand the effect of the highly stratified, and sparse, sampling system on the kinds of inference possible, while simultaneously making the most from the available data. The methodology, currently a work in progress, was reviewed by a PFMC SSC methodology review panel (which included reviewers from the Center for Independent Experts) in March of 2018.

D10. Community sustainability cooperatives

Contact: Aaron Mamula (aaron.mamula@noaa.gov)

Investigators: Rosemary Kosaka (FED, SWFSC) and Aaron Mamula (FED, SWFSC)

This project began in 2016 and was detailed in last year's TSC report. In FY2018, we plan to finalize a NOAA Technical Memorandum detailing results from our study of the Monterey Bay Fisheries Trust and Morro Bay Community Quota Fund. We have also started a second phase of this project which will add data from the Half Moon Bay, CA area.

D11. Social networks and peer effects among groundfish fishermen

Contact: Aaron Mamula

Investigators: Aaron Mamula (FED, SWFSC), Nancy Haskell (University of Dayton), Trevor Collier (University of Dayton).

Prior to the imposition of individual transferable quotas (the 'Catch Share Program') in the West Coast groundfish fishery, vessel participation in formal harvesting cooperatives was limited. Since 2011, there has been a notable rise in the number of formal harvesting cooperatives operating in the fishery. These cooperatives operate in a variety of ways: Bycatch Risk Pools aim to reduce harvesters' operational uncertainty by providing a type of insurance against unexpected harvest of constraining species, Groundfish Marketing Associations focus on improving market conditions for fishermen through brandings and marketing, and Community Quota Funds attempt to stabilize groundfish landings in particular port areas by supplying local fishermen with quota in the amounts and species-designations required to keep local vessels active. Although harvesting cooperatives tend to differ in operational methods, they work on the common principal that individual information pooled as a collective can increase productive efficiency and profitability of the harvesting sector. In late FY2016 we initiated a research project to empirically evaluate the benefits to fishing firms of participation in harvesting cooperatives. The focus of this project is to compare changes in economic and financial success of members of formal harvesting cooperatives relative to non-members.

A manuscript from this work is currently in review at the journal, *Land Economics*.

D12. VMS logbook matching update

Contact: Aaron Mamula

Investigators: Alice Thomas-Smyth (UCSC, FED, SWFSC), Cameron Speir (FED, SWFSC), Rosemary Kosaka (FED, SWFSC), Aaron Mamula (FED, SWFSC)
The SWFSC/FED/Economics group has been working with high resolution spatial data collected from vessel monitoring systems for several years. The goals of this work have been discussed in previous TSC updates but will be summarized here for completeness. Along the U.S. West Coast VMS is used primarily to enforce moratoria on fishing in various federally mandated closed areas and, as such, applies principally to groundfish fishing vessels. One goal of our work with VMS data is to create more detailed maps of the spatial distribution of groundfish fishing effort. Trawl and fixed-gear logbooks provide starting and ending positions of fishing events. VMS data, because they record vessel locations which are updated hourly, can be used with logbook and observer data to create more detailed maps of where groundfish fishing effort actually occurs. A second goal of our work with VMS data is to evaluate the spatial distributions of non-groundfish fishing effort. Since VMS units are required on all West Coast fishing vessels that have the potential to interact with groundfish, the data can be used to assess the location of fishing effort targeting other important West Coast fisheries such as Dungeness crab, salmon, and albacore. The focus of this project for FY2018 we will be completing a set of software tools that facilitate spatial analysis of VMS data in the ArcGIS environment.

D13. California Saltwater Sportfishing Survey
Contact: Rosemary Kosaka (rosemary.kosaka@noaa.gov)
Investigators: Rosemary Kosaka (FED, SWFSC)
The California Salwater Sportfising Survey was implemented in 2014 to collect information about angler effort, participation, expenditures, and preferences for different regulatory tools and target species, particularly California groundfish. Effort and participation estimates are underway and a summary report is ongoing.

D14. The Western Groundfish Conference
The 20th Western Groundfish Conference was held in Seaside, CA, February 13-16 of 2018, and included nearly 200 participants, over 80 presented papers and over 50 presented posters. Sue Sogard, Tom Laidig and John Field (FED) were on the conference organizing committee and did considerable planning for this event along with colleagues from the International Pacific Halibut Commission, the California Department of Fish and Wildlife, local academic institutions (Moss Landing Marine Labs, UCSC, UCSB), and non-governmental organizations (The Nature Conservancy). Many other FED staff helped to plan and host the conference. The TSC also sponsored the opening session of the conference entitled "*Ups and downs of descending device policy and science*," other sessions included biology, ecology, habitat, stock assessment and management.

D15. Collaborative Research Efforts to Collect Biological Data
Contact: Melissa Monk (Melissa.monk@noaa.gov)
We have been working with two collaborative research programs to collect much needed biological data on nearshore rockfishes. The California Collaborative Fisheries Research Project

(led by Dr. Rick Starr at Moss Landing Marine Lab and Dr. Dean Wendt at Cal Poly) is a fishery-independent hook-and-line survey to monitor the rockfish stock within the Marine Protected Area (MPA) network along the California Coast. The CCFRP charters Commercial Passenger Fishing Vessels (CPFVs or charter/party boats) and samples fixed grid cells both within the MPAs and at adjacent reference sites. In 2017 the CCFRP expanded from MLML and Cal Poly to a coastwide project and now includes 5 universities. We are working with each of these universities to collect both otoliths for age and growth and also fin clips for genetic analysis. In 2017, MLML and Cal Poly collected approximately 330 pairs of otoliths, and Humboldt State University collected 221 pairs of rockfish otoliths.

Dr. Dean Wendt's research group at Cal Poly conducts an onboard observer survey aboard the CPFV vessels that uses the same methodology as the CDFW's California Recreational Fisheries Survey (CRFS). In addition to observing approximately 40 trips per year, the research group has started collecting otoliths from rockfish species aboard the CPFV vessels. The group collected 445 pair of otoliths from CPFVs in 2017.

E. GROUNDFISH PUBLICATIONS OF THE SWFSC, 2017 – PRESENT

E1. Primary Literature Publications

Ainley, D.G., Santora, J.A., Capitolo, P.J., Field, J.C., Beck, J.N., Carle, R.D., Donnelly-Greenan, E., McChesney, G.J., Elliott, M., Bradley, R.W. and Lindquist, K. 2018. Ecosystem-based management affecting Brandt's Cormorant resources and populations in the central California Current region. Biological Conservation 217:J 407-418.

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Madrigal, B., Stimpert, A.K., Yoklavich, M.M. and W.W. Wakefield. 2017. Anthropogenic noise generated by mobile vehicles used to survey rockfishes in the Channel Islands, California [abstract]. Journal of the Acoustical Society of America 141(5):3865.

Miller, R.R., J.C. Field, J.A. Santora, M.H. Monk, R.Kosaka and C. Thomson. 2017. Spatial valuation of California marine fisheries as an ecosystem service. Canadian Journal of Fisheries and Aquatic Sciences 74: 1732-1748. doi.org/10.1139/cjfas-2016-0228.

Santora, J.A., E.L. Hazen, I.D. Schroeder, S.J. Bograd, K.M. Sakuma and J.C. Field. 2017. Impacts of ocean climate variability on biodiversity of pelagic forage species in an upwelling ecosystem. Marine Ecology Progress Series 580: 205–220. https://doi.org/10.3354/meps12278.

Santora, J.A., Sydeman, W.J., Schroeder, I.D., Field, J.C., Miller, R.R. and B.K. Wells. 2017. Persistence of trophic hotspots and relation to human impacts within an upwelling marine ecosystem. Ecological Applications 27(2):560-574.

Sogard, S.M., and S.A. Berkeley. 2017. Patterns of movement, growth, and survival of adult sablefish (Anoplopoma fimbria) at contrasting depths in slope waters off Oregon. Fishery Bulletin 115(2):233-251.

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and prey-switching by a seabird predator impact juvenile salmon survival. Journal of Marine Systems 174: 54–63.

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E2. Other Publications

Bjorkstedt, Eric P., Garcia-Reyes, M., Losekoot, M., Sydeman, W., Largier, J. and B. Tissot. 2017. Oceanographic context for baseline characterization and future evaluation of MPAs along California's North Coast. Technical report to California Sea Grant for Projects R/MPA-31A, R/MPA-31B, and R/MPA-31C.

Chen, D.C. 2017. Larval Rockfish Diversity Abundance Dynamics in Association with a Marine Protected Area in the Southern California Bight. MS Thesis, University of San Diego.

Dick, E.J., Berger, A., Bizzzarro, J., Bosley, K., Cope, J., Field, J., Gilbert-Horvath, L., Grunloh, N., Ivens-Duran, M., Miller, R., Primitiva-Johnson, K., and B.T. Rodomsky. 2017. The combined status of blue and deacon rockfishes in U.S. waters off California and Oregon in 2017. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/

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Field, J.C. and X. He. 2018. Stock assessment update of blackgill rockfish, *Sebastes melanostomus*, in the Conception and Monterey INPFC areas for 2017. Pacific Fishery Management Council, Portland, Oregon.

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He, X., and J. Field. 2017. Effects of recruitment variability and fishing history on estimation of stock-recruit relationships: Three case studies from U.S. West Coast fisheries. In: Report of the

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Monk, M. H. ,He, X., and J. Budrick. 2017. Status of the California Scorpionfish (*Scorpaena guttata*) Off Southern California in 2017. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/.

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