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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Edited by Melissa Monk

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

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 John Crofts assumed the role of Deputy Director on September 1, 2019. John Crofts was formerly a NOAA Corps Commander who spent most of his NOAA Corps career involved in NMFS and specifically, SWFSC science. All SWFSC divisions support 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 (division director position currently unfilled), and the Fisheries Resources Division (led by Dr. Annie Yau). 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 three of the four research branches conduct studies focused on groundfish. The FED recently underwent a reorganization due to supervisor retirements and new hires. Dr. Steve Lindley is currently the acting supervisor of the Fisheries Economics team. The Molecular Ecology team (led by Dr. Carlos Garza) studies the molecular ecology and phylogeny salmonids and groundfish. Dr. John Field now oversees a larger Fisheries Assessment Group with three teams, Fisheries and Ecosystem Oceanography (led by Dr. John Field), Habitat and Groundfish Ecology (led by Dr. E.J. Dick) and Fisheries Assessment Modeling (led by Dr. Michael O'Farrell).

All of the teams within the Fisheries Assessment Group support the needs of NMFS and the Pacific Fishery Management Council, one of which is groundfish stock assessment. 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 Fisheries Resource Division in La Jolla currently represents the SWFSC on the Pacific Council's Groundfish Management Team, and several scientists from the Fisheries Ecology Division in Santa Cruz currently serve on the Pacific Council's Scientific and Statistical Committee.

There is also much collaboration among the three teams within the Fisheries Assessment Group. The Fisheries Assessment Modeling team primarily conducts stock assessments for both groundfish and salmon, focusing on research to advance fisheries assessment methods. The Habitat and Groundfish Ecology team utilizes a number of survey tools, e.g., visual surveys conducted with remotely operated vehicles (ROV), human-occupied submersibles, autonomous underwater vehicles (AUV), scuba, hook-and-line fishing and captive rearing, to study deep-water demersal communities and groundfish ecology. The Fisheries and Ecosystem Oceanography team within the group is responsible for leading the annual pelagic juvenile rockfish recruitment and ecosystem assessment survey along the West Coast.

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)
Larval Rockfish Investigators: Andrew Thompson, William Watson

During the past seven years (2013-2020), the ichthyoplankton and molecular ecology laboratories at the SWFSC, La Jolla, built species-specific larval rockfish time-series by genetically sequencing individual larvae from winter CalCOFI samples between 1998 and 2013. Results of this work are currently published in a master's thesis and two peer-reviewed scientific publications, and time-series from blue rockfish (*Sebastes mystinus*) were used by the Pacific Fisheries Management Council to inform the status of this stock.

In 2019-2020 we are continuing to analyze this data. For example, a SIO master's student (Jessica Freeman) is utilizing nonparametric multivariate and Bayesian analyses to better understand drivers of larval rockfish dynamics. In addition, a postdoctoral researcher (Noah Ben-Aderet) removed otoliths from a subset of six species collected between 1998 and 2013. He has completed measuring otolith core width as a proxy for maternal investment and outer band width as a proxy for growth rate. He is currently conducting analyses to test whether environmental conditions during parturition affect maternal investment and if maternal investment and/or environmental conditions impact rate of growth. The ultimate goal of this project is to identify mechanisms that impact rockfish recruitment and determine if larval condition can predict recruitment success.

In 2019-2020, we initiated another genetics project seeking to identify rockfishes in CalCOFI samples. Rather than sequencing individual larvae, we extracted DNA from the ethanol in which CalCOFI samples are stored. We then used metabarcoding techniques similar to those used for environmental DNA analysis to sequence DNA from all fishes in a sample. It turned out that the traditional primers used for fish metabarcoding (MiFish 12S) discriminated poorly among rockfish species. Hence, we designed rockfish-specific metabarcode primers within the cytochrome *b* gene. We metabarcoded DNA from four stations per year between 1998 and 2019 and used recently developed bioinformatics pipelines to quantify the number of DNA reads for each species in a sample. Initial results demonstrate that we are able to identify most rockfish species from ethanol preservative. The metabarcoding work is led by Zachary Gold, a Ph.D. student from UCLA. The metabarcode work will be one of the chapters of his dissertation thesis. Zack is graduating in 2020 and a manuscript on this effort should be ready for submission to a peer-reviewed journal in late 2020.

We began in 2019-2020 a collaboration with the NWFSC to explore larval rockfish dynamics before, during, and after the 2014-2016 Marine Heatwave. We obtained from Ric Brodeur and Toby Auth rockfish larvae collected annually off the Newport Hydrological Line from 2013-2019. Prior to the closure of the SWFSC due to the coronavirus pandemic, we completed tissue extractions from all larvae (approximately 1800) and sequenced and identified approximately 1000. We were on track to complete identification by the end of April, but had to postpone lab work due the closure of the Center. Once the SWFSC reopens, we should be able to complete the identifications in about a month if we can work at our pre-shutdown pace.

Finally, we continued to update larval fish identifications from historic CalCOFI surveys to current taxonomic standards. We currently have completed all surveys from July 1961 through December 2015, and samples collected during the primary rockfish reproductive seasons, winter and spring, of 2016-2019. This provides a 58-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. macdonaldi, S. paucispinis*).

B.2 Research on Juvenile Rockfish at the SWFSC

The Rockfish Recruitment and Ecosystem Assessment survey completed it's 37th survey year in June of 2010. Survey results indicated continued declines for pelagic young-of-the-year (YOY) rockfish (*Sebastes* spp.) and sanddabs (*Citharichthys* spp.), with strongly negative anomalies following near average levels in 2018 and very high abundance levels in the 2013-2017 period. YOY Pacific hake (*Merluccius productus*) were at low abundance in central California, although were they fairly abundant in the Southern California Bight. No YOY lingcod (Ophiodon elongates) were encountered in the 2019 survey. A manuscript detailing the relationship between pelagic juvenile rockfish abundance and oceanographic conditions was reported on extensively in the 2019 TSC report, and published later in 2019 (Schroeder et al., 2019. This analysis evaluated the strong relationship between high YOY rockfish abundance and greater contributions of Subarctic water to California Current source waters, which help in the interpretation of recruitment patterns and trends.

An ongoing study pivots from the temporal analysis to spatial distribution patterns of YOY rockfish, providing an analysis of the climatology of pelagic YOY rockfish distribution in years in which coastwide data are available (between 2004 and 2019), to better inform general distribution patterns by species and guild, as well as to provide guidance on the need to use coastwide data to inform recruitment indicators in stock assessments. The analysis indicates that approximately half of the variance in the time series during climatology years is shared broadly among regions, but that the other half tends to be explained by differential abundance patterns north and south of major biogeographic boundaries, such as Cape Blanco, Cape Mendocino and Point Conception. This effort follows on the heels of a somewhat similar effort for pelagic thalacians (salps and pyrosomes) reported in Miller et al. (2019), albeit for a shorter time series (2011-2019). A manuscript is in preparation and should be submitted or completed by the 2021 TSC report.

C. BY SPECIES, BY AGENCY

C1. Nearshore rockfish stock assessments

C1.a. Gopher and Black and Yellow Rockfish Complex Stock Assessment

Contact: Melissa Monk (melissa.monk@noaa.gov)

The SWFSC conducted a full stock assessment for gopher rockfish and black-and-yellow rockfish as a complex in U.S. waters off the coast of California south of Cape Mendocino (40° 10' N. latitude) using data through 2018. Gopher rockfish and black-and-yellow rockfish are genetically indistinguishable and historical catches between the two species could not be reliable separated. This was the first stock assessment to include data for black-and-yellow rockfish and the second full assessment for gopher rockfish (last assessed in 2005). Since 2000, annual total landings of catch and discards of the complex have ranged between 70-169mt, with landings (catch + discards) in 2018 totaling 92 mt. The 2019 estimated spawning output relative to unfished equilibrium spawning output is above the target of 40% of unfished spawning output at 43.82% (95% asymptotic interval: 33.57%-54.06%).

C2.b. Cowcod Stock Assessment

Contact: E.J. Dick (edward.dick@noaa.gov)

The SWFSC conducted a full stock assessment of *Sebastes levis* ("Cowcod") for the Southern California Bight (SCB), defined as U.S. waters off California and south of Point Conception (34° 27' North latitude). Waters north and south of the SCB are not considered in the assessment due to sparse data. Depletion-Based Stock Reduction Analysis was used to estimate yields for U.S. waters north of the SCB. The stock was declared overfished in 2000 and retention of cowcod was prohibited from January 2001 until January 2011. Since then, a small quota has been allocated to the trawl fishery as part of the Pacific Groundfish Trawl Rationalization Program, but retention remains prohibited in all other sectors. Reported total annual removals for cowcod over the last ten years have not exceeded 2 mt, averaging 1.3 mt per year. The 2019 stock assessment suggests the stock has increased to 57% of unfished equilibrium biomass (SB0) in 2019, with a 95% asymptotic interval (hereafter "interval") of 42% to 72%. The Pacific Fishery Management Council declared cowcod rebuilt with the acceptance of the new stock assessment.

C2. Shelf Rockfish

C2.a. Rockfish barotrauma and release device research at SWFSC La Jolla Lab

The Genetics, Physiology, and Aquaculture program at the SWFSC in La Jolla continues to evaluate the effects of barotrauma on rockfish (*Sebastes* spp.) catch and release. This work has focused on three major areas: 1. Tagging studies with acoustic transmitters to document the survival rates and sublethal effects of catch and release and barotrauma on important management species such Cowcod (*S. levis*) and Bocaccio (*S. paucispinis*) (Fig X), 2. Laboratory studies examining the sensitivity of rockfishes to hypoxia both before and immediately following laboratory induced barotrauma using hyperbaric chambers, and 3. Working with the recreational fishing community in California to measure the effectiveness and angler preference for different types of commercially available descending devices used to release rockfishes suffering from barotrauma.

Analysis of acoustic tagging work to date has shown species-specific long-term survival rates of 50.0% for Cowcod (n=46, CI= 35.7-70.5%) and 89.5% for Bocaccio (n=41, CI 80.2-99.8%). For Cowcod (which showed much lower survival rates), fish length, sea surface temperature, and dissolved oxygen levels at depth all significantly affected survival. For fish that survived, general additive models (GAMs) of post-release behavior showed that capture and barotrauma affected Cowcod and Bocaccio for up approximately 60 days post release. Dissolved oxygen also significantly affected post-release behavior. The modeled impact of dissolved oxygen on both survival rate and post-release behavior have led to on-going laboratory-based studies to examine the effects of hypoxia on Cowcod and Bocaccio behavior and physiology. Specifically this work is examining behavioral avoidance to low oxygen using a custom-built shuttle-box system, and determining the effects of hypoxia on metabolism through respirometry trials. Better understanding how low levels of dissolved oxygen contribute to mortality and rockfish behavior will allow for refinement of the catch-and-release process and the implementation of release guidelines that maximize survival. In addition, such work can provide insight into limits on rockfish suitable habitat.

Research testing the effectiveness of descending devices released 2,275 rockfish from 32 species. While there were some significant differences between device types, all devices were effective for releasing rockfishes back to depth. Initial post-release mortality (defined as all mortality events observable from the vessel while fishing) across all devices was relatively low (7.5%) in capture depths less than 100 m. These results suggest that rockfishes should be released at least half-way to the bottom (preferably directly to the bottom) for the device to be effective in minimizing post-release mortality. 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 was recently published in *Fisheries Research* by Bellquist et al. (2019).

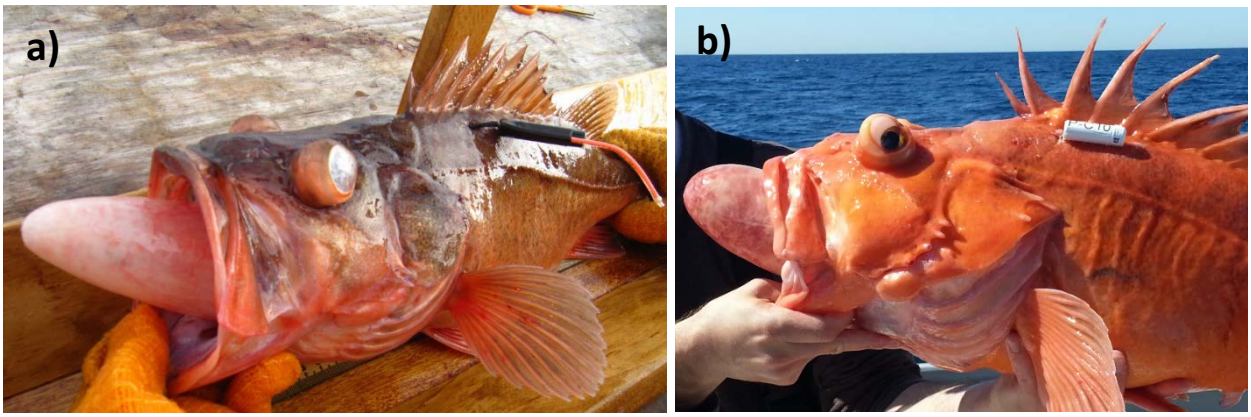

Figure X: Acoustic transmitter attachment and external barotrauma indicators for a) 47.5 cm FL Bocaccio tagged with a V9 single-anchored transmitter displaying a bloated body, everted esophagus, exophthalmia, and ocular emphysema. b) 64.0 cm Cowcod tagged with a double anchored V13 transmitter showing a bloated body, everted esophagus, exophthalmia, and the first onset of ocular emphysema (anterior-dorsal portion of eye).

D. OTHER RELATED STUDIES

D1. SWFSC FED Habitat Ecology Team 2018-19 Research on California 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. Expanding Pacific Research and Exploration of Submerged Systems Campaign

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

In 2018, a team of federal and non-federal partners initiated a new phase of collaborative ocean science off the western United States. The **EX**panding **P**acific **R**esearch and **E**xploration of **S**ubmerged **S**ystems (EXPRESS) campaign targets deepwater areas off California, Oregon, and Washington. The core focus of campaign activities is the collection of spatially explicit deepwater habitat information including multibeam, backscatter, and visual data on continental shelf, shelf edge, and slope habitats. This goal will be attained through partnerships between NOAA (NOS and NMFS), BOEM, USGS, and MBARI. From initial successes, this nascent interagency effort quickly evolved into a major field program engaging and exciting scientists and marine resource managers spanning numerous disciplines and organizations. EXPRESS members were involved in 15 research expeditions in 2019 including the 30-day deep sea coral cruise aboard the NOAA ship *Reuben Lasker* (see D3 below) and multiple west coast mapping surveys aboard the NOAA ship *Fairweather*. Six EXPRESS expeditions are currently planned for 2020.

D3. FY19 NMFS Deep-sea coral EXPRESS expedition, 1 Oct-7 Nov 2019

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

A 30-day deep-sea coral expedition was conducted 1 Oct - 7 Nov, 2019 off the coast of Washington, Oregon, and California. The expedition was supported by NMFS' Deep Sea Coral Research and Technology Program and was jointly planned and staffed by NOAA (CINMS,

NWFSC, SWFSC), BOEM, and USGS under the EXPRESS campaign (See D2 above). Research conducted during this cruise is part of the four year West Coast Deep Sea Coral Initiative. The goals of the expedition were to 1) Collect Essential Fish Habitat baseline information at 7 sites proposed for modification the Pacific Fishery Management Council, 2) Revisit previously surveyed sites to document if changes have occurred over time, 3) Survey areas of potential wind energy off southern Oregon and central California, 4) Collect information to validate BOEM supported cross-shelf habitat suitability models, and 5) Collect samples to help in identifying west coast corals and sponges and expand use of new technologies.

The expedition began in Willapa Canyon in southern Washington and worked its way south to the Catalina Basin. Two underwater survey vehicles were used; the NWFSC and PIFSC's autonomous underwater vehicle (AUV) and the Global Foundation for Ocean Exploration's (GFOE) remotely operated vehicle (ROV). Benthic habitats were surveyed for the presence of deep-sea corals (DSC), sponges, and fishes (Fig X, XX). Water chemistry, DSC, sponge, and geologic samples were collected for a variety of researchers.

Fifteen unique areas were sampled along the coast at depths from 133 - 1245 m. A total of 18 ROV and 24 AUV dives were completed along with almost 400 water samples for eDNA and POM studies. Thirty five deep sea coral, 31sponge, and 14 geologic samples were collected. Over 88 fish, 32 coral, and 32 sponge taxa were identified including some potentially new species of DSC and sponges

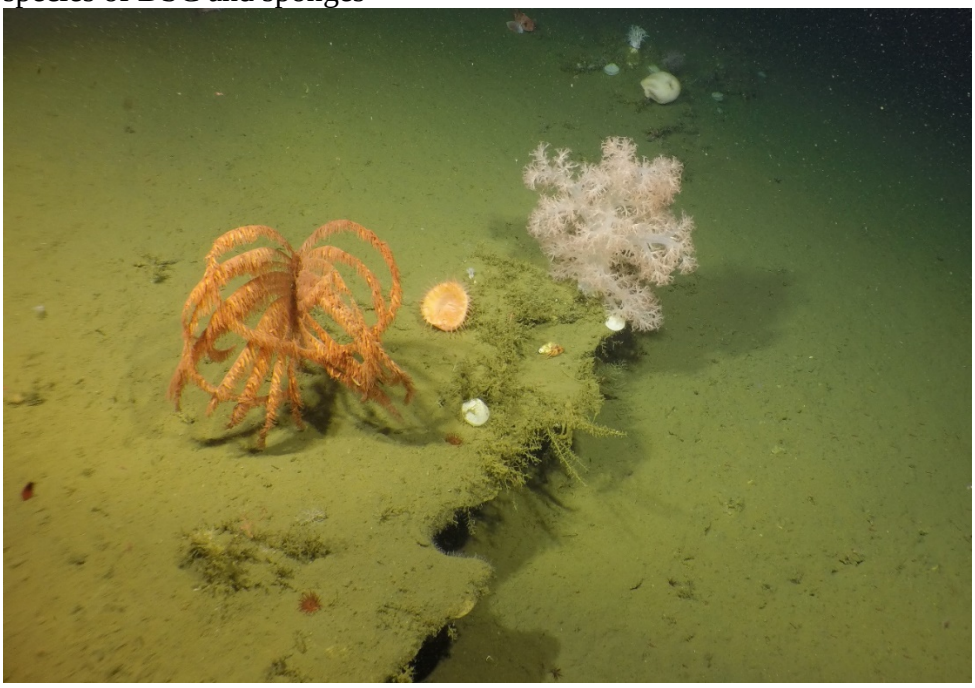

Figure X. An orange black coral (*Bathypathes* spp.) and a white soft coral (*Gersemia* spp.) at ~1100 m at Cordell Bank National Marine Sanctuary.

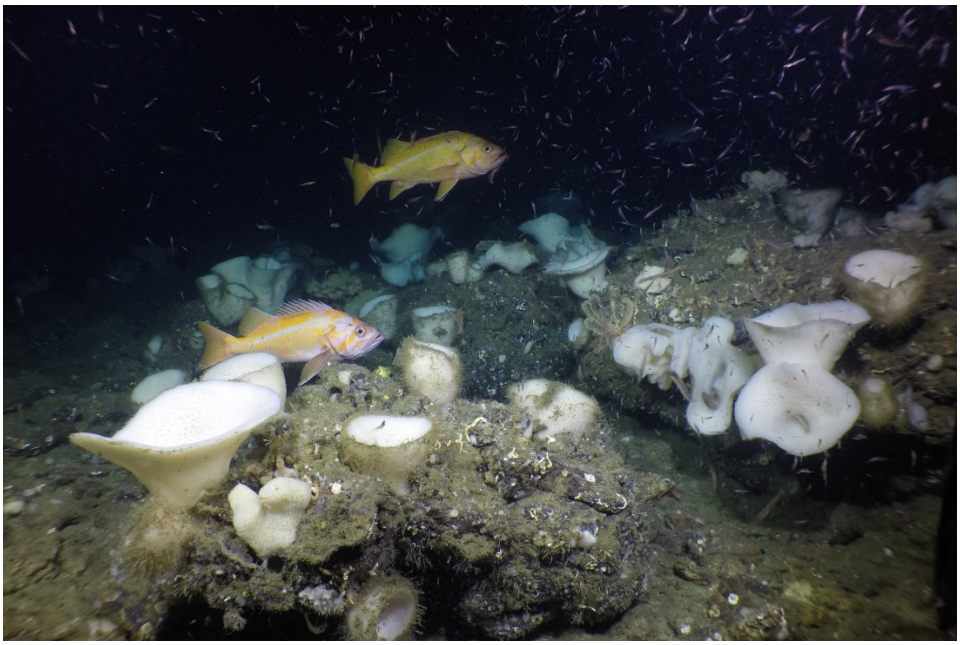

Figure XX. Two canary rockfish (*Sebastes pinniger*) within a field of sponges on Daisy Bank off central Oregon in ~140 m depth.

D4. Revise Habitat Use Database (HUD) for 5-Year Essential Fish Habitat Review
Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

During 2017, a final draft of the HUD was completed for all 117 species of groundfish identified in the current PFMC Groundfish Fishery Management Plan (FMP). The updated draft version of the HUD was then reviewed by West Coast EFH Coordinator, John Stadler, and retired NWFSC-FRAM fisheries research biologist, Waldo Wakefield. At their requests, several additions and modifications were made during 2018. A final, updated version of the HUD was be completed in May 2019. Its publicly availability through the NWFSC/FRAM Data Warehouse (https://www.nwfsc.noaa.gov/data/map) has been delayed because Todd Hay, who was integral to the QA/QC component of the project and the process of posting it on-line, left his NMFS position and no alternative plan to complete the project has yet been determined.

D5. Conduct Habitat Suitability Probability Modeling for 5-Year Essential Fish Habitat Review
Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

Support was provided to Waldo Wakefield (NWFSC, retired) and Bran Black (Oregon State University) to inform Habitat Suitability Modeling efforts for adult life stages of the 92 groundfish species that are directly managed under the PFMC Groundfish Fishery Management Plan. Using information contained in the updated HUD (see D4 above), input data were provided for latitude, depth, and habitat association inputs for Bayesian analysis. Model outputs were then displayed graphically in GIS on a scale of 0-1 that estimates the probability that any particular

location (i.e., 25 m x 25 m pixel in the output map) is suitable habitat for a particular species. Modeling efforts continued throughout 2018, and were completed during May 2019.

D6. Complete Data Quality layer for Cross-Shelf Benthic Habitat Suitability Modeling Project

Contact: Joseph J. 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 is ongoing. During 2017, a coastwide substrate map, initially created for the 2005 PFMC review of EFH for West Coast groundfishes, 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. During 2018, a data quality layer was compiled to improve the utility of the map for modeling purposes by weighing the reliability of various seafloor induration data. This updated substrate map and companion data quality layer were then used as an environmental input in coral and infauna modeling efforts. Metadata were created for the GIS products, and appropriate sections of the final report were written and submitted during the spring of 2019.

D7. Organize and Host West Coast Groundfish Food Habits Workshop
Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

With support from the West Coast Region office and Office of Sustainable Fisheries, a Groundfish Food Habits Workshop was conducted at NMFS-FED in Santa Cruz during September 24-25, 2018 with over 20 participants from 4 different NMFS Science Centers, academics, CDFW biologists, and NGOs. The main goals of the Workshop were to 1) become informed of past and current research on groundfishes, as well as pelagic fishes, sea birds, and marine mammals, 2) learn how to initiate a focused food habits program from Centers that have established programs (i.e., AFSC, NEFSC), and 3) bring together SWFSC and NWFSC scientists to plan and coordinate future work. This Workshop was highly effective in achieving its goals and helped to inform the development of the SWFSC's Center for Ecosystem Science Committee. A final technical report from the Workshop was completed and submitted to all Workshop participants, the West Coast Region and Office of Sustainable Fisheries, and SWFSC-CESC on September 24, 2019.

D8. 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. The review panel provided several recommendations for additional work, and indicated that subsequent to a future review, it would be feasible to recommend that this approach for estimating the species composition of California rockfish landings be recommended as the best available science to inform stock assessments in the 2021 stock assessment cycle.

D9. Rockfish Reproductive Ecology Laboratory and Field Studies

Contact: sabrina.beyer@noaa.gov

Ongoing studies at the SWFSC Fisheries Ecology Division in partnership with the University of California Santa Cruz highlight spatiotemporal variability in reproductive output, including the production of multiple annual larval broods among California rockfishes.

A recent laboratory study of Rosy Rockfish (*Sebastes rosaceus*) documented reproductive plasticity in response to different temperature and feeding regimes affecting female body condition, with respect to maternal size. Females released zero to five larval broods annually, with larger females releasing a greater number compared with small females. Warmer water temperature decreased the time interval between brood releases, likely reflecting faster egg and larval development at warmer temperatures. However, warmer temperature did not increase the total number of broods and was likely in tradeoff with increased metabolic demand at warmer temperature. Well-fed females, in better body condition had higher fecundity as a function of both larger sized broods and a greater number of annual broods. Conversely, mature females in poor body condition at the start of the reproductive season did not reproduce, possibly evidence of skipped spawning. Reproductive plasticity in 0, 1 or more broods a year in response to the environment likely contributes to high inter-annual variation in population larval production and may affect recruitment patterns important for fisheries. Understanding the causes and consequences of reproductive plasticity will be critical for developing sustainable management strategies and to predict the response of reproductive success and fishery productivity to changing climate conditions. A manuscript of the laboratory study is undergoing NOAA internal review in preparation for submission to a scientific journal (authors: Sabrina Beyer, Suzanne Alonzo and Susan Sogard).

Field collections of Rosy Rockfish from two locations in central and southern California over the 2019-2020 reproductive season documented spatial differences in reproductive patterns. Multiple brooding was prevalent among females in the southern population collected near Anacapa Island in the Santa Barbara Channel and much less prevalent among females collected in central California in the Monterey Bay. Overall, southern females were larger in size and highly more productive through the production of multiple larval broods. The length of the parturition season was longer in Southern California. Southern females began releasing larvae in January, two months ahead of females in central California and continued to be gestating fertilized embryos into August. In Central California, females were collected with eyed-larvae over a shorter period from March through June.

A time-series of fecundity data was expanded by one additional year of collections in Central California at Cordell Bank in January 2020 to document interannual variability in reproductive effort correlated with oceanographic conditions in a range of economically important rockfishes. Samples of gravid Chilipepper (*S. goodei*), Bocaccio (*S. paucispinis*), Yellowtail (*S. flavidus*) and Widow (*S. entomelas*) rockfishes will be incorporated into a nearly 20 year time-series of fecundity data dating back to the 1980s and 1990s and spanning a range of environmental conditions in the Central region of the California Current to better understand environmental drivers of reproductive plasticity and maternal reproductive effort.

E. GROUNDFISH PUBLICATIONS OF THE SWFSC, 2019 – PRESENT

E1. Primary Literature Publications

Baetscher, D.S., Anderson, E.C., Gilbert-Horvath, E.A., Malone, D.P., Saarman, E.T., Carr, M.H., and Garza, J.C. 2019. Dispersal of a nearshore marine fish connects marine reserves and adjacent fished areas along an open coast. Molecular Ecology 28:1611-1623.

Bellquist, L., Beyer, S. Arrington, M., Maeding, J., Siddall, A., Fischer, P., Hyde, J., Wegner, N.C. 2019. Effectiveness of descending devices to mitigate the effects of barotrauma among rockfishes (*Sebastes* spp.) in California recreational fisheries. Fisheries Research 215:44-52.

Bizzarro, J.J., Gilbert-Horvath, E.A., Dick, E.J., Berger, A.M., Schmidt, K.T., Pearson, D., Petersen, C., Kautzi, L.A., Miller, R.R., Field, J.C., and Garza, J.C. 2020. Genetic identification of blue rockfish (*Sebastes mystinus*) and deacon rockfish (*S. diaconus*) to enable life history analyses for stock assessment. Fishery Bulletin 118:37-50.

Gao, J, and Munch, S.B. 2019. A function-valued trait approach to estimating the genetic basis of size at age and its potential role in fisheries-induced evolution. Evolutionary Applications 12:964-976.

Haltuch, M.A., Brooks, E.N., Brodziak, J., Devine, J.A., Johnson, K.F., Klibansky, N., Nash, R.D.M., Payne, M.R., Shertzer, K.W., Subbey, S., and Wells, B.K. 2019. Unraveling the recruitment problem: A review of environmentally-informed forecasting and management strategy evaluation. Fisheries Research 217:198-216.

Hamilton, S.L., Kashef, N.S., Stafford, D.M., Mattiasen, E.G., Kapphahn, L.A., Logan, C.A., Bjorkstedt, E.P. and Sogard, S.M. 2019. Ocean acidification and hypoxia can have opposite effects on rockfish otolith growth. Journal of Experimental Marine Biology and Ecology 521:151245.

Haskell, N., Mamula, A. and Collier, T.C. 2019. Competition or cooperation? Peer effects in the Pacific Coast groundfish fishery. Land Economics 95:258-278.

He, X., and Field, J.C.. 2019. Effects of recruitment variability and fishing history on estimation of stock-recruitment relationships: Two case studies from U.S. West Coast fisheries. Fisheries Research 217:21-34.

Holder, A.M., and Field, J.C. 2019. An exploration of factors that relate to the occurrence of multiple brooding in rockfishes (*Sebastes* spp.). Fishery Bulletin 117:180-188.

Lefebvre, L.S., Friedlander, C.L. and Field, J.C. 2019. Reproductive ecology and size-dependent fecundity in the petrale sole (*Eopsetta jordani*) in waters off California, Oregon, and Washington. Fishery Bulletin 117:291-302.

Miller, R.R., Santora, J.A., Auth, T.D., Sakuma, K.M., Wells, B.K. Field, J.C. and Brodeur, R.D. 2019. Distribution of pelagic thaliaceans, *Thetys vagina* and *Pyrosoma atlanticum*, during a period of mass occurrence within the California Current. CalCOFI Reports 60:94-108.

Samhouri, J.F., Ramanujam, E., Bizzarro, J.J., Carter, H., Sayce, K. and, Shen S. 2019. An ecosystem-based risk assessment for California fisheries co-developed by scientists, managers, and stakeholders. Biological Conservation 231:103-121.

Schroeder, I.D., Santora, J.A., Bograd, S.J., Hazen, E.L., Sakuma, K.M., Moore, A.M., Edwards, C.A., Wells, B.K. and Field, J.C. 2019. Source water variability as a driver of rockfish recruitment in the California Current Ecosystem: implications for climate change and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 76:950-960.

Speir, C., Ridings, C., Marcum, J., Drexler, M., and Norman, K. In press. Measuring health conditions and behaviors in fishing industry participants and fishing communities using the Behavioral Risk Factor Surveillance Survey (BRFSS). ICES Journal of Marine Science.

Stimpert, A.K., B.C. Madrigal, W.W. Wakefield, and Yoklavich, M.M. 2019. Acoustic influence of underwater mobile survey vehicles on the soundscape of Pacific rockfish habitat. Journal of the Acoustical Society of America 146:EL45-EL51.

E2. Other Publications

Baetscher, D. S. 2019. Larval dispersal of nearshore rockfishes. Ph.D. dissertation, University of California, Santa Cruz. 173 p.

Dick, E.J., and He, X. 2019. Status of cowcod (*Sebastes levis*) in 2019. Pacific Fishery Management Council, Portland, Oregon. 184 p.

Gertseva, V., Matson, S.E., Taylor, I., Bizzarro, J., and Wallace, J. 2019. Stock assessment of the Longnose Skate (Beringraja rhina) in state and Federal waters off California, Oregon and Washington. Pacific Fishery Management Council, Portland, Oregon. 238 p.

Mamula, A., Kohler, C., Kosaka, R., Varney, A., and Norman, K. 2019. West Coast Fishing Communities Socio-Economic Data Model: technical documentation and guidelines for use. NOAA Technical Memorandum NMFS-SWFSC-621. 140 p.

Mamula, A. and Kosaka, R. 2019. Community Sustainability Cooperatives in Central California: Continued fishery participation through quota share holdings in the Pacific Coast groundfish fishery. NOAA Technical Memorandum NMFS-SWFSC-620. 70 p.

Mamula, A., Thomas-Smyth, A., Speir, C., Kosaka, R., and Pearson, D. 2020. Matching Vessel Monitoring System data to trawl logbook and fish ticket data for the Pacific groundfish fishery. NOAA Technical Memorandum NMFS-SWFSC-623. 76 p.

Monk, M.H., and He, X. 2019. The combined status of gopher (*Sebastes carnatus*) and black-and-yellow rockfishes (*Sebastes chrysomelas*) in U.S. waters off California in 2019. Pacific Fishery Management Council, Portland, Oregon. 200 p.

Sakuma, K. 2019. Cruise report, NOAA Ship Reuben Lasker RL-19-03, May 5 - June 7, 2019: Rockfish recruitment and ecosystem assessment. NOAA National Marine Fisheries Service, SWFSC Fisheries Ecology Division, Santa Cruz, California. 19 p.

Taylor, I. G., Gertseva, V., Stephens, A. and Bizzarro, J. 2019. Status of Big Skate (*Beringraja binoculata*) off the U.S. Pacific Coast in 2019. Pacific Fishery Management Council, Portland, Oregon.