NMFS Southwest Fisheries Science Center

Draft Agency Report to the Technical Subcommittee

of the Canada-U.S. Groundfish Committee

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Edited by Xi He and John Field

With contributions from Aaron Mamula
Susan Sogard, William Watson, Nick Wegner and Mary Yoklavich

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 Director is Dr. Francisco Werner and the Deputy Director is Kristen Koch. 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 (formerly the Protected Resources Division, led by Dr. Lisa Ballance), and the Fisheries Resources Division (led by 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), located in Santa Cruz and directed by Dr. Steve Lindley, comprises two research branches. The Fisheries Branch (led by Michael Mohr) conducts research and stock assessments in salmon population analysis, economics, groundfish, and fishery oceanography of salmonids and groundfish. The Ecology branch (led by Dr. Susan Sogard) conducts research on the early life history of fishes, salmonid ocean and estuarine ecology, habitat ecology, and the molecular ecology of fishes. 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. An FED economist 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. Identifying multiple brooding in rockfishes

Contact: Susan Sogard (susan.sogard@noaa.gov)
Investigators: David Stafford (UCSC), Lyndsey LeFebvre (UCSC), Neosha Kashef (UCSC), Sabrina Beyer (UCSC), John Field (FED, SWFSC) & Susan Sogard (FED, SWFSC)

Viviparous rockfishes (*Sebastes* spp.) most commonly produce one brood annually, however, multiple brooding within a reproductive season has been documented in a handful of rockfish species. Prevalence of multiple brooding appears to co-vary with geographic location and female size, with increased occurrence in southern California and in larger females. Our lab has observed evidence of multiple brooding in central California in chilipepper (*S. goodie*, Figure 1), rosy rockfish (*S. rosaceus*), speckled rockfish (*S. ovalis*), squarespot rockfish (*S. hopkinsi*), cowcod (*S. levis*) and boccacio (*S. paucispinis*) but the drivers of this process are unclear. Efforts are currently focused on Chilipepper rockfish off of central and southern California as a "model" population from which to better understand this phenomena, due to their healthy stock status, the observation that younger, smaller fish may also undergo atreasia (abortive maturation) which has consequences to maturity estimation, and a rich and growing dataset as a consequence of ongoing research efforts. Identification of multiple brooding, and determination of the proportion of occurrence, is essential for accurate projections of spawning output.

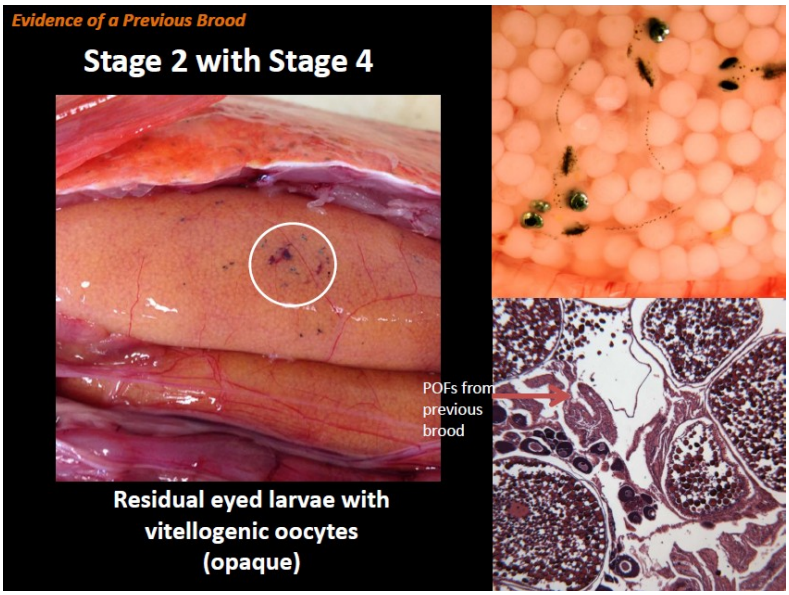


Figure 1. Evidence of multiple broods in a chilipepper rockfish. Residual larvae remaining in the ovary are evident with all three methods of macroscopic examination (left photo), microscopic inspection (top right photo) and histology (bottom right photo). POF = post-ovulatory follicle.

B2. Effects of Hypoxia & Ocean Acidification on Critical Swimming Speed & Aerobic Scope in Rockfishes (*Sebastes* spp.)

Contact: Susan Sogard (susan.sogard@noaa.gov)
Investigators: Neosha Kashef (UCSC), David Stafford (UCSC), Scott Hamilton (MLML), Evan Mattieson (MLML) & Susan Sogard (FED, SWFSC)

Future climate change predicts a 'double whammy' of reduced oxygen (hypoxia) occurring in conjunction with reduced pH (ocean acidification) in nearshore habitats of the California Current. We are using controlled laboratory experiments to test the sublethal effects of low dissolved oxygen and low pH on behavior and physiology of juvenile rockfishes. Initial experiments tested each stressor separately at 4 levels; future experiments will test varying combinations of the two stressors. Critical swimming speed was reduced for both species tested (blue and copper rockfish) at the lower levels of both stressors. Aerobic scope additionally declined with reduced dissolved oxygen levels for copper rockfish, but only at the most extreme treatment (Figure 2). Analyses are underway for other physiological responses as well as changes in gene expression associated with each treatment.

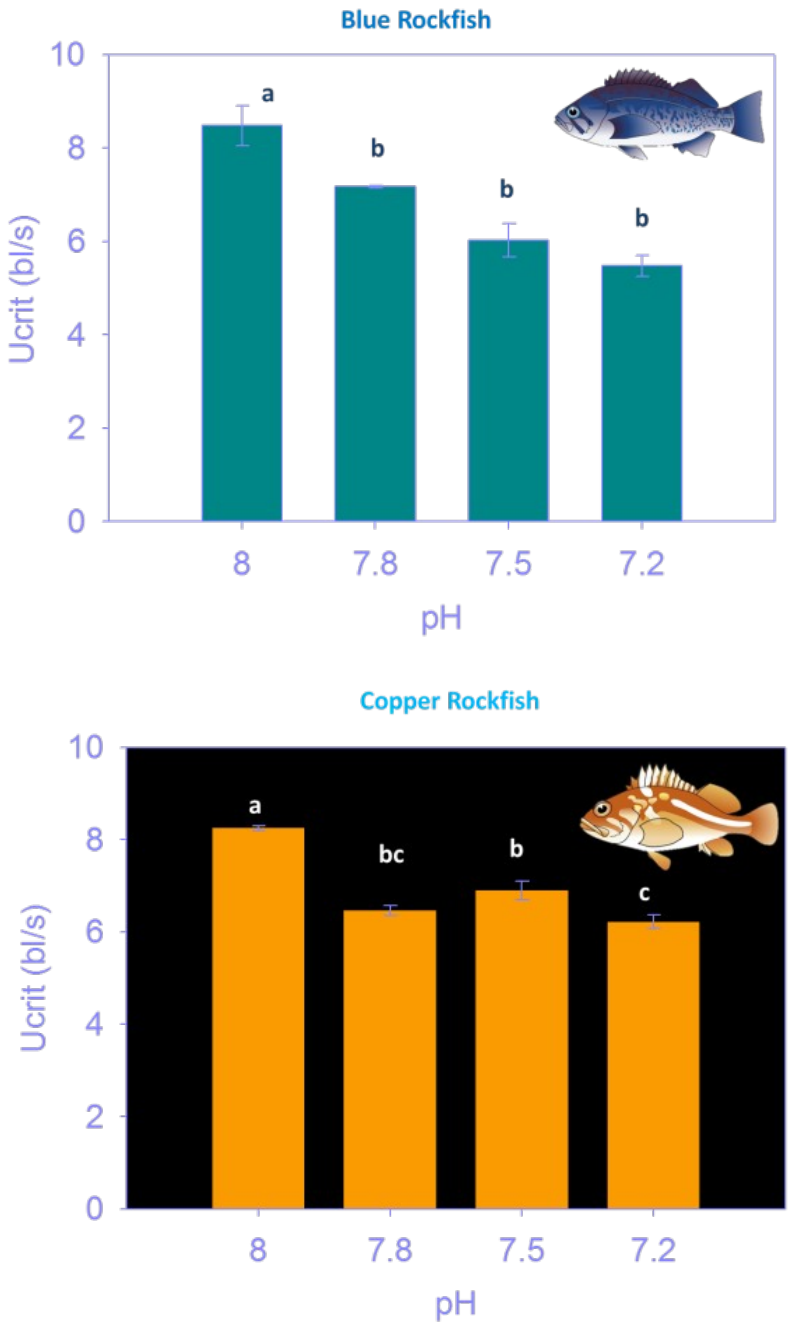


Figure 2. Critical swimming speed (Ucrit) as a function of pH in juvenile blue and copper rockfish. Bars with different letters were significantly different.

B3. Ecosystem indicators for the Central California Coast, May-June 2015

Investigators: John Field and Keith Sakuma, Fisheries Ecology Division, SWFSC

The Fisheries Ecology Division of the SWFSC has conducted an annual midwater trawl survey for pelagic juvenile (young-of-the-year, YOY) rockfish (*Sebastes spp*.) and other groundfish off of Central California (approximately 36 to 38°N) since 1983, and has enumerated most other pelagic micronekton encountered in this survey since 1990 (Ralston et al. 2015). The survey, conducted in late spring (May-June), expanded the spatial coverage to include waters from the U.S./Mexico border north to Cape Mendocino in 2004. The primary objectives are to estimate the abundance of YOY rockfish and other groundfish for stock assessments and fisheries oceanography studies, but the survey also quantifies trends in the abundance and composition of other components of the micronekton forage assemblage (including other juvenile fishes, krill, coastal pelagic species, and mesopelagic species), as well as the collection of oceanographic information (CTD casts, continuous data on surface conditions and productivity, and acoustic data) and seabird and marine mammal abundance data. The data for the 2015 survey are preliminary, and corrections have been made in catch data for previous years which have resulted in very slight changes to overall abundance trends.

Figure 3: High pelagic young-of-the-year (YOY) rockfish catches off of Central California in the Spring of 2015

The 2015 data generally show a continuation of the very high catches of juvenile rockfish and Pacific sanddab in the core, southern and northern California areas; in fact in both the core and southern areas mean catches were the highest observed in the entirety of the time series (Figure 3, and see photo). Catches of octopus, lingcod (*Ophiodon elongates*), Pacific hake (*Merluccius productus*) and several other groundfish were also high, although north of Cape Mendocino, catches of YOY rockfish and her groundfish were at very low levels in both 2014 and 2015 (R. Brodeur, unpublished data). In addition to the high catches of YOY rockfish and other groundfish, catches tended to be very high for a suite of both less commonly encountered and less consistently reported (over the course of the time series) species, including record high numbers of pelagic red crabs (*Pleuroncodes planipes*), California spiny lobster (*Panulirus interruptus*) phyllosoma (pelagic larvae), and the largely subtropical krill *Nyctiphanes simplex*. Additionally, these included the first time catches (in this survey) of the greater argonaut (*Argonauta arga*), the slender snipefish (*Macroramphosus gracilis*), and the subtropical krill

Euphausia eximia. These catches were likely a consequence of the 2014-2015 "blob" (warm water event) in the NE Pacific and the ongoing development of El Niño conditions throughout the region, however the 2015 survey results were unusual in that during past warm events (such as 1983, 1998 and 2005-06), YOY rockfish and other groundfish catches were at record low, rather than record high levels (Figure 4).

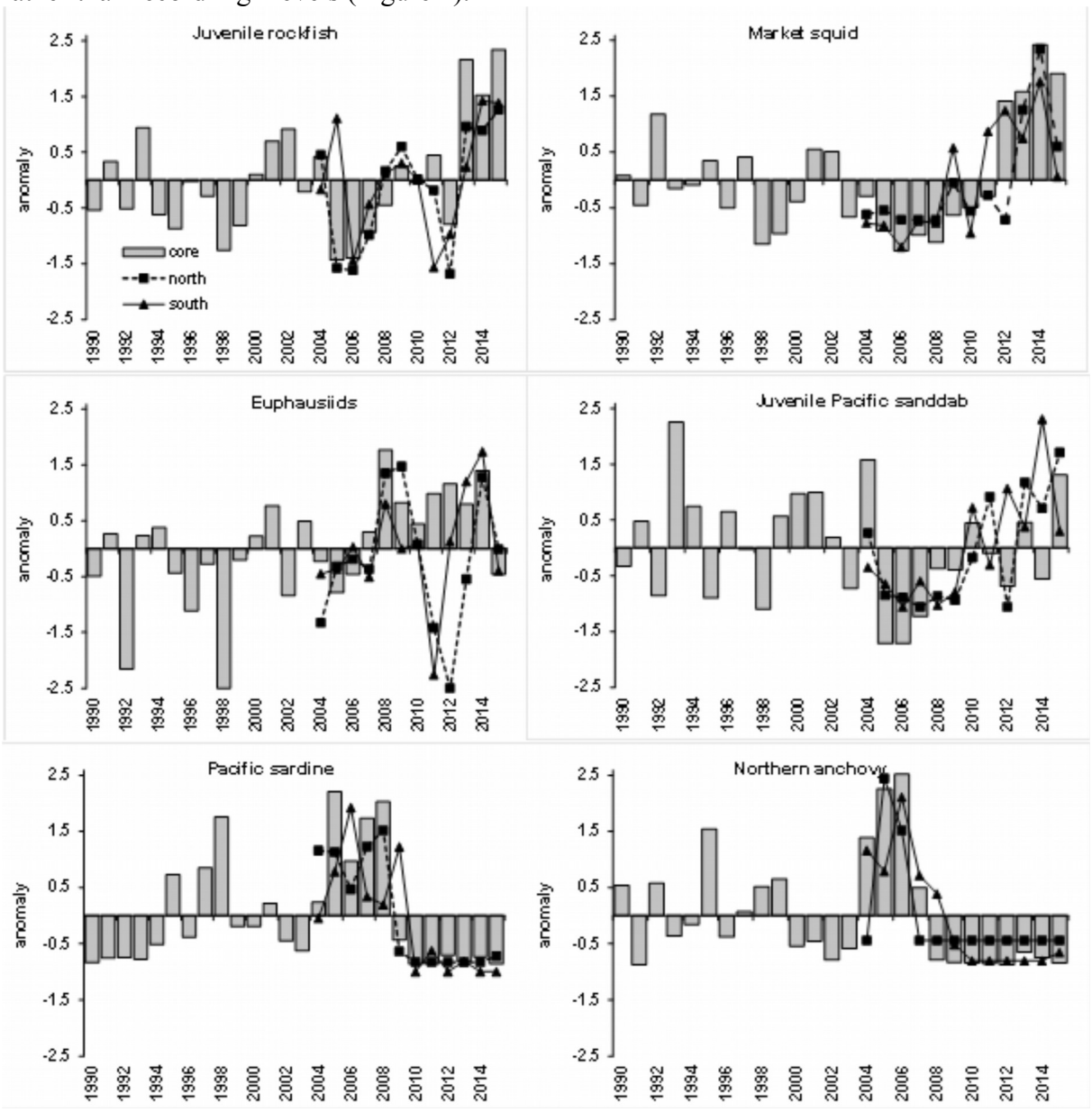


Figure 4: Long-term standardized anomalies of several of the most frequently encountered pelagic forage species from rockfish recruitment survey in the core (Central California) region (1990-2014) and the southern and northern California survey areas (2004-2014, excluding 2012 for the northern area).

B4. Research on larval rockfish at the SWFSC

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

Over the past year (2015-2016) the Ichthyoplankton Ecology and Molecular Ecology labs within the Fisheries Resources Division in La Jolla completed molecular identification of larval rockfishes collected from winter core CalCOFI stations between 1998 and 2013. The overall aim of this research is 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. Methodologically, the project involved sorting rockfishes (which can mostly only be identified to the genus level based on morphology) from ethanol-preserved plankton samples, sequencing mitochondrial DNA from individual larvae and matching larval sequences to those from adults that have previously been identified to the species level. In total, we identified 39 species from the CalCOFI samples. Preliminary results indicate that the rockfish assemblage is dominated by diminutive species not targeted by fishing pressure. However, abundances of both targeted and untargeted species increased significantly over the 15-year period (Figure 5) and targeted species were relatively more prominent in recent years. We are currently in the process of completing analysis of this data and preparing manuscripts detailing the results. We are also evaluating the utility of this data for stock assessment.

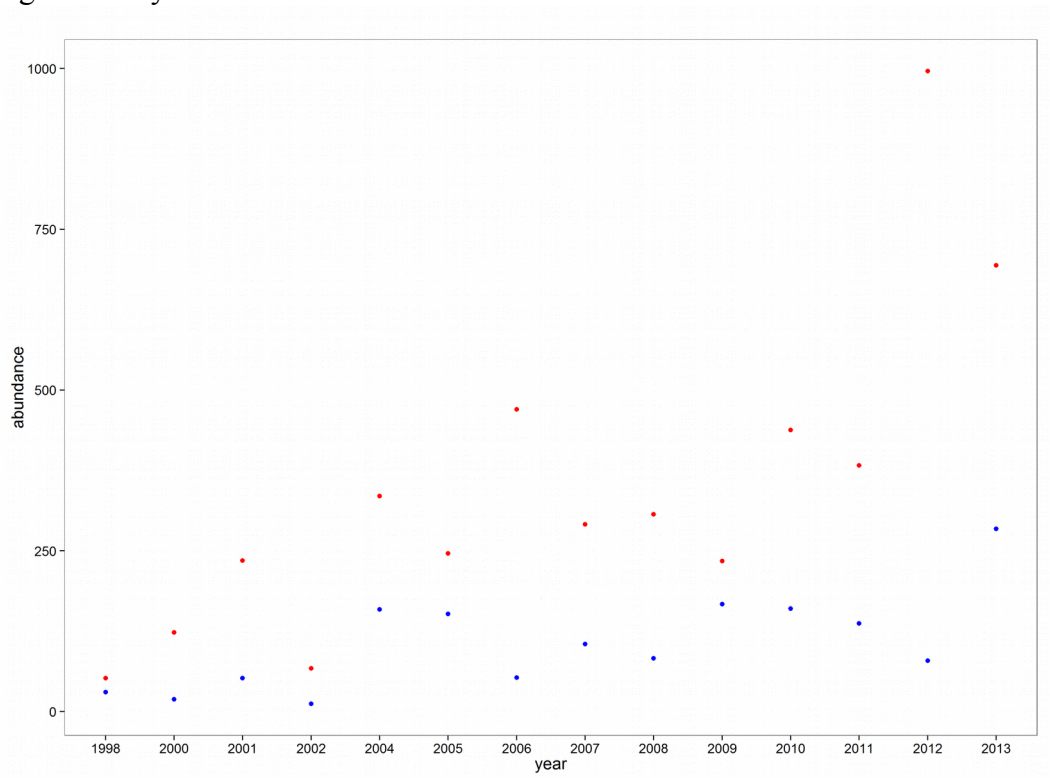


Figure 5. Total abundance of targeted (blue) and untargeted (red) rockfish larvae from winter CalCOFI samples.

In addition, we genetically identified larval rockfishes from a 2005 cruise that conducted fine-scale ichthyoplankton sampling from 95 stations witihn the southern California Bight (SCB). Here, we identified 36 rockfish species. Results indicated that targeted species were mostly

found in the western portion of the SCB while untargeted species were more widespread (Figure 6). The abundance of targeted species was negatively correlated with temperature, primary productivity and depth and positively correlated with the amount of hard substrate on the benthos. By contrast, abundances of untargeted larvae were correlated positively only with hard substrate. These findings have been published (Thompson et al. 2016).

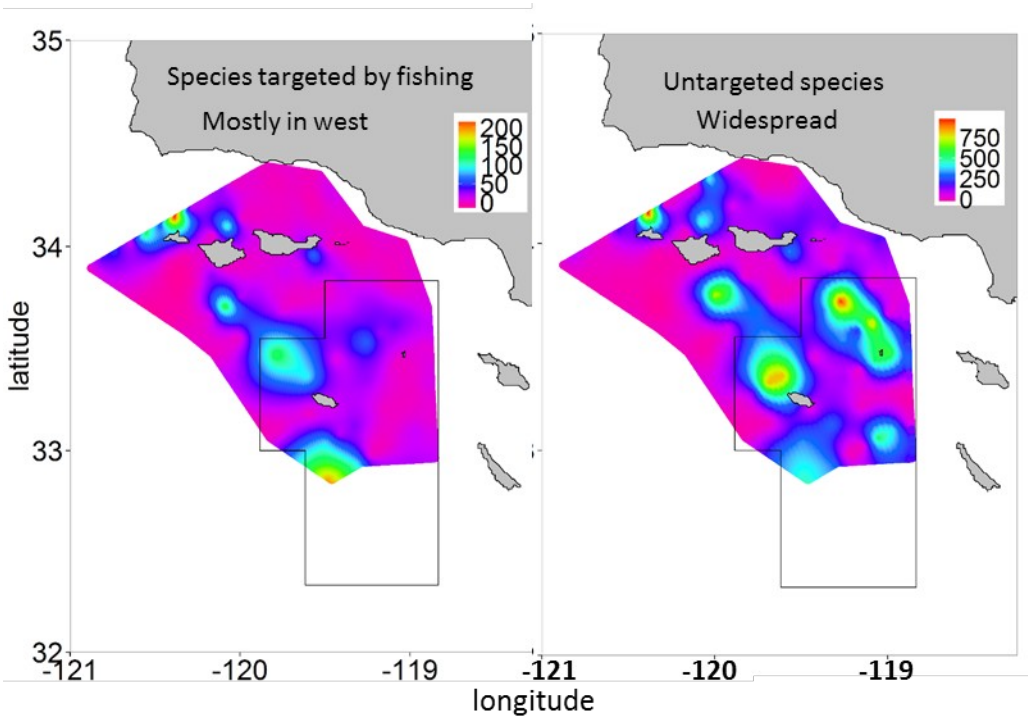


Figure 6. Abundances of larval rockfishes in winter 2005. Left panel depicts species targeted by fishing and the right panel untargeted species.

Finally, we have continued updating larval fish identifications from historic CalCOFI surveys to current taxonomic standards. We currently have completed all surveys from mid-1964 through 2012, and by the end of this year expect to complete samples collected during the first half of 1964 in addition to completing samples collected in 2013. This will provide a 49 year time series of larval abundances of the rockfish species visually identifiable as larvae (*S.aurora, S. diploproa, S. goodei, S. jordani, S. levis, S. paucispinis*).

C. BY SPECIES, BY AGENCY

C1. Nearshore rockfish stock assessments

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

A full stock assessment for China rockfish (*Sebastes nebulosus*) was conducted in 2015 (Dick et al., 2015) and was reviewed by an external panel in July 2015. The assessment was then adapted by the Pacific Fisheries Management Council for fishery management. This assessment reports the status of the China rockfish resource in U.S. waters off the coast of the California, Oregon, and Washington using data through 2014. China rockfish are modelled with three independent

stock assessments to account for spatial variation in exploitation history as well as regional differences in growth and size composition of the catch. The northern area model is defined as Washington State Marine Catch Areas. The central area model spans from the Oregon-Washington border to 40°10′ N. latitude. The southern area model spans 40°10′ N. latitude to the U.S.-Mexico border. However, very little catch of China rockfish occurs south of Point Conception, California (34°27′ N. latitude).

Estimated spawning output in the northern area (Washington State) declined between the 1960s and 1990s but has been largely stable during the past two decades. The estimated relative depletion level (spawning output relative to unfished spawning output) of the northern stock in 2015 is 73.4%. The central area model for China rockfish estimates that spawning output is just above the biomass target in 2015. The rate of spawning output decline is estimated to be steepest during the 1980s to 1990s and continued to decline from the early 2000s at a slower rate to an estimated minimum of 39.6% in 2014. The estimated relative depletion level of the central stock in 2015 is 61.5%. The assessment for the southern management area suggests that China rockfish were lightly, but steadily exploited since the early 1900s, with more rapid declines in spawning output beginning with development of the recreational Fishery in the 1950s. The estimated relative depletion level of the southern stock in 2015 is 29.6% (~95% asymptotic interval: ± 25.0% - 34.3%). Although spawning output in the southern area is more depleted than the central and northern areas, it is the only area with an increasing trend over the past 15 years.

C2. Shelf Rockfish

C2.a. Rockfish barotrauma and survival research at SWFSC Lo 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 rockfish (*Sebastes* spp.) suffering from barotrauma and released using recompression devices. This work relies upon the use of externally attached acoustic tags equipped with depth and accelerometer sensors to send data to a receiver array that allows us to determine survival and behavior of released fish. In 2015 we recovered 21 out of 22 acoustic receivers deployed at our main study site on the 43 fathom bank, and to date we now have data back from 54 bocaccio (*S. paucispinis*), 47 cowcod (*S. levis*), 13 sunset rockfish (*S. crocotulus*), 12 bank rockfish (*S. rufus*), and three starry rockfish (*S. constellatus*) that had been outfitted with accelerometer and depth sensing transmitters. The large number of receivers in our array have allowed us to incorporate 3D tracking of individual fish in addition to the basic behavior and survival data. These tracking data will thus provide a rare insight into natural movements (horizontal and vertical) at fine temporal (~ 4min data points) and spatial scales, allowing us to better understand habitat and foraging behavior that will ultimately inform capture probabilities in visual and acoustic based surveys.

In addition to fish tracking, multiple oxygen as well as temperature and depth loggers were deployed between 80 and 200m at the 43 fathom bank to characterize the seasonal incursion of hypoxic water into this important depth habitat for rockfishes in southern California and allow us to monitor behavior of fish in relation to oxygen saturation. Twelve of our tagged bocaccio were also outfitted in 2014/2015 with dissolved oxygen sensor tags to monitor fine-scale oxygen preferences. Additional bocaccio have been brought into captivity for measurement of both

$O_{2critical}$ and $O_{2lethal}$ levels to determine their sensitivity to hypoxia. These data show that bocaccio need approximately 58% oxygen saturation to meet full metabolic demands and that below 28% saturation aerobic respiration sets in. Planned lab experiments using hyperbaric respirometery chambers will evaluate the effect of simulated capture and recompression on these values. Together the lab and field data will be used to better understand post-release survival of rockfishes and whether there may be seasonal variation in these estimates due to shoaling of hypoxic water masses.

While our research has shown relatively high survival rates of adult cowcod and other species released with descending devices at the 43-fathom bank, recent increases in the incidental catch of juvenile cowcod in Southern California within legal fishing limits have highlighted the need for additional estimates of post-release survival of juvenile animals captured at shallower depths. In addition, information is limited regarding the extent to which descending devices are actually used in the recreational fleet and the effectiveness of each type of descending device. In cooperation with both the recreational Commercial Passenger Fishing Vessel (CPFV) fleet and commercial (live-fish) vessels, we have recently begun a project to use acoustic telemetry to measure movements and survival of juvenile cowcod along the San Diego coastal shelf. As part of this project, we will also estimate angler preferences for and effectiveness of different descending devices onboard CPFVs. This project will yield three products: quantitative information essential to rebuilding cowcod populations, significantly improved collaborative relationships between numerous stakeholders, and greatly increased public awareness of rockfish management efforts.

C2.b. Stock assessments

Contact: John Field (john.field@noaa.gov)

Two stock assessments were conducted in 2015. One is a full stock assessment for Bocaccio (*Sebastes paucispinis*. It is the first time the stock is fully assessed since 2009, and also the first time that the otolith ageing data were used in the recent assessments (He et al., 2015). The second one is an update stock assessment for Chilipepper rockfish (*Sebastes goodei*) in the California Current (Filed et al., 2015). Both assessments were adapted by the Pacific Fisheries Management Council for fishery management.

This Bocaccio assessment reports the status of the species off of the West Coast of the United States, from the U.S.-Mexico border to Cape Blanco, Oregon (representing the Conception, Monterey and Eureka INPFC areas). Although the range extends considerably further north, there is some evidence that there are two demographic clusters of Bocaccio, centered around southern/central California and the West Coast of British Columbia, with a relative rarity of Bocaccio (particularly smaller fish) in the region between Cape Mendocino and the mouth of the Columbia River. In addition to catch, survey and length composition data, ageing data (from over 8,000 otoliths) from the recent ageing project in the Fisheries Ecology Division were used in the assessment. The assessment estimates increasing trends of total biomass and spawning outputs in recent years, and a current (2015) depletion level for the stock is estimated to be 36.8% of unfished level.

The Chilipepper assessment is an update for the stock between the U.S./Mexico border and the Columbia River, and is the first update since 2007. The update maintins the same fundamental

model structure as the 2007 assessment. New estimates of historical catch data from catch reconstructions were included in the model. Commercial and recreational age and length composition data from 2007-2014, as well as a revised NWFSC bottom trawl survey index, and a revised pelagic juvenile survey abundance index (as an indicator of year class strength) were included in the update. Age composition data not available in 2007, primarily from bottom trawl surveys, were included. Some refinements to life history data (relative fecundity, maturity relationship) were also made. Most data revisions or additions had some influence on model estimates of stock status, but very few resulted in substantive changes to the model estimate of relative stock status. The stock depletion is estimated to be 63.9% of unfished level, well above the target level.

D. OTHER RELATED STUDIES

D1. SWFSC FED Habitat Ecology Team 2015-16 Research on California Demersal Communities

Contact: Mary Yoklavich (mary.yoklavich@noaa.gov)

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 overfished 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 as groundfish habitat. The HET uses a variety of underwater vehicles to survey demersal fishes, macro-invertebrates (including members of deep-water coral communities), and associated seafloor habitats off 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 deepsea corals. The following are a few examples of recent projects conducted by the HET and collaborators.

D2. Characterizing deep-sea coral and sponge communities in areas of high bycatch in bottom trawls off Northern California

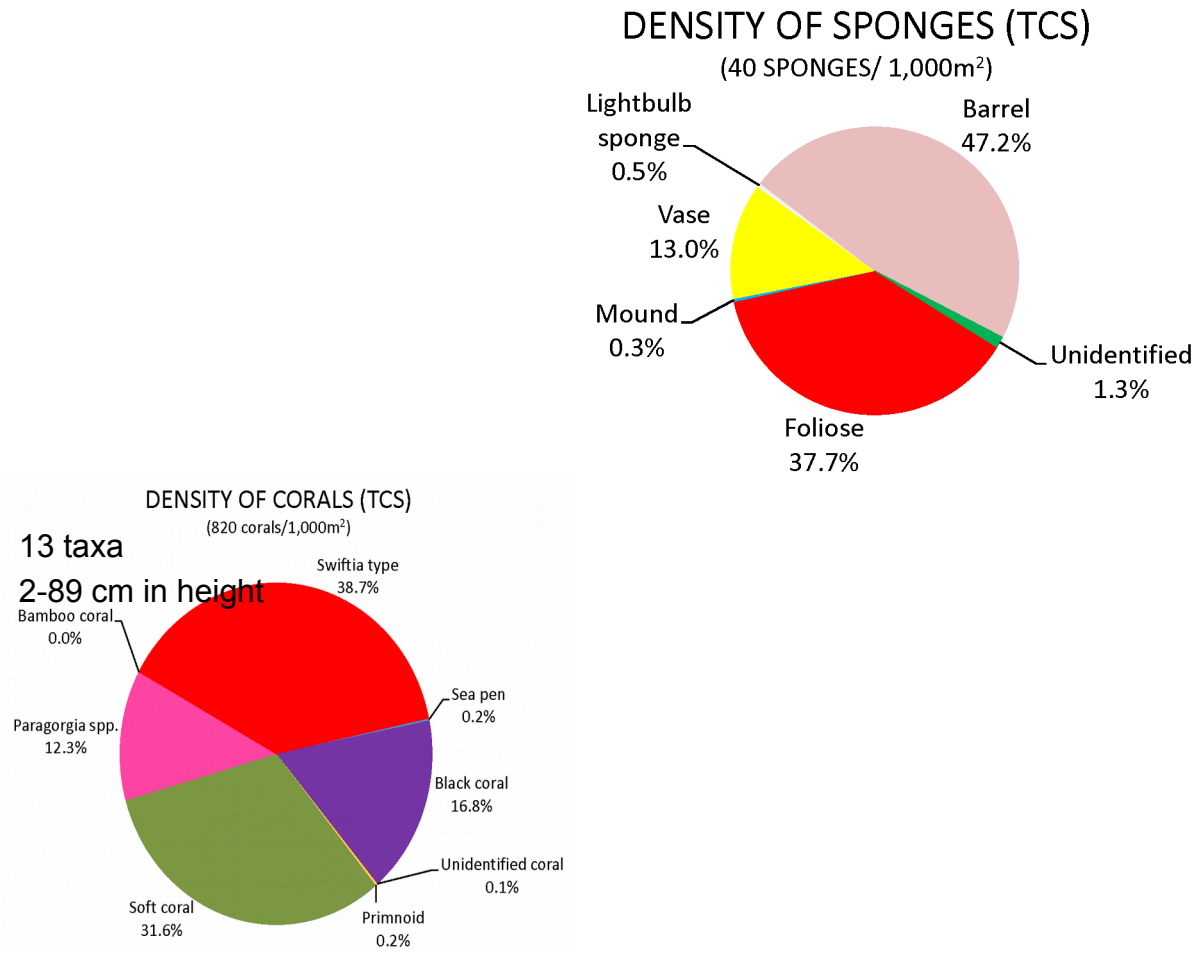
Contact: Mary Yoklavich (mary.yoklavich@noaa.gov)

The FED Habitat Ecology Team and NWFSC collaborators recently used an autonomous underwater vehicle (AUV) and towed camera system (TCS) to visually survey deep-sea corals, sponges, and seafloor habitats for the first time in areas of longtime trawl fishing off northern California. During an 11-day cruise aboard the R/V Point Sur, researchers completed 6 dives with the AUV and 9 deployments of the TCS, and spent over 42 hours underwater at depths of 586-1169 meters from the Oregon-California border to the Mendocino Ridge.

Over 60,000 images of corals, sponges, fishes and other marine life were recorded with digital, paired still cameras during daytime operations. Nearly 48,000 corals from at least 23 taxa were observed, including black corals, bamboo corals, and gorgonians, some of which may be hundreds if not thousands of years old. Sponges occurred on most of the dives, with a total of

5,200 individuals represented by 13 taxa. There were only a few instances of fishes (mostly Sebastolobus spp.) in close association with corals and sponges.

Fishermen have long known that corals occur in this area off northern California, having retrieved parts of corals in their fishing nets along with the harvested fishes. Areas of relatively high numbers of corals also have been recorded in NMFS West Coast groundfish bottom trawl surveys. From the exploration of these sites with cameras, we have begun to determine the extent of these coral colonies for the first time. The highlight of the cruise was discovering forests of relatively small corals on rocky ridges adjacent to the trawl grounds. These areas of rough terrain likely have received less fishing pressure in recent years, with the elimination of large roller gear on the trawl nets. Further analyses of data from this cruise and additional surveys in nearby areas will improve our understanding of the influence of fishing on coral communities and will inform decisions to protect and conserve these sensitive habitats.

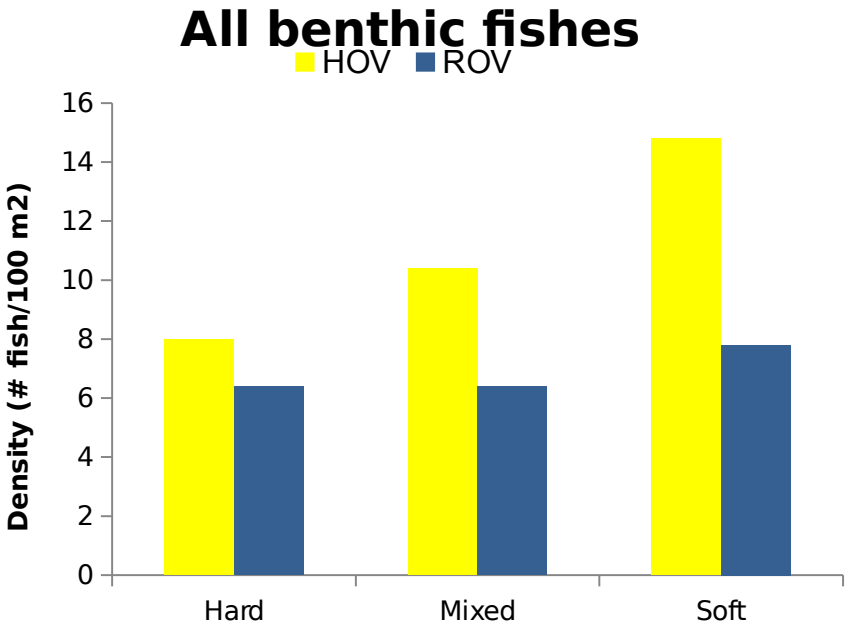


Density of coral and sponge taxa from surveys conducted with a towed camera system (TCS) at depths 600-770 m off northern California.

D3. Evaluating densities and related behaviors of Pacific groundfishes using two visual-survey vehicles

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

Visual surveys of sea floor communities in deep water are becoming more common, and the results are being used to provide fishery-independent abundance estimates and to improve stock assessments for some groundfish species. When selecting a survey vehicle for visual assessments, associated assumptions, biases, and limitations must be considered. To examine some of these issues, the HET estimated fish densities using two survey vehicles (a manned submersible and a remotely operated vehicle [ROV]), and considered vehicle capabilities and fish reactions as related to these estimates. Visual surveys were conducted in three benthic habitat types in deep water off the coast of central California. Over 4,000 fishes were counted from the manned submersible and >6,000 from the ROV. Fish densities were estimated from 28 paired strip transects.



Higher densities of benthic fishes were observed from submersible surveys than from ROV surveys in hard, mixed, and soft habitats. Interestingly, a higher percentage of benthic fishes reacted to the ROV compared to the submersible, which may in turn reflect the lower densities in ROV surveys. Differences in fish detection and identification also were observed between vehicles, for example densities of unidentified rockfishes, unidentified Sebastomus, and unidentified fishes were significantly lower in submersible surveys compared to ROV surveys.

D4. FY16-17 NMFS Untrawlable Habitat Strategic Initiative: Southern California Bight Test Bed

Contact: Mary Yoklavich (mary.yoklavich@noaa.gov)

NMFS Untrawlable Habitat Strategic Initiative (UHSI) Team has initiated field research in the Southern California Bight 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 will be used to observe rockfish movement and behavior in response to various survey tools (e.g., AUV, manned submersible, and other systems)

in order to estimate efficiency of these tools to count and measure demersal rockfish species. In FY16 we are developing and testing the necessary tools and deployment methods, and monitoring fish reactions to underwater lighting of various types and intensities. We also are characterizing the spectral sensitivity and reflectance of rockfishes in order to minimize impacts of light on fishes while maximizing detection and identification of the fishes. A full-scale field study will be conducted in FY17. The research in Southern California complements an ongoing experiment conducted in the Gulf of Mexico (GOM) to monitor the effects of mobile optical and acoustic survey gear in shallow water using ambient light. The GOM study yielded important information on fish reaction to survey vehicles and provides valuable insights on survey and equipment designs. The UHSI experiments in Southern California will be conducted by a team of researchers from Southwest Fisheries Science Center, Northwest Fisheries Science Center, and Alaska Fisheries Science Center, along with academic partners.

D5. Diet composition and foraging ecology of U.S. West Coast groundfishes, with applications for fisheries management
Contact: Joseph Bizzarro (joseph.bizzarro@noaa.gov)

Determining the prey composition and foraging habitats of U.S. West Coast groundfishes is a mandated but neglected component of the Magnuson-Stevens Fishery Conservation and Management Act. To address this lack of consideration, HET researchers and NWFSC collaborators accumulated and analyzed diet composition data for 18 species of interest to the Pacific Fishery Management Council's review of West Coast groundfish essential fish habitat (EFH). A Major Prey Index was developed to evaluate relative importance among 47 prey taxa. Using this metric, euphausiids, polychaetes, amphipods, brachyuran crabs, and unidentified teleosts were the most important major prey items. When 14 generalized prey categories were used, fishes represented the dominant taxon (mean weight/volume = 32.3%), followed by shrimps (11.5%), crabs (10.0%), and euphausiids (9.5%). From a PERMANOVA analysis, species-specific differences were the primary source of variability in diet composition among tested variables (life stage, habitat, taxonomic group). West Coast groundfishes mainly were characterized as mesopredators having estimated trophic levels ranging from 3.4 to 4.2. Foraging habitats differed significantly within functional (benthic, demersal, pelagic) and taxonomic (elasmobranch, roundfish, rockfish, flatfish) groups. Using hierarchical agglomerative cluster analysis we identified a benthic guild (juvenile, juvenile–adult Dover Sole; juvenile–adult English Sole) that forages on polychaetes and hard-shelled molluscs and a midwater guild (juvenile Pacific Hake; juvenile–adult Darkblotched Rockfish) that forages on euphausiids. Our findings fill important data gaps in the trophic ecology and habitat-based management of commercially important species and can be used to inform future reviews of West Coast groundfish EFH.

D6. SWFSC FED Economics Team Activities
Contact: Aaron Mamula (aaron.mamula@noaa.gov)

Landing receipts are an important source of economic data on West Coast commercial harvest. Currently, considerable effort is required to join these data with other important sources of economically relevant information such as permit ownership, vessel characteristics, and dealer/processor information. SWFSC/FED economists have been working with PacFIN staff to create database views that will expedite the retrieval of economic and behavioral data from

PacFIN. Through a collaboration with Rob Ames at PacFIN, we have created an economic data view which combines landings receipts data with information on i) all federal and state commercial fishing permits attached to each vessel identifier and ii) key characteristics (length, weight, horsepower) of each vessel. This view also contains a field assigning each landing to an economically relevant sector designation. SWFSC/FED economists and PacFIN staff are continuing to work on enhancements to the PacFIN database. Ongoing projects include: i) adding a data table to PacFIN which will contain important location and employment information obtained from a survey of fish buyers, dealers and processors, and ii) the addition of tables containing key demographic and economic information for coastal counties. The tables will facilitate the economic analysis of impacts to fishing communities of important environmental, biological, or management changes in commercial fisheries.

The FED Economics Team continues to analyze data from the 2014 survey of California groundfish anglers. That survey was detailed in the 2015 TSC report. The team also continues to work with VMS data under a project initiated in 2014. VMS data is currently being utilized to gain insight into important socio-economic linkages between major West Coast fisheries.

E. GROUNDFISH PUBLICATIONS OF THE SWFSC, 2015 – PRESENT

E1. Primary Literature Publications

Aalto, E. A., E.J. Dick, and A.D. MacCall. 2015. Separating recruitment and mortality time lags for a delay-difference production model. Canadian Journal of Fisheries and Aquatic Sciences 72(2):161-165.

Beyer, S.G., Sogard, S.M., Harvey, C.J., and J.C. Field. 2015. Variability in rockfish (*Sebastes* spp.) fecundity: species contrasts, maternal size effects, and spatial differences. Environmental Biology of Fishes 98:81-100.

Bizzarro, J. J., K. M. Broms, M. G. Logsdon, D. A. Ebert, M. M. Yoklavich, L. A. Kuhnz, and A. P. Summers. 2014. Spatial segregation in eastern North Pacific skate assemblages. PLoS ONE 9(10): 1-26 e109907.

Bjorkstedt, E., J.C. Field, M. Love, L. Rogers-Bennett and R. Starr. 2016. Marine Fisheries. In: Ecosystems of California. University of California Press pp. 779-815.

He, X., J.C. Field, S.G Beyer, and S.M. Sogard. 2015. Effects of size-dependent relative fecundity specifications in fishery stock assessments. Fisheries Research 165:54-62.

He, X., J.C. Field, D.E. Pearson, and L.S. Lefebvre. In review. How many conditional age-at-length data are needed to estimate growth in stock assessment models? Fisheries Ressearch.

Lefebvre, L.S., and J. C. Field. 2015. Reproductive complexity in a long-lived deepwater fish, the blackgill rockfish. Transactions of the American Fisheries Society 144(2):383-399.

Lefebvre, L.S., Payne, A.M. and J.C. Field. 2016. Reproductive dynamics of Pacific sanddab, *Citharichthys sordidus*, off the central coast of California. Journal of Sea Research 107:100-111.

Marks, C.I., R.T. Fields, J.C. Field, R.R. Miller, S.G. Beyer, S.M. Sogard, R.M. Starr, D. Wilson-Vandenberg, D. Howard. 2015. Changes in size composition and relative abundance of fishes in Central California after a decade of spatial fishing closures. CalCOFI Reports 56: 119-132. Available online at http://calcofi.org/ccpublications/ccreports/calcofi-reports-toc/565-crtoc-vol-56-2015.html.

Ralston, S., J.C. Field and K.S. Sakuma. 2015. Longterm variation in a central California pelagic forage assemblage. Journal of Marine Systems 146: 26–37. http://dx.doi.org/10.1016/j.jmarsys.2014.06.013.

Sogard, S.M. and S.A. Berkeley. In review. Patterns of movement, growth, and survival of adult sablefish in contrasting depths in slope waters off Oregon. Fish. Bull.

Thompson AR, Hyde JR, Watson W, Chen DC, Guo LW 2016. Rockfish assemblage structure and spawning locations in southern California identified through larval sampling. Marine Ecology Progress Series 547:177-192.

Wedding, L. and M. M. Yoklavich. 2015. Habitat-based predictive mapping of rockfish density and biomass off the central California coast. Marine Ecology Progress Series 540:235-250.

E2. Other Publications

Clarke, M.E., C. Whitmire, and M.M. Yoklavich. 2015. State of deep-sea coral and sponge ecosystems of the U.S. West Coast: 2015. In: Hourigan, T.F., P.J. Etnoyer, S.D. Cairns, and C.F. Tsao (eds.) The state of deep-sea coral and sponge ecosystems of the United States: 2015. NOAA Technical Memorandum. NOAA, Silver Spring, p. 5.1 - 5.42.

Dick, E.J. M. Monk, I. Taylor, M. Haltuch, T.S. Tsou, and P. Mirick. 2015. Status of China rockfish off the U.S. Pacific Coast in 2015. Pacific Fishery Management Council, Portland, Oregon, 515 p.

Field, J., S.G. Beyer, and X. He. 2015. Status of the Chilipepper Rockfish, *Sebastes goodie*, in the California Current for 2015. Pacific Fishery Management Council, Portland, Oregon, 172 p.

He, X., J.C. Field, D.E. Pearson, L. Lefebvre, and S. Lindley. 2015. Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2015. Pacific Fishery Management Council, Portland, Oregon, 458 p.

Monk, Melissa H., Rebecca R. Miller, John Field, E.J. Dick, Deb Wilson-Vandenberg, and Paul Reilly. 2016. Documentation for California Department of Fish and Wildlife's Onboard Sampling of the Rockfish and Lingcod Commercial Passenger Fishing Vessel Industry in Northern and Central California (1987-1998) as a relational database. NOAA Technical Memorandum NMFS-SWFSC-558 (63 p.).

Pearson, D. E., L.S. Lefebvre, and X. He. 2015. Developing age determination criteria for bocaccio (*Sebastes paucispinus*). NMFS Technical Memorandum NMFS-SWFSC-541. 24 p..

Wakefield, W. Waldo, Mary M. Yoklavich, Chris G. Romsos, Joseph J. Bizzarro, Curt E. Whitmire, and Marlene Bellman. 2013. Data to support a review of Essential Fish Habitat for Pacific Coast groundfish [abstract]. In: George W. Boehlert et al. (eds.), Oregon Marine Renewable Energy Environmental Science Conference proceedings, p. 119-120. U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific Region, OCS Study BOEM 2013-0113.

Yoklavich, M., J. Reynolds, and D. Rosen. 2015. A comparative assessment of underwater visual survey tools: Results of a workshop and user questionnaire. NOAA Technical Memorandum NMFS-SWFSC-547. 44 p.

Yoklavich, M. and W. Wakefield. 2015. Pacific Coast Region. In: Our living oceans: habitat: Status of the habitat of U.S. living marine resources, p. 189-221. NOAA Technical Memorandum NMFS-F/SPO-75.