

NMFS Southwest Fisheries Science Center



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

April 2015

Edited by Xi He and John Field

With contributions from John Hyde,
Susan Sogard, Cindy Thomson, William Watson, 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 three SWFSC laboratories 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. Effects of hypoxia on embryonic development, larval mortality and growth in rockfishes

Investigators: Neosha Kashef (UCSC), David Stafford (UCSC), & Susan Sogard (FED, SWFSC)

Viviparous rockfishes (*Sebastes* spp.) are exposed to varying oxygen levels during gestation in the dynamic oceanographic environment of the California Current. For species reproducing in spring, upwelling drives productivity by delivering nutrient rich water to nearshore habitat paired with low levels of oxygen. With climate change upwelling may vary in timing, frequency and intensity with the potential for rockfishes to have increased exposure to hypoxic waters both temporally and spatially. To learn more about the effects of hypoxia on rockfish reproduction we exposed female fishes with unfertilized eggs to 2, 4 and 8 mg/l oxygen levels – levels known to occur in their natural environment. Exposure continued for the duration of gestation and embryonic development was monitored every three days. After parturition larvae were placed in treatment tanks at the same three oxygen levels to evaluate depletion rates of lipid reserves, growth and mortality rates. Mothers in low dissolved oxygen treatments had higher incidence of embryo mortality and deformity. Preliminary results suggest that 50% mortality occurs sooner for post-parturition larvae reared in lower oxygen water. These data indicate that exposure to low oxygen concentrations during gestation and in early life stages may be both detrimental to larval production and survival. Information about the effects of oxygen on early life history of rockfishes will be valuable in informing future fisheries management.

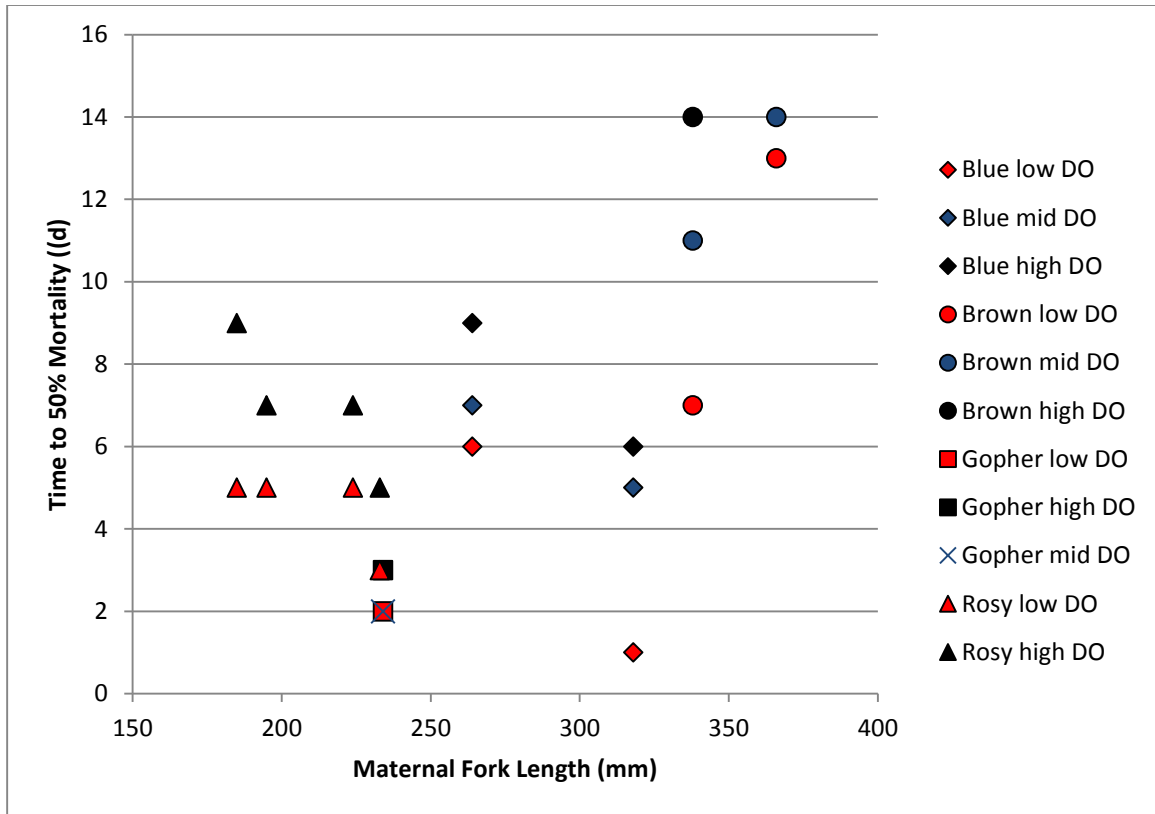


Figure B1. Time until 50% mortality of post-parturition rockfish larvae held in 3 dissolved oxygen levels; low = 2 mg L⁻¹, mid = 4 mg L⁻¹, and high = 8 mg L⁻¹. Sample sizes included 2 blue rockfish, 2 brown rockfish, 1 gopher rockfish, and 4 rosy rockfish females. Larvae were held in groups of 500.

B2. Ecosystem indicators for the Central California Coast, May-June 2014

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 juvenile rockfish (*Sebastes* spp.) and other pelagic micronekton along the Central California coast in late spring (May-June) since 1983. Along with oceanographic information, the survey targets pelagic juvenile (young-of-the-year, YOY) rockfish and the micronekton forage assemblage (including other juvenile fishes, krill, coastal pelagic species, and mesopelagic species) for fisheries oceanography studies and stock assessments (Ralston et al. 2014). The data for the 2014 survey are preliminary. The SWFSC portion of the 2014 survey began on May 2nd, 2014 and ran through June 17th, 2014, onboard the R/V Ocean Starr, a research vessel under contract from Stabbert Maritime. A NWFM survey team continued the survey into the waters off of Oregon and Washington at that time, however those results are not reported here.

The standardized anomalies from the mean of the log (x+1) catch rates are shown by year for six key YOY groundfish and forage groups (Figure 1), including all YOY rockfish, market squid

(*Doryteuthis opalescens*), krill (primarily *Euphausia pacifica* and *Thysanoessa spinifera*), YOY Pacific sanddab (*Citharichthys sordidus*), Pacific sardine (*Sardinops sagax*) and Northern anchovy (*Engraulis mordax*). Notably, 2013 and 2014 had among the highest ever observed catches of juvenile rockfish, sanddab and market squid in the core, southern and northern areas, following an unusually stable trend of high krill abundance and very low abundance of Pacific sardine and northern anchovy in preceding years. The longer time series for juvenile rockfish suggests that 1984 and 1985 were years of comparable high abundance for juvenile rockfish (Ralston et al. 2013). In both 2013 and 2014, these observations were consistent with high reported catches of YOY rockfish and other groundfish in power plant impingement surveys, scuba surveys, commercial and recreational fishermen, and from food habits studies of seabirds and other predators in this region. Trends from the southern (Southern California Bight) and northern (north of Point Reyes to Cape Mendocino) areas, which have been sampled only since 2004, were highly consistent with these “core area” trends for Central California for most species. The observed dynamics of the YOY groundfish and high turnover invertebrates is thought to largely represent shifts in productivity associated with higher survival of early life history stages for these species, while the trends observed for coastal pelagic and mesopelagic species are thought to be more likely related to shifts in their distribution.

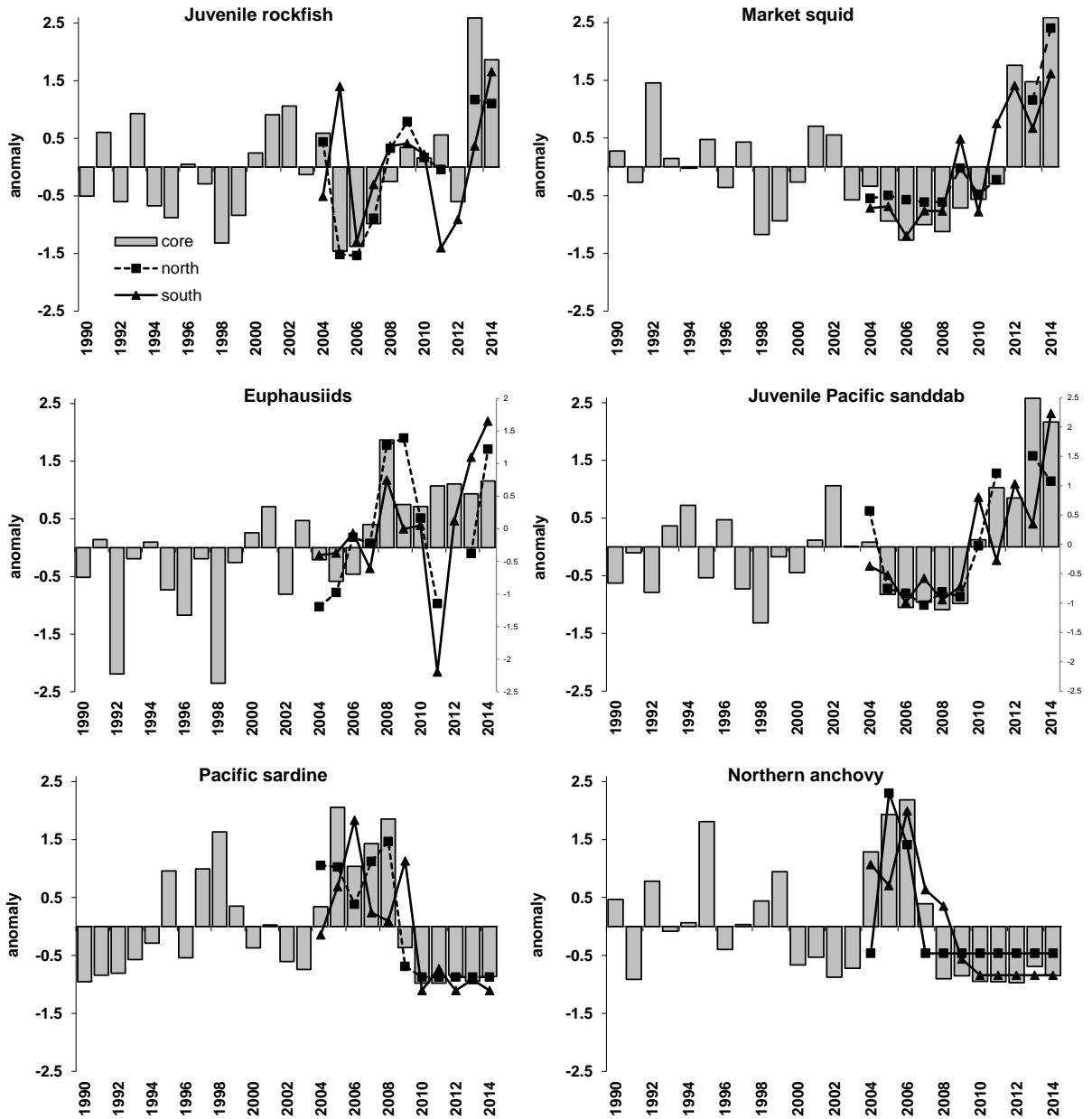


Figure B2: Long-term standardized anomalies of several of the most frequently encountered pelagic forage species from rockfish recruitment survey in the core (Central California) region (1990-2014) and the southern and northern California survey areas (2004-2014, excluding 2012 for the northern area).

B3. Research on larval rockfish at the SWFSC

Over the past year (2014-15) the Ichthyoplankton Ecology and Molecular Ecology labs within the Fisheries Resources Division in La Jolla continued to conduct molecular identification on larval rockfishes collected from CalCOFI cruises. The overall aim of this research is to develop species-specific larval rockfish time-series and then use these 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 involves sorting rockfishes (which can mostly only be identified to genus 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. We are focusing on winter CalCOFI cruises because rockfish larvae are more abundant then relative to other seasons. During the past year we completed sorting all ethanol-preserved winter samples between 1998 and 2013 and those from spring 2013. We also completed genetic identification of samples from 1998-2001, 2004-05, and 2011-2013. We anticipate that all genetic identifications will be completed by July 2015. Much of this work was made possible by funding from NOAA's Fisheries and the Environment program. In addition to the molecular identification-based research, we have continued updating larval fish identifications from historic CalCOFI surveys to current taxonomic standards. We currently have completed all surveys from mid-1965 through 2011, and by the end of this year expect to complete samples collected during the first half of 1965 in addition to completing all 2012 samples. This provides a nearly 50 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

The Pacific Fishery Management Council requested a full assessment of China rockfish in 2015, which will be used to inform harvest guidelines for the 2017-18 management cycle. Assessment scientists at the NMFS SWFSC (E. Dick and M. Monk) are working with co-authors from the NWFSC (I. Taylor and M. Haltuch), as well as staff from state agencies, to complete the revised assessment. The previous assessment, completed in 2013, was based on a new "data-moderate" assessment format, and found that the northern subpopulation (from Cape Mendocino, California, to the US-Canada border) was below target biomass with a declining trend in abundance. The subpopulation south of Cape Mendocino was above target biomass with an increasing trend in recent years.

The revised, "full" assessment will consider additional data sources including age and length composition data and new indices of abundance, namely a trip-based index of recreational catch and effort from Washington's Ocean Sampling Program, and a nearshore commercial logbook index for Oregon. The assessment will also examine data sources to inform assumptions about stock structure in the model, as this was a point of extensive discussion during the 2013 assessment.

C2. Shelf Rockfish

C2.a. Rockfish barotrauma and survival research at SWFSC Lo Jolla Lab

The SWFSC Genetics and Physiology program 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. Building upon previous work we expanded our receiver array at the 43 fathom bank to allow us to incorporate 3D tracking of individual fish in addition to the basic behavior and survival data that we were previously collecting. These tracking data will provide a rare insight into natural movements (horizontal and vertical) at fine temporal (~ 4min data points) and spatial (+/- a few meters) scales, allowing us to better understand habitat and foraging behavior which ultimately will inform capture probabilities in visual and acoustic based surveys. In addition to fish tracking, multiple oxygen as well as temperature & depth loggers are deployed between 80 and 200m 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.

In FY14/15 we deployed 40 accelerometer and depth sensor tags on bocaccio (*S. paucispinis*) and 14 on cowcod (*S. levis*). Twelve of the 40 bocaccio were also fitted with dissolved oxygen sensor tags to monitor fine-scale oxygen preferences. An additional 15 bocaccio have been brought into captivity for measurement of both $O_{2critical}$ and $O_{2lethal}$ with evaluation of how acclimation to normoxic and hypoxic conditions affect these measures. Planned lab experiments using hyperbaric respirometry 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.

C2.b. Stock assessments

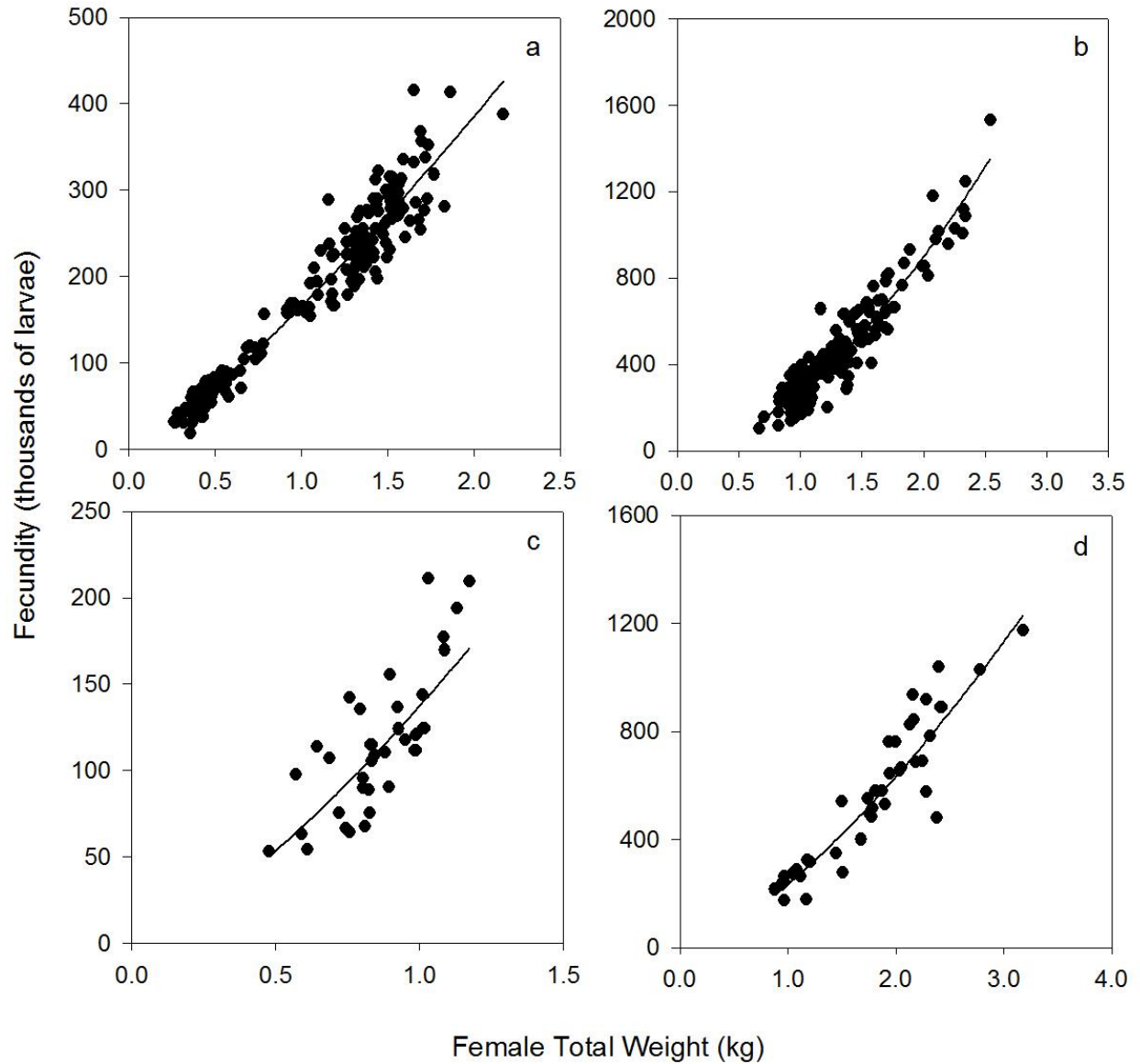
FED staffs are conducting two shelf rockfish stock assessments (Bocaccio and Chilipepper Rockfish) in 20015. The Bocaccio assessment model is to be a full assessment and will be reviewed by a STAR Panel in July 2015, while the Chilipepper is an assessment update (updates include new data but do not change the data inputs or basic model structure) of the 2007 stock assessment. The 2007 update found the Chilipepper rockfish stock to be above target levels, with catches and harvest levels far below the target levels due to area closures implemented to rebuild co-occurring species (such as Bocaccio and Canary rockfish). As catches have remained low since that time, and survey indices have continued to indicate high recruitment (juvenile indices) and high abundance levels (bottom trawl surveys), the stock is anticipated to continue to be above target levels.

For the Bocaccio stock assessment, a comprehensive study has been undertaken since 2014 to age Bocaccio since no age data were used in Bocaccio stock assessments in the recent stock assessments and were recommended by the last stock assessment reviews. The ageing process included development of ageing criteria, ageing validation, and analysis of ageing errors

(Pearson et al. in review). Over 10,000 Bocaccio otoliths have been aged, and a simulation study to examine effects of numbers of age data on estimations of fish growths in stock assessment models was also conducted (He et al. in review). The Bocaccio stock assessment will be conducted using the latest available Stock Synthesis (SS) program.

C2.c. Relative fecundity of rockfish and their effects in fishery stock assessments

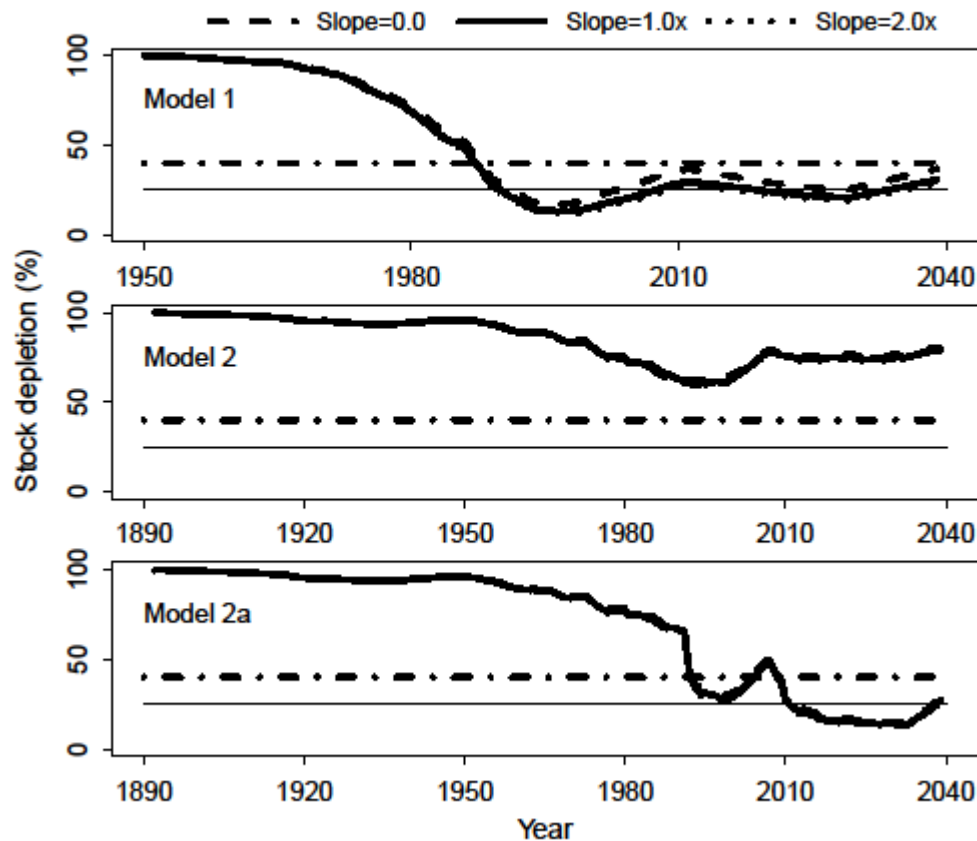
A study was conducted to investigate the reproductive ecology of four rockfish species residing in the California Current: Chilipepper, *Sebastes goodei*; Yellowtail rockfish, *S. flavidus*; Speckled rockfish, *S. ovalis*; and Blackgill rockfish, *S. melanostomus* (Beyer et al. 2015). Females were sampled from Northern to Southern California during the winter parturition season (November through March) of 2009, 2010, 2011 and 2012 to assess spatiotemporal trends in fecundity. Maternal length and weight were positively correlated with relative fecundity (Φ_{rel} , larvae per g somatic weight) in all four species, indicating a disproportionately greater reproductive output by larger, older females. Yellowtail rockfish had the highest absolute fecundity and Φ_{rel} , the greatest maternal size effect, and produced the smallest sized eggs. For Yellowtail rockfish and Chilipepper, fecundity varied spatially among sampling locations, but did not significantly vary over time within the years sampled (sample sizes for Speckled and Blackgill rockfish were too small to allow spatiotemporal comparisons). Two reproductive strategies were evident as Yellowtail rockfish and Blackgill rockfish produced a single brood of larvae annually in contrast to Chilipepper and Speckled rockfish, which both produced multiple broods in Southern California and to a lesser extent in Central California, complicating estimates of annual fecundity. There was some evidence that egg production was positively correlated with female condition, indicating that environmental variability in oceanographic conditions and productivity may drive changes in fecundity and reproductive strategy (i.e., single versus multiple broods) in these species.



Figuer C2c.1. Relationship of absolute fecundity (Φ) with maternal size (weight; kg) for Chilipepper (a), Yellowtail rockfish (b), Speckled rockfish (c), and Blackgill rockfish (d)

A study was conducted to examine effects of misspecifications of size-specific fecundity (Φ_{rel}) functions on estimated stock assessment parameters and related management quantities using two stocks (Chilipepper and Blackgill rockfish) as case studies and three sets of simulation models, chosen to represent wide ranges of life and fishing histories (He et al. 2015). The results showed that misspecification effects were relatively small when stocks were less depleted (e.g. 75% of virgin spawning output), but could lead to more substantive misspecifications in more depleted stocks with slower growth and lower mortality rates. For example, we found that stock was estimated to be as much as 20% less depleted if a strong size-specific Φ_{rel} exists in a population, but no size-specific Φ_{rel} is used in the model. This represents a non-trivial shift in the perception of status for most stocks. The results also showed that overestimating the strength

of the size-specific Φ_{rel} function in stock assessment models led to smaller estimation errors in assessment outputs compared to underestimating the size-specific Φ_{rel} . The results are insightful with respect to the importance of gathering data on size-dependent Φ_{rel} and other aspects of reproductive ecology, as well as with respect to the nature of assumptions that are made with regards to reproductive ecology in data limited situations.



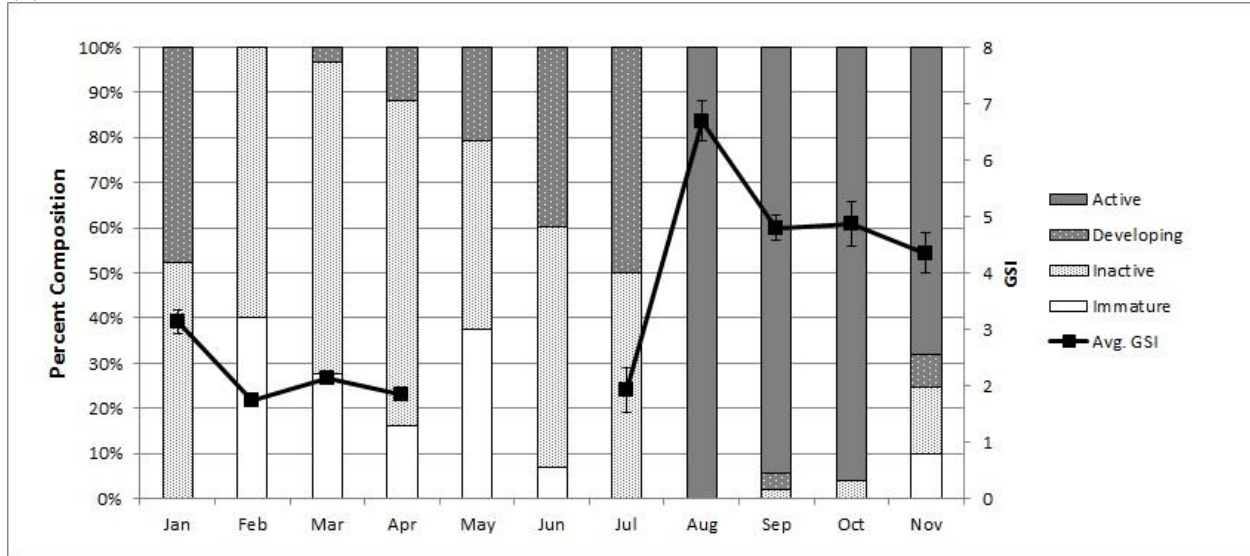
Figuer C2c.2. Time series of median stock depletion from three individually simulated assessment runs with three slopes of weight-specific relative fecundity (Φ_{rel}) functions for three simulated operating models, each with a base run slope of 1x. Two horizontal lines are management references (solid = overfished limit; dotdash = management target).

C2.d. Reproductive biology of Pacific Sanddab

A manuscript is in review (first presented at the International Flatfish Symposium in 2014) which reports the results of a series of studies were initiated in 2012 to evaluate the reproductive dynamics of female Pacific sanddab (*Citharichthys sordidus*) initially in support of a 2013 stock assessment of that species (Levebvre et al. in review). The study presents data on the annual reproductive cycle (based on both macroscopic and histological observations); length at maturity; batch fecundity; spawning fraction and spawning interval, based on both field collected and captive female Pacific sanddabs. Results suggest

that during the reproductive season (from approximately May through January) the fraction of spawning females ranged from 42 to 98%, indicating that females were spawning on a near daily basis throughout much of the season. A comparison of the size at maturity from historical studies relative to this study also suggested a downward shift in the size at maturity since the 1940s, although the magnitude and cause of this shift remain unknown. Pacific sanddab were determined to have asynchronous oocyte development and indeterminate fecundity. Absolute batch fecundity was variable, and significantly related to maternal length, while relative batch fecundity was weakly but significantly related to maternal length. Studies of captive fish demonstrated that females were capable of spawning on successive days, and values of fecundity and I were similar to those estimated from wild-caught fish.

(a)



(b)

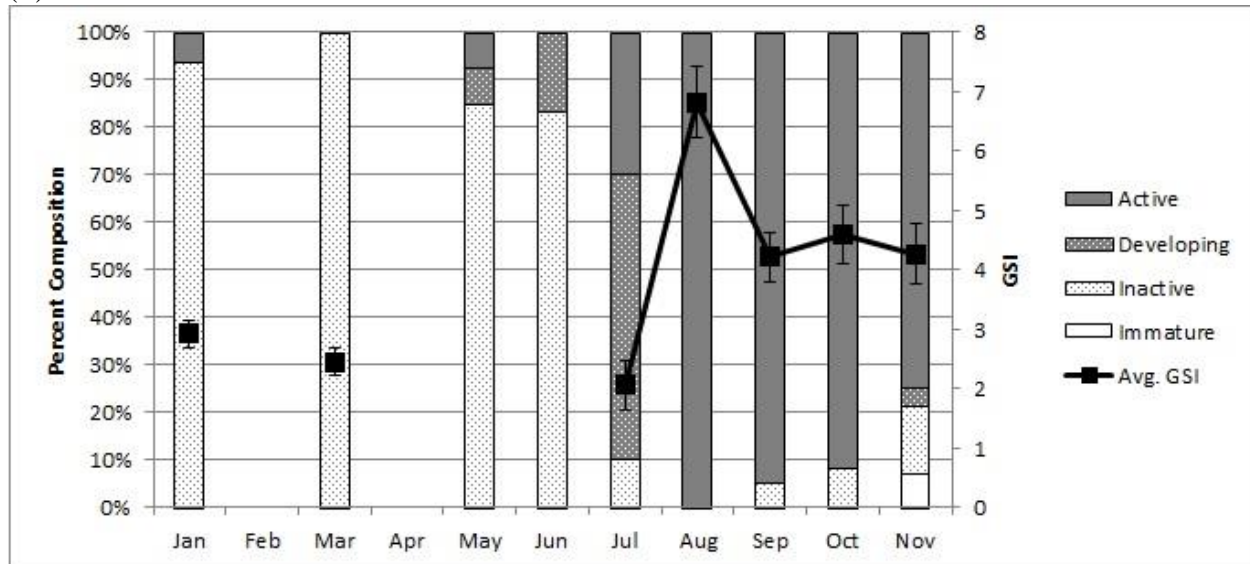


Figure C2.d. Percent composition of females in gross maturity categories and average GSI values for Pacific sanddab (*Citharichthys sordidus*) collected March 2012-April 2013 for (a) all females collected (n=312), with gross maturity based on macroscopic staging and (b) females examined histologically (n=97).

D. OTHER RELATED STUDIES

D1. Estimating unfished potential of Cowcod abundance off central and southern California

Investigators: Mary Yoklavich and David Huff

We are developing models to predict cowcod (*Sebastes levis*) abundance using data collected during visual surveys conducted from a human-occupied submersible off central and southern California and from data on a number of habitat variables. Potential model covariates have been extracted from a regional oceanographic modeling system (ROMS) via a data-assimilated, 8-day overlapping analysis spanning the period 1980-2011. This analysis provides estimates of salinity, temperature, and ocean currents at 1/10-degree resolution. A coupled biological model provides estimates of diatoms, NO₃, particulate organic nitrogen, predatory zooplankton, meso- and microzooplankton, nanophytoplankton, dissolved organic nitrogen, irradiance, NH₄, Chlorophyll a, and SiOH₄. All values were extracted for depths near the seafloor at sample locations and were time-averaged over a one-month period corresponding to sample date. The data also have been extracted for the spatial extent of the study area over the entire sampling period to develop climatologies that may be used for model predictions and to display the quantity and extent of available habitat. We estimated surface productivity from spatial extents that correspond to persistent positive temporal deviations from a 10-year climatology developed with remotely sensed chlorophyll concentrations. A digital elevation model (DEM) provided depth, slope, and other derived seafloor features at 90-meter resolution.

Cowcod are designated as overfished, and consequently occupancy in their rocky habitat is very low. We are developing generalized additive models to estimate ‘unfished potential abundance’ within cowcod depths and bottom types. Selected models included bottom temperature and current velocity and primary productivity as predictors. We are identifying a reference condition to calibrate our statistical model, using data from sites with the greatest number of ‘fishable’ sized rockfishes of any species. With this approach we try to avoid the pitfall of developing a model in which the number of individuals observed might not represent all suitable habitat because of the depleted condition of the stock. Potential cowcod abundance can be compared between Southern California Bight and the Central Coast. Comparisons can be made with more traditional assessments that are based on fishery data. Our results also can help in understanding affects of climate change on fish distributions.

Contact: mary.yoklavich@noaa.gov

D2. Habitat-based predictive mapping of rockfish density and biomass off the central California coast

Investigators: Mary Yoklavich and Lisa Wedding

Understanding the association between components of habitat and fish distribution and abundance is important in order to achieve accurate stock assessments. We developed generalized additive models (GAM) and spatially predictive maps of rockfish abundance at the individual species level using habitat descriptors collected from visual surveys and fine-scale bathymetry. We advanced beyond presence/absence and presence only models to create predictive maps of density (number of fish/100 m²) and biomass (kg of fish/100 m²) for *Sebastes rosaceus* (Rosy rockfish) and *S. constellatus* (Starry rockfish), both common species in commercial and recreational fisheries along the central coast of California. Selected models included co-variables of seafloor depth, complexity, substratum type, and heterogeneity. Predicted density and biomass of both species were highest in areas of complex rock on the continental shelf off Point Lobos and Point Sur in 50-90 m (*S. rosaceus*) and 80-120 m (*S.*

constellatus) water depth. We estimated absolute abundance of these species in our entire central California study area. Our results will be useful both in stock assessments of these data-poor species as well as in allocation of fishing effort, catches, and other space-based management decisions.

Contact: mary.yoklavich@noaa.gov

D3. A Comparative Assessment of Visual Survey Tools: Results of a workshop and user questionnaire

Investigators: Mary Yoklavich, Jennifer Reynolds, Dirk Rosen

Visual surveys of seafloor habitats and associated organisms are being used more commonly in marine science, and yet researchers and resource managers continue to struggle in choosing among available underwater tools and technologies. In this report, we present the results of a comprehensive questionnaire and a corresponding workshop that address the capabilities, limitations, operational considerations, and cost for five mobile, visual, survey tools: remotely operated vehicles (ROV) used in both shallow and deep water; autonomous underwater vehicles (AUV); human-occupied vehicles (HOV); towed camera sleds (TCS); and human divers recording data (scuba). These tools were considered specifically in the context of their use during systematic surveys of benthic organisms (i.e., fishes, megafaunal invertebrates) and components of their seafloor habitats. This information represents the knowledge, interests, and expertise of a broad group of marine scientists, engineers, and resource managers, and provides specific, practical guidance as well as insight on what is needed to advance the use of these tools and improve data collection for a variety of science and management applications.

Contact: mary.yoklavich@noaa.gov

D4. A summit on the role of deep-sea corals and sponges as habitat for managed species off the West Coast and Alaska.

Investigators: Mary Yoklavich, Steve Copps, Jon Heifetz, Tom Hourigan, Milton Love, Sean Rooney, Chris Rooper, John Stadler, Bob Stone, Brian Tissot, Fan Tsao, Waldo Wakefield, and Curt Whitmire

Understanding the function of deep-sea corals and sponges (DSC&S) as groundfish habitat is fundamental to the review and management of groundfish essential fish habitat (EFH) for the Pacific Fishery Management Council (PFMC), the North Pacific Fishery Management Council (NPFMC), and other Councils. Whereas the vulnerability of DSC&S may evoke strong calls for conservation, there is limited information on the distribution, abundance, and ecological function of DSC&S taxa. The role of DSC&S as a component of groundfish EFH, in particular, is not well established. Strong associations between rockfishes and DSC&S have been documented from visual surveys conducted in Alaska (e.g., Aleutian Islands and parts of the Gulf of Alaska) and between rockfishes and sponges in Grays Canyon off Washington, but not from other similar surveys off the West Coast. A key consideration is whether similar levels of association of DSC&S and groundfishes along the West Coast can be inferred from visual surveys conducted in areas of Alaska with similar habitats.

To improve our understanding of the role of DSC&S as habitat (particularly EFH) for groundfishes, NMFS convened a web-enabled series of 8 seminars from August 2014 to February 2015. These science-based seminars were presented by researchers with expertise in associations and functions of DSC&S as habitat and attracted significant interest and discussion nationwide. To download the seminars, go to <https://swfsc.noaa.gov/DeepseaCoralSeminars/>. Following the webinar series, a core group met at an in-person Summit at NOAA's Sand Point facilities in Seattle, Washington 3–5 March 2015. The Summit brought together 13 researchers and other subject-matter experts from NMFS Alaska Fisheries Science Center, Northwest Fisheries Science Center, Southwest Fisheries Science Center, West Coast Region, Office Habitat Conservation, and academia to summarize the scientific understanding of the association and functions of DSC&S as habitat for groundfishes off the West Coast and Alaska. A white paper on Summit outcomes has been submitted to the PFMC in the context of their deliberations related to Pacific Coast groundfish EFH; this document will be submitted to the NPFMC in the coming months. A review paper on this topic is forthcoming.

Contact: mary.yoklavich@noaa.gov

D5. SWFSC FED Economics Team Activities

In 2014 the FED's Economics Team completed an economic survey of California groundfish anglers. The main objective of the survey was to assess the effects of recreational groundfish regulations on angler preferences and behavior. The survey was designed in coordination with the California Department of Fish and Wildlife and groundfish biologists at FED and the University of California, Santa Barbara. Analysis of survey data is currently underway.

The Economics Team completed two manuscripts that are in internal review.

- Thomas-Smyth, A., A. Mamula and C. Speir. Assessing the accuracy of high spatial resolution effort data: comparing VMS and logbook data in the California groundfish trawl fishery.
This paper develops a feasible GIS-based method of integrating trawl logbook data with high-resolution spatial data from Vessel Monitoring Systems (VMS). This work includes use of a speed-based criteria for inferring fishing activity from VMS data, and tow path reconstruction based on bathymetric interpolation of fishing locations between the start and end coordinates of tows reported in logbooks.
- Mamula, A. and T. Collier. Multifactor productivity, environmental change, and regulatory impacts in the US West Coast groundfish trawl fishery, 1994-2013.
This paper estimates multifactor productivity for vessels participating in the West Coast Limited Entry Groundfish Trawl Fishery from 1994 to 2013. The paper focuses on the impact of regulatory changes (including the 2003 vessel buyback and 2011 catch share program) on productivity, and analyzes productivity dynamics across spatial, behavioral and scale dimensions.

E. GROUNDFISH PUBLICATIONS OF THE SWFSC, 2014 – 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.
- Bjorkstedt, Eric, J.C. Field, M., Love, L.R. Bennett, and R. Starr. In press. California's marine fisheries: tradeoffs in transition. In: *Ecosystems of California*. University of California Press.
- Botsford, L.W., M.D. Holland, J.C. Field, and A. Hastings. 2014. Cohort resonance: a significant component of fluctuations in recruitment, egg production, and catch of fished populations. *ICES Journal of Marine Science* 71(8):2158-2170.
- Carruthers, T.R., A.E. Punt, C. J. Walters, A. MacCall, M.K. McAllister, E.J. Dick, and J. Cope. 2014. Evaluating methods for setting catch limits in data-limited fisheries. *Fisheries Research* 153:48-68
- Haltuch, M. A., O. S. Hamel, K. R. Piner, P. McDonald, C. R. Kestelle, and J. C. Field. 2013. A California Current bomb radiocarbon reference chronology and petrale sole (*Eopsetta jordani*) age validation. *Canadian Journal of Fisheries and Aquatic Sciences* 70(1):22-31.
- He, X., J.C. Field, S.G Beyer, and S.M. Sogard. 2015. Effects of size-dependent relative fecundity specifications in fishery stock assessments. *Fish. Res.* 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? *Fish. Res.*
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