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# **DRAFT**

# **RESEARCH AND DATA NEEDS**

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**2018**



**PACIFIC FISHERY MANAGEMENT COUNCIL**

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## ACRONYMS AND DEFINITIONS

Acronym	Definition
ABC - acceptable biological catch	The ABC is a scientific calculation of the sustainable harvest level of a fishery and is used to set the upper limit of the annual total allowable catch. It is calculated by applying the estimated (or proxy) harvest rate that produces maximum sustainable yield to the estimated exploitable stock biomass (the portion of the fish population that can be harvested).
barotrauma	Physical trauma or injury to a fish due to pressure change. When a fish is rapidly brought from deep water to the surface, the drop in pressure can cause a variety of physical problems, such as severe expansion of the swim bladder and gas bubbles in the blood.
CalCOFI	California Cooperative Oceanic Fisheries Investigations
catch per unit of effort	The quantity of fish caught (in number or weight) with one standard unit of fishing effort. For example, the number of fish taken per 1,000 hooks per day, or the weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance.
CCA	Cowcod Conservation Area
CCE	California Current Ecosystem
CCLME	California Current Large Marine Ecosystem
CCS	California Current System
CDFW	California Department of Fish and Wildlife
coastal pelagic species	Coastal pelagic species are schooling fish, not associated with the ocean bottom, that migrate in coastal waters. They usually eat plankton and are the main food source for higher-level predators such as tuna, salmon,

Acronym	Definition
	most groundfish, and humans. Examples are herring, squid, anchovy, sardine, and mackerel.
coded-wire tag	Coded-wire tags are small pieces of stainless steel wire that are injected into the snouts of juvenile salmon and steelhead. Each tag is etched with a binary code that identifies its release group.
cohort	In a stock, a group of fish born during the same time period.
COP	Council Operating Procedures
Council	Pacific Fishery Management Council
CPFV	Commercial passenger fishing vessel (charter boat)
CPS	Coastal pelagic species. See above.
CPUE	Catch per unit of effort.
CWT	Coded-wire tag. See above.
DIT	Double index tagging
EBFM	Ecosystem-Based Fishery Management
EEZ	Exclusive Economic Zone. See below.
EFH	Essential fish habitat. See below.

Acronym	Definition
EFHCA	Essential fish habitat conservation area. These are areas where certain types of bottom-contact gear are prohibited as a means of minimizing the adverse effects of the bottom fishery on groundfish EFH.
EIS	Environmental impact statement. See below.
El Niño Southern Oscillation	Abnormally warm ocean climate conditions, which in some years affect the eastern coast of Latin America (centered on Peru) often around Christmas time. The anomaly is accompanied by dramatic changes in species abundance and distribution, higher local rainfall and flooding, and massive deaths of fish and their predators. Many other climactic anomalies around the world are attributed to consequences of <i>El Niño</i> .
EMS	Electronic monitoring system
Endangered Species Act	An act of Federal law that provides for the conservation of endangered and threatened species of fish, wildlife, and plants. When preparing fishery management plans, councils are required to consult with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service to determine whether the fishing under a fishery management plan is likely to jeopardize the continued existence of an ESA-listed species or to result in harm to its critical habitat.
ENSO	El Niño Southern Oscillation
Environmental impact statement	As part of the National Environmental Policy Act (NEPA) process, an EIS is an analysis of the expected impacts resulting from the implementation of a fisheries management or development plan (or some other proposed action) on the environment. EISs are required for all fishery management plans as well as significant amendments to existing plans. The purpose of an EIS is to ensure the fishery management plan gives appropriate consideration to environmental values in order to prevent harm to the environment.
EPO	Eastern Pacific Ocean
ESA	Endangered Species Act. See above.

Acronym	Definition
essential fish habitat	Those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.
Exclusive Economic Zone	A zone under national jurisdiction (up to 200 nautical miles wide) declared in line with the provisions of the 1982 United Nations Convention of the Law of the Sea, within which the coastal State has the right to explore and exploit, and the responsibility to conserve and manage, the living and non-living resources.
exempted fishing permit	A permit issued by National Marine Fisheries Service that allows exemptions from some regulations in order to study the effectiveness, bycatch rate, or other aspects of an experimental fishing gear. Previously known as an “experimental fishing permit.”
Fathom	Used chiefly in measuring marine depth. A fathom equals 6 feet.
FEIS	Final Environmental Impact Statement (see EIS, NEPA).
FEP	Fishery Ecosystem Plan
Fm	Fathom (6 feet)
FMP	Fishery management plan. See above.
FRAM	Fishery Regulation Assessment Model. Typically used for salmon.
FWS	U.S. Fish and Wildlife Service
GSI	Genetic stock identification



Acronym	Definition
Habitat areas of particular concern	Subsets of essential fish habitat (see EFH) containing particularly sensitive or vulnerable habitats that serve an important ecological function, are particularly sensitive to human-induced environmental degradation, are particularly stressed by human development activities, or comprise a rare habitat type.
HAPC	Habitat areas of particular concern. See above.
Harvest guideline(s)	A numerical harvest level that is a general objective, but not a quota. Attainment of a harvest guideline does not require a management response, but it does prompt review of the fishery.
HCR	Harvest control rule
Highly migratory species	In the Council context, highly migratory species in the Pacific Ocean include species managed under the HMS Fishery Management Plan: tunas, sharks, billfish/swordfish, and dorado or dolphinfish.
HMS	Highly migratory species. See above.
HMS FMP	Highly Migratory Species Fishery Management Plan. This is the fishery management plan (and its subsequent revisions) for the Washington, Oregon, and California Highly Migratory Species Fisheries developed by the Council and approved by the Secretary of Commerce.
IATTC	Inter-American Tropical Tuna Commission
IFQ	Individual fishing quota. See below.
IMECOCAL	A program in Baja California concerning small pelagics and climate change.
Incidental catch or incidental species	Species caught when fishing for the primary purpose of catching a different species.

Acronym	Definition
Incidental take	The “take” of protected species (such as listed salmon, marine mammals, sea turtles, or sea birds) during fishing. “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct.
Individual transferable (or tradable) quota	A type of quota (a part of a total allowable catch) allocated to individual fishermen or vessel owners and which can be transferred (sold, leased) to others.
IO-PAC	A regional input-output model
ISC	International Scientific Committee
ITQ	Individual Transferable (or Tradable) Quota. See above.
KRFC	Klamath River fall Chinook
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act. See below.
Magnuson-Stevens Fishery Conservation and Management Act	The MSFCMA, sometimes known as the “Magnuson-Stevens Act,” established the 200-mile fishery conservation zone, the regional fishery management council system, and other provisions of U.S. marine fishery law.
Marine Mammal Protection Act	The MMPA prohibits the harvest or harassment of marine mammals, although permits for incidental take of marine mammals while commercial fishing may be issued subject to regulation. (See “incidental take” for a definition of “take”.)
Maximum sustainable yield	An estimate of the largest average annual catch or yield that can be continuously taken over a long period from a stock under prevailing ecological and environmental conditions. Since MSY is a long-term average, it need not be specified annually, but may be reassessed periodically based on the best scientific information available.

Acronym	Definition
MMPA	Marine Mammal Protection Act. See above.
MPA	Marine protected areas
MSA	Magnuson-Stevens Fishery Conservation and Management Act. See above.
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act. See above.
MSY	Maximum sustainable yield. See above.
National Marine Fisheries Service	A division of the U.S. Department of Commerce, National Ocean and Atmospheric Administration (NOAA). NMFS is responsible for conservation and management of offshore fisheries (and inland salmon). The NMFS Regional Director is a voting member of the Council.
NGO	Nongovernmental organization
NMFS	National Marine Fisheries Service. See above.
NMFS NWFSC	National Marine Fisheries Service Northwest Fisheries Science Center
NMFS NWR	National Marine Fisheries Service Northwest Region
NMFS SWFSC	National Marine Fisheries Service Southwest Fisheries Science Center
NMFS SWR	National Marine Fisheries Service Southwest Region
NOAA	National Oceanic & Atmospheric Administration. The parent agency of National Marine Fisheries Service.
ODFW	Oregon Department of Fish and Wildlife

Acronym	Definition
ONMS	Office of National Marine Sanctuaries
Optimum yield	The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems. The OY is developed on the basis of the Maximum Sustained Yield from the fishery, taking into account relevant economic, social, and ecological factors. In the case of overfished fisheries, the OY provides for rebuilding to a level that is consistent with producing the Maximum Sustained Yield for the fishery.
OY	Optimum yield. See above.
PacFIN	Pacific Fisheries Information Network
Pacific States Marine Fisheries Commission	The PSMFC is a non-regulatory agency that serves Alaska, California, Idaho, Oregon, and Washington. PSMFC (headquartered in Portland) provides a communication exchange between the Pacific Fishery Management Council and the North Pacific Fishery Management Council, and a mechanism for Federal funding of regional fishery projects. The PSMFC provides information in the form of data services for various fisheries.
PaCOOS	Pacific Coast Ocean Observing System
PBT	Parentage-based-tagging
PFMC	Pacific Fishery Management Council
PNW	Pacific Northwest
PSMFC	Pacific States Marine Fisheries Commission. See above.

Acronym	Definition
Quota	A specified numerical harvest objective, the attainment (or expected attainment) of which causes closure of the fishery for that species or species group.
RFMO	Regional Fishery Management Organization
SAFE	Stock assessment and fishery evaluation. See below.
Scientific and Statistical Committee	An advisory committee of the Council made up of scientists and economists. The Magnuson-Stevens Act requires that each council maintain an SSC to assist in gathering and analyzing statistical, biological, ecological, economic, social, and other scientific information that is relevant to the management of Council fisheries.
SI	Sacramento Index
SS2	Stock Synthesis 2 – Population assessment program.
SS3	Stock Synthesis 3
SSC	Scientific and Statistical Committee. See above.
STAR	Stock assessment review
STAR Panel	Stock Assessment Review Panel. A panel set up to review stock assessments for particular fisheries. In the past there have been STAR panels for sablefish, rockfish, squid, and other species.
Stock Assessment and Fishery Evaluation	A SAFE document is a document prepared by the Council that provides a summary of the most recent biological condition of species in the fishery management unit, and the social and economic condition of the recreational and commercial fishing industries, including the fish processing sector. It summarizes, on a periodic basis, the best available information concerning the past, present, and possible future condition of the stocks and fisheries managed in the FMP.

Acronym	Definition
TIQ	Trawl Individual Quota
Vessel Monitoring System	A satellite communications system used to monitor fishing activities—for example, to ensure that vessels stay out of prohibited areas. The system is based on electronic devices (transceivers), which are installed onboard vessels. These devices automatically send data to shore-based “satellite” monitoring system.
WCGOP	West Coast Groundfish Observer Program
WCPFC	Western and Central Pacific Fisheries Commission
WG	Working Group

## 1.0 INTRODUCTION

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) includes directives to 1) prevent overfishing, 2) rebuild depressed fish stocks to levels of abundance that produce maximum sustainable yield (MSY), 3) develop standardized reporting methodologies to assess the amount and type of bycatch, 4) adopt measures that minimize bycatch and bycatch mortality, to the extent practicable, 5) describe and identify essential fish habitat (EFH), and 6) assess the impact of human activities, including fishing impacts, on habitat. The MSA also encourages the participation of the fishing industry in fishery research. Additionally, Standard 8 mandates consideration of the effects of fishery management measures on communities. These directives require substantial data collection and research efforts to support Pacific Fishery Management Council (Council) management of West Coast fisheries.

Section 302(h)(7) of the MSA requires Regional Fishery Management Councils to:

*“(7) develop, in conjunction with the scientific and statistical committee, multi-year research priorities for fisheries, fisheries interactions, habitats, and other areas of research that are necessary for management purposes, that shall—*

*(A) establish priorities for 5-year periods;*

*(B) be updated as necessary; and*

*(C) be submitted to the Secretary and the regional science centers of the National Marine Fisheries Service for their consideration in developing research priorities and budgets for the region of the Council.”*

This report is intended to document and communicate the Council’s research and data needs through 2023, thereby fulfilling the Council’s responsibilities under MSA Section 302(h)(7).

### 1.1 Schedule of Document Development and Review

For 2017-2018 revisions, the Council’s Scientific and Statistical Committee (SSC) streamlined the process listed under Council Operating Procedure 12 in response to the anticipated heavy Council and SSC workload. At the November 2017 Council meeting in Costa Mesa, California, the SSC reviewed the initial draft document and planned the development of a revised draft for public review. At the April 2018 Council meeting briefing book deadline, the SSC released a revised draft for Council advisory body review. At the June 2018 Council meeting in Spokane, Washington, the Council reviewed the revised draft and received comments and recommendations from its advisory bodies and the public before adopting a draft for public review. At the September Council meeting in Seattle, Washington, the Council approved this final document which records and communicates the Council’s research and data needs through 2023 to ensure continued well-informed Council decision-making into the future and to fulfill the Council’s responsibilities under the MSA.

## **1.2 Document Organization**

This document represents a summary of research and data needed by the Council to implement its responsibilities as defined by the MSA, the Regulatory Flexibility Act, and other pertinent legislation. The document is largely organized around overarching fishery management topics such as economic and social science components, ecosystem-based fishery management (EBFM), marine protected areas (MPA), and EFH issues. Following these overarching topics, the document includes detailed sections that focus on each of the Council's four fishery management plans (FMPs). Because each FMP or management component has a unique Council history and its own issues and data needs, each section is organized in a style best suited for its particular research and data needs. Where appropriate, these sections address continuing issues and identify important emerging issues.

The bulleted list below represents the set of general criteria used in this most recent exercise as guiding principles rather than explicitly defined rules for developing research and data needs.

- Projects address long-term fundamental needs of West Coast fisheries.
- Projects improve the quality of information, models, and analytical tools used for biological assessment and management.
- Projects increase the long-run market competitiveness and economic profitability of the industry.
- Projects contribute to the understanding by decision-makers of social and economic implications in meeting biological and conservation objectives.
- Projects provide data and/or information to meet the requirements of the MSA, the Regulatory Flexibility Act, and other applicable laws.

## **1.3 Communication and Coordination**

This document has been posted to Council web page and transmitted to many West Coast organizations and agencies to broadly communicate Council needs and to solicit research support. Groups to be included in the distribution include the other seven Regional Fishery Management Councils, Headquarters as well as West Coast Regional Offices and Science Centers of National Marine Fisheries Service (NMFS), West Coast states, the Pacific States Marine Fisheries Commission (PSMFC), tribal management agencies, the National Ocean Service's Office of National Marine Sanctuaries (ONMS), West Coast National Marine Sanctuaries, and Sea Grant.

Following completion and distribution, as time and workload allow, the Council Chair and staff may meet with representatives from the NMFS West Coast Region and the NMFS Northwest and Southwest Science Centers, ONMS, and PSMFC to develop a consensus on high priority initiatives needed to respond to Council needs that would be conveyed to NMFS.



## 2.0 ECOSYSTEM-BASED FISHERIES MANAGEMENT AND MARINE PROTECTED AREAS

### 2.1 Introduction

Ecosystem science can be useful both in its application to FMP species-group management, and to aid in long-term Council planning on ecosystem-wide concerns. The Council has taken a number of concrete steps in recent years to increase the information and tools available to implement an ecosystem-based fishery management (EBFM) approach and make ecosystem considerations an integral part of fishery management. The Council created a Fishery Ecosystem Plan (FEP) in 2013 and will review the FEP in 2018. The purpose and need statement of the PFMC FEP (below) provides useful guidance for identifying the types of research and data needed to support EBFM and a means to prioritize those needs.

*The purpose of the FEP is to enhance the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations, and management policies that coordinate Council management across its Fishery Management Plans (FMPs) and the California Current Ecosystem (CCE). An FEP should provide a framework for considering policy choices and trade-offs as they affect FMP species and the broader CCE.*

*The needs for ecosystem-based fishery management within the Council process are:*

*Improve management decisions and the administrative process by providing biophysical and socio-economic information on CCE climate conditions, climate change, habitat conditions, and ecosystem interactions.*

*Provide adequate buffers against the uncertainties of environmental and human-induced impacts to the marine environment by developing safeguards in fisheries management measures.*

*Develop new and inform existing fishery management measures that take into account the ecosystem effects of those measures on CCE species and habitat, and that take into account the effects of the CCE on fishery management.*

*Coordinate information across FMPs for decision-making within the Council process and for consultations with other regional, national, or international entities on actions affecting the CCE or FMP species.*

*Identify and prioritize research needs and provide recommendations to address gaps in ecosystem knowledge and FMP policies, particularly with respect to the cumulative effects of fisheries management on marine ecosystems and fishing communities.*

The Council has completed two Ecosystem initiatives under the FEP. The first initiative provided protection to unfished forage fish stocks. The second undertook a coordinated review of ecosystem indicators. The Council now receives an annual report on the state of the California Current from the California Current Integrated Ecosystem Assessment (CCIEA) and has implemented a regular process to review the report and prospective changes and additions to it. In September 2017, the

Council initiated a Climate and Communities Initiative under its Fishery Ecosystem Plan. The Climate and Communities Cross-Fishery Management Plan Climate Initiative is intended to analyze the effects of near-term climate shift and longer-term climate change on the California Current Ecosystem and Council-managed fisheries and associated fishing communities. At the time this document was being prepared, the Ecosystem Work Group was planning for a series of webinars on the effects of climate variability/change on the California Current Ecosystem and a subsequent report describing major Council decision types that may benefit from increased ecosystem science input. Coincident with the preparation of the Council's five-year research and data needs plan, NOAA fisheries is developing a Western Regional Implementation Plan for the nationwide 2016 NOAA Fisheries' [EBFM Road Map](#). NOAA fisheries has also developed a Western Region Action Plan for climate change impacts on fisheries, which includes a number of research initiatives that relate to EBFM.

## 2.2 Progress on Highest Priority EBFM Issues from 2013

The 2013 PFMC Research and Data Needs document identified a number of research and data priorities to pursue between 2013 and 2017. These were categorized into highest priorities, high benefit, moderate benefit, and emerging issues. The highest priority issues are listed below and progress on each of them over the last five years is briefly described. While some of these issues have been fully addressed, others are ongoing concerns and remain as priorities for the next five years.

- **Identify ecosystem-related objectives at all levels of assessment and management. This includes stock assessments, habitat analyses, and coast-wide and regional ecosystem status reports.** The FEP at Chapter 2 provides the PFMC's objectives for the FEP itself, which are intended to build upon and link to the goals and objectives of the PFMC's four FMPs. Chapter 5 of the FEP describes the PFMC's broad priorities for the CCE, to be considered within big-picture ocean resource management deliberations. The Western Regional Implementation Plan for the [EBFM Road Map](#) will include a number of specific actions and mileposts for implementing EBFM and should be completed in 2018. The [Western Regional Action Plan \(WRAP\): NOAA Fisheries Climate Science Strategy](#) lists a number of general objectives, and for each lists a range of specific actions to be taken to achieve those objects and timeframes for these actions. The WRAP is discussed in more depth below under the climate change research priority
- **Identify an approach for evaluating the benefits of various management tools in relation to achieving EBFM management objectives.** No single specific approach has been identified for evaluating benefits of management tools in achieving EBFM objectives. This reflects the diversity of management tools and objectives of EBFM. However, management strategy evaluation (MSE) has emerged as a useful general approach for comparing the relative performance of management tools and strategies in achieving a variety of objectives, including EBFM objectives. The Council has been briefed on MSEs that include ecosystem outcomes. MSE's have been used to test harvest control rules that include environmental drivers for Sacramento River Winter Chinook and Pacific Sardine. An MSE considering environmental drivers of sablefish

recruitment was presented to the Council in March 2018, (at which time we can add a bit more here). In addition, a number of evaluations of current and prospective management actions and strategies have been evaluated using Atlantis ecosystem models of the CCE and the Atlantis model was reviewed by the SSC. *Developing approaches for evaluating benefits of EBFM management tools and actions remains a highest priority.*

- **Provide a status of the ecosystem report to the Council annually that includes, but is not limited to, evaluation of current and future oceanographic condition, analysis of ecosystem responses to management measures and these conditions, updated habitat mapping or evaluation, observations of recruitment patterns across species, shifts in species distribution and community composition, and changes in trophic dynamics.** The California Current Integrated Ecosystem Assessment (CCIEA), which is an ongoing collaborative effort of the Northwest and Southwest Fisheries Science Centers, provided the Council with an initial California Current Ecosystem Status Report in November 2012 and has been providing annual status reports at the Council's March meeting since 2014. These reports, and other IEA publications can be found on the [CCIEA website](#). The content of the report has evolved over time and will continue to do so. It currently contains information about: climate and ocean drivers; focal components of ecological integrity (e.g., forage fish, marine mammals, seabirds, salmon, and groundfish); human activities; and human wellbeing. The SSC has reviewed the individual indicators included in the report as well as general methodologies for presenting information (e.g., ways of representing uncertainty and trends) and has implemented a process for the SSC Ecosystem Subcommittee to review newly proposed indicators and IEA products in September of each year. The PFMC's second FEP initiative, a Coordinated Ecosystem Indicator Review, provided a PFMC-wide process in 2015-2016 for all of the Council advisory bodies and the public to review and comment on longer-term planning for the contents and indicators in the Ecosystem Status Report.
- **Identify key physical and biological indicators for prediction of salmon early ocean survival and groundfish recruitment, as well as other conditions that are directly applicable to management.** The NWFSFSC has compiled a set of indices that together provide indications of salmon survival for Columbia River salmon, particularly fall run Chinook (i.e., the "stoplight indicators" which are included in the annual ecosystem status reports provided to the Council by the CCIEA). The Sacramento River Winter Chinook forecast model includes a temperature covariate, and multiple environmental covariates were considered for inclusion in the Sacramento River Fall Chinook forecast. A number of different surveys (trawl survey, hook and line, and SWFSFSC juvenile, and a number of localized surveys in California) contribute to estimates of groundfish recruitment. The harvest control rule for Pacific sardine is based on a temperature-recruitment relationship. A management strategy evaluation (MSE) considering environmental drivers of sablefish recruitment was presented to the Council in March 2018. *Identifying (and evaluating reliability of) physical and biological indicators for prediction of salmon early ocean survival and groundfish recruitment remains a highest priority.*

- **Identify how the climate might be changing on long time scales in a way that will affect fisheries (i.e., climate change).** There are a variety of projects completed and ongoing focused on this question. The Centers anticipate completing Climate Vulnerability Assessments for PFMC-managed species in 2018, which should help prioritize future scientific work on the effects of climate on fish stocks and fisheries. Additionally, the PFMC's Climate and Communities FEP initiative will bring more PFMC and public attention to the potential longer-term effects of climate change on fisheries resources and fishing communities. A Western Regional Action Plan (WRAP), NOAA Fisheries Climate Strategy was released as a SWFSC Technical Memorandum in 2016 (NOAA NW/SW Fisheries Science Centers 2016). The WRAP identifies strengths, weaknesses, priorities, and actions to implement the National Climate Science Strategy (NCSS) on the US West Coast over the next 3-5 years. The WRAP catalogues a number of published research studies on climate impacts on various marine species in Table 2 and publications that provide management advice to address climate impacts on various species and humans in Table 3. The WRAP also lists specific objectives and specific research milestones for the next 3-5 years. NOAA has made considerable progress on ocean acidification research related to the CCE. The NWFSC has built an experimental state-of-the-art facility for growing animals in conditions that mimic pre-industrial, current, and future ocean carbon dioxide levels to observe changes in animal growth, survival and behavior. To more closely mimic conditions that marine organisms experience in the ocean, scientists use the ocean acidification facility to reproduce the natural changes that occur in carbon dioxide levels, temperature, and oxygen concentrations at daily, weekly and seasonal scales. NWFSC scientists and partners are currently studying the biological effects of ocean acidification on larval geoduck, Pacific oyster, Olympia oyster, pinto abalone, krill and copepods (zooplankton that are food for the fish we eat), Dungeness crabs, herring and rockfish. NWFSC scientists and partners are using ecosystem models to identify how changes in the parts of the food web that are considered to be directly vulnerable to acidification will affect the entire food web in Puget Sound, including how changes in prey species will affect harvested fish, threatened species, and other valuable marine resources. NWFSC researchers are making precise measurements of ocean acidity as part of sampling zooplankton and fish to understand the relationship between carbon dioxide and key species in Puget Sound. *Understanding the potential effects of climate change on fisheries remains a highest priority moving forward.*
- **Identify indices of ecosystem state (on appropriate temporal and spatial scales, e.g., demarcation points might be Point Conception, Point Año Nuevo, San Francisco Bay, Point Reyes, Cape Mendocino, Cape Blanco, Columbia River, Cape Flattery).** The CCIEA has identified a number of indices to track ecosystem state and continues to develop additional indices. The CCIEA website provides charts of these indices and also the ability to download the data behind them (<https://www.integratedecosystemassessment.noaa.gov/regions/california-current-region/indicators/climate-and-ocean-drivers.html>). *Identifying spatially refined indices of ecosystem state that are useful to management remains a highest priority.*
- **Estimate total catch for target and non-target species and their prey and predators.**

The Pacific Fisheries Information Network (PacFIN), a collaboration between member state and federal fishery agencies, assembles and serves landings data for all commercial marine fisheries on the West Coast. The state agencies supply data on the amount of fish landed at authorized dealers through the fish ticket system. One complication is that dealers often purchase fish in categories driven by the market or ease of identifying the fish rather than by species. To address these sometimes imprecise grouping and to identify contamination within the categories the states implemented a port sampling program to subsample purchased fish to elucidate the true composition of the purchased fish and to identify their area of catch. The subsampled data is used to create species composition and area composition proportions which are calculated and applied at strata supported by the data. While fish ticket data provides a full accounting of landings, it does not provide information about discarded catch. A full accounting of catch of all species taken in limited entry groundfish fisheries and of groundfish taken in some other fisheries is produced by the [NWFSC Fisheries Observation Science Program](#). The West Coast Groundfish Observing program and the At-sea Hake observer program provide comprehensive estimates of catch, including discards, of all species taken in West Coast limited entry groundfish and hake fisheries. The NWFSC observer program deploys observers in federally and state managed fisheries that target groundfish or take them as bycatch to collect data necessary to provide annual total mortality estimates (e.g., pink shrimp, California halibut, open access fixed gear, nearshore fixed gear). These bycatch reports combine landings and observer discard estimates to provide expanded discard estimates for all species occurring in fisheries that are observed. Incidental takes of groundfish in other unobserved fisheries are also provided in these reports to the extent they are available. Information on discards from other fisheries is not collected. Thus, there remains a gap in the data need to estimate all catch of target and non-target species. It is not clear how substantial or important this gap is.

- **Evaluate the effect of fishing on habitat and response of habitat to spatial closures.** There is a substantial literature on effects of fishing gear on habitat including a National Research Council study on the effects of trawling and dredging on seafloor habitat (National Research Council 2002). There have also been studies of regeneration of habitat in rockfish conservation areas in British Columbia (e.g., Marliave and Challenger 2009). Although there has not been a systematic study of the response of habitat to spatial closures on the Pacific Coast, a large amount of data is available to evaluate this response. The SWFSC uses a variety of survey tools and approaches to study macro-invertebrates (including members of deep-water coral communities), and associated seafloor habitats in water depths from 20 to 900 meters off the entire California coast. Habitat-specific distribution and densities of juvenile and adult life stages of numerous Pacific Coast demersal species have been determined from non-extractive, visual surveys conducted with remotely operated vehicles (ROV), human-occupied submersibles, autonomous underwater vehicles (AUV), scuba, laser line scan, and towed cameras, coupled with seafloor maps of the continental shelf and upper slope. These surveys provide habitat-specific assemblage analyses on multiple spatial scales; fishery-independent stock assessments; baseline monitoring of MPAs; documentation of marine debris on the seafloor and incidence of damage to deep-water corals and sponges in areas of high trawl bycatch;

and input to new ways to manage on an ecosystem basis. SWFSC habitat research is often conducted in collaboration with academic partners from University of California Santa Barbara, University of California Cooperative Extension Sea Grant Program, Moss Landing Marine Labs, Washington State University, and Oregon State University, and with our colleagues from other NMFS Science Centers and National Marine Sanctuaries. While substantial progress has been made on determining effects of fishing on habitat, continued progress remains a highest priority.

- **Encourage development of probabilistic/stochastic ecosystem-based models that incorporate environmental variation and anthropogenic disturbances to guide harvest policies and enable risk assessment for fishing strategies.** An MSE conducted to compare potential harvest control rules for Sacramento River Winter Chinook<sup>1</sup> includes an aspect of environmental variability (i.e., temperature) which is partially under anthropogenic control (due to regulated release of water from a dam), along with assessment of risks (to both the stock and to fishing opportunity). The harvest control rule for Pacific sardine is based on a temperature-recruitment relationship. A management strategy evaluation (MSE) considering environmental drivers of sablefish recruitment will be presented to the Council in March 2018. Extending these types of models to other species and stocks remains a highest priority. *Development of probabilistic/stochastic ecosystem-based models that incorporate environmental variation and anthropogenic disturbances remains a highest priority.*
- **Provide report on trophic interactions among exploited species and model consequences of fishing at various levels on predators or prey and/or the changes in biomass that may be expected due to major shifts in climate, oceanographic parameters such as acidification, and temperature, as well as anticipated effects on productivity.** Substantial progress has been made on this priority with development of an Atlantis Ecosystem model for the California Current. The model has been used to inform assessments of the cumulative effects of Pacific Coast groundfish fisheries,<sup>2</sup> evaluate alternative strategies and evaluate potential effects of ocean acidification. Further work is needed on spatial aspects of predator-prey interactions, e.g., the effects of localized depletion on colony-based central place foragers. The SSC supported this priority in 2014, when it [hosted a joint review](#) of the Atlantis CCE model with the Center for Independent Experts.
- **Estimate total population size (or collect existing time series) of higher-level carnivores, including seabirds and marine mammals, and estimate forage needs and foraging efficiencies (to provide an estimate of not only their food**

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<sup>1</sup> [http://www.pcouncil.org/wp-content/uploads/2017/08/F2a\\_SRWCW\\_Rpt1\\_SEPT2017BB.pdf](http://www.pcouncil.org/wp-content/uploads/2017/08/F2a_SRWCW_Rpt1_SEPT2017BB.pdf)

<sup>2</sup> <http://www.westcoast.fisheries.noaa.gov/publications/nepa/groundfish/1516spexfeis.pdf>



requirements, but the prey density needed for them to acquire these food resources). [The SWFSC California Current Marine Mammal Assessment Program](#) conducts a wide variety of cetacean and pinniped research in the Pacific Ocean including but not limited to the CCE. Research categories include: Marine Mammal Acoustics; Research Vessel Line-Transect Surveys; Bayesian Trend Analyses; Aerial Line-Transect Surveys; Photogrammetric Surveys of Pinniped Rookeries; Bycatch Estimates of Protected Species in Commercial Fisheries; Marine Mammal Stock Assessments; Sea Lion Diet/Food Habits. The Marine Mammal Protection Act (MMPA) requires that the National Marine Fisheries Service (NMFS) and the Fish and Wildlife Service (FWS) develop Stock Assessment Reports (SARs) for all marine mammal stocks that occur regularly in U.S. waters. Stock assessments for California Current marine mammals and related publications can be found on the [SWFSC website](#) in on the program page for the California Current Marine Mammal Assessment Program. The SWFSC also studies seal lion diet and monitors prey consumption. The NWFSC Marine Mammal and Seabird Ecology Team conducts research on Southern Resident killer whales (SRKWs), other marine mammals, and seabirds in the Pacific Northwest. Marine mammal research focuses on habitat and foraging ecology, marine mammal physiology and behavior, and marine mammal acoustics. Seabird research focuses on foraging and breeding ecology, seabird–fisheries interactions, and seabirds as important components of marine ecosystems. Projects include assessing seabird diet and productivity in Puget Sound and the California Current, contaminant levels in seabirds and their fish prey, factors influencing avian predation on Pacific salmon, and seabird bycatch in West coast groundfish fisheries.

### **2.3 Progress on Highest Priority Research MPA Issues from 2013**

The 2013 PFMC Research and Data Needs document identified several research and data priorities related to Marine Protected Areas (MPAs). MPAs, marine reserves, and essential fish habitat (EFH) were previously covered in a separate section of the research and data needs document, but this document incorporates general MPA and marine reserve research in the EBFM research section. EFH research relevant to specific species groups is included in the sections on those species groups (e.g., groundfish, salmon, CPS, HMS).

2013 priorities for MPAs were categorized into highest priorities, high benefit, moderate benefit, and emerging issues. The highest priority issues are listed below. There are extensive and ongoing research efforts dedicated to understanding physical, biological and socio economic effects of marine reserves, including research programs focused marine reserves and MPAs along the Pacific Coast. It is beyond the scope of this document to review all of this research in detail, but substantial progress has been made in addressing the 2013 MPA priorities. We cite examples of this below, but note that these examples do not represent a full accounting of research and monitoring efforts that relate to these priorities.

- **Identify type and scale of information needed to conduct stock assessments after establishment of marine reserves and evaluate the feasibility and cost of collecting**

**such information.** MPAs that are effective should by design alter both the density and the demographic structure of exploited populations, leading to increased heterogeneity in such structure which in turn can violate the assumptions of many stock assessment models. Although there have been some efforts to evaluate this bias (e.g., Ono et al. 2015), an improved understanding of how protected areas impact specific stock assessments is needed. Performing separate assessments for fished areas and MPAs, or performing spatial assessments that include movement rates can reduce errors and bias (McGilliard et al. 2014), but spatial stock assessments are very data intensive and need greater exploration to better evaluate performance. Fishery independent surveys can provide insights into the magnitude of MPA effects, but at times such surveys are also constrained in such areas. For example, the West Coast Groundfish bottom trawl survey does not conduct tows in the Cowcod Conservation Areas (CCAs) in the southern California Bight. Alternative means of exploring relative or absolute abundance of assessed species (for example, through the use of larval surveys in the CCAs) can help to resolve questions regarding the impact of spatial management on the information content of surveys and the potential impact on assessments.

- **Information on the location and type of harvest and effort relative to a proposed marine reserves and MPAs is needed in order to begin to evaluate the degree of impact and effectiveness of the creation of marine reserves. Use of Before/After/Control/Impact (BACI) research design methods improves the inference of harvest and habitat relations in marine reserves.** Over the past couple decades this has been the approach of choice for scientifically rigorous and defensible studies for determining differences in a control vs. treatment area and has been applied to marine reserves monitoring elsewhere in the world. There is a large literature on this which we cannot review here. [The California Collaborative Fisheries Research Program \(CCFRP\)](#) was designed to help monitor the 29 MPAs off central California and evaluate their effectiveness as a management tool for marine conservation. The sampling methodology focuses on comparing paired areas inside and outside of MPAs and hopes to observe changes in the MPAs since implementation. Tagged fish are providing information on fish movement, and ultimately with a long enough time series, scientists hope the information can be used in stock assessments for nearshore species. [Oregon Department of Fish and Wildlife](#) has an extensive program of ecological monitoring and human dimensions research on marine reserves.
- **Research is needed to understand the biological and socioeconomic effects of marine reserves and determine the extent to which acceptable biological catches would need to be modified when marine reserves are implemented, over the short term and long term.** There is a large body of literature on the socioeconomic effects of marine reserves and effort and catch displacement related to them. A general conclusion that can be drawn from this literature is that the effects of a marine reserve are dependent on the specific characteristics of the reserve and the marine life it protects, but also on the management outside the reserve and the incentives that creates. While some studies have found effort along the edge of reserves may increase to take advantage of spillover, a recent study of the Pacific groundfish trawl fishery under IFQs found the opposite with vessels avoiding the edge of the RCAs to avoid rockfish catch for which quotas were



scarce (Miller and Deacon 2017). We are unaware of efforts to adjust ABCs to account for marine reserves along the Pacific Coast or studies suggesting this is appropriate. However, as discussed above, assessments can be biased as a result of reserves, and changes to assessments and surveys may be necessary.

- **Information on advection of eggs and larva and pre-settlement juveniles from marine reserves would help answer whether an individual marine reserve or network of marine reserves serve as either sources, sinks, or both of future fish populations. In other words, are the marine reserves providing offspring to the areas outside the marine reserve (a source) or is the outside area providing offspring to the marine reserve that may function as a nursery area and protection for the growing larva and juveniles (a sink)? Research emphasizing the differences between areas upstream and downstream of major geographical features may enhance our understanding of dispersal patterns of eggs and larva and therefore the optimal placement of marine reserves. Knowledge of when in the life cycle density-dependent effects occur is important in the assessment of the effects of marine reserves (as it is in assessing conventional catch management). Information is needed on movement patterns of species (e.g., fish home ranges, residence times, distance for foraging forays) in different habitats (rocky and soft bottom), in different locales, and throughout the year to determine the appropriate sizing, spacing and scale of MPAs.** There is a large and growing body of literature on these topics including empirical and modeling studies of Pacific coast species. We are unable to review this literature here, but we note again that there is ongoing research along the Pacific Coast, including tagging studies being undertaken by the CCFRP for marine reserves off Central California. A number of academic labs have long running research programs on these questions, e.g., [Mark Carr's lab at UC Santa Cruz](#) and [Steve Gaines at UC Santa Barbara](#). Monitoring programs run by the National Marine Sanctuary Program and ODFW also continue to contribute to understanding these issues.
- **Increased biological and socioeconomic monitoring of existing marine reserves and other areas of restricted fishing, such as EFH Conservation Areas (EFHCAs), in order to gain information that might be extrapolated to evaluate the creation of additional reserves on the west coast.** Several monitoring programs exist as described above.
- **Biological and physical indicators should be developed and monitored over long time scales to assess the effectiveness of reserves.** It is not clear to what extent this has occurred for existing reserves and MPAs along the Pacific Coast but this remains an important priority. Before monitoring can occur, it is necessary to establish modern (and where possible, historic) baseline conditions of species and habitats. Likewise, long-term closure areas that later become re-opened (e.g., trawl RCA, EFHCAs) to fishing should be evaluated against the baseline to determine impacts of renewed fishing pressure (see Groundfish EFH section). Monitoring programs for MPAs established by the Council that can evaluate performance on stated goals and objectives should be established.

## 2.4 New Highest Priority Issues

New highest Priority research and data needs related to ecosystems and MPAs are listed below. Note that several of the 2013 priorities discussed above remain highest priorities. As this was noted in the discussion above, these priorities are not repeated in this section. Given the broad applicability of ecosystem-based management principles, many of the research priorities identified in this chapter are duplicative or closely related to FMP-specific recommendations in later chapters. As funding becomes scarcer, it is important to identify these linkages or cross-FMP initiatives to see where research in one FMP can have multiple benefits.

- Strategic evaluation of ecosystem monitoring programs: To ensure that limited resources are used most effectively, a systematic assessment of data collections and monitoring programs should be undertaken. The assessment should evaluate the consequences of losing or scaling back specific programs and opportunities for adapting or replacing programs with more cost-effective alternatives. The review should also explore opportunities to support robust management decisions in the event that some data collection efforts are curtailed, ideally using a management strategy evaluation approach. Since most monitoring programs support FMP specific management decisions, this priority may be reflected in other sections of this document, but many data collection and monitoring programs have broader cross-FMP value and it will be important to maintain a broader ecosystem perspective when evaluating specific programs to account of the value of programs beyond their FMP specific uses and to identify opportunities to meet needs of multiple FMPs with single program.
- Improve understanding of the effects of increasing predator populations (seabirds, marine mammals), in concert with environmental variability and forage variability, on salmon and other managed and fisheries resources.
- Conduct comprehensive stomach analysis to determine trophic interactions among and within target and non-target species. This information would be essential for assessments of the California Current Large Marine Ecosystem (CCLME) and represents the cross-FMP linkages that are sought under the developing EBM FMP.
- Investigate the potential for emerging technologies such as environmental DNA (eDNA) to complement and augment existing ocean monitoring. Focus in particular on the value of eDNA for difficult to sample species.
- Evaluate effects of fishing on habitat and non-target species for any rockfish conservation areas re-opened to fishing after long closures. Baseline evaluations should be conducted before areas are re-opened and BACI (Before-After, Control-Impact) sampling framework should implemented.
- Investigate how viability and resilience of coastal communities are affected by changes in ecosystem structure and function, including short- and long-term climate shifts.
- Develop an improved understanding of how ecosystem science (new ecosystem indices,

management tools, etc.) can be used effectively in the Council process. (e.g., next generation ecosystem MSEs that include e.g., governance considerations)

- Better connect ecosystem indices to assessments and biologically or socially meaningful reference points.
- Monitor, model, and predict changes in distribution of species related to changes in ocean conditions and climate. Identify how climate change will affect spatio-temporal ocean distributions and the overlap between predator-prey assemblages. Identify how distribution shifts will impact jurisdictions and communities.
- Continue development of ecosystem-based models (including Atlantis) that incorporate environmental variation and anthropogenic disturbances to guide harvest policies and enable risk assessment for fishing strategies.
- Use data being collected as part of long-term monitoring of existing reserves and MPAs for detecting shifts in the ecosystem that may affect fish stocks and trigger changes in fishery management, including changes in ocean chemistry (e.g., pH, temperature, salinity), species range shifts, timing of juvenile recruitment pulses, poor juvenile recruitment years, and population size structures (in areas outside of reserves, being monitored as part of a BACI monitoring design)
- Integrate National Marine Sanctuary Condition Reports into the IEA's ecosystem status and trends reports. The five national marine sanctuaries on the U.S. west coast (Channel Islands, Cordell Bank, Greater Farallones, Monterey Bay and Olympic Coast national marine sanctuaries F) produce Sanctuary Condition Reports every 5 to 10 years. A Condition Report provides a summary of resource condition specifically water quality, habitat, living resources and maritime archaeological resources in the sanctuary; describes pressures on those resources and the current condition and trends of sanctuary resources; and summarizes management responses to pressures that threaten the integrity of the sanctuary's marine environment. The west coast sanctuaries are partnering with the NOAA CCIEA team and states to use similar ecosystem indicators as the CCIEA for the condition reports.

## **2.5 Other New and Continuing Priority Issues**

In addition to the highest priority issues discussed above there are a number of research and data needs that would provide high and moderate benefits, and there is a continuing need to monitor and predict broad-scale and long-term oceanographic condition. Several of these issues were listed as high or moderate priority in 2013 but have not been fully addressed and remain important issues. They have been carried forward to this document along with new issues that have been identified.

### **2.5.1 High Benefit**

- Identify key indicators for recruitment, growth, spatial availability, and overall California Current Ecosystem (CCE) productivity. Continue and expand studies to better understand

the mechanistic drivers of observed levels of variability in recruitment, growth and distribution.

- Examine ecological interactions for influence on managed and non-managed species, including predator-prey relationships, competition, and disease. Investigate the role of FMP species in the food web, including analysis of behavioral interactions (e.g., functional response) between predators and prey.
- Better understand spatial structure and geographic range (meta-population structure) of managed stocks and investigate what are the most appropriate spatial scales for management.
- Assess high and low frequency changes in the availability of target stocks, and the vulnerability of bycatch species, in response to dynamic changes in climate and oceanographic conditions (such as seasonal changes in water masses, changes in temperature fronts or other boundary conditions, and changes in prey abundance).
- Assess near-shore distribution of FMP species for habitat needs and fishery vulnerability during nursery and pre-reproductive life stages. Characterize the influence of nearshore marine, estuarine, and freshwater water quality on survival, growth, and productivity.
- Collect data on distribution, diet, and abundance of target and non-target species and their prey and predators on finer spatial scales, following a prioritization exercise that identifies target species in greatest need of finer-scale assessment and non-target species that may function as indicators of trophic interactions and ecosystem condition. This could and should include continuation of existing time series. Such time series are of particular importance with respect to more accurate modeling of the dynamic nature of food web interactions in this highly variable ecosystem, including modeling the consequences of variable climate conditions on mechanistic interactions between predators and their prey, as models that are able to “fit” time series of food habits will be viewed as considerably more reliable than those which cannot.
- Develop and implement a monitoring strategy for determining the prevalence of HAB toxins in fish tissues, especially coastal pelagic species (sardine, herring, and anchovy), in the CCE in relation to regulatory limits for human consumption. While this is mainly an issue for public health departments, the monitoring should be integrated with the fishery management system.
- Develop indicators of harmful algal blooms (HABs) and the phytoplankton community (diatoms vs. dinoflagellates) for the entire CCE to identify and track changes to the base of the marine food web. Evaluate relationships with other indicators of climatic and oceanographic conditions, fisheries productivity, and fisheries participation (because HAB toxins can close important fisheries such as Dungeness crab, potentially redirecting effort to other fisheries).
- Evaluate the influence of climatic/oceanographic conditions on the population dynamics of FMP species. Develop indicators to track that influence, such as for upwelling, sea surface temperatures, Pacific Decadal Oscillation, chl-a, and zooplankton index. Evaluate the efficacy of incorporating habitat and environmental factors within the current stock assessment modeling framework (Stock Synthesis 3). Model effects of climate forcing and other ecosystem interactions (e.g., trophic interactions) on productivity and assess utility of simulated estimates of the unexploited biomass over time (a “dynamic B0”) rather than

the static estimate of long-term, mean, unfished abundance. Such an evaluation could help the Council focus on priorities for EFH consultation and input.

- Evaluate potential for greater conflicts between water use for agriculture and providing stream flow and habitat for anadromous fish. This is already a major issue in California but could become a bigger issue in Northwest as more precipitation falls as rain and snowpack declines. While this is a management issue largely outside the control of the Council, it has the potential to strongly impact salmon fishery management in the future.

### **2.5.2        *Moderate Benefit***

- Investigate how fishing activity affects ecosystem structure and function, particularly spatial and temporal fishing patterns and their relation to changing patterns in the ecosystem (cumulative impacts of all FMP fisheries).
- Evaluate effectiveness of standardized bycatch reporting methodologies in all FMP fisheries and develop quantitative information on the extent of the cumulative bycatch of all FMP fisheries. [Assure bycatch reporting methodologies includes habitat forming species.](#)
- Evaluate the tradeoffs society is willing to make across the alternative ecological benefits fishery resources provide.
- Apply Non-market valuation techniques to estimate existence or other non-use values that are applicable to FMP target species, as well as the non-target species that interact with FMP target species.
- Develop methods and linkages to socio-economic data and modeling to assess effects of changes in resource availability, climate, and regulations on West Coast fisheries.
- Develop an approach for interpreting the values for indicators, including the development of thresholds, where appropriate.
- Use of hydrodynamic modeling, otolith elemental analysis or genetic fingerprinting and parental analysis to determine origin of benthic juvenile groundfish and formulate hypotheses for larval dispersal and stock structure.
- Better evaluate the potential for MPAs to provide a basis for fisheries harvest control rules, particularly in data-poor assemblages (such as nearshore species in the West Coast Groundfish FMP) through the use of the “density ratio method,” which would essentially use the relative density (inferred by catch rates) inside MPAs to inform harvest rate adjustments outside of MPAs (by assuming the catch rates within MPAs represent an “unfished” condition).

### **2.5.3        *Broad-Scale and Long-Term Oceanographic Conditions***

Changes in temperature, oxygen saturation, and ocean pH are key oceanographic features that help to define both habitability and productivity for much of the CCE, have both direct and indirect

impacts on fisheries species, and are expected to change with future climate variability. Future research considerations that would improve the Council's ability to incorporate oceanographic conditions into EBFM are:

- Direct physiological effects of temperature, pH, and dissolved oxygen changes on managed and non- FMP forage species, including, but not limited to: tolerance limits, growth rate, and reproductive rate,
- Current spatial and depth boundaries of all FMP and non-FMP forage species in regards to temperature, pH, and dissolved oxygen,
- Spatially-specific trend analysis of temperature, pH, and dissolved oxygen changes specific to the EFH of all FMP and non-FMP forage species,
- Spatially-specific forecasts of temperature, pH, and dissolved oxygen changes specific to the EFH of all FMP and non-FMP forage species, and
- Spatially-specific trend and forecast of temperature, pH, and dissolved oxygen effects on food chain base (primary and secondary production) for all FMP and non-FMP forage species.

## 2.6 References

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## 3.0 ECONOMICS AND SOCIAL SCIENCE COMPONENTS

### 3.1 Introduction

This section focuses on research and data needed to (1) support and expand the use of economic and social information in Council deliberations and regulatory analyses, (2) improve understanding of the social, economic, biological and ecological tradeoffs involved when applying an existing policy or considering alternative policies to achieve a given objective (e.g., capacity management, stock rebuilding), (3) improve the Council's ability to monitor the economic and social status of fisheries and fishing communities, (4) provide retrospective evaluations of past policies that could help inform future policies, and (5) advance National Standard 8, "Consider fishing communities to provide for their sustained participation and to minimize adverse economic impacts."

In the previous Research and Data Needs Report the following issues were identified as "Highest Priority". Progress on these issues is summarized below.

#### ***Data Priorities:***

- Commercial cost-earnings and recreational surveys
  - The Groundfish Economic Data Collection (EDC) program was successfully implemented by the NWFSC starting in 2010. It consists of an annual census of financial information from harvesters and processors that participate in the West Coast Groundfish Limited Entry Trawl Program. The EDC program is ongoing.
  - Cost-earning surveys for other fisheries are conducted less frequently. The last cost-earning surveys were completed as follows: Fixed Gear Groundfish (2015-2016), Groundfish Open Access which also includes participants in salmon, shrimp and crab fisheries (2015-2016). Coastal Pelagic Species fisheries (2009), HMS drift gillnet and harpoon swordfish fisheries (2010), and the HMS albacore surface hook-and-line fishery (1999). Periodic recreational angler and charter boat (commercial passenger fishing vessels, or CPFV) surveys. The last charter boat survey collected data from 2012.
- Spatial data on catch and effort for commercial and recreational fisheries
  - Commercial logbook data collected by state and federal logbook programs are available for the limited entry groundfish trawl, limited entry groundfish fixed gear, and some HMS fisheries. Observer data that is integrated with logbook spatial data is also available for limited entry groundfish trawl trips and provides information on catch and discards at the tow level. Groundfish logbook data are managed by PacFIN and are used in regulatory impact analyses, such as EFH as well as behavioral modeling and other economic analyses.

- Observer data are collected by NMFS for the drift-gillnet swordfish fishery, for use in regulatory impact analysis, cost benefit analysis, behavioral modeling, and other purposes.
- Observer data are also collected by NMFS for the California deep-set pelagic longline fishery beyond the Exclusive Economic Zone since 2005 to document the incidental capture of sea turtles and seabirds.
- Vessel Monitoring System (VMS) data related to the groundfish fishery have become available to analysts. Analysis of this data set is ongoing at the NWFSC and SWFSC. VMS data are also available for some vessels while participating in other fisheries, including state managed fisheries, but not all vessels are covered by VMS.
- California maintains a database of Commercial Passenger Fishing Vessel (CPFV) logbooks that can be accessed for stock assessment or economic modeling.
- Regular sources of location data are not available or not accessible for most other commercial or recreational fisheries. Washington and Oregon have implemented logbook programs for Dungeness crab, but these are not managed by PacFIN and are not as easily accessible for regular analysis. Oregon has a logbook program for its nearshore (non-trawl) commercial groundfish fishery, which informed stock assessments conducted during 2015 and 2017, but has not been used to date in economic studies

***Modeling and analysis priorities:***

- Expansion of the Council’s regional input-output model, IO-PAC, to cover all FMP fisheries and fishery sectors.
  - The IO-PAC model now includes groundfish and salmon as well as crab and shrimp, but does not include HMS or CPS.
- Recreational fishing values
  - There has been some work estimating recreational values for bottomfish species and salmon. In particular, discrete choice experiment survey data have been used by the NWFSC to estimate values in the context of hatchery and wild salmon (Anderson and Lee, 2013) and in the context of different sets of closures for Puget Sound (Anderson, Lee, and Levin, 2013). The models were also used as part of a larger food web modeling application that included recreational values as one component (Plummer et al., 2012).
  - The NWFSC and SWFSC are currently collecting discrete choice data in California, Oregon, and Washington. Once collected, data may be used to estimate economic welfare measures for angler trips, and marginal changes in bag-limits and



expected catch, as well as information regarding substitution between species for salmon, groundfish, tuna, and other recreationally targeted species.

- Models of fleet dynamics for commercial harvesters and recreational charter boats, including spatial and fishery choice behavior
  - A location choice model using a random utility model (RUM) framework has been developed for the limited entry groundfish trawl fleet with sub-models for port-based fleets. The model was parameterized with 2011-2012 data. The model has not yet been used for regulatory analysis but is available for use. A closely related model was developed by Peter Kuriyama and was parameterized with data through 2014.
  - A model of Commercial Passenger Fishing Vessel (CPFV) trip choice is in progress
- Continued development and validation of indicators of community dependence on fisheries and community well-being and resilience that can be linked to regulations, economic conditions, and other relevant factors
  - Community-level indicators of fishing dependence and vulnerability have been developed and are a regular part of the CCIEA.
- Improved integration of economic and social science methods and data into bycatch and catch forecasting models used by the Groundfish Management Team to develop management alternatives for the Council
  - Not completed
- Incorporation of economic and social metrics and fishery behavioral models into management strategy evaluations of alternative harvest control rules to help clarify social, economic, biological and ecological trade-offs
  - Not completed
- Analysis of economic and social effects of the groundfish catch share program on fishery participants and fishing communities
  - A review of the West Coast Groundfish Trawl Catch Share Program was completed in 2017.

### **3.2 Highest Priority Issues**

Highest priority items were identified based on whether they have broad potential for improving the economic and social content of Council deliberations and analyses, or address an important management issue that would benefit from advanced modeling or analysis to facilitate

understanding of its economic and social implications. Further discussion of these items is provided in Sections 3.3 (Ongoing Issues) and 3.4 (Emerging Issues).

The Council notes that, at present, economic and social data and analyses tend to be more robust for commercial than recreational fisheries.

***Data priorities (note that no priority ordering within this list is implied):***

**Continued support for commercial and recreational cost-earnings surveys in all FMP-managed fisheries, including the Groundfish Economic Data Collection (EDC) Program:** Commercial fishery cost/earnings data should be collected and routinely updated to ensure that they reflect changing regulatory and market conditions. Groundfish catcher vessels, processors and catcher-processors involved in the groundfish catch share program are subject to a mandatory EDC Program. Voluntary cost-earnings surveys are conducted on a two or three-year rotating basis that cover other fisheries in which groundfish vessels participate (shrimp, crab), as well as the salmon troll and net fisheries. Maintenance of these data collection and efforts updating other fisheries (such as the drift gillnet, albacore surface hook-and-line, harpoon, limited longline, and emerging deep-set buoy gear) is necessary for analysis of regulations and contribute to SAFE documents.

**Development of a survey of all groundfish catch share quota share owners, including owners not currently actively engaged in fishing operations:** This information would allow for a more complete evaluation of the effects of catch share programs.

**Periodic surveys of fishing communities and participants to collect information on social, demographic, and economic characteristics suitable for use in social impact analyses for each FMP:** Regular economic and social data collection regarding crew, non-processing, and other stakeholders are needed. Social and economic data sources that provide a more complete picture of the demographic profile of fishing industry participants are needed. These data would be useful in addressing questions regarding the “graying of the fleet” and provide for evaluation of potential policies to attract and assist new industry participants. These studies may also help identify broadly held perceptions that are not reflected in available quantitative data and can provide more precise understanding of the social aspects of the fishery. Additionally, identification of any discrepancies between public perceptions and fishery data can both help the Council weigh public testimony in reaching a decision and help with communicating outcomes. The Pacific Coast Groundfish Trawl Social Study (PCGSS) surveys conducted in 2010 and 2012 are an example of this type of data. Development of data sources for other (non-groundfish) fisheries is a priority.

**Development of data sources on seafood markets and supply chains relevant to West Coast fisheries.**

**Development of data sources for community-level indicators related to recreational fishing:** Indicators, such as for community vulnerability, resilience, and fishing dependence, currently exist for commercial fisheries and are regularly presented as part of the annual CCIEA report. Similar information related to recreational fisheries would provide a more complete accounting of the

status of coastal communities and provide information for use in evaluation the impacts of management actions and climate-related changes.

**Periodic recreational angler and charter boat (commercial passenger fishing vessels, CPFV)**

**surveys:** Angler surveys are needed to estimate the economic value and regional economic impacts of recreational fisheries. Such surveys are conducted fairly routinely on the Pacific coast and have been facilitated in recent years by improved electronic coverage of recreational license holders, including addresses/phone numbers. When supplemented by intercept interviews or other means of contacting anglers who are not in the license frame, such dual frame approaches are effective for collection of representative economic data. Estimates of aggregate fishing effort (number of participants as well as number of trips by mode and trip type) are also needed for all states in order to expand survey results from the sample to the population.

**Improved data on location of catch and effort for commercial and recreational fisheries:**

Spatial information by fishery type is needed at a scale that is useful for harvest, ecosystem, and habitat-based management activities. High resolution catch and effort are needed to evaluate and forecast social and economic effects from a range of spatial management issues including (but not limited to) EFH and other protected habitat areas and for anticipating the effects of other activities (e.g., wave energy development, aquaculture projects) on fisheries. Spatial data on fishing trips should include both landing sites and areas fished. Improvements in the quality of spatial data may include expanded use of VMS, observer, and logbook data and development of VMS and electronic monitoring data as possible sources for analyses

***Modeling and analysis priorities (note that no priority ordering within this list is implied):***

**Continued development and validation of community-level indicators:** Validation of indicators of community dependence on fisheries and community vulnerability and resilience to ensure that they can be linked to regulations, economic conditions, and other relevant factors is needed. Also, continued development of measures of human well-being, job satisfaction, and social capital for fisher and fishing communities is needed.

**Recreational valuation and impact models and studies:** Angler participation models, behavioral choice models, and net economic value estimates are needed for recreational salmon, HMS, and groundfish fisheries. Both revealed choice methods (including the analysis of logbook data) and stated preference methods (including the fielding of discrete choice experiments) are needed to address a variety of conservation and management questions. Some recent modeling and valuation estimates are available for the Pacific Northwest but only for specific locations and species.

**Models of fleet dynamics for commercial harvesters and recreational charter boats, including spatial and fishery choice behavior:**

Models of commercial fleet dynamics (e.g., spatial behavior, fishery choices) can help managers understand fishing behavior and predict the effects of proposed regulations. Such models could use observed historical data on fishing site choice and include historical activity in previously closed areas, as well as areas that have remained open in the recent past. Such models should be capable of assessing whether closure impacts would be felt disproportionately by a particular port or region. These models could draw on

qualitative information from fishery participants to inform model design and assess the plausibility of forecasted results. Models of charter (CPFV) fleet dynamics are needed that reflect the multi-species nature of the fishery, economic incentives of charter operators to provide not just fish but a “fishing experience,” and adaptations of charter vessels to regulatory, market and environmental conditions. Such models could be used to determine whether charter fleet dynamics yield single-species catches per unit of effort (CPUE) that can reasonably be used as an index of relative abundance for that species. These types models should be capable of addressing a range of research questions and management issues, including (but not limited to):

- Evaluating spatial management measures, such as the implementation or revision of closed areas
- Evaluation fishery participation and movement between fisheries including both federal and state fisheries. These models are important to understand cross-participation patterns by fishers in multiple fisheries.
- Evaluating effects of climate change and/or fishery management changes (e.g., harvest limits or seasonal closures) on effort and participation. For example, the rebuilding process for some constraining groundfish stocks will be completed in the near future. Behavioral models of participation, gear choice, and species targeting are needed to project catch as constraining quotas are raised and new areas are possibly opened (or closed) to all or some fishing. These types of analyses are especially applicable to catch forecasts in the in the groundfish and salmon fisheries.

**Models that incorporate bycatch:** Bycatch has become a central issue in west coast fisheries management. Interactions of vessels and gear with marine mammals and other protected species has become an increasingly important consideration in fisheries management. Alternative approaches to managing and reducing bycatch, bycatch mortality, and effects of gear on habitat should be evaluated – with cost-effectiveness and incentive compatibility included among the evaluation criteria. Fleet dynamics models described above may be useful in such evaluations.

**Integrate social science into Management Strategy Evaluations (MSEs):** This includes developing 1) appropriate social and economic performance metrics and 2) behavioral models that model how humans respond to changes in management, stock abundance, and species distribution.

**Fishery-specific topics on the effects of the West Coast Groundfish Trawl Catch Share Program including:**

- Determine the causes of low utilization rates in the groundfish fishery.
- Evaluate the effects of potential changes to the catch share program including changes in accumulation limits, alternate uses for adaptive management quota, and policies designed to achieve social objectives.
- Assess the cost-effectiveness of maintaining 100% observer coverage.
- Research on inter-sector interactions for groundfish fisheries. One example is the conflicts between the IFQ and non-IFQ fisheries for sablefish south of 36° N lat.
- Enhance understanding of quota exchange values, including information on the full value of market exchanges. Better understanding of how quota markets are functioning and how that could be improved are needed. This may require additional data collection, such as follow-up surveys after market transactions.

- Better understanding of product recovery rates. This may require new information on transfer of processed and unprocessed fish between processors and may ultimately result in more accurate assessment of processor profitability.

**Fishery-specific topics for HMS:** Analysis of the Council’s developing Swordfish Fishery Management and Monitoring Plan, to include determining the economic and social effects of domestic swordfish fishing off the West Coast on fishery participants and fishing communities; comparing the economic performance, commercial volume of production and bycatch impacts of different methods of swordfish fishing; and assessing the potential for increased domestic swordfish production to substitute for imports

### **3.3 Ongoing Issues**

Ongoing issues are categorized into two types of activities: data collection/augmentation and model development/analysis. Some of the data and modeling needs identified in this section are relevant to social as well as economic issues.

#### **3.3.1 Data Collection and Augmentation**

Core data needs pertain to fundamental information relevant to understanding economic behavior and estimating the economic value and impact of fisheries, and conduct the analyses described in section 3.2 (Highest Priority Issues).

Currently, landings receipt data provide fairly coarse measures of fishing effort (numbers of vessels and landings). Analysts must rely on these measures or use logbooks, which are not available for most fisheries. Adding finer measures of effort (e.g., number of days fished, days at sea, sets, tows) associated with each landing would make the fish tickets more useful for economic analysis.

Inclusion of crewmember IDs on landings receipts would greatly improve our understanding of the economic effects of regulations on crew and communities, and provide routine information on this data-poor segment of the commercial fishery. Similarly, such IDs for skippers would allow for inclusion skipper-specific effects in economic models.

#### **3.3.2 Model Development and Analysis**

Continued use and extension of economic impact models: A regional input-output model (IO-PAC) developed by the Northwest Fisheries Science Center (NWFSC) was reviewed by the SSC and has been used to analyze alternatives for the groundfish harvest specification process, the development of annual salmon SAFE documents, and other analyses. IO-PAC can also be used to model impacts for Dungeness crab and pink shrimp, but has not been extended to the HMS or CPS fisheries.

Continued development and incorporation of economic and social analysis into IEA reports, especially development of behavioral and community dynamics models into the CCIEA. The presentation of social and economic indicators in the annual CCIEA report has been useful to the

Council and stakeholders. Further analysis, including the fleet dynamics models mentioned below, would help provide additional information on the effects of ecosystem changes on West Coast fisheries.

Maintenance of fisheries economic and social baseline data at the community level is needed. Economic and social profiles of coastal communities significantly involved in west coast fisheries were compiled several years ago. Additional information that could enhance the utility of these profiles for management includes the following:

- Community-specific trends in major commercial and recreational fisheries, and factors affecting these trends
- Infrastructure availability and needs (for commercial fisheries, recreational fisheries, other marine resource-related uses)
- The presence and location of processors and buying stations, charter (CPFV) activity, and other fishery-dependent businesses.
- Financial aspects of infrastructure development and maintenance.

Retrospective analysis of major historical regulatory actions (e.g., time-area restriction for the drift gillnet fishery for swordfish, the Pacific Leatherback Conservation Area Closure, Rockfish Conservation Areas and Essential Fish Habitat closures, the groundfish trawl vessel buyback, salmon fishery closures in the late 2000s, and the groundfish catch share program) to determine the actual economic and social effects fisheries and fishing communities and the extent to which the Council's goals for each action were achieved. Retrospective analysis would also help determine whether and how each measure might be effective in addressing similar issues in the future.

Analysis of the economic and social effects of alternative capacity management programs - including limited entry and catch shares - on fishery participants and fishing communities. Important non-trawl fisheries to consider are open access groundfish and coastal pelagic species. Models are needed to analyze the transition from open access to limited entry or limited entry to catch shares in terms of regional economic impacts, effects on costs, earnings and harvest capacity of the fleet, and community effects.

Analysis of consolidation patterns and impacts on fishing communities and fishers.

Analysis of barriers to entry into Pacific coast fisheries.

Analyses of how fishermen use quota and quota poundage trading to manage choke species and related issues.

### **3.4 Emerging Issues**

Growing attention is being paid to more holistic approaches to management that focus on the relationship of fisheries to habitat, bycatch, and environmental and domestic/global market conditions, and that consider non-fishery activities and values that may be enhanced by ecosystem

approaches to management. As above, these needs are divided into two activities: data collection/augmentation, and model development/analysis.

### **3.4.1      *Data Collection and Augmentation***

Many of the data needs previously identified in Section 3.3.1 are relevant to emerging as well as continuing issues. To achieve the modeling associated with EBFM that is discussed in Section 2.4, fishery data will need to be integrated with data on habitat, environment, market conditions and other human activities. Such integration will likely pose challenges in terms of data availability and lack of standardization in the measurement and temporal/spatial scale of individual data elements. Cooperative data collections that pool resources and expertise of agencies, fishermen, and research entities may prove beneficial to all involved.

Develop trip definitions for different Council-managed fisheries that can be used to identify unique trips over multiple independent data sets including vessel-level observer, logbook and landings records.

Cleaner codes for the fishing methods used in Council managed fisheries could help simplify economic and social data analysis. For example, the finfish species codes in the PacFIN database are tightly organized, while the description of gears and fishing methods embodied in PacFIN gear codes is less clean. One possible approach would be to implement the FAO's standardized international system of gear codes in PacFIN.

Additional data or cost allocation studies on fishery management program administration. The extent to which cost recovery fees cover program costs is currently unclear. Also, program administration may be a consideration when evaluating cost-effectiveness of policy options.

Research on whether observed cash prices for quota pounds accurately represent value. Non-cash transfers of quota are common in this market. Are there other methods for estimating quota value?

### **3.4.2      *Model Development and Analysis***

More integrated tools with EBFM in mind. A characterization is needed of all commercial and recreational fisheries within the California Current Ecosystem, including spatial distribution and behavioral linkages between complementary and substitute fishing activities, is needed. In addition, an analytical framework that accounts for dynamic and inter-regional interactions among industries and households would improve estimates of economic impacts, and comparison of costs and benefits among management alternatives.

Incorporating variability in fishing opportunity in to social and economic evaluations. Fisheries and communities benefit not only from the size of harvest opportunities but also the stability of such opportunities and the flexibility afforded by a diversity of such opportunities. Management approaches that enhance fishery stability and flexibility should be identified and evaluated.

Models and analysis of how management and other factors affect risk-taking and safety of West Coast fishermen.

Computable bioeconomic models of fishing effort that are spatial and include effects of economic and environmental factors (e.g. prices, sea surface temperatures) are needed to predict effects of changes in regulatory, habitat, environmental, and market constraints on participation and harvest in the ocean commercial, ocean sport, tribal, and in-river sport salmon fisheries.

Stated preference surveys and other non-market valuation techniques could be used to estimate existence or other non-use values associated with threatened and endangered species, ecosystem protection, and stock rebuilding plans.

Causal analysis of the effects of fishery management measures on fleet dynamics and communities, for example capacity control and rationalization in the groundfish fishery, spatial-temporal closures of the Pacific swordfish drift gillnet fishery, and area management in the salmon fishery. The recently West Coast Groundfish Trawl Catch Share Program Five-Year Review provided a detailed summary of conditions in the fishery before and after the transition to catch shares, but was unable in most cases to attribute observed changes to program implementation. Causal analyses would, for example, compare observed changes to a credible counterfactual estimate of what would have occurred if specific management measures had not been implemented.

Evaluation of the economic and social effects of fishery disaster declarations:

- Are disaster funds distributed to fishery participants in a way that allows for continued participation in the fishery and addresses observed economic and social impacts?
- Is the magnitude of the disaster funding appropriate for the level of impact?
- What factors can predict future requests for disaster assistance and are we likely to see requests increase, given that most of the recent requests are climate-based declarations?

Assessment of the economic status of the salmon (commercial and recreational) and CPS fisheries. As a result of the data collections pursuant to the West Coast Groundfish Trawl Catch Share Program Five-Year Review, there is wealth of economic, financial, and social data available to characterize the status of fishery participants. Less is known about participants in other fisheries. This is particularly relevant for salmon and CPS fisheries that have been affected by closures and catch limits in recent years. This work could take on many dimensions but could include:

- Characterize the individuals, families, firms, organizations, and communities involved in the fishery.
- Evaluate profitability, capacity use, fixed costs, and viability by region.
- Evaluate the social and economic impacts of historical and potential regional closures and low abundance, including evaluation of distributional effects and impacts on other fisheries.
- Describe market dynamics (price determination, barriers to market access, value chain analysis).

Information is also needed on the emerging deep-set buoy gear for swordfish. Little to nothing is known about its potential profitability, including the impacts of various configurations of buoys, and the number of vessels and buoys that are likely to enter this fishery. Buoys that are in addition to current drift gillnet fishing potentially increases overall fishing capacity. Information is also



need for potential markets, prices, quantities caught and landed, bycatch, and price differentials for quality compared to drift gillnet caught swordfish.

An important bycatch issue for trans-boundary swordfish and sharks is the impact of regulations upon potential spillovers or leakages of production abroad to foreign fisheries, trade leakages due to imports of these foreign-caught fish, consumption leakages through increased consumption of these foreign-caught fish that are imported – which includes impacts upon consumers of potentially lower quality and foreign catch, and conservation leakages of potentially increased net bycatch associated with the production leakage even after accounting for reduced domestic bycatch. These spillovers or leakages can potentially reduce domestic producer and consumer net benefits and increase net bycatch.

Information and analysis are also needed to support evaluation of alternative configurations of the swordfish and shark fisheries, such as, for example, a vessel buyback program of drift gillnet vessels. The impact of altered numbers of drift gillnet vessels and vessels setting on deep-set buoy gears upon bycatch, volume and composition of landings, imports, and exports, and producer and consumer benefits requires evaluation.

Information and analysis are also needed to support potential expansion of the California deep-set pelagic longline fishery beyond the Exclusive Economic Zone. Many of these vessels fish under the Hawaiian pelagic fishery management plan, and analysis may be required of the potential allowance of such a fishery based in the west coast under the PPMC HMS Plan.

Enhanced reporting of social and economic indicators in SAFE documents. Periodic assessments of current fishery status are contained in SAFE documents produced for each FMP. Quantitative descriptions of economic status are generally limited to basic information such as landings, ex-vessel revenues and fishing effort. Cost-earnings surveys, the Groundfish EDC Program, recreational angler surveys, charter boat (CPFV) surveys, the IO-PAC model, and recreational valuation models provide the means to enhance the utility of SAFE documents. Information on profitability of commercial operations, economic value of recreational fisheries, employment and income impacts, and other community effects should be included in SAFE documents as such information becomes available. For example, quota share prices can be good indicators of economic status for groundfish catch share fisheries.

Models and analyses of fish product supply chains, market development, price-characteristic relationships, and imports and exports. Some of this work could consider potential market demand for rebuilt rockfish species. Additional work could evaluate impacts of local sourcing, eco-certification, etc.

## **4.0 GROUNDFISH FISHERY MANAGEMENT PLAN**

### **4.1 Introduction**

The focus of this section is on research and data needs to support quantitative stock assessments and management of groundfish stocks in the FMP, and the role of, and risks to, groundfish essential fish habitat. Identification of research and data needs is a routine part of the groundfish Stock Assessment Review (STAR) process. Progress on high priority groundfish R&D items identified in the 2013 Research and Data Needs document is briefly summarized immediately below and followed by high priority groundfish R&D items identified for the 2018 Research and Data Needs document. The 2008 document included essential fish habitat (EFH) items for groundfish in an appendix. The current document includes subsections below with priority groundfish EFH items developed by the Council's Habitat Committee.

### **4.2 Progress on 2013 Research and Data Needs**

The groundfish section of the 2013 Research and Data Needs document was organized into the following major categories: (1) fishery-independent data, which are data collected independently of the fisheries (e.g., bottom-trawl research surveys); (2) fishery-dependent data, which are data collected from fishing operations (e.g., on-board observers) or from fish captured by the fisheries (e.g., port samples); and (3) stock assessment issues, which relate to assumptions and technical details of the quantitative stock assessment models.

The subsections below indicates research and data needs identified in 2013 for which there has been progress and briefly summarizes the progress. Research and data needs identified in 2013 for which there has been no progress are not included.

### **4.3 Fishery-Independent Data**

#### **4.3.1 *Continue to conduct annual comprehensive shelf and slope bottom trawl survey***

The Northwest Fisheries Science Center (NWFSC) has continued its annual survey of the shelf and slope off the U.S. West Coast. The data from this comprehensive long-term annual survey have been used in almost every groundfish assessment on the U.S. West Coast.

#### **4.3.2 *Continue to explore additional survey methods***

The NWFSC shelf and slope survey cannot access rocky areas, where a number of rockfish species occur. Also, trawl survey efforts are currently closed in the Cowcod Conservation Area (CCA). There have been several projects (described below) aimed at developing alternative methods to assess abundance of fish in untrawlable areas as well as other areas not well-surveyed by the current bottom trawl survey.

Alternative methods recommended in 2013 for which there has been progress include:

- *Continue exploring survey methods to survey untrawlable areas.* Survey methods to survey untrawlable areas (Autonomous Underwater Vehicles, submersibles, drop cameras, acoustics, towed cameras, light detection and ranging, etc.). There has been notable progress on the development of a range of visual survey methods over the past five years, with numerous surveys, publications and applications, although few have progressed to the point of informing stock assessments by virtue of either relative abundance time series or absolute abundance estimates. Continued hook-and-line surveys, further described below, have also continued to add to available data for untrawlable areas.
- *Continue whiting midwater acoustic surveys on a frequent basis and consider potential expansion to include rockfish surveys.* Midwater acoustic surveys for Pacific hake have been conducted on a biennial basis in conjunction with Canada and the data used to inform the annual stock assessments prepared under the auspices the Agreement between the Government of Canada and the Government of the United States of America on Pacific Hake/Whiting. In addition, the NWFSC completed winter acoustic surveys in 2016 and 2017 to further our understanding of hake spawning behavior.
- *Maintain the California Cooperative Oceanic Fisheries Investigations (CalCOFI) egg and larval production surveys.* The CalCOFI egg and larval production surveys have been conducted annually since 1951. In recent years, genetic methods have allowed for the identification of larval rockfish (*Sebastes*) to the species level, enabling the development of relative abundance indices for a broader suite of species than was previously possible using solely morphological features (Thompson et al. 2017). However, time series based on genetic analyses are currently only available as far back in time as 1998. Longer abundance indices based on data from these surveys have been used in groundfish assessments for bocaccio, chilipepper, cowcod, and shortbelly rockfish. A newer genetics-based time series was developed for the blue/deacon rockfish assessment. It helped inform the development of a data-poor model in the southern region, but ultimately was not included in the assessment model due to differences between the survey index area and the stock boundaries.
- *Continue exploring the use of hook-and-line or longline gear for surveying rockfish populations.*
  - The NWFSC, in collaboration with the PSMFC and the CPFV industry, has conducted an annual hook and line survey in the Southern California Bight since 2004 (with a pilot survey in 2003). Data from this survey have been used to generate abundance indices for several key species of shelf rockfish including bocaccio, cowcod, and greenspotted rockfish.
  - The International Pacific Halibut Commission has conducted annual hook-and-line survey off the northern portion of the US since 1998. This survey has provided data on a number of groundfish species, including yelloweye rockfish.

## 4.4 Fisheries-Dependent Data

### 4.4.1 *Improve on fishery monitoring and data collection*

High quality fishery-dependent data are a key component to inform groundfish stock assessments and management. The NMFS and state fishery agencies maintain systems to gather fish ticket (landings receipts) data that provide a census of the magnitude and composition of the landed catch, gather logbooks that document areas of capture, collect port sampling information that provides estimates of species composition of aggregated landings and biological characteristics of target and bycatch species, and collect at-sea observer information to document catch discarded at sea.

- *Continue research on barotrauma and the use of recompression, or descending devices, for released rockfish*, particularly for deeper waters (> 30 fm), over a broader suite of species, including overfished species. Experiments in southern California demonstrate that descending devices substantially reduce rockfish mortality relative to merely releasing the fish at the surface (Chen 2012). Between 2013 and 2018, ODFW research staff conducted post-recompression barotrauma survival and behavior studies on deacon rockfish (9-54 m) and with canary rockfish and yelloweye rockfish in depths from 46-84 m and in 175-200 m (Hannah et.al. 2014 and Rankin et.al. 2017).
- *Continue to monitor catch and discard in commercial fisheries at-sea*. Work continued on monitoring catches and discards in commercial fisheries at-sea under two observer programs operated by the NWFSC on the U.S. West Coast: the At-Sea Hake Observer Program, which monitors the at-sea hake processing vessels, and the West Coast Groundfish Observer Program (WCGOP), which monitors catcher vessels that deliver their catch to a shore-based processor or a mothership. Electronic monitoring systems are also being used, discussed below.
- *Review the process for determining the species viability and the resulting discard mortality estimates for Pacific halibut* and possibly other species in the commercial fisheries. Although there has been no recent comprehensive review of halibut viability scoring and discard mortality estimation, in 2017 members of the Groundfish Management Team and staff from the Pacific States Marine Fisheries Commission evaluated methods for determining Pacific Halibut discard mortality rates for electronically monitored groundfish bottom trawl trips (PFMC 2017a).
- *Further explore use of electronic monitoring system (EMS) in commercial fisheries* to monitor catch, estimate discard and identify species composition of the discarded portion of the catch. The PSMFC in conjunction with WCGOP has extensively researched the accuracy of using EMS on catch shares vessels to monitor at-sea discarding (PFMC 2018a). Thanks to this research, beginning in 2015, under an exempted fishing permit program, EMS is now allowed on approved catch shares boats fishing bottom and midwater trawl or pot. The potential for cost savings of using EMS compared to observers appears to differ based on gear type, but an exact number has yet to be produced, due in part to remaining uncertainties around the cost burden of data storage. The WCGOP has also begun pilot

research on using inexpensive EM systems to monitor catch on small, otherwise unobservable vessels.

- *Continue to collect information on the size composition of the discarded portion of the commercial catch.* For many species the WCGOP has continued to collect information on the size composition of the discarded portion of the commercial catch and these data have been used to inform stock assessments.
- *Evaluate protocols and priorities for biological sampling.* While there have been no formal evaluations of the protocols and priorities for collecting the biological samples (lengths and age structures) that support stock assessments, the WCGOP and A-SHOP have continued to work with stock assessors to ensure that biological data collected are relevant to and can support stock assessments.
- *Evaluate and improve the recreational fishery catch and effort estimates.* The accuracy and precision of recreational catch and effort estimates for minor fishing modes, such as beach and bank anglers, private access sites, and night fishing, needs to be further investigated and improved. In 2016 the ODFW conducted an MRIP funded small-scale pilot project to try to determine if an update to the shore and estuary estimates used are still appropriate.
- *Improve discard estimates in the recreational groundfish fishery,* particularly for non-retention species. ODFW continues to deploy observers on 100 charter trips annually to collect data on discards at sea (species composition and size). Data on discards are also collected by at-sea observers on commercial passenger fishing vessels in California.
- *Reconcile discrepancies between recreational data (catch and biological samples) between the state agencies and RecFIN.* The state agencies continue to work with RecFIN to refine estimates.
- *Continue to conduct size and species-selectivity research for groundfish trawl and non-trawl fisheries.* Researchers with the PSMFC and NWFSC have continued to explore how different configurations of gear, primarily trawl, impact composition and amount of bycatch (e.g., Lomelli and Wakefield 2016; Lomelli et al. 2017).

#### **4.4.2      *Develop a coastwide system for electronic fish ticket and fishery logbook data***

Electronic fish ticket data have been available since 2011 for the Trawl Individual Quota (catch-share) fishery through the NMFS Vessel Accounts Database. The eTix system itself began in 2008 (reference).

#### **4.4.3      *Continue to improve historical catch time series***

Data bases with historical groundfish reconstructions for landed catches prior to 1981 have been developed for California commercial and recreational fisheries (Ralston et al. 2010) and Oregon commercial fisheries (Karnowski et al. 2014), and a reconstruction for Washington for rockfish species was produced for the rockfish stock assessments completed in 2017. A Council-sponsored *Historical Groundfish Catch reconstruction Workshop* was held in November 2016 (PFMC

2017b). In addition, revised landings for Oregon were developed to apportion unidentified rockfish to species (1987-1999, PFMC 2017c).

## **4.5 Life History Data**

The NMFS and state fishery agencies continued collecting and analyzing data on life history parameters that influence stock assessments.

*Further genetic research to confirm that species such as vermillion and blue rockfish may each represent two morphologically similar, but genetically distinct species.* Genetic research completed in 2015 (Frable et al.) indicated that the species known as blue rockfish was in fact two distinct species, blue rockfish (*Sebastes mystinus*) and deacon rockfish (*S. diaconus*). Previous research (Hyde et al. 2008) similarly divided vermillion rockfish into two separate species (*S. miniatus* and *S. crocotulus*). These species inhabit different depths with one species living mostly above and the other below 100 m.

## **4.6 Stock Assessment Issues**

### **4.6.1 *Improve on methods to assess data-poor and data-moderate stocks***

Depletion-Based Stock Reduction Analysis (DB-SRA) and Depletion-Corrected Average Catch (DCAC) were approved by the Council in 2010 as methods to estimate OFLs and set harvest specifications for data-poor stocks. XDB-SRA and exSSS are Council-approved extensions to the data-poor methods that incorporate biomass indices (e.g., based on surveys or fishery CPUE) for assessing data-moderate stocks. They were approved in 2013.

### **4.6.2 *Further advance modeling approaches and data analyses***

- *Provide guidance on use of priors for steepness and natural mortality.* Under the SSC's direction the Council's stock assessments for rockfish have used a prior for steepness that was updated biennially based on results from the most recent rockfish stock assessments. For estimating (or fixing) natural mortality, many stock assessments in recent years have used a prior informed by maximum age or other life history traits, based on Hamel (2015). For the 2017 stock assessments a set of Accepted Practices and Guidelines provided guidance on use of priors for steepness and natural mortality (<https://www.pccouncil.org/groundfish/stock-assessments/terms-of-reference/>).
- *Continue to develop and evaluate standard methods to process biological data for assessment model input files, including those related to input sample sizes and data weighting procedures. Explore alternative error distribution assumptions used for compositional data.* The Center for the Advancement of Population Assessment Methodology sponsored a workshop in 2015 that considered different approaches for weighting compositional data in stock assessment models (Maunder et al. 2017). One new approach, based on using the Dirichlet multinomial distribution (Thorson et al. 2017), was

incorporated in the Stock Synthesis software released in 2017 (version 3.30). However, the approach has not been widely used in West Coast groundfish stock assessments.

- *Continue to explore methods to include environment variables in stock assessment.* Work is underway to explore the use of environmental indices to inform recruitment estimates in stock assessments for sablefish (PFMC, 2018b).
- *Evaluate biological reference points, HCRs and policies used for groundfish, to ensure the best available scientific information is utilized for management decision-making. Harvest policies should be tested to determine whether they are robust to decadal-scale environmental variation and directional climate change.* Work is underway to explore the use of a dynamic biological reference point (driven by environmental change) in setting annual catch limits for sablefish (PFMC 2018b).

#### **4.6.3 Improve on stock assessment data and methods reporting**

- *Provide documentation on best practices.* For the 2017 stock assessment cycle, and to a lesser extent for the 2015 cycle, the SSC attempted to provide clear guidance on some of the practices that stock assessment teams (STATs) should use during development of stock assessments. For the 2017 cycle the SSC produced a set of *Accepted Practices and Guidelines for Groundfish Stock Assessments*, circulated to all the STATs that covered many of the issues that commonly arise during assessment development and subsequent review (<https://www.pcouncil.org/groundfish/stock-assessments/terms-of-reference/>). Also, Council staff placed a set of background documents on an ftp site for access by STAR Panelists and interested parties for stock assessment reviews (STARs) during 2017.

### **4.7 Development of the 2018 Groundfish Research and Data Needs**

The highest priority needs summarized below were developed from a systematic review by members of the SSC's Groundfish Subcommittee (GFSC) of 544 individual recommendations made by stock assessment authors, by STAR panels, by participants at the stock assessment process review meetings that were held after two of the three biennial stock assessment cycles that occurred since preparation of the 2013 Research and Data Needs document, as well as all the recommendations from the 2013 Research and Data Needs document. The GFSC also considered an additional 12 items identified in the reports of the Groundfish Historical Catch Reconstruction Workshop (PFMC 2017b) and the Groundfish Productivity Workshop (PFMC 2017d). The complete list of 556 recommendations that the GFSC considered is in Appendix I (Section 8.0).

The 2018 Groundfish FMP research and data needs below follow the same basic organization as used for the 2013 Groundfish FMP Research and Data Needs, with sections on fishery-independent data, fishery-dependent data, life history data, and stock assessment issues. There is also an additional section on management issues, followed by a section on research and data needs associated with groundfish EFH.

## 4.8 Fishery-Independent Data

Fishery-independent data are data collected independently of the fisheries, for example a scientific research survey that uses a bottom trawl, an acoustic fish sounder, or plankton nets to catch fish eggs and larvae.

### 4.8.1 *Continue existing surveys*

Scientific surveys of fish resources, which can provide measures of stock size that are untainted by changes in fishing gear and fishing grounds, can be crucial sources of information for stock assessments. The influence on an assessment of the data from a survey increases with the geographic scope of the survey (e.g., the survey covers all or most of the entire geographic range) and its temporal duration (e.g., a short survey provides little information on trends). The ordering of the following specific survey items, which were identified by the GFSC as having highest priority status, is not intended to be a priority ranking.

- *Continue the annual NWFSC Shelf-Slope trawl survey.* Continuation of the annual NWFSC Shelf-Slope trawl survey will improve the precision of estimates of absolute stock size and productivity, which are reliant upon observing some contrast in stock trend (other than a one-way trip) with an unbroken survey index.
- *Maintain the California Cooperative Oceanic Fisheries Investigations (CalCOFI) egg and larval production surveys.* Although the CalCOFI survey has limited latitudinal coverage, it is an important source of information on (recruitment? spawning biomass?) for some rockfish species (Thompson et al. 2016; Thompson et al. 2017). Abundance indices based on data from these surveys have been used in a number of groundfish assessments, including bocaccio, chilipepper, cowcod, and shortbelly rockfish. Advances in genetic analysis of larval tissues has enabled the identification of nearly all rockfish (*Sebastes*) larvae to the species level since 1998, and consequently time series may also be possible for at least 15 additional species.

### 4.8.2 *Develop new surveys*

The following specific items were identified in the Research and Data Needs for several stock assessments. The ordering is not intended to be a priority ranking.

- *Develop a coastwide fishery independent nearshore survey.* A standardized fishery independent survey sampling nearshore fish in all three states would provide a more reliable index of abundance than the indices developed from catch rates in recreational and commercial fisheries. The information value of such surveys will depend on the consistency in sampling methods over time and space and will require many years of sampling before an informative index could be obtained. Any potential survey should have the capacity to monitor abundances of species of different sizes that reside in multiple habitats.
- *Continue to explore additional survey methods.* Although informative for many groundfish species, the current NWFSC shelf and slope survey cannot access rocky areas, where a



number of rockfish species occur. Also, trawl survey efforts are currently closed in the Cowcod Conservation Areas (CCAs), which is likely to include habitat for a number of rockfish species. Since 2014 the NWFSC hook-and-line survey has been able to survey in the CCAs. Regardless, there is a need to develop alternative methods to assess fish densities in untrawlable areas as well as other areas not well-surveyed by the current bottom trawl survey. If possible, the alternative survey methods (e.g., Autonomous Underwater Vehicles, submersibles, drop cameras) should have less impact than trawl surveys on habitats and scarce resources (e.g., corals, overfished yelloweye rockfish). All new survey methods should be thoroughly evaluated before being used in stock assessments.

#### **4.8.3      *Comprehensively evaluate whether the Triennial survey should be split into early and late segments.***

Some stock assessments have split the Triennial survey index into two segments, whereas other assessments have used the Triennial survey as a single index. The issue of whether or not the Triennial survey should be split, and the basis for that decision, needs resolution.

### **4.9      Fisheries-Dependent Data**

Fishery-dependent data are data collected directly from commercial or recreational fishing operations, which means that the characteristics of the catch are largely determined by the fishing vessel and gear rather than under the direction of a scientific sampling plan.

#### **4.9.1      *Catch reconstructions***

Despite the Council-sponsored *Historical Groundfish Catch Reconstruction Workshop* held in 2016 (PFMC 2017b), issues remain regarding the catch series used in groundfish stock assessments. The issues focus primarily on groundfish catches taken prior to 1981, which is the first year for which the Pacific Fishery Information Network (PacFIN) system houses data series on the landed catch from West Coast commercial fisheries. The ordering of the following specific items, which were identified by the GFSC as having highest priority status, is not intended to be a priority ranking.

- *Complete the WA historical catch reconstruction.* The states of California and Oregon have completed comprehensive historical landed catch reconstructions. Washington historical data are not yet available for all species.
- *Thoroughly review the historical catch reconstructions; develop uncertainty measures.* The series of historical catches of individual rockfish species, which are important sources of uncertainty in stock assessments of rockfish and flatfish, should be explored in more detail. A thorough look at historical commercial fishery landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for. For some species recreational harvests are also an important feature of historical removals; for other species discards at sea are an important feature of historical removals. Furthermore, catch reconstructions should not just develop best estimates of

rockfish and flatfish catch by species, but should also characterize the uncertainty of historical catch estimates by identifying periods of greater and lesser uncertainty. For example, rockfish species compositions taken during early years when there were limited slope fisheries should be very different from species compositions taken during later years when fisheries on the slope were more prevalent.

- *Provide better documentation of the process used to construct the historical catch and discard time series.* Improved documentation is required to clearly outline the process used to construct the historical catch and discard time series from the various data sources. Such documentation should also include the process for construction of alternative catch histories that are used to propagate such uncertainty into the stock assessment.
- *Continue to improve the historical catch and discard time series.* There is ongoing progress to develop new statistical procedures for apportioning landings of general categories of fish (e.g., rockfish) to individual species. The approaches may allow the development of more refined estimates of historical catches, including uncertainty estimates. A methodology review of one new approach and its application to data from California will occur in March 2018. Implementing these procedures into a coastwide data system such as PacFIN will require substantial additional planning and work.
- Transfer copies of state catch reconstructions and contributing databases to PacFIN so there is a single repository. A process will need to be established so reconstructions in PacFIN can be updated as the states make revisions to their reconstructions.

#### **4.9.2 Discard monitoring**

Although there is a comprehensive data collection system on the West Coast that monitors the landed commercial catch, in many fisheries there are appreciable numbers of fish that are caught and discarded dead at sea. In addition to accounting for the weight of dead, discarded fish, stock assessments need to account for possible differences in the characteristics of the discarded fish. Often small fish are discarded more frequently than large fish. The following two items were identified by the GFSC as having highest priority status (no priority ranking intended).

- *Continue to monitor catch and discard in commercial fisheries at-sea.* The At-Sea Hake Observer Program, which monitors the at-sea hake processing vessels, and the West Coast Groundfish Observer Program (WCGOP), which monitors catcher vessels that deliver their catch to a shore-based processor or a mothership. These two programs provide information that is important to stock assessments and also for the total catch accounting required for the management of the trawl catch share program. The methods used by WCGOP to estimate discard and total groundfish removals should be well-documented and reviewed by the SSC to ensure that the most reliable estimates are generated. Additionally, a method should be developed to evaluate observer coverage levels, and how that might influence management, stock assessments, and fleet behavior.
- *Improve discard estimates in the recreational groundfish fishery.* Discard estimates in the recreational groundfish fishery, particularly for non-retention species, should be improved. Additional data should be collected on size composition of recreational discard.

#### **4.9.3 Fishery CPUE analysis**

Many nearshore stocks are not regularly caught by the NWFSC bottom trawl survey, which does not conduct bottom trawl tows in water shallower than 55 m (30 fathoms). For these stocks the primary source of information on trends in biomass are from indices derived from fishery catch rates (catch-per-unit-effort, CPUE). The following specific items were identified by the GFSC as having highest priority status (no priority ranking intended).

- *Explore use of a multi-species approach to develop CPUE indices for nearshore species.* Fishery-dependent CPUE indices are likely to be the only trend information for many nearshore species for the foreseeable future. Indices from a multi-species hook-and-line fishery may be influenced by regulatory changes, such as bag limits, and by interactions with other species (e.g., black rockfish) due to hook competition. It may be possible to address many of these concerns if a multi-species approach is used to develop the indices, allowing potential interactions and common forcing to be evaluated.
- *Produce accepted practices for developing fishery CPUE indices.* Research is needed to develop objective criteria for setting the threshold when applying the Stephens and MacCall (2004) method of selecting CPUE records. Research is needed to evaluate the influence of assumptions affecting application of geostatistical models such as the Vector Autoregressive Spatio-Temporal (VAST) model developed by James Thorson (NWFSC, <http://www.FishStats.org>). An additional consideration with recreational CPUE data is the potential for hook saturation affecting indices for less common species (e.g., China rockfish) when more common species such as black rockfish are in high abundance.
- *Further work is needed to understand the properties of recreational CPUE data.* Although there have been some recent advances in the analytical methods used to derive abundance indices from CPUE data, further work is needed to understand the properties of recreational CPUE data (e.g., method evaluation with simulation data or cross-validation studies). In particular, the effect of management changes and alternative fishing opportunities should be evaluated.

#### **4.9.4 Continue to conduct size and species-selectivity research for groundfish trawl and non-trawl fisheries.**

Size and species selectivity is important for stock assessments, establishing and understanding potential impacts of management measures, fisheries monitoring, and for fisherman (e.g., to maximize catches of marketable species and sizes while reducing catches of unmarketable, overfished, or threatened/endangered species). Individual accountability due to the IFQ program provides greater incentives for IFQ fishermen to utilize the most selective fishing practices available. Unfortunately, most selectivity studies available for fishermen, managers, and researchers are dated and were conducted during a period where the fisheries, assemblages, and gears were much different than presently seen. Other potentially needed selectivity studies (e.g., on non-trawl West Coast groundfish fisheries) have not been conducted at all. Note that recently selectivity studies have been undertaken or are currently underway to evaluate the selectivity of sorting grids and various trawl-codend mesh size and mesh shapes for various groundfish species caught in the trawl fishery (e.g., Lomelli and Wakefield 2016; Lomelli et al. 2017).

## **4.10 Life History Data**

The age-structured stock assessments that the Council commonly uses for determining overfishing levels and annual catch limits for groundfish species require life history information on growth, maturation, fecundity, and natural mortality. The general items listed below were identified by the GFSC as having highest priority status (no priority ranking intended). Not included in this list are the numerous stock- or species-specific recommendations that were provided in individual stock assessment documents and STAR Panel reports.

### **4.10.1      *Continue to collect data on habitat-related and climate-driven variability in life history traits.***

It has been shown that a number of species exhibit spatial variability in life history traits. It is therefore recommended to continue to collect data to capture habitat-related and climate-driven variability in life history traits, and explore methods to integrate this information into stock assessments.

### **4.10.2      *Explore the importance of temporal or spatial changes in growth, fecundity, and other traits.***

Additional research would be important to explore whether other life history parameters, such as growth and fecundity vary spatially or change over time as well. This information will help in defining spatial structure of future models.

### **4.10.3      *Improve existing meta-analyses for natural mortality and steepness.***

Research could improve existing meta-analyses for natural mortality and steepness, which both contribute to the implied yield curve. Directions for improvements include (1) explaining variability between methods in natural mortality estimates, included in the Hamel natural mortality method and (2) developing a larger database of species for estimating steepness, perhaps by including species from other regions, e.g., Canada and Alaska.

### **4.10.4      *Studies to help estimate natural mortality and growth, including tagging studies.***

Ageing to help estimate pertinent parameters in the model (e.g., natural mortality, growth), perhaps including new methods such as tagging. Tagging studies would also further investigate the assumption of an ontogenetic movement pattern seen for many species.

## **4.11 Stock Assessment Issues**

Stock assessment models include a framework of equations for predicting the observed data that are input to the assessment. The assessment software selects a set of “best estimates” for the parameters embedded in the equations by evaluating how well the equations predict the observed data. The predictions are generally influenced by assumptions regarding the set of model equations

and by a set of fixed parameters that cannot be directly estimated. The general items listed below concern issues affecting how stock assessment models are structured and constructed, either in terms of the set of model equations or the set of fixed parameters. They were identified by the GFSC as having highest priority status (no priority ranking intended). Not included in this list are numerous stock- or species-specific recommendations that were provided in individual stock assessment documents and STAR Panel reports.

#### **4.11.1 Stock boundaries**

Stock assessment models assume that the fish represented by the model constitute a single, self-sustaining population, thereby ignoring the possibilities of (a) more than one self-sustaining population in the region encompassed by the assessment or (b) the immigration of fish (of the same species) from other spatial regions. Very early in the stock assessment process the stock assessment team must decide how to set the spatial boundaries for the stock (or stocks) they are modeling because this decision influences how the data will be partitioned and the model constructed. The following stock boundary items were identified by the GFSC as having highest priority status (no priority ranking intended).

- *Further investigate the structure of transboundary stocks and evaluate implications of connectivity.* A number of stock assessments utilize international boundaries to delineate stocks even though stocks' ranges are not limited always to the area managed by the Council. These stocks include sablefish, spiny dogfish, blackgill rockfish, canary rockfish, widow rockfish, yelloweye rockfish, Pacific ocean perch, and others. It is therefore recommended to further investigate the structure of transboundary stocks and evaluate implications of stocks' connectivity with Canada on the north, and Mexico on the south, and, in some cases, explore the possibility of joint stock assessments in future years.
- *Develop an objective procedure for evaluating the stock boundaries.* An objective procedure for evaluating the stock boundaries is needed for all rockfish (and potentially other west coast assessments). Such a procedure would more directly point to directions for future research or collaboration across national/international political boundaries.
- *Evaluate the impact of not accounting for any Canadian portion of population.* Given that the population ranges for many West Coast species extend north to the border with Canada, it is important that future research would evaluate the impact of not accounting for any Canadian portion of population abundance. Such an analysis would require evaluation of movement along the coast; such information is currently lacking.

#### **4.11.2 Spatial models**

Stock assessment models generally assume that the fish represented by the model are uniform in their biological traits such as length-at-age, age-composition, and fecundity. Similarly, the models must make assumptions about how to represent the fishing process, which is very likely to vary geographically. The GFSC selected the following items related to spatial distribution as warranting the highest priority (no priority ranking intended).

- *Further explore models that account for spatial structure of the stock, including spatial differences in life history parameters (multi-area assessments).* It is also recommended to further explore models that account for migration patterns (via incorporating tagging data) as this feature is currently available within the Stock Synthesis modeling framework.
- *Conduct research on the recruitment redistribution process for area-specific models.* Work is recommended on the recruitment redistribution process for area-specific models to either support or reject the assumptions behind the spatial recruitment distribution dynamics inherent in stock synthesis. Restricting the recruitment percentage parameters to single values across years may be overly constraining. Options to address this could include time blocking or revising the model structure such that it would take the ratio of spawning stock on one or the other side to help inform how recruitment is distributed over time.

#### **4.11.3 Age-reading error**

Many of the Council groundfish stock assessments are based on models constructed using the Stock Synthesis assessment software and use observations of age composition to inform the model on the strength of year-classes. Stock Synthesis includes a provision that allows the assessment analyst to account for age-reading error in the age composition observations. Developing the information needed to accurately account for age-reading error is a time-consuming process, with the consequence that many groundfish stock assessments rely on dated or limited information on age-reading error. The GFSC identified the following items relating to age-reading error as highest priority (no priority ranking intended).

- *Investigate more precise aging methods.* Investigate aging methods that could prove more precise than current break-and-burn methods. More accurate age data would facilitate tracking cohorts to older ages, improving estimates of historical year-class strengths. Further studies to investigate the potential for bias in aging methods should be conducted; these results will have a strong effect on natural mortality estimates.
- *Improved age-reading and age-validation methods are needed.* A concerted effort is needed to prioritize collection, collect, process, conduct cross-validation of reads between laboratories and validate age using bomb carbon calibration, oxytetracycline/tagging or radiometric analysis of otoliths from the commercial and recreational fisheries in all three states allowing geographic comparisons with additional funds earmarked for this purpose. This would substantially improve estimates of growth, recruitment deviations and age composition required to make some assessments viable (e.g., yellowtail rockfish south) or move stocks from Category 2 to Category 1 status with reduced scientific uncertainty.

#### **4.11.4 Data-poor and data-moderate assessments**

The Council and the Northwest and Southwest Fisheries Science Centers do not have the capacity to conduct and review more than about 10 to 12 full stock assessments during each biennial groundfish stock assessment and harvest specifications process. Further, many groundfish species do not have the full suite of data needed to conduct full stock assessment. Consequently the Council relies on so-called data-poor and data-moderate stock assessments for setting OFLs and

ACLs for many stocks. The following data-poor and data-moderate assessment items were identified by the GFSC as having highest priority status (no priority ranking intended).

- *Develop tools for incorporating catch uncertainty in data-poor and data-moderate assessments.* Catch time series in data-poor and data-moderate methods are currently assumed to be known, and tools for incorporating catch uncertainty into these methods should be developed.
- *Determine how to best describe uncertainty in data-moderate assessments.* Data-moderate assessments are likely to have greater uncertainty in their results than full assessments since much fewer data are used in data-moderate assessments. Further work is needed to determine how to best describe uncertainty in data-moderate assessments.

#### **4.11.5 Environmental or ecosystem influences**

As a general rule groundfish stock assessments do not explicitly consider temporal variations in environmental or ecological forces that may alter the biological processes (e.g., growth, natural mortality) influencing a stock's productivity. This is usually done for the sake of parsimony. Simple stock assessment models often perform as well as (or better than) more complex ones. Further, assessments are used to make projections into the future for which there is usually no information regarding the environmental or ecological factors that might be used as drivers in the stock assessment. The GFSC identified the following items on environmental or ecosystem influences as highest priority (no priority ranking intended).

- *Continue to evaluate methods to capture information on environmental and ecosystem variability in stock assessments.* Historical records of particularly large year classes (e.g., 1947 reported by sport fishermen in central California) could be investigated to better inform the historical period. As time series for the more recent data rich period become longer, continued evaluation of environmental mechanisms that drive variable year class strength should become more fruitful and should lead to improvements in the treatment of recruitment variability in assessments.
- *Explore possible influence of the "warm blob".* Research assessing the effects of the unprecedented warm ocean conditions off the West Coast of the U.S., first detected in late 2013 and persisting into 2016, on rockfish populations is needed. The abundance of young-of-the-year rockfish was unusually high during this period (Sakuma et al. 2016) and some stock assessments (e.g., bocaccio) have subsequently inferred successful recruitment to adult populations since that time. Specifically, investigations are needed that focus on how temperature and other water conditions at depth, in rockfish habitat correspond to high sea-surface temperatures recorded throughout those years, and how the fish respond to those changing conditions. Research is needed that examines whether fish move in response to changing temperatures, where, and how they move, as well as whether the conditions influence life history parameters and aspects such as mortality, feeding, fecundity and other reproductive considerations. What oceanographic and climatic forces are responsible and how long these conditions are expected to persist are also critical pieces of knowledge.

#### **4.11.6      *Evaluate benefits of adopting complex versus simpler assumptions and models.***

Current models used to assess groundfish stocks are complex, with many parameters being estimated, yet often the data used to fit these models are sparse. Also, complex models make it difficult to understand how specific data elements affect model outcomes. The benefits of adopting the complex model should be evaluated relative to simpler assumptions and models.

#### **4.11.7      *Additional surveys, tagging studies or other research to locate older female rockfish.***

Additional surveys, tagging studies or other research is needed to attempt to locate older female rockfish for species such as black rockfish and yellowtail rockfish. The need to accommodate the data by using dome-shaped age-based selectivity suggests a behavioral cause for unavailable old females. Automated underwater vehicles, video landers and/or an acoustic or additional tagging studies might be one plausible option. Others include focused studies on locations mentioned during discussions of anecdotal accounts of concentrations of larger fish found in certain places. Some form of sampling to confirm the existence of a considerable biomass of older females unavailable to the ocean recreational fishery is required.

#### **4.11.8      *Develop accepted practices for using domed versus asymptotic selection.***

For many species including blue, black rockfish, canary rockfish and yellowtail rockfish, how most appropriately to treat selectivity for both retained and discarded catch in the recreational sectors has major implication for the outcome of the assessment. Simulation analysis of the assumptions and the implications for the outcomes as well as field studies to identify the potential circumstances that would justify use of a domed selectivity curve should be explored. This would help address whether it is most appropriate to use a dome shaped curve indicative of larger size classes being unavailable vs. having suffered higher mortality and being considered dead as represented by an asymptotic selectivity curve commonly known as the hide them or kill them hypotheses, respectively. The choice to hide or kill them depending on the choice of shape of the selectivity curve results in very different outcomes in assessments and addressed differently across assessment areas within assessments (e.g., black rockfish) and between assessments of stocks with similar attributes (e.g., canary vs. black rockfish) and further analysis across species may help provide best practices for future authors and guide future assessment efforts.

#### **4.11.9      *Continued simulation-estimation tests of alternative stock-recruitment relationships in stock assessment models.***

The Stock Synthesis software has a limited number of options for specifying stock-recruitment relationships. The vast majority of West Coast groundfish assessments conducted with Stock Synthesis have used the Beverton and Holt formulation, which largely predetermines the relationship between the steepness parameter and the level of depletion associated with the long-term maximum sustainable harvest (Mangel et al. 2013). For example, a Beverton and Holt stock-recruitment relationship having a steepness value of 0.6 will have a relative  $B_{MSY}$  value that is



about 35% of the unfished biomass (Punt et al. 2008). The productivity relationship underlying the DB-SRA software has no similarly constrained relationship between steepness and relative  $B_{MSY}$ . Ongoing research should continue to explore the properties of alternative two- and three-parameter stock-recruitment relationships and their potential usefulness in West Coast groundfish assessments.

## **4.12 Management Issues**

The Council's process for managing groundfish species relies on stock assessment estimates of current stock status relative to biological reference points and projections of future stock trajectories to produce and evaluate OFLs and ACLs for the future. There may be advantages from modifying the projection and management procedures. The GFSC identified the following two items as highest priority.

### **4.12.1 *Consider management strategy evaluations of alternative harvest policies.***

Consider management strategy evaluations of alternative harvest policies that formally evaluate trade-offs among catch and resource stability, assessment uncertainty and environmental forcing. For example, contrast more "aggressive" but presumably more volatile harvest policies (higher SPR rates) against those that cap target (but not necessarily limit) harvest levels at the equilibrium MSY catch level (e.g., eliminate the "fishing down" to equilibrium level practice). To be done at the complex, overall fisheries and ecosystem level (not stock by stock), and to include a range of productivity (e.g., steepness) values consistent with the current range (not average) values.

### **4.12.2 *Consider management strategy evaluations of alternative stock-recruitment relationships and their effect on biological reference points.***

The Council's harvest control rules for groundfish stocks rely on biological reference points to set a target level of spawning biomass (or spawning output) and a target rate of fishing mortality. For most stocks these targets are based on proxy values rather than being estimated directly. For example, for rockfish species  $B_{40\%}$  (the biomass that is 40% of the unfished biomass) is a proxy for  $B_{MSY}$  and  $F_{50\%}$  (the fishing mortality that reduces pre-recruit spawning potential to 50% of the unfished level) is a proxy for  $F_{MSY}$ . For many stocks there is poor correspondence between the two proxies, meaning that long-term fishing at the  $F_{MSY}$  proxy value (e.g.,  $F_{50\%}$  for a rockfish species) does not drive the stock's biomass to the  $B_{MSY}$  proxy level (40% of unfished for a rockfish species). A management strategy evaluation could be used to evaluate the potential benefits of modifying the harvest control rule and its component reference points.

## **4.13 Essential Fish Habitat – Priority Research and Data Needs**

The MSA requires the Council to periodically (at least every 5 years) review the EFH provisions of FMPs and revise or amend those provisions as warranted. In 2010, the Council initiated the groundfish EFH review process that updates the 2006 EFH review (Amendment 19). The review process is nearing conclusion in 2018. Some pertinent new information included seafloor substrate

maps, bottom trawl intensity maps, and maps of biogenic species bycatch and observations. For many locations or datasets, there was a lack of sufficient resolution, spatial coverage, or consistent methodologies to answer questions about the quantitative and qualitative contribution of habitat components to groundfish abundance and healthy stock structure, or to determine the effects of fishing gear on habitats and associated species.

As with the 2006 EFH review, the EFH review currently underway illuminates the need for habitat-focused studies in order to understand and manage the habitat needs of more than 90 species in the groundfish FMP. This includes improved understanding and management of the effects of fishing, and non-fishing factors, such as changing ocean conditions, on groundfish populations. A substantial investment of research effort is needed to address the growing list of habitat-focused questions. The research priorities established for 2018-2023 should therefore guide research efforts with the goal of informing the Council's next EFH review process.

The highest priority research and data needs for groundfish EFH are organized by topic: (1) EFH components and ecological function, (2) fishing impact analyses and associated baseline, (3) non-fishing impacts, (4) research in EFHCAs, and (5) fishery and other data needs.

#### **4.13.1 EFH Components and Ecological Function**

##### *Habitat mapping*

- Describe and classify soft-unconsolidated sediment types into dunes, mobile sand sheets, sediment waves and ripples, etc. These features may be foraging habitat for groundfish species. Conduct studies to map features and assess fish-habitat associations.
- Develop bathymetric maps and interpretative substrate from a backlog of sonar mapping data that was not examined or used in the current groundfish EFH process.
- Create an integrated data set from the “aggregate seabed habitat” data to produce seamless substrate and relief maps suitable for analyses at the scale of biogeographic regions.

Assess species distribution and habitat utilization during nursery and pre-reproductive life stages in nearshore waters.

Evaluate the role of deep-sea coral and sponges and other habitat-forming invertebrates (HFI), as habitat for managed groundfish species. Deep-sea coral and sponges were described as priority habitat for groundfish species in Amendment 19 and recently in Amendment 28. NOAA's Deep Sea Coral Research and Technology Program recently completed a ten-year status and knowledge report on deep-sea coral and sponge ecosystems, with a section on fishing interactions (Hourigan, et al. 2017). Program funding is directed, in part, at understanding the role of deep-sea corals as habitat for federally-managed species, and the development of technologies and methods to reduce interactions with fishing gear. The program rotates its research efforts between U.S. regions. The West Coast is the focus of the 2018-2021 period and will include recommendations from the Council's Habitat Committee:

- Quantify associations of fish with deep-sea corals and other habitat-forming invertebrates (HFI) and compare to fish densities in similar habitats but without HFI.

- Evaluate the functional relationships of HFI with managed groundfish species, such as fish spawning, recruitment, nursery, shelter, feeding aggregations, and compare the functional equivalency with other habitats that support groundfish but that lack significant HFI densities.
- Examine response of HFI to re-openings and closures of EFHCAs and RCAs.
- Conduct studies to map the distribution and abundance of HFI species, with emphasis in EFHCAs and areas of potential high risk from fishing and non-fishing impacts.

*Evaluate the role of methane seeps and associated structure as habitat for managed species.* Recent surveys have identified hundreds of new sites of bubble plumes and nutrient-rich cold methane seeps. Energetic activity and associated microbial communities transform sediment into hard substrate which in turn create habitat for deep sea corals and sponges (Levin et al. 2016). Little is known about the role of methane seeps as habitat for managed species, but a recent discovery of egg-casings of the Pacific white skate incubating near a hydrothermal vent suggests that seeps may provide a functional role as nursery habitat (Salinas-de-León, et al. 2018). Additional evidence of fish association with seeps is reported for commercial species such as longspine thornyhead, sablefish and Dover sole (Bowden et al. 2013; Grupe et al. 2015). The Council directed that the role of methane seeps as habitat for groundfish species be added to Appendix B of the FMP. This direction is timely as renewed interest for oil, gas and mineral exploration off the west coast would likely be interested in seep areas. Understanding the role of methane seeps as unique or rare deep water habitats could result in the Council designating seeps as Habitat Areas of Particular Concern (HAPC) in the next EFH review. HAPC designation would encourage greater scrutiny of federal actions in these sensitive deep water environments.

*Groundfish prey for under-sampled groundfish FMP species:*

- Develop criteria for defining major prey species for all life stages of groundfish species.
- Compile lists of major prey species for all stocks and life stages in the groundfish FMP.
- Evaluate the distribution of major prey species for groundfish species.
- Evaluate potential adverse effects from fishing and non-fishing activities on the major prey species of groundfish species.

#### **4.13.2 Fishing Impact Analyses and Associated Baseline Data**

The Groundfish EFH 2006, Record of Decision states that, “Three variables are fundamental to assessing the status of habitat: The locations and intensity of fishing impacts, the sensitivity of specific habitat types to specific impacts at differing levels of intensity, and the potential for habitat to recover between impact events.” The lack of long-term studies, control sites and research areas hinders the ability to fully evaluate impacts to habitat and associated species, and recovery. The Council has not established research areas to meet its habitat objectives, but it is possible to conduct controlled impact studies through direct collaboration with trawlers. In Amendment 28, some areas closed to bottom trawl since 2002 (core-RCA off OR and CA) and 2006 (some EFHCAs) will be reopened to trawling. *These re-openings provide unprecedented opportunities*

*to facilitate applied research to address management questions about impacts and recovery of habitats and associated species, and the benefits of long-term closures for fish populations.*

The following research topics would also support management questions.

- Several studies since Amendment 19 have documented significant *impacts of trawling on soft sediment habitats* (PFMC 2012). Conduct studies in the core-RCA before trawling is re-initiated to establish a modern baseline for fish, mega-macroinvertebrates, and habitat conditions. Recovery rates of long-lived, habitat forming invertebrate species (HFI) is estimated at 50 -100 years so true baseline for these species in trawled areas cannot be determined. But a modern baseline (i.e., 2002 core-RCA implementation) would support impact studies of shorter-lived HFI, other macroinvertebrates and associated fish species.
- Collaborate with trawlers to *establish long-term research areas* to serve as controls in the core RCA, as well as treatment areas to conduct controlled commercial trawling. Ideally, in areas having no or minimal shrimp trawling or NMFS survey trawling. Alternatively, establish control sites within nearby EFHCAs of similar habitat and depth as the treatment areas.
- Examine the *relationship between an individual trawl pass and the level of disturbance and recovery of benthic macro-invertebrates*. Develop new models for estimating fishing impacts on biogenic and physical habitats and recovery times, such as the model used in the Alaska 2006 EFH process.
- Conduct studies to *characterize and quantify the effects of other bottom-contact gear types and mid-water trawl gear* on soft bottom and rocky habitats. Western Groundfish Observer Program data documents HFI bycatch in midwater gear, but midwater trawl was eliminated from the groundfish EFH review during scoping.
- Examine the *cumulative impacts of fishing gear* (including line, weights, traps and pots) including derelict fishing gear on important habitats such as rocky reefs and eelgrass beds.
- *Test bottom trawl gear modifications* that minimize bottom contact duration and intensity, such as those implemented in the NPFMC bottom trawl fishery (Rose, et al 2009).

#### **4.13.3 Non-Fishing Impacts**

Examine the effects of ocean acidification on susceptible groundfish prey species, and the potential consequences for groundfish.

Evaluate adverse effects of hypoxic zones on resident species in rocky habitats, and susceptible species (e.g., petrale sole) in soft-bottom habitats.

Gather baseline information of fisheries and habitat resources at the initial stages of offshore energy development projects.

#### **4.13.4 Research in EFH Closed Areas (EFHCAs)**

Conduct high-resolution seafloor mapping and high-resolution habitat maps in EFHCAs previously mapped at low resolution or not mapped.

Collect baseline data on species and habitat condition in existing (Amendment 19) and future (Amendment 28) EFHCAs, and monitor effects of these closures on species and habitat over time.

Monitor effects of new bottom trawling in EFHCAs identified for reopening under Amendment 28.

Conduct studies in EFHCAs to determine the effects of benthic habitat protection for promoting groundfish productivity.

Evaluate the boundaries of the EFHCAs as new seafloor habitat maps become available to identify area where protections should be refined.

#### **4.13.5 Fishery and Other Data Needs**

*Expand logbook programs to other fishery sectors that could impact groundfish habitats, such as all bottom-contact gear, or any gear that contacts the seafloor, including MWT gear. Require and incorporate start and end positions where lacking, to improve spatial precision of fishing locations.*

*Increase VMS ping rate to improve the spatial resolution of fishing locations for enforcement of EFHCAs. VMS track line data would be extremely helpful in assessing the effects of fishing gear on EFH and should be available for research purposes.*

*Evaluate changes in the distribution of fishing effort and determine if changes to current management measures and gear restrictions intended to protect EFH may be warranted.*

*Update the table in the EIS for Amendment 19 (NMFS 2005) that addresses relative ranking of gear types in terms of their habitat impacts (Summary of mean sensitivity levels and recovery times for all combinations of major gear types, including new gear types and midwater trawl, and bottom habitat types: Appendix 10 of Appendix A, Table 3).*

*Evaluate new information on EFH relative to Level 1-4 (as defined in the EFH guidance at 50 CFR 600.815(a)(iii)) and compare to information level available in establishing the 2006 groundfish EFH regulations.*

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## 5.0 SALMON FISHERY MANAGEMENT PLAN

### 5.1 Introduction

In the previous Research and Data Needs report, two highest priority issues were identified for Research Issues and four highest priority issues were identified for Data Issues. The issues, and the progress on them, are summarized below:

#### Research Issues:

*Advances in Genetic Stock Identification (GSI), Parentage Based Tagging (PBT), otolith marking, and other techniques make it feasible to use a variety of stock identification technologies to assess fishery impacts and migration patterns.* The increasing necessity for weak-stock management puts a premium on the ability to identify naturally-reproducing stocks and stocks that contribute to fisheries at low rates. In many instances, the coded wire tag (CWT) system alone does not provide the desired level of information. Alternative techniques may provide more information at the same fishery sampling rates; for example, all fish should be identifiable to genetic reporting group of origin whereas not all fish have CWTs.

Substantial progress has been made on this issue in the past thirteen years. GSI, either collected dockside or in combination with at-sea sampling by fishermen, has provided detailed information regarding spatial patterns in encounters and stock contributions to ocean fisheries for Chinook salmon. Washington, Oregon, and California fisheries have been sampled for multiple years, and some results published for applications to ocean fisheries off California and Oregon<sup>3</sup>. Use of genetic methods in fisheries management depends on continuing coast-wide annual data collection, and would require representative sampling of all fishery strata. Such representative sampling might be most easily achieved via dockside sampling. To maximize the utility of the data collected, GSI sampling should be accompanied by aging of sampled fish (e.g., by reading scales or otoliths).

Spatial patterns in encounters with Chinook salmon in the commercial salmon fishery have been estimated using a coast-wide microsatellite database for Chinook and a single-nucleotide polymorphism (SNP) database in California. A similar database for coho salmon is under development, but needs additional resources to coordinate efforts for the entire coast. SNP panels should be standardized for use across labs and populations along the whole coast. GSI is being used on an in-season basis in Canada to manage salmon fisheries off the west coast of Vancouver Island and in the Strait of Georgia, and the possibility of such management in US waters should be analyzed. Genetic techniques have improved so that samples can be analyzed within 24-48 hours of arrival at the laboratory.

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<sup>3</sup> Satterthwaite et al. 2014 TAFS 143:117-133, Bellinger et al. 2015 PLOS One 10(7):e0131276, Satterthwaite et al. 2015 Fisheries Research 73:2380–2394, Otto et al. 2016 ICES JMS 73:2380–2394.

All spawners used for spring, summer, and fall Chinook hatchery programs upstream of Bonneville Dam are now genotyped, allowing identification of progeny with PBT. Samples from hatchery coho stocks upstream of Bonneville Dam have been collected and are awaiting genotyping. Full parental genotyping is also in place for multiple Chinook and coho hatchery programs in California. Tissue samples are collected but not yet genotyped from all tribal and some state Chinook salmon harvest indicator programs in Puget Sound and on the Olympic Peninsula. Full parental genotyping of spawners is the basis to identify the stock and age of individual fish, and careful implementation of PBT can yield additional release-group-specific information. This technique can provide data for cohort reconstruction, migration and straying studies, survival-rate comparisons, and other fine-scale questions.

Work on increased use of both GSI and PBT to inform management remains a highest priority research issue.

***The development of habitat-based models that incorporate environmental variation and anthropogenic disturbances to evaluate harvest policies and enable risk assessment for different fishing strategies is encouraged.*** Overfishing definitions are required to relate to the MSY exploitation rate ( $F_{MSY}$ ).  $F_{MSY}$  is related to productivity, which varies annually in the freshwater and the marine environments. Techniques for evaluating productivity, or survival, in freshwater and marine habitats are needed to set appropriate harvest targets and associated conservation guidelines such as escapement goals and overfishing determinations.

Various habitat-based models have been developed, but in general they are not being applied to harvest management. While many of these models are focused on habitat restoration without explicitly incorporating harvest practices, improvements in modeling have been made since 2013. Statistically-based life cycle models attempt to integrate various sources of uncertainty (including variation in habitat availability and harvest management) to evaluate overall effects on numbers of adults, and therefore are addressing some of the serious gaps in previous life cycle models. In addition, the pilot Fisheries-specific Habitat Objectives report<sup>4</sup> examined via scenarios how habitat restoration can restore fishing opportunity. Improved applications to harvest management would require refined population dynamic components to these models that incorporate life history variation, annual variation in freshwater and marine habitats, mixed stock fisheries, and different fishing practices.

There is the potential for using these habitat-based models to evaluate exploitation rates consistent with recovering depressed stocks. Other possible contributions could be improved understanding of climate variability and environmental influences on survival and stock productivity. Once satisfactory habitat-based models of population dynamics have been developed, they can be used in management strategy evaluations (MSEs) to simulate alternate management scenarios. This

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<sup>4</sup>[http://www.pcouncil.org/wp-content/uploads/2016/11/IR5\\_SUP\\_ElectricOnly\\_FisherySpecificHabitatObjectivesWestCoastPilotFinalDraft\\_NOV2016BB.pdf](http://www.pcouncil.org/wp-content/uploads/2016/11/IR5_SUP_ElectricOnly_FisherySpecificHabitatObjectivesWestCoastPilotFinalDraft_NOV2016BB.pdf)

would be a valuable contribution to harvest management, but to become useful, substantial development efforts are needed. MSEs for relatively abundant stocks (e.g., Sacramento River fall Chinook [SRFC] in most years) will be challenging because the realized exploitation rate on an abundant stock is often quite different from what the harvest control rule would allow due to constraints imposed by co-occurring stocks. Though there has not been much progress on this issue since the 2013 Research and Data Needs Report, the MSE conducted to compare potential harvest control rules for Sacramento River winter Chinook<sup>5</sup> includes some aspects of environmental variability (river temperature) and assessment of risks (to both the stock and to the fishing community). This remains a highest priority research issue.

## **Data Issues:**

***California Central Valley Fall Chinook Assessment and Management.*** A sharp decline in SRFC abundance led to widespread fishery closures in 2008-2010, and the SRFC met the criteria for being overfished in 2018. Following the decline, increased attention has been directed at better understanding the dynamics of the SRFC stock. The 2013 Research and Data Needs document called for estimation of age-specific river harvest and escapement of SRFC, development of a cohort reconstruction model for SRFC, continued evaluation of hatchery contributions to harvest and escapement, and evaluating alternative forecast models for SRFC. Currently, at least 25 percent of SRFC production releases are marked and tagged with a CWT. This represents a large improvement on earlier marking and tagging practices that had been inconsistently applied. In addition, a Central Valley Chinook escapement monitoring plan developed in 2012 has been implemented, resulting in more standardized data collection and methods used to estimate escapement. Such changes could allow for development of new models for use in assessment and management of SRFC. CDFW produced a series of reports quantifying hatchery contributions to harvest and escapement<sup>6</sup>. A range of alternatives for forecasting SRFC were explored, and a new forecast model was adopted in 2013<sup>7</sup> for use beginning in 2014.

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<sup>5</sup> [http://www.pcouncil.org/wp-content/uploads/2017/08/F2a\\_SRWCW\\_Rpt1\\_SEPT2017BB.pdf](http://www.pcouncil.org/wp-content/uploads/2017/08/F2a_SRWCW_Rpt1_SEPT2017BB.pdf)

<sup>6</sup> Kormos, B., M. Palmer-Zwahlen, and A. Low. 2012. Recovery of coded-wire tags from Chinook salmon in California's Central Valley Escapement and Ocean Harvest in 2010. Fisheries Branch Administrative Report 2012-02.

Palmer-Zwahlen, M. and B. Kormos. 2013. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011. Fisheries Branch Administrative Report 2013-02.

Palmer-Zwahlen, M. and B. Kormos. 2015. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and Ocean Harvest in 2012. Fisheries Branch Administrative Report 2015-04.

<sup>7</sup> [http://www.pcouncil.org/wp-content/uploads/C2a\\_ATT5\\_SI\\_FORECAST\\_sep\\_17\\_13\\_NOV2013BB.pdf](http://www.pcouncil.org/wp-content/uploads/C2a_ATT5_SI_FORECAST_sep_17_13_NOV2013BB.pdf)

Work in the form of scale age analysis is also underway to produce age-specific escapement estimates that are intended for use in sibling regressions and cohort reconstructions that incorporate both hatchery- and natural-origin fish. Analysis of maturation rates will also be possible using age-specific escapement data. Current forecasting methods do not account for differences in maturation rates between hatchery- and natural-origin fish or environmental impacts on individual brood strength. Applying age-specific abundance forecasts to SRFC management should result in improved stock assessments and fishery modeling. Scale readers are in the process of analyzing scales from 2011 to 2017. Scale analysis from 2006 to 2010 is complete with reports in progress.

The research and data needs for this stock remain a highest priority issue, and include items related to the development of new models and to investigations aimed at improving the current assessment.

- *Estimation of age-specific river harvest and escapement.* Continued collection and analysis of CWTs (and/or tissue samples for PBT analysis) and scales collected from river fishery and escapement surveys can allow for estimation of age-specific return information. Estimates of age-specific river harvest and escapement is a priority because it is necessary for cohort reconstruction.
- *Development of a cohort reconstruction model for SRFC.* Cohort reconstructions would allow for more accurate estimation of ocean abundance, age-specific exploitation rates, maturation rates, and other metrics that could be used to improve management.
- *Continued evaluation of the contribution of hatchery-origin SRFC to ocean harvest, river harvest, and escapement.*
- *Continued evaluation of alternative forecast models for the Sacramento Index (SI).* Current management of SRFC depends heavily on the SI forecast. Although the forecast model was revised in 2013 for initial use in the 2014 fishing season, there is value in further forecast evaluation for this key stock.
- *Evaluation of the effects of hatchery release practices on survival, maturation rates, exploitation rates, and straying rates.* In response to recent drought conditions, there was an increase in the downstream transport of hatchery-produced SRFC. Trucking or barging fish downstream may avoid high mortality risk posed by poor river conditions, but may also increase straying rates. This transport of fish may also constrain the timing of ocean entry, which has been related to ocean survival and maturation rates. Application of cohort reconstructions to individual hatchery release groups would allow quantification of these effects.
- ***Klamath and California Coastal Chinook Management.*** The 2013 Research and Data Needs document called for increased monitoring of California Coastal Chinook (CC-Chinook), an evaluation of the concordance of Klamath River fall Chinook (KRFC) and CC-Chinook ocean spatial distributions, increased collection of Klamath River spring

Chinook (KRSC) escapement and river harvest data, investigating potential trends in maturation rates of KRFC, evaluation of Klamath Chinook contributions to fisheries north versus south of Point Reyes, and an evaluation of the onshore versus offshore distribution of Klamath Chinook. CDFW has described and begun implementing plans for improved monitoring of CC-Chinook<sup>8</sup>, and a joint CDFW-NMFS workshop explored current and near future alternatives for more active management of CC-Chinook<sup>9</sup>. Comparisons of Klamath (both seasonal runs combined) and CC-Chinook ocean distributions were made using two years of GSI information from commercial fisheries<sup>10</sup> and five years of GSI information from recreational fisheries<sup>11</sup>. There has not been formal investigation of trends in KRFC maturation rates, although these are estimated annually using cohort reconstruction methods. Comparisons have been made of the stock composition and contact rates of Klamath Chinook north versus south of Point Reyes based on both CWT<sup>12</sup> and GSI<sup>13</sup> data. The 2015 salmon methodology review explored whether there were adequate tag recoveries to add a management line at Point Reyes to the current management models, concluding there were not<sup>14</sup>. Otto et al. (2016)<sup>15</sup> modeled catch of Klamath Chinook off Oregon as a function of bathymetry, distance from shore, and other covariates. Preliminary analyses of GSI data off the coast of California suggest potential differences between Klamath and Central Valley Chinook in their onshore versus offshore distribution. The following data needs for Klamath and CC- Chinook remain a highest priority issue.

- *Increased collection of basic escapement data for California Coastal Chinook.* Current escapement data for populations in this Evolutionarily Significant Unit is sparse and generally confined to small portions of the available spawning habitat. More complete escapement survey coverage is needed.

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<sup>8</sup> Lacy et al. 2016. California Department of Fish and Wildlife Plan for Assessment and Management of California Coastal Chinook Salmon. CDFW Fisheries Administrative Report 2016-02.

<sup>9</sup> O'Farrell et al. 2015. California coastal Chinook salmon fishery management: future prospects. NOAA Tech. Memo. NMFS-SWFSC-542.

<sup>10</sup> Satterthwaite et al. 2014 Transactions of the American Fisheries Society 143:117-133

<sup>11</sup> Satterthwaite et al. 2015 Fisheries Research 73:2380–2394

<sup>12</sup> [http://www.pcouncil.org/wp-content/uploads/2015/10/D2\\_Att4\\_PtReyes\\_PtSur\\_Mgt\\_Lines\\_Corrected\\_Nov2015BB.pdf](http://www.pcouncil.org/wp-content/uploads/2015/10/D2_Att4_PtReyes_PtSur_Mgt_Lines_Corrected_Nov2015BB.pdf)

<sup>13</sup> Satterthwaite et al. 2015 Fisheries Research 73:2380–2394

<sup>14</sup> [http://www.pcouncil.org/wp-content/uploads/2015/11/D2a\\_Sup\\_SSC\\_Rpt\\_Nov2015BB.pdf](http://www.pcouncil.org/wp-content/uploads/2015/11/D2a_Sup_SSC_Rpt_Nov2015BB.pdf)

<sup>15</sup> Otto et al. 2016 ICES Journal of Marine Science 73:2380-2394

- *Increased collection and reporting of Klamath River spring Chinook escapement and river harvest data.*
- *Investigation of the existence of trends in KRFC age-specific maturation rates, and the effect such trends may have on abundance forecasting.*

## Mark-Selective Fisheries

***A more accurate assessment of total fishing-related mortality for natural stocks of coho and Chinook is needed. The ability of existing management models to predict and assess non-catch mortalities needs to be evaluated and the models modified, if needed.*** Fishery management regimes designed to reduce impacts through selective fishing, or non-retention, depend on the accuracy of estimates of non-catch mortality. In recent years, an increasing proportion of impacts of Council fisheries on naturally-spawning stocks have been caused by non-catch mortality as regulations such as landing ratio restrictions and mark-selective retention have been employed. Research using standardized methodologies (e.g., handling, holding, reporting, post-mortem autopsies, etc.), is needed to better estimate release mortality rates, encounter rates, and drop-off rates associated with gears and techniques that are typically employed in different areas and fisheries. Special attention needs to be paid to mid-term and long-term mortality. Fleet profile data (i.e., fishing technique and gear compositions) are needed to estimate release mortality rates for individual fisheries.

Harvest models have been modified to incorporate non-catch mortality. The current FRAM used for coho and Chinook salmon should work well when exploitation rates are relatively low, but, as selective fisheries become more intense, these models will tend to underestimate total mortality of the unmarked stocks. Theoretical development of unbiased methods for estimating non-catch mortalities has been conducted, evaluated using simulations, and reviewed and implemented for coho FRAM. The evaluation of their performance is a required next step. These harvest models become more sensitive to estimates of non-catch fishing mortality as the selective fisheries modeled become more intense. Uncertainty and risk need to be explicitly incorporated into these models as they are developed. This remains a highest priority data issue.

***Continue double index tagging (DIT) of all exploitation rate indicator stocks and electronic sampling for them in all fisheries.***

With increased implementation of mark-selective fisheries that use the adipose fin clip as a mass mark, CWT and marked groups no longer represent unmarked groups and cannot be used to estimate exploitation of natural or unmarked stocks in the presence of mark-selective fisheries. DIT releases have been implemented to address this change in the CWT program. DIT releases consist of paired tag groups, one marked, and the other unmarked. The relationship between marked and unmarked groups in a DIT pair provides a means to estimate encounters of the unmarked group in mark-selective fisheries. The tagged and unmarked fish are released to provide a representative for natural production. This remains a highest priority data issue.

Evaluation of DIT as a means to monitor and assess mark-selective fisheries remains a high priority, and is currently underway in the Pacific Salmon Commission Selective Fisheries Evaluation Committee. Development of methods to incorporate information from DIT studies into current harvest models is needed.

New research issues and data issues for salmon management are discussed and prioritized in the following two sections. Other high priority needs associated with hatchery fish and their interactions with wild stocks are also identified. All research and data projects listed in this chapter are considered either “highest priority needs” or “high priority needs” according to their ability to meet the criteria listed in the introduction to this report.

## **5.2 Research Issues**

### **5.2.1 *New Highest Priority Research Issues***

Data and information issues are covered in the next section. Section 7.4 (which addresses emerging issues) contains additional information on the highest priority research and data needs.

#### **Explicit Consideration of Uncertainty and Risk**

Given the increased emphasis on stock-specific concerns and principles of precautionary management, the Council should receive information necessary to evaluate the degree of risk associated with the regulations under consideration.

Current planning models employed by the Council are deterministic. Most aspects of salmon management, such as abundance forecasts and effort response to regulations, are not known with certainty. Research is needed to evaluate the accuracy of existing planning models, characterize the risk to stocks and fisheries of proposed harvest regimes, and to effectively communicate information on uncertainty for use in the Council’s deliberations.

### **5.2.2 *High Priority Research Issues***

#### **Alternatives to Time-Area Management**

The annual planning process for salmon centers on the crafting of intricate time-area management measures by various groups. The feasibility of using alternative approaches (e.g., pre-defined decision rules to establish upper limits on fishery impacts, individual quotas, effort limitation) to reduce risk of error, decrease reliance on preseason abundance forecasts, improve fishery stability, simplify regulations, and reduce management costs needs to be investigated. For instance, the integration of Council preseason planning processes with the abundance-based coho management frameworks in use by the Pacific Salmon Commission, and by the State of Washington and Western Washington Treaty Tribes, needs to be evaluated.

## **Stock Migration and Distribution**

The Council currently employs “single pool” type models (i.e., ocean fisheries operate simultaneously on the entire cohort) for evaluating alternative regulatory proposals. Under certain conditions, such models can produce results that are inconsistent with expectations of biological behavior. For example, if a fishery off Central California is closed to coho fishing for a given time period, the fish that were saved become available to fisheries off the Northwest Coast of Washington in the next time period. Research is needed to determine the feasibility of incorporating explicit migration mechanisms into planning models.

## **Ocean Distribution of Natural Stocks**

Continued research is needed to improve our ability to estimate contributions of natural stocks in ocean fisheries and escapement. Progress has been made on this issue using genetics in coho salmon and using CWTs in Chinook salmon, and further work focusing on distributions of different stocks will help further refine zones of harvest management for mixed stock fisheries. Potential research areas include 1) basic research on stock distribution and migration patterns, and association studies to determine the degree to which hatchery stocks can be used to represent the distribution and migration patterns of natural stocks; 2) GSI and related technologies, otolith marking, and scale studies; and 3) improved statistical methods and models.

## **Limiting Factors**

Research is needed to identify and quantify those factors in the freshwater habitat which limit the productivity of salmon stocks. Research should focus on 1) quantifying relationships between habitat factors and salmon production; 2) measuring the quantity and quality of these habitat factors on a periodic basis; 3) evaluating habitat restoration projects for both short-term and long-term effects; and 4) evaluating how different stocks within the FMP differ in their limiting factors. Activities such as water diversions, dams, logging, road building, agriculture, hydroelectric projects, and development have reduced production potential by adversely affecting freshwater conditions and habitat availability. Furthermore, emerging changes in marine condition from extreme temperatures, hypoxia, increases in marine mammal predation, and prey availability also have the potential to act as limiting factors in marine habitats. Habitat quality and quantity are crucial for the continued survival of wild stocks.

## **New Forecast and Harvest Models**

Develop and refine forecast and harvest models for numerous west coast salmon stocks including Klamath River spring Chinook, Central Valley spring Chinook, California coastal Chinook, Oregon coastal Chinook, and Central California coastal coho. This information could then be used to establish or reevaluate appropriate conservation and management objectives.

## **Forecast Precision and Accuracy**

Investigate the precision and accuracy of existing and new abundance forecasts, including examination of forecast models incorporating environmental variables (as was done for the SRFC



forecast in 2013<sup>16</sup>). Develop estimates of uncertainty for stock assessments and abundance and harvest models used in fishery management. Develop models of fishery participation and location modeling to allow for analyses such as:

- Improve forecasts of catch and participation as a function of regulations and run size.
- Compare abundance forecast error to implementation error — i.e., is the main constraint on our management now our ability to accurately forecast abundance, or to achieve our target harvest rate?
- Evaluate fishery impacts of extreme climate events (e.g., marine heatwaves or string ENSO/PDO fluctuations) in terms of participation rates and trip level cost.

## **Model Evaluation and Improvement**

A framework for regular evaluation of model performance should be developed for salmon harvest models to identify possible errors, biases, and areas for improvement. This could include pre- and post-season comparisons and comparisons of model predictions to independent estimates of stock composition of catch and overall stock impacts (e.g., genetic methods).

## **Impacts of Dam Removal**

If dam removal in the upper Klamath River basin proceeds as planned, it will have short- and long-term implications for the natural-area spawning habitat capacity for the Klamath - Trinity basin, and reference points may need to be adjusted accordingly. Depending on what happens with hatchery programs in the basin, this may also have implications for the number of CWT recoveries available to inform harvest models and thus the level of stratification that is appropriate, as well as representation of different Chinook life histories for the basin.

## **5.3 Data Issues**

### **5.3.1 Highest Priority Data Issues**

Research issues are covered in the previous section and Section 6.5 contains additional information on high priority research and data needs related to emerging issues.

## **Fisheries Data Collection and Modeling Improvements**

Better information should lead to better fishery management decisions and improved fishery performance relative to preseason expectations.

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<sup>16</sup> [http://www.pcouncil.org/wp-content/uploads/C2a\\_ATT5\\_SI\\_FORECAST\\_sep\\_17\\_13\\_NOV2013BB.pdf](http://www.pcouncil.org/wp-content/uploads/C2a_ATT5_SI_FORECAST_sep_17_13_NOV2013BB.pdf)

### **5.3.2      *High Priority Data Issues***

#### **Documentation and Data Sharing**

Complete and updated documentation is needed for management models (particularly FRAM) and for retrospective changes made to data uploaded to the Regional Mark Information System (RMIS). CWT release and recovery data not already reported to RMIS should be uploaded.

#### **Mass Marking**

Estimates of mark rates are essential for planning mark-selective fisheries. The accuracy of mark rates at release needs to be evaluated as well as the variability of mark-induced mortalities under operational conditions.

#### **Environmental Influences on Survival**

Estimates of natural survival and stock distribution in the estuary and ocean, year-to-year, age-to-age, and life-history variability, and relationships to measurable parameters of the environment (i.e., temperature, upwelling, etc.) are needed. Substantial predictive errors in forecasts based on previous year returns and apparent large-scale, multi-stock fluctuations in abundance suggest important large-scale environmental effects. Some work has been done for coho salmon and is in development for Chinook salmon. Included in the information needs are long-term and short-term relationships between environmental conditions and fluctuations in Chinook and coho salmon survival, abundance, and maturation rates.

#### **Freshwater Habitat**

Improve fine scale mapping of salmon distributions in freshwater. These will improve designation of EFH for Pacific Coast salmon. The lack of specific and comprehensive distribution data has prevented detailed delineation and fine-scale mapping of EFH. In particular, better evaluation of habitat conditions – including water quality, riparian vegetation, and land-use - for different life stages (returning adults, eggs in redds, rearing juveniles, and smolts) will facilitate links between EFH delineation and habitat-based life cycle models (see above).

#### **Cohort Reconstruction**

Develop full cohort reconstructions for all Council-managed Chinook and coho salmon stock complexes. This would require additional escapement monitoring for some stocks and full reporting of freshwater recoveries of CWT. Scale-age analysis will be a key component to producing cohort reconstructions applicable to natural-origin fish.

#### **Monitoring Data**

Understanding the value of information derived from monitoring data and cost-effectiveness analysis of monitoring programs and strategies. Budget constraints may require limiting data

collection efforts. Developing estimates of the relative value of data collection programs and locations would help direct limited budget resources to the highest information value uses.

### **5.3.3      *Interaction of Hatchery and Natural-Origin Salmon***

In addition to the above high-priority items a number of issues related to hatchery/wild salmon interactions are of ongoing interest:

#### **Genetics**

Determine the extent to which there may be gene flow between hatchery and wild stocks, and the extent to which such gene flow may have heritable effects on the fitness of wild stocks. A genetic technique that is being applied to this problem is PBT. If all mating adults can be captured and genotyped, then offspring can be linked to their specific parents. This has great power for identifying the relative success of various hatchery/wild matings, but is limited in practice to relatively small systems and systems where all returning adults can be captured.

#### **Freshwater Ecology**

Investigate the ecological effects (competition, predation, displacement) of hatchery fish on natural production in freshwater. All life stages from spawner to egg to smolt may be affected.

#### **Estuary Ecology**

Migration timing, habitat utilization patterns, competition for food or space, and predator interactions are areas of interest. Differences between hatchery and natural smolts in these areas could help address the questions of the importance of density-dependent growth and survival and potential negative effects of hatchery releases on natural stock production.

#### **Early Ocean Life-history**

Points of comparison between hatchery and wild stocks could include: ocean distribution, migration paths and timing, size and growth, food habits, and survival rates.

#### **Identification of Hatchery Fish**

The presence of hatchery fish may interfere with the accurate assessment of the status of natural stocks. This problem may be alleviated by the use of mass-marking, otolith marking, CWTs, genetic marking, or other technologies to estimate the contribution of hatchery fish to fisheries and naturally-spawning populations. As long as all hatchery releases are marked and tagged at known rates, it is possible to estimate (post-hoc) the proportion of hatchery origin fish in harvest and escapement. However, research is needed on marking/tagging/sampling strategies that allow identification of hatchery-origin fish in real time without interfering with the capacity for "rare stock enrichment" to allow adequate recoveries of tags from less abundant stocks with reasonable sampling effort in ocean fisheries.

## **Supplementation**

Research is needed to investigate the utility of using artificial propagation to supplement and rebuild natural stocks. Guidelines for the conduct of supplementation to preserve genetic diversity and legacy of populations should be developed where needed (in many cases these have been developed during the Hatchery Scientific Review Group process). Special care is needed to ensure that supplementation programs do not unintentionally jeopardize natural runs.

## **Trucking/barging**

Research is needed into the consequences of trucking or barging hatchery-origin fish in response to poor in-river conditions, both in terms of direct impacts resulting from increases in stray rates and in terms of the consequences for management systems that assume tagged hatchery-origin fish can be used as indicators for natural-origin fish in the same stock complex that do not benefit from such adaptive trucking.

## **5.4 Emerging Issues**

### **Genetic Stock Identification and Parentage Based Tagging**

Several emerging issues are related to the high priority assigned to the implementation of genetic technologies in weak stock fishery management. Research tasks and products necessary for this to be successful are:

- Development and application of technologies to collect high-resolution at-sea and dockside genetic data and associated information (time, location and depth of capture, ocean conditions, scales, etc.).
- Identification of stock distribution patterns useful for fisheries management and appropriate management strategies to take advantage of these distribution patterns.
- Development of pre-season and in-season management models to implement these management strategies and integrate them with Council management.
- Continue to evaluate whether PBT sampling and tag recovery programs can be practically and cost-effectively implemented to provide information for annual stock assessment needs, and update or revise the analysis performed for the Pacific Salmon Commission as genotyping costs change or new marking/tagging/sampling strategies are proposed. Genotyping all spawners used for hatchery production would allow non-lethal identification of hatchery origin fish at any life stage.
- Tissue samples should be collected and saved from entire broodstock of programs desired to contribute to PBT while sampling regimes for mixed-stock fisheries are devised. As time passes, genotyping costs decline. When sampling regimes are finalized and costs optimized, samples from fishery mixtures and broodstocks of years that could have contributed to that mixture can be processed. This information, in conjunction with scale aging of GSI samples not assigned to hatchery parents, would also provide a means for

testing the common harvest model assumption that hatchery stocks are appropriate indicators of wild stocks.

- Complete development of a coastwide GSI database, at the appropriate spatial scale, for wild Chinook and coho salmon stocks

## **Ecosystem and Essential Fish Habitat Issues**

Long-term fluctuations in salmon abundance have proven to be difficult to predict and can create significant instability in the conservation, management, and economics of salmon and salmon fisheries. A better understanding of marine and freshwater conditions and their impacts on salmon populations is needed. Recent declines in west coast salmon populations serve as a reminder of the volatility of salmon populations over time.

Additional analyses are needed which describe the impact of environmental variability in the CCE on seasonal to decadal time scales to the distribution and population structure of salmon. This effort is broadly relevant to other species in the Council's FMPs and is closely related to ecosystem research, and the PFMC's Climate Initiative. Progress has been made on this issue based on the IEA's annual summaries of freshwater habitat conditions across the Pacific Coast, and additional efforts to address ocean conditions favorable to marine life stages will further improve our understanding of annual variation in habitat characteristics. Additional progress should include:

- Tools that describe the environmental state and potential habitat utilization for near-shore anadromous fish.
- Determination of potential effects of ocean acidification on salmon prey species (e.g., crab larvae, copepods), and upon sensory functions of salmon.

Ecosystem-based research needs arose as the Council developed its FEP. Some of these research needs are similar and complementary to needs identified elsewhere in the document. The following ecosystem considerations specific to salmon are included here for emphasis:

- Develop tools that describe the environmental state and potential habitat utilization for near-shore anadromous fish, including coastwide sampling of juvenile distributions, monitoring and characterization of the forage base for juvenile and adult salmon, and fine-scale mapping of stock-specific ocean habitat and catch distributions.
- Examine temporal trends in regional salmon harvest rates and measure their covariation with temporal and spatial patterns of environmental variability. Characterize temporal changes in size, age, and migration timing of heavily exploited salmon stocks to evaluate correlations with harvest and environmental patterns. Assess the evolutionary effects of fishing season timing and location.
- Characterize the influence of nearshore marine, estuarine, and freshwater water quality on survival, growth, and reproduction of salmon.
- Assess the influence of sea surface temperature anomalies and other ocean indicators for incorporation in models used to forecast adult abundance.
- Evaluate maturation rates of wild and hatchery salmon stock returns to fresh water.

- Develop targets and metrics for monitoring regional ecosystem and/or population-level effects of climate change on the distribution and survival of salmon.
- Evaluate the positive and negative effects of hatchery production on a region-specific basis. Factors to consider include impacts (demographic and genetic) on wild stocks, the extent to which hatchery production supplements versus displaces natural production, and contributions of hatchery-origin fish to harvest and to the diets of predators in the CCE. Consider the extent to which changes in hatchery practices that affect maturation and/or straying rates may mediate or exacerbate these tradeoffs.
- Develop cumulative risk assessment models and other tools to evaluate the cumulative effects of human activities (habitat reduction, hydropower generation, hatchery production, harvest) and ocean conditions (seasonal variations, interannual and inter-decadal climate shifts, long-term climate change) on West Coast salmon productivity, population status, and predator-prey relationships.

## 6.0 COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

### 6.1 Introduction

In the previous Research and Data Needs report, multiple highest priority issues were identified. The issues, and the progress on them, are summarized below:

- **Establish a long-term index of abundance(s) for the CPS assemblage off the USA Pacific coast that is based on a sound and representative sampling design, which necessarily will require systematic/synoptic survey efforts, both temporally (annual) and spatially (Mexico to British Columbia).** The acoustic trawl method (ATM) survey has been included in several recent Pacific sardine assessments and is being further evaluated for use with other CPS stocks. A methodology review for the ATM survey in 2018 concluded that the survey can be used to provide relative indices of biomass for all CPS finfish for use in integrated stock assessments, subject to caveats. The Panel also concluded that ATM survey results should be used as relative indices when conducting assessments and providing management advice. SWFSC staff continue to engage in discussions, meetings, conferences, etc. with academic colleagues and federal administrators and researchers from Mexico and Canada. However, with the exception of more accurate landings information becoming available recently and some discussions regarding collaborative survey efforts in the future, only limited progress has been made to date including Mexican data in assessments.
- *Coordinate more timely exchange of fishery catch and biological port samples for age structures for both Pacific sardine and Pacific mackerel in the northern and southern end of their respective ranges. In particular, efforts must be made to develop a systematic and long-term program of data exchange with Mexico.* Pacific sardine and Pacific mackerel are not currently captured by fisheries in Canada. In the recent past, sardine monthly catches and port samples (length compositions) were provided annually to the SWFSC by DFO Canada. Catch data for all CPS are provided to the SWFSC on request by INAPESCA. Pacific sardine port samples have been provided by INAPESCA on a sporadic basis, and have not been updated since 2009. To date, no Pacific mackerel length or age data have been available, but recent landings in Mexico have been minimal. To date, no formal CPS data sharing agreements have been made between the U.S., Canada, and Mexico.
- *Re-evaluate the HCRs for Pacific sardine and Pacific mackerel, as well as other members of the broader assemblage, including northern anchovy (two substocks) and jack mackerel. Since the establishment of the current MSY-proxy control rule in the CPS FMP more than a decade ago, modeling tools have advanced and data on CPS have been accumulated. Moreover, recent research suggests that the relationship between  $F_{MSY}$  and temperature, which is a formal part of the HCR for Pacific sardine, may no longer be meaningful for management purposes. Simulation modeling that addresses Pacific sardine and Pacific mackerel should be undertaken and potential management strategy evaluations should consider the broader CPS assemblage as well, given biology and fishery operations are generally similar across the individual species.* The HCR for Pacific sardine was re-evaluated in a series of analyses and an MSE conducted during

2013-2014. Ultimately, a revised measure of temperature was retained in the HCR. Similar work has not been completed for Pacific mackerel and other CPS. The SSC and CPSMT outlined several options for a revised HCR and reference points for Northern Anchovy.

- ***Biological research studies should be developed for individual species based on a long-term program that allows stock parameters to be evaluated in an efficient and timely manner. In this context, age/growth, maturity/longevity, diet, natural mortality, etc. projects should be conducted on a systematic basis and consider the broader assemblage over the long-term. For example, presently, the ageing error time-series for Pacific mackerel used in an ongoing stock assessments is outdated, potentially biased, and would benefit from further age/growth analysis in the laboratory; such work was recently conducted for Pacific sardine. Finally, a life history studies program should be ongoing and include CPS in general.*** Biological studies of the CPS assemblage are ongoing at the SWFSC. CPS have been sampled at sea for size, age, and reproduction during the acoustic-trawl surveys. The ability to process CPS biological samples in the laboratory has been somewhat limited due to budgetary and human resource limitations at the Center.
- ***Federally-mandated ecosystem considerations are now critical requirements of most marine resource management frameworks and as such, dictate a broader research and stock assessment direction for CPS than currently in place. In this context, a general, more adaptive approach for conducting supportive research and formal assessments for CPS should be developed in accordance with the amount of information available, the uncertainty associated with the available data and time series, the fraction of the quota which is taken coastwide (domestic and international landings), and the (historical) frequency of formal assessments and review.*** Frequency of CPS assessments depends upon availability of reliable abundance estimates from coastwide surveys. To date, the SWFSC's acoustic-trawl (AT) survey has only been approved for use in Pacific sardine assessments. The AT survey is undergoing a methodology review in Jan-Feb 2018 where the survey will be evaluated for use in assessing other CPS stocks (anchovy, Pacific and jack mackerels).

## **6.2 Research Issues**

### **6.2.1 Highest Priority Research**

- Develop a method for estimating the variance of the biomass inshore of the ATM survey from the CDFG/CWPA aerial survey. The estimates of biomass from surveyed transects can be extrapolated to unsurveyed areas, but this will require additional sampling to ensure that the extent of between-area differences in density can be quantified to inform proper stratification of expansions and to allow variance to be estimated.
- Conduct research to refine the estimates from the ATM survey:
  - Study the vertical distribution of fish to determine if CPS in the surface blind-zone represent a stable and/or variable portion of the overall density of significance to the stock assessment. This could be done using vessel sonars or acoustic moorings.
  - Continue to collect target strength data using best available technology with associated relevant biological information to improve current target strength models.



- Use net monitoring devices to monitor the trawl during all hauls. The optimal instrumentation is trawl sonar, which monitors the variable geometry of the trawl opening, and the distribution of fish within and outside the trawl opening
- Analyze the effect of the adaptive sampling on the bias of estimates of biomass using simulation or through reanalyzing various subsets of conducted transects.
- Test efficiency (and suitability) of the existing trawl.
- Develop methods to verify that the sizes and species encountered by the acoustic gear during the daytime are the same as those encountered using trawls at night.
- Explore options to quantify potential fish avoidance under a range of survey conditions. This could involve combining systematic collection of additional data during surveys, as well as dedicated experiments.
- Validate the assumption that all CPS finfish are spread out at the surface.

## **6.2.2      *Highest Priority Data Needs***

- Develop standard data processing procedures for CPS, similar to those developed for groundfish species, and a ‘data document’ that provides, in considerable detail, how the basic data sources are constructed. Much of this information has been published in the past, but a single (and ‘living’) document describing the basic data will assist assessment authors and future review panels.
- Use the Tri-national Sardine Forum and MEXUS-Pacifico (i.e., the NMFS-Instituto Nacional de Pesca Forum) to share fishery, survey, and biological information among researchers in Mexico, Canada, and the USA. The long-term benefits of this forum will be greatly enhanced if it can be formalized through international arrangements.
- Continue to explore and expand independent nearshore survey methods and efforts to estimate the proportions of the populations that may not currently be surveyed by the ATM surveys.
- Collect (and analyse) data to estimate the abundance of northern anchovy, jack mackerel and Pacific mackerel.

## **6.3      Continuing Issues**

### **6.3.1      *Research***

#### **General**

- Modify Stock Synthesis so that the standard errors of the logarithms of age-1+ biomass can be reported. These biomasses are used when computing the Overfishing Level, the Acceptable Biological catch, and the Harvest Level, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not age-1+ biomass.
- Develop a way to automatically profile over current biomass within Stock Synthesis. It is relatively easy to profile over parameters such as  $R_0$ . However, CPS management is based on the estimate of current biomass so that quantity rather than  $R_0$  should be profiled over.

- Reduce aging error and bias by coordinating and standardizing aging techniques and performing an aging exchange (double blind reading) to validate aging and estimate error. Standardization might include establishing a standard “birth month” and criteria for establishing the presence of an outer annuli. The outcome of comparative ageing studies should be provided with every assessment.
- Improve ageing of survey and fisheries samples to allow age composition data to be used in assessments.
- Current EFH of CPS is based on annually varying isoclines of marine temperature. These boundaries should be further evaluated in light of other environmental factors (e.g., currents, dissolved oxygen, and prey). Additional work should focus on species variation within the FMP Evaluations should examine differential risk of climate change and ocean acidification upon invertebrates (market squid) compared to fish in the CPS group. The Climate Vulnerability Assessment has made important progress on this topic; further work incorporating climate trends will further help evaluate this issue.
- Further considerations should be given to research necessary to describe, identify, and map EFH based on at least level 2 and level 3 information, and ideally, level 4 information. More specific information on the preferred habitats of CPS is needed for spatially refining areas of EFH (not the whole EEZ).

### **6.3.2 Pacific Sardine**

- Collect and analyze growth data for Mexico, southern California, northern California, the Pacific Northwest (PNW) and the offshore areas to quantitatively evaluate differences in growth among areas. This evaluation would need to account for differences between Mexico and the USA on how birthdates are assigned, and the impact of spawning on growth.
- Further develop an MSE to test the survey projection method for Pacific Sardine if a full-year projection method is proposed as the basis for calculating OFLs and ABCs.
- Examine the timing and magnitude of spawning off California and the PNW.
- Further research stock structure of Pacific sardine. Assessments are currently based on the working hypothesis of a northern and a southern subpopulation that can be distinguished using environmental data (e.g., sea surface temperature, chlorophyll-a, etc.). Research should continue to focus on stock structure of Pacific sardine using existing tagging data and additional tagging experiments, trace element analysis, and microsatellite DNA markers.
- Assess changes in early life history information from CalCOFI samples to evaluate the response of Pacific sardine to climate change.
- Explore assessment models that consider a much longer time-period (e.g., 1931 onwards) to determine whether it is possible to model the entire period and determine whether this leads to a more informative assessment as well as provide a broader context for evaluating changes in productivity.
- Ongoing aerial surveys in California should be expanded to cover more CPS habitat off California and PNW. Additional validation of assumptions concerning observer biomass estimations and species identifications are needed. The review panel noted that no adequate estimates of variance are currently available; it will be necessary to develop and implement

a variance estimation method before estimates can be used for management. Review of a variance estimation method could be accomplished during a STAR Panel.

- At present all U.S. catch is counted against the ACL for the northern population, while landings south of Point Conception are often composed of the southern population during the winter and spring. The assessment accounts for only catch of the northern population, discriminating catch of each of the populations on the basis of the distribution model. This inconsistency in assessment and tracking of catch inseason should be resolved to manage on the basis of landings of only catch identified as being from blocks identified as being occupied by the northern population using the distribution model used to discriminate between landings of each population in the assessment.
- Re-evaluate some of the details of the landings differentiation methodology outlined in Demer and Zwolinski (2014a) in the context of its current use. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. In addition (a) re-evaluate the relative importance (costs) of the two types of mistakes that can be made by a two-class classifier (false positives and false negatives), and (b) explore whether there are other techniques (e.g., random forests) that might yield a better overall classifier, given that the goal of the analysis is prediction.
- Consider spatial models for Pacific sardine that can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age; this should include an analysis of age-structure on the mean distribution of sardine in terms of inshore-offshore (especially if industry partner-derived data were available).

### **6.3.3 Pacific Mackerel**

- Revisit biological parameters, such as maturity-at-age, ageing error, sex ratio, sex-specific parameters, and natural mortality rates ( $M$ ), e.g., examine sex- and/or age-specific  $M$ .
- Continue to refine the CPFV index of abundance. This index can be improved by: (a) developing a single database that includes the raw trip-level data, (b) conducting analyses in which the trip is the unit of analysis and trip-within-vessel is treated as a random effect and the factors associated with blocks within region are explicitly modelled, and (c) conducting analyses in which an attempt is made to include catch-rates of other classes of target species as covariates.

### **6.3.4 Market Squid**

- Conduct additional work on reproductive biology, including the potential fecundity of newly mature females, the duration of spawning, egg output per spawning episode, the temporal patterns of spawning, and the growth of relatively large immature and adult squid. Also, further clarity regarding this species' age/growth dynamics (via laboratory statolith studies), both spatially and temporally, would benefit management efforts directed towards this important commercial resource off California.

- Gain a better understanding of (and quantify, if possible) impacts to substrate used to attach eggs and to the egg masses themselves. Information about egg survival and paralarvae production per unit area in different types of spawning habitats is needed for understanding potential impacts from fishing and non-fishing activities in shallow water.
- Improve information on the distribution and depth of squid spawning grounds, as well as the dispersal of adults and paralarvae, along the West Coast (information north of Central California is particularly limited).

## 6.4 Data Needs

### General

- Develop a coastwide (Mexico to British Columbia, Canada) synoptic survey of sardine and Pacific mackerel biomass, i.e., coordinate a coastwide sampling effort (during a specified time period) to reduce "double-counting" caused by migration. The acoustic-trawl survey now covers the bulk of the USA west coast, but does not yet cover waters off Baja Mexico. Development of a coastwide survey needs to account for the distribution of the CPS at various times of the year.
- Gain more information about the status of the CPS resources in the north using egg pumps during NMFS surveys, sonar surveys, and spotter planes.
- Increase fishery sampling for age structures (Pacific sardine and Pacific mackerel) in the northern and southern end of the range. Establish a program of port sample data exchange with scientists from Mexico (Instituto Nacional de la Pesca [INP], Ensenada). There has been interest in coastwide management for the Pacific sardine fishery, which would entail a more consistent and well-supported forum for discussion between the USA, Mexico, and Canada. Recent USA-Mexico bilateral meetings indicated willingness from Mexico to continue scientific data exchange and cooperation on research, and engage in discussions of coordinated management. Mexico suggested that the MEXUS-Pacifico Cooperation Program would be a good venue for starting that discussion. Additionally, the annual Trinational Sardine Forum results in effective exchange of data and ideas on the science and economics of coastwide sardine management.
- Further increase the existing collaboration between industry and state and federal agencies to improve the overall data collection and analysis processes for CPS.
- Improve information on salmon and other bycatch in the CPS fishery. The NMFS Southwest Region initiated a pilot observer program for California-based commercial purse seine fishing vessels targeting CPS in July 2004 with hopes of augmenting and confirming bycatch rates derived from CDFW dockside sampling. Future needs of the CPS observer program include: standardization of data fields, development of a fishery-specific Observer Field Manual, construction of a relational database for the observer data, creation of a statistically-reliable sampling plan, and increasing sample sizes (spatially and temporally) to ensure an adequate number of trips are 'observed' to produce statistics that are representative of the fishing fleets at large.
- The Santa Cruz Southwest Fishery Science Center conducts a young of year rockfish survey off of California providing indices of abundance and length composition data for both larval and adult life history stages from bongo tows and mid-water trawl gear

respectively. This data was informative in the 2016 update in informing whether to take future recruitment from the stock recruit curve or to use the average of the last three years of recruitment. This data may be informative as a recruitment index as well as an adult index of abundance in future assessments. Length compositions from this study can be used to supplement other data sources such as the ATM survey for which length compositions and sampling nearshore is more limited. Encountered CPS could be sampled at sea for age and reproduction as well as length, which is already collected during the survey.

- Develop methods to extract information from the acoustic data about numbers of schools and their size and spacing. Time series of school statistics, along with other stock characteristics, might become useful in studies of state and interaction dynamics of stocks.
- Examine the effects of the sample size of fish collected in trawls in terms of uncertainty and variability in indices and size and age compositions, and consider ways to increase sample size. Low sample size to estimate relative abundance by species affects indices more than the sizes collected, but the latter is important for estimating size and age structure. While increasing the length of trawls will help to some extent, other approaches may be more efficient.

#### **6.4.1      *Pacific Sardine***

- Include regular systematic sampling of adult sardine in biological surveys for: 1) reproductive parameters for the daily egg production method; 2) population weight-at-age; and 3) maturity schedule. Specifically, adults collected during survey trawls must be collected and analyzed more routinely in the future than has been the case in the past.
- Make use of relevant technical developments for remote sensing of fish schools using satellites and drones. For example, Sentinel 2 satellites are now providing (at no cost) multi-spectral images at 10m resolution with five day repeat intervals, suggesting that it should now be possible to rapidly scan large areas for apparent schools. A drone-mounted camera could give coverage of a relatively small coastal area, showing how school visibility changes in repeat observations.
- Examine whether undercounting bias in aerial surveys, due to depth distribution of schools below the visible range, could be estimated from school metrics (i.e., school depth, thickness, general shape, etc.) derived from sonars on fishing vessels assisting with the surveys. The sampling effort required to produce a robust estimate of bias would depend on the variability of vertical depth distribution within a defined survey period.
- Comprehensively document criteria used to decide when to conduct aerial surveys and how experts distinguish species to properly extrapolate data to unsurveyed areas as well as deriving the appropriate variance estimates of biomass and density estimates.

#### **6.4.2      *Pacific Mackerel***

- Continue efforts obtain total catch, length, age, and biological data on a timely basis from Mexican fisheries for inclusion in stock assessments. Survey data (Investigaciones Mexicanas de la Corriente de California [IMECOCAL] program) should be obtained and analyses conducted to determine whether these data could be combined with the CalCOFI data to construct a coastwide index of larval abundance.

- Collect biological (e.g., length, age, sex) data on mackerel caught in the Pacific Northwest. These data could further assist in understanding whether and to what extent selectivity for the commercial fishery is dome-shaped. The aging of Pacific sardine in the Pacific Northwest should be coordinated with researchers conducting ageing in California.

#### **6.4.3      *Market Squid***

### **6.5      *Emerging Issues***

#### **6.5.1      *Pacific Sardine***

- Review the data on maturity-at-age to assess whether there have been changes over time in maturity-at-age, specifically whether maturity may be density-dependent.
- Account for the potential for sardine from different stock subcomponents to recruit to adjacent stock areas in the assessment model. To do so requires development of a new assessment model or modification of an existing one. Consider spatial models for Pacific sardine, which can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better-represent the latitudinal variation in size-at-age.
- Develop an index of juvenile abundance. The indices used in the assessment pertain only to spawning fish. An index of juvenile abundance, for examples based on the survey conducted by the NMFS Santa Cruz laboratory, will enhance the ability to identify strong and weak year-classes earlier than is the case at present.
- Account for the total number of batches of eggs produced during a season (annual fecundity) when defining fecundity-at-age. While the spawning frequency during the peak season does not appear to be age-dependent, the length of the spawning season may be longer in older fish. This may affect the stock-recruitment relationship. Whether visual estimates of activity (presence of developed gonads) from port-collected samples can be used to estimate length-specific timing and duration of spawning across the stock's range should be explored.

#### **6.5.2      *Pacific Mackerel***

- Examine the disparity between the observed recruitment dynamics (boom-bust) and the underlying spawner-recruit model (uncorrelated recruitment deviations).
- Document the catch history from 1926-27 to 2006-07 in a single report.

#### **6.5.3      *Market Squid***

- The use of target egg escapement levels as biological reference points for managing this resource is partly predicated on the assumption that the spawning that takes place prior to capture is not affected by the fishery and ultimately, fully contributes to future recruitment. However, it is possible that incubating eggs are disturbed by the fishing gear, since the fishery takes place directly over shallow spawning beds, resulting in unaccounted egg mortality. It is also possible that the process of capturing ripe squid by purse seine might induce eggs to be aborted, which could also affect escapement assumptions. In this context, the CalCOFI ichthyoplankton collections contain approximately 20 years of unsorted

market squid specimens that span at least two major El Niños. This untapped resource might be useful in addressing questions about population response to El Niño conditions.

#### **6.5.4      *Northern Anchovy and Jack Mackerel***

Population estimates of anchovy and jack mackerel are in need of an update. Reasonable estimates of their current biomass are needed for sound ecosystem management, particularly before ecosystem models can be used to accurately forecast dynamics of planktivorous organisms in the food web. One potential direction for these species is to use similar fishery-independent methods developed for species such as Pacific sardine and Pacific mackerel.

#### **6.5.5      *Habitat and Distribution***

Characterize and map the ocean spatial distribution patterns of abundance both seasonally and interannually. CPS may have aggregated distributions tied to spatially and temporally fixed areas of high productivity, which could be useful to fisheries that pursue them.

### **6.6      Ecosystem Issues**

Ecosystem-based research needs arose as the Council developed its FEP. Some of these research needs are similar and complementary to needs identified elsewhere in the document. The following ecosystem considerations specific to CPS are included here for emphasis:

- Evaluate the role of CPS resources in the ecosystem, the influence of climatic/oceanographic conditions on CPS, and predatory/prey relationships. Increase the use of fishery information to estimate seasonal reproductive output (e.g., fat/oil content).
- Conduct studies of krill concentrations and CalCOFI larval data in association with annual and intra-annual variations in environmental conditions may provide insights into predator-prey relationships, ocean productivity, and climate change (also see Section 2.3).
- Climate or ecosystem indicators are not included in the annual stock assessments for Pacific sardine and Pacific mackerel, the actively managed species in the FMP. If significant climate-productivity relationships could be developed for Pacific sardine and Pacific mackerel, as well as for other CPS, assessments would benefit since CPS are known to be quite sensitive to long and short-term climate change in the CCLME.
- A management concern of the Council under EBFM will be the evaluating trade-offs between increasing/decreasing the yield of CPS and the potential yield loss/gain of a predator that may be in another Council FMP or be of concern in terms of its ecological importance. Ecological and economic considerations come to the fore to evaluate optimum yield, since OY depends crucially on the relative net benefits provided to society through these interactions.
- Determine whether climate change and ocean acidification pose differential risk to invertebrates (squid) compared to fish in the CPS group.

**Pacific Sardine:** At present all U.S. catch is counted against the ACL for the northern population, while landings south of Point Conception are often composed of the southern

population during the winter months and spring. The assessment accounts for only for catch of the northern population discriminating catch of the basis of the environmental model. This inconsistency in assessment and tracking of catch inseason should be resolved to manage inseason on the basis of landings of only catch identified as being from the northern population.

**Pacific Sardine and Northern Anchovy:** The Santa Cruz Southwest Fishery Science Center conducts a young of year rockfish survey off of California providing indices of abundance and length composition data for both larval and adult life history stages from bongo tows and midwater trawl gear respectively. This data was informative in the 2016 update in informing whether to take future recruitment from the stock recruit curve or to use the average of the last three years or recruitment. This data may be informative as a recruitment index as well as an adult index of abundance in future assessments. Length compositions from this study can be used to supplement other data sources such as the ATM survey for which length compositions have been limited. Encountered CPS could be sampled at sea for age and reproduction as well as length, which is already collected during the survey.



## 7.0 HIGHLY MIGRATORY SPECIES FISHERY MANAGEMENT PLAN

### 7.1 Introduction

The Council's Fishery Management Plan (FMP) for U.S. West Coast Fisheries for Highly Migratory Species (HMS) covers a taxonomically broad range of species including tunas, billfishes, and sharks. The spatial extent of the Pacific Ocean used as habitat for these species extends well beyond the U.S. Exclusive Economic Zone (EEZ). The HMS FMP recognizes that stock assessment and management of these species cannot be done unilaterally – rather it must be done in conjunction with other nations that exploit these species, throughout their range.

In the Pacific Ocean, HMS are managed by two regional fishery management organizations (RFMOs) – the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC) – that together cover the breadth of the Pacific Ocean habitat for the species included in the Council's HMS FMP (Figures 1 and 2). Stock assessments and related research are conducted under the auspices of these RFMOs. U.S. scientists (whose affiliations include NMFS, academia, nongovernmental organizations, and the fishing industry) participate in both RFMO processes.

A third scientific organization – the International Scientific Committee (ISC) on Tuna and Tuna-like Species in the North Pacific Ocean – provides scientific advice on the status of North Pacific HMS stocks that straddle the 150° W. longitude boundary between the RFMOs. The ISC is not an RFMO in that it does not manage HMS international fisheries. Rather, it is the science provider to the WCPFC Northern Committee in charge of conducting stock assessments and developing advice to base management decisions for northern straddling stocks such as North Pacific albacore, Pacific bluefin tuna, swordfish, and striped marlin.

For stock assessments, the overarching priority is to permit accurate and timely status determinations and monitoring of trends in population abundance and fishing mortality for all stocks, with priority given to stocks that are most important to and most affected by Council-managed fisheries. Stock assessments rely on three main categories of data: (1) indices of abundance, (2) accounting of total fishing mortality (“fisheries statistics”), and (3) biology and life history characteristics. Thus, in addition to prioritizing stocks in terms of management need, this chapter also identifies priority data gaps for each stock. A comprehensive prioritization would consider these data gaps across the full set of stocks and evaluate which data sources should be added, enhanced, or maintained to produce some optimal level of information. In some cases, it may be desirable to collect information on a stock with relatively lower management priority if higher priority stocks are already being adequately assessed. This balancing of the need to address data-poor stocks while also maintaining and improving timeliness and accuracy of assessments for stocks of highest management priority must also take into account the transboundary nature of HMS stocks—as mentioned above, NMFS cannot make status determinations or track catches for most HMS stocks without cooperation from other countries.

Stock assessment priorities will also have to factor in the MSA requirements. All the Council's HMS stocks are managed under international treaty agreements and, as such, are exempted from

annual catch limit and accountability measure requirements. However, all still require an estimate of the overfishing limit (OFL) and application of status determination criteria. The HMS sharks include some of the most data-poor stocks in the FMP. In some cases, it may be necessary to give priority to sharks of lower management priority (e.g., thresher sharks) to obtain basic fisheries information (e.g., total annual catch) and meet the acceptable biological catch and stock status requirements.

Research and data needs for the Council's HMS FMP have been organized in this chapter by those of highest priority, followed by issues that are emerging as high priority and then other related issues. These needs cover a range of HMS management issues, from stock assessments to protected species interactions, EFH, and fisheries economics. Section 8.2 highlights progress made relative to the Council's 2013 Research and Data Needs report. Sections 8.3 through 8.5 identify new and continuing research and data needs.

## **7.2 Progress on Highest Priority Issues**

In the 2013 Research and Data Needs report, multiple highest priority issues were identified. Only those issues where corresponding studies have been identified and completed are summarized below:

- *North Pacific Albacore: age and growth, with the goal of updating growth rates and identifying regional differences in growth rates.* A length-conditional approach was used to estimate a sex-combined growth curve that resulted in a similar pattern to previous curves for intermediate ages (age 2-6) but lead to different asymptotic lengths (Xu et al. 2016). Growth estimates from this study may not be representative of the stock due to potential spatial differences in growth because of age- and sex-specific movement. A simulation study was also conducted to evaluate the interaction between the age-based process of movement and the length-based process of gear selection on the estimation of growth rates (Lee et al. 2017a). Assuming samples are random at age can lead to bias with the subsequent inclusion of the length-based process of gear selection. When applying a length-conditional approach, information on the age structure of the sampled area is needed to ensure an unbiased estimate of the growth parameters when age-based movement is occurring.
- *North Pacific Albacore: reproductive biology, with the goal of updating the maturity schedule and identifying regional differences.* Sex ratio, spawning season, spawning fraction, and the relationship between fork length and maturity rate were examined using histological observations of ovary samples (Ashida et al. 2016). Gender-specific maturity ogives have also been assessed using histological examination of testes or gonads (Chen et al. 2016).

- *North Pacific Albacore: development of new indices of abundance particularly from fisheries that regularly catch recruitment-age albacore (age 1), e.g. the U.S. recreational fishery.* Size compositions from the U.S. pelagic longline fishery were re-examined and fleet definitions revisited to improve area-based consistency in size composition data used in assessment (Teo 2016). Core seasonal areas were identified by life stage (juvenile and adult) and cluster analyses identified the aggregation of areas into two fleets. Newly developed abundance indices for juvenile and adult albacore (Teo 2017a, Teo 2017b) were not recommended for use as a primary index of abundance, but rather used in sensitivity model runs.
- *North Pacific Albacore: migration and habitat utilization, with the goal of determining migration and habitat use patterns, improving fishery catch-effort standardization and fishery selectivity/catchability estimates.* Size data from the Japanese longline fishery were evaluated using cluster analysis to investigate spatial patterns in fish size (Ochi et al. 2016).
- *North Pacific Albacore: natural mortality with the goal of estimating natural mortality rates using well-designed tagging experiments.* A meta-analysis was conducted to calculate prediction intervals and priors for natural mortality (Kinney and Teo 2016). The study indicates that age-specific natural mortality estimates presented in the paper could be used for the next assessment.
- *Swordfish: development of new indices of abundance.* Swordfish CPUE was modeled with relationships to environmental and spatial variables (Su et al. 2017). Results showed hot spot areas with consistently high relative abundance, which could inform time-area management procedures.
- *Swordfish: evaluate the simplified treatment of spatial population structure.* Alternative stock structure hypotheses were evaluated using size composition statistics from Taiwanese distant water longliners (Chang et al. 2017). A three-stock hypothesis was best supported from the data.
- *Shortfin Mako Shark: examine stock structure and boundaries of the species and relationships to other populations.* Modeling of spatiotemporal distributions using fishery CPUE data has been conducted in the western and central North Pacific, and this effort has identified hot spots and seasonal north-south distribution shifts which could be used to reduce capture risk as bycatch (Kai et al. 2017a). A spatiotemporal index of abundance using fishery data has also been completed for Shortfin Mako (Kai et al. 2017b).
- *Pacific bluefin tuna: increased port sampling of commercial bluefin length frequencies is needed in the Eastern Pacific Ocean (EPO), particularly of the fish destined for the pens in farming operations.* Stereoscopic cameras are currently being used to obtain counts of fish and individual fish lengths, which then are used to develop length/weight compositions for the farming/ranch sector (Dreyfus-Leon and Aires-daSilva 2015).

- *Pacific bluefin tuna: estimate age-specific migration rates of bluefin tuna from the Western and Central Pacific Ocean to the Eastern Pacific Ocean and understand the factors that influence those rates, since this in turn strongly influences the availability of bluefin in the EPO.* Simulations have been conducted to evaluate alternative model structures that account for (either explicitly or implicitly) movement in the population dynamics model (Lee et al. 2017b).
- *Pacific bluefin tuna: improve standardization of abundance indices.* There have been several ICS working papers devoted to updating and improving Japanese and Taiwanese longline fishery abundance indices for Pacific bluefin tuna in recent years. Cluster analyses to account for targeting shifts have been recently completed (Sakai et al. 2016).
- *Interactions with protected species and prohibited species: develop probability-based estimates of unobserved bycatch for observer programs.* Ratio estimates for marine mammal, sea turtle, and seabird bycatch for the California drift gillnet fishery have been developed (Martin et al. 2015; Carretta et al. 2017).

### 7.3 Highest Priority Issues

Research and data needs for the major HMS species and HMS fisheries interactions pertinent to the Council are partitioned in this section into issues relevant for all HMS species (section 7.3.1) followed by species-specific additional priority issues. Due to the large spatial coverage and interjurisdictional movement of HMS, the Council may not be well situated to respond to all the specific research and data needs identified in this chapter. The Council is more likely to have a direct opportunity to contribute to those needs identified below that are followed by an asterisk.

Although there are many highest priority issues listed in the section, the two identified as the most important at this time include:

- support the development of management strategy evaluations for North Pacific albacore and Pacific bluefin tuna, including the collection of economic data and specification of economic-related management objectives and performance metrics; and
- understanding the stock structure of North Pacific swordfish.

#### 7.3.1 Issues Relevant to All HMS Stocks

Fisheries Statistics: Timely submission of national fishery data is essential for producing timely and up-to-date stock assessments. Additional resources are needed to monitor the submission of these data, to provide adequate database management, and to adequately document the entire database system, including metadata catalogs. Electronic reporting systems increase data entry convenience for industry participants, reduce processing time and costs for data managers, and significantly improve the quality of data being collected through validation checks. The continued development of an electronic fish ticket system for HMS species would greatly improve the availability, timeliness, and accuracy of fishery landings data. The development of a US West Coast, multi-fisheries electronic logbook system would provide similar results for logbook data.

Biological Studies: Biological information is a critical building block for stock assessments and should be reviewed and updated regularly to capture changes in population parameters as they occur. Studies on age, growth, and maturity need to be conducted (or updated) for HMS species. In many cases, stock assessment models rely on biological information that was either collected decades ago (e.g., 1950s and 1960s) or assumed from similar species.

There is a critical need to reassess the biological information and to conduct contemporary research studies to update this information. More specifically, there is a need for improved data and to conduct and/or continue studies on:

- development of indices of abundance, particularly from fisheries that regularly catch HMS \*;
- influence of environmental conditions on biological parameters, including recruitment, growth, migration, habitat use, and catchability \*;
- increase age and length data through port and biological sampling \*;
- continued age and growth information, with the goal of identifying spatiotemporal and gender-specific differences in growth rates;
- reproductive biology, further evaluation of spatial differences in maturity schedules and implications for stock assessment;
- migration and habitat utilization, with the goal of determining migration and habitat use patterns, improving fishery catch-effort standardization and fishery selectivity/catchability estimates;
- improve understanding of HMS interactions with protected species and prohibited species; and
- natural mortality with the goal of estimating natural mortality rates using well-designed tagging experiments.

Stock Assessment and Management Studies: Demand for more frequent and more precise information on the status of HMS stocks and the sustainability of HMS fisheries in general is likely to increase. In particular, there is a general need to:

- evaluate the utility of formally adding tagging data into HMS assessments \*;
- develop models of fisher participation that predict levels of effort and catch by region based on biological and ecological conditions in the target fishery as well as conditions in other fisheries in which fishers participate, particularly the salmon troll fishery \*;
- further develop and improve abundance indices from commercial and recreational fisheries \*;

- evaluate the effects of including environmental indices in assessments that have been developed as indicators of HMS population dynamics \*;
- evaluate the effects of changes to assessment model structure and assumptions, by testing the assessment model with data generated by a simulation model tuned to HMS biology;
- evaluate the treatment of spatial population structure in HMS stock assessment;
- evaluate the expected outcomes (e.g., cost/benefit) of initiating an age structure collection design and age reading workflow that would feed into assessment;
- conduct cost/benefit analyses to elicit tradeoffs between the timing of conducting HMS assessments and resource limitations; and
- explore stock-recruitment relationships, with the goal of improving or confirming the assumptions of the current stock-recruitment relationship.

Economic Studies: There is a need to develop models of recreational fisher participation that predict levels of effort and catch, and measures of economic value (including willingness to pay measures) by region and species based on economic, biological, and ecological conditions in the target species fishery as well as conditions in other fisheries in which fishers participate. This is of particular importance for albacore tuna, yellowfin tuna, and Pacific bluefin tuna.

### **7.3.2 Pacific Bluefin Tuna**

Fisheries Statistics: The timeliness of data reporting, as outlined in Section 7.3.1, is important for Pacific bluefin tuna. Additionally, continuing the increased port sampling of commercial bluefin length frequencies is needed in the Eastern Pacific Ocean (EPO), particularly of the fish destined for the pens in farming operations.

Biological Studies: In addition to those issues outlined in Section 7.3.1, there is also a need for improved data and to conduct and/or continue studies on:

- development of seasonal and perhaps area-based weight-length relationships because the condition factor for Pacific bluefin tuna appears to vary both seasonally and regionally \*;
- estimation of natural mortality rates, because assessment results are highly sensitive to the assumed mortality rates; and
- further evaluation of robust stock assessment approaches to estimate age-specific migration rates of Pacific bluefin tuna from the Western and Central Pacific Ocean to the Eastern Pacific Ocean and understand the factors that influences those rates, since this in turn strongly influences the availability of bluefin tuna in the EPO.

Stock Assessment and Management Studies: There is a need to support the development of a management strategy evaluation for Pacific bluefin tuna that is being initiated by the ISC, given

the stock is currently at a very low stock size. In addition to the issues outlined in Section 7.3.1, there is a need to:

- continue improvement with standardization of abundance indices;
- develop an abundance index from spotter plane data from the EPO; and
- incorporate tagging data and environmental indices into the assessment model.

### **7.3.3 North Pacific Albacore**

Fisheries Statistics: The timely submission of national fishery data to the ISC Albacore Workgroup data manager is essential for producing timely and up-to-date stock albacore assessments. The collection of economic data and subsequent specification of economic related management objectives and performance metrics would benefit the ongoing management strategy evaluation effort for North Pacific albacore.

Biological Studies: Update studies on growth and maturity have recently been completed for North Pacific albacore, but further work is required, particularly with respect to growth. Consequently, the stock assessment models used by the ISC Albacore Workgroup still rely on some biological information that was collected largely in the 1950s and 1960s, although updated length-weight schedules have been applied and the recent age, growth, and maturity studies have provided new information (see Section 7.2). In addition to those issues outlined in Section 7.3.1, there is also a need for improved data and to conduct and/or continue studies on:

- development of new indices of abundance particularly from fisheries that regularly catch recruitment-age albacore (age 1), e.g., the U.S. recreational fishery \*.

Stock Assessment and Management Studies: The development of a general simulation framework for albacore is needed to evaluate alternative management procedures (e.g., data collection, stock assessment, harvest control rules) and explore robust policies given system uncertainties relative to management objectives (e.g., management strategy evaluation). In addition to the issues outlined in section 8.3.1, this framework could also be used to:

- evaluate the attainment of management objectives, such as achieving on-average (target) and avoiding (limit) biological reference points for albacore, and the explicit tradeoffs among objectives;
- evaluate the simplified treatment of spatial population structure in the current albacore assessment; and
- investigate the drivers of biomass scaling in the SS3 model used for the most recent (2017) stock assessment.

### **7.3.4      *Swordfish***

Biological Studies: In addition to those issues outlined in Section 7.3.1, there is also a need for improved data and to conduct and/or continue studies on:

- examination of age and growth data from locally-caught fish \*; and
- evaluation of swordfish distribution by season and age within the outer portions of the EEZ and high seas.

Stock Assessment and Management Studies: In addition to the issues outlined in section 7.3.1, there is a need to:

- conduct additional work on effort standardization; and
- further evaluate swordfish stock structure in the Southern California Bight, given that tagging studies indicate mixing of the Western and Central Pacific stock with the Eastern Pacific stock.

Economic Studies: Explore economic viability of deep-set buoy gear as an alternative to methods currently in use to target swordfish off the west coast (harpoon, longline, and drift gillnet gear). Continue to research the best options to promote developing and testing novel gears (e.g., linked buoy gear or deep-set daytime longlining) to reduce protected species interactions and increase swordfish catch. Gauge the impact on global swordfish production and trade of unilateral measures to regulate West Coast fishing effort.

### **7.3.5      *Sharks***

Most of the tunas covered in the HMS FMP are being assessed on a regular basis, with varying degrees of completeness and sophistication. Some of the billfishes—particularly striped marlin and swordfish—are either being assessed or have assessments planned soon. On the other hand, stock assessments for sharks have been few and far between, though an assessment for common thresher shark was completed in 2016. This situation should not be taken to imply that sharks are unimportant, nor should it be inferred that sharks are less vulnerable to the effects of fishing than are the tunas and billfishes. In fact, because of the key vital rates of most sharks (especially reproductive rates that are lower than those for tunas and billfishes), many HMS shark species are likely to be more vulnerable to overfishing than other HMS. The Pacific RFMOs have begun to prioritize shark stock assessments. The WCPFC, IATTC and ISC have assessed some shark stocks and plan to do more over the next several years, but given the fact that many species are not targeted and fishery data are scant, there will be many challenges.

As with the other transboundary species covered by the HMS FMP, most shark species cannot be assessed or managed unilaterally by the Council. Some species are highly oceanic with ranges like that of tunas (e.g., blue shark and shortfin mako shark). Others are more coastal—with a substantial portion of their habitat shoreward of the U.S. EEZ—but exhibit north-south migrations with significant catches in Mexican waters (e.g., common thresher shark). The net effect is that accounting for the total catch of sharks over their entire period (several decades) and areas of exploitation is not possible. Furthermore, there is a paucity of the biological samples needed to



characterize the size of animals taken from the fisheries that account for most of the catch. Active biological studies (age, growth, maturity, food habits, etc.) are ongoing (NMFS, State, non-profit, and academic researchers) and understanding the biological characteristics for at least some shark species is probably sufficient for stock assessment purposes. However, without an accurate history of total catch, effort, and the corresponding size samples, stock assessment efforts and concomitant management by the Council will be problematic.

The following specific research priorities have been identified for the two shark species of greatest priority to the Council with respect to their importance in U.S. West Coast commercial and recreational fisheries:

**Common thresher shark:**

- obtain improved recreational catch estimates \*;
- obtain improved recreational catch estimates \*;
- further evaluate maturity and reproductive schedules and resolve existing data conflicts for this species in the California Current (e.g., potential for misidentification) \*;
- examine spatiotemporal stock structure and boundaries of the species and relationships to other populations;
- estimate total annual stock-wide catch;
- improve commercial fishery monitoring in Mexican waters; and
- estimate age and growth rates, including comparisons of growth rates in other areas.

**Shortfin mako shark:**

- estimate distribution, abundance, and size in areas to the south and west of the West Coast EEZ;
- estimate total annual stock-wide catch;
- examine stock structure and boundaries of the species and relationships to other populations; and
- estimate age and growth rates (current growth estimates differ widely).

## **7.4 Emerging Priority Issues**

### **7.4.1 Blue shark**

As noted above, relatively little assessment and research activity has been focused on shark species compared to the existing work being done on other HMS, such as tunas. Stock assessments for blue shark in the North Pacific have been completed by the ISC in recent years (2013, 2014, and 2017). Blue shark catch was relatively high in the California CPFV fishery of the late 1980s, but has declined markedly. Blue sharks are encountered in relatively small numbers coastwide in commercial and recreational fisheries. The 2017 assessment of blue shark suggests that the population in the North Pacific is not overfished and overfishing is not occurring. The U.S. portion of the total blue shark catch (U.S. west coast and Hawaii) has been about 1% in recent years. Specific research needs have been identified for blue sharks:

- improve information on the stock-recruitment relationship;
- improve the monitoring of catch and discards;
- monitor sex and size composition of catches;
- provide estimates of natural mortality through tagging studies;
- determine the migratory movements of juvenile and maturing fish from the EEZ to high seas; and
- examine the Pacific-wide stock structure and interactions among populations using genetics and other techniques.

### **7.4.2 Striped Marlin**

Fisheries Statistics: The timeliness of data reporting, as outlined in Section 7.3.1, is important for striped marlin. The catch statistics for striped marlin are considerably less well-developed than those for other HMS stocks (e.g., albacore), and significant effort is needed to ensure that the total catch from all nations is well-estimated.

Biological Studies: In addition to those issues outlined in Section 7.3.1, there is also a need for improved data and to conduct and/or continue studies on:

- examination of age and growth data from locally-caught fish \*; and
- stock structure for striped marlin in the Pacific Ocean because several stock structure hypotheses are credible, such that a synoptic, critical review of all available information (fisheries data, ichthyoplankton data, and genetic studies) would help to either resolve the issue or at least to reduce the number of credible hypotheses.

Stock Assessment and Management Studies: In addition to the issues outlined in Section 7.3.1, there is a need to:

- conduct additional work on effort standardization.

#### **7.4.3      *Tropical Tuna Species and Dorado***

The commercially-important tropical tuna species, namely yellowfin, bigeye, and skipjack tuna, are principally harvested in the EPO by vessels from the Central and Latin American fishing fleets. Although a small West Coast-based U.S. flag purse seine fishery opportunistically harvests these tunas, the U.S. fleet has little activity in the main EPO fishery at present. The tropical yellowfin, bigeye, and skipjack tunas are no longer taken in large numbers by West Coast-based commercial fisheries.

The California CPFV fleet is the principal U.S. West Coast fishery for dorado, which are often taken in the Mexican EEZ. Dorado can be a significant portion of the total CPFV annual catch and has been the leading species in some years, followed by yellowfin tuna, Pacific bluefin tuna, and albacore tuna. Specific recommendations on dorado research include:

- determination of the stock structure of dorado in the eastern Pacific, and
- investigation of how important floating objects and other-species associations are relative to life history.

#### **7.4.4      *Pelagic and Bigeye thresher sharks***

These species occur in far lower frequency than common thresher sharks in U.S. West Coast fisheries. Nevertheless, they are taken in Council-managed fisheries and studies of their life history and ecology, and temporal and spatial catch monitoring will help inform management along the West Coast and in other areas.

### **7.5      Ecosystem and Other Ongoing Issues**

#### **7.5.1      *Interactions with Non-target, Protected, and Prohibited Species***

More complete catch information and data on interactions with non-target, protected, and prohibited species are needed for most HMS fisheries. There is inadequate understanding of the fisheries on some HMS stocks that are shared with Mexico (e.g., species composition of shark catches in Mexican fisheries), and inadequate data exchange with Mexico. These fisheries are likely affecting both protected species and prohibited species of fish. Further, research and data collection is needed for non-target species that are taken in large numbers, and potentially marketable, by HMS fisheries for which stock status is unknown and where West Coast catches have been increasing (e.g., opah).

The HMSMT recently began producing bycatch performance metrics for the drift gillnet fishery using a simple ratio estimator to estimate bycatch in the unobserved portion of effort. These tend to exhibit bias for species subject to large interannual variation in observed catch relative to the level of effort, including for rare-event bycatch species with many zero observer counts (see Martin et al. 2015). The ratio estimator at 20% observer coverage will simply multiply whatever is observed by 5, resulting in an estimate of 0 if no interactions are observed, which is downwardly biased in case of unobserved interactions, and 5 times the interaction count if any are observed, which is upwardly biased for rare event bycatch. This effect can cause significant underestimation or overestimation of bycatch within a single year. Therefore, research is needed to compare the precision of the ratio estimator to various recently developed alternatives, including Bayesian prediction, boosted regression tree, bootstrap, and spatial model-based estimators of unobserved bycatch. If it is determined that the ratio estimator approach performs poorly compared to alternative methods, a reevaluation of the methods used to estimate bycatch may be warranted.

Of additional interest is the benefit of higher levels of observer coverage in the drift gillnet fishery above the 20% level that was traditionally targeted. While the costs of higher levels of observer coverage have been estimated, a question remains about the benefits of increased coverage, whether due to more effective regulation of the fishery or better protection of stocks affected by bycatch. One concern regarding the current level of observer coverage is due to a potential bias in the observer data. There is potential for fishers to change their fishing practices (location or gear methodology) to avoid bycatch with observers are onboard. If this is the case, the portion of the fishery observed would not be representative of the entire fishery. Additional analysis to determine whether such a bias exists is warranted and can be conducted by comparing information from fishing locations in observer data to fishing locations in other data sources (e.g., vessel monitoring system).

More work is needed to better understand possible impacts of the HMS fisheries on protected species of sea turtles, birds, and marine mammals. For example, there is a need to investigate the post-release survivorship of protected species, such as turtles and seabirds that are caught as bycatch in the HMS fisheries. The development of EcoCast shows promise for forecasting the distribution of key target and protected species and should continue to be explored. In addition, fisheries-independent research is required to better understand distribution and habitat use by turtles and to determine the linkages to ecosystem parameters (oceanographic and biological). This includes data on turtle migration seasonality and migration routes, genetic stock composition of populations by species, and habitat use to better understand turtle life histories and likely periods of interaction with fisheries. Predictive models, such as seasonal coastal ocean ecosystem models, that integrate oceanography, ecosystem parameters (e.g., prey distribution), and habitat use of turtles are needed. More work on the sizes and structures of turtle populations by species would improve the ability to evaluate protected species interactions with HMS fisheries, compliance with relevant laws (e.g., ESA), and success of management regulations. Continued research on the abundance and distribution of marine mammals is also critical, particularly for HMS fisheries operating within the West Coast EEZ. The need for comprehensive data is particularly the case with HMS stocks that are shared with Mexico, where there is inadequate understanding and data exchange for HMS fisheries that are likely affecting both protected species distribution patterns and migration routes of prohibited species of fish. Improved habitat data for target and prohibited

species north of Point Conception, where there has similarly been very little research on habitat associations, could also reveal insights about the potential differences in both geographic and vertical distribution of target and prohibited species.

Some specific research priorities include:

- explore how regulating the U.S. West Coast Pacific swordfish fishery affects international trade in swordfish and the potential unintended consequences for protected species interactions in foreign fisheries \*;
- examine habitat use of leatherback turtles and other species of concern, including target species, to better understand the potential for reducing bycatch;
- continue to explore whether hotspots or temperature bands can be identified in near-real-time to provide information to fishermen regarding locations with potentially high interaction risks (e.g., using EcoCast);
- compare bycatch rates of drift gillnet versus shallow-set longline gear, which target swordfish, both by mining observer data and conducting gear comparison studies in the fishery areas;
- compare the effectiveness of methodologies either recently developed or in use for estimating the amount of unobserved bycatch for observer programs with less than 100 percent observer coverage; and
- evaluate the cost/benefit tradeoffs of increasing observer coverage above the levels that were historically used in HMS fisheries

### **7.5.2      *Essential Fish Habitat***

There is very little specific information on the migratory corridors and habitat dependencies of these large mobile fish; how they are distributed by season and age throughout the Pacific and within the West Coast EEZ, and how oceanographic changes in habitat affect production, recruitment, and migration. Research is needed to better define EFH and to identify specific HAPCs, such as pupping grounds, key migratory routes, feeding areas, and where adults aggregate for reproduction. A particularly important need is to identify the pupping areas of thresher and mako sharks, which are presumed to be within the southern portion of the West Coast EEZ, judging from the occurrence of post-partum and young pups in the areas (e.g., NMFS driftnet observer data). Areas where pregnant females congregate may be sensitive to perturbation, and the aggregated females and pups there may be vulnerable to fishing. The nearshore distribution of juvenile sharks needs to be assessed for habitat needs and fishery vulnerability during nursery and pre-reproductive life stages in general. The five year review of the HMS FMP essential fish habitat description is overdue and should be updated.

### **7.5.3      *Management Unit Species Catch Data***

Total catch data are likely inaccurate for some HMS fisheries due to inadequate at-sea data collection programs, logbook programs, and shoreside sampling programs for West Coast fisheries and unreported catch by international fisheries. Catch data needs to include:

- total catch information (including incidental and bycatch) and protected species interactions for surface hook-and-line, purse seine, and recreational fisheries, and additional at-sea sampling of drift gillnet fisheries;
- catch composition data for harpoon gear;
- size composition of bycatch in drift gillnet fisheries; and
- condition (e.g., live, dead, good, poor) of discarded catch in all HMS fisheries.

Additional work needs to be done to develop ways to adequately sample recreational fisheries, particularly shore-based anglers and private vessels. There is a need to develop methods for sampling private marinas and boat ramps to determine catch, and the level of bycatch and protected species interactions, as well as sample the catch for length and weight of fish caught to convert catches reported in numbers to catches by weight. Better catch and effort estimates are also needed for HMS recreational fishing tournaments, in particular those tournaments focusing on common thresher and mako sharks.

### **7.5.4      *Survivability of Released Fish***

Little is known of the long-term survivorship of hooked fishes after release, the effectiveness of recreational catch-and-release methods on big game fishes (pelagic sharks, tunas, and billfishes) and of methods to reduce bycatch mortality in longline fishing. Controlled studies of the survivability of hooked and released pelagic sharks and billfishes are needed to determine the physiological responses to different fishing gears, and the effects of time on the line, handling, methods of release, and other factors. Appropriate discard mortality rates, by species, need to be identified to quantify total catch (including released catch). Alternative gears and methods to increase survivability of recreationally-caught fish and to minimize unwanted bycatch in fisheries should be identified.

### **7.5.5      *Stock Assessment Review***

Pacific HMS stock assessments are carried out by the RFMOs and by the ISC. The processes used to conduct the assessments and to have them critically reviewed varies considerably across the organizations and the species being assessed. Although the ISC has used the Center for Independent Experts to peer-review some assessment, in most cases for HMS the level of critical peer review does not approach that of the Council's STAR process. This may become an issue for the Council if international management regulations begin to affect U.S. coastal fisheries more than they do at present. The Council may want to consider having some member(s) of its SSC

participate in these international processes. This will provide the Council with a better perspective on the stock assessments and the ensuing international management advice.

#### **7.5.6      *Archival PacFIN Data Cleanup***

Continue to review and provide subsequent revisions of archival PacFIN data is needed to improve the accuracy of historical commercial landings and revenues for longline landings. New code has recently been added to allow users to more accurately categorize landings data by fishery when producing tables of commercial landings and revenues, which is used in the HMS SAFE document.

#### **7.5.7      *Gauge the Impact of Local Catch on CPUE***

Concerns are often raised about the possible effects of fishing pressure generated by U.S. fisheries operating off the west coast on the catch rates of HMS. However, given the Pacific-wide range and the predominance of non-U.S. fishing effort outside the West Coast EEZ as a source of fishing mortality for most HMS, it is not clear whether or to what extent locally-driven fishing mortality affects local abundance or CPUE. Research to gauge what levels of U.S. catch result in measurable decreases in CPUE would be helpful for determining at what level of catch the local depletion due to domestic HMS catch would begin to limit opportunities for targeting HMS off the West Coast.

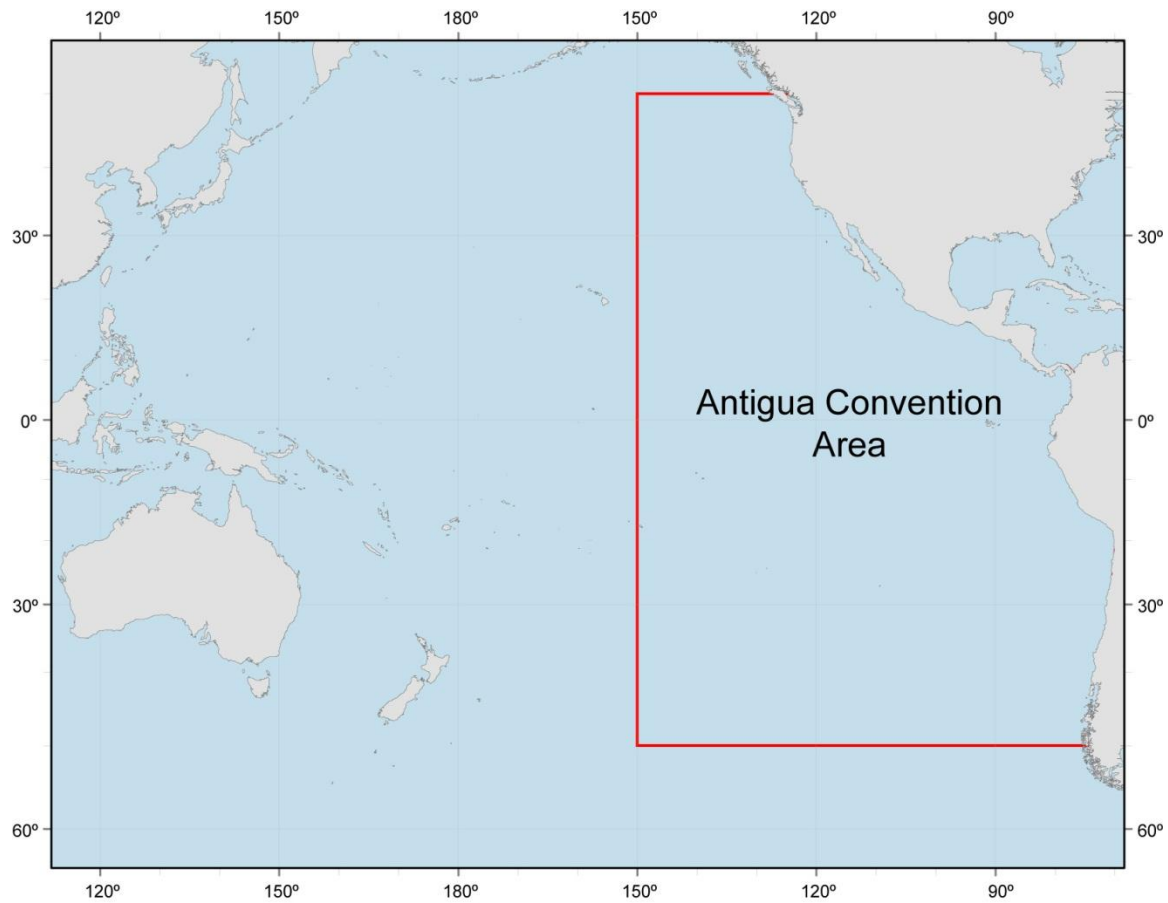
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## Inter-American Tropical Tuna Commission (IATTC)



**Figure 1. Area covered by the Inter-American Tropical Tuna Commission (IATTC). The Antigua Convention refers to the recent international treaty that revised the IATTC boundaries.**

## Western and Central Pacific Fisheries Commission (WCPFC)

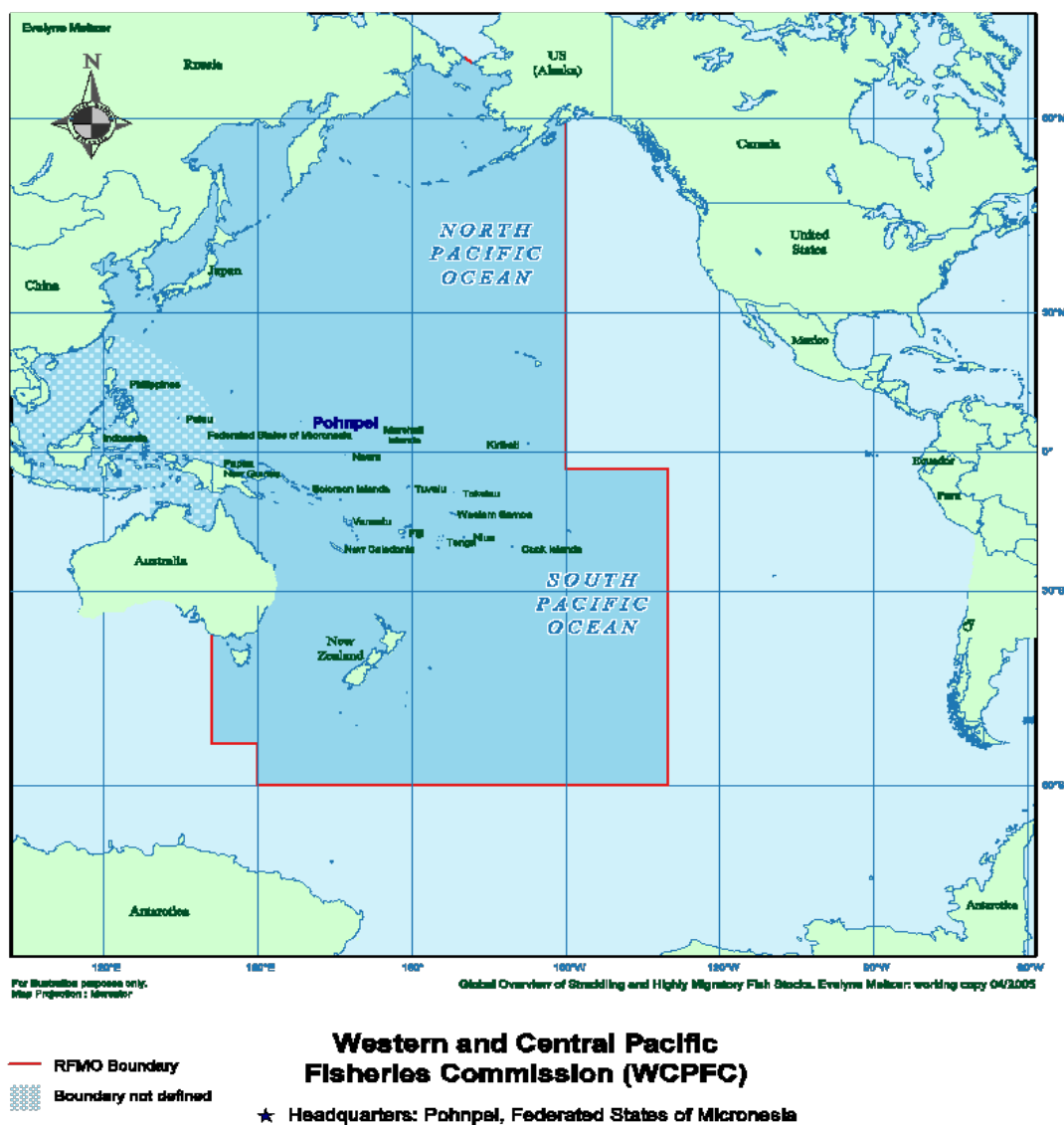


Figure 2. Area covered by the Western and Central Pacific Fisheries Commission (WCPFC).

## 8.0 APPENDIX I - RESEARCH AND DATA NEEDS ITEMS FROM GROUND FISH ASSESSMENTS AND RELATED REPORTS

Item #	Item descriptor	Item details as presented in the various documents
<b>Items from the PFMC 2013 Research and Data Needs document</b>		
1	Continue to conduct annual comprehensive shelf and slope bottom trawl survey	An annual slope survey in the U.S. Vancouver, Columbia, Eureka, Monterey, and a portion of the Conception International North Pacific Fisheries Commission areas was initiated by NMFS NWFSC in 1998. In 2003, the range of the slope survey was extended in depth onto the shelf and in latitude to the entire coast from the Mexican to Canadian border. The data from this survey have been used in almost every groundfish assessment on the U.S. West Coast. It is essential to continue this comprehensive annual survey, since a consistent long-term survey index informs estimates of abundance and productivity of groundfish stocks.
2	Continue to explore additional survey methods	Although informative for many groundfish species, the current NWFSC shelf and slope survey cannot access rocky areas, where a number of rockfish species occur. Also, trawl survey efforts are currently closed in the Cowcod Conservation Area (CCA), which is likely to include habitat for a number of rockfish (based on fishermen's knowledge and the observation of catch rates at similar habitats along the boundaries of the CCA). There is, therefore, a need to develop alternative methods to assess abundance of fish in these untrawlable areas as well as other areas not well-surveyed by the current bottom trawl survey. Also, low yield and long rebuilding times of some rockfish, including yelloweye and canary rockfish, highlight a need to develop alternative methods of estimating abundance and biomass trends that have a lesser impact on resources than trawl surveys. All new survey methods should be thoroughly evaluated before being used in stock assessments.

Item #	Item descriptor	Item details as presented in the various documents
3	Continue to explore methods to survey untrawlable areas ...	Continue exploring survey methods to survey untrawlable areas, including those that employ Autonomous Underwater Vehicles, submersibles, drop cameras, acoustics, towed cameras, light detection and ranging, etc. In recent years, small-scale surveys have been conducted using these non-invasive methods. Studies should be conducted to evaluate the comparative costs of these alternative survey methods for groundfish assessment.
4	Continuation of whiting midwater acoustic surveys on a frequent basis ...	Continuation of whiting midwater acoustic surveys on a frequent basis and potential expansion to include rockfish surveys for species that spend the majority of their life history in the midwater portion of the water column. Acoustic survey frequency is under study by the Joint Management Committee of the Agreement Between the Government of Canada and the Government of the United States of America on Pacific Hake/Whiting. Issues that could be addressed include – acoustic survey frequency, the use of acoustic surveys for other midwater groundfish (e.g., widow rockfish and yellowtail rockfish), acoustic survey design (including target strength), and development of an age-1 hake index. This exploration should examine the trade-offs of increased survey frequency versus time off the water for researchers to do other important projects. Research should be conducted on survey design and acoustic methods to make the survey as accurate and informative as possible. Trade-offs associated with continuing to combine the surveys for sardine and whiting should be explored. Additionally, validate acoustic surveys using non-extractive CamTrawl methods in West Coast fishery surveys.
5	Maintain California Cooperative Oceanic Fisheries Investigations (CalCOFI) egg and larval production surveys.	Maintain California Cooperative Oceanic Fisheries Investigations (CalCOFI) egg and larval production surveys. Abundance indices based on data from these surveys have been used in a number of groundfish assessments, including bocaccio, chilipepper and shortbelly rockfish. It has been recommended to expand processing of biological samples collected, and improve survey data on canary and widow rockfish. It is also important to further explore the use of genetic methods to accurately identify larval fish species in plankton samples.

Item #	Item descriptor	Item details as presented in the various documents
6	Research should be conducted using automated image recognition ...	Research should be conducted using automated image recognition (computer vision) over a variety of resource management applications. Incorporation of computer vision image recognition concepts into West Coast research and management objectives offers promise in advanced electronic monitoring strategies, aerial surveys of forage fish, marine mammal surveys, recreational vessel effort estimates, vessel-based automated bird-cam surveys, as well as other applications.
7	Continue exploring the use of hook-and-line or longline gear for surveying rockfish populations ...	Continue exploring the use of hook-and-line or longline gear for surveying rockfish populations, since this gear is inexpensive and can be deployable on a variety of bottom types. Since 2004, the hook and line survey has been conducted by NMFS NWFSC in collaboration with the PSMFC and the CPFV industry. This survey has been collecting data to generate abundance indices for several key species of shelf rockfish in the Southern California Bight, including bocaccio, the vermilion rockfish complex and greenspotted rockfish. The International Pacific Halibut Commission has conducted annual hook-and-line survey since 1998; this survey provides data on a number of groundfish species, including yelloweye rockfish. Explore conducting hook-and-line surveys with new barotrauma mitigation techniques within the CCA to provide data in this untrawlable area.
8	Explore tagging programs as a potentially useful source of information on trends for nearshore species ...	Explore tagging programs as a potentially useful source of information on trends for nearshore species, such as black rockfish. When the tagging program is smaller in scale than the range of the stock assessed, quantitative prior probability distribution on tagging catchability should be developed.
9	Evaluate the usefulness of current seafloor maps ...	Evaluate the usefulness of current seafloor maps off the Pacific coast to better interpret survey abundance indices.

Item #	Item descriptor	Item details as presented in the various documents
10	Explore utility of genetic tags in estimation of population size.	Explore utility of genetic tags in estimation of population size.
11	Improve on fishery monitoring and data collection	Collection of high quality fishery-dependent data continues to be one of the highest priorities for groundfish assessment and management. Fish ticket data are needed to census the landed catch, logbooks to document areas of capture, port sampling to estimate species composition of aggregated landings and biological characteristics of target and bycatch species, and observer program to document catch discarded at sea.
12	Continue research on barotrauma and the use of recompression, or descending devices ...	Continue research on barotrauma and the use of recompression, or descending devices, for released rockfish, particularly for deeper waters (> 30 fm), over a broader suite of species, including overfished species. Estimates of discard mortality rates in recreational fisheries should be re-evaluated because the ability to survive barotrauma or hooking or trapping injuries may vary by depth and among species. Progress has been made in understanding short-term effects of barotrauma on some groundfish species. Additional work is needed to examine long-term physiological effects of capture and release on reproductive output of groundfish species, which could have implications for stock productivity and, therefore, management. Alternative release methods (e.g. post-capture release at depth) have been shown to be effective in reducing short-term mortality, but additional work is needed to accurately quantify the effects of real world implementation of these methods on discard mortality, for use in assessment and management.

Item #	Item descriptor	Item details as presented in the various documents
13	Research designed to evaluate mortality of discarded groundfish under various conditions ...	Research designed to evaluate mortality of discarded groundfish under various conditions (e.g., gear types, depths, water and air temperatures, etc.) is needed for stock assessments and management. Currently, discard-mortality assumptions (some < 100 percent mortality) are applied to selected species in recreational, commercial non-trawl, and trawl fisheries. These estimates may have been derived by research conducted in other regions (e.g., Alaska), or during narrow environmental or operational conditions (e.g., only during shallow-water sets or low-water temperature condition). Much research has shown that discard mortality may vary considerably (and predictably) over a range of conditions. For example, recent articles discuss the impact of water temperature on discard mortality. The need for these types of experiments may be prioritized based on the level of discard relative to stock status (e.g., the assumed discard mortality proportion for some stocks may have no meaningful impact on the stock).



Item #	Item descriptor	Item details as presented in the various documents
14	Continue to monitor catch and discard in commercial fisheries at-sea.	Continue to monitor catch and discard in commercial fisheries at-sea. Currently there are two observer programs operated by the NMFS NWFSC on the U.S. West Coast. These programs include the At-Sea Hake Observer Program, which monitors the at-sea hake processing vessels, and the West Coast Groundfish Observer Program (WCGOP), which monitors catcher vessels that deliver their catch to a shore-based processor or a mothership. The At-Sea Hake Observer Program dates back to the 1970s, while WCGOP was implemented in 2001. The WCGOP began with gathering data for the limited entry trawl and fixed gear fleets. Observer coverage has expanded to include the California halibut trawl fishery, the nearshore fixed gear, and pink shrimp trawl fishery. Since 2011, the U.S. West Coast groundfish trawl fishery has been managed under a new groundfish catch share program. The WCGOP provides 100 percent at-sea observer monitoring of catch for the new, catch share based Individual Fishing Quota (IFQ) fishery, including both retained and discarded catch. The WCGOP also provides estimates of discard and total groundfish removals from commercial, recreational, and research sources (including incidental catch from non-groundfish fisheries) for use in stock assessment and management. The methods used by WCGOP to estimate discard and total groundfish removals should be well-documented and reviewed by the SSC to ensure that the most reliable estimates are generated. Additionally, a method should be developed to evaluate observer coverage levels, and how that might influence management, stock assessments, and fleet behavior.
15	Review the process for determining the species viability and the resulting discard mortality estimates for Pacific halibut ...	Review the process for determining the species viability and the resulting discard mortality estimates for Pacific halibut and possibly other species in the commercial fisheries. The current mortality rates applied to the viability of released Pacific halibut is based on work conducted in Alaska in the 1970s, and updating this research may provide additional insight. Additionally, explore a method that would apply a formula consisting of variables such as tow/set time, temperature, and time on deck, etc. to determine viability, rather than the current visual estimate. This method might have the added benefit of easing some of the workload on the observers, since they would no longer have to conduct Pacific halibut viability estimates.

Item #	Item descriptor	Item details as presented in the various documents
16	Monitoring needs for the Trawl IQ program.	The limited entry trawl fishery now operates under a catch-share program that requires full observer coverage and full sorting to species. The system for monitoring the landed catch should be evaluated to determine the levels of species contamination that may be occurring.
17	Further explore use of electronic monitoring system (EMS) in commercial fisheries ...	Further explore use of electronic monitoring system (EMS) in commercial fisheries to monitor catch, estimate discard and identify species composition of the discarded portion of the catch. Studies should be designed and conducted to test reliability of EMS in collecting the data. Also, efforts should be devoted to evaluate costs of EMS data collection and processing, compared to observers' costs.
18	Continue to collect information on the size composition of the discarded portion of the commercial catch ...	Continue to collect information on the size composition of the discarded portion of the commercial catch, because it is unlikely that discards have the same size composition as retained catch. In some cases, the size composition of discard can also provide information about the magnitude of recruiting year classes.
19	Protocols and priorities for biological sampling (lengths and age structures) should be evaluated ...	Protocols and priorities for biological sampling (lengths and age structures) should be evaluated to ensure that sufficient data are being collected to support existing and new stock assessments. Significant gaps in the age and growth information have been identified for a number of stock assessments, including sablefish (for which age sampling from the commercial fishery has generally been sparse compared to other groundfish) and petrale sole, among others. There is a need to optimize the use of available resources (i.e., port samplers) in a way that provides maximum benefit to stock assessments.
20	The accuracy and precision of recreational catch and effort estimates for minor fishing modes ...	The accuracy and precision of recreational catch and effort estimates for minor fishing modes, such as beach and bank anglers, private access sites, and night fishing, needs to be further investigated and improved.

Item #	Item descriptor	Item details as presented in the various documents
21	Improve discard estimates in the recreational groundfish fishery ...	Discard estimates in the recreational groundfish fishery, particularly for non-retention species, should be improved. Additional data should be collected on size composition of recreational discard.
22	Develop a single database that holds all recreational data in a consistent format ...	Recreational data (catch and biological samples) are currently available from several sources, including the state agencies and RecFIN. Total mortality estimates between these sources do not always match. A single database that holds all recreational data in a consistent format would reduce time spent by assessment scientists obtaining and processing these data, and ensure that the best available information is utilized by the assessments.
23	Develop additional cooperative research programs.	Cooperative research programs are required under the recently reauthorized MSA and are playing an increasing role in west coast fishery science and management and could be utilized to expand data collection as fishing opportunities have decreased and research needs increased. However, it is critical to design programs and implement the necessary data evaluations and analyses to ensure that ongoing and future cooperative research work can be used in fishery management (i.e., fishery models, stock assessments, etc.) on a timely basis.
24	Improve the spatial coverage of logbook haul location information ...	Improve the spatial coverage of logbook haul location information with additional 'location' fields added to trawl logbooks and WCGOP forms for interval or periodic recordings of GPS coordinates by fishers and observers. The haul information currently recorded in trawl logbooks does not provide accurate coverage of the area fished because only set and end locations are required. Interpolation methods provide only a coarse estimate of spatial coverage.

Item #	Item descriptor	Item details as presented in the various documents
25	Continue to conduct size and species-selectivity research for groundfish trawl and non-trawl fisheries.	Continue to conduct size and species-selectivity research for groundfish trawl and non-trawl fisheries. Size and species selectivity is important for stock assessments, establishing and understanding potential impacts of management measures, fisheries monitoring, and for fisherman (e.g., to maximize catches of marketable species and sizes while reducing catches of unmarketable, overfished, or threatened/endangered species). Individual accountability due to the IFQ program provides greater incentives for IFQ fishermen to utilize the most selective fishing practices available. Unfortunately, most selectivity studies available for fisherman, managers, and researchers are dated and were conducted during a period where the fisheries, assemblages, and gears were much different than presently seen. Other potentially needed selectivity studies (e.g., on non-trawl West Coast groundfish fisheries) have not been conducted at all. Note that recently selectivity studies have been undertaken or are currently underway to evaluate the selectivity of sorting grids and various trawl-codend mesh size and mesh shapes for various groundfish species caught in the trawl fishery.
26	Develop a coastwide system for electronic fish ticket and fishery logbook data	Development of an integrated system for reporting of electronic fish ticket data and logbook information on the U.S. West Coast would provide real-time and near real-time information needed to address a variety of stock assessment and inseason management needs. Fish ticket data and logbook information, along with data from the WCGOP, are used to reconcile the total catch by area, and determine bycatch rates associated with target species. Currently, logbook data can lag by as much as a year, which delays the entire process of catch reconciliation. An electronic fish ticket and logbook system would substantially increase the timeliness of landings and discard estimates produced. Electronic data are now available for the new IFQ fishery through the NMFS Vessel Accounts Database. Currently, the IFQ fishery is the only one which is completely covered by electronic tickets. Washington and

Item #	Item descriptor	Item details as presented in the various documents
		Oregon are exploring expansion of their electronic fish ticket systems to other fisheries, but the potential range of coverage or possible timing of any expansion is not yet clear.

Item #	Item descriptor	Item details as presented in the various documents
27	Continue to improve historical catch time series	<p>Historical catch information is essential for fisheries stock assessment; without knowing the catch history it is difficult to understand how a stock responds to exploitation. Recent catch data (from 1981 on) are available from the PacFIN, a regional fisheries database that manages fishery-dependent information in cooperation with NMFS and West Coast state agencies. Catch information prior to 1981 is sparse and there is no database analogous to PacFIN to handle those data. In the recent past, historical reconstruction of catches prior to 1981 has been conducted by assessment authors for each assessment individually, and authors have often approached the problem differently, using different data sources and a variety of methods. A coordinated effort to reconstruct West Coast groundfish historical catches has been recommended, to provide a comprehensive species-specific time-series for use in stock assessments to help improve the reliability of historical catches by identifying and drawing on preferred data sources, as well as applying a standardized method across all species. Such a coordinated effort should also facilitate review of stock assessments in the future. Progress has been made in reconstructing California commercial and recreational, and Oregon commercial landings. However, historical time-series of Oregon recreational and Washington commercial and recreational landings are not yet complete. In addition to providing the best reconstructed catch histories by species, alternative catch streams should be developed to reflect differences in data quantity and quality for different time periods. Such alternative catch streams would be very useful for exploring assessment models' sensitivity to uncertainty in catch history, rather than applying a simple multiplier to entire catch time-series, which is currently the case for most groundfish assessments. An evaluation of time-series of historical discard is also needed, although it is recognized that historical discard data are extremely limited. A database for historical (pre-PacFIN) time series of groundfish landings should be established. Ideally, in addition to providing the best reconstructed catch histories by species, this database would also include estimates of uncertainty in these catch time-series. Also, process for updating and revising this database should be well-established.</p>

Item #	Item descriptor	Item details as presented in the various documents
28	Investigate impact of fishing gear on habitats	A major effort was made to prepare a comprehensive Environmental Impact Statement (EIS) analysis for the EFH amendment to the FMP. The EIS was based on Geographic Information System analysis that included integration of substrate maps of the Northeast Pacific Ocean off the Pacific coast, habitat suitability maps for groundfish species, and maps of fishing impacts and habitat sensitivity. The analysis discovered a complete lack of information on fishing impacts specific to Pacific coast habitats, and estimates of habitat sensitivity to fishing gear and habitat recovery were borrowed from studies in other areas. It is, therefore, recommended to conduct studies to evaluate the effects of fishing on Pacific coast benthic habitats. These studies should be conducted on a variety of bottom habitat types and using different gear types. They should focus on both short- and long-term fishing effects on benthic communities and bio-geological processes. The Council is currently engaged in reviewing groundfish EFH and has tentatively identified research and data needs through the EFH Review Committee. The higher priority items are included in Appendix II of this document.
29	Life History Data	Life history parameters determine the productivity of a stock, and therefore affect estimates of stock status and management quantities related to spawning stock biomass. There have been a number of data and research needs related to life history parameters identified during Council deliberations and in the most recent stock assessments.
30	Refine the estimates of maturity and fecundity ...	Refine the estimates of maturity and fecundity for a number of species, including sablefish, yelloweye rockfish, and petrale sole. Assessment results for these species were found to be sensitive to changes in maturity and fecundity parameters, yet the available information is outdated, in addition to being variable among sources, years, and regions.

Item #	Item descriptor	Item details as presented in the various documents
31	Improve the quality of age data.	Improve the quality of age data. Prioritize age reading of groundfish otoliths. Accurate, timely, and comprehensive age data is critical to the stock assessment process. If age data were more accurate, cohorts could be better tracked to older ages, and estimates of historical year-class strengths may be improved. Quality of age data could be improved through validation studies and exchange of age structures among labs. Also, ageing methods that could provide more precise age estimates should be explored. Studies to investigate the potential for bias in ageing methods should be conducted, as the results of these studies may have a strong effect on natural mortality estimates used in stock assessments.
32	Continue to collect data on habitat-related and climate-driven variability in life history traits	It has been shown that a number of species exhibit spatial variability in life history traits. It is therefore recommended to continue to collect data to capture habitat-related and climate-driven variability in life history traits, and explore methods to integrate this information into stock assessments.
33	Identify unassessed species that lack basic life history information.	A number of unassessed species lack basic life history information, such as growth, length-weight relationships, maturity, and fecundity. These species should be identified and studies should be designed to estimate parameters for these life history traits.
34	Further genetic studies to confirm distinct species (e.g., vermillion and blue rockfish).	Recent genetic research indicates that such species as vermillion and blue rockfish may each represent two morphologically similar, but genetically distinct species. Further genetic studies are needed to confirm these findings. These studies should be designed to investigate differences in spatial distribution between potentially different species, the extent of intermixing, differences in growth, maturity, and longevity.



Item #	Item descriptor	Item details as presented in the various documents
35	Stomach analysis to determine trophic interactions of groundfish.	Conduct comprehensive stomach analysis to determine trophic interactions of groundfish. This information would be essential for assessments of the CCLME
36	Improve on methods to assess data-poor and data-moderate stocks	A substantial progress has been made in developing and implementing methods to assess data-poor and data-moderate stocks. The Depletion-Based Stock Reduction Analysis (DB-SRA) and Depletion-Corrected Average Catch (DCAC) method have been adopted by the Council to estimate OFLs and set harvest specifications for data-poor stocks. XDB-SRA and exSSS have recently been developed to assess data-moderate stocks.
37	Improve inputs used by the data-poor and data-moderate methods ...	Improve inputs used by the data-poor and data-moderate methods, including natural mortality (M), a ratio of BMSY to B0, a ratio of FMSY to M, and reduction in abundance, or delta parameter (which represents stock depletion).
38	Develop tools for incorporating catch uncertainty ...	Catch time series in data-poor and data-moderate methods are currently assumed to be known, and tools for incorporating catch uncertainty into these methods should be developed.
39	Simulation studies to evaluate utility of data-poor and data-moderate methods ...	Performance of data-poor and data-moderate stock assessments has been evaluated through comparing data-limited and data-moderate assessment results with outputs from full assessments. Simulation studies are needed to further evaluate utility of these data-poor and data-moderate methods in real applications.
40	Determine how to best describe uncertainty in data-moderate assessments ...	Data-moderate assessments are likely to have greater uncertainty in their results than full assessments since much fewer data are used in data-moderate assessments. Further work is needed to determine how to best describe uncertainty in data-moderate assessments.

Item #	Item descriptor	Item details as presented in the various documents
41	Evaluate benefits of adopting complex versus simpler assumptions and models.	Current models used to assess groundfish stocks are complex, with many parameters being estimated, yet often the data used to fit these models are sparse. Also, complex models make it difficult to understand how specific data elements affect model outcomes. The benefits of adopting the complex model should be evaluated relative to simpler assumptions and models.
42	Develop guidance on how to best use priors in stock assessment models.	In a number of recent stock assessments, Bayesian prior probability distributions for natural mortality (M) and stock-recruitment steepness (h) derived from meta-analyses of different species and different methods were utilized. Guidance should be provided on how to best use these (and other) priors in stock assessment models to account for uncertainty in parameter estimates and propagate this uncertainty to the assessment results.
43	Continue to develop and evaluate standard methods to process biological data ...	Continue to develop and evaluate standard methods to process biological data for assessment model input files, including those related to input sample sizes and data weighting procedures. Explore alternative error distribution assumptions used for compositional data.
44	Conduct studies to help determine most appropriate selectivity assumptions ...	Conduct studies to help determine which selectivity assumptions (dome shape vs. asymptotic) are most appropriate for the various groundfish stocks, including lingcod and other species with age-structured assessment models.
45	Further explore models that account for spatial structure of the stock ...	Further explore models that account for spatial structure of the stock, with spatial differences in life history parameters (multi-area assessments). It is also recommended to further explore models that account for migration patterns (via incorporating tagging data) as this feature is currently available within the Stock Synthesis modeling framework.

Item #	Item descriptor	Item details as presented in the various documents
46	Continue to explore methods to include environment variables in stock assessment.	Continue to explore methods to include environment variables in stock assessment. Previous work has illustrated methods to relate recruitment to environmental factors using Stock Synthesis, but environmental forcing applied to other population parameters has not been fully explored. When selecting environmental variables to include in an assessment model, cross-validation should be used to ensure a derived relationship between climate forcing and a parameter is robust.
47	Further investigate the structure of transboundary stocks and evaluate implications of stocks' connectivity ...	A number of stock assessments utilize international boundaries to delineate stocks even though stocks' ranges are not limited always to the area managed by the Council. These stocks include sablefish, spiny dogfish, blackgill, canary, widow, yelloweye rockfish, Pacific ocean perch, and others. It is therefore recommended to further investigate the structure of transboundary stocks and evaluate implications of stocks' connectivity with Canada on the north, and Mexico on the south, and, in some cases, explore the possibility of joint stock assessments in future years.
48	Continue to evaluate biological reference points, HCRs and policies used for groundfish ...	Continue to evaluate biological reference points, HCRs and policies used for groundfish, to ensure the best available scientific information is utilized for management decision-making. Harvest policies should be tested to determine whether they are robust to decadal-scale environmental variation and directional climate change.
49	Further explore how best to account for (and report) uncertainty in stock assessments.	Further explore how best to account for (and report) uncertainty in stock assessments. Explore alternative approaches to evaluate scientific uncertainty associated with OFL estimates, as the method that is currently in place does not include all sources of scientific uncertainty.

Item #	Item descriptor	Item details as presented in the various documents
50	Further work is needed to understand the properties of recreational CPUE data ...	The use of recreational fishery CPUE in stock assessments has increased, particularly for assessing nearshore species for which there are no other reliable indices of abundance. Although there have been some recent advances in the analytical methods used to derive abundance indices from CPUE data, further work is needed to understand the properties of recreational CPUE data (e.g., method evaluation with simulation data or cross-validation studies). In particular, the effect of management changes and alternative fishing opportunities should be evaluated.
51	Establish an online database for all the data relevant to groundfish stock assessments ...	Establish a database for all the data relevant to groundfish stock assessments, with a current point of contact identified for each source. This database should be accessible online and include details about the nature and quality of the data in each source. Such a database would help stock assessors make informed decisions on which sources could be useful in their assessment as well as expedite the process of requesting the data.
52	Develop a concise set of documents that describe current best practices ...	Develop a concise set of documents (and update them when needed) that describe current best practices in treating data from sources commonly used in stock assessments and in deriving assessment model inputs. These documents would include, for instance, a description of methods to calculate survey abundance indices via Generalized Linear Mixed Model, and an approach used to develop prior probability distributions for natural mortality (M) and stock-recruitment steepness (h). Ideally, these documents would be reviewed by the SSC prior to the assessment cycle.
53	Communicate the current best practices ...	The current best practices (item above) should be well-communicated among stock assessment scientists and the SSC.

#### Items from the 2013 aurora rockfish stock assessment document

Item #	Item descriptor	Item details as presented in the various documents
54	Conduct more complete reading of the available aurora rockfish otoliths.	This was the first year in which aurora rockfish otoliths were read to develop age data. There was insufficient time to read all of the otoliths or even cover all of the years for which aurora rockfish otoliths were collected from the fisheries or surveys. Additional age data could provide additional information for the model to estimate such parameters as natural mortality and recruitment deviations. Additionally, validation methods, such as the bomb radiocarbon chronometer, could be used to validate the ages and ageing method for aurora rockfish.
55	Aurora rockfish maturity study that includes analysis of atresia.	The base model does not use newly available information of female maturity collected within the NWFSC shelf-slope survey in 2012. This new information includes data on mass atresia (a form of skipped spawning), at far greater numbers than that reported in Thompson and Hannah (2010). More data on aurora rockfish maturity will be collected this year on the NWFSC shelf-slope survey, which could confirm the information on mass atresia or indicate variability between years. This information could better inform the maturity curves used in the assessment.
56	Examine assumption that aurora rockfish spawning output is proportional to spawning biomass.	The base model assumes spawning output is proportional to spawning biomass. For many rockfish species, fecundity has been shown to have a non-linear relationship with female weight. Determining this relationship for aurora rockfish would improve the estimation of spawning output and depletion.
57	Improve the meta-analysis for steepness.	Improve the meta-analysis for steepness. This would include consideration of fixed and estimated parameters, assumptions, and the quality of the information on maturity and fecundity in the component assessments, as well as correlations in recruitments among assessments due to environmental drivers.

Item #	Item descriptor	Item details as presented in the various documents
58	Continued research of GLMM applications to survey data.	The application of the GLMM software elicited many unresolved questions. Continued research and articulation of that statistical approach and the options available (e.g. extreme catch events) will greatly benefit both STAT application and STAR Panel understanding of the model and its advantages.
59	Research on the most appropriate method for data-weighting.	Further research on the most appropriate method for data-weighting is greatly needed. Simulation testing and comparison of standard and new (Francis 2011) methods would benefit future assessments of this and other stocks.
60	Research on the spatial structure of the aurora rockfish stock is needed, including genetic analysis.	Development of information on the spatial structure of the stock is needed, including genetic analysis, investigation of differences in and size at maturity, and information on aurora rockfish off of Canada and Mexico.
61	Additional indices to anchor the aurora rockfish assessment.	The development of additional indices could provide further information to anchor the assessment. While direct adult biomass indices are unlikely to surface, there may be some possibility to develop a larval abundance index from the CalCOFI data set. This index reflects a measure of spawning biomass.

#### **Items from the 2013 aurora rockfish STAR Panel report**

62	Workshop on weighting composition data, including initial input values.	A workshop should be held to evaluate (a) methods for the iterative reweighting of composition data (e.g., current approach based on SS3 calculation of effective N versus Francis approach) and (b) methods for developing initial weightings (the initial input N values).
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Item #	Item descriptor	Item details as presented in the various documents
63	Workshop on methods for constructing survey GLMM estimates.	A workshop should be held to evaluate methods for constructing survey GLMM estimates. Topics that should be explored include: (a) the effect of treating vessels as random when in fact the vessels hardly vary from one year to the next; (b) possible aliasing of the index values with the Vessel x Year interactions; and (c) using information from the GLMM for combining length composition data collected by different vessels. One goal for the workshop should be to provide adequate documentation of the GLMM methods that will be used to produce survey biomass indices for future assessments and guidelines on how the analyses, including diagnostics, should be presented in stock assessment reports.
64	Continue routine collection of slope rockfish otoliths; catalog historical collections.	Port sampling programs should continue their routine collection of otoliths of slope rockfish species. A catalog of historical collections that have not been aged should be developed.
65	Thorough review of historical slope rockfish catch reconstructions, including uncertainty measures.	The series of historical catches of individual rockfish species, which are important sources of uncertainty in stock assessments of rockfish, should be explored in more detail. The STAR Panel agrees with the statement in the draft assessment document for rougheye rockfish that “A thorough look at historical landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for”. Furthermore, catch reconstructions should not just develop best estimates of rockfish catch by species, but should also characterize the uncertainty of historical catch estimates by identifying periods of greater and lesser uncertainty. For example, rockfish species compositions taken during early years when there were limited slope fisheries should be very different from species compositions taken during later years when fisheries on the slope were more prevalent.
66	Technical guidance on how to construct decision tables ...	The SSC should develop detailed technical guidance on how to construct decision tables, including a summary of lessons learned from a review of approaches applied in past stock assessments.

Item #	Item descriptor	Item details as presented in the various documents
67	Surveys for slope rockfish and other species living in untrawlable habitats ...	Investigate better fishery-independent data collection methods for slope rockfish and other species living in untrawlable habitats (e.g., surveys using submersibles or remotely operated vehicles).
68	Develop and use consistent nomenclature for identifying standard data sets ...	To lessen the potential for confusion in assessment documents and presentations, STATS in the future should be encouraged to develop and use consistent nomenclature for identifying standard data sets. For example, during the Review the “AFSC triennial shelf survey” was also described as the “triennial survey” and as “AKSHLF”.
69	More age-reading data for the next assessment; validate the ageing method ...	The STAR Panel agrees with the STAT regarding the importance of (a) producing additional age-reading data for use in the next assessment of aurora rockfish and (b) validating the ageing method and age readings.
70	Studies on reproductive biology (maturity, fecundity, and mass atresia) ...	The STAR Panel agrees with the STAT regarding the importance of collecting additional information on reproductive biology (maturity, fecundity, and mass atresia) in aurora rockfish. This will allow analyses that better establish the relationship between effective fecundity and length, and between effective fecundity and weight.
71	Expanded meta-analysis for steepness ...	The STAR Panel agrees with the STAT regarding the need for further development of the meta-analysis for steepness, including “consideration of fixed and estimated parameters, assumptions, and the quality of the information on maturity and fecundity in the component assessments, as well as correlations in recruitments among assessments due to environmental drivers”.



Item #	Item descriptor	Item details as presented in the various documents
72	Studies to establish the stock structure of aurora rockfish ...	The STAR Panel agrees with the STAT regarding the need for information on the stock structure of aurora rockfish with the aim of evaluating the assumption that the US West Coast stock is isolated from aurora rockfish off Canada and Mexico.
73	Explore CalCOFI based index of juveniles ...	The STAR Panel agrees with the STAT that there should be exploration of developing an index of larval abundance of aurora rockfish from the CalCOFI surveys.

#### **Items from the 2013 Bocaccio update stock assessment document**

74	Explore the influence of large scale area closures and other management actions on the survey indices and the assessment.	Since large scale area closures and other management actions were initiated in 2001, the spatial distribution of fishing mortality has changed over both large and small spatial scales. Not only has this effectively truncated several abundance indices (recreational CPUE), this confounds the interpretation of survey indices for surveys that do not sample in the Cowcod Conservation Areas (CCAs), as insights from larval surveys suggest that the greatest abundance of bocaccio is found in that area. This, in turn, infers that fishing mortality is greater on the fraction of the stock currently outside of the CCAs. The declining trend in the NWFSC trawl survey index, which is inconsistent with other data sources and the base model results, may reflect a reduced rate of rebuilding and stock recovery in central and northern California waters.
75	Capitalize on progress made in developing age reading criteria for bocaccio.	Recently, some progress has been made in developing age reading criteria for bocaccio, and age data are expected to be available for the next full assessment.

#### **Items from the 2013 cowcod stock assessment document**

Item #	Item descriptor	Item details as presented in the various documents
76	Biomass index needed for area north of SCB and south of Cape Mendocino	Annual Catch Limits for the area south of Cape Mendocino are currently defined as twice the ACL set for the SCB. A reliable estimate of absolute abundance and/or a time series of relative abundance is needed to assess the status of cowcod in waters between Point Conception and Cape Mendocino.
77	Sampling within the Cowcod Conservation Areas is needed.	Fishery-independent (extractive) surveys are not currently sampling inside the Cowcod Conservation Areas, which likely contain a large fraction of the population. To better understand rebuilding progress, this policy could be reconsidered given the more optimistic results of the assessment.
78	Additional information is needed on cowcod stock structure and life history traits ...	Additional information is needed on cowcod stock structure and life history traits, including but not limited to dispersal between U.S. and Mexican waters, and potential differences in life history characteristics (e.g. growth, maturity, fecundity, longevity) among the recently identified genetic lineages.
79	Regular visual surveys of cowcod abundance.	Consider regular, but not necessarily annual, visual surveys of absolute cowcod abundance in the SCB (inside & outside the CCAs) and central California.

#### **Items from the 2013 cowcod STAR Panel report**

80	Investigate the stock structure of cowcod, including connectivity with Mexico ...	Investigate the stock structure of cowcod in adjacent areas, especially the population in waters off Mexico.
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Item #	Item descriptor	Item details as presented in the various documents
81	Re-investigate the CPFV data as basis for CPUE-based biomass index.	Re-investigate the CPFV data to attempt to produce a CPUE time series to be used as an index of relative abundance. The CPFV data have a historical basis for inclusion and produce a time-series that has a smaller interannual variability than other indices.
82	Incorporate uncertainty in maturity into assessments.	Age-at-maturity and other life history parameters are inherently uncertain for cowcod and require further investigation. Future assessments should consider incorporating the uncertainty associated with age at 50% maturity.
83	Incorporate uncertainty in catches into assessments.	Investigate methods to include uncertainty in historical catches in the modeling.
84	Evaluate the methods used to reconstruct historical catches ...	Evaluate the methods used to reconstruct historical catches of cowcod and other rockfish.
85	Continue the NWFSC Hook-and-Line and visual surveys, extend into Cowcod Conservation Areas.	The STAT team expressed the most confidence in the NWFSC Hook-and-Line and visual surveys. The STAT team and STAR Panel recommend continuing these indices into the future and extending the NWFSC Hook-and-Line survey into the CCAs.
86	Develop priors for model parameters (?? other than for h and M ??)	Priors for model parameters, based on rockfish, should be developed.

#### Items from the 2013 darkblotched rockfish stock assessment document

Item #	Item descriptor	Item details as presented in the various documents
87	More complete use of available fishery otoliths to expand age composition data.	The base model does not use commercial age composition data for years that lacked coast wide samples. The additional age data could provide information necessary for the model to estimate such parameters as natural mortality. Future research could ascertain whether additional otoliths exist for these years, and whether they could be aged using current ageing methods. Also, alternative fleet structures (with state specific fisheries) could be explored to take use of as much available age data as possible.
88	Expand maturity options in Stock Synthesis to allow expression of maturity information (with mass atresia) as a function of female length.	The base model uses newly available information of female maturity collected within the NWFSC shelf-slope survey. This new information includes data on mass atresia (a form of skipped spawning), not previously available for the assessment. At present, Stock Synthesis allows incorporation of this information only when maturity is expressed as a function of age. Effort should be devoted to expand maturity options in Stock Synthesis to allow expression of maturity information (with mass atresia) as a function of female length. Also, continued collection of maturity samples would allow future researchers to explore differences in maturity at age, either spatially or over time.
89	Explore spatial variability in growth and fecundity.	Additional research would be important to explore whether other life history parameters, such as growth and fecundity vary spatially or change over time as well. This information will help in defining spatial structure of future models.
90	Evaluate the impact of not accounting for any Canadian portion of population.	Given that the population range extends north to the border with Canada, it is important that future research would evaluate the impact of not accounting for any Canadian portion of population abundance. Such an analysis would require evaluation of movement of darkblotched along the coast, which information is currently lacking.

Item #	Item descriptor	Item details as presented in the various documents
91	Improve existing meta-analyses for natural mortality and steepness.	Future research could also improve existing meta-analyses for natural mortality and steepness, which both contribute to the implied yield curve. Directions for improvements include (1) explaining variability between methods in natural mortality estimates, included in the Hamel natural mortality method and (2) developing a larger database of species for estimating steepness, perhaps by including species from other regions, e.g., Canada and Alaska.
92	Explore the utility of model-based index standardization techniques (spatial models).	Imprecision in the indices of abundance derived from survey sampling, due a low probability the species occurrence, is one of the sources of uncertainty in this assessment. Future research could explore the utility of model-based index standardization techniques; in particular, those using spatial modeling approaches. Spatial models could potentially account for the component of sampling variance arising from the random allocation of sampling tows either in or outside of suitable habitat. Such models could potentially decrease residual variance and imprecision of the resultant indices of abundance.
93	Improve the MCMC options in ADMB, e.g., changing the Hamiltonian MCMC option.	Finally, we note that Markov chain Monte Carlo sampling using the Metropolis algorithm was unable to obtain a sufficient number of independent samples within a feasible time period. However, it had trouble primarily with a single parameter (variance inflation for a survey index). We therefore recommend to improve MCMC options in ADMB, perhaps by making necessary changes to the Hamiltonian MCMC option (i.e., by allowing samples to be thinned during running, and hence making longer MCMC chains feasible for the ADMB implementation of Hamiltonian sampling).

#### Items from the 2013 darkblotched rockfish STAR Panel Report

Item #	Item descriptor	Item details as presented in the various documents
94	Make more comprehensive use of available but unread ageing structures.	The base model does not use commercial age composition data for years that lacked coast wide samples. The additional age data could provide information necessary for the model to estimate such parameters as the CVs defining the distribution of lengths at older ages and natural mortality. Future research could ascertain whether additional otoliths exist for these years, and whether they could be aged using current ageing methods. Also, alternative fleet structures (with state specific fisheries) could be explored to take use of as much currently available age data as possible.
95	Use age data from California that are available but are excluded from the model.	There is a large quantity of age data from California that is currently being excluded from the model (<2002, and from other states >2008). Work should be continued to try to incorporate these data into the model, potentially by restructuring the fleets, reading additional historical ages, or other means. This would help to reconcile and make consistent the treatment of length data and age data over time and space. Additional ages may help to allow estimation of the CV parameters for male and female growth and perhaps explore alternate approaches to the growth parameters themselves.
96	Use a prior for female M in the next assessment ...	Use a prior for female M in the next assessment – the current likelihood profile indicates that it may be estimable given a reasonably informative prior.
97	Expand maturity options in Stock Synthesis to allow maturity information including mass atresia ...	The base model uses newly available information of female maturity collected within the NWFSC shelf-slope survey. This new information includes data on mass atresia (a form of skipped spawning), not previously available for the assessment. At present, Stock Synthesis allows incorporation of this information only when maturity is expressed as a function of age. Effort should be devoted to expand maturity options in Stock Synthesis to allow expression of maturity information (with mass atresia) as a function of female length.

Item #	Item descriptor	Item details as presented in the various documents
98	Continued collection and analysis of maturity samples ...	Continued collection of maturity samples would allow future researchers to explore differences in maturity at age, either spatially or over time.
99	Explore the importance of temporal or spatial changes in growth, fecundity, and other traits ...	Additional research would be important to explore whether other life history parameters, such as growth and fecundity vary spatially or change over time as well. This information will help in defining spatial structure of future models.
100	Evaluate the impact of not accounting for any Canadian portion of population ...	Given that the population range extends north to the border with Canada, it is important that future research would evaluate the impact of not accounting for any Canadian portion of population abundance. Such an analysis would require evaluation of movement of darkblotched (including larvae) along the coast, which information is currently lacking.
101	Improve existing meta-analyses for natural mortality and steepness ...	Future research could also improve existing meta-analyses for natural mortality and steepness, which both contribute to the implied yield curve. Directions for improvements include (1) explaining variability between methods in natural mortality estimates, included in the Hamel natural mortality method and (2) developing a larger database of species for estimating steepness, perhaps by including species from other regions, e.g., Canada and Alaska.
102	Use natural mortality in a likelihood profile as a diagnostic ...	As a diagnostic, a natural mortality value, as indicated by the likelihood profile that is very different value than that used in the model indicates some model misspecification. Additional effort should be made to determine what features (such as the CV of length at age for old fish, selectivity, steepness, or other model structure) might be creating this pattern.

Item #	Item descriptor	Item details as presented in the various documents
103	Pursue making this assessment fully Bayesian ...	Continue to pursue making this assessment fully Bayesian. This will allow for probabilistic interpretation of the results, as well as far more efficient reporting and treatment of uncertainty in terms of the decision table, use of priors, etc.
104	STATs should include sensitivities of likely decision table axes of uncertainty ...	Recommend that STAT teams to present a sensitivity analysis (Tables and Figures) in the draft document for any axis of uncertainty that is likely to be considered for the decision table. This would facilitate efficient discussions during the meeting.
105	Routinely include a time-series of species-specific Canadian (B.C.) landings ...	It would be helpful to routinely include a time-series of species-specific Canadian (B.C.) landings for comparison with U.S. landings and trends.
106	Report treatment and results of model tuning procedures ...	The specific treatment and results of model tuning procedures should be reported in the document including all input/output sample sizes, effective sample sizes, sigmas, RMSEs (including recruitment deviations), that are applicable.
107	Standard summary of raw data, model fits, results, and diagnostics for survey GLMMs.	For survey GLMM analyses, the STAT teams need to report a standard summary of the raw data, and fitting of the model including both results and diagnostics. Additional research should attempt to identify (and perhaps simulation test) a method for model selection including the error distribution, the treatment of random vs. fixed effects and the inclusion of ECE mixture distributions that can be reliably applied across all species.
108	Guidance on selecting fecundity relationships ...	General recommendation to identify where and when E.J. Dick's fecundity relationships are better than existing data for a given species.



Item #	Item descriptor	Item details as presented in the various documents
<b>Items from the 2013 data moderate stock assessments document</b>		
109	Continued research on the uncertainty in the catch histories of all groundfishes.	Continued research on the uncertainty in the catch histories of all groundfishes. Catch is a critical component of these and all stock assessments, especially when attempting to define population scale. Reconstructions of historical catches are still needed for certain areas, time periods, and fisheries. Currently, reconstructed catches are available for California's commercial and recreational fisheries extending back to 1916 and 1928, respectively (Ralston et al. 2010). Oregon has completed a reconstruction for its commercial catch since 1876 (V. Gertseva, NMFS; pers. comm.), but recreational catch prior to 1980 is assumed to be zero in this analysis. Recreational catch in Washington was reconstructed to 1975 for these assessments, and interpolated back to 1960. A thorough reconstruction of historical commercial catches (prior to 1981) is urgently needed for Washington. Estimates of uncertainty in historical catch reconstructions are needed for all states. Reconstructed catches tend to be most precise for common species, and progressively less precise as species become uncommon. Because data-poor and data-moderate assessments focus on the less common species, quantification of the precision of catch reconstructions is especially important to these assessments.
110	Improved model selection criteria for the GLMM model.	Model selection criteria for the GLMM model, including insight when to consider the ECE models. The lognormal model frequently showed different time series behavior than the gamma and ECE models, the latter of which usually gave consistent results. The ability to determine whether lognormal or gamma is most appropriate, as well as understanding when the ECE approach should be considered will help formulate the best index treatment.
111	Guidance on splitting or maintaining the full time series for the Triennial survey.	Further consideration as to when it is appropriate to split or maintain the full time series for the Triennial survey. While this proved of little sensitivity in these examples, it could be important in some instances.

Item #	Item descriptor	Item details as presented in the various documents
112	Explore why the NWFSC survey showed poor behavior or limited information for all stocks.	The NWFSC survey showed poor behavior or limited information for all stocks. Understanding why this may be (including the residual patterns) will help diagnose its use as a data input for catch and index only models.
113	Develop a prior for survey catchability (q) values to enhance the interpretation of scale.	Further understanding of reasonable or probable catchability (q) values will enhance the interpretation of scale, a generally weakly informed output of these catch and index-only models that are dependent on trawl surveys. We already have an extensive collection of estimated q values from data-rich assessments, assuring feasibility. Priors on q would be useful in several respects: (a) Priors could be used to link the time series of triennial and NWFSC survey abundance estimates, greatly enhancing their information content. (b) For lightly-fished species such as striptail rockfish, a prior distribution of q would allow quantitative estimation of ABC and OFL so that management can make informed decisions regarding fishery development and conservation. Values of ABC and OFL should not require experience from an intense historical fishery to be quantitatively acceptable. (c) Improved understanding of multispecies patterns in survey q could be useful for evaluating survey performance and diagnosis (see recommendation #4).
114	Compare XDB-SRA and exSSS models to understand why they may give different results.	More direct attempts to compare XDB-SRA and exSSS models to understand why they may give different results. Reconciling the use of different productivity assumptions (i.e., priors) in XDB-SRA and exSSS is a major part of this work. Progress was made during the STAR panel, but much more work is needed.
115	Further development of exSSS and XDB-SRA capabilities and speed of execution ...	Given the success of the efforts reported herein, more attempts at data-moderate assessment are anticipated. Further development of exSSS and XDB-SRA capabilities and speed of execution would be beneficial. One useful area of development is quantitative treatment of historical catch imprecision (see recommendation #1).

Item #	Item descriptor	Item details as presented in the various documents
116	Explore using data-moderate models to provide tractable linkages to ecosystem models.	Single-species stock assessment models are still unable to address systematic changes in productivity due to external factors such as inter-species relationships and low-frequency aspects of climate change. Relatively simple data-moderate models may provide tractable linkages to ecosystem models, and are relatively easy to modify to reflect ecosystem forces.
117	Exploration of trans-boundary assessments with Canada.	Exploration of trans-boundary assessments with Canada should be initiated, and would benefit all parties. This also requires development of data inputs including historical catch reconstructions. Due to their transparency, data-moderate assessments may play an especially useful role in promoting trans-boundary fishery science.

#### **Items from the 2013 data moderate stock assessments STAR Panel Report**

118	Pre-assessment data workshops needed ...	The Panel strongly emphasizes the value of conducting a data workshop during which catches, indices, biology, and other data inputs are reviewed.
119	Consider treating latitude and depth as continuous covariates in survey GLMMs ...	Consider developing GLMM models in which latitude and depth are treated as continuous covariates rather than as factors.
120	Keypunch the CA historical CPFV data ...	The historical CPFV drift-specific data should be keypunched, which should allow the algorithm for developing CPFV-based data indices to be improved.
121	Develop habitat maps to inform observer CPUE analyses ...	Habitat maps should be developed so that structural rather than true zeros are designated using data which are independent from the data used to determine the indices.

Item #	Item descriptor	Item details as presented in the various documents
122	Revisit approach for selecting error models in survey GLMMs ...	Revisit the approach used to select among error models and whether to include ECE components when conducting the GLMM analyses.
123	Consider using vessel as a random effect in analysis of Triennial survey data.	Consider including a vessel factor (as a random effect) when developing indices for the Triennial survey.
124	Comprehensive evaluation of whether to split the Triennial survey series.	Splitting the triennial survey into early and last periods became established practice without looking at the issue comprehensively or considering the loss of information from breaking a time series. A comprehensive evaluation of the issues and trade-offs is still needed.
125	Investigate source of consistency across assessments in NWFSC survey residual patterns ...	Consistent residual patterns in NWFSC surveys for a number of assessments suggests there may be some unknown factor affecting survey catchability, or that some factor is affecting the productivity of multiple stocks in the same way.
126	Reconsider how many DM assessments can be reviewed in a single STAR.	Nine stocks proved to be too many assessments to review at this STAR Panel. Reviewing a smaller number of assessments (4-8) may be more feasible goal for STAR Panel review, depending on the level of pre-STAR panel review of data inputs. If area-specific models are considered in addition to coast-wide models, additional time or fewer stocks should be scheduled. However, the first time that any assessment method or stock assessment is reviewed is always the most challenging, and future STAR Panels may find that the review goes much smoother.
127	Continue reviewing DM assessments at full STAR Panels ...	The Panel recommends that data-moderate assessments continue to be reviewed at full STAR panels for at least for the next assessment cycle. As methods become standardized

Item #	Item descriptor	Item details as presented in the various documents
		and the review process becomes more routine, it should be anticipated that review process can be streamlined somewhat.
128	Develop minimum standards for “acceptable” and “preferred” model outputs ...	Objective criteria should be developed to specify minimum standards for model outputs to be considered “acceptable” and “preferred” and included in the Terms of Reference for stock assessments. Such criteria might include minimum goodness-of-fit criteria and acceptable limits on posterior distributions.
129	Conduct model comparisons of XDB-SRA vs XSSS outside of the STAR process.	While the Panel made some progress in comparing XDB-SRA and exSSS, our strategy of attempting to isolate the sources of difference between the two models ultimately proved unsuccessful, and resulted in complex requests to the STAT that were difficult to accomplish in the available time. The Panel suggests that some of the model comparison work is more appropriate outside the STAR panel review process, particularly as it involves fundamental differences in how stock productivity is modeled.
130	Develop standardized sensitivity runs, diagnostic plots, and performance statistics for DM assessments ...	A standardized set of sensitivity runs, diagnostic plots, and performance statistics, such as runs tests on the residuals, should be developed to rapidly evaluate the performance of data-moderate assessments. Some pre-STAR panel planning involving the STAT and SSC to develop an analysis “package” could be helpful.
131	Consider quality versus quantity of data-moderate assessment reviews ...	As with any assessment and review process, there is a trade-off between the number of data-moderate assessments and quality of the assessment and review. This trade-off should be taken into account when planning for future STAR panel reviews of data-moderate assessments.

Item #	Item descriptor	Item details as presented in the various documents
132	Use MSE to explore performance of exSSS and XDB-SRA ...	The MSE should be further explored to evaluate to performance of exSSS and XDB-SRA. Other potential topics include error in the catch time series, uninformative indices of abundance, and time-varying productivity. The MSE could also be used to test whether more constrained models, such as fixing steepness or BMSY/B0, results in improved model performance.

#### Items from the 2013 longspine thornyhead stock assessment

133	Age and growth information are needed (otolith ages not reliable).	Age and growth information are needed for future stock assessments. Otoliths have been collected in good quantities from the NWFSC survey, but at this time the ageing methods are not believed to be reliable. Additional research on ageing methods for thornyheads would be valuable. This could involve investigation of biochemical aging methods, for example an analysis of telomere length in relation to body length.
134	Towed camera survey to assess the abundance in deeper water.	A survey using a towed camera to assess the abundance in deeper water. The proportion of the stock and its size range in deeper water is unknown. Further exploration of perceived differences in catchability (q) between towed cameras and trawl nets should also be explored.
135	More tows or visual surveys south of 34.5 deg. N. latitude.	More tows or visual surveys south of 34.5 deg. N. latitude. Because the southern Conception Area is a large potential habitat for thornyheads, more effort should be directed to describing their distribution in this area, for inclusion in future assessments.
136	Revisit the thornyhead historical catch reconstruction.	An investigation of the possible discontinuity in the reconstructed thornyhead historical catches would be useful for future assessments.

Item #	Item descriptor	Item details as presented in the various documents
<b>Items from the 2013 longspine thornyhead STAR Panel Report</b>		
137	Investigate historical catch reconstruction for thornyheads.	Investigate historical catch reconstruction for thornyheads. Potentially have a workshop to sort out the catch histories for longspine and shortspine thornyheads. Washington also needs to complete their historical catch reconstruction so there is a move in a forward direction for formally reviewing all of the west coast estimates.
138	Comprehensive likelihood profile analyses of fixed parameters ...	Evaluate the influence of the fixed parameters by providing likelihood profiles for these parameters for different values, or release some of the fixed parameters step by step to investigate the influence of each.
139	Validate the ageing method and otolith readings ...	Ageing method validation and further otolith reading.
140	Explore simpler system for management advice based on survey biomass ...	Use simpler methods of providing management advice based on the estimated biomass from the NWFSC combo survey.
<b>Items from the 2013 petrale sole stock assessment document</b>		
141	Completion of a Washington catch reconstruction.	In the past many assessments have derived historical catches independently. The states of California and Oregon have completed comprehensive historical catch reconstructions. At the time of this assessment, a comprehensive historical catch reconstruction is not available for Washington. Completion of a Washington catch reconstruction would provide the best

Item #	Item descriptor	Item details as presented in the various documents
		possible estimated catch series that accounts for all the catch and better resolves historical catch uncertainty for flatfish as a group.
142	Maturity and fecundity relationships for petrale sole	Due to limited data, new studies on both the maturity and fecundity relationships for petrale sole would be beneficial.
143	Increased collection of commercial fishery age data; re-aging any available CA historical samples.	Increased collection of commercial fishery age data as well as re-aging any available historical samples from California would help reduce uncertainty. While some recent age data were made available from California, sample sizes could be increased and this data collection needs to continue into the future. Without good age data, the ability to estimate year-class strength and the extent of variation in recruitment is compromised.
144	Re-age surface reads using break-and-burn.	Where possible, historical otolith samples aged using a combination of surface and break-and-burn methods should be re-aged using the break-and-burn method. Early surface read otoliths should also be re-aged using the break and burn method. Historical otoliths aged with a standard method will allow the further evaluation of the potential impacts of consistent under aging using surface methods, changes in selectivity during early periods of time without any composition information, and potential changes in growth.
145	IFQ program influence on fleet behavior (discards, fishery selectivity, and fishing locations) ...	The effect of the implementation of the IFQ (catch shares) program that began during 2011 on fleet behavior, including impacts on discards, fishery selectivity, and fishing locations would benefit from further study.



Item #	Item descriptor	Item details as presented in the various documents
146	Studies on stock structure, seasonal movement of petrale sole, and US / Canada movements.	Studies on stock structure and movement of petrale sole, particularly with regard to the winter-summer spawning migration of petrale sole and the likely trans-boundary movement of petrale sole between U.S. and Canadian waters seasonally.
147	Spatial variability in productivity processes such as growth, recruitment, and maturity.	The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research.

#### **Items from the 2013 petrale sole STAR Panel Report**

148	Complete the WA historical catch reconstruction ...	The states of California and Oregon have completed comprehensive historical catch reconstructions. Washington historical data are not yet available. Completion of Washington historical catch reconstruction would provide a better catch series.
149	Update maturity and fecundity relationships with samples from CA ...	Update both the maturity and fecundity relationships using samples with wider geographic coverage to include California, and from more recent years for petrale sole would be beneficial.
150	Stock structure and movement of petrale sole, including transboundary and seasonal movement ...	Studies on stock structure and movement of petrale sole indicating transboundary movement of petrale sole between U.S. and Canadian waters, particularly with regard to the winter-summer spawning migration. It will be informative to include a time-series plot of fishery catch from Canadian waters in future assessment.

Item #	Item descriptor	Item details as presented in the various documents
151	Increased collection of commercial fishery age data, especially CA ...	Increased collection of commercial fishery age data as well as re-aging any available historical samples from California would help reduce uncertainty. While some recent age data were made available from California, sample sizes could be increased and this data collection needs to continue into the future. Without good age data, the ability to estimate year-class strength and the extent of variation in recruitment is compromised.
152	Re-age surface reads using break-and-burn.	Where possible, historical otolith samples aged using a combination of surface and break-and-burn methods should be re-aged using the break-and-burn method. Early surface read otoliths should also be re-aged using the break and burn method. Historical otoliths aged with a standard method will allow the further evaluation of the potential impacts of consistent under-aging using surface read methods, changes in selectivity during early periods without any composition information, and potential changes in growth.
153	IFQ program influence on fleet behavior (discards, fishery selectivity, and fishing locations) ...	The effect of the implementation of the IFQ (catch shares) program that began during 2011 on fleet behavior, including impacts on discards, fishery selectivity, and fishing locations, would benefit from further study.
154	Studies on stock structure, seasonal movement of petrale sole, and US / Canada movements.	The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research.
155	Delta-GLMM approach: explore using catch with effort as an offset (not CPUE) ...	Investigate using effort as an offset in the model. That is, rather than modeling catch/effort = effects, use catch = effort*effects. When a log-link is used then log(effort) can be included as an additive offset, and most GLMM packages include this option. The advantage of this approach is that it is easy to investigate if catch is proportional to effort or not. For example, it may be that CPUE can be higher when effort is low than when effort is high.

Item #	Item descriptor	Item details as presented in the various documents
156	Delta-GLMM approach: further consideration of the impacts of trip limits ...	Include further consideration of the impacts of trip limits on CPUE. Such limits were gradually introduced since 2006 in the winter fisheries and this may impact CPUE. This consideration should involve consultations with fleet members to understand how their fishing behavior was affected by trip limits.
157	Delta-GLMM approach: CPUE standardization should be considered low priority ...	Given that this CPUE series will not be extended and, following the changes made for the final base case model, the results showed little sensitivity to its treatment, the STAR panel concluded that additional work on the CPUE standardization should be considered low priority for future petrale assessments.
158	STATs should include sensitivities of likely decision table axes of uncertainty ...	Recommend that STAT teams present a sensitivity analysis (Tables and Figures) in the draft document for any axis of uncertainty that is likely to be considered for the decision table. This would facilitate efficient discussions during the meeting.
159	Routinely include a time-series of species-specific Canadian (B.C.) landings ...	It would be helpful to routinely include a time series of species-specific Canadian (B.C.) landings for comparison with U.S. landings and trends.
160	Report treatment and results of model tuning procedures ...	The specific treatment and results of model tuning procedures should be reported in the document including all input/output sample sizes, effective sample sizes, sigmas, RMSEs (including recruitment deviations), that are applicable.
161	Standard summary of raw data, model fits, results, and diagnostics for survey GLMMs.	For survey GLMM analyses, the STAT teams need to report a standard summary of the raw data, and fitting of the model including both results and diagnostics. Additional research should attempt to identify (and perhaps simulation test) a method for model selection

Item #	Item descriptor	Item details as presented in the various documents
		including the error distribution, the treatment of random vs. fixed effects and the inclusion of ECE mixture distributions that can be reliably applied across all species.
162	Option in Stock Synthesis for maturity-at-length with an asymptote < 1.0 to reflect atresia ...	Maturity schedules are often largely determined by size and not age. An additional option is needed in Stock Synthesis to allow the modeling of maturity-at-length with an asymptote < 1.0 to reflect atresia or skip-spawning.
163	Guidance on selecting fecundity relationships ...	General recommendation to identify where and when E.J. Dick's fecundity relationships are better than existing data for a given species.

#### Items from the 2013 rougheye and black-spotted rockfish stock assessment document

164	Comprehensive look at historical landings, species compositions, and discarding practices.	The historical landings and discards are uncertain for rougheye rockfish and improvements would increase the certainty that fishing removals are applied appropriately. Because landings are assumed to be known exactly in the assessment model, uncertainty in the predictions does not include uncertainty in the landings. A thorough look at historical landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for.
165	Collection of additional age data; improved understanding of the life-history traits.	Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for rougheye rockfish. The collection of additional age data and improved understanding of the life-history of rougheye rockfish may reduce that uncertainty.

Item #	Item descriptor	Item details as presented in the various documents
166	Further research on the maturity and fecundity of rougheye rockfish ...	There are few studies on the maturity of rougheye rockfish and only one has reported the results of a histological analysis. Further research on the maturity and fecundity of rougheye rockfish, the potential differences between areas, the possibility of changes over time, and differences between rougheye rockfish and blackspotted rockfish would greatly improve the assessment of these species.
167	Investigating the ageing error and bias in rougheye rockfish.	There is a considerable amount of error in the age data and the ageing of rougheye rockfish has not been validated. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment.
168	Better understanding of the stock structure and biology of rougheye and blackspotted rockfishes.	This assessment reports the status of rougheye and blackspotted rockfish as a pooled complex because it is extremely difficult to separate the catches of each species even in recent data, and attempting to do so would greatly increase the uncertainty in the predictions. Because little is known about the respective biology and catch histories of the two species, it is unclear whether managing them as a complex may place one species at disproportionate risk of overfishing relative to the other. We recommend additional research that will provide insight into the distribution, life history, biological characteristics, and catch and discard profiles of the two species. Such an endeavor would like require the efforts of at sea observers in all fleets, biologists aboard fishery-independent surveys, and port samplers along the entire West Coast requiring broad, inter-agency collaboration.
169	Explore the connectivity of West Coast with fish north of the U.S.-Canada border.	This is a stock assessment for rougheye rockfish off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between rougheye rockfish north of the U.S.-Canada border.

Item #	Item descriptor	Item details as presented in the various documents
<b>Items from the 2013 rougheye and black-spotted rockfish STAR Panel Report</b>		
170	Workshop on weighting composition data, including initial input values.	A workshop should be held to evaluate (a) methods for the iterative reweighting of composition data (e.g., current approach based on SS3 calculation of effective N versus the Francis approach) and (b) methods for developing initial weightings (the initial input N values).
171	Workshop on methods for constructing survey GLMM estimates.	A workshop should be held to evaluate methods for constructing survey GLMM estimates. Topics that should be explored include: (a) the effect of treating vessels as random when in fact the vessels hardly vary from one year to the next; (b) possible aliasing of the index values with the Vessel x Year interactions; and (c) the using information from the GLMM for combining length composition data collected by different vessels. One goal for the workshop should be to provide adequate documentation of the GLMM methods that will be used to produce survey biomass indices for future assessments and guidelines on how the analyses, including diagnostics, should be presented in stock assessment reports.
172	Continue routine collection of slope rockfish otoliths; catalog historical collections.	Port sampling programs should continue their routine collection of otoliths of slope rockfish species. A catalog of historical collections that have not been aged should be developed.

Item #	Item descriptor	Item details as presented in the various documents
173	Thorough review of historical slope rockfish catch reconstructions, including uncertainty measures.	The series of historical catches of individual rockfish species, which are important sources of uncertainty in stock assessments of rockfish, should be explored in more detail. The STAR Panel agrees with the statement in the draft assessment document that “A thorough look at historical landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for”. Furthermore, catch reconstructions should not just develop best estimates of rockfish catch by species, but should also characterize the uncertainty of historical catch estimates by identifying periods of greater and lesser uncertainty. For example, rockfish species compositions taken during early years when there limited slope fisheries should be very different from species compositions taken during later years when fisheries on the slope were more prevalent.
174	Technical guidance on how to construct decision tables ...	The SSC should develop detailed technical guidance on how to construct decision tables, including a summary of lessons learned from a review of approaches applied in past stock assessments.
175	Surveys for slope rockfish and other species living in untrawable habitats ...	Investigate better fishery-independent data collection methods for slope rockfish and other species living in untrawable habitats (e.g., surveys using submersibles or remotely operated vehicles).
176	Collect additional age data and other life-history information ...	The STAR Panel agrees with the STAT regarding the importance of collecting additional age data and other information that will improve our understanding of the life-history characteristics of rougheye and blackspotted rockfish, with the aim of reducing the uncertainty regarding natural mortality.

Item #	Item descriptor	Item details as presented in the various documents
177	Sampling efforts should collect genetic material in association with otolith sampling ...	The survey and port sampling efforts should collect genetic material in association with otolith sampling to provide a clear basis for distinguishing between rougheye and blackspotted rockfish. Also, researchers in the PFMC arena should collaborate with ongoing AFSC and Department of Fisheries and Oceans Canada genetic studies of rougheye and blackspotted rockfish.
178	Targeted studies or analyses of the missing 30-44 cm fish caught in the 250-300 m depth zone by the NWFSC survey.	Prior to the next assessment of either rougheye or blackspotted rockfish (or their complex), there should be targeted studies or analyses to investigate what caused the lack 30-44 cm fish caught in the 250-300 m depth zone by the NWFSC shelf/slope survey.
179	Additional studies of the maturity and fecundity ...	The STAR Panel agrees with the STAT regarding the importance of additional studies of the maturity and fecundity of rougheye and blackspotted rockfish. Further, any fish used for maturity and fecundity studies should be subjected to genetic analysis to definitively identify what species it is.
180	Validate the ageing method but using samples that have genetic species ID.	The STAR Panel agrees with the STAT regarding the importance of validating the ageing method for rougheye and blackspotted rockfish. Further, any fish used for age-validation studies should be subjected to genetic analysis to definitively identify what species it is.
181	Improved understanding of stock structure and biology of rougheye and blackspotted rockfishes.	The STAR Panel agrees with the STAT regarding the importance of “understanding the stock structure and biology of rougheye and blackspotted rockfishes” and their recommendation for “... additional research that will provide insight into the distribution, life history, biological characteristics, and catch and discard profiles of the two species”.



Item #	Item descriptor	Item details as presented in the various documents
182	Define basin-wide connectivity of rougheye [and blackspotted] rockfish ...	The STAR Panel agrees with the STAT regarding the importance of “basin-wide understanding of stock structure, connectivity, and distribution” for rougheye and blackspotted rockfish, with the aim of defining “the connectivity between rougheye [and blackspotted] rockfish north of the U.S.-Canada border”.

#### Items from the 2013 sanddab stock assessment document

183	Better information on discards and sanddab species apportionments.	The proportion of the total catch of Pacific sanddab were discarded is uncertain. Discard rates varied among fisheries and states. The WCGOP has provided important information on discard rates, as well as length composition of discards in recent years. It will be important to continue to collect these data in future years. In addition, it will be helpful to record the catch of Pacific sanddab separately from other sanddab species. This is particularly informative when length composition data for both retained and discarded catches are available for the species.
184	Continue estimating catch and collecting length data for Pacific sanddabs in the recreational fishery.	Continue estimating catch and collecting length compositions of Pacific sanddabs in the recreational fishery. An increased sample size of length data from both retained and discarded catches from the fishery will provide more accurate information on estimates of fishery selectivity.
185	Species-level information needed from juvenile groundfish survey.	Coastwide juvenile groundfish survey data is available for most years since 2001, and have been used in assessments of other groundfish. However, sanddabs were not identified to the species level in the northern survey areas, and thus truly coast-wide data is not available for this species. Data from a more limited geographic range does not indicate a strong correlation between juvenile abundance and subsequent recruitment to the adult population,

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		however species level data in recent years may provide useful information on the annual recruit strength and may help in estimating the stock recruitment relationship.
186	Continue collecting data on reproductive biology of Pacific sanddabs ...	Continuations of collecting data on reproductive biology of Pacific sanddabs will provide more comprehensive data for future assessments. This is particularly important that data are to be collected from the northern area (i.e. Oregon and Washington) and from the southern California. More data from other seasons (i.e. winter months) will also provide more complete information on spawning frequencies and spawning seasons. Consideration of the potential causes, and consequent influence on model results and dynamics, of the apparent shift in the maturity curve from maturity estimates in the 1950s would also be beneficial.
187	Consider Pacific sanddab information from Mexico and Canada.	Stock and catch data from both Mexico and Canada have not been used in this assessment. Although there are some data and samples from the Canadian catches on Pacific sanddab, there is no information from Mexican fisheries on the species. Data gathering on the Pacific sanddab catches from Mexican waters will be useful to estimate potential impacts on the U.S. stock.
188	Stock structure uncertain given no genetic studies on the stock structure of this species.	Pacific sanddab along the U.S. coast have been treated as a single stock in this assessment, as there is no genetic study on the stock structure of this species. Although this assumption is likely reasonable given the extended larval duration (200 to 250 days) of pelagic young-of-the-year sanddabs, genetic studies on the stock structure of Pacific sanddab could help to determine potential stock structure in future assessments.

Item #	Item descriptor	Item details as presented in the various documents
189	Research on factors influencing catchability for small flatfish in bottom trawl surveys.	The discrepancy between the survey biomass estimates and the model estimates of total biomass suggest either that the survey is dramatically overestimating total biomass for some unknown reason, or that the model is unconstrained to estimating a lower biomass. Alternative sources of information, or alternative types of analyses, may shed light on both the factors that appear to drive variability in catchability for small flatfish in bottom trawl surveys would be beneficial. Alternative means of analyzing trawl survey data, or of conducting more focused surveys that could shed light on catchability issues and relative abundance and density of this species in the ecosystem, may also be beneficial.
190	Research on ecosystem changes that may have altered natural mortality rates for sanddabs.	Pacific sanddabs play an important role in the ecosystem, and likely experience high natural mortality rates, rates which are likely to vary both with size and age, and over space and time. A greater understanding of the appropriate mortality functions and the extent to which ecosystem changes may have altered natural mortality rates in either space or time would benefit future assessments.

#### **Items from the 2013 sanddab STAR Panel Report**

191	Explore discrepancy between survey- and model-based estimates of biomass ...	Exploration of the biomass estimates derived from trawl surveys, especially the NWFSC shelf/slope survey to address the discrepancy between survey- and model-based estimates of biomass.
192	Historical reconstruction of landings and discards.	Evaluate historical reconstructions of landings and discards.

Item #	Item descriptor	Item details as presented in the various documents
193	Explore possible time-variation in life history traits ...	Explore the possibility of time-varying life history parameters (e.g., regime shifts that potentially affect maturity, M, and growth).
194	Explore influence of individual data sources on model results ...	Further explore the influence of the individual data sources on model results.
195	Develop nearshore abundance index for sanddabs ...	Explore ways to index the abundance of sanddabs in nearshore areas (i.e., waters shallower than 55 m) where the trawl surveys were not conducted.
196	Explore possible stock structure for sanddabs, including connectivity with fish off Mexico ...	Explore potential stock structure of this population, including the population in waters off Mexico and Canada.

**Items from the 2013 shortspine thornyhead stock assessment document**

197	More investigation into maturity of shortspine.	More investigation into maturity of shortspine is necessary to understand the patterns in maturity observed in the samples collected in 2011 and 2012.
198	Information on possible migration of shortspine thornyheads ...	Information on possible migration of shortspine thornyheads would be valuable for understanding stock dynamics. Analysis of trace elements and stable isotopes in shortspine otoliths may provide valuable information on the extent of potential migrations. Possible connections between migration and maturity could likewise be explored.

Item #	Item descriptor	Item details as presented in the various documents
199	Improve understanding of survey catchability of thornyheads.	A greater understanding of catchability of thornyheads would help define the scale of the populations. This could include a survey using a towed camera to assess the abundance in water beyond the 1280 m range of the trawl surveys. Further exploration of perceived differences in catchability between towed cameras and trawl nets could also be explored. Understanding the relative catchability of shortspine and longspine thornyhead, which are difficult to distinguish in camera observations, would have to be a component of such investigations. Differences in selectivity between the AFSC Slope survey and the NWFSC surveys may be the result of behavioral interactions with different footropes. Understanding these interactions would also improve understanding of catchability.
200	Additional research on ageing methods for thornyheads is needed.	Age data would be valuable for future stock assessments. Otoliths have been collected in good quantities from the NWFSC survey, but at this time the ageing methods are not believed to be reliable. Additional research on ageing methods for thornyheads would be valuable.
201	Better understanding of the connection between thornyheads and bottom type.	A greater understanding of the connection between thornyheads and bottom type could be used to refine the indices of abundance. Thornyheads are very well sampled in trawlable habitat, but the extrapolation of density to a survey stratum could be improved by accounting for the proportion of different bottom types within a stratum and the relative density of thornyheads within each bottom type.
202	Comprehensive catch reconstruction is needed.	A comprehensive catch reconstruction for shortspine and longspine thornyheads should be completed to estimate landings for each species prior to 1981 in each of the three states.

Item #	Item descriptor	Item details as presented in the various documents
203	Exploration of simpler assessment methods for thornyheads ...	Exploration of simpler assessment methods for thornyheads and evaluation of whether such methods would provide a more robust management strategy than the current approach. It is likely that any significant reduction in the size of the shortspine thornyhead population would be apparent in the NWFSC Combo Survey index. A method for setting and/or adjusting catch limits based on either absolute values or trends in the survey has the potential to be much less labor intensive than the current assessment approach.
204	More tows or visual surveys south of 34.5 deg. N. lat. including the large Cowcod Conservation Area.	More tows or visual surveys south of 34.5 deg. N. lat. including the large Cowcod Conservation Area. Because the southern Conception Area is a large potential habitat for thornyheads, more sampling effort would help refine the estimations of their abundance in this area.

#### **Items from the 2013 shortspine thornyhead STAR Panel Report**

205	Studies to help estimate natural mortality and growth, including tagging studies ...	Ageing to help estimate pertinent parameters in the model (e.g. M, growth), perhaps including new methods such as tagging. Tagging studies would also further investigate the assumption of an ontogenetic movement pattern seen for this species.
206	Evaluate recent maturity data and develop ogive ...	Maturity ogive to evaluate the pattern seen in the most recent data collected.
207	Evaluate historical catch reconstructions for thornyheads ...	More efforts to reconstruct historical catches for thornyheads.

Item #	Item descriptor	Item details as presented in the various documents
208	Investigate simpler, more robust assessment methods for thornyheads ...	Investigate alternative, simpler methods that may be more robust.

**Items from the 2015 arrowtooth flounder data-moderate stock assessment document – rejected for use in management**

209	Further exploration of using co-occurring flatfish species as predictors of discards.	Historical estimates of discards are a large contributor to total removals. The current modelling exercise of using co-occurring flatfish species as predictors of discard could use further exploration.
210	Further exploration of large difference in biomass between MLE and Bayesian results.	Such large difference in biomass between MLE and Bayesian results was unexpected. Further investigation into these large differences is warranted.
211	Explore using the upper limit of $\ln R_0$ priors to exclude the unlikely scenarios.	Further exploration in the upper limits of $\ln R_0$ priors to exclude the unlikely scenario of the current state being at unfished conditions.
212	Explore differences between the MCMC and XSSS models ...	Greater understanding of the differences between the MCMC and XSSS models could help inform a better convergence criterion when using AIS.

**Items from the 2015 stock assessment process review meeting report**

213	Pre-STAR data/modeling workshop to critically review proposed data and methods for index development ...	Explore a series of webinars or a data/modeling workshop to critically review proposed data and methods for index development that will be used in assessments. Bring the SSC Groundfish Subcommittee in when there are proposed indices available for evaluation. This
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Item #	Item descriptor	Item details as presented in the various documents
		would occur after the STATs and data experts agree on the appropriate data to be used (e.g., data filtering, interpretation of the historical data, etc.).
214	Develop a 10-year stock assessment prioritization plan ...	Develop a 10-year stock assessment prioritization to allow state agencies and science centers to better plan data collection and analysis (e.g., ageing priorities, etc.).
215	Training webinars with PacFIN and RecFIN database managers and STATs ...	Facilitate training webinars with PacFIN and RecFIN database managers and STATs to learn how to best access these data. PacFIN webinars could happen now, but such a training webinar for accessing RecFIN data will have to wait for the database to be migrated to the new SQL framework.
216	Once assessment priorities are decided, compile and make available past CIE reports.	Once assessment priorities are decided, Council staff should compile past CIE reports and post them on the web site. SSC reports on their assessment reviews should also be housed on the Council assessment web pages.
217	Guidance on whether data-moderate assessments are appropriate for stocks with previous full assessments.	Data-moderate assessments are appropriate for improving a data-poor assessment of a stock, but may not be appropriate for a stock previously assessed using a full assessment. A STAR Panel should be dedicated for reviewing data-moderate assessments.
218	Consider historical catches relative to estimated biomass to inform stock assessment prioritization.	A simple comparison of historical catches relative to estimated biomass should be done to decide whether any new stock assessment should be prioritized. For example, it was probably not worth conducting an assessment for stripetail rockfish, where the historical catch was a very small percentage of the estimated OFL.



Item #	Item descriptor	Item details as presented in the various documents
219	Refine the ToR language on how best to resolve competing models ...	Refine the language in the Terms of Reference on how best to resolve competing models in an assessment.
220	ToR should more clearly define the STAR panel's role as primarily a review body.	More clearly describe the nature of the STAR panel in the Terms of Reference as primarily a review body, with a limited capacity to investigate identified and agreed (STAR panel and STAT) major problems. If agreed solutions to major problems can be readily identified, sufficient time must still be allowed for full review of the resulting model(s) if they substantially differ from the original drafts presented.
221	Establish a deadline for providing data to STATs.	Establish a deadline (e.g., at least one month prior to the internal document review deadline) for providing data to STATs. This should be consistent with any data review process and codified in the Terms of Reference.
222	Provide guidance for modeling and reporting discard data in an assessment.	Establish best practices for modeling and reporting discard data in an assessment. John Wallace has analyzed historical discard data using standardize approaches. This analysis should be evaluated by the SSC and the GMT to formalize best practices.

#### **Items from the 2015 black rockfish stock assessment document**

223	Research on age- and sex-dependent mortality or accessibility to fishing and sampling gears.	Further investigation into the movement and behavior of older (> age 10) females to reconcile their absence in fisheries data. If the females are currently inaccessible to fishing gear, can we find where they are?
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Item #	Item descriptor	Item details as presented in the various documents
224	Appropriate natural mortality values for females versus males.	Appropriate natural mortality values for females and males. This will help resolve the extent to which dome-shaped age-based selectivity may be occurring for each.
225	Improved historical catch reconstructions for black rockfish, particularly the historical trawl fishery catches.	All states need improved historical catch reconstructions. The trawl fishery catches in particular require particular attention. Given the huge historical removals of that fleet in each state, the assessment is very sensitive to the assumed functional form of selectivity. A synoptic catch reconstruction is recommended, where states work together to resolve cross-state catch issues as well as standardize the approach to catch recommendations.
226	Identifying stanzas or periods of uncertainty in the historical catch series for sensitivity runs.	Identifying stanzas or periods of uncertainty in the historical catch series will aid in the exploration of catch uncertainty in future assessment sensitivity runs.
227	Continue and expand the ODFW black rockfish tagging study.	The ODFW tagging study off Newport should be continued and expanded to other areas. To provide better prior information on the spatial distribution of the black rockfish stock, further work should be conducted to map the extent of black rockfish habitat and the densities of black rockfish residing there.
228	Develop a coastwide fishery independent nearshore survey.	An independent nearshore survey should be supported in all states to avoid the reliance on fishery-based CPUE indices.
229	Research on stock structure for nearshore species.	Stock structure for black rockfish is a complicated topic that needs further analysis. How this is determined (e.g., exploitation history, genetics, life history variability, biogeography, etc.) and what this means for management units needs to be further refined. This is a general issue for all nearshore stocks that likely have significant and small scale stock structure among and within states, but limited data collections to support small-scale management.

Item #	Item descriptor	Item details as presented in the various documents
<b>Items from the 2015 black rockfish STAR Panel Report</b>		
230	Continued research on stock structure ...	Continued research on stock structure, including whether national/international boundaries are appropriate.
231	Continued research on catch histories, including uncertainty ...	Continued research on catch histories, including uncertainty and alternative catch streams to be used in sensitivity analysis.
232	Continued research on definition and measurement of habitat.	Continued research on definition and measurement of black rockfish habitat.
233	Continued research on preparation of composition data ...	Continued research on preparation of composition data: post-stratification and scaling supported by a detailed analysis of the data.
234	Pre-STAR data workshop ...	A specific data workshop, perhaps for all species prioritized for assessment, could examine information across a broad range of species due for assessment, and would also assist with the development of more specific documentation of protocols used to compile best available data sets for stock assessment, continue acceptance of agreed procedures for standardization of abundance indices, and also begin work on procedures for the development of alternative data series that capture uncertainty – particularly for historical catch and discards.
235	Assessment documents to include responses to pre-STAR Data Workshop recommendations ...	The outline for stock assessments (Appendix B in the 2014 Terms of Reference) includes a section for addressing previous STAR Panel recommendations. If a data workshop precedes the stock assessment, as here for black rockfish, the outline should also include a section on

Item #	Item descriptor	Item details as presented in the various documents
		how the recommendations from the data workshop were addressed. A similar process should be outlined to address recommendations from previous CIE reviewers.
236	Consider developing a coastwide fishery-independent survey for nearshore stocks.	Consider the development of a coastwide fishery-independent survey for nearshore stocks. As the current base model structure has no direct fishery-independent measure of recent rebuilding of the adult portion of the stock, any work to commence collection of such a measure for nearshore rockfish, or use of existing data to derive such an index would greatly assist with this assessment.
237	Multi-species simulation study to test performance of the Stephens-MacCall filtering of sport fishery CPUE data.	For abundance indices a multi-species simulation study to test whether the Stephens-MacCall filtering may lead to a bias in abundance estimates given differences in abundance trends among species should be considered. It is the understanding of the panel that some simulation testing has been done; these results should be made generally available. A comparison of alternative filtering procedures should also be considered.
238	Develop objective procedure for sub-model error structure selection in CPUE standardization ...	CPUE standardization protocols need improvement: an objective procedure for sub-model error structure (usually gamma or lognormal here) is required for delta-GLM procedures. Consistency is required for the model selection process – preferably using a priori candidate models rather than a stepwise selection. For Washington and California: removal of the restriction on having the same explanatory variables for the binomial and positive catch rate models. There is no reason why the presence/absence of the species should be explained by the same variables which explain the magnitude of the positive catch rates.

Item #	Item descriptor	Item details as presented in the various documents
239	AIC tables from CPUE model building do not appear to report the correct AIC values ...	CPUE standardization protocols need improvement: The AIC tables do not appear to report the correct AIC values in some cases. In particular, models with 1 or 2 additional variables, which were likely confounded with other variables, often had the exact same AIC value as the less complex model. While this is technically possible, it is highly unlikely and its consistency is worrying.
240	Better diagnostics for each CPUE analysis ...	CPUE standardization protocols need improvement: Better diagnostics for each CPUE analysis: plots of the binomial and positive catch rate year effects in addition to the combined year effects; plots of all estimated effects; production of year:area interactions and a comparison of the trends by area. In cases where the trend in CPUE index differs across areas, the aggregate CPUE index is affected by the method used to weight the CPUE from the areas. Evaluation of the effect of alternative weighting methods on the aggregate standardized CPUE index should be evaluated in these cases.
241	Provide explanations for effects of the standardization on the “nominal” indices ...	CPUE standardization protocols need improvement: The effects of the standardization on the “nominal” or unstandardized indices should also be shown and explained (i.e., which variables have caused a shift in the trend).
242	Make the SS3 input data interface more user-friendly ...	SS3: The input interface is not user-friendly and requires considerable knowledge of formatting requirements and the meaning of some settings in relation to how the model is configured or parameterized.
243	Process error added to biomass indices should be expressed as a variance not a standard deviation.	SS3: The addition of extra standard deviation for biomass indices should be correctly implemented. Standard deviations do not add arithmetically. To apply a constant process error to a time series of biomass indices requires that the variances be added (i.e., square the standard deviations, add them together, and take the square root).

Item #	Item descriptor	Item details as presented in the various documents
244	Priors set in normal space versus others set in log space creates confusion ...	SS3: The fact that some priors are set in normal space and others are set in log space creates confusion on inputting these priors.
245	Develop an “expert system” front end for Stock Synthesis ...	SS3: Many of the problems could be solved by creating an “expert system” front end which creates the input files exactly how SS3 needs them (i.e., no erroneous white space or unprintable characters) transforms parameters from arithmetic space as needed, and checks for obvious user errors (e.g., a row of 1s being added to the standard deviations).
246	Improve input errors messages in Stock Synthesis and develop debugging tools ...	SS3: Improved debugging tools are necessary to help track down sources of errors messages such as “-1.INDs”
247	Add text information to R4SS plots (e.g., survey Q, extra SD) ...	R4SS: The plots showing the fits to the indices could also include useful information such as the estimated q and whether extra SD was added to the input SD (users look at the plots but they may not look at the report file). A plot to assist with comparison of all abundance indices where all indices are plotted with available biomass determined by selectivity (such a plot was developed for China rockfish during a recent STAR Panel).
248	Include calculation of unexploitable spawning output in R4SS ...	R4SS: Calculation of unexploitable spawning output: the procedure developed here should be considered as a standard diagnostic for all assessments.
249	Show units of spawning output in the r4ss plots ...	R4SS: The units of spawning output should be shown in the r4ss plots, as confusion was caused when spawning output is defined as egg production that may not necessarily be proportional to spawning stock biomass.

Item #	Item descriptor	Item details as presented in the various documents
250	Provide guidance on the appropriate levels to use for jittering ...	R4SS: Assistance with appropriate levels for jittering: Jason Cope has used a procedure for setting appropriate ranges for jittering that might be considered as an objective method for standard practice.

#### Items from the 2015 black rockfish STAR Panel Report

251	Additional surveys, tagging studies or other research to locate older female black rockfish ...	There are considerable avenues of future research that should help to inform future assessments. Key among them is additional surveys, tagging studies or other research to attempt to locate older female black rockfish. The need to accommodate the data by using dome-shaped age-based selectivity suggests a behavioral cause for unavailable old females. Automated underwater vehicles, video landers and/or an acoustic or additional tagging studies might be one plausible option. Others include focused studies on locations mentioned during the meeting, when anecdotal accounts of concentrations of larger fish found in certain places were discussed. Some form of sampling to confirm the existence of a considerable biomass of older females unavailable to the ocean recreational fishery is required.
252	Continued investigations into the tagging study data and the inferred or plausible estimates of catchability ...	Continued investigations into both the tagging study data and the inferred or plausible estimates of catchability associated with that study should be maintained. The relative importance of this study in anchoring the model would suggest that some level of effort could be maintained (currently the study is not ongoing) and/or expanded to other areas of the coast (an optimal study would include all available state waters). Movement patterns can and should also continue to be explored, in order to better understand the level at which regions represent open or closed populations, as there are clearly a fraction of black rockfish that undergo substantial movements at times.

Item #	Item descriptor	Item details as presented in the various documents
253	Age validation and re-ageing of historical otoliths	Age validation is important to more accurately evaluate the age composition data. A number of historical ages were reportedly excluded from the model due to concerns over differences among age readers, historical structures from trawl and recreational fisheries in particular should be re-aged by reliable readers and included in future assessments. Another unusual pattern was the greater degree of aging error suggested for Oregon black rockfish, this issue should be resolved in concert with the previous issue by more rigorously examining ageing error across readers.
254	Consider developing a fishery-independent nearshore survey, particularly across state boundaries ...	A fishery-independent nearshore survey, particularly across state boundaries, is essential to any future accurate assessments of nearshore resources, which almost exclusively rely on fishery dependent data.
255	Reconsider the magnitude of historical trawl catches of black rockfish ...	Although historical catches did not appear to be a substantial axis of uncertainty in this model, the relatively low magnitude of trawl catches in the early years of the fishery (e.g., 1940s-1950s) were somewhat inconsistent with the relatively greater magnitude of trawl and fixed gear landings in California and Washington during this period. Anecdotal accounts of the relative importance of black rockfish in Oregon trawl fisheries during the 1940s (in which they were described as one of four key species in the fishery) would suggest that historical catches be reconsidered to the extent practicable in future assessments.

#### Items from the 2015 Bocaccio stock assessment document

256	Stock structure and boundaries	Stock structure and stock boundaries for Bocaccio rockfish on the West Coast remains an important issue to consider with respect to both future assessments and future management actions.
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Item #	Item descriptor	Item details as presented in the various documents
257	The influence of large scale area closures and other management actions ...	Since large scale area closures and other management actions were initiated in 2001, the spatial distributions of fishing effort (fishing mortality) have changed over both large and small spatial scales. This confounds the interpretation of survey indices for surveys that do not sample in the Cowcod Conservation Areas (CCAs), although the decision to begin sampling for the NWFSC hook and line survey within the CCAs should begin to address this issue with time.
258	Consider possible changes reproductive biology (maturity and fecundity).	Recently updated reproductive biology data (maturity and fecundity) show some differences in length and weight specific fecundity in Bocaccio from those used in the past assessments. Regional differences (southern and northern California, as well as southern Oregon), and multiple brood spawning, are poorly understood.
259	Need better understanding of interactions of Bocaccio with other predator and prey species.	As Bocaccio is one of the most abundant and important piscivorous rockfish species, and its interactions with other predator and prey species are poorly known, information regarding diet and movement patterns associated with habitat and prey abundance are key in order to further understand its roles in the ecosystem of the California waters. Northward migratory behaviors of juvenile and young adults are indicated by length frequency data, but such behaviors are also poorly understood. Studies on these behaviors and their associations with oceanographic or other ecological factors can help future assessments in defining stock structure as well as explaining high variability in stock recruitments.

#### Items from the 2015 Bocaccio STAR Panel Report

260	Develop an objective procedure for evaluating the stock boundaries ...	An objective procedure for evaluating the stock boundaries is needed for all rockfish (and potentially other west coast assessments). Such a procedure would more directly point to
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Item #	Item descriptor	Item details as presented in the various documents
		directions for future research or collaboration across national/international political boundaries.
261	Explore better ways to model productivity for stocks with large episodic recruitment ...	Explore better ways to model productivity for stocks like bocaccio that exhibit large episodic recruitment patterns. Lognormal distributions are not a good way to model the recruitment variability for such stocks.
262	Develop technical methods for capturing and propagating recruitment uncertainty ...	The strength of recent recruitments is a major uncertainty for bocaccio. Technical methods for capturing and propagating this uncertainty are needed in stock synthesis (especially for axes of uncertainty), perhaps by an improved procedure to fix particular recent recruitment deviations.
263	Research is needed to better quantify spawning output recruitment linkage ...	The relationship between stock size and spawning output is critical for interpretation of the CalCOFI index, which is perhaps the most useful index in the bocaccio assessment. Research is needed to better quantify spawning output. This research could include evaluation of environmental correlations of spawning output, and studies of both the prevalence, and the potential demographic and environmental drivers of multiple broods (multiple spawning events by an individual fish within a given spawning season).
264	Continued processing and analysis of historical CalCOFI samples ...	The Panel recommends continued processing of historical CalCOFI samples from northern transects in the early 1950s through the late 1960s. These data would add to the index used in the assessment model, and improve understanding of spatial patterns in population dynamics.

Item #	Item descriptor	Item details as presented in the various documents
265	Pre-STAR data workshops should be held ...	A data workshop prior to STAR panel review, perhaps for all rockfish stocks due for assessment, should be scheduled to examine assessment information across a broad range of species. The workshop could document protocols used to compile data sets for stock assessment, establish agreed procedures for standardization of abundance indices, and develop alternative data series that capture uncertainty—particularly for historical catch and discards.
266	Research into modeling the weird survey selection pattern for Bocaccio.	Several estimated selectivity patterns in the bocaccio assessment are very unusual. The NWFSC trawl survey has a curiously flat selection pattern at young ages, and triennial survey has a strongly peaked selectivity at young ages. Research into alternative ways to model the selection pattern of these surveys is needed. Possible approaches include 1) use of age-specific natural mortality, 2) splitting the surveys into separate indices for juveniles (age 0 and/or1) and older fish.
267	Continue the NMFSC hook and line surveys inside the Cowcod Conservation Areas.	Available information indicates that the CCAs are a center of abundance for bocaccio. Surveying inside the CCA during the NMFSC hook and line surveys should be continued, though several years of data will be required before the information can be used to inform the assessment. Consideration should also be given to extending the NWFSC trawl survey into the CCAs. A simple analysis of potential catch rates of cowcod, and the impact of survey take on stock rebuilding, would allow the benefits of surveying inside CCA to be compared to potential costs.

Item #	Item descriptor	Item details as presented in the various documents
268	Develop age data series from the NWFSC hook and line survey ...	Age data from the NWFSC hook and line survey would increase the utility of the survey for assessment of bocaccio by better defining the selectivity pattern for large fish.

#### Items from the 2015 Canary rockfish stock assessment document

269	Gather, document, analyze, and evaluate Canadian data sources for a joint assessment for use in a spatial model,	The canary rockfish stock has high density near the US-Canadian border, so previous assessment authors and STAR panel reports have recommended an assessment model that incorporates landings, abundance index, and compositional data from both US and southern British Columbia regions. However, we do not believe that incorporating heterogeneous data from different sampling programs and management jurisdictions is feasible without using a spatial model (e.g., our base model), both because different jurisdictions are likely to have different exploitation histories, and because different regions are likely to have different data sources (invalidating the second-stage expansion used in coast-wide models). Given the use of a spatial model, we recommend that efforts proceed to gather, document, analyze, and evaluate Canadian data sources for a joint assessment.
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Item #	Item descriptor	Item details as presented in the various documents
270	Coast-wide pilot study for an alternative sampling method (e.g., hook-and-line sampling) of untrawlable areas.	Direct observation of canary rockfish suggests that individuals are often associated with rocky habitat, and therefore may not be available to the bottom trawl gear used to obtain coast-wide fishery-independent data in the California Current. Recent research suggests that, when (1) a portion of the population is unavailable to survey sampling gear, and (2) the proportion of the population that is unavailable varies among years (e.g., due to density-dependent habitat selection), then survey indices are likely not representative of stock-wide trends in abundance. Therefore, we highly encourage a coast-wide pilot study for an alternative sampling method (e.g., hook-and-line sampling), as well as its calibration against the existing bottom trawl survey via paired sampling methods (J. T. Thorson et al., 2013).
271	Initiate tag-resighting studies to estimate interannual movement rates to inform a spatial assessment model.	A spatial model replaces problematic assumptions in a coast-wide model (i.e., an equally mixed stock in which every individual fish and fishing operation has equal probability of encounter, no spatial variation in density or exploitation history) with other difficult assumptions (Punt et al., 2015). In particular, our base model represents the assumption that movement is negligible among strata. We therefore recommend that tag-resighting studies be initiated to estimate interannual movement rates.

Item #	Item descriptor	Item details as presented in the various documents
272	Research to construct better informed priors for steepness and natural mortality.	We also note that this assessment, like many other rockfish assessments in the California Current (e.g., darkblotched rockfish) is highly sensitive to assumptions regarding life history characteristics including natural mortality rate and the steepness of the stock-recruit relationship. We therefore recommend ongoing research for these and other life history parameters that form the primary axis of uncertainty for many rockfishes. In particular, research regarding steepness could involve exploration of the impact of autocorrelation within a species, cross-correlation among species, and model mis-specification leading to bias in the reconstruction of spawning output for species included in the prior. Steepness research could also involve a management strategy evaluation to evaluate the potential impact of rapid changes in the assumed value of steepness on management performance (i.e., false positives in detecting overfished or rebuilt stocks). Research regarding natural mortality could involve continued investigations of the relationship between natural mortality and the Brody growth coefficient, as well as how to incorporate prior information regarding this relationship into Stock Synthesis.

#### Items from the 2015 canary rockfish STAR Panel Report

273	Pre-STAR process to sign-off on input data.	The historical catch data ultimately used in the assessment differed from that which was given in the original draft assessment presented for review at the panel. The review process would be improved by ensuring that any such issues (i.e. disagreements about the best available historical catch) are resolved well in advance of the assessment review meeting. One possible approach might be to have an earlier step in the process intended to sign-off on the input data, analogous to the way that the STAR panel signs-off on the stock assessments. Ongoing efforts to reconstruct Washington catch data, in the way that has already been done for Oregon and California, should help to resolve these issues in the medium term, but until then, there will still be a need to work with agreed, interim catch estimates for inclusion in stock assessments.
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Item #	Item descriptor	Item details as presented in the various documents
274	Develop uncertainty estimates for historical catch series ...	Catch and discard history for this stock in US waters is highly uncertain. While the STAT was able to construct alternative upper and lower bounds for catch using simple multipliers on certain years of historical catch, this is arbitrary. Work to assess the uncertainty related to each individual data source would allow a better investigation of the overall combined uncertainty and its effect on stock assessments.
275	Improved documentation of the process used to construct the historical catch and discard time series ...	Improved documentation is required to clearly outline the process used to construct the historical catch and discard time series from the various data sources. Such documentation should also include the process for construction of alternative catch histories that are used to propagate such uncertainty into the stock assessment.
276	Additional work on the geospatial index ...	Additional work on the geospatial index is required to better resolve differences in abundance trends among areas.
277	Work towards a combined US/Canadian stock assessment ...	Work towards a combined US/Canadian stock assessment would greatly aid our overall understanding of stock status.
278	Sub-divide the trawl fleet into separate bycatch components ...	If data permit, the trawl fleet should be divided into separate components so that bycatches in the shrimp and pelagic trawls are separated from catches in the main bottom trawl fleet. In the current assessment, composition data for the trawl fleet have a major influence on the estimated stock trends, so it would be desirable to use data that are more representative of the main fleet in order to improve estimated selectivity of the fleet.

Item #	Item descriptor	Item details as presented in the various documents
279	Basic life history research to help resolve assessment uncertainties in natural mortality and steepness ...	Basic life history research may help to resolve assessment uncertainties regarding appropriate values for natural mortality and steepness, and how to best account for the apparent loss of older females in the population.

#### **Items from the 2015 chilipepper rockfish update stock assessment document**

280	Explore possible significance of multiple brood production and the spatial or physical drivers.	Although considerable information on the reproductive ecology of this species has been compiled, the possible significance of multiple brood production and the spatial or physical drivers of such factors is highly uncertain and should be explored.
281	Exploration of methods for modeling time-varying growth.	Greater exploration of methods for modeling time-varying growth are essential, there remains a need to explore a model that uses conditional age-at-length data and a need to explore other possible drivers of variable growth rates.
282	Continued evaluation of the coastwide juvenile index.	Continued evaluation of the coastwide juvenile index should be an important element of both future research and future assessments, particularly with respect to the mechanisms that drive such strong variability in cohort strength, and the potential use of a compensatory relationship between pelagic YOY and the population at later ages.

#### **Items from the 2015 China rockfish stock assessment document**

283	Record the number of hours fished in Washington for each dockside sport fishery sample ...	The number of hours fished in Washington should be recorded for each dockside sample (vessel) so that future CPUE can be measured as angler hours rather than just number of anglers per trip. This will allow for a more accurate calculation of effort.
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Item #	Item descriptor	Item details as presented in the various documents
284	Record the number of hours fished in Oregon for each dockside sport fishery sample ...	The number of hours fished in Oregon should be recorded for each dockside sample (vessel), instead of the start and end times of the entire trip. This will allow for a more accurate calculation of effort.
285	Guidance on habitat-based methods vs Stephens-MacCall and other filtering methods for onboard sport fishery observer data.	Compare the habitat-based methods used to subset data for the onboard observer indices to Stephens-MacCall and other filtering methods.
286	Research on the sensitivity of Stephens-MacCall when the target species is “rare”.	Explore the sensitivity of Stephens-MacCall when the target species is “rare” or not common encountered in the data samples.
287	Explore benefits / costs of a standardized fishery independent survey sampling nearshore rockfish in all three states ...	A standardized fishery independent survey sampling nearshore rockfish in all three states would provide a more reliable index of abundance than the indices developed from catch rates in recreational and commercial fisheries. However, information value of such surveys would depend on the consistency in methods over time and space and would require many years of sampling before an informative index could be obtained.
288	Conduct a coastwide evaluation of genetic structure of China rockfish.	A coastwide evaluation of genetic structure of China rockfish is a research priority. Genetic samples should be collected at sites spaced regularly along the coast throughout the range of the species to estimate genetic differences at multiple spatial scales (i.e., isolation by distance).
289	Develop better methods to allocate reconstructed recreational catches to sub-state regions ...	Difficulties were encountered when attempting to reconstruct historical recreational catches at smaller spatial scales, and in distinguishing between landings from the private and charter regions ...

Item #	Item descriptor	Item details as presented in the various documents
		vessels. Improved methods are needed to allocate reconstructed recreational catches to sub-state regions within each fishing mode.
290	Schedule a pre-STAR data workshop to review assessment input data and standardization procedures.	There was insufficient time during the STAR Panel review to fully review the abundance indices used in the China rockfish assessments. Consideration should be given to scheduling a data workshop prior to STAR Panel review for review of assessment input data and standardization procedures for indices, potentially for all species scheduled for assessment. The nearshore data workshop, held earlier this year, was a step in this direction, but that meeting did not deal with the modeling part of index development.
291	Fix problem in analyses of MRFSS data where there were multiple intercept interviews.	The Marine Recreational Fisheries Statistics Survey (MRFSS) index in Oregon was excluded from the assessment model because it was learned that multiple intercept interviews were done for a single trip. Evaluate whether database manipulations or some other approach can resolve this issue and allow these data to be used in the assessment.
292	Evaluate performance of Stephens-MacCall filtering when there are changes in management restrictions and in relative abundance of different species.	Many of the indices used in the China rockfish assessment model used the Stephens-MacCall (2004) approach to subset the CPUE data. Research is need to evaluate the performance of the method when there are changes in management restrictions and in relative abundance of different species. Examination of the characteristics of trips retained/removed should be a routine part of index standardization, such as an evaluation of whether there are time trends in the proportion of discarded trips.

Item #	Item descriptor	Item details as presented in the various documents
293	Explore use of a multi-species approach to develop the CPUE indices for nearshore species.	Fishery-dependent CPUE indices are likely to be the only trend information for many nearshore species for the foreseeable future. Indices from a multi-species hook-and-line fishery may be influenced by regulatory changes, such as bag limits, and by interactions with other species (e.g., black rockfish) due to hook competition. It may be possible to address many of these concerns if a multi-species approach is used to develop the indices, allowing potential interactions and common forcing to be evaluated.
294	Consider the development of a fishery-independent survey for nearshore stocks.	Consider the development of a fishery-independent survey for nearshore stocks. As the current base model structure has no direct fishery-independent measure of stock trends, any work to commence collection of such a measure for nearshore rockfish, or use of existing data to derive such an index would greatly assist with this assessment.
295	Basic life history research to resolve uncertainties for natural mortality and steepness.	Basic life history research may help to resolve assessment uncertainties regarding appropriate values for natural mortality and steepness.
296	Consider modeling discarded catch using selectivity and retention functions rather than inputting discards as part of catch.	Examine length composition data of discarded fish from recreational onboard observer programs in California and Oregon. Consider modeling discarded catch using selectivity and retention functions in Stock Synthesis rather than combining retained and discarded catch and assuming they have identical size compositions. Another option would be to model discarded recreational catch as a separate fleet, similar to the way commercial discards were treated in the southern model.
297	Continue collection and ageing of China rockfish otoliths.	Ageing data were influential in the China rockfish stock assessments. Collection and ageing of China rockfish otoliths should continue. Samples from younger fish not typically selected by the fishery are needed to better define the growth curve.

Item #	Item descriptor	Item details as presented in the various documents
298	Consider evaluating depletion estimators using within season CPUE indices.	Consider evaluating depletion estimators of abundance using within season CPUE indices. This approach would require information on total removals on a reef-by-reef basis.
299	Consider how to further incorporate habitat data into the assessment of nearshore species.	The extensive use of habitat information in index development is a strength of the China rockfish assessment. Consideration should be given to how to further incorporate habitat data into the assessment of nearshore species. The most immediate need seems to be to increase the resolution of habitat maps for waters off Oregon and Washington, and standardization of habitat data format among states.
300	Explore options in stock synthesis to reasonably constrain recruitment deviations.	Although all the current models for China rockfish estimated implausibly large recruitment deviations when allowed to do so, particularly early in the modeled time period, further exploration of available options in stock synthesis could produce acceptable results. In addition, this work may provide guidance on any additional options that could be added to stock synthesis to better handle this situation. For example, assuming different levels autocorrelation in the stock-recruit relationship for data-moderate stocks may help curb the tendency to estimate extreme recruitment with sparse datasets.
301	Research needed on data-weighting methods in stock assessments.	Research is needed on data-weighting methods in stock assessments. In particular, a standard approach for conditional age-at-length data is needed. The Center for the Advancement of Population Assessment Methodology (CAPAM) data weighting workshop, scheduled for later this year, should make important progress on this research need.

#### Items from the 2015 China rockfish STAR Panel Report

Item #	Item descriptor	Item details as presented in the various documents
302	Conduct a coastwide evaluation of genetic structure of China rockfish.	A coastwide evaluation of genetic structure of China rockfish is a research priority. Genetic samples should be collected at sites spaced regularly along the coast throughout the range of the species to estimate genetic differences at multiple spatial scales (i.e., isolation by distance).
303	Improved methods are needed to allocate reconstructed recreational catches to sub-state regions ...	Difficulties were encountered when attempting to reconstruct historical recreational catches at smaller spatial scales, and in distinguishing between landings from the private and charter vessels. Improved methods are needed to allocate reconstructed recreational catches to sub-state regions within each fishing mode.
304	Schedule pre-STAR data workshop for review of assessment input data and index standardization procedures.	There was insufficient time during the STAR Panel review to fully review the abundance indices used in the China rockfish assessments. Consideration should be given to scheduling a data workshop prior to STAR Panel review for review of assessment input data and standardization procedures for indices, potentially for all species scheduled for assessment. The nearshore data workshop, held earlier this year, was a step in this direction, but that meeting did not deal with the modeling part of index development.
305	Fix problem in analyses of MRFSS data where there were multiple intercept interviews.	The Marine Recreational Fisheries Statistics Survey (MRFSS) index in Oregon was excluded because it was learned that multiple intercept interviews were done for a single trip. Evaluate whether database manipulations or some other approach can resolve this issue and allow these data to be used in the assessment.

Item #	Item descriptor	Item details as presented in the various documents
306	Evaluate performance of Stephens-MacCall filtering when there are changes in management restrictions and in relative abundance of different species.	Many of the indices used in the China rockfish assessment model used the Stephens and MacCall (2004) approach to subset the CPUE data. Research is need to evaluate the performance of the method when there are changes in management restrictions and in relative abundance of different species. Examination of the characteristics of trips retained/removed should be a routine part of index standardization, such as an evaluation of whether there are time trends in the proportion of discarded trips.
307	Explore use of a multi-species approach to develop the CPUE indices for nearshore species.	Fishery-dependent CPUE indices are likely to be the only trend information for many nearshore species for the foreseeable future. Indices from a multi-species hook and line fishery may be influenced by regulatory changes, such as bag limits, and by interactions with other species (e.g. black rockfish) due to hook competition. It may be possible to address many of these concerns if a multi-species approach is used to develop the indices, allowing potential interactions and common forcing to be evaluated.
308	Consider the development of a fishery-independent survey for nearshore stocks.	Consider the development of a fishery-independent survey for nearshore stocks. As the current base model structure has no direct fishery-independent measure of stock trends, any work to commence collection of such a measure for nearshore rockfish, or use of existing data to derive such an index would greatly assist with this assessment.
309	Basic life history research to resolve uncertainties for natural mortality and steepness.	Basic life history research may help to resolve assessment uncertainties regarding appropriate values for natural mortality and steepness.
310	Collection and ageing of China rockfish otoliths should continue.	Ageing data were influential in the China rockfish stock assessments. Collection and ageing of China rockfish otoliths should continue. Samples from younger fish not typically selected by the fishery are needed to better define the growth curve.

Item #	Item descriptor	Item details as presented in the various documents
311	Consider evaluating depletion estimators using within season CPUE indices.	Consider evaluating depletion estimators of abundance using within season CPUE indices. This approach would require information on total removals on a reef-by-reef basis.
312	Consider how to further incorporate habitat data into the assessment of nearshore species.	The extensive use of habitat information in index development is a strength of the China rockfish assessment. Consideration should be given to how to further incorporate habitat data into the assessment of nearshore species. The most immediate need seems to be to increase the resolution of habitat maps for waters off Oregon and Washington, and standardization of habitat data format among states.
313	Explore options in stock synthesis to reasonably constrain recruitment deviations.	Although all the current models for China rockfish estimated implausibly large recruitment deviations when allowed to do so, particularly early in the modeled time period, further exploration of available options in stock synthesis could produce acceptable results. In addition, this work may provide guidance on any additional options that could be added to stock synthesis to better handle this situation. For example, assuming different levels autocorrelation in the stock-recruit relationship for data-moderate stocks may help curb the tendency to estimate extreme recruitment with sparse datasets.
314	Simulation-estimation evaluation of data moderate assumptions (asymptotic selectivity, no rec-devs).	The China rockfish models made a number of simplifying assumptions, such as asymptotic fishery selectivity, and no deviations from the stock-recruit curve. It would be worthwhile to conduct a simulation-estimation exercise to evaluate potential errors associated with the assumptions commonly made for data-moderate assessments that use length and age data.
315	Research needed on data-weighting methods in stock assessments.	Research is needed on data-weighting methods in stock assessments. In particular, a standard approach for conditional age-at-length data is needed. The Center for the Advancement of Population Assessment Methodology (CAPAM) data weighting

Item #	Item descriptor	Item details as presented in the various documents
		workshop, scheduled for later this year, should make important progress on this research need.
<b>Items from the 2015 darkblotched rockfish stock assessment document</b>		
316	Additional population genetics research to elucidate potential spatial stock structure.	Additional population genetics research to elucidate potential spatial stock structure would be valuable for assessment and management, to ensure prevention of local depletion and preserve genetic diversity.
317	Additional research on darkblotched movement ...	Additional research on darkblotched movement including migration patterns by latitude and depth, diurnal migration patterns through the water column, relative time spent off-bottom versus midwater, relating movements to size, age and sex would be valuable for further understanding this rockfish's ecological niche, stock structure, and lend insight to catchability and gear selectivity patterns.
318	Evaluate the impact of not accounting for any Canadian portion of population ...	Given that the population range extends north to the border with Canada, it is important that future research would evaluate the impact of not accounting for any Canadian portion of population abundance. Such an analysis would require evaluation of movement of darkblotched along the coast; such information is currently lacking.
319	Continued collection and analysis of maturity and fecundity data ...	Continuing collection of maturity and fecundity data on darkblotched rockfish would allow further research into latitudinal variability in life history parameters that again would advance understanding this species stock structure. Multi-year data would also allow evaluation of temporal changes in darkblotched maturity and fecundity.



Item #	Item descriptor	Item details as presented in the various documents
320	Additional research into natural mortality, as it relates to length and age ...	Additional research into natural mortality, as it relates to length and age would be valuable to enable more realistic and accurate modeling of this parameter, which is a common source of uncertainty in assessment of this, and other rockfish species. The Councill and Harford method is an example of one approach; it models natural mortality as a decaying function of size, with assumptions that mortality rates should be constrained by lifetime mortality rate.
321	Research to improve existing meta-analyses for natural mortality and steepness ...	Future research could also improve existing meta-analyses for natural mortality and steepness, which both contribute to the implied yield curve. Directions for improvements could include (1) weighting methods in natural mortality prior estimates included in the Hamel meta-analysis, and (2) developing a larger database of species for estimating steepness, perhaps by including species from other regions, e.g., Canada and Alaska.
322	Research to establish optimum methods for modeling selectivity patterns ...	Research into establishing optimum methods for more precise modeling of selectivity patterns is needed. Either asymptotic or dome-shaped selectivity assumptions are frequently used in stock assessments, when neither may be the best available representation of selectivity. Assumptions of a dome shape can suggest a “cryptic” biomass, or create confounding with natural mortality assumptions, potentially inflating abundance indices (Crone et al. 2013). Assumptions of asymptotic shape may also not be realistic. Simulation studies could be performed to empirically evaluate varying degrees of intermediate selectivity shapes, and how best to effectively implement them in existing stock assessment software platforms.

Item #	Item descriptor	Item details as presented in the various documents
323	Explore possible influence of the "warm blob" ...	Research assessing the effects of the unprecedented warm ocean conditions off the West Coast of the U.S. during 2014 and 2015, on rockfish populations is needed. Specifically, investigations are needed that focus on how temperature and other water conditions at depth, in rockfish habitat correspond to high sea-surface temperatures recorded throughout those years, and how the fish respond to those changing conditions. Research is needed that examines whether fish move in response to changing temperatures, where, and how they move, as well as whether the conditions influence life history parameters and aspects such as mortality, feeding, fecundity and other reproductive considerations. What oceanographic and climatic forces are responsible and how long these conditions are expected to persist are also critical pieces of knowledge.

#### **Items from the 2015 darkblotched rockfish STAR Panel Report**

324	Develop uncertainty estimates for historical catch series ...	Catch and discard history for this stock in US waters is highly uncertain. While the STAT was able to construct alternative upper and lower bounds for catch using simple multipliers on certain years of historical catch, this is arbitrary. Work to assess the uncertainty related to each individual data source would allow a better investigation of the overall combined uncertainty and its effect on stock assessments.
325	Improved documentation of the process used to construct the historical catch and discard time series ...	Improved documentation is required to clearly outline the process used to construct the historical catch and discard time series from the various data sources. Such documentation should also include the process for construction of alternative catch histories that are used to propagate such uncertainty into the stock assessment.

Item #	Item descriptor	Item details as presented in the various documents
326	Develop an index for the older fish in this stock ...	It is highly undesirable that the lack of an abundance index for the older fish in the population most affected by fishing (particularly in recent years) forces the model to rely on composition data for information on abundance trends. Unfortunately, such an index is currently unavailable, but would have the potential to considerably improve future stock assessments if commenced in the future.
327	Work towards a combined US/Canadian stock assessment ...	Work towards a combined US/Canadian stock assessment should be pursued.

#### Items from the 2015 kelp greenling stock assessment document

328	Develop fishery-independent surveys of abundance for nearshore species ...	Fishery-independent surveys of abundance for nearshore species, including Kelp Greenling, would provide information about population trends that don't rely on data collected directly from the fishery and the inherent complexities that those data entail. Surveys that result in a time series of information covering a representative spatial extent of the population would be most advantageous.
329	Improved data collection of the recreational shore and estuary-boat fleets ...	Improved data collection relevant to basic fishery statistics (catch/effort) for recreational shore and estuary-boat fleets, including biological sampling where possible, to monitor changes in these highly dynamic fishing modes.
330	Collection of kelp greenling gender information by Ocean Recreational Boat Samplers (ORBS).	The collection of gender-specific information is generally straightforward given the visual ease (color and markings) of identifying adult Kelp Greenling by gender and the collection of this information should be implemented for Ocean Recreational Boat Samplers (ORBS).

Item #	Item descriptor	Item details as presented in the various documents
331	Conduct double-reads of Kelp Greenling otoliths.	The double reading of Kelp Greenling otoliths would provide some indication into error and bias for this influential source of information.
332	Research into Kelp Greenling stock structure ...	Kelp Greenling stock structure needs to be studied and the results accounted for in future assessments. In particular, ontogenetic and gender-related movement according to offshore depth and spawning seems plausible for Kelp Greenling, and data to support that hypothesis would be beneficial for future assessments.
333	Explore implications and complexities of managing a stock where both genders contribute to spawning potential ...	Research into the implications and complexities of managing a stock where both genders contribute to spawning potential (e.g., through a Management Strategy Evaluation) would help guide future assessments and management for species such as Kelp Greenling (males exhibit nest-guarding behavior).

#### **Items from the 2015 kelp greenling STAR Panel Report**

334	Develop estimates of reader error for kelp greenling.	Acquire estimates of reader error for kelp greenling through routine double-reading samples of otoliths rather than relying on error estimates for other species, which may not accurately reflect actual read errors for this species.
335	Acquire more age-readings, particularly of younger fish in estuaries.	Acquire more age-readings, particularly of younger fish caught in the shore based or estuary fisheries, and try to estimate the full set of growth parameters.

Item #	Item descriptor	Item details as presented in the various documents
336	Consider seasons or a shorter time step for the model than a year to fix issue of estimating very rapid growth ...	Consider seasons or a shorter time step for the model than a year (e.g., a quarter) or request a modification to Stock Synthesis to allow non-integer growth increments to increase accuracy for the estimated growth rate and error.
337	Begin composition data weighting with the number of samples.	Composition data weighting should start with the number of samples as the effective sample size rather than the number of fish.
338	Sample catches from the shore and estuary fisheries ...	Sample catches from the shore and estuary fisheries so that they can be estimated and characterized.
339	Explore later model starting point, where removals become more reliable ...	Explore starting the model at the historical point where removals become more reliable (e.g., 1970-1980) and estimate initial conditions reflecting prior exploitation such as free numbers at age and an offset to equilibrium recruitment.
340	Consider estimating recruitment deviations for the entire model period.	Consider estimating recruitment deviations for the entire time-period of the assessment model.
341	Density estimates from visual surveys and other methods to derive a prior for unexploited biomass ...	Density estimates from visual surveys and other methods could be used to derive a prior for unexploited biomass (perhaps transformed to R0). This could help with the very poorly estimated scale in the current assessment.
342	Consider a single stock assessment model for Washington, Oregon and California ...	Future assessments should consider assessing a single stock for Washington, Oregon and California; this analysis could include explicit spatial areas and or state-based fleets as necessary. This was also a specific recommendation of the 2005 STAR panel. Expanding

Item #	Item descriptor	Item details as presented in the various documents
		the spatial scale could make the interpretation of steepness based on life history theory more straightforward.
343	The next kelp greenling assessment should be an update ...	The next assessment should be an update, given the status and trends. There is no urgency to update the assessment, unless negative trends appear in biological or catch-rate data.
344	Consider a different target SPR rate for kelp greenling ...	Given current estimates of growth and natural mortality, kelp greenling is probably much more productive than an F45% policy would imply. None of the data series show any signal of depletion. The SSC may wish to consider recommending a different target SPR rate for this species.
345	Guidance on starting from an exploited state to avoid problems of extreme historical catch uncertainty.	It may be more accurate in some circumstances to consider when historical catch history is so uncertain that the model should be started in a later year with the initial depletion estimated by the model.
346	Consider the development of a coastwide fishery-independent survey for nearshore stocks.	Consider the development of a coastwide fishery-independent survey for nearshore stocks. Any work to commence collection of such a measure for nearshore stocks, or use of existing data to derive such an index would greatly assist with this assessment.
347	Clean up the MRFSS database and fully document it.	MRFFS data are difficult to use properly, making quantities derived from it potentially unreliable. Broadly, the MRFSS database needs to be cleaned (e.g., removing derived estimates that are not easily identified as such and that currently appear to be observed ‘data’), better documented, and made more accessible for future assessment authors. It is

Item #	Item descriptor	Item details as presented in the various documents
		important that the work of cleaning and interpreting these data not have to be repeated for each assessment. No further MRFSS data will ever be collected.
348	Evaluation of the Stephens-MacCall method for filtering recreational CPUE data.	For CPUE abundance indices, further evaluation of the Stephens-MacCall method would be valuable to ensure that the filtering method is robust. For example, the Stephens-MacCall method for filtering logbook records produced anomalous inclusion of the same species as both a positive and negative indicator in similar datasets. Pooling among similar series (e.g., charter boats and private boats from the same areas) to develop the filtering criteria could make this more stable. More generally, a multi-species simulation study to test whether the Stephens-MacCall filtering may lead to a bias in abundance estimates given differences in abundance trends among species should be considered. It is the understanding of the panel that some simulation testing has been done; these results should be made generally available. A comparison of alternative filtering procedures should also be considered.
349	Definition and measurement of habitat for nearshore species such as kelp greenling ...	Definition and measurement of suitable habitat for nearshore species such as kelp greenling, especially when combined with density estimates, would assist assessments, particularly as an independent indicator of plausible relative scale of modeled virgin biomass by area/region/state.
350	Age-reading effort should routinely include double-reads for estimating ageing error.	Whenever age-readings are done, some portion of the effort should routinely include double-reads for estimating ageing error.

Item #	Item descriptor	Item details as presented in the various documents
351	Develop an alternative likelihood for compositional data (condition length on age) ...	Consider developing an alternative likelihood formulation for compositional data (condition length on age) to make better use of ages to inform on population age structure where a significant proportion of aged fish are within one standard deviation of the asymptotic length. This would be limited to sampling that is random with respect to age or length.

#### Items from the 2015 petrale sole update stock assessment document

352	Complete a Washington historical catch reconstruction for flatfish species.	In the past many assessments have derived historical catches independently. The states of California and Oregon have completed comprehensive historical catch reconstructions. At the time of this assessment, a comprehensive historical catch reconstruction is not available for Washington. Completion of a Washington catch reconstruction would provide the best possible estimated catch series that accounts for all the catch and better resolves historical catch uncertainty for flatfish as a group.
353	New studies on petrale sole maturity and fecundity relationships.	Due to limited data, new studies on both the maturity and fecundity relationships for petrale sole would be beneficial.
354	Re-age surface reads using break-and-burn.	Where possible, historical otolith samples aged using a combination of surface and break-and-burn methods should be re-aged using the break-and-burn method. Early surface read otoliths should also be re-aged using the break-and-burn method. Historical otoliths aged with a standard method will allow the further evaluation of the potential impacts of consistent under ageing using surface methods, changes in selectivity during early periods of time without any composition information, and potential changes in growth.



Item #	Item descriptor	Item details as presented in the various documents
355	IFQ program influence on fleet behavior (discards, fishery selectivity, and fishing locations) ...	The effect of the implementation of the IFQ (catch shares) program that began during 2011 on fleet behavior, including impacts on discards, fishery selectivity, and fishing locations would benefit from further study.
356	Studies on stock structure, seasonal movement of petrale sole, and US / Canada movements.	Studies on stock structure and movement of petrale sole, particularly with regard to the winter-summer spawning migration of petrale sole and the likely seasonal trans-boundary movement of petrale sole between U.S. and Canadian waters.
357	Spatial variability in productivity processes such as growth, recruitment, and maturity.	The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research.

**Items from the 2015 sablefish update stock assessment document**

358	Continue the annual NWFSC Shelf-Slope trawl survey.	Continuation of the annual NWFSC Shelf-Slope trawl survey will improve the precision of estimates of absolute stock size and productivity, which are reliant upon observing some contrast in stock trend (other than a one-way trip) with an unbroken survey index. Only a longer, more informative survey time-series will provide stock-specific and data-based information on the steepness parameter governing the sablefish stock-recruit relationship
359	Update all relative survey indexes using the latest methods ...	Update all relative survey indexes of abundance to use the latest delta-GLMM methods and investigate additional model structures.

Item #	Item descriptor	Item details as presented in the various documents
360	Evaluate potential causes of residual patterns ...	Evaluate potential causes of residual patterns in the fit to larger cohorts in the age data (particularly the 1999 and 2000 cohorts) and to the size data (particularly for the hook-and-line fishery).
361	Evaluate potential causes of residual patterns ...	Evaluate potential causes of residual patterns in the fit to discard data, particularly for the pot fishery with respect to the early years of recorded discards.
362	Greater standardization of state and federal biological sampling programs to reduce sampling variability ...	Compared to other groundfish, age sampling of sablefish from the commercial fishery has generally been sparse. Work toward further standardization of state and federal biological sampling programs to reduce sampling variability would make the data more informative. For example, in a given year at least one state collects sexed-length observations, while at least one does not. If an increased fraction the catch was available for sampling at-sea, or in-port in a non-dressed form, then more consistent demographic information could result.
363	Investigate more precise aging methods ...	Investigate aging methods that could prove more precise than current break-and-burn methods. More accurate age data would facilitate tracking cohorts to older ages, improving estimates of historical year-class strengths. Further studies to investigate the potential for bias in aging methods should be conducted; these results will have a strong effect on natural mortality estimates.
364	Guidance on how to treat unsexed samples.	Explore the effect of assigning unsexed fishery composition data to males and females using a 50:50 ratio or some other justified sex ratio, versus excluding the samples as was done in the 2011 assessment.

Item #	Item descriptor	Item details as presented in the various documents
365	Continue to monitor and explore differences in discard rates ...	Continue to monitor and explore differences in discard rates with the implementation of the catch share system.
366	Routine sampling to refine maturity and fecundity estimates.	Routine collection of samples to refine estimates of biological parameters, particularly maturity and fecundity, could increase the reliability of this assessment.
367	Continued refinement of the historical landings estimates for Washington ...	Continued refinement of the historical landings estimates for Washington, subsequent to the large data entry of historical fish-ticket information currently underway, will likely produce a more accurate time-series of mortality and would complement the completed efforts to reconstruct California and Oregon landings.
368	Evaluate spatial aspects, including the northern boundary with Canada, and the connectivity with offshore seamounts.	Given the migratory nature and broad distribution of sablefish along the Pacific Rim, it is important to continue to evaluate the spatial aspects of the assessments, including the northern boundary with Canada, and the connectivity with offshore seamounts. A joint assessment with Canadian and Alaskan scientists could be warranted, following the approach taken by the International Pacific Halibut Commission.
369	Continue to evaluate methods to capture information on environmental and ecosystem variability ...	Continue to evaluate methods to capture information regarding environmental and ecosystem variability in stock assessments. Further, historical records of particularly large year classes (e.g., 1947 reported by sport fishermen in central California) could be investigated to better inform the historical period.
370	Explore the accuracy of the dressed to whole weight conversions ...	There is uncertainty in the accuracy of the dressed to whole weight conversions used in some situations to estimate fishery landings. Following Oregon's lead, this topic should be

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		investigated, and total landed catch estimates adjusted, according to the best available conversion information.

#### Items from the 2015 widow rockfish stock assessment document

371	Improved historical catches and a measure of uncertainty on the historical landings ...	The historical landings and discards are uncertain for Widow Rockfish and improvements would increase the certainty that fishing removals are applied appropriately. Because landings are assumed to be known exactly in the assessment model, uncertainty in the predictions does not include uncertainty in the landings. A thorough look at historical landings, species compositions, and discarding practices would potentially account for and possibly reduce the uncertainty. More importantly, though, a measure of uncertainty on the estimated historical landings would allow for reasonable sensitivities to be investigated.
372	Better use of data to improve estimates of natural mortality ...	Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for Widow Rockfish. The collection of additional age data, re-reading of older age samples, reading old age samples that are unread, and improved understanding of the life-history of Widow Rockfish may reduce that uncertainty.
373	Maturity and fecundity studies for widow rockfish.	There are few studies on the maturity of Widow Rockfish and even less recent information. There have been no studies that reported results of a histological analysis. Further research on the maturity and fecundity of Widow Rockfish, the potential differences between areas, the possibility of changes over time would greatly improve the assessment of these species.

Item #	Item descriptor	Item details as presented in the various documents
374	Investigating the ageing error and bias for widow rockfish.	There is a considerable amount of error in the age data and potential for bias. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment.
375	Basin-wide understanding of stock structure, biology, connectivity, and distribution.	This is a stock assessment for Widow Rockfish off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between Widow Rockfish north and south of the U.S.-Canada border.

#### **Items from the 2015 widow rockfish STAR Panel Report**

376	Exclude or reconcile anomalies in the weight-length data from the PacFIN Biological Data System.	Minor anomalies in the weight-length data from the PacFIN Biological Data System (BDS) should be excluded or reconciled.
377	Conduct a reanalysis of the foreign at-sea index that best overlaps the period of largest stock decline ...	A reanalysis of the foreign at-sea index that best overlaps the period of largest stock decline could be conducted before the next assessment. In particular, an analysis should consider effort measures that include search as well as towing time, given the schooling nature of this species. Other fishery indices are unlikely to have an appreciable impact on the results and may not be worth reanalyzing.

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378	Consider widow rockfish in any future discussions about trans-national stocks.	Widow rockfish should be considered in any future discussions about trans-national stocks. Although a joint assessment with Canada may be difficult to arrange, it should be explored. It is possible that lack of information from Canada affects estimates of productivity and, in particular, steepness. Until such time as a joint assessment can be conducted, evaluation of relative catches and trend information on abundance in Canadian waters would also be helpful. Potential exchange also clouds the clear interpretation of what represents steepness for this stock.
379	Collect and analyze updated maturity data given current stock distribution ...	Updated maturity data representing the current stock distribution should be collected and analyzed, preferably using histological methods.
380	Explore letting the steepness prior inform the estimation.	Since there was so little information in the data on steepness, the informative prior might be strong enough to allow for estimation in future assessments. This should be explored.
381	Remove the juvenile survey index given its very high estimated variance.	Based on the variability estimated for the juvenile index, it should be removed from future analyses unless it can be improved and validated. Specifically, the estimated variance is greater than the RMSE of the recruitments, so it will add more noise than signal at the end of the time-series when there are no other data to inform recruitment. This decreases the predictive ability of the model.
382	Report (and include) recreational removals of widow rockfish ...	Although recreational removals are low in relation to other removals for this stock, these should at least be reported in a table for comparison in future documents.

Item #	Item descriptor	Item details as presented in the various documents
383	Consider including Hook & Line and Net removals in other fleets ...	It may improve the model if the H&L and NET fisheries are combined with other fleets, as these represent very little removals and noisy data. Removals of these data did not appreciably change the results for this assessment and their selectivity showed similar patterns to other fleets. Removing these as separate fleets would likely to make the modelling simpler with no loss of signal.
384	Use fishery conditional age at length compositional data as run-time permits.	Select one or more fleets (as run-time allows) and create conditional age at length data in order to inform growth and selectivity from more than just the most recent years where survey data are available.
385	Pre-STAR data workshop to consider data and standardization procedures.	A specific data workshop, perhaps for all species prioritized for assessment, could examine information across a broad range of species due for assessment, and would also assist with the development of more specific documentation of protocols used to compile best available data sets for stock assessment, continue acceptance of agreed procedures for standardization of abundance indices, and also begin work on procedures for the development of alternative data series that capture uncertainty, particularly for historical catch and discards.
386	Develop objectives procedures for evaluating stock boundaries ...	Additional work is required to further develop an objective procedure for evaluating the chosen stock boundaries across all rockfish (and potentially all other) assessments may be beneficial, and also more directly point to required directions for future research or assessment collaboration across national/international political boundaries. Further investigation is required for whether the stock boundaries assumed in the assessment are appropriate for management as well as scientific assessment.

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387	Conduct detailed examination of input data independent of the stock assessment (e.g., to inform potential strata).	There is a need for more detailed examination of input data independent of the stock assessment, particularly in relation to sample size and representativeness. An examination of data sources by year and sub-area in particular may suggest appropriate methods for post-stratification of composition data. Potential stratification that should be considered should include season, latitude, depth, and boat type.
388	Report on how recommendations (data workshop and previous CIE reviewers) were addressed.	Reports should include a section on how the recommendations from any data workshop and previous CIE reviewers were addressed. This would be an extension of the section for addressing previous STAR Panel recommendations (Appendix B in the 2014 Terms of Reference).
389	Additional work is required on catch histories (e.g., uncertainty from plausible ranges for %species).	Additional work is required in developing catch histories. An evaluation of the plausible range of proportions of species in the aggregated catch on the reconstructed catch time series is recommended. It would be most useful not only to provide single best estimates, but to define ranges suitable for use in bracketing uncertainties and sensitivity analyses.
390	Formal historical catch reconstruction for WA ...	The state of Washington still needs a formal catch reconstruction to standardize approaches across assessments and ensure the best available estimates are being used.



Item #	Item descriptor	Item details as presented in the various documents
391	Objective procedure for identifying sub-model error structure in delta-GLMMs ...	An objective procedure for identifying sub-model error structure (usually gamma or lognormal here) is required for delta-GLM procedures. Consistency is required for the model selection process, preferably using a priori candidate models rather than a stepwise selection. The standard delta-GLM procedure should allow for different factors to be considered in the binomial and sub-models. A standard set of diagnostics should be provided to review panels for each abundance index including: plots of the binomial and positive catch rate year effects in addition to the combined year effects; plots of all estimated effects; production of year:area interactions. The effects of the standardization on the “nominal” or unstandardized indices should also be shown and explained (i.e., which variables have caused a shift in the trend). It may be far more efficient to produce and review this output for groups of species together, rather than try to include it in each species-specific review.
392	Report the extreme catch encounter probability in ECE / delta-LGMM models ...	Reporting the extreme catch encounter probability in the ECE models would be an interesting diagnostic and additional piece of information for understanding how frequent exceptional catches are estimated to be.
393	Expand and weight conditional age at length data ...	Expand and weight conditional age at length data to accurately represent both the sampling process and the numbers of fish predicted in each strata. This achieves logical consistency among data sets, choices of the number of length bins, and imparts the greatest amount of orthogonal information possible to the assessment model. Where length sampling is random, marginal length data should be associated with conditional age at length data (by year and fleet) such that the recruitment information contained in the ages is not lost relative to what would be included if using marginal age compositions.

Item #	Item descriptor	Item details as presented in the various documents
394	Develop an objective procedure for using maximum age with a natural mortality prior ...	An objective procedure using maximum age for a natural mortality prior needs to be developed and fully explored. Specifically, unless age samples were collected prior to significant exploitation, the oldest fish may be missing from the observed data, ageing error will tend to bias the maximum age to higher values and there may be sampling bias (e.g. domed selectivity). A percentile based method (e.g. use the 90th percentile) is likely to be more robust than using the single maximum age. Other information (e.g., GSI, growth, exploitation rates etc.) should be included, where possible in the derivation of the M prior.
395	Develop process for conducting a likelihood profile over uncertain rec-dev estimates ...	Where there is significant uncertainty in a very recent recruitment estimate (informed by very little data), it may be helpful to perform a likelihood profile over the strength of that year-class (running the model adjusting that deviation in the par file and using a “noest” option) to see where the primary signal was coming from.
396	Develop tool for aggregated residual plots (weighted and combined across all fleets) ...	Aggregated residual plots (weighted and combined across all fleets would help to understand whether the model is fitting the available data adequately, even where patterns in residuals might show trade-off among fleets. This could reduce the over interpretation of residual patterns within the fit to a single fleet.
397	Develop standard process for iterative reweighting when there are length plus age data ...	Where there are marginal age- and length-compositional data being used from the same fish, iterative reweighting should be done first, then at the final stage an additional multiplier of 0.5 should be applied and no additional iteration performed. This retains the goals of both logically consistent reweighting and down weighting the doubly-used data.
398	More routine use of MCMC ...	MCMC results are a useful tool to measure uncertainty and diagnose problems in the assessment as well as provide an alternative to MLE-based results, which can differ

Item #	Item descriptor	Item details as presented in the various documents
		appreciably in terms of point estimates and uncertainty (Stewart et al. 2013). MCMC should be routinely used and reported where possible.
399	Include at least one diagnostic model run with the full time-period of estimated recruitment deviations ....	Producing at least one model run with the full time-period of estimated recruitment deviations would be a very helpful diagnostic and could be a plausible base case depending on the model behavior.
400	Use monitoring of the most reliable indices to trigger full assessments ...	Triggering a future full assessment could be based on monitoring the most reliable indices, such as surveys with confidence bounds. In comparing observed and predicted values, values outside confidence limits may suggest a higher priority for more immediate assessment.
401	Develop procedures for examining sources of information that identify strong recruitment events ...	Procedures for examining sources of information on recruitment events is required. This could include profile over recruitment events or partition likelihood components.
402	Develop tools to examine observed and expected sex ratio by age and through time ...	A method to examine observed and expected sex ratio by age and through time would resolve questions about the consistency of sex ratios being produced for the modeled population.
403	Develop tools to create residual plots that are weighted across data sources ...	Developing residual plots that are weighted across data sources would allow comparisons to be made that might help to identify common patterns.

Item #	Item descriptor	Item details as presented in the various documents
404	Remove the Stock Synthesis feature that limits composition data weights to be greater than 1.	Removal of the re-scaling to 1 problem after weighting is applied to composition data
405	Develop standard procedures for selecting the most appropriate data weighting system.	Development of standard procedures for the selection of the most appropriate weighting system that should be applied to input data (additional sd for indices, harmonic mean/Francis/other for length and marginal age comps, harmonic mean/Francis/other for conditional age-at-length data).

#### Items from the 2017 arrowtooth flounder stock assessment

406	Reevaluation and reconstruction of historical flatfish removals, including Arrowtooth Flounder.	Historical estimates of discards are a large contributor to total removals. The current modelling exercise of using co-occurring flatfish species as predictors of discard could use further exploration. The Arrowtooth Flounder catch history for Washington should be reconstructed using all available data including catch by gear and by region. The reconstruction should include an envelope of high and low values to set bounds for exploration of alternative catch histories. As has been recommended previously by a variety of STAR Panels, the reconstruction of historical landings needs to be done comprehensively (i.e., with other species) to ensure efficiency and consistency.
407	Exploration of foreign fleet catches of flatfish.	There were large removals of rockfish species by foreign fleets during the mid-1960s to mid-1970s (Rogers, 2003). We were unable to locate information on possible removals of flatfish species by the foreign fleet but it seems likely that some flatfish catches occurred. This should be explored for the next assessment of Arrowtooth Flounder and may also be relevant for the assessment of Dover Sole.

Item #	Item descriptor	Item details as presented in the various documents
408	Reevaluation of the value of stock-recruitment steepness for Arrowtooth Flounder.	In the base case model, steepness was set at 0.902 based on Dorn's meta-analysis (personal communication). While model results are not sensitive to the value of steepness, it would have an effect on MSY calculations and OFL and ABC values at lower stock sizes.
409	Research to provide information on survey catchability.	The absolute scale of the stock is still quite uncertain. The calculated catchability associated with the NWFSC slope-shelf trawl survey ranges from 0.2 to 0.8 across the three states of nature.
410	Evaluation of stock boundaries and the feasibility of a bilateral assessment with Canadian scientists.	This could perhaps be accomplished through the Technical Subcommittee of the US Canada groundfish working group.
411	Explore source of discrepancies between CalCOM and PacFIN compositional data.	Given concerns that the PacFIN system may include biological data for California that are not fully compatible with the software used to process the PacFIN data to produce expanded compositional data, we obtained expanded data from CalCOM (D. Pearson, SWFSC) but they did not appear reasonable (see Figure 9). The source(s) of these discrepancies should be investigated and resolved. Ideally the information from all three states should be housed in PacFIN because this would allow development of standardized data processing and error-checking and facilitate the development of stock assessments.
412	Evaluation of maturity and fecundity relationships.	New studies on both the maturity and fecundity relationships for Arrowtooth Flounder would be beneficial. The maturity versus length relationship used in this update and the 2007 assessment is based on a study done in 1993.

Item #	Item descriptor	Item details as presented in the various documents
413	Age-reading error study.	The age-reading errors assumed for this assessment were taken directly from the 2007 assessment; that assessment took the standard deviation of aging error from an assessment of English Sole. A study is needed to conduct and analyze cross-readings of Arrowtooth Flounder otoliths (surface and break-and-burn reads) to develop improved ageing error vectors for the next assessment of Arrowtooth Flounder (even if it is only an update assessment).
414	Age-reading of otoliths from the fishery off California.	A collection of unread Arrowtooth Flounder otoliths that is available for fish landed in California should be read to provide possibly more representative age-at-length compositions for the fishery. The fishery age-at-length compositions in this update assessment were based entirely on fish landed in Oregon and Washington.
415	Evaluation of the spatial variability of productivity processes.	The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research. This stock shows clear evidence of a latitudinal gradation in abundance and other traits.

#### **Items from the 2017 stock assessment process review meeting report**

416	Require STATs to detail changes to the assessment from the pre-STAR draft ...	Prepare a detailed list of changes to the assessment from the pre-STAR draft originally distributed (e.g., an errata sheet). To the extent possible, there should not be extensive changes to an assessment after the pre-STAR draft is distributed.
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Item #	Item descriptor	Item details as presented in the various documents
417	Require STATs to prepare a formal written response to STAR requests ...	STATs prepare a formal response to STAR requests with a written explanation of how the new analysis affected model results. It is helpful when STATs provide extractable figures and/or tables with their responses to STAR requests.
418	ToR should more clearly define documentation needed for STAR-rejected assessments ...	The Terms of Reference needs to be clear on the process and level of documentation needed when an assessment is rejected by the STAR panel or withdrawn by the STAT and not recommended for mop-up. For example, in the case of yellowtail rockfish south, the STAT withdrew the assessment and it was not clear what documentation the STAT needed to provide in the assessment document.
419	Produce stand-alone documentation of key data sources.	Better stand-alone documentation of key data sources is needed.
420	Guidance on selecting the maximum age used in the prior for natural mortality.	Better guidance on selecting max age for an M prior is needed.
421	Establish an August GFSC meeting for pre-approval of assessments before SSC review.	Formally establish an August GFSC meeting for pre-approval of assessments before they are reviewed by the full SSC.
422	Carefully review the Accepted Practices guidelines.	Carefully review the Accepted Practices guidelines. For example, should STATS be required to provide a sensitivity run that used Dirichlet multinomial data weighting?

Item #	Item descriptor	Item details as presented in the various documents
423	Establish formal pre-assessment workshops to evaluate data and methods for index development.	Emphasize need for pre-assessment workshops to evaluate data. Need to carefully evaluate the timing of data workshops and guidance on the types of data displays and analyses that would aid in efficiently evaluating assessment data in advance of a STAR panel. This is connected to a thorough QA/QC of data archived in PacFIN and RecFIN.

#### **Items from the 2017 blackgill rockfish update stock assessment document**

424	Research to reduce uncertainty in ageing error and possible bias ...	Age estimates are highly uncertain, and this species has proven very difficult to age. There is some indication of aging bias between ages developed for the 2011 assessment and for this update, despite the fact that they were aged by the same reader, using the same criteria. Conducting cross reads with other laboratories, as well as additional age validation, are important factors for future efforts.
425	Improved information on maturity ...	Histology studies have shown that this species is slow to mature and often undergoes abortive maturation, particularly at younger ages (smaller sizes), complicating maturity estimates. There also appear to be latitudinal clines in growth, maturity and potentially other life history parameters that are not accounted for in the model.
426	Reanalysis of historical catch to account for shifts in fishing depth ...	Despite considerable investment in catch reconstruction efforts, historical catches remain uncertain for this stock due to the lack of historical species composition data and spatial patterns of fishery development in California waters. Efforts to analyze spatially explicit historical catch data have indicated that fisheries for this and other rockfish species tended to fish deeper waters, further offshore, in more inclement weather over time, suggesting that historical catches of this deeply distributed species may be overestimated.



Item #	Item descriptor	Item details as presented in the various documents
427	Method to explore stock characteristics in the Cowcod Conservation Areas.	A large fraction of blackgill habitat is currently closed to both fishing and survey effort in the Cowcod Conservation Areas (CCAs), complicating efforts to interpret both catch and survey data. Alternative means of exploring relative or absolute abundance in this region is a key research priority.
428	Research into oxygen minimum zones traits and potential changes ...	Greater investigation into the likely or plausible consequences of a shoaling of the oxygen minimum zone (OMZ) on blackgill habitat will aid in evaluating threats to this species that may be posed by global climate change.

#### **Items from the 2017 blue rockfish & deacon rockfish stock assessment document**

429	Nearshore survey.	A fisheries-independent nearshore survey should be supported to improve estimates of abundance trends (not having to rely on fisheries data for such trends) and, if possible, absolute abundance. Population scale has proven difficult to estimate for many nearshore species without informative data.
430	Collection of gender- and species-specific data.	Gender- and species-specific information from the recreational fishery should be collected for BDR given differences in growth and natural mortality by gender and the importance of this fishery to overall catches. This information should continue to be collected for commercial fisheries. For California, collection of age data (particularly from the recreational fishery) is a priority for stock assessment of BDR and other species important to recreational fisheries.

Item #	Item descriptor	Item details as presented in the various documents
431	A study of the stock structure of Blue and Deacon Rockfish.	Stock structure for Blue Rockfish and Deacon Rockfish needs further study and the results accounted for in future assessments. In particular, ontogenetic and gender-related movement according to offshore depth and spawning seems plausible, and data to inform tests of that hypothesis would be beneficial for future assessments given the lack of larger/older males in the fisheries data. Given that the vast majority of catches for BDR are in the nearshore waters, the intersection of seasonal movements to offshore habitat coupled with fleet dynamics could play an important role determining vulnerability. Alternative sub-stock boundaries, those that do not lie on political borders, should also be explored.
432	Further analyses on natural mortality values for females and males.	This will help resolve the extent to which gender-based selectivity (e.g., dome-shaped or relative male-to-female scales) may be occurring, and whether natural mortality and such complex selectivity patterns can be estimated (and when they cannot).
433	Historical catch reconstructions for recreational fleets in Oregon.	Ocean-boat landings comprise the vast majority of landings for BDR, but there has been no rigorous attempt at a catch reconstruction beyond linking catch to license sales (as was done for this assessment).
434	Accurate accounting of removals for recreational (estuary-boat and shore fishing modes).	Fisheries exploited by the recreational sector are traditionally hard to monitor. Since 2005, there has been no comprehensive information collected about catch or effort or biological information from estuary-boat and shore fishing modes. Although these modes do not represent major fisheries for BDR in terms of landed catch, they do tend to catch smaller individuals. Biological data on smaller individual is a data gap for this and many other nearshore rockfish species.
435	Calibration and validation of BDR ages.	Formal ageing criteria for BDR should be developed and standardized and ages validated.

Item #	Item descriptor	Item details as presented in the various documents
436	Control rules for stocks managed as part of a stock complex.	BDR is currently managed as part of two “Minor Nearshore Rockfish” stock complexes (each representing over 10 stocks), north and south of 40° 10’ N. latitude. The contribution of BDR (currently “Blue Rockfish”) to the northern complex OFL in 2017 is over half the yield (roughly 56% of the combined OFL), and 23% of the OFL for the southern complex. The STAT recommends research on the risks associated with management of stocks in a complex (e.g. the probability of overfishing component stocks), as a function of the degree of variability in the OFL contribution of each stock. Stocks that are managed as part of a complex and determined to be above target biomass are of particular concern, as their OFL contribution may exceed MSY (or its proxy). In the absence of a species-specific catch limit, alternative measures could be evaluated using management strategy evaluation, including alternative control rules for stocks managed within a complex (e.g. a “40-10” harvest control rule combined with a yield cap set equal to MSY or its proxy; see also Froese et al. 2010).
437	Mandatory port sampling.	In California, commercial port samplers can be refused access to landings. This could result in biased estimates of species, length, and age compositions, as well as estimates of commercial landings, particularly if catch that is made available to the sampler is not representative of the total catch in a sampling stratum.

#### Items from the 2017 blue rockfish & deacon rockfish STAR Panel Report

Item #	Item descriptor	Item details as presented in the various documents
438	Develop a fishery independent survey for nearshore species off Oregon ...	A fishery independent survey should be developed for nearshore species off Oregon. Several possibilities should be explored. For a nearshore survey to viable over the long term, it will be important to keep the cost of the survey low and engage in a collaborative effort with the fishing industry. An effort should be made to distribute sampling sites according to a design that would allow both local and state-wide estimates of abundance, and to evaluate density both in nearshore and offshore waters. Some alternatives for a near-shore survey include: (a) An acoustic survey for rockfish distributed in mid-water such as black rockfish and blue/deacon rockfish. Anecdotal information suggests that black rockfish and blue/deacon rockfish schools are distinguishable. Descending cameras can be used for species identification. The preliminary acoustic project to survey black and blue/deacons rockfish needs to be peer-reviewed. Acoustic surveys can produce an estimate of absolute abundance if properly calibrated and acoustic target strength is sufficiently well known. (b) ROV surveys of rocky reef habitat. ROV surveys are usually used to survey near-bottom species, which may be a problem for species that are often found in the water column, such as black rockfish and blue/deacon rockfish. An ROV survey can produce absolute estimate for abundance for near-bottom species if the sighting function can be estimated, quantitative methods are used to estimate density. (c) A standardized hook-and-line survey such as is used by the California Collaborative Fisheries Research Program to study changes in density inside and outside MPAs, and is being developed by the Washington Department of Fish and Wildlife. This would only provide an index of relative abundance, so a time series would be needed to inform the assessment.
439	Better characterization of nearshore habitat is needed for fishery CPUE index development.	Better characterization of habitat is needed for fishery CPUE index development. Oregon and southern California do not have the same coverage of mapping as the rest of California in nearshore waters. Other environmental descriptors in addition to rocky reef substrate and depth strata should be evaluated.

Item #	Item descriptor	Item details as presented in the various documents
440	Develop objective criteria for setting the threshold when applying the Stephens and MacCall method ...	Ad hoc criteria are used to identify a threshold when applying the Stephens and MacCall method of selecting records for CPUE index development. Further research is needed to determine whether threshold selection criteria can be optimized.
441	Evaluate modeling discard as a separate fleet versus using retention functions.	Modeling discard as a separate fleet, as was done for blue/deacon rockfish, is a simple and intuitive approach, but the strengths and weaknesses of this approach are unclear. This method should be compared to the more standard approach of modeling discard with retention curves to ensure the model results are not strongly affected by the method used.
442	The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable ...	The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable in many cases. Characterizing uncertainty of the final assessment model is important, and MCMC offers advantages over asymptotic approximations using the Hessian or likelihood profiles.
443	Provide guidance on different methods for constructing decision tables ...	Several alternative approaches were used this year to construct decision tables, and some approaches may be better than others. The stock assessment TOR should outline the various methods that can be used, and provide recommendations if possible on preferred approaches.
444	Additional genetic work to separate the geographical distribution on blue and deacon rockfish.	Additional genetic work is needed to separate the geographical distribution on blue and deacon rockfish. The SWFSC juvenile rockfish survey is a good platform for genetic samples because it is a fisheries independent survey and the survey spans the geographic area where transition occurs from predominately blue rockfish to predominately deacon rockfish. If the relatively clear break in geographic distribution at San Francisco is reinforced by additional information, consideration should be given to separate assessments

Item #	Item descriptor	Item details as presented in the various documents
		north and south of this boundary. DNA sampling of historically collected otoliths should continue.
445	Evaluate the effect of MPAs creation on nearshore recreational fishery CPUE in CA.	Evaluate the effect of MPAs creation on nearshore recreational fishery CPUE indices in California.
446	Age validation study to develop reliable ageing criteria ...	Age validation study is need given differences in ageing criteria between the SWFSC and the Oregon age readers for blue/deacon rockfish.
447	Develop routine procedures to sample the California nearshore fishery for ageing structures or biological data.	There appears to be no routine sampling procedures in place to sample the catch for ageing structures or biological data in the California nearshore fishery. Collection of representative ageing data is important for stock assessment and should be instituted for nearshore species.
448	Consider a formal process of soliciting local and traditional knowledge regarding blue/deacon rockfish behavior.	Consider a formal process of soliciting local and traditional knowledge regarding blue/deacon rockfish behavior, seasonal and ontogenetic movement, and density by depth strata to inform the next assessment.

#### Items from the 2017 Bocaccio update stock assessment document

Item #	Item descriptor	Item details as presented in the various documents
449	Stock structure research.	Stock structure and stock boundaries for Bocaccio rockfish on the West Coast remain an important issue to consider with respect to both future assessments and future management actions.
450	Survey in the Cowcod Conservation Area (or other fix to index issues) ...	Since large scale area closures and other management actions were initiated in 2001, the spatial distributions of fishing effort (fishing mortality) have changed over both large and small spatial scales. This confounds the interpretation of survey indices for surveys that do not sample in the Cowcod Conservation Areas (CCAs), although the decision to begin sampling for the NWFSC hook and line survey within the CCAs should begin to address this issue with time.
451	Maturity and fecundity research (e.g., multiple broods) ...	Recently updated reproductive biology data (maturity and fecundity) show some differences in length and weight specific fecundity in Bocaccio from those used in the past assessments. Regional differences (southern and northern California, as well as southern Oregon), and multiple brood spawning, are poorly understood.
452	Diet and movement associated with habitat and prey abundance (ecosystem effects) ...	Information regarding diet and movement patterns associated with habitat and prey abundance are key in order to further understand their roles in the ecosystem of the California waters. Northward migratory behaviors of juvenile and young adults are indicated by length frequency data, but such behaviors are also poorly understood.

**Items from the 2017 California scorpionfish stock assessment document**

Item #	Item descriptor	Item details as presented in the various documents
453	Improved estimates of natural mortality ...	Natural mortality: Both natural mortality and steepness were fixed in the base model. The natural mortality estimate used the assessment was based on maximum age. The collection of age data for older females may improve the ability to estimate female natural mortality in the model. The NWFSC trawl survey was the only available source of age data for this assessment, of which there were a number of age-1 fish and the data were dominated by males. It may also be possible to evaluate mortality by quantifying predation by major predators of scorpionfish, such as octopus. A tagging study to estimate natural mortality for scorpionfish should be considered. This project could be designed as a cooperative research project with the charter fleet in southern California.
454	Meta-analysis for steepness ...	California scorpionfish has not been fished to a level where information on steepness is available. A meta-analysis of steepness should be done for species with the same reproductive strategy as scorpion fish.
455	Data for the stock south of the U.S. border ...	No available information on the status of California scorpionfish in Mexico could be found. A number of emails were sent to researchers in Mexico and none were returned. It is known that a portion of the stock resides in Mexico and that boat leaving from San Diego target California scorpion fish off the Coronado Islands.
456	Data on sex ratios from the recreational or commercial fisheries ...	The sex ratio in the only published work by Love et al. (1987) and samples from the NWFSC trawl survey were skewed towards males. Data on sex ratios from the recreational or commercial fisheries would help in determining the sex ratio of the population.
457	Aggregative behavior in both spawning and non-spawning seasons ...	Aggregative behavior in both spawning and non-spawning seasons of California scorpionfish is not well understood. Studies are needed to evaluate the environmental or ecological conditions that govern this behavior.



Item #	Item descriptor	Item details as presented in the various documents
458	Fecundity/maturity studies are needed.	A reproductive biology study of California scorpionfish is needed. There are currently no estimates of fecundity for California scorpionfish. The hard copies of data from the only estimates of maturity for California scorpionfish by Love et al. (1987) are no longer available. Some data on the spatial distribution of the eggs are available from CalCOFI, but were not keypunched to the species level. California scorpionfish mature at a young age, and additional data can help inform the maturity ogive. No studies have been done of the relationship between weight and reproductive output. California scorpionfish have a different reproductive strategy than rockfish, and seasonal protection of spawning areas may help maintain reproductive capacity of the stock.
459	Discard mortality study is needed.	Many scorpionfish are discarded at sea. The assessment used estimates of discard mortality of a distantly related species (lingcod) in a different ecological setting (Karpov 1996). Studies of discard mortality are needed to parameterize the assessment model.
460	Further exploration of relationship between environmental conditions and recruitment ...	The relationship between environmental conditions and recruitment for scorpionfish should be further explored. Preliminary exploration using CalCOFI temperature data suggested that a relationship existed, but other time series may correlate more strongly given that scorpionfish are a near-shore species. Scorpionfish appear to be a relatively hardy and adaptable species and may expand northward in a warming climate.
461	Improved method for choosing threshold in Stephens and MacCall filtering.	Ad hoc criteria are used to identify a threshold when applying the Stephens and MacCall method of selecting records for CPUE index development. Further research is needed to determine whether threshold selection criteria can be optimized.
462	Guidance on modeling discards, separate fleet versus retention curves ...	Modeling discard as a separate fleet, as was done for California scorpionfish, is a simple and intuitive approach, but the strengths and weaknesses of this approach are unclear. This

Item #	Item descriptor	Item details as presented in the various documents
		method should be compared to the more standard approach of modeling discard with retention curves to ensure the model results are not strongly affected by the method used.
463	Improved MCMC in Stock Synthesis ...	The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable in many cases. Characterizing uncertainty of the final assessment model is important, and MCMC offers advantages over asymptotic approximations using the Hessian or likelihood profiles.
464	Guidance on developing decision tables ...	Several alternative approaches were used this year to construct decision tables and some approaches may be better than others. The stock assessment TOR should outline the various methods that can be used, and provide recommendations if possible on preferred approaches.
465	Additional biological information from the special trawl surveys.	Additional biological information (sex, otoliths, depth distribution) should be collected for California scorpionfish during the Publicly Owned Treatment Works (POTWs) trawl survey and the Southern California Bight Regional Monitoring Project (SCCWRP) trawl survey.
466	An age validation study is needed	An age validation study is needed for California scorpionfish.
467	Species-specific identification of scorpionfish eggs in CalCOFI.	CalCOFI ichthyoplankton surveys in southern California do not currently identify scorpionfish eggs to species, though it is possible to do this in southern California waters. Species-specific identification of scorpionfish eggs is recommended to develop spawning output index for use in the next stock assessment.

Item #	Item descriptor	Item details as presented in the various documents
<b>Items from the 2017 California scorpionfish STAR Panel Report</b>		
468	Conduct a reproductive biology study of California scorpionfish ...	A reproductive biology study of California scorpionfish is needed. The maturity estimates that were used in the assessment are dated and cannot be reproduced. No studies have been done of the relationship between weight and reproductive output. Scorpionfish have a different reproductive strategy than rockfish, and seasonal protection of spawning areas may help maintain reproductive capacity of the stock.
469	Studies of discard mortality are needed for this species.	Many scorpionfish are discarded at sea. The assessment used estimates of discard mortality of a distantly related species (lingcod) in a different ecological setting. Studies of discard mortality are needed to parametrize the assessment model.
470	Further study of relationships between environmental conditions and recruitment for scorpionfish.	The relationship between environmental conditions and recruitment for scorpionfish should be further explored. Preliminary exploration using CalCOFI temperature data suggested that a relationship existed, but other time series may correlate more strongly given that scorpionfish are a near-shore species. Scorpionfish appear to be a relatively hardy and adaptable species and may expand northward in a warming climate.
471	Develop objective criteria for setting the threshold when applying the Stephens and MacCall method ...	Ad hoc criteria are used to identify a threshold when applying the Stephens and MacCall method of selecting records for CPUE index development. Further research is needed to determine whether threshold selection criteria can be optimized.
472	Evaluate modeling discard as a separate fleet versus using retention functions.	Modeling discard as a separate fleet, as was done for California scorpionfish, is a simple and intuitive approach, but the strengths and weaknesses of this approach are unclear. This

Item #	Item descriptor	Item details as presented in the various documents
		method should be compared to the more standard approach of modeling discard with retention curves to ensure the model results are not strongly affected by the method used.
473	The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable ...	The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable in many cases. Characterizing uncertainty of the final assessment model is important, and MCMC offers advantages over asymptotic approximations using the Hessian or likelihood profiles.
474	Provide guidance on different methods for constructing decision tables ...	Several alternative approaches were used this year to construct decision tables and some approaches may be better than others. The stock assessment TOR should outline the various methods that can be used, and provide recommendations if possible on preferred approaches.
475	Collect additional biological information for scorpionfish during the trawl surveys ...	Additional biological information (sex, otoliths, depth distribution) should be collected for California scorpionfish during the Publicly Owned Treatment Works (POTWs) trawl survey and the Southern California Bight Regional Monitoring Project (SCCWRP) trawl survey.
476	Conduct an age validation study for scorpionfish.	An age validation study is needed for California scorpionfish.
477	Species-specific identification of scorpionfish eggs in CalCOFI.	CalCOFI ichthyoplankton surveys in southern California do not currently identify scorpionfish eggs to species, though it is possible to do this in southern California waters. Species-specific identification of scorpionfish eggs is recommended to develop spawning output index for use in the next stock assessment.

Item #	Item descriptor	Item details as presented in the various documents
478	Meta-analysis for steepness ...	A meta-analysis of steepness should be done for species with the same reproductive strategy as scorpionfish.
479	Aggregative behavior in both spawning and non-spawning seasons ...	Aggregative behavior in both spawning and non-spawning seasons of California scorpionfish is not well understood. Studies are needed to evaluate the environmental or ecological conditions that govern this behavior.
480	Improved estimates of natural mortality from predator information.	The natural mortality estimate used the assessment was based on maximum age. It may be possible to evaluate mortality by quantifying predation by major predators of scorpionfish, such as octopus.
481	Consider a tagging study to estimate natural mortality ...	Tagging study to estimate natural mortality for scorpionfish should be considered. This project could be designed as a cooperative research project with the charter fleet in southern California.

#### **Items from the 2017 darkblotched rockfish update stock assessment document**

482	Additional population genetics research to elucidate potential spatial stock structure.	Additional population genetics research to elucidate potential spatial stock structure would be valuable for assessment and management, to ensure prevention of local depletion and preserve genetic diversity.
483	Additional research on darkblotched movement ...	Additional research on darkblotched rockfish movement including migration patterns by latitude and depth, diurnal migration patterns through the water column, relative time spent off-bottom versus midwater, relating movements to size, age and sex would be valuable for

Item #	Item descriptor	Item details as presented in the various documents
		further understanding this rockfish's ecological niche, stock structure, and lend insight to catchability and gear selectivity patterns.
484	Evaluate the impact of not accounting for any Canadian portion of population ...	Given that the population range extends north to the border with Canada, it is important that future research would evaluate the impact of not accounting for any Canadian portion of population abundance. Such an analysis would require evaluation of movement of darkblotched rockfish along the coast; such information is currently lacking. There also appears to be no published Canadian assessment available for darkblotched that includes recruitment trends by year to see if there is any synchrony in recruitment on either side of the border.
485	Continued collection and analysis of maturity and fecundity data ...	Continuing collection of maturity and fecundity data on darkblotched rockfish would allow further research into latitudinal variability in life history parameters that again would advance understanding this species stock structure. Multi-year data would also allow evaluation of temporal changes in darkblotched rockfish maturity and fecundity.
486	Additional research into natural mortality, as it relates to length and age ...	Additional research into natural mortality, as it relates to length and age would be valuable to enable more realistic and accurate modeling of this parameter, which is a common source of uncertainty in assessment of this, and other rockfish species.
487	Research to improve existing meta-analyses for natural mortality and steepness ...	Future research could also improve existing meta-analyses for natural mortality and steepness, which both contribute to the implied yield curve. Directions for improvements could include (1) weighting methods in natural mortality prior estimates included in the

Item #	Item descriptor	Item details as presented in the various documents
		Hamel meta-analysis, and (2) developing a larger database of species for estimating steepness, perhaps by including species from other regions, e.g., Canada and Alaska.
488	Research to establish optimum methods for modeling selectivity patterns ...	Research into establishing optimum methods for more precise modeling of selectivity patterns is needed. Either asymptotic or dome-shaped selectivity curves are frequently used in stock assessments, when neither may be the best available representation of selectivity. A dome shape selection can suggest a “cryptic” biomass, or create confounding with natural mortality assumptions, potentially inflating abundance indices (Crone et al. 2013). Assumptions of asymptotic shape may also not be realistic.
489	Explore possible influence of the "warm blob" ...	Research assessing the effects of the unprecedented warm ocean conditions off the West Coast of the U.S., first detected in late 2013 and persisting into 2016, on rockfish populations is needed. Specifically, investigations are needed that focus on how temperature and other water conditions at depth, in rockfish habitat correspond to high sea-surface temperatures recorded throughout those years, and how the fish respond to those changing conditions. Research is needed that examines whether fish move in response to changing temperatures, where, and how they move, as well as whether the conditions influence life history parameters and aspects such as mortality, feeding, fecundity and other reproductive considerations. What oceanographic and climatic forces are responsible and how long these conditions are expected to persist are also critical pieces of knowledge.

#### Items from the 2017 lingcod stock assessment document

490	Age validation of lingcod aging ...	Age validation of lingcod aging is needed to verify the level of age bias, if any.
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Item #	Item descriptor	Item details as presented in the various documents
491	Transboundary stock assessment and the management framework ...	A transboundary stock assessment and the management framework to support such assessments would be beneficial.
492	A survey in untrawlable habitat and/or a near shore survey ...	A survey in untrawlable habitat and/or a near shore survey would improve this stock assessment. Other survey techniques could include longline, combined lingcod/sablefish pot survey, or trap surveys.
493	Investigate environmental covariates for recruitment and time-varying growth ...	Investigate environmental covariates for recruitment and time-varying growth and availability inshore.
494	Guidance on modeling the impact of nest-guarding on reproductive output ...	The impact of nest-guarding on reproductive output should be investigated. The current assessment focuses on female spawning biomass as the limiting factor in reproductive output, but nest guarding by lingcod males and the availability of nesting habitat may also play roles. A cursory look at the proportion of sex ratio in the catch did not appear to indicate any serious changes for either north or south populations in recent years. However, we do not know what kind of change in sex ratio would indicate a serious change in reproductive success.
495	Investigation of the proportion of lingcod caught in Mexico and landed in U.S. ports ...	Investigation of the proportion of fish caught in Mexico and landed in U.S. ports as there is evidence that California recreational fisheries, primarily out of San Diego, are fishing in Mexican waters. These catches should be allocated appropriately between U.S. and Mexican waters.

#### Items from the 2017 lingcod STAR Panel Report



Item #	Item descriptor	Item details as presented in the various documents
496	Develop screening criteria to identify bad data ...	Prior to the next iteration of this assessment the age data available from the fishing fleets should be carefully screened to identify and possibly rectify aberrant data.
497	Study to cross-validate age-readings of lingcod from different labs.	There should be a study to cross-validate age-readings of lingcod among the different laboratories contributing age data to the assessment. It may be necessary to develop laboratory-specific (and possibly year-specific) ageing-error vectors.
498	Compile information on lingcod catches, abundance trends, and age-compositions from Canadian and Mexican authorities ...	Available information on lingcod catches, abundance trends, and age-compositions should be acquired from Canadian and Mexican authorities to take an initial step towards a more spatially-comprehensive view of lingcod population trends and dynamics.
499	The next full assessment should explore a spatial model that encompasses the northern and southern areas ...	The next iteration of this assessment could be an update assessment. If a full assessment is done it should explore developing a spatial model that encompasses the northern and southern areas rather than again treating them as independent stocks, as in the current and previous assessments.
500	Modify the software used to develop length- and age-compositions to flag fish that are unsexed.	Modify the software used to develop length- and age-compositions from PacFIN data so that unsexed fish are flagged rather than including them in compositions after the automatic application of an assumed sex-ratio (e.g., 50:50). If the analysts preparing the composition data need to develop sex-ratio coefficients to accommodate unsexed fish (e.g., by length-bin), the assessment documents should clearly state the methods and data used for this purpose and the resulting sex-ratio coefficients.
501	Evaluate marginal age-compositions to confirm that the raw data are consistent with	If assessments use marginal age-compositions the STATs should evaluate whether the raw data are consistent with random sub-sampling from the available lengths. If the ages appear

Item #	Item descriptor	Item details as presented in the various documents
	random sub-sampling from the available lengths.	to have been subsampled non-randomly (e.g., no more than 5 fish from any length-bin), the age data should be suitably expanded to reflect the variable sampling fraction.
502	Develop a standard approach for combining conditional age-at-length sample data into annual CAAL compositions.	A standard approach for combining conditional age-at-length sample data into annual CAAL compositions should be developed and reviewed. If age data are not selected in proportion to the available lengths, simple aggregation of the ages by length-bin may provide biased views of the overall age-composition and year-class strength.
503	Comprehensively evaluate whether the Triennial survey should be split into early and late segments ...	Comprehensively evaluate whether the Triennial survey should be split into early and late segments and the basis for making the decision. The lingcod assessment split the Triennial survey into separate early and late surveys, whereas there was a single Triennial survey in the draft assessment for Pacific ocean perch brought to this STAR.

#### **Items from the 2017 Pacific ocean perch stock assessment document**

504	More exhaustive use of existing age data to reduce uncertainty in natural mortality ...	Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for Pacific ocean perch. The collection of additional age data, re-reading of older age samples, reading old age samples that are unread, and improved understanding of the life history of Pacific ocean perch may reduce that uncertainty.
505	Improved understanding of the steepness parameter	The amount of stock resilience, steepness, dictates the rate at which a stock can rebuild from low stock sizes. Improved understanding regarding the steepness parameter for US west coast Pacific ocean perch will reduce our uncertainty regarding current stock status.

Item #	Item descriptor	Item details as presented in the various documents
506	Basin-wide understanding of stock structure, biology, connectivity, and distribution ...	This is a stock assessment for Pacific ocean perch off of the west coast of the US and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the US west coast observations would help to define the connectivity between Pacific ocean perch north and south of the US-Canada border.

#### **Items from the 2017 Pacific ocean perch STAR Panel Report**

507	Further investigate of the POP stock structure.	Further investigation of POP stock structure is recommended. One approach would be to look for correlations of U.S. West Coast recruitment deviations and survey biomass estimates with corresponding results from POP assessments in Canada and the Gulf of Alaska.
508	Comprehensively evaluate the appropriateness of using the Triennial survey ...	Comprehensively evaluate the appropriateness of using the Triennial survey in assessments for other rockfish species and whether the survey should be split into early and late segments. The lingcod assessment reviewed during this STAR split the Triennial survey into separate early and late surveys, whereas the draft POP assessment brought to the STAR had a single Triennial survey.
509	Explore whether conditional age-at-length data can be treated as random samples of the age-composition.	Explore the assumption that conditional age-at-length data are random samples of the age-composition.

Item #	Item descriptor	Item details as presented in the various documents
510	Develop a standard approach for combining conditional age-at-length sample data into annual CAAL compositions.	A standard approach for combining conditional age-at-length sample data into annual CAAL compositions should be developed and reviewed. If age data are not selected in proportion to the available lengths, simple aggregation of the ages by length-bin may provide biased views of the overall age-composition and year-class strength.
511	Further explore the VAST approach for constructing relative abundance indices.	Further explore the VAST approach for constructing relative abundance indices. The upcoming workshop at the Center for the Advancement of Population Assessment Methodology (CAPAM) will address this issue.

#### **Items from the 2017 yelloweye rockfish assessment document**

512	Continue fishery sampling, despite limited opportunities.	The available data for yelloweye rockfish remains relatively sparse given the limited sampling effort available under the rebuilding plan. It is essential to continue yelloweye data collection, especially in this recent period, when commercial and recreational catches are considerably lower than the historical period, to provide a fuller picture of age structure and population dynamics. Further length and age collections will also refine estimate of year class strength in the late 2000s, which will improve estimates of stock status and productivity.
513	Improved meta-analyses for natural mortality and steepness ...	Poorly informed parameters, such as natural mortality and stock-recruit steepness will continue to benefit from meta-analytical approaches until there is enough data to estimate them internal to the model. A more thorough examination of yelloweye longevity off the West Coast of the United States is needed to get a better understanding of natural mortality.

Item #	Item descriptor	Item details as presented in the various documents
514	Systematic comparison of age estimates between the two ageing labs ...	The age data used in this assessment were generated by two ageing laboratories, the WFDW ageing lab and the NWFSC ageing lab. Even though growth estimates from these two labs are similar, there are still questions regarding the level of bias and precision in the ages coming from each lab. A larger, systematic comparison of age estimates between labs as well as with outside agencies could help resolve the issue of between-lab agreement. To this end, WDFW and NWFSC labs have been in correspondence and are currently seeking resolution to this issue.
515	Improved historical catches; separate catch and biological records between OR & WA.	Continue to refine historical catch estimates. Disentangling catch and biological records between Oregon and Washington would allow further spatial exploration. A better quantification of uncertainty among different periods of the catch history among all states would also be beneficial. These issues are relevant for all West Coast stock assessments.
516	Continue to evaluate the spatial structure of the assessment ...	Continue to evaluate the spatial structure of the assessment, including the number and placement of boundaries between areas. While this assessment took a step back from a more refined spatial resolution given data limitations, further detailed examination of yelloweye rockfish stock structure would be useful. This includes the exploration of area-specific life history characteristics and recruitment.
517	Develop and implement a comprehensive visual survey ...	Develop and implement a comprehensive visual survey, as currently available bottom trawl surveys do not encounter yelloweye rockfish often and the hook-and-line IPHC survey targets halibut and incidentally encounters rockfish.

Item #	Item descriptor	Item details as presented in the various documents
518	Transboundary assessment and the management framework (US, Canada, & Mexico) ...	Yelloweye rockfish is a transboundary stock with Canada. However, a legal mandate and management framework for using the advice of a transboundary stock assessment does not exist. Data sharing is currently happening at a scientific level with Canadian scientists. A transboundary (including Mexico) stock assessment and the management framework to support such assessments would be beneficial. This is relevant to many stocks off the West Coast of the United States.

#### Items from the 2017 yelloweye rockfish STAR Panel Report

519	Increase the sampling effort for length and age data for yelloweye rockfish ...	Although data are available from a number of sources to inform this model, both index and compositional data to inform this stock remain relatively sparse. Efforts to increase sampling for length and age data would be very beneficial for future assessment efforts.
520	Resolve differences between ageing labs in results for yelloweye rockfish ...	In evaluating the results of age determination cross-reads between WDFW and NWFSC age estimates, it has become apparent that there may be some bias in age estimation methods by one or another of these laboratories. Specifically, there is some indication that while there was strong agreement on fish up to age 32, age estimates produced by WDFW efforts for older individuals are significantly older than estimates on the same fish produced by both the NWFSC and the Alaska Department of Fish and Game (ADFG). Given the high sensitivity of the model results to the presumed values of natural mortality, which are greatly informed by age distributions, further investigation into the likely causes of these discrepancies would be a very high research priority. Additional research efforts to confirm age estimation results using age validation methods (such as bomb radiocarbon or lead 210 validation) would also be beneficial in resolving such differences.

Item #	Item descriptor	Item details as presented in the various documents
521	Investigate application of a geostatistical approach to IPHC survey data for yelloweye rockfish.	The IPHC longline survey index is based on a delta-GLMM in which station effects represent the spatial information to inform the model. As most stations do not regularly encounter yelloweye, this approach results in exclusion of nearly half of the positive observations available from this survey to inform the index. Analysis to investigate whether a geostatistical approach, using the VAST package and/or other geostatistical methods, instead of fixed station effects, may improve the information content of this index for future assessments.
522	Development of appropriate survey methods (hook & line or visual) for yelloweye rockfish.	A long standing research recommendation for this (and other) stocks has been the development of appropriate surveys (such as some form of hook and line, and/or visual survey) that could lead to indices that might better inform assessments. Selectivity of the surveys was a large source of uncertainty identified in the sensitivity analysis (Figure 9). When selectivity was estimated the model the result was dome shaped for not only the recreational fisheries, but for others as well resulting in depletion of 72.8% and implausible values of spawning biomass in 2017 (2412 mt vs. 323 mt for the base case). While the degree of dome shape resulting from free estimation may not be plausible, estimation of a representative selectivity proved difficult without data to inform what size classes were present yet unobserved. Assuming selectivity is asymptotic results in more conservative estimates of scale and depletion. As the current base model estimated asymptotic selectivity for all fishery independent and fishery-dependent data sources, despite some indication that older, larger fish may be more associated with rockier habitat, greater evaluation of data from recent or ongoing visual surveys could be beneficial in helping to inform likely selectivity patterns in future assessments. A closely related observation is that this stock appears to be considerably less vulnerable to the NWFSC bottom trawl survey in California waters relative to those off of Oregon and Washington, a pattern noted for other stocks as well (e.g., yellowtail rockfish). Understanding these possible differences in catchability, as may be associated with habitat preferences or other factors, would be beneficial.

Item #	Item descriptor	Item details as presented in the various documents
523	Refinement of the historical catch reconstruction.	Many historical catch estimates remain highly uncertain and would benefit from greater refinement and improvement, including the potential to develop estimates of uncertainty over time and greater precision with respect to catch versus landing locations, if feasible (note that more explicit recommendations are highlighted in the catch reconstruction workshop report from 2016).
524	Research on the recruitment redistribution process for area-specific models ...	Future work is recommended on the recruitment redistribution process for area-specific models to either support or reject the assumptions behind the spatial recruitment distribution dynamics inherent in stock synthesis. The restriction to a single value across years may be constraining- options to address this could include time blocking or revising the model structure such that it would take the ratio of spawning stock on one or the other side to help inform how recruitment is distributed over time.
525	Work towards a combined US/Canadian stock assessment.	As the yelloweye rockfish population at the northern end of the range likely represents a transboundary stock and resource, work towards a combined US/Canadian stock assessment would greatly aid our overall understanding of stock status.
526	Develop standard documentation of common data streams and sources ...	Common documentation of data streams and sources to support fishery independent and fishery dependent indices and compositional data could reduce the burden on assessment analysts to provide details about each data source, and allow reviewers a robust source of information on the most important, common data sources for any given stock assessment cycle.

#### Items from the 2017 yellowtail rockfish stock assessment document



Item #	Item descriptor	Item details as presented in the various documents
527	A survey method for midwater species is needed.	A problem common to assessments of all stocks caught in the midwater is the lack of a targeting survey. Because limits on the take of depleted midwater stocks have impeded fishing for many species, the lack of such a survey is an ongoing financial burden on industry.
528	Research on the missing older females: dead or inaccessible?	Research to determine whether old females of a variety of rockfish species actually have a mortality rate different than that of younger females. Assessments variously treat the discrepancies seen in sex ratios of older fish as either mortality-related or due unavailability to the fishery (e.g., ontogenetic movement offshore, or to rockier habitats). As these assumptions impact model outcomes very differently, resolving this issue would greatly improve confidence in the assessments.
529	Reliable recording of gear type (mid-water vs bottom trawl)	A hindrance to analysis of the commercial fishery is the inability to distinguish between midwater and trawl gear, particularly in data from the 1980s-1990s. Reliable recording of gear type will ensure that this does not continue to be problematic for future assessments.
530	Next northern assessment should be an update.	We recommend that the next assessment of the Northern stock be an update to this assessment, unless fishing patterns change dramatically, or new sources of data are discovered.
531	Suggestion for the next full northern assessment: current fishery CPUE index.	A commercial index in the North. This is by far the largest segment of the fishery, and the introduction of the trawl rationalization program should mean that an index can be developed for the current fishery when the next full assessment is performed.

Item #	Item descriptor	Item details as presented in the various documents
532	Suggestion for the next full northern assessment: historic fishery logbook CPUE index.	Further investigation into an index for the commercial logbook dataset from earlier periods.
533	Suggestion for the next full northern assessment: further analysis of growth patterns.	Further analysis of growth patterns along the Northern coast. The previous full assessment subdivided the Northern stock based on research showing differential growth along the coast, and although data for the assessment is no longer available along the INPFC areas used in that analysis, there may be some evidence of growth variability that would be useful to include in a future assessment.
534	Suggestion for the next southern assessment: longer time series from the juvenile survey.	A longer time series of the juvenile rockfish CPUE in the south, which will of course only be available after several years have elapsed.
535	Suggestion for the next southern assessment: time series of ages from the fishery.	A time series of recent ages for the Southern model. The commercial age time series currently stops in 2002. Otoliths have been collected for all years in the Hook & Line survey, however only samples from 2004 have been aged. There may also be a collection otoliths associated with research at the SWFSC, and these should be investigated as well.

#### **Items from the 2013 yellowtail rockfish STAR Panel Report**

Item #	Item descriptor	Item details as presented in the various documents
536	Investigate competing hypotheses for the lack of older female yellowtail rockfish ...	The age data available for the northern model are strongly indicative of a higher natural mortality rate for female yellowtail rockfish. Yellowtail are one of several rockfish species that demonstrate this apparent difference in sex ratios at age, and historically there has been concern regarding whether differential natural mortality rates throughout the lifespans of populations are reasonable, whether these differences reflect greater mortality rates of older females, or whether these difference reflect some manifestation of dome-shaped age-based selectivity (such that older females are less vulnerable to fisheries or surveys, presumably as a result of habitat associations). These models did not explore alternative explanations for these differences at the level that has been done for other stock assessments (such as Canary and Black Rockfish, where increasing natural mortality rates for females with age, as well as both size- and age-based dome-shaped selectivity have been explored). Given the richness of age data for yellowtail rockfish in the north, additional investigations that better quantify the phenomena, and evaluate potential mechanisms for the observed discontinuities, should be pursued.
537	Explore the potential for using fishery CPUE data to inform a relative abundance index ...	The draft northern yellowtail assessment models included indices of relative abundance based on fishery-dependent time series, including a trawl logbook CPUE index and an index of abundance based on yellowtail bycatch in the at-sea Pacific whiting fishery. Upon greater discussion of challenges associated with the development of these indices, particularly with regards to possible differences by state in the resolution of market categories in the logbook data, and how the bycatch rate information was standardized for the whiting fishery bycatch index, the STAT recommended exclusion of both indices in the final base model. However, as the indices were influential with respect to model results, greater exploration of the potential for these data to inform a relative abundance index, particularly for the trawl logbook CPUE data, would benefit future assessment efforts.

Item #	Item descriptor	Item details as presented in the various documents
538	Consider developing alternative survey methods (e.g., acoustic surveys, midwater trawl surveys) for yellowtail rockfish ...	As yellowtail rockfish is a semipelagic species, it may not always be reliably sampled in bottom trawl surveys, particularly if the depth distribution is sensitive to environmental conditions (for example, for widow rockfish it has been suggested in the past that El Niño years or other periods of low productivity, individuals may have a more benthic, relative to pelagic, distribution and therefore be more vulnerable to bottom trawl surveys). Consideration of alternative survey methods (e.g., acoustic surveys, midwater trawl surveys) and/or the means to account for changes in catchability that may be associated with environmental factors, could improve the ability of survey indices to track stock abundance.
539	Develop comprehensive sampling of CA fisheries for yellowtail rockfish ...	For the southern yellowtail model, the STAT and STAR Panel discussed a number of priorities. Given the importance of age and length compositional data, and the sparseness of such data available for the southern model, developing additional age data from available sources (such as the hook and line survey, and reproductive ecology studies at the SWFSC) should be a fairly high priority. The means to best ensure reasonably comprehensive sampling of commercial, and if possible recreational, fisheries catches with sex and maturity information is also a high priority for this (and other) stocks, particularly to the extent that future management changes enable greater fishing activities and landings for these populations.
540	Further exploration of recreational and fisheries-independent indices for the southern model for yellowtail rockfish ...	Additional efforts to improve recreational and fisheries-independent indices for the southern model should also be undertaken. For example, there were conflicting trends in the onboard observer index (reflecting yellowtail catches throughout all California waters) and the NWFSC hook and line survey (reflecting catches in the northern part of the Southern California Bight). Investigating whether this reflects a fundamental difference in signal, or whether this might reflect regional differences in catch rates, which could be evaluated by subsetting the recent onboard observer data to overlap the spatial scale of the hook and line survey, would be worth greater scrutiny in advance of any future assessment.

Item #	Item descriptor	Item details as presented in the various documents
541	Greater evaluation of region-specific life history parameters to inform stock structure ...	As both genetic studies and past assessments have indicated differences in stock structure and life history parameters, greater evaluation of region-specific life history parameters (such as growth, maturity, fecundity) would also likely benefit future assessment efforts both within and between the two assessment areas. For example, as the NWFSC hook and line survey is at the southern extent of the range of the southern stock, this might include potential differences in growth and maturity among different subregions within the southern model range, to evaluate the potential utility of indices and age data from that survey in a future southern base model. Such studies should be feasible based on the relatively rich amount of data available to inform the northern assessment.
542	Explore the potential utility of a juvenile rockfish index in the southern model for yellowtail rockfish ...	It was ultimately not possible to fully evaluate the influence of the pelagic juvenile index on the southern model results during the panel review, however there was some concern that the index could have been overly influential in the model due to the lack of age or length compositional data in the recent time period that might conflict with the juvenile abundance signal. Greater scrutiny regarding the potential utility of this index should be given if the index is to be included in future models
543	Work towards a combined US/Canadian stock assessment for yellowtail rockfish in the north ...	As northern yellowtail presumably represents a transboundary stock and resource, work towards a combined US/Canadian stock assessment would greatly aid our overall understanding of stock status.

Item #	Item descriptor	Item details as presented in the various documents
544	Develop standard documentation of common data streams and sources ...	Common documentation of data streams and sources to support fishery independent and fishery dependent indices and compositional data could reduce the burden on assessment analysts to provide details about each data source, and allow reviewers a robust source of information on the most important, common data sources for any given stock assessment cycle.

#### Items from the 2016 catch reconstruction review report

545	Pre-STAR review by state data stewards of the historical catch reconstructions.	During the development of stock assessments there should a review by state data stewards early in the process of the historical catch reconstructions to ensure that STAT teams are aware of any items that should be considered regarding how to fill in data gaps in landings or species compositions.
546	Standardize conversion factors to expand landed weights to whole fish for fish that are processed at sea.	Conversion factors to expand landed weights to whole fish should be standardized for fish that are processed at sea and landed as headed and gutted product, as fillets, or as just livers.
547	A copy of the HAL database should be placed in the PacFIN system.	A copy of the HAL [Historical Annotated Landings] database should be placed in the PacFIN system.
548	Place copies of state catch reconstructions and contributing databases in PacFIN.	Copies of state catch reconstructions and contributing databases should be transferred to PacFIN so there is a single repository. A process will need to be established so reconstructions in PacFIN can be updated as the states make revisions to their reconstructions.

Item #	Item descriptor	Item details as presented in the various documents
549	Revise the California catch reconstruction to account for unspecified sole.	The existing California catch reconstruction should be revised to account for unspecified sole.
550	Develop methods that use trawl logbook data to inform the estimates of species proportions.	Model-based methods for hindcasting landings should explore the potential for using trawl logbook data (tow locations and/or tow depths) to inform the estimates of species proportions that are applied to landings. Trawl logbook data are available back to the 1960s for Oregon, to the 1950s for Washington, and back even further for California.
551	Workshop to explore methods and data that could be used to account for at-sea discards in historical catch reconstructions.	Current historical catch reconstructions only account for the landed portion of the catch. The Council should consider sponsoring a workshop to explore methods and data series that could be used to account for at-sea discards in historical catch reconstructions.

#### **Items from the 2017 stock productivity review report**

552	Continued simulation-estimation tests for two-parameter and three-parameter models in stock assessments.	The Panel recommends directed research on: a. Continued simulation-estimation tests for both two-parameter and three-parameter models in stock assessments.
553	Evaluation of three-parameter models and alternative leading parameters for incorporation into Stock Synthesis.	The Panel recommends directed research on: b. Evaluation of different three-parameter models and alternative leading parameters for incorporation into Stock Synthesis.

Item #	Item descriptor	Item details as presented in the various documents
554	Exploration and evaluation of three-parameter curves in stock assessments, either when developing stock assessments, or for existing models.	The Panel recommends directed research on: c. Exploration and evaluation of three-parameter curves in stock assessments, either when developing stock assessments, or for existing models.
555	Further development of priors for leading parameters of stock-recruit models (e.g., BMSY/B0 and slope at the origin).	The Panel recommends directed research on: d. Further development of priors for leading parameters of stock-recruit models is needed, such as BMSY/B0, and slope at the origin. Non-parametric approaches to meta-analysis should be considered to directly estimate leading parameters.
556	Develop dynamic B0-based reference points to be included the West Coast stock assessment toolbox.	The Panel recommends that dynamic B0-based reference points be included the West Coast stock assessment toolbox, since they may be helpful to understand stock dynamics under regime shifts and directional climate change.