STATUS OF THE PACIFIC COAST GROUNDFISH FISHERY

Stock Assessment and Fishery Evaluation

DESCRIPTION OF THE FISHERY

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Acronyms and Abbreviations

ABC	Acceptable biological catch
ACL	Annual catch limit
ACT	Annual catch target
AFSC	Alaska Fisheries Science Center
AIS	Adaptive Importance Sampling
AM	Accountability measure
B_0	Unfished spawning biomass or spawning output
$B_{X\%}$	Spawning biomass at X% of unfished spawning biomass or spawning output
BC	British Columbia
BDR	Blue and deacon rockfishes
BDS	Biological Data System (in the PacFIN database)
B_{MSY}	Spawning biomass predicted to produce MSY
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CA	California
CCA	Cowcod Conservation Area
CCE	California Current Ecosystem
CCFRP	California Collaborative Fisheries Research Program
CCIEA	California Current Integrated Ecosystem Assessment
CDFG	California Department of Fish and Game (now CDFW)
CDFW	California Department of Fish and Wildlife
CFR	Code of Federal Regulations
Council	Pacific Fishery Management Council
CP	Catcher-processor
CPFV	Commercial passenger fishing vessel
CPS	Coastal pelagic species
CPUE	Catch per unit of effort
CRFS	California Recreational Fisheries Survey
CV	Coefficient of variation
DB-SRA	Depletion-based stock reduction analysis
DCAC	Depletion-corrected average catch
DMR	Discard mortality rate
DNA	Deoxyribonucleic acid
DO	Dissolved oxygen
DTL	Daily trip limit (fishery)
DTS	Dover sole, thornyheads, and sablefish
E	Exploitation
EA	Environmental Assessment
EC	Ecosystem component
EDCP	Economic Data Collection Program
EEZ	Exclusive Economic Zone
EFH	Essential fish habitat
EFHCA	Essential fish habitat conservation area
EFP	Exempted fishing permit
EIS	Environmental Impact Statement
EM	Electronic monitoring
ENSO	El Niño Southern Oscillation
EO	Executive Order
EPIRB	Emergency Position Indicating Radio Beacon

ESA	Endangered Species Act
ExSSS	Extended Simple Stock Synthesis
F	Fishing mortality
FEIS	Final Environmental Impact Statement
FEP	Fishery Ecosystem Plan
fm	Fathom
FMP	Fishery Management Plan
F_{MSY}	Predicted fishing mortality rate at MSY
FR	Federal Register
FSSI	Fish Stock Sustainability Index
GBYR	Gopher and black-and-yellow rockfishes
GLM	Generalized Linear Model
GLMM	Generalized Linear Mixed Model
GMT	Groundfish Management Team
H	Stock-recruitment steepness
HA	Hectares
HCR	Harvest control rule
HG	Harvest guideline
IFQ	Individual fishing quota
INPFC	International North Pacific Fisheries Commission
IOPAC	Input-output model for West Coast fisheries
IPHC	International Pacific Halibut Commission
IUCN	International Union for the Conservation of Nature
JMC	Joint Management Committee in the U.S.-Canada Pacific Whiting Treaty process
JTC	Joint Technical Committee in the U.S.-Canada Pacific Whiting Treaty process
k	Von-Bertalanffy Growth Coefficient
LE	Limited entry
LEFG	Limited entry fixed gear
M	Instantaneous rate of natural mortality
MCMC	Markov Chain Monte Carlo
MFMT	Maximum Fishing Mortality Threshold
MHW	Marine heat wave
MRFSS	Marine Recreational Fisheries Statistical Survey
MS	Mothership
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSE	Management strategy evaluation
MSST	Minimum Stock Size Threshold
MSY	Maximum sustainable yield
mt	Metric ton
mtDNA	Mitochondrial deoxyribonucleic acid
NCS	Northern California sub-stock
NEPA	National Environmental Policy Act
NIOSH	National Institute for Occupational Safety and Health
nm	Nautical miles
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWFSC	Northwest Fisheries Science Center
OA	Open access
ODFW	Oregon Department of Fish and Wildlife
OFL	Overfishing limit
OFS	Overfished species

OMZ	Oxygen minimum zone
OR	Oregon
ORS	Oregon sub-stock
ORBS	Ocean Recreational Boat Survey
OY	Optimum yield
P*	Overfishing probability
PacFIN	Pacific Fisheries Information Network
PDO	Pacific Decadal Oscillation
PFD	Personal flotation device
PFMC	Pacific Fishery Management Council
POP	Pacific ocean perch
POTW	Publicly-Owned Treatment Works
PR	Private/rental boats
PSA	Productivity-susceptibility analysis
PSMFC	Pacific States Marine Fisheries Commission
PWCC	Pacific Whiting Conservation Cooperative
q	Catchability coefficient
QP	Quota pounds
QS	Quota share
R_0	Virgin recruitment
Rec	Recreational
RecFIN	Recreational Fisheries Information Network
RCA	Rockfish Conservation Area
RREAS	Rockfish Recruitment and Ecosystem Analysis Survey
SAFE	Stock Assessment and Fishery Evaluation
SCB	Southern California Bight
SCS	Southern California sub-stock
SPR	Spawning potential ratio
SRG	Scientific Review Group in the U.S.-Canada Pacific Whiting Treaty process
SSC	Scientific and Statistical Committee
SSS	Simple Stock Synthesis
STAR	Stock Assessment Review
STAT	Stock assessment team
SWFSC	Southwest Fisheries Science Center
TAC	Total allowable catch
T_{MAX}	The statutory maximum allowable time for a stock to rebuild
T_{MIN}	The biologically-determined minimum time for a stock to rebuild
T_{TARGET}	The target year to rebuild a stock specified in a rebuilding plan
US	United States
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USSR	Union of Soviet Socialist Republics
V	Vulnerability
VAST	Vector Autoregressive Spatial Temporal (model)
VMS	Vessel monitoring system
WA	Washington
WCGBT	West Coast Groundfish Bottom Trawl (Survey)
WCGOP	West Coast Groundfish Observer Program
WDFW	Washington Department of Fish and Wildlife
WMC	Whiting Mothership Cooperative
XDB-SRA	Extended Depletion-based Stock Reduction Analysis

YOY	Young-of-the-year
YRCA	Yelloweye Rockfish Conservation Area

CHAPTER 1 DESCRIPTION OF THE WEST COAST GROUNDFISH FISHERY

The West Coast groundfish fishery occurs in the West Coast Exclusive Economic Zone (EEZ), which extends from the U.S.-Mexico border north to the U.S.-Canada border from 3-200 nautical miles (nm) offshore of the continental United States (Figure 1-1).

The West Coast groundfish fishery has been in existence for over 100 years with documented commercial landings of some species off California in the late 1890s. West Coast indigenous peoples have subsisted on some groundfish species for thousands of years. The U.S. government has recognized four West Coast tribes (Makah, Quileute, Hoh, and Quinault in northern Washington) with fishing rights in the West Coast EEZ in treaties ratified over 100 years ago.

This chapter documents the evolution of West Coast groundfish fishery management.

Figure 1-1. The Exclusive Economic Zone off the U.S. West Coast where the Pacific Fishery Management Council has jurisdiction in Federal fisheries management.

1.1 Legal Authority for Federal Fishery Management

Federal management of the West Coast groundfish fishery and the creation of the Pacific Fishery Management Council (hereafter "Council" or "PFMC") was enabled by passage of the Magnuson-Stevens Fishery Management and Conservation Act (MSA) in 1976 and implementation of the Pacific Coast Groundfish Fishery Management Plan (FMP) in 1982. Prior to implementation of the MSA and FMP, management of domestic groundfish fisheries was under the jurisdiction of the states of Washington, Oregon, and California. State regulations had been in effect on the domestic fishery for more than 100 years, with each state acting independently in both management and enforcement. Many fisheries overlapped state boundaries and participants often operated in more than one state. As management and a lack of uniformity of regulations became a difficult problem, it stimulated the formation of the Pacific States Marine Fisheries Commission (PSMFC) in 1947. PSMFC has no regulatory power but acts as a coordinating entity with authority to submit specific recommendations to states for their adoption. Between MSA implementation in 1977 and the implementation of the groundfish FMP in 1982, state agencies worked with the Council to address conservation issues.

Management of foreign fishing operations began in February 1967 when the U.S. and U.S.S.R. signed the first bilateral fishery agreement affecting trawl fisheries off Washington, Oregon, and California. The U.S. later signed bilateral agreements with Japan and Poland for fishing off the U.S. West Coast. Each of these agreements was renegotiated to reduce the impact of foreign fishing on important West Coast stocks, primarily rockfish, Pacific whiting, and sablefish. When the U.S. extended its jurisdiction to 200 nm upon signing the MSA, the National Marine Fisheries Service (NMFS) developed and implemented the preliminary management plan for the foreign trawl fishery off the Pacific Coast. From 1977 to 1982, the foreign fishery was managed under that plan. Many of these regulations were incorporated into the FMP, which provided for continued management of the foreign fishery.

Joint-venture fishing, where domestic vessels caught the fish to be processed aboard foreign vessels, began in 1979 and by 1989 had entirely supplanted directed foreign fishing. These joint ventures primarily targeted Pacific whiting. Joint-venture fisheries were then rapidly replaced by wholly domestic processing; by 1991, foreign participation had ended and U.S.-flagged motherships (MS), catcher-processors (CPs), and shore-based vessels had taken over the Pacific whiting fishery. Since then, U.S. fishing vessels and seafood processors have fully utilized Pacific Coast fishery resources.

1.1.1 Magnuson-Stevens Fishery Management and Conservation Act

The MSA is the principal law governing marine fisheries in the United States, although other applicable Federal laws, such as the Endangered Species Act and the National Environmental Policy Act, as well as Executive Orders need to be complied with under any Federal fisheries action. The primary goals of the MSA were to extend control of U.S. waters to 200 nautical miles (nm) in the ocean (i.e., the Exclusive Economic Zone or EEZ); to phase out foreign fishing activities; to prevent overfishing, especially by foreign fleets; to allow overfished stocks to recover; and to conserve and manage fishery resources. Achieving optimum yield (OY) of managed stocks is a primary mandate of the MSA.

Passage of the MSA also created the Regional Fishery Management Councils, with the PFMC being one of eight nationwide charged with recommending fishery policy and regulations to NMFS for federally-managed fisheries in the EEZ.

The MSA includes 10 national standards for management, which declare that conservation and management measures shall:

1. Prevent overfishing while achieving optimum yield.
2. Be based upon the best scientific information available.
3. Manage individual stocks as a unit throughout their range, to the extent practicable; interrelated stocks shall be managed as a unit or in close coordination.
4. Not discriminate between residents of different states; any allocation of privileges must be fair and equitable.
5. Where practicable, promote efficiency, except that no such measure shall have economic allocation as its sole purpose.
6. Take into account and allow for variations among and contingencies in fisheries, fishery resources, and catches.
7. Minimize costs and avoid duplications, where practicable.
8. Take into account the importance of fishery resources to fishing communities to provide for the sustained participation of, and minimize adverse impacts to, such communities (consistent with conservation requirements).
9. Minimize bycatch or mortality from bycatch.
10. Promote safety of human life at sea.

Congress has twice made significant revisions to the MSA, first in 1996 with the passage of the Sustainable Fisheries Act (SFA), and in 2007 with the MSA Reauthorization Act. Both acts provided more stringent conservation standards with the SFA specifying standards for rebuilding overfished stocks and the 2007 reauthorization specifying standards for minimizing the risk of overfishing a stock.

1.2 The Groundfish Fishery Management Plan

The Pacific Coast Groundfish FMP was implemented in 1982 to achieve MSA objectives for the West Coast groundfish fishery.

Most of the stocks managed in the current FMP (Table 2-1) were incorporated in the initial FMP with additional stocks added under Amendment 27 in 2015 (see Section 2.5.9). The largest groundfish gear type in terms of volume of landings since the implementation of the FMP is bottom trawl and the variety of species in the FMP was predicated by the mix of species landed in that fishery.

1.3 Fishery Rationalization

Groundfish fishery rationalization, a plan to promote economic efficiency and to maximize the net value of groundfish production, began with an effort to reduce capacity in the fishery and reduce derby fisheries where fishermen race to catch a limited quota. These efforts complied with MSA mandates and FMP objectives to promote domestic fisheries, promote safety at sea, and take into account the dependence of fishing communities and participants on groundfish resources while adhering to conservation requirements.

Rationalization of the West Coast groundfish fishery was initiated in the 1990s with a license limitation program and creation of the limited entry (LE) and open access (OA) sectors under Amendment 6 in 1992 (implemented for the 1994 fishery). Owners of vessels who met a minimum landing requirement within a qualifying period of July 11, 1984 through August 1, 1988 were given limited entry permits endorsed for the gear that was used to meet the requirement and endorsed for the size of the vessel. Minimum landing requirements were set with the intent of establishing limited entry fleets that were the size of the active fleet in 1987. Permits were endorsed for trawl, longline, and fishpot vessels, and were allowed to qualify for more than one gear endorsement (but only one permit was issued for each vessel). Under Amendment 6, most harvestable yields (i.e., stock-specific fishery harvest guidelines) were allocated to the limited entry sectors, while remaining yields were allocated to the OA sector.

The license limitation program created under Amendment 6 was recognized as a start to slow the growth in capacity and the Council immediately began consideration of an individual fishing quota (IFQ) program for the limited entry fixed gear (LEFG) sector under Amendment 8. However, with passage of the SFA, Congress imposed a moratorium on implementing new IFQ programs through October 1, 2000 and Amendment 8 was therefore not adopted.

The limited entry sectors were rationalized in different ways and the following sections describe how sector management rationalization evolved. The Council is continuing to refine these sector management strategies to achieve greater economic efficiencies and to maximize resource production and fishery profits.

1.3.1 Rationalization of the Limited Entry Fixed Gear Fishery

With the implementation of the license limitation program, there was also the formalization of the trawl/non-trawl allocations for northern sablefish (discussed more below). Industry representatives for participants in the non-trawl sablefish fisheries expressed their desire that the fishery be managed on a seasonal basis (as opposed to the year-round policy the Council pursued for most sectors of the groundfish fishery). Amendment 9 was adopted in 1996 to allow participation in the seasonal primary sablefish fishery by limited entry fixed gear vessels with enough catch history to have sablefish endorsements on their permits. LEFG permits with sablefish endorsements enable targeting of sablefish under higher cumulative landing limits in the primary sablefish fishery north of 36° N. lat. than those without a sablefish endorsement.

The original structure of the primary sablefish season created under Amendment 9 allocated equal cumulative landing limits that led to a race for fish and shorter, more dangerous derby fisheries. A regulatory amendment established a three-tier system for fisheries starting in 1998, which provided each vessel with a single cumulative limit; however, sablefish endorsement holders were ranked into three different tiers based on their permit histories, with the lowest tier (tier 3) having the lowest qualification requirements and receiving the lowest cumulative limits. While somewhat more equitable than the cumulative limit program, the three-tier system still required some fishermen to make large cutbacks in their harvest levels while allowing others to expand. The fishery still had to be managed as a modified derby, and the seasons were still too short (between 6-9 days) to allow fishermen to operate safely.

In 2001, after the Congressional moratorium on new IFQ programs expired, Amendment 14 implemented the permit stacking program, in which up to three sablefish-endorsed permits could be registered for use with a single vessel and that vessel could then have access to the primary season sablefish cumulative limits associated with each of those permits. Amendment 14 also established the longer April 1 to October 31 primary sablefish season so that each vessel could fish against its limits at its own speed. The limit structure of the primary fishery under Amendment 14 specifies landing limits for tiers 1 and 2, which are 3.85 and 1.75 times greater, respectively, than tier 3 limits.

1.3.2 Rationalization of the Limited Entry Trawl Fishery

In 2003, Congress financed a $46-million capacity-reducing buyback loan for permanent removal of 91 limited entry trawl vessels (35 percent of permits) from the bottom trawl and associated fisheries to reduce capacity and increase economic efficiency in the limited entry trawl sector. In 2004, the Council began development of a trawl catch share program with consideration of IFQs.

Amendment 20, implemented in 2011, created the trawl catch share program where participants in the limited entry shorebased trawl sector (consisting of trawl vessels delivering to shoreside processors) are managed under a system of IFQs and participants in the limited entry at-sea sectors (consisting of large trawl vessels that catch and process whiting at sea) are managed under a system of harvesting cooperatives.

Participants in the trawl catch share program are subject to 100 percent at-sea monitoring of their catch. One effect of trawl rationalization is a significant decrease in at-sea discarding, which was an increasing problem under trip limits due to vessels high-grading for higher priced fish and the effect of species-specific trip limits in a mixed stock fishery. There has also been increased specialization in the shoreside trawl fishery with participants tailoring their fishing strategies to their quota portfolio and their vessels' capabilities.

1.3.3 Goals and Objectives of the Fishery Management Plan

The Pacific Coast Groundfish FMP provides a framework for managing West Coast groundfish fisheries, with some specified management prescriptions such as prohibitions, formal allocations, and conservation mandates. The management framework is designed to provide flexibility to meet changing social and economic needs of the fishery and fluctuations in marine resources supporting the fishery. The following goals have been established in order of priority for managing West Coast groundfish fisheries, to be considered in conjunction with the National Standards of the MSA.

Management Goals

Goal 1 - Conservation. Prevent overfishing and rebuild overfished stocks by managing for appropriate harvest levels and prevent, to the extent practicable, any net loss of the habitat of living marine resources.

Goal 2 - Economics. Maximize the value of the groundfish resource as a whole.

Goal 3 - Utilization. Within the constraints of overfished species rebuilding requirements, achieve the maximum biological yield of the overall groundfish fishery, promote year-round availability of quality seafood to the consumer, and promote recreational fishing opportunities.

Objectives. To accomplish these management goals, a number of objectives will be considered and followed as closely as practicable:

Conservation

Objective 1. Maintain an information flow on the status of the fishery and the fishery resource which allows for informed management decisions as the fishery occurs.

Objective 2. Adopt harvest specifications and management measures consistent with resource stewardship responsibilities for each groundfish species or species group. Achieve a level of harvest capacity in the fishery that is appropriate for a sustainable harvest and low discard rates, and which results in a fishery that is diverse, stable, and profitable. This reduced capacity should lead to more effective management for many other fishery problems.

Objective 3. For species or species groups that are overfished, develop a plan to rebuild the stock as soon as possible, taking into account the status and biology of the stock, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock within the marine ecosystem.

Objective 4. Where conservation problems have been identified for non-groundfish species and the best scientific information shows that the groundfish fishery has a direct impact on the ability of that species to maintain its long-term reproductive health, the Council may consider establishing management measures to control the impacts of groundfish fishing on those species. Management measures may be imposed on the groundfish fishery to reduce fishing mortality of a non-groundfish species for documented conservation reasons. The action will be designed to minimize disruption of the groundfish fishery, in so far as consistent with the goal to minimize the bycatch of non-groundfish species, and will not preclude achievement of a quota, harvest guideline, or allocation of groundfish, if any, unless such action is required by other applicable law.

Objective 5. Describe and identify essential fish habitat (EFH), adverse impacts on EFH, and other actions to conserve and enhance EFH, and adopt management measures that minimize, to the extent practicable, adverse impacts from fishing on EFH.

Economics

Objective 6. Within the constraints of the conservation goals and objectives of the FMP, attempt to achieve the greatest possible net economic benefit to the nation from the managed fisheries.

Objective 7. Identify those sectors of the groundfish fishery for which it is beneficial to promote year-round marketing opportunities and establish management policies that extend those sectors' fishing and marketing opportunities as long as practicable during the fishing year.

Objective 8. Gear restrictions to minimize the necessity for other management measures will be used whenever practicable. Encourage development of practicable gear restrictions intended to reduce regulatory and/or economic discards through gear research regulated by an exempted fishing permit (EFP).

Utilization

Objective 9. Develop management measures and policies that foster and encourage full utilization (harvesting and processing), in accordance with conservation goals, of the Pacific Coast groundfish resources by domestic fisheries.

Objective 10. Recognize the multispecies nature of the fishery and establish a concept of managing by species and gear or by groups of interrelated species.

Objective 11. Develop management programs that reduce regulations-induced discard and/or which reduce economic incentives to discard fish. Develop management measures that minimize bycatch to the extent practicable and, to the extent that bycatch cannot be avoided, minimize the mortality of such bycatch. Promote and support monitoring programs to improve estimates of total fishing-related mortality and bycatch, as well as those to improve other information necessary to determine the extent to which it is practicable to reduce bycatch and bycatch mortality.

Social Factors.

Objective 12. When conservation actions are necessary to protect a stock or stock assemblage, attempt to develop management measures that will affect users equitably.

Objective 13. Minimize gear conflicts among resource users.

Objective 14. When considering alternative management measures to resolve an issue, choose the measure that best accomplishes the change with the least disruption of current domestic fishing practices, marketing procedures, and the environment.

Objective 15. Avoid unnecessary adverse impacts on small entities.

Objective 16. Consider the importance of groundfish resources to fishing communities, provide for the sustained participation of fishing communities, and minimize adverse economic impacts on fishing communities to the extent practicable.

Objective 17. Promote the safety of human life at sea.

1.3.4 Evolution of Federal Management and Resource Conservation Strategies

The first Federal management measures implemented for the groundfish fishery were cumulative landing limits, also known as "trip limits", for select species. One of the objectives in the early days of Federal groundfish management, based on the scientific understanding of achieving maximum sustainable yield (MSY), was to fish stocks down to the estimated biomass that produces MSY (B_{MSY}) to "optimally" utilize these resources. Increased understanding of rockfish sustainability evolved to a realization that harvest rates for these species were too aggressive, and more conservative limits were specified for rockfish beginning in the late 1990s.

The Sustainable Fisheries Act prompted Amendments 11 and 12, which incorporated new provisions for developing a rebuilding plan and managing the recovery of overfished species. Based on those provisions, nine stocks were declared overfished from 1999 to 2002 (Pacific ocean perch, bocaccio, lingcod, canary rockfish, cowcod, darkblotched rockfish, widow rockfish, yelloweye rockfish, and Pacific whiting). A tenth stock, petrale sole, was declared overfished in 2010.

A number of significant management measures were implemented in the late 1990s/early 2000s to respond to these overfished species' declarations and reduce the fishery mortality rates on these species. Area closures in habitats where these species occur began in 2000 with the closure of the two Cowcod Conservation Areas (CCAs) in the southern California Bight (see section 2.4.10). The first of the gear-specific Rockfish Conservation Areas (RCAs), depth-based areas defined by latitudinal and longitudinal waypoints closed to certain gears, was implemented in late 2002 before coastwide RCAs were implemented at the start of 2003. Large footrope trawls (footrope diameters > 8 in.) were prohibited for landing any shelf rockfish beginning in 2000. Small footropes on bottom trawls keep the gear out of high relief, rocky habitats where many of these overfished rockfish occur, since larger footropes are needed to be able to "bounce" or roll over these structures without destroying the nets. Coupled with retention prohibitions for many of these species (e.g., cowcod and yelloweye rockfish were and still are prohibited species), these measures effectively rebuilt nine of the ten overfished species with only yelloweye rockfish currently managed under a rebuilding plan (see section 2.3.1).

The 2007 MSA re-authorization prompted Amendment 23, which created the current harvest management framework of overfishing limits (OFLs), acceptable biological catches (ABCs), annual catch limits (ACLs), and accountability measures (AMs) to reduce the risk of overfishing (i.e., exceeding an OFL; see section 2.7).

1.4 Current Fishery Structure Overview

The Pacific coast groundfish fishery is a year-round mixed stock fishery occurring from the shores of California, Oregon, and Washington (in the case of recreational fisheries) to deep water areas off the continental shelf in the West Coast EEZ (Figure 1-1). The fishery is complex and a diverse set of vessels and gear types are used to harvest groundfish. There is a separate Tribal fishery. The non-Tribal fishery is comprised of commercial and recreational sectors. The commercial fishery is divided into LE trawl and non-trawl sectors, as well as an OA sector (Figure 1-2). Recreational fisheries are managed by each of the coastal states.

The FMP stocks and stock complexes targeted in the Pacific coast groundfish fishery are described in Chapter 2. Some of these species are primarily harvested in state waters. In these cases, it is common for these stocks and stock complexes to be managed with harvest guidelines specified in Federal regulations and managed by the coastal states. FMP stocks incidentally caught in other state-managed fisheries (e.g., California halibut trawl) are usually managed with yield set-asides to reduce the probability of overfishing these stocks. Details of groundfish sector management follows.

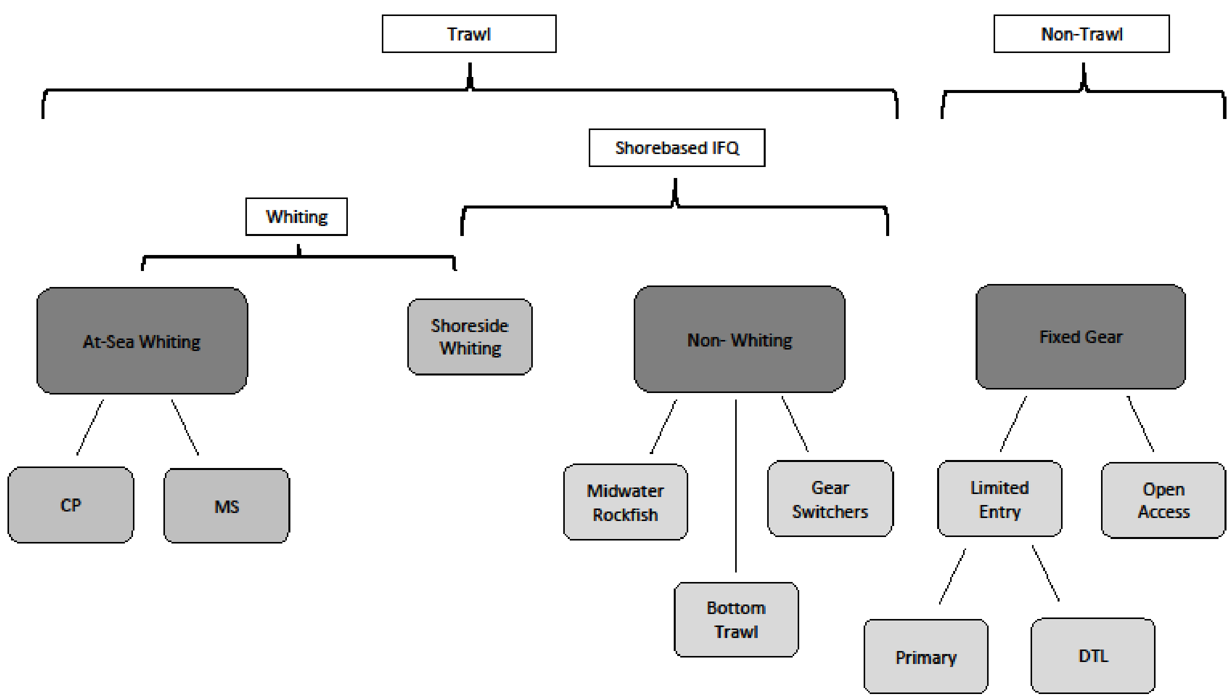

Figure 1-2. Sectors and subdivisions of the non-Tribal commercial Pacific coast groundfish fishery.

1.4.1 Sectors of the Groundfish Fishery

1.4.1.1 Trawl Sectors

Shorebased IFQ Sector

The Shorebased IFQ sector was created in 2011 with implementation of the trawl catch share program. Shorebased IFQ management is market-based and each participant in the shorebased IFQ sector is responsible for managing their catch. Quota share (QS) owners receive quota pounds (QP) at the start of each year for 30 species, which can then be used by vessels with limited entry trawl endorsed permits to harvest these species. Total catch (landings plus at-sea discards)[1] are debited against the QP held in vessels' accounts with possible significant penalties, both monetary and loss of fishing access, levied against those participants catching in excess of whatever quota they hold or can obtain from other participants in this system of transferable quotas. Participants in the shorebased IFQ sector are subject to a series of control mechanisms to limit consolidation, including QS accumulation limits (the percentage of QS that can be owned by one entity) and annual vessel limits (the amount of catch a vessel can harvest of a species in a year).

While all vessels in the shorebased IFQ sector can trade quota up to control limits, there is a diversity of target strategies. The largest trawl vessels in the sector target pelagic species, such as Pacific whiting, widow rockfish, and yellowtail rockfish with midwater trawl nets and other vessels target other IFQ species using a variety of trawl and fixed gears. Vessels in the sector specialize in targeting Pacific whiting, midwater rockfish, and a variety of non-whiting IFQ species using bottom trawls and/or fixed gears.

Vessels that target Pacific whiting in the shorebased IFQ sector target whiting with midwater trawls and deliver their catch to shoreside processors (this fishery is known as the shoreside whiting fishery). Some vessels also cross-participate in the Mothership fishery. There are separate quotas for each sector and intersector quota trading is prohibited. Such vessels need to declare which fishery they are engaged in and debit their catch against sector-specific quota.

Some of the whiting vessels in the shorebased IFQ sector have voluntarily formed the Shoreside Whiting Cooperative. While not formally recognized in the Federal groundfish regulations, cooperative members have created bycatch risk pools (i.e., pooled quota for constraining bycatch species available to members) and other cooperative agreements. Approximately two-thirds of shoreside whiting vessels have participated in the cooperative between 2012-2018. Table 1-1 shows the number of vessels participating in the shoreside whiting fishery from 2011-2019, with the associated catch and percent attainment of Pacific whiting.

[1] Total catch of most quota species is debited against quota; however, mortality rates are applied to discards of Pacific halibut, sablefish, and lingcod to determine the portion of the discards of these species debited against quota in vessel accounts.

Table 1-1. Participating Shoreside whiting vessels with catch, allocation, and percent attainment of Pacific whiting, 2011-2019.

Year	Number of Vessels	Total Catch (mt)	Post-Tribal Reapportionment Allocation (mt)	Percent Attainment
2011	26	90,978	92,818	98.0%
2012	24	65,666	68,662	95.6%
2013	24	97,634	98,297	99.3%
2014	25	98,717	127,835	77.2%
2015	22	58,357	124,607	46.8%
2016	23	86,176	141,007	61.1%
2017	25	146,568	169,547	86.5%
2018	26	130,052	169,127	76.9%
2019	27	143,747	169,126	85.0%

The midwater rockfish fishery has re-emerged after it was closed in 2002 after canary and widow rockfish were declared overfished (see sections 2.4.8 and 2.4.26, respectively). Starting in 2016 following the rebuilding of widow rockfish in 2015 and canary rockfish in 2017, the midwater rockfish strategy has been able to resume targeting of pelagic rockfish. One of the catalysts for this fishery's re-emergence was the gear regulations EFP and subsequent rulemaking and the year-round midwater EFP that allowed midwater trawling before May 15 to better provide stable year-round markets. Widow rockfish is the primary target of this fishery and saw 94 percent attainment in 2019, with yellowtail rockfish north of 40°10' N. lat. having 74 percent attainment. Bocaccio and chilipepper rockfishes were historically main targets off of California in the 1980s and 1990s, but attainments of these stocks remain relatively low due to a reduction in fleet capacity and a lack of processing infrastructure and markets. Canary rockfish are considered a potential constraining species since they are far less abundant than the main target stocks that they can co-occur with (e.g., in 2019, the canary rockfish IFQ allocation is 15 times lower than that of widow and yellowtail rockfishes).

Most non-whiting shorebased IFQ vessels target multiple species, including Dover sole, thornyheads, and sablefish (i.e., DTS) and flatfish using bottom trawls. Table 1-2 shows the number of vessels participating in the bottom trawl fishery from 2011-2018 and the total mortality and revenue from those vessels. The species that dominated the average catch in the bottom trawl fishery from 2011-2018 were Dover sole (37 percent), petrale sole (11 percent), arrowtooth flounder (9.4 percent), and sablefish (7.7 percent). Dover sole, petrale sole, and sablefish north of 36° N. lat. were the top three contributing species to revenue from 2011-2019, with revenue from those species accounting for an average of 75 percent of total revenue.

Table 1-2. The number of active bottom trawl vessels and total catch (mt) and revenue (millions of $) derived from groundfish landings, 2011-2018.

Year	Number of Vessels	Total Catch (mt)	Total Revenue ($Millions)
2011	71	19,612	$24.6
2012	66	19,490	$22.9
2013	68	21,324	$25.2
2014	63	18,721	$23.7
2015	59	18,078	$24.9
2016	57	18,818	$25.6
2017	62	19,496	$29.2
2018	58	17,036	$21.2

A provision was included in the trawl catch share program to allow shorebased IFQ vessels to use non-trawl gears (known as gear switching) to target their quota. Gear switching was envisaged as a strategy to harvest species not otherwise accessible in a mixed stock trawl fishery with some conservation benefits due to less bottom habitat disturbance. While some shorebased IFQ vessels do use both trawl gear and fixed gear within a fishing year, the primary target of vessels deploying fixed gear is sablefish. From 2011-2018, approximately 30 percent of the total available pounds (allocation plus surplus carryover) for sablefish north of 36° N. lat. was taken by IFQ vessels using fixed gear. The overwhelming majority of IFQ activity south of 40°10' N. lat. is by fixed gear vessels. Other species, such as shortspine thornyheads and blackgill rockfish, are harvested at a much smaller magnitude with fixed gear. An average of 96 percent of all IFQ fixed gear landings between 2011-2019 were comprised of sablefish. Table 1-3 shows the number of vessels and permits that harvested IFQ species with fixed gear.

Table 1-3. Number of vessels and permits associated with IFQ fixed gear landings, 2011-2019.

Year	Vessels	Permits
2011	24	24
2012	25	26
2013	18	18
2014	21	20
2015	18	18
2016	19	19
2017	17	17
2018	17	17
2019	16	16

At-Sea Whiting Trawl Sectors

The at-sea whiting trawl sectors (CP and MS) have been managed with cooperatives since 2011. Unlike the shorebased IFQ sector characterized for its diversity of target species and strategies, the at-sea sectors strictly target Pacific whiting in sector-specific harvest cooperatives. When the trawl catch share program was implemented in 2011, the at-sea sectors were also managed with allocations for select species (canary rockfish, darkblotched rockfish, widow rockfish, and

Pacific ocean perch), which were constraining for all trawl sectors. As of 2020, all non-whiting groundfish species are managed with yield set-asides in the at-sea whiting fisheries.

Catcher-processors (CP) catch and process Pacific whiting at sea. Vessels in the CP sector have been operating under a harvest cooperative, the Pacific Whiting Conservation Cooperative, since 1997. The CP fleet is capped in terms of participation by the ten CP-endorsed permits. There are no processing limits for the vessels, unlike the MS vessels discussed below. There is an ownership limit on the number of permits (five) that can be owned by a single entity in the case of dissolution of the CP cooperative. In such a case, the vessels in the CP sector are managed under an IFQ system.

Table 1-4 shows the number of active CP vessels and catch by year from 2011-2019. From 2011-2019, one of the ten permits in the sector has been latent (i.e., not assigned to a vessel).

Table 1-4. Participating vessels in the Catcher-Processor sector with total catch, apportionment, and percent attainment of Pacific whiting, 2011-2019.

Year	Number of Vessels	Total Catch (mt)	Post-Tribal Reapportionment Allocation (mt)	Percent Attainment
2011	9	71,665	75,138	95.4%
2012	9	55,668	55,584	100.2%
2013	9	78,041	79,574	98.1%
2014	9	103,266	103,486	99.8%
2015	9	68,484	100,873	67.9%
2016	9	108,804	114,149	95.3%
2017	9	137,130	137,252	99.9%
2018	9	116,050	136,912	84.8%
2019	9	116,147	136,912	84.8%

The MS sector is comprised of motherships (large processing vessels) and catcher vessels that target Pacific whiting and deliver their catch to motherships at sea. The Whiting Mothership Cooperative (WMC) was formed by the owners of the 37 catcher vessel limited entry trawl permit holders endorsed for operation in the MS sector based on historical participation. As in the CP sector, there is a limit on the number of MS permits (six) an entity can control. The WMC receives the allocation based on the cumulative catch histories of member vessels, which is the entirety of the sector's allocation since all catcher vessels have committed to the WMC since 2011. The MS cooperative operates in a pool system with an apportionment of the total whiting and any allocations/set-asides across five pools throughout the season based on the number of vessels participating. Table 1-5 shows the number of mothership processors and catcher vessels delivering Pacific whiting from 2011-2019 and the total catch compared to the post-tribal reapportionment[2].

[2] Unused Pacific whiting quota allocated to the tribal fishery can be reapportioned late in the season to the non-tribal whiting fishery when the tribes formally declare their whiting fishery has ended.

Table 1-5. Participating vessels in the Mothership sector with total catch, apportionment, and percent attainment of Pacific whiting, 2011-2019.

Year	Number of Motherships	Number of Catcher Vessels	Total Catch (mt)	Post-Tribal Reapportionment Allocation (mt)	Percent Attainment
2011	5	18	50,150	53,039	94.6%
2012	5	16	38,197	39,235	97.4%
2013	5	18	52,522	56,170	93.5%
2014	5	19	62,038	73,049	84.9%
2015	3	14	27,664	71,204	38.9%
2016	6	17	65,018	80,575	80.7%
2017	5	15	66,257	96,884	68.4%
2018	5	17	67,163	96,644	69.5%
2019	6	19	52,648	96,644	54.5%

1.4.1.2 Non-Trawl Sectors

The non-trawl sectors include commercial (LEFG and OA) and recreational fisheries managed with a variety of cumulative landing limits, area restrictions, and gear restrictions. Historically, the commercial sectors have been grouped into the "nearshore" and "non-nearshore" fisheries recognizing the fisheries that occur within state nearshore waters off California and Oregon and coastwide fishing activities further offshore, primarily targeting sablefish. Washington closed its state waters to commercial fisheries in 1995. While these fisheries may target different stocks, the nearshore and non-nearshore fisheries operate within the same series of trip limits depending on if they possess a limited entry permit or are participating in the open access fishery.

Limited Entry Fixed Gear

The LEFG sector is comprised of vessels fishing under a sablefish-endorsed LEFG permit and vessels fishing under an LEFG permit without a sablefish endorsement. All LEFG permits are also endorsed for their qualifying gear type (longline or traps/fishpots). An LEFG-permitted vessel with a sablefish endorsement can fish in the April – October primary sablefish fishery north of 36° N. lat. and LEFG permits without a sablefish endorsement target northern sablefish in the daily-trip-limit (DTL) fishery. Sablefish-endorsed permits allow participation in the DTL fishery before and after the primary season or when the cumulative trip limit is attained during the primary season. The primary sablefish fishery is also known as the "tier fishery" since there are three tiers of cumulative landing limits specified for participants. The tier fishery was developed as a part of Amendment 14 and provides vessels with the opportunity to stack up to three "tier" permits associated with various landing limits for sablefish north of 36° N. lat. The tiers are cumulative sablefish landing limits that vary between Tier 1, 2, and 3 vessels at a ratio of 3.85:1.75:1. The sablefish allocation for the LEFG sector is typically apportioned 85 percent to the primary fishery and 15 percent to the DTL fishery.

All other species coastwide are managed with trip limits that are typically higher than those provided to OA vessels.

Open Access

Open access groundfish vessels are not subject to any permit requirements and, for most stocks, have lower landing limits than those provided to LEFG vessels. There are OA vessels that target groundfish (i.e., directed OA) and vessels that catch groundfish while targeting non-groundfish species (i.e., incidental OA, e.g., salmon troll and pink shrimp). Those OA vessels landing nearshore groundfish species in the nearshore fishery are subject to state LE permits and limits in California and Oregon; Washington prohibited nearshore commercial fishing in 1995. Those OA vessels targeting sablefish offshore are subject to the OA DTL limits, which are typically smaller than LEFG DTL limits.

Recreational Fisheries

Recreational fisheries are managed by the coastal states with Federal limits and management measures decided in the PFMC process. States cannot manage their recreational fisheries to exceed Federal limits (ACLs, harvest guidelines (HGs), etc.); however, the states can specify more conservative management measures than specified in Federal regulations.

Recreational fisheries primarily target groundfish using hook and line angling gears, although groundfish are also targeted by divers using spears. Recreational fisheries extend from shorebased modes (fishing off the beach or man-made structures, such as wharves and jetties) to boat-based modes, including private boats and charter/commercial passenger fishing vessels (CPFVs). Each state manages their respective recreational fisheries to federally-specified state HGs for select stocks (e.g., HGs for rockfish species managed in the Nearshore Rockfish complex north of 40°10' N. lat., yelloweye rockfish, canary rockfish). Total recreational catch (landings plus estimated discard mortalities) counts against any specified non-trawl allocations.

1.4.2 The Tribal Fishery

There are four West Coast tribes (Makah, Hoh, Quinault Indian Nation, and Quileute) with treaty rights to harvest federally-managed groundfish in their Usual and Accustomed (U&A) fishing areas (§660.4). Under these treaties, the four coastal treaty tribes manage their fisheries within their respective U&As. All allocations of groundfish species to the tribes are deducted from ACLs as a set-aside before any non-tribal allocations are made. The tribal sablefish allocation is specified in the FMP at 10 percent of the northern ACL. The tribal allocation of Pacific whiting is decided annually in a consultation with NMFS. Tribal allocations of other groundfish species are decided biennially in the PFMC process for setting harvest specifications and management measures.

1.5 Groundfish Sector Allocations

Formal allocations (i.e., those prescribed in the FMP) of important stocks to different sectors of the groundfish fishery are important policy decisions designed to share the resource equitably according to need and foster longer-term stability and economic efficiency in the fishery.

In 1987, an allocation of sablefish north of 36° N. lat. was established for non-tribal commercial fisheries that provided 52 percent to the trawl fishery and 48 percent to the non-trawl gear groups. This allocation was later adjusted to 58 percent and 42 percent for trawl and non-trawl, respectively and included an allocation to the treaty tribes, as well as the limited entry trawl, LEFG, and open access sectors (Figure 1-3).

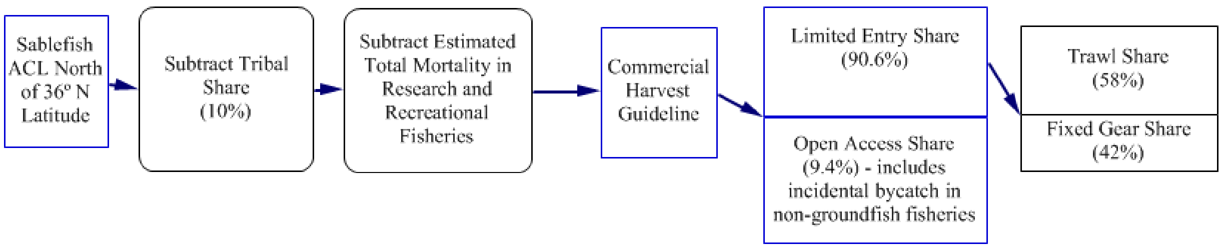

Figure 1-3. Fixed intersector allocations of sablefish north of 36° N. lat.

Pacific whiting allocations were decided in the 1990s. The allocations for non-tribal sectors apply after a yield amount is set aside to accommodate tribal whiting fisheries and other non-tribal non-directed fishing activities (e.g., pink shrimp and research). The non-tribal commercial share of whiting is allocated to limited entry whiting trawl sectors with 42 percent for the shoreside whiting sector, 24 percent for the at-sea mothership whiting sector, and 34 percent for the at-sea catcher-processor whiting sector.

Formal sector allocations for 19 important target stocks (arrowtooth flounder, chilipepper rockfish S of 40°10' N. lat., darkblotched rockfish, Dover sole, English sole, lingcod, longspine thornyhead N of 34°27' N. lat., longspine thornyhead S of 34°27' N. lat., Pacific cod, Pacific ocean perch, petrale sole, sablefish N of 36° N. lat., sablefish S of 36° N. lat., shortspine thornyhead N of 34°27' N. lat., shortspine thornyhead S of 34°27' N. lat., splitnose S of 40°10' N. lat., starry flounder, widow rockfish, and yellowtail rockfish N of 40°10' N. lat.) and three stock complexes (Other Flatfish, Slope Rockfish N of 40°10' N. lat., and Slope Rockfish S of 40°10' N. lat.) in the limited entry trawl fishery were decided under Amendment 21 and implemented in 2011 coincident with the trawl catch share program. Under Amendment 29, formal allocations for lingcod S of 40°10' N. lat., Slope Rockfish S of 40°10' N. lat., petrale sole, and widow rockfish were removed from the FMP and will transition to biennial allocations decided every two years starting in 2021. The formal allocations prescribed in the FMP through Amendments 21 and 29 are shown in Table 1-6.

Table 1-6. Allocation percentages for limited entry trawl and non-trawl sectors specified for FMP groundfish stocks and stock complexes under Amendments 21 and 29 (most percentages based on average 2003-2005 total catch by sector).

Stock or Complex	All Non-Treaty LE Trawl Sectors	All Non-Treaty Non-Trawl Sectors
Stocks		
Arrowtooth flounder	95%	5%
Chilipepper rockfish S of 40°10' N. lat.	75%	25%
Darkblotched rockfish	95%	5%
Dover sole	95%	5%
English sole	95%	5%
Lingcod N of 40°10' N. lat.	45%	55%
Longspine thornyhead N of 34°27' N. lat.	95%	5%
Pacific cod	95%	5%
Pacific ocean perch	95%	5%
Sablefish S of 36° N. lat.	42%	58%
Shortspine thornyhead N of 34°27' N. lat.	95%	5%
Shortspine thornyhead S of 34°27' N. lat.	50 mt	Remaining Yield
Splitnose rockfish S of 40°10' N. lat.	95%	5%
Starry flounder	50%	50%
Yellowtail rockfish N of 40°10' N. lat.	88%	12%
Stock Complexes		
Other Flatfish	90%	10%
Slope Rockfish N of 40°10' N. lat.	81%	19%

CHAPTER 2 GROUNDFISH STOCKS, THEIR STATUS, AND DESCRIPTION OF THE MANAGEMENT SYSTEM

There are over 100 stocks managed under the Pacific Coast Groundfish FMP. The actual number of FMP stocks is equivocal since all endemic species of the genera *Sebastes*, *Arhynchobatidae*, and *Macrouridae* are included and new species of these diverse genera are periodically described in the literature providing results of genetic/taxonomic research. These species include over 64 species of rockfish in the family *Scorpaenidae*, seven roundfish species, 12 flatfish species, assorted sharks, all endemic skates and grenadiers, ratfish, and a few miscellaneous bottom-dwelling marine fish species. Table 2-1 depicts the latitudinal and depth distributions of groundfish species managed under the groundfish FMP and Figure 1-1 depicts management area divisions.

The following sections contain information on the life histories of a subset of the groundfish managed under the groundfish FMP. While reading these sections, it is important to keep in mind how certain life history traits of the species have important implications on how the stocks are sustainably managed.

In contrast to the highly variable, and often volatile, population cycles of many coastal pelagic and invertebrate populations in the California Current, many of the resident groundfish in the California Current have evolved entirely different life history approaches to coping with environmental variability. Sablefish, Dover sole, spiny dogfish, and a large number of rockfish (*Sebastes* and *Sebastolobus*) species have life spans that typically span decades, and in some extreme examples may reach ages of 100 or greater (Beamish*, et al.* 2006; Love*, et al.* 2002). Although large initial catches of many rockfish had given the impression that these stocks were also highly productive, a growing body of scientific evidence soon made it clear that many of these species were incapable of sustaining high intensity fishing pressure using modern fishing methods (Francis 1986; Gunderson 1977; Gunderson 1984; Leaman and Beamish 1984).

Among the concerns raised in some of the early research and analyses were that the large standing stocks of older individuals were simply maintaining themselves within the dynamic bounds of their ecosystem, and that the failure to consider the role of such longevity in Northeast Pacific groundfish could lead to management challenges. Factors such as extreme longevity, low natural mortality, increasing fecundity with age, and infrequent reproductive success (recruitment) were explicitly considered when initial harvest rate strategies were developed for the Council (Clark 1991). However, the paucity of data and magnitude of some of these factors as related to the low productivity of many species were not fully appreciated in many early studies, and are now known to be important considerations in developing harvest rate guidelines and management policies (Clark 2002; Dorn 2002a). Consequently, harvest rates for many species have been reduced repeatedly in recent years to account for the improved knowledge regarding the overall productivity of these stocks. As new information continues to emerge regarding the significance of diverse age structures and other factors in sustaining groundfish resources (Berkeley 2004; Berkeley*, et al.* 2004; Bobko and Berkeley 2004), such information continues to be evaluated and incorporated into the stock assessment and assessment review processes that provide the scientific basis upon which management decisions are made.

Management of these groundfish species is based on principles outlined in the MSA, groundfish FMP, and National Standard Guidelines, which provide guidance on the ten national standards in the MSA. Stock assessments are based on resource surveys, catch trends in West Coast fisheries, and other data sources.

Table 2-1. Latitudinal and depth distributions of groundfish species (adults) managed under the Pacific Coast Groundfish Fishery Management Plan. [a/]

Common Name	Scientific Name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Flatfish Species					
Arrowtooth flounder	*Atheresthes stomias*	N 34° N. lat.	N 40° N. lat.	10-400	27-270
Butter sole	*Isopsetta isolepis*	N 34° N. lat.	N 34° N. lat.	0-200	0-100
Curlfin sole	*Pleuronichthys decurrens*	Coastwide	Coastwide	4-291	4-50
Dover sole	*Microstomus pacificus*	Coastwide	Coastwide	10-500	110-270
English sole	*Parophrys vetulus*	Coastwide	Coastwide	0-300	40-200
Flathead sole	*Hippoglossoides elassodon*	N 38° N. lat.	N 40° N. lat.	3-300	100-200
Pacific sanddab	*Citharichthys sordidus*	Coastwide	Coastwide	0-300	0-82
Petrale sole	*Eopsetta jordani*	Coastwide	Coastwide	10-250	160-250
Rex sole	*Glyptocephalus zachirus*	Coastwide	Coastwide	10-350	27-250
Rock sole	*Lepidopsetta bilineata*	Coastwide	N 32°30' N. lat.	0-200	summer 10-44, winter 70-150
Sand sole	*Psettichthys melanostictus*	Coastwide	N 33°50' N. lat.	0-100	0-44
Starry flounder	*Platichthys stellatus*	Coastwide	N 34°20' N. lat.	0-150	0-82
Rockfish Species [b/]					
Aurora rockfish	*Sebastes aurora*	Coastwide	Coastwide	45-420	160-270
Bank rockfish	*Sebastes rufus*	S 39°30' N. lat.	S 39°30' N. lat.	17-135	115-140
Black rockfish	*Sebastes melanops*	N 34° N. lat.	N 34° N. lat.	0-200	0-30
Black-and-yellow rockfish	*Sebastes chrysomelas*	S 40° N. lat.	S 40° N. lat.	0-20	0-10
Blackgill rockfish	*Sebastes melanostomus*	Coastwide	S 40° N. lat.	48-420	125-300
Blackspotted rockfish	*Sebastes melanostictus*	Coastwide	N 40° N. lat.	27-400	27-250
Blue rockfish	*Sebastes mystinus*	Coastwide	Coastwide	0-300	13-50
Bocaccio	*Sebastes paucispinis*	Coastwide	S 40° N. lat., N 48° N. lat.	15-180	54-82
Bronzespotted rockfish	*Sebastes gilli*	S 37° N. lat.	S 37° N. lat.	41-205	110-160
Brown rockfish	*Sebastes auriculatus*	Coastwide	S 40° N. lat.	0-70	0-50

Common Name	Scientific Name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Calico rockfish	*Sebastes dallii*	S 38° N. lat.	S 33° N. lat.	10-140	33-50
California scorpionfish	*Scorpaena gutatta*	S 37° N. lat.	S 34°27' N. lat.	0-100	0-100
Canary rockfish	*Sebastes pinniger*	Coastwide	Coastwide	27-460	50-100
Chameleon rockfish	*Sebastes phillipsi*	37°-33° N.	37°-33° N.	95-150	95-150
Chilipepper rockfish	*Sebastes goodei*	Coastwide	34°-40° N.	27-190	27-190
China rockfish	*Sebastes nebulosus*	N 34° N. lat.	N 35° N. lat.	0-70	2-50
Copper rockfish	*Sebastes caurinus*	Coastwide	S 40° N. lat.	0-100	0-100
Cowcod	*Sebastes levis*	S 40° N. lat.	S 34°27' N. lat.	22-270	100-130
Darkblotched rockfish	*Sebastes crameri*	N 33° N. lat.	N 38° N. lat.	16-300	96-220
Deacon rockfish	*Sebastes diaconus*	N 35° N. lat.	N 40°10' N. lat.	4-27	4-27
Dusky rockfish	*Sebastes ciliatus*	N 55° N. lat.	N 55° N. lat.	0-150	0-150
Dwarf-Red rockfish	*Sebastes rufinanus*	33° N. lat.	33° N. lat.	>100	>100
Flag rockfish	*Sebastes rubrivinctus*	S 38° N. lat.	S 37° N. lat.	17-100	Shallow
Freckled rockfish	*Sebastes lentignosus*	S 33° N. lat.	S 33° N. lat.	22-92	22-92
Gopher rockfish	*Sebastes carnatus*	S 40° N. lat.	S 40° N. lat.	0-45	5-20
Grass rockfish	*Sebastes rastrelliger*	S 44°40' N. lat.	S 40° N. lat.	0-25	0-8
Greenblotched rockfish	*Sebastes rosenblatti*	S 38° N. lat.	S 38° N. lat.	33-217	115-130
Greenspotted rockfish	*Sebastes chlorostictus*	S 47° N. lat.	S 40° N. lat.	27-110	50-100
Greenstriped rockfish	*Sebastes elongatus*	Coastwide	Coastwide	33-220	27-136
Halfbanded rockfish	*Sebastes semicinctus*	S 36°40' N. lat.	S 36°40' N. lat.	32-220	32-220
Harlequin rockfish c/	*Sebastes variegatus*	N 40° N. lat.	N 51° N. lat.	38-167	38-167
Honeycomb rockfish	*Sebastes umbrosus*	S 36°40' N. lat.	S 34°27' N. lat.	16-65	16-38
Kelp rockfish	*Sebastes atrovirens*	S 39° N. lat.	S 37° N. lat.	0-25	3-4
Longspine thornyhead	*Sebastolobus altivelis*	Coastwide	Coastwide	167-	320-550
Mexican rockfish	*Sebastes macdonaldi*	S 36°20' N. lat.	S 36°20' N. lat.	50-140	50-140
Olive rockfish	*Sebastes serranoides*	S 41°20' N.	S 40° N. lat.	0-80	0-16
Pacific ocean perch	*Sebastes alutus*	Coastwide	N 42° N. lat.	50-450	110-250
Pink rockfish	*Sebastes eos*	S 37° N. lat.	S 35° N. lat.	40-200	40-200
Pinkrose rockfish	*Sebastes simulator*	S 34° N. lat.	S 34° N. lat.	54-160	108
Puget Sound rockfish	*Sebastes emphaeus*	N 40° N. lat.	N 40° N. lat.	6-200	6-200
Pygmy rockfish	*Sebastes wilsoni*	N 32°30' N. lat.	N 32°30' N. lat.	17-150	17-150
Quillback rockfish	*Sebastes maliger*	N 36°20' N. lat.	N 40° N. lat.	0-150	22-33
Redbanded rockfish	*Sebastes babcocki*	Coastwide	N 37° N. lat.	50-260	82-245
Redstripe rockfish	*Sebastes proriger*	N 37° N. lat.	N 37° N. lat.	7-190	55-190
Rosethorn rockfish	*Sebastes helvomaculatus*	Coastwide	N 38° N. lat.	65-300	55-190

Common Name	Scientific Name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Rosy rockfish	*Sebastes rosaceus*	S 42° N. lat.	S 40° N. lat.	8-70	30-58
Rougheye rockfish	*Sebastes aleutianus*	Coastwide	N 40° N. lat.	27-400	27-250
Semaphore rockfish	*Sebastes melanosema*	S 34°27' N. lat.	S 34°27' N. lat.	75-100	75-100
Sharpchin rockfish	*Sebastes zacentrus*	Coastwide	Coastwide	50-175	50-175
Shortbelly rockfish	*Sebastes jordani*	Coastwide	S 46° N. lat.	50-175	50-155
Shortraker rockfish	*Sebastes borealis*	N 39°30' N.	N 44° N. lat.	110-	110-220
Shortspine thornyhead	*Sebastolobus alascanus*	Coastwide	Coastwide	14-	55-550
Silvergray rockfish	*Sebastes brevispinis*	Coastwide	N 40° N. lat.	17-200	55-160
Speckled rockfish	*Sebastes ovalis*	S 38° N. lat.	S 37° N. lat.	17-200	41-83
Splitnose rockfish	*Sebastes diploproa*	Coastwide	Coastwide	50-317	55-250
Squarespot rockfish	*Sebastes hopkinsi*	S 38° N. lat.	S 36° N. lat.	10-100	10-100
Sunset rockfish	*Sebastes crocotulus*	S 34°27' N. lat.	S 34°27' N. lat.	55-164	55-110
Starry rockfish	*Sebastes constellatus*	S 38° N. lat.	S 37° N. lat.	13-150	13-150
Stripetail rockfish	*Sebastes saxicola*	Coastwide	Coastwide	5-230	5-190
Swordspine rockfish	*Sebastes ensifer*	S 38° N. lat.	S 38° N. lat.	38-237	38-237
Tiger rockfish	*Sebastes nigrocinctus*	N 35° N. lat.	N 35° N. lat.	30-170	35-170
Treefish	*Sebastes serriceps*	S 38° N. lat.	S 34°27' N. lat.	0-25	3-16
Vermilion rockfish	*Sebastes miniatus*	Coastwide	Coastwide	0-150	4-130
Widow rockfish	*Sebastes entomelas*	Coastwide	N 37° N. lat.	13-200	55-160
Yelloweye rockfish	*Sebastes ruberrimus*	Coastwide	N 36° N. lat.	25-300	27-220
Yellowmouth rockfish	*Sebastes reedi*	N 40° N. lat.	N 40° N. lat.	77-200	150-200
Yellowtail rockfish	*Sebastes flavidus*	Coastwide	N 37° N. lat.	27-300	27-160
Roundfish Species					
Cabezon	*Scorpaenichthys marmoratus*	Coastwide	Coastwide	0-60	0-27
Kelp greenling	*Hexagrammos decagrammus*	Coastwide	N 40° N. lat.	0-25	0-10
Lingcod	*Ophiodon elongatus*	Coastwide	Coastwide	0-233	0-40
Pacific cod	*Gadus macrocephalus*	N 34° N. lat.	N 40° N. lat.	7-300	27-160
Pacific whiting	*Merluccius productus*	Coastwide	Coastwide	20-500	27-270
Sablefish	*Anoplopoma fimbria*	Coastwide	Coastwide	27->1,000	110-550
Cartilaginous Fish Species					
Aleutian skate	*Bathyraja aleutica*	N of 40°10' N. lat.	N of 40°10' N. lat.	8-876	50-120
Bering/sandpaper skate	*Bathyraja interrupta*	N of 32°30' N. lat.	N of 32°30' N. lat.	13-820	30-750
Big skate	*Beringraja binoculata*	Coastwide	N 34°27' N. lat.	2-440	2-60
California skate	*Raja inornata*	Coastwide	S 39° N. lat.	0-367	0-10
Leopard shark	*Triakis semifasciata*	S 46° N. lat.	S 46° N. lat.	0-50	0-2

Common Name	Scientific Name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Longnose skate	*Beringraja rhina*	Coastwide	N 46° N. lat.	30-410	30-340
All other skates	Endemic species in the family *Arhynchobatidae*				
Ratfish	*Hydrolagus colliei*	Coastwide	Coastwide	0-499	55-82
Roughtail/black skate	*Bathyraja trachura*	Coastwide	Coastwide	116-1,394	400-1,090
Soupfin shark	*Galeorhinus zyopterus*	Coastwide	Coastwide	0-225	0-225
Spiny dogfish	*Squalus suckleyi*	Coastwide	Coastwide	0->640	0-190
Other Species					
Finescale codling	*Antimora microlepis*	Coastwide	N 38° N. lat.	190-1,588	190-470
Giant grenadier	*Coryphaenoides pectoralis*	Coastwide	Coastwide	77-1,914	383-601
Pacific grenadier	*Coryphaenoides acrolepis*	Coastwide	N 38° N. lat.	85-1,350	500-1,350
All other grenadiers	Endemic species in the family *Macrouridae*				

a/ Data from (Casillas, et al. 1998), (Eschmeyer, et al. 1983), (Hart 1988), (Miller and Lea 1972), (Love, et al. 2002), (Frable, et al. 2015), and NMFS survey data. Depth distributions refer to offshore distributions, not vertical distributions in the water column.

b/ The category "rockfish" includes all genera and species of the family Scorpaenidae, even if not listed, that occur in the Washington, Oregon, and California area.

c/ Only two occurrences of harlequin rockfish south of 51° N. lat. (off Newport, OR and La Push, WA; (Casillas, et al. 1998)).

The passage of the SFA in 1996 and the reauthorization of the MSA in 2006 incorporated the current conservation and rebuilding mandates into the MSA. These mandates, including abundance-based standard reference points for declaring the status of a stock (overfished/rebuilding; in a "precautionary" status; or at levels that can support MSY (healthy or "rebuilt")), were subsequently incorporated in the groundfish FMP with adoption of Amendments 11, 12, and 23. These reference points are determined relative to an estimate of the "virgin" or unexploited spawning biomass of the stock, denoted as B_0, which is defined as the average equilibrium abundance of a stock's spawning biomass before it is affected by fishing-related mortality.[3] B_0 is then used to estimate MSY, as identified in the MSA and National Standard Guidelines. MSY represents a theoretical maximum surplus production from a population of constant size; National Standard Guidelines define it as "the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions." For a given population and set of ecological conditions, there is a biomass that produces MSY (denoted as B_{MSY}), which is less than the equilibrium size in the

[3] The current abundance of a stock relative to its unfished level is commonly written as a percentage or a proportion; this value represents the stock's depletion level. In addition to using a comparison between current spawning biomass and unfished spawning biomass to determine this reference point, some stock assessment authors compare current and unfished levels of spawning output or of total stock biomass, depending on the information that is available.

absence of fishing (B_0)[4]. The harvest rate used to achieve or sustain B_{MSY} is referred to as the Maximum Fishing Mortality Threshold (MFMT, denoted as F_{MSY}). Three harvest specification reference points defined in the groundfish FMP provide guidance in setting the harvest rate: an OFL, an ABC, and an ACL (see section 2.7 for more information on harvest specifications). The Council identifies the ACL as the management target for each species or species complex. When the stock biomass is determined to be lower than $B_{MSY,}$ the ACL is set to an adequately low level to rebuild the stock to a healthy level in a timely fashion.

The biomass level that produces MSY (i.e., B_{MSY}) is generally unknown and assumed to be variable over time due to long-term fluctuations in ocean conditions, so that no single value is appropriate. Furthermore, F_{MSY} is tightly linked to an assumed level of density dependence in recruitment, and there is insufficient information to determine that level for many West Coast groundfish stocks. Therefore, the use of approximations or proxies is necessary; absent a more accurate determination of $F_{MSY,}$ the Council applies default MSY proxies (see section 2.7 for more details). The Council adopts management actions aimed to maintain abundance of each stock at or above the specified B_{MSY} target. The threshold for declaring a stock overfished is when the stock's spawning biomass declines to less than the specified Minimum Stock Size Threshold or MSST (i.e., 12.5 percent of B_0 or $B_{12.5\%}$ for assessed flatfish stocks and $B_{25\%}$ for all other groundfish stocks). A rebuilding plan that specifies how total fishing-related mortality is constrained to achieve an MSY abundance level within the legally allowed time is required by the MSA and groundfish FMP when a stock is declared overfished.

Of the more than 100 species managed under the groundfish FMP, only a portion are individually managed; the remaining species are managed and accounted for in stock complexes (see section 2.5). The Council has also decided to continue to manage some assessed stocks in complexes to avoid management complications such as disruption to the trawl rationalization program. Catch-based and other data-limited methods described in section 2.8.1 are used to set OFLs for unassessed stocks. Additionally, there is a category of stocks that are incidentally caught in groundfish fisheries for which no harvest limits are specified. This category of stocks, termed Ecosystem Component (EC) species, are not considered to be in the fishery and are neither targeted nor generally retained for sale or personal use. EC species are determined not to likely become subject to overfishing or to be overfished in the absence of conservation and management measures. There is a monitoring requirement for species designated as EC species to the extent that any new pertinent scientific information becomes available (e.g., catch trends, vulnerability, etc.) to determine changes in their status or their vulnerability to the fishery. The Council has specified an EC designation for some species currently managed in the FMP (see section 2.5.9).

When the total fishing mortality (i.e., landed catch plus dead discards) of a West Coast groundfish stock or stock complex exceeds the specified OFL for that stock or complex, the stock is considered to be subject to overfishing. Total mortality is estimated by the NMFS Northwest Fisheries Science Center and reported for all managed West Coast stocks and complexes in total mortality reports. Summaries of the status of West Coast groundfish stocks and complexes (and the other federally-managed stocks and complexes nationally), are provided by the NMFS Fish Stock Sustainability Index (FSSI).

[4] Generally, population sizes above B_{MSY} are assumed to be less productive because of competition for resources or other density-dependent factors.

2.1 Productivity and Susceptibility Assessment of Stocks to Overfishing

The vulnerability to potential overfishing of a stock to the fishery for each groundfish stock in the FMP was determined as a first step in assisting with two specific tasks set forth in the FMP: 1) to define species as either "in the fishery" or as an "ecosystem component," and 2) identify stock complexes. In addition, the vulnerability scores were considered when prioritizing stock assessments and determining data collection needs.

The Productivity-Susceptibility Assessment (PSA) approach of Patrick et al. (2009) was used to characterize vulnerability and has two components: 1) productivity as defined by life history traits, and 2) susceptibility to current fishing practices (Cope*, et al.* 2011). Each vulnerability component is comprised of several attributes (10 productivity and 12 susceptibility attributes) and the weighted mean score of all attributes defines the overall productivity and susceptibility score. Table 2-2 includes the vulnerability scores for all species in the FMP relative to the current fishery. Table 2-3 shows the vulnerability scores for currently overfished or rebuilding rockfish species relative to the fishery circa 1998. Scores are presented in two dimensions, with productivity on the x-axis and susceptibility on the y-axis (Figure 2-1). Cope et al. (2011) established vulnerability reference points of assessed and unassessed West Coast groundfish stocks to determine vulnerability groups as follows:

- $V \geq 2.2$ indicate species of major concern.
- $2.0 \leq V < 2.2$ indicate species of high concern.
- $1.8 \leq V < 2.0$ indicate species of medium concern.
- $V < 1.8$ indicate species of low concern.

Rockfish and elasmobranchs showed the highest vulnerabilities (>2.0), with the deepest-residing members of those groups often the most vulnerable, though there were several species of nearshore rockfish (China, quillback, and copper rockfish) with some of the highest scored vulnerabilities. Flatfishes in general showed the lowest vulnerabilities.

In addition to scoring each productivity and susceptibility attribute, the quality of the data used for each score was also recorded (Table 2-2, Table 2-3, and Figure 2-2). Data quality is scored for each productivity and susceptibility attribute, with the overall data quality score calculated as the weighted mean of all attributes. A scoring scale of 1-5 was used, with the best data score being 5.

Recording the data quality can highlight vulnerability scores that can be improved with additional data or that should be interpreted with caution because of questionable data contribution. Data quality scores can also be used to justify future data collection on particular attributes.

In general, susceptibility was harder to score (lower data quality) than productivity. Flatfishes as a group had the least informed species, but elasmobranchs and several rockfish species also showed low-quality data informing vulnerability scores (Table 2-2 and Figure 2-2).

PSA analyses are anticipated to be re-done periodically. Productivity scores are not expected to vary much over time since they are based on life history traits. However, susceptibility scores may vary based on changes in fishing practices and/or management, as well as an updated understanding of the stock's interaction with the fishery. As susceptibility scores change, so do the vulnerability scores.

Table 2-2. Overall scores and results of the Productivity and Susceptibility Assessment (PSA) ranked from most to least vulnerable to overfishing relative to the current West Coast fishery.

Stock ID	Stock Name	Productivity	Susceptibility	Vulnerability
21	Copper rockfish	1.95	1.60	2.27
67	Rougheye rockfish	1.17	2.33	2.27
72	Shortraker rockfish	1.22	2.38	2.25
20	China rockfish	1.33	2.29	2.23
58	Quillback rockfish	1.31	2.43	2.22
61	Redstripe rockfish	1.31	2.33	2.16
22	Cowcod	1.25	2.00	2.13
77	Spiny dogfish	1.11	1.98	2.13
10	Bronzespotted rockfish	1.37	2.14	2.12
16	California skate	1.33	2.00	2.12
35	Greenblotched rockfish	1.28	2.24	2.12
2	Aurora rockfish	1.89	2.29	2.10
76	Speckled rockfish	1.33	2.29	2.10
65	Rosethorn rockfish	1.19	2.05	2.09
81	Starry rockfish	1.25	2.14	2.09
7	Blackgill rockfish	1.22	2.08	2.08
84	Tiger rockfish	1.25	2.10	2.06
70	Sharpchin rockfish	1.36	2.24	2.05
86	Vermilion rockfish	1.22	2.02	2.05
87	Widow rockfish	1.31	2.16	2.05
18	Chameleon rockfish	1.39	2.20	2.03
3	Bank rockfish	1.28	1.88	2.02
55	Pink rockfish	1.33	2.14	2.02
60	Redbanded rockfish	1.28	2.05	2.02
74	Silvergray rockfish	1.22	1.95	2.02
75	Soupfin shark	1.11	1.71	2.02
8	Blue rockfish	1.22	2.16	2.01
17	Canary rockfish	1.61	2.43	2.01
43	Leopard shark	1.26	2.00	2.00
88	Yelloweye rockfish	1.22	1.92	2.00
4	Big skate	2.45	2.05	1.99
11	Brown rockfish	1.72	2.08	1.99
26	Dusky rockfish	1.75	1.76	1.99
36	Greenspotted rockfish	1.39	2.14	1.98
30	Flag rockfish	1.83	1.80	1.97
40	Honeycomb rockfish	1.36	2.10	1.97
89	Yellowmouth rockfish	1.61	2.38	1.96

Stock ID	Stock Name	Productivity	Susceptibility	Vulnerability
5	Black rockfish	1.21	2.14	1.94
39	Harlequin rockfish	1.31	1.95	1.94
54	Petrale sole	1.70	2.44	1.94
83	Swordspine rockfish	1.33	2.00	1.94
9	Bocaccio	1.28	2.04	1.93
24	Darkblotched rockfish	1.39	2.24	1.92
34	Grass rockfish	1.61	2.29	1.89
66	Rosy rockfish	1.61	2.29	1.89
37	Greenstriped rockfish	1.28	1.76	1.88
90	Yellowtail rockfish	1.33	1.88	1.88
48	Olive rockfish	1.69	2.33	1.87
79	Squarespot rockfish	1.61	2.24	1.86
51	Pacific grenadier	1.44	1.95	1.82
56	Pinkrose rockfish	1.31	1.67	1.82
78	Splitnose rockfish	1.28	1.60	1.82
47	Mexican rockfish	1.50	2.00	1.80
73	Shortspine thornyhead	1.33	1.68	1.80
82	Stripetail rockfish	1.39	1.81	1.80
63	Rock greenling	1.78	2.29	1.77
33	Gopher rockfish	1.56	2.00	1.76
85	Treefish	1.67	2.10	1.73
59	Ratfish	1.63	2.05	1.72
6	Black-and-yellow rockfish	1.83	1.68	1.70
50	Pacific ocean perch	1.44	1.67	1.69
53	Pacific whiting	2.00	2.36	1.69
13	Cabezon	1.33	2.48	1.68
45	Longnose skate	1.53	1.80	1.68
68	Sablefish	1.61	1.88	1.64
42	Kelp rockfish	1.83	2.12	1.62
41	Kelp greenling	1.83	2.04	1.56
44	Lingcod	1.75	1.92	1.55
25	Dover sole	1.36	2.57	1.54
27	Dwarf-red rockfish	1.06	1.88	1.54
46	Longspine thornyhead	1.47	1.16	1.54
29	Finescale codling	2.45	2.10	1.48
14	Calico rockfish	1.39	2.04	1.46
32	Freckled rockfish	1.80	1.96	1.44
57	Pygmy rockfish	1.78	1.71	1.42
64	Rock sole	1.95	1.95	1.42
15	California scorpionfish	1.28	0.00	1.41
19	Chilipepper	1.83	0.00	1.35
49	Pacific cod	2.11	2.00	1.34
62	Rex sole	2.05	1.86	1.28
31	Flathead sole	2.25	1.92	1.26

Stock ID	Stock Name	Productivity	Susceptibility	Vulnerability
38	Halfbanded rockfish	2.00	1.76	1.26
52	Pacific sanddab	2.40	2.10	1.25
23	Curlfin sole	1.72	1.75	1.23
69	Sand sole	2.35	2.05	1.23
1	Arrowtooth flounder	1.33	2.05	1.21
28	English sole	2.30	2.05	1.19
12	Butter sole	1.78	1.76	1.18
71	Shortbelly rockfish	1.94	1.40	1.13
80	Starry flounder	2.15	1.60	1.04

Table 2-3. Retrospective Productivity and Susceptibility Assessment (PSA) vulnerability scores of currently overfished or rebuilding rockfish species ranked from most to least vulnerable to overfishing relative to stock status and the fishery circa 1998.

Stock Name	Stock ID	Susceptibility	Vulnerability
Yelloweye rockfish	18_H	2.80	2.53

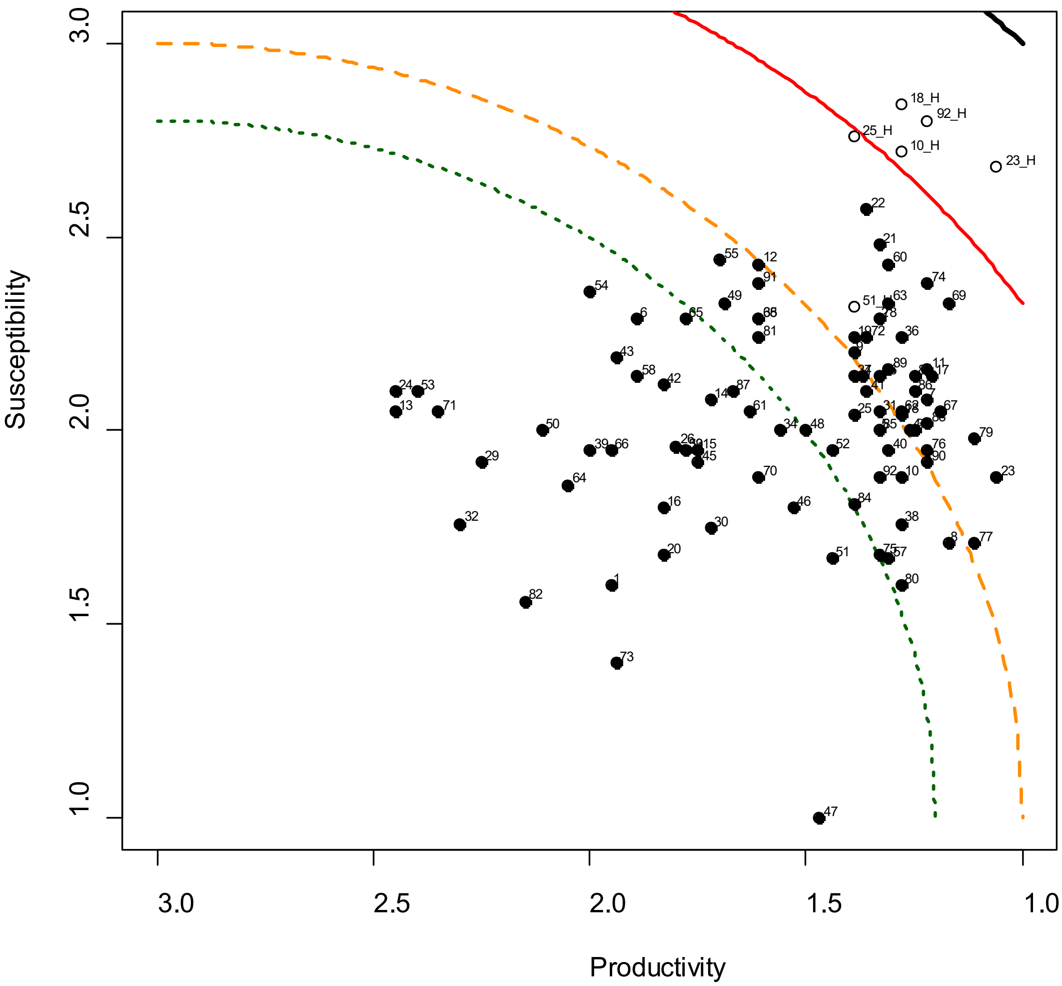

Figure 2-1. Productivity and Susceptibility Analysis (PSA) plot for species in the West Coast groundfish FMP. Contours delineate areas of relative vulnerability (V, i.e., distance from the origin), with the highest vulnerability above the solid red line (V = 2.2), high vulnerability above the orange broken line (V=2), medium vulnerability above the green dotted line (V=1.8), and the lowest vulnerability below the green dotted line. The maximum vulnerability (V=2.8) is indicated with the solid black line. Solid circles are based on current PSA scores. Open circles are based on PSA scores circa 1998. Numbers refer to the Stock ID in Table 2-2 and Table 2-3.

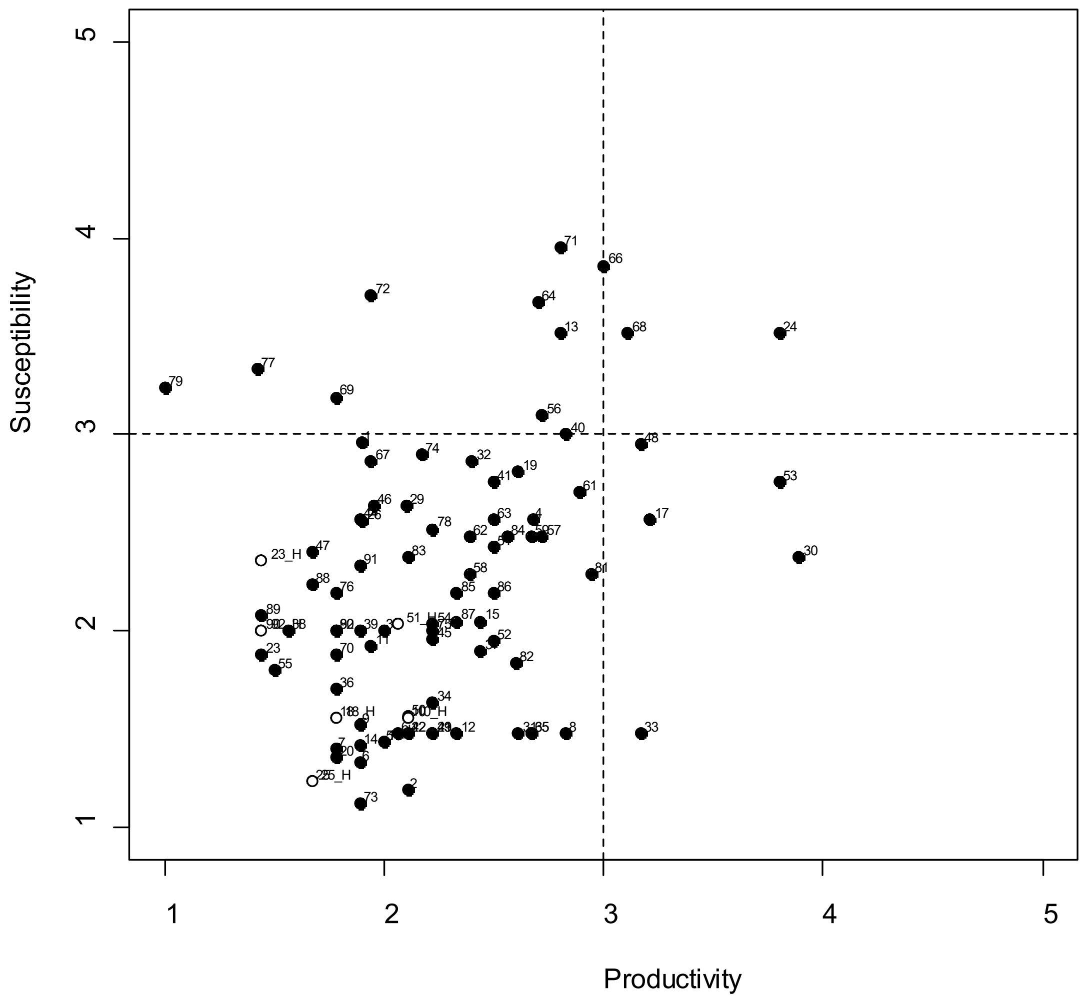

Figure 2-2. Data quality plots for the productivity and susceptibility scores in the PSA for each species (represented numerically in Table 2-2 and Table 2-3) in the West Coast groundfish FMP. Higher scores indicate lower data quality. Vertical and horizontal lines provide a general guide to relative data quality with values above 3 on either axis considered data-limited.

2.2 Stock Assessments and Rebuilding Analyses Used to Estimate Stock Status and Inform Management Decisions

Stock assessments are used for setting harvest specifications by providing estimates of MSY, OFL, the MFMT, the minimum stock size threshold (MSST), and ABC. Stock assessments are also used to determine the status of a fish population or subpopulation (stock) in terms of estimating population size, reproductive status (e.g., spawning biomass, fecundity, etc.), fishing mortality, and whether current catches are sustainable. In the terms of the Groundfish FMP, stock assessments provide: 1) an estimate of the current biomass and reproductive potential (generally expressed as spawning biomass or spawning output), 2) an estimate of F_{MSY} (the harvest rate estimated to produce MSY) or proxy thereof translated into exploitation rate or spawning potential ratio (SPR; see section 2.8.1 for a description of SPR), 3) the estimated biomass corresponding to MSY (B_{MSY}), or a proxy thereof, 4) estimated unfished biomass (B_0), and 5) the estimated variance (or a confidence interval) for the estimate of current biomass. With the exception of Pacific whiting, which is assessed annually as specified in the Agreement with Canada on Pacific Hake/Whiting, groundfish stock assessments are conducted on a two-year cycle. Given the large number of groundfish species and limited state and Federal resources, a subset of all groundfish stocks are assessed in each stock assessment cycle. Overfished species' stock assessments are typically conducted every two years, although a catch report can be substituted for an assessment to monitor compliance with adopted rebuilding plans. The process for setting groundfish specifications involves the adoption of new and updated stock assessments. During the biennial specification process, the Council's Scientific and Statistical Committee (SSC) reviews stock assessments and rebuilding analyses for overfished/rebuilding species and makes recommendations to the Council relative to the standards of the best available science and the soundness of the scientific information relative to management decisions. The Council then approves all or a portion of the stock assessments or recommends further analysis.

The perception of stock status and productivity may change substantially between stock assessments. Such changes can result from technical changes in the assessment model, including how a given assessment model is structured, the assumptions used to fix or estimate key parameters (i.e., whether parameters such as natural mortality and steepness are fixed, estimated freely, or estimated with an informative prior), and the evolution of methods for developing data time series and estimates of uncertainty from different sources of raw data. The population dynamics of target species themselves are responsive to a mix of complex (and often poorly understood) biological, oceanographic, and interspecies interactions. New data sources (e.g., new data types, extensions of existing data sets, incorporation of environmental factors into assessments) can result in changes in parameter estimates and model outputs.

All stock assessments are subject to a peer review process, consistent with the MSA (§302(g)(1)(E)). The process considers components of the assessments starting with data collection and continuing through to scientific recommendations and information presented to the Council and its advisors. The terms of reference for the groundfish stock assessment process defines the expectations and responsibilities for various participants in the groundfish stock assessment review (STAR) process and outlines the guidelines and procedures for a peer review process. The STAR process is a key element in an overall process designed to review the technical merits of stock assessments and other scientific information used by the SSC. This process allows the Council to make timely use of new fishery and survey data, to analyze and understand these data as completely as possible, to provide opportunity for public comment, and to assure that the results are as accurate and error-free as possible.

Harvest specifications and the science used as the basis for management decision-making are derived from the most recent assessments and/or rebuilding analyses prepared for those stocks that are informed by an assessment. The newest assessments were those prepared and adopted in 2019 and the oldest assessments informing management decisions for fisheries in 2021 and beyond were updated from a few stock assessments conducted and adopted in 2007 by re-running the projections from old assessments using actual catches since the assessment was conducted. Table 2-4 presents a summary of the management quantities estimated by the base models of the most recent assessments informing management in 2021 and beyond. Table 2-5 lists life history parameters from the stocks assessed since 2005, excluding those conducted using Extended Depletion-based Stock Reduction Analysis (XDB-SRA); steepness of the spawner-recruitment curve (h), recruitment variability (sigma-r), the von Bertalanffy Equation growth constant (k), and natural mortality (M) are each important contributors to the understanding of the productivity and resiliency of these stocks. Table 2-6 lists life history parameters from the stocks assessed in 2013 using XDB-SRA; B_{MSY}, F_{MSY}, M, B_{MSY}/B_0, and F_{MSY}/M inform the relative productivity and resiliency of these stocks.

All stock assessments, STAR panel reports, and rebuilding analyses used to inform management decisions on West Coast groundfish stocks and fisheries can be found on the Council's web site at https://www.pcouncil.org/stock-assessments-star-reports-stat-reports-rebuilding-analyses-terms-of-reference/groundfish-stock-assessment-documents/.

2.2.1 Types of Assessments Used in Managing Groundfish Stocks

The Council uses various types of assessments that range from data-rich full assessments (also known as benchmark assessments) to data-limited methods used to only estimate an OFL. The Council decides which groundfish stocks will be assessed and based on SSC recommendations, what type of assessment will be used (i.e., full, update, data-moderate, data-limited) each cycle. These stock assessment priorities are decided in even years and assessments are conducted, reviewed, and adopted in odd years. Results from these assessments are used to inform management decisions for the following biennial cycle, which begins in the next odd year. The SSC reviews all assessments and recommends to the Council if they represent the best scientific information available for the stock, and whether and how they can be used to inform Council decisions.

The SSC categorizes stocks based on the type of assessment and the quality of data informing that assessment. The FMP harvest specification framework calls for increasing uncertainty buffers translated into lower ABCs (and ACLs) for stocks informed by less certain assessments (see section 2.8.2). Stock categories range from category 1, characterized by stocks informed by full assessments with reasonably good estimates of year class strength, to category 3 stocks where there is only a data-limited estimate of the OFL. A more detailed description of the assessment models used in current groundfish management follows.

2.2.1.1 Data-Limited Assessments

Data-limited assessments employ catch-based or other (e.g., trawl survey biomass * M) statistics to estimate an OFL for a stock. Stock status cannot be determined using these types of assessment since there are no time series of survey or other abundance indices used in a data-limited assessment. The most rudimentary data-limited assessment is simply setting the OFL to a proportion of the average historical catch. However, there is great uncertainty whether that is a "true" OFL since the historical catch used to compute the average could have been unsustainably high. Therefore, the SSC categorizes stocks informed by a data-limited assessment as category 3 stocks, thus mandating a higher buffer to determine the ABC. While data-limited methods are characterized as "assessments" here, stocks with OFLs informed with data-limited methods are considered unassessed since there is no estimate of relative depletion or status. Other approved data-limited methods (Depletion-Corrected Average Catch (DCAC), Depletion-Based Stock Reduction Analysis (DB-SRA), and Simple Stock Synthesis), more sophisticated than average catch, are described below.

Depletion-Corrected Average Catch

The DCAC method provides an estimate of the OFL for data-limited stocks of uncertain status (MacCall 2009). DCAC adjusts historical average catch to account for one-time "windfall" catches that are the result of stock depletion, producing an estimate of yield that was likely to be sustainable over the same period. Advantages of the DCAC approach for determining sustainable yield for data-limited stocks include: 1) relatively minimal data requirements (i.e., an historical catch time series), 2) biologically-based adjustment to catch-based yield proxies with transparent assumptions about relative changes in abundance (e.g., a production function with compensation exists for the stock), and 3) simplicity in computing.

Depletion-Based Stock Reduction Analysis

The DB-SRA method extends the DCAC method by 1) restoring the temporal link between production and biomass, and 2) evaluating and integrating alternative hypotheses regarding changes in abundance during the historical catch period (Dick and MacCall 2011). This method combines DCAC's distributional assumptions regarding life history characteristics and stock status with the dynamic models and simulation approach of stochastic stock reduction analysis.

Simple Stock Synthesis

A similar approach to DB-SRA, or Simple Stock Synthesis (SSS) can also be conducted in Stock Synthesis (Cope 2013).

2.2.1.2 Data-Moderate Assessments

Data-moderate assessments are less complicated than full assessments and can therefore be reviewed more expeditiously. Unlike a full assessment, which is reviewed by a STAR panel and the SSC, only the SSC reviews a data-moderate assessment[5].

[5] While this is technically true, the SSC and Council elected to do a more rigorous review of data-moderate assessments in a STAR panel in 2013, the first year data-moderate assessments were conducted on the West Coast.

Data-moderate assessments combine catch-based methods with a time series of relative abundance estimates from one or more surveys or other types of abundance indices (e.g., catch per unit of effort (CPUE) time series). This type of assessment represents the minimal structure of an assessment used to determine stock status according to the NMFS National Stock Assessment Improvement plan (Mace*, et al.* 2001). These assessments exclude compositional age and length data, which are used to determine survey and/or fishery selectivities and to estimate other parameters in a full assessment model. The addition of compositional data complicates an assessment, requiring more review time to understand what data are driving model results. Data-moderate assessments were therefore developed to increase the number of groundfish stocks assessed given the resources available to conduct and review assessments each cycle. There are two data-moderate assessment models in current use that have been reviewed and recommended by the SSC: Extended Simple Stock Synthesis (exSSS) and XDB-SRA. These are described in more detail below.

Since data-moderate assessments are less informative than full assessments, the SSC categorizes stocks informed with such an assessment as category 2 stocks.

Extended Simple Stock Synthesis

ExSSS is based on sampling parameters (steepness, natural mortality, and depletion) from prior distributions and using Stock Synthesis to solve for virgin recruitment (R_0) given inputs for selectivity, growth, and fecundity. ExSSS extends Simple Stock Synthesis, originally a data-limited method reviewed by the SSC, by allowing index data (and potentially length and age data) to be used for parameter estimation using the Stock Synthesis platform. Parameter estimation for exSSS is based on the Adaptive Importance Sampling (AIS) methods (Cope*, et al.* 2015b; Wetzel and Punt 2015). ExSSS assumes that recruitment is related deterministically to the stock-recruitment relationship. The outputs from exSSS include biomass trajectories, as well as estimates of (and measures of uncertainty for) the OFL. The prior for depletion is based on the results of a regression of depletion on the PSA vulnerability score (see section 2.1 and (Cope*, et al.* 2015b)).

ExSSS was used in the 2013 data-moderate assessments of English sole, rex sole, sharpchin rockfish, stripetail rockfish, and yellowtail rockfish north of 40°10' N. lat. and the 2019 assessment of cabezon off Washington,

Extended Depletion-Based Stock Reduction Analysis

XDB-SRA, an extension of DB-SRA, is an assessment method approved by the SSC for use in data-moderate assessments. XDB-SRA can be implemented within a Bayesian framework, with the priors for the parameters updated based on index data. The additional parameters in XDB-SRA compared with DB-SRA include the catchability coefficient (q) for each index of abundance, and the extent of observation variance additional to that inferred from sampling error (a). The priors for these parameters have a weakly informative log-normal and a uniform distribution, respectively. While XDB-SRA is an approved data-moderate assessment model, it can also be parameterized to incorporate compositional data.

XDB-SRA was used in the 2013 data-moderate assessments of brown, China, and copper rockfish, as well as the 2013 full assessment of cowcod in the Southern California Bight.

SS-CL and SS-CL+Index

New data-moderate assessment methods were adopted and used in 2021 - Stock Synthesis with Catches and Lengths (SS-CL) and Stock Synthesis with Catches and Lengths informed with one or more fishery-independent abundance indices (SS-CL+Index). These length-based assessment methods do not use age composition data or fishery dependent abundance indices since the use of these data require more extensive evaluation during review. Reviews of assessments using these methods are done more expeditiously by the SSC. These methods are robust to full assessments when there are length-composition data only and there were at least 20 years of data as discussed in the SSC's evaluation of these methods. Length-based methods are deemed particularly useful for assessments where age data are sparse. These methods were used in 2021 assessments of copper rockfish, quillback rockfish, and squarespot rockfish.

2.2.1.3 Full Stock Assessments

Full, or benchmark, stock assessments are those where Stock Assessment Teams (STATs) can propose new models and explore new data to determine the status and dynamics of a fish stock. The Council has a rigorous process for first determining those stocks that will be assessed and, once determined, how they will be reviewed (the process is codified in the Stock Assessment and Review Terms of Reference, which is updated every other year). Full assessments are more rigorously reviewed than other types of assessments since they are inherently more complicated. A week-long STAR panel meeting occurs with STATs presenting assessment models to a panel of experts (typically comprised of one SSC Groundfish Subcommittee member who chairs the meeting, one West Coast groundfish assessment expert, and two independent reviewers from the Center of Independent Experts). Additionally, one Groundfish Management Team (GMT) representative, one Groundfish Advisory Subpanel representative, and a member of the Council staff attends STAR panel meetings as advisors. The STAR panel prepares a report recommending whether the assessment is robust enough to be used in management, along with other detailed recommendations on how to interpret assessment results and how to improve the assessment next time it is conducted. STAR panel reports also detail the model and data explorations that occurred during the review. The draft assessment and STAR panel report are then reviewed by the SSC. The assessment is only adopted for use in management decision-making if recommended by the SSC.

Stocks assessed with SSC-endorsed full assessments are categorized either as category 1 or category 2 depending on the quality of data informing the assessment, relative uncertainty of model estimates, and/or whether individual year class strength (i.e., recruitment) is estimated.

Stock Synthesis

Most of the groundfish assessments on the U.S. West Coast currently used to inform management decisions have been conducted using Stock Synthesis. Stock Synthesis provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population and with multiple stock sub-areas. Selectivity can be cast as age-specific only, size-specific in the observations only, or size-specific with the ability to capture the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Some SS features include ageing error, growth estimation, spawner-recruitment relationship, and movement between areas. SS is most flexible in its ability to utilize a wide diversity of age, size, and aggregate data from fisheries and surveys. The ADMB C++ software in which SS is written searches for the set of parameter values that maximize the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian and Markov Chain Monte Carlo (MCMC) methods. A management layer is also included in the model allowing uncertainty in estimated parameters to be propagated to the management quantities, thus facilitating a description of the risk of various possible management scenarios, including forecasts of possible ACLs. The structure of Stock Synthesis allows for building of simple to complex models depending upon the data available. The latest version of SS used in most of the assessments done in 2021 is version 3.30.19.0.

2.2.1.4 Update Assessments

An update assessment uses the model structure of the stock's last full, SSC-endorsed assessment, but is generally restricted to the addition of new data that have become available since the last full assessment. It must carry forward the fundamental structure of the last full assessment reviewed and endorsed by a STAR panel, the SSC, and the Council. Assessment structure here refers to the population dynamics model, data sources used as inputs to the model, the statistical platform used to fit the model to the data, and how the management quantities used to set harvest specifications are calculated. Particularly when an update assessment is developed, no substantial changes should be made to 1) the sources of data used (data sources can be updated to correct data entry errors), 2) the software used in programming the assessment (newer versions of assessment software can be used), 3) the assumptions and structure of the population dynamics model underlying the stock assessment, 4) the statistical framework for fitting the model to the data and determining goodness of fit, and 5) the analytical treatment of model outputs in determining management reference points.

Major changes to the assessment should be postponed until the next full assessment. Minor alterations to the input data and the assessment can be considered as long as the update assessment clearly documents and justifies the need for such changes. A step-by-step transition (via sensitivity analysis) from the last full assessment to an update assessment under review should be provided. Minor alterations can be considered under only two circumstances: first, when the addition of new data reveals an unanticipated sensitivity of the model, and second, when there are clear and straightforward improvements in the input data and how it is processed and analyzed for use in the model. Examples of minor alterations include: 1) changes in how compositional data are pooled across sampling strata, 2) the weighting of the various data components (including the use of methods for tuning the variances of the data components), 3) changes in the time periods for the selectivity blocks, 4) correcting data entry errors, and 5) bug fixes in software programming. This list is not meant to be exhaustive, and other alterations can be considered if warranted. Ideally, improved data or methods used to process and analyze data would be reviewed by the SSC prior to being used in assessments.

The SSC reviews all update assessments; a STAR panel review is not needed since the assessment only updates the last full, STAR panel-reviewed assessment.

2.2.1.5 Rebuilding Analyses

Rebuilding analyses use the results of stock assessments and project stock rebuilding periods under alternative harvest control rules in a stochastic fashion. In other words, a rebuilding analysis involves projecting the status of the overfished/rebuilding resource into the future under a variety of alternative harvest strategies to determine the probability of recovery to B_{MSY} (or its proxy) within a pre-specified timeframe. Rebuilding analyses are used to develop new rebuilding plans or in consideration for modifying existing rebuilding plans; rebuilding plans dictate the target year to rebuild a stock, the harvest control rules for rebuilding the stock, and any other special management measures designed to foster rebuilding. Rebuilding analyses are also used to determine the OFLs and ACLs for overfished/rebuilding stocks. The Terms of Reference for Groundfish Rebuilding Analysis provide the required projections and outputs in a rebuilding analysis.

A rebuilding analysis consists of 1) estimation of B_0 (and hence B_{MSY} or its proxy), 2) selection of a method to generate future recruitment, 3) specification of the mean generation time (defined as the predicted time it would take for a mature female in the population to replace herself), 4) calculation of the minimum and maximum times to recovery, and 5) identification and analysis of alternative harvest strategies and rebuilding times. Most rebuilding analyses are done using software developed by Dr. André Punt from the University of Washington.[6]

The Puntalyzer uses a "Monte Carlo simulation" to derive a probability estimate for a given rebuilding strategy. This method projects population growth many times in separate simulations. It accounts for possible variability by randomly choosing the value of a key variable, generally the deviation in recruitment about the stock-recruitment relationship, but also allows for uncertainty in the estimated parameters of the stock assessment. Because of this variability in a key input value, each simulation will show a different pattern of population growth. As a result, a modeled population may reach the target biomass that defines a rebuilt stock (B_{MSY}) in a different year in each of the simulations.

This technique is first used to calculate minimal time to rebuild a stock given its level of depletion and productivity from the time of implementing the first rebuilding plan (T_{MIN}) in probabilistic terms, which is defined as the time needed to reach the target biomass in the absence of fishing with a 50 percent probability. In other words, in half the simulations, the target biomass was reached in some year up to and including the computed T_{MIN}. Given T_{MIN}, the maximum legal time to rebuild (T_{MAX}) is computed as 10 years or by adding the value of one mean generation time to T_{MIN}, if T_{MIN} is greater than or equal to 10 years. In cases where there is consideration for modifying an existing rebuilding plan, the shortest time to rebuild is calculated as the biological limit for the stock to rebuild in the absence of fishing beginning in the year the modified rebuilding plan is implemented; this limit is denoted, "$T_{F=0}$".

[6] Available at http://puntlab.washington.edu/software/.

A target rebuilding year, T_{TARGET}, is set as a year at T_{MIN} (or $T_{F=0}$) or greater, which does not exceed T_{MAX}, and which is as short as possible, taking into account the status and biology of the stock, the needs of fishing communities, recommendations by international organizations in which the U.S. participates, and the interaction of the stock of fish within the marine ecosystem. Prior to Amendment 16-4, the Council set T_{TARGET} in part by considering the probability of rebuilding the stock by T_{MAX}. The Council may continue to review the probability of rebuilding the stock by T_{MAX} given differing harvest control rules, a reference parameter known as "P_{MAX}."

It is important to recognize that some of the terms introduced and described above represent policy decisions at the national level and the Council **does not have a choice** in setting their values. The dates for T_{MIN} and T_{MAX} are determined based on guidelines established at the national level. Mean generation time is a biological characteristic that cannot be chosen by policymakers. Thus, the Council cannot choose these values and then use them as a basis for management. Defined in national guidelines, T_{MIN} is a consequence of the productivity of the fish stock and is calculated by fishery biologists based on information they estimate for a particular stock. Similarly, T_{MAX}, which is calculated from T_{MIN}, does not represent a Council choice.

Policy flexibility comes into play in determining T_{TARGET}, or the time by which the stock is projected to rebuild. When developing a management strategy, the Council can choose a fishing mortality rate and corresponding annual level of fishing. However, when rebuilding overfished/rebuilding species, the choice of the harvest control rule is based on the value of T_{TARGET}, keeping in mind that these values cannot be chosen independently of one another. In other words, the Council may choose one value and derive the other from it, but they cannot choose these values independently of the other.

The current groundfish rebuilding plan parameters are depicted in Table 2-7.

Table 2-4. Management quantities estimated from the most recent stock assessments informing management in 2023 and beyond.

Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
Arrowtooth flounder	2017	0.87	65,448 mt	56,710 mt	97,118 mt	18,355 mt	0.184	6,635 mt	$F_{30\%}$
Aurora rockfish	2013	0.64	2,626 mt	1,673 mt	4,366 mt	1,213 mt	0.025	67 mt	$F_{50\%}$
Big skate	2019	0.79	2,525 mt	1,999 mt	25,339 mt	505 mt	0.071	590 mt	$F_{50\%}$
Black rockfish (CA)	2015	0.33	1,062 mt	353 mt	5,773 mt	425 mt	0.075	343 mt	$F_{50\%}$
Black rockfish (OR)	2015	0.60	1,385 mt	836 mt	7,819 mt	554 mt	0.116	518 mt	$F_{50\%}$
Black rockfish (WA)	2015	0.43	1,356 mt	582 mt	5,645 mt	542 mt	0.086	337 mt	$F_{50\%}$
Blackgill rockfish	2017	0.39	2,064 B larvae	812 B larvae	7,917 mt	919 B larvae	0.022	178 mt	$F_{50\%}$
Blue & Deacon rockfishes (CA N of Pt. Con.)	2017	0.37	2,178 M eggs	812 M eggs	6,654 mt	871 M eggs	0.045	306 mt	$F_{50\%}$
Blue & Deacon rockfishes (OR)	2017	0.69	431 M eggs	296 M eggs	1,773 mt	192 M eggs	0.056	78 mt	$F_{50\%}$
Bocaccio b/	2017	0.49	7,411 M larvae	3,603 M larvae	25,293 mt	3,302 M larvae	0.082	1,857 mt	$F_{50\%}$
Brown rockfish	2013	0.42	1,794 mt	727 mt	1,454 mt	718 mt	0.102	149 mt	$B_{40\%}$
Cabezon (CA S of Pt. Con.)	2019	0.49	205 mt	101 mt	208 mt	79 mt	0.129	17 mt	$F_{45\%}$
Cabezon (CA N of Pt. Con.)	2019	0.65	986 mt	643 mt	1,317 mt	379 mt	0.14	118 mt	$F_{45\%}$
Cabezon (OR)	2019	0.53	335 mt	177 mt	358 mt	128.6 mt	0.161	46.4 mt	$F_{45\%}$
California scorpionfish	2017	0.54	1,624 mt	882 mt	1,915 mt	724 mt	0.1502	232 mt	$F_{50\%}$
Canary rockfish	2015	0.56	7,491 M eggs	4,156 M eggs	35,966 mt	2,996 M eggs	0.044	1,226 mt	$F_{50\%}$
Chilipepper rockfish	2015	0.64	7,042 M larvae	4,502 M larvae	35,039 M larvae	2,133 mt	0.095	2,165 mt	$F_{50\%}$
China rockfish (S of 40°10’ N. lat.)	2015	0.30	66.5 B eggs	18.565 B eggs	446.54 mt	30.6 B eggs	0.0476	19.5 mt	$F_{50\%}$
China rockfish (40°10’ N. lat. – 46°16’ N. lat.)	2015	0.62	65.1 B eggs	40.033 B eggs	496.73 mt	30 B eggs	0.0484	14.5 mt	$F_{50\%}$

Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
China rockfish (N of 46° 16’ N. lat.)	2015	0.73	24.4 B eggs	17.950 B eggs	207.26 mt	11.3 B eggs	0.0458	5.8 mt	$F_{50\%}$
Copper rockfish (S of 34°27' N. lat.)	2021	0.18	233.04 M eggs	42.28 M eggs	494.62 mt	92.2 M eggs	0.05	54.4 mt	$B_{40\%}$
Copper rockfish (CA N of 34°27' N. lat.)	2021	0.39	415.81 M eggs	163.51 M eggs	1,713.88 mt	166.33 M eggs	0.06	110.85 mt	$B_{40\%}$
Copper rockfish (OR)	2021	0.74	38.75 M eggs	28.51 M eggs	281.30 mt	15.50 M eggs	0.08	12.46 mt	$B_{40\%}$
Copper rockfish (WA)	2021	0.42	7.65 M eggs	3.203 M eggs	34.65 mt	3.06 M eggs	0.072	2.347 mt	$B_{40\%}$
Cowcod	2019	0.57	285 B eggs	163 B eggs	2,494 mt	127 B eggs	0.043	73 mt	$F_{50\%}$
Darkblotched rockfish	2017	0.40	3,544 M eggs	1,419 M eggs	20,718 mt	2,166 M eggs	0.019	477 mt	$F_{50\%}$
Dover sole	2021	0.79	294,070 mt	232,065 mt	481,200 mt	74,498 mt	0.12	22,891 mt	$F_{30\%}$
English sole	2013	0.88	29,238 mt	25,719 mt	46,968 mt	7,833 mt	0.404	3,875 mt	$F_{30\%}$
Gopher & black-and-yellow rockfishes (S of 40°10’ N. lat.)	2019	0.44	1,261 M eggs	553 M eggs	1,281 mt	563 M eggs	0.111	134 mt	$F_{50\%}$
Greenspotted rockfish	2011	0.35	1,357.8 B eggs	449.9 B eggs	3,110 mt	621 B eggs	.034 N; .024 S	95.6 mt	$F_{50\%}$
Greenstriped rockfish	2009	0.81	7,090 M eggs	5,736 M eggs	29,391 mt	3,101 M eggs	0.044	738 mt	$F_{50\%}$
Kelp greenling (OR)	2015	0.80	397 mt	316 mt	1,131 mt	152 mt	0.18	130 mt	$F_{45\%}$
Lingcod (S of 40°10’ N lat.)	2021	0.39	26,443.6 mt	10,415 mt	13,594 mt	7,093.73 mt	0.0874	810.758 mt	$F_{45\%}$
Lingcod (N of 40°10’ N lat.)	2021	0.64	17,159.8 mt	11,010.2 mt	24,989 mt	7,098.53 mt	0.2224	3,644.93 mt	$F_{45\%}$
Longnose skate	2019	0.57	12,252 mt	6,923 mt	51,447 mt	2,450 mt	0.039	860 mt	$F_{50\%}$
Longspine thornyhead	2013	0.75	39,134 mt	29,436 mt	68,131 mt	15,654 mt	0.060	2,487 mt	$F_{50\%}$
Pacific ocean perch	2017	0.77	6,889 M eggs	5,280 M eggs	129,191 mt	2,296 M eggs	0.033	1,823 mt	$F_{50\%}$

Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
Pacific sanddabs	2013	0.96	c/	c/	c/	c/	c/	c/	c/
Pacific whiting	2021	0.59	1,658,000 mt	981,000 mt	1,789,000 mt	332,000 mt	0.183	148,000 mt	$F_{40\%}$
Petrale sole	2019	0.39	33,406 mt	13,078 mt	23,900 mt	8,866 mt	0.173	3,135 mt	$F_{30\%}$
Quillback rockfish (CA)	2021	0.14	55.08 M eggs	7.75 M eggs	70.6 mt	22.03 M eggs	0.05	8.8 mt	$B_{40\%}$
Quillback rockfish (OR)	2021	0.47	19.71 M eggs	9.21 M eggs	79.06 mt	7.88 M eggs	0.05	3.24 mt	$B_{40\%}$
Quillback rockfish (WA)	2021	0.39	17.19 M eggs	6.64 M eggs	34.65 mt	7.67 M eggs	0.04	2.86 mt	$F_{50\%}$
Rex sole	2013	0.80	3,808 mt	2,966 mt	18,497 mt	1,026 mt	0.464	1,646 mt	$F_{30\%}$
Rougheye & blackspotted rockfishes	2013	0.47	5,394 mt	2,552 mt	8,176 mt	2,491 mt	0.027	194 mt	$F_{50\%}$
Sablefish	2021	0.58	168,875 mt	97,802 mt	278,378 mt	64,848 mt	0.045	8,350 mt	$F_{45\%}$
Sharpchin rockfish	2013	0.68	7,887 mt	4,947 mt	12,767 mt	3,482 mt	0.050	270 mt	$F_{50\%}$
Shortspine thornyhead	2013	0.74	189,765 mt	140,753 mt	244,400 mt	75,906 mt	0.015	2,034 mt	$F_{50\%}$
Spiny dogfish	2021	0.42	32.57 M pups	13.61 M pups	255,616 mt	13.03 M pups	0.003	358 mt	$B_{40\%}$
Splitnose rockfish	2009	0.66	12,853 M eggs	8,426 M eggs	74,772 mt	5,006 M eggs	0.033	1,244 mt	$F_{50\%}$
Squarespot rockfish (CA)	2021	0.37	20.64 M eggs	7.73 M eggs	116.2 mt	8.26 M eggs	0.26	9.67 mt	$B_{40\%}$
Starry flounder	2005	0.50	7,158 mt	3,566 mt	7,638 mt	1,830 mt	0.229	1,848 mt	$F_{30\%}$
Stripetail rockfish	2013	>0.775	c/	c/	c/	c/	c/	c/	c/
Vermilion & sunset rockfishes (S of 34°27' N lat.)	2021	0.48	977.834 M eggs	471.178 M eggs	3,665.87 mt	391.134 M eggs	0.139	155.76 mt	$B_{40\%}$
Vermilion & sunset rockfishes (CA N of 34°27' N lat.)	2021	0.43	1,145.18 M eggs	489.439 M eggs	3,564.4 mt	458.073 M eggs	0.071	145.61 mt	$B_{40\%}$
Vermilion rockfish (OR)	2021	0.73	29.24 M eggs	21.35 M eggs	377.77 mt	11.7 M eggs	0.06	8.32 mt	$B_{40\%}$
Vermilion rockfish (WA)	2021	0.56	2.75 M eggs	1.55 M eggs	23.22 mt	1.10 M eggs	0.06	0.81 mt	$B_{40\%}$

Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
Widow rockfish	2019	0.92	87,995 mt	80,910 mt	189,576 mt	39,259 mt	0.084	7,240 mt	$F_{50\%}$
Yelloweye rockfish	2017	0.28	1,139 M eggs	323 M eggs	3,569 mt	508 M eggs	0.022	105 mt	$F_{50\%}$
Yellowtail rockfish (N of 40°10' N. lat.)	2017	0.75	15 T eggs	11.278 T eggs	130,219 mt	6.7 T eggs	0.051	5,115 mt	$F_{50\%}$

a/ Estimates pertain to the most recent assessment year.
b/ Bocaccio biomass and MSY estimates are reduced by 7.4 percent from the values reported in the 2015 assessment since the assessment applies to the West Coast population south of Cape Blanco at 43° N. lat. and the stock is managed for the area south of 40°10' N. lat. The proportional reduction is based on historical catches by area.
c/ The assessment results were only used for informing status since the scale of the population could not be adequately determined.

Table 2-5. Parameters estimated and/or assumed in base models in the most recent West Coast groundfish stock assessments, excluding those done using XDB-SRA.

Stock	ln(R0)	Steepness (h)		Sigma-r	von-Bertalanffy Growth Coefficient (k)		Natural Mortality (M)		
		value	est.?		F	M	F	M	est.?
Arrowtooth flounder	10.83	0.90	N	0.8	0.17	0.36	0.216	0.300	N
Aurora rockfish	6.64	0.78	N	0.5	0.09	0.09	0.035	0.037	a/
Big skate	8.90	0.40	N	0.3	b/	b/	0.449	0.449	Y for Females Males assumed equal to Females
Black rockfish (CA)	7.61	0.773	N	0.5	0.15	0.21	0.18	0.13	Y
Black rockfish (OR)	8.21	0.773	N	0.5	0.21	0.34	0.17 step up to 0.2 at age 10	0.17	N
Black rockfish (WA)	7.65	0.773	N	0.5	0.18	0.23	0.16	0.15	Y
Blackgill rockfish (S of 40°10' N. lat.)	7.85	0.718	N	0.5	0.023	0.04	0.063	0.065	N
Blue & deacon rockfishes (CA N of Pt. Con.)	8.44	0.645	Y	0.5	0.118	0.115	0.119	0.315	Y
Blue & deacon rockfishes (OR)	7.04	0.718	N	0.5	0.203	0.487	0.159	0.159	N

Stock	ln(R0)	Steepness (h)		Sigma-r	von-Bertalanffy Growth Coefficient (k)		Natural Mortality (M)		
		value	est.?		F	M	F	M	est.?
Bocaccio	8.83	0.718	N	1.0	0.226	0.311	0.180	0.180	Y
Cabezon (CA S of Pt. Con.)	5.21	0.70	N	0.5	0.21	0.33	0.26	0.35	Y
Cabezon (CA N of Pt. Con.)	6.57	0.70	N	0.5	0.21	0.33	0.24	0.28	Y
Cabezon (OR)	4.68	0.70	N	0.5	0.329	0.178	0.24	0.154	a/
California scorpionfish	8.19	0.718	N	0.6	0.292	0.212	0.235	0.235	Y
Canary rockfish	7.96	0.773	N	0.5	0.129	0.224	0.0521 at age 6 ramping up to age 14+	0.0521	N
Chilipepper rockfish	10.64	0.57	N	1.0	0.17-0.24 c/	0.17-0.24 c/	0.160	0.200	N
China rockfish (S of 40°10' N. lat.)	5.04	0.773	N	0.5	0.144	0.144	0.070	0.070	N
China rockfish (40°10' N. lat. – 46° 16' N. lat.)	4.27	0.773	N	0.5	0.159	0.159	0.070	0.070	N
China rockfish (N of 46° 16' N. lat.)	3.53	0.773	N	0.5	0.147	0.147	0.070	0.070	N
Copper rockfish (S of 34°27' N lat.)	5.50	0.72	N	0.6	0.231	0.238	0.108	0.108	N
Copper rockfish (CA N of 34°27' N lat.)	6.03	0.72	N	0.6	0.206	0.231	0.108	0.108	N
Copper rockfish (OR)	3.66	0.72	N	0.6	0.206	0.231	0.108	0.108	N
Copper rockfish (WA)	2.03	0.72	N	0.6	0.206	0.231	0.108	0.108	N
Cowcod (S of 40°10' N. lat.)	5.19	0.72	N	e/	0.055	0.055	0.088	0.088	Y
Darkblotched rockfish	8.01	0.72	N	0.75	0.19	0.24	0.054	0.069	a/
Dover sole	12.27	0.80	N	0.35	0.13	0.14	0.108	0.114	N
English sole	11.45 d/	0.87 d/	Y	e/	0.36	0.48	0.24 d/	0.27 d/	Y
Gopher & black-and-yellow rockfishes (S of 40°10' N. lat.)	8.05	0.72	N	0.5	0.107	0.107	0.193	0.193	N
Greenspotted rockfish (CA N of Pt. Con.)	6.15	0.76	N	0.7	0.057	0.057	0.065	0.065	N
Greenspotted rockfish (CA S of Pt. Con.)	6.65	0.76	N	0.7	0.042	0.042	0.065	0.065	N
Greenstriped rockfish	9.62	0.69	N	0.84	0.11	0.15	0.080	0.080	N

Stock	ln(R0)	Steepness (h)		Sigma-r	von-Bertalanffy Growth Coefficient (k)		Natural Mortality (M)		
		value	est.?		F	M	F	M	est.?
Kelp greenling (OR)	7.28	0.70	N	0.65	0.26	0.26	0.360	0.318	N
Lingcod (S of 40°10' N lat.)	7.72	0.502	Y	0.6	0.136	0.401	0.17	0.22	Y
Lingcod (N of 40°10' N lat.)	9.73	0.801	Y	0.6	0.152	0.282	0.42	0.41	Y
Longnose skate	9.47	0.40	N	0.3	0.04	0.04	0.22	0.22	N
Longspine thornyhead	11.82	0.60	N	0.6	0.109	0.109	0.111	0.111	N
Pacific ocean perch	9.40	0.50	N	0.7	0.167	0.198	0.054	0.054	N
Pacific whiting	14.63	0.807	Y	1.4	f/	f/	0.230	0.230	Y
Petrale sole	9.92	0.841	Y	0.4	0.142	0.238	0.159	0.164	Y
Quillback rockfish (CA)	3.17	0.72	N	0.6	0.20	0.20	0.06	0.06	N
Quillback rockfish (OR)	2.14	0.72	N	0.6	0.20	0.20	0.06	0.06	N
Quillback rockfish (WA)	2.00	0.72	N	0.6	0.20	0.20	0.06	0.06	N
Rex sole	9.51 d/	0.89 d/	Y	e/	0.39	0.39	0.23 d/	0.12 d/	Y
Rougheye & blackspotted rockfishes	6.19	0.78	N	0.4	0.081	0.081	0.042	0.042	Y
Sablefish	9.71	0.70	N	1.4	0.3433	0.3713	0.0726	0.0605	Y
Sharpchin rockfish	8.23 d/	0.77 d/	Y	e/	0.17	0.20	0.07 d/	0.07 d/	Y
Shortspine thornyhead	10.32	0.60	N	0.5	0.018	0.018	0.051	0.051	N
Spiny dogfish	9.87	2.83 g/	Y	0.2	0.028	0.368	0.065	0.065	N
Splitnose rockfish	9.54	0.58	N	1.0	0.156	0.165	0.048	0.048	N
Squarespot rockfish (CA)	5.94	0.72	N	0.7	0.12	0.25	0.13	0.13	N
Starry flounder (OR & WA)	7.96	0.80	N	1.0	0.251	0.426	0.510	0.760	N
Starry flounder (CA)	7.23	0.80	N	1.0	0.251	0.426	0.510	0.760	N
Vermilion & sunset rockfishes (S of 34°27' N lat.)	6.70	0.73	Y	0.5	0.156	0.137	0.130	0.130	Y; Male M fixed to Fem M
Vermilion & sunset rockfishes (CA N of 34°27' N lat.)	6.04	0.72	N	0.5	0.147	0.199	0.086	0.080	Y
Vermilion rockfish (OR)	2.79	0.72	N	0.6	0.146	0.180	0.080	0.073	Y

Stock	ln(R0)	Steepness (h)		Sigma -r	von-Bertalanffy Growth Coefficient (k)		Natural Mortality (M)		
		value	est. ?		F	M	F	M	est.?
Vermilion rockfish (WA)	0.91	0.72	N	0.6	0.093	0.109	0.085	0.087	Y
Widow rockfish	10.81	0.72	N	0.85	0.1719	0.2361	0.1444	0.1549	Y
Yelloweye rockfish	5.39	0.718	N	0.5	0.06	0.06	0.044	0.044	N
Yellowtail rockfish (N of 40°10' N. lat.)	10.83	0.72	N	0.5	0.140	0.352	0.174	0.025	Y

a/ Female M was fixed and male M was estimated as an offset to female M.
b/ Growth was modeled using the Growth Cessation model (Maunder, et al. 2018).
c/ The base case model allowed growth for each sex to differ between blocks of time, based on freely estimating the K parameter.
d/ This value is the median of the posterior distribution of estimates for this parameter. These estimates were not summarized in tabular form in the 2013 data-moderate assessments' document (Cope, et al. 2014) but were provided by the Stock Assessment Team after the assessment was published.
e/ Recruitment variability (sigma-r) not estimated.
f/ The 2021 Pacific whiting assessment uses weight-at-age, thus there is no estimate of growth. Weight-at-age varies between years; therefore, growth is time-varying.
g/ While steepness was not estimated or assumed in the conventional sense of a Beverton-Holt stock-recruitment relationship, a value for steepness (defined as recruitment relative to R_0 at a spawning depletion level of 0.2) can be derived from the parameters above according to the relationship provided by Gertseva et al. (2021).

Table 2-6. Population parameters estimated and/or derived in base models in 2013 West Coast groundfish stock assessments using XDB-SRA.

Stock	B_0	Estimated Parameters				B_{MSY}	F_{MSY}
		M	F_{MSY}/M	B_{MSY}/B_0	$Delta_{2000}$		
Brown rockfish	3588	0.133	0.971	0.399	0.698	1,383.4	0.130

2.3 Overfished and Rebuilding Groundfish Stocks

The NMFS reports the status of stocks managed under rebuilding plans as "overfished" if the current stock status is below the MSST and as "rebuilding" if over the MSST but not yet at or above the target B_{MSY} threshold (i.e., rebuilt). Currently, there are no overfished West Coast groundfish stocks.

Yelloweye rockfish is the only rebuilding rockfish stock on the West Coast at the start of 2021. The stock has shown adequate progress towards rebuilding based on the most recent (2017) assessment. The target rebuilding year for yelloweye rockfish was specified as 2029 under the Council's adopted rebuilding plan implemented in 2019.

Stock rebuilding parameters estimated from the most recent yelloweye rockfish rebuilding analysis and current rebuilding parameters specified at the start of 2021 are provided in Table 2-7.

Table 2-7. Rebuilding parameters estimated in the most recent rebuilding analyses and specified in rebuilding plans for rebuilding groundfish stocks at the start of the 2023-2024 management cycle.

Stock	T_{MIN}	$T_{F=0}$	T_{MAX}	T_{TARGET}	Harvest Control Rule Specification
Yelloweye rockfish	2026	2026	2070	2029	SPR 65%

2.3.1 Yelloweye Rockfish

Distribution and Life History

Yelloweye rockfish (*Sebastes ruberrimus*) range from the Aleutian Islands, Alaska, to northern Baja California, Mexico, and are common from Central California northward to the Gulf of Alaska (Eschmeyer*, et al.* 1983; Hart 1988; Love*, et al.* 2002; Miller and Lea 1972; O'Connell and Funk 1986). The stock occurs in water 25 m to 550 m deep with 95 percent of survey catches occurring from 50 m to 400 m (Allen and Smith 1988). Yelloweye rockfish are bottom dwelling, generally solitary, rocky reef fish, found either on or just over reefs (Eschmeyer*, et al.* 1983; Hart 1988; Love*, et al.* 2002; Miller and Lea 1972; O'Connell and Funk 1986). Boulder areas in deep water (>180 m) are the most densely-populated habitat type, and juveniles prefer shallow-zone broken-rock habitat (O'Connell and Carlile 1993). They also reportedly occur around steep cliffs and offshore pinnacles (Rosenthal*, et al.* 1982). The presence of refuge spaces is an important factor affecting their occurrence (O'Connell and Carlile 1993).

Yelloweye rockfish are ovoviviparous and give birth to live young in June off Washington (Hart 1988). The age of first maturity is estimated at six years and all are estimated to be mature by eight years (Wyllie Echeverria 1987). They can grow to 91 cm (Eschmeyer*, et al.* 1983; Hart 1988) and males and females probably grow at the same rates (Love 1996; O'Connell and Funk 1986). The growth rate levels off at approximately 30 years of age (O'Connell and Funk 1986) and the maximum reported age is 147 years (Love 2011). Yelloweye rockfish are a large predatory reef fish that usually feeds close to the bottom (Rosenthal*, et al.* 1982). They have a widely varied diet, including fish, crabs, shrimps and snails, rockfish, cods, sand lances, and herring (Love*, et al.* 2002). Yelloweye rockfish have been observed underwater capturing smaller rockfish with rapid bursts of speed and agility. Major food items of yelloweye rockfish include cancroid crabs, cottids, righteye flounders, adult rockfishes, and pandalid shrimps (Steiner 1978). Quillback and yelloweye rockfish have many trophic features in common (Rosenthal*, et al.* 1982).

Stock Status and Management History

The first yelloweye rockfish stock assessment on the U.S. West Coast was conducted in 2001 (Wallace 2002). This assessment incorporated two area assessments: one off Northern California using CPUE indices constructed from Marine Recreational Fisheries Statistical Survey (MRFSS) sample data and California Department of Fish and Game (CDFG; now California Department of Fish and Wildlife) data collected on board CPFVs, and the other off Oregon using Oregon Department of Fish and Wildlife (ODFW) sampling data. The assessment concluded yelloweye rockfish stock biomass in 2001 was at about seven percent of unexploited biomass in Northern California and 13 percent of unexploited biomass in Oregon. The assessment revealed a 30-year declining biomass trend in both areas with the last above-average recruitment occurring in the late 1980s. The assessment's conclusion that yelloweye rockfish biomass was well below the 25 percent of unexploited biomass threshold for overfished stocks led to this stock being declared overfished in 2002. Until 2002, yelloweye rockfish was listed in the "Remaining Rockfish" complex on the shelf in the Vancouver, Columbia, and Eureka INPFC[7] areas and the "Other Rockfish" complex on the shelf in the Monterey and Conception areas. Since then, yelloweye rockfish harvest is now tracked separately and managed against a species-specific ACL.

In June 2002, the SSC recommended that managers should conduct a new assessment incorporating Washington catch and age data. This recommendation was based on evidence that the biomass distribution of yelloweye rockfish on the West Coast was centered in waters off Washington and that useable data from Washington were available. Based on that testimony, the Council recommended completing a new assessment in the summer of 2002, before a final decision was made on 2003 management measures. Methot et al. (Methot*, et al.* 2003) did the assessment, which confirmed the overfished status (24 percent of unfished biomass) and provided evidence of higher stock productivity than originally assumed. The assessment also treated the stock as a coastwide assemblage. The 2002 rebuilding analysis (Methot and Piner 2002a) informed the yelloweye rockfish rebuilding plan adopted under FMP Amendment 16-3 in 2004. The rebuilding plan established a target rebuilding year of 2058 and a harvest control rule of F = 0.0153.

A coastwide 2006 yelloweye rockfish assessment estimated a stock depletion of 17.7 percent of the unfished level at the start of 2006 (Wallace*, et al.* 2006). New data sources in the assessment included the Washington Department of Fish and Wildlife (WDFW) 2002 submersible survey and the International Pacific Halibut Commission (IPHC) annual longline survey. Further revisions in

[7] The International North Pacific Fisheries Commission (INPFC) was established by the International Convention for the High Seas Fisheries of the North Pacific Ocean in 1952, and comprised Canada, Japan, and the United States of America as members. The INPFC contributed significantly to the understanding of the life history and distribution of anadromous species, groundfish, crab, and marine mammals in the North Pacific Ocean and Bering Sea. The INPFC dissolved when the North Pacific Anadromous Fish Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean came into effect on February 16, 1993.

the assessment included reducing natural mortality from 0.045 to 0.036 and increasing steepness from 0.437 to 0.45.

The 2006 rebuilding analysis (Tsou and Wallace 2006) was used to inform a revision of the yelloweye rockfish rebuilding plan under FMP Amendment 16-4. Given the significant negative socioeconomic impacts associated with the projected OYs under the constant harvest rate modeled in the rebuilding analysis, the Council elected to gradually ramp down the harvest rate beginning in 2007 before resuming a constant harvest rate rebuilding strategy in 2011. The harvest rate ramp-down strategy, which projected annual OYs of 23 mt, 20 mt, 17 mt, and 14 mt, respectively in 2007-2011, was projected to extend rebuilding by less than one year relative to the more conservative constant harvest rate strategy analyzed. The ramp-down strategy afforded more time to consider new Yelloweye rockfish Conservation Areas and other management measures designed to reduce the harvest rate to prescribed levels. Therefore, the Amendment 16-4 rebuilding plan incorporated the ramp-down strategy before resuming a constant harvest rate (SPR = 71.9 percent) in 2011. The rebuilding plan also specified a target rebuilding year of 2084.

The 2007 updated stock assessment for yelloweye rockfish estimated a stock depletion of 16.4 percent of initial, unfished biomass (Wallace 2008a). The long-term biomass trajectory in the 2007 updated assessment was very similar to that in the 2006 assessment. The 2007 rebuilding analysis (Wallace 2008b) indicated rebuilding progress was on track under the ramp-down strategy; therefore, no revisions were made to the rebuilding plan.

The full 2009 yelloweye rockfish assessment estimated a stock depletion of 20.3 percent of initial, unfished biomass at the start of 2009 (Stewart*, et al.* 2009). The resource was modeled as a single stock, but with three explicit spatial areas: Washington, Oregon, and California. Each area was modeled simultaneously with its own unique catch history and fishing fleets (recreational and commercial), with the stocks linked via a common stock-recruit relationship with negligible adult movement among areas. The assumed level of historical removals and estimated steepness were identified as the main axes of uncertainty.

The 2009 yelloweye rockfish rebuilding analysis (Stewart 2009b) was used to inform a revised rebuilding plan that was implemented under FMP Amendment 16-5. The revised rebuilding plan implemented in 2011 specified a constant harvest rate (SPR = 76 percent) strategy (the ramp-down strategy was abandoned) and a target year to rebuild the stock of 2074.

The 2011 yelloweye rockfish assessment (Taylor and Wetzel 2011), an update of the 2009 assessment, estimated stock depletion at 21.4 percent of initial, unfished biomass at the start of 2011 (Figure 2-3). The update assessment results were very similar to those in the previous assessment. The 2011 yelloweye rockfish rebuilding analysis (Taylor 2011) indicated rebuilding progress was on schedule, and no revisions were made to the rebuilding plan.

A full yelloweye rockfish assessment was conducted in 2017 indicating the stock was at a 28.4 percent depletion at the start of 2017 (Gertseva and Cope 2017b). Yelloweye rockfish was again modeled as a single stock with a shared stock-recruitment relationship, but between two rather than three assessment areas. Oregon and Washington were combined in a single area due to difficulties separating the catch and compositional data of fish caught in one state but landed in the other, with California as a second area. A comparison to a single area assessment showed no appreciable differences in outcomes. A state-specific assessment with three areas was not evaluated, but the results from the two-area base model showed close correspondence to the results from the 2011 update assessment.

This assessment was the first for yelloweye rockfish to combine sexes due to similar growth parameters. The assessment period was extended back to 1889 as a result of updates to the historical catch series. Indices of abundance from fishery-dependent and fishery-independent data sources were found to be uninformative (although they were retained) with the catch, age, and length composition data driving the results of the assessment. Steepness was fixed at 0.718 based on the meta-analysis for rockfish species. The previous assessment allowed natural mortality and steepness to be estimated, while this assessment fixed both of these key parameters, which allowed recruitment deviations to be estimated for this species. The assessment was sensitive to steepness and whether selectivity was allowed to be freely estimated. There is continued uncertainty regarding the differences in age assignments from reading otoliths between institutions, which has implication for estimates of natural mortality. Additional uncertainty results from uninformative indices of abundance and assumed values of steepness. The SSC upgraded the stock to a category 1 since recruitment deviations were estimated.

The Council adopted a new yelloweye rockfish rebuilding plan that was implemented in 2019. The harvest rate was increased from an SPR harvest rate (see Section 2.8.3 for a description and definition of the spawning potential ratio) of 76 percent to an SPR of 65 percent and the target rebuilding year was changed from 2074 to 2029. The more optimistic rebuilding projections in the 2017 yelloweye rockfish rebuilding analysis (Gertseva and Cope 2017a) prompted this change to ease some of the constraints to commercial and recreational fisheries brought about by the very low available harvest of yelloweye rockfish under the previous rebuilding plan. While the higher ACLs of 48 and 49 mt in 2019 and 2020, respectively, are specified under the SPR harvest rate of 65 percent, the Council adopted more conservative management measures designed to maintain a lower impact (e.g., sector-specific ACTs based on an SPR harvest rate of 70 percent).

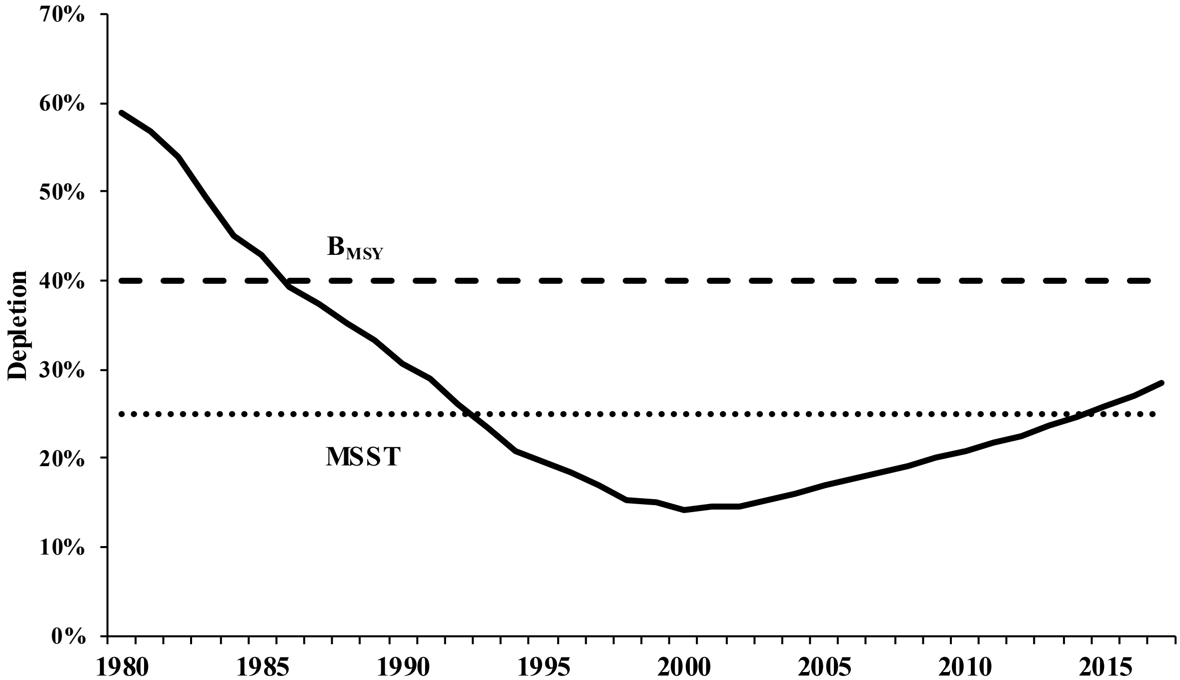

Figure 2-3. Relative depletion of yelloweye rockfish from 1980 to 2017 based on the 2017 stock assessment.

Stock Productivity Relative to Rebuilding Success

Recruitment dynamics in the 2017 assessment are assumed to follow Beverton-Holt stock-recruit function that includes an updated value of the steepness parameter (h). The steepness parameter was inestimable, and, therefore, it is fixed at the value of 0.718, which is the mean of the steepness prior probability distribution, derived from the 2017 meta-analysis of category 1 rockfish assessments. R_0 is estimated to inform the magnitude of the initial stock size. 'Main' recruitment deviations were estimated for modeled years that had information about recruitment, between 1980 and 2015. Peak recruitment events were estimated in years 1982-1984, 2002, 2008-2010 (Figure 2-4).

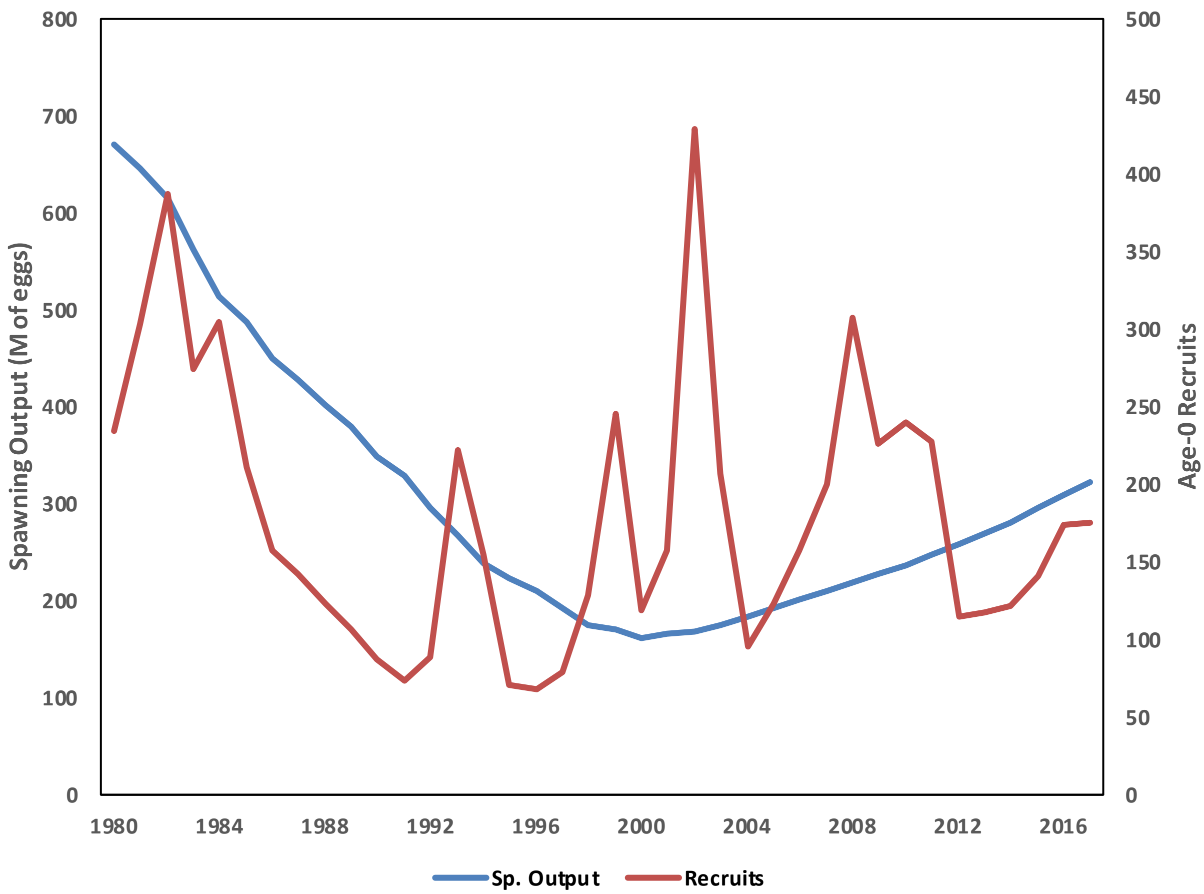

Figure 2-4. Time series of estimated yelloweye rockfish spawning output and recruitments for the base-case model in the 2017 assessment (Gertseva and Cope 2017b).

Fishing Mortality

Yelloweye rockfish are caught coastwide in all sectors of the fishery. Yelloweye rockfish are particularly vulnerable to hook and line gears, which are effective in the high relief habitats they reside. The current non-trawl RCA and the recreational depth closures are primarily configured based on yelloweye rockfish distribution and projected impacts in these hook and line fisheries. Small footrope trawls, including selective flatfish trawls, do not have the rollers and anti-chafing protection needed to fish in high relief habitats. Mandating these gears for trawl efforts on the shelf shoreward of the trawl RCA, the configuration of the trawl RCA, and a small IFQ allocation of yelloweye rockfish are the primary strategies currently used to minimize trawl impacts on yelloweye rockfish. Yelloweye rockfish are also a bycatch species in the Pacific halibut fishery (Love*, et al.* 2002).

Yelloweye rockfish are mostly encountered north of 36° N. lat. Yelloweye rockfish occur in depths from 25 to 475 m and are most commonly found at depths from 91 to 180 m (Love*, et al.* 2002).

Fishing mortality rates estimated in the 2017 assessment have been in excess of the current F_{MSY} harvest rate for rockfish (SPR = 50 percent) from 1977 through 2001 (Figure 2-5). Relative exploitation rates (catch/biomass of age-8 and older fish) are estimated to have peaked at 14.3 percent in 1997 but have been at or less than 0.8 percent after 2001. The F_{MSY} exploitation rate assuming the proxy SPR of 50 percent is 2.2 percent. Annual yelloweye rockfish harvest rates in the 1977-2001 period averaged over five times the estimated $F_{MSY,}$ and spawning biomass declined rapidly during that period.

The commercial RCAs substantially reduce yelloweye rockfish impacts. North of 40°10’ N. lat., the highest bycatch rates of yelloweye rockfish occur in waters less than 100 fm. Yelloweye rockfish have a patchy distribution and, as such, using fleetwide bycatch rates over a large area (north and south of 40°10’ N. lat.) may misrepresent actual catch rates. North of Cape Alava, yelloweye rockfish bycatch rates are lowest inside of the 60 fm line; bycatch rates would increase substantially if shoreward RCAs were moved from the 60 fm line to the 75 fm line. The seaward boundary of the non-trawl RCA extends out to 150 fm year-round south of 40°10’ N. lat. The seaward boundary of the non-trawl RCA north of 40°10’ N. lat. is at 100 fm year-round.

Area closures and a prohibition on retention are the main strategies used to minimize recreational yelloweye rockfish impacts. The California recreational fishery is subject to depth restrictions that are more restrictive in the northern management areas where yelloweye rockfish are more prevalent. The California Department of Fish and Wildlife (CDFW) evaluated and has available four potential yelloweye rockfish conservation areas (YRCAs), which include habitat in both state and Federal waters where high yelloweye rockfish encounter rates have been documented. If implemented, YRCAs are anticipated to reduce yelloweye rockfish impacts during the open fishing seasons in both the Northern Groundfish Management Area and the North-Central North of Pt. Arena Groundfish Management Area, possibly allowing for a longer fishing season. To date, these YRCAs have not been implemented but would remain available management measures that can be routinely implemented inseason if needed.

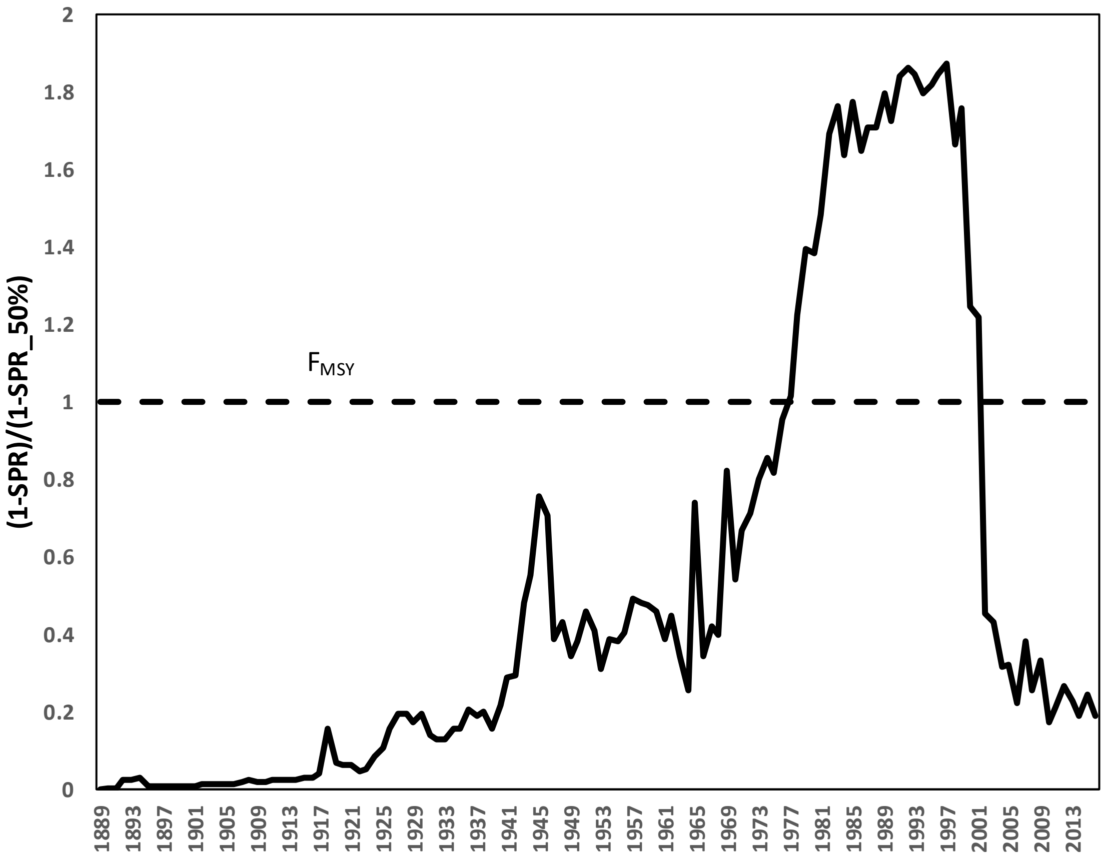

Figure 2-5. Time series of estimated relative exploitation rates (catch/biomass of age-8 and older fish) relative to the F_{MSY} target of yelloweye rockfish, 1889-2016 (Gertseva and Cope 2017b).

Catch monitoring uncertainty is high, given the relatively small contribution of yelloweye rockfish to rockfish market categories and the relatively large scale of recreational removals. In addition, since 2001, management restrictions have required nearly all yelloweye rockfish caught by recreational and commercial fishermen to be discarded at sea. Precisely tracking recreational catch inseason, especially in the California recreational fishery, has been a challenge.

Rebuilding Duration and Probabilities

The SSC evaluated progress to rebuilding in 2017 when they endorsed the new rebuilding analysis (Gertseva and Cope 2017a). Catches have been less than ACLs, and the stock is rebuilding faster than anticipated from the previous rebuilding analysis. The SSC concluded that rebuilding progress has been adequate.

The probability of rebuilding changes from 0 to 100 percent over a single year (2027). This is an unexpected result, but for yelloweye rockfish this occurs because a sequence of good year classes that spawned from 2007 to 2011 will join the spawning population starting around 2020 such that the projected spawning biomass will exceed the target biomass by 2027. The results of the rebuilding analysis do not depend strongly on forecasted recruitment. The rapid change in rebuilding probability is a consequence of this rebuilding analysis not accounting for uncertainty about starting biomass and age-structure, which is acceptable under the Terms of Reference for Groundfish Rebuilding Analyses.

2.4 Non-Overfished Groundfish Stocks

2.4.1 Arrowtooth flounder

Distribution and Life History

Arrowtooth flounder (*Atheresthes stomias*) range from the southern coast of Kamchatka in Russia to the northwest Bering Sea and Aleutian Islands to San Simeon, California. Arrowtooth flounder is the dominant flounder species on the outer continental shelf from the western Gulf of Alaska to Oregon. They are members of the family Pleuronectidae, the right-eyed flounders. Arrowtooth flounder reach sizes of nearly 90 cm and can live to 27 years. Eggs and larvae are pelagic; juveniles and adults are demersal (Garrison and Miller 1982; NOAA 1990). Juveniles and adults are commonly found on sand or sandy gravel substrates, but occasionally occur over low-relief rock-sponge bottoms. Arrowtooth flounder exhibit a strong migration from shallow water summer feeding grounds on the continental shelf to deep water spawning grounds over the continental slope (NOAA 1990). Depth distribution may vary from as little as 50 m in summer to more than 500 m in the winter (Garrison and Miller 1982; NOAA 1990; Rickey 1995).

Arrowtooth flounder are oviparous with external fertilization, and eggs are about 2.5 mm in diameter. Spawning may occur deeper than 500 m off Washington (Rickey 1995). Arrowtooth flounder are batch spawners (Rickey 1995). They spawn in the deeper continental shelf waters (>200 m) in the late fall through early spring and appear to move inshore during the summer (Zimmerman and Goddard 1996). The larvae spend approximately four weeks in the upper 100 m of the water column (Fargo and Starr 2001) and settle to the bottom in the late winter and early spring. Larvae eat copepods, their eggs, and copepod nauplii (Yang 1995; Yang and Livingston 1985). Juveniles and adults feed on crustaceans (mainly ocean pink shrimp and krill) and fish (mainly gadids, herring, and pollock) (Hart 1988; NOAA 1990).

Arrowtooth flounder exhibit two feeding peaks, at noon and midnight. Arrowtooth flounder are piscivorous, but they also eat shrimp, worms, and euphausiids (Love 1996). Buckley et al. (1999) analyzed 380 arrowtooth flounder stomachs that were collected in 1989 and 1992 from Oregon and Washington and found that hake (*Merluccius productus*) and unidentified gadids dominate their stomach contents (45 percent and 22 percent, respectively) followed by herring (19 percent; *Clupea pallasi*), mesopelagics (0.5 percent), rex sole (1 percent; *Glyptocephalus zachirus*), slender sole (*Lyopsetta exilis*) and other small flatfish (3 percent), other arrowtooth flounder (1.5 percent), other unidentified flatfish (1 percent), pandalid shrimp (~3 percent), and euphausiids (3 percent). Yang (1995) analyzed 1,144 stomachs from arrowtooth flounder collected in the Gulf of Alaska, and found that walleye pollock (*Theragra chalcogramma*) composed 66 percent of the arrowtooth flounder diet, although arrowtooth flounder smaller than 40 cm primarily feed on capelin (*Mallotus villosus*), herring, and shrimp. Gotshall (1969) examined 425 arrowtooth flounder stomachs from northern California throughout the 1960s and found that pandalid shrimp made up nearly 40 percent of the prey by volume, along with other shrimps, crabs, euphausiids, Pacific sanddabs

(*Citharichthys sordidus*), and slender sole. However, Gotshall's samples were taken directly from shrimp beds, so higher concentrations of shrimp would be expected. It is clear that arrowtooth flounder have a broad diet, consuming most of the common fish and invertebrates found on soft bottom substrate and in the water column.

Predators of juvenile arrowtooth flounder include skates, dogfish, shortspine thornyhead, halibut, coastal sharks, orcas, toothed whales, and harbor seals (Field*, et al.* 2006). Adult arrowtooth flounder are likely to be vulnerable only to the largest of these predators.

Female arrowtooth flounder off Oregon reach 50 percent maturity at 8 years of age, and males at 4 years (Hosie 1976). Rickey (1995) found that arrowtooth flounder reach 50 percent maturity at lengths of 36.8 cm for females and 28 cm for males off Washington, and 44 cm for females and 29 cm for males off Oregon. As a comparison, female length at 50 percent maturity is 47 cm in the Gulf of Alaska (Turnock*, et al.* 2005) and 38 cm in British Columbia (Fargo and Starr 2001).

Stock Status and Management History

Arrowtooth flounder are commonly caught by trawl fleets off Washington and Oregon, but they are frequently discarded due to low flesh quality. For this reason, the market for arrowtooth flounder has been fairly limited over the last 50 years. It is likely that the stock off the U.S. West Coast is linked to the population off British Columbia and, possibly, to the stock in the Gulf of Alaska. However, for assessment purposes it is assumed that the U.S. West Coast population is a unit stock.

The West Coast stock of arrowtooth flounder was assessed in 1993 (Rickey 1993), and a full stock assessment was done in 2007 (Kaplan and Helser 2008). Three components of the arrowtooth flounder fishery were used in modeling: the mink food fishery in the 1950s-1970s, a targeted fillet/headed-and-gutted fishery that began around 1981, and a "bycatch fleet" that represents West Coast trawl effort with arrowtooth flounder bycatch but no landings. Estimates of historical catch are highly uncertain. The model contains assumed fixed values for natural mortality and steepness of the stock-recruitment relationship. Likelihood profiles suggest that the estimates of biomass and depletion are not sensitive to values of steepness. Assumed values of natural mortality have a small effect on estimated depletion, but strongly influence the estimates of absolute biomass.

The base model shows a period of moderate depletion through the 1950s and 1960s, followed by a rebuilding of the stock beginning in the late 1970s. Strong year classes, in particular the 1999 year class, have led to an increase in the stock since the late 1990s. The spawning biomass at the beginning of 2007 was estimated to be 63,302 mt and 79 percent of the estimated unfished spawning biomass. Total biomass at the start of 2007 was estimated to be 85,175 mt. The 2007 stock assessment estimated that the arrowtooth flounder stock has never fallen below the overfished threshold.

An update of the full 2007 assessment of arrowtooth flounder was prepared in 2017 (Sampson*, et al.* 2017). Changes from the 2007 assessment included use of updated pre-2007 landings, discards, and composition data; updated abundance indices; updated natural mortality estimates; and the addition of 10 years of catch, composition, and Northwest Fisheries Science Center (NWFSC) slope-shelf survey data. Large recruitments that occurred in 2011-2013, coupled with declining fishing mortality, have resulted in an upward trend in biomass. The assessment update estimates spawning biomass of almost 57,000 mt, with a depletion of 87 percent in 2017, which is much higher than the B_{MSY} proxy of $B_{25\%}$ for Council managed flatfish species. Biomass trajectories prior to 2007 were substantially different compared to the previous assessment.

The Council maintained the default harvest control rules of ACL = ABC (cat. 2 sigma; P* = 0.4) for 2021 and beyond. A catch-only projection update of the 2017 update assessment inform harvest specifications for 2023 and beyond.

Stock Productivity

Arrowtooth flounder are a very productive stock with high growth rates, high natural mortality rates, and a high stock-recruitment steepness. A mean flatfish steepness of 0.8 was determined in a 2010 meta-analysis conducted by the SSC and described in the 2011-2012 specifications Final Environmental Impact Statement (FEIS) (PFMC and NMFS 2011). A steepness of 0.902 was assumed in the 2007 arrowtooth flounder assessment based on a flatfish meta-analysis conducted by Dorn (2002a) and the same value was assumed in the 2017 update. Arrowtooth flounder received a relatively high productivity score of 1.95 in the PSA analysis (Table 2-2).

The 2017 assessment estimated strong recent recruitments in 1999 and 2011 to 2013.

Fishing Mortality

The target F_{MSY} SPR harvest rate for arrowtooth flounder is 30 percent. The 2017 assessment estimated annual SPR harvest rates between 2007 and 2016 of 41-81 percent, substantially lower than the target. Exploitation of arrowtooth flounder has remained below the F_{MSY} target throughout the entire assessment period and the ACL has never been exceeded.

Arrowtooth flounder are a trawl-dominant species and are not particularly valuable. Given that arrowtooth flounder are caught on the northern shelf where Pacific halibut and yelloweye rockfish are caught incidentally to arrowtooth flounder, this is not a species with a high attainment, since valuable quota for these highly constraining species would have to be invested to target arrowtooth flounder. Management uncertainty is low with 100 percent observer coverage for the trawl fleet under trawl rationalization. The PSA vulnerability score of 1.21 indicates a low concern of overfishing.

2.4.2 Big Skate

Distribution and Life History

Big skate (*Raja binoculata*) are the largest skate species in North America with a documented maximum length of 244 cm total length and a maximum weight of 91 kg (Eschmeyer*, et al.* 1983). The species name "binoculata" (two-eyed) refers to the prominent ocellus at the base of each pectoral fin. Big skate range from the Bering Sea to Cedros Island in Baja California but are uncommon south of Pt. Conception. Big skate occur in coastal bays, estuaries, and over the continental shelf, usually on sandy or muddy bottoms, but occasionally on low strands of kelp.

Big skate have a shallow depth distribution of 3-800 m but are most common in the 3-110 m depth zone. It frequents progressively shallower water in the northern parts of its range.

Skates are the largest and most widely distributed group of batoid fish with approximately 245 species ascribed to two families (Ebert and Compagno 2007; McEachran 1990). Skates are benthic fish that are found in all coastal waters but are most common in cold temperatures and polar waters (Ebert and Compagno 2007).

There are about eleven species of skates from either of three genera (*Amblyraja*, *Bathyraja*, and *Raja*) present in the Northeast Pacific Ocean off California, Oregon and Washington (Ebert 2003). Of that number, just three species (longnose skate, *Raja rhina*; big skate, *Raja binoculata*; and sandpaper skate, *Bathyraja interrupta*) make up over 95 percent of survey catches in terms of biomass and numbers, with the longnose skate leading in both categories (62 percent of biomass and 56 percent of numbers).

Mating has been observed with distinct pairing and embrace. Big skate are oviparous and lay horned egg cases up to a foot in length with up to seven embryos per egg case (Eschmeyer*, et al.* 1983). The female deposits her eggs in pairs on sandy or muddy flats; there is no discrete breeding season and egg-laying occurs year-round (Ebert 2003). Females may use discrete spawning beds, as large numbers of egg cases have been found in certain localized areas (IUCN/SSC Shark Specialist Group 2005). The young emerge after 9 months and measure 18–23 cm (7–9 in). Female big skates mature at 1.3–1.4 m (4 ft 3 in–4 ft 7 in) long and 12–13 years old, while males mature at 0.9–1.1 m (2 ft 11 in–3 ft 7 in) long and seven to eight years old (Bester 2009). The growth rate of big skates in the Gulf of Alaska are comparable to those off California but differ from those off British Columbia. The lifespans of big skates off Alaska are up to 15 years, while those off British Columbia are up to 26 years.

Big skates are usually seen buried in sediment with only their eyes showing. They feed on polychaete worms, mollusks, crustaceans, and small benthic fishes. Polychaetes and mollusks comprise a slightly greater percentage of the diet of younger individuals. A known predator of big skates is the broadnose sevengill shark (*Notorhynchus cepedianus*); the eyespots on the skates' wings are believed to serve as decoys to confuse predators. Juvenile northern elephant seals (*Mirounga angustirostris*) are known to consume the egg cases of the big skate. Known parasites of the big skate include the copepod *Lepeophtheirus cuneifer*.

Stock Status and Management History

Big skate are caught in commercial and recreational fisheries on the West Coast using line and trawl gears. Big skate are commercially utilized to a limited extent by removing the pectoral fins (skate wings) for sale in fresh fish markets.

Big skate were managed in the Other Fish complex until 2015 when they were designated an EC species. When the Council considered designating all skates except longnose skate as EC species, the GMT estimated that catches of big skate averaged 95 mt from 2007–2011 with large landings of Unspecified Skate (see Table 4-33 in the 2015-2016 Harvest Specifications and Management Measures Final Environmental Impact Statement). Subsequent analysis of Oregon port sampling data not available when the Council considered the EC designation indicated about 98 percent of the recent Unspecified Skate landings in Oregon were comprised of big skate. The GMT revised the total mortality estimates of big skate coastwide using these new data (Table 2-8). Such large landings indicate targeting of big skate has occurred and an EC designation was not warranted. Based on this evidence, the Council decided to redesignate big skate as an actively managed species in the fishery. Big skate were managed with stock-specific harvest specifications starting in 2017.

The SSC-endorsed OFL of 541 mt for 2017-2020 is calculated by applying approximate MSY harvest rates to estimates of stock biomass from the NWFSC West Coast Bottom Trawl Survey (see Agenda Item H.6.a, Supplemental Attachment 6, November 2013). The survey-based biomass estimate is likely underestimated since big skate are distributed to the shore and no West Coast trawl surveys have been conducted shallower than 55 m. This adds a level of precaution to the management of big skate with stock-specific management reducing management uncertainty and the risk of overfishing the stock. There was consideration for managing big skate in a complex with longnose skate, the other actively managed West Coast skate species, but the two species have disparate distributions and fishery interactions (longnose is much more deeply distributed than big skate) and that option was not endorsed. The Council chose to set the ACL equal to the ABC with a P* of 0.45.

The first full assessment of big skate was conducted in 2019, which estimated big skate to be healthy with an estimated depletion of 79 percent at the start of 2019 (Taylor*, et al.* 2019). The retrospective estimates of stock status indicate the stock has not been highly exploited and has maintained a high level of abundance in the last 100 years (Figure 2-6). Strong assumptions were required to estimate historical discards (and dead catches), as big skate have only been sorted from other skate species since 2015. The data provide little information about the scale of the population, necessitating the use of a new prior for the NMFS bottom trawl survey catchability (q) developed by the STAT during the STAR Panel review to maintain stable model results. The prior was updated from the one developed in the 2007 longnose skate stock assessment (Gertseva and Schirripa 2008) to better account for big skate occurrences in shallower water than the surveyed region. The assessment model provided weak support for the assumed steepness of 0.4. As in longnose skate, the major axis of uncertainty in the decision table was q of the trawl survey.

The SSC endorsed the big skate assessment as a category 2 assessment since recruitment deviations were not estimated. The Council selected the default harvest control rule for big skate where the ACL equals the ABC under a P* of 0.45.

Table 2-8. 2010-2015 total mortality (mt) of big skate by sector in West Coast fisheries.

Sector	2010	2011	2012	2013	2014	2015
Incidental OA						
Landings	3.0	5.2	1.1	3.8	2.0	3.8
Discards	0.0	0.6	0.1	0.0	0.0	0.0
Total	3.0	5.7	1.1	3.8	2.1	3.8
Non-Trawl						
Landings	16.2	9.7	3.3	6.4	8.9	3.3
Discards	1.6	2.7	6.7	5.1	3.3	3.3
Total	17.8	12.4	10.1	11.5	12.2	6.6
Trawl						
Landings	173.2	236.1	227.7	123.6	354.3	276.7
Discards	28.8	35.9	30.6	36.5	43.8	43.8
Total	202.0	272.0	258.3	160.1	398.1	320.4
Tribal						
Landings	3.8	5.5	12.4	10.3	9.7	16.9
Discards	0.1	0.1	0.0	0.0	0.0	0.0
Total	3.8	5.5	12.4	10.3	9.7	16.9
Total All Sectors	226.6	295.7	281.8	185.8	422.1	347.8

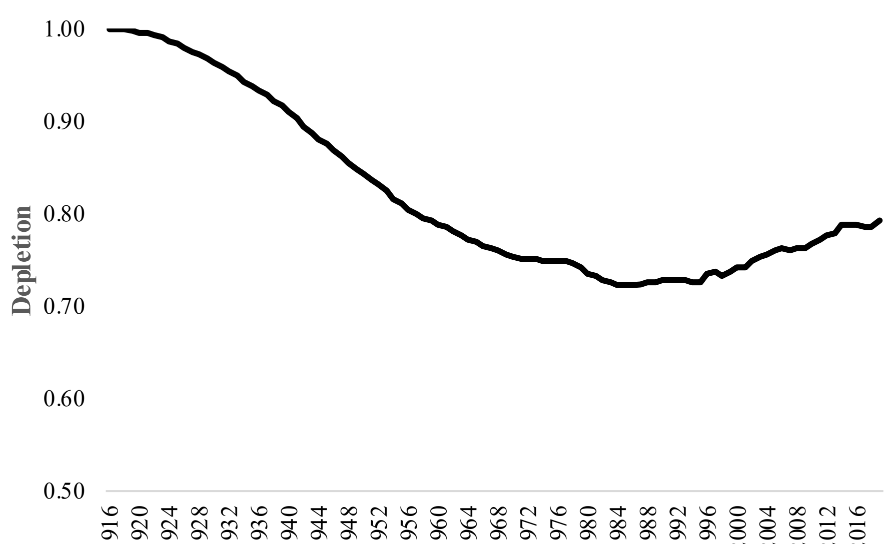

Figure 2-6. Relative depletion of big skate from 1916 to 2019 based on the 2019 stock assessment.

Stock Productivity

In general, elasmobranchs have relatively low productivity given the K-type reproductive strategy of producing few eggs per female with a significant parental energy investment to increase survival of those few eggs (e.g., production of egg cases and relatively large yolk masses). A relatively low Beverton-Holt steepness of 0.4 was assumed in the 2019 big skate assessment.

Fishing Mortality

Historically, skates in general have not been high-priced fishery products. They are taken mostly as bycatch in other commercially important fisheries (Bonfil 1994). Although skates are caught in almost all demersal fisheries and areas off the U.S. West Coast, the vast majority (almost 97 percent) are caught with trawl gear.

Landing records indicate that skates have been retained on the U.S. Pacific Coast at least since 1916 (Martin and Zorzi 1993). Little is known about the species composition of West Coast skate fisheries, particularly prior to 1990. With few exceptions, big skate landings have been reported, along with other skate species, under the market category "Unspecified Skates."

Historically, only the skinned pectoral fins or "wings" were sold, although a small portion of catch would be marketed in the round (whole). The wings were cut onboard the boat and the remainder discarded. Currently, West Coast skates are marketed both whole and as wings. Skates wings are sold fresh or fresh-frozen, as well as dried or salted and dehydrated, for sale predominantly in Asian markets (Bonfil 1994; Martin and Zorzi 1993). It appears that the demand for whole skates did increase greatly during the mid-1990s, as evidenced by the increase in the number of trips where skates were landed. While skates were encountered predominantly as bycatch previously, landings data from this period reveal greater targeting of skates by some vessels. After a few years, the whole-skate market cooled due to downturns in Asian financial markets (Peter Leipzig, Fishermen's Marketing Association, pers. com. as cited by Gertseva and Schirripa (2008)).

Harvest rates estimated by the base model indicate catch levels have been below the 100 percent relative fishing intensity upper limit defined as 50 percent SPR (0.5 1-SPR in Figure 2-7). SPR is calculated as the lifetime spawning potential per recruit at a given fishing level relative to the lifetime spawning potential per recruit with no fishing. The annual exploitation rate of age 2+ fish has been below 2 percent over the recent 10-year period.

A vulnerability score of 1.99 indicates a medium concern for overfishing the stock.

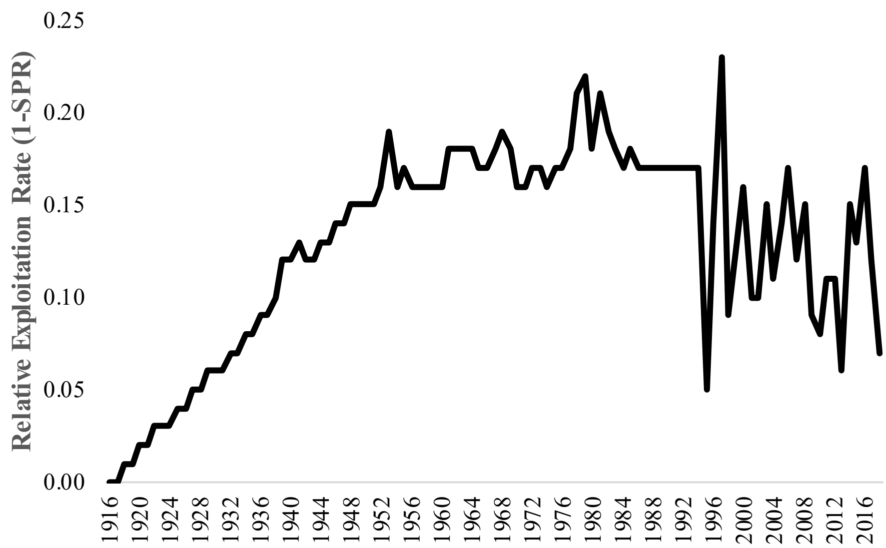

Figure 2-7. Relative exploitation rate of big skate, 1916-2018, from the 2019 stock assessment.

2.4.3 Black Rockfish off California

Distribution and Life History

Black rockfish (*Sebastes melanops*) are found from Southern California (San Miguel Island) to the Aleutian Islands (Amchitka Island) and they occur most commonly from San Francisco northward (Hart 1988; Miller and Lea 1972; Phillips 1957; Stein and Hassler 1989). Black rockfish occur from the surface to greater than 366 m; however, they are most abundant at depths less than 54 m (Stein and Hassler 1989). Off California, black rockfish are found along with the blue, olive, kelp, black-and-yellow, and gopher rockfishes (Hallacher and Roberts 1985). The abundance of black rockfish in shallow water declines in the winter and increases in the summer (Stein and Hassler 1989). Densities of black rockfish decrease with depth during both the upwelling and non-upwelling seasons (Hallacher and Roberts 1985). Off Oregon, larger fish seem to be found in deeper water (20 m to 50 m) (Stein and Hassler 1989). Black rockfish off the northern Washington coast and outer Strait of Juan de Fuca exhibit no significant movement. However, fish appear to move from the central Washington coast southward to the Columbia River, but not into waters off Oregon. Movement displayed by black rockfish off the northern Oregon coast is primarily northward to the Columbia River (Culver 1986). Black rockfish form mixed sex, midwater schools, especially in shallow water (Hart 1988; Stein and Hassler 1989). Black rockfish larvae and young juveniles (<40 mm to 50 mm) are pelagic, but are benthic at larger sizes (Laroche and Richardson 1980).

Black rockfish have internal fertilization and annual spawning (Stein and Hassler 1989). Parturition occurs from February through April off British Columbia, January through March off Oregon, and January through May off California (Stein and Hassler 1989). Spawning areas are unknown, but spawning may occur in offshore waters because gravid (egg-carrying) females have been caught well offshore (Dunn and Hitz 1969; Hart 1988; Stein and Hassler 1989). Black rockfish can live to be more than 20 years in age. The maximum length attained by the black rockfish is 60 cm (Hart 1988; Stein and Hassler 1989). Off Oregon, black rockfish primarily prey on pelagic nekton (anchovies and smelt) and zooplankton such as salps, mysids, and crab megalops. Off Central California, juveniles eat copepods and zoea, while adults prey on juvenile rockfish, euphausiids, and amphipods during upwelling periods. During periods without upwelling, they primarily consume invertebrates. Black rockfish feed almost exclusively in the water column (Culver 1986). Black rockfish are known to be eaten by lingcod and yelloweye rockfish (Stein and Hassler 1989).

Stock Status and Management History

A black rockfish assessment was completed in 2003 and pertained to the portion of the coastwide stock occurring off the coasts of Oregon and California (Ralston and Dick 2003) or the southern stock unit. Alternative harvest levels in the 2003 assessment were ranged to capture the major uncertainty of historical landings prior to 1978. Black rockfish catches prior to 1945 were assumed to be zero in the assessment. Many gaps in historical landings of black rockfish since 1945 were evident, and these landings were reconstructed using a variety of data sources. The base model assumed cumulative landings of black rockfish from all fisheries was 17,100 mt from 1945 to 1977. The 2003 assessment concluded the southern California-Oregon stock of black rockfish was in healthy condition with a 2002 spawning output estimated to be at 49 percent of its unexploited level.

The southern stock of black rockfish was again assessed in 2007 (Sampson 2008) using a similar approach and structure as the 2003 assessment, but included historical catch series that extended back to 1916 with relatively large catches of black rockfish in California during World War II. The 2007 assessment estimated the southern stock was at 70 percent of its unfished level at the start of 2007. The 2007 assessment was structured into six fisheries: a set of trawl, commercial non-trawl, and recreational fisheries for Oregon and California, respectively. The fisheries for each state were based on fish capture location rather than where they were landed and therefore represented separate geographic areas. The model in the 2007 assessment did not include any underlying spatial structure in the population dynamics. Like the previous southern stock assessment, abundance indices for tuning the assessment were based on recreational CPUE data with two independent indices available for each state. The standard research trawl surveys along the U.S. West Coast do not operate in shallow enough water to catch appreciable numbers of black rockfish and therefore do not provide any fishery independent index of stock biomass for black rockfish. The 2007 assessment had two additional abundance indices that were not available for the previous assessment: a black rockfish pre-recruit index for 2001-2006 and estimates from a tag-recapture study of exploitable black rockfish abundance off Newport, Oregon for 2003-2005. The 2007 assessment for the southern stock of black rockfish used the same sex- and age-specific formulation for natural mortality (M) that was used in the assessment for northern black rockfish, but there is little evidence to confirm that the assumed formulation is correct. The 2003 assessment for southern black rockfish used much smaller values for M that were more consistent with observed values for the maximum age of southern black rockfish.

A new full assessment of black rockfish in waters off California was conducted in 2015 (Cope, *et al.* 2015a). This was the first assessment ever of the California black rockfish stock in isolation. Cope et al. (2015a) estimated the California black rockfish stock was at a 33 percent depletion at the start of 2015 (Figure 2-8). While the stock is estimated to be below the biomass target and in the precautionary zone, the assessment estimates the stock has been increasing in abundance in the last 20 years. The stock is projected to be above the biomass target by the start of 2017 due to the strength of very strong year classes in 2008 and 2009.

The 2015 California black rockfish assessment modeled four fleets (trawl fishery, non-trawl dead-landed fish commercial fishery, non-trawl live fish commercial fishery, and the recreational fishery) and four surveys (onboard CPFV survey (1988-1999), onboard CPFV survey (2000-2014), research samples, and dockside CPUE survey). All life history parameters were modeled as sex-specific, including natural mortality. Steepness was fixed at the meta-analysis prior.

The primary challenge for the black rockfish assessment in all three states is the absence of larger, older female black rockfish in fisheries catches, a phenomenon that has long been a challenge in developing plausible assessments for black rockfish and other species that exhibit this tendency. Past modeling approaches have explored both "hiding" larger, older females (e.g., applying dome-shaped selectivity to fisheries, which often results in what are considered to be implausibly high "cryptic" biomass levels of large, old, unavailable fish) or "killing" off larger, older females (one common formulation being a ramp up in natural mortality rates with age) in order to fit the observed data. The most dramatic model specification in the California model, in relation to past assessments, is the choice to estimate sex-specific natural mortality rather than assuming dramatic changes (i.e., a ramp) in natural mortality.

The SSC categorized black rockfish off California as a category 1 stock. The Council adopted the default harvest control rule for black rockfish off California in 2019 and beyond of ACL = ABC with a P* of 0.45. A catch only-projection of black rockfish was provided to inform harvest specifications for 2021 and beyond.

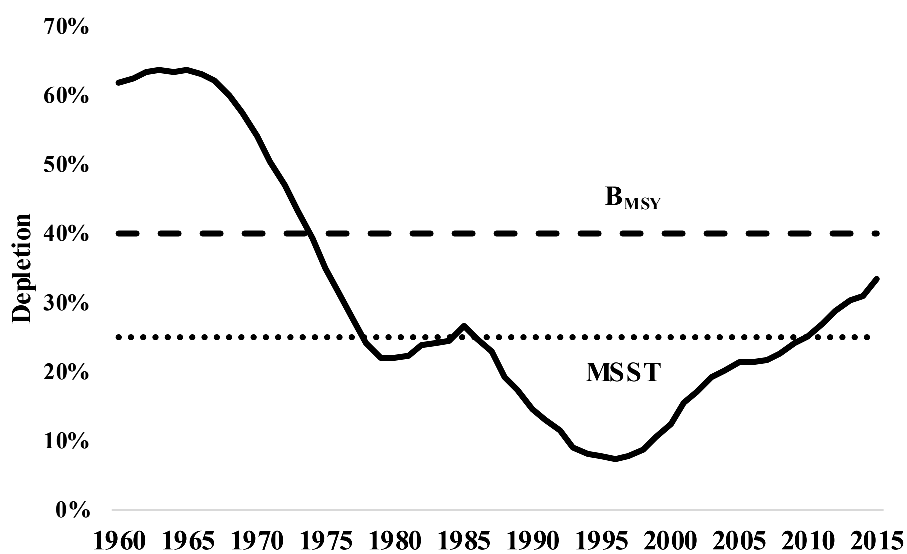

Figure 2-8. Relative depletion of black rockfish off California from 1960 to 2015 based on the 2015 stock assessment.

Stock Productivity

The 2015 California black rockfish assessment assumed a steepness of 0.773 based on the meta-analysis of rockfish steepness. The PSA productivity score of 1.33 indicates a stock of moderate productivity.

The 2015 California black rockfish assessment estimated a few extraordinarily high recruitment events that are supported by the length composition data, index data, and on-the-water reports. The largest recruitments since 1960 are the 1976-1977 and 2008-2010 year classes (Figure 2-9).

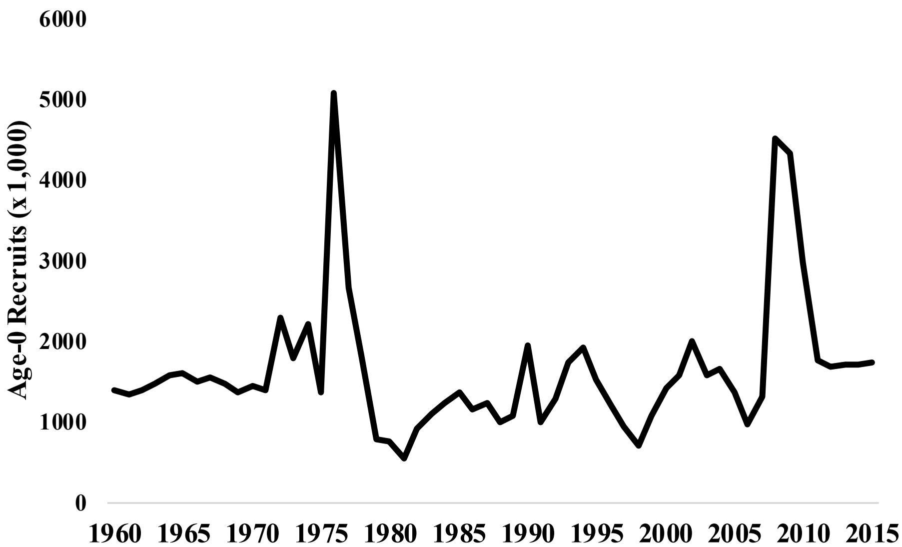

Figure 2-9. Estimated recruitments of black rockfish off California, 1960-2014 (from Cope, *et al.* 2015).

Fishing Mortality

The nearshore commercial and recreational fisheries that take black rockfish are managed well in California and ACLs/OYs have not been exceeded. The PSA vulnerability score of 1.94 indicates a stock of medium concern for overfishing.

While black rockfish off California have been well managed with no years when total mortality has exceeded specified harvest limits, exploitation rates have routinely exceeded the newly calculated F_{MSY} rate since 1970 in retrospect (Figure 2-10).

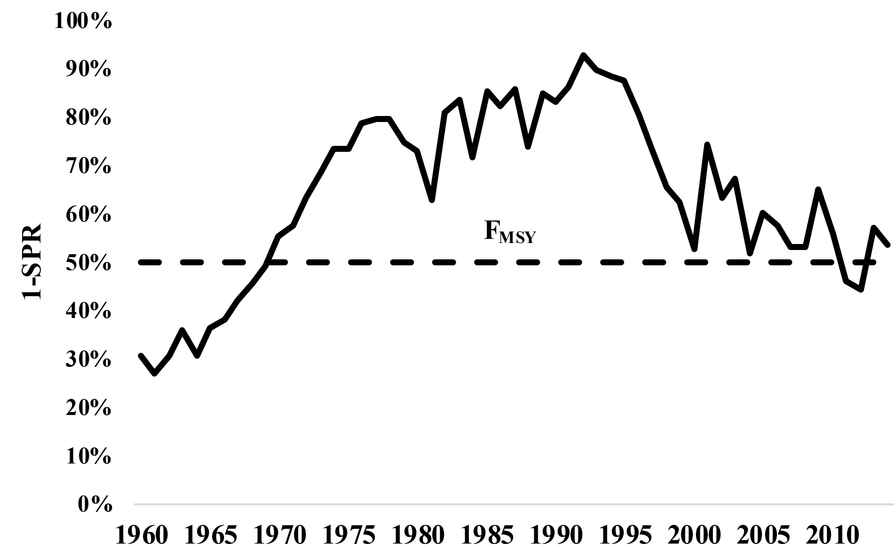

Figure 2-10. Time series of estimated SPR harvest rates of black rockfish off California, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.4.4 Black Rockfish off Washington

Distribution and Life History

See the description of black rockfish distribution and life history in section 2.4.3.

Stock Status and Management History

The black rockfish stock found between Cape Falcon, Oregon and the U.S. Canadian border was first assessed in 1994 (Wallace and Tagart 1994). Estimated biomass was 60 percent of the unfished level and female egg production was estimated to be 43 percent of the unfished level. A harvest guideline of 517 mt for this area was specified beginning in 1995 based on assessment results. Catches remained well below the harvest guideline in the years after the assessment.

The 1999 assessment of the black rockfish stock north of Cape Falcon, Oregon determined the stock was at 45 percent of the unfished level (Wallace, *et al.* 1999). The population was regarded as healthy and stock abundance was estimated to be slightly increasing after a period of low abundance in the late 1980s and early 1990s.

An assessment of the northern stock was done in 2007, which estimated a depletion of 53.4 percent of the unfished level (Wallace, *et al.* 2008). The base model for the 2007 assessment assumed a female natural mortality rate to be age-specific using age at first and full maturity for inflections (10 and 15). A constant natural mortality rate of 0.16 was assumed for males and young females (< 10 years of age), and a rate of 0.2 was assumed for old females (>=15 years of age). Model sensitivity analysis showed that model configurations using higher natural mortality for older females provided better overall fits to the data. In the model, spawning biomass and age 3+ biomass reached the lowest levels in 1995, following poor recruitment and intense fishing in the late 1980s. The population trajectory remained just above minimum stock size threshold, and the model indicated that the stock is currently well above the management target of $B_{40\%}$.

A new full assessment of black rockfish in waters off Washington was conducted in 2015 (Cope, *et al.* 2015a). This assessment changed the boundaries of the assessment from Cape Falcon, Oregon to the state's southern border at the Columbia River. Cope et al. (2015a) estimated the Washington black rockfish stock was at a 43 percent depletion at the start of 2015 (Figure 2-11). The stock had never fallen below the B_{MSY} target from 1982-1997 and has remained above the target since then.

The 2015 Washington black rockfish assessment modeled three fleets (trawl fishery, non-trawl dead-landed fish commercial fishery, and the recreational fishery) and two surveys (a dockside CPUE survey and a tagging CPUE survey). All life history parameters were modeled as sex-specific, including M. Steepness was fixed at the meta-analysis prior.

The primary challenge for the black rockfish assessment in all three states is the absence of larger, older female black rockfish in fisheries catches, a phenomenon that has long been a challenge in developing plausible assessments for black rockfish and other species that exhibit this tendency. Past modeling approaches have explored both "hiding" larger, older females (e.g., applying dome-shaped selectivity to fisheries, which often results in what are considered to be implausibly high "cryptic" biomass levels of large, old, unavailable fish) or "killing" off larger, older females (one common formulation being a ramp up in natural mortality rates with age) in order to fit the observed data. The most dramatic model specification in the Washington model, in relation to past assessments, is the choice to estimate sex-specific natural mortality rather than assuming dramatic changes (i.e., a ramp) in natural mortality.

The SSC categorized black rockfish off Washington as a category 1 stock. The Council adopted the default harvest control rule for black rockfish off Washington in 2019 and beyond of ACL = ABC with a P* of 0.45. A catch only-projection of black rockfish was provided to inform harvest specifications for 2021 and beyond.

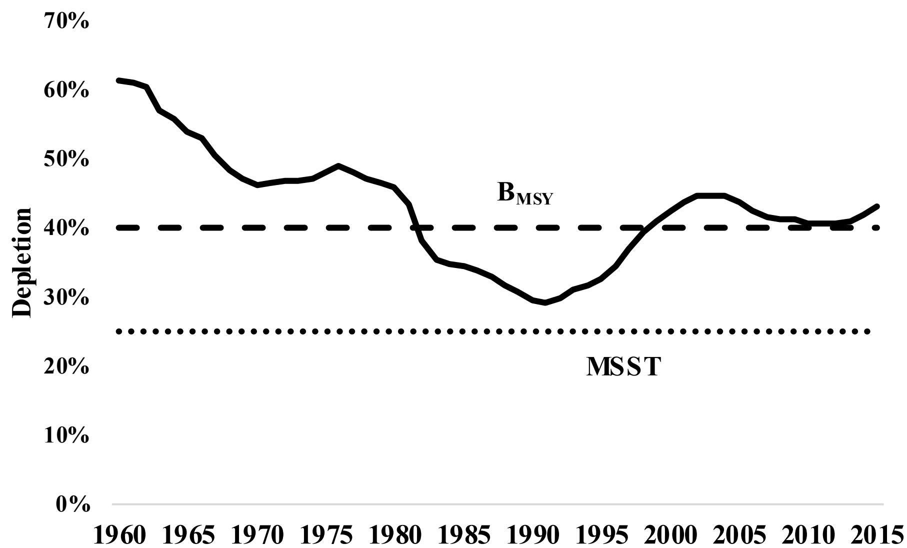

Figure 2-11. Relative depletion of black rockfish off Washington from 1960 to 2015 based on the 2015 stock assessment.

Stock Productivity

The 2015 Washington black rockfish assessment assumed a steepness of 0.773 based on the meta-analysis of rockfish steepness. The PSA productivity score of 1.33 indicates a stock of moderate productivity.

The 2015 Washington black rockfish assessment indicated stock recruitment is dynamic (Figure 2-12). This is the most informed recruitment time series relative to the other two black rockfish assessments, which is consistent with the extent of length and age compositions available to the assessment. As in the California assessment, results indicate elevated recruitment in the late 2000s.

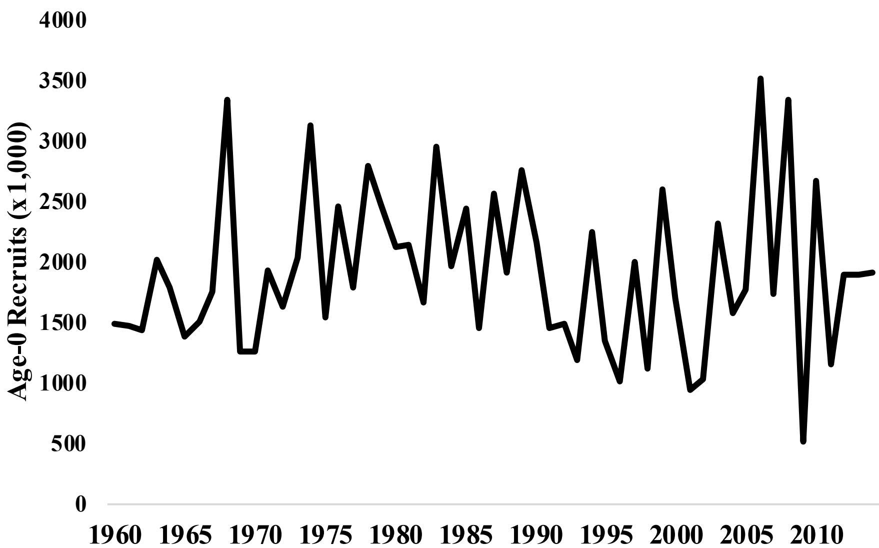

Figure 2-12. Estimated recruitments of black rockfish off Washington, 1960-2014 (from Cope, *et al.* 2015).

Fishing Mortality

The nearshore recreational fishery (the nearshore commercial fishery was eliminated in 1995) that take black rockfish is managed well in Washington and ACLs/OYs have not been exceeded. The PSA vulnerability score of 1.94 indicates a stock of medium concern for overfishing.

While black rockfish off Washington have been well managed with no years when total mortality has exceeded specified harvest limits, exploitation rates have periodically exceeded the newly calculated F_{MSY} rate since 1976 in retrospect (Figure 2-13). However, fishing intensity has shown a dramatic decline since the late 1990s and has fluctuated mostly below the target since.

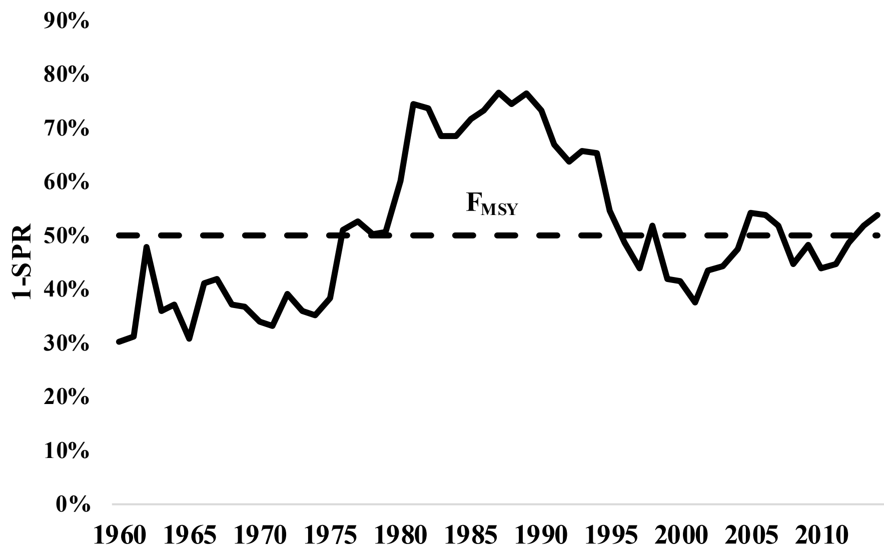

Figure 2-13. Time series of estimated SPR harvest rates of black rockfish off Washington, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.4.5 Bocaccio

Distribution and Life History

Bocaccio (*Sebastes paucispinis*) is a rockfish species that ranges from Stepovak Bay on the Alaskan Peninsula (as well as Kodiak Island, Alaska) to Punta Blanca, Baja California, Mexico (Hart 1988; Miller and Lea 1972). Love, et al. (2002) and Thomas and MacCall (2001) describe bocaccio distribution and life history. Bocaccio are historically most abundant in waters off central and southern California. The southern bocaccio stock is most prevalent in the 54-82 fm depth zone (Casillas*, et al.* 1998).

Bocaccio are found in a wide variety of habitats, often on or near bottom features, but sometimes over muddy bottoms. They are found both nearshore and offshore (Sakuma and Ralston 1995). Larvae and small juveniles are pelagic (Garrison and Miller 1982) and are commonly found in the upper 100 m of the water column, often far from shore (MBC 1987). Large juveniles and adults are semi-demersal and are most often found in shallow coastal waters over rocky bottoms associated with algae (Sakuma and Ralston 1995). Adults are commonly found in eelgrass beds, or congregated around floating kelp beds love (Love*, et al.* 1990; Sakuma and Ralston 1995). Young and adult bocaccio also occur around artificial structures, such as piers and oil platforms (MBC 1987). Although juveniles and adults are usually found around vertical relief, adult aggregations also occur over firm sand-mud bottoms (MBC 1987). Bocaccio move into shallow waters during their first year of life (Hart 1988), then move into deeper water with increased size and age (Garrison and Miller 1982).

Bocaccio are ovoviviparous (live young are produced from eggs that hatch within the female's body) (Garrison and Miller 1982; Hart 1988). Love et al. (1990) reported the spawning season to last nearly an entire year (>10 months). Parturition occurs during January to April off Washington, November to March off Northern and Central California, and October to March off Southern

California (MBC 1987). Fecundity ranges from 20,000 to 2,300,000 eggs. In California, two or more broods may be born per year (Love*, et al.* 1990). The spawning season is not well-known in northern waters. Males mature at three to seven years, with about half maturing in four to five years. Females mature at three to eight years, with about half maturing in four to six years (MBC 1987).

Maximum age of bocaccio was radiometrically determined to be at least 40 years, and perhaps more than 50 years. Bocaccio are difficult to age, and stock assessments used length measurement data and growth curves to estimate the age composition of the stock (Ralston and Ianelli 1998). New techniques were developed for ageing bocaccio, and age data were therefore used for the first time in the 2015 assessment (He*, et al.* 2015).

Larval bocaccio eat diatoms, dinoflagellates, tintinnids, and cladocerans (Sumida and Moser 1984). Copepods and euphausiids of all life stages (adults, nauplii and egg masses) are common prey for juveniles (Sumida and Moser 1984). Both Phillips (1964) and Love et al. (2002) described bocaccio rockfish as almost exclusively piscivorous, and include other rockfish, Pacific whiting, sablefish, anchovy, mesopelagic fishes and squid as the key prey for large juvenile and adult bocaccio. Bocaccio are eaten by sharks, salmon, other rockfishes, lingcod, albacore, sea lions, porpoises, and whales (MBC 1987). Adult bocaccio are often caught with chilipepper rockfish and have been observed schooling with speckled, vermilion, widow, and yellowtail rockfish (Love*, et al.* 2002). As pelagic juveniles, they may compete with chilipepper, widow, yellowtail, shortbelly rockfish, and other pelagic juvenile rockfishes for both food and habitat (Reilly*, et al.* 1992).

Stock Productivity

He and Field (2018; 2015) fixed steepness at its prior mean of 0.718. This prior was estimated using a likelihood profile approximation to a maximum marginal likelihood mixed-effect model for steepness from ten category 1 rockfish species off the U.S. West Coast (Pacific ocean perch, bocaccio, canary rockfish, chilipepper, black, darkblotched rockfish, gopher, splitnose, widow, and yellowtail rockfish). This likelihood profile model is intended to synthesize observation-level data from assessed species, while avoiding the use of model output and thus improving upon previous meta-analyses (Dorn 2002a; Forrest*, et al.* 2010). This methodology has been simulation tested and has been recommended by the SSC for use in stock assessments.

Recruitment for bocaccio is highly variable, with a small number of year classes tending to dominate the catch in any given fishery or region. Recruitment appears to have been at very low levels throughout most of the 1990s, but several recent year classes (1999, 2010, and 2013) have been relatively strong, given the decline in spawner abundance, and have resulted in an increase in abundance and spawning output. The 2013 recruitment is among the highest observed for bocaccio in the past two decades, which is expected to lead to high biomass levels over the next few years (Figure 2-14).

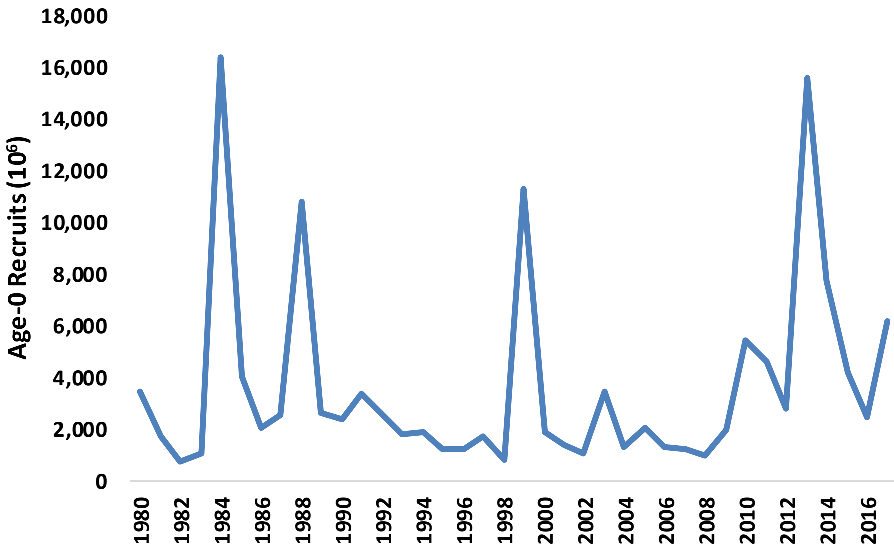

Figure 2-14. Estimated bocaccio recruitments, 1980-2017 (from He and Field 2018).

Stock Status and Management History

Bocaccio are managed as two separate West Coast populations. The southern stock exists south of Cape Mendocino and the northern stock north of Cape Mendocino (the northern stock density is limited south of 48° N. lat. with increasing abundance off Cape Flattery, Washington and points north). It is unclear whether this stock separation implies stock structure. The distribution of the two populations and evidence of lack of genetic intermixing suggests stock structure, although MacCall (2002) reported some evidence for limited genetic mixing of the two populations. Nonetheless, assessment scientists and managers have treated the two populations as independent stocks north and south of Cape Mendocino.

Bocaccio have long been an important component of California rockfish fisheries. Catches increased to high levels in the 1970s and early 1980s as relatively strong year-classes recruited to the stock. The Council began to recommend increasingly restrictive regulations after an assessment of the southern stock in 1990 (Bence and Hightower 1990) indicated that fishing rates were too high. The southern stock suffered poor recruitment during the warm water conditions that prevailed off Southern California beginning in the late 1980s. The 1996 assessment (Ralston, *et al.* 1996) indicated the stock was in severe decline. NMFS formally declared the stock overfished in March 1999 after the groundfish FMP was amended to incorporate the tenets of the Sustainable Fisheries Act. MacCall et al. (1999) confirmed the overfished status of bocaccio and estimated spawning output of the southern stock to be 2.1 percent of its unfished biomass.

In the 2002 assessment (MacCall 2002) relative abundance increased slightly from the previous assessment (4.8 percent of unfished biomass), potential productivity (as evidenced from the steepness of the spawner/recruit relationship, which reflects the level of compensatory production at low stock sizes) appeared lower than previously thought, making for a more pessimistic outlook. Furthermore, the 2002 assessment revealed that although the 1999 year class was the strongest in several years, it was weak relative to the range of possibilities considered in the 1999 assessment.

The 2002 rebuilding analysis (MacCall and He 2002) predicted the stock would not rebuild within maximum time legally possible (T_{MAX}) even with no fishing-related mortality. Total mortality in 2003 fisheries was restricted to less than 20 mt as a means of conserving the stock while minimizing adverse socioeconomic impacts to communities.

The 2003 bocaccio assessment (MacCall 2003b) estimated a higher stock biomass (7.4 percent depletion) relative to the 2002 assessment. The instantaneous rate of natural mortality was changed from 0.2 to 0.15. Additional CalCOFI data indicated an increasing abundance trend due to recruitment of the 1999 year class. This was corroborated by a dramatic increase in recreational CPUE, which was at a record high level in central California north of Pt. Conception. The 2003 rebuilding analysis suggested the stock could rebuild to B_{MSY} within 25 years while sustaining an OY of approximately 300 mt in 2004 (MacCall 2003a).

The 2003 assessment was updated in 2005 and 2007 (MacCall 2006b; MacCall 2008b) using the original 2003 base model (i.e., STATc) in SS1. These assessments were used to establish annual specifications and management measures consistent with a strategy of a higher OY than the impacts anticipated under the suite of management measures adopted. This strategy was designed to buffer the effects of a large recruitment event like that observed for the 1999 year class. Such effects include disruption to fisheries as experienced in previous years when fisheries closed early to avoid young bocaccio. This buffer strategy, which addressed the large, episodic recruitment pattern inherent in the stock's dynamics, became a tenet of the bocaccio rebuilding plan.

A bocaccio rebuilding plan was adopted by the Council in 2004 under Amendment 16-3 (PFMC 2004). The rebuilding plan established a target rebuilding year of 2023 and a harvest control rule of F = 0.0498. (It was later clarified in the 2005 rebuilding analysis (MacCall 2006a) that the target rebuilding year had been incorrectly stated in the rebuilding plan to be 2023 since the 2003 rebuilding analysis indicated that a 50 percent probability rebuilding would require 23 years, and that this assumed a beginning date of 2004 (the first simulated year). Therefore, the Council amended the rebuilding plan's target year to 2026.

A new rebuilding analysis was conducted in 2007 (MacCall 2008a) based on the results of the 2007 stock assessment (MacCall 2008b). The 2007 bocaccio rebuilding analysis showed a similar rebuilding trajectory to that adopted in Amendment 16-4, and the rebuilding plan was maintained for the 2009-2010 management cycle.

A new bocaccio assessment (Field*, et al.* 2009) and rebuilding analysis (Field and He 2009) were prepared in 2009. Field et al. (2009) extended the assessment north of Cape Mendocino to Cape Blanco, Oregon; the U.S. West Coast stock north of this point has not been assessed. Indications of strong 2009 and 2010 year classes were projected to result in increased abundance. Depletion in 2011 was estimated at 26 percent (18.7 -33.1 percent), with the stock projected to be rebuilt by 2019. Based on these analyses, the Council changed the target year for rebuilding bocaccio from 2026 to 2022; the amended rebuilding plan was implemented in 2011.

A bocaccio stock assessment update (Field 2011b) and rebuilding analysis (Field 2011a) were prepared in 2011. The 2011 bocaccio assessment was originally scheduled to be an update of the 2009 full assessment; however, the STAT had some limited changes in the 2009 model structure since a strict update estimated that the 2010 year class was extraordinarily and unrealistically strong, based on length frequency data collected in the 2010 NMFS trawl survey. The modified update was ultimately reviewed, endorsed by the SSC, and adopted for use in management decision-making. The 2011 bocaccio rebuilding analysis indicated rebuilding progress was well ahead of schedule with a predicted median year to rebuild of 2021 or one year earlier than the target rebuilding year (Field 2011a). The Council elected to maintain the revised rebuilding plan implemented in 2011.

An update of the 2011 bocaccio assessment model was prepared in 2013, which confirmed the 2009 and 2010 year classes were indeed strong (Field 2013). The assessment estimated a depletion of 31.4 percent at the start of 2013 (Figure 2-15) and predicted the stock would rebuild by 2015. The SSC recommended maintaining the current rebuilding plan for the 2015-2016 management cycle and a full assessment be done in 2015 to confirm this prediction. The SSC further recommended against preparing a rebuilding analysis in 2013.

A full assessment of bocaccio in 2015 indicated the stock was at 36.8 percent of initial, unfished spawning biomass at the start of 2015 or just under the biomass target of 40 percent (He*, et al.* 2015). Data inputs and model structure generally followed those of the 2009 assessment, with the exceptions that age data for bocaccio were included for the first time, natural mortality was estimated rather than fixed, and the steepness of the stock-recruitment curve was set to 0.773 rather than estimated. Strong recruitment was estimated for 2010 and 2011, although it was not estimated to be as strong as it was in previous assessments. There were early indications of strong recruitment for 2013. Results were sensitive to the choice of data-weighting. The 2015 assessment was conducted for the portion of the West Coast population south of Cape Blanco at 43° N. lat. Since the rebuilding plan is for the portion of the stock south of 40°10’ N. lat., the biomass estimates in the assessment were reduced by 7.4 percent based on historical catches by area.

A 2017 update to the 2015 assessment was conducted (He and Field 2018), which estimated a depletion in 2017 of 48.6 percent, which is above the B_{MSY} proxy of $B_{40\%}$, in large part due to recent strong recruitment events (1999, 2010, and 2013 year classes). Minor changes to the 2015 assessment included updated catches for the commercial and recreational fisheries, updated indices of abundance, new fishery and survey length composition data, and the recently updated priors on steepness and natural mortality. In addition, the method used to estimate the juvenile index was changed to correct a methodological error but there was little impact on the results. The SSC endorsed the new assessment as a category 1 assessment and the stock was declared rebuilt in June 2017.

The default harvest control rule for stocks that are declared rebuilt is ACL = ABC under the previously specified P* value used to decide the ABC. In this case, the P* is 0.45 and the 2019 and 2020 ABCs and ACLs for bocaccio south of 40°10’ N. lat. are 2,097 mt and 2,011 mt, respectively.

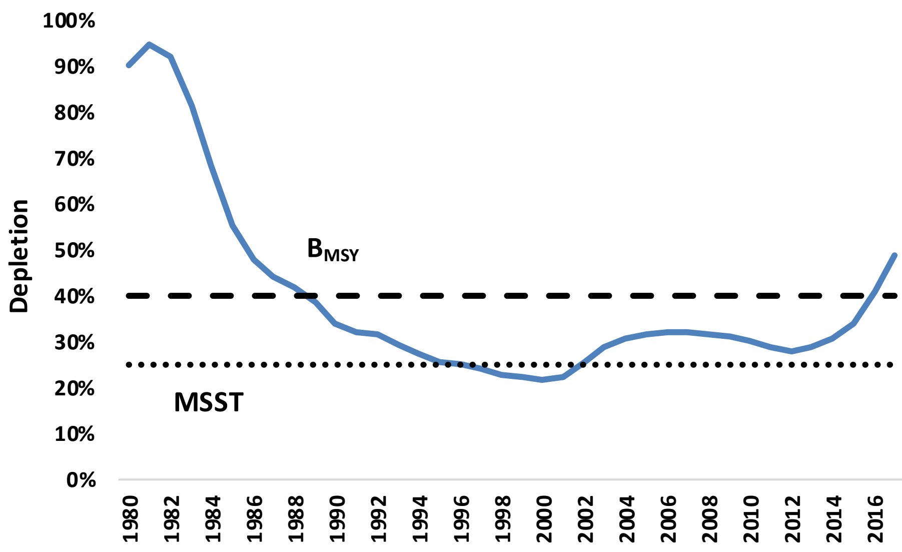

Figure 2-15. Relative depletion of bocaccio south of 40°10' N. lat. from 1980 to 2017 based on the 2017 stock assessment update.

Fishing Mortality

The presence of banner 2010 and 2013 year classes in the bocaccio stock is not entirely unexpected. Bocaccio stock production is characterized by high episodic recruitment and relatively rapid juvenile growth rates Field, et al. 2009. Juvenile bocaccio also recruit to shallow waters and are consequently caught in nearshore recreational fisheries as evidenced by dramatic spikes in both catch rates and the percentage of the total southern California rockfish catch that is bocaccio following strong recruitment events. Unlike most rockfish species where recruitment to fisheries usually takes several years due to low growth rates, juvenile bocaccio can recruit to nearshore fisheries in California within a year or two of parturition.

Given the bocaccio stock is now considered healthy with a spawning output above the B_{MSY} target, the harvest control rule reverts from the SPR harvest rate of 77.7 percent specified in the rebuilding plan to ACL = ABC under the default P* of 0.45. This rule will be implemented starting in 2019.

2.4.6 Cabezon off California

Distribution and Life History

Cabezon (*Scorpaenichthys marmoratus*) are distributed along the entire West Coast of the continental United States. They range from central Baja California north to Sitka, Alaska (Love 1996; Miller and Lea 1972). Cabezon are primarily a nearshore species found intertidally and among jetty rocks, out to depths of greater than 100 m (Love 1996; Miller and Lea 1972).

Cabezon are known to spawn in recesses of natural and manmade objects, and males are reported to show nest-guarding behavior (Garrison and Miller 1982). Spawning is protracted, and there appears to be a seasonal progression of spawning that begins off California in winter and proceeds northward to Washington by spring. Spawning off California peaks in January and February (O'Connell 1953) while spawning in Puget Sound (Washington State) occurs for up to 10 months (November-August), peaking in March–April (Lauth 1987). Laid eggs are sticky and adhere to the surface where deposited. After hatching, the young-of-the-year spend 3–4 months as pelagic larvae and juveniles. Settlement takes place after the young fish have attained 3–5 cm in length (Lauth 1987; O'Connell 1953). It is apparent that females lay multiple batches in different nests, but whether these eggs are temporally distinct enough to qualify for separate spawning events is not understood (Lauth 1987; O'Connell 1953).

Stock Status and Management History

Cabezon in California waters was first assessed in 2003; depletion was estimated at 34.7 percent at the start of 2003 (Cope*, et al.* 2004). The assessment delineated two stocks (north and south) at the Oregon-California border, a distinction based on differences in the catch history, CPUE trends, and biological parameters (mainly growth) between the two areas. Due to the lack of data for the northern population, the assessment focused on only the southern population. As with most nearshore groundfish stocks, this assessment lacked a fishery-independent index of abundance, and consequently relied on recreational CPUE indices and information about larval abundance.

The 2005 assessment modeled two California substocks north and south of Point Conception (Cope and Punt 2006). Historically, the recreational fishery had been the primary source of removals of cabezon in California; however, commercial catches had become a major source of removals in the ten years preceding the assessment because of the developing live-fish fishery. Removals were reconstructed back to 1916, when the commercial fishery began. The estimated stock depletions of the northern and southern substocks of cabezon at the start of 2005 were 40.1 percent and 28.3 percent, respectively.

The 2009 full assessment estimated a stock depletion of 48.3 percent of unfished biomass at the start of 2009 (Cope and Key 2009). The 2009 assessment modeled two California substocks and evaluated the population as a coastwide California stock. The SSC recommended combining the results of the area models for the two California substocks of cabezon for use in deciding statewide harvest specifications.

New full assessments of cabezon stocks in California and Oregon were conducted in 2019 (Cope, *et al.* 2019). The 2019 assessment again modeled two California stocks north and south of Pt. Conception at 34°27' N. lat. The southern California substock (SCS) was estimated to be at a 49 percent depletion (Figure 2-16) and the northern California substock (NCS) was estimated to be at a 65 percent depletion (Figure 2-17) at the start of 2019. Model structure and data were modestly changed from the 2009 assessment in the California models. Changes include the addition of the California Collaborative Fisheries Research Program (CCFRP) survey index and use of informative priors for natural mortality (M) and the growth coefficient (k) in the NCS model. Due to a lack of age data, the SCS model fixes growth at the NCS model estimates, constraining the model's ability to estimate uncertainty and natural mortality. Major uncertainties include M and growth for the California models, which are informed by little (NCS) or no (SCS) age data. The SSC recommended both assessments be designated category 1 and model results should again be summed to determine harvest specifications for cabezon in California waters.

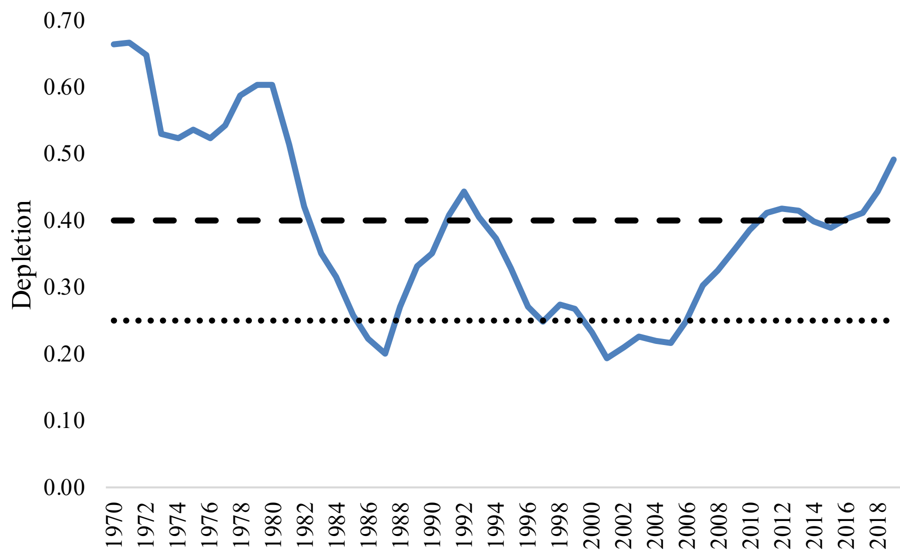

Figure 2-16. Relative depletion of cabezon south of Pt. Conception from 1970 to 2019 based on the 2019 stock assessment update.

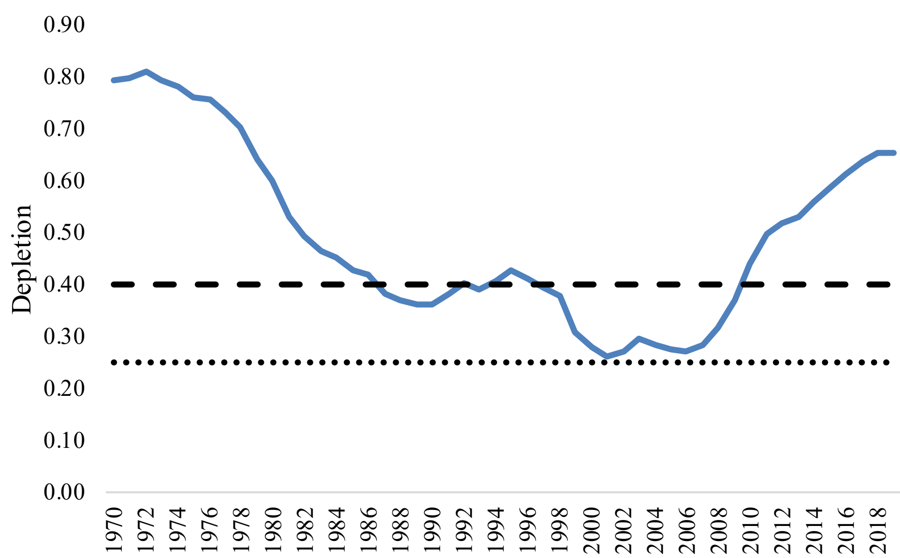

Figure 2-17. Relative depletion of cabezon north of Pt. Conception from 1970 to 2019 based on the 2019 stock assessment.

Stock Productivity

The 2019 cabezon assessment assumed a steepness of 0.7 for all models. The PSA productivity score of 1.72 indicates a stock of relatively high productivity.

Recruitment deviations were estimated from 1970-2016 for both of the assessed substocks. Recruitment patterns are distinctly different for the substocks occurring north and south of Pt. Conception at 34°27’ N. lat. (Figure 2-18 and Figure 2-19). Large recruitment events in the 1970s and 1990s in the north and the south have increased spawning biomass to healthy levels. Interannual variation in recruitment is greater in the north. Large recruitments in the southern substock were estimated immediately after major El Niño events (e.g., 1984 and 1994 recruitments).

Since strong recruitment events in the late 1990s and early 2000s for the southern California substock, recent recruitment has been mostly lower or around average (Figure 2-18). This recruitment is informed mostly by length composition data, but removal history also influences the estimates. The 2009 stock assessment also suggested similar recruitment dynamics. Despite the drop in relative stock status to levels around the limit reference point in the early 1980s and the large spike in recruitment during that same time, there is not enough information in the assessment to estimate recruitment compensation (steepness), thus all recruitment is based on a fixed assumption of steepness (0.7) and recruitment variability (0.5).

Recruitment patterns for the northern California substock are much different from that estimated in southern California. Recent recruitment is a mix of positive and negative recruitments, with a very large recruitment detected in 2016, the last year a recruitment deviation was estimated (Figure 2-19). Recruitment estimation uncertainty is high, and recruitment is informed mostly by length composition data, with some contribution from the survey index and removal history. Recruitments are much more muted compared to the 2009 stock assessment, though with similar peaks. These lower in magnitude recruitments lead to a steeper drop in the population biomass at the peak of the live-fish fishery before the more recent recruitments allow for a rapid population increase. Despite these fluctuations in biomass, there is not enough information in the assessment to estimate recruitment compensation (steepness), thus all recruitment is based on a fixed assumption of steepness (0.7) and recruitment variability (0.5).

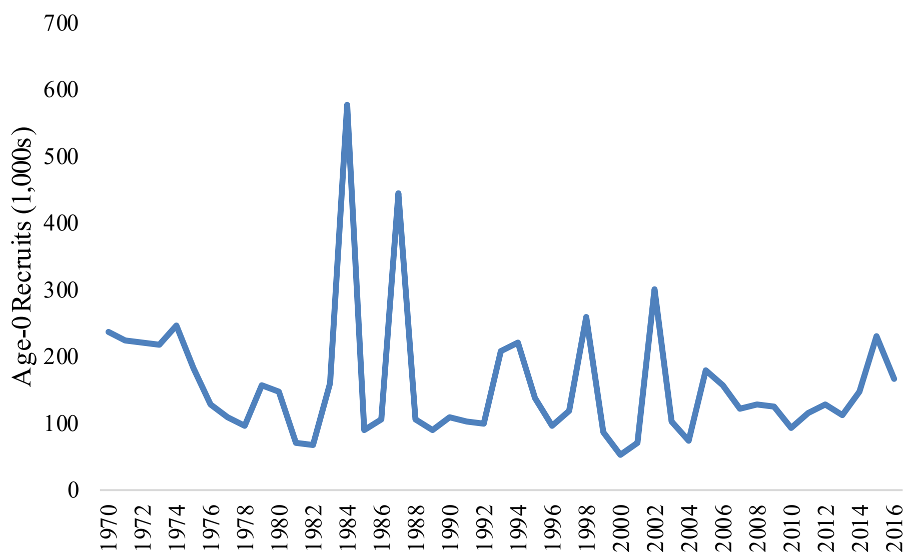

Figure 2-18. Estimated recruitments of cabezon in California south of Pt. Conception, 1970-2016.

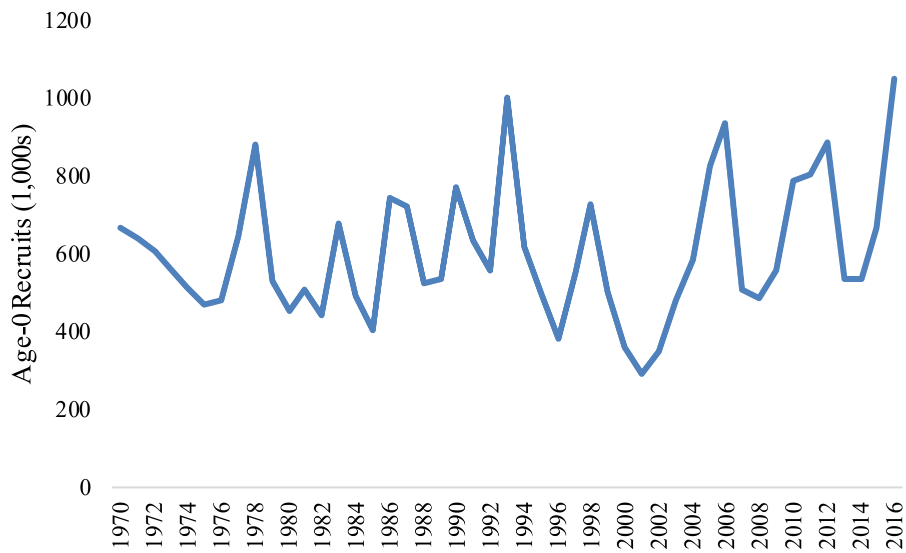

Figure 2-19. Estimated recruitments of cabezon in California north of Pt. Conception, 1970-2016.

Fishing Mortality

SCS fishing intensity showed a steady increase from the 1960s to peak levels in the 1980s through the mid-1990s (Figure 2-20). From that time fishing intensity steadily declined to the low levels seen in the early 1960s. The maximum relative fishing rate ((1-SPR)/ (1-SPR45 percent)) was 1.46 in 1986, well above the target level. Current relative fishing rates are much lower and generally decreasing, fluctuating around 0.50.

NCS fishing intensity showed a steady increase from the 1950s to a distinct peak in 1998, then steadily declined to the low levels seen in the early 1970s (Figure 2-21). The maximum relative fishing rate ((1-SPR)/ (1-SPR45 percent)) was 1.39 in 1998, well above the target level. Current relative fishing rates are much lower, fluctuating around 0.60.

The PSA vulnerability score of 1.68 indicates a low risk of overfishing.

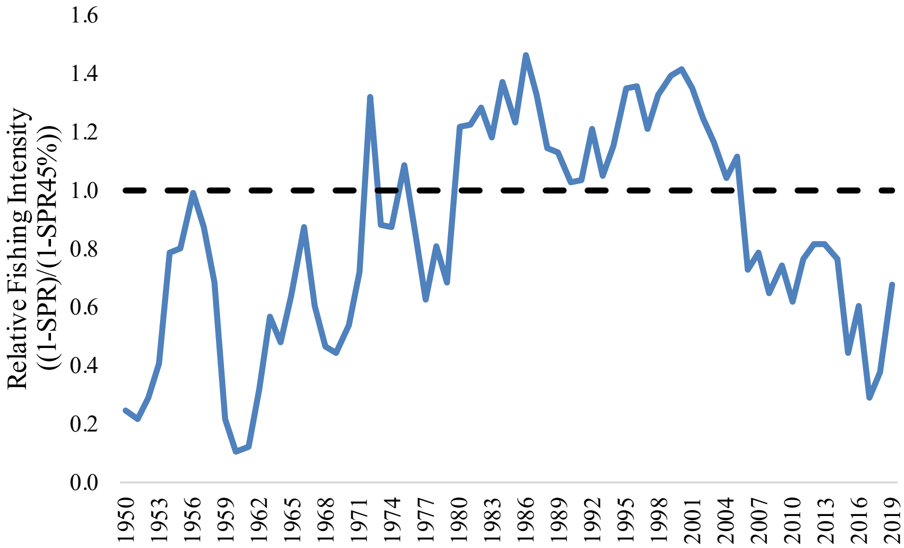

Figure 2-20. Relative fishing intensity of cabezon in California south of Pt. Conception, 1950-2018.

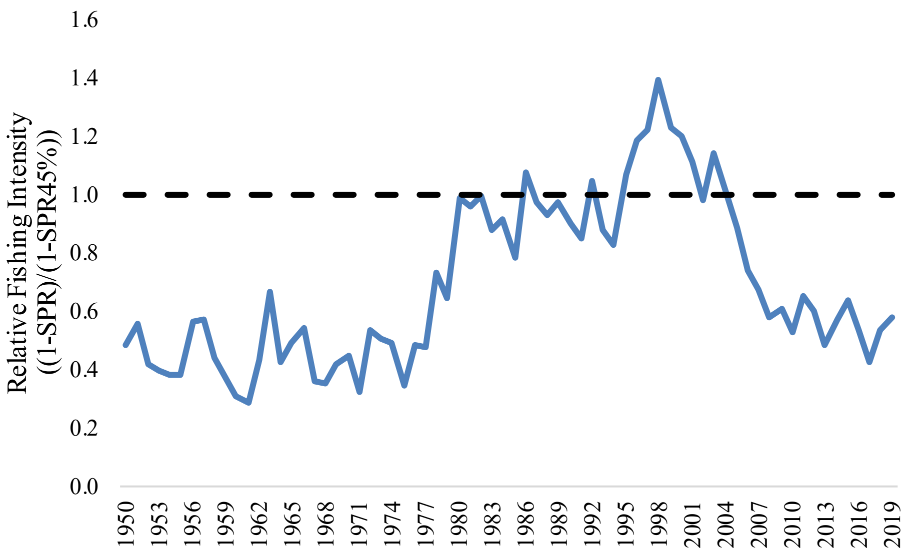

Figure 2-21. Relative fishing intensity of cabezon in California north of Pt. Conception, 1950-2018.

2.4.7 California Scorpionfish South of 34°27' N. Lat.

Distribution and Life History

California scorpionfish (*Scorpaena guttata*), also known locally as sculpin, is a generally benthic species found from central California to the Gulf of California in depths between the inter-tidal and about 170 m (Eschmeyer*, et al.* 1983; Love*, et al.* 1987). California scorpionfish generally inhabits rocky reefs, but in certain areas and seasons they aggregate over sandy or muddy substrate (Frey 1971; Love*, et al.* 1987). Catch rate analysis and tagging studies show that most, but not all, California scorpionfish migrate to deeper water to spawn during May-September (Love*, et al.* 1987). Tagging data suggest that they return to the same spawning site (Love*, et al.* 1987), but information is not available on non-spawning season site fidelity. California scorpionfish are quite mobile and may not be permanently tied to a particular reef (Love*, et al.* 1987).

California scorpionfish spawn from May through August, peaking in July (Love*, et al.* 1987). The species is oviparous, producing floating, gelatinous egg masses in which the eggs are embedded in a single layer (Orton 1955). California scorpionfish utilize the "explosive breeding assemblage" reproductive mode in which fish migrate to, and aggregate at traditional spawning sites for brief periods (Love*, et al.* 1987). These spawning aggregations have been targeted by fishermen. Few California scorpionfish are mature at one year of age, but over 50 percent are mature by age two and most are mature by age three (Love*, et al.* 1987).

The species feeds on a wide variety of foods, including crabs, fishes, octopi, isopods and shrimp, but juvenile Cancer crabs are the most important prey (Limbaugh 1955; Love*, et al.* 1987).

Stock Status and Management History

California scorpionfish were assessed in 2005 (Maunder*, et al.* 2006) in the southern California Bight south of Point Conception at 34°27' N. lat. to the U.S.-Mexico border. The stock assessment indicated the California scorpionfish stock was healthy with an estimated spawning stock biomass of 79.8 percent of its initial, unfished biomass in 2005.

In most years, 99 percent or more of the landings occur in the southern California ports. The California nearshore FMP includes California scorpionfish. The stock is managed by the state under provisions for improved fishery monitoring and research data collection.

A catch-only update of the 2005 assessment was prepared in 2015 to inform harvest specifications in 2017 and beyond. The California scorpionfish OFLs adopted for 2017 and 2018 were from projections in the catch-only update assuming the Expected Catch scenario for future removals. The SSC downgraded the California scorpionfish stock to a category 2 from a category 1 stock based on the age of the assessment.

A new full assessment of California scorpionfish was conducted in 2017 and indicated the stock was healthy with a depletion of 54.3 percent at the start of 2017 (Monk*, et al.* 2018) (Figure 2-22). The 2017 assessment updated catches back to 1916, used a more disaggregated fleet structure, included additional indices of abundance, and added conditional age-at-length data. Indices of abundance as well as composition data were derived from 1) Publicly Owned Treatment Works

(POTW) trawl surveys, 2) the NWFSC trawl survey, 3) the Southern California Bight regional monitoring program trawl survey, and 4) the onboard observer survey for retained catch. Additional composition data was derived from a nuclear power generating station impingement survey. The SSC determined the 2017 assessment as a category 1 stock assessment.

The Council adopted a new harvest control rule for California scorpionfish of ACL = ABC under a P* of 0.45 starting in 2019 based on projections indicating the stock would remain healthy in the next ten years under this harvest control rule. The 2019 and 2020 ABCs and ACLs for California scorpionfish are 313 mt and 307 mt, respectively.

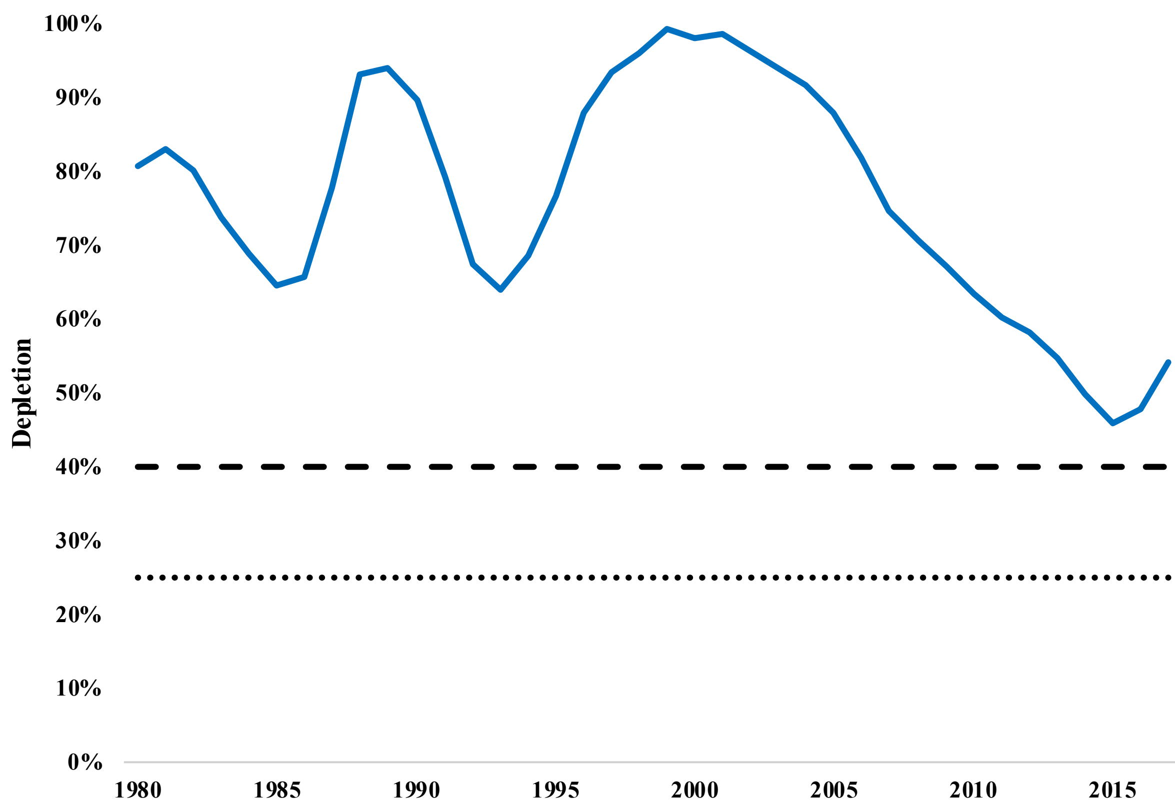

Figure 2-22. Relative depletion of California scorpionfish from 1980 to 2017 based on the 2017 stock assessment.

Stock Productivity

A steepness value of 0.718 was assumed for California scorpionfish in the 2017 assessment. The PSA productivity score of 1.83 indicates a stock of relatively high productivity.

Recruitment deviations were estimated from 1965-2016 in the 2017 assessment. Historically, there are estimates of large recruitment from 1975-1977, 1984-1985, and in 1993 and 1996 (Figure 2-23). There is early evidence of a strong recruitment in 2013. The four lowest recruitments estimated within the model (in ascending order) occurred in 2012, 2011, 1989, and 1988.

The nearly sinusoidal pattern in biomass (Figure 2-22) and recruitments (Figure 2-23) was found to be moderately correlated with water temperature (the CalCOFI temperature index), indicating that the patterns in recruitment are at least partially driven by environmental factors.

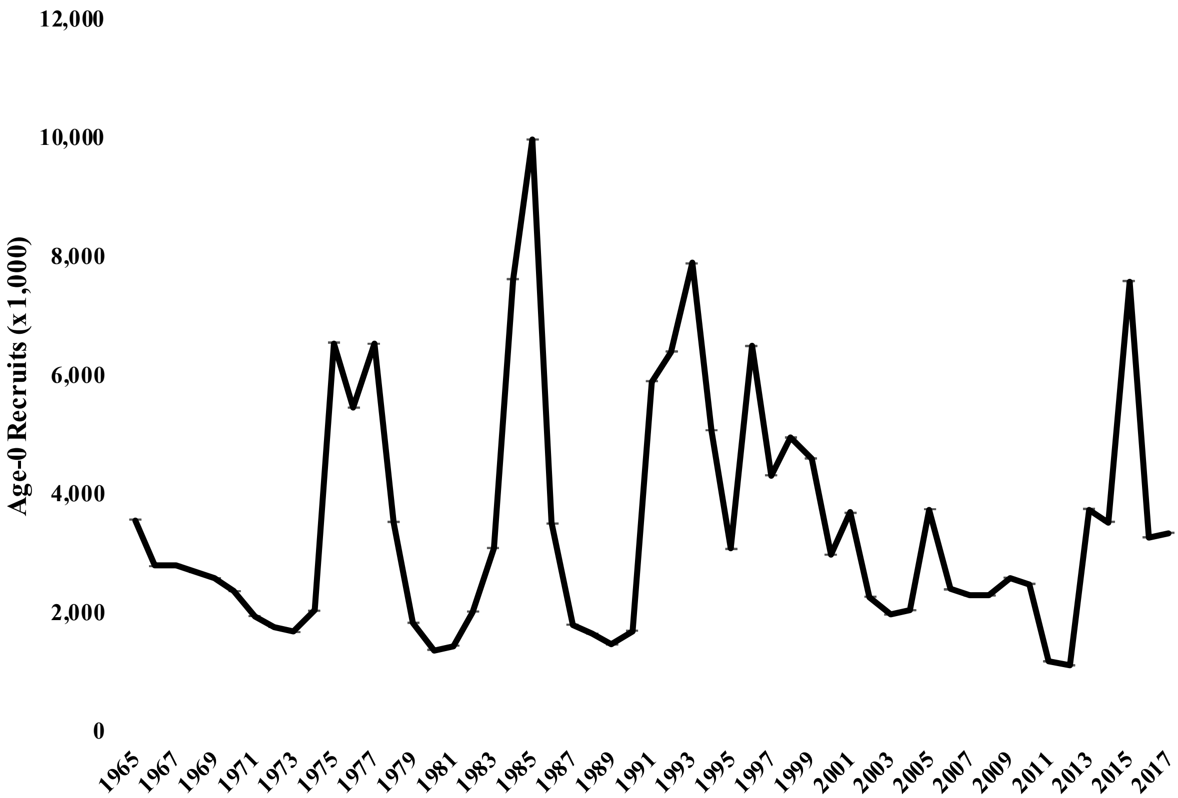

Figure 2-23. Estimated California scorpionfish recruitments, 1965-2017 (from Monk et al. 2017).

Fishing Mortality

A substantial but unknown portion of the stock occurs in Mexican waters. The exploitation of the stock in Mexican waters is unknown and the connectivity of that stock with the U.S. stock in the Southern California Bight is also unknown.

Commercial catch records for scorpionfish were available beginning in 1916. Commercial catches were the dominant removals until the 1960s when the recreational catch became dominant. Harvest rates estimated in the base model of the 2017 assessment have never exceeded management target levels. The estimated relative depletion is currently greater than the 40 percent unfished spawning output target. Recent exploitation rates on California scorpionfish were predicted to be significantly below target levels.

A short, but sharp decline in spawning stock biomass occurred between 1965 and 1985, followed by a period of cyclical variation in spawning biomass, and then a decline from 2000 to 2015. The stock showed increases in stock size in 2015 due to a combination of strong recruitment and smaller catches in 2015 and 2016.

The PSA vulnerability score of 1.41 indicates a low risk of overfishing.

2.4.8 Canary Rockfish

Distribution and Life History

Canary rockfish (*Sebastes pinniger*) are distributed in the northeastern Pacific Ocean from the western Gulf of Alaska to northern Baja California; however, the species is most abundant from British Columbia to central California (Hart 1988; Love*, et al.* 2002; Miller and Lea 1972). Adults are primarily found along the continental shelf shallower than 300 m, although they are occasionally observed in deeper waters. Juvenile canary rockfish are found in shallow and intertidal areas (Love*, et al.* 2002).

Canary rockfish spawn in the winter, producing pelagic larvae and juveniles that remain in the upper water column for 3-4 months (Love*, et al.* 2002). These juveniles settle in shallow water around nearshore rocky reefs, where they may congregate for up to three years (Boehlert 1980; Sampson 1996) before moving into deeper water. The mean size of individuals captured in the trawl survey shows a characteristic ontogenetic shift to deeper water with increasing body size. The degree to which this ontogenetic shift may be accompanied by a component of latitudinal dispersal from shallow rocky reefs is unknown. Canary rockfish are a medium to large-bodied rockfish, achieving a maximum size of around 70 cm. Female canary rockfish reach slightly larger sizes than males.

Adult canary rockfish primarily inhabit areas in and around rocky habitat. They form very dense schools, leading to an extremely patchy population distribution that is reflected in both fishery and survey encounter rates.

Canary rockfish are relatively long-lived, with a maximum observed age of 95 years; however, only males are commonly observed above the age of 50, while females tend to be rare above age 30. The degree to which this pattern reflects behavioral differences translating to reduced availability to fishery and survey fishing gear, or an increase in relative mortality for older females has been the focus of much discussion and remains unclear. A similar pattern has been observed for black rockfish (*Sebastes melanops*) and yellowtail rockfish (*Sebastes flavidus*), closely related, but more pelagic species with a similar distribution (Cope*, et al.* 2015a; Wallace and Lai 2006).

Canary rockfish off the West Coast exhibit a protracted spawning period from September through March, probably peaking in December and January off Washington and Oregon (Hart 1988; Johnson*, et al.* 1982). Female canary rockfish reach sexual maturity at roughly eight years of age. Like many members of Sebastes, canary rockfish are ovoviviparous, whereby eggs are internally fertilized within females, and hatched eggs are released as live young (Bond 1979; Golden and Demory 1984; Kendall and Lenarz 1986). Canary rockfish are a relatively fecund species, with egg production being correlated with size (e.g., a 49-cm female can produce roughly 0.8 million eggs, and a female that has realized maximum length (approximately 60 cm) produces approximately 1.5 million eggs (Gunderson 1971).

Very little is known about the early life history strategies of canary rockfish. The limited research that has been conducted indicates that larvae are strictly pelagic (near the ocean surface) for a short period of time and begin to migrate to demersal waters during the summer of their first year of life. Larvae develop into juveniles around nearshore rocky reefs, where they may congregate for up to three years (Boehlert 1980; Sampson 1996). Evaluations of length distributions by depth demonstrate an increasing trend in mean size of fish with depth (Methot and Stewart 2006). From 1990 through the 2011 update assessment, stock assessments have assumed a base natural mortality rate of 0.06 (94 percent adult annual survival when there is no fishing mortality). The natural mortality rate prior was updated in the 2015 assessment (Thorson and Wetzel 2015) to 0.0521 based on a maximum age of 84 years (Love*, et al.* 2002). Due to the rarity of old females in both survey and catch data, female canary rockfish have long been assumed to have increasing natural mortality rates with age (Golden and Wood 1990).

Little is known about ecological relationships between canary rockfish and other organisms. Adult canary rockfish are often caught with bocaccio, sharpchin, yelloweye rockfish, and yellowtail rockfishes, and lingcod. Researchers have also observed canary rockfish associated with silvergray and widow rockfish. Young-of-the-year feed on copepods, amphipods, and young stages of euphausiids. Adult canary rockfish feed primarily on euphausiids, as well as pelagic shrimp, cephalopods, mesopelagic fishes and other prey (Brodeur and Percy 1984; Lee 2002; Phillips 1964). Small canary rockfish are consumed by seabirds, Chinook salmon, lingcod, and marine mammals.

Stock Status and Management History

Canary rockfish have long been an important component of rockfish fisheries. The Council began to recommend increasingly restrictive regulations after an assessment in 1994 (Sampson and Stewart 1994) indicated that fishing rates were too high. Prior to passage of the Sustainable Fisheries Act of 1996, there was no requirement for stock assessments to estimate biomass status; and until 1997 the Council's default target rate for fishing mortality corresponded to an SPR of 35 percent. Thorson and Wetzel (2015) estimated that the abundance of the canary rockfish stock dropped below B_{MSY} ($B_{40\%}$) in 1983 and below the MSST in 1990, at which time the annual catch was more than double the current estimate of the MSY level. Harvest rates in excess of the current fishing mortality target for rockfish (SPR = 50 percent) is estimated to have begun in the late 1970s and persisted through 1999. Recent management actions appear to have curtailed the rate of removal such that overfishing has not occurred since 1999, and recent SPR values are in excess of 90 percent.

A 1999 stock assessment showed the stock had declined to 6.6 percent of unfished biomass in the northern area (Columbia and U.S. Vancouver management areas) (Crone*, et al.* 1999) and in the southern area (Conception, Monterey, and Eureka areas) (Williams*, et al.* 1999). The stock was declared overfished in January 2000. The first rebuilding analysis (Methot 2000) used results from the northern area assessment to project rates of potential stock recovery. The stock was found to have extremely low productivity, defined as production of recruits in excess of the level necessary to maintain the stock at its current, low level. Rates of recovery were highly dependent upon the level of recent recruitment, which could not be estimated with high certainty. The initial rebuilding OY for 2001 and 2002 was set at 93 mt based upon a 50 percent probability of rebuilding by the year 2057, a medium level for these recent recruitments, and maintaining a constant annual catch of 93 mt through 2002.

A coastwide 2002 canary rockfish assessment estimated stock depletion to be 7.9 percent at the start of 2002 (Methot and Piner 2002b). A canary rockfish rebuilding plan was adopted in 2003 under Amendment 16-2 based on the results of the 2002 rebuilding analysis (Methot and Piner 2002a). The rebuilding plan established a target rebuilding year of 2074 and the harvest control rule of F = 0.022 (with a P_{MAX} of 60 percent).

A full canary rockfish assessment was done in 2005 indicating a stock depletion of 9.0 percent at the start of 2005 (Methot and Stewart 2006). The assessment was based on two equally plausible models; one with differential male and female gear selectivities and one without gender-specific selectivities. A critical uncertainty in canary rockfish assessments was the lack of older, mature females in surveys and other assessment indices. There were two competing explanations for this observation. Older females could have a higher natural mortality rate, resulting in their disproportionate disappearance from the population. Alternatively, survey and fishing gears may be less effective at catching them, perhaps because older females are associated with habitat inaccessible to most trawl gear. If this is the case, then these fish (which, because of their higher spawning output, may make an important contribution to future recruitment) are part of the population, but remain poorly sampled. Methot and Stewart (2006) assumed a linear increase in female natural mortality from 0.06 at age 6 to approximately 0.09 at age 14. In the base model (differential male-female selectivity) B_0 was estimated to be 34,798 mt, resulting in a depletion level of 5.7 percent. In the alternate model (no difference in selectivity) B_0 was estimated to be 33,872 mt, with a depletion level of 11.3 percent. The steepness of the spawner-recruitment relationship, which largely determines the rate of increase in recruitment as the stock rebuilds, was estimated to be 0.33 in the base model, and 0.45 in the alternate model. The approved canary rockfish rebuilding analysis (Methot 2006) blended the two models by alternately re-sampling between the two input parameter sets.

The 2005 canary rockfish rebuilding analysis (Methot 2006) was used to inform the revised canary rockfish rebuilding plan adopted under Amendment 16-4, which specified a target rebuilding year of 2063 and a constant harvest strategy (SPR = 88.7 percent). Amendment 16-4 rebuilding plans were implemented in 2007.

The 2007 canary rockfish assessment estimated relative depletion level was 32.4 percent at the start of 2007 (Stewart 2008b). This was a significant departure from the previous assessment and largely driven by a higher assumed steepness (h = 0.51) relative to past assessments. The 2007 assessment was unable to estimate steepness as had been done in the 2005 assessment, largely because the 2007 assessment treated the triennial bottom trawl survey as two separate indices due to changes between the 1992 and 1995 surveys in the seasonal timing. The 2007 canary rockfish rebuilding analysis (Stewart 2008a) predicted the SPR harvest rate in the rebuilding plan (88.7 percent) would rebuild 42 years earlier (2021) than the originally estimated rebuilding schedule (2063). A modification of the Amendment 16-4 canary rockfish rebuilding plan specifying a target rebuilding year of 2021 while maintaining the SPR harvest rate of 88.7 percent was implemented in 2009.

The 2009 canary rockfish assessment (Stewart 2009c), an update of the 2007 assessment, estimated stock depletion at 23.7 percent at the start of 2009. This change in stock status was due to a lower estimate of initial, unfished biomass (B_0) largely attributable to the inclusion of revised historical California catches from a formal reconstruction of 1916-1980 California catch data (Ralston, *et al.* 2010). The 2009 canary rockfish rebuilding analysis (Stewart 2009a) predicted the stock would not rebuild to the target year of 2021 with at least a 50 percent probability even in the absence of fishing-related mortality starting in 2011 ($T_{F=0}$). The rebuilding plan was revised by changing the target to rebuild the stock to 2027 while maintaining the 88.7 percent SPR harvest rate; the revised rebuilding plan was implemented in 2011.

Another update assessment was prepared in 2011 (Wallace and Cope 2011), which estimated stock depletion was 23.2 percent at the start of 2011 (Figure 2-24). This change in stock status was due to a lower estimate of initial, unfished biomass (B_0) largely attributable to the inclusion of revised historical Oregon catches from a formal reconstruction of Oregon catch data. For the period 2000-2011, the spawning biomass was estimated to have increased from 11.2 percent to 23.2 percent of the unfished biomass level.

The 2011 canary rockfish rebuilding analysis (Wallace 2011) predicted the stock would not rebuild to the target year of 2027 with at least a 50 percent probability. The rebuilding plan was revised slightly by changing the target to rebuild the stock to 2030 while maintaining the 88.7 percent SPR harvest rate; the revised rebuilding plan was implemented in 2013.

A full assessment of canary rockfish was conducted in 2015 (Thorson and Wetzel 2015), which indicated the stock was rebuilt with a depletion of 56 percent at the start of 2015 (Figure 2-24). A number of revisions were made to the data used for stock assessment, including: 1) a new method of index standardization for NWFSC trawl survey using a geo-statistical delta-generalized linear mixed model (GLMM), 2) a new steepness value (0.773) based on an updated meta-analysis of steepness, 3) a re-estimated relationship for maturity, 4) new ageing error tables, and 5) a re-estimated length-weight relationship. Ageing data based on surface otolith reads were added to the assessment using an ageing-error table appropriate to surface reads. This added about 10 years of historical ageing data to the model. The primary factors driving the improvement in stock status are the use of a higher steepness value, the reduction in harvest due to the rebuilding plan, and above average recruitments in 2001-2003, and in 2007 and 2010. The SSC explained the relatively strong effect of steepness on estimated stock status is a reason for concern about the reliability of model results since steepness is a relatively uncertain parameter value. However, it should be noted that even a relatively low steepness of 0.6 (e.g., the low state of nature in the steepness decision table) results in a biomass estimate above the rebuilding target.

The Council adopted the default harvest control rule of ACL equal to the ABC under a P* of 0.45 to inform harvest specifications in 2019 and beyond. A catch-only projection for canary rockfish was provided in 2021 to inform harvest specifications for 2023 and beyond.

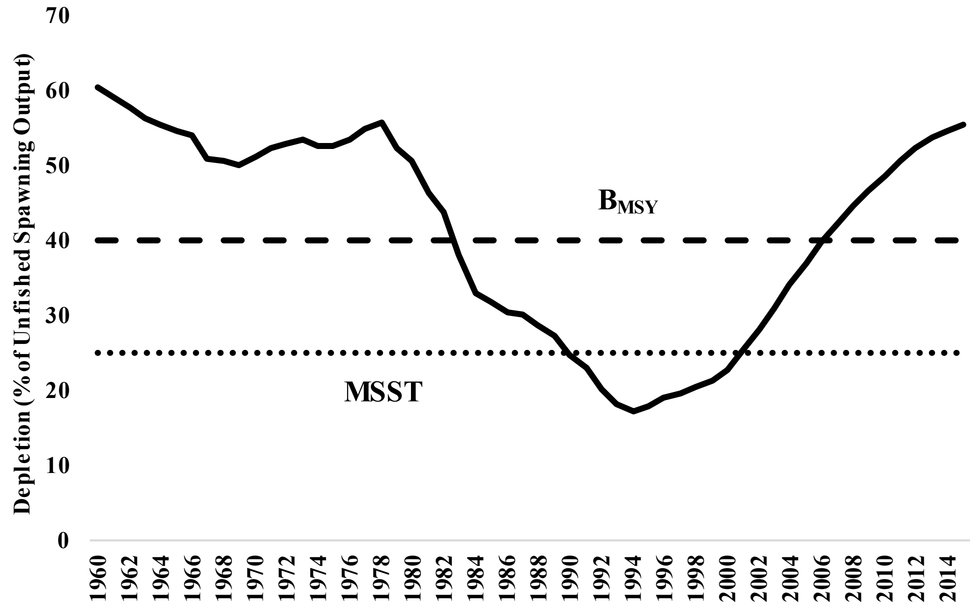

Figure 2-24. Relative depletion of canary rockfish from 1960 to 2015 based on the 2015 stock assessment.

Stock Productivity

The 2015 canary rockfish assessment assumed a steepness of 0.773 based on the meta-analysis of rockfish steepness. The PSA productivity score of 1.61 indicates a stock of moderate productivity.

The estimate of rebuilding rate for canary rockfish in the 2015 assessment is informed by prior information regarding the strength of recruitment compensation in other rockfishes. In 2015, this prior information indicates that recruitment compensation for rockfishes is in-line with other taxa worldwide (i.e., a steepness of 0.773). Given this high level of recruitment compensation, recruitment is not estimated to have substantially declined for canary rockfish during the decreased spawning output in the 1980s-2000s (Figure 2-25), such that 1984 and 1997 both have estimated recruitment near the estimated average level for the unfished population. Recovery after the decrease in fishing during the 2000s has been particularly aided by strong recruitment during 2001-2003, and again by strong cohorts in 2007 and 2010 (which are projected to impact spawning output in the coming years).

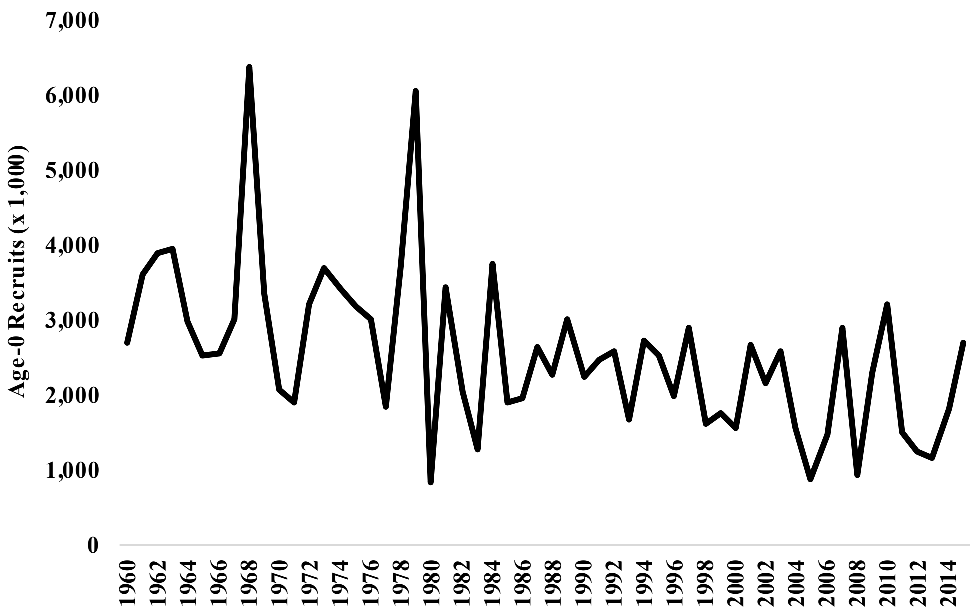

Figure 2-25. Estimated canary rockfish recruitments, 1960-2015 (from Thorson and Wetzel 2015).

Fishing Mortality

Rockfishes in the California Current are managed to have a target SPR of 50 percent of its equilibrium value in a population given current fishing. By contrast, the fishing intensity for canary rockfish for all recent years (2005-2014) would result in an equilibrium SPR of >96 percent (Figure 2-26). Current fishing corresponds to a harvest rate (i.e., total catch divided by biomass of all fishes aged 5 and older) of 0.09-0.2 percent for all recent years. Harvest rates were previously as high as 20 percent in the 1980s and early 1990s, and fishing rates were above the level that would result in 50 percent equilibrium SPR for the majority of years from 1966-1999. Large decreases in harvest rate were accomplished between 1993-1994 (1993: 17.1 percent, 1994: 9.4 percent) and 1999-2000 (1999: 4.8 percent, 2000: 0.8 percent).

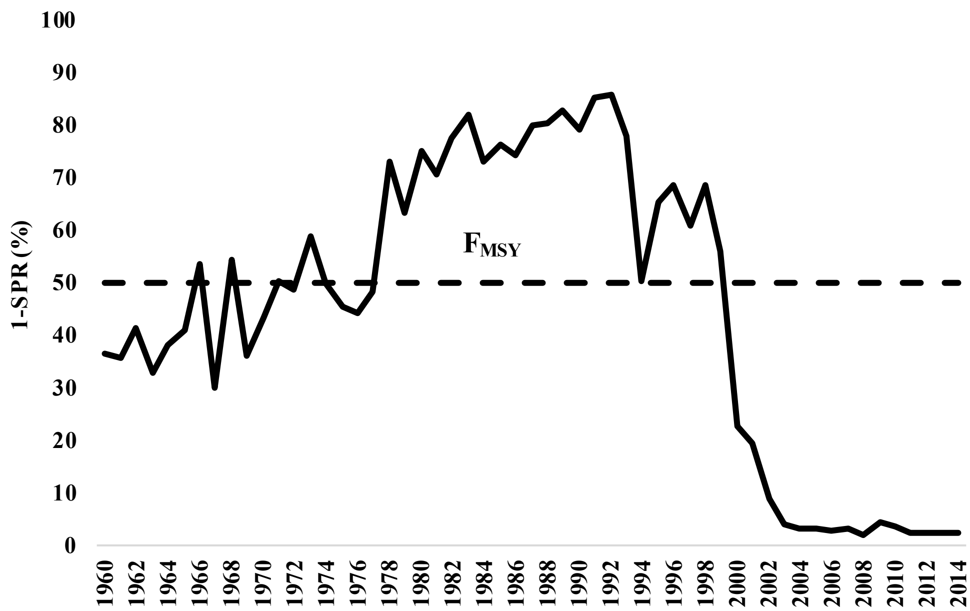

Figure 2-26. Estimated spawning potential ratio (SPR) of canary rockfish relative to the current F_{MSY}, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.4.9 Chilipepper Rockfish

Distribution and Life History

Chilipepper rockfish (*Sebastes goodei*) are found from Magdalena Bay, Baja California, Mexico, to as far north as the northwest Coast of Vancouver Island, British Columbia (Allen 1982; Hart 1988; Miller and Lea 1972). The region of greatest abundance is found between Point Conception and Cape Mendocino, California. Chilipepper have been taken as deep as 425 m, but nearly all in survey catches were taken between 50 and 350 m (Allen and Smith 1988). Adults and older juveniles usually occur over the shelf and slope; larvae and small juveniles are generally found near the surface. In California, chilipepper are most commonly found associated with deep, high relief rocky areas and along cliff drop-offs (Love*, et al.* 1990), as well as on sand and mud bottoms (MBC 1987). They are occasionally found over flat, hard substrates (Love*, et al.* 1990). Love (1996) does not consider this to be a migratory species. Chilipepper may travel as far as 45 m off the bottom during the day to feed (Love 1996). Chilipepper rockfish are described as an elongate fish with reduced head spines similar in appearance to both shortbelly rockfish (at smaller sizes, although shortbelly rockfish tend to be slimmer) and bocaccio rockfish (bocaccio tend to have larger mouths).

Chilipeppers are ovoviviparous and eggs are fertilized internally (Reilly*, et al.* 1992). Chilipepper school by sex just prior to spawning (MBC 1987). In California, fertilization of eggs begins in October and spawning occurs from September to April (Oda 1992) with the peak occurring during December to January (Love*, et al.* 2002). Chilipepper may spawn multiple broods in a single season (Love*, et al.* 2002). Females of the species are significantly larger, reaching lengths of up to 56 cm (Hart 1988). Males are usually smaller than 40 cm (Dark and Wilkins 1994). Males mature at two years to six years of age, and 50 percent are mature at three years to four years. Females mature at two years to five years with 50 percent mature at three years to four years (MBC 1987). Females may attain an age of about 27 years, whereas the maximum age for males is about 12 years (MBC 1987).

Larval and juvenile chilipepper eat all life stages of copepods and euphausiids, and are considered to be somewhat opportunistic feeders (Reilly*, et al.* 1992). In California, adults prey on large euphausiids, squid, and small fishes such as anchovies, lanternfish, and young Pacific whiting (Hart 1988; Love*, et al.* 2002). Chilipepper are found with widow rockfish, greenspotted rockfish, and swordspine rockfish (Love*, et al.* 2002). Juvenile chilipepper compete for food with bocaccio, yellowtail rockfish, and shortbelly rockfish (Reilly*, et al.* 1992). Pelagic juveniles are preyed upon by a wide range of predators, including seabirds, salmon, lingcod, and marine mammals. Larger piscivorous fishes, marine mammals, and in recent years jumbo squid are among the predators of larger adults.

Stock Status and Management History

Chilipepper have been one of the most important commercial target species in California waters since the 1880s and were historically an important recreational target in Southern California waters. With the exception of excluding foreign fishing effort from the U.S. EEZ in the late 1970s, management actions were modest (and usually general to all rockfish and other groundfish) prior to the implementation of the Groundfish FMP in 1982. When the FMP was implemented, management for the groundfish trawl fishery was based on individual vessel trip limits, which were set at 40,000 lbs per trip on the *Sebastes* (all rockfish species) complex. These limits were maintained until 1991, when they were reduced to 25,000; in 1993 the trip limit system was revised from daily to biweekly trip limits, which were set at 50,000 lbs (south of Cape Mendocino). The trip limit regime continued to evolve in its absolute amounts and temporal duration (monthly, bimonthly) throughout the 1990s, with a general trend towards lower limits as conservation concerns arose for other rockfish species (particularly bocaccio rockfish in the region south of Mendocino). The chilipepper catch in the bottom trawl fishery has been managed under an IFQ system since 2011.

Chilipepper rockfish were assessed in 1998 (Ralston*, et al.* 1998), at which time the stock south of 40°10’ N. lat. was estimated to be at 46 percent to 61 percent of unfished biomass.

A full chilipepper assessment for the stock in waters off California and Oregon was conducted in 2007 (Field 2008). The 2007 assessment estimated a substantial increase in the spawning biomass of chilipepper rockfish in recent years, due to a strong 1999 year class as well as greatly reduced harvest rates in commercial and recreational fisheries. The 2007 assessment’s base model result suggests a spawning biomass of 23,889 mt in 2006, corresponding to approximately 70 percent of the unfished spawning biomass of 33,390 mt and representing a near tripling of spawning biomass from the estimated low of 8,696 mt (26 percent of unfished) in 1999. The strong 1999 year class represents the largest estimated historical recruitment and is the primary cause for the current population trajectory. Several strong year classes have been observed in recent years (2009-2010, 2013-2014) and these recent recruitments are already leading to a fast rate of increase in abundance and larval production.

The 2007 assessment was first used in 2008 to decide 2009 and 2010 chilipepper harvest specifications. The Council consideration for 2011 and 2012 was whether or not to remove chilipepper rockfish from the Shelf Rockfish North complex and manage it coastwide. Chilipepper rockfish are predominantly found south of 40°10' N. lat. Prior to 2007 they were only assessed in the area south of 40°10' N. lat. To date, chilipepper rockfish have been managed with stock-specific harvest specifications south of 40°10' N. lat. and within the Shelf Rockfish North complex north of 40°10' N. lat. When the stock assessment area was extended for the 2007 chilipepper stock assessment, it was extended to the stock's entire West Coast range through waters off Oregon (chilipepper rockfish are not believed to occur in waters off Washington). However, it was decided to continue to manage chilipepper rockfish south of 40°10' N. lat. with stock-specific harvest specifications and as part of the Shelf Rockfish complex north of 40°10' N. lat.

An update of the 2007 assessment of chilipepper rockfish south of 40°10' N. lat. was conducted in 2015 (Field, *et al.* 2015), which indicated the stock was at 64 percent of its unfished biomass at the start of 2015 (Figure 2-27). Changes from the 2007 assessment include using an updated version of the Stock Synthesis model, which results in better treatment of time-varying growth; updated historical catch estimates; a new 2003-2014 time block to account for changes in recreational fishery selectivity; updated maturity and fecundity relationships; updated ageing error estimates; and 8 additional years of data.

The SSC designated chilipepper as a category 1 stock and recommended that the next assessment be a full assessment due to the length of time since the last full assessment.

The relative biomass apportioned to the stock south of 40°10' N. lat. was estimated to be 93 percent of the coastwide biomass based on average historical landings.

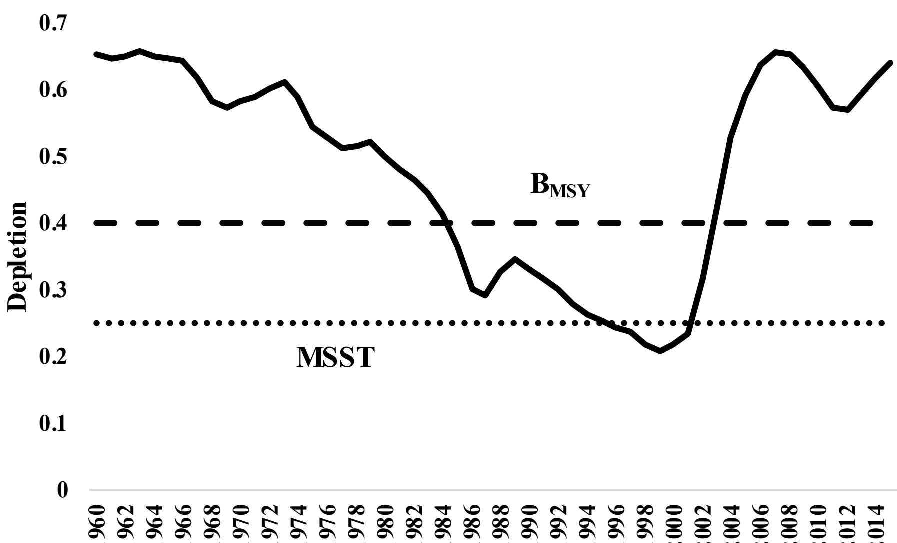

Figure 2-27. Relative depletion of chilipepper rockfish from 1960 to 2015 based on the 2015 stock assessment update.

Stock Productivity

Steepness in the 2007 assessment and 2015 update was fixed at 0.57, which was the mean of the prior probability distribution in the rockfish meta-analysis available in 2007. Since steepness was thought to be poorly specified in the model, this parameter was chosen as the major axis of uncertainty. The decision table projected outcomes for a low productivity and a high productivity model using steepness values of 0.34 and 0.81, respectively. The PSA productivity score of 1.83 indicates a stock of relatively high productivity, especially for a rockfish.

Recruitment for chilipepper rockfish is highly variable, with a small number of year classes tending to dominate the catch in any given fishery or region. As age and length data are only available for the late 1970s onward, estimates of year class strength are most informative from the 1970s to the present. The 1984 and 1999 year classes were among the strongest in that time period; however, several very strong year classes have been observed in recent years (2009-2010, 2013-2014) and are already leading to a fast rate of increase in abundance and larval production (Figure 2-28).

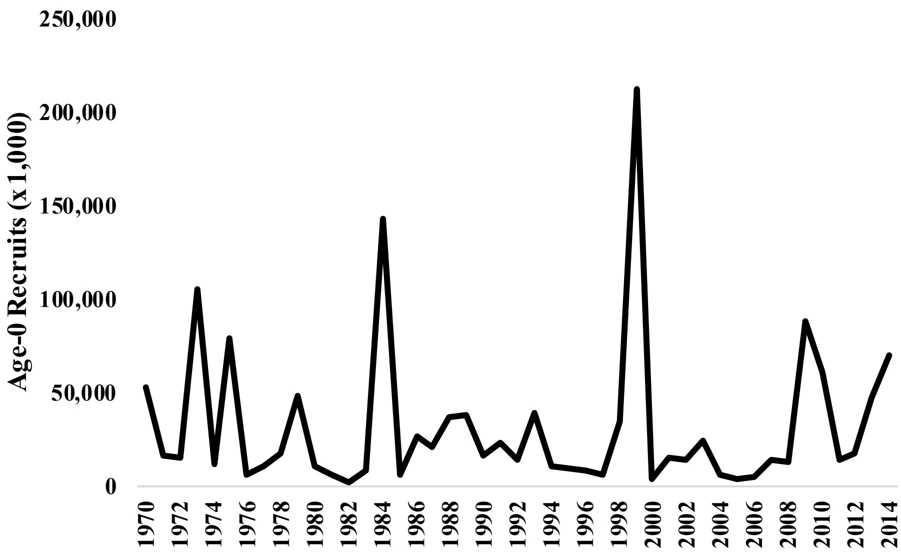

Figure 2-28. Estimated chilipepper rockfish recruitments, 1970-2014 (from Field, *et al.* 2015).

Fishing Mortality

Chilipepper rockfish have been one of the most important commercial target species in California since the late 1800s and was also a recreational target in southern California waters. Catches and exploitation rate have declined substantially since the early 1990s. While chilipepper has always been an important target species in California, the exploitation rate has rarely exceeded the F_{MSY} target of a 50 percent SPR. Exploitation rates declined substantially since the late 1990s with the implementation of more restrictive management measures to rebuild depleted stocks.

Throughout most of the past three decades, domestic landings have ranged between approximately 2,000 and 3,000 mt; however, since 2002 landings have averaged less than 100 mt per year. The highest exploitation rates occurred from the late 1980s through the mid-1990s, when they were above target levels and the stock was approaching its lowest estimated historical levels. From the late 1990s through the present, exploitation rates have been declining significantly down to incidental levels, as a result of management measures implemented to rebuild co-occurring depleted rockfish species (particularly bocaccio, but including canary rockfish, widow, cowcod and yelloweye rockfish). Discards are assumed to be negligible in the historical period; however, regulatory discards have been substantial in recent years, more than doubling the total catch relative to landings since 2002. Trawl discards have been negligible since implementation of the IFQ program in 2011.

The PSA vulnerability score of 1.35 indicates a low risk of overfishing.

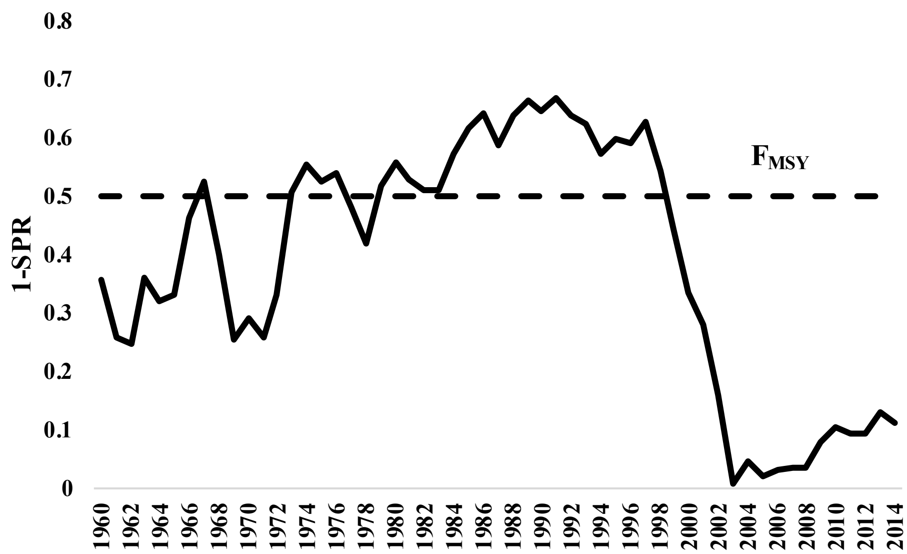

Figure 2-29. Estimated spawning potential ratio (SPR) of chilipepper rockfish relative to the current F_{MSY}, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.4.10 Cowcod

Distribution and Life History

Cowcod (*Sebastes levis*) is a species of large rockfish with a distribution from Newport, Oregon, to central Baja California, Mexico (Love et al., 2002). They are most common from Cape Mendocino (California) to northern Baja California, in depths from 50-300 m. Hess et al. (2014) recently used genetic and otolith microchemistry tools to study cowcod population structure from California to Oregon. Specifically, they tested the hypothesis that a phylogeographic boundary exists at Point Conception. Their results supported a hypothesis of two primary lineages with a geographic boundary falling south of, rather than at Point Conception. Both lineages co-occur in the Southern California Bight (SCB), with no clear pattern of depth stratification or spatial structure within the Bight. Within lineages, there is evidence for considerable gene flow across the Point Conception boundary. Cowcod found north of Point Conception consist primarily of a single lineage, also found in northern areas of the SCB.

Cowcod are easily identified at all life stages, including larvae. Adults are piscivorous, with a diet consisting mainly of fishes, squids, and octopi. Cowcod are considered to be parademersal (transitional between a midwater pelagic and benthic species). Larvae develop into a pelagic juvenile stage, settling to benthic habitats after about 3 months. Juvenile cowcod were once thought to associate primarily with soft sediments, but Love and Yoklavich (2008), using visual surveys, found juveniles mainly associate with low-relief, hard substrate. Young-of-the-year were observed over a wide depth range (52-277 m), with juveniles slightly deeper, and adults mainly deeper than 150 m. Larger juveniles increasingly associate with high-relief, complex rocky substrate, the primary habitat for adult cowcod. Adult cowcod are generally solitary, but occasionally aggregate (Love*, et al.* 1990). Although cowcod are generally not migratory, they may move, to some extent, to follow food (Love 1996).

Cowcod are a long-lived, slow-growing species that require a decade or more to reach sexual maturity. Fertilization is internal, with females giving birth to planktonic larvae mainly during winter months. Spawning peaks in January in the SCB (MacGregor 1986) and large females may produce up to three broods per season (Love*, et al.* 1990). Larvae emerge at about 5.0 mm (MacGregor 1986).

Cowcod are a highly fecund species, with large females producing 2 million eggs (fecundity is dependent on size and ranges from 181,000 to 1,925,000 eggs) (Love*, et al.* 2002). Dick et al. (2009) found no evidence of increasing weight-specific fecundity (i.e., spawning output is roughly proportional to spawning biomass).

Maximum observed age for cowcod is 55 years (Love*, et al.* 2002). Dick et al. (2007) estimated the natural mortality rate (M) using three methods, reporting a range of values from 0.027 to 0.064 based on Beverton's (1992) method, a range of total mortality (Z) estimates from 0.038 to 0.072 based on catch curve analysis, and Hoenig's geometric mean regression. Females reach 90 percent of their maximum expected size by 42 years.

Little is known about ecological relationships between cowcod and other organisms. Small cowcod feed on planktonic organisms such as copepods. Juveniles eat shrimp and crabs, and adults eat fish, octopus, and squid (Allen 1982). Adults consume a wide range of prey items, but are primarily piscivorous (Love*, et al.* 2002).

Stock Status and Management History

While cowcod are not a major component of the groundfish fishery, they are highly desired by both recreational and commercial fishers because of their bright color and large size. The cowcod stock in the Conception area was first assessed in 1998 (Butler*, et al.* 1999b). Abundance indices decreased approximately tenfold between the 1960s and the 1990s, based on CPFV logs (Butler*, et al.* 1999b). Recreational and commercial catch also declined substantially from peaks in the 1970s and 1980s, respectively.

NMFS declared cowcod in the Conception and Monterey management areas overfished in January 2000, after Butler et al. (1999b) estimated the 1998 spawning biomass to be at 7 percent of B_0, well below the 25 percent minimum stock size threshold. Because cowcod is a fairly sedentary species, closed areas were established in 2001 to reduce cowcod mortality. Two Cowcod

Conservation Areas (CCAs), in the SCB, were selected due to their high density of cowcod. The larger of the two areas (CCA West) is a 4,200 square mile area west of Santa Catalina and San Clemente Islands. A smaller area (CCA East) is about 40 miles offshore of San Diego and covers about 100 square miles. Bottom fishing is prohibited deeper than 20 fm within the CCAs.

A cowcod rebuilding analysis was completed in 2003 which validated the assumption that non-retention regulations and area closures had been effective in constraining cowcod fishing mortality (Butler, *et al.* 2003). These encouraging results were based on cowcod fishery-related landings in recreational and commercial fisheries, although the assessment included discard information only with respect to CPFV observations (which indicated negligible discards in that sector). This rebuilding review pointed out a common problem among the analyses of overfished species: reliance on landings (fishery-dependent) data for providing relative abundance values becomes increasingly difficult as the allowable catch is decreased and fishery observer data remains low. Monitoring stock status and recovery thus becomes increasingly difficult in the absence of fishery-independent surveys.

As in the 1999 assessment, the 2005 cowcod assessment (Piner, *et al.* 2006) considered only the cowcod population in SCB (from the U.S.-Mexico border north to Point Conception) population, as this is the area in which cowcod are most abundant, adult habitat is most common, and catches are highest. The 2005 assessment used only two data sources, the CPFV time series and the visual survey estimate data (Yoklavich, *et al.* 2007). The model was developed in Stock Synthesis 2, and although the base model estimated only three parameters (two of which were "nuisance parameters," the other was equilibrium recruitment), the STAR Panel determined that this simplicity was appropriate given the paucity of data. The assessment provided a set of results corresponding to three different values for assumed steepness (h), the key parameter in the stock-recruitment relationship (h=0.4, 0.5, and 0.6) and one the key uncertainties in the assessment. The assessment estimated that the 2005 spawning biomass was 18 percent of unfished levels and within a range of 14 to 21 percent depending on the value assumed for steepness, a considerably more optimistic result than the 1999 assessment. The corresponding 2005 cowcod rebuilding analysis (Piner 2006) was used to develop the cowcod rebuilding plan adopted in the groundfish FMP under Amendment 16-4. The rebuilding plan established a target rebuilding year of 2039 and an SPR of 90 percent.

A full cowcod assessment was conducted in 2007, which estimated spawning biomass to be 3.8 percent of its unfished level at the start of 2007 (Dick, *et al.* 2007). The 2007 cowcod assessment was an age-structured production model assuming a Beverton-Holt stock-recruitment function with deterministic recruitment, fit to the aggregated CPFV logbook index and the 2002 visual survey biomass estimate (Yoklavich, *et al.* 2007). Productivity parameters were fixed (steepness = 0.6, natural mortality = 0.055), leaving only R_0 to be estimated. Spawning biomass in 2007 was estimated to be between 3.4 percent and 16.3 percent of the unfished level. The poor precision of this estimate was due to 1) a lack of data to inform estimates of stock productivity, and 2) conflicting information from fishery-dependent and fishery–independent data. However, even the most optimistic model, which assumed a high-productivity stock and ignored declines in CPFV catch rates, suggested that spawning biomass was below 25 percent since 1980. Since retention of cowcod was prohibited and bycatch was thought to be minimal, it was considered unlikely that overfishing was an issue. It is likely that the 2007 base model underestimated the uncertainty about stock status given steepness and the natural mortality rate were treated as fixed and known in the model.

The 2007 assessment was originally prepared as an "update" stock assessment; however, while preparing the update, an error was discovered in the previous assessment's specification of the selectivity curve. Several revisions were proposed, including new estimates of historical landings, a corrected growth curve, and a two-fishery model. The 2007 assessment used Stock Synthesis 2, revised estimates of historical commercial catch, contained corrections to gear selectivity curves, utilized a revised growth curve, and separated the catch into commercial (all gears) and recreational fisheries rather than a single fishery. Recreational catches in the 2007 assessment were identical to those in the previous assessment, but estimates of commercial catches had been updated to reflect three additional data sources: 1) recovered port samples from Southern California (1983-1985), 2) regional summaries of total rockfish landings (1928-1968) provided by the NMFS Southwest Fisheries Science Center (SWFSC) Environmental Research Division, and 3) California rockfish landings by region (1916-1927), published in CDF&G Fish Bulletin No. 105 (1958).

The 2007 rebuilding analysis (Dick and Ralston 2007) estimated a new T_{MAX} of 2098, 24 years later than the date estimated by Piner (2006), due in part to the corrections described above, but only 1 year earlier than the 2099 date estimated previously (Butler*, et al.* 2003). It was noted in the rebuilding analysis that rebuilding scenarios were extremely uncertain for this data-limited species, particularly with respect to steepness. Moreover, there was widespread concern about the ability to monitor the stock, and consequently to evaluate progress towards rebuilding in the future. The 2007 rebuilding analysis projections indicated that it would not be possible to rebuild the cowcod stock by 2039, even if all the catches are eliminated, and the estimated time to rebuild under the current harvest rate (SPR = 90 percent) was 26 years greater than the target year of 2039 adopted under Amendment 16-4. Therefore, a modification of the Amendment 16-4 cowcod rebuilding plan was implemented in 2007 which prescribed a target year of 2072 and an SPR harvest rate of 82.1 percent.

The 2007 cowcod assessment was updated in 2009, with stock depletion estimated to be 4.5 percent of its unfished level at the start of 2009 (Dick*, et al.* 2009). Estimates of female spawning stock biomass in 2009 were highly uncertain. Spawning biomass had declined from an unfished biomass of 2,101-2,461 mt to 93-441 mt in 2009. The 2009 cowcod rebuilding analysis (Dick*, et al.* 2009) was used to reconsider the cowcod rebuilding plan adopted under Amendment 16-4 as mandated in a legal challenge (*NRDC v. Locke*). The revised rebuilding plan, implemented in 2011, prescribed a target year of 2068 and an SPR harvest rate 82.7 percent.

The 2013 cowcod assessment estimated stock depletion to be 33.9 percent of unfished spawning biomass at the start of 2013 (Dick and MacCall 2013). The 2013 assessment suggested that cowcod in the SCB constitute a smaller, but more productive stock than was estimated from previous assessments. The 2013 assessment used the XDB-SRA modeling platform to estimate stock status, scale, and productivity. Dick et al. (2013) fit five fishery-independent data sources: four time series of relative abundance (CalCOFI larval abundance survey, Sanitation District trawl surveys, NWFSC trawl survey, and NWFSC hook and line survey), and the 2002 Yoklavich et al. (2007) visual survey estimate of absolute abundance.

A new cowcod assessment was conducted in 2019 indicating the stock was rebuilt with a depletion of 57 percent at the start of 2019 (Dick and He 2019). NMFS declared the stock rebuilt in September 2019 based on the results of the new assessment. The 2019 used the Stock Synthesis model rather than the Bayesian surplus production model (XDB-SRA) used in the 2013 assessment. The new assessment includes indices from six fishery-independent data sources (most of which were also included in the 2013 model), as well as length and age composition data. A major contributor of uncertainty with the cowcod assessment is the lack of adequate data (particularly age data) for estimating growth, natural mortality, and recruitment.

The base model estimates that spawning output has been steadily increasing since the late 1980s when the stock was estimated to be at 9 percent of unfished level (Figure 2-30). The current depletion estimate is 57 percent of unfished spawning output in 2019. Sensitivity analyses demonstrate that when the lower productivity assumptions associated with the 2013 model are applied to the current model (e.g., lower steepness and M), the model results are very comparable to those of the 2013 model. Uncertainty in current stock status and productivity is greatly underestimated by the base model due to lack of sufficient information in estimating natural mortality, the form and parameters of the stock recruitment relationship, recruitment variability, and historical fishery selectivity. Catch uncertainty affects the precision of population scale (and therefore yield) and is not accounted for in the current assessment. Therefore, the STAT recommended that target yields be set well below the MSY proxy until data become available to better inform stock productivity and status.

The SSC endorsed the cowcod stock assessment as a category 2 assessment since recruitment deviations were not estimated. The Council selected a new harvest control rule where ACL equals ABC under a P* of 0.4 for 2021 and beyond.

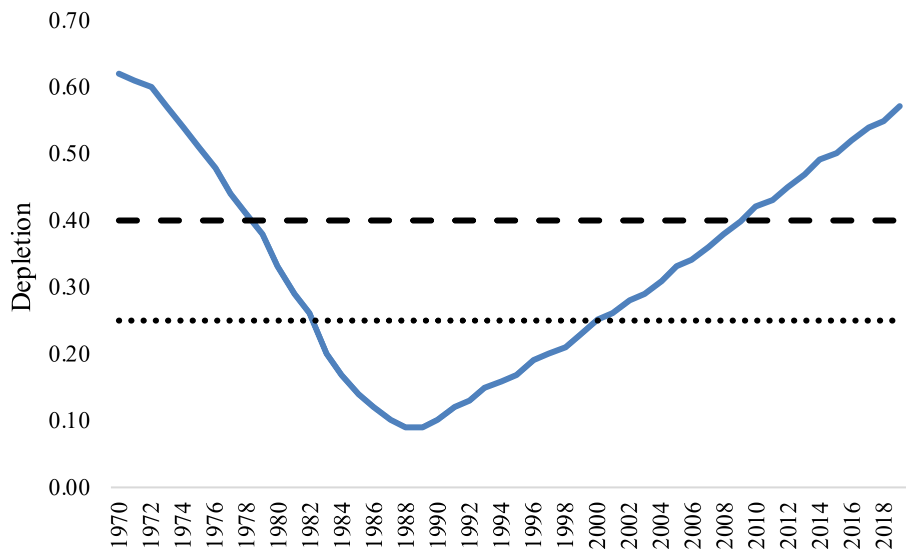

Figure 2-30. Relative depletion of cowcod south of 40°10' N. lat. from 1970 to 2019 based on the 2019 stock assessment.

Stock Productivity

As in the previous assessment, production in the 2013 assessment is assumed to be a deterministic function of spawning biomass. Recruitment pulses may be evident in the abundance indices, but insufficient information is available to reliably estimate the relative strength of individual year classes. A Beverton-Holt steepness of 0.72 based on the rockfish meta-analysis prior was assumed in the 2019 assessment.

Fishing Mortality

The annual (equilibrium) SPR harvest rate (1-SPR) for cowcod has been less than 4 percent of target for over a decade (Figure 2-31). Historically, the SPR harvest rate reached target levels by 1920-1930, and later regularly exceeded the target for roughly 30 years, from the mid-1960s to the mid-1990s. As a percentage of age-10+ biomass (i.e., exploitation rate), harvest rates peaked at around 40 percent in the 1980s, but have declined to levels below 1 percent since retention of cowcod was prohibited in 2001. Exploitation history relative to the target SPR harvest rate (0.5) and the target spawning output (40 percent of unfished spawning output) is shown in Figure 2-31. The estimated $SPR_{50\%}$-based proxy for MSY is 73 mt per year, which corresponds to an annual harvest rate of roughly 4 percent of age 10+ biomass.

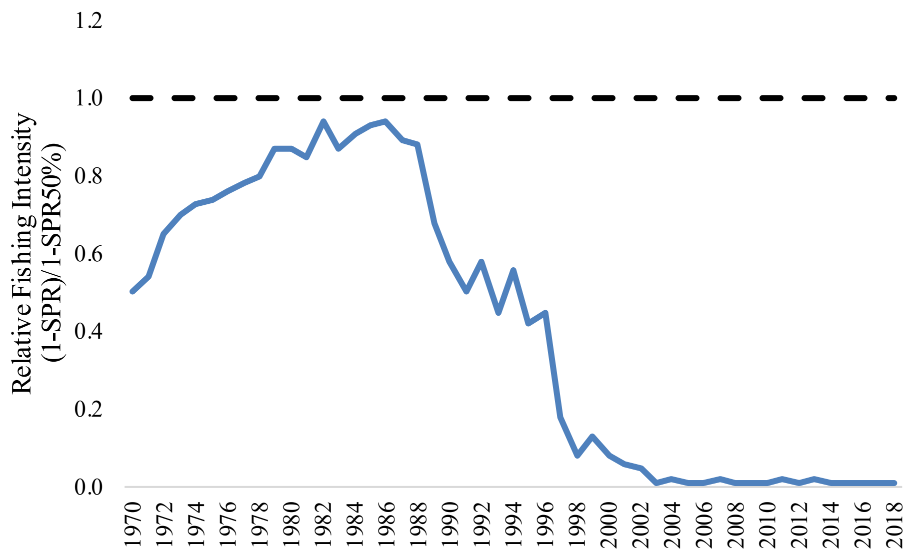

Figure 2-31. Relative fishing intensity of cowcod south of Pt. Conception, 1970-2018.

2.4.11 Darkblotched Rockfish

Distribution and Life History

Darkblotched rockfish (*Sebastes crameri*) are found from Santa Catalina Island off Southern California to the Bering Sea (Miller and Lea 1972; Richardson and Laroche 1979). They are most abundant from Oregon to British Columbia. Darkblotched rockfish primarily occur on the outer shelf and upper slope off Oregon, Washington, and British Columbia (Richardson and Laroche 1979). Based upon genetic information and the absence of large-scale gaps in catches, there are no clear stock delineations for darkblotched rockfish in U.S. waters. This does not mean there are not more fine scale groupings to be found, and in fact, darkblotched rockfish catches are characterized by infrequent large tows of larger fish. Distinct population groups have been found off the Oregon coast between 44°30' N. lat. and 45°20' N. lat. (Richardson and Laroche 1979). This species co-occurs with an assemblage of slope rockfish, including Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*).

Darkblotched rockfish mate from August to December, eggs are fertilized from October through March, and larvae are released from November through April (Love*, et al.* 2002). Older larvae and pelagic juvenile darkblotched rockfish are found closer to the surface than many other rockfish species. Pelagic juvenile settle at 4 to 6 cm in length in about 55 to 200 m (Love*, et al.* 2002). As many other Sebastes, this species exhibits ontogenetic movement, with fish migrating to deeper waters as they mature and increase in size and age (Lenarz 1993; Nichol 1990).

Darkblotched rockfish are among the longer living rockfish; the data used in the most recent assessment (Gertseva*, et al.* 2015) includes individuals that have been aged to be 98 years old. The maximum reported age of darkblotched rockfish is 105 years (Love*, et al.* 2002). As with many other *Sebastes* species, darkblotched rockfish exhibit sexually dimorphic growth; females reach larger sizes than males, while males attain maximum length earlier than females (Love*, et al.* 2002; Nichol 1990; Rogers*, et al.* 2000).

Darkblotched rockfish are ovoviviparous (Nichol and Pikitch 1994). Insemination of female darkblotched rockfish occurs from August to December, and fertilization and parturition occur from December to March off Oregon and California, and primarily in February off Oregon and Washington (Hart 1988; Nichol and Pikitch 1994; Richardson and Laroche 1979). Fecundity is dependent on size and ranges from 20,000 to 610,000 eggs.

Little is known about ecological relationships between darkblotched rockfish and other organisms. Pelagic juveniles feed on planktonic organisms such as copepods. Adults are often caught with other fish such as Pacific ocean perch and splitnose rockfish. Mid-water animals such as euphausiids and amphipods dominate the diet of adult fish. Albacore and Chinook salmon consume pelagic juveniles (Hart 1988). Little is known about predation of adults.

Stock Status and Management History

Darkblotched rockfish are caught primarily with commercial trawl gear, as part of a complex of slope rockfish, which includes Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*). Catches of darkblotched rockfish first became significant in the mid-to-late 1940s due to increased demand for fish protein during World War II. During the mid-1960s to mid-1970s darkblotched rockfish were caught by both domestic and foreign fleets (Rogers 2003b). Domestic landings rose from the late 1970s until the late 1980s, although limits on rockfish catch were first instituted in 1983, when darkblotched rockfish was managed as part of a group of around 50 species (designated as the Sebastes complex) (Rogers*, et al.* 2000). During the 2000s, progressive steps have been taken to reduce the catch of darkblotched rockfish, following the declaration of its overfished status in 2001.

The first full assessment of the darkblotched rockfish stock was conducted in 2000, which estimated stock depletion at 14–31 percent of its unfished level, depending on assumptions regarding the historic catch of darkblotched rockfish in the foreign fishery from 1965-1978 (Rogers*, et al.* 2000). The base model assumed 10 percent of foreign catch was comprised of darkblotched rockfish, leading to the conclusion that the spawning stock biomass was at 22 percent of its unfished level. NMFS declared darkblotched rockfish to be overfished in 2001 based on these results.

The 2001 rebuilding analysis for the stock (Methot and Rogers 2001) incorporated results of the 2000 Alaska Fisheries Science Center (AFSC) triennial slope trawl survey and modeled a more recent time series of recruitments. Incorporating these data resulted in a downward revision of the estimated recruitment and abundance throughout the time series compared to what had been used in the Rogers et al. (2000) assessment. This led to a revised estimate of spawning stock biomass at the beginning of 2002 of 14 percent of its unfished level and a longer projected rebuilding period.

A 2003 assessment and rebuilding update for darkblotched rockfish (Rogers 2003a) estimated a lower depletion ($B_{11\%}$), but provided evidence of strong recent recruitment not yet recruited to the spawning population. This analysis was used to inform the darkblotched rockfish rebuilding plan adopted under Amendment 16-2, which established a target rebuilding year of 2030 and a fishing mortality rate of F = 0.027. A revised darkblotched rockfish rebuilding plan was implemented in 2004 that specified a higher harvest rate (F = 0.032) to avoid negative socioeconomic impacts.

The 2005 full darkblotched rockfish assessment estimated a spawning stock depletion of 16 percent of unfished biomass at the start of 2005 (Rogers 2005a). The assessment estimated strong recruitment of the 1999 and 2000 year classes. The 2005 rebuilding analysis (Rogers 2005b) was used to inform a revised rebuilding plan adopted under Amendment 16-4 and implemented in 2007. The revised rebuilding plan specified a target year of 2011 and a constant harvest rate strategy (SPR = 60.7 percent).

The 2007 darkblotched rockfish assessment estimated a stock depletion of 22.7 percent at the start of 2007 (Hamel 2008c). The 2007 darkblotched rockfish rebuilding analysis (Hamel 2008a) predicted the median time to rebuild would be 19 years later than the target year of 2011 under the SPR harvest rate adopted under Amendment 16-4. The Council revised the Amendment 16-4 rebuilding plan by specifying a target year to rebuild the stock of 2028 and decreasing the harvest rate (SPR = 62.1 percent).

The 2007 darkblotched rockfish assessment was updated in 2009 and 2011. The 2009 stock assessment update estimated a stock depletion of 27.5 percent at the start of 2009 (Wallace and Hamel 2009). The 2009 darkblotched rockfish rebuilding analysis (Wallace 2009) was used to inform a revised rebuilding plan, which was implemented in 2011 The revised rebuilding plan specified a target year to rebuild the stock of 2025 and decreased the harvest rate to SPR = 64.9 percent. The 2011 stock assessment update estimated a stock depletion of 30.2 percent at the start of 2009 (Stephens, *et al.* 2011). No revisions to the rebuilding plan were made based on the 2011 assessment update and accompanying rebuilding plan (Stephens 2011).

A full darkblotched rockfish stock assessment in 2013 (Gertseva and Thorson 2013) estimated a stock depletion of 36 percent at the start of 2013 (Figure 2-32). The assessment also predicted the stock would be rebuilt by the start of 2015. The improved stock status and rebuilding outlook were largely attributed to 1) reduced fishing mortality under the rebuilding program; 2) inferences that follow from more favorable perceptions of steepness, fecundity, and age at maturity of the stock; and 3) length and age data indicating relatively large recruitments in 1999, 2000, and 2008.

A full assessment of darkblotched rockfish conducted in 2015 (Gertseva, *et al.* 2015) estimated a stock depletion of 39 percent at the start of 2015 or just under the 40 percent target. Revisions that were made to the data used for stock assessment included 1) a new method of index standardization for NWFSC trawl survey using a geo-statistical delta-GLMM, 2) a new steepness value based on an updated meta-analysis of steepness, 3) a new value for natural mortality, 4) an updated maturity at length relationship, 5) a re-estimated length-weight relationship, and 6) additional ageing data. Changes to the assessment model were relatively minor but included a change from two fleets to three fleets, with the at-sea hake fishery now modeled as a separate fishery, and a change from asymptotic selectivity for the shore-based fishery to dome-shaped selectivity.

A 2017 update to the 2015 full assessment of darkblotched rockfish was conducted (Wallace and Gertseva 2018), which estimated stock depletion at 40.03 percent at the start of 2017 or over the B_{MSY} proxy of $B_{40\%}$. Changes to the model include revision of the historical catch estimates, new length and age data, and an updated prior on steepness. The SSC endorsed the update assessment as a category 1 assessment.

The Council adopted the default harvest control rule of ACL = ABC (P* = 0.45) for darkblotched rockfish to inform harvest specifications in 2019 and beyond. A catch only-projection of darkblotched rockfish was provided to inform harvest specifications for 2023 and beyond.

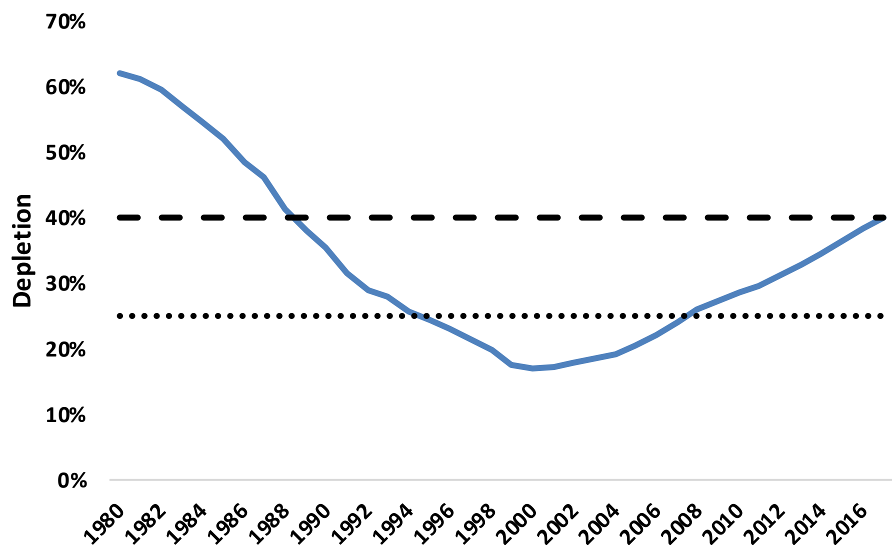

Figure 2-32. Relative depletion of darkblotched rockfish from 1980 to 2017 based on the 2017 stock assessment update.

Stock Productivity

Wallace and Gertseva (2018) fixed steepness at its prior mean of 0.72. This prior was estimated using a likelihood profile approximation to a maximum marginal likelihood mixed-effect model for steepness from ten category 1 rockfish species off the U.S. West Coast (Pacific ocean perch, bocaccio, canary rockfish, chilipepper, black, darkblotched rockfish, gopher, splitnose, widow, and yellowtail rockfish). This likelihood profile model is intended to synthesize observation-level data from assessed species, while avoiding the use of model output and thus improving upon previous meta-analyses (Dorn 2002a; Forrest*, et al.* 2010). This methodology has been simulation tested and has been recommended by the SSC for use in stock assessments.

Recruitment was modeled in the 2017 assessment assuming a Beverton-Holt relationship and recruitment deviations were informed by data from 1960 to 2013. Recent strong year classes include 1999, 2008, and 2013 with 2013 being the largest estimated in the time series (Figure

2-33). Stock abundance is predicted to continue to increase as these cohorts recruit into the fishery and spawning population.

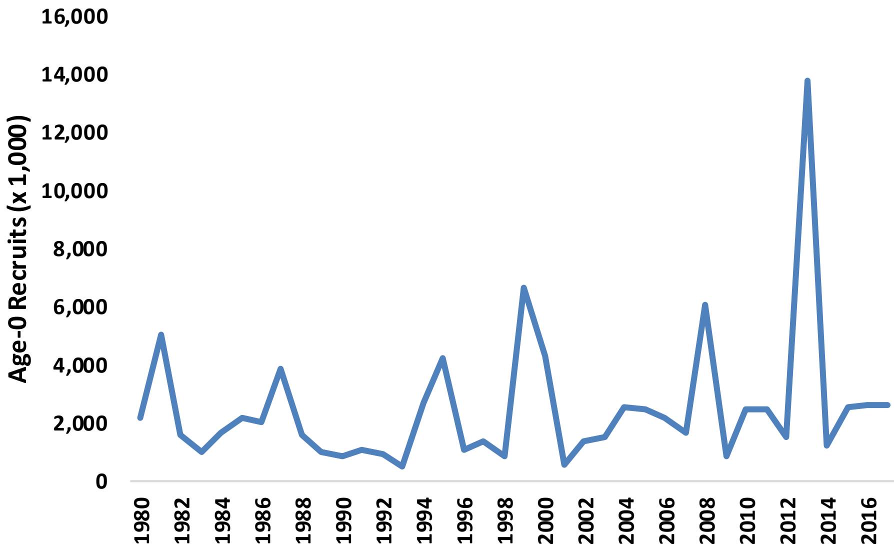

Figure 2-33. Estimated recruitments of darkblotched rockfish, 1980-2017.

Fishing Mortality

Historically, the darkblotched rockfish was fished beyond the F_{MSY} threshold of $F_{50\%}$ between 1966 and 1968, during the peak years of the Pacific ocean perch fishery, in 1973, and for a prolonged period between from 1981 and 2000 (Figure 2-34). The spawning output of darkblotched rockfish dropped below the B_{MSY} target for the first time in 1989, as a result of intense fishing by foreign and domestic fleets (Figure 2-32). It continued to decline and reached the level of 17 percent of its unfished output in 2000. Since 2000, when the stock was declared overfished, the spawning output slowly increased primarily due to management regulations implemented for the stock. The 2017 assessment indicated the stock had attained the B_{MSY} target of $B_{40\%}$ by the start of 2017 and the stock was declared rebuilt in June 2017.

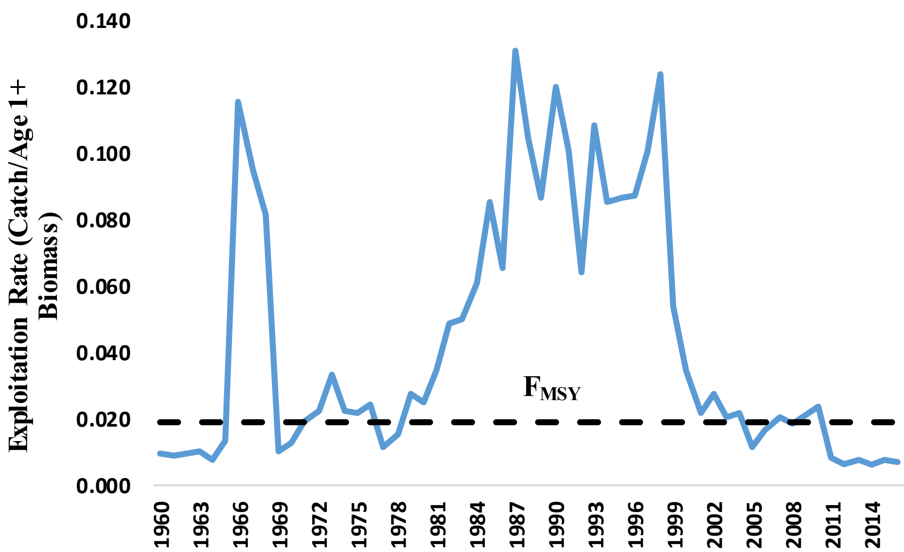

Figure 2-34. Time series of estimated exploitation rates (catch/age 1+ biomass) of darkblotched rockfish, 1960-2016 relative to the exploitation rate corresponding to F_{MSY} (SPR = 50%).

2.4.12 Dover Sole

Distribution and Life History

Dover sole (*Microstomus pacificus*) are distributed from the Navarin Canyon in the northwest Bering Sea and westernmost Aleutian Islands to San Cristobal Bay, Baja California, Mexico (Hagerman 1952; Hart 1988; NOAA 1990). Dover sole are a dominant flatfish on the continental shelf and slope from Washington to Southern California. Adults are demersal and are found from 9 m to 1,450 m, with highest abundance below 200 m to 300 m (Allen and Smith 1988). Adults and juveniles show a high affinity toward soft bottoms of fine sand and mud. Juveniles are often found in deep nearshore waters. Dover sole are considered to be a migratory species. In the summer and fall, mature adults and juveniles can be found in shallow feeding grounds, as shallow as 55 m off British Columbia (Westrheim and Morgan 1963). By late fall, Dover sole begin moving offshore into deep waters (400 m or more) to spawn. Although there is an inshore-offshore seasonal migration, little north-south coastal migration occurs (Westrheim and Morgan 1963).

Spawning occurs from November through April off Oregon and California in waters 80 m to 550 m depth at or near the bottom (Hagerman 1952; Hart 1988; NOAA 1990; Pearcy*, et al.* 1977). Dover sole are oviparous and fertilization is external. Larvae are planktonic and are transported to offshore nursery areas by ocean currents and winds for up to two years. Settlement to benthic living occurs mid-autumn to early spring off Oregon, and February through July off California (Markle*, et al.* 1992). Juvenile fish move into deeper water with age and begin seasonal spawning and feeding migrations upon reaching maturity.

Dover sole larvae eat copepods, eggs, and nauplii, as well as other plankton. Juveniles and adults eat polychaetes, bivalves, brittle stars, and small benthic crustaceans. Dover sole feed diurnally by sight and smell (Dark and Wilkins 1994; Gabriel and Pearcy 1981; Hart 1988; NOAA 1990).

Dover sole larvae are eaten by pelagic fishes like albacore, jack mackerel and tuna, as well as sea birds. Juveniles and adults are preyed upon by sharks, demersally feeding marine mammals, and to some extent by sablefish (NOAA 1990). Dover sole compete with various eelpout species, rex sole, English sole, and other fishes of the mixed species flatfish assemblage (NOAA 1990).

Stock Status and Management History

Dover sole have been the target of trawl operations along the West Coast of North America since World War II and were almost certainly caught prior to the war as incidental take in directed fisheries for English sole and petrale sole. Almost all of the harvests have been taken by groundfish trawl, and in particular as part of the Dover sole, shortspine thornyhead, longspine thornyhead, and sablefish (DTS) trawl strategy. Annual landings from U.S. waters averaged 6,700 mt during the 1960s, 12,800 mt during the 1970s, 18,400 mt during the 1980s, 12,400 mt during the 1990s, and 7,200 mt since 2000.

The 1997 Dover sole stock assessment (Brodziak, *et al.* 1997) treated the entire population from the Monterey area through the U.S.-Vancouver area as a single stock based on research addressing the genetic structure of the population. Under a range of harvest policies and recruitment scenarios, the 1997 model projected that spawning biomass would increase from the estimated year-end level in 1997 through the year 2000 due to growth of the exceptionally large 1991 year class and to the lower catches observed in the fishery since 1991.

Dover sole were next assessed in 2001, resulting in an estimated spawning stock size of 29 percent of the unexploited biomass (Sampson and Wood 2001). The unexploited spawning stock biomass was estimated to be 176,500 mt and the stock steadily declined from the 1950s until the mid-1990s with little subsequent variation. The 1991 year class was the last strong one estimated in that assessment, consistent with the 1997 assessment.

The 2005 Dover sole assessment indicated the stock was above target levels and had an increasing abundance and biomass trend since the late 1990s (Sampson 2005). The final base model estimated the unexploited spawning stock biomass to be slightly less than 300,000 mt and spawning biomass at the start of 2005 was estimated to be about 189,000 mt, equivalent to 63 percent of the unexploited level. Spawning biomass and age 5+ biomass (roughly corresponding to the exploitable biomass) were estimated to have reached their lowest points in the mid-1990s and rose steadily since. The estimated increases in biomass since the mid-1990s were due primarily to strong year classes in 1990 and 1991, and exceptionally strong year classes in 1997 and 2000.

A new Dover sole assessment was done in 2011, which indicated the stock was healthy with a 2011 spawning stock biomass depletion of 83.7 percent of unfished biomass (Hicks and Wetzel 2011). The assessment was based on the length- and age-structured model developed in SS. The data included fishery landings, length and age data, as well as abundance indices from the NMFS AFSC triennial slope surveys, and from the NWFSC slope and shelf/slope surveys. The extension of the NWFSC shelf/slope survey was new to this assessment and added a considerable amount of information, including age data, which were fit in the model as conditional age-at-length vectors. Also, recent data on discarding collected by the West Coast Groundfish Observer Program

(WCGOP), including length data, were used to determine retention curves and selectivity for the commercial fleets.

A major difference between the 2011 and 2005 assessments is that the current estimate of annual natural mortality is 0.117 for males and 0.114 for females, as opposed to 0.09 for both in the last assessment. These estimates made use of a prior probability distribution developed by Dr. Owen Hamel. A lognormal distribution was used to characterize the variability of length-at-age. In addition, selectivity curves for the slope surveys were modeled using cubic splines which allows for a greater possibility of shapes. Lastly, the female selectivity curves were not forced to asymptote at one, allowing for the possibility of differential sex selection.

A new assessment of Dover sole in 2021 estimated a depletion of 79 percent at the start of 2021 {Wetzel, 2021 #1282; Figure 2-35}. Results from this assessment were consistent with those from the 2011 assessment. Model estimates show that the scale of the spawning biomass is uncertain and that the stock size is well above the target reference point and has been above the target reference point throughout the duration of the fishery. The scale of the estimates of stock size are lower than from the 2011 assessment, driven by improved parameterization of survey selectivity (double normal and sex-specific). There are several sources of uncertainty in the model, including the level of recruitment variability, sensitivity to the treatment of natural mortality (M), and sensitivity to alternative selectivity parameterizations.

The default harvest control rule for Dover Sole is ABC based on a category 1 sigma and a P* of 0.45 and an ACL of 50,000 mt. An annual catch of 50,000 mt can be sustained through 2024. The harvest control rule will necessarily default to ACL = ABC (P* = 0.45) beginning in 2025 since the ABC is predicted to be less than 50,000 mt (Table 2-9).

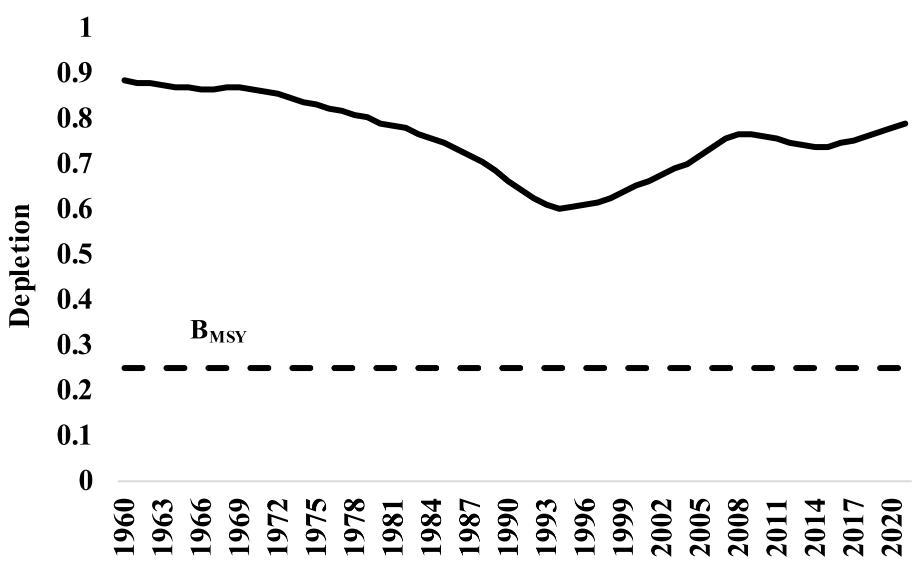

Figure 2-35. Relative depletion of Dover sole from 1960 to 2021 based on the 2021 stock assessment.

Table 2-9. Projected harvest specifications, biomass, and depletion for West Coast Dover sole assuming the default harvest control rule.

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion
2023	63,834	59,685	473,658	230,918	0.79
2024	55,859	51,949	424,499	207,333	0.71
2025	49,608	45,937	385,189	187,284	0.64
2026	44,769	41,277	353,944	170,449	0.58
2027	41,053	37,646	329,174	156,459	0.53
2028	38,217	34,892	309,580	144,943	0.49
2029	36,050	32,770	294,004	135,500	0.46
2030	34,389	31,088	281,550	127,779	0.43
2031	33,108	29,797	271,541	121,483	0.41
2032	32,100	28,762	263,391	116,323	0.40

Stock Productivity

Steepness in the 2021 Dover sole assessment was fixed at 0.8, the mean steepness estimated in the SSC's 2010 meta-analysis of flatfish productivity (PFMC and NMFS 2011). While the 2021 assessment was considered data-rich, estimates of steepness are uncertain partly because the stock has not been fished to low levels to understand potential recruitment at low spawning biomass. The PSA productivity score of 1.8 indicates a stock of relatively high productivity.

Recruitment deviations were estimated to be above average in the late 1990s, below average in the early 2000s, and then generally above average between 2008-2012 (Figure 2-36). Years with the highest recruitment deviations were estimated to have occurred in 2000 and 2009 with the lowest between 2003 - 2005. The stock is predicted to have never fallen to low enough levels that the effects of steepness are obvious.

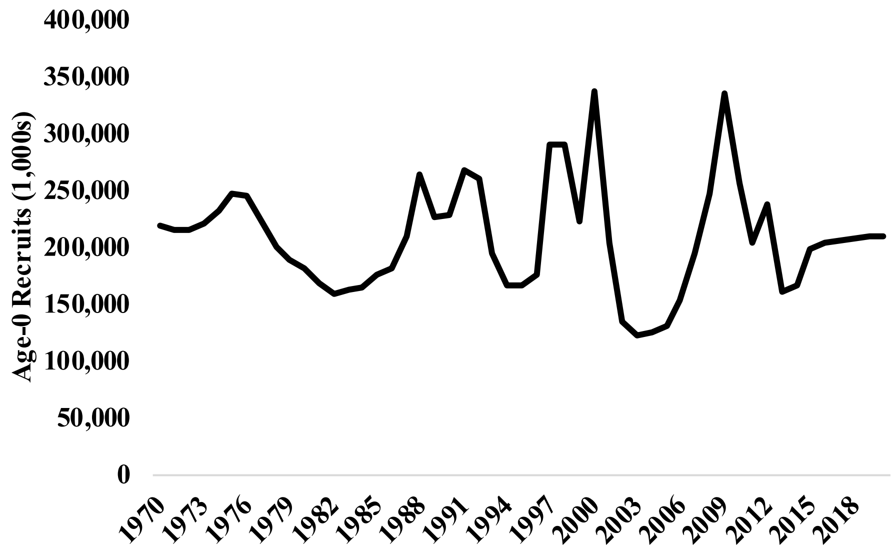

Figure 2-36. Estimated recruitments of Dover sole, 1970-2020.

Fishing Mortality

The spawning biomass of Dover sole reached a low in the mid-1990s before beginning to increase throughout the last decade. The estimated depletion has remained above the 25 percent biomass target and it is unlikely that the stock has ever fallen below this threshold. Throughout the 1970s, 1980s, and 1990s the exploitation rate and SPR generally increased, but never exceeded the SPR 30 percent F_{MSY} target (Figure 2-37). Recent exploitation rates on Dover sole have been much lower than F_{MSY}, even after management increased catch levels in 2007.

Sablefish quota is needed to target Dover sole and the other DTS species using trawl gear. Sablefish IFQ quota is also used in a single-species target fishery using fixed gears. The competition and price for sablefish quota are affected by Asian sablefish demand and supply from north Pacific fisheries outside the West Coast EEZ (e.g., BC and the Gulf of Alaska fisheries). It may be the case that the supply and demand of West Coast Dover sole will remain limited until there is an increased harvestable surplus of sablefish above recent levels.

Dover sole are caught primarily by bottom trawls and are managed using IFQs in the rationalized fishery. Despite Dover sole being an important target species, an average of 15 percent of the annual quota has been attained on average (2011-2019) in the IFQ fishery.

The PSA vulnerability score of 1.54 indicates a low risk of overfishing.

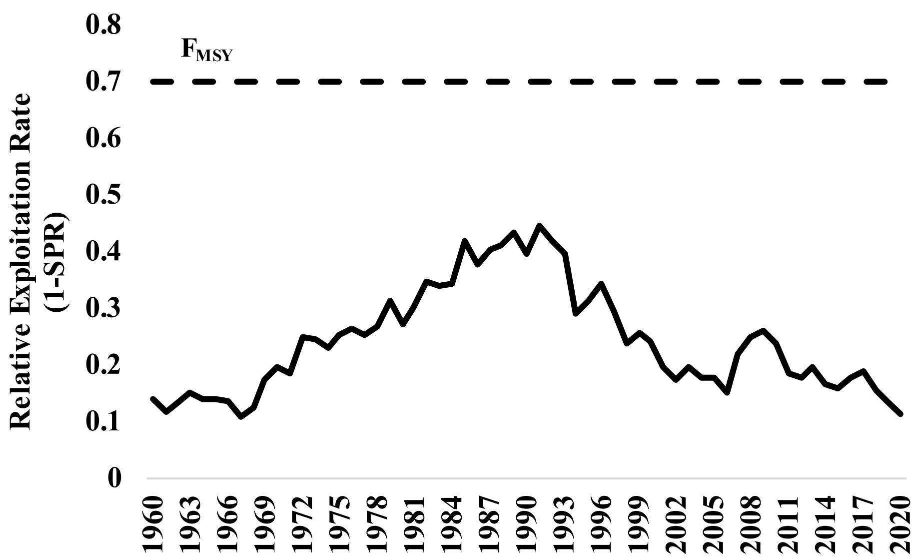

Figure 2-37. Estimated annual relative exploitation rate of West Coast Dover sole relative to the current proxy F_{MSY} target, 1960-2020.

2.4.13 English Sole

Distribution and Life History

English sole (*Parophrys vetulus*) are found from Nunivak Island in the southeast Bering Sea and Agattu Island in the Aleutian Islands, to San Cristobal Bay, Baja California Sur, Mexico (Allen and Smith 1988). In research survey data, nearly all occurred at depths greater than 250 m (Allen and Smith 1988). Adults and juveniles prefer soft bottoms composed of fine sands and mud (Ketchen 1956), but also occur in eelgrass habitats (Pearson and Owen 1992). English sole use nearshore coastal and estuarine waters as nursery areas (Krygier and Pearcy 1986; Rogers*, et al.* 1988). Adults make limited migrations. Those off Washington show a northward post-spawning migration in the spring on their way to summer feeding grounds and a southerly movement in the fall (Garrison and Miller 1982). Tagging studies have identified separate stocks based on this species' limited movements and meristic characteristics (Jow 1969).

Spawning occurs over soft-bottom mud substrates (Ketchen 1956) from winter to early spring, depending on the stock. Eggs are neritic and buoyant, but sink just before hatching (Hart 1988); juveniles and adults are demersal (Garrison and Miller 1982). Small juveniles settle in the estuarine and shallow nearshore areas all along the coast, but are less common in southerly areas, particularly south of Point Conception. Large juveniles commonly occur up to depths of 150 m. Although many post larvae may settle outside of estuaries, most will enter estuaries during some part of their first year of life (Gunderson, et al. 1990). Some females mature as three-year-olds (26 cm), but all females over 35 cm long are mature. Males mature at two years (21 cm). Females attain much larger sizes than males. Landings by the fishery are composed primarily of female fish, but at-sea discards of small fish include large numbers of male English sole.

Larvae are planktivorous. Juveniles and adults are carnivorous, eating copepods, amphipods, cumaceans, mysids, polychaetes, small bivalves, clam siphons, and other benthic invertebrates

(Allen 1982; Becker 1984; Hogue and Carey 1982; Simenstad*, et al.* 1979). English sole feed primarily by day, using sight and smell, and sometimes dig for prey (Allen 1982; Hulberg and Oliver 1979). A juvenile English sole's main predators are piscivorous birds such as great blue heron (*Ardia herodias*), larger fishes, and marine mammals. Adults may be eaten by marine mammals, sharks, and other large fishes.

Stock Status and Management History

English sole have been captured by the bottom trawl fishery operating off the western coast of North America for over a century. Stewart (2006) found that peak catches from the southern area occurred in the 1920s with a maximum of 3,976 mt of English sole landed in 1929, and peak catches from the northern area occurred in the 1940s to the 1960s with a maximum of 4,008 mt landed in 1948. Landings from both areas have generally declined since the mid-1960s and have been at nearly historical lows in recent years

The first English sole stock assessment was conducted in the INPFC Columbia and U.S. Vancouver areas and used Virtual Population Analysis (Golden*, et al.* 1986). This model covered only the years 1966 to 1983. A dynamic pool model was used to get an estimate of MSY based on the recruitments produced by the cohort analysis. Many previous studies using cohort analysis and CPUE statistics have been conducted. Of note from these analyses was that they identified a very large year class in 1961 (Hayman*, et al.* 1980).

The next West Coast assessment of English sole was conducted in 1993 (Sampson and Stewart 1993). That assessment considered the female portion of the stock off Oregon and Washington during the years 1977-1993 because the landings were dominated by females (greater that 90 percent by weight). The English sole spawning biomass was found to be increasing and it was concluded that the fishery was sustainable at (then) contemporary harvest levels.

The 2005 assessment of English sole (Stewart 2006) modeled a single coastwide stock, although both commercial and fishery independent data sources were treated separately for a southern (INPFC Conception and Monterey) and a northern (INPFC Eureka, Columbia and U.S. Vancouver) area. The assessment found that English sole spawning biomass had increased rapidly over the last decade after a period of poor recruitments from the mid-1970s to the mid-1990s, which left the stock at nearly historically low levels. Strong year classes were estimated for 1995, 1996, and 1999. The data indicated that the 1999 year class may be the largest in the time-series. There was substantial uncertainty related to certain parameters in the assessment, specifically biomass, recruitment, and relative depletion, as indicated by the wide confidence intervals for those parameters. Nevertheless, sensitivity analyses indicated that the conclusion that current spawning biomass exceeds the target level ($B_{40\%}$) was robust to all three of these sources of uncertainty. The spawning biomass at the beginning of 2005 was estimated to be 31,379 mt, which corresponds to 91.5 percent of the unexploited equilibrium level.

The 2007 update assessment (Stewart 2008c) confirmed the magnitude of increased biomass through a large quantity of age data through 2006, which became available. The 2007 assessment also included data on fishery length and age (primarily from Washington) that was previously unavailable. These new data provided substantially improved information regarding recent year class strengths and current stock status. The spawning biomass at the beginning of 2007 was estimated to be 41,906 mt, which corresponded to 116 percent of the unexploited equilibrium level.

Cope et al. (2014) assessed English sole using the data-moderate exSSS model platform. The English sole assessment was conducted for a coastwide stock and stock depletion was estimated to be 88 percent at the start of 2013 (Table 2-4). The current spawning biomass was estimated to be 25,719 mt. Since the new English sole assessment was conducting using data-moderate methods, the stock was downgraded from a category 1 to a category 2 stock.

The Council adopted the default harvest control rule of ACL = ABC (P* = 0.45) for English sole in 2019-2020. The 2019 and 2020 English sole ABCs and ACLs are 10,090 mt and 10,135 mt, respectively.

Stock Productivity

There is little evidence for a strong stock-recruitment relationship, with some of the largest recruitments occurring at moderate levels of spawning biomass. This corresponds to the relatively high estimate of steepness of 0.8-0.87 in recent assessments. In general, recruitment deviations are well-informed by the data between 1940 and 2000.

Following two decades of low recruitments, strong year classes were estimated for 1995, 1998-2000, and 2002. The data indicate that the 1999 year class was the largest in the time-series.

The PSA productivity score of 2.25 indicates a very productive stock, which is true for most nearshore and shelf flatfishes.

Fishing Mortality

The estimated SPR for English sole has never been below the proxy target of 30 percent for flatfish. Exploitation rates were highest from the late 1940s to the early 1990s. Since 1992, the intensity of exploitation has been substantially less, resulting in higher SPR levels. This corresponds to a relative exploitation rate (catch/biomass of age 3 and older fish) history that is high from the late 1940s to the early 1990s, and steadily declining to very low levels over the last 15 years.

English sole are primarily caught by groundfish bottom trawls. Management uncertainty is low with the 100 percent observer coverage for the groundfish trawl fleet under trawl rationalization. Very small amounts of English sole were landed in the 2011 IFQ fishery with only 1 percent of the quota attained. This is due to low trawl effort on the shelf since such efforts require investment of limited quota for Pacific halibut, darkblotched rockfish, and yelloweye rockfish.

The PSA vulnerability score of 1.19 shows a very low concern of overfishing on the stock.

2.4.14 Lingcod North and South of 40°10' N. Lat.

Distribution and Life History

Lingcod (*Ophiodon elongatus*), a top order predator of the family *Hexagrammidae*, ranges from Baja California, Mexico, to Kodiak Island in the Gulf of Alaska. Lingcod are demersal at all life stages (Allen and Smith 1988; NOAA 1990; Shaw and Hassler 1989). Adult lingcod prefer two main habitat types: slopes of submerged banks 10 m to 70 m below the surface with seaweed, kelp, and eelgrass beds and channels with swift currents that flow around rocky reefs (Emmett*, et al.* 1991; Giorgi and Congleton 1984; NOAA 1990; Shaw and Hassler 1989). Juveniles prefer sandy substrates in estuaries and shallow subtidal zones (Emmett*, et al.* 1991; Hart 1988; NOAA 1990). As the juveniles grow, they move to deeper waters. Adult lingcod are considered a relatively sedentary species, but there are reports of migrations of greater than 100 km by sexually immature fish (Jagielo 1990; Mathews and LaRiviere 1987; Matthews 1992; Smith*, et al.* 1990).

Mature females live in deeper water than males and move from deep water to shallow water in the winter to spawn (Forrester 1969; Hart 1988; Jagielo 1990; LaRiviere*, et al.* 1980; Mathews and LaRiviere 1987; Matthews 1992; Smith*, et al.* 1990). Mature males may live their whole lives associated with a single rock reef, possibly out of fidelity to a prime spawning or feeding area (Allen and Smith 1988; LaRiviere*, et al.* 1980; Shaw and Hassler 1989). Spawning generally occurs over rocky reefs in areas of swift current (Adams 1986; Adams and Hardwick 1992; Giorgi and Congleton 1984; LaRiviere*, et al.* 1980). After the females leave the spawning grounds, the males remain in nearshore areas to guard the nests until the eggs hatch. Hatching occurs in April off Washington, but as early as January and as late as June at the geographic extremes of the lingcod range. Males begin maturing at about two years (50 cm), whereas females mature at three plus years (76 cm). In the northern extent of their range, fish mature at an older age and larger size (Emmett*, et al.* 1991 Adams, 1992 #438; Hart 1988; Mathews and LaRiviere 1987; Miller and Geibel 1973; Shaw and Hassler 1989). The maximum age for lingcod is about 20 years (Adams and Hardwick 1992).

Lingcod are a visual predator, feeding primarily by day. Larvae are zooplanktivores (NOAA 1990). Small demersal juveniles prey upon copepods, shrimps, and other small crustaceans. Larger juveniles shift to clupeids and other small fishes (Emmett*, et al.* 1991; NOAA 1990). Adults feed primarily on demersal fishes (including smaller lingcod), squids, octopi, and crabs (Hart 1988; Miller and Geibel 1973; Shaw and Hassler 1989). Lingcod eggs are eaten by gastropods, crabs, echinoderms, spiny dogfish, and cabezon. Juveniles and adults are eaten by marine mammals, sharks, and larger lingcod (Miller and Geibel 1973; NOAA 1990).

Stock Status and Management History

Lingcod have been a target of commercial fisheries since the early 1900s in California, and since the late 1930s in Oregon and Washington waters. Recreational fishermen have targeted lingcod since the 1920s in California. A smaller recreational fishery has taken place in Washington and Oregon since at least the 1970s. Although historically the catches of lingcod have been greater in the commercial sector than in the recreational sector, this pattern has been reversed since the late 1990s.

In 1997, Jagielo, et al. (1997) assessed the size and condition of the portion of the stock in the Columbia and Vancouver areas (including the Canadian portion of the Vancouver management area), and concluded the stock had fallen to below ten percent of its unfished size at 8.8 percent of its unfished biomass. The Council responded by imposing substantial harvest reductions coastwide, reducing the harvest targets for the Eureka, Monterey, and Conception areas by the same percentage as in the north.

In 1999, Adams, et al. (1999) assessed the southern portion of the stock and concluded the condition of the southern stock was similar to the northern stock with a depletion of $B_{15\%}$, thus confirming the Council had taken appropriate action to reduce harvest coastwide. Based on these assessments, the lingcod stock was declared overfished in 1999. A rebuilding plan establishing a target year of 2009 and harvest rates of F = 0.0531 and F = 0.0610 for fisheries in the northern and southern areas, respectively was adopted and implemented in 2000.

Jagielo et al. (2000) conducted a coastwide lingcod assessment and determined the total biomass increased from 6,500 mt in the mid-1990s to about 8,900 mt in 2000. In the south, the population had also increased slightly from 5,600 mt in 1998 to 6,200 mt in 2000. In addition, the assessment concluded previous aging methods portrayed an older population, whereas new aging efforts showed the stock to be younger and more productive. Therefore, the ABC and OY were increased in 2001 on the basis of the new assessment. A revised rebuilding analysis of coastwide lingcod (Jagielo and Hastie 2001) confirmed the major conclusions of the 2000 assessment and rebuilding analysis, but slightly modified recruitment projections to stay on the rebuilding trajectory to reach target biomass in 2009.

The lingcod rebuilding plan was formally adopted by the Council and incorporated into the FMP under Amendment 16-2. The rebuilding plan established a target rebuilding year of 2009 and the harvest control rule of F = 0.0531 for fisheries in the northern areas and F = 0.0610 for fisheries in the southern areas (with a P_{MAX} of 60 percent). Depth-based restrictions and a winter season fishing closure to protect nest-guarding males were also implemented as part of the rebuilding plan.

Jagielo et al. (2004) conducted a coastwide assessment for lingcod in 2003 that indicated the lingcod stock had achieved the rebuilding objective of $B_{40\%}$ in the north with a 68 percent depletion, but was at a 31 percent depletion in the south. The Council's SSC, working in concert with the lead assessment author, recalculated the coastwide lingcod stock status in March 2004 using actual 2003 harvests (the assessment, which was completed during 2003, assumed harvest would be equal to the specified OY in 2003). Their calculations indicated that the spawning biomass at the start of 2004 was within 99.3 percent of B_{MSY} ($B_{40\%}$) on a coastwide basis. The harvest control rule was recalculated to be F = 0.17 for fisheries in the northern areas and F = 0.15 for fisheries in the southern areas.

The 2005 coastwide assessment (Jagielo and Wallace 2006) again modeled two populations of lingcod north and south of 40°10’ N. lat. On a coastwide basis, the lingcod population was concluded to be fully rebuilt, with the spawning biomass in 2005 estimated to be 64 percent of its unfished level. Within the separate area models, current biomass was estimated to be closer to unfished biomass in the north ($B_{87\%}$) than in the south ($B_{24\%}$). Given that the lingcod stock is managed on a coastwide basis, the Council announced the lingcod stock to be fully rebuilt in 2005, which is four years earlier than the target rebuilding year established in the rebuilding plan.

The 2009 lingcod assessment modeled two populations north and south of the California-Oregon border at 42° N. lat. (Hamel, *et al.* 2009). Both populations were healthy with stock depletion estimated at 62 and 74 percent for the north and south, respectively.

The Council and NMFS elected to maintain the management line for lingcod at 40°10' N. lat. by specifying separate ACLs north and south of that line. This action was intended to not overly encumber the commercial fishing industry, which is required to fish within a single management area within one trip. Specifying the lingcod management line at 42° N. lat. would create two management areas stratified at 40°10' N. lat. and 42° N. lat. This would especially burden vessels home ported out of Brookings, Crescent City, Eureka, and Ft. Bragg since they would have to restructure their current fishing practices to avoid a violation of the management line crossover provisions. It is stated in the 2009 assessment that a management break at Cape Mendocino would likely be more biologically accurate than stratifying the assessment north and south of 42° N. lat. In general, given the crossover provisions and the other regulations that foster area management strategies, the fewer latitudinal management lines there are, the less burdened the offshore commercial fishery will be. Two major biogeographic breaks occur on the West Coast at Pt. Conception at 34°27' N. lat. and Cape Mendocino approximately at 40°10' N. lat., and many stocks show differences north and south of these latitudes. These biogeographic breaks are probably the more appropriate latitudes to specify management lines, given how north-south physical processes such as current patterns tend to be different, creating stock differences for species affected by these different physical processes.

The lingcod STAT evaluated the swept area biomass estimates calculated annually (2003-2010) from the NMFS NWFSC trawl survey, which indicated that 48 percent of the lingcod biomass for the stock south of 42° N. lat. occurred between 40°10' N. lat. and 42° N. lat. Therefore, 48 percent of the 2013 and 2014 OFLs projected in the 2009 lingcod assessment for the southern lingcod stock were added to OFLs proposed for the stock north of 40°10' N. lat. Likewise, 48 percent of the projected OFLs for the southern stock were subtracted from the OFLs proposed for the stock south of 40°10' N. lat. Given that the trawl survey is the main fishery-independent tuning index of biomass in the assessment, using swept area biomass from the trawl survey to estimate relative biomass north and south of 40°10' N. lat. was considered appropriate.

New full assessments of lingcod were conducted in 2017 with northern (Washington and Oregon) and southern (California) stock assessments (Haltuch, *et al.* 2018). The 2017 assessments indicated the stock was healthy in the north with a depletion of 57.9 percent and in the precautionary zone in the south with a depletion of 32.9 percent at the start of 2017. A number of revisions relative to the previous assessment were made to the data used for these stock assessments including: 1) shifting the start of the assessment to 1889, 2) splitting the commercial fleet into trawl and fixed gear components and the northern recreational fleet into Oregon and Washington components, 3) re-analysis of commercial fishery CPUE data and the Alaska Fisheries Science Center Triennial survey index using vector autoregressive spatial temporal (VAST) software, 4) addition of three fishery-dependent and one fishery-independent CPUE indices, 5) updating length-weight relationships and the prior on natural mortality, 6) new maturity relationship based on recent data collections, 7) re-estimating ageing error from double read age data, and 8) updating landings and composition data. The main model structure changes from the last assessment were the addition of selectivity parameters for fleets that were split by gear or geographic area, altering the plus and minus groups for length and age composition bins, and constructing a broader set of time blocks for selectivity. Also, conditional age-at-length composition data were directly incorporated into the model. The SSC endorsed these assessments as category 1 assessments in both areas.

The 2019 and 2020 harvest specifications were projected from the 2017 assessment. The relative biomass of lingcod (and subsequently the OFLs, ABCs, and ACLs) were reapportioned from the assessment area stratification north and south of 42° N. lat. to the management area stratification north and south of 40°10’ N. lat. by using the most recent 5-year (2012-2016) average percentage of trawl survey lingcod biomass in California occurring north of 40°10’ N. lat. The analysis indicated 21.31 percent of the average survey biomass in California occurred north of 40°10’ N. lat. Therefore, 21.31 percent of the projected harvest specifications from the southern assessment area were apportioned to the lingcod north of 40°10’ N. lat. harvest specifications.

New assessments for lingcod north and south of 40°10’ N. lat. were conducted in 2021. The northern lingcod assessment estimates the stock has never been overfished and currently at a depletion of 61 percent of unfished biomass {Figure 2-38, Taylor, 2021 #1280}. The southern lingcod assessment estimates the stock declined below target levels from the late 1980s to early 2000s but increased since then due to a series of strong recruitment year-classes and was just below the management target with 39 percent depletion at the start of 2021 {Figure 2-39, Johnson, 2021 #1281}.

In terms of differences between northern and southern models, estimated natural mortality (M) rates were 0.42/year and 0.41/year for females and males in the northern model whereas M values for the southern model were 0.17/year and 0.22/year for females and males, respectively. Steepness was also estimated and varied between northern and southern models, with higher estimates in the northern model at 0.80. While both models fit relative abundance indices well, there was considerable tension among many data sources, particularly between age and length composition data. The SSC designated both assessments category 2 and recommended full assessments be conducted the next time.

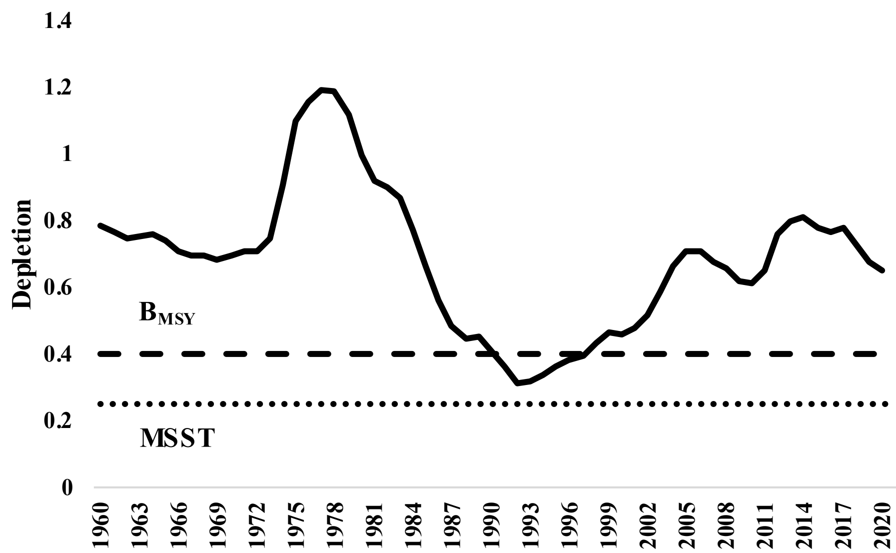

Figure 2-38. Relative depletion of lingcod north of 40°10’ N lat. from 1960 to 2021 based on the 2021 stock assessment.

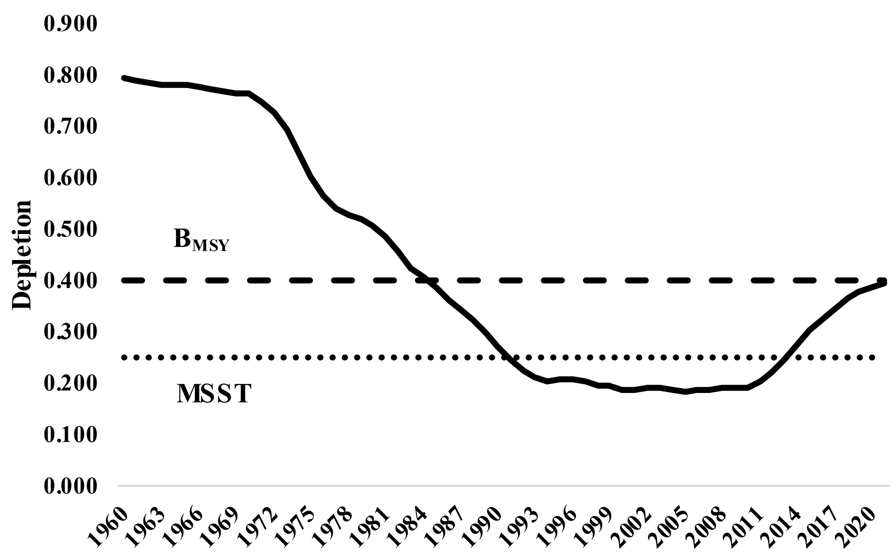

Figure 2-39. Relative depletion of lingcod south of 40°10’ N lat. from 1960 to 2021 based on the 2021 stock assessment.

Stock Productivity

Steepness and natural mortality were estimated using informed priors in the 2021 lingcod assessments. Estimates of key productivity parameters (i.e., M and h) differ significantly among the two areas, indicating that the southern stock is less productive than the northern stock (Table

2-5). Additionally, the north model estimates almost equal M for females and males (0.418 and 0.414 respectively), whereas the south model has a lower estimate of female M than male M (0.17 and 0.222). The M estimates are uncertain in both models, although more so in the south than the north. The PSA productivity score of 1.75 indicates a stock of relatively high productivity.

Lingcod appear to have moderate variability in estimates of recruitment with recruitment variability (σR) fixed at 0.6. Given the pandemic and the lack of recent survey information, there was little information in the data to estimate recruitment in 2019. The last large recruitment event for both the northern and southern lingcod stocks occurred in 2013 and a smaller event may have also occurred within the last half-decade though its magnitude is more uncertain (Figure 2-40 and Figure 2-41).

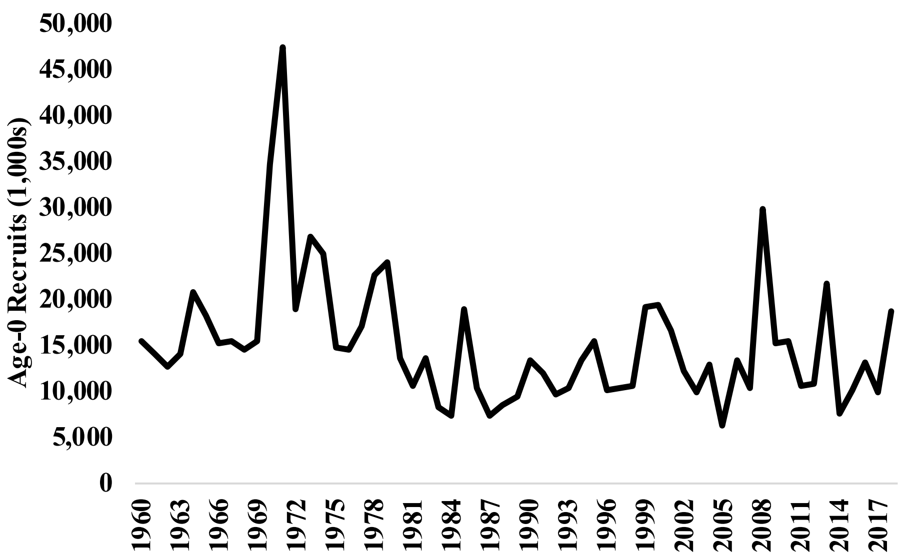

Figure 2-40. Estimated recruitments of lingcod north of 40°10' N lat., 1960-2018 from the 2021 assessment.

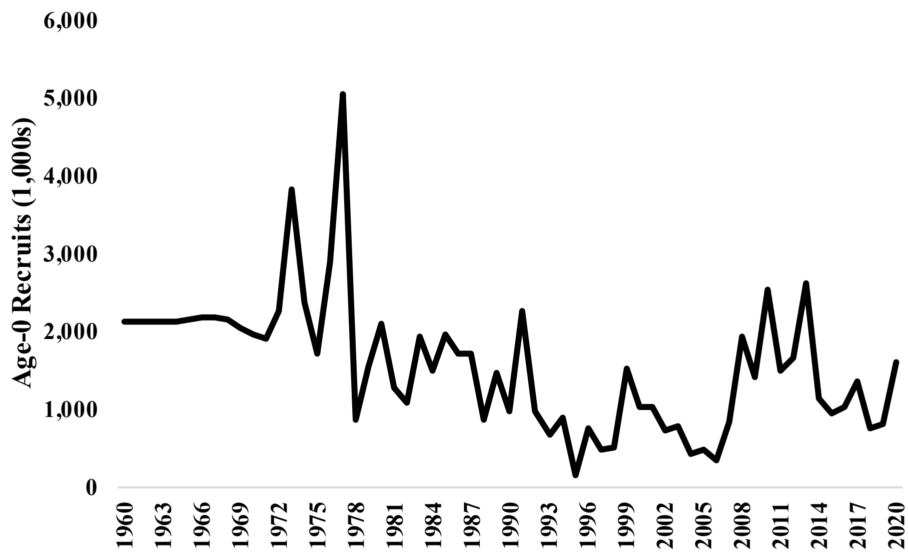

Figure 2-41. Estimated recruitments of lingcod south of 40°10' N lat., 1960-2018 from the 2021 assessment.

Fishing Mortality

The harvest rate in the north was estimated to have never been above the target proxy harvest rate (Figure 2-42). Recent estimates of fishing intensity indicate stability within the fishery and are close to pre-1950 estimates. The relative fishing intensity is estimated to have peaked in 1991.

The southern stock was estimated to have been harvested above the target proxy harvest rate from the 1970s to approximately the late 1990s and again in the early 2000s (Figure 2-43). The relative fishing intensity is estimated to have peaked in 1989. Recent estimates of harvest have all been below the target proxy harvest rate and the estimate of fishing intensity for the terminal year was the lowest estimated since 2011.

The PSA vulnerability score for lingcod is 1.55, indicating a low risk of overfishing of the stock.

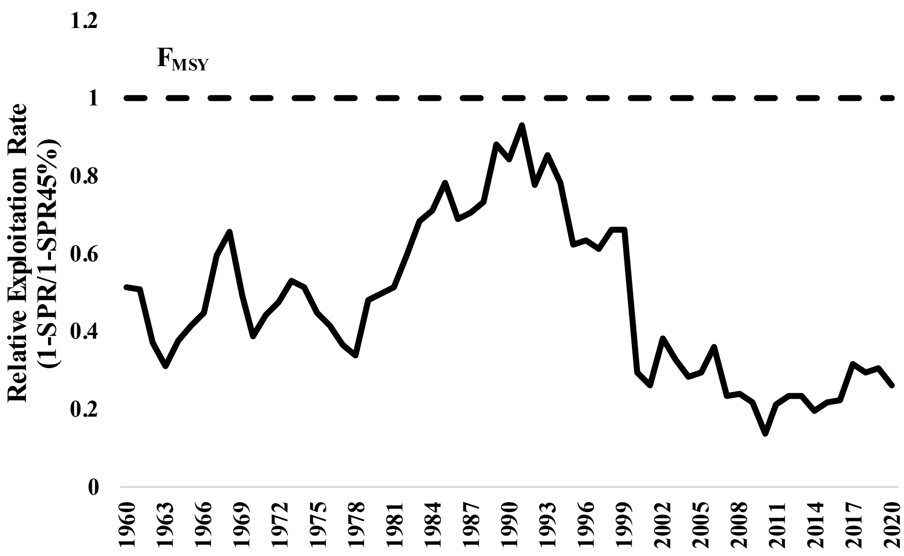

Figure 2-42. Estimated annual relative exploitation rate of lingcod north of 40°10' N lat. relative to the current proxy F_{MSY} target, 1960-2020.

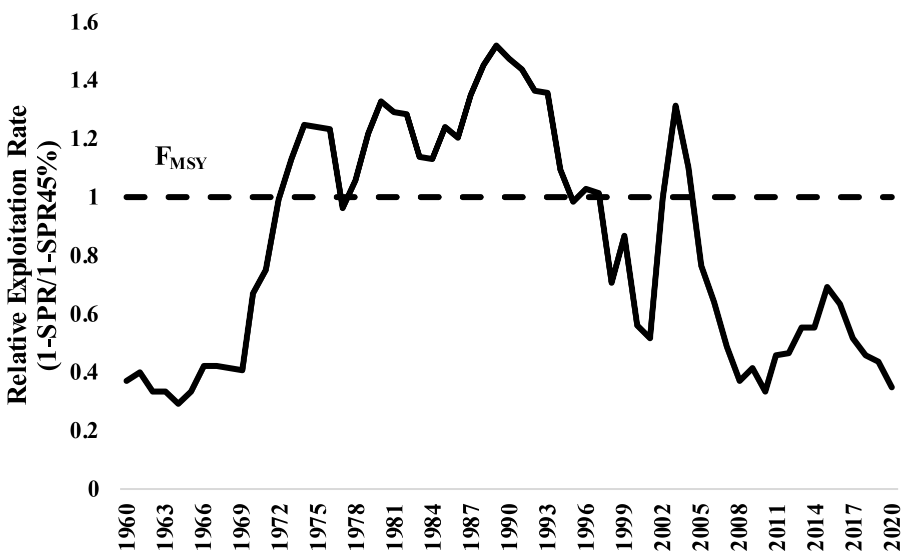

Figure 2-43. Estimated annual relative exploitation rate of lingcod south of 40°10' N lat. relative to the current proxy F_{MSY} target, 1960-2020.

2.4.15 Longnose Skate

Distribution and Life History

Skates are the largest and most widely distributed group of batoid fish with approximately 245 species ascribed to two families (Ebert and Compagno 2007; McEachran 1990). Skates are benthic fish that are found in all coastal waters but are most common in cold temperatures and polar waters (Ebert and Compagno 2007).

There are about eleven species of skates from either of three genera (*Amblyraja*, *Bathyraja*, and *Raja*) present in the Northeast Pacific Ocean off California, Oregon, and Washington (Ebert 2003). Of that number, just three species (longnose skate *Beringraja rhina*, big skate *B. binoculata*, and sandpaper skate *Bathyraja interrupta*) make up over 95 percent of survey catches in terms of biomass and numbers, with the longnose skate leading in both categories (62 percent of biomass and 56 percent of numbers). Species compositions of fishery landings also show that longnose skate are the predominant skates in commercial catches. On average, longnose skate represents 75 percent of total skate landings in Oregon for the last 20 years and 45 percent in Washington for the last 10 years. There are no species composition data available for commercial landings in California, but anecdotal evidence suggests that the majority of skates landed there are longnose skates.

The distribution of the longnose skate is limited to the eastern Pacific Ocean. It is found from the southeastern Bering Sea to just below Punta San Juanico, southern Baja California, and Gulf of California at depths of 9-1,069 m (Love*, et al.* 2005). Longnose skates do not exhibit a size-specific pattern in distribution relative to bottom depth; average fish size does not vary greatly with depth.

Currently, there is no information available that indicates the existence of multiple breeding units in the Northeast Pacific Ocean. Several tagging studies have found that elasmobranchs, such as sharks and skates, can undertake extensive migrations within their geographic range (Martin and Zorzi 1993; McFarlane and King 2003). This behavior suggests the likelihood that there is a high degree of genetic mixing within the population, across its range. As a result, the longnose skate population off California, Oregon and Washington is modeled in this assessment as a single stock.

The life history of skates is characterized by late maturity, low fecundity and slow growth to large body size (King and McFarlane 2003; Moyle and Cech 1996; Walker and Hislop 1998). Skates invest considerable energy in developing a few large, well-protected embryos. These characteristics are associated with a K-type reproductive strategy, as opposed to r-type strategy, wherein reproductive success is achieved by high productivity and early maturity (Hoenig and Gruber 1990).

Longnose skate are oviparous. After fertilization, the female forms tough, but permeable egg cases that surround eggs and then deposits these egg cases onto the sea floor at daily to weekly intervals for a period of several months or longer (Hamlett and Koob 1999). The eggs within egg cases incubate for several months in a benthic habitat. Inside the egg cases, the embryos develop with nourishment provided by yolk. The longnose skate is known to have only a single embryo per egg case (David Ebert, Moss Landing Marine Laboratories, pers. com. as cited by Gertseva and Schirripa (2008)). When the yolk is depleted and the juvenile is fully formed, it exits the egg case. Once hatched, the young skate is similar in appearance to an adult, but smaller in size. Upon reaching maturity, skates enter the reproductive stage, which lasts for the remainder of their lives (Frisk*, et al.* 2002; Pratt and Casey 1990). On average off the continental U.S. Pacific Coast, female longnose skates mature between 11-18 years, which corresponds to 75-125 cm in total length (Thompson 2006). The life span of the longnose skate is not well known, although individuals up to 23 years of age have been found (Thompson 2006). Longnose skates attain a maximum length of about 145 cm, although individuals as large as 180 cm have been reported off the U.S. West Coast (Thompson 2006).

The reproductive cycle of oviparous skates has been observed for a few species but not for longnose skate. These studies indicate that egg production generally occurs throughout the year although there have been some instances where seasonality in egg laying was observed (Hamlett and Koob 1999). Information on fecundity of longnose skate is extremely limited. Holden (1974) found that species of the family *Rajidae* are the most fecund of all elasmobranchs and can lay 100 egg cases per year, although eggs may not be produced every year. Frisk et al. (2002) estimated that annual fecundity for skates similar in size with longnose may be less than 50 eggs per year; however, those eggs exhibit high survival rates due to the large parental investment. Overall, little is known about breeding frequency, egg survival, hatching success and other early life history characteristics of longnose skate.

Stock Status and Management History

Longnose skate was managed in a complex of dissimilar species, the Other Fish complex, from 1982, when the Groundfish FMP was implemented through 2008. In 2009, longnose skate was removed from the Other Fish complex and managed with stock-specific harvest specifications.

Gertseva and Schirripa (2008) assessed the West Coast longnose skate stock in 2007. The spawning stock biomass was estimated to be at 66 percent of its unfished biomass at the start of 2007. Based on that assessment, a constant catch strategy (OY = 1,349 mt) was implemented in 2009 based on a 50 percent increase in the average 2004-2006 landings and discard mortality. The constant catch strategy was revised in 2013 by implementing an ACL of 2,000 mt to provide greater access to the stock and to limit disruption of current fisheries. This level of harvest was projected to maintain the population at a healthy level as projected in the 10-year forecast for longnose skate in the 2007 assessment (Gertseva and Schirripa 2008).

The SSC recommended changing the proxy F_{MSY} rate for longnose skate and other elasmobranchs from an SPR of 45 percent to an SPR of 50 percent beginning in 2015. This recommendation, driven primarily by conservation concerns for spiny dogfish (see section 2.4.23), was adopted to determine OFLs in 2017 and beyond consistent with this lower harvest rate.

A new longnose skate assessment conducted in 2019 estimated stock depletion at 57 percent at the start of 2019 (Gertseva*, et al.* 2019). The assessment includes considerable improvements to landings and discard estimates relative to those in the 2007 assessment, a particular challenge for skate stocks given that landings were not routinely recorded to the species level prior to 2009. Natural mortality and the West Coast Groundfish Bottom Trawl (WCGBT) Survey catchability coefficient (q) are estimated using informative priors. The catchability of the WCGBT survey is used to set the low and high states of nature in the decision table.

The 2019 assessment estimates longnose skate spawning biomass has slowly declined from unfished levels at the start of the assessment in 1916, with a relatively flat trend from the early 2000s to present (Figure 2-44).

The SSC designated longnose skate as a category 2 stock given the lack of recruitment deviations in the assessment model, the model's inability to fit the indices, and the weak information content of the available data. The SSC recommended the next assessment could be an update, provided future fishing removals remain well below the OFL.

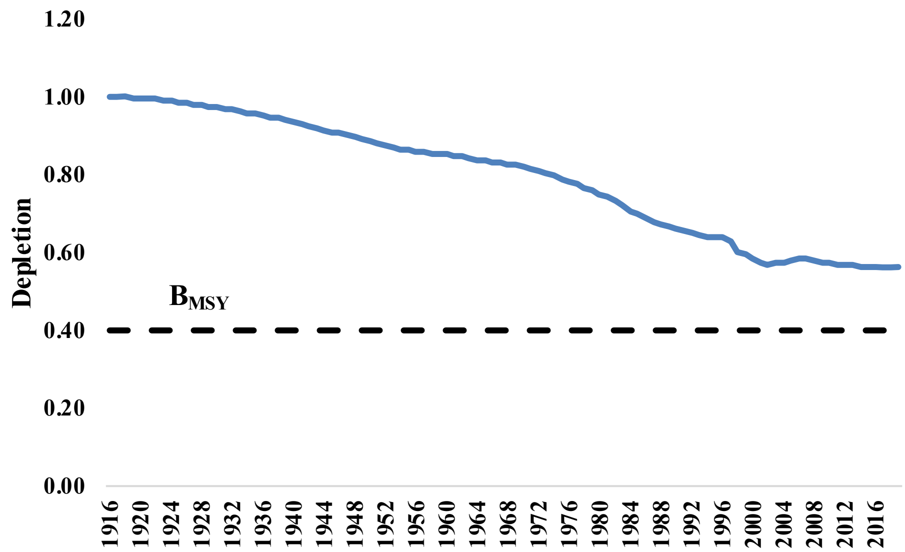

Figure 2-44. Relative depletion of longnose skate from 1916 to 2019 based on the 2019 stock assessment.

Stock Productivity

Steepness of the stock-recruitment curve was fixed at a value of 0.4 in the 2019 assessment to reflect the K-type reproductive strategy of the longnose skate. Recruitments were deterministically provided using this steepness value and a Beverton-Holt stock-recruitment relationship since the data in the 2019 assessment was not informative of relative year-class strength. In general, elasmobranchs have relatively low productivity given the K-type reproductive strategy of producing few eggs per female with a significant parental energy investment to increase survival of those few eggs (e.g., production of egg cases and relatively large yolk masses).

Fishing Mortality

Historically, skates in general, and longnose skate in particular, have not been high-priced fishery products. They are taken mostly as bycatch in other commercially important fisheries (Bonfil 1994). Although skates are caught in almost all demersal fisheries and areas off the U.S. West Coast, the vast majority (almost 97 percent) are caught with trawl gear.

Landing records indicate that skates have been retained on the U.S. Pacific Coast at least since 1916 (Martin and Zorzi 1993). Little is known about the species composition of West Coast skate fisheries, particularly prior to 1990. With few exceptions, longnose skate landings have been reported, along with other skate species, under the market category "Unspecified Skates", until 2009 when a sorting requirement for longnose skate was required.

Historically, only the skinned pectoral fins or "wings" were sold, although a small portion of catch would be marketed in the round (whole). The wings were cut onboard the boat and the remainder discarded. Currently, West Coast skates are marketed both whole and as wings. Skates wings are sold fresh or fresh-frozen, as well as dried or salted and dehydrated, for sale predominantly in Asian markets (Bonfil 1994; Martin and Zorzi 1993). It appears that the demand for whole skates did increase greatly during the mid-1990s, as evidenced by the increase in the number of trips where skates were landed. While skates were encountered predominantly as bycatch previously, landings data from this period reveal greater targeting of skates by some vessels. After a few years, the whole-skate market cooled due to downturns in Asian financial markets (Peter Leipzig, Fishermen's Marketing Association, pers. com. as cited by Gertseva and Schirripa (2008)).

Historically, the exploitation rate for the longnose skate has been low. Relative exploitation rates (calculated as dead catch/biomass of age-2 and older fish) are estimated to have been below one percent during the last decade. For the recent and historical period, the assessment estimates that longnose skate was fished at a rate below the relative SPR target (calculated as 1-SPR/1-$SPR_{50\%}$) (Figure 2-45). Relative SPR for 2018 is estimated to be 48 percent, which is below SPR target.

A vulnerability score of 1.68 indicates a low concern for overfishing the stock.

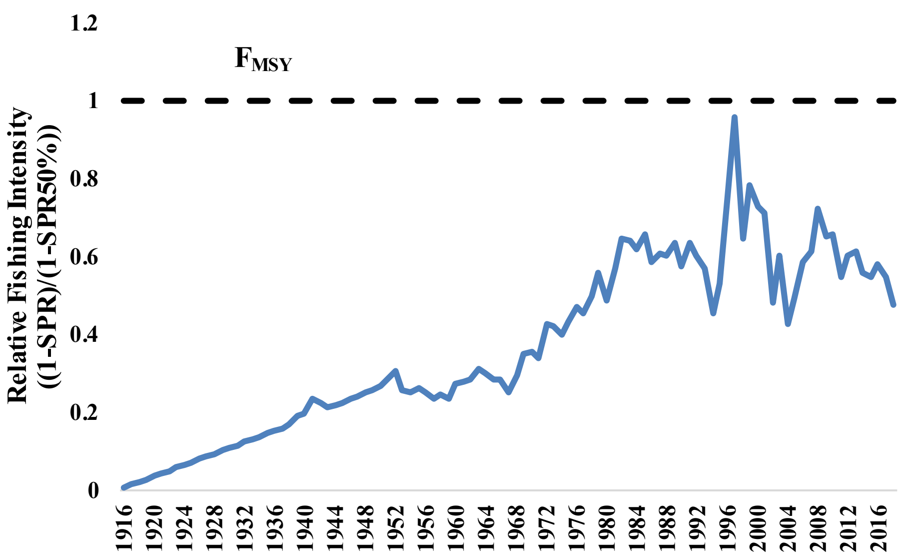

Figure 2-45. Relative fishing intensity of longnose skate, 1916-2018.

2.4.16 Longspine Thornyhead

Distribution and Life History

Longspine thornyhead (*Sebastolobus altivelis*) occur from the southern tip of Baja, California, to the Aleutian Islands (Jacobson and Vetter 1996; Orr, *et al.* 1998). There appears to be no distinct geographic breaks in stock abundance along the West Coast (Fay 2006; Rogers, *et al.* 1997). Adult longspine thornyhead are bottom dwellers and inhabit the deep waters of the continental slope throughout their range.

Longspine thornyhead occur at depths greater between 201 and 1,756 m, most typically between 500 and 1,300 m (Love*, et al.* 2002), and a peak in abundance and spawning biomass in the oxygen minimum zone (OMZ) at about 1,000 m depth (Jacobson and Vetter 1996; Wakefield 1990). Longspine thornyhead are better adapted to deep water than shortspine thornyhead (Siebenaller 1978; Siebenaller and Somero 1982). Wakefield (1990) estimated that in Central California, 83 percent of the longspine thornyhead population resides within an area of the continental slope bounded by 600 and 1,000 m depth.

Unlike shortspine thornyhead, the mean size of longspine thornyhead is similar throughout the depth range of the species (Jacobson and Vetter 1996). Camera sled observations indicate that longspine thornyheads do not school or aggregate, and are distributed relatively evenly over soft sediments (Wakefield 1990). Differences in density of individuals at depth do occur with lat., with higher densities of longspine thornyhead in deep water (1,000-1,400 m) off Oregon than off central California (Jacobson and Vetter 1996).

The strong relationship between depth and size found in shortspine thornyhead (Jacobson and Vetter 1996) is not observed for longspine thornyhead, with the distribution of longspine thornyhead being relatively uniform with depth (Rogers*, et al.* 1997). Unlike shortspine thornyhead, longspine thornyhead do not undergo an ontogenetic migration to deeper waters (Wakefield 1990).

Longspine thornyhead prefer muddy or soft sand bottoms in deep-water environments characterized by high pressure and low oxygen concentrations. These are low productivity (Vetter and Lynn 1997) and low diversity (Haigh and Schnute 2003) habitats where food availability is limited. Longspine thornyhead have adapted to this environment with an extremely slow metabolism that allows it to wait up to 180 days between feedings (Vetter and Lynn 1997). They are not territorial, and do not school. They have no swim bladders; instead, oil in the bones and spines provides floatation. Video observations from submersibles and remotely operated vehicles indicate that thornyhead are sit-and-wait predators that rest on the bottom and remain motionless for extended periods (John Butler, NOAA Fisheries, Southwest Fisheries Science Center, CA, as cited in Jacobson and Vetter (1996)).

The spawning season for longspine thornyhead appears to be extended, and occurs over several months during February, March, and April (Best 1964; Moser 1974; Pearcy 1962; Wakefield and Smith 1990). Both thornyhead species produce a bi-lobed jellied egg mass that is fertilized at depth and which then floats to the surface where final development and hatching occur (Pearcy 1962). An extended larval and pelagic juvenile phase follows, which is thought to be 18-20 months long (Jacobson and Vetter 1996; Moser 1974; Wakefield 1990). Juvenile longspine thornyhead settle on the continental slope at depths between 600 and 1,200 m (Wakefield 1990). Moser (1974) reports a mean length at settlement of 4.2-6.0 cm, although pelagic juveniles up to 69 mm in length have been collected in midwater trawls off Oregon (J. Siebenaller unpublished data, as cited in Wakefield and Smith (1990)).

Following settlement, longspine thornyhead are strictly benthic (Jacobson and Vetter 1996). No apparent pulse in recruitment during the year was observed by Wakefield and Smith (1990), perhaps due to the long (4-5 months) spawning season, variation in growth rates, and variation in the duration of the pelagic period (Wakefield and Smith 1990). There is potential for cannibalism because juveniles settle directly on to the adult habitat (Jacobson and Vetter 1996).

Adult females release between 20,000 and 450,000 eggs over a 4-5 month period (Best 1964; Moser 1974). Wakefield (1990) and Cooper et al. (2005) both found linear relationships between fecundity and somatic weight. The data analyzed by Cooper et al. (2005) indicated that fecundity of longspine thornyhead between 20 and 30 cm in length ranged from 20,000 to 50,000 eggs.

There is considerable uncertainty regarding age and growth of thornyheads (Jacobson and Vetter 1996), although data indicate that longspine thornyhead are long lived. Age estimates of over 40 years have been obtained from otoliths using thin-section and break- and-burn techniques (Ianelli, *et al.* 1994). High frequencies of large longspine thornyhead may be due to a strongly asymptotic growth pattern, with accumulation of many age groups in the largest size-classes (Jacobson and Vetter 1996).

Size-at-age data (Ianelli*, et al.* 1994) indicate that longspine thornyhead grow to a maximum size of about 30 cm total length at ages of about 25-45 years, with little or no sexual dimorphism in length at age – longspine thornyhead in British Columbia, Canada also display no sexual dimorphism (Starr and Haigh 2000). Orr et al. (1998) report a maximum length for longspine thornyhead of 38 cm, although individuals of this size are rare in both trawl surveys and commercial landings. Growth increments on otoliths suggest that juveniles reach 80 mm after 1 year of life as demersal juveniles (Wakefield unpublished data, as cited in (Wakefield and Smith 1990)), which would correspond to an age of 2.5 - 3 years old.

Longspine thornyhead are ambush predators (Jacobson and Vetter 1996). They consume fish fragments, crustaceans, bivalves, and polychaetes and occupy a tertiary consumer level in the food web. Pelagic juveniles prey largely on herbivorous euphausiids and occupy a secondary consumer level in the food web (Love 1996; Smith and Brown 1983). Sablefish and shortspine thornyhead commonly prey on longspine thornyhead (Buckley*, et al.* 1999).

Stock Status and Management History

Longspine thornyhead are exploited in the limited entry deep-water trawl fishery operating on the continental slope that also targets shortspine thornyhead, Dover sole and sablefish (i.e., the DTS fishery). A very small proportion of longspine thornyhead landings is due to non-trawl gears (gillnets, hook and line). Longspine thornyhead and shortspine thornyhead make up a single market category; however, they have been managed under separate harvest specifications since 1992. Beginning in 2011, trawl catches of longspine thornyhead north of 34°27’ N. lat. have been managed using individual fishing quotas.

The thornyhead fishery developed in Northern California during the 1960s. The fishery then expanded north and south, and the majority of the landings of longspine thornyhead have since been in the Monterey, Eureka, and Columbia INPFC areas, with some increase in landings from the Conception (southern CA) and Vancouver (northern WA) INPFC areas in recent years (Fay 2006).

The most recent stock assessment of West Coast longspine thornyhead was done in 2013. This was the fifth assessment done for longspine thornyhead, but only the second in which it was assessed individually (earlier assessments were of longspine thornyhead and shortspine thornyhead in combination). Previous assessments were conducted by Jacobson (Jacobson 1990; 1991), Ianelli et al. (1994), Rogers et al. (1997), and Fay (2006). The 1990 and 1991 assessments were very similar. Important features included reviews of available biological data, and analyses of trends in mean lengths from port samples and catch rates calculated from logbook data. Swept-area and video biomass estimates were used to estimate average biomass levels and exploitation rates in the Monterey to U.S.-Vancouver management areas. The available data were used to conduct per-recruit analyses of yield, revenue, and spawning biomass, and to develop estimates of the then target level of $F_{35\%}$.

Ianelli et al. (1994) assessed the coastwide abundance of longspine thornyhead and shortspine thornyhead based on slope survey data, an updated analysis of the logbook data, and fishery length-composition data to estimate the parameters of length-based Stock Synthesis models, under different assumptions regarding discarding practices.

The Rogers et al. (1997) assessment used a length-based version of Stock Synthesis 1 to fit an age-structured model to data for the Monterey, Eureka, Columbia and Vancouver INPFC areas. Models were fitted to biomass estimates and length data from the AFSC slope surveys (1988-1996), a logbook CPUE index, discarded proportions by year, and length composition data from California and Oregon. Sensitivity to discard rates based on changes in prices and minimum size were explored.

The 2005 assessment of longspine thornyhead estimated spawning biomass in 2005 was approximately 71 percent of unfished spawning biomass (Fay 2006). The model assumed one coastwide stock with one coastwide trawl fishery. Results from the base model suggested that the length compositions from the slope surveys were influencing recruitment in the model, such that the model estimated slightly higher recruitment in the early 1990s, which then declined in the mid to late 1990s.

The 2013 longspine thornyhead assessment indicated a stock depletion of 75 percent at the start of 2013 (Stephens and Taylor 2013). The assessment was highly uncertain with respect to 1) important fishery data (historical catches and discards) and key population vital rates (maturity, age and growth) are highly uncertain, 2) the surveys did not cover the entire depth distributions of the species, 3) key parameters (e.g., M and h) are fixed, and 4) models are sensitive to small changes in assumptions. R_0 was used to bracket uncertainty. The SSC categorized the stock as a category 2 stock given relatively high assessment uncertainty.

The Council adopted the default harvest control rule for longspine thornyhead of ACL equal to 76 percent of the coastwide ABC with a P* of 0.4 for the stock north of 34°27' N. lat. and 24 percent of the coastwide ABC for the stock south of 34°27' N. lat. The apportionment of coastwide OFLs and ABCs is based on the 2003-2012 average swept area biomass estimated north and south of Pt. Conception at 34°27' N. lat. in the NWFSC trawl survey. A catch only-projection of longspine thornyhead was provided to inform harvest specifications for 2021 and beyond.

Stock Productivity

Stephens and Taylor (2013) estimated annual longspine thornyhead recruitment using a Beverton-Holt stock-recruitment function and assuming a steepness value of 0.6. Most 2013 rockfish assessments used a steepness prior of 0.779, estimated from a meta-analysis of rockfish assessment results. This value might be expected in the 2013 longspine thornyhead assessment; however, rockfish ecology and reproduction are quite different from those of thornyheads, which (for example) do not give birth to live young but rather spawn floating egg masses.

Steepness in the shortspine thornyhead assessment was fixed at 0.6 both in the 2005 and 2013 models (Hamel 2006c; Taylor and Stephens 2013). This value was justified based on consistency between the modeling approach and management targets, in addition to being within a range of biologically reasonable values. For consistency, steepness for the longspine thornyhead model was also fixed at 0.6.

Annual deviations about this stock-recruitment curve were estimated for the years 1944 through 2012. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates. The 2013 longspine thornyhead assessment is relatively uninformative of relative year class strength since ages were not used in the model (thornyheads are notoriously difficult to age). Therefore, a length-based assessment with an assumed steepness is used to determine recruitment.

Fishing Mortality

The estimated exploitation rate of longspine thornyhead was above the current F_{MSY} harvest rate through much of the 1990s and, in hindsight, given the current target harvest rate, overfishing was occurring. However, stock biomass was estimated to have never dropped below the target B_{MSY} level. There is very little risk of overexploitation of longspine thornyhead given their deep distribution beyond the 700 fm limit to West Coast bottom trawling implemented under Amendment 19.

The PSA vulnerability score of 1.54 for longspine thornyhead also indicates a low concern for potential overfishing of the stock.

2.4.17 Pacific Cod

Distribution and Life History

Pacific cod (*Gadus macrocephalus*) are widely distributed in the coastal north Pacific, from the Bering Sea to Southern California in the east, and to the Sea of Japan in the west. Adult Pacific cod occur as deep as 875 m (Allen and Smith 1988), but the vast majority occurs between 50 m and 300 m (Allen and Smith 1988; Love 1996; NOAA 1990). Along the West Coast, Pacific cod prefer shallow, soft-bottom habitats in marine and estuarine environments (Garrison and Miller 1982), although adults have been found associated with coarse sand and gravel substrates (Garrison and Miller 1982; Palsson 1990). Larvae and small juveniles are pelagic; large juveniles and adults are parademersal (Dunn and Matarese 1987) NOAA 1990). Adult Pacific cod are not considered to be a migratory species. There is, however, a seasonal bathymetric movement from deep spawning areas of the outer shelf and upper slope in fall and winter to shallow middle-upper shelf feeding grounds in the spring (Dunn and Matarese 1987).

Pacific cod have external fertilization (Hart 1988; NOAA 1990) with spawning occurring from late fall to early spring. Their eggs are demersal. Larvae may be transported to nursery areas by tidal currents (Garrison and Miller 1982). Half of females are mature by three years (55 cm) and half of males are mature by two years (45 cm) (Dunn and Matarese 1987). Juveniles and adults are carnivorous and feed at night (Allen and Smith 1988; Palsson 1990) with the main part of the adult Pacific cod diet being whatever prey species is most abundant (Kihara and Shimada 1988; Klovach*, et al.* 1995). Larval feeding is poorly understood. Pelagic fish and sea birds eat Pacific cod larvae, while juveniles are eaten by larger demersal fish, including Pacific cod. Adults are preyed upon by toothed whales, Pacific halibut, salmon shark, and larger Pacific cod (Hart 1988; Love 1996; NOAA 1990; Palsson 1990). The closest competitor of the Pacific cod for resources is the sablefish (Allen 1982).

Stock Status and Management History

The West Coast population of Pacific cod has never been formally assessed. Targetable amounts of Pacific cod occur off northern Washington infrequently since the West Coast EEZ is at the southern limit of their distribution. The Pacific cod OFL has been set at the highest annual historical catch observed for the stock (in 1985) and ACLs/OYs have been set at half that amount. The SSC rates Pacific cod as a category 3 stock since the OFL is based on such a data-limited method.

The Council adopted the default harvest control rule for Pacific cod with the 2019 and 2020 ACL of 1,600 mt based on half the 3,200 mt OFL. The ABC is based on a P* of 0.4.

Stock Productivity

The PSA productivity score of 2.11 indicates a relatively high productivity and the vulnerability score of 1.34 for Pacific cod indicates a low concern for potential overfishing of the stock.

Fishing Mortality

Pacific cod occur periodically in targetable amounts off northern Washington. In some years they are targeted because the abundance of this fringe population (in the context of the species' distribution off the West Coast) is large enough to be targeted and, in some years, they are not available. The annual total mortality of Pacific cod has ranged from 39 mt (2008) to 1,415 mt (2004) during 2002-2012. The ACL of 1,600 mt has never been exceeded.

2.4.18 Pacific Ocean Perch

Distribution and Life History

Pacific ocean perch (POP, *Sebastes alutus*) are most abundant in the Gulf of Alaska, and have been observed off of Japan, in the Bering Sea, and south to Baja California, although they are sparse south of Oregon and rare in southern California (Eschmeyer*, et al.* 1983; Gunderson 1971; Miller and Lea 1972). They primarily inhabit waters of the upper continental slope (Dark and Wilkins 1994) and are found along the edge of the continental shelf (Archibald, *et al.* 1983). Pacific ocean perch occur as deep as 825 m, but usually are at 200 m to 450 m and along submarine canyons and depressions (Love, *et al.* 2002). Throughout their range, POP are generally associated with gravel, rocky, or boulder type substrate (Ito, *et al.* 1986). Larvae and juveniles are pelagic; subadults and adults are benthopelagic (living and feeding on the bottom and in the water column). Adults form large schools 30 m wide, to 80 m deep, and as much as 1,300 m long (NOAA 1990). They also form spawning schools (Gunderson 1971). Juvenile POP form ball-shaped schools near the surface or hide in rocks (NOAA 1990).

Pacific ocean perch winter and spawn in deeper water (>275 m). In the summer (June through August) they move to feeding grounds in shallower water (180 m to 220 m) to allow gonads to ripen (Archibald, *et al.* 1983; Gunderson 1971; NOAA 1990). They are slow-growing and long-lived; the maximum age has been estimated at about 98 years (Heifetz, *et al.* 2000). They can grow up to about 54 cm and 2 kg (Archibald, *et al.* 1983; Beamish 1979; Gunderson 1971; Ito, *et al.* 1986; Mulligan and Leaman 1992; NOAA 1990). POP are carnivorous. Larvae eat small zooplankton. Small juveniles eat copepods, and larger juveniles feed on euphausiids (krill). Adults eat euphausiids, shrimps, squids, and small fish. Immature fish feed throughout the year, but adults feed only seasonally, mostly April through August (NOAA 1990). POP predators include sablefish and Pacific halibut.

Stock Status and Management History

POP were harvested exclusively by U.S. and Canadian vessels in the Columbia and Vancouver INPFC areas prior to 1966. Large Soviet and Japanese factory trawlers began fishing for POP in 1965 in the Vancouver area and in the Columbia area a year later. Intense fishing pressure by these foreign fleets occurred from 1966 to 1975. The mandates of the MSA, passed by Congress in 1976, eventually ended foreign fishing within 200 miles of the United States coast.

The POP resource off the West Coast was and was estimated to have been overfished before implementation of the groundfish FMP in 1982, and Council actions to conserve the resource likewise predate the FMP. Large removals of POP in the foreign trawl fishery, followed by significant declines in catch and abundance, led the Council to limit harvest beginning in 1979. A 20–year rebuilding plan for POP was adopted in 1981. Rebuilding under this original plan was largely influenced by a cohort analysis of 1966-1976 catch and age composition data (Gunderson 1979), updated with 1977-1980 data (Gunderson 1981), and an evaluation of trip limits as a management tool (Tagart, *et al.* 1980). This was the first time trip limits were used by the Council to discourage targeting and overharvest of an overfished stock, and it remains a management strategy in use today in the West Coast groundfish fishery. In addition to trip limits, the Council significantly lowered the OY for POP. After twenty years of rebuilding under the original plan, the stock stabilized at a lower equilibrium than estimated in the pre-fishing condition. While continuing stock decline was abated, rebuilding was not achieved as the stock failed to increase in abundance to B_{MSY}.

Ianelli and Zimmerman (1998) estimated POP female spawning biomass in 1997 to be at 13 percent of its unfished level, thereby confirming that the stock was overfished. NMFS formally declared POP overfished in March 1999 after the groundfish FMP was amended to incorporate the tenets of the Sustainable Fisheries Act. The Council adopted and NMFS enacted more conservative management measures in 1999 as part of a redoubled rebuilding effort.

A 2000 POP assessment suggested the stock was more productive than originally thought (Ianelli, *et al.* 2000). A revised POP rebuilding analysis was completed and adopted by the Council in 2001 (Punt and Ianelli 2001). This analysis estimated a T_{MIN} of 12 years and a T_{MAX} of 42 years. It was noted in the rebuilding analysis that the ongoing retrospective analysis of historic foreign fleet catches was likely to change projections of POP rebuilding.

The 2003 POP assessment (Hamel, *et al.* 2003) incorporated updated survey and fishery data including the retrospective of foreign fleet catches (Rogers 2003b). The assessment covered areas from southern Oregon to the U.S. border with Canada, the southern extent of POP distribution. The overall conclusion was that the stock was relatively stable at approximately 28 percent of its unfished biomass ($B_{28\%}$). Of all the changes and additions to the data, the historical catch estimates had the greatest effect, resulting in lower estimates of both equilibrium unfished biomass (B_0) and MSY.

A POP rebuilding plan was adopted in 2003 under Amendment 16-2. The rebuilding plan was informed by a revised rebuilding analysis based on the 2000 assessment and conducted in 2001 (Punt and Ianelli 2001). The rebuilding plan established a target rebuilding year of 2027 and a harvest control rule of F = 0.0082 (with a P_{MAX} of 70 percent).

The 2003 assessment estimated a stock depletion of 28 percent at the start of 2003 (Hamel, *et al.* 2003). The 2003 rebuilding analysis (Punt, *et al.* 2003) was used to amend the harvest control rule and set annual POP OYs for the 2004-2006 period. The amended harvest control rule was F = 0.0257.

The 2003 POP assessment was updated in 2005, 2007, and 2009. The 2005 update assessment estimated a stock depletion of 23.4 percent of its unfished level at the start of 2005 (Hamel 2006b). The 2005 POP rebuilding analysis (Hamel 2006a) was used to inform revisions to the POP rebuilding plan. The revised rebuilding plan, which was adopted under Amendment 16-4, specified a target rebuilding year of 2017 and a constant harvest rate strategy (SPR = 86.4 percent).

The 2007 POP assessment update estimated a stock depletion of 27.5 percent at the start of 2007 (Hamel 2008d). The 2007 rebuilding analysis indicated rebuilding was progressing ahead of schedule (Hamel 2008b). No modifications to the rebuilding plan were made.

The 2009 POP assessment estimated a stock depletion of 28.6 percent at the start of 2009 (Hamel 2009b). The 2009 POP rebuilding analysis (Hamel 2009a) predicted rebuilding would not occur by the target year of 2017 with at least a 50 percent probability even in the absence of fishing-related mortality beginning in 2011 (i.e., $T_{F=0}$). Therefore, the rebuilding plan was revised by changing the target rebuilding year to 2020 while maintaining the constant SPR harvest rate of 86.4 percent.

A full assessment in 2011 estimated a stock depletion of 19.1 percent at the start of 2011 (Hamel and Ono 2011). The significant decrease in the estimated depletion of the stock was largely due to a much higher estimate of initial, unfished biomass (B_0). Previous assessments assumed a large recruitment in the late 1950s provided the higher biomass to support the estimated removals by the foreign fleets without any data to support that assumption. The assumption in the 2011 assessment is that the large foreign fleet catch fished the biomass down to critical levels, thus resulting in a substantially larger B_0 estimate. The 2011 assessment also estimated a longer sequence of higher recruitment based on fitting to the data available for early years of the assessment period. The 2011 rebuilding analysis (Hamel 2011) predicted rebuilding would not occur by the target year of 2020 with at least a 50 percent probability even in the absence of fishing-related mortality beginning in 2013 (i.e., $T_{F=0}$). Therefore, the rebuilding plan was revised by changing the target rebuilding year to 2051 while maintaining the constant SPR harvest rate of 86.4 percent.

A 2017 full assessment of POP indicated the stock was successfully rebuilt with an estimated depletion of 76.6 percent (above the target of 40 percent) at the start of 2017 (Wetzel*, et al.* 2017). Unlike past assessments, the 2017 assessment estimated the stock was never overfished and was in the precautionary zone with a depletion between 37 and 39 percent during 1971-1995 (Figure 2-46).

Similar to the 2011 assessment, the 2017 assessment models the population as a single stock off of the U.S. West Coast from northern California to the Canadian border. A number of revisions were made to the data used for the 2017 stock assessment including: 1) disaggregating the one combined fleet used in 2011 to four component fleets, 2) using new historical catch reconstruction landings for Washington, 3) starting the model in 1918, 4) re-analyzing all of the fishery-independent indices using VAST, 5) dropping the fishery CPUE logbook index, 6) dropping the Triennial survey index, 7) updating maturity and fecundity relationships, and 8) updating landings and composition data.

There remains considerable uncertainty associated with the steepness parameter, which is the main driver of the large change in status and scale between the 2011 assessment and the 2017 assessment. It was concluded that the available data in the 2017 assessment was insufficient to estimate steepness. It is usual in this situation to base the assessment on the mean of the prior for steepness, but this value led to an unrealistically low estimate of survey catchability. Therefore, the assumed steepness was set equal to 0.5 in the assessment.

The SSC recommended the next assessment be a full assessment given the considerable uncertainty associated with the 2017 assessment. They also recommended the next assessment should reconsider the Triennial survey. The SSC recommended that the POP assessment be assigned to category 2 owing to the extreme sensitivity of the model outputs to changes to the specifications of the model.

The Council adopted the default harvest control rule of setting the ACL equal to the ABC under the previous P* (0.45) for a newly rebuilt stock for 2019 and beyond.

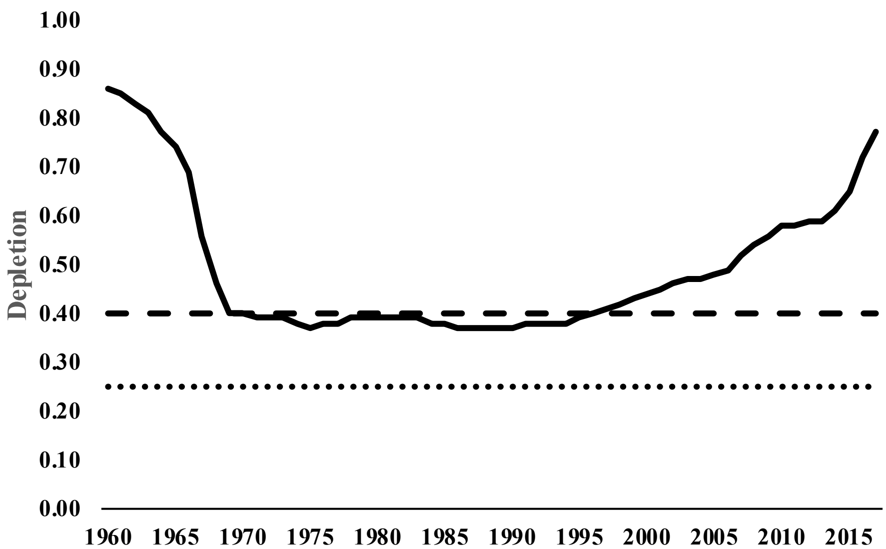

Figure 2-46. Relative depletion of Pacific ocean perch from 1960 to 2017 based on the 2017 stock assessment.

Stock Productivity

Stock-recruitment steepness was assumed to be 0.5 in the 2017 POP stock assessment base model. The 2017 assessment assumed no connectivity with the other assessed POP stocks in Canada and Alaska. POP off the U.S. West Coast (mostly Washington and Oregon) are at the southern end of the range where there are enough POP to be commercially important, and the numbers seen are likely related to movement across the Canadian border, as well as reproductive success (recruitment), stock status, and fishing mortality north of the border. The actual productivity of the West Coast POP stock may be higher than implied by the 2017 steepness assumption; however, assuming the mean prior of steepness in the most recent meta-analysis of category 1 assessments (h = 0.718) led to an unrealistically low estimate of survey catchability. Such model uncertainties led to the stock being downgraded to a category 2 assessment.

Recruitment deviations were estimated for the entire assessment period. There is little information regarding recruitment prior to 1965, and the uncertainty in these estimates is expressed in the model. Past assessments estimated large recruitments in 1999 and 2000. In recent years, a recruitment of unprecedented size is estimated to have occurred in 2008 (Figure 2-47). Additionally, there is early evidence of a strong recruitment in 2013. The four lowest recruitments estimated within the model (in ascending order) occurred in 2012, 2003, 2005, and 2007 (Figure 2-47).

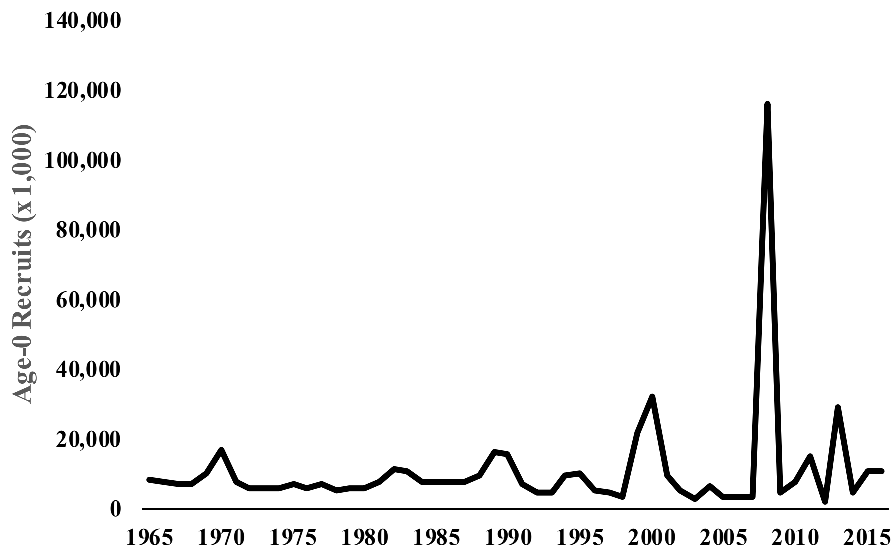

Figure 2-47. Time series of estimated (age-0) Pacific ocean perch recruitments, 1965-2016 from the 2017 assessment.

Fishing Mortality

Historically, the West Coast was severely overfished by the foreign trawl fisheries in the mid-1960s. POP are caught almost exclusively by groundfish trawl gear and predominantly bottom trawls operating on the outer continental shelf and slope north of 43° N. lat. POP are distributed from 30-350 fm, with the core distribution between 110-220 fm.

The spawning output of POP reached a low in 1989 (Figure 2-46). Landings for POP decreased significantly in 2000 compared to previous years with implementation of the POP rebuilding plan. The estimated relative depletion was possibly below the target biomass level between the 1970s and 1990s, but has likely remained above the target otherwise, and currently is significantly greater than the 40 percent unfished spawning output target. Throughout the late 1960s and the early 1970s the exploitation rate and values of relative spawning potential (1-SPR) were mostly above target levels (Figure 2-48). Recent exploitation rates on POP were predicted to be significantly below target levels.

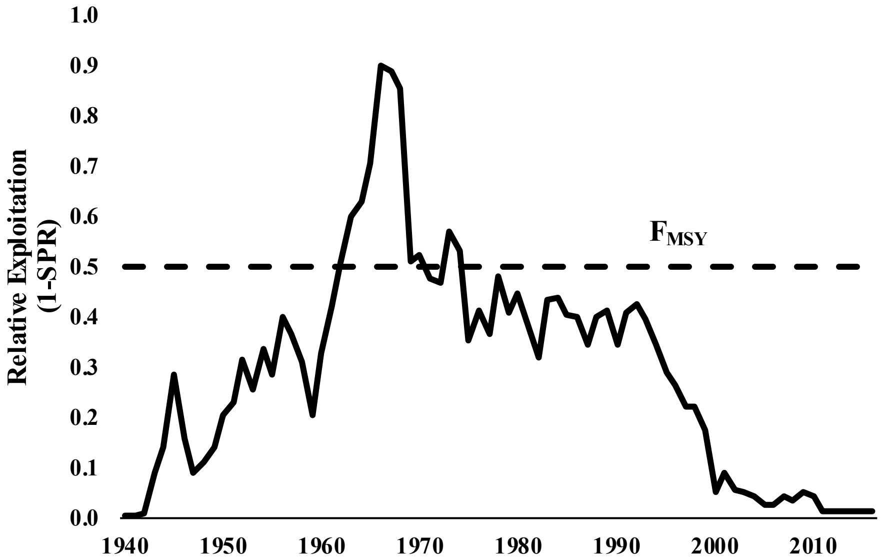

Figure 2-48. Estimated annual relative exploitation rate of West Coast Pacific ocean perch relative to the current proxy F_{MSY} target, 1940-2016.

2.4.19 Pacific Whiting

Distribution and Life History

Pacific whiting (*Merluccius productus*), also referred to as Pacific hake, is a semi-pelagic schooling species distributed along the West Coast of North America generally ranging from 25° N. lat. to 55° N. lat. It is among 18 species of hake from four genera (being the majority of the family *Merluccidae*), which are found in both hemispheres of the Atlantic and Pacific Oceans (Alheit and Pitcher 1995; Lloris*, et al.* 2005). The coastal stock of Pacific whiting is currently the most abundant groundfish population in the California Current system. Smaller populations of this species occur in the major inlets of the Northeast Pacific Ocean, including the Strait of Georgia, Puget Sound, and the Gulf of California. Genetic studies indicate that the Strait of Georgia and the Puget Sound populations are genetically distinct from the coastal population (Iwamoto*, et al.* 2004; King*, et al.* 2012). Genetic differences have also been found between the coastal population and hake off the West Coast of Baja California (Vrooman and Paloma 1977). The coastal stock is also distinguished from the inshore populations by larger body size and seasonal migratory behavior.

The coastal stock of Pacific whiting typically ranges from the waters off southern California to northern British Columbia and in some years to southern Alaska, with the northern boundary related to fluctuations in annual migration. In spring, adult Pacific whiting migrate onshore and northward to feed along the continental shelf and slope from northern California to Vancouver Island. In summer, Pacific whiting often form extensive midwater aggregations in association with the continental shelf break, with highest densities located over bottom depths of 200–300 m (Dorn and Methot 1991; Dorn and Methot 1992).

Older Pacific whiting exhibit the greatest northward migration each season, with two- and three-year old fish rarely observed in Canadian waters north of southern Vancouver Island. During El Niño events (warm ocean conditions, such as occurred in 1998), a larger proportion of the stock migrates into Canadian waters, apparently due to intensified northward transport during the period of active migration (Agostini*, et al.* 2006; Dorn 1995). In contrast, La Niña conditions (colder water, such as occurred in 2001) result in a southward shift in the stock's distribution, with a much smaller proportion of the population found in Canadian waters, as seen in the 2001 survey.

Spawning occurs from December through March, peaking in late January (Smith 1995). Pacific whiting are oviparous with external fertilization. Eggs of the Pacific whiting are neritic and float to neutral buoyancy (Bailey 1982; Bailey*, et al.* 1982; NOAA 1990). Hatching occurs in five days to six days, and within three months to four months juveniles are typically 35 mm (Hollowed 1992). Juveniles move to deeper water as they get older (NOAA 1990). Females mature at three years to four years (34 cm to 40 cm) and nearly all males are mature by three years (28 cm). Females grow more rapidly than males after four years; growth ceases for both sexes at 10 to 13 years (Bailey*, et al.* 1982).

All life stages feed near the surface late at night and early in the morning (Sumida and Moser 1984). Larvae eat calanoid copepods, as well as their eggs and nauplii (McFarlane and Beamish 1986; Sumida and Moser 1984). Juveniles and small adults feed chiefly on euphausiids (NOAA 1990). Large adults also eat amphipods, squid, herring, smelt, crabs, and sometimes juvenile whiting (Bailey 1982; Dark and Wilkins 1994; McFarlane and Beamish 1986). Eggs and larvae of Pacific whiting are eaten by pollock, herring, invertebrates, and sometimes Pacific whiting. Juveniles are eaten by lingcod, Pacific cod, and rockfish species. Adults are preyed on by sablefish, albacore, pollock, Pacific cod, marine mammals, soupfin sharks, and spiny dogfish (Fiscus 1979; McFarlane and Beamish 1986).

Stock Status and Management History

The history of the coastal whiting fishery is characterized by rapid changes brought about by the development of foreign fisheries in 1966, joint-venture fisheries in the early 1980s, and domestic fisheries in 1990s. Since implementation of the Magnuson-Stevens Fishery Conservation and Management Act in the U.S. and the declaration of a 200-mile fishery conservation zone in the U.S. and Canada in the late 1970s, annual quotas (or catch targets) have been used to limit the catch of Pacific hake in both zones by foreign and domestic fisheries. Scientists from both countries historically collaborated through the Technical Subcommittee of the Canada-U.S. Groundfish Committee (TSC), and there were informal agreements on the adoption of annual fishing policies. During the 1990s, disagreements between the U.S. and Canada on the allotment of the catch limits between U.S. and Canadian fisheries led to quota overruns; 1991-1992 quotas summed to 128 percent of the limit, while the 1993-1999 combined quotas were 107 percent of the limit on average. In 2003, a bilateral Pacific whiting management agreement was signed by both countries that created formal allocations of the harvestable surplus, as well as an international process for assessing and managing the stock. This international process was fully implemented in 2012.

Pacific whiting is managed consistent with the Agreement with Canada on Pacific Hake/Whiting. Annual catch limits, now called TACs (total allowable catches), for Pacific whiting are adopted on an annual basis after a stock assessment is completed by a Joint Technical Committee (JTC) and reviewed in February by an international Scientific Review Group (SRG). In March, the JTC and SRG present the assessment to the Joint Management Committee (JMC), the international decision-making body. The JMC presents their TAC recommendations to their respective government officials before these TACs are implemented in regulations. The coastwide TAC for the U.S. West Coast and Canada is allocated 26.12 percent to Canada and 73.88 percent to the U.S. under Article III (2) of the Agreement.

A 2022 stock assessment for Pacific whiting has been conducted (Edwards*, et al.* 2022) and endorsed by the SRG in the U.S./Canada Pacific Whiting Treaty Process. The 2022 whiting assessment indicates the median estimate of the 2022 relative spawning biomass (depletion) is 65 percent. The median relative spawning biomass has progressively declined since 2019, due to the aging large cohorts (2010, 2014, and 2016) and relatively high catches. Based on limited data, the 2020 cohort looks likely to be large.

Results from the base model indicate that since the 1960s, Pacific whiting female spawning biomass has ranged from well below to above unfished equilibrium. Model estimates suggest that it was below the unfished equilibrium in the 1960s, at the start of the assessment period, due to lower than average recruitment. The stock is estimated to have increased rapidly and was above unfished equilibrium in the mid-1970s and mid-1980s (after two large recruitments in the early 1980s). It then declined steadily to a low in 1999. This was followed by a brief increase to a peak in 2002 as the very large 1999 year class matured. The 1999 year class largely supported the fishery for several years due to relatively small recruitments between 2000 and 2007. With the aging 1999 year class, median female spawning biomass declined throughout the late 2000s, reaching a time-series low of 0.605 million mt in 2010. Median spawning biomass is estimated to have peaked again in 2013 and 2014 due to a very large 2010 year class and an above-average 2008 year class. The subsequent decline from 2014 to 2016 is primarily from the 2010 year class surpassing the age at which gains in weight from growth are greater than the loss in weight from mortality (growth-mortality transition). The 2014 year class is estimated to be large, though not as large as the 1999 and 2010 year classes, increasing the biomass in 2017. The estimated biomass has declined since 2017 as the 2014 year class moves through the growth-mortality transition (and the 2010 year class continues to do so) during a time of record catches.

The 2021 coastwide TAC for Pacific whiting was not decided by the JMC given an impasse in the U.S.-Canada treaty process. The U.S.-adjusted TAC decided by NMFS is 369,400 mt for the 2021 fishery.

Stock Productivity

Pacific whiting exhibit high relative productivity as evidenced by fast growth, a high natural mortality rate (M), and high steepness in the Beverton-Holt stock-recruitment function. The prior for steepness in the 2021 Pacific whiting assessment is based on the median (0.79), 20th (0.67) and 80th (0.87) percentiles from the Myers et al. (1999) meta-analysis of the family *Gadidae*, and has been used in previous U.S. assessments since 2007.

Pacific Hake appear to have low recruitment with occasional large year-classes. Very large year classes in 1980, 1984, and 1999 supported much of the commercial catch from the 1980s to the mid-2000s. From 2000 to 2007, estimated recruitment was at some of the lowest values in the time series, but this was followed by an above average 2008 year class. Current estimates continue to indicate a very strong 2010 year class comprising 64 percent of the coast-wide commercial catch in 2014, 33 percent of the 2016 catch, 23 percent of the 2018 catch, and 15 percent of the 2020 catch. The decline from 2014 to 2016 was due to the large influx of the 2014 year class (50 percent of the 2016 catch was age-2 fish from the 2014 year class; this was larger than the proportion of age-2 fish, 41 percent, from the 2010 year class in 2012). The median estimate of the 2010 year class is just below the highest ever (for 1980), with a 46 percent probability that the 2010 year class is larger than the 1980 year class. The model currently estimates small 2011, 2013, 2015, and 2018 year classes (median recruitment well below the mean of all median recruitments).

The PSA productivity score for Pacific whiting (P = 2.00) is relatively high and the low vulnerability score (V = 1.69) indicates a low concern for potential overfishing.

Fishing Mortality

Median relative fishing intensity on the stock is estimated to have been below the target of 1.0 for all years. Median exploitation fraction (catch divided by biomass of fish of age-2 and above) peaked in 1999 and then reached similar levels in 2006 and 2008. Over the last five years, the exploitation fraction was the highest in 2017. Median relative fishing intensity is estimated to have declined from 92.7 percent in 2010 to 45.5 percent in 2015, and then it leveled off around 75 percent from 2016 to 2019 before dropping to 65.9 percent in 2020. The exploitation fraction has increased from a recent low of 0.05 in 2012 to 0.13 in 2017 and has remained relatively stable since then (dropping no further than 0.11).

2.4.20 Petrale Sole

Distribution and Life History

Petrale sole (*Eopsetta jordani*) is a right-eyed flounder in the family Pleuronectidae ranging from the western Gulf of Alaska to the Coronado Islands, northern Baja California, (Hart 1988; Kramer and O'Connell 1995; Love*, et al.* 2002) with a preference for soft substrates at depths ranging from 0-550 m (Love*, et al.* 2002). In northern and central California petrale sole are mostly found on the middle and outer continental shelf (Allen*, et al.* 2006).

There is little information regarding the stock structure of petrale sole off the U.S. Pacific coast. Tagging studies show adult petrale sole can move up to 350-390 miles, having the ability to be highly migratory with the possibility for homing ability (Alverson and Chatwin 1957; MBC 1987). Juveniles show little coastwide or bathymetric movement while studies suggest that adults generally move inshore and northward onto the continental shelf during the spring and summer to feeding grounds and offshore and southward during the fall and winter to deep water spawning grounds (Hart 1988; Love 1996; MBC 1987). Adult petrale sole can tolerate a wide range of bottom temperatures (Perry*, et al.* 1994).

Mixing of fish from multiple deep water spawning grounds likely occurs during the spring and summer when petrale sole are feeding on the continental shelf. Fish that were captured, tagged, and released off the northwest Coast of Washington during May and September were subsequently recaptured during winter from spawning grounds off Vancouver Island (British Columbia, 1 fish), Heceta Bank (central Oregon, 2 fish), Eureka (northern California, 2 fish), and Halfmoon Bay (central California, 2 fish) (Pederson 1975). Fish tagged south of Fort Bragg (central California) during July 1964 were later recaptured off Oregon (11 fish), Washington (6 fish), and Swiftsure Bank (southwestern tip of Vancouver Island, 1 fish) (D. Thomas, California Department of Fish and Game, Menlo Park, CA, cited by Sampson and Lee (1999)).

The highest densities of spawning adults off of British Columbia, as well as of eggs, larvae, and juveniles are found in the waters around Vancouver Island. Adults may utilize nearshore areas as summer feeding grounds and non-migrating adults may stay there during winter (Starr and Fargo 2004).

Petrale sole spawn during the winter at several discrete deep water sites (270-460 m) off the U.S. West Coast, from November to April, with peak spawning taking place from December to February (Best 1960; Casillas*, et al.* 1998; Castillo 1995; Castillo*, et al.* 1993; Garrison and Miller 1982; Gregory and Jow 1976; Harry 1959; Love 1996; Moser 1996; Reilly*, et al.* 1994). Females spawn once each year and fecundity varies with fish size, with one large female laying as many as 1.5 million eggs (Porter 1964). Petrale sole eggs are planktonic, ranging in size from 1.2 to 1.3 mm, and are found in deep water habitats at water temperatures of 4–10 degrees C and salinities of 25–30 ppt (Alderdice and Forrester 1971; Best 1960; Gregory and Jow 1976; Ketchen and Forrester 1966). The duration of the egg stage can range from approximately 6 to 14 days (Alderdice and Forrester 1971; Casillas*, et al.* 1998; Hart 1988; Love 1996).

Petrale sole larvae are planktonic, ranging in size from approximately 3 to 20 mm, and are found up to 150 km offshore foraging upon copepod eggs and nauplii (Casillas*, et al.* 1998; Hart 1988;

MBC 1987; Moser 1996). The larval duration, including the egg stage, spans approximately 6 months with larvae settling at about 2.2 cm in length on the inner continental shelf (Pearcy, *et al.* 1977). Juveniles are benthic and found on sandy or sand-mud bottoms (Eschmeyer, *et al.* 1983; MBC 1987) and range in size from approximately 2.2 cm to the size at maturity, 50 percent of the population is mature at approximately 38 cm and 41 cm for males and females, respectively (Casillas, *et al.* 1998). No specific areas have been identified as nursery grounds for juvenile petrale sole. In the waters off British Columbia, Canada larvae are usually found in the upper 50 m far offshore, juveniles at 19–82 m and large juveniles at 25–125 m (Starr and Fargo 2004).

Adult petrale sole achieve a maximum size of around 50 cm and 63 cm for males and females, respectively (Best 1963; Pedersen 1975). The maximum length reported for petrale sole is 70 cm (Eschmeyer, *et al.* 1983; Hart 1988; Love, *et al.* 2002) while the maximum observed break and burn age is 31 years (Haltuch, *et al.* 2013).

Petrale sole juveniles are carnivorous, foraging on annelid worms, clams, brittle star, mysids, sculpin, amphipods, and other juvenile flatfish (Casillas, *et al.* 1998; Ford 1965; Pearsall and Fargo 2007). Predators of juvenile petrale sole include adult petrale sole as well as other larger fish (Casillas, *et al.* 1998; Ford 1965) while adults are preyed upon by marine mammals, sharks, and larger fishes (Casillas, *et al.* 1998; Love 1996; Trumble 1995).

One of the ambushing flatfishes, adult petrale sole have diverse diets that become more piscivorous at larger sizes (Allen, *et al.* 2006). Adult petrale sole are found on sandy and sand-mud bottoms (Eschmeyer, *et al.* 1983) foraging for a variety of invertebrates including, crab, octopi, squid, euphausiids, and shrimp, as well as anchovies, hake, herring, sand lance, and other smaller rockfish and flatfish (Birtwell, *et al.* 1984; Casillas, *et al.* 1998; Ford 1965; Kravitz, *et al.* 1977; Love 1996; Pearsall and Fargo 2007; Reilly, *et al.* 1994). On the continental shelf petrale sole generally co-occur with English sole, rex sole, Pacific sanddab, and rock sole (Kravitz, *et al.* 1977).

Castillo (1992) and Castillo et al. (1995) suggest that density-independent survival of early life stages is low and show that offshore Ekman transportation of eggs and larvae may be an important source of variation in year class strength in the Columbia INPFC area. The effects of the Pacific Decadal Oscillation (PDO) on California current temperature and productivity (Mantua, *et al.* 1997) may also contribute to non-stationary recruitment dynamics for petrale sole. The prevalence of strong late 1990s year classes for many West Coast groundfish species suggest that environmentally driven recruitment variation may be correlated among species with relatively diverse life history strategies.

Stock Status and Management History

Petrale sole were lightly exploited during the early 1900s. By the 1950s the petrale sole fishery was well-developed and showing clear signs of depletion and declines in catches and biomass. Wetzel (2019) estimated petrale sole biomass on the U.S. West Coast dropped below the $B_{25\%}$ management target during the 1960s and generally stayed there through 2012. The stock declined below the $B_{12.5\%}$ overfished threshold from the early1980s until the early 2000s. Since 2000 the stock has increased, reaching a peak of 14.4 percent of unfished biomass in 2005, followed by a decreasing trend through 2010. The petrale sole biomass currently shows an increasing trend with.

the estimated relative depletion level in 2019 is 39.1 percent, which is above the B_{MSY} target of $B_{25\%}$.

Early stock assessments only assessed petrale sole in the combined U.S.-Vancouver and Columbia INPFC areas (i.e., petrale in these areas were treated as a unit stock, using time series of data that began during the 1970s) (Demory 1984; Turnock, *et al.* 1993). The first assessment used stock reduction analysis and the second assessment used the length-based Stock Synthesis model. The third petrale sole assessment utilized the hybrid length-and-age-based Stock Synthesis 1 model, using data from 1977–1998 (Sampson and Lee 1999), and structured the data into separate seasonal fisheries - one for the winter spawning ground fishery that harvests larger fish and another for the rest of the year. Sampson and Lee (1999) estimated petrale sole stock depletion at 42 percent of unfished biomass at the start of 1999.

The 2005 petrale sole assessment (Lai, *et al.* 2006) was conducted assuming two separate stocks: the northern stock encompassing the U.S. Vancouver and Columbia INPFC areas and the southern stock including the Eureka, Monterey, and Conception INPFC areas. Petrale sole in the north was estimated to be at 34 percent of unfished spawning stock biomass in 2005. In the south, the stock was estimated to be at 29 percent of unfished spawning stock biomass. Biomass trends were qualitatively similar in both areas, and also showed consistency with petrale sole trends in Canadian waters. Both stocks were estimated to have been below the Council's MSST of $B_{25\%}$[8] from the mid-1970s until very recently. Estimated harvest rates were in excess of the target fishing mortality rate of $F_{40\%}$[9] during this period as well. Petrale sole in both areas showed large recent increases in stock size, which was consistent with the strong upward trend in the shelf survey biomass index. In 2005, the STAR panel noted that the petrale sole stock trends were similar in both northern and southern areas in spite of the different modeling choices made for each area, and that a single coastwide assessment should be considered (Dorn, *et al.* 2006).

The 2009 petrale assessment estimated a stock depletion of 11.6 percent of its unfished biomass at the start of 2009 (Haltuch and Hicks 2009b). That result compelled NMFS to declare the stock overfished in 2010. The 2009 assessment treated petrale sole as a single coastwide stock, with the fleets and landings structured by state (WA, OR, CA) area of catch. The data series for historical catches was extended back to 1876, the first year of estimated exploitation for the stock.

New proxy management reference points used to manage FMP flatfish stocks, such as petrale sole, were implemented in 2011 under FMP Amendment 16-5 (also referred to as Secretarial Amendment 1) (PFMC and NMFS 2011). The proxy F_{MSY} harvest rate or MFMT of $F_{40\%}$, which is applied to the estimated exploitable biomass to determine the OFL, was changed to $F_{30\%}$; the B_{MSY} target of $B_{40\%}$ was changed to $B_{25\%}$; and the MSST of $B_{25\%}$, was changed to $B_{12.5\%}$. The SSC recommended these new proxy reference points to manage flatfish stocks based on a meta-analysis of the relative productivity of assessed West Coast flatfish species and other assessed Pleuronectid species internationally. The precautionary ACL harvest control rule, referred to as the 25-5 rule and analogous to the 40-10 rule for other groundfish stocks (see Figure 2-137 and section 2.8.3 for

[8] $B_{25\%}$ was the MSST or overfished threshold for all groundfish stocks from the implementation of Amendment 12 in 1998 through 2010.

[9] $F_{40\%}$ was the F_{MSY} proxy harvest rate for all flatfish stocks from 1997-2011. Prior to 1997, the proxy F_{MSY} harvest rate was $F_{35\%}$.

more detail on these ACL harvest control rules), was also adopted for flatfish stocks under Amendment 16-5.

The 2009 rebuilding analysis (Haltuch and Hicks 2009a) was used to consider a petrale sole rebuilding plan for petrale sole, which was implemented under FMP Amendment 16-5. The rebuilding plan specified a target year of 2016 and the strategy of using the 25-5 harvest control rule after 2011 to set harvest levels (the 2011 ACL was set equal to the ABC to avoid unnecessary negative socioeconomic impacts). An emergency rule was implemented to reduce the 2010 petrale OY to 1,200 mt.

The 2011 petrale assessment estimated a stock depletion of 18 percent of its unfished biomass at the start of 2011 (Haltuch, *et al.* 2011). The assessment indicated an increasing spawning biomass trend with above average year classes recruiting into the spawning biomass. The 2011 rebuilding analysis (Haltuch 2011) indicated rebuilding was ahead of schedule and predicted spawning biomass would likely attain the B_{MSY} target of $B_{25\%}$ by the start of 2013. No modifications were made to the rebuilding plan based on this result.

The 2013 petrale assessment (Haltuch, *et al.* 2013) estimated a stock depletion of 22.3 percent of its unfished biomass at the start of 2013 and short of the prediction from the 2011 rebuilding analysis; spawning biomass is predicted to reach the B_{MSY} target by the start of 2014. The 2013 stock assessment continued with the coastwide stock assessment but was restructured to summarize petrale sole landings by the port of landing and combined Washington and Oregon into a single fleet but structured seasonally based on winter (November to February) and summer (March to October) fishing seasons. The down-weighting of the trawl CPUE index used in the 2011 assessment was largely responsible for the more pessimistic result and the one-year lag in rebuilding relative to the previous assessment. However, the estimation of recent recruitments indicated two very strong year classes (2007 and 2008; Figure 2-50) recruiting into the spawning population, which increases the likelihood of imminent success in rebuilding this stock.

An update of the 2013 full petrale sole assessment was conducted in 2015 (Stawitz, *et al.* 2015). The update assessment indicated the coastwide petrale sole stock was successfully rebuilt with a depletion of 31 percent at the start of 2015 (Figure 2-49). Improvement in the estimated stock status (relative to the 2013 model projection) is attributed to greater strength of the 2006-2008 year classes, and a consistent increasing trend in the NWFSC trawl survey index. The SSC noted the NWFSC trawl survey appears to be an excellent indicator of petrale sole trends and should be monitored to evaluate the need for a new assessment in the future.

An update assessment of petrale sole in 2019 indicated a depletion of 39 percent at the start of 2019 (Wetzel 2019). The most influential new information is the updated NWFSC groundfish bottom trawl survey index, which initially continued the sharply increasing trend observed in the 2011-2014 period, with indications of a leveling off and a downturn in the latest year (2018). Landings have increased in the last four years (2015-2018) relative to the previous four years (2011-2014), consistent with the stock being rebuilt and continuing to increase in abundance. The trajectory of the stock is forecast to decline as the large 2006-2008 cohorts are fished down, as recent recruitments (2010-2016) have been below average. The estimated steepness in the new assessment declined slightly (from 0.90 to 0.84) relative to the 2015 assessment estimate.

The Council adopted the default harvest control rule of ACL = ABC (P* = 0.45) for petrale sole for 2021 and beyond. A catch-only projection for petrale sole was provided in 2021 to inform harvest specifications for 2023 and beyond.

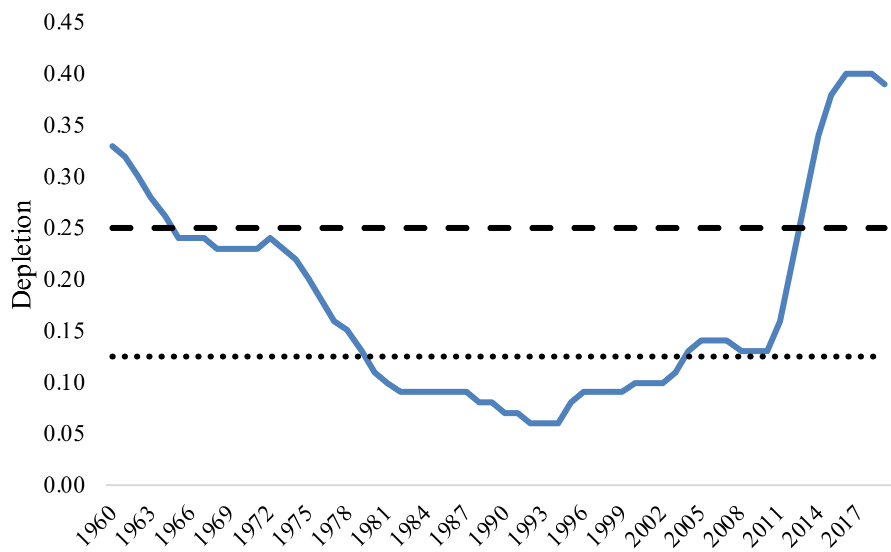

Figure 2-49. Relative depletion trend from 1960 to 2019 for petrale sole based on the 2019 stock assessment update.

Stock Productivity

Petrale have high stock productivity with an estimated stock-recruitment steepness of 0.84 (Wetzel 2019); the prior for this estimate was based on a meta-analysis of flatfish species in the family *Pleuronectidae* (Myers, *et al.* 1999). The time-series of estimated recruitments shows a relationship with the decline in spawning biomass, punctuated by larger recruitments in 2006, 2007, and 2008 (Figure 2-50). However, recruitment in recent years (2013-2017) is estimated to be less than the expected mean recruitment indicating an absence of strong incoming recruitment. The largest estimated recruitments estimated within the model (in ascending order) occurred in 2006, 1998, 1966, 2007, and 2008. The four lowest recruitments estimated within the model (in ascending order) occurred in 1986, 1992, 1987, and 2003.

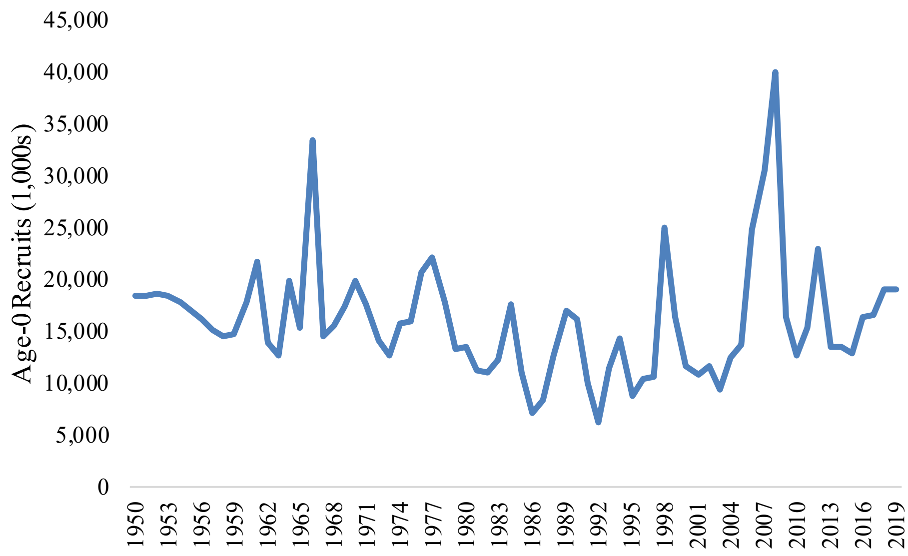

Figure 2-50. Time series of estimated (age-0) petrale sole recruitments, 1950-2019.

Fishing Mortality

Most of the petrale sole catch is made by deep-water demersal trawls at depths of 164-252 fm. Since discovery of petrale spawning grounds during the 1950s and 1960s, petrale sole catch statistics have exhibited marked seasonal variation, with substantial portions of the annual harvest taken from the spawning grounds in December and January. From the inception of the fishery in 1876 through the mid-1940s, the majority of catches occurred between March and October (the summer fishery), when the stock is dispersed over the continental shelf. The post-World War II period witnessed a steady decline in the amount and proportion of annual catches occurring during the summer months (March-October). Conversely, petrale catch during the winter season (November–February), when the fishery targets spawning aggregations, has exhibited a steadily increasing trend since the 1950s. Since the mid-1980s, catches during the winter months have been roughly equivalent to or exceeded catches throughout the remainder of the year. In 2009, catches of petrale sole began to be restricted due to declining stock size.

Petrale sole exhibit distinct seasonal depth migrations with higher abundance on the shelf during summer months and higher abundance in distinct spawning areas during winter months. Hence, RCA structures for this species could vary seasonally if RCA management is needed to control fishing mortality. The general pattern for petrale sole is a shallower depth distribution during the summer months (periods 3 and 4) and a deeper depth distribution during the winter months (periods 1 and 6). Petrale sole are typically in transition as they migrate between shallow and deeper depths during periods 2 and 5.

Petrale sole are caught almost exclusively by bottom trawl gears. Therefore, the uncertainty in catch monitoring and accounting is low, given the mandatory 100 percent observer coverage and near real-time reporting of total catches in the rationalized groundfish trawl fisheries.

The relative spawning biomass of petrale sole was estimated to have dropped below the management target (25 percent) for the first time in 1965 (Figure 2-49). The stock continued to decline and first fell below the minimum stock size threshold level of 12.5 percent in 1980 (although, at the time the management target and thresholds were not set at the current values of 25 percent and 12.5 percent). The relative spawning biomass reached its lowest level in 1993 at 5.8 percent, with the stock remaining around the threshold stock size until approximately 2010. In 2009 petrale sole was formally declared overfished. Fishing mortality rates sharply declined during the rebuilding period, relative to rates in previous years, which exceeded the target (Figure 2-51). The 2015 update stock assessment estimated the stock to have rebuilt to the management target (25 percent) in 2014. This update estimates that the relative spawning biomass exceeded 25 percent in 2013 with harvest rates in the most recent years remaining under of the target rate (Figure 2-51).

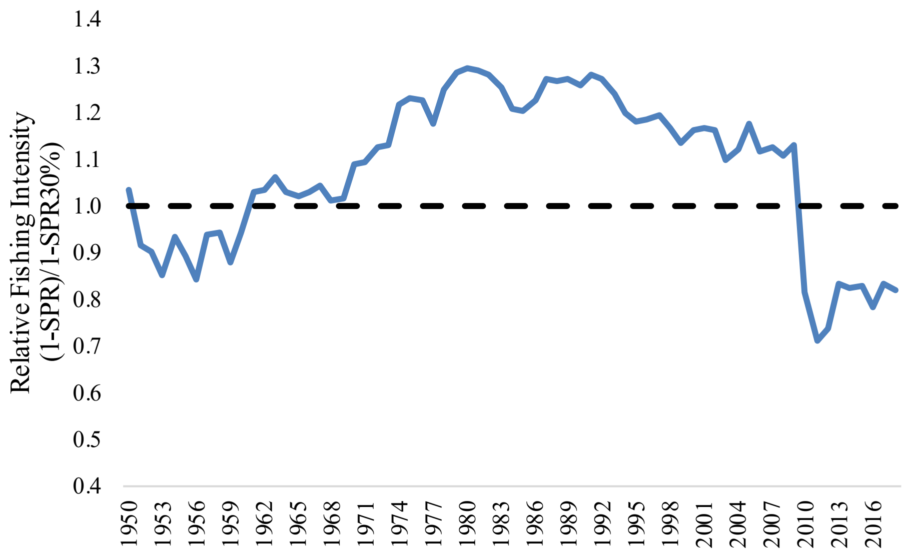

Figure 2-51. Relative fishing intensity of petrale sole, 1950-2018.

2.4.21 Sablefish

Distribution and Life History

Sablefish, or black cod, (*Anoplopoma fimbria*) are distributed in the northeastern Pacific Ocean from the southern tip of Baja California, northward to the north-central Bering Sea and in the Northwestern Pacific Ocean from Kamchatka, southward to the northeastern coast of Japan. Although few studies have critically evaluated issues regarding the stock structure of this species, it appears there may exist at least three different stocks of sablefish along the West Coast of North America: (1) a stock that exhibits relatively slow growth and small maximum size that is found south of Monterey Bay (Cailliet, *et al.* 1988; Phillips and Inamura 1954); (2) a stock that is characterized by moderately fast growth and large maximum size that occurs from northern California to Washington; and (3) a stock that grows very quickly and contains individuals that reach the largest maximum size of all sablefish in the northeastern Pacific Ocean, distributed off

British Columbia, Canada and in the Gulf of Alaska (Mason, *et al.* 1983; McFarlane and Beamish 1983a). Large adults are uncommon south of Point Conception (Hart 1988; Love 1996; McFarlane and Beamish 1983b; NOAA 1990). Adults are found as deep as 1,900 m, but are most abundant between 200 m and 1,000 m (Beamish and McFarlane 1988; Kendall and Matarese 1987; Mason, *et al.* 1983). Off southern California, sablefish are abundant to depths of 1,500 m (MBC 1987). Adults and large juveniles commonly occur over sand and mud (McFarlane and Beamish 1983a; NOAA 1990) in deep marine waters. They were also reported on hard-packed mud and clay bottoms in the vicinity of submarine canyons (MBC 1987).

Spawning occurs annually in the late fall through winter in waters greater than 300 m (Hart 1988; NOAA 1990). Sablefish are oviparous with external fertilization (NOAA 1990). Eggs hatch in about 15 days (Mason, *et al.* 1983; NOAA 1990) and are demersal until the yolk sac is absorbed (Mason, *et al.* 1983). Age-zero juveniles become pelagic after the yolk sac is absorbed. Older juveniles and adults are benthopelagic. Larvae and small juveniles move inshore after spawning and may rear for up to four years (Boehlert and Yoklavich 1985; Mason, *et al.* 1983). Older juveniles and adults inhabit progressively deeper waters. Estimates indicate that 50 percent of females are mature at five years to six years (24 inches) and 50 percent of males are mature at five years (20 inches).

Sablefish larvae prey on copepods and copepod nauplii. Pelagic juveniles feed on small fishes and cephalopods—mainly squids (Hart 1988; Mason, *et al.* 1983). Demersal juveniles eat small demersal fishes, amphipods, and krill (NOAA 1990). Adult sablefish feed on fishes like rockfishes and octopus (Hart 1988; McFarlane and Beamish 1983a). Larvae and pelagic juvenile sablefish are heavily preyed upon by seabirds and pelagic fishes. Juveniles are eaten by Pacific cod, Pacific halibut, lingcod, spiny dogfish, and marine mammals, such as Orca whales (Cailliet, *et al.* 1988; Hart 1988; Love 1996; Mason, *et al.* 1983; NOAA 1990). Sablefish compete with many other co-occurring species for food, mainly Pacific cod and spiny dogfish (Allen 1982).

Stock Status and Management History

Formal stock assessments of sablefish began in 1984. The first coastwide assessment established regulations on the sablefish fishery off the U.S. Pacific coast which were implemented as trip limits in October 1982. Since 1982, the sablefish fishery has been managed intensively, with limited entry and open access programs used in various manners to limit catches.

In 2001, two assessments were completed and reviewed by a STAR Panel: one by NMFS (Schirripa and Methot 2001) and one by the Pacific Groundfish Conservation Trust (Hilborn, *et al.* 2001). The two assessments were in agreement, and the Council adopted the NMFS assessment for management purposes. Schirripa and Methot (2001) focused on evaluating the sensitivity of the model and the outcomes to changes in the survey data. These changes included the combining of the AFSC slope survey data and the NWFSC Industry Co-operative Survey data using a statistical Generalized Linear Models (GLM) procedure. This analysis made it possible to extend the southern boundary of the assessment south to Point Conception at 34°27' N. lat. rather than 36° N. lat. used in previous assessments. The assessment indicated a normal decline in biomass since the late 1970s due to the fishing down of the unfished stock and an unexpected decline in recruitment during the early 1990s. It introduced for the first time, the possibility that sablefish recruitment may be linked to environmental factors. A seemingly meaningful relationship was demonstrated between changes in northern and southern copepod abundances and sablefish recruitment. Conditions and projections in the model considered two competing "states of nature" to calculate the mean virgin recruitment: a "density-dependent" state that used the average of 1975-1991 recruitments, and a "regime shift" state that used the 1975-2000 recruitments. To account for this uncertainty, the Council adopted a 2002 ABC based on the proxy harvest rate ($F_{45\%}$) adjusted to reflect the distribution north and south of 36° N. lat. This was done because a plan amendment would be needed to change the management area since Groundfish FMP Amendment 14 specified only the area north of 36° N. lat.

The Council also wanted to verify industry reports of a large abundance of juvenile sablefish, an observation that was confirmed to some extent by preliminary results from the 2001 NMFS slope survey. Based on these considerations, the Council recommended a new expedited assessment be done in 2002. This update assessment (Schirripa 2002), by definition, sought to document changes in the estimates of the status of the stock by only considering newly available data for 2001 while not considering any new changes in the model structure or model assumptions. The expedited assessment confirmed fishermen's anecdotal reports of a large 1999 year class, which was also apparent in the preliminary results of the 2001 slope survey.

The 2005 sablefish assessment estimated stock depletion at 34.3 percent of unfished biomass (Schirripa and Colbert 2006). The assessment fit a relationship between sea level and recruitment deviations for the period 1973-2003 and used that relationship to hindcast recruitment variability back to 1925. The 2005 assessment found that spawning stock biomass had steadily declined since 1900 and suggested that there was little evidence that recruitment from 2001-2005 was as high as that for the strong 1999 and 2000 year classes. As a result, the assessment's biomass projections indicate a short-term increase, followed by a continued decline.

The 2007 updated sablefish assessment estimated spawning depletion to be 38.3 percent of unfished biomass at the start of 2007 (Schirripa 2008). This increase from 2005 was attributed in part to the continued recruitment of the strong 1999 and 2000 year classes into the spawning stock biomass. The assessment also estimated a series of poor recruitments in the mid- to late-1990s, and if fished at the full OY level, depletion was forecasted to decrease for the next five years.

The 2011 sablefish assessment estimated spawning stock biomass to be at 33 percent of its unfished biomass at the beginning of 2011 (Stewart*, et al.* 2011). The resource was modeled as a single stock; however, there is some dispersal to and from offshore seamounts and along the coastal waters of the continental U.S., Canada, Alaska, and across the Aleutian Islands to the western Pacific which was not explicitly accounted for in this analysis. Environmental time-series including both sea-surface height (used in previous sablefish assessments) and zooplankton abundance were also investigated. These environmental indices were not used in the 2011 assessment in the interest of parsimony since they did not affect results.

An update of the 2011 sablefish assessment was conducted in 2015 (Johnson*, et al.* 2015), which indicated spawning biomass to be 34.5 percent of its unfished level (Figure 2-52). There were only minor changes to the 2011 assessment when updating to the new version of Stock Synthesis. All data inputs were updated, additional corrections to data were made (e.g., discards), and new software was used to generate survey indices using delta-GLMMs. The SSC recommended a more thorough review is needed of standardized procedures and new software used to produce fishery size and age compositions, used for the first time in the current assessment cycle, especially in the context of sablefish. Port sampling data for sablefish are more complicated than for other groundfish species because there is a complex set of size-graded market categories for sablefish and many of the fish are landed in dressed condition.

A new full assessment of sablefish conducted in 2019 (Haltuch, *et al.* 2019) indicated the stock was at 39 percent of unfished biomass at the start of 2019 (Figure 2-52). Major changes in the 2019 assessment include pooling of hook and line and pot gear into a single fixed gear fishery, the exclusion of all the length composition data (except data associated with the NMFS trawl survey) due to tensions among data sources in the model, a change in the fixed steepness value from 0.60 to 0.70, and the inclusion of a recruitment index based on the environmental time series of sea level. In addition to tension between length and age data, other major uncertainties were associated with spatial and temporal variability in growth, spatial stock structure, and the modeling of retention curves. Despite these uncertainties, the NMFS trawl survey index and compositional data are informative with respect to both abundance trends and recruitment variability. Spawning output has been relatively stable over the past decade with depletion close to the management target level during that time. In 2019, the sablefish stock was estimated to be at 39 percent of unfished spawning output.

A 2021 update of the 2019 sablefish assessment indicated the 2021 depletion is 57.9 percent of the unfished level {Figure 2-52; Kapur, 2021 #1279}. Catch projections indicate that catch attainment consistent with current harvest policies would result in the stock declining from 57.9 percent of the unfished level in 2021 to approximately 50 percent of the unfished level in 2031.

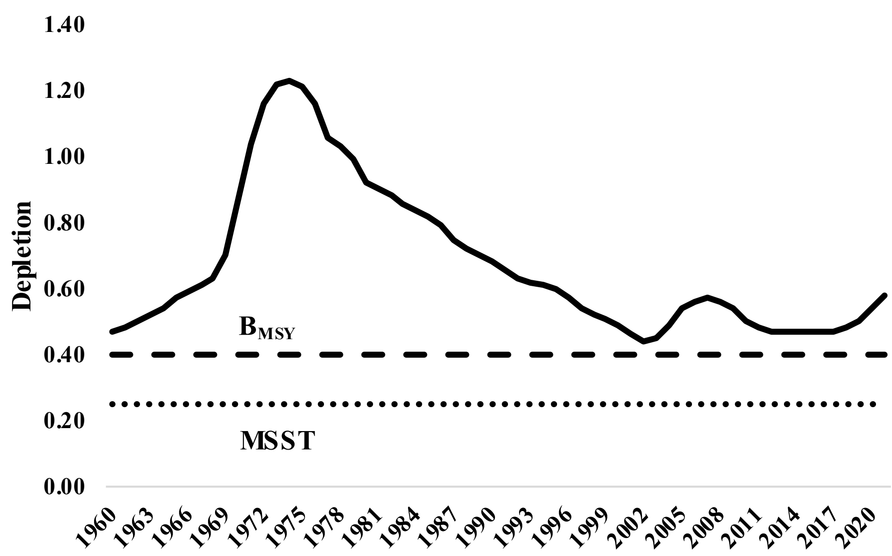

Figure 2-52. Relative depletion of sablefish from 1960 to 2021 based on the 2021 stock assessment.

Stock Productivity

Sablefish recruitment is estimated to be quite variable with large amounts of uncertainty in individual recruitment events. A period with generally higher frequencies of strong recruitments spans from the early 1950s through the 1970s, followed by a lower frequency of large recruitments during 1980 forward, contributing to stock declines, with some recent larger recruitments pushing the population higher in the past few years (Figure 2-53). The period with a higher frequency of high recruitments contributed to a large increase in stock biomass that subsequently declined throughout much of the 1970s forward. Less frequent large recruitments during the mid-1980s through 1990 slowed the rate of stock decline, with another series of large recruitments during 1999 and 2000 leading to a leveling off in the stock decline. The above-average cohorts from 2008, 2010, 2013, and 2016 are contributing to an increasing spawning stock size.

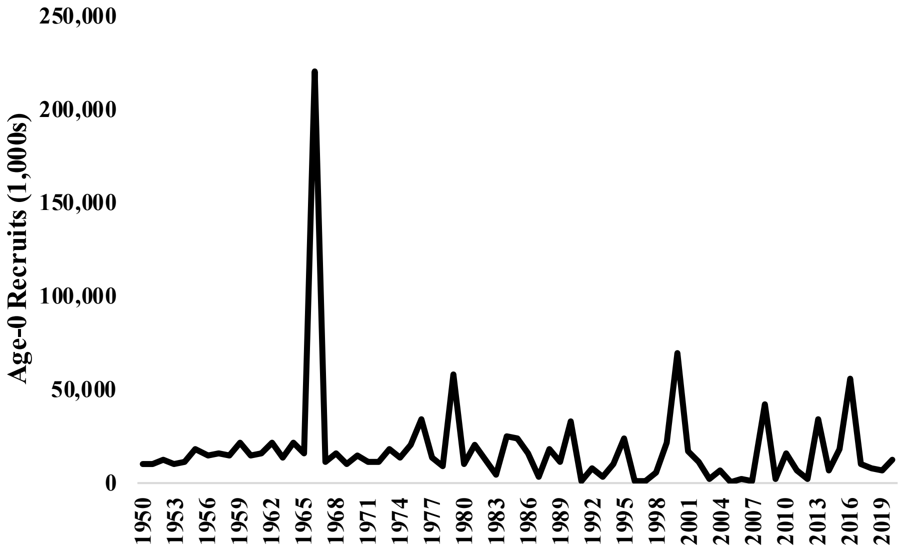

Figure 2-53. Estimated sablefish recruitments, 1950-2020.

Fishing Mortality

Sablefish is one of the most important groundfish stocks on the West Coast and the most commercially valuable groundfish stock on a per pound basis. Sablefish is a major target species in commercial trawl and non-trawl fisheries and is readily caught with trawls, longlines, and sablefish pots/traps on the shelf and slope.

During the first half of the 20th century, it is estimated that sablefish were exploited at relatively modest levels. Relative fishing intensity of sablefish was above the proxy F_{MSY} harvest rate during nearly half of the years from 1976 through 2000, has been below the target since, and was between 0.62 and 0.76 from 2015-2019, descending to 0.40 in 2020 (Figure 2-54).

The PSA vulnerability score of 1.64 indicates a relatively low concern for potential overfishing.

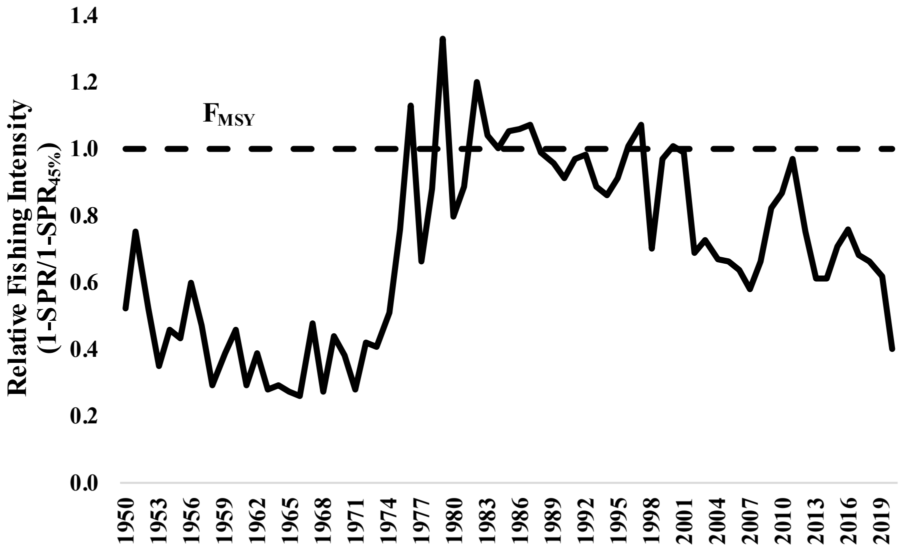

Figure 2-54. Relative fishing intensity of sablefish, 1950-2020.

2.4.22 Shortspine Thornyhead

Distribution and Life History

Shortspine thornyhead (*Sebastolobus alascanus*) are found in the waters off of the West Coast of the United States from northern Baja California to the Bering Sea. They are found from 20 to over 1,500 m in depth. The majority of the spawning biomass occurs in the oxygen minimum zone between 600 and 1,400 m, where longspine thornyhead are most abundant (Bradburn*, et al.* 2011; Jacobson and Vetter 1996). The distribution of the smallest shortspine thornyhead suggests that they tend to settle at around 100–400 m and are believed to have ontogenetic migration down the slope, although large individuals are found across the depth range.

Shortspine thornyhead do not appear to be distributed evenly across the West Coast, with higher densities of thornyheads in shallower areas (under 500 m) off of Oregon and Washington, and higher densities in deeper areas off of California. The mean latitude of the largest shortspine thornyhead is slightly further north than of the medium sizes, suggesting the possibility of either a J-shaped migration, differential patterns of recruitment, or regional differences in exploitation history.

Although their densities vary, shortspine thornyhead are present in almost all trawlable areas below 500 m. They are caught in 91 percent of the trawl survey hauls below 500 m and 94 percent of the commercial bottom trawl hauls below 500 m. In camera tows, thornyheads are seen to be spaced randomly across the sea floor (Wakefield 1990), indicating a lack of both of schooling and territoriality.

Genetic studies of stock structure do not suggest separate stocks along the West Coast. Siebenaller (1978) and Stepien (1995) found few genetic differences among shortspine thornyhead along the Pacific coast. Stepien (1995) suggested there may be a separate population of shortspine thornyhead in the isolated area around Cortes Bank off San Diego, California. Stepien (1995) also suggested that juvenile dispersion might be limited in the area where the Alaska and California currents split. This occurs towards the northern boundary of the assessment area, near 48° N. lat.

Stepien et al. (2000), using a more discerning genetic material (mtDNA), found evidence of a pattern of genetic divergence corresponding to geographic distance. However, this study, which included samples collected from southern California to Alaska, did not identify a clear difference between stocks even at the extremes of the range. No such pattern was seen in longspine thornyhead, which suggests that the shorter pelagic stage (~1 yr. vs. ~2 yrs.) of shortspine thornyhead may contribute to an increased genetic separation with distance.

Shortspine thornyhead along the West Coast spawn pelagic, gelatinous masses between December and May (Erickson and Pikitch 1993; Pearson and Gunderson 2003; Wakefield 1990). Juveniles settle at around 1 year of age (22- 27 mm in length), likely in the range of 100-200 m (Vetter and Lynn 1997), and migrate down the slope with age and size, although large individuals are found across the depth range.

Shortspine thornyhead grow very slowly, but may continue growing throughout their lives, reaching maximum lengths of over 70 cm. Females appear to reach larger sizes than do males. Maturity in females has been estimated as occurring near 18 cm, at 8-10 years of age (Pearson and Gunderson 2003), although new information suggests that patterns of maturity may be more complex.

Shortspine thornyhead and longspine thornyhead have historically been caught with each other and with Dover sole and sablefish, making up the DTS fishery. Other groundfish species that frequently co-occur in these deep waters include a complex of slope rockfishes, rex sole, longnose skate, roughtail skate, Pacific grenadier, giant grenadier, Pacific flatnose as well as non-groundfish species such as Pacific hagfish and a diverse complex of eelpouts. Shortspine thornyhead typically occur in shallower water than the shallowest longspine thornyhead and migrate to deeper water as they age. When shortspine thornyhead have reached a depth where they overlap with longspine thornyhead, they are typically larger than the largest longspine thornyhead. Shortspine thornyhead stomachs have been found to include longspine thornyhead, suggesting a predator-prey linkage between the two species.

Thornyheads spawn gelatinous masses of eggs which float to the surface. This may represent a significant portion of the upward movement of organic carbon from the deep ocean (Wakefield 1990). Thornyheads have been observed in towed cameras beyond the 1,280 m limit of the current fishery and survey, but their distribution, abundance, and ecosystem interactions in these deep waters are relatively unknown.

Stock Status and Management History

Beginning in 1989, both thornyhead species were managed as part of the deep water complex with sablefish and Dover sole (DTS). In 1991, the Council first adopted separate ABC levels for thornyheads and catch limits were imposed on the thornyhead group. Harvest guidelines were instituted in 1992 along with an increase in the minimum mesh size for bottom trawl fisheries. In 1995 separate landing limits were placed on shortspine thornyhead and longspine thornyhead and trip limits became more restrictive. Trip limits (predominantly 2-month limits on cumulative vessel landings) have often been adjusted during the year since 1995 in order to not exceed the HG or OY for that year. At first, the HG for shortspine thornyhead was set higher than the ABC (1,500 vs. 1,000 mt in 1995-1997) in order to allow a greater catch of longspine thornyhead, which was considered a relatively underutilized and healthy stock. In 1999 the OY was set at less than 1,000 mt and remained close to that level through 2006. As a result of the 2005 shortspine thornyhead assessment, catch limits increased to about 2,000 mt per year and have remained near that level to the present.

Ianelli et al. (Ianelli*, et al.* 1994) assessed the coastwide abundance of longspine thornyhead and shortspine thornyhead based on slope survey data, an updated analysis of the logbook data, and fishery length-composition data to estimate the parameters of length-based Stock Synthesis models, under different assumptions regarding discarding practices.

The assessment of thornyheads in 1997 covered the area from Central California at 36° N. lat. to the U.S.-Canada border (Rogers*, et al.* 1997). The STAR Panel expressed concern that management requires more detailed information on thornyheads than could be obtained from the available data. In 1998, two separate stock assessments covering the area north of 36° N. lat. were prepared and accepted by the Council (NMFS and OT 1998; Rogers*, et al.* 1998). A synthesis of these two assessments was used to set the harvest specifications for 1999 and 2000. Given that the synthesis estimated 1999 depletion at 32 percent of virgin biomass, the Council used the precautionary 40-10 policy to set the OYs for those two years.

There were a range of uncertainties in the 2001 assessment of shortspine thornyhead, not the least of which was the estimated biomass (Piner and Methot 2001). The assessment was extended south to Point Conception (in contrast to past surveys, which were limited to stocks north of the 36° N. lat. management area boundary). The authors concluded the 2001 spawning biomass ranged between 25 percent and 50 percent of unexploited spawning biomass. As was also the case in the 1998 assessment, the uncertainty in abundance largely revolved around the uncertainty in recruitment and survey q, or catchability, of shortspine thornyhead in slope surveys. The authors also concluded that the trend in stock biomass was increasing and the stock was not depleted. Based on estimated biomass and application of the GMT-recommended F=0.75M principle (which approximated an $F_{50\%}$ proxy harvest rate for shortspine thornyhead), the assessment authors and GMT recommended a slight increase in the ABC and OY for 2002. They also recommended that the harvest specifications be set for two areas divided by Point Conception at 34°27' N. lat., rather than the previous policy to separate the management areas at the Conception-Monterey border (36° N. lat.). Despite the uncertainty in biomass estimates and determination of whether shortspine thornyhead should be treated as a "precautionary zone" stock, these recommendations did treat the stock as such by applying the 40-10 adjustment.

The 2005 stock assessment estimated the shortspine thornyhead spawning stock biomass to be at 62.9 percent of its initial, unfished biomass in 2005 (Hamel 2006c). The 2005 assessment extended the southern border of the assessment area from Point Conception to the Mexican border (32.5° N. lat.). Including the entire Conception area resulted in a larger basis for unfished biomass, given that this area was estimated to contain nearly half of the stock's total West Coast biomass. It was noted that there could be regional management concerns with this stock because while the assessment OY was coastwide, there are differences in historic exploitation rates north and south of Point Conception. It was also noted the biomass estimate south of Pt. Conception was more uncertain than that in the north.

The 2013 stock assessment estimated the shortspine thornyhead spawning stock biomass to be at 74.2 percent of its initial, unfished biomass in 2013 (Taylor and Stephens 2013). A longer time series of the coastwide NWFSC trawl survey biomass estimates were included in this assessment relative to the 2005 assessment. Therefore, the STAT concluded there was no greater uncertainty in the biomass south of Pt. Conception relative to estimates for the rest of the coast. As in the previous assessment, no age data were used in the 2013 assessment and growth parameters were fixed at the same values used in 2005.

The Council adopted the default harvest control rule for shortspine thornyhead of ACL equal to 65.4 percent of the coastwide ABC with a P* of 0.4 for the stock north of 34°27' N. lat. and 34.6 percent of the coastwide ABC for the stock south of 34°27' N. lat. The apportionment of coastwide OFLs and ABCs is based on the 2003-2012 average swept area biomass estimated north and south of Pt. Conception at 34°27' N. lat. in the NWFSC trawl survey. A catch-only projection for shortspine thornyhead was provided in November 2019 to inform harvest specifications for 2021 and beyond.

Stock Productivity

Taylor and Stephens (2013) estimated annual shortspine thornyhead recruitment using a Beverton-Holt stock-recruitment function and assuming a steepness value of 0.6. Most 2013 rockfish assessments used a steepness prior of 0.779, estimated from a meta-analysis of rockfish assessment results. This value might be expected in the 2013 shortspine thornyhead assessment; however, rockfish ecology and reproduction are quite different from those of thornyheads, which (for example) do not give birth to live young but rather spawn floating egg masses.

Steepness in the shortspine thornyhead assessment was fixed at 0.6 both in the 2005 and 2013 models (Hamel 2006c; Taylor and Stephens 2013). This value was justified based on consistency between the modeling approach and management targets, in addition to being within a range of biologically reasonable values.

Annual deviations about this stock-recruitment curve were estimated for the years 1944 through 2012. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates. The 2013 shortspine thornyhead assessment is relatively uninformative of relative year class strength since ages were not used in the model (thornyheads are notoriously difficult to age). Therefore, a length-based assessment with an assumed steepness is used to determine recruitment.

Fishing Mortality

Landings of shortspine thornyhead were estimated to have risen to a peak of 4,815 mt in 1989, followed by a sharp decline during a period of trip limits and other management measures imposed in the 1990s. Since the institution of separate trip limits for shortspine thornyhead and longspine thornyhead, the fishery had more moderate removals of between 1,000 and 2,000 mt per year from

1995 through 1998. Landings fell below 1,000 mt per year from 1999 through 2006, then rose to 1,531 in 2009 and have declined since that time.

Exploitation rates in terms of spawning potential ratio indicates that the exploitation slightly exceeded the F_{MSY} target for a single year in 1985 and then for the period 1989-1994. However, the stock status is estimated to have never fallen below the $B_{40\%}$ management target.

2.4.23 Spiny Dogfish

Distribution and Life History

In the Northeast Pacific, spiny dogfish (*Squalus suckleyi*) occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts (Ebert 2003; Ebert, *et al.* 2010).

The U.S. West Coast spiny dogfish stock likely has interaction and overlap with dogfish observed off British Columbia. About 1,300 dogfish were tagged along the coast of Washington from 1942-1946, during the period of the strong directed fishery for dogfish. Only 50 of these fish were recaptured and had tags returned (4 percent), of which 54 percent were recaptured within U.S. coastal waters, while 32 percent were recaptured in coastal Canada and 12 percent in the inside waters of Puget Sound and the Strait of Georgia. One fish was recaptured in coastal Japanese waters (7 years after being tagged). Because many of the releases were close to the U.S.-Canada border and the fractions do not take into account the relative fishing pressure within each area, this study is of limited use in providing reliable information about dogfish movement rates.

A spatial population dynamics model (Taylor 2008), which included these tagging data (along with much larger tagging experiments conducted in Canada and inside U.S. waters of Puget Sound) estimated movement rates of about 5 percent per year between the U.S. coastal sub-population of dogfish and that found along the West Coast of Vancouver Island in Canada. The model also estimated movement rates of less than 1 percent per year between the U.S. coastal sub-population of dogfish and that in the Puget Sound.

These sharks appear to prefer areas in which the water temperature ranges from 5 to 15° C, often making latitudinal and depth migrations to follow this optimal temperature gradient (Brodeur, *et al.* 2009). There is also evidence of seasonal movement along the coast based on both tagging data and timing of historical fisheries (Ketchen 1986). One estimate of the seasonal movement along the Pacific coast is a North-South shift of about 600 km from winter to summer (Taylor 2008). This seasonal pattern is not as extreme as that found among spiny dogfish in Atlantic waters of the U.S., which are likely due to larger fluctuations in temperature. Dogfish have also been captured in high-seas salmon gillnets across the North Pacific between about 40° and 50° N. lat. (Nakano and Nagasawa 1996), but the extent of these wide-ranging pelagic movements is poorly understood.

The biology and life history of spiny dogfish are relatively well studied (Campana*, et al.* 2009; Di Giacomo*, et al.* 2009; Taylor 2008; Tribuzio 2009; Tribuzio*, et al.* 2009; Tribuzio*, et al.* 2010; Vega*, et al.* 2009). This species is an opportunistic feeder that consumes a wide range of prey (whatever is abundant). Schooling pelagic fish, such as herring, make up the majority of its diet. They also feed on invertebrates such as shrimp, crab, and squid. In turn, dogfish are preyed upon by larger cod, hake, and other spiny dogfish (Beamish*, et al.* 1992; Brodeur*, et al.* 2009; Tanasichuk*, et al.* 1991). Larger species of sharks, as well as seals and killer whales, also feed on dogfish.

Spiny dogfish have internal fertilization and ovoviviparous development. The internal development takes place over 22-24 months, the longest gestation period known for sharks. The number of pups in each litter ranges between 5 and 15 individuals depending on the size of the female (larger females bearing more pups). The size at birth is generally between 20 and 30 cm for both genders. Male spiny dogfish are reported to grow faster than females, but females reach larger sizes. This species is the latest maturing (with 50 percent female maturity reported at 35.5 years) and longest lived of all elasmobranchs (Cortes 2002; Saunders and McFarlane 1993; Smith*, et al.* 1998; Taylor 2008). Life history traits of spiny dogfish make the species highly susceptible to overfishing and slow to recover from stock depletion since its slow growth, late maturation, and low fecundity are directly related to recruitment and spawning stock biomass (Holden 1974; King and McFarlane 2003).

Stock Status and Management History

Spiny dogfish on the U.S. West Coast have been utilized for almost a thousand years, with those in Puget Sound first used by Native Americans (Bargmann 2009). The exploitation of spiny dogfish in coastal waters started in the 20th century. Even though the history of spiny dogfish utilization on the U.S. West Coast included a brief but intense commercial fishery in the 1940s, in general this species is not highly prized and is mostly taken as bycatch in other fisheries.

Prior to 1936, coastal catches of spiny dogfish were extremely minimal, but in 1936, shortly after it was discovered that livers of spiny dogfish have high level of vitamin A, a large-scale fishery for dogfish developed in the Pacific Northwest. Before World War II, Northeast Pacific dogfish livers could not compete with the cheaper and more potent sources of vitamin A from Europe. But when World War II started and European supplies were cut, dogfish shark livers became the major source of vitamin A in the United States, and the spiny dogfish fishery grew rapidly along the Pacific coast. The processed liver oils were used in pharmaceuticals, food processing, and animal feed (Bargmann 2009; Ketchen 1986).

During the liver fishery, dogfish were targeted by three major gear groups, including setlines, set nets, and bottom trawls. The timing of the dogfish liver fishery coincided with the development of bottom trawling in the U.S. Northwest, and though at the onset of the fishery the catches by trawl were low, by the mid-1940s trawling was the dominant type of fishing for dogfish.

In 1945, a sharp decline in spiny dogfish catches began. This decline occurred despite continued strong demand for vitamin A and high prices for dogfish livers, but because of decreased availability of the species in the Northeast Pacific (Bargmann 2009; Ketchen 1986). In 1950, with the advent of synthetic vitamins, demand for spiny dogfish livers declined and catches in the Northeast Pacific virtually ended.

Between 1950 and 1974, the landings of spiny dogfish remained minimal. By the late 1950s it was reported that species availability had increased. Also, in the late 1950s-early 1960s, dogfish earned a bad reputation among fishermen. They were blamed for driving off commercially valuable species such as herring and mackerel, while consuming large numbers of them. Spiny dogfish have also been observed biting through nets to get to their fish prey, releasing many of them and damaging fishing gear in the process. They were also reported damaging gear when become entangled in commercial nets. As a result, fishermen were trying to avoid areas with higher densities of dogfish (such as soft bottoms, for example) to prevent encountering dogfish and potentially damaging their gear.

A market opportunity for dogfish developed in the mid-1970s. In Europe, spiny dogfish has long been used an inexpensive source of human food, for fish and chips in particular. A decline in the European dogfish supply provided an opportunity for developing an export dogfish food fishery on the U.S. West Coast. Also, during the late 1970s, shark cartilage started to be used in cancer treatment, and a portion of spiny dogfish catches have since been sold for medical research and treatment (Gregory Lippert, WDFW, pers. com. as cited by Gertseva and Taylor (2011)). As before, three types of gear were involved in catching dogfish (bottom trawl, setlines, and sunken gill nets), but since the mid-1980s catches by gillnets have been minimal.

Spiny dogfish is a common bycatch species, often caught in other fisheries and largely discarded. For instance, it has long been incidentally caught in the hake fishery, which is almost exclusively conducted with midwater trawls. Large-scale harvesting of Pacific hake in the U.S. began in 1966, when factory trawlers from the Soviet Union and other countries began targeting this stock. After the 200-mile U.S. EEZ was declared in 1977, a joint-venture fishery was initiated between U.S. trawlers and Soviet factory trawlers acting as motherships (larger, slower ships for fish processing and storage while at sea). By 1989 the U.S. fleet capacity had grown to a level sufficient to harvest the entire quota, and no further foreign fishing was allowed. The Pacific hake fishery is currently 100 percent observed at sea and data on bycatch species, including spiny dogfish, is being routinely collected.

Spiny dogfish on the U.S. West Coast has been managed under the Other Fish complex since implementation of the Groundfish FMP by the Council in 1982. In 2005, reduction in the Other Fish ABC was implemented due to removal of the California substock of cabezon from the Other Fish complex. The same year, a 50 percent precautionary OY reduction was implemented to accommodate uncertainty associated with managing unassessed stocks. In 2006, a trip limit for spiny dogfish was imposed for U.S. West Coast waters which varied between 45 and 91 mt per two months for all gears. In 2009, another ABC reduction was implemented due to removal of longnose skate from the Other Fish complex and the 50 percent OY reduction was maintained.

Gertseva and Taylor (2011) estimated the spawning stock output of spiny dogfish to be 44,660 thousands of fish (95 percent confidence interval: 8,937-80,383), which represents 63 percent of the unfished spawning output level. While this depletion level indicates the stock is currently healthy, fishing at the target SPR of 45 percent was expected to severely reduce the spawning output over the long term because of the extremely low productivity and other reproductive characteristics of the stock. The Council partially addressed this by setting a more conservative spiny dogfish ABC for 2013 by specifying a P* of 0.3.

The Council further decided to manage spiny dogfish with stock-specific harvest specifications beginning in 2015. The SSC also investigated establishing a more conservative F_{MSY} harvest rate for spiny dogfish and other elasmobranchs in recognition of their lower productivity. The SSC recommended and the Council adopted a more conservative proxy 50 percent SPR harvest rate as an interim measure for elasmobranchs. The 50 percent SPR was based on an SSC meta-analysis of *Chondrichthyes* species using the posterior distribution for F_{MSY}/M values as reported by Zhou et al. (2012). The SSC said they may further investigate sustainable harvest rates for Council-managed elasmobranchs as more information becomes available in the future.

A new stock assessment for spiny dogfish conducted in 2021 indicates the stock is just over the management target at 41.8 percent of unfished biomass {Figure 2-55, Gertseva, 2021 #1278}. The estimated spawning output in 2021 under the new assessment decreased from 18,354,000 pups projected in the previous assessment to 13,613,000 pups. Bridging analyses adding and updating data indicated that the scale of the assessment had changed as a result of 1) revised estimates for catchability (*q*) for the Northwest Fisheries Science Center (NWFSC) West Coast Bottom Trawl Survey (WCBTS) changing from 0.27 to 0.43, 2) new WCBTS composition data, and 3) new research indicating a gestation period of two years rather than one reducing fecundity estimates to half that assumed previously contributing to the change to the perception of stock status and harvest levels.

Improvements from the 2011 assessment included updated fisheries and survey-related data, abundance indices estimated using the VAST modeling approach, revised historical discard estimates, updated selectivity assumptions from asymptotic to dome-shaped with sex-specific offset, updated biological parameters, and updated tuning for age data. The magnitude of historical discards remains one of the main concerns in assessment data. Age determination is another unresolved issue for female dogfish, which has impacts on the growth parameters and the assumed natural mortality rate.

The West Coast Groundfish Survey *q* was fixed at 0.43 in the final base model, though it is subject to considerable uncertainty due to lack of contrast in the data included in the assessment and an inability to qualify 1) seasonal migrations (of up to 600 km) during the summer relative to the timing of the survey that operated from April through October that likely affects availability, 2) potential net avoidance given strong swimming abilities, 3) the distribution of a portion of the stock shoreward of the survey area, and 4) availability to the net itself given their semi-pelagic habits. The relatively flat likelihood profile for *q* implies that the data are uninformative about this parameter even though it is influential on the scale and depletion in the assessment. Catchability is listed as the major axis of uncertainty in decision tables and the best estimate determines the lower and upper bounds. The uncertainty in *q* is problematic since it affects the estimates of key parameters including natural mortality (*M*) and growth, creating tension in the model between these variables. There is a tradeoff between *M* and *q*, and the model fit improved when *M* was lower and *q* was higher.

The estimate of steepness for spiny dogfish is among the lowest values reported for marine fish stocks. The F_{MSY} of 0.003yr-1 corresponds to an SPR harvest rate of 90 percent while an SPR of 88.3 percent corresponds to $B_{40\%}$ given the value for steepness. The current $SPR_{50\%}$ F_{MSY} harvest rate proxy appears inconsistent with the biology if these results are correct. The SSC highlighted the SPR proxy is significantly higher than the SPR estimated to correspond to MSY and the stock is predicted to collapse if it is fished at a SPR of 50 percent. While a spawner-recruitment relationship meta-analysis might help inform a more ideal HCR, such an analysis is unlikely to be possible given the limited number of species with this life history.

The stock was designated category 2 since recruitment deviations are not estimated and data do not inform scale well. The SSC recommended the next assessment of spiny dogfish be a full assessment due to the technical issues discussed in the assessment and STAR panel report.

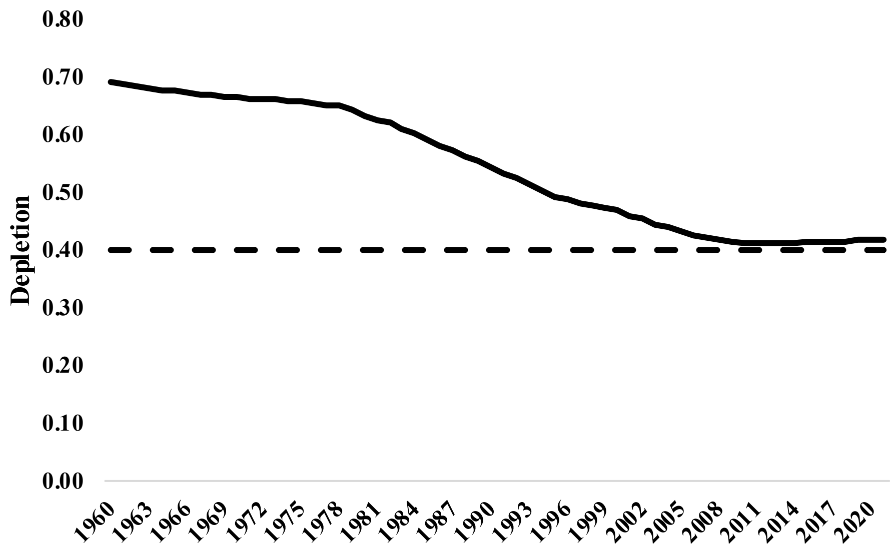

Figure 2-55. Relative depletion of spiny dogfish from 1960 to 2021 based on the 2021 stock assessment.

Stock Productivity

Spiny dogfish have a relatively low stock productivity due to slow growth, late maturation, and low fecundity. The fecundity of dogfish in the Northeast Pacific Ocean has been well studied, with pregnant females having relatively few pups per litter (5 to 15) and with relatively little variability among individuals. Unlike fish producing millions of eggs, the low fecundity of dogfish suggests both low productivity in general and a more direct connection between spawning output and recruitment than for many species.

Gertseva et al. (2021) modeled the spiny dogfish spawner-recruit relationship using a functional form which allowed a more explicit modeling of pre-recruit survival between the stage during which embryos can be counted in pregnant females to their recruitment as age-0 dogfish. The recruits were taken deterministically from the stock-recruit curve since the relatively large size of dogfish pups at birth (20-30cm) suggest that variability in recruitment would be lower than for a species with a larval stage, which is subject to higher mortality rates.

While steepness was not estimated or assumed in the conventional sense of a Beverton-Holt stock-recruitment relationship, a value for steepness (defined as recruitment relative to R_0 at a spawning depletion level of 0.2) can be derived from the parameters above according to the relationship provided by Gertseva et al. (2021). The calculated value of steepness is 0.283, indicating a great degree of compensation or density-dependent recruitment.

Fishing Mortality

Spiny dogfish catches have exceeded the proxy F_{MSY} harvest rate during the vitamin A fishery in the 1940s and during multiple periods in the last 40 years, most recently in 2008 (Figure 2-56).

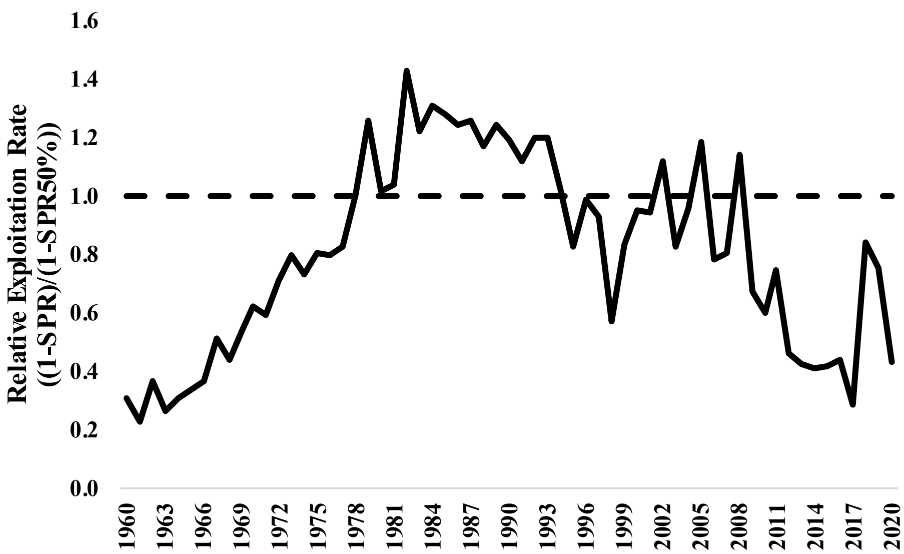

Figure 2-56. Estimated annual relative exploitation rate of spiny dogfish relative to the current proxy F_{MSY} target, 1960-2020.

2.4.24 Splitnose Rockfish South of 40°10' N. Lat.

Distribution and Life History

Splitnose rockfish (*Sebastes diploproa*) are distributed from the northern Gulf of Alaska (Prince William Sound) to central Baja California and occur at depths between 91-795 meters. Adults are the most abundant between British Columbia and southern California at depths from 215 to 350 meters (Alverson*, et al.* 1964; Gunderson and Sample 1980; Love*, et al.* 2002). The species is distinguished by having a deeply notched upper jaw, which inspired its Greek name diploproa, meaning "double prow". Splitnose rockfish are commonly seen on low-relief mud fields of the continental shelf and upper slope, often near isolated rock, cobble, or shell debris. Solitary individuals are often found resting on the seafloor, although they occasionally form schools that move more than 100 meters in the water column (Love*, et al.* 2002; Rogers 1994).

Splitnose rockfish co-occur with an assemblage of slope rockfish, including Pacific ocean perch (*Sebastes alutus*), darkblotched rockfish (*Sebastes crameri*), yellowmouth rockfish (*Sebastes* *reedi*), and sharpchin rockfish (*Sebastes zacentrus*) off Washington and Oregon, and stripetail rockfish (*Sebastes saxicola*), darkblotched rockfish and shortspine thornyhead (*Sebastolobus alascanus*) off central California. Pacific ocean perch and darkblotched rockfish are the most abundant members of that assemblage off the coasts of Oregon and Washington, but splitnose rockfish and darkblotched rockfish dominate off the northern coast of California. Lesser amounts of splitnose have also been noted in the deep water DTS assemblage and with shrimp catch (Rogers 1994; Rogers and Pikitch 1992; Weinberg 1994).

There are no clear stock delineations for splitnose rockfish in the U.S. waters. No molecular markers have yet been developed for this species, and no genetic data are currently available to suggest the presence of stock structure (Waples*, et al.* 2008). No distinct breaks are seen in the fishery landings and catch distributions. Survey catches imply a continuous distribution. The spatial dynamic cluster analysis of the NWFSC survey abundance indices (Cope and Punt 2009) provided no evidence of spatial stock structure for splitnose rockfish off Washington, Oregon, and California.

Splitnose rockfish are documented in the literature to live to at least 86 years (Bennett*, et al.* 1982), although a fish encountered in a NMFS survey was aged at 103 years old. This is a small species – the maximum size reported in the literature is 46 cm (Love*, et al.* 2002); the vast majority of individuals caught in NMFS surveys were under 44 cm in fork length, although a few fish larger than this were caught.

Splitnose rockfish exhibit sexual dimorphism in growth. Although the males grow to their maximum lengths earlier than females, females reach larger sizes than males (Boehlert 1980; Love*, et al.* 2002). It was hypothesized that life history characteristics may vary with lat., but that is uncertain. Boehlert and Kappenman (1980) detected greater size-at-age with increasing lat. and suggested more rapid growth of fish in the northern end of their range. Analysis of the NWFSC shelf-slope survey data did not show a distinct gradient in growth rate between north and south, although the asymptotic length (Linf) exhibits a latitudinal gradient (Gertseva*, et al.* 2009). Growth of splitnose rockfish was found to correlate with climate and environmental variables, including sea surface temperature, the (ENSO) index, and the PDO (Black 2009; Black*, et al.* 2008); more information is needed to develop climate-growth relationships for stock assessment purposes.

Female splitnose rockfish off California mature at 6-9 years old (18-23 cm long) (Echeverria 1987), and their fecundity increases with size (Phillips 1964). Splitnose rockfish mature somewhat later off British Columbia - both males and females reach 50 percent maturity at size of 27 cm (Westrheim 1975). Like other rockfishes, splitnose utilize internal fertilization and bear live young (Love*, et al.* 2002). This species can exhibit a long reproductive season, with young larvae found in all months off southern California, from January to September off central California, from March to September in Oregon, and in July off Washington (Love*, et al.* 2002; Moser*, et al.* 2000).

Young juveniles live at the surface for several months, then go through a transitory midwater residence, and finally settle to benthic habitats near the end of their first year of life (Love*, et al.* 2002). During their first year, splitnose have been found living among drifting vegetation in Puget Sound and southern California, and under floating objects in Queen Charlotte Sound, British

Columbia (Shaffer*, et al.* 1995). Pelagic juvenile splitnose feed on calanoid copepods and amphipods (Shaffer*, et al.* 1995), while benthic juveniles and adults eat krill, copepods, sergestid shrimps and amphipods. Splitnose are prey of Steller sea lions and other pinnipeds (Love*, et al.* 2002).

Size-composition data for splitnose rockfish show a strong gradient of body size with depth, with smaller fish in shallow waters, suggesting ontogenetic movements of splitnose rockfish to deeper waters with increasing size and age, a common phenomenon in the genus *Sebastes* (Boehlert 1980).

Stock Status and Management History

Limits on domestic rockfish catches were first instituted in 1983, with splitnose rockfish managed as a part of the *Sebastes* complex, which included around 50 species. The ABC for the *Sebastes* complex was estimated for each INPFC area along the coast based on historic landings. In 1994, the *Sebastes* complex was divided into southern and northern management areas, and harvest guidelines were established for the complex in each area. The southern area included the Conception, Monterey and Eureka INPFC areas, and the northern area included the Columbia and U.S.-Vancouver INPFC areas.

In response to a concern that deep water species off Oregon and Washington might have been overharvested, Rogers (1994) conducted a preliminary assessment of splitnose rockfish, which focused on compiling and reviewing the available data. However, since the data were sparse and no evident trends in biomass or mean size were detected, the results were inconclusive. In 1996 the status of several rockfish species, which were part of the *Sebastes* complex, were assessed (Rogers*, et al.* 1996), and ABCs for splitnose rockfish in the southern area were calculated to be 868 mt for the southern management area and 274 mt for the northern management area. These amounts were not specified individually but included in the total ABCs for the *Sebastes* complex.

In 1998, unusually high splitnose rockfish landings drove *Sebastes* complex harvests in the southern management area sharply upward. In 1999, for the first time, splitnose rockfish were individually separated from the southern *Sebastes* complex. Individual ABCs and OYs for splitnose rockfish in that area have been specified along with splitnose-specific trip limits since then. The ABC for the southern management area was set at 868 mt, as estimated in the 1996 assessment of the remaining rockfish in the *Sebastes* complex (Rogers*, et al.* 1996).

Additionally, in 1999, the general *Sebastes* complex was divided into nearshore, shelf, and slope assemblages, and the dividing line between the northern and southern management areas was shifted southward to 40°10' N. lat., near Cape Mendocino. Since that time, in the northern area, splitnose has been managed under trip limits for slope rockfish. In 2000, harvest specifications for splitnose rockfish were set for the Conception and Monterey areas only, and 48 mt for the Eureka area were added to the northern rockfish ABC. Also, a precautionary adjustment of the OY (reduced from the ABC by 25 percent) was specified to account for the limited nature of the assessment. In 2000, the ABC and OY for splitnose rockfish south of 40°10' N. lat. were reduced based on the revised F_{MSY} harvest rate policy. During the last 10 years, the coastwide landings and total catch of splitnose rockfish were relatively low, and the limits established for the area south of 40°10' N. lat. have not been exceeded.

Gertseva et al. (2009) assessed splitnose rockfish coastwide and determined the stock was healthy with a depletion of 66 percent at the start of 2009. Since 1999, the splitnose spawning output was estimated to have been increasing in response to below-average removals and above-average recruitment during the last decade. At the beginning of 2009 the estimated spawning stock output was 8,426 million eggs. Uncertainty in the model was explored though asymptotic variance estimates and sensitivity analyses. Asymptotic confidence intervals were estimated within the model and reported throughout the assessment for key model parameters and management quantities. Uncertainty in recent recruitment was used to define alternative states of nature and develop the decision table.

The Council adopted the default harvest control rule of ACL = ABC (P* = 0.45) for splitnose rockfish for 2019 and beyond. Splitnose rockfish are managed with stock-specific harvest specifications south of 40°10' N. lat. and within the Slope Rockfish complex north of 40°10' N. lat. The projected coastwide OFLs, ABCs, and ACLs for splitnose rockfish are apportioned north and south of 40°10' N. lat. using average historical (1916-2008) landings with 64.2 percent apportioned south of 40°10' N. lat.

Stock Productivity

Steepness of the stock-recruitment curve was fixed at a value of 0.58 in the 2009 splitnose rockfish assessment, as estimated by a meta-analysis for unassessed rockfish. Recruitment deviations were estimated for each year between 1960 and 2006, which was the period best informed by the data based on evaluation of the variance of the recruitment deviations. Prior to 1960 and after 2006, recruits were taken deterministically from the stock-recruit curve. The model estimated above-average recruitments in the most recent years beginning 1999, which along with low catches during the last decade determine a population increase in recent and early forecast years. Uncertainty in recent recruitment was used to define alternative states of nature and develop the decision table.

Fishing Mortality

Splitnose rockfish have been taken incidentally in fisheries such as the trawl fisheries targeting POP, mixed slope rockfish, and other deep water targets, but have not been a commercial target species. Splitnose rockfish were lightly exploited until the 1940s, when the trawl fishery for rockfish first became important. With the development of the POP fishery (a species with which splitnose rockfish co-occur), spawning output of splitnose rockfish began to decline. A sharp drop in the 1960s was associated with large harvests of POP by foreign trawl fleets operating in the U.S. EEZ. Another drop occurred in 1998 when the increased availability of splitnose rockfish led to high removals off California. Since 1999, the splitnose spawning output was estimated to have been increasing in response to below-average removals and above-average recruitment during the last decade.

It was decided to continue management of splitnose rockfish with stock-specific specifications south of 40°10' N. lat. and under the Slope Rockfish complex north of 40°10' N. lat. when the coastwide splitnose rockfish assessment was first used to inform management in 2011. A north-south apportionment based on the average 1916-2008 assessed area catch resulted in 64.2 percent of the stock-specific specifications in the southern area and 35.8 percent for the contribution of splitnose rockfish to the Slope Rockfish North complex being used to apportion harvest specifications since 2011. The Council recommended continuing this management strategy largely due to the implications of determining the uncertain catch history by trawl permit to initially allocate trawl splitnose quota shares (QS) under Amendment 20. Since splitnose rockfish are not targeted and predominantly discarded at sea, little data would be available to determine catch history.

2.4.25 Starry Flounder

Distribution and Life History

Starry flounder (*Platichthys stellatus*) have a very broad geographic distribution around the rim of the North Pacific Ocean and have been recorded from Los Angeles to the Aleutian Islands, although they are rare south of Point Conception (Kramer and O'Connell 1995; Orcutt 1950). Off the U.S. West Coast starry flounder are found commonly in nearshore waters, especially in the vicinity of estuaries (Baxter 1999; Kimmerer 2002; NOAA 1990; Orcutt 1950; Pearson 1989; Sopher 1974). It has quite a shallow bathymetric distribution, with most individuals occurring in waters less than 80 m, although specimens have been collected off the continental shelf in excess of 350 m (Kramer and O'Connell 1995; Orcutt 1950). They are most often found on gravel, clean shifting sand, hard stable sand, and mud substrates.

Spawning occurs primarily during the winter months of December and January, at least in central California (Orcutt 1950); it may occur somewhat later in the year (February-April) off British Columbia and Washington (Hart 1988; Love 1996). Egg/larval development apparently takes about 2-3 months to occur. Offspring principally remain within the estuaries until age two, when many have migrated to the adjacent ocean habitats (Baxter 1999; Kimmerer 2002; Orcutt 1950). Reproductive maturity occurs at age two years for males and age three years for females, when the fish are 28 cm and 35 cm, respectively. Tagging studies have shown that fish are relatively sedentary and move little during their adult lives (Love 1996); however, there is little information on regional variation in stock structure.

Starry flounder consume crabs, shrimps, worms, clams and clam siphons, other small mollusks, small fish, nemertean worms, and brittle stars (Hart 1988).

Stock Status and Management History

The U.S. West Coast starry flounder stock was assessed in 2005 (Ralston 2006). The assessment was based on the assumption of separate biological populations north and south of the California-Oregon border. The assessment used catch data, relative abundance indices derived from trawl logbook data, and an index of age-1 abundance from trawl surveys in the San Francisco Bay and Sacramento-San Joaquin River estuary. Unlike most other groundfish stock assessments, no age- or length-composition data were directly used in the assessment. Both the northern and southern populations were estimated to be above the target level of 40 percent of virgin spawning biomass (44 percent in Washington-Oregon and 62 percent in California), although the status of this data-limited species remained fairly uncertain compared to that of many other groundfish species. One of the most significant areas of uncertainty in the assessment was the estimate of natural mortality rate, which was quite high (0.30 for females and 0.45 for males).

Starry flounder were managed in the Other Flatfish complex until 2007, when the stock was removed from the complex and managed with stock-specific specifications determined from the assessment. Starry flounder have never been overfished or subject to overfishing.

A new starry flounder assessment was not conducted in 2015 and the 2005 assessment was out of date for informing harvest specifications in 2017 and beyond. A DB-SRA assessment of starry flounder was conducted, reviewed, and approved in 2017 to inform harvest specifications in 2019 and beyond. The OFL of 652 mt is the sum of estimated California and Oregon OFLs of 354 mt and 298 mt, respectively. Harvest specifications in 2019 and beyond are based on the default harvest control rule of ACL equal to ABC with a P* of 0.4. The starry flounder stock has consistently been harvested at about 2 percent of the allowable harvest and there are no conservation concerns for this under-utilized stock.

Stock Productivity

Recruitment deviations were estimated in both the northern and southern starry flounder assessment models, although selectivity patterns were fixed external to the model after analysis of trawl length composition information from the Pacific Fisheries Information Network (PacFIN)-Biological Data System (BDS) database and sport length composition information from the Recreational Fisheries Information Network (RecFIN) database. Growth and other life history parameters were also fixed, largely based on a detailed study of starry flounder by Orcutt (1950). Finally, spawner-recruit steepness ($h = 0.80$) and recruitment variability ($\sigma r = 1.00$) were also held constant.

Starry flounder is a relatively productive stock with a PSA productivity score of 2.15. They are also not vulnerable to potential overfishing ($V = 1.04$).

Fishing Mortality

Starry flounder are mostly caught in nearshore recreational fisheries. Historically, they were also caught in nearshore trawl efforts; however, this catch is rare today given that Washington and California have closed their state nearshore waters to trawling. Both the northern and southern stocks were estimated to be well above the $B_{25\%}$ B_{MSY} threshold ($B_{44\%}$ in Washington-Oregon and $B_{62\%}$ in California). In addition, recent exploitation rates have been well below the F_{MSY} proxy for flatfish.

2.4.26 Widow Rockfish

Distribution and Life History

Widow rockfish (*Sebastes entomelas*) range from Albatross Bank off Kodiak Island to Todos Santos Bay, Baja California, Mexico (Eschmeyer*, et al.* 1983; Miller and Lea 1972; NOAA 1990). They occur over hard bottoms along the continental shelf (NOAA 1990) and prefer rocky banks, seamounts, ridges near canyons, headlands, and muddy bottoms near rocks. Large widow rockfish concentrations occur off headlands such as Cape Blanco, Cape Mendocino, Point Reyes, and Point Sur. Adults form dense, irregular, midwater and semi-demersal schools deeper than 100 m at night and disperse during the day (Eschmeyer, *et al.* 1983; NOAA 1990; Wilkins 1986). All life stages are pelagic, but older juveniles and adults are often associated with the bottom (NOAA 1990). All life stages are fairly common from Washington to California (NOAA 1990). Pelagic larvae and juveniles co-occur with yellowtail rockfish, chilipepper, shortbelly rockfish, and bocaccio larvae and juveniles off Central California (Reilly, *et al.* 1992).

Widow rockfish are ovoviviparous, have internal fertilization, and brood their eggs until released as larvae (NOAA 1990; Reilly, *et al.* 1992). Mating occurs from late fall-early winter. Larval release occurs from December through February off California, and from February through March off Oregon. Juveniles are 21 mm to 31 mm at metamorphosis, and they grow to 25 cm to 26 cm over three years. Age and size at sexual maturity varies by region and sex, generally increasing northward and at older ages and larger sizes for females. Some mature in three years (25 cm to 26 cm), 50 percent are mature by four years to five years (25 cm to 35 cm), and most are mature in eight years (39 cm to 40 cm) (NOAA 1990). The maximum age of widow rockfish is 28 years, but rarely over 20 years for females and 15 years for males (NOAA 1990). The largest size is 53 cm and about 2.1 kg (Eschmeyer, *et al.* 1983; NOAA 1990).

Widow rockfish are carnivorous. Adults feed on small pelagic crustaceans, midwater fishes (such as age-one or younger Pacific whiting), salps, caridean shrimp, and small squids (Adams 1987; NOAA 1990). During spring, the most important prey item is salps, during the fall fish are more important, and during the winter widow rockfish primarily eat sergestid shrimp (Adams 1987). Feeding is most intense in the spring after spawning (NOAA 1990). Pelagic juveniles are opportunistic feeders, and their prey consists of various life stages of calanoid copepods, and euphausiids (Reilly, *et al.* 1992).

Stock Status and Management History

Widow rockfish are an important commercial species from British Columbia to central California, particularly since 1979, when Oregon trawl fisherman demonstrated the ability to make large catches at night using midwater trawl gear. Many additional participants entered the fishery resulting in a rapid increase in landings of widow rockfish (Love, *et al.* 2002). Widow rockfish are a minor component of the recreational groundfish fisheries.

The first West Coast assessments for widow rockfish were performed in 1988, 1990, 1993, and 1997 (Hightower and Lenarz 1990; Lenarz and Hightower 1988; Ralston and Pearson 1997; Rogers and Lenarz 1993). In 1988 the assessment involved the use of cohort analysis and the stock synthesis program. In 1993 and 1997, the age-based version of the stock synthesis program was used to assess the status of widow rockfish.

Williams et al. (2000) assessed the coastwide stock of widow rockfish in 2000. The spawning output level (8,223 million eggs), based on that assessment and a revised rebuilding analysis (Punt and MacCall 2002) adopted by the Council in June 2001, indicated the stock was at 23.6 percent of the unfished level (33,490 million eggs) in 1999. The widow rockfish stock was declared overfished in 2001 based on this assessment result.

It was concluded in the 2003 assessment (He*, et al.* 2003) that the widow rockfish stock size was at 24.7 percent of the unfished biomass and that stock productivity was considerably lower than previously thought. Results from the 2003 widow rockfish rebuilding analysis were used to develop the first widow rockfish rebuilding plan, which was adopted in April 2004 under Amendment 16-3 to the groundfish FMP. The rebuilding plan established a target rebuilding year of 2038 and a harvest control rule of F = 0.0093.

A full assessment was completed in 2005 for widow rockfish (He*, et al.* 2006a). The base model estimated that spawning biomass declined steadily since the early 1980s and that spawning output in 2004 was 31 percent of the unexploited level, above the Council's overfished threshold. Further, spawning output in the base model was estimated to have never dropped below the 25 percent overfished threshold. The 2005 rebuilding analysis indicated that the stock was much closer to reaching a rebuilt biomass than previously estimated: under the 2005 rebuilding analysis (He*, et al.* 2006b), T_{MIN} was estimated to be 2013, compared to a T_{MIN} of 2026 in the 2003 analysis (He*, et al.* 2003). This rebuilding analysis was used to modify the widow rockfish rebuilding plan, which was adopted under Amendment 16-4 in 2006. The target rebuilding year under the modified rebuilding plan was 2015 and the harvest control rule was an SPR harvest rate of 95 percent.

An updated assessment was done in 2007 (He*, et al.* 2008) using the same age-based model (written in ADMB) and data compiling procedures used in the previous assessment. The estimated total biomass in 2006 was 120,132 mt and the estimated depletion rate was 35.5 percent of the unfished spawning output. The population was projected to recover to the target in 2009, which was six years earlier than the target year in the rebuilding plan. Based on these results, the SSC recommended no changes to the rebuilding plan.

A full assessment of widow rockfish was conducted in 2009 (He*, et al.* 2009), which indicated the stock was at 38.5 percent of its unfished spawning output at the start of 2009. The 2009 assessment differed from the previous assessment in several respects: a) the assessment used Stock Synthesis 3 (SS3) rather than a custom-designed model, b) the catch history was revised and extended back to 1916, c) catch, age, and survey data were updated with data from 2007 and 2008, and d) data from the NWFSC trawl survey were included in the assessment. Widow rockfish were modeled as a single stock with two areas and four fisheries.

A full assessment of widow rockfish was conducted in 2011 (He*, et al.* 2011), which indicated the spawning stock biomass was successfully rebuilt with a depletion of 51 percent at the start of 2011. However, there was considerable uncertainty regarding the stock assessment’s finding that the stock had rebuilt. Productivity and status of this stock were highly uncertain because the available biomass indices were not informative. Nonetheless, the SSC considered the base model of the new widow rockfish assessment to be the best available science.

A new full assessment of widow rockfish was conducted in 2015 (Hicks and Wetzel 2015), which indicated the stock was at 75.1 percent depletion at the start of 2015 (Figure 2-57). A number of revisions were made to the data used for the 2015 stock assessment, including: 1) a new method of index standardization for NWFSC groundfish bottom trawl survey using a geo-statistical delta-GLMM model, 2) a new steepness value (0.798) based on an updated meta-analysis of steepness (the prior distribution on steepness in the meta-analysis was recalculated without the widow values), 3) a prior distribution developed for the natural mortality parameter from an analysis of a maximum age of 54 years, 4) updated methods of expanding fishery length and age composition, and survey conditional age at length, and 5) new ageing error tables. For this assessment, there was a more thorough investigation of available age and length data, increasing the amount of these data relative to previous assessments. In addition, Washington historical landings were reconstructed. Other changes from the last assessment included how fisheries were structured and how selectivity was modeled. The index was split based on a shift in the Q value in a single fleet rather than have two separate fleets as was done in previous assessments.

An update of the 2015 assessment of widow rockfish was conducted in 2019, which indicated the stock was at 92 percent depletion at the start of 2019 (Adams, *et al.* 2019). The updated data and time series include a notable (albeit noisy) upward trend over most of the last few years that was fit reasonably well by the model and driven by several recent strong year classes (2008, 2010, 2013, and 2014). The revised depletion estimate was slightly lower than what was projected in the 2015 assessment, but maintains the ongoing increase in abundance, such that the model estimated a 2019 depletion of 92 percent. The axis of uncertainty for the decision table was a combination of natural mortality, steepness, and the strength of the 2013 recruitment.

The Council adopted the default harvest control rule for widow rockfish where the ACL equals the ABC under a P* of 0.45 for 2019 and beyond.

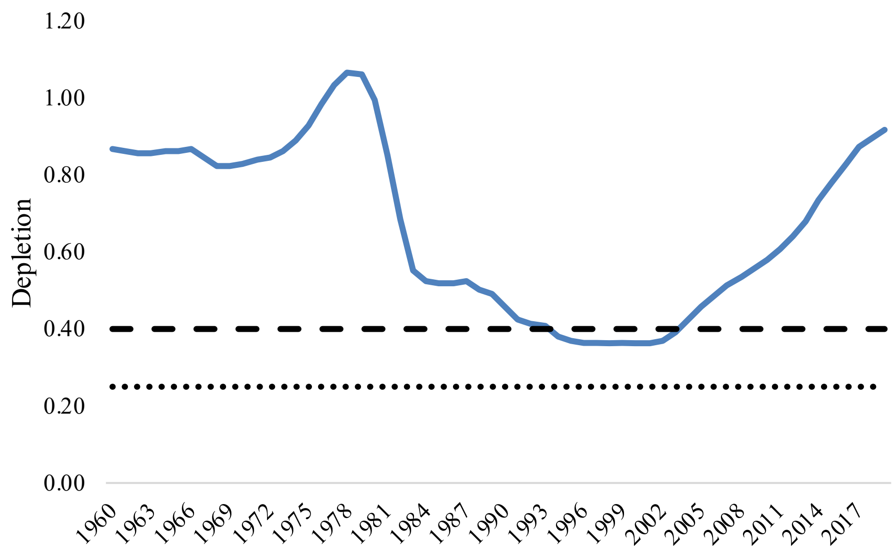

Figure 2-57. Relative depletion of widow rockfish from 1960 to 2019 based on the 2019 stock assessment update.

Stock Productivity

The 2019 widow rockfish assessment assumed a steepness of 0.72 based on a meta-analysis of rockfish steepness. The PSA productivity score of 1.31 indicates a stock of moderate productivity.

Recruitment deviations were estimated in the 2019 assessment for the entire time series modeled. Recruitment deviations were estimated for the entire time series modeled. There is little information regarding recruitment prior to 1965, and the uncertainty in these estimates is expressed in the model. There are very large, but uncertain, estimates of recruitment in 2013, 1970, 2008, and 1971 (Figure 2-58). Other large recruitment events (in descending order of magnitude) occurred in 1978, 2014, 1981, 2010, and 1991. The five lowest recruitments (in ascending order) occurred in 2012, 2011, 1976, 2007, and 1973. Estimates of recruitment appear to be episodic and characterized by periods of low recruitment. Two of the four largest estimated recruitments happened in the last 11 years.

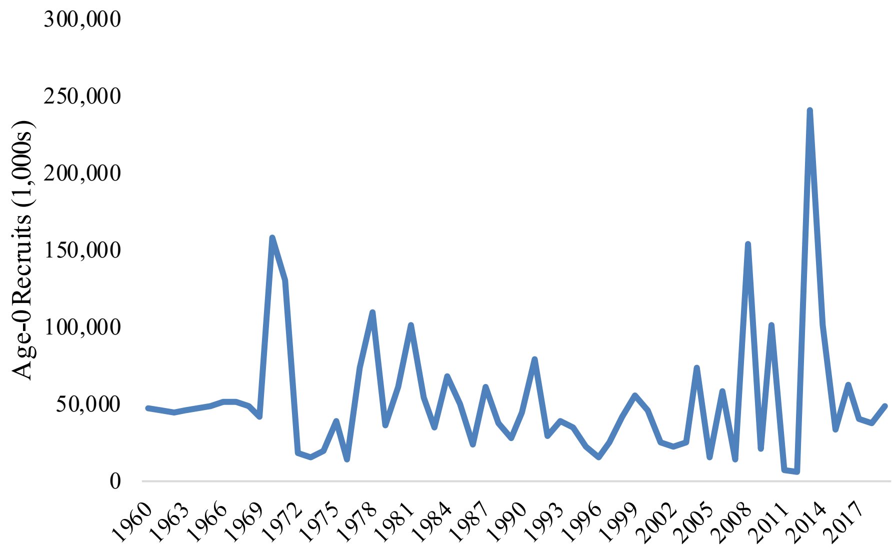

Figure 2-58. Estimated widow rockfish recruitments, 1960-2019 (from Adams et al. 2019).

Fishing Mortality

Widow rockfish are caught mostly in midwater trawls used to target Pacific whiting and, before 2002 (and increasingly after 2011), used to target widow and yellowtail rockfish. The spawning biomass of widow rockfish reached a low in 2001 before increasing due to low catch levels (Figure 2-57). The lower 95 percent confidence interval of the estimated depletion dipped below the overfished threshold in the very late 1990s and early 2000s, but has remained above that level otherwise, and currently the depletion estimate is significantly greater than the spawning biomass target. Throughout the 1980s and 1990s the exploitation rate and (1-SPR) were mostly above target levels (Figure 2-59). Exploitation rates between 2001 and 2016 on widow rockfish are estimated to have been substantially below target levels, however, have increased in the last two years (2017-2018).

Management uncertainty is low since widow rockfish is a trawl-dominant species and there is mandatory 100 percent observer coverage in trawl fisheries.

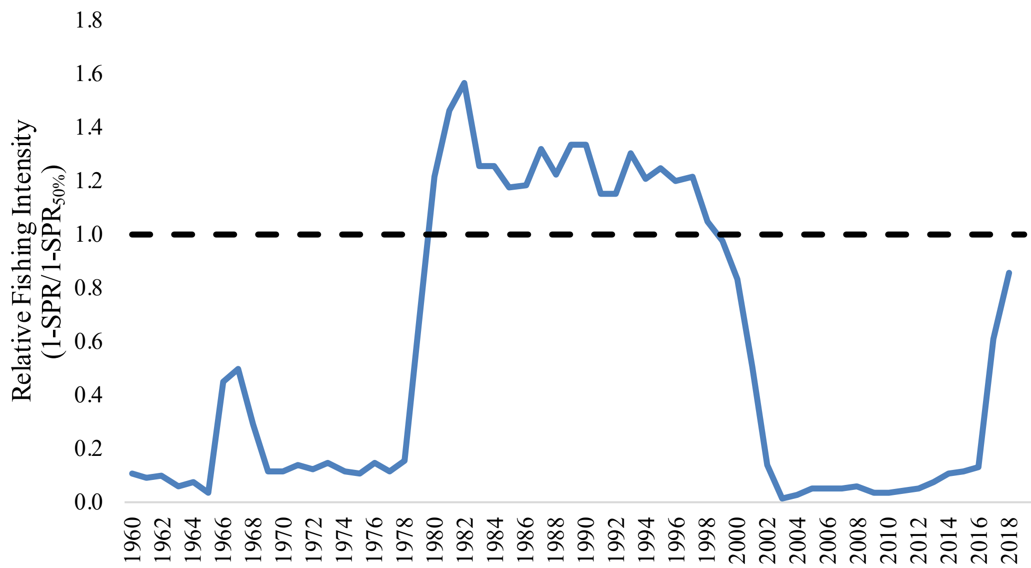

Figure 2-59. Relative fishing intensity of widow rockfish, 1960-2018.

2.4.27 Yellowtail Rockfish North of 40°10' N. Lat.

Distribution and Life History

Yellowtail rockfish (*Sebastes flavidus*) range from San Diego, California, to Kodiak Island, Alaska (Fraidenburg 1980; Gotshall 1981; Lorz*, et al.* 1983; Love*, et al.* 2002; Miller and Lea 1972; Norton and MacFarlane 1995). The center of yellowtail rockfish abundance is from Oregon to British Columbia (Fraidenburg 1980). Yellowtail rockfish are a common species abundant over the middle shelf (Carlson and Haight 1972; Fraidenburg 1980; Tagart 1991; Weinberg 1994). Yellowtail rockfish are most common near the bottom, but not on the bottom (Love*, et al.* 2002; Stanley*, et al.* 1994). Yellowtail rockfish adults are considered semi-pelagic (Stanley*, et al.* 1994; Stein*, et al.* 1992) or pelagic, which allows them to range over wider areas than benthic rockfish (Pearcy 1992). Adult yellowtail rockfish occur along steeply sloping shores or above rocky reefs (Love*, et al.* 2002). They can be found above mud with cobble, boulder and rock ridges, and sand habitats; they are not, however, found on mud, mud with boulder, or flat rock (Love*, et al.* 2002; Stein*, et al.* 1992). Yellowtail rockfish form large (sometimes greater than 1,000 fish) schools and can be found alone or in association with other rockfishes (Love*, et al.* 2002; Pearcy 1992; Rosenthal*, et al.* 1982; Stein*, et al.* 1992; Tagart 1991). These schools may persist at the same location for many years (Pearcy 1992).

Yellowtail rockfish are viviparous (Norton and MacFarlane 1995) and mate from October to December. Parturition peaks in February and March and from November to March off California (Westrheim 1975). Young-of-the-year pelagic juveniles often appear in kelp beds beginning in April and live in and around kelp in midwater during the day, descending to the bottom at night (Love*, et al.* 2002; Tagart 1991). Male yellowtail rockfish are 34 cm to 41 cm in length (five years to nine years) at 50 percent maturity, females are 37 cm to 45 cm (six years to ten years) (Tagart 1991). Yellowtail rockfish are long-lived and slow-growing; the oldest recorded individual was

64 years old (Fraidenburg 1980; Tagart 1991). Yellowtail rockfish have a high growth rate relative to other rockfish species (Tagart 1991). They reach a maximum size of about 55 cm in approximately 15 years (Tagart 1991). Yellowtail rockfish feed mainly on pelagic animals, but are opportunistic, occasionally eating benthic animals as well (Lorz*, et al.* 1983). Large juveniles and adults eat fish (small Pacific whiting, Pacific herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms (euphausiids, salps, and pyrosomes) (Love*, et al.* 2002; Phillips 1964; Rosenthal*, et al.* 1982; Tagart 1991).

Stock Status and Management History

Until late 2002, yellowtail rockfish were harvested as part of a directed midwater trawl fishery. Yellowtail rockfish are common in both commercial and recreational fisheries throughout its range, and commonly occur with canary rockfish and widow rockfishes (Cope and Haltuch 2012). Despite its popularity in commercial and recreational fisheries, its association with those highly regulated species has greatly decreased removals over the last decade. From the end of 2002 through 2010, implementation of the RCAs and small landings limits designed to only accommodate incidental bycatch eliminated directed midwater fishing opportunities for yellowtail rockfish in non-tribal trawl fisheries. A limited opportunity to target yellowtail rockfish in the trawl fishery has been available since 2011 under the trawl rationalization program, yet low quotas for widow rockfish, canary rockfish, and for other constraining stocks had limited midwater targeting of yellowtail rockfish. With the improved status of widow and canary rockfish, the industry is developing a strategy to better target their allocations of yellowtail and widow rockfish.

Yellowtail rockfish are currently managed with stock-specific harvest specifications north of 40°10’ N. lat. and within the southern Shelf Rockfish complex south of 40°10’ N. lat. There has never been an assessment of the southern stock and the OFL contribution of yellowtail rockfish to the southern Shelf Rockfish complex is based on a DB-SRA estimate.

Yellowtail rockfish on the U.S. West Coast north of 40°10’ N. lat. were assessed in 1984 (Weinberg*, et al.* 1984), 1986 (Coleman 1986), 1988 (Tagart 1988), 1993 (Tagart 1993), 1996 (Tagart and Wallace 1996), and 1997 (Tagart*, et al.* 1997) to determine harvest specifications for the stock. A full assessment in 2000 (Tagart*, et al.* 2000) was the first that estimated stock status with an estimated depletion of 60.5 percent at the start of 2000. Lai et al. (2003) updated the 2000 assessment and estimated stock depletion was 46 percent at the start of 2003. Another assessment update was prepared in 2005 (Wallace and Lai 2006) with an estimated depletion of 55 percent at the start of 2005.

A data-moderate assessment of yellowtail rockfish north of 40°10’ N. lat. was conducted in 2013 (Cope*, et al.* 2014). The estimated depletion at the start of 2013 was 67 percent and the spawning biomass was estimated to be 50,043 mt. This was a large biomass increase relative to previous estimates and can be attributed to the low removals in the last 10 years.

A full assessment of yellowtail rockfish north of 40°10’ N. lat. was conducted using Stock Synthesis in 2017, which indicated the stock was healthy with a 75 percent depletion at the start of 2017 (Stephens and Taylor 2017) (Figure 2-60). The estimate of natural mortality of females for the northern model was 0.174, and that for males was 0.15. Steepness was fixed at the mean of the prior (0.718). The final base model is heavily reliant on compositional data, although fishery-independent survey indices are somewhat informative. Then SSC categorized the 2017 yellowtail rockfish assessment as a category 1 assessment.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and beyond.

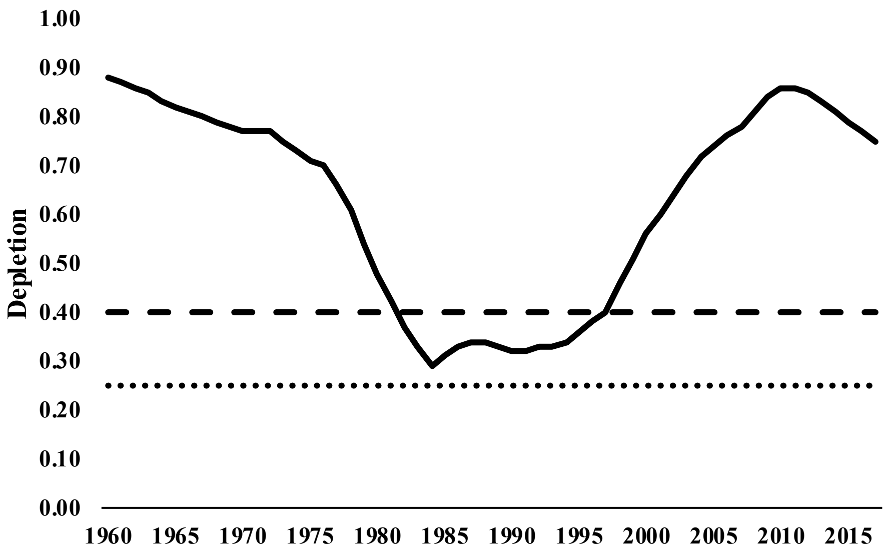

Figure 2-60. Relative depletion of yellowtail rockfish north of 40°10' N. lat. from 1960 to 2017 based on the 2017 stock assessment.

Stock Productivity

Steepness was fixed at the mean of the prior (0.718) of the most recent meta-analysis of rockfish steepness. Due to the low susceptibility of yellowtail rockfish to fisheries removals, the vulnerability to overfishing of yellowtail rockfish is relatively low (V = 1.88), though the productivity of this species is also relatively low (P = 1.33) based on other life history traits, including a longevity to almost 70 years.

Recruitments of yellowtail rockfish north of 40°10' N. lat. have ranged from roughly 17.5 million to 88 million since 1989 with particularly large year classes in 1989-1991, 1998-2000, 2006, 2008, and 2010 (Figure 2-61).

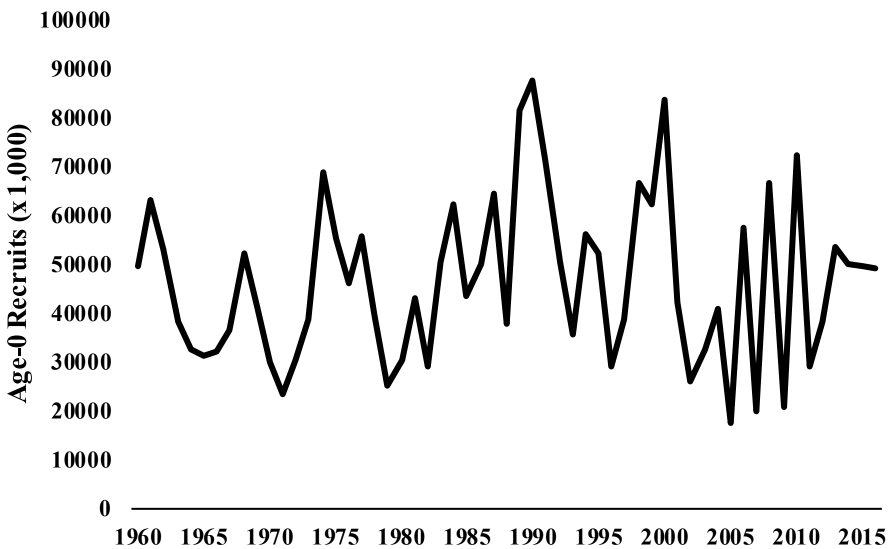

Figure 2-61. Estimated recruitments of yellowtail rockfish north of 40°10' N. lat., 1960-2016 (from Stephens and Taylor 2017).

Fishing Mortality

Fishing mortality of yellowtail rockfish north of 40°10' N. lat. was relatively high and the stock experienced overfishing relative to the current SPR-based harvest rate limit ($F_{50\%}$) in the 1980s and 1990s with direct targeting by midwater trawl gear of yellowtail and widow rockfish (Figure 2-62). The elimination of that fishery in 2003 to reduce impacts on widow rockfish (and canary rockfish to some degree), coupled with RCA implementation, significantly reduced fishing mortality of yellowtail rockfish. Fishing intensity has been well within the management limits in recent years and exploitation rates (catch divided by age 4+ biomass) are estimated to have been less than 2 percent per year.

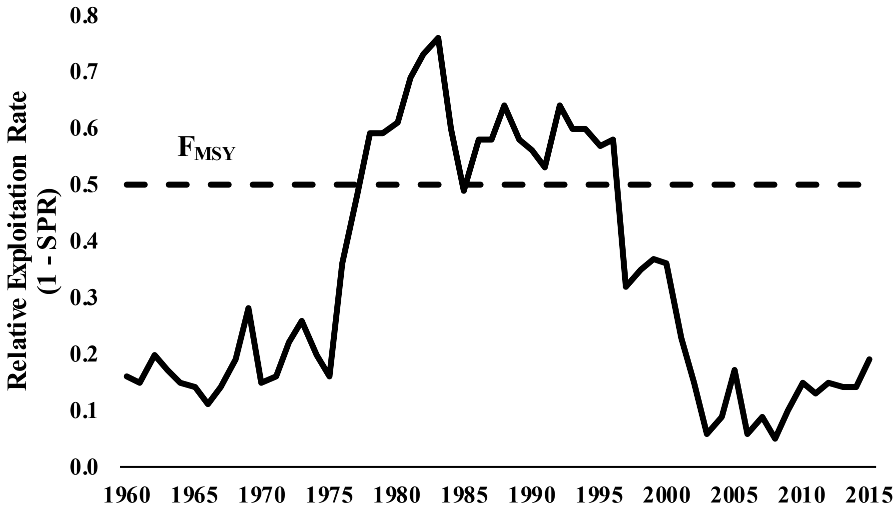

Figure 2-62. Estimated spawning potential ratio (SPR) of yellowtail rockfish north of 40°10' N. lat. relative to the current F_{MSY}, 1960-2015. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5 Groundfish Stock Complexes

There are eleven stock complexes for which ACLs were specified through the 2023-2024 management cycle. These complexes are the Nearshore, Shelf, and Slope Rockfish complexes north and south of 40°10' N. lat., the Other Flatfish, the Other Fish, the Oregon Black/Blue/Deacon Rockfish, the Oregon Cabezon/Kelp Greenling, and the Washington Cabezon/Kelp Greenling complexes. The Oregon Black/Blue/Deacon Rockfish, the Oregon Cabezon/Kelp Greenling, and the Washington Cabezon/Kelp Greenling complexes were newly specified stock complexes in 2019.

Most of the component stocks comprising the stock complexes are unassessed category 3 stocks with OFLs that are determined using data-limited methods such as DB-SRA, DCAC, or average historical catch (see Section 2.8.1). In cases where assessments were used to inform OFLs for component stocks managed in stock complexes, the OFLs were projected from those assessments using proxy F_{MSY} harvest rates. A more detailed description of the assessed stocks managed in stock complexes follows.

These complexes are the status quo management structure for these stocks as described in Federal regulations. In March 2022, NMFS notified the Council they would not make any status determinations for any of the stocks assessed in 2021, including quillback rockfish, pending an FMP amendment that specifies stocks in need of conservation and management (i.e., actively managed stocks), defines stock delineations and management boundaries for purposes of making status determinations, and stock complexes that align better with National Standard 1 guidelines. Status determinations would then be made after such an FMP amendment is approved by NMFS. While status determinations have not been officially made for the stocks/species assessed in 2021, those assessments are considered the best scientific information available and will inform management in 2023 and beyond.

It is anticipated the Council will continue to manage West Coast fisheries under the stock structure described in this SAFE document in 2023-24 and consider stock complex restructuring in an FMP amendment process in the interim. New stock definitions and stock complex structures are anticipated for managing fisheries in 2025 and beyond. If quillback rockfish in California and other stocks assessed in 2021 (or 2023) and subsequently defined in the FMP are considered to be below the MSST, rebuilding plans will be developed in time for implementation in 2025.

2.5.1 Nearshore Rockfish North and South of 40°10' N. Lat.

The nearshore rockfish complexes north and south of 40°10' N. lat. Are comprised of both assessed and unassessed species. Of the stocks managed in the nearshore rockfish complexes, only blue and deacon rockfishes north of Pt. Conception, brown rockfish, China rockfish, copper rockfish, gopher and black-and-yellow rockfishes in California north of Pt. Conception, and quillback rockfish have been assessed. The following section defines these complexes in terms of their component stocks and provides further detail on those component stocks that have been assessed.

The Nearshore Rockfish complex north of 40°10' N. lat. Is composed of the following species: black-and-yellow rockfish (*Sebastes chrysomelas*), blue rockfish (*S. mystinus*) off northern California and Washington, brown rockfish (*S. auriculatus*), calico rockfish (*S. dalli*), China rockfish (*S. nebulosus*), copper rockfish (*S. caurinus*), deacon rockfish (*S. diaconus*) off northern California and Washington, gopher rockfish (*S. carnatus*), grass rockfish (*S. rastrelliger*), kelp rockfish (*S. atrovirens*), olive rockfish (*S. serranoides*), quillback rockfish (*S. maliger*), and treefish (*S. serriceps*).

The Nearshore Rockfish complex south of 40°10' N. lat. Is further subdivided into the following management categories: 1) shallow nearshore rockfish [comprised of black-and-yellow rockfish (*Sebastes chrysomelas*), China rockfish (*S. nebulosus*), gopher rockfish (*S. carnatus*), grass rockfish (*S. rastrelliger*), and kelp rockfish (*S. atrovirens*)], and 2) deeper nearshore rockfish [comprised of blue rockfish (*S. mystinus*), brown rockfish (*S. auriculatus*), calico rockfish (*S. dalli*), copper rockfish (*S. caurinus*), deacon rockfish (*S. diaconus*), olive rockfish (*S. serranoides*), quillback rockfish (*S. maliger*), and treefish (*S. serriceps*)].

2.5.1.1 Blue and Deacon Rockfish off California

Distribution and Life History

Blue rockfish (*Sebastes mystinus*), now known to include deacon rockfish (*S. diaconus*), range from Baja California Sur, Mexico to British Columbia, Canada, although they are most commonly found between Oregon and central California (Love 2011). The two species were assessed as a complex in 2017 (see the next section; Dick*, et al.* 2017). Deacon rockfish was formally separated from blue rockfish based on morphometric and microsatellite genetic analyses by Frable et al. (2015). Thus, the 2017 blue and deacon rockfishes (BDR) assessment was done as a complex of the two species because almost all of the historical data available consist of mixed BDR in unknown proportions. While genetic studies have found that, at least in recent decades, deacon rockfish are more common north of Monterey Bay, and blue rockfish more common to the south, catch and index data were separated at the Oregon/California border due to management history.

The two species appear to be mixed to some degree throughout the entire range of the two areas assessed.

BDR inhabit kelp forests and rocky reefs in relatively shallow depths usually to about 90 meters (50 fm) (Miller and Lea 1972; Reilly 2001), but have been landed as deep as 549 meters (300 fm) (Love*, et al.* 2002). These two species are sympatric from northern California to central Oregon (Frable*, et al.* 2015). BDR can occupy depths from the shallow intertidal zones out to 149 m at Stonewall Banks (Hannah and Blume 2016), but are also found 500 km west of Washington at Cobb seamount where depths range from 33 – 820 m (Douglas 2011). However, these fish are most commonly encountered in depths from 0 – 55 m (Love 2011) as schools can surface feed. BDR are schooling semi-pelagic species commonly found aggregating with black rockfish, canary rockfish, widow rockfish, yellowtail rockfish, olive rockfish, and blacksmiths. BDR are residential, with their movements restricted to a small area, usually near the kelp canopy or pinnacles for shelter and spatial orientation (Jorgensen*, et al.* 2006; Lea*, et al.* 1999; Miller and Geibel 1973).

BDR are primarily "selective opportunity" planktivores (Gotshall*, et al.* 1965; Love and Ebeling 1978). As juveniles, they feed on planktonic crustacea, hydroids, and algae (Miller and Geibel 1973). Adults also consume fish, squid, tunicates, scyphozoids, bull kelp nori, and pelagic gastropods (Hobson*, et al.* 1996; Lea*, et al.* 1999; Love*, et al.* 2002). Many of these prey items are made available from the relaxation of upwelling or southerly winds, explaining high blue rockfish numbers in the summer off central and northern California, where these conditions are well developed (Hobson and Chess 1988; Love*, et al.* 2002). Due to their great abundance in kelp forests, blue rockfish juveniles are recognized as a key species in the piscivore trophic web of these ecosystems (Hallacher and Roberts 1985).

Stock Status and Management History

The blue rockfish stock in California waters north of Pt. Conception was assessed in 2007 and the stock's depletion was estimated to be 29.7 percent of its unfished spawning output at the start of 2007 (Key*, et al.* 2008); therefore, the stock was considered to be in the precautionary zone. Blue rockfish were not a highly sought species historically, but an increase in catches in the 1970s resulted in a continuous decline in spawning biomass through the early 1990s. The abundance of blue rockfish was at the management target ($B_{40\%}$) in 1980 and at the overfished threshold in 1982. Spawning biomass reached a minimum (10 percent of unexploited) in 1994 and 1995; however, there has been a constant increase since then.

During the 2009 and 2010 biennial specifications process, the Council contemplated removing blue rockfish from the Nearshore Rockfish complexes. Blue rockfish was managed within the Nearshore Rockfish complexes because of scientific uncertainty and management needs, given the interaction of blue rockfish with other nearshore species. When blue rockfish occur offshore, they can be targeted separately from other nearshore rockfish, but those that occur inshore mix with other nearshore rockfish stocks. Blue rockfish are managed under California's Nearshore Fishery Management Plan which has mandatory sorting requirements for landed catch. Landings are routinely tracked and monitored, thereby reducing management uncertainty.

The Council had implemented precautionary management of the California population of blue rockfish since 2009 by setting a harvest guideline for California fisheries based on the sum of the 40-10 adjusted ACL contribution north of Pt. Conception and the ABC contribution south of Pt. Conception. This HG had not been exceeded. Beginning in 2019, there is no blue rockfish harvest guideline for the population occurring off California since the stock was projected to be healthy starting in 2019.

A new assessment of BDR, assessed as a complex of the two species, was conducted in 2017 for the populations of these two species off California north of Pt. Conception and Oregon (Dick*, et al.* 2017). The California assessment estimates that the BDR population reached a low depletion level of 15.6 percent in 2007, and had recovered nearly to the target level, being at 37.3 percent of the unfished spawning output in 2017 (Figure 2-63). A strong 2013 year class appears to be entering the population.

While genetic studies have found that, at least in recent decades, deacon rockfish are more common north of Monterey Bay, and blue rockfish more common to the south, catch and index data were separated at the Oregon/California border due to management history. The two species appear to be mixed to some degree throughout the entire range of the two areas assessed.

The 2017 BDR assessment for California is generally consistent with the results of the 2007 assessment. The scale of the stock is similar, and proxy ($SPR_{50\%}$) estimates of MSY are similar (275 mt per the 2007 assessment and 306 mt per the 2017 assessment). However, estimates of recent stock size based on the 2017 assessment are imprecise, which results in imprecise forecasts of yield. The California assessment includes several fishery-dependent and –independent sources, though no comprehensive survey of adults. There is a general lack of recent age data, and the assessment is sensitive to the inclusion or exclusion of age information in the form of conditional age-at-length data from relatively recent research projects.

Steepness and natural mortality were both estimated in the 2017 California BDR assessment. While estimation of steepness is unusual, especially for a species without a strong fishery-independent index, the "two-way trip" pattern of depletion history may provide more information on steepness, and the estimation of steepness and natural mortality provides for more realistic quantification of uncertainty coming out of the assessment for use in the decision table. The estimated value of steepness, 0.65, is close to the mean of the prior distribution for rockfish, 0.72. Similar to natural mortality, uncertainty in the Beverton-Holt steepness parameter contributes to the imprecision of recent BDR biomass. However, population scale (unfished spawning output) in the California model is robust to changes in these parameters, relative to the Oregon model (see Stock Status and Management History of Oregon BDR in Section 2.5.2). Catches of blue and deacon rockfish are strongly skewed toward females. The current assessment accounts for this through gender-specific growth and natural mortality. An alternative (or parallel) hypothesis is that males are less vulnerable to the fishery (i.e., have a gender-specific selectivity). The California BDR model was not able to estimate gender-specific selectivity curves given the available data.

The SSC endorsed the use of the California BDR stock assessment as the best scientific information available for status determination and management as a category 2 assessment due to BDR being a complex of two species. The sigma value derived from the decision table for the

California assessment is larger than the category 2 sigma of 0.72 (0.783) and this value was used in calculating the scientific uncertainty buffer used to determine ABCs.

The Council adopted default harvest specifications (ACL = ABC with a P* of 0.45) for the California BDR contribution to the Nearshore Rockfish complexes north and south of 40°10' N. lat. Without a 40-10 adjustment to the 2019 and beyond ACLs since the stock is projected to be above the B_{MSY} target of 40 percent depletion beginning in 2019 (projected depletion in 2019 is 42.1 percent). The California harvest specifications were apportioned north and south of 40°10' N. lat. Based on an approach that combines existing habitat information with a catch-per-unit-effort proxy for fish density (see Appendix D in the 2017 BDR assessment). This approach estimated a relative biomass of California BDR north of 40°10' N. lat. Of 10 percent and the harvest specifications were apportioned accordingly. A catch only-projection of BDR in California was provided to inform harvest specifications for 2021 and beyond.

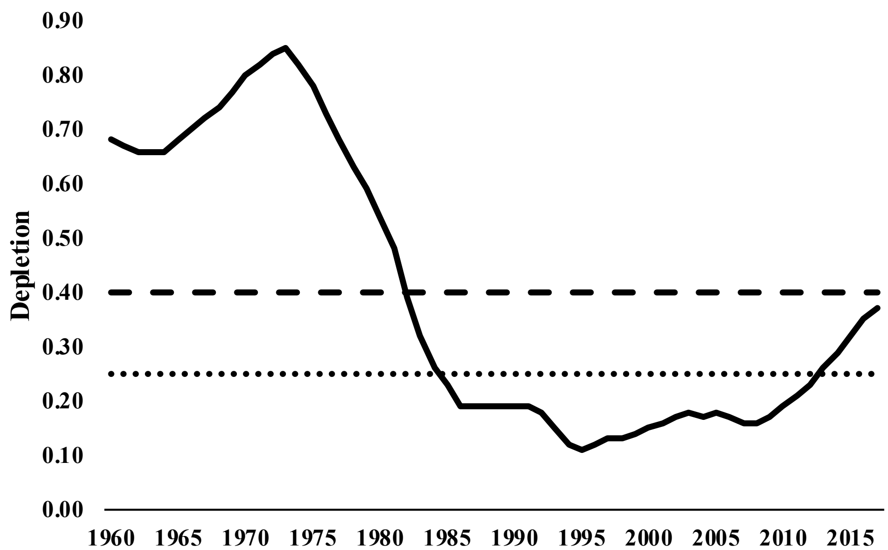

Figure 2-63. Relative depletion of blue and deacon rockfish off California from 1960 to 2017 based on the 2017 stock assessment.

Stock Productivity

A Beverton-Holt steepness of 0.65 was estimated in the 2017 California BDR assessment, which is close to the median steepness of 0.718 in the current rockfish meta-analysis. The GMT's PSA analysis indicates a relatively high vulnerability to potential overfishing (V = 2.01) due partly to a relatively low relative productivity (P = 1.22) (Table 2-2).

A recent, strong recruitment in 2013 has contributed to the recent increase in BDR biomass in California (Figure 2-64). This recruitment is informed by several independent data sets, was observed by multiple juvenile rockfish surveys, and is also supported by length composition data in the 2017 California assessment model. Above-average recruitments in 2008 and 2009 are largely driven by recent age data covering the years 2010-2011, but the 2007 recruitment appears to be supported by multiple data sources, as well.

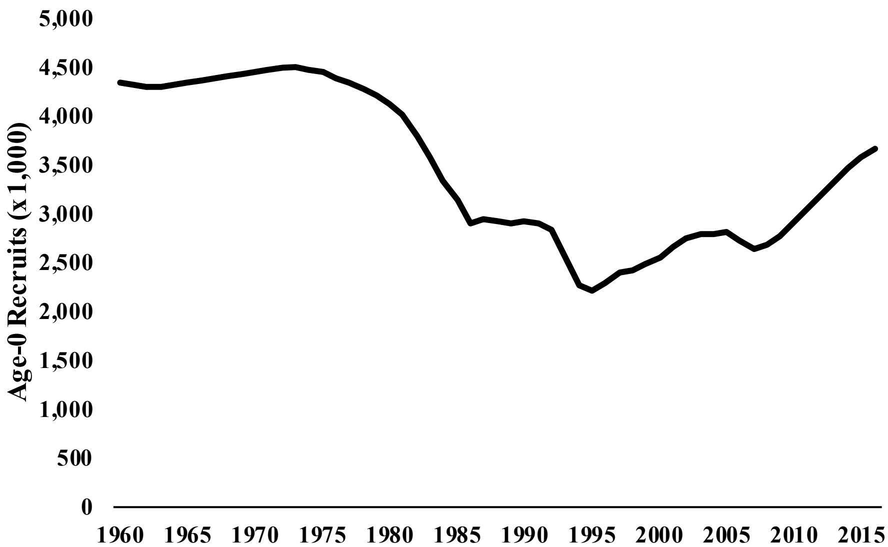

Figure 2-64. Estimated recruitments of blue and deacon rockfishes off California, 1960-2016 (from Dick et al. 2017).

Fishing Mortality

BDR have been an important part of the recreational fishery in California since the late 1950s (Mason 1998; Reilly*, et al.* 1993; Wilson-Vandenberg*, et al.* 1996). Commonly taken by Commercial Passenger Fishing Vessels (CPFVs, aka partyboats), skiffs, and divers, it is among the most frequently caught species north of Point Conception (Karpov*, et al.* 1995). However, since the mid-1980s the California recreational catch has declined significantly, especially in the south. This may be a result of overfishing from the more heavily populated southern coast (Love*, et al.* 1998), where there is more angling opportunity due to more favorable access and ocean conditions (Bennett*, et al.* 2004); poor recruitment resulting from a long-term shift away from preferred cold, productive waters (Jarvis*, et al.* 2004; Love*, et al.* 2002); or the effect of increasingly strict fishing regulations.

The California BDR catch has played a relatively minor role in the commercial fishery compared to the recreational fishery. This has remained true, even with the advent of the live-fish fishery in the late 1980s, although the contribution of blue rockfish has been increasing in recent years. Since the preferred dinner plate-sized catch for this fishery results in immature fish being targeted in many cases, there is concern over the potential implications of the increasing effort in this fishery. Selection of younger, smaller individuals has led to lower lifetime egg production and consequently, threatened population viability (O'Farrell and Botsford 2005; O'Farrell and Botsford 2006).

The annual (equilibrium) SPR harvest rate for BDR in California has been below target since 2008 (Figure 2-65). Prior to 2008, the harvest rate exceeded the target for over 30 years, regularly reaching levels 50 percent above target in the 1980s and 1990s. As a percentage of total biomass (ages 0+), California harvest rates peaked at 15-20 percent in the 1980s and 1990s but have since declined to levels below 3 percent for the past decade. Harvest rates in California are currently below target, and the stock is approaching the proxy target biomass (Figure 2-65). Estimates of MSY for the California portion of the stock are 3 to 4 times larger than the Oregon stock.

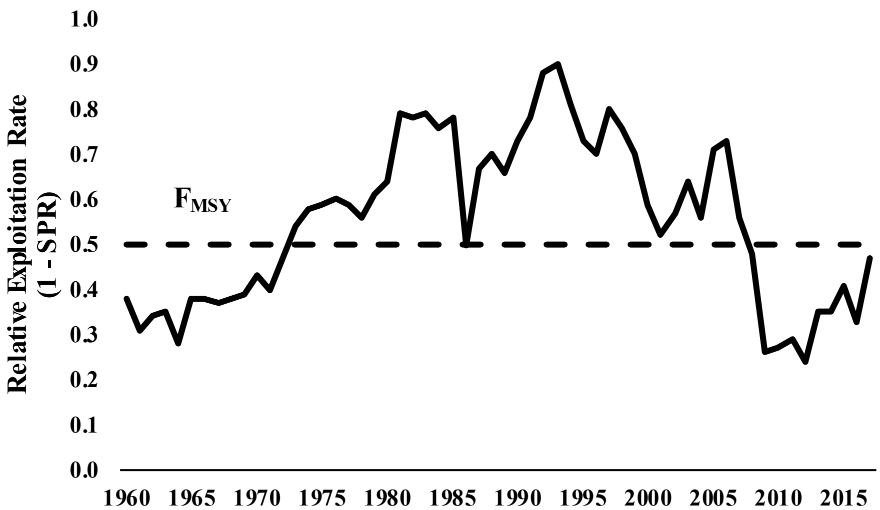

Figure 2-65. Estimated spawning potential ratio (SPR) of blue and deacon rockfish off California relative to the current F_{MSY}, 1960-2016. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5.1.2 Brown Rockfish

Distribution and Life History

Brown rockfish (*Sebastes auriculatus*) are distributed from Prince William Sound to southern Baja California in Mexico, but are most abundant on the U.S. West Coast south of Bodega Bay, California (Love*, et al.* 2002). They occur from very shallow inshore waters out to 135 m (74 fm). Brown rockfish are a sedentary rockfish found in shallow water and bays (Eschmeyer*, et al.* 1983), among sheltering weed-covered rocks or around pilings (Lamb and Edgell 1986). Brown rockfish show distinct genetic differentiation by distance in coastal populations off California (Buonaccoursi*, et al.* 2005), though no distinct break is obvious to define substocks. Life history information is not spatially resolved. While coastwide populations may be subject to localized depletion because of reef-specific associations and small home ranges, no subpopulations have been distinguished.

Brown rockfish have been aged to 34 years (Love*, et al.* 2002).

Stock Status and Management History

Brown rockfish are managed in the northern and southern Nearshore Rockfish complexes. A single coastwide data-moderate assessment of brown rockfish was conducted in 2013 (Cope*, et al.* 2014). The assessment estimated the brown rockfish stock to be healthy with a depletion of 42 percent of its unfished biomass at the start of 2013. The brown rockfish assessment used two CPUE indices of the California recreational fisheries derived from dockside intercept surveys during 1980-2003 (north and south of Point Conception). The assessment also used two observer-based recreational CPUE indices from CPFV during 1999-2011 south of Point Conception and during 1988-2011 between Point Conception and Cape Mendocino. No indices were constructed for north of 40°10' N. lat. Since this is a rare species north of Cape Mendocino. While coastwide landings were used in the assessment, only about 1 percent of the cumulative coastwide landings of brown rockfish were from fisheries north of 40°10' N. lat. Based on the proportion of cumulative removals during 1916-2012. It was assumed that the population in the north followed the same trends as the southern population and this apportionment was used to parse harvest specifications to the Nearshore Rockfish complexes north and south of 40°10' N. lat.

Projections of harvest specifications for brown rockfish for 2017 and beyond using the base model in the 2013 data-moderate assessment were provided in 2015 (Agenda Item I.4, Attachment 4, November 2015) since long term projections were inadvertently omitted from the 2013 assessment.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and 2020 harvest specifications. The 2019 and 2020 ABC and ACL contribution of brown rockfish to the Nearshore Rockfish complex north of 40°10' N. lat. Is 1.9 mt. The 2019 and 2020 ABC and ACL contributions of brown rockfish to the Nearshore Rockfish complex south of 40°10' N. lat. Are 162.4 mt and 166.1 mt, respectively.

Stock Productivity

Brown rockfish has a notably elevated vulnerability to overfishing (V = 1.99) but a relatively high productivity score for a rockfish (P = 1.72) in the GMT's PSA analysis (Table 2-2).

Fishing Mortality

Estimated exploitation rates for brown rockfish were at or above the MSY harvest level during most years between 1973 and 2003, but have remained below the MSY harvest level since then (Cope, *et al.* 2014). Median spawning biomass declined rapidly during the 1970s and 1980s but has shown an increasing trend since the mid-1990s. The fishing mortality rate in 2012 was estimated to be 63 percent of F_{MSY}.

2.5.1.3 China Rockfish

Distribution and Life History

China rockfish (*Sebastes nebulosus*) range from Kachemak Bay in the Gulf of Alaska to Redondo Beach and Nicholas Island in the Southern California Bight but are most abundant from Prince William Sound to northern California (Love, *et al.* 2002). They occur primarily in nearshore and shelf waters in depths ranging from 3 to 128 m. China rockfish are a solitary species associated with high relief habitats, especially boulder fields with many crevices. They are territorial and a study off Vancouver Island indicates that individuals are likely to move 10 m or less within their territories.

China rockfish are long-lived with the oldest age reported at 79 years (Love*, et al.* 2002). Males and females mature at about the same size and age with some fish mature at 26 cm and all fish mature at 30 cm. The maximum size is reported to be 45 cm. Larval release occurs off California from January to June peaking in January. Larvae are released later in the season in the Gulf of Alaska during April to August with peak release in May.

China rockfish prey on benthic organisms including brittle stars, crabs, shrimps, chitons, and small fishes. Nudribranchs, octopi, snails, and red abalone were observed prey for China rockfish off central and northern California.

Stock Status and Management History

China rockfish are managed in the northern and southern Nearshore Rockfish complexes. Separate data-moderate assessments of China rockfish north and south of 40°10' N. lat.[10] Were conducted in 2013 (Cope*, et al.* 2014). The China rockfish population south of 40°10' N. lat. Was estimated to be healthy with a depletion of 66 percent of its unfished biomass at the start of 2013. However, the population north of 40°10' N. lat. Was estimated to be more depleted and in the precautionary zone with a depletion ratio of 37 percent at the start of 2013. The southern China rockfish assessment used a CPUE index of the California recreational fisheries derived from dockside intercept surveys during 1980-2003, as well as an observer-based recreational CPUE index from CPFVs during 1988-2011 as indices of abundance. The northern China rockfish assessment used a CPUE index of the Oregon and northern California recreational fisheries derived from dockside intercept surveys during 1980-2003 and an Oregon onboard charter boat index during 2001-2012 as indices of abundance and assumed the population off Washington followed the same trends. The Council decided to continue to manage China rockfish in the Nearshore Rockfish complexes in 2015-2016.

A full assessment of China rockfish was conducted in 2015 using the Stock Synthesis 3 modeling platform (Dick*, et al.* 2015). The Northern area from the 2013 assessment was split into Northern and Central areas for the 2015 assessment, and models were developed for three separate areas: Washington, Oregon plus California north of Cape Mendocino, and California south of Cape Mendocino. Differences in growth, size-composition data, exploitation history, and biogeographic boundaries formed the basis to split the assessment into separate areas along the coast. New data for the 2015 assessment included length and age compositions starting as early as the 1970s. The models included seven fishery-dependent indices of abundance (three indices for each of the Southern and Central areas, and one for the Northern area). Maturity and fecundity relationships were also updated. Steepness was fixed in all models at 0.773, and the natural mortality rate was estimated for the Northern and Southern areas and fixed at the estimated value, 0.07, for all areas. The Northern assessment modeled years from 1967 (when catch began) to 2015, whereas the other two areas covered the period 1900-2015. For the Southern area model, discard data were modeled as a separate fleet. For all models, the selectivity of landings was asymptotic, and growth was estimated. Recruitment deviations were not estimated, so recruitment is assumed to be that from

[10] Separate China rockfish data-moderate assessments were also conducted north and south of the California-Oregon border at 42º N lat. at the Council's request. The SSC recommended the Council's choice of a management line for China rockfish should dictate which assessments should be used to set harvest specifications. The Council's decision to continue to manage the stock within the Nearshore Rockfish complexes north and south of 40º10' N lat. in 2015 and beyond rendered the second set of assessments stratified at 42º N lat. moot.

the stock-recruitment curve in each area for each year. The SSC designated China rockfish a category 2 stock since recruitment deviations were not estimated.

The spawning stock biomass for China rockfish is estimated to be above the B_{MSY} proxy of $B_{40\%}$ in the Northern and Central areas ($B_{73.4\%}$ and $B_{61.5\%}$, respectively at the start of 2015) and in the precautionary zone ($B_{29.6\%}$ at the start of 2015) in the Southern area, while increasing in recent years (Figure 2-66, Figure 2-67, and Figure 2-68).

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and beyond. A catch only-projection of China rockfish was provided to inform harvest specifications for 2021 and beyond.

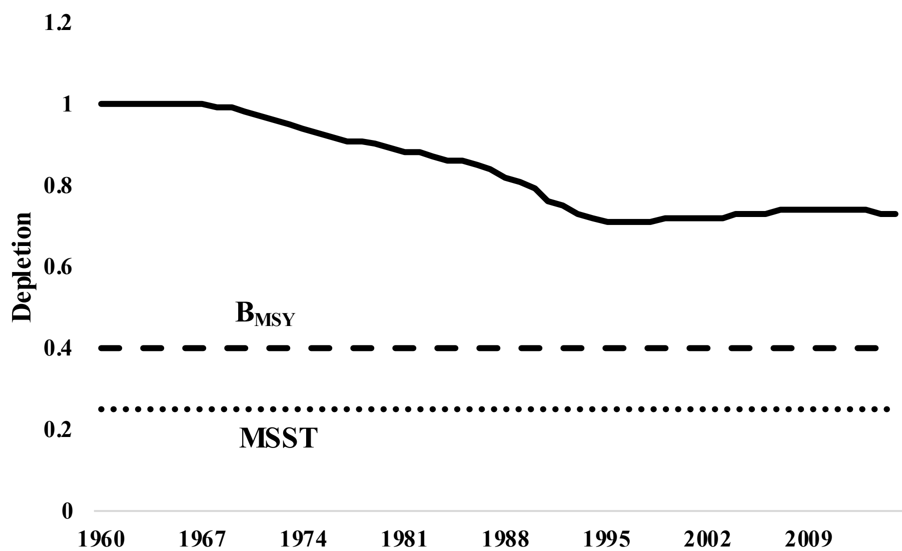

Figure 2-66. Relative depletion of China rockfish in the Northern assessment area (off Washington) from 1960 to 2015 based on the 2015 stock assessment.

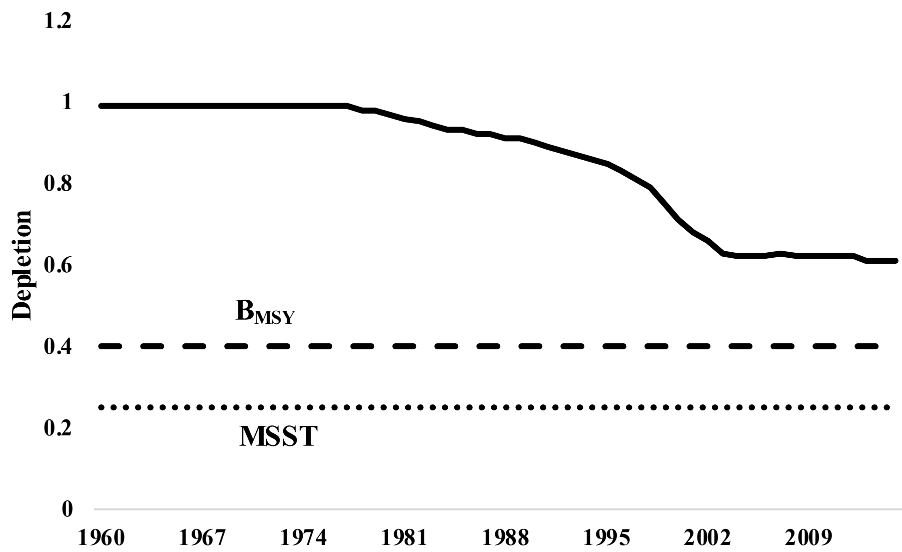

Figure 2-67. Relative depletion of China rockfish in the Central assessment area (off Oregon and California north of 40°10' N. lat.) from 1960 to 2015 based on the 2015 stock assessment.

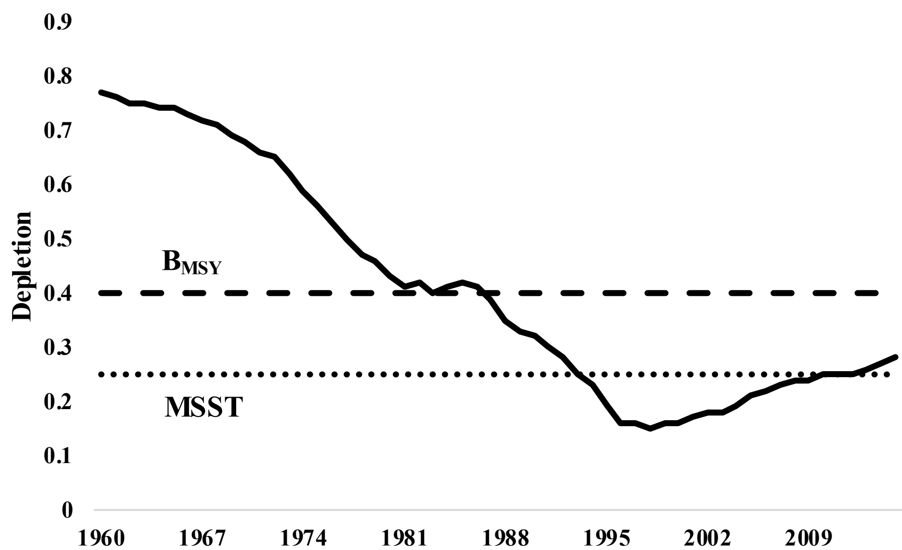

Figure 2-68. Relative depletion of China rockfish in the Southern assessment area (south of 40°10' N. lat.) from 1960 to 2015 based on the 2015 stock assessment.

Stock Productivity

The 2015 China rockfish assessments assumed a steepness of 0.773 based on the meta-analysis of rockfish steepness in 2015. The productivity score for China rockfish is relatively low (P = 1.33) and there is a major vulnerability to potential overfishing (V = 2.23).

Fishing Mortality

China rockfish are an important species in the nearshore recreational and commercial fisheries on the West Coast. They are particularly valuable in the commercial live-fish fishery where their unique coloration and high-quality flesh commands the highest prices for rockfish delivered as a live product on the West Coast. California and Oregon allow nearshore commercial fisheries while Washington does not.

Harvest rates estimated by the northern area model for Washington have never exceeded management target levels (Figure 2-69). Model results for the central area suggest that harvest rates have briefly exceeded the current proxy MSY value around 2000 but have remained below the management target in the last decade (Figure 2-70). Historical harvest rates for China rockfish rose steadily in the southern management area until the mid-1990s and exceeded the target SPR harvest rate for several decades and is just below the target harvest rate as of 2013 (Figure 2-71).

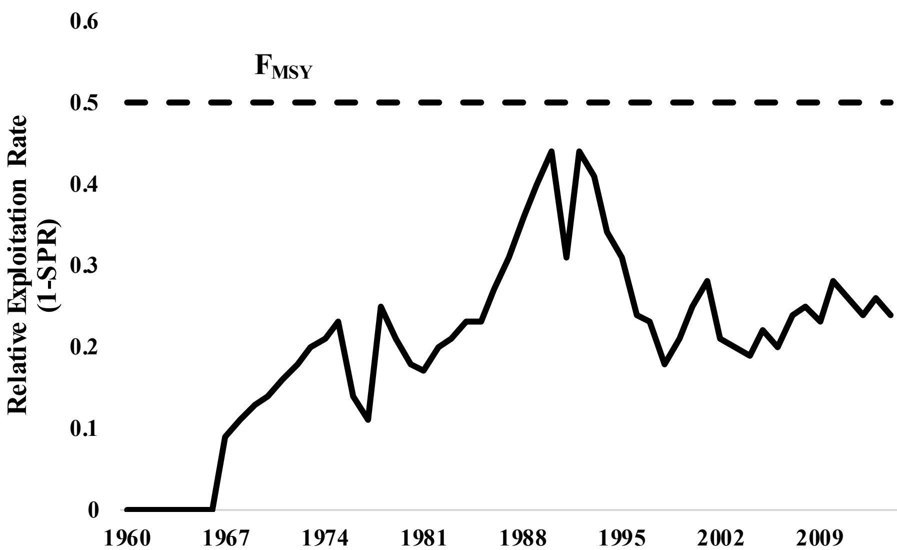

Figure 2-69. Estimated relative exploitation rate of China rockfish in the Northern assessment area (off Washington) relative to the current F_{MSY}, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

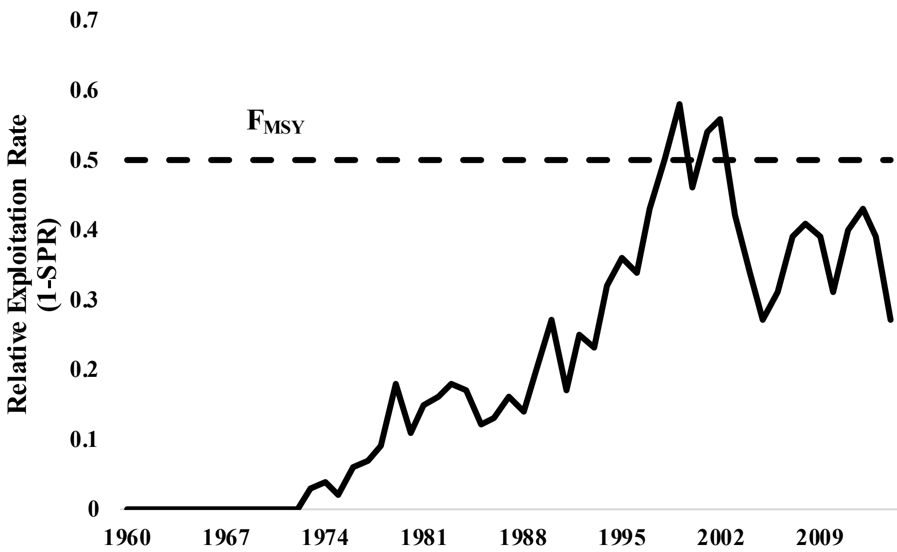

Figure 2-70. Estimated relative exploitation rate of China rockfish in the Central assessment area (off Oregon and California north of 40°10' N. lat.) relative to the current F_{MSY}, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

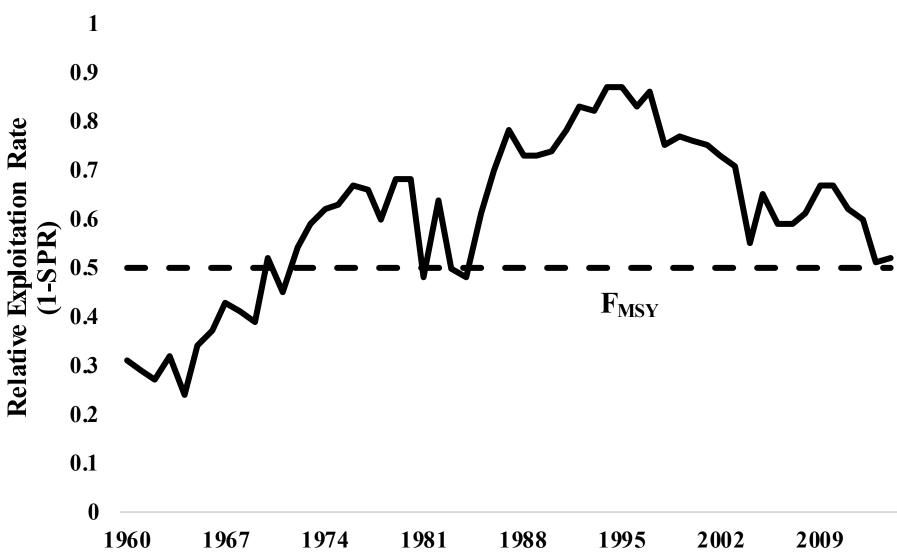

Figure 2-71. Estimated relative exploitation rate of China rockfish in the Southern assessment area (south of 40°10' N. lat.) relative to the current F_{MSY}, 1960-2014.

2.5.1.4 Copper Rockfish

Distribution and Life History

Copper rockfish (*Sebastes caurinus*) is a relatively long-lived rockfish estimated to live at least 50 years (Love 1996). They are a medium- to large-sized nearshore rockfish found from Mexico to Alaska. The core range is comparatively large, from northern Baja Mexico to the Gulf of Alaska, as well as in Puget Sound. Copper rockfish have historically been a part of both commercial and recreational fisheries throughout its range.

Copper rockfish are commonly found in waters less than 130 meters in depth in nearshore kelp forests and rocky habitat (Love 1996). The diets of copper rockfish consist primarily of crustaceans, mollusks, and fish (Bizzarro*, et al.* 2017; Lea*, et al.* 1999). The body coloring of copper rockfish varies across the coast with northern fish often exhibiting dark brown to olive with southern fish exhibiting yellow to olive-pink variations in color (Miller and Lea 1972), which initially led to them being designated as two separate species (*S. caurinus* and *S. vexillaris*).

Subadult and adult copper rockfish are found primarily in boulder fields and over high relief rocks, although they also inhabit low relief rock substrata. They perch on the substrata or hover a few meters above the bottom in aggregations and as solitary individuals (Love*, et al.* 2002). Depending on the habitat and the geographic location, coppers are often found with vermilion, brown, black, dusky, silvergray, yelloweye rockfish, quillback, or tiger rockfishes. Coppers have small home ranges in high relief habitats (<10 m^2) and large home ranges in low relief habitats (<4,000 m^2).

Numerous genetic studies have been performed looking for genetic variation in copper rockfish with variable outcomes. Genetic work has revealed significant differences between Puget Sound and coastal stocks (Dick*, et al.* 2014). Stocks along the West Coast have not been determined to be genetically distinct populations but significant population subdivision has been detected, indicating limited oceanographic exchange among geographically proximate locations (Buonaccorsi*, et al.* 2002; Johansson*, et al.* 2008). A specific study examining copper rockfish populations off the coast of Santa Barbara and Monterey California identified a genetic break between the north and south with moderate differentiation (Sivasundar and Palumbi 2010).

Stock Status and Management History

Copper rockfish are managed in the northern and southern Nearshore Rockfish complexes. Separate data-moderate assessments of copper rockfish north and south of 34°27’ N. lat. Were conducted in 2013 (Cope*, et al.* 2014). Both copper rockfish populations were estimated to be healthy with depletions of 76 percent and 48 percent of unfished biomass at the start of 2013 for the southern and northern populations, respectively. The southern copper rockfish assessment used a CPUE index of the California recreational fisheries derived from dockside intercept surveys during 1980-2003, as well as an observer-based recreational CPUE index from CPFVs during 1999-2011 as indices of abundance. The northern copper rockfish assessment used a CPUE index of the California recreational fisheries derived from dockside intercept surveys during 1980-2003, an observer-based recreational CPUE index from CPFVs during 1988-2011, and an Oregon onboard charter boat index during 2001-2012 as indices of abundance. The northern copper rockfish assessment assumed the population off Washington followed the same trends.

While coastwide landings were used in the 2013 assessment, only about 4.9 percent of the cumulative coastwide landings of copper rockfish were from fisheries north of 40°10’ N. lat. Based on the proportion of cumulative removals during 1916-2012. It was assumed that the population in the north followed the same trends as the southern population and this apportionment was used to parse 2015-2022 harvest specifications to the Nearshore Rockfish complexes north and south of 40°10’ N. lat.

New data-moderate stock assessments were conducted in 2021 for copper rockfish south of Pt. Conception (Wetzel, *et al.* 2021b), north of Pt. Conception in California (Wetzel, *et al.* 2021a), Oregon (Wetzel, *et al.* 2021d), and Washington (Wetzel, *et al.* 2021c). The assessments estimate 2021 depletions of 18.1 percent (Figure 2-72), 39.3 percent (Figure 2-73), 73.6 percent (Figure 2-74), and 42 percent (Figure 2-75) for the stocks in California south of Point Conception, California north of Pt. Conception, Oregon, and Washington, respectively. The SSC's Groundfish Subcommittee recommended the California assessments could be combined for making a status determination of copper rockfish statewide since there was little evidence of stock structure north and south of Pt. Conception. The estimated depletion of copper rockfish in California is 31.7 percent of unfished biomass. However, formal status determinations were not made pending an FMP amendment to define stocks in the FMP.

While the 2021 assessments provided justification for the modeled areas, there is considerable uncertainty in stock structure. All models relied primarily on length-composition data, most of which came from recreational fleets. There were retrospective patterns in these assessments. All four assessments had reduced data availability from 2020 due to COVID-19 impacts on data collection agencies. Age-length estimates (and hence the growth curve) for northern California may not be representative because they rely on data from Oregon and Washington where water temperatures are different and growth may differ as a result.

The SSC recommended a category 2 designation on for all the copper rockfish assessments for informing harvest specifications in 2023 and beyond.

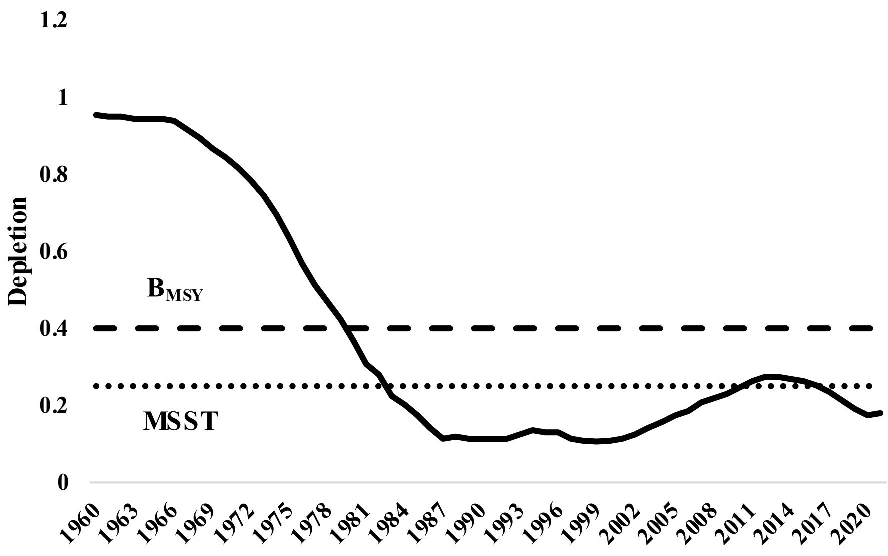

Figure 2-72. Estimated depletion of copper rockfish in California south of 34°27' N lat. Relative to management reference points, 1960-2021.

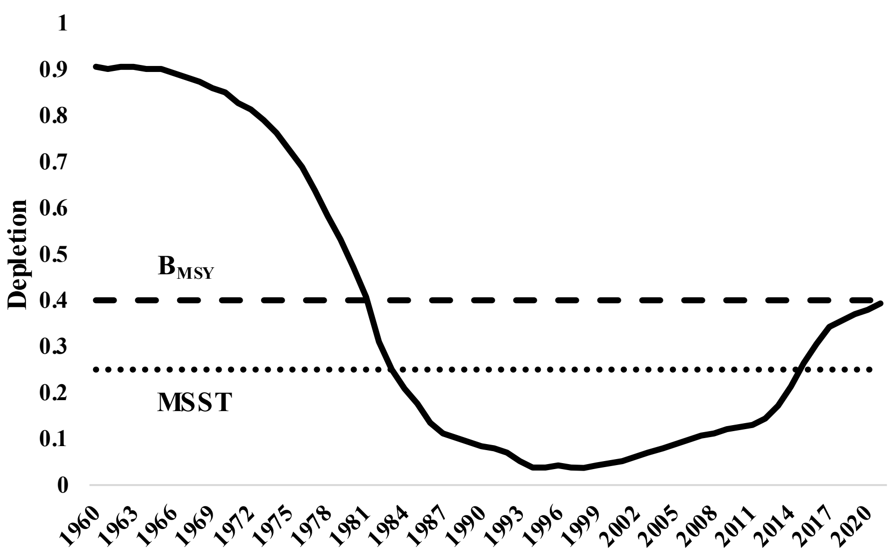

Figure 2-73. Estimated depletion of copper rockfish in California north of 34°27' N lat. Relative to the management target, 1960-2021.

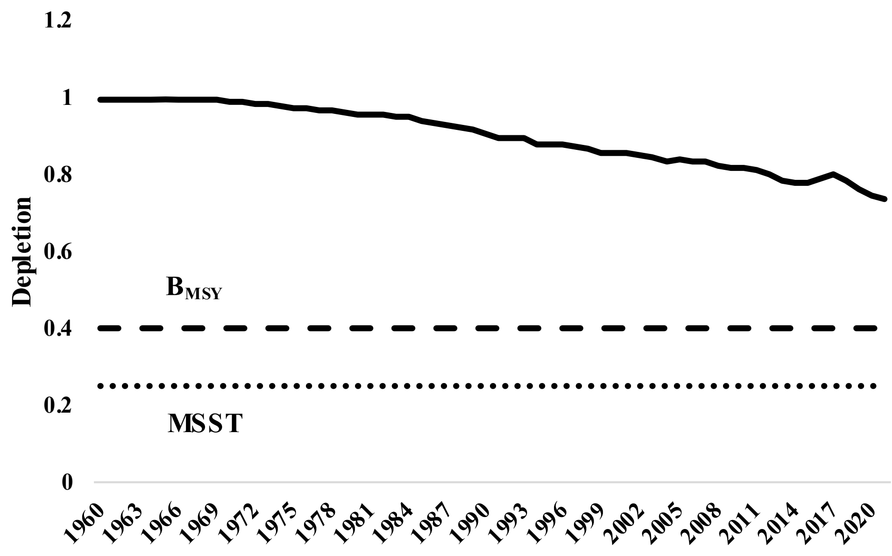

Figure 2-74. Estimated depletion of copper rockfish in Oregon relative to the management target, 1960-2021.

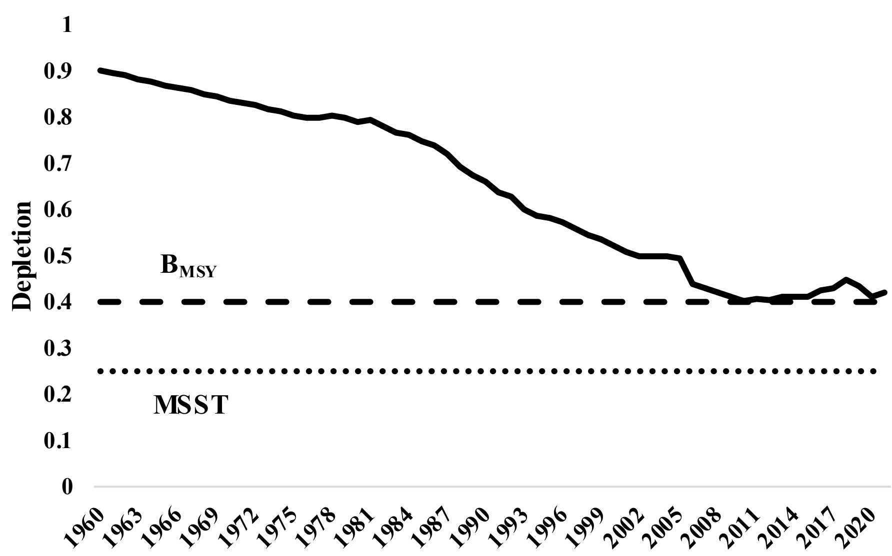

Figure 2-75. Estimated depletion of copper rockfish in Washington relative to the management target, 1960-2021.

Stock Productivity

The PSA productivity score of 1.95 for copper rockfish indicates a high relative productivity among rockfish species. There is a relatively major vulnerability of potential overfishing (V = 2.27) for the stock, which ranks as the highest vulnerability score in the GMT's analysis of species managed under the Groundfish FMP (tied with rougheye rockfish; Table 2-2).

Annual recruitment deviations were not estimated in the Southern California base model due to confounding between recent high catches, estimated low stock abundance, and recruitment deviations. A rise in catches could be related to above average recruitment. A steepness of 0.72 was assumed in the deterministic stock-recruitment relationship modeled in the 2021 assessment.

Recruitment deviations were estimated for the stock in California north of 34°27' N. lat. Strong recruitments are estimated to have occurred in 2008, 2009, and 2010 (Figure 2-76). While there could have been three above average recruitments occurring in subsequent years, alternatively there may have been a single year with high recruitment that the model is unable to accurately assign to a single year due to the variability in length data. Above average recruitment in 2008 has been estimated in other rockfish assessments off the West Coast (Gertseva, *et al.* 2015; Hicks and Wetzel 2015; Wetzel, *et al.* 2017). The SSC noted the model for Northern California estimated a pattern of high recruitment during the 1960s and lower recruitment during the 1970s, which is not consistent with trends in the recruitment for other rockfishes during that time.

Annual recruitment deviations were not estimated in the Oregon or Washington and a steepness of 0.72 was assumed in the deterministic stock-recruitment relationships modeled in these 2021 assessments.

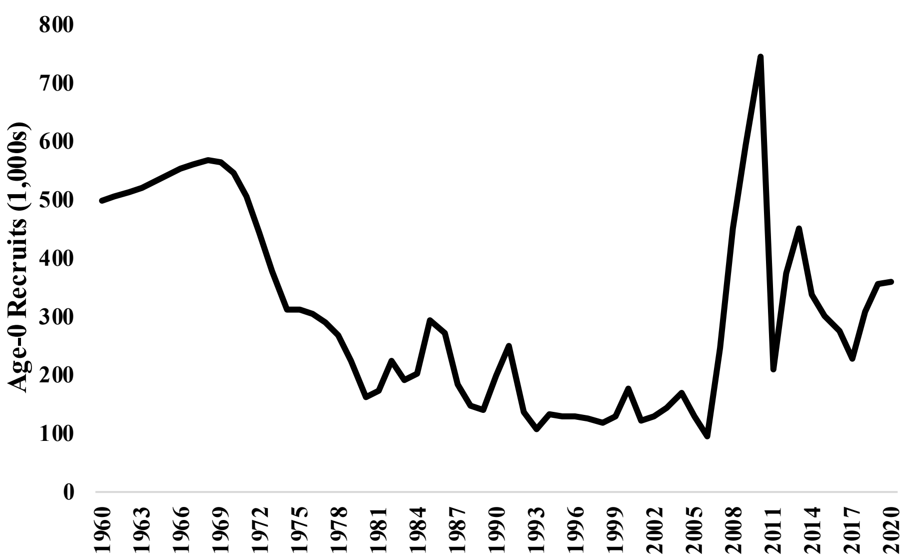

Figure 2-76. Estimated recruitment of copper rockfish in California north of 34°27' N lat., 1960-2020.

Fishing Mortality

Copper rockfish are caught in both commercial and recreational fisheries off the coast of California. Recreational removals have been the largest source of fishing mortality of copper rockfish. Commercial catch of copper rockfish increased with the advent of the live fish market in the 1980s. The proportion of copper rockfish being landed live vs. dead since 2000 by California commercial fleets ranges between 50 to greater than 70 percent in the southern and northern areas, respectively.

The 2021 southern California assessment estimates fishing mortality rates exceeded the F_{MSY} proxy for thirty years in the 1970s through the 1990s, within F_{MSY} for the next decade, and above that limit in most years during the last decade (Figure 2-77).

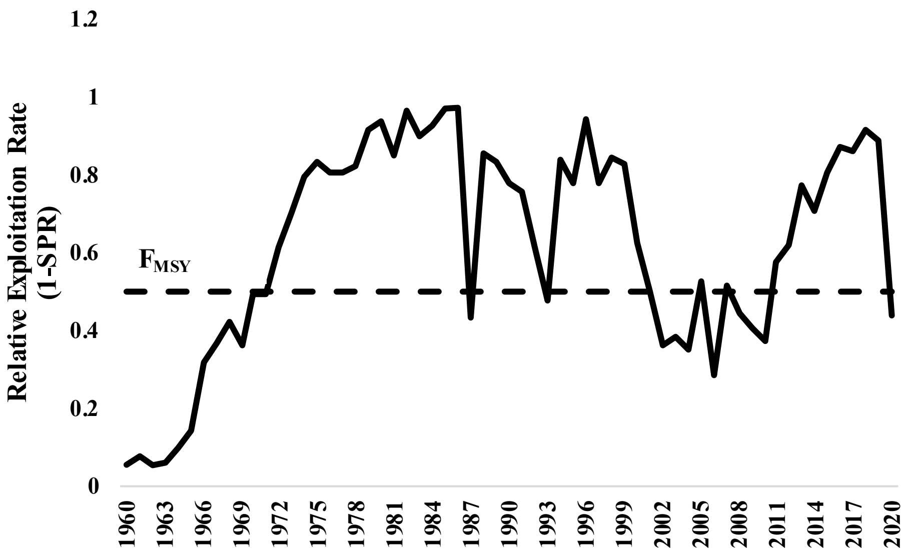

Figure 2-77. Estimated annual relative exploitation rate of copper rockfish in California south of 34°27' N lat. Relative to the current proxy F_{MSY} target, 1960-2020.

The 2021 northern California assessment estimates fishing mortality rates exceeded the F_{MSY} proxy for thirty years in the 1970s through the early-2000s and were variably above and below the F_{MSY} proxy since 2004, averaging 46.8 percent of the proxy from 2004 to 2020 (Figure 2-78).

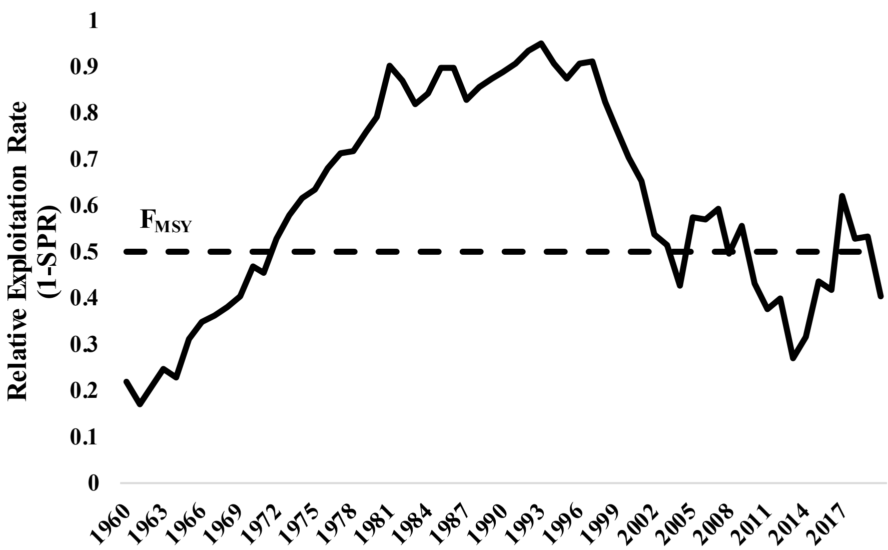

Figure 2-78. Estimated annual relative exploitation rate of copper rockfish in California north of 34°27' N lat. Relative to the current proxy F_{MSY} target, 1960-2020.

Copper rockfish are caught in both commercial and recreational fisheries in Oregon. While most of the catch from the late-1960s through the early-1980s was from the commercial fishery, the recreational fishery has taken the largest proportion of the catch since then averaging 72 percent from 1980-2020. Currently, the commercial fishery is centered on the southern Oregon coast and copper rockfish are primarily landed live with some landings made to the fresh market.

The 2021 assessment estimates relative exploitation rates have progressively increased since the late-1960s and have never exceeded the F_{MSY} proxy (Figure 2-79).

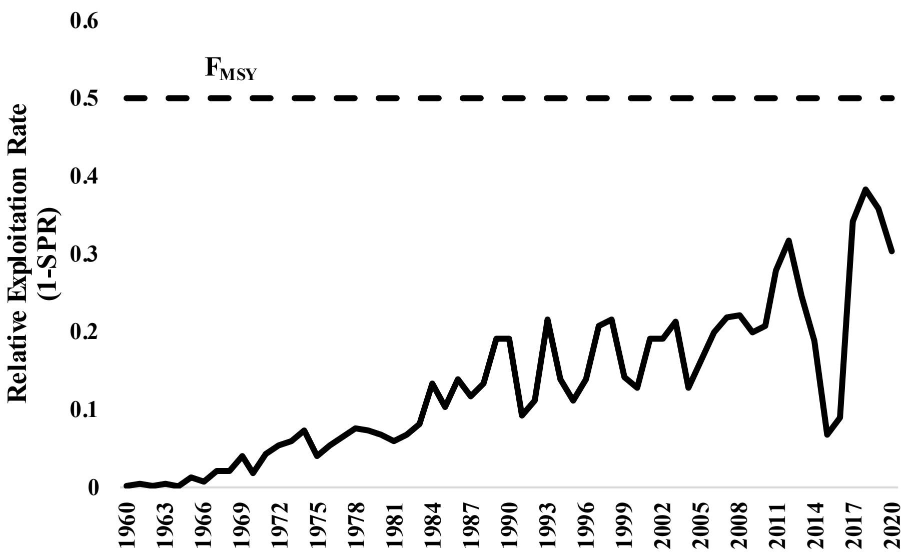

Figure 2-79. Estimated annual relative exploitation rate of copper rockfish in Oregon relative to the current proxy F_{MSY} target, 1960-2020.

Copper rockfish is primarily caught off Washington in the recreational fishery with very little mortality from commercial fishing off the coast of Washington. Copper rockfish has not been targeted by commercial fisheries in Washington waters; commercial fixed gears and trawls were banned in state waters in 1995 and 1999. Copper rockfish has been a target of recreational fishing starting as early as 1935, with catches stabilizing around 2,500 – 3,000 fish per year starting around 1980 with the exception of select years with high (2005) or low catches (2015).

The relative exploitation rate has been above and below the F_{MSY} proxy in recent years (Figure 2-80).

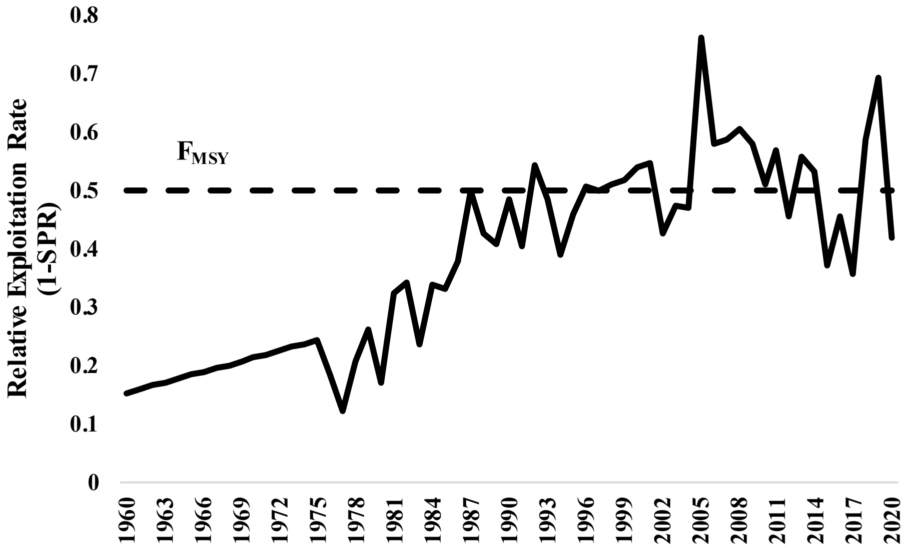

Figure 2-80. Estimated annual relative exploitation rate of copper rockfish in Washington relative to the current proxy F_{MSY} target, 1960-2020.

2.5.1.5 Gopher Rockfish

Distribution and Life History

Gopher rockfish (*Sebastes carnatus*) range from Eureka, California, to San Roque, central Baja California (Miller and Lea 1972), but are most common from Mendocino County to Santa Monica Bay, California (Love 1996). Gopher rockfish is a residential and demersal species, associated with kelp beds or rocky reefs, from the intertidal to about 264 ft (80 m), most commonly between 30 and 120 ft (9-37 m) (Eschmeyer, *et al.* 1983; Love 1996; Love, *et al.* 2002). One tagging study off central California (Lea, *et al.* 1999) revealed that gopher rockfish exhibit minor patterns of movement (<1.5 nm, 2.8 km) with all fish being recaptured on the same reef system where they were tagged. Another study, conducted by Matthews (1986), reported movements up to 1.2 km (0.65 nm) by gopher rockfish that traveled from a low-relief natural reef to a high-relief artificial reef. The change in substrate type may have been a factor in the movement in the Matthews study.

Gopher rockfish settle out of the plankton as large larvae (2 cm. or less in length) primarily in the canopies of giant and bull kelp (*Macrocystis pyrifera* and *Nereocystis luetkeana*, respectively) where they remain close to the fronds (Love, *et al.* 2002). Settlement occurs primarily in June and July. With growth, older individuals move down the kelp stipes to the bottom where they take up residence in rocks and crevices. They are largely territorial with home ranges of 10-12 m^2 (Love, *et al.* 2002).

Gopher rockfish are closely related to black-and-yellow rockfish (*Sebastes chrysomelas*) and kelp rockfish (*Sebastes atrovirens*). Gopher and black-and-yellow rockfish are distinct morphologically by color and inhabit different depth ranges (gopher have a deeper depth range) but cannot be distinguished genetically (Love, *et al.* 2002). This presents an interesting phenomenon in how speciation in rockfish may occur. There are theories that interbreeding may be lessened by individuals only breeding with others of the same color. If it is determined the two species are actually one, then the name *S. carnatus* will prevail since it was described first (Love, *et al.* 2002).

Stock Status and Management History

Gopher rockfish was assessed for the first time in 2005 and estimated stock depletion under the base model was 97 percent of its unfished biomass at the start of 2005 (Key*, et al.* 2006). Although the distribution of gopher rockfish extends south into the Southern California Bight, the assessment was restricted to the stock north of Point Conception. The assessment is based on landings and length composition data from commercial and recreational fisheries (primarily hook and line gear) and an index of relative abundance (CPUE) from the CPFV Sportfish Survey database. These data sources were used to estimate population trends from 1965 to 2004. There are no fishery-independent indices of stock biomass for gopher rockfish. Assessment results indicate an upward trend in gopher rockfish biomass since the 1980s and estimates of 2005 abundance ranged between 60 percent and 110 percent of average unfished stock size; this range of depletion levels is the result of alternative emphases in the model given to the CPFV in the CPUE index, a data element identified as a major source of uncertainty.

During the 2007-2008 biennial specifications process, the Council decided to continue managing gopher rockfish within the Nearshore Rockfish South complex since there was adequate resource protection under the California Nearshore Fishery Management Plan and managing gopher rockfish with stock-specific harvest specifications could disrupt that plan.

The OFL contribution of gopher rockfish to the Nearshore Rockfish complex south of 40°10' N. lat. and north of 34°27' N. lat. Is based on the equilibrium MSY proxy estimated in the 2005 assessment of 101 mt. The OFL contribution for the population occurring south of 34°27' N. lat. is based on a 2011 DCAC estimate. These data-poor methods for determining OFLs were used since the 2005 assessment was considered out of date and the SSC did not recommend a catch-only update of that assessment. These data-poor methods also compelled the SSC to rate gopher rockfish as a category 3 stock. The historical catches of gopher rockfish are so minimal there is no OFL contribution to the Nearshore Rockfish complex north of 40°10' N. Lat.

New genetic evidence suggests that gopher rockfish and black-and-yellow rockfish are the same species. A full assessment of gopher rockfish and black-and-yellow rockfish as a complex of the two previously-described species south of 40°10' N. lat. Was conducted in 2019 (Monk and He 2019). Spawning output has been steadily decreasing since the mid-2000s when the stock was estimated to be at 77 percent of unfished spawning output, the highest level since the early-1970s, to a current depletion estimate of 44 percent of the unfished level (Figure 2-81).

The current assessment includes information from landings, discards, age and length composition data, and six sources of fishery-dependent and fishery-independent abundance indices, including indices and age data from the CCFRP. Major sources of uncertainty are the potential for spatial and species-specific differences in life history parameters (e.g., growth) and that the abundance indices were not fit well in the model. Steepness and M were fixed in the base model, while recruitment deviations and growth were estimated.

The SSC designated the 2019 assessment of gopher and black-and-yellow rockfishes as category 2, largely due to the fact that this assessment is for a species complex. The SSC recommended that the next assessment be a full assessment if there are substantial increases in information (i.e., improved information on growth, or an improved age-0 index); otherwise, it could be an update assessment.

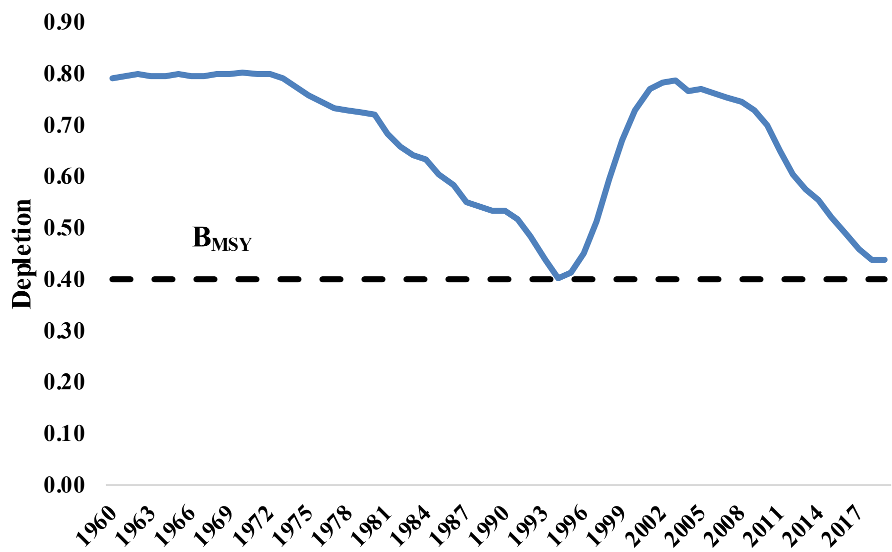

Figure 2-81. Relative depletion of gopher and black-and-yellow rockfishes off California south of 40°10' N. lat. From 1960 to 2019 based on the 2019 stock assessment.

Stock Productivity

Recruitments were modeled in the 2019 assessment assuming a Beverton-Holt relationship, with an assumed steepness of 0.72 based on the current meta-analysis of rockfish steepness. Recruitment variability was fixed at sigma r = 0.5. Recruitment deviations were estimated from 1979-2018 (Figure 2-82). There are estimates of very strong recruitment in 1991, with high recruitment pulses for a number of other years including 1994-1995 and 2014-2015.

The PSA productivity score of 1.56 for gopher rockfish indicates a moderate relative productivity among rockfish species. There is a relatively low vulnerability of potential overfishing (V = 1.76) for the stock.

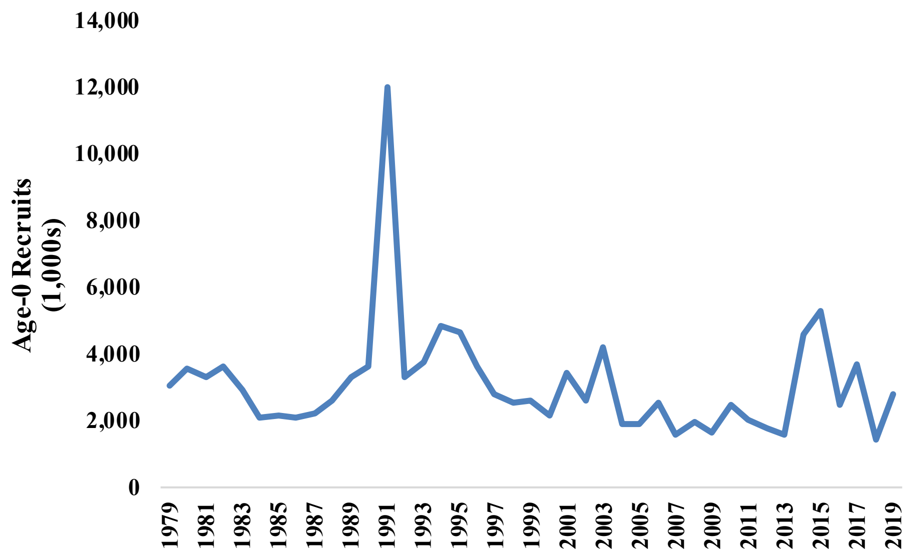

Figure 2-82. Estimated recruitments of gopher and black-and-yellow rockfishes south of 40°10' N. lat., 1979-2019.

Fishing Mortality

Gopher and black-and-yellow (referred to from hereon as GBYR when discussing the complex) rockfish have been a minor component of the commercial and recreational rockfish fishery since at least the late 1960s. The commercial catch histories of the two species cannot easily be separated; from 1916-1936 only black-and-yellow rockfish were reported in the landings, and an average of 0.04 mt of black-and-yellow rockfish are reported from 1937-1983. Black-and-yellow rockfish reappear in the landings in 1984 with 7.2 mt landed commercially. From 1985-1988 the trend switches and only black-and-yellow rockfish appear in the commercial landings, with gopher rockfish averaging 0.1 mt landed, and 0 mt reported in 1987. From 1988 and on, the landings are dominated by gopher rockfish, and both species are represented in the commercial landings. The landings from south of Point Conception are minor throughout the time period, with peaks in the 1950s and 1960s for gopher rockfish. Black-and-yellow rockfish are rare south of Point Conception and it is therefore expected that these catches are minimal.

The live fish fishery began in the early 1990s, with the first reported commercial landings of live gopher rockfish in 1993, and black-and-yellow rockfish a year later. By 1995, over half (57 percent; 39 mt) of the commercial landings were from the live fish fishery. This increased quickly over the next few years and has been on average 84 percent of the landed gopher and black-and-yellow rockfish since 2000. The majority of the landings are from gopher rockfish north of Point Conception. Landings of live GBYR south of Point Conception were higher in the late 1990s, (max. 3.2 mt in 1999), and have been averaging 0.4 mt since 2003.

The ex-vessel value of GBYR increased from less than $40,000 in 1984 and peaked at $680,452 in 1996. The ex-vessel revenue has been fairly stable at around $500,000 a year since 2007. Prior to the live fish fishery in 1994, the average price per pound for either species was around $2 a pound. The live fish fishery increased the value of both species to an average of $6-$8 a pound, with maximum reported value of either a gopher or black-and-yellow rockfish was $20 a pound in 2003.

The recreational GBYR fishery for California is most prominent north of Point Conception throughout the entire catch history from 1928 to 1980.

Harvest rates estimated by the base model in the 2019 assessment indicate catch levels have been below the limits that would be associated with the SPR = 50 percent limit (corresponding to a relative fishing intensity of 100 percent) (Figure 2-83). The relative inverse SPR increased over the last decade from a low period from 2004-2008, ranged from 0.64 to 0.77 of the F_{MSY} limit from 2009-2015, and ranged from 0.80 to 0.82 from 2016-2018 (Figure 2-83).

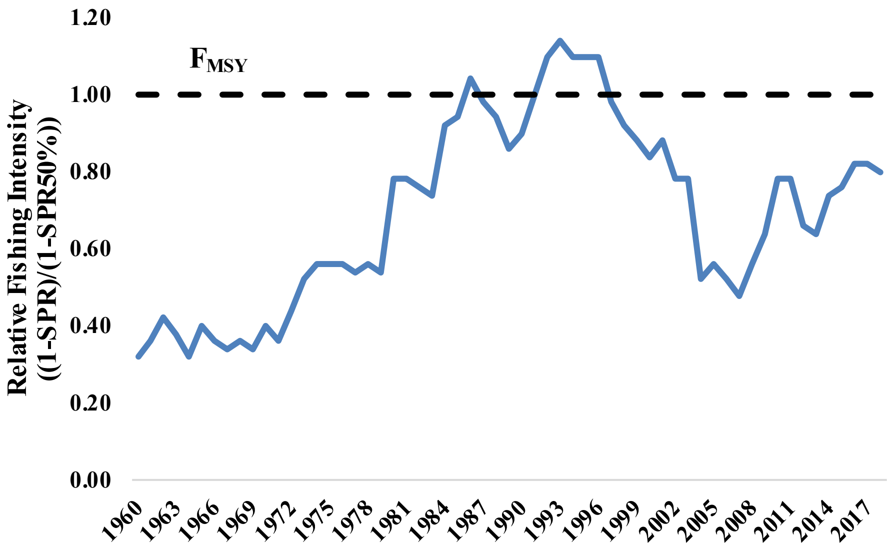

Figure 2-83. Relative fishing intensity of gopher and black-and-yellow rockfishes in California south of 40°10' N. lat., 1960-2018.

2.5.1.6 Quillback Rockfish

Distribution and Life History

Quillback rockfish (*Sebastes maliger*) are a medium- to large-sized nearshore rockfish found from southern California to the Gulf of Alaska (Love*, et al.* 2002). Off the U.S. West Coast quillback rockfish are primarily located north of central California, with few observations south of Point Conception. Quillback rockfish have historically been part of both commercial and recreational fisheries throughout their range.

Quillback rockfish are found in waters less than 274 meters in depth in nearshore kelp forests and rocky habitat (Love*, et al.* 2002). The diets of quillback rockfish consist primarily of benthic and pelagic crustaceans and fish (Murie 1995). The body coloring of adult quillback rockfish is brown with yellow to orange blotching and light-colored dorsal saddle patches (Love*, et al.* 2002). As their name suggests, quillback rockfish have long dorsal fin spines.

Limited studies have evaluated genetic variation in quillback rockfish across the U.S. West Coast. Genetic work has revealed significant differences between Puget Sound and coastal stocks of quillback rockfish (Seeb 1998; Stout*, et al.* 2001); however, Seeb (1998) did not find significant differentiation in populations of quillback rockfish between coastal Washington and Alaska. Significant population sub-division along the U.S. West Coast has been detected for the closely related, and more well-studied copper rockfish (*S. caurinus*), indicating limited oceanographic exchange among geographically proximate locations (Buonaccorsi*, et al.* 2002; Johansson*, et al.* 2008; Seeb 1998). High site-fidelity (Hannah and Rankin 2011) and relatively small home ranges (Tolimieri*, et al.* 2009) for quillback rockfish suggests patterns of isolation-by-distance as found for other rockfish.

Stock Status and Management History

Quillback rockfish are managed in the northern and southern Nearshore Rockfish complexes. New data-moderate assessments were conducted in 2021 for quillback rockfish in California, Oregon, and Washington. The California stock was estimated to be below the MSST with a 14 percent depletion at the start of 2021 (Figure 2-84) (Langseth*, et al.* 2021a). The Oregon and Washington stock depletions were estimated to be 47 percent (Figure 2-85) (Langseth*, et al.* 2021c) and 39 percent (Figure 2-86) (Langseth*, et al.* 2021b) in Oregon and Washington, respectively at the start of 2021. However, formal status determinations were not made pending an FMP amendment to define stocks in the FMP.

The data-moderate quillback assessments were modeled using the SS-CL framework and relied primarily on length composition data, most of which came from the recreational fleet. These assessments included two fleets (a recreational fleet and a commercial fleet), externally estimated biological relationships (length-weight, length-age, natural mortality, fecundity, and maturity), double-normal selectivity, and the stock-recruitment relationship was Beverton-Holt (h = 0.72). Recruitment deviations were estimated for California and Oregon, and the model for Washington assumed deterministic recruitment.

The stock off the California coast was assessed as a separate stock from other populations off the U.S. West Coast based on the fairly sedentary nature of quillback rockfish (Hannah and Rankin 2011; Tolimieri*, et al.* 2009), which likely limits movement of fish between California and Oregon (see Section 2.5.1.6 for more details on the Oregon and Washington assessments). Additionally, the exploitation history and magnitude of removals off the California coast differ from those in Oregon. Although the population of quillback rockfish in California is assessed statewide, given the range of quillback rockfish, this assessment is primarily of quillback rockfish north of Point Conception. Catches of quillback rockfish south of Point Conception were rare.

There was substantial uncertainty in the California model given sensitivity to assumed growth and mortality parameters. The use of growth from fish sampled in Oregon and Washington, applied in the California assessment presents an unresolved uncertainty, since California is subject to higher water temperatures that can affect growth rates making them potentially unrepresentative.

For the Oregon model, the key sensitivities are whether annual recruitment deviation should be estimated, which has an effect on the model scale in 2021, and assuming asymptotic recreational selectivity, which reduces the fraction of unfished spawning biomass. In the Washington model, there was more variability in model estimates, and sensitivity to estimating parameters (*M*, CV of larger individuals, and L infinity), as well as sensitivities around recruitment, and estimation of recruitment deviations.

The SSC recommended a category 2 designation for the California and Oregon stocks and a category 3 designation for the Washington stock for informing harvest specifications in 2023 and beyond. The OFL for Washington quillback is the MSY under the proxy F_{MSY} harvest rate of $SPR_{50\%}$.

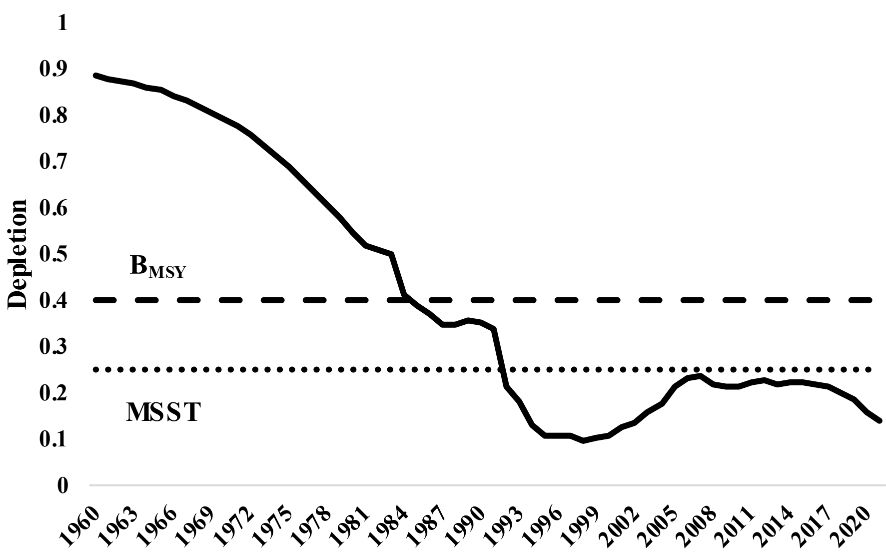

Figure 2-84. Estimated depletion of quillback rockfish in California relative to the management target, 1960-2021.

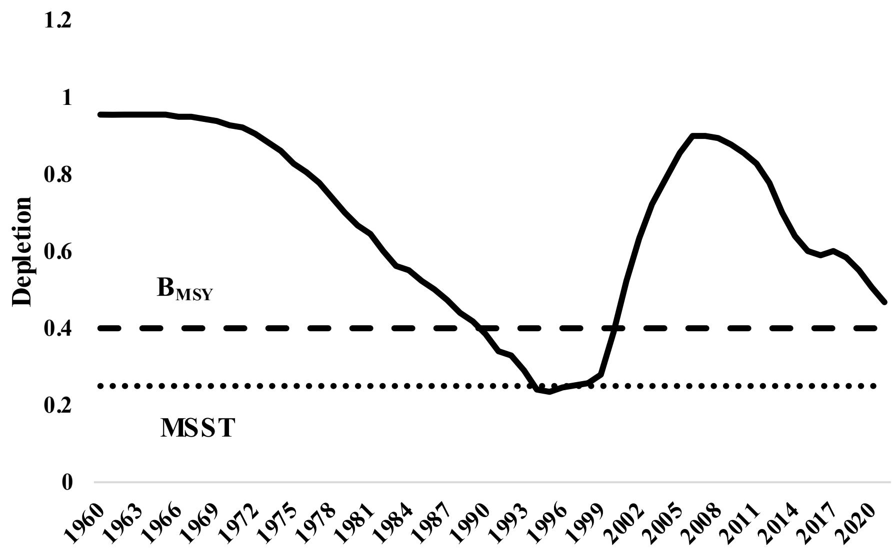

Figure 2-85. Estimated depletion of quillback rockfish in Oregon relative to the management target, 1960-2021.

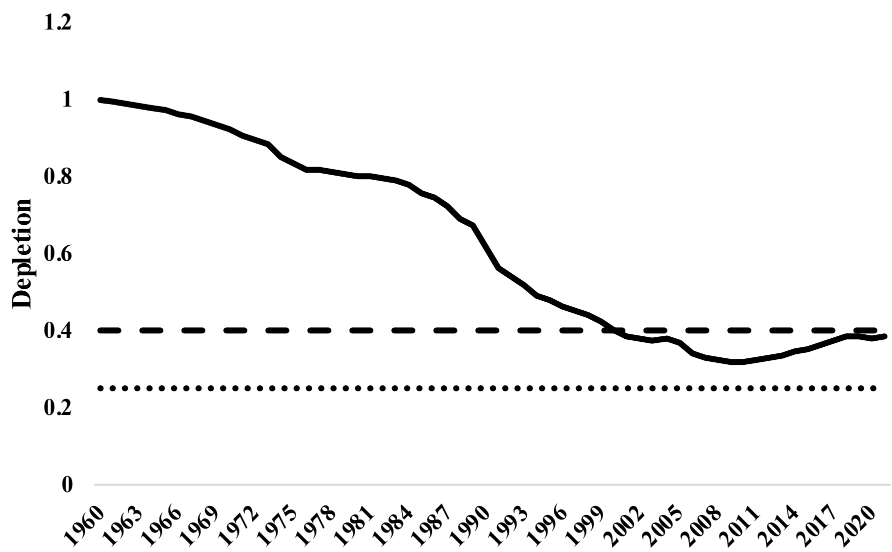

Figure 2-86. Estimated depletion of quillback rockfish in Washington relative to the management target, 1960-2021.

Stock Productivity

The PSA productivity score of 1.31 for quillback rockfish indicates a moderate relative productivity among rockfish species. There is a relatively major vulnerability of potential overfishing (V = 2.22; Table 2-2).

Strong recruitment events were estimated for the California stock prior to 2000 and in 2011. Recruitment deviations in 1987, 1996, and 1999 were particularly strong (Figure 2-87) and resulted in an increase in biomass during the early 2000s. While the largest recruitment deviations were estimated to have occurred in these three specific years, the surrounding years in the 1980s and 1990s also have above average recruitment estimated. Below average recruitment was estimated in all years since 2000, with the exception of 2011.

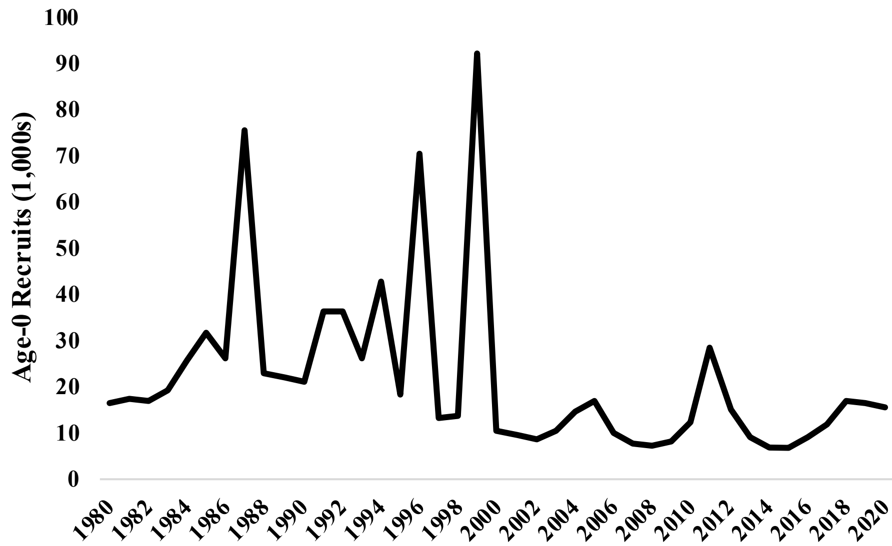

Figure 2-87. Estimated recruitment of quillback rockfish in California, 1980-2020.

Strong recruitment events were estimated for the Oregon stock to have occurred in 1993, 1995, 1999, and 2012 which resulted in a substantial increase in biomass during the late 1990s and early- to mid-2000s (Figure 2-88). While the largest recruitment deviations were estimated to have occurred in these four specific years, the surrounding years in the 1990s also have above average recruitment estimated, whereas the surrounding years in the 2000s have lower than average recruitment estimated.

The Washington stock-recruitment relationship is deterministic and recruitment deviations were not estimated due to extreme model sensitivity to recruitment estimation.

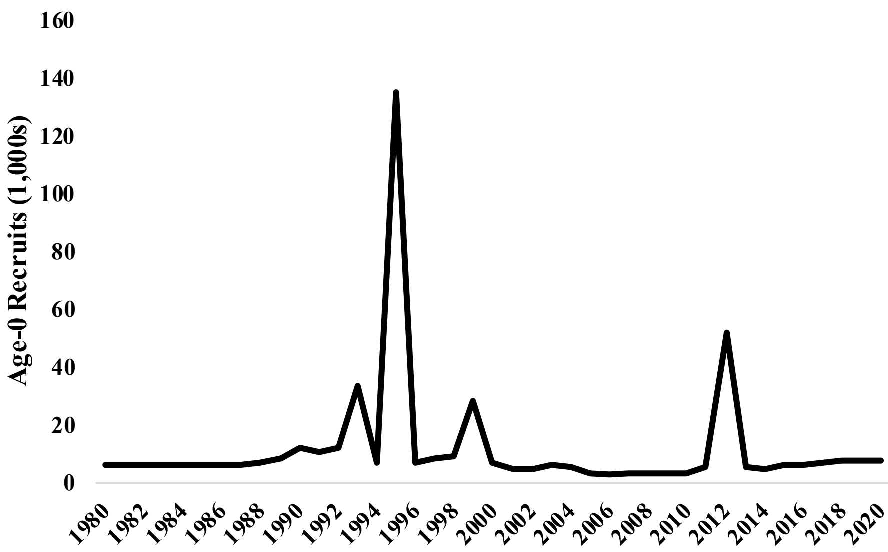

Figure 2-88. Estimated recruitment of quillback rockfish in Oregon, 1980-2020.

Fishing Mortality

Quillback rockfish off the coast of California are caught in both the recreational and commercial fisheries. Recreational removals are the largest source of fishing mortality and represent approximately 70 percent of the total removals of quillback rockfish across all years in the assessment. The majority of the commercial landings for quillback rockfish occurred between 1990 and 2008 with the advent of the live fish market in the 1980s, and apart from 1945-1946, in 1984, and in the last four years, commercial landings for quillback rockfish have been less than 2 mt per year. From 2003 to 2020, total removals from all fishing fleets have averaged 9.85 mt annually.

The relative exploitation rate of California quillback has been above the proxy F_{MSY} harvest rate in most years since the mid-1970s according to the new assessment (Figure 2-89).

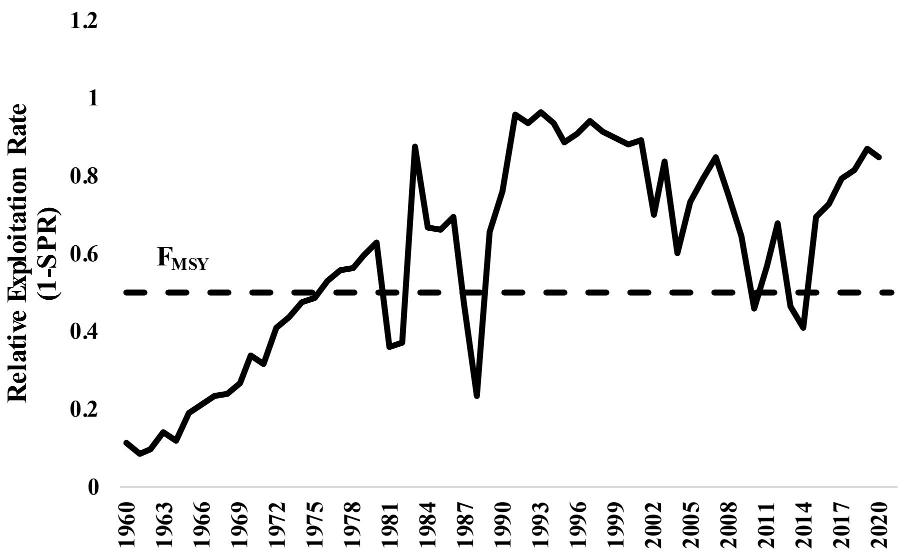

Figure 2-89. Estimated annual relative exploitation rate of quillback rockfish in California relative to the current proxy F_{MSY} target, 1960-2020.

Quillback rockfish off the coast of Oregon are caught in both the recreational and commercial fisheries. Recreational removals are the largest source of fishing mortality and represent approximately 59 percent of the total removals of quillback rockfish across all years in the assessment. Quillback rockfish is one of several rockfish species targeted by a nearshore, primarily live-fish fixed gear fishery centered on Oregon's southern coast. Quillback rockfish have been landed primarily with hook and line gear, though a substantial portion have been landed with bottom longline gear as well. Overall, 94.2 percent of quillback rockfish landings are from these two gear types (2000 – 2020). In the most recent years, longline landings have eclipsed hook and line landings. Landings from other gear types, including fish pot and trawl, are sporadic and minimal relative to hook and line and longline gears. Commercial landings for quillback rockfish increased from the mid-1960s to 1974 and have since fluctuated between approximately 0.4 and 4.5 mt annually. From 2003 to 2020, total removals from all fishing fleets have averaged 6.6 mt annually.

The relative exploitation rate of Oregon quillback has been above the proxy F_{MSY} harvest rate in most years since the mid-1970s according to the new assessment (Figure 2-90).

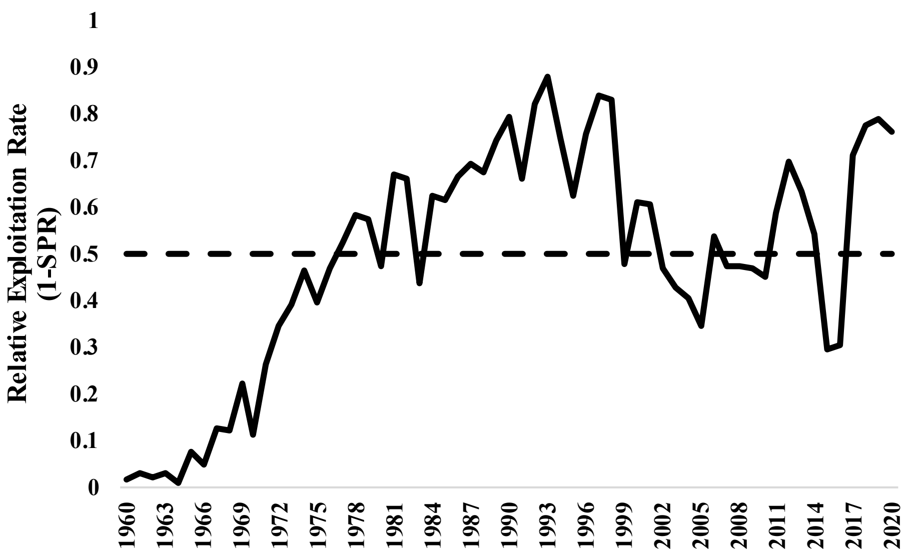

Figure 2-90. Estimated annual relative exploitation rate of quillback rockfish in Oregon relative to the current proxy F_{MSY} target, 1960-2020.

Off the Washington coast, quillback rockfish is primarily caught in the recreational fishery, and in general, is not targeted by either commercial or recreational fleets. Washington state waters, which mostly encompass the depths preferred by quillback rockfish, were closed to commercial fixed gears in 1995 and to trawling in 1999. In response to the development of the live-fish fishery in California and Oregon, Washington took preemptive action in 1999 by prohibiting the landing of live fish. There are four treaty tribes along the Washington coast that continue to fish under separate commercial rules and are not subject to the state water closure. These tribes occasionally land small amounts of quillback rockfish. Recreational removals are the largest source of fishing mortality and represent approximately 94 percent of the total removals of quillback rockfish across all years in the assessment. From 2003 to 2020, total removals from all fishing fleets have averaged 3.0 mt annually.

The relative exploitation rate of Washington quillback has been above the proxy F_{MSY} harvest rate in most years since 1987 according to the new assessment (Figure 2-91).

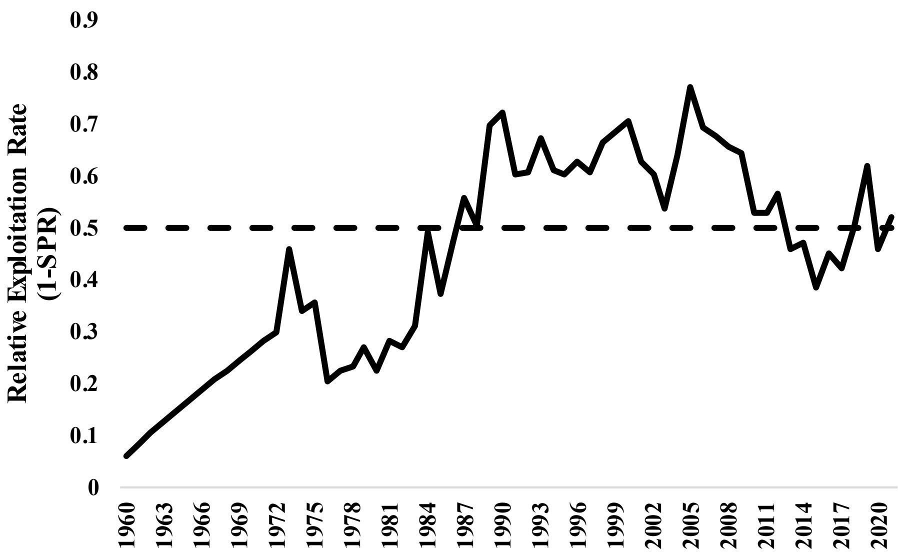

Figure 2-91. Estimated annual relative exploitation rate of quillback rockfish in Washington relative to the current proxy F_{MSY} target, 1960-2020.

2.5.2 Oregon Black/Blue/Deacon Rockfishes

2.5.2.1 Black Rockfish off Oregon

Distribution and Life History

See the description of black rockfish distribution and life history in section 2.4.3.

Stock Status and Management History

The stock status and management history of the Oregon black rockfish stock is provided in the previous section (see Section 2.4.3) since one assessment was done for California and Oregon stocks together prior to 2015.

A new full assessment of black rockfish in waters off Oregon was conducted in 2015 (Cope*, et al.* 2015a). This was the first assessment ever of the Oregon black rockfish stock in isolation. Cope et al. (2015a) estimated the Oregon black rockfish stock was at a 61 percent depletion at the start of 2015 and the stock has never fallen below the B_{MSY} target (Figure 2-8).

The 2015 Oregon black rockfish assessment modeled five fleets (trawl fishery, non-trawl dead-landed fish commercial fishery, non-trawl live fish commercial fishery, recreational ocean fishery, and recreational shore fishery) and six surveys (onboard CPFV CPUE survey, tagging abundance survey, MRFSS CPUE survey, Oregon Recreational Boat Survey (ORBS) CPUE survey, commercial logbook CPUE survey, and a research survey for small fish). All life history parameters were modeled as sex-specific, including M. Steepness was fixed at the meta-analysis prior.

The primary challenge for the black rockfish assessment in all three states is the absence of larger, older female black rockfish in fisheries catches, a phenomenon that has long been a challenge in developing plausible assessments for black rockfish and other species that exhibit this tendency. Past modeling approaches have explored both “hiding” larger, older females (e.g., applying dome-shaped selectivity to fisheries, which often results in what are considered to be implausibly high “cryptic” biomass levels of large, old, unavailable fish) or “killing” off larger, older females (one common formulation being a ramp up in natural mortality rates with age) in order to fit the observed data. While the step in M used in the Oregon black rockfish assessment is similar in concept to the past models use of a ramp in M, the magnitude of that step is much smaller (step from 0.17 to 0.20, rather than a ramp from 0.16 to 0.24). Selectivity also differs from the last model, as well as from the California and Washington models, in the use of both sex-specific length- and age-based selectivity forms. Selectivity for the ascending portion of the selection curves for all five of the fleets was modeled using length-based selection with no differences in length selection by sex. The trawl fishery assumed asymptotic for both sexes, but with the allowance of a female offset to male selectivity. The live-fish fishery selectivity was shared by both sexes (dome-shaped), but the dead-fish fishery was modeled as a female offset in the dome-shaped parameters. The recreational ocean fishery used an age-based selectivity offset on the descending limb for females relative to males, which were assumed fully-selected at all ages (length-selectivity was used to describe the active male selectivity in this fishery). Similar to the live fish fishery, the recreational shore was dome-shaped and shared for both sexes. Therefore, the Oregon assessment explained the lack of older females by both “killing them” with higher M for older fish and “hiding them” with dome-shaped selectivity. Finally, the most dramatic model specification in the Oregon assessment is that the catchability parameter for the tagging study was fixed at 0.25. This choice significantly reduced the sensitivity of the model to other model specifications (e.g., changing natural mortality values), and formed the basis for the decision table axis of uncertainty.

The SSC categorized black rockfish off Oregon as a category 2 stock since recruitment deviations were not estimated in the model, as well as the greater overall uncertainty associated with the Oregon black rockfish assessment.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2021 and 2022 harvest specifications. These ACL contributions are also specified as harvest guidelines for 2021 and 2022 Oregon fisheries with the intent to prevent overfishing under management in this state-specific stock complex.

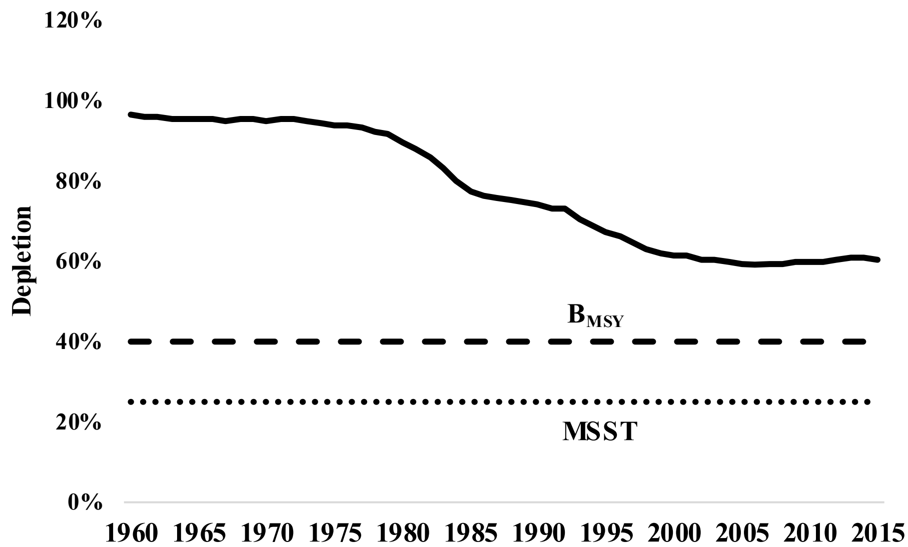

Figure 2-92. Relative depletion of black rockfish off Oregon from 1960 to 2015 based on the 2015 stock assessment.

Stock Productivity

The 2015 Oregon black rockfish assessment assumed a steepness of 0.773 based on the meta-analysis of rockfish steepness. The PSA productivity score of 1.33 indicates a stock of moderate productivity.

Recruitment of black rockfish off Oregon is highly uncertain and the model did not estimate recruitment deviations.

Fishing Mortality

The nearshore commercial and recreational fisheries that take black rockfish are managed well in Oregon, and ACLs/OYs have not been exceeded. The PSA vulnerability score of 1.94 indicates a stock of medium concern for overfishing.

Over the entire stock's history, the fishing rate has been less than the 50 percent SPR target fishing rate (Figure 2-93).

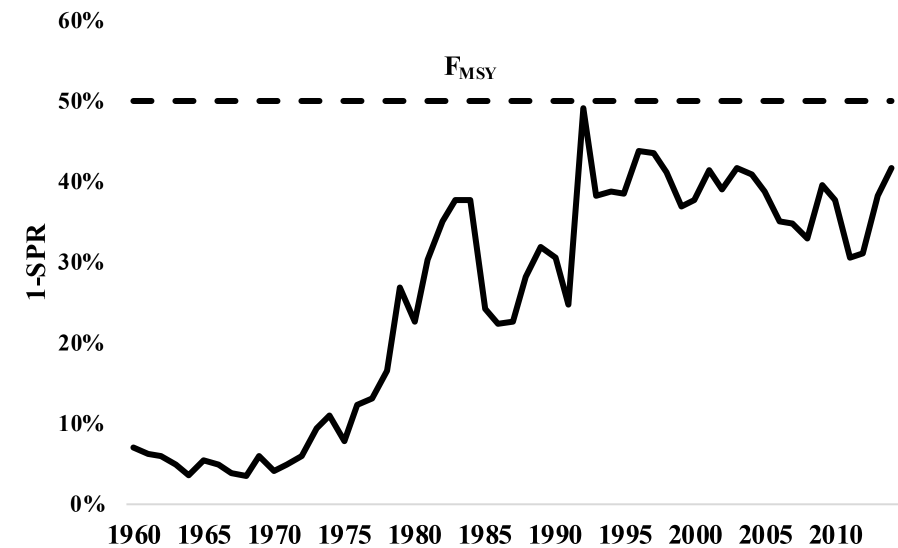

Figure 2-93. Time series of estimated SPR harvest rates of black rockfish off Oregon, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5.2.2 Blue and Deacon Rockfish off Oregon

Distribution and Life History

See Distribution and Life History of Blue and Deacon Rockfish in Section 2.5.1.

Stock Status and Management History

A new assessment of BDR, assessed as a complex of the two species, was conducted in 2017 for the populations of these two species off Oregon (Dick*, et al.* 2017). The Oregon BDR population is estimated to have been relatively lightly exploited, and to be healthy yet at a historically low level of depletion, 68.6 percent of the unfished spawning output in 2017 (Figure 2-94). The 2013 year class is estimated to be strong in Oregon waters, as in California.

The most significant uncertainty for the Oregon BDR model is the size of population scale, the treatment and value of natural mortality, and gender-specific selectivity. The development of a comprehensive fishery-independent index of abundance will help to resolve uncertainty in population scale. The treatment of selectivity and natural mortality was a major structural consideration that was explored in the development of the base case model. In particular, alternative approaches to estimating female and male natural mortality and gender specific selectivity were evaluated to account for differences in male selectivity (gear retention for the slower growing males) and availability (for sex-ratio reasons other than that attributed to natural mortality) relative to females in the catch. There was little information in the data to estimate gender-specific selectivity patterns, and most modeling attempts resulted in non-convergence or unrealistic results. The catch history for recreational fishing modes in years prior to 1979 and for the shore (and estuary) mode in recent years (2006-2014) is quite uncertain. In this assessment, historical catch reconstructions for these fleets included using a simple linear ramp, proportional fishing license sales ramp, and an extrapolation based on information available in the time series. The Oregon BDR assessment does not display a two-way trip like the California assessment and is based on fewer and shorter indices. Thus, both steepness and natural mortality are fixed in the base model.

The SSC endorsed the use of the Oregon BDR stock assessment as the best scientific information available for status determination and management as a category 2 assessment due to BDR being a complex of two species. The sigma value derived from the decision table for the Oregon assessment is larger than the category 2 sigma of 0.72 (0.803) and this value was used in calculating the scientific uncertainty buffer used to determine ABCs.

The Council adopted default harvest specifications (ACL = ABC with a P* of 0.45) for the Oregon BDR contribution to the new Oregon Black/Blue/Deacon Rockfish complex. The 2019 and 2020 ABC and ACL contributions of Oregon BDR to the Oregon Black/Blue/Deacon Rockfish complex are 101.5 mt and 98.4 mt, respectively.

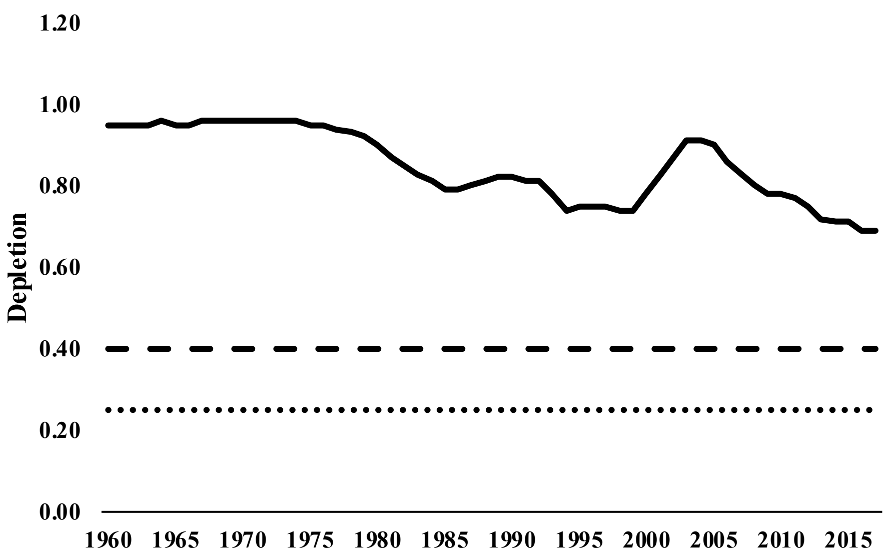

Figure 2-94. Relative depletion of blue and deacon rockfish off Oregon from 1960 to 2017 based on the 2017 stock assessment.

Stock Productivity

A Beverton-Holt steepness of 0.718 was assumed in the Oregon BDR model based on the mean of the prior distribution of the most recent meta-analysis of rockfish steepness. There was an attempt to estimate steepness in the Oregon BDR model, but a lack of contrast in exploitation lead to little information about steepness.

Recruitment variability was dynamic for BDR (Figure 2-95) and indicated well above average recruitment in 2013. Other years with relatively high estimates of recruitment were 1993, 1994, and 1995. The BDR stock in Oregon has not been depleted to levels that would provide information on how recruitment changes with spawning output at low spawning output levels (i.e., inform the steepness parameter).

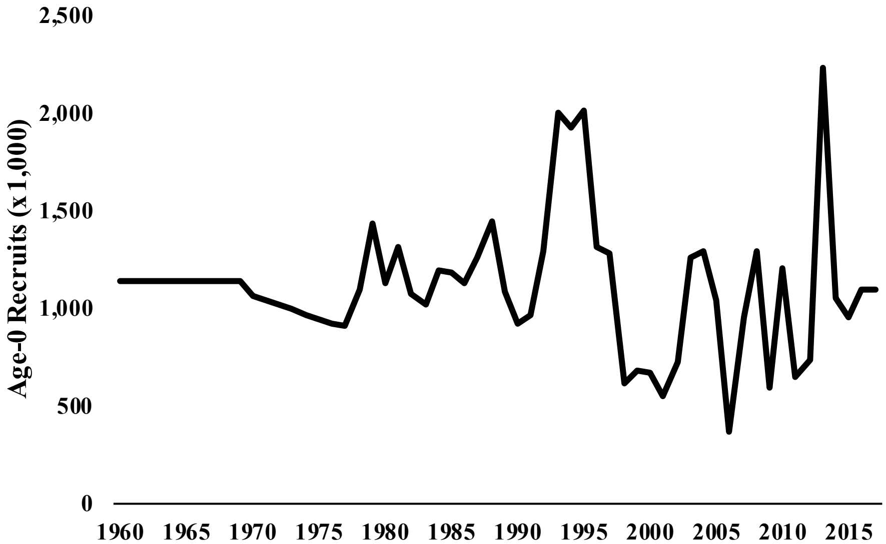

Figure 2-95. Estimated recruitments of blue and deacon rockfishes off Oregon, 1960-2016 (from Dick et al. 2017).

Fishing Mortality

Harvest rates in Oregon have generally increased through time until the mid-1990s when harvest was reduced to a relatively stable level beginning in the 2000s (Figure 2-96). The maximum relative harvest rate was 0.92 in 1993 (or 92 percent of the target level) before declining again to around 0.40 in recent years (Figure 2-96). Summary fishing mortality rates have been around 0.02 in recent years. Fishing intensity is estimated to have been below the target throughout the time series [(1-SPR) / (1-$SPR_{50\%}$) < 1]. In 2016, Oregon BDR biomass is estimated to have been 1.73 times higher than the target biomass level, and fishing intensity remains lower than the SPR fishing intensity target. The equilibrium curve is shifted left, as expected from the high fixed steepness, showing a more productive stock than the $SPR_{50\%}$ reference point would suggest.

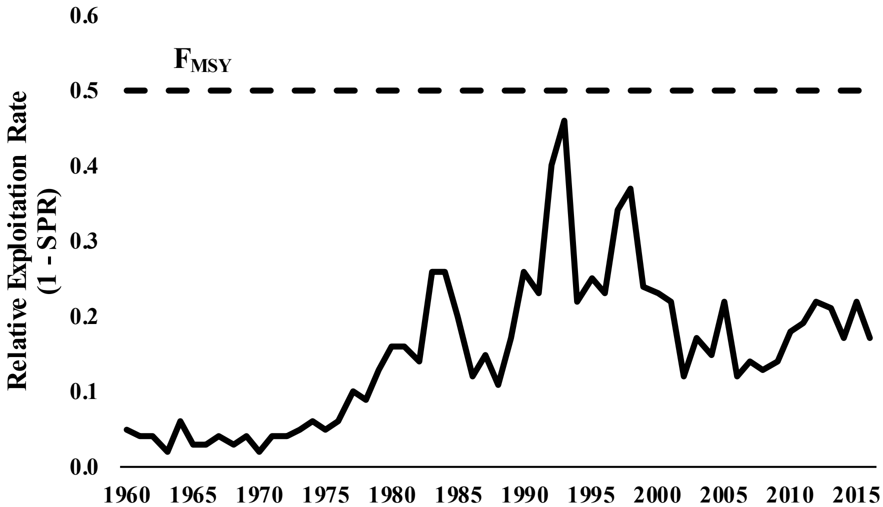

Figure 2-96. Estimated spawning potential ratio (SPR) of blue and deacon rockfish off Oregon relative to the current F_{MSY}, 1960-2016. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5.3 Shelf Rockfish North and South of 40°10' N. Lat.

The shelf rockfish complexes north and south of 40°10' N. lat. Are comprised of both assessed and unassessed species. Of the stocks managed in the shelf rockfish complexes, chilipepper rockfish north of 40°10' N. lat. (the assessment for the northern stock only covers the area from 40°10' N. lat. To Cape Blanco, OR at 43° N. lat. – see section 2.4.9 for more details), greenspotted rockfish, greenstriped rockfish, and stripetail rockfish have been assessed. The following section defines these complexes in terms of their component stocks and provides further detail on those component stocks that have been assessed.

The Shelf Rockfish complex north of 40°10' N. lat. Is comprised of the following species: bronzespotted rockfish (*Sebastes gilli*); bocaccio (*Sebastes paucispinis*); chameleon rockfish (*S. phillipsi*); cowcod (*S. levis*); dusky rockfish (*S. ciliatus*); dwarf-red rockfish (*S. rufianus*); flag rockfish (*S. rubrivinctus*); freckled rockfish (*S. lentiginosus*); greenblotched rockfish (*S. rosenblatti*); greenspotted rockfish (*S. chlorostictus*); greenstriped rockfish (*S. elongatus*); halfbanded rockfish (*S. semicinctus*); harlequin rockfish (*S. variegatus*); honeycomb rockfish (*S. umbrosus*); Mexican rockfish (*S. macdonaldi*); pink rockfish (*S. eos*); pinkrose rockfish (*S. simulator*); pygmy rockfish (*S. wilsoni*); redstripe rockfish (*S. proriger*); rosethorn rockfish (*S. helvomaculatus*); rosy rockfish (*S. rosaceus*); silvergray rockfish (*S. brevispinis*); speckled rockfish (*S. ovalis*); squarespot rockfish (*S. hopkinsi*); starry rockfish (*S. constellatus*); stripetail rockfish (*S. saxicola*); sunset rockfish (*S. crocotulus*); swordspine rockfish (*S. ensifer*); tiger rockfish (*S. nigrocinctus*); and vermilion rockfish (*S. miniatus*).

The Shelf Rockfish complex south of 40°10' N. lat. Is composed of the following species: bronzespotted rockfish (*Sebastes gilli*); chameleon rockfish (*S. phillipsi*); dusky rockfish (*S. ciliatus*); dwarf-red rockfish (*S. rufianus*); flag rockfish (*S. rubrivinctus*); freckled rockfish (*S. lentiginosus*); greenblotched rockfish (*S. rosenblatti*); greenspotted rockfish (*S. chlorostictus*); greenstriped rockfish (*S. elongatus*); halfbanded rockfish (*S. semicinctus*); harlequin rockfish (*S.

variegatus); honeycomb rockfish (*S. umbrosus*); Mexican rockfish (*S. macdonaldi*); pink rockfish (*S. eos*); pinkrose rockfish (*S. simulator*); pygmy rockfish (*S. wilsoni*); redstripe rockfish (*S. proriger*); rosethorn rockfish (*S. helvomaculatus*); rosy rockfish (*S. rosaceus*); silvergray rockfish (*S. brevispinis*); speckled rockfish (*S. ovalis*); squarespot rockfish (*S. hopkinsi*); starry rockfish (*S. constellatus*); stripetail rockfish (*S. saxicola*); sunset rockfish (*S. crocotulus*); swordspine rockfish (*S. ensifer*); tiger rockfish (*S. nigrocinctus*); vermilion rockfish (*S. miniatus*); and yellowtail rockfish (*S. flavidus*).

2.5.3.1 Greenspotted Rockfish

Distribution and Life History

Greenspotted rockfish (*Sebastes chlorostictus*) are found in waters off the West Coast of North America, ranging from Copalis Head, Washington to Isla Cedros, Baja California (approximately 25° to 47° N. lat.). Abundance of this species is greatest from northern Baja California to Mendocino County in California. Greenspotted rockfish associate with several benthic habitat types between depths of 30-363 m, although adults are most common between 60 and 240 m (Love, *et al.* 2002).

Greenspotted rockfish are a long-lived and slow growing species, with sedentary adults associating with a wide variety of benthic habitats. Maximum reported age is 51 years (Benet, *et al.* 2009). Estimates of maximum length for greenspotted rockfish are in the vicinity of 50 cm. Benet et al. (2009) report maximum fork length as 48 cm for central California. Miller and Gotshall (1965) report 51 cm total length for the same area, but did not attempt to distinguish between greenspotted rockfish and pink rockfish (*Sebastes eos*), which grow to 56 cm (Love, *et al.* 2002). Commercial port samplers in California have reported individuals larger than 50 cm fork length (up to 57 cm), although fish of this size appear to be rare (CALCOM, 2011). In southern California, Love et al. (1990) report maximum length as 50 cm total length. Sexual dimorphism is not apparent in greenspotted rockfish (Benet, *et al.* 2009; Lenarz and Wyllie Echeverria 1991; Mason 1998), although latitudinal differences in weight-at-length, length-at-age, and size-at-maturity have been observed.

Seasonal maturation and size at maturity vary with lat., a trend commonly seen in rockfishes (Benet, *et al.* 2009; Love, *et al.* 1990). In central and northern California, spawning months have been reported from March to September, with peak parturition from April to June (Benet, *et al.* 2009; Wyllie Echeverria 1987). In southern California spawning months begin in February and extend through July, with peak parturition in April (Love, *et al.* 1990). Benet et al. (2009) estimate length at 50 percent maturity for female greenspotted as 26 cm, consistent with a previous estimate of 27 cm (Wyllie Echeverria 1987) based on females from the same area. In southern California, Love et al. (1990) report length at 50 percent maturity as 22 cm (converted to fork length from total length). Love et al. (1990) detected evidence of multiple broods in females from southern California (ovaries containing eyed larvae and large numbers of fertilized or unfertilized eggs). No evidence of multiple broods was found in studies of greenspotted rockfish north of Point Conception (Benet, *et al.* 2009; Wyllie Echeverria 1987).

Several studies have reported on habitat associations for greenspotted rockfish. Yoklavich et al. (2000) quantified deep, rocky habitat in Monterey Bay. They observed smaller greenspotted rockfish in shallow depths (75-174 m) and reported strong associations with heterogeneous habitats (cobble-mud, mud-boulder, rock-mud, and rock-ridge). Laidig et al. (2009) studied habitat associations of demersal fishes from a manned submersible in central California, observing 809 greenspotted rockfish. They mainly encountered immature individuals (86 percent of greenspotted were <25 cm), identifying positive associations with all habitat types (boulder, brachiopod beds, cobble) other than mud. The predominance of juvenile rockfish in the study area suggests that the areas and depths surveyed may be nursery grounds for juvenile rockfish and/or transitional zones as individuals move toward adult habitats (Laidig*, et al.* 2009). Juvenile greenspotted rockfish are commonly seen in traps targeting spot prawn in Monterey Bay, usually in low-relief habitats (Dick*, et al.* 2011).

Adult greenspotted rockfish are generally sedentary, and associate with a wide range of habitat types. Yoklavich et al. (2000) observed 426 greenspotted rockfish (fourth highest abundance of observed species) in Monterey Bay, noting that adults were common near rocky outcrops, ridges, caves, and overhangs. Anderson et al. (2009) described greenspotted rockfish as characteristic of transition zones between hard and soft sediments, based on in situ observations across Cordell Bank in central California. They classified habitat for greenspotted rockfish over a range of spatial scales. At the finest scale (1-10s of m), greenspotted were found to have weak associations with four of five possible categories: mud, boulders, cobbles, and rock (sand being the fifth category). At intermediate scales (10-100s of m) Anderson et al. (2009) characterized greenspotted habitat as depths between 100-300 m and soft and mixed sediment types.

Movements of greenspotted rockfish have been monitored using acoustic tagging experiments. Starr et al. (2002) implanted acoustic tags in six adults in Monterey Bay, finding that adults exhibit limited horizontal movement and almost no vertical movement. They also identified two movement patterns. In the first pattern, 94 percent of time was spent within a 0.58 km2 area. The second pattern involved larger movements, with excursions up to 3 km, but 60 percent of time was spent within the 1.6 km^2 study area. Lowe et al. (2009) monitored 4 adult greenspotted rockfish near oil platforms in southern California using acoustic tags. Probabilities of detection near the release sites dropped by 14 percent in one year of monitoring. Two individuals returned to their release sites after a 7-month absence.

Williams and Ralston (2002) studied the distribution and co-occurrence of rockfishes over continental shelf and slope habitats using fishery-independent trawl survey data. Greenspotted rockfish were consistently caught (>80 percent co-occurrence) with bocaccio, chilipepper, stripetail (*S. saxicola*), and shortbelly rockfish. Williams and Ralston (2002) proposed species assemblages for management purposes, including greenspotted in a “southern shelf” assemblage along with bocaccio, chilipepper, shortbelly rockfish, stripetail, greenstriped, and cowcod. Since greenspotted rockfish is not a primary target of commercial fisheries, its association with other desirable shelf rockfish species (e.g., bocaccio and chilipepper) is likely a driving force behind historical exploitation of this species.

Molecular systematic studies (Hyde and Vetter 2007) report that greenspotted rockfish are closely related to pink rockfish and greenblotched rockfish (*S. rosenblatti*). Greenspotted rockfish can be distinguished from pink and greenblotched rockfishes by a smooth lower jaw, lacking scales found on the lower mandibles of the other two species (Love*, et al.* 2002).

Stock Status and Management History

The 2011 greenspotted rockfish assessment conducted for the portion of the stock off California was modeled as two area assessments north and south of Point Conception at 34°27' N. lat. The assessment indicates the stock is in the precautionary zone with spawning biomass depletions of 30.6 percent and 37.4 percent for the stocks north and south of Point Conception, respectively. The stocks have shown substantial biomass increases since implementation of the RCAs in 2003. Shelf rockfish are particularly well protected by the RCAs, and greenspotted rockfish catches have been negligible since 2003. The Council recommended continuing to manage greenspotted rockfish within the Shelf Rockfish complexes since catch histories were too uncertain to allocate QS in the IFQ fishery.

The OFL contribution of greenspotted rockfish to the Shelf Rockfish North complex was based on apportioning 22.2 percent of the projected OFLs from the assessment for the stock north of Point Conception, which is the average estimated catch proportion in the assessment for the stock occurring in the area between 40°10' N. lat. And the California-Oregon border at 42° N. lat. The OFL contribution for the portion of the stock occurring north of 42° N. lat. Was derived using DB-SRA. The SSC categorized the assessed portion of the stock as a category 2 stock since recruitments were not estimated. The unassessed portion of the stock was categorized as a category 3 stock.

The Council adopted the default harvest control rule of ACL equal to the ABC With a P* of 0.45 with the 40-10 adjustment to the ACL (since the stock is in the precautionary zone) for 2019 and 2020 harvest specifications. The 2019 and 2020 ACL contribution of greenspotted rockfish north of 40°10' N. lat. To 42° N. lat. To the Shelf Rockfish complex north of 40°10' N. lat. Is 8.2 mt and the ACL contribution of greenspotted rockfish north of 42° N. lat. Is 5.1 mt. The 2019 and 2020 ACL contributions of greenspotted rockfish south of 40°10' N. lat. To the Shelf Rockfish complex south of 40°10' N. lat. Are 70.9 mt and 70.7 mt, respectively.

Stock Productivity

Length and age composition data available for the 2011 greenspotted rockfish assessment contained insufficient information to reliably resolve year-class strength. Both base models assumed that recruitment followed a deterministic Beverton-Holt stock-recruitment relationship, so trends in recruitment reflected trends in estimated spawning output.

While the productivity score for greenspotted rockfish is relatively low (P = 1.39), the susceptibility score is sufficiently low to estimate a medium vulnerability to potential overfishing (V = 1.98).

Fishing Mortality

Greenspotted rockfish are not usually a primary target of commercial or recreational fisheries. Regulations affecting this species are typically intended to alter fishing mortality of primary targets and/or overfished/rebuilding species. For example, implementation of RCAs statewide and CCAs in southern California has greatly reduced fishing mortality for greenspotted rockfish in the past decade.

Historical harvest rates for greenspotted rockfish peaked in the mid-1980s in southern California but continued to rise in northern California until about a decade later. SPR harvest rates exceeded the current proxy MSY value in northern California from 1973-2000, and from 1969-1998 in southern California. Biomass in both regions is currently below target (<40 percent unfished spawning output), but above the MSST, and equilibrium SPR harvest rates have been below the proxy MSY level since 2001 in the north and since 1999 in the south.

2.5.3.2 Greenstriped Rockfish

Distribution and Life History

Greenstriped rockfish (*Sebastes elongatus*) can be found in abundance from British Columbia to Northern Baja California, but range from Chirikof Island in the Aleutian Islands (Gulf of Alaska) to central Baja California (Love*, et al.* 2002). Adults may inhabit depths between 12 and 500 meters, but are more commonly found between 100 and 250 m, and adults typically move to deeper water as they mature (Love*, et al.* 2002; Shaw and Gunderson 2006). This species of rockfish is found with other congeners or alone in a wide range of habitats, which include rocky outcroppings. However, unlike most other species of rockfish they seem to prefer mud or sand bottoms (Love*, et al.* 2002; Shaw and Gunderson 2006).

A genetic study of greenstriped rockfish was recently undertaken by Jon Hess (pers. Comm., NWFSC, NOAA as cited in by Hicks et al. (2009)) to study the stock structure of greenstriped rockfish. The genetic variability was remarkably low and showed less variability than most other rockfish species, even when including samples from Puget Sound. However, latitudinal differences in life-history traits have been observed.

Typical of other species of the genus *Sebastes*, greenstriped rockfish are long-lived with maximum observed ages greater than 50 years (Love*, et al.* 2002). Females grow larger than males, but typically mature at about the same length, between 18 and 24 cm, which corresponds to an age between 7 and 10 years. A latitudinal cline in maturity has been observed with fish maturing at a smaller size in the southern areas (Wyllie Echeverria 1987).

Greenstriped rockfish give birth to live young and the fecundity of a 0.5 kilogram female is on average around 200,000 eggs (Dick 2009), although a wide range of fecundity has been reported (Love*, et al.* 2002). The reproductive development of males and females is slightly offset with mating occurring in December through February, fertilization occurring in early spring, and parturition occurring about a month later in late spring (Shaw and Gunderson 2006). Females have the ability to store sperm during the time between copulation and fertilization to ensure the availability of spermatozoa when oocyte maturation has occurred (Shaw and Gunderson 2006).

However, in southern latitudes, parturition may occur from January to July and females in Southern California may release two broods during this time (Love*, et al.* 2002). Juveniles settle to the bottom at about 3 cm in length in autumn and are commonly found along the interface of fine sand and clay. Maturing adults typically move to deeper water (Love*, et al.* 2002).

A wide range of prey items make up the diet of greenstriped rockfish. They will feed from the water column or the bottom on such things as fish, krill, shrimps, copepods, amphipods, and squid. Other fish species may prey on greenstriped rockfish. They have been found in the stomachs of king salmon (Love*, et al.* 2002). Reefs with small numbers of piscivorous rockfish had much higher numbers of small rockfish, such as greenstriped rockfish, than reefs with high numbers of piscivorous rockfish (PFMC 2006).

Stock Status and Management History

Greenstriped rockfish are a bycatch species with little market value mainly due to its small size, and it has been reported that fillets from this species have a short shelf life (Love*, et al.* 2002). As a result, there has not been a long-term directed fishery for this species. However, greenstriped rockfish are often observed in landings from various fisheries, although in small proportions. The most common occurrence of greenstriped rockfish is in trawl fisheries, but they are often caught in recreational fisheries, especially when fishing vessels drift off of the rocks.

After many attempts to start trawl fisheries off the West Coast of the United States in the late 1800s, the availability of the otter trawl and the diesel engine in the mid-1920s helped the trawl fisheries expand (Douglas 1998). The trawl fisheries really became established during World War II when demand increased for shark livers and bottomfish. A mink food fishery also developed during World War II (Jones and Harry 1960). Foreign fleets began fishing for rockfish in the mid-1960s until the EEZ was implemented in 1977 (Rogers 2003b). Since 1977, landings of rockfish were high until management restrictions were implemented in 2000.

Greenstriped rockfish are often caught in bottom trawls, but a long-term directed fishery has not occurred for this species and historical discarding rates are not well known. There have been many reports of greenstriped rockfish occurring in various fisheries, even as early as 1884 (Goode 1884). Fishermen report that greenstriped rockfish are ubiquitous and are rarely if ever caught in great numbers.

A coastwide assessment of greenstriped rockfish was done in 2009, which indicated stock depletion was at 81 percent of its unfished biomass at the start of 2009 (Hicks*, et al.* 2009). The coastwide greenstriped harvest specifications were apportioned beginning in 2011 using the mean of the 2003-2008 swept area biomass estimates north of 40°10' N. lat. (84.5 percent) from the NMFS trawl survey. This stock has continued to be managed within the Shelf Rockfish complexes due to the complications associated with managing this species with IFQs. Species pulled out of a complex managed with IFQs must be converted into an IFQ management unit under the Amendment 20 rules. Greenstriped rockfish is a trawl-dominant bycatch species that is rarely landed due to their diminutive size and low market desirability. An initial allocation of quota share for greenstriped would be less than straightforward given the unreliable catch history. The SSC rated the greenstriped stock as category 2 on the basis of the very uncertain catch history in the 2009 assessment that prevented the estimation of discrete year classes.

The SSC downgraded greenstriped rockfish to a category 3 species in 2021 given the age of the assessment. They recommended the OFL for 2023 and beyond be set at the estimated MSY under the F_{MSY} proxy (SPR of 50 percent) of 738 mt. The status quo apportionment of the coastwide OFL of 84.5 percent to the north of 40°10' N. lat. was maintained.

Stock Productivity

Recruitment deviations were estimated in the 2009 assessment starting in 1970. The estimates showed that recruitment was highly variable for greenstriped rockfish with high values in 1971, 1984, 1993, and 1998, and low estimates of recruitment in the 1990s, early 1970s, and 2006. The age data from the NWFSC trawl survey were very consistent with these estimates and precisely showed a very strong 1993 cohort.

While the greenstriped productivity score is relatively low (P = 1.28), the susceptibility to high exploitation was also low leading to a medium vulnerability to potential overfishing (V = 1.88).

Fishing Mortality

The spawning output of greenstriped rockfish reached a low in the late 1990s before beginning to increase throughout the last decade. The estimated depletion has remained above the 40 percent of unfished spawning output target and it is unlikely that the stock has ever fallen below this threshold. Throughout the 1970s, 1980s, and 1990s the exploitation rate and SPR have generally increased and occasionally exceeded current estimates of the harvest rate limit (SPR = 50 percent). Recent exploitation rates on greenstriped rockfish have been very small, which is primarily due to management actions in the late 1990s and early 2000s to rebuild other species.

2.5.3.3 Squarespot Rockfish

Distribution and Life History

Squarespot rockfish (*Sebastes hopkinsi*) is a dwarf species of rockfish commonly found in depths between 60 – 123 m (33-68 fm), hovering over or sheltering in rocky reef habitat and aggregating with other smaller rockfishes (Love*, et al.* 2002). Squarespot rockfish are yellow-brown, brown, or tan on the back and sides with lighter colored bellies. Squarespot rockfish has sex-specific growth with females reaching larger sizes (29 cm) than males (23 cm).

Stock Status and Management History

Squarespot rockfish are managed in the northern and southern Shelf Rockfish complexes, although they are rare north of 40°10' N. lat. With 0.3 percent of average annual landings occurring in northern California. Squarespot rockfish are generally undesirable in the recreational and commercial fishery due to their small size. Females grow larger than males, and only nearing their maximum length do they reach a size that is marginally acceptable to anglers, thus the landings are primarily composed of older females.

A length-based data-moderate stock assessment was conducted for squarespot rockfish in California in 2021, which indicated the stock was at 37 percent of unfished biomass at the start of

2021 {Figure 2-97; Cope, 2021 #1300}. There are no prior assessments for this species, and since 2010, the DCAC method has been used to set annual catch limits, based on assuming a relative depletion of 40 percent. This species is treated as one stock in the assessment as there is no evidence of population structure. Due to its small size, squarespot rockfish are not targeted by the recreational or commercial fisheries. Catches mostly consist of large females. Thus, the fishery mainly affects spawning biomass. The assessment model did not fit the NWFSC Hook and Line Survey index and associated length compositions.

The SSC designated the squarespot rockfish assessment as category 2, the default for data-moderate assessments. The SSC recommended the next squarespot rockfish assessment be a data-moderate assessment.

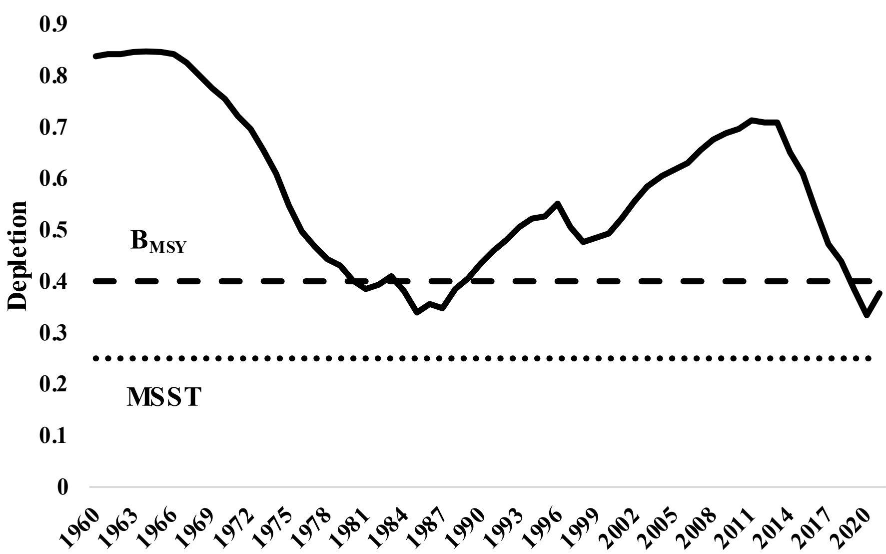

Figure 2-97. Estimated depletion of squarespot rockfish in California relative to the management target, 1960-2021.

Stock Productivity

Stock-recruitment steepness for squarespot rockfish was fixed at the prior of 0.72 in the 2021 assessment and treated as deterministic. Therefore, recruitment deviations were not estimated.

Fishing Mortality

The relative exploitation rate of squarespot rockfish was above the F_{MSY} proxy harvest rate between the 1970s and early 1980s, below the target for much of the time from the mid-1980s to early 2010s, and most of the recent several years have exceeded the target (Figure 2-98).

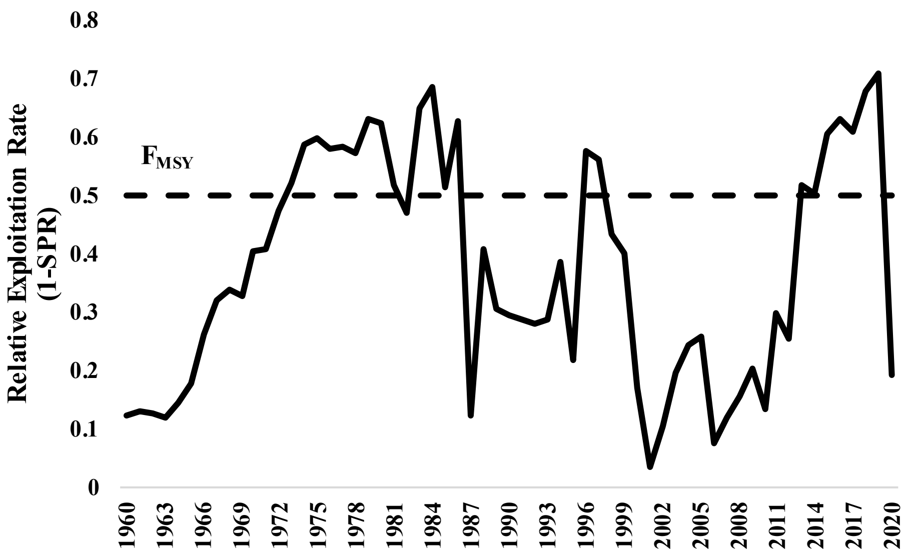

Figure 2-98. Estimated annual relative exploitation rate of squarespot rockfish in California relative to the current proxy F_{MSY} target, 1960-2020.

2.5.3.4 Stripetail Rockfish

Distribution and Life History

Stripetail rockfish (*Sebastes saxicola*) are found from Yakutat Bay in the eastern Gulf of Alaska to Bahia Sebastian Vizcaino in central Baja California, but are more common from coastal British Columbia to southern California (Love, *et al.* 2002). They occur in depths ranging from 25 to 547 m but are most abundant between 100 and 200 m. Adult stripetail are benthically oriented and are most often associated mud, sand, and other low relief habitats. Stripetails are found in the same habitats as splitnose rockfish, greenstriped rockfish, Dover sole, and thornyheads.

Stripetail rockfish live at least 38 years and females grow faster (after reaching maturity) and achieve a larger size than males. Stripetail rockfish are relatively small-sized rockfish with a maximum size of 41 cm and 1 kg (Love, *et al.* 2002). Female stripetails along the California coast are mature by 18 cm or about 9 years of age. Off California, larval release occurs from November to March with peak release occurring off central and northern California in February and in December in the Southern California Bight (Love, *et al.* 2002). Females produce between 15,000 and 230,000 eggs.

Stripetails are primarily water column planktivores feeding mainly on krill and copepods. They are preyed on by a number of predators including Chinook salmon.

Stock Status and Management History

Stripetail rockfish are managed in the northern and southern Shelf Rockfish complexes. They are a relatively minor component stock to these complexes since stripetail are not targeted nor landed in large amounts.

A new data-moderate assessment of stripetail rockfish was conducted in 2013, which indicated the stock was healthy with a depletion exceeding 77.5 percent (Cope*, et al.* 2014). The 2013 assessment did not produce a reliable estimate of the scale of the stock's biomass; therefore, the SSC did not recommend using the OFL estimates in the assessment. However, the SSC did recommend the available data in the assessment provided strong evidence that the stock was well above the target B_{MSY} and that the assessment results could be used for status determination. Given that the assessment-based OFLs were not endorsed by the SSC, the OFL continues to be based on a DB-SRA methodology and the stock is therefore categorized as a category 3 stock.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and 2020 harvest specifications. The 2019 and 2020 ACL contribution of stripetail rockfish to the Shelf Rockfish complex north of 40°10' N. lat. Is 33.7 mt. The 2019 and 2020 ACL contribution of stripetail rockfish to the Shelf Rockfish complex south of 40°10' N. lat. Is 19.7 mt.

Stock Productivity

Two recruitment events reported in trawl studies off California from 1973-1993 occurred during El Niños (Love*, et al.* 2002). It is not clear from the literature whether this is a representative recruitment pattern for the stock.

The PSA productivity score of 1.39 for stripetail rockfish indicates a relatively low productivity among rockfish species. There is a moderate vulnerability of potential overfishing (V = 1.8) for the stock.

Fishing Mortality

Stripetail rockfish are not targeted in commercial or recreational fisheries due to their small size. However, they are caught incidentally in bottom trawl fisheries due to their occurrence in low relief, trawlable habitats. They are rarely landed in current trawl fisheries although they were frequently landed and sold for animal food in the 1950s and 1960s. The stock has never experienced overfishing with the exploitation rate remaining well below the proxy SPR = 50 percent F_{MSY} harvest rate for rockfish.

2.5.3.5 Vermilion and Sunset Rockfishes

Distribution and Life History

Vermilion rockfish (*Sebastes miniatus*) range from Prince William Sound, Alaska, to central Baja California at depths of 6 m to 436 m (Love*, et al.* 2002). However, they are most commonly found from central Oregon to Punta Baja, Mexico at depths of 50 m to 150 m (Hyde and Vetter 2009). Hyde and Vetter (2009) describe vermilion rockfish as residents of shallower depths (<100 m) than their sibling species, sunset rockfish (*Sebastes crocotulus*). Adult fish tend to cluster on high relief rocky outcrops and kelp forests. North of Point Conception, California, some adults reside in shallower water, living in caves and cracks (Love*, et al.* 2002). Vermilion rockfish have shown high site fidelity (Hannah and Rankin 2011 (only tagged one vermilion rockfish), (Lea*, et al.* 1999), and low to average larval dispersal distance (Hyde and Vetter 2009). Lowe et al. (2009)

suggested that vermilion rockfish have a lower site fidelity than previously believed but acknowledged that their observations of movements to different depths may have been due to differences in depth distribution between the species. Vermilion rockfish have been aged to over 80 years, but few fish have been aged above 60 years, with females growing larger than their male counterparts. Fifty percent of females are mature at 5 years and about 37 cm, with males likely maturing at shorter lengths than females (Love*, et al.* 2002).

Vermilion rockfish are viviparous, and females produce an estimated 63,000 to 2,600,000 eggs per brood, with larger fish releasing a substantially larger number of larvae. In southern California, vermilion rockfish larvae are released between July and March. In central and northern California, this release occurs in September, December, and April-June (Love*, et al.* 2002). Hyde and Vetter (Hyde and Vetter) suggest that low larval dispersal may be due to weak poleward flow of nearshore waters corresponding with peak vermilion rockfish larval release.

Young-of-the-year vermilion rockfish settle out of the water column during two primary recruitment periods per year, first from February to April and a second from August to October, and settlement has been observed in May off southern California (Love*, et al.* 2002). Young-of-the-year vermilion and sunset rockfish are both mottled brown with areas of black, and older juveniles turn a mottled orange or red color (Love*, et al.* 2002). Larvae measure about 4.3 mm and juvenile fish are found in depths of 6-36 m, living near sand and structure. After two months, juveniles travel deeper and live on low relief rocky outcrops and other structures (Love*, et al.* 2002). Adult vermilion rockfish predominantly eat smaller fish, though sometimes they pursue euphausiids and other various macroplankton (Phillips 1964). Love et al. (2002) noted their diet includes octopuses, salps, shrimps, and pelagic red crabs.

Stock Status and Management History

Vermilion rockfish are managed in the northern and southern Shelf Rockfish complexes. Prior to the identification of sunset rockfish as a separate species (Hyde*, et al.* 2008), historical studies of "vermilion" rockfish, particularly those conducted south of Point Conception, California, could have included a mixture of both species. Also, many current studies and data sets (e.g., landing statistics) do not distinguish between the species.

Two assessments of vermilion rockfish in California north and south of Pt. conception were conducted in 2005 but were not endorsed by the SSC to inform management. Vermilion assessments were again conducted in 2013 but were not reviewed at the designated STAR panel due to lack of time.

Stock assessments for vermilion and sunset rockfishes were conducted in 2021 for California south of Pt. Conception, California north of Pt. Conception, Oregon, and Washington. This spatial structure reflects the distribution of this cryptic species complex, with vermilion rockfish found throughout the region, most sunset rockfish found south of Point Conception, with a small but uncertain proportion of sunset rockfish north of Point Conception. The models for all regions estimated stocks as being above management targets in 2021, with depletions of 48.2 percent in southern California (Figure 2-99), 42.7 percent in northern California (Figure 2-100), 73 percent in Oregon (Figure 2-101), and 56 percent of unfished biomass in Washington (Figure 2-102).

However, formal status determinations were not made pending an FMP amendment to define stocks in the FMP.

Model complexity decreased from south to north as fewer data sources were available and sample sizes declined with distance from the center of the species' primary distribution in central/southern California. This is also consistent with the diminishing relative abundance of sunset rockfish from central California. All area models had data on catch, length, age, and conditional age-at length, estimate growth and recruitment deviations, and use Francis weighting. Natural mortality is estimated separately for males and females using the Hamel prior with a median of 0.1, though fixed to be the same for both genders in the southern California model. Steepness was fixed at 0.72 in all model areas except for southern California, where it is estimated at 0.73.

The SSC designated the assessments in southern California and Washington as category 2 and category 1 in northern California and Oregon. The category 2 designation in southern California reflects the mixed stock complex in that region. The category 2 designation in Washington reflects the data limitations and wider confidence bounds on the stock status estimates in that region. The category 1 designations in northern California and Oregon are because those regions are predominantly comprised of vermilion rockfish. The SSC recommended full assessments for all regions next time these species are assessed.

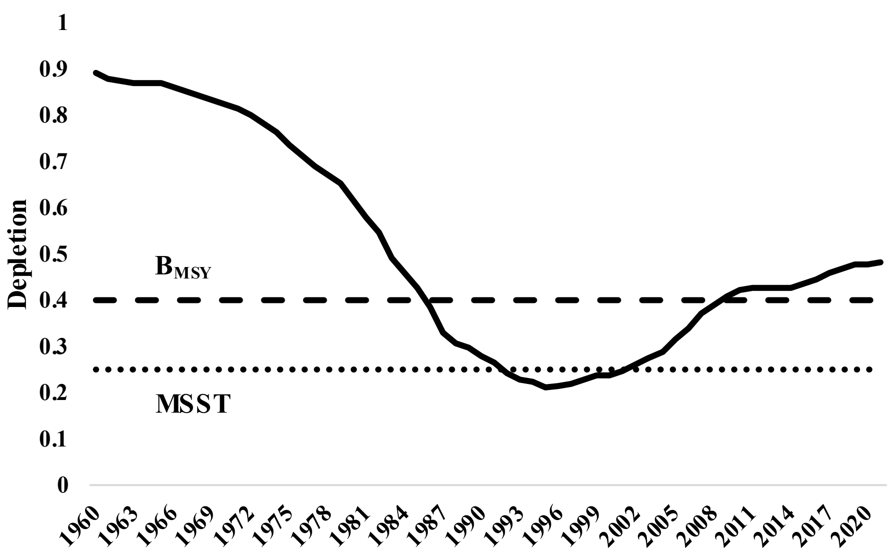

Figure 2-99. Estimated depletion of vermilion and sunset rockfishes in California south of 34°27' N lat. Relative to the management target, 1960-2021.

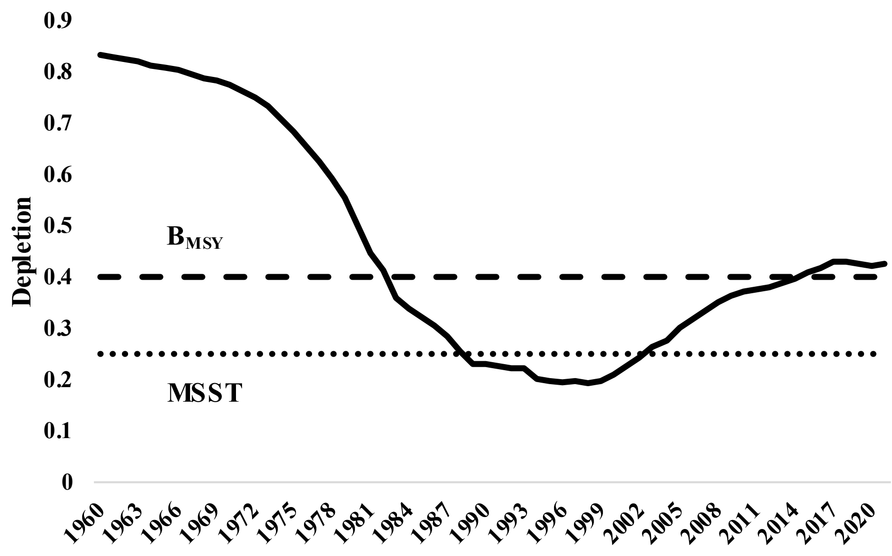

Figure 2-100. Estimated depletion of vermilion and sunset rockfishes in California north of 34°27' N lat. Relative to the management target, 1960-2021.

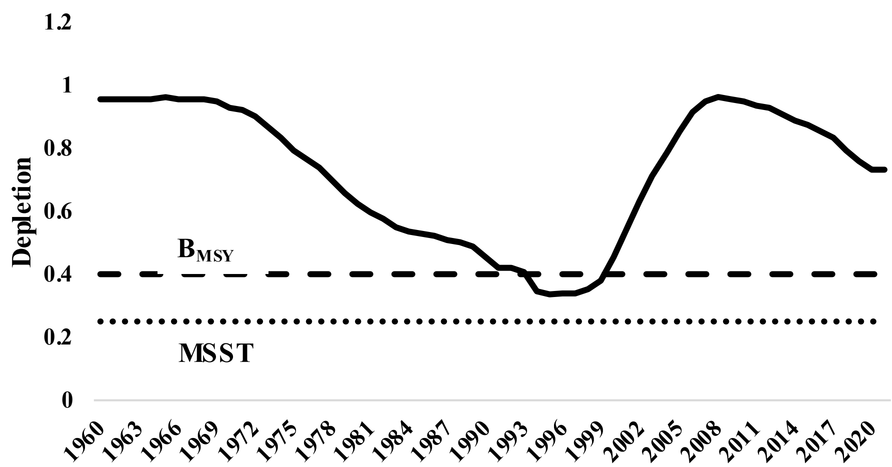

Figure 2-101. Estimated depletion of vermilion rockfish in Oregon relative to the management target, 1960-2021.

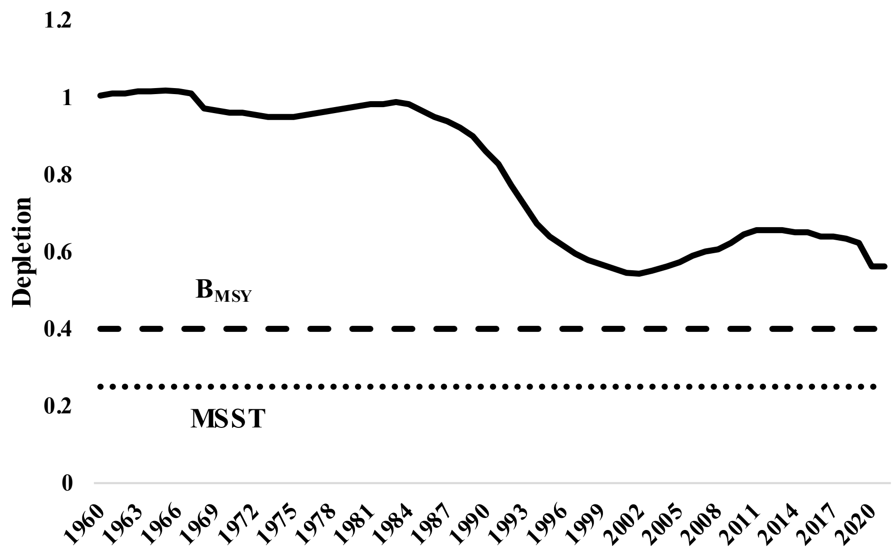

Figure 2-102. Estimated depletion of vermilion rockfish in Washington relative to the management target, 1960-2021.

Stock Productivity

A Beverton-Holt steepness of 0.72 (the meta-analytical prior) was assumed in the vermilion assessments in northern California, Oregon, and Washington. A steepness of 0.73 was estimated using the prior in the southern California assessment.

The PSA productivity score of 1.22 for vermilion rockfish indicates a relatively low productivity among rockfish species. There is a moderate vulnerability of potential overfishing (V = 2.05) for the stock.

Major recruitments in southern California were consistently estimated by both primary sources of age data (NWFSC hook and line and trawl surveys), with a strong 1999 year class estimated even when either data set was removed (Figure 2-103). Other years with relatively high estimates of recruitment were 1983-84, 1999, and 2016. These are consistent with estimates of strong year classes in other rockfish stock assessments. Recent recruitments (2011-2020) have been above average in most years that are well-informed by data, although extended periods of below-average recruitment (e.g., 2001-2006) have also occurred and future trends in recruitment are highly uncertain.

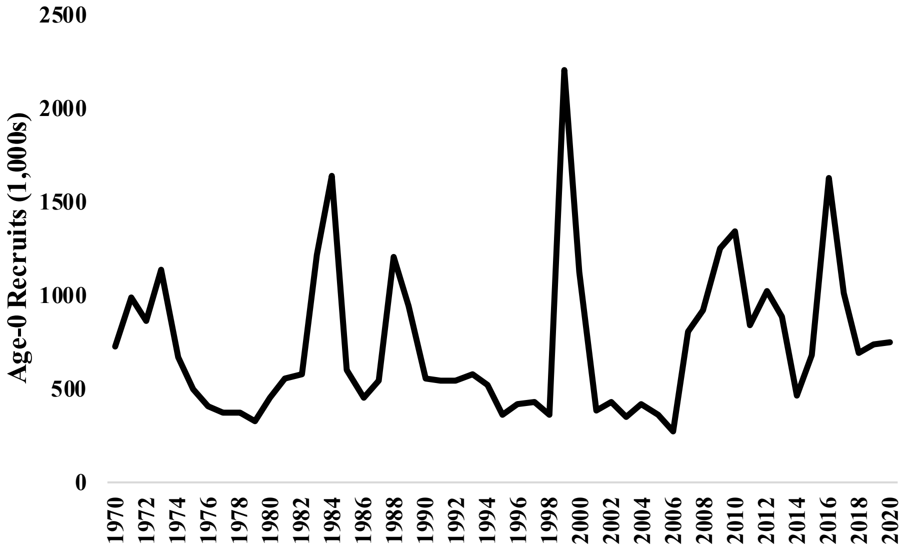

Figure 2-103. Estimated recruitment of vermilion and sunset rockfishes in California south of 34°27' N lat, 1970-2020.

Recruitment deviations were estimated from 1970-2020 with a recent, strong recruitment in 2016 that has contributed to the recent increase in vermilion rockfish biomass in northern California (Figure 2-104). The second highest estimated recruitment occurred in 1985 and is more certain than the estimated 2016 recruitment.

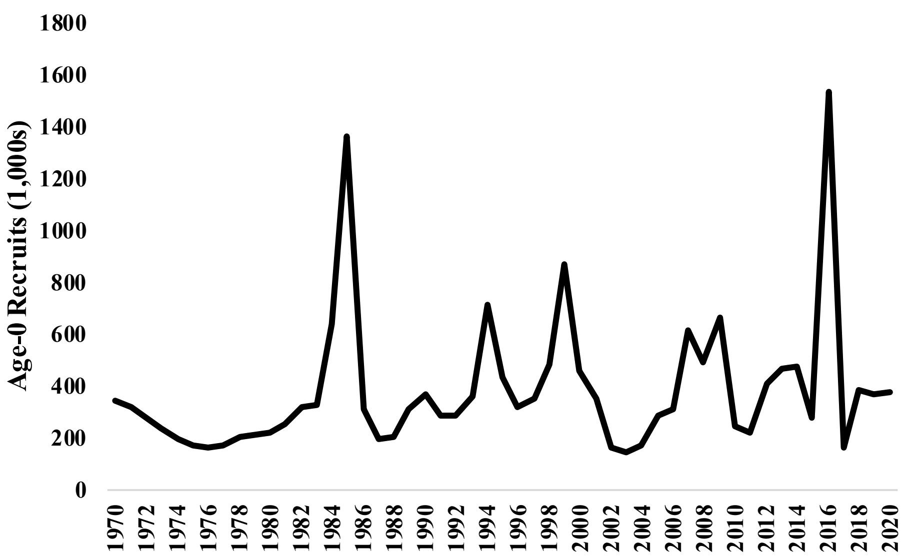

Figure 2-104. Estimated recruitment of vermilion and sunset rockfishes in California north of 34°27' N lat, 1970-2020.

Data informing recruitment of vermilion rockfish in Oregon were most informative from the 1990s to the mid-2010s. Peak years of recruitments are found in years 1993, 1994, 1998, 2005, and 2015 (Figure 2-105).

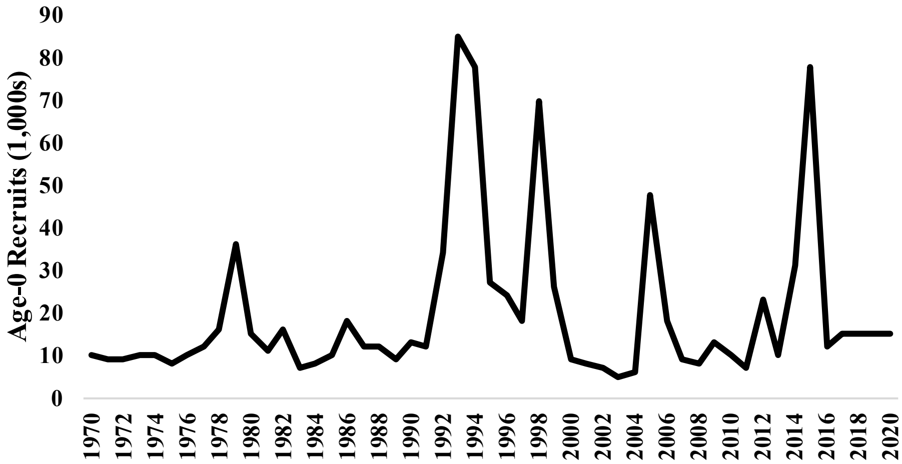

Figure 2-105. Estimated recruitment of vermilion rockfish in Oregon, 1970-2020.

Recruitment information is weak for the Washington vermilion assessment; informative recruitments start to appear in the 1980s and peak in early 2000s. Data were most informative from the 1990s to the mid-2010s. Peak years of recruitments are found in years 1995-1996, 1999-2000, 2006, and 2011 (Figure 2-106).

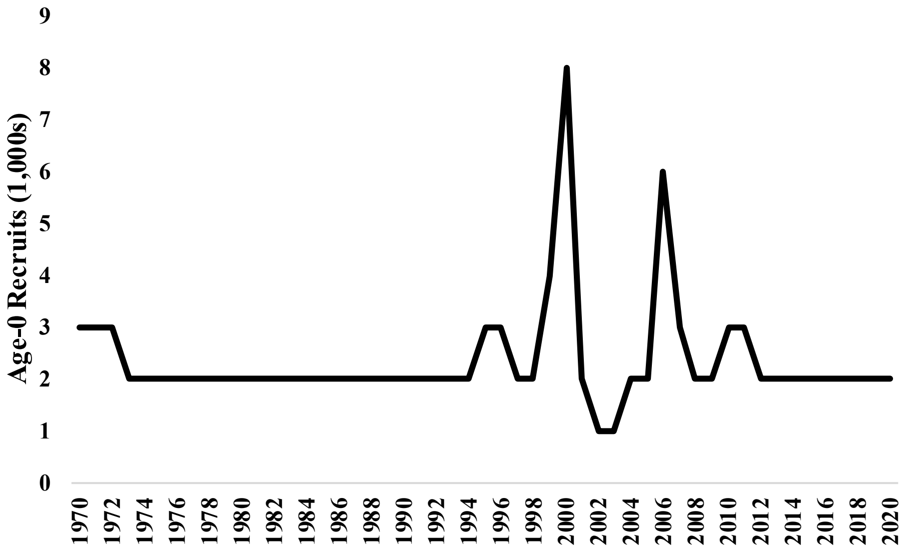

Figure 2-106. Estimated recruitment of vermilion rockfish in Washington, 1970-2020.

Fishing Mortality

The annual (equilibrium) SPR harvest rate for vermilion rockfish in southern California has fluctuated around the management target for the past decade, with a recent spike in 2019 (Figure 2-107). Prior to 2011, the fishing intensity exceeded the target for a number of years in the 1980s and 1990s, regularly reaching levels 50 percent above target. As with current estimates of spawning output, recent estimates of equilibrium SPR are highly uncertain, ranging from 45 percent to 104 percent of target in 2020, and 102 percent to 172 percent of target in 2019. As a percentage of biomass (ages 4+), southern California harvest rates peaked in the 1980s and 1990s but have since declined to near-target levels for the past decade.

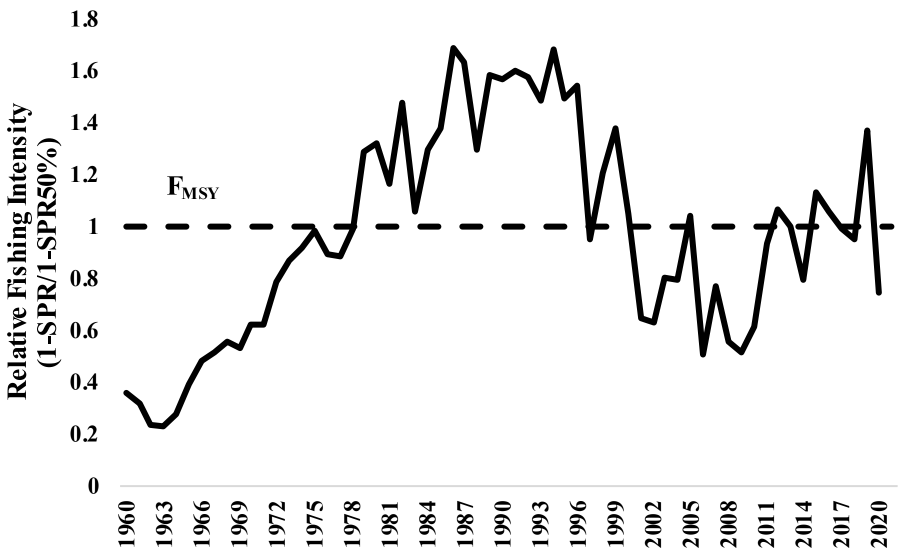

Figure 2-107. Estimated annual relative fishing intensity of vermilion and sunset rockfishes in California south of 34°27' N lat. Relative to the current proxy F_{MSY} target, 1960-2020.

The annual (equilibrium) SPR for vermilion rockfish was above target from 2017-2019 (Figure 2-108). Prior to 2011, the fishing intensity exceeded the target for a number of years, regularly reaching levels 50 percent above target in the 1980s and 1990s. As with current estimates of spawning output, recent estimates of equilibrium SPR are highly uncertain, ranging from 68 percent to 129 percent of target in 2020. As a percentage of total biomass (ages 4+), California harvest rates peaked in the 1980s and 1990s, but have since declined to levels below 10 percent for the past decade. Harvest rates in northern California were near target in 2020, but above target in the three previous years.

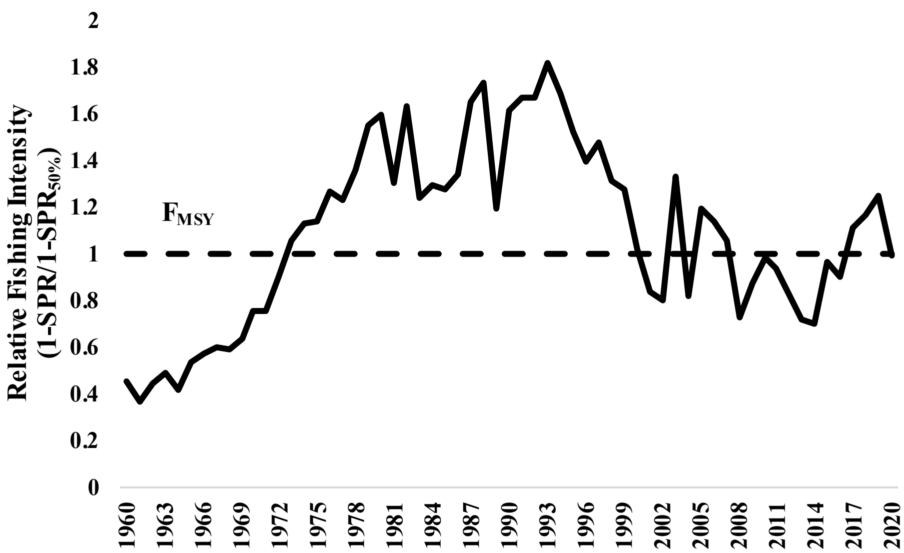

Figure 2-108. Estimated annual relative fishing intensity of vermilion and sunset rockfishes in California north of 34°27' N lat. Relative to the current proxy F_{MSY} target, 1960-2020.

Trends in fishing intensity largely mirrored that of landings until the 1990s when recruitment pulses overcame the catches to lower overall fishing intensity. The maximum fishing intensity was 0.84 in 1993, above the target SPR-based harvest rate of 0.50 (Figure 2-109). Current levels of 0.47 for 2020 are near the fishing limit. Fishing intensity over the past decade has ranged between 0.27 and 0.51 and the exploitation rate has been high.

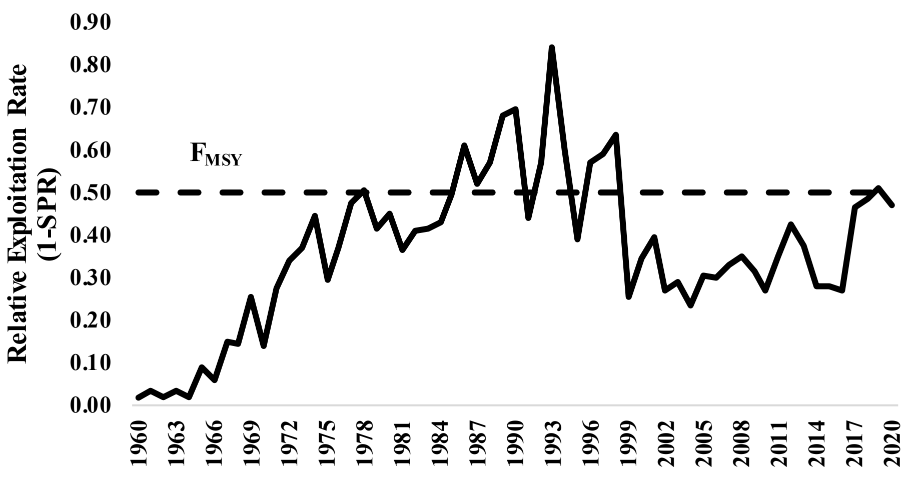

Figure 2-109. Estimated annual relative exploitation rate of vermilion rockfish in Oregon relative to the current proxy F_{MSY} target, 1960-2020.

Trends in fishing intensity largely mirrored that of landings. The maximum fishing intensity was 0.75 in 2019, above the target SPR-based harvest rate of 0.50 (Figure 2-110). Current levels of 0.4 for 2020 are below the retrospectively estimated fishing limit, but 2019 was the highest on record. Fishing intensity over the past decade has ranged between 0.4 and 0.75 and the exploitation rate has been moderate.

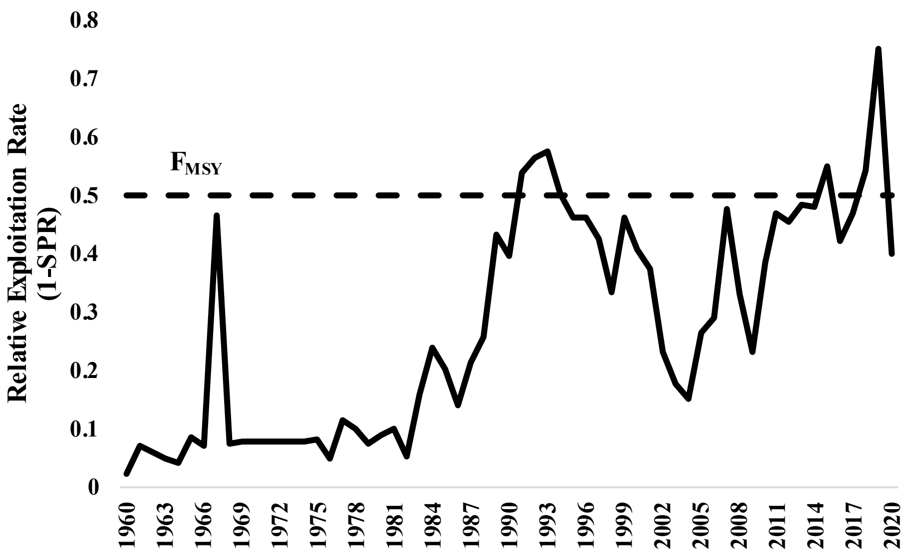

Figure 2-110. Estimated annual relative exploitation rate of vermilion rockfish in Washington relative to the current proxy F_{MSY} target, 1960-2020.

2.5.4 Slope Rockfish North and South of 40°10' N. Lat.

The slope rockfish complexes north and south of 40°10' N. lat. Are comprised of both assessed and unassessed species. Of the stocks managed in the slope rockfish complexes, aurora rockfish, blackgill rockfish south of 40°10' N. lat., rougheye rockfish (and blackspotted rockfish), and sharpchin rockfish have been assessed. There is an older assessment of bank rockfish that was done in 2000 (Piner*, et al.* 2000) that was limited in area and is not used in current management. The following section defines these complexes in terms of their component stocks and provides further detail on those component stocks that have been assessed.

The Slope Rockfish complex north of 40°10' N. lat. Is comprised of the following species: aurora rockfish (*Sebastes aurora*); bank rockfish (*S. rufus*); blackgill rockfish (*S. melanostomus*); blackspotted rockfish (*S. melanostictus*); redbanded rockfish (*S. babcocki*); rougheye rockfish (*S. aleutianus*); sharpchin rockfish (*S. zacentrus*); shortraker rockfish (*S. borealis*); splitnose rockfish (*S. diploproa*); and yellowmouth rockfish (*S. reedi*).

The Slope Rockfish complex south of 40°10' N. lat. Is composed of the following species: aurora rockfish (*Sebastes aurora*), bank rockfish (*S. rufus*), blackgill rockfish (*S. melanostomus*), Pacific ocean perch (*S. alutus*), redbanded rockfish (*S. babcocki*), rougheye rockfish (*S. aleutianus*), sharpchin rockfish (*S. zacentrus*), shortraker rockfish (*S. borealis*), and yellowmouth rockfish (*S. reedi*).

2.5.4.1 Aurora Rockfish

Distribution and Life History

Aurora rockfish (*Sebastes aurora*) are encountered between the Queen Charlotte Islands (British Columbia, Canada) south to mid-Baja California (Mexico). Off of the United States, they are common from northern Oregon to southern California, and are most abundant in the area around Point Conception, California. They occur at depths from 200 to 700 m (~100 to 400 fm) with the median depth increasing to the south, such that they are most abundant from 350 to 550 m in the north and 400 to 600 m in the south.

While there are areas of greater abundance off of northern Oregon and especially off of Point Conception, California, the population appears continuous over the entire coast, so that there is no clear point for stock delineation. Survey catches exhibit a continuous distribution along the entire coast, though with areas of higher and lower abundances along the coast.

Aurora rockfish is a long-lived rockfish species, with maximum observed age of 125 years on the U.S. West Coast based upon otoliths aged in the 2013 assessment (Hamel, *et al.* 2013). This is slightly greater than the maximum of 118 years seen by Thompson and Hannah (2010) and consistent with a maximum age greater than 75 as reported by Love et al. (2002). As with many rockfish species, aurora rockfish exhibit both spatially varying and sexually dimorphic growth, with females reaching a slightly larger size than males. Off of Oregon, females reached an asymptotic length of 36.9 cm, while males reached only 33.6 cm (Thompson and Hannah 2010). Asymptotic size and size at age decreases with lat., and since the bulk of the stock is south of Oregon, the average asymptotic lengths are quite a bit lower than those reported above.

Thompson and Hannah (2010) found the age at 50 percent maturity for female aurora rockfish to be 12.56 years and the length at 50 percent maturity to be 25.54 cm. Maturity data collected coastwide during the 2012 NWFSC trawl survey found similar values, though with more evidence of atresia in older and larger fish than observed in the Thomson and Hannah study.

Aurora rockfish larvae have been collected off of California in months ranging from November to August, with abundance peaking in May and June, corresponding to the observation of females with developed embryos from March to May off of California and in May in Oregon (Love, *et al.* 2002). Thompson and Hannah (2010) also found that parturition peaked in May off of Oregon. Auroras settle on the bottom when they reach a length of about 3.3 cm (Love, *et al.* 2002).

Aurora rockfish display ontogenetic movement, with smaller fish found in shallower waters (below 400-450 m). They are distributed over both hard and soft substrates (Love, *et al.* 2002).

Aurora rockfish co-occurs with many prominent groundfish targets such as Dover sole, sablefish, thornyheads, and hake, though are most reported in the catch of splitnose rockfish. Aurora rockfish contributes to the overall California Current ecosystem as both predator on crustaceans and small fishes, and as prey to larger fishes, marine mammals, and large squid. Juvenile aurora rockfishes are preyed on by salmon, birds, and other fishes (Love 2011).

Several aspects of aurora rockfish population biology are affected by the ecosystem. The recruitment of many species of rockfish appears to be high in 1999, suggesting that environmental conditions influence the spawning success and survival of larvae and juvenile rockfish, including aurora rockfish. The mechanism behind this observation is not well understood, but zooplankton abundance, changes in water temperature and currents, distribution of prey and predators, and amount and timing of upwelling are all possible linkages. Changes in the environment may also directly influence age-at-maturity, fecundity, growth, and survival, which can affect stock status determination and its susceptibility to fishing. Thompson and Hannah (2010) found variations in growth corresponding to individual years based upon dendrochronological techniques and otoliths, and found a correlation between an observed growth anomaly in otoliths and sea level in individual years.

Stock Status and Management History

Aurora rockfish reside in deep waters below 200 m. The primary gear type that has been used to catch aurora rockfish and other deep water rockfish has been trawl gear. The use of trawls off the West Coast of the United States dates to the late 1800s, though there was little fishery expansion until the availability of the otter trawl and the diesel engine in the mid-1920s (Douglas 1998). Trawl fisheries were mainly conducted on the shelf and became more established during World War II when demand increased for groundfish. Mink farms were also a major destination of groundfish removals in the 1940s and 1950s (Jones and Harry 1960). Foreign fleets began fishing for rockfish, including deeper waters of the slope, in the mid-1960s, with declining participation until the 200-mile EEZ was implemented in 1977 (Rogers 2003b). Peaks in the foreign catch have typically been seen in the mid-1960s for rockfishes, but for aurora rockfish, the largest catches were taken in the early 1970s. Foreign fishing was limited in the northern regions by 1970, shifting effort southward and more into aurora rockfish habitat. After 1977, domestic landings of rockfish increased rapidly until about 1990. Subsequent declines in rockfish landings were driven by declining biomass levels and implementation of new, more restrictive management practices, particularly between 1997 and 2002.

Documented and estimated removals of aurora rockfish do not reach consistently large levels until the 1980s. Aurora rockfish are and have been historically most commonly taken from central California to Oregon, tightly coupled with catches of splitnose rockfish. The term "rosefish" was often used to describe either splitnose or aurora rockfish and has been used as a reporting category in California since 1982. Aurora rockfish remains largely a non-targeted member of the slope rockfish complexes.

Limits on select rockfishes, which included the co-occurring species splitnose, were established in 1982. The first imposed catch limits on a coastwide *Sebastes* complex (aurora being one of the 50 rockfishes in the complex) were instituted in 1983. This complex was divided into two management areas north and south of 43° N. lat. (separating the Eureka and Columbia INPFC areas) in 1994. Ongoing concern that shelf and slope rockfishes may be undergoing overfishing led the attempt by Rogers et al. (1996) to describe the status of most rockfishes contained in the *Sebastes* complex. Aurora rockfish information content was low, so only estimates of exploitation rates were provided, indicating the stock was undergoing very high exploitation rates relative to biomass estimates in both management areas.

The *Sebastes* complex was subsequently divided into nearshore, shelf, and slope complexes effective in the year 2000 and the dividing line between the northern and southern management areas was shifted to 40°10' N. lat. Aurora rockfish has been managed under trip limits for the slope rockfish complexes in both the north and south management areas from 2000-2010. Beginning in 2011, bottom trawl catches of slope rockfish north and south of 40°10' N. lat. Have been managed under an IFQ system.

The first assessment of the West Coast stock of aurora rockfish was conducted in 2013 (Hamel, *et al.* 2013); the assessment estimated stock depletion was at 64 percent of its unfished equilibrium at the start of 2013 and had never dropped below its B_{MSY} target (Figure 2-111). The assessment was an age-based full assessment with natural mortality identified as the major axis of uncertainty. The SSC categorized aurora rockfish as a category 1 stock based on the assessment. However, the uncertainty in estimated biomass in the 2013 assessment was greater than for other category 1 assessments resulting in a higher sigma value ($\sigma = 0.39$) for defining the ABC buffer (see section 0 for more details).

Coastwide OFLs of aurora rockfish are apportioned north (19 percent) and south (81 percent) of 40°10' N. lat. Based on average trawl survey biomass. The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and 2020 harvest specifications. The 2019 and 2020 ACL contribution of aurora rockfish to the Slope Rockfish complex north of 40°10' N. lat. Is 16.7 mt. The 2019 and 2020 ACL contribution of aurora rockfish to the Slope Rockfish complex south of 40°10' N. lat. Is 71.0 mt.

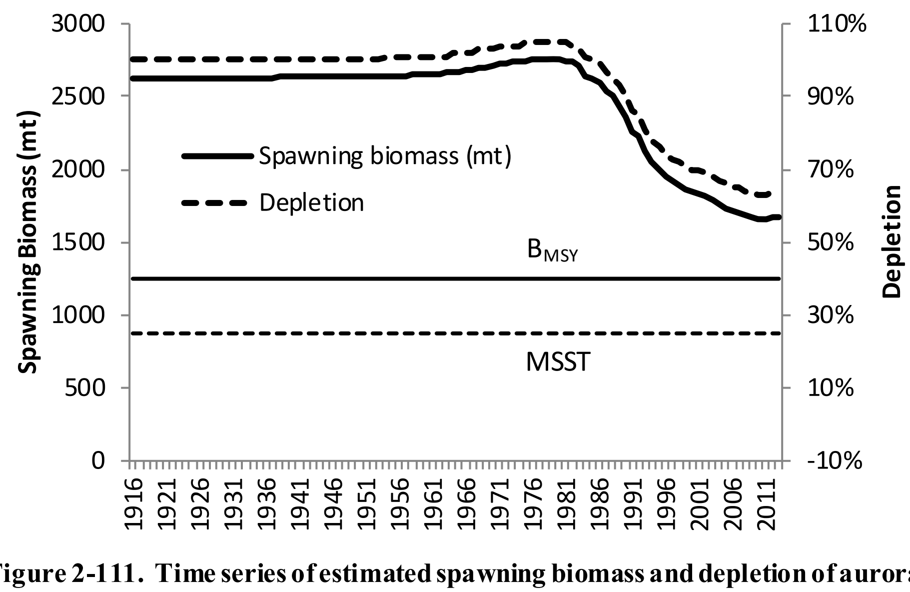

Figure 2-111. Time series of estimated spawning biomass and depletion of aurora rockfish, 1916-2013.

Stock Productivity

Steepness was fixed to the mean of the most recent rockfish steepness prior ($h = 0.779$; Thorson, 2013) in the 2013 assessment. Recruitment deviations were estimated from 1916 (the beginning of the modeling period), with a ramp towards bias correction beginning in 1962, full-bias adjustment beginning in 1970 and ending in 2008, and a ramping back down to no bias correction in 2012. Two of the largest contemporary recruitment events are found in 1999 and 2007 (Figure 2-112). Despite the inclusion of estimated ageing error, discerning individual year classes remains difficult and significant correlation exists between the estimated strength of adjacent year classes, which may be primarily due to ageing error rather than actual correlation in recruitment strength.

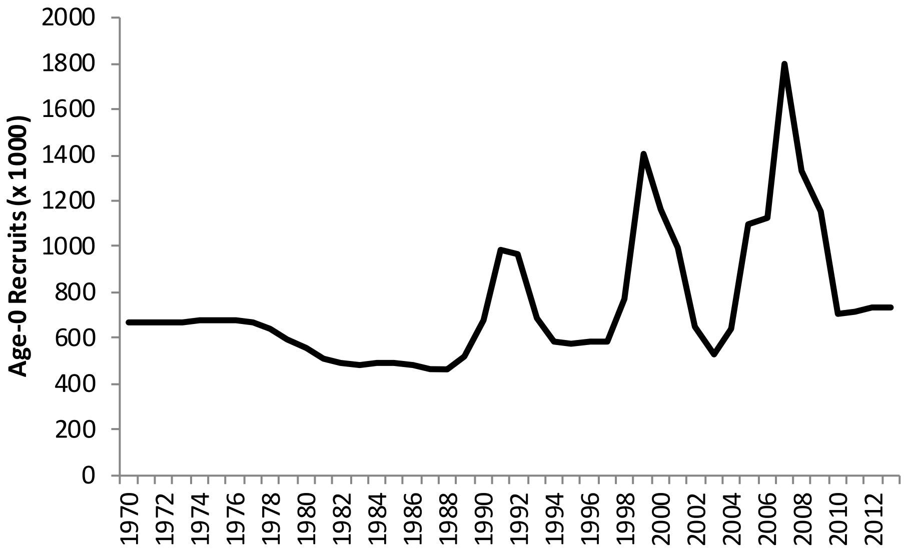

Figure 2-112. Time series of estimated age-0 recruits of aurora rockfish on the U.S. West Coast, 1970-2013.

Fishing Mortality

Hamel et al. (2013) estimated that exploitation of aurora rockfish has been relatively low, with total catch estimated to have exceeded the current management harvest rate limits in 7 years (1983, 1988-1990, and 1992-1994), during the early peak in trawl catches (Figure 2-113). Recent levels of removals have remained moderate. There seems to be very low risk that current removals are causing overfishing.

While stock-specific OFLs/ABCs were not historically set for aurora rockfish specifically, the reauthorized Magnuson-Stevens Act of 2006 and FMP Amendment 23 required OFLs for all species in a management plan, including those managed in stock complexes. The first OFL contributions were calculated using DB-SRA and provided in 2011. The 2015 and beyond OFLs are projected from the 2013 assessment. Recent catches since 2002 have been below the 2015 OFL and ABC.

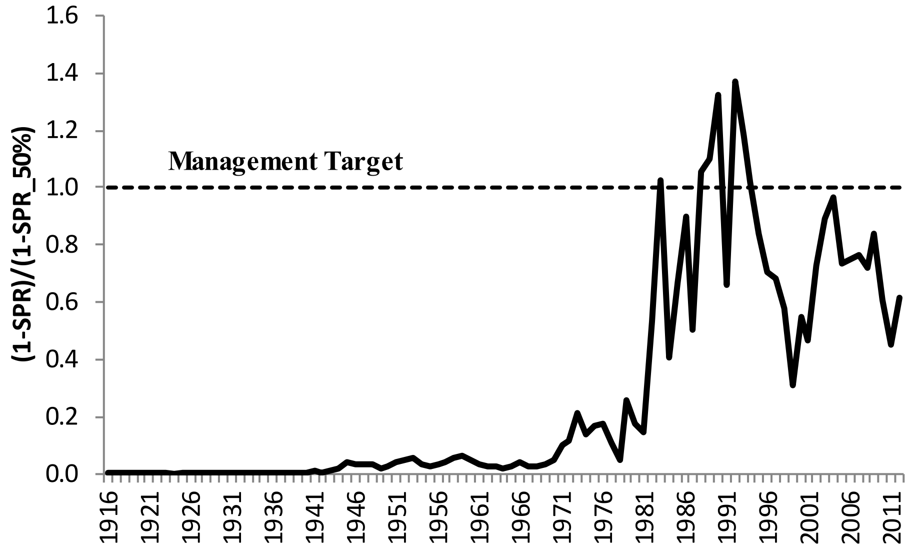

Figure 2-113. Time series of estimated relative spawning potential ratio (1-SPR/1-SPR(Target=0.50)) for aurora rockfish, 1916-2012. Values of relative SPR above 1.0 reflect harvests in excess of the current overfishing proxy.

2.5.4.2 Blackgill rockfish

Distribution and Life History

Blackgill rockfish (*Sebastes melanostomus*), also known at times as blackmouth rockfish or deepsea rockfish, range from at least central Vancouver Island to central Baja California (Love*, et al.* 2002). However, the species is relatively uncommon north of Cape Mendocino and occurs in the greatest densities in the Southern California Bight (SCB). The name very accurately describes the most identifying characteristic of adult blackgill rockfish, in that they have black pigmentation on the rear edge of their gill cover, as well as in the fold above the upper jaw and inside of the mouth. The rest of the fish appears pink with brown and white blotches underwater, or reddish with distinct brown saddles upon capture. It is a medium-sized (to about 62 cm maximum length) and deep bodied species. Additional descriptions and meristics can be found in Love et al. (2002) for adults and Moser (1996) for larvae and juveniles.

Hyde and Vetter (2007) did not find any evidence for close molecular or evolutionary relationships between blackgill rockfish and other rockfish species. Blackgill rockfish were found to be moderately related with several other slope or deep shelf species (*S. aurora*, *S. phillipsi*, *S. gilli*, *S. diploproa*, and *S. melanosema*) as well to a suite of mostly rare and poorly known species from the Gulf of California (*S. sinensis*, *S. peduncularis*, and *S. cortezi*) or southern California.

Blackgill rockfish are a slope rockfish species and are generally rare in waters less than 100 meters and most abundant in waters between 300 and 500 meters depth. Love et al. (2002) report a depth distribution of 87 to 768 meters; however, from ten years of data from the NWFSC combined trawl survey, only one haul greater than 600 meters encountered blackgill rockfish (that tow was at 647 meters) and the shallowest fish was encountered at 133 meters. Survey data suggest that smaller fish tend to be encountered in shallower water and larger fish in deeper water; survey data also suggest few small fish in waters north of Cape Mendocino. Juveniles are often seen over soft bottom habitats with low relief. Adults are usually associated with high relief rocky outcrops, canyons or deep rock pinnacles, although fishermen often report taking them in midwater (Kronman 1999; Love*, et al.* 2002).

Little is known about the population structure of blackgill rockfish. Like most rockfish, larvae and juveniles circulate in the plankton for 3-4 months. Love et al. (2002) report that some juveniles may be pelagic for up to 7 months; however, this may be atypical. Thus, like most shelf and slope species, blackgill rockfish likely disperse over long distances before settling to the bottom. Abundance south of the U.S./Mexico border is uncertain, but there appear to be substantial numbers and catches of blackgill rockfish in many areas, and pelagic juveniles have been found as far south as Punta Abreojos, in southern Baja California (Moser and Ahlstrom 1978). The CalCOFI Ichthyoplankton survey has been used to develop or explore indices of relative abundance for several rockfish species for which larvae can be morphologically identified to species (Moser*, et al.* 2000), and such indices have been used as relative abundance indices for assessments of bocaccio (Field*, et al.* 2009) and shortbelly rockfish (Field*, et al.* 2008) as well as northern anchovy (Jacobson and Lo 1994), Pacific sardine (Hill*, et al.* 2008), and California sheephead (Alonzo*, et al.* 2008). Unfortunately, blackgill rockfish is not among the species that have been historically sorted to the species level using morphological methods, although recent developments have led to the potential to use genetic methods to identify historical and contemporary *Sebastes* from the ichthyoplankton archives (e.g., (Taylor*, et al.* 2004), J. Hyde, FRD/SWFSC, unpublished data). Thus, it is possible that these collections could provide relative abundance information from past and contemporary monitoring programs.

Moser and Ahlstrom also found that blackgill rockfish represented approximately 16 percent of the total number of rockfish specimens encountered in a series of midwater trawls for late larvae and juvenile stage rockfish done in the early 1970s (prior to most historical exploitation). By contrast, from ongoing pelagic juvenile surveys run by the Fisheries Ecology Division used to develop juvenile (pre-recruit) indices for some species, blackgill rockfish comprised only about 3 percent of juveniles collected from the southern California region from 2004 through 2010 (K. Sakuma and J. Field, unpublished data as cited in Field and Pearson (2011)). However, these results are not likely to be comparable unless seasonal and depth of survey efforts are accounted for; the Moser and Ahlstrom (1978) study in particular fished depths ranging from 0 to 600 meters using an Isaacs-Kidd midwater trawl, while the FED survey uses a considerably larger (modified Cobb) midwater trawl and typically only fishes at 30 meters headrope depth. There is at least some potential to consider relative abundance indices of age-0 juveniles from the FED/SWFSC survey in the future, although given the very slow growth and difficulty in ageing of blackgill rockfish, it is unlikely that validation of survey indices or improved understandings of high frequency variation in year class strength will be of substantial near term benefit to the model.

Nearly two-thirds of all U.S. landings are from waters south of Point Conception, for which blackgill rockfish accounted for as much as 20 to 30 percent of total *Sebastes* landings in the SCB during the 1980s, when deep water fixed gear fisheries rapidly expanded (more details in catch history section). Nearly all of the remaining landings took place between Conception and Cape Mendocino, such that less than 1.3 percent of historical California landings have come from waters north of Cape Mendocino. Landings in Oregon waters are even less, and only trace landings of blackgill rockfish are reported from Washington waters. Trawl survey abundance data (discussed later in the document) are consistent with these results, although they represent the period following the greatest extent of exploitation: surveys that took place from the 1970s through the late 1990s had virtually no coverage in southern waters where blackgill rockfish are the most abundant.

Blackgill rockfish have among the deepest distribution of all of the California Current *Sebastes* (although the three *Sebastolobus* species are common at considerably greater depths) and live at the edge of the low oxygen (hypoxic) conditions that characterize the slope waters of the California Current. Below these depths, species diversity declines to a smaller suite of species that have adapted to cope with low oxygen waters, notably the DTS complex species (Dover sole, thornyheads and sablefish), which have evolved a range of adaptive strategies including metabolic suppression, slow growth rates, late ages at maturity, and ambush (rather than active searching) predation methods (Childress and Seibel 1998; Jacobson and Vetter 1996; Koslow*, et al.* 2000; Vetter and Lynn 1997). These low oxygen waters, known as the oxygen minimum zone (OMZ), are a natural feature of the Eastern Pacific Rim and other regions characterized by high surface productivity and/or the upwelling of oxygen-poor source waters (Helly and Levin 2004). The California Current has a relatively deeper OMZ than the Equatorial Eastern Tropical Pacific or the Humboldt Current (Helly and Levin 2004), with the zone starting at approximately 500 to 600 meters depth in the waters off of southern and central California. The observation that blackgill rockfish are likely the most deeply distributed medium-size *Sebastes* (at least in southern California Current waters) suggests that they have adapted to live on the edge of the OMZ, where oxygen availability is rapidly declining relative to shelf waters, although no *Sebastes* species appears able to tolerate the very low oxygen conditions within the OMZ itself.

Seibel (2011) describes two oxygen thresholds that are temperature dependent (as opposed to species or situation-specific), one in which virtually all species are capable are of physiologically adjusting or adapting to declining oxygen availability, and a second for which no further adjustment or adaptation in aerobic oxygen utilization is possible. Seibel (2011) describes this latter threshold as one at which "organisms that are not specifically adapted to low oxygen will suffer physiological stress and eventual death." Importantly, this threshold falls just below the currently observed oxygen levels throughout the slope waters of much of the California Current, implying that any expansion of the OMZ in this region is likely to have tremendous impacts on the vertical distribution of populations and the species composition of ecosystems. Equally importantly, there is already some evidence of a shoaling (shallowing) of the depth of the OMZ throughout the California Current (Bograd*, et al.* 2008; Whitney*, et al.* 2007), with Bograd et al. (2008) reporting oxygen declines of 20-30 percent at depths of approximately 300 to 500 meters in the waters of the Southern California Bight, the region in which most of the blackgill rockfish biomass resides. A shoaling of the OMZ has been predicted to be a likely or plausible response to global climate change due to the fact that oxygen is less soluble in warmer waters, and warming is also expected to increase stratification in the upper ocean, which will both reduce oxygen supply and increase oxygen demand at depth (Keeling*, et al.* 2010; Sarmiento*, et al.* 1998; Seibel 2011).

For blackgill rockfish, it is the shoaling of the OMZ at depth that is likely to be the greatest long-term threat, as such a shoaling would likely represent a severe compression of the available habitat for this species. McClatchie et al. (2010) evaluated potential scenarios for hypoxia to impact the habitat of cowcod, a rebuilding shelf species that is a focus of management in the SCB. They found that as much as 37 percent of deep (240-350 m) cowcod habitat is currently affected by hypoxia, but that if the current trends of a shoaling OMZ continue for 20 years, this could increase to 55 percent of deep habitat, as well as an additional 18 percent of habitat in the 180 to 240 m depth range. These numbers would presumably differ substantially for blackgill rockfish, which have a very different (considerably deeper) distribution; due to their proximity to the OMZ, they may be at considerably greater risk to the longer-term impacts of shoaling. Moreover, changes in the characteristics and dynamics of the OMZ could lead to changes in the forage base for blackgill rockfish, which are described as foraging primarily on mesopelagic fishes which undergo dial migrations from the edge of the OMZ to surface waters in order to feed.

Blackgill rockfish feed on small mesopelagic fishes, such as myctophids and bathylagids (Love, *et al.* 2002). Isaacs and Schwartzlose (1965), Genin et al. (1988), Koslow (2000) and Genin (2004) describe the mechanisms by which vertical migrants, such as zooplankton and mesopelagic fishes, become trapped by topographic features. High densities of deep water adapted resident species are consequently found in the relatively small, confined areas where these diurnally migrating prey become aggregated. Such observations are consistent with the reports by fishermen of isolated deep banks, pinnacles, or other habitat features often hosting very large numbers of fish over a relatively small spatial range, such that vertical hook and line gear (which can be more precisely targeted at small habitat features) is the gear of choice for targeting these species (as opposed to horizontal, or set, hook and line gear often used to target species in deeper slope waters, such as sablefish and thornyheads, which tend to be more widely dispersed).

With respect to predators and predation mortality, it is likely that sablefish and shortspine thornyhead are among the most important predators of blackgill rockfish. Both species are large (up to 100 and 75 cm, respectively, although individuals greater than 80 or 65 cm of either species are uncommon) and largely piscivorous ambush predators that are typically (along with longspine thornyhead and Dover sole) the most abundant and commercially important groundfish in the continental slope ecosystem (Lauth 2000). Food habits information for adult sablefish found that *Sebastolobus* and *Sebastes* species, particularly *Sebastolobus altivelis*, are key prey items, representing 15 percent to 30 percent of total prey by volume (Buckley*, et al.* 1999; Laidig*, et al.* 1997). Similarly, shortspine thornyhead preyed heavily on *S. altivelis*, unidentified *Sebastes*, and other fishes (Buckley*, et al.* 1999). Although no *S. melanostomus* were conclusively identified in either study, other slope rockfish species (*S. crameri*, *S. diploproa*, and *S. alutus*) were. The lack of specimens is likely due to both studies' focused sampling in northern California, Oregon, and Washington slope waters, rather than the south-central and southern California waters in which *S. melanostomus* are most abundant.

Stock Status and Management History

Blackgill rockfish have historically represented a minor part of California rockfish landings north of Point Conception, but a substantial fraction of landings occur south of Pt. Conception. Based on consultations with fishery participants, Butler et al. (1999a) and Kronman (1999) defined the southern California targeted fishery for blackgill rockfish as being a relatively recent phenomenon. Although longline fishing had long been the primary means of catching rockfish in southern California waters, increased participation and declines in the catches of many highly desired shelf species (such as vermilion rockfish and cowcod) contributed to a gradual shift in effort towards deeper and more offshore waters. Moreover, improvements in technology and gear (such as LORAN, affordable acoustic systems, electric line haulers) helped ease the difficulties of fishing (and relocating good fishing sites) in deeper waters. Additionally, set nets (gillnets) also began to be deployed at a larger scale in southern California in the 1970s and 1980s, often targeting deep reefs for large bocaccio, cowcod, blackgill rockfish, bank, and other rockfish species.

Such developments seem to have been associated with a geographic expansion of the regions fished, such that fishing locations were sequentially depleted and new fishing locations discovered and developed over time. The first stock assessment for blackgill rockfish (Butler, *et al.* 1999a) noted that there was significant evidence for sequential depletion of blackgill rockfish in localized areas. This included reports from fishery participants that many pinnacles or other fishing sites that routinely yielded 20,000 pounds of blackgill rockfish per trip in the early days of the fishery were now only yielding 500 or so pounds per trip and were often covered with lost gear. Similarly, in a review of historical southern California fisheries, Kronman (1999) also documented the rapid growth and development of the blackgill rockfish fishery specifically as one in which fishermen would often "completely decimate" rockfish spots with deep fishing vertical line gear, based on the accounts of the participants themselves. Consequently, there was an ongoing shift to newer fishing spots, generally further offshore and to greater depths, as well as greater experimentation with alternative gears and target species.

These observations suggest the potential for a situation in which the stock may have undergone the "sequential depletion" of biomass from available habitat patches. If so, this would suggest that a traditional (non-spatial) stock assessment assumption of evenly distributed fishing mortality across space is substantially flawed. In fact, if the fishery were sequentially depleting specific areas, the length frequency information would not be likely to suggest a shift to smaller fish over time as the length frequencies could essentially reflect "unfished" population structure for the duration over which the new habitats were discovered and exploited. The consequences of failing to recognize such patterns can lead to overexploitation and collapse, and such processes have been described for several marine invertebrate populations (Karpov et al. 2000, Orensanz et al. 2000) as well as temperate water reef fishes (Epperly and Dodrill 1995, Rudershausen et al. 2008). Ongoing efforts to analyze historical block summary data have the potential to identify such shifts and consider whether such factors are likely to be important for West Coast groundfish species such as blackgill rockfish, as well as to determine whether there is sufficient data to estimate spatial effects or develop spatially-explicit models more capable of accounting for such factors.

Management of blackgill rockfish has generally not been to the species level, but rather as part of the "*Sebastes* complex" in the PFMC era (prior to which management was under the direction of the CDFG). Blackgill rockfish have historically been managed in a complex with eleven other species of rockfishes called "remaining rockfish" and all "other" rockfish. The PFMC historically used trip limits, and later cumulative trip limits (over set time periods), to slow the pace of harvest based on allowable biological catch and to promote a year-round fishery. For all commercial gear types, the limits were initiated in 1983 when the PFMC imposed a monthly limit of 40,000 pounds per trip for the entire coastwide *Sebastes* complex, a limit that stayed in place through 1990. After recognizing the differential spatial distribution of the remaining rockfishes and the fisheries that target them, harvest limits on both open access and limited entry fisheries were divided between the northern and southern *Sebastes* complexes, and trip limits began to be implemented at variable levels over both time (month and year) and space (north and south of Mendocino), often with species-specific limits in addition to the overall limit on *Sebastes* catches. Although early limits applied to both trawl and fixed gears, beginning in 1995 fixed gear limits (hook and line and pot, primarily, as gill nets were phased out through the 1990s) were set to 10,000 lbs of *Sebastes* per trip, which persisted through the 1990s.

Consequently, prior to 1999 cumulative trip limits had been historically high relative to landings of blackgill rockfish from individual trips, and unlikely to have impacted fishing for blackgill rockfish and catches. Limits were dramatically reduced in 1999 for the southern *Sebastes* complex; 2-month cumulative limit of 3,500 pounds for limited entry and 3,600 pounds per month for open access. Since 2000, blackgill rockfish has been managed as part of the Slope Rockfish complexes, with limits ranging from 3,000-50,000 pounds per 2 months; Tables 1-3 show the trip limits implemented since 2000 for this complex for the limited entry trawl, LEFG and open access fixed gear fisheries.

In 2001 the CCAs were established prohibiting fishing in depths greater than 20 fm and the deep offshore banks within the CCAs are optimal habitat for this species. RCAs implemented to protect rebuilding shelf species, such as bocaccio, cowcod, canary rockfish and widow rockfish, do not encompass the depths at which most blackgill rockfish are encountered. Such measures may have had an indirect effect, by virtue of shifting effort to deeper waters, although for much of California the overall effect has been a sharp decline in active participation in the trawl fishery.

The first assessment for blackgill rockfish was conducted in 1998 and estimated stock depletion was between 40 and 54 percent of its unfished equilibrium at the start of 1998 (Butler*, et al.* 1999a). That assessment assumed a unit stock in southern and central California (Conception INPFC area) and was based on a stock reduction analysis assuming constant recruitment. The dynamics of the simple model were tuned to average mortality rates from catch curves and landings data. Fishery selectivity was assumed to mirror maturity at size/age; trends in fishable/mature biomass were then estimated.

A second blackgill rockfish stock assessment was completed in 2005 indicating a stock depletion of 52 percent (Helser 2006). This assessment expanded the geographic range of that in Butler et al. (1999a), including both the Monterey and Conception INPFC areas, where over 90 percent of the landings have occurred. The assessment was based on catch and length composition data from commercial fisheries and indices of relative abundance and size composition from the AFSC shelf trawl survey and the AFSC slope survey. The modeling approach included fishery and survey length compositions to explicitly estimate selectivity. The assumed natural mortality rate was identified as a key axis of uncertainty for this stock.

A third full assessment of blackgill rockfish was conducted in 2011 for the stock south of 40°10' N. lat. (Field and Pearson 2011), which estimated the stock was below target with a depletion of 30 percent of its unfished biomass at the start of 2011 (Figure 2-114). The spawning output of blackgill rockfish was at high levels in the mid-1970s and began to decline steeply in the late 1970s through the 1980s, consistent with the rapid development and growth of the targeted fishery. The biomass reached a low of approximately 18 percent of the unfished level in the mid-1990s. Since that time, catches have declined and spawning output has increased. The estimated depletion level in 2011 is 30.2 percent.

Catch data used in the assessment are generally reliable throughout the time period, although there is a lot of uncertainty in catch data prior to the early 1980s. Ageing is very difficult for this species, which appears to have highly variable size at age, as well as apparent regional differences in growth rates and potentially other life history traits. The lack of a reliable, long-term, fishery-independent survey index that reflects abundance from the entire range of the stock is problematic. In general, natural mortality and growth parameters comprised the greatest contribution to model uncertainty.

An update of the 2011 blackgill rockfish assessment was conducted in 2017, which indicated the spawning stock was at 39.4 percent depletion, just shy of the 40 percent management target, at the start of 2017 (Field and He 2018). Changes to the model since the last assessment include a new fishery selectivity time block to account for changes in trawl fishery retention since implementation of catch-shares in 2011; updated and corrected maturity; updated fecundity relationships; updated indices of abundance; updated steepness value and recent length and age data. The model results were consistent with the 2011 assessment.

The SSC endorsed the use of the blackgill rockfish stock assessment as the best scientific information available for status determination and management as a category 2 assessment since the 2011 assessment and subsequently the 2017 update were essentially production models, i.e., recruitment deviations were not estimated.

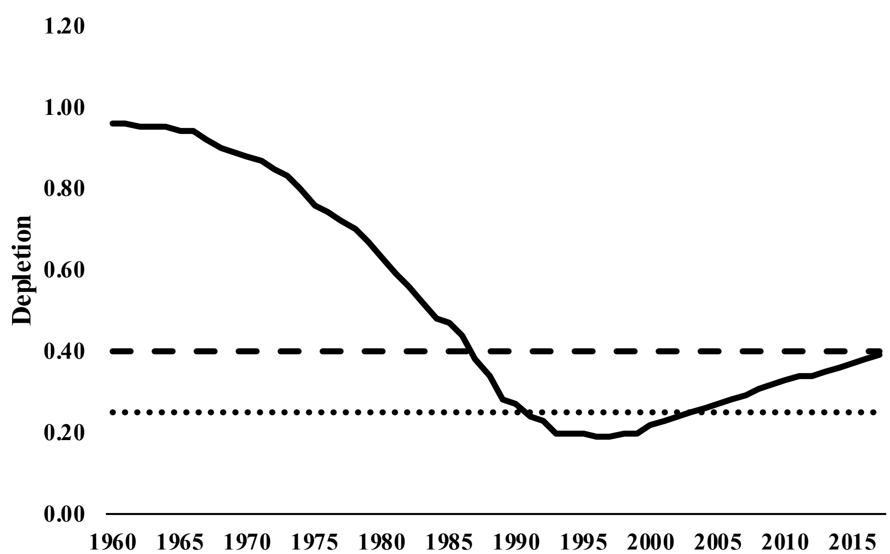

Figure 2-114. Relative depletion of blackgill rockfish from 1960 to 2017 based on the 2017 stock assessment.

The Council had decided to remove blackgill rockfish from the southern Slope Rockfish complex and manage the stock with stock-specific harvest specifications starting in 2018; however, the rulemaking has been delayed and it is uncertain when this management change will be implemented.

The Council adopted default harvest specifications (ACL = ABC with a P* of 0.45) for the blackgill rockfish contribution to the Slope Rockfish complexes north and south of 40°10' N. lat. Without a 40-10 adjustment to the 2019 and beyond ACLs for the southern portion of the stock since the stock is projected to be above the B_{MSY} target of 40 percent depletion beginning in 2018 (projected depletion in 2019 is 40 percent). A catch only-projection of blackgill rockfish south of 40°10' N. lat. Was provided to inform harvest specifications for 2021 and beyond.

Stock Productivity

In the 2011 full assessment and in the subsequent 2017 update assessment, the Beverton-Holt model was used to describe the stock-recruitment relationship. The log of the unexploited recruitment level was treated as an estimated parameter; recruits were taken deterministically from the stock-recruit curve. Recruitment deviations were not estimated, as the lack of obvious cohorts in either age or length data and the high degree of ageing uncertainty make plausible estimates unlikely. The estimated recruitment is projected to be at relatively high levels due to the fixed value of steepness (h = 0.718) based on the mean of the prior distribution of the most recent meta-analysis of rockfish steepness. This trend, however, is consistent with the trends from the survey data.

Blackgill rockfish have a relatively high potential vulnerability to overfishing (V = 2.08) driven by a combination of low productivity (P = 1.22) and relatively high susceptibility to being caught in the fishery (Table 2-2). The low productivity is due to the stock being long-lived (max. age = 87 yrs.; (Love*, et al.* 2002)), with late maturation, and relatively low natural mortality.

Fishing Mortality

Catches of blackgill rockfish primarily occur in the Southern California Bight south of Pt. Conception at 34°27' N. lat. Where the species is caught in both directed fixed gear (hook and line) and historically, gillnet fisheries. Landings of this species are estimated to have risen slowly from very low levels (approximately 20-30 mt) in the 1950s, and then climbed rapidly in the 1970s and 1980s as improvements in technology and declines in other target species led fishermen to target blackgill rockfish in deeper and more offshore waters. Landings peaked in the mid-1980s at just over 1,000 mt and have declined to approximately 100 mt to 150 mt in recent years.

The 2017 blackgill rockfish assessment base model estimates that the SPR was below the current target (of 50 percent of the unfished level) from the mid-1970s through most of the 1990s (Figure 2-115), and irregularly in the 2000s. SPR rates have been near or above target levels for most years since the very late 1990s, corresponding to an apparent increase in stock abundance (Figure 2-114). Over the past four years, SPR rates have ranged between 0.70 and 0.82, corresponding to exploitation rates roughly half of the OFL (0.50).

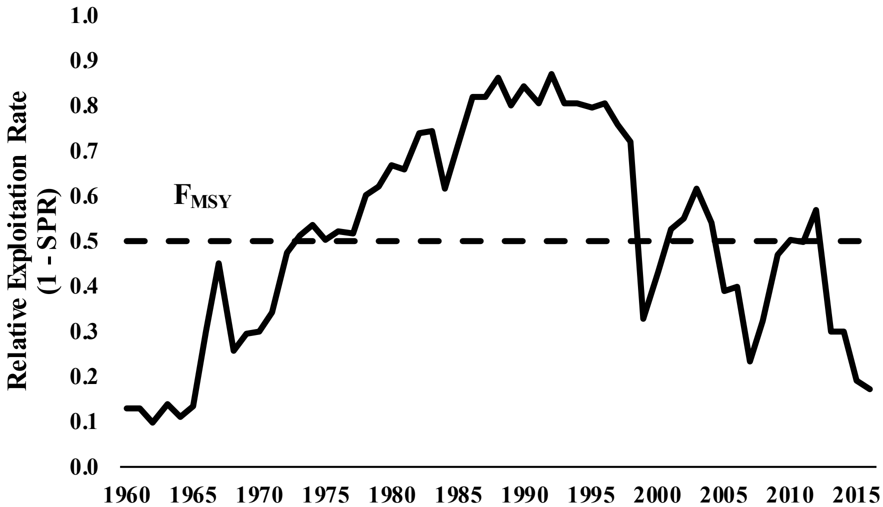

Figure 2-115. Estimated spawning potential ratio (SPR) of blackgill rockfish relative to the current F_{MSY}, 1960-2016. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5.4.3 Rougheye/Blackspotted Rockfish

Distribution and Life History

Rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) are slope rockfish that share broad overlap in their depth and geographic distributions from the Eastern Aleutian Islands along the North American continental margin to southern Oregon, with blackspotted rockfish's range extending east beyond the Aleutian chain to the Pacific Coast of Japan (Gharrett*, et al.* 2005; Hawkins*, et al.* 2005; Orr and Hawkins 2008). It is very difficult to visually distinguish between the two species and they have been persistently confused in surveys and catches. Off the U.S. West Coast the two species have been reported as rougheye rockfish or in an even more generic rockfish category. It has only been from recent genetic studies in the early 2000s that the two separate species have been identified and described (Orr and Hawkins 2008).

Both species are encountered at depths shallower than 100 m to at least 439 m; however, blackspotted rockfish tend to be more prevalent in deeper waters (Hawkins et al. 2005, Orr and Hawkins 2008). Genetic information is not available to provide positive species identification in historical survey and landings information, but these data indicate that density of the nominal rougheye rockfish complex decreases sharply south of the Oregon-California border at 42° N. lat. Studies suggest that rougheye rockfish account for a greater proportion of the species complex along the coast of Washington and Oregon than in Alaskan waters (Gharrett*, et al.* 2005; Hawkins*, et al.* 2005; Orr and Hawkins 2008). Recent discussions with port samplers in southern Oregon suggest that both rougheye and blackspotted rockfish are encountered with some regularity in the commercial trawl and fixed gear landings in Charleston, Port Orford, and Brookings, with blackspotted rockfish composing approximately one third to one half of identified specimens (C. Good and N. Wilsman, ODFW, pers. Comm. As cited in Hicks et al. 2013).

The West Coast of the U.S. is the southern portion of the range of rougheye rockfish, and it is likely that the population north of the U.S.-Canada border is not a separate stock. The connectivity of rougheye populations throughout its range is unknown.

Compared with other rockfish species on the West Coast of the U.S., rougheye rockfish life-history is poorly described and the recent resurrection of the two species classification (rougheye and blackspotted rockfishes) has further complicated the understanding of life-history characteristics. Rougheye rockfish are often associated with boulders and steep habitats, and are typically found alone or in small aggregations (Love*, et al.* 2002). Younger fish may school and are often found in shallower waters on the shelf, and larger fish may form larger aggregations in the Pacific Northwest during the autumn and winter.

Rougheye rockfish give birth to live young with larvae released between February and June and at lengths between 4.5-5.3 mm (Love*, et al.* 2002). There are no studies on the fecundity of rougheye rockfish on the West Coast of the U.S.

A wide range of prey items make up the diet of rougheye rockfish. Crangid and pandalid shrimps make up the majority of their diets, and larger individuals, greater than 30 cm, feeding upon other fishes (Love 2011). They are also known to feed upon gammarid amphipods; mysids, crabs, polychaetes, and octopuses (Love 2011; Love*, et al.* 2002).

Stock Status and Management History

Rougheye and blackspotted rockfish (henceforth denoted as rougheye) are landed as part of the slope rockfish complexes north and south of 40°10' N. lat.; however, they are rarely caught in the south. The historical reconstruction of landings for rougheye rockfish suggests that fixed gear fisheries have caught rougheye rockfish since the turn of the 20th century and landings in the trawl fishery are estimated to have increased into the 1940s. Landings remained relatively constant throughout the 1950s and into the 1960s before the foreign trawl fleet increased catches into the 1970s. The declaration of the EEZ resulted in the buildup of a domestic fleet and landings increased rapidly into the late 1980s and early 1990s. Subsequently, landings declined in the late 1990s and have been between 100 and 200 mt in recent years. Trawl, longline, and Pacific whiting at-sea trawl fisheries make up the majority of the catch.

Rougheye rockfish are a desirable market species and discarding has been low, historically. However, management restrictions (e.g., trip limits) have resulted in increased discarding since 2000. Trawl rationalization was introduced in 2011, and since then very little discarding of rougheye rockfish has occurred.

Hicks et al. (2013) conducted the first assessment of the U.S. West Coast stock of rougheye and blackspotted rockfish as a complex of two species. The coastwide population was modeled assuming parameters for combined sexes (a single-sex model) and assuming removals beginning in 1916. The predicted spawning biomass from the base model generally showed a slight decline over the entire time series with a period of steeper decline during the 1980s and 1990s. Since 2000, the spawning biomass has stabilized and possibly increased because of reduced catches and above average recruitment in 1999. The 2013 spawning biomass relative to unfished equilibrium spawning biomass was estimated to be 47 percent of its unfished equilibrium at the start of 2013.

The stock has been estimated to be healthy throughout the time series in the new assessment (Figure 2-116).

Coastwide OFLs of rougheye rockfish are apportioned north (98 percent) and south (2 percent) of 40°10' N. lat. Based on average landings during 1985-2012. The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and beyond harvest specifications. A catch only-projection of rougheye and blackspotted rockfishes was provided to inform harvest specifications for 2021 and beyond.

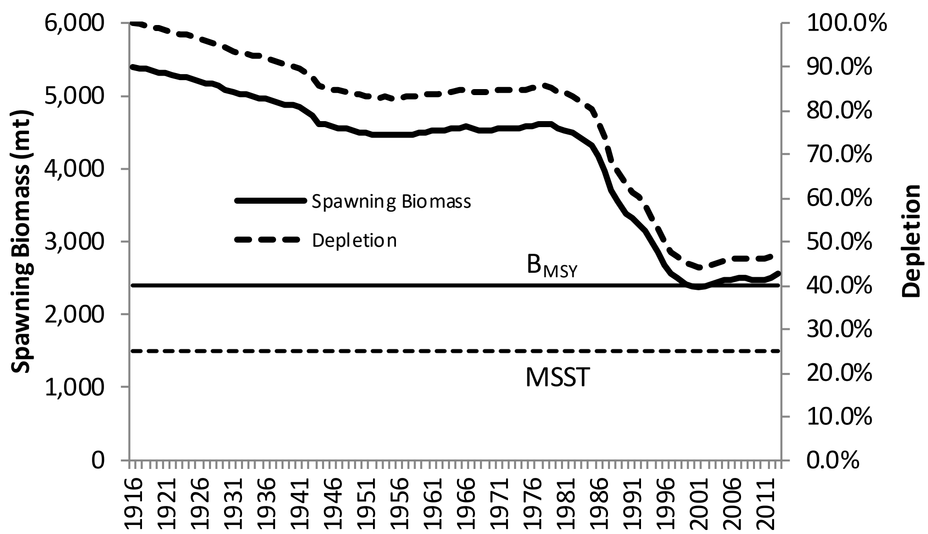

Figure 2-116. Time series of estimated spawning biomass and depletion of rougheye/blackspotted rockfish, 1916-2013 (from Hicks et al. 2013).

Stock Productivity

The parameter for steepness of the spawner-recruit relationship was fixed at 0.779 in the 2013 assessment based on a steepness meta-analysis for West Coast rockfishes (Jim Thorson, NWFSC). There is little information regarding recruitment prior to 1980, and the uncertainty in these estimates is expressed in the assessment. Estimates of recruitment appear to oscillate between periods of low and high recruitment. The four largest recruitments were estimated in 1999, 1998, 2001, and 1988, and the four smallest recruitments were estimated in 2002, 2006, 2005, and 1995 (Figure 2-117).

Rougheye rockfish have the highest potential vulnerability to overfishing (V = 2.27) driven by a combination of low productivity (P = 1.17) and relatively high susceptibility to being caught in the fishery (Table 2-2). Despite this, the 2013 assessment estimated the stock to be above the $B_{40\%}$ spawning biomass target. The low productivity is due to the stock being long-lived (max. age = 205 yrs.; (Love, *et al.* 2002)), with late maturation, and relatively low natural mortality.

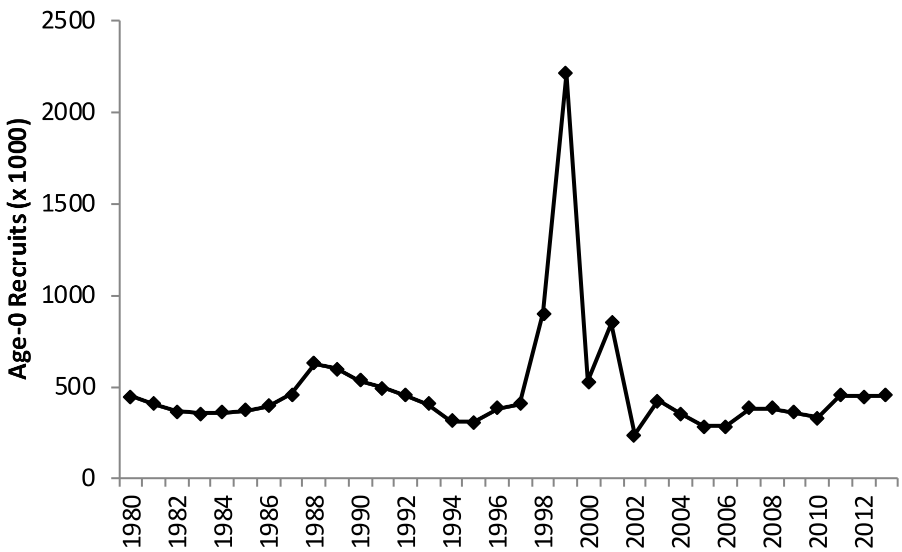

Figure 2-117. Time series of estimated age-0 recruits of rougheye/blackspotted rockfish on the U.S. West Coast, 1980-2013 (from Hicks et al. 2013).

Fishing Mortality

Rougheye rockfish are not often targeted by a specific fishery, but are desirable and marketable, thus are typically retained when captured. They are often captured in bottom trawl, midwater trawl, and longline fisheries. Small numbers have been observed in pot, shrimp, and recreational fisheries.

After many attempts to start trawl fisheries off the West Coast of the United States in the late 1800s, the availability of the otter trawl and the diesel engine in the mid-1920s helped the trawl fisheries expand (Douglas 1998). Trawl fisheries really became established during World War II when demand increased for shark livers and bottomfish. A mink food fishery also developed during World War II (Jones and Harry 1960). Foreign fleets began fishing for rockfish in the mid-1960s until the EEZ was implemented in 1977 (Rogers 2003b). Since 1977, landings of rockfish were high until management restrictions were implemented in 2000. Longline catches of rougheye rockfish are present from the turn of the century and continue in recent years, targeting sablefish and halibut.

A long-term directed fishery has not occurred for rougheye rockfish and historical discarding practices are not well known. Rougheye rockfish inhabit deeper water as adults, which were fished less often historically.

Throughout the 1980s and 1990s exploitation rates (1-SPR) were mostly above target levels (Figure 2-118). Recent exploitation rates on rougheye rockfish were predicted to be near target levels.

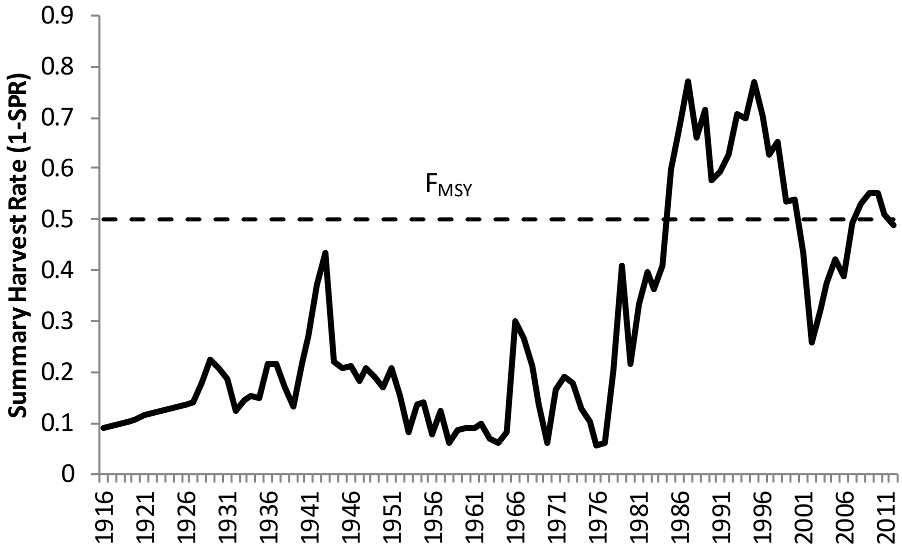

Figure 2-118. Estimated spawning potential ratio (SPR) of rougheye and blackspotted rockfish relative to the current F_{MSY}, 1916-2012. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5.4.4 Sharpchin Rockfish

Distribution and Life History

Sharpchin rockfish (*Sebastes zacentrus*) range from the western Aleutian Islands (Attu Is.) to Southern California, though the core range is northern California to the Gulf of Alaska in waters between 100 m and 300 m (Love*, et al.* 2002). There is no indication of population structure in sharpchin rockfish. Sharpchin rockfish is a smaller-sized rockfish that inhabits waters up to 500 m, typically over muddy-rock habitats.

Mitochondrial DNA analyses indicate sharpchins are related mostly to harlequin, Puget Sound, and pygmy rockfishes (Love*, et al.* 2002).

Sharpchin rockfishes live to at least 58 years (Love*, et al.* 2002). Females attain a larger size than males with a reported maximum size of 45 cm (Love*, et al.* 2002). Off Oregon and Washington, the size at 50 percent maturity for females is 22 cm with all females being mature at 30 cm. The size at 50 percent maturity is larger for samples farther north with 25 cm and 28 cm reported off British Columbia and the Gulf of Alaska, respectively. Larval releases occur from March to June off California and Oregon and during July off British Columbia.

Sharpchin eat a variety of prey including krill, shrimps, gammarid amphipods, copepods, and small fishes.

Stock Status and Management History

Sharpchin rockfish are managed in the northern and southern Slope Rockfish complexes.

A new data-moderate assessment of sharpchin rockfish was conducted in 2013, which indicated the stock was healthy with a depletion of 68 percent at the start of 2013 (Cope*, et al.* 2014). The SSC recommended the 2013 assessment be used for setting harvest specifications and upgraded the stock from a category 3 to a category 2 stock. The coastwide OFLs were apportioned 80 percent to the north of 40°10' N. lat. and 20 percent to the south to determine the OFL contributions to the Slope Rockfish complexes based on swept area biomass estimates from the triennial survey.

Projections of harvest specifications for sharpchin rockfish for 2019 and beyond using the base model in the 2013 data-moderate assessment were provided in 2015 (Agenda Item I.4, Supplemental Attachment 8, November 2015) since long term projections were inadvertently omitted from the 2013 assessment.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2019 and 2020 harvest specifications. The 2019 and 2020 ACL contribution of sharpchin rockfish north of 40°10' N. lat. to the Slope Rockfish complex north of 40°10' N. lat. are 322.1 mt and 317.7 mt, respectively. The 2019 and 2020 ACL contribution of sharpchin rockfish south of 40°10' N. lat. to the Slope Rockfish complex south of 40°10' N. lat. are 80.5 mt and 79.4 mt, respectively.

Stock Productivity

A high steepness of 0.77 was estimated in the 2013 sharpchin rockfish assessment, near the prior used in the assessment.

Sharpchin have a relatively low productivity (P = 1.36) and a relatively high vulnerability (V = 2.05) to overfishing based on the PSA scores derived prior to the 2013 assessment (Table 2-2).

Fishing Mortality

Sharpchin are not a major commercial target, though they are taken in large numbers and commonly seen in trawls that target Pacific ocean perch. They are taken most commonly of Oregon and Washington with POP, darkblotched rockfish, splitnose, and yellowmouth rockfish. While they are common in West Coast bottom trawl catches, their smaller size makes them less valuable than the larger rockfish species. They are rarely taken in recreational fisheries.

2.5.5 Oregon Cabezon/Kelp Greenling

The Oregon Cabezon/Kelp Greenling stock complex is comprised of cabezon (Scorpaenichthys marmoratus) and kelp greenling (Hexagrammos decagrammus) off Oregon. Both of these stocks have been assessed.

2.5.5.1 Cabezon off Oregon

Distribution and Life History

See the description of cabezon distribution and life history in section 2.4.6.

Stock Status and Management History

The 2009 assessment of the Oregon substock of cabezon (Cope and Key 2009) was the first for cabezon in Oregon waters. The assessment indicated a healthy stock status for Oregon cabezon at 52.4 percent depletion at the start of 2009. Only one index of abundance was used for modeling the Oregon cabezon substock (the ORBS CPUE index). The Oregon model was robust to almost all data and parameter manipulation trials except the removal of the ORBS survey. Removal of the only abundance index causes the population to drop sharply below the overfished level and absolute biomass to be much smaller than in the base case. Unlike the assessments for the California substocks, the assessment of the Oregon cabezon substock does not show recent increases in spawning biomass. While the uncertainty in the estimated depletion level of the Oregon substock is generally low, uncertainty in the estimated spawning biomass is high.

A new full assessment of the cabezon substock in Oregon was conducted in 2019 (Cope*, et al.* 2019). Cabezon spawning output was estimated to be 177 mt in 2019 (~95 percent asymptotic intervals:129-226 mt), which when compared to unfished spawning output (335 mt) equates to a depletion level of 53 percent (~95 percent asymptotic intervals: 43-63 percent; Figure 2-119) in 2019. In general, spawning output had been trending downwards until the early 2000s, after which it became more stable throughout the rest of the time series with a slight increase from 2017 through 2019 due to an above average recruitment estimate for the 2014 year class. Stock size is estimated to be at the lowest level throughout the historic time series in 2014, but the stock is estimated to be above the management target of $B_{40\%}$.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2021 and 2022 harvest specifications. The 2021 and 2022 ABC and ACL contributions of cabezon to the Oregon Cabezon/Kelp Greenling complex are 54.5 mt and 52.2 mt, respectively. These ACL contributions are also specified as the harvest guidelines for 2021 and 2022 Oregon fisheries with the intent to prevent overfishing under management in this state-specific stock complex.

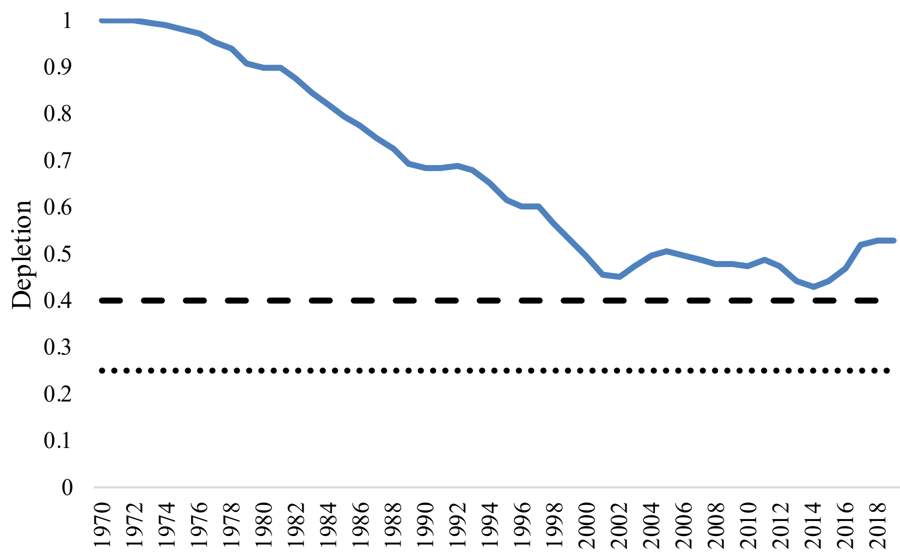

Figure 2-119. Relative depletion of cabezon in Oregon from 1970 to 2019 based on the 2019 stock assessment.

Stock Productivity

Steepness in the 2009 assessment of the Oregon substock of cabezon was assumed to be 0.7. Recruitment in the Oregon substock of cabezon was estimated to be less dynamic than that for the California substocks. The PSA productivity score of 1.72 indicates a stock of relatively high productivity.

A recent, above average, recruitment event in 2014 contributed to the recent increase in cabezon biomass in Oregon (Figure 2-120). This recruitment is informed by composition data, two relative abundance indices, and corresponds to reports from fishermen and port biologists of a recent increase in cabezon. Other years with relatively high estimates of recruitment were 1999, 2000, and 2002. The 2009 stock assessment also suggested that 1999 was an above average year class.

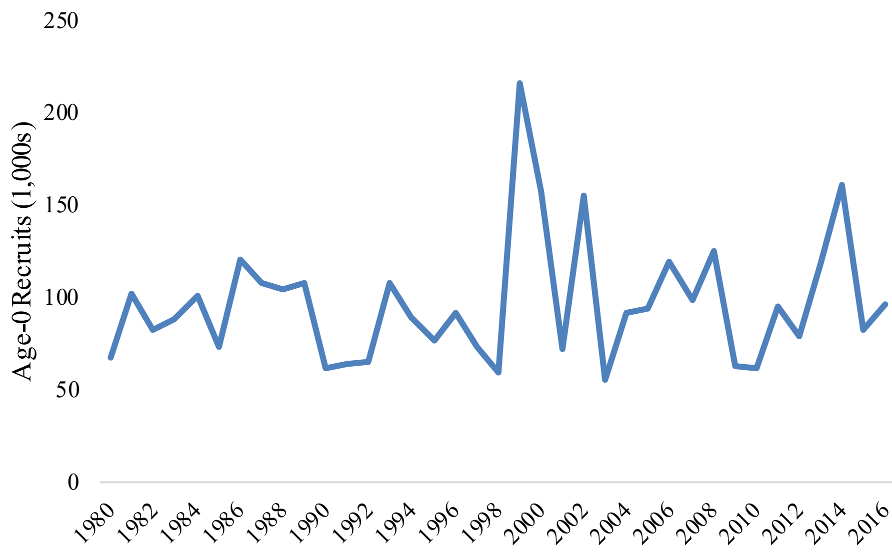

Figure 2-120. Estimated recruitments of cabezon in Oregon, 1980-2016.

Fishing Mortality

Harvest rates in Oregon have generally increased through time until reaching a more stable (but still variable from year to year) level beginning in the 2000s (Figure 2-121). The maximum relative harvest rate was 1.16 in 2001 (or 116 percent of the target level) before declining again to around 0.80 in recent years.

The PSA vulnerability score of 1.68 indicates a low risk of overfishing.

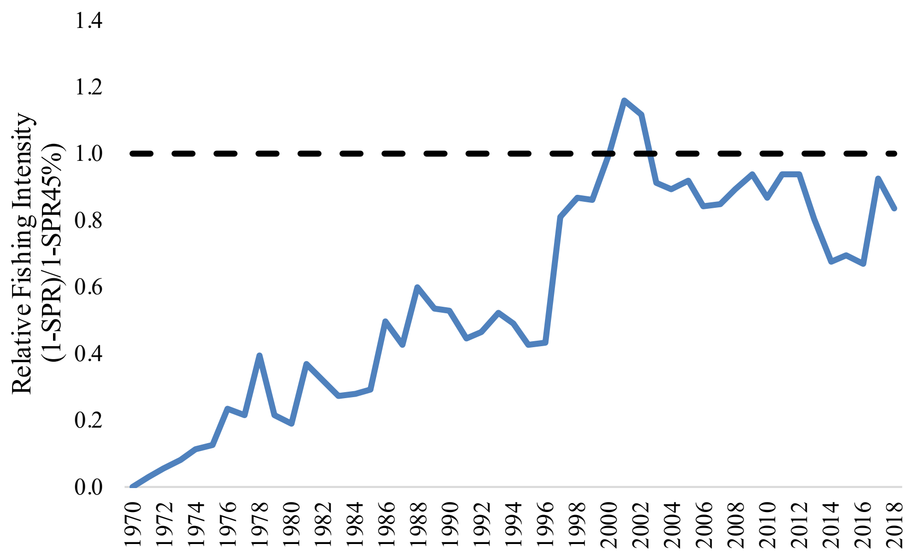

Figure 2-121. Relative fishing intensity of cabezon in Oregon, 1970-2018.

2.5.5.2 Kelp Greenling off Oregon

Distribution and Life History

Kelp greenling (*Hexagrammos decagrammus*) is a demersal, solitary finfish in the family *Hexagrammidae*, which also includes lingcod. Kelp greenling are endemic to nearshore rocky reef, kelp forest, and eelgrass habitats of the Northeast Pacific Ocean (Bodkin 1986; Eschmeyer, *et al.* 1983; Pacunski and Palsson 2001). This species ranges from southern California, north to the Aleutian Islands (Miller and Lea 1972), but are rarely found south of Point Conception, California (Feder*, et al.* 1974). The main population range and fisheries activities are from central California (including the Channel Islands) north through Oregon. Kelp greenling is primarily a nearshore species found intertidally and among rocks and kelp, usually down to depths of <50 m, though they can be found out to depths >150 m (Love 1996; Miller and Lea 1972). Kelp greenling tend to remain within three meters of benthic substrates and are often observed resting on the bottom (Rosenthal 1980). These fish tolerate salinities ranging from 5 ppt to 45 ppt (Zahr 1984), an adaptation allowing this species to occupy estuarine habitats. Evidence suggests kelp greenling may display ontogenetic movement, with smaller fish in shallower waters (DeMartini 1986; ODFW 2002).

In Oregon's nearshore, kelp greenling are found in association with finfish species including *Hexagrammids*, *Scorpaenids*, and *Cottids* among others (Easton*, et al.* 2015). Black rockfish, lingcod, China rockfish, canary rockfish, quillback rockfish, copper rockfish, yellowtail rockfish, yelloweye rockfish, rock greenling (*Hexagrammos lagocephalus*), Irish lords (*Hemilepidotus* spp.), and surfperches are species commonly co-occurring with kelp greenling. Many of these species are also exploited in Oregon's nearshore fishery.

There is little direct information on the stock structure of kelp greenling off the U.S. West Coast. Little is also known of kelp greenling movement patterns, but given their nearshore distribution and the territorial behavior of adults (Barker 1979; Bryant 1978; DeMartini 1986), they are not believed to migrate great distances. Once settled, kelp greenling in California waters are thought to establish home ranges at least 500 – 3,000 m^2 (Love 2011). Typical of nearshore reef fishes, kelp greenling subpopulations are often spatially discrete, suggesting the possibility of increasing genetic differentiation as distance along the coast increases (Palumbi 2003).

Kelp greenling are sexually dimorphic at maturity with notable chromatic differences between the sexes. Adult females are generally light gray with yellow fins and speckled orange-brown spots across the entire body. Adult males are commonly olive-brown with blue tinged fins. Males have blue spots surrounded by rings of reddish-brown spots on the anterior portion of the body. Considerable variation in coloration exists by season, geographic location and among individuals of the same sex.

Kelp greenling spawn sub-tidally in shallow rocky areas. Female kelp greenling batch spawn (Kurita, *et al.* 1995) producing at least three clutches of eggs (Crow, *et al.* 1997) during the primary reproductive season of September through December (Rodomsky, *et al.* 2015). Golf ball to tennis ball sized egg clutches are deposited sub-tidally, adhering to shallow benthic substrates of rock, kelp or biological composition in nests established by males (DeMartini 1986). It is apparent that females lay multiple batches in different nests, but whether these eggs are temporally distinct enough to qualify for separate spawning events has not been determined (Crow 1995; Crow, *et al.* 1997; Rothrock 1983). Clutches collected from Washington waters averaged 4,340 eggs each (SE = 311) with egg diameters ranging from 2.2 to 2.5 mm (mean = 2.3 mm) and egg weights from 6.8 to 8.7 mg (mean = 7.6 mg, (DeMartini 1986)). The role of female kelp greenling in reproduction ends with egg deposition.

Male kelp greenling have a significant paternal role in reproduction. Territorial during the reproductive season, males establish nests, fertilize eggs, fan eggs to increase oxygenation, and guard nests from predation. Sneak spawning by non-territorial males has been observed (Crow, *et al.* 1997). Nests are 0.001 m^2 to 7 m^2 in size and may hold one to 11 clutches (Crow 1995; Crow, *et al.* 1997; DeMartini 1986; Howard and Silverberg 2001). Clutches in a single nest are often in various stages of development and are contributed to by multiple females, indicating a polygamous mating system (Crow, *et al.* 1997). Embryos require 30 days to develop when held in 10°C water in a laboratory (DeMartini 1986). Laid eggs are sticky and adhere to the surface where deposited. After hatching, the young-of-the-year spend several months as epipelagic larvae and juveniles (Gorbunova 1970). Settlement takes place in the nearshore after a planktonic phase when the young fish have attained 5-7 cm in length (Burge and Schultz 1973; Matarese, *et al.* 1989; ODFW 2002; Robinson, *et al.* 1968a; Robinson, *et al.* 1968b). Growth is rapid in the first three years for both sexes, thereafter slowing dramatically (ODFW 2002; Rodomsky, *et al.* 2015). Adult kelp greenling reach a maximum size of 63 cm (total length) and 2.1 kg (Love 2011). In Oregon marine waters, kelp greenling rarely grow over 50 cm and live at least 17 years (Rodomsky, *et al.* 2015).

Kelp greenling is a diurnal generalist mesopredator of Northeast Pacific nearshore ecosystems (Frid, *et al.* 2012). This species uses both ram and suction feeding (Nemeth 1997) to prey on crustaceans, polychaete worms, echinoderms, mollusks, fish eggs (including kelp greenling), small fishes and algae (Bryant 1978). In turn, kelp greenling is preyed upon by a wide variety of organisms including black rockfish, Pacific halibut (*Hippoglossus stenolepis*), lingcod, cabezon, salmonids, seabirds, pinnipeds, and mink (*Mustela vison*) among others.

Stock Status and Management History

The first assessment of kelp greenling was completed in 2005 by Cope and MacCall (Cope and MacCall 2006). The assessment treated the stock as two completely independent sub-stocks divided at the California-Oregon border (excluding Washington, as there have been no substantial fisheries off its coast). There are substantial differences between the two assessments with respect to assessment period, model assumptions, results, and uncertainties. An important difference between the two sub-stocks is the first year for which historical catch data are available (1916 for California and 1981 for Oregon). The Oregon sub-stock has some age-at-length data, which were included in the assessment. The estimate of depletion for the Oregon sub-stock (49 percent of its unfished biomass at the start of 2005) is more certain than estimates of absolute abundance, which are highly imprecise. For the California sub-stock, substantial uncertainty could not be resolved regarding growth and natural mortality rates, as well as the shape of the selectivity pattern for the shore mode fishery. Due to these factors, it was not possible to formulate a model for California. The 2005 kelp greenling assessment was used only for status determination since the assessment could not adequately estimate the scale of the population's spawning biomass. The SSC lost confidence in the 2005 assessment in 2014 when it was realized the historical catch data informing the assessment were based on MRFSS estimates rather than the accepted ORBS estimates.

Berger et al. (2015) conducted an assessment of kelp greenling in Oregon waters and determined the population was healthy with a depletion of 80 percent at the start of 2015. The assessment assumed a single, two-sex population for waters off the Oregon coast and modeled the period 1915-2014. The model included four fleets which were defined as a combined commercial fleet (hook and line, and bottom longline) and three recreational fleets (ocean-boat, estuary-boat, and shore). Data included in the model were catches and associated length composition data, three fishery dependent CPUE series, and three series of conditional age-at-length data. The scale of the biomass was sensitive to the assumed value for natural mortality.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.45 for 2021 and 2022 harvest specifications.

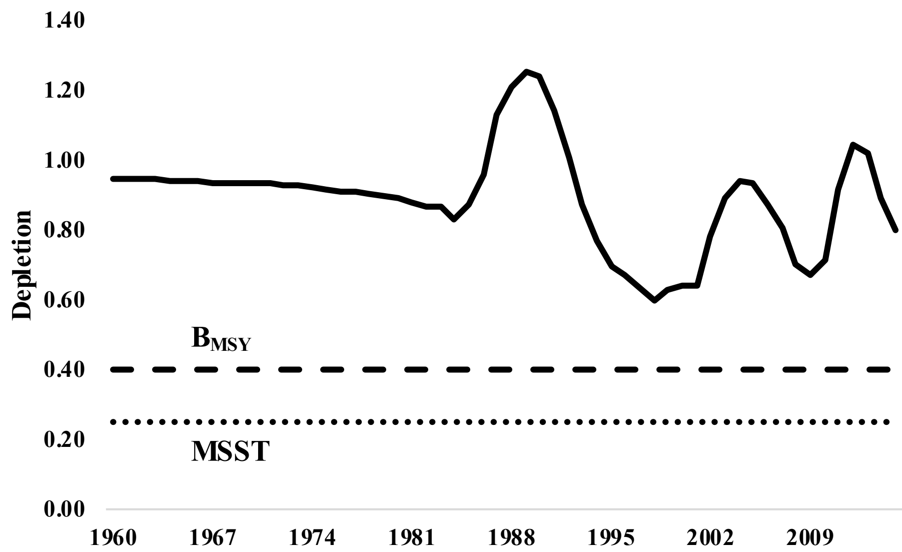

Figure 2-122. Relative depletion of kelp greenling off Oregon from 1960 to 2015 based on the 2015 stock assessment.

Stock Productivity

The 2015 kelp greenling assessment assumed a steepness of 0.7. Recruitment variability is notably dynamic for kelp greenling (Figure 2-123) and indicated above average recruitment in 2009. Other years with relatively high estimates of recruitment were 1985 and 2000. In recent years (2012-2014), the 2015 base case assessment model had difficulty estimating recruitment levels because of a lack of cohort information contained in the most recent data.

The PSA productivity score of 1.83 indicates a relative moderate productivity of kelp greenling. Kelp greenling are judged to have a low vulnerability (V = 1.56) of potential overfishing for the stock.

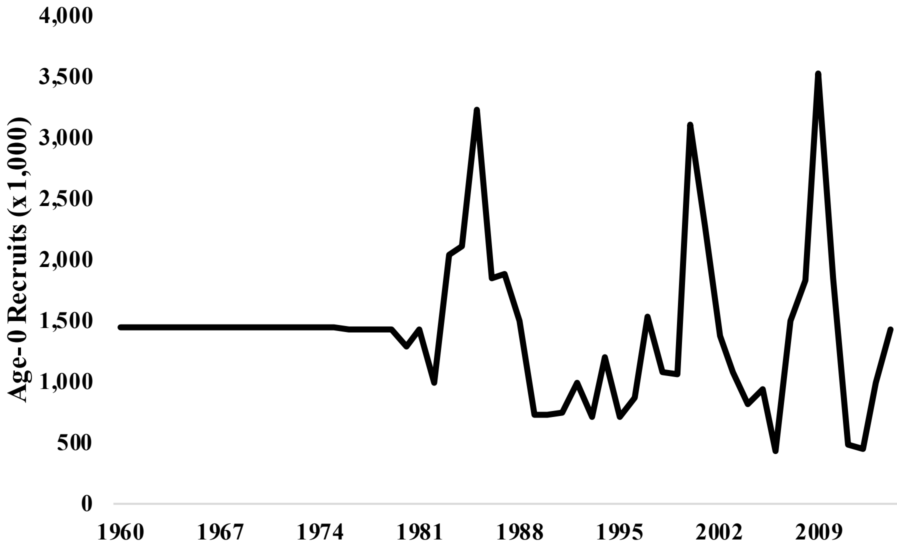

Figure 2-123. Estimated recruitments of kelp greenling off Oregon, 1960-2015 (from Berger, *et al.* 2015).

Fishing Mortality

Harvest rates of kelp greenling off Oregon have been generally increasing through time, reaching a maximum in 2002 (51 percent of the target level) before declining again to 21 percent of the limit in 2014 (Figure 2-124). Fishing intensity is estimated to have been below the target throughout the time series. In 2014, kelp greenling biomass was estimated to have been at 2.24 times higher than the target biomass level, while experiencing fishing intensity 4.76 times lower than the SPR fishing intensity target.

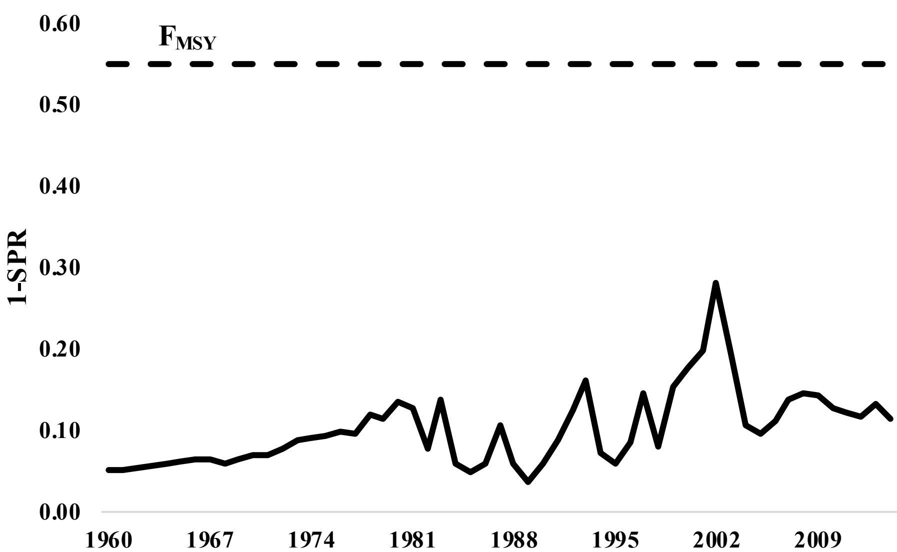

Figure 2-124. Estimated spawning potential ratio (SPR) of kelp greenling off Oregon relative to the current F_{MSY}, 1960-2014. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

2.5.6 Washington Cabezon/Kelp Greenling

The Washington Cabezon/Kelp Greenling stock complex is comprised of cabezon (*Scorpaenichthys marmoratus*) and kelp greenling (*Hexagrammos decagrammus*) off Washington. Both of these stocks are unassessed and managed as category 3 assessments of OFL.

2.5.7 Other Flatfish

The Other Flatfish complex contains most of the flatfish species managed in the Groundfish FMP (with the exception of arrowtooth flounder, Dover sole, English sole, petrale sole, and starry founder[11]). These species include butter sole (*Isopsetta isolepis*), curlfin sole (*Pleuronichthys decurrens*), flathead sole (*Hippoglossoides elassodon*), Pacific sanddab (*Citharichthys sordidus*), rex sole (*Glyptocephalus zachirus*), rock sole (*Lepidopsetta bilineata*), and sand sole (*Psettichthys melanostictus*).

2.5.7.1 Pacific Sanddabs

Distribution and Life History

Pacific sanddab (*Citharichthys sordidus*) is a left-eyed flounder of the family *Paralichthyidae* and is widely distributed along the Pacific West Coast from the Bering Sea to Cabo San Lucas, Baja California (Arora 1951; Hart 1988; Kramer and O'Connell 1995; Love*, et al.* 2005; Miller and Lea 1972; Rackowski and Pikitch 1989). Early studies reported that the species is the most abundant in the north-central portion of California from Eureka to San Francisco, but were also fairly common in southern California (Rackowski and Pikitch 1989). Early studies also reported that the species is usually found at depths between 18 m and 275 m and most commonly found at depths between 35 m and 95 m (Arora 1951; Demory 1971; Hart 1988; Miller and Lea 1972; Roedel 1953). On Oregon's continental shelf, Pacific sanddab is the most abundant small flatfish on sandy-bottom in the depths between 74 and 102 m (Pearcy 1978). Young Pacific sanddab (ages 0 and 1) are also found to be concentrated in the same depth range (Donohoe 2000). Pacific sanddab was also found to be relatively more abundant in shallow waters at higher latitudes (Chamberlain 1979).

Pacific sanddab are generally not considered a primary target for commercial fisheries along the U.S. West Coast, but they are nevertheless highly prized by the commercial and recreational fisheries for their excellent edibility (CDFG 2001), and have long been an important component of the nearshore flatfish fishery, commanding a high price in fresh fish markets (Arora 1951). Commercial catches of Pacific sanddab were mostly from bottom trawl fisheries, and there is a long history of catches. Recreational catches of Pacific sanddab are from the hook and line fishery and most of this catch is from southern California waters. Some recreational anglers target Pacific sanddab in southern California, mostly from small boats and CPFVs (CDFG 2001).

Pacific sanddabs can growth to 35cm in length. They are sexually dimorphic, with females attaining larger sizes than males. Analysis of growth rates for both sexes between the southern

[11] Starry flounder is being considered for management in the Other Flatfish complex starting in 2017 (see Section 2.4.25).

and northern areas (divided at the California-Oregon border at 42° N. lat.) showed no significant difference in growth rates for both sexes between the two areas.

There are no genetic or tagging studies informing stock structure of Pacific sanddab along the U.S. Pacific coast. Bottom trawl surveys in recent years (both NWFSC and triennial surveys) showed that Pacific sanddab are commonly caught along the coastal areas of all U.S. waters.

Pacific sanddabs play an important role in the coastal ecosystems in the U.S. waters, particularly because they are a relatively abundant species and are important prey items to a wide range of marine predators, including piscivorous fishes, sea mammals, and sea birds (Field*, et al.* 2006; Levin*, et al.* 2006).

Stock Status and Management History

Pacific sanddabs have been under Federal management since the implementation of the groundfish FMP in 1982 and managed within the Other Flatfish complex of unassessed flatfish species. The management performance in recent years for Pacific sanddab has been good; the average 2005-2012 total annual catch has been about 23 percent of the stock's ACL/OY contribution to the Other Flatfish complex.

A coastwide assessment of Pacific sanddab was done in 2013 indicating the stock was at 95.5 percent of its unfished biomass (He*, et al.* 2013). The SSC recommended in 2013 that this assessment not be used for deciding harvest specifications since the scale of the stock's biomass could not be adequately estimated. However, the status estimate was precise enough to conclude the stock was well above the B_{MSY} proxy of $B_{25\%}$. The SSC recommended the stock continue to be categorized as a category 3 stock given the OFL estimate from the assessment depends on the biomass estimate, which was not estimated with adequate precision. The OFL estimate is therefore based on the DB-SRA method used since 2011.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.4 for 2021 and 2022 harvest specifications.

Stock Productivity

A steepness prior of 0.8 was used in the 2013 assessment. Annual recruitment deviations were estimated between 1966 and 2011. Annual recruitment deviations were treated in a log-normal distribution with σ_R fixed at 0.45. Low recruitments occurred from the early 2000s to the mid-2000s. Recruitments in recent years have been at or above the long-term average, with a strong recruitment in 2010.

The PSA productivity score of 2.4 indicates a very high relative productivity of Pacific sanddabs. This leads to a very low vulnerability (V = 1.25) of potential overfishing for the stock.

Fishing Mortality

There is a long history of commercial catches on Pacific sanddab (Barss 1976). Sette and Fiedler (1928) reported that landings of flatfish in California waters were first reported in 1892. The first available landings of Pacific sanddab in Oregon waters were in 1942 (Karnowski*, et al.* 2014). There were also commercial catches for mink foods in both California and Oregon waters in the 1950s and 1960s (Best 1959; Best 1961; Nitsos and Reed 1965). Reported total catches of Pacific sanddab were high in the late 1920s. And there was an increasing trend from the 1960s and reached the highest catch level in the late 1990s. Discards of Pacific sanddab in commercial trawl fisheries were high, primarily due to its small size (Sampson 2002). Catches of the species in recent years were in the range of 200 mt and 400 mt, well below the OFL contribution of the stock to the Other Flatfish complex of 4,801 mt.

2.5.7.2 Rex Sole

Distribution and Life History

Rex sole (*Glyptocephalus zachirus*) is a right-eyed flounder of the family *Pleuronectidae* ranging from central Baja California to the Aleutian Islands and the western Bering Sea. They are common from southern California to the Aleutian Islands. They are distributed over mud and sand bottom habitat in deeper depths, are commonly found in waters up to at least 500 m, and range down to more than 1,100 m.

Rex sole grow slowly and are relatively long-lived for a flatfish with a maximum age of 29 years (Cope*, et al.* 2014). Females grow faster and attain a larger size than males.

Stock Status and Management History

Rex sole are currently managed in the Other Flatfish complex.

A data-moderate assessment of rex sole using the exSSS model was conducted in 2013, which indicated the stock was healthy with a depletion of 80 percent at the start of 2013 (Cope*, et al.* 2014). The SSC recommended the 2013 assessment be used for setting harvest specifications and upgraded the stock from a category 3 to a category 2 stock.

Projections of harvest specifications for rex sole for 2017 and beyond using the base model in the 2013 data-moderate assessment were provided in 2015 (Agenda Item I.4, Supplemental Attachment 8, November 2015) since long term projections were inadvertently omitted from the 2013 assessment.

The Council adopted the default harvest control rule of ACL equal to the ABC with a P* of 0.4 for 2021 and 2022 harvest specifications.

Stock Productivity

A steepness prior of 0.89 was estimated in the 2013 assessment, higher than the mean prior value.

The PSA productivity score of 2.05 indicates a high relative productivity of rex sole. This leads to a low vulnerability (V = 1.28) of potential overfishing for the stock.

Fishing Mortality

Rex sole are a very commonly occurring species in the fishery-independent trawl surveys and are very accessible to trawl fisheries. Targeting for rex sole in commercial fisheries has varied over the years, with major removals occurring in the mid-1900s to provide feed for mink farms. They have not been targeted heavily in the last few decades. While their flesh is tasty and of high quality, they are small fish with very thin fillets and therefore less desired in commercial markets.

Females are larger than males and are most commonly caught. Males are small enough to escape the minimum mesh size of West Coast bottom trawls.

2.5.8 Other Fish

The Other Fish stock complex is comprised of kelp greenling (*Hexagrammos decagrammus*) off California and leopard shark (*Triakis semifasciata*) (primarily off California). Both of these stocks are unassessed and managed as category 3 stocks.

2.5.9 Ecosystem Component Species

The species designated as EC species in the groundfish FMP are displayed in Table 2-10. An EC species can be so designated if it is not targeted, is not subject to overfishing or being overfished in the absence of conservation measures, and not generally retained for sale or personal use. No harvest specifications or management reference points are required for EC species; however, there is a monitoring requirement to determine potential changes in their status or their vulnerability to the fishery. An unexpected increasing catch trend infers an EC species' vulnerability to overfishing may have increased, compelling a consideration to reclassify the stock as "in the fishery". Any designation of a species as an EC species or a change from an EC designation to a species considered to be "in the fishery" requires an FMP amendment.

The following species were designated EC species under FMP Amendment 24, which was implemented in 2011: big skate, California skate, all other endemic skates, soupfin shark, finescale codling, Pacific grenadier, all other endemic grenadier species, and spotted ratfish. The Council decided in 2015 under Amendment 27 to remove the EC designation for big skate and redesignate the species as actively managed with stock-specific harvest specifications (see Section 2.4.2). The rationale for this consideration was based on new evidence that big skate are targeted in trawl fisheries and retained for sale in greater amounts than previously understood. When the Council considered designating all skates except longnose skate as EC species, the GMT estimated that catches of big skate averaged 95 mt from 2007–2011 with large landings of Unspecified Skate (see Table 4-33 in the 2015-2016 Harvest Specifications and Management Measures Final Environmental Impact Statement). Subsequent analysis of Oregon port sampling data not available when the Council considered the EC designation indicated about 98 percent of the recent Unspecified Skate landings in Oregon were comprised of big skate. The GMT revised the total mortality estimates of big skate coastwide using these new data (Table 2-8). Such large landings indicate targeting of big skate has occurred and an EC designation was not warranted.

Shortbelly rockfish was recommended to be designated an EC species under FMP Amendment 29, which is anticipated to be implemented in 2021.

Table 2-10. Ecosystem Component Species managed under the FMP in 2021 and beyond.

Common Name	Scientific Name
Shortbelly rockfish	*Sebastes jordani*
Aleutian skate	*Bathyraja aleutica*
Bering/sandpaper skate	*B. interrupta*
California skate	*Raja inornata*
Roughtail/black skate	*Bathyraja trachura*
All other skates except big and longnose skate	Endemic species in the family *Arhynchobatidae*
Pacific grenadier	*Coryphaenoides acrolepis*
Giant grenadier	*Coryphaenoides pectoralis*
All other grenadiers	Endemic species in the family *Macrouridae*
Finescale codling (aka Pacific flatnose)	*Antimora microlepis*
Ratfish	*Hydrolagus colliei*
Soupfin shark	*Galeorhinus zyopterus*

2.5.9.1 Shortbelly Rockfish

Distribution and Life History

Shortbelly rockfish (*Sebastes jordani*) range from Punta Baja in Baja California (Klingbeil 1976) as far north as La Perouse Bank off of British Columbia, and as far west as the Cobb seamount off the southern Washington coast (Pearson*, et al.* 1993). However, they are most abundant along the continental shelf break between the northern end of Monterey Bay and Point Reyes, California (particularly in the regions of Ascension Canyon and the Farallon Islands), and around the Channel Islands in the Southern California Bight (Love*, et al.* 2002; Moser*, et al.* 2000; Pearson*, et al.* 1991; Phillips 1964). Although stock structure is poorly understood, genetic analysis of fish collected between San Diego and Cape Mendocino suggests a single coastwide stock, with slight differences in allele frequencies across Point Conception (Constable 2006). The shortbelly rockfish is one of the most abundant rockfish species in the California Current and is a key forage species for many piscivorous fish, birds, and marine mammals.

Shortbelly rockfish feed primarily on juvenile and adult euphausiids, and are an important prey item to a wide range of piscivorous fishes, seabirds, and marine mammals (Chess*, et al.* 1988; Lowry and Carretta 1999; Sydeman*, et al.* 2001). Merkel (1957) reported that juvenile shortbelly rockfish were important prey of Chinook salmon along the central California coast in late spring and summer, accounting for more than 60 percent of those identified to species. For many breeding California seabirds, as much as 90 percent of their diet is comprised of pelagic stages of juvenile (age 0) rockfish during the late spring and early summer breeding seasons, and unexploited species (such as shortbelly rockfish) generally account for more than two thirds of the juvenile rockfish identified (Ainley*, et al.* 1993; Miller and Sydeman 2004; Sydeman*, et al.* 2001). However, there is considerable interannual and interdecadal variability in the frequency of rockfish in seabird diets. Throughout the 1990s, foraging rates on juvenile rockfish by central California seabirds declined for both exploited and unexploited rockfish species primarily in response to changes in ocean conditions associated with poor recruitment for rockfish (Miller and Sydeman 2004; Mills*, et al.* 2007; Sydeman*, et al.* 2001). Although rockfish have rarely been identified to the species level in the diets of many California Current marine mammals (Antonelis and Fiscus 1980; Morejohn*, et al.* 1978; Perez and Bigg 1986; Stroud*, et al.* 1981), shortbelly rockfish were among the five most significant prey items for California sea lion (*Zalophus californianus*) in the Channel Islands (Lowry and Carretta 1999) and are frequently encountered in sea lion food habits samples off of Central California (Weise and Harvey 2005). Shortbelly rockfish are also described as important prey to thresher sharks (Preti*, et al.* 2004), longnose skate (Robinson*, et al.* 2007), and jumbo squid (Field*, et al.* 2007), among others. Consequently, shortbelly rockfish are an important forage species to a wide range of predators throughout the California Current ecosystem, and generally have a trophic position and life history traits more similar to forage fishes than most other *Sebastes*.

Stock Status and Management History

The expectation of eventual development of a domestic commercial fishery (Kato 1981) led to past efforts to estimate stock abundance and productivity (Lenarz 1980, Pearson et al. 1989, Pearson et al. 1991) as well as evaluations of commercial potential. The first ABC for shortbelly rockfish was set by the Council at 10,000 mt for 1983 through 1989. A stock assessment by

Pearson et al. (Pearson*, et al.* 1991) estimated that allowable catches for shortbelly rockfish might range from 13,900 to 47,000 mt per year, based on life history data and hydroacoustic survey estimates of abundance. Subsequently, the Council established an ABC of 23,500 mt, which was reduced to 13,900 mt in 2001 based on observations of poor recruitment throughout the 1990s and the continued lack of a targeted fishery. Yet despite several attempts to develop a commercial fishery for shortbelly rockfish, domestic fishery landings have never exceeded 80 mt per year along the West Coast.

A shortbelly rockfish assessment was done as an academic exercise in 2007 to understand the potential environmental determinants of fluctuations in the recruitment and abundance of an unexploited rockfish population in the California Current ecosystem (Field*, et al.* 2008). The results of the assessment indicated the shortbelly rockfish stock was healthy with an estimated spawning stock biomass of 67 percent of its unfished biomass in 2005 (Figure 2-125).

Shortbelly rockfish is an abundant species that is not targeted in any commercial or recreational fisheries or caught in substantial amounts. However, shortbelly rockfish is a valuable forage fish species in the California Current ecosystem with fluctuations in stock recruitment and biomass driven by environmental conditions. The consequence of fisheries, including high and low estimates of plausible discards, were estimated to be negligible (P<0.01) in all years with the exception of the foreign fisheries of the mid-1960s (Field*, et al.* 2008). Shortbelly rockfish were initially considered for an EC species categorization under Amendment 23. Rather than classifying shortbelly rockfish as an EC species, the Council chose to recommend a very restrictive ACL of 50 mt for the 2011-2012 and the 2013-2014 management cycles. The ACL was increased to 500 mt beginning in 2015 to prevent unavoidable bycatch from prematurely shutting down emerging midwater trawl fisheries targeting yellowtail and widow rockfish. The 500 mt ACL was still less than 10 percent of the ABC and was a level of harvest meant to accommodate unavoidable incidental bycatch of shortbelly rockfish while allowing most of the harvestable surplus of the stock to be available as forage for species in the California Current ecosystem.

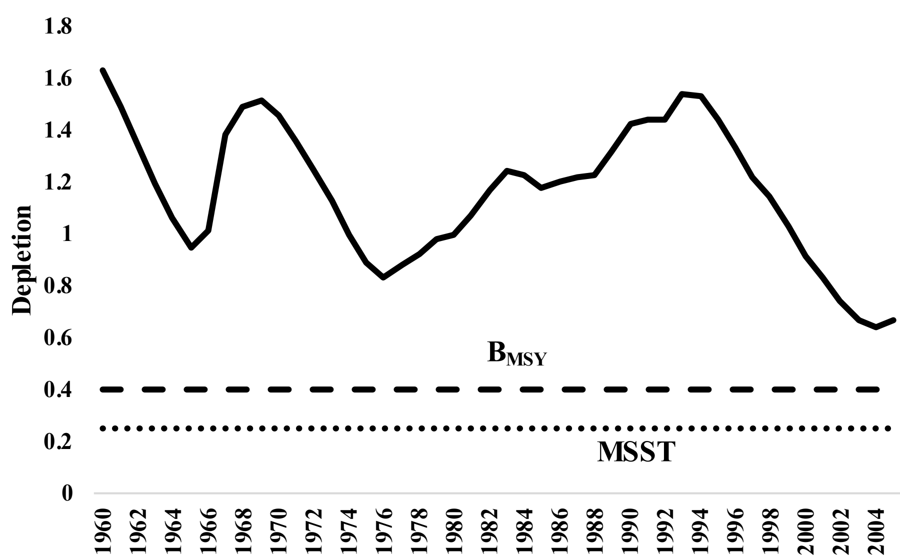

Figure 2-125. Relative depletion of shortbelly rockfish from 1960 to 2005 based on the 2007 stock assessment.

While shortbelly rockfish are most abundant along the continental shelf break between the northern end of Monterey Bay and Point Reyes, California and around the Channel Islands in the Southern California Bight (Love, et al. 2002; Moser, et al. 2000; Pearson, et al. 1991; Phillips 1964), they have increasingly been encountered and incidentally caught in midwater trawl fisheries in waters north of 40°10' N. lat. As far north as northern Washington. The observed magnitude of encounters of shortbelly rockfish north of 40°10' N. lat. In recent years is unprecedented and may be the result of a climate change-driven distributional shift and/or the effect of large recruitments. It appears both explanations are contributing factors given evidence of continued high recruitment and abundance in the core habitats off southern and central California.

The ACL was raised to 500 mt in 2015 in anticipation of the re-emergence of the midwater trawl rockfish fishery after widow and canary rockfish were declared rebuilt. Incidental bycatch remained low until 2017 when it abruptly increased by an order of magnitude and has been increasing since (Figure 2-126 and Table 2-11). Most of this bycatch occurred in the Pacific whiting midwater trawl fisheries north of 40°10' N. lat. The shortbelly rockfish ACL of 500 mt was exceeded in 2018 and 2019.

The Council and NMFS adopted an increase in the 2020 ACL to 3,000 mt to avoid premature closure of the 2020 Pacific whiting fishery. The Council recommended shortbelly rockfish be designated an EC species for 2021 and beyond.

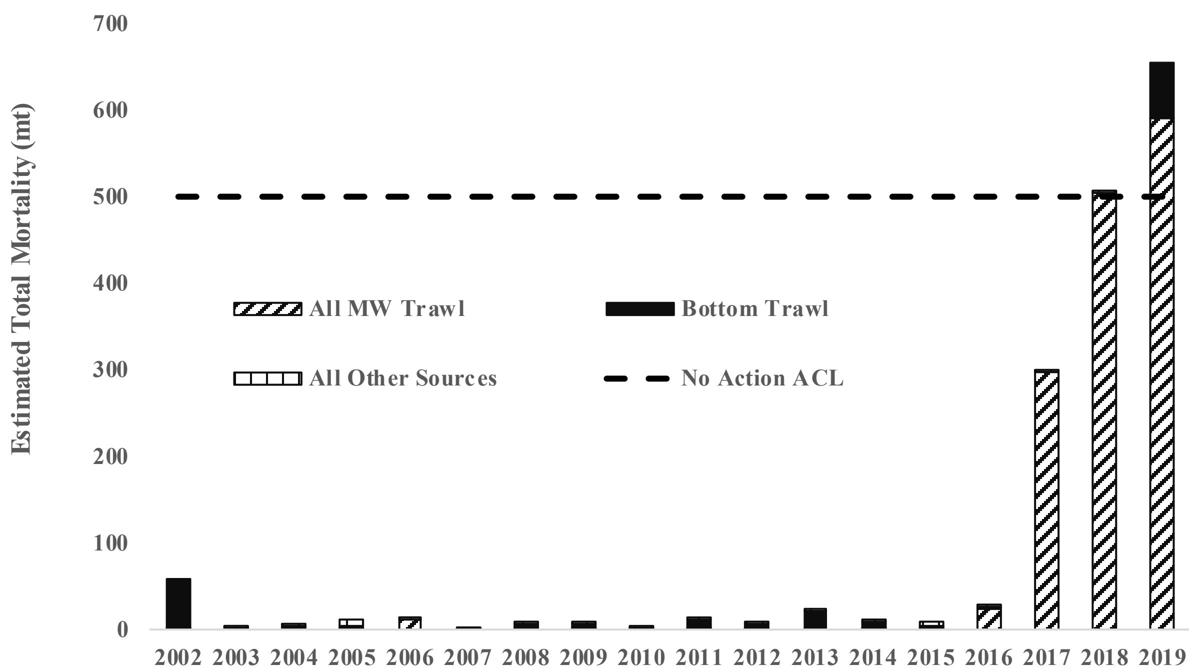

Figure 2-126. Total fishing-related mortality of shortbelly rockfish on the West Coast, 2002-2019. Mortalities in 2019 are preliminary estimates. The dotted horizontal line is the 2019 ACL.

Table 2-11. Estimated total fishing-related mortality (in mts) by sector of shortbelly rockfish on the U.S. West Coast, 2002-2019.

Year	Commercial Fisheries							WA Tribal Shoreside	Research	Estimated Fishing Mortality	2020 ACL	All MW Trawl	All Other Sources	Percent of 500 mt ACL Attainment c/
	IFQ/Co-op Management						Non-IFQ							
	Bottom Trawl	Fixed Gear	Midwater Rockfish	Shoreside Midwater Hake	At-sea Midwater CP	At-sea Midwater MSCV	Total b/							
2002	56.61	--	--	0.07	0.48	0.10	0.00	--	--	57.26	500.00	0.65	0.00	11%
2003	0.47	--	--	0.04	0.49	0.02	0.01	--	--	1.03	500.00	0.55	0.01	0%
2004	5.29	--	--	0.01	0.00	0.02	6.51	--	--	18.33	500.00	0.03	0.09	4%
2005	0.84	--	--	--	0.01	2.69	1.91	--	8.21	15.56	500.00	2.69	8.21	3%
2006	0.84	--	--	0.28	0.31	11.24	0.00	--	1.10	13.77	500.00	11.82	1.10	3%
2007	0.24	--	--	--	0.00	0.01	0.08	0.03	0.33	0.77	500.00	0.01	0.38	0%
2008	7.03	--	--	0.00	--	--	0.02	--	1.21	8.27	500.00	0.00	1.23	2%
2009	7.42	--	--	0.05	--	--	0.00	--	1.09	8.57	500.00	0.05	1.09	2%
2010	2.47	--	--	0.33	--	0.00	0.24	--	1.77	5.04	500.00	0.33	1.77	1%
2011	10.55	--	--	0.00	--	--	0.21	--	1.45	12.42	500.00	0.00	1.45	2%
2012	5.46	--	--	0.09	0.02	0.27	0.38	--	1.22	7.82	500.00	0.38	1.22	2%
2013	18.22	0.00	0.02	2.12	0.00	0.73	3.49	0.02	0.50	28.59	500.00	2.87	0.52	6%
2014	8.02	0.00	--	0.01	0.01	0.00	8.92	--	0.74	26.61	500.00	0.02	0.74	5%
2015	4.49	--	0.01	0.73	0.02	0.01	0.93	--	3.09	10.21	500.00	0.77	3.09	2%
2016	0.60	--	0.00	22.88	0.24	1.91	2.23	--	2.16	32.26	500.00	25.03	2.16	6%
2017	0.58	--	3.64	125.31	140.81	27.73	21.57	0.01	0.57	341.78	500.00	297.48	0.62	68%
2018	0.69	--	31.75	243.65	85.89	142.16	3.72	0.00	0.48	512.07	500.00	503.45	1.19	102%
2019 a/	64.41	--	--	214.34	31.13	344.25	0.00			654.13	500.00	589.72	0.00	131%
2002-2019 average	10.79	0.00	7.09	38.12	18.53	35.41	2.79	0.02	1.71	97.47		79.77	1.38	19%
2002-2009 average	9.84	0.00	0.00	0.08	0.08	3.49	1.42	0.03	2.39	10.88		2.43	2.02	2%
2002-2016 average	8.57	0.00	0.01	2.05	0.14	1.42	1.66	0.03	1.91	16.43		3.01	1.54	3%
2018-2019 average	32.55	0.00	31.75	229.00	58.51	243.20	1.86	0.00	0.48	583.10		546.59	0.59	117%

a/ 2019 catches are incomplete and considered draft until reconciled by the West Coast groundfish Observer Program (anticipated in September 2020). The estimated total catch was obtained from the Apex Dashboard (Report GMT007) on the PacFIN web site on May 26, 2020.

b/ Non-IFQ fisheries total includes CA halibut, Sea Cucumber, Pink Shrimp, Ridgeback Prawn, Non-nearshore Fixed Gear, Nearshore Fixed Gear, and Incidental Open Access fisheries.

c/ The ACL (OY prior to 2011) was 13,900 mt from 2002-2008; 6,900 mt from 2009-2010; 50 mt from 2011-2014; and 500 mt from 2015-2019.

Stock Productivity

Field et al. (2008) assumed a steepness of 0.65 in a Mace-Doonan stock-recruitment relationship (Mace and Doonan 1988) in the 2007 shortbelly rockfish assessment. The data in the assessment model were insufficient for estimating steepness; therefore, an assumed value was used based on the Dorn (2002b) meta-analysis of rockfish steepness available at the time the assessment was conducted.

Recruitment deviations of shortbelly rockfish from 1960-2005 were estimated in the 2007 assessment; however, there was greater confidence in relative year class strength from 1975-2005 (Figure 2-127). The model suggested a long period of poor recruitment through most of the 1990s, associated with a significant decline in biomass (Figure 2-125). The interesting conclusion of the 2007 shortbelly rockfish assessment was how apparent environmental determinants of shortbelly rockfish recruitment and not fishing mortality affected biomass and stock status.

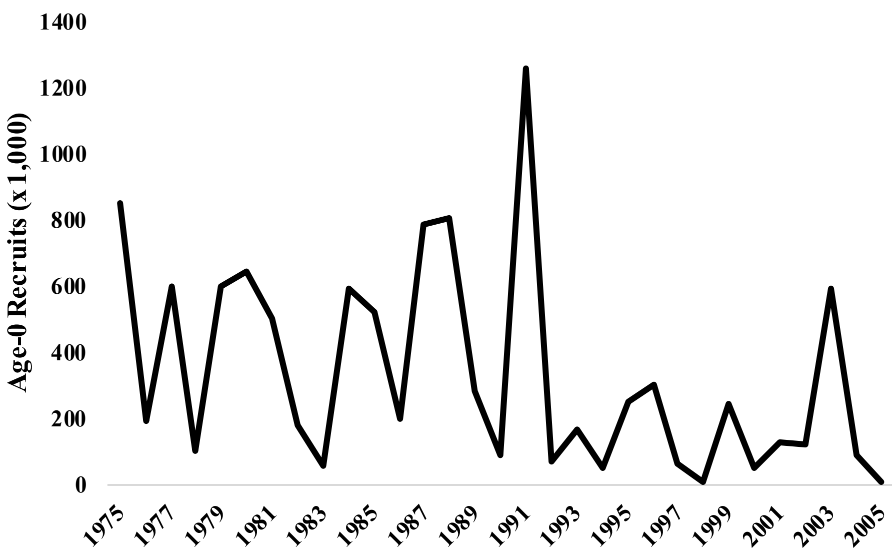

Figure 2-127. Estimated shortbelly rockfish recruitments, 1975-2005 (from Field, *et al.* 2008).

It is posited the order of magnitude increase in shortbelly rockfish bycatch since 2017 was due to a climate change-driven northerly range extension accompanied by exceptionally large recruitment. The pink shrimp trawl bycatch of shortbelly rockfish in 2017 increased by nearly an order of magnitude relative to the average bycatch in the previous 15 years before returning to an average level in 2018 (21.54 mt of the 2017 non-IFQ mortality of 21.57 mt occurred in the pink shrimp fishery (Table 2-11). Incidental rockfish caught in recent year pink shrimp fisheries tend to be very small young-of-the-year (YOY) fish given the fish excluder grates mandated in pink shrimp trawls. The 2017 spike in shortbelly rockfish bycatch in the pink shrimp fishery is indicative of a large recruitment.

Two data sets with information on shortbelly rockfish, the Rockfish Recruitment and Ecosystem Analysis Survey (RREAS) and the California Cooperative Oceanic Fisheries Investigations

(CalCOFI) survey sets were examined to provide some insight into overall population size and distribution, respectively.

The RREAS uses midwater (30 m) trawls to capture young-of-the-year rockfishes and provides an index of annual rockfish recruitment (Dick*, et al.* 2018; Dick and MacCall 2013). The "Core" RREAS sample locations are between Monterey Bay and Bodega Bay, California and have been sampled annually since 1990 (Figure 2-128). The survey expanded to include North-Central, South-Central, and Southern parts of California in 2004 and far North California in 2013. The RREAS provides information on the relative number of rockfish that survive to become pelagic juveniles. Because mortality for pelagic juveniles is much lower than for larvae, the number of pelagic juveniles correlates positively with the number of one-year old rockfish the following year and the number of adults in subsequent years. Thus, if the number of pelagic juveniles is high (i.e., recruitment is high), then it is likely that there will be high numbers of adults in the future. Because 50 percent of 2-year old shortbelly rockfish are sexually mature (Love*, et al.* 2002), a high recruitment class is likely to augment the spawning stock biomass after just two years.

The California Current Ecosystem (CCE) experienced a Marine Heatwave (MHW) from 2014-2016, resulting in the warmest 3-year period on record (Jacox*, et al.* 2016). The unusual oceanographic conditions during the MHW were highly conducive for shortbelly rockfish recruitment (Figure 2-129). All RREAS regions recorded historically high shortbelly rockfish recruitment between 2013 and 2016, and recruitment in the Core region was more than an order of magnitude higher than previous values dating back to 1990. Recruitment remained high in 2017 throughout California, and recruitment was 2nd highest in 2017 since 2013 in the North. The extraordinarily high recruitment events between 2013 and 2017 suggest that overall adult shortbelly rockfish population size was very high in 2018 and 2019.

CalCOFI has systematically collected plankton samples off California since 1951 and is the longest-running ocean monitoring program on the planet. The patterns of mean shortbelly rockfish larvae abundance collected by oblique net tows (McClatchie 2014) during winter, which is the peak shortbelly rockfish spawning season (Moser*, et al.* 2001; Moser*, et al.* 2000) were examined (Figure 2-130). Larval abundance correlates with adult biomass (Hsieh*, et al.* 2005), and larval abundances is used as an index of spawning stock biomass (Dick and MacCall 2013). If larval abundance is low in southern California, then it is likely that adult population size is also low. Shortbelly rockfish larval abundance was slightly below average in 2018 in southern California. Larval abundance in 2018 was the 26th highest out of 48 sample years. It thus appears that while shortbelly rockfish are not booming in southern California, they are present at levels consistent with the long-term average.

Taken together, RREAS and CalCOFI surveys suggest that the overall shortbelly rockfish population was very high in 2018-2019, and that the population size in southern California is at close to average level. The presence of shortbelly rockfish in southern California does not necessarily preclude the possibility that the bulk of the population moved from central or northern California into Oregon and Washington, but it does show that this species has not abandoned the southern portion of its range within California.

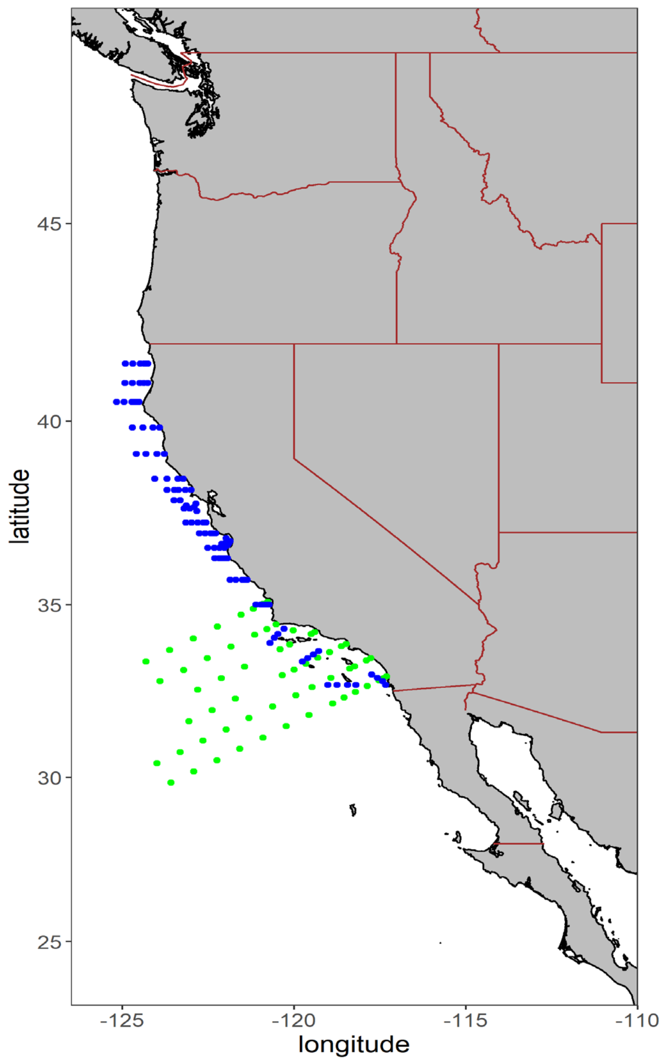

Figure 2-128. Locations of RREAS and CalCOFI sampling. RREAS locations are subdivided among North, North-Central, Core, North-Southern and Southern regions. The CalCOFI stations depict the 66 core stations that have been sampled regularly since 1951.

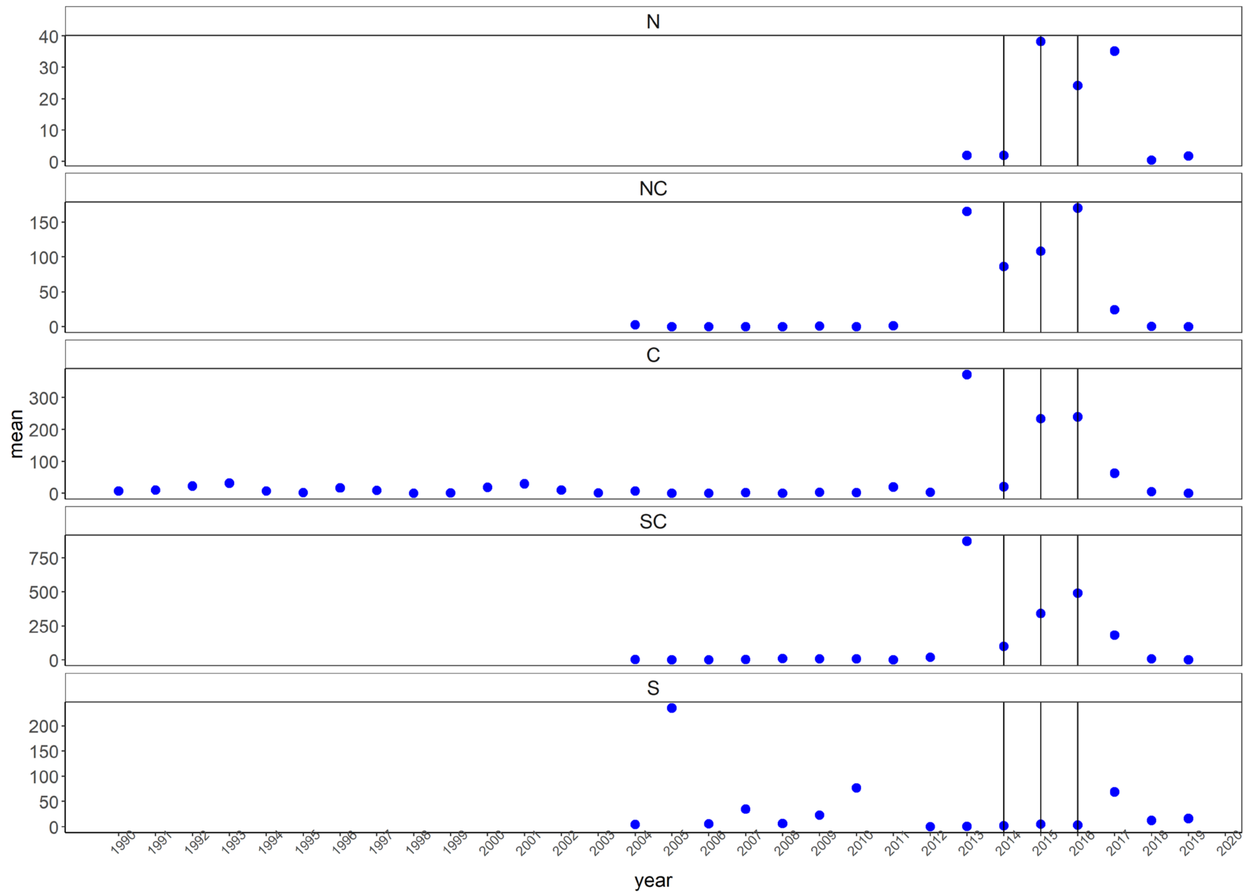

Figure 2-129. Mean abundance of young of the year shortbelly rockfishes from North (N), North-Central (NC), Core (C), South-Central (SC) and South (S) regions of the RREAS.

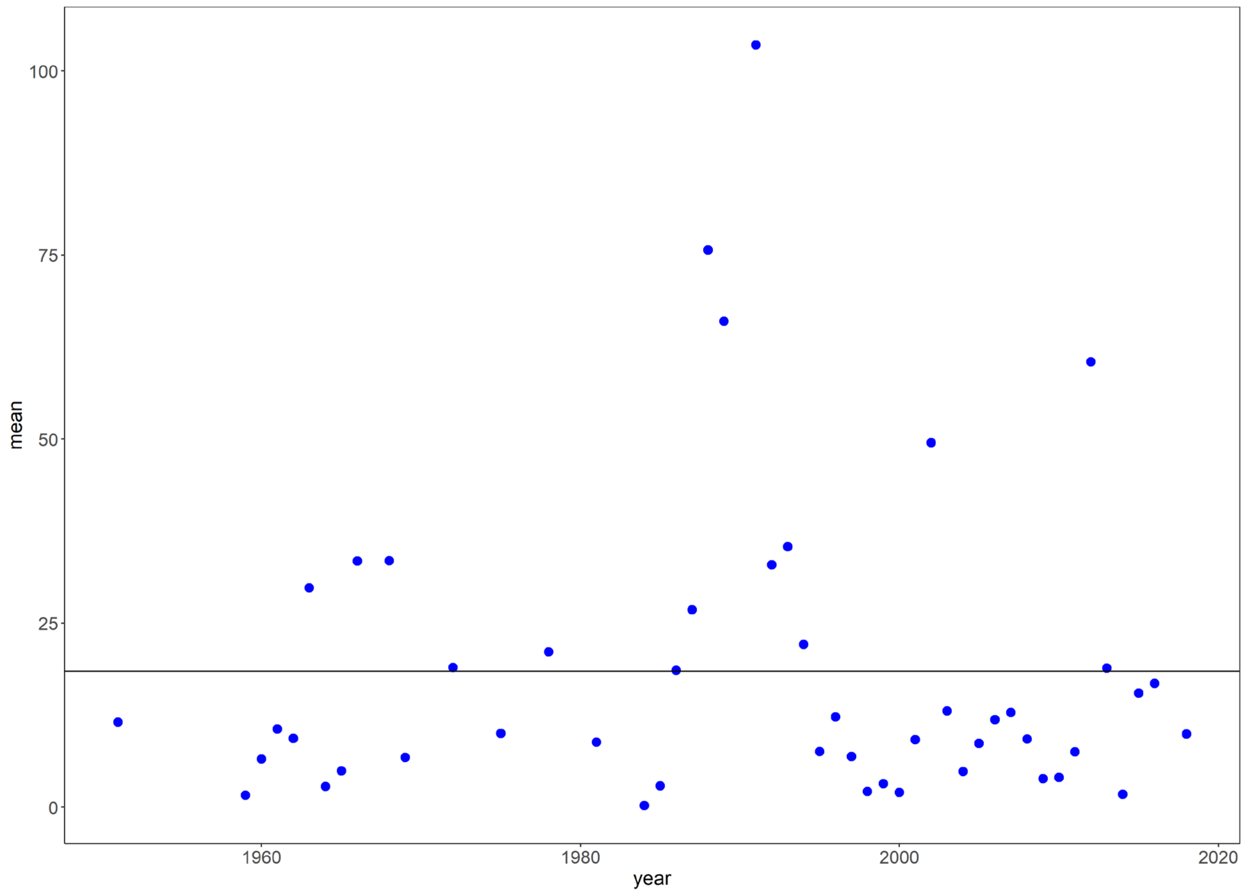

Figure 2-130. Mean winter larval shortbelly rockfish abundances from core CalCOFI stations from 1951-2018. Identification of 2017 abundances are not yet complete and 2017 data were excluded from the plot.

Schroeder et al. (2018) indicate that several strong recruitment years could continue to impact the midwater trawl fishery in 2020 and beyond. The 2018 and 2019 high bycatch levels were driven by relatively strong 2013 and 2014 year classes off central California. As the shortbelly rockfish recruits aged, they moved north into Oregon and Washington. Schroeder et al. (2018) show that 2013 was the highest recruitment anomaly of any rockfish in any year since records began in 1983 (Figure 2-131). If individuals from this record year class continue to remain in the north, off of Oregon and Washington, they will continue to be encountered as bycatch in coming years. Furthermore, Schroeder et al. (2018) show that there were also atypically high year classes in 2014, 2015, and 2016 that could start to become encountered as bycatch in 2019, and beyond.

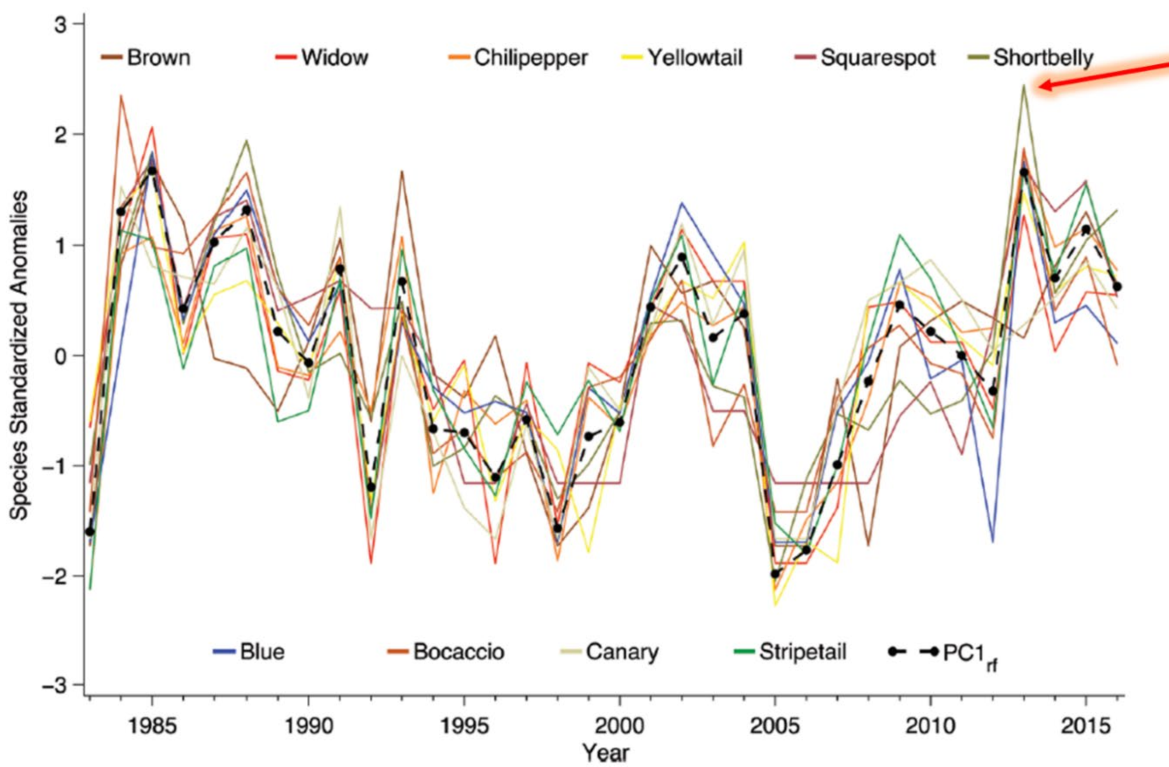

Figure 2-131. Standardized abundance anomalies of the top ten most abundant pelagic juvenile rockfish species and the common trend (Principal Component 1 rockfish; PC1rf) collected by the RREAS midwater trawls from 1983-2016 (this is figure 3 from Schroeder et al. 2018). The glowing red arrow is pointing to the 2013 standardized shortbelly rockfish anomaly.

Encounters of shortbelly rockfish in the NMFS West Coast Bottom Trawl Survey were also evaluated. While the bottom trawl survey does not deploy gear selective to a pelagic rockfish such as shortbelly rockfish, the relative encounter rate of shortbelly rockfish north and south in the survey over time shows there have been increased encounters of shortbelly rockfish in the survey off Oregon and Washington since 2013. In addition, there has been a significantly increased encounter rate in the north since 2017 without a coincident decrease in the shortbelly rockfish encounter rate off California (Figure 2-132). This supports the conclusion that the shortbelly rockfish population did not simply shift to northern waters and the relative abundance of shortbelly rockfish in waters off California has not decreased in recent years. Increased encounters of shortbelly rockfish in northern midwater trawl fisheries is more likely the result of increased recruitment and biomass coastwide coupled with an expansion of its geographic range on the West Coast. It is unclear whether this pattern of abundance and distribution will persist.

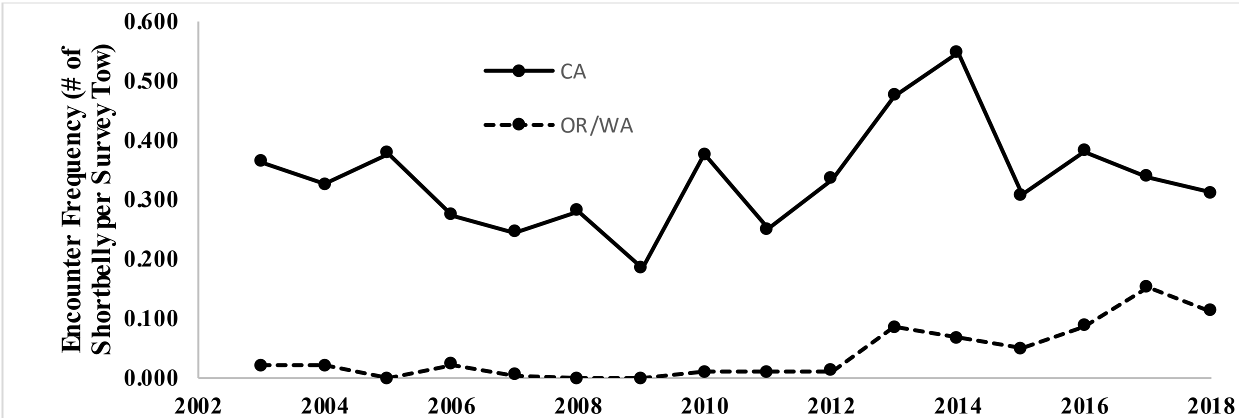

Figure 2-132. Encounter frequency (number of positive tows with shortbelly rockfish/total number of tows each year) of shortbelly rockfish in the NMFS West Coast Bottom Trawl Survey, 2003-2018.

The standardized abundance anomalies shown in Figure 2-131 from Schroeder et al. (2018) can obscure the massive strength of the 2013-2016 year classes and expected population boom. Standardized anomalies put all species on the same scale so that the data can be used in a multivariate Principal Components Analysis, but this can obscure true abundance variability. To better understand and put into context the actual abundance differences, RREAS abundance data from 1990-2016 for the 10 rockfish species analyzed by Schroeder et al. (2018) were used to calculate mean abundances for each species in each year using delta means (delta mean is a technique to calculate means for data that are zero-inflated). Evaluation of mean abundance rather than standardized anomalies illuminates the scale of shortbelly rockfish recruitment from 2013-2016 (Figure 2-133). Shortbelly rockfish mean recruit abundance in 2013 was 25 times higher than the next largest non-shortbelly rockfish yearly mean (chilipepper rockfish in 1993). Further, shortbelly rockfish recruitment in 2013 was more than three orders of magnitude (4,303) times higher than the average yearly recruitment among all rockfishes from 1990-2012. Each of the shortbelly rockfish recruitment classes from 2013-2016 were larger than any recruitment class for any species besides shortbelly rockfish from 1990-2012. Shortbelly rockfish recruitment and subsequent adult populations are currently the highest observed.

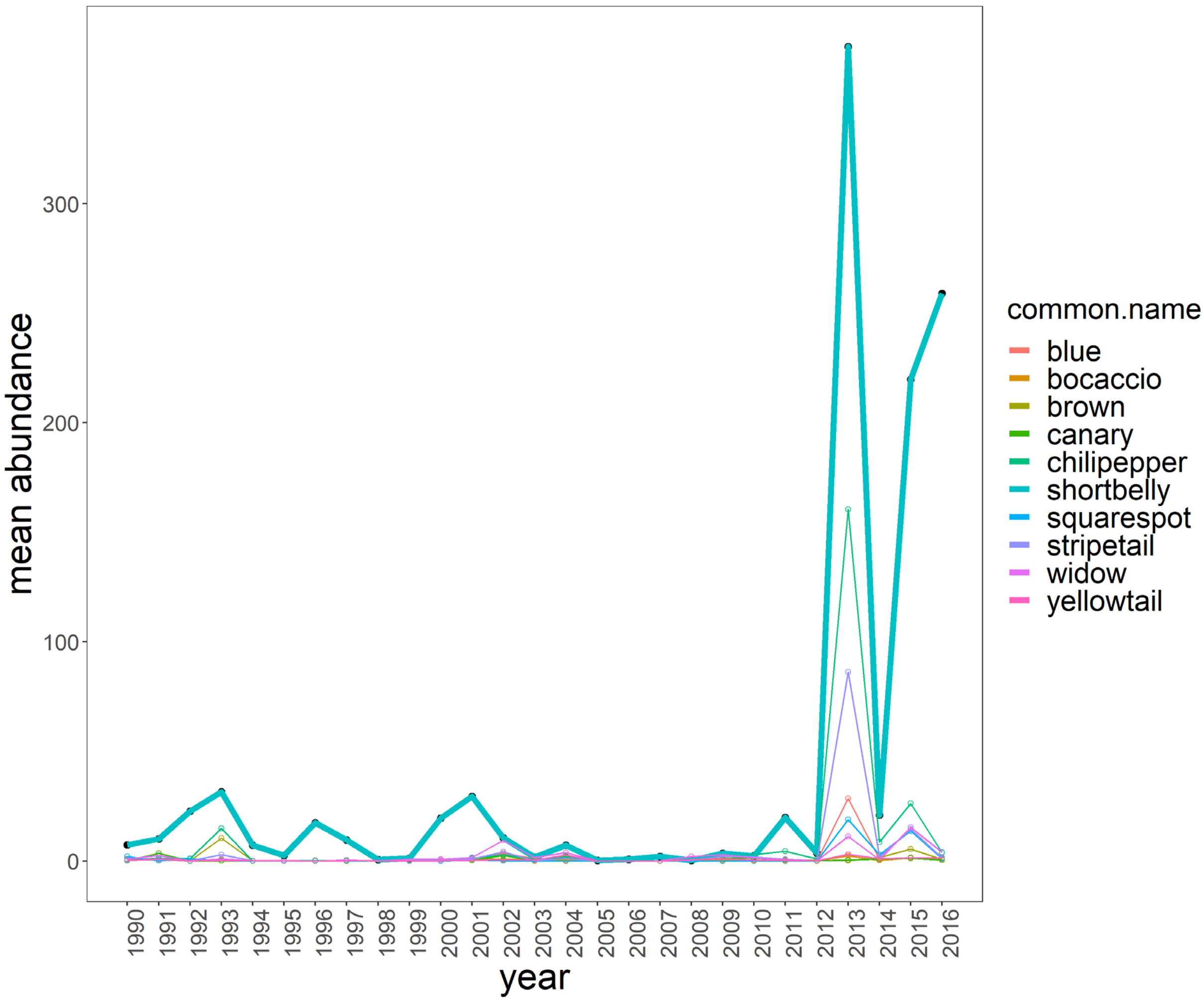

Figure 2-133. Mean yearly abundances, based on number of individuals per 15-minute tow time, from 1990-2016 for the ten rockfishes analyzed by Schroeder et al. (2018). The heavy, turquoise line depicts shortbelly rockfish.

Shortbelly rockfish recruitment in 2013 was 51 times higher than 2004 and 1,750 times higher than 2005. This suggests that shortbelly rockfish population sizes in 2019 may be on the order of 1,000 times greater than in 2005. The overall adult shortbelly rockfish population size is currently high and abundance will likely remain high over the next decade based on high recent recruitment. It is not fully understood why so many individuals moved north in recent years and whether this incursion will continue.

Fishing Mortality

Shortbelly rockfish are not targeted in any West Coast fisheries and were incidentally caught in very small amounts prior to 2017. Love et al. (2002) reported that shortbelly rockfish were commonly caught incidentally with trawl gear in the San Francisco-Monterey region during the development of the trawl fishery in the 1930s and 1940s when they were often referred to as steamer rockcod, as they tended to be common in the steamer lanes south of San Francisco. However, as a result of the small size and poor marketability, only modest domestic landings (1 to 65 mt per year) have been reported in the last 25 years. Historical landings were almost certainly less. Phillips (1939) reported that *S. jordani* accounted for 1 lb. out of 332,630 lbs examined in Monterey wholesale fish markets between 1937 and 1938. Nitsos (1965) reported trace amounts (approximately 1,000 lbs out of 1,920,000 lbs landed) of *S. jordani* landed in Monterey ports from trawlers in 1962-1963, but none were reported from ports other than Monterey. There was historically a short period in which large numbers of shortbelly rockfish were caught during the foreign fisheries of the 1960s and 1970s (Rogers 2003b). These landings (nearly 15,000 mt through 1976, over half of which was taken in 1966) were presumably incidental to the targeting of other rockfish and Pacific hake. Only in the early days of the foreign fisheries (the mid-1960s) were Pacific hake pursued in large numbers south of Cape Mendocino, which is when the bulk of documented historical landings of shortbelly rockfish occurred. Since the early 1970s the Pacific hake fishery has been prosecuted primarily off of Oregon and Washington, and to a lesser extent off of Northern California (generally north of Cape Mendocino).

The available data for historical bycatch rates of shortbelly rockfish are extremely sparse. Shortbelly rockfish had historically been caught incidentally, at times in large numbers, by trawlers targeting other pelagic rockfish (usually chilipepper and widow rockfish). As large hauls of shortbelly rockfish are not marketable but occasionally foul the mesh of typical groundfish trawls, more experienced fishermen generally recognize shortbelly rockfish sign (as well as habitat preferences) on their acoustics, and work to actively avoid schools. This is the challenge of the current midwater trawl fisheries' participants north of 40°10' N. lat. who have no previous experience with shortbelly rockfish. They must now learn to differentiate shortbelly rockfish schools on their sonars to avoid bycatch, which diminishes the value of their target catch of Pacific whiting and pelagic rockfish.

The current exploitation rate of shortbelly rockfish is unknown. However, evidence of recent strong recruitment and continued undiminished densities in its historically predominant habitats south of 40°10' N. lat., there is little apparent risk of current exploitation affecting the stock's function as an important forage in the California Current ecosystem.

2.6 Discard Mortality Rates Used to Manage West Coast Groundfish Stocks

Some groundfish species caught in the West Coast groundfish fishery are discarded at sea because they are incidentally caught, are not marketable (i.e., market-induced discards), are caught in excess of allowable cumulative landing limits, or are not of a legal size to keep (i.e., regulatory discards). Discard mortality rates (DMRs) are linked to the type of fishing practice or gear. Commercial trawl DMRs and fixed gear (e.g., hook and line, pot, etc.) DMRs vary by gear type/sector. It is important to note that midwater trawl gear does not typically have DMRs. Recreational fishery DMRs often differ from commercial DMRs; thus, a species may not exhibit the same DMR across all fisheries. The SSC recommended DMRs by gear type by species or species complex which were modeled in approved stock assessments to be used to manage the fishery. These DMR are also applied to estimated discards of these species to estimate total discard mortality when reconciling total mortality in West Coast groundfish fisheries. The DMRs are applied to end-of-year catch data to develop a total mortality amount for species in the Pacific Coast Groundfish FMP (Somers*, et al.* 2020).

2.6.1 Commercial Fisheries

As noted above, the West Coast commercial fishery utilizes multiple gear types to target the fishery resource. Each gear type, and resulting fishery practice, affects mortality rates of the discarded fish. The following discussion details the rationale for species and gear related DMRs. Table 2-12 shows the DMRs by commercial gear type (fixed and trawl) used in the most recent assessments for lingcod, big skate, longnose skate, sablefish, and spiny dogfish.

2.6.1.1 Lingcod

The GMT recommended using the 50 percent mortality rate for lingcod discarded in West Coast bottom trawl fisheries based on a study that evaluated tow duration and time on deck of trawl-caught lingcod that were ultimately discarded (Parker*, et al.* 2003). Additionally, Davis and Olla (2002) examined tow duration, air temperature, and increased air exposure on lingcod. This study showed increased air and water temperatures likely increase mortality in lingcod. Both the 2009 and 2017 lingcod stock assessment modeled the 50 percent DMR for discarded lingcod in trawl fisheries (Hamel*, et al.* 2009). The GMT recommended a seven percent lingcod DMR be used for the IFQ fixed gear and non-trawl fixed gear commercial fisheries (Table 2-12), qualified by being north or south of 40°10' N. lat. (Table 2-14 and Table 2-15), as well as discards in recreational fisheries (Table 2-17). These DMRs are based on a study off California evaluating immediate and delayed mortality of lingcod caught using these gears (Albin and Karpov 1996).

Quota pounds (QP) for lingcod caught and discarded in the trawl catch shares fishery are debited from IFQ accounts based on the gear-specific DMRs used in stock assessments and year-end catch accounting (Table 2-12). This change was implemented in 2019; previously 100 percent of the discarded lingcod QP were debited from accounts.

2.6.1.2 Big and Longnose Skate

No studies have been conducted to estimate DMRs for either big or longnose skate (or any other skate). In tagging studies conducted in Canada (Gordon McFarlane, Pacific Biological Station, Fisheries and Oceans Canada, pers. com. as cited in (Gertseva and Schirripa 2008)), tagged skates were recovered several times in trawl surveys, indicating that skates can survive trawl capture and on-deck sorting time. Anecdotal evidence from commercial fisheries also indicates that skates are generally durable and can handle capture and release well. However, many factors, such as trawl time, handling techniques, and time spent on the deck certainly affect skate survival. Gertseva and Schirripa (2008) assumed that 50 percent of commercially-discarded skates die in the 2007 longnose skate assessment. This DMR of 50 percent is assumed for these actively managed skate species, big and longnose skates, for bottom trawl fisheries (Table 2-12). These rates are not applied to bycatch in the pink shrimp trawl fishery.

2.6.1.3 Sablefish

Sablefish DMRs have been the subject of numerous research studies and analyses supporting historical sablefish stock assessments. Sablefish, lacking a swim-bladder (and therefore the propensity for severe barotrauma), have a very good chance of survival after capture depending on the specific conditions they experience during the process. Generally warmer water results in higher mortality, as the physiological stress of transitioning from very cold bottom temperatures to warmer surface water and air temperatures can be great (Davis*, et al.* 2001). Further, some gears, such as pot and hook and line gear, are less physically damaging to sablefish than, for example, spending an extended period of time in a trawl cod-end with a large catch volume. Treatment and handling of captured fish, including time-on-deck is also important for subsequent survival. The GMT reviewed the research studies informing sablefish discard mortality and recommended the mortality rates of 50 percent for trawl discards and 20 percent for fixed gear discards (Table 2-12); however, for age-0, regardless of fishery, the DMR is assumed to be 100 percent (Johnson et al. 2015). These rates are not applied in nearshore or pink shrimp fisheries. The 2015 update assessment (Johnson et al., 2015) followed the Stewart et al. (2011) assumed DMRs, by gear type of 50 percent for trawl discards and 20 percent for fixed gear discards.

QP for sablefish caught and discarded in the trawl catch shares fishery are debited from IFQ accounts based on the gear-specific DMRs used in stock assessments and year-end catch accounting (Table 2-12). This change was implemented in 2019; previously 100 percent of the discarded sablefish QP were debited from accounts.

2.6.1.4 Spiny Dogfish Shark

There have been no studies performed on discard mortality of spiny dogfish in the Northeast Pacific Ocean for the bottom trawl or the hook and line fleet. In spiny dogfish assessments conducted elsewhere, different values of discard mortality were assumed, from five percent to 50 percent for bottom trawl and from six percent to 75 percent for hook and line gears, but all sources noted considerable uncertainty in these estimates. Gertseva and Taylor (2011) assumed trawl discard mortality to be 100 percent and hook and line discard mortality to be 50 percent (Table 2-12). The WCGOP/FOS programs use the 50 percent rate for all longline gear in the IFQ, Pacific halibut derby and non-nearshore fixed gear sectors. These two programs assume a 100 percent mortality for all other sectors.

Table 2-12. Mortality rates applied in bottom trawl and fixed gear fisheries. Species without a rate listed for a given fishery and gear were assumed to have a 100 percent mortality rate. Source: Supplemental GMT Report June 2017

Species	Fishery	Gear	Discard Mortality Rate
Big Skate	California Halibut	Trawl	50%
	IFQ Bottom Trawl	Trawl	50%
	LE Bottom Trawl	Trawl	50%
Lingcod	California Halibut	Trawl	50%
	IFQ Bottom Trawl	Trawl	50%
	IFQ Fixed Gear	Line	7%
	LE Bottom Trawl	Trawl	50%
	Non-Nearshore Fixed Gear	Line	7%
	Pacific Halibut Derby	Line	7%
Longnose Skate	California Halibut	Trawl	50%
	IFQ Bottom Trawl	Trawl	50%
	IFQ Fixed Gear	Line and Pot	50%
	LE Bottom Trawl	Trawl	50%
	Non-Nearshore Fixed Gear	Line and Pot	50%
	Pacific Halibut Derby	Line	50%
Sablefish	California Halibut	Trawl	50%
	IFQ Bottom Trawl	Trawl	50%
	IFQ Fixed Gear	Line and Pot	20%
	LE Bottom Trawl	Trawl	50%
	Non-Nearshore Fixed Gear	Line and Pot	20%
	Pacific Halibut Derby	Line	50%
Spiny Dogfish Shark	IFQ Fixed Gear	Line	50%
	Non-Nearshore Fixed Gear	Line	50%
	Pacific Halibut Derby	Line	50%

2.6.2 Nearshore Discard Mortality Rates

Rockfish (*Sebastes* spp.), as well as other nearshore species, DMRs are dependent on the species, depth of capture, and gear type. The GMT updated the surface-release DMRs by depth for rockfish, and other co-occurring species, caught in nearshore commercial fisheries in (see Agenda Item I.2.a, GMT Report 1 and GMT Report 2, March 2017. The changes to the model were:

- Updating the gear proportions by depth with recent data.
- Calculation of regional DMRs to match the WCGOP estimation strata (i.e., north and south of 40°10' N. lat.).
- Utilized the Council approved changes to the "sport-like" surface DMRs.
- Incorporating a bias modifier to calibrate the gear proportions from WCGOP (a sub-sample of landings) to reflect the gear proportions from fish tickets in PacFIN.

The GMT assumed the same DMRs by depth and species for nearshore commercial fisheries using recreational hook and line gear (i.e., rod and reel gear) as recommended by the SSC for recreational fisheries (Table 2-13). For rockfish caught using non-recreational gear types (e.g., longline, dinglebar, etc.), a 100 percent DMR was applied by the GMT in their work on harvest specifications and management measures. Discard rates were weighted by depth bin for recreational and non-recreational gear types by the proportion of these gears types deployed in the Oregon nearshore commercial fishery using 2004-2006 Oregon logbook data (Table 2-13). The mortality rates in the deepest depth bin, >30 fm, as shown in Table 2-14, did not use the above prescribed method due to small sample sizes informing bycatch and discard at those deeper depths and are considered risk-averse. The combined weighted discard rates for all nearshore commercial gears by rockfish species and depth bin were updated in 2017 and qualified above or below the nearshore DMRs for rockfish, by depth, for commercial fisheries north and south of 40°10' N. lat. (Table 2-14 and Table 2-15).

Table 2-13. Proportion of recreational and non-recreational gears used in 2004-2006 Oregon nearshore commercial fisheries based on logbook data.

Gear Type	Depth Bin		
	0-10 fm	11-20 fm	>20 fm
Recreational	86.6%	72.3%	60.7%
Non-recreational	13.4%	27.7%	39.3%

Table 2-14 and Table 2-15 show the updated nearshore DMRs for rockfish species, by depth bins, for areas north and south of 40°10' N. lat. Table 2-16 shows the commercial nearshore DMRs for non-rockfish, co-occurring species, by depth.

Table 2-14. Nearshore discard mortality rates for rockfish, by depth, commercial fisheries north of 40°10' N. lat. Source: Supplemental GMT Report June 2017

Species	Depth Bins			
	0-10 fm	10-20 fm	20-30 fm	>30 fm
Black & Yellow Rockfish	20%	31%	52%	100%
Black Rockfish	18%	28%	46%	63%
Blue/Deacon Rockfish	25%	37%	57%	100%
Boccaccio Rockfish	26%	39%	59%	100%
Brown Rockfish	19%	30%	49%	100%
Calico Rockfish	19%	30%	49%	100%
Canary rockfish	27%	43%	65%	100%
China Rockfish	20%	31%	52%	100%
Copper Rockfish	26%	40%	61%	100%
Gopher Rockfish	26%	40%	62%	100%
Grass Rockfish	29%	50%	72%	100%
Kelp Rockfish	18%	27%	46%	100%
Olive Rockfish	39%	50%	68%	100%
Quillback Rockfish	27%	41%	64%	100%
Tiger Rockfish	26%	41%	63%	100%
Treefish	21%	32%	54%	100%
Vermilion Rockfish	26%	40%	62%	100%
Widow Rockfish	27%	42%	64%	100%

Species	Depth Bins			
	0-10 fm	10-20 fm	20-30 fm	>30 fm
Yelloweye rockfish	28%	45%	67%	100%
Yellowtail Rockfish	17%	25%	43%	50%

Table 2-15. Nearshore discard mortality rates for rockfish, by depth, for commercial fisheries south of 40°10' N. lat.

Species	Depth Bins			
	0-10 fm	10-20 fm	20-30 fm	>30 fm
Black & Yellow Rockfish	54%	65%	72%	100%
Black Rockfish	53%	63%	69%	96%
Blue/Deacon Rockfish	57%	67%	75%	100%
Boccaccio Rockfish	57%	68%	76%	100%
Brown Rockfish	54%	64%	71%	100%
Calico Rockfish	54%	65%	72%	100%
Canary rockfish	60%	73%	82%	100%
China Rockfish	58%	71%	79%	100%
Copper Rockfish	57%	69%	77%	100%
Gopher Rockfish	57%	69%	78%	100%
Grass Rockfish	59%	74%	84%	100%
Kelp Rockfish	53%	62%	69%	100%
Olive Rockfish	65%	74%	81%	100%
Quillback Rockfish	58%	70%	79%	100%
Tiger Rockfish	58%	70%	78%	100%
Treefish	55%	65%	73%	100%
Vermilion Rockfish	58%	69%	78%	100%
Widow Rockfish	58%	70%	79%	100%
Yelloweye rockfish	59%	72%	81%	100%
Yellowtail Rockfish	53%	61%	67%	94%

Table 2-16. Nearshore discard mortality rates for all depths in West Coast commercial fisheries (Somers, *et al.* 2020).

Species Group	Species	DMR
Ecosystem Component	Spotted Ratfish	7%
	Soupfin Shark	7%
	Sandpaper Skate	7%
	All other skates other than Longnose and Big Skate	7%
Other Fish Species	Big Skate	7%
	Cabezon (CA)	7%
	Cabezon (OR)	7%
	Kelp Greenling (CA)	7%
	Kelp Greenling (OR)	7%
	Lingcod	7%
	Longnose Skate	7%
	Spiny Dogfish Shark	7%
Flatfish	Butter Sole	7%
	Pacific Halibut	7%
	Pacific Sanddab	7%
	Petrale Sole	7%
	Rock Sole	7%
	Sand Sole	7%

2.6.3 Recreational

The GMT analyzed the disposition of observed discards of groundfish species released at the surface of recreational charter fishing efforts off California and Oregon to determine depth-based DMRs using recreational hook and line gear. The GMT considered “surface” mortality (i.e., mortality that is observable when a fish is brought to the surface, handled on deck, and thrown back) from charter observations, as well as short-term, below-surface mortality that has been documented in research trials to a limited extent using underwater cameras or divers. Using a guild-based GLM analysis comparing mortality rates of species with similar depth-distributions and vertical orientation in the water column, the GMT determined mortality rates for species with limited discard observations. The GMT calculated the upper 95 percent confidence intervals of surface mortality rates to illustrate the uncertainty associated with GLM predictions. Since upper 95 percent confidence limits for surface mortality approach 100 percent at depths greater than 30 fm, mortality beyond this depth was assumed to be 100 percent. The two exceptions to this approach were yellowtail and black rockfish, given their relatively low mortality rates. The depth-based discard mortality matrix developed by the GMT shows a wide variation in rockfish mortality rates by depth reflecting the diversity of rockfish adaptations to barotrauma (Table 2-17). Yellowtail and black rockfish, which are more pelagic than most of the other rockfish, tend to suffer less barotrauma and therefore exhibit lower surface-release mortality rates.

Estimates of surface release discard mortalities for groundfish species that lack a swim bladder (e.g., lingcod and flatfishes) were based on research efforts off California (Albin and Karpov 1996). The seven percent DMR is assumed for such species; however, the analysis only considered FMP species lacking a swim bladder and therefore the seven percent DMR does not apply to non-FMP species. The resulting depth-based surface release mortality rates for various groundfish species released using recreational hook and line gears were implemented in 2009 to determine discard mortalities (Table 2-17).

Table 2-17. Discard mortality rates by depth of groundfish species released at the surface in West Coast recreational fisheries using hook-and-line gear.

Species Group	Species	Depth Bin			
		0-10 fm	11-20 fm	21-30 fm	>30 fm
Rockfish	Black Rockfish	11%	20%	29%	63%
	Black-and-yellow Rockfish	13%	24%	37%	100%
	Blue Rockfish	18%	30%	43%	100%
	Bocaccio	19%	32%	46%	100%
	Brown Rockfish	12%	22%	33%	100%
	Calico Rockfish	24%	43%	60%	100%
	Canary rockfish	21%	37%	53%	100%
	China Rockfish	13%	24%	37%	100%
	Copper Rockfish	19%	33%	48%	100%
	Gopher Rockfish	19%	34%	49%	100%
	Grass Rockfish	23%	45%	63%	100%
	Kelp Rockfish	11%	19%	29%	100%
	Olive Rockfish	34%	45%	57%	100%
	Quillback Rockfish	21%	35%	52%	100%
	Tiger Rockfish	20%	35%	51%	100%
	Treefish	14%	25%	39%	100%
	Vermilion Rockfish	20%	34%	50%	100%
	Widow Rockfish	21%	36%	52%	100%
	Yelloweye rockfish	22%	39%	56%	100%
	Yellowtail Rockfish	10%	17%	25%	50%
Other Fish	Cabezon	7%	7%	7%	7%
	California scorpionfish	7%	7%	7%	7%
	Kelp Greenling	7%	7%	7%	7%
	Lingcod	7%	7%	7%	7%
	Pacific Cod	5%	32%	53%	97%
General Cat.	Flatfish	7%	7%	7%	7%
	Sharks and Skates	7%	7%	7%	7%
	Dogfish	7%	7%	7%	7%

2.6.4 Pacific Halibut Discard Mortality Rates

Pacific halibut are managed by the IPHC and they establish DMRs for use in the fishery at-large. There are considerable data on post-release survivorship of Pacific halibut and the IPHC has established release viability condition codes, which can be translated into DMRs. These condition codes are assigned to discarded halibut by observers when they asses the condition of Pacific halibut upon release (West Coast Groundfish Observer Program Manual). Condition codes are specific to fishery gear, but, in general, contain three condition codes: excellent, poor, or dead.

In 2017, the Council tasked the SSC to review the GMT's proposed methodology for determining Pacific halibut DMRs for camera-based - (EM) as historically halibut caught on EM trips were assigned 90 percent mortality (corresponding with the dead viability category) because video reviewers could not determine the condition of the halibut using the IPHC key, as it requires hands-on assessment. Given that the 90 percent DMR is conservative compared to the observer viability approach, and because halibut bycatch can be constraining, the Council requested development of alternative EM DMRs that better reflect the estimated mortality of the halibut discarded on EM trips and more closely align with the rates used on observed trips. The GMT presented a time-on-deck methodology, which was endorsed by the SSC, for halibut discarded on bottom trawl trips (Agenda Item F.11.a, GMT Report 1, November 2017).

In terms of management and catch accounting, for IFQ bottom trawl trips north of 40°10' N. lat. with onboard observers, discarded Pacific halibut are debited from the vessel's individual bycatch quota account based on the viability of the discarded fish. Whereas on EM EFP trips, the rates vary by gear type. For bottom trawl trips, the DMR is based on time on deck. For discarded halibut on non-whiting midwater trawl trips, they are assigned the default IPHC mortality rate of 90 percent mortality for optimized retention trips and a 100 percent mortality for maximized retention trips.

2.6.5 Descending Devices

Research on rockfish barotrauma mitigation for canary rockfish, cowcod, and yelloweye rockfish was evaluated to determine depth-based mortality rates associated with release using descending devices. Recent research has shown the effects of barotrauma can be mitigated in physoclistous (i.e., the swim bladder is not connected to the alimentary canal via a pneumatic duct) fish such as rockfish by releasing them at depth by using descending devices (Hannah, *et al.* 2012; Jarvis and Lowe 2008; Parker, *et al.* 2006; Pribyl, *et al.* 2012). The GMT determined depth-based DMRs associated with the use of descending devices for these stocks in a Bayesian Hierarchical model that considered the uncertainty of using other species as a proxy for these three, as well as the uncertainty associated with missing observations in one or more depth bins. They also calculated the upper 60 percent, 75 percent, 90 percent, and 95 percent confidence intervals so the Council could choose their preferred level of risk tolerance, given the uncertainties characterized in the analysis. The Council decided to recommend the mortality estimates calculated for these three stocks at the 90 percent upper confidence interval (Table 2-18). The Council also explained that these rates may be revised in the future as more research emerges informing survival of rockfish released at sea using descending devices. The Council also asked that these rates be applied retrospectively in recreational fisheries to estimate total mortality of these species for those samples where adequate sampling information exists.

Table 2-18. Discard mortality rates by depth of canary rockfish, cowcod, and yelloweye rockfish released in West Coast recreational fisheries using descending devices.

Depth (fm)	Canary rockfish	Cowcod	Yelloweye rockfish
0-10	21%	21%	22%
10-20	25%	35%	26%
20-30	25%	52%	26%
30-50	48%	57%	27%
>50	100%	100%	100%

2.7 Impact Projection Models

2.7.1 Non-Nearshore Model

The non-nearshore model projects bycatch impacts for limited entry and open access fixed gear vessels that are fishing seaward of the non-trawl Rockfish Conservation Area (NT_RCA). The main focus is on bycatch of yelloweye rockfish. This model was reviewed by the Pacific Fishery Management Council's SSC in 2013 and endorsed as "best available science and appropriate for use in the 2015-16 specifications process." (Agenda Item F.7.b, Supplemental SSC Report, June 2013 West Coast Groundfish Observer Program (WCGOP) observations on discards and landed catch 2002-2021 provide the primary data input for estimating bycatch with Pacific Fishery Information Network (PacFIN) fish ticket data also providing information on the distribution of catch among gear types. Data from 2021 were the most recent data available at the time of the analysis. The core structure of the projection model has not been changed from 2019-2020 biennial process. The model is fully documented as Appendix D to the Pacific Coast Groundfish Fishery 2019-2020 Harvest Specifications and Management Measures.[12]

As also described in the analytical document (Agenda Item F.1, Attachment 7, June 2020), sablefish is the primary target for vessels fishing in these sectors. The sablefish (*Anoplopoma fimbria*) annual catch limit (ACL) north of 36° N. lat. Is apportioned according to the formal intersector allocations shown in Figure 1-3. Management measures are intended to keep the total mortality—i.e., discard mortality and landings—within the allocation for each sector. Because of the economic importance of sablefish, the bycatch impact analysis assumes that the annual sablefish allocation will be fully attained by the fixed gear fleets seaward of the NT_RCA. WCGOP bycatch observations are therefore expressed as a ratio to the expected landings of sablefish.

[12] The 125 and 150 fathom projection bins were removed for 2019-2020 as yelloweye rockfish bycatch has been fairly static in the fishery and if an issue were to arise inseason, the PFMC Groundfish Management Team (GMT) would assess the movement of the line at that time with the most recent data.

The model continues to combine data from the fixed gear sablefish fishery north of 40°10' N. lat. and 40°10' to 36° N. lat. from the years 2002-2021. Data from each year is weighted equally. There are tradeoffs with data accuracy and precision involved with stratifying observations to finer levels across attributes (i.e., time, area, depth, and gear type). Aggregating data across years allows reporting of retained and discarded catch of groundfish species by gear type at a finer latitudinal and depth scale than would otherwise be possible. Differences in the encounter rate of yelloweye rockfish (and previously canary rockfish) between depths and areas are the major focus of the model and so these stratifications have taken priority. The data is stratified by gear because of the differences in the rate of encounter between pot and longline gear types.

Data summarizing observed retained and discarded catch from fishing efforts north of 40°10' N. lat. are stratified across three alternative depth ranges that are used to evaluate the potential impact of extending the seaward boundary of the NT_RCA on bycatch levels. As described in the Agenda Item F.6, Attachment 2, June 2022, the seaward NT_RCA boundary is the key bycatch management measures in these non-nearshore sectors. Although the range of depths recorded for an individual fixed gear set by observers is commonly much smaller than for observed trawl tows, there is some uncertainty in the assignment of catch and discard from many sets to a specific 25 fm interval. For this exercise, the average of the beginning and ending depths of each set was used to represent the depth at which all fish on the set were caught.

The area stratification used in this model was developed first for use in the 2009-10 biennial management cycle. This stratification was arrived at through consideration of canary rockfish and yelloweye rockfish bycatch north of 40° 10' N. lat. by depth and area and provides the Council with the option of employing differential seaward RCA boundaries within these areas. Four subareas were identified bounded by: 1) Cape Mendocino 40°10' N. lat. to the boundary of the northern Eureka International North Pacific Fishery Commission (INPFC) statistical area at 43°30' N. lat.; 2) Northern Eureka INPFC boundary to Cascade Head at 45°03' N. lat.); 3) Cascade Head to Point Chehalis (46°54' N. lat.), and 4) Point Chehalis to the U.S.-Canada border (49° N. lat.). Several alternative boundaries were evaluated. Analysts determined that the four listed above provided the greatest contrast and reliability between areas of high and low yelloweye rockfish bycatch. Since rockfish bycatch in the pot gear fleet is small and there are limited numbers of pot gear observations in some areas, results for this group are summarized with respect to depth only (without subareas). Note at the beginning of the 2017-2018 biennium, the seaward boundary of the NT_RCA was moved from 150 fm to 125 fm in the area between 34°27′ N. lat. and 40°10′ N. lat.

To produce estimates of catch by area, the model must assume a distribution of sablefish catch north of 40°10' N. lat. and in the area between 40°10' N .lat. and 36° N. lat. by gear types (longline vs. pot) for both the open access and limited entry sectors. The assumed distribution is based on fish ticket landings for the years 2002-2021. The 2002-2021 average of WCGOP observed landings are then used to project the distribution of the longline catch north of 40°10' N. lat. among the four management subareas. The model then applies WCGOP observed discard rates to these projected catch distributions using the appropriate area, depth, and gear stratification to produce annual estimates of discard for the rebuilding rockfish (e.g., yellowtail rockfish) encountered by the non-nearshore fixed gear sectors. Discard rates were calculated by dividing the total observed discard weight for each species by the weight of retained sablefish. Data is available for all species encountered in the non-nearshore sectors; yet focuses on yelloweye rockfish and the potential need to adjust the seaward boundary of the NT_RCA to lower their catch. The total mortality of other groundfish species discarded and landed by these sectors is reviewed and accounted for annually and will be addressed if catch reaches levels where a sector allocation or other catch limit is at risk of being exceeded. If necessary, the structure and data in this model could be used to project bycatch of species for which discard becomes a concern in the non-nearshore sectors.

2.7.1.1 Sablefish Daily Trip Limit Model Description

The models used to project sablefish landings by the Limited Entry Fixed Gear (LEFG) and Open Access (OA) Daily Trip Limit (DTL) sectors are multiple linear regression models that use trip limits and or expected inflation-adjusted sablefish price per pound to predict bimonthly landings, separately for each sector. They are also used for inseason management. Detailed descriptions of the models can be found in Appendix A of the 2011-2012 harvest specifications EIS. The models were originally produced by members of the GMT, Oregon Department of Fish and Wildlife (ODFW), National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center (SWFSC), and Northwest Fisheries Science Center (NWFSC) in 2006 (LEFG) and 2009 (OA). Changes in model specification are made as needed over time to increase accuracy of projections where possible. Changes since the 2017-18 harvest specifications include: new landings data through 2021 were added to all four models. The time range of data included in each model varies from 2011-2021, to 2015-2021, depending on its information content for making projections. Due to COVID-related impacts in 2020, historical landings from 2021 in the OA sector north of 36° N. lat. were weighted twice as high as those from 2020 and 2019, with data from 2018 and earlier given even lower weights. Accuracy of prediction varies among the four models. Of the four, the best fit of predicted to actual bimonthly landings is produced by the model for the LEFG sector north of 36° N. lat. (LEN), with an R2 value of 0.8059. Using the most recent data, the worst fit between predicted and actual landings comes from the model for the OA sector north of 36° N. lat. (OAN), with an R2 value of 0.3038. However, in spite of the relatively low model fit, landings in the OAN sector have been less than 23 percent of the landings target since 2017, and, therefore, there is little concern of exceeding the landing share. Prediction outputs and input variables for each of the DTL sectors are shown in Table 2-19.

Table 2-19. Predictions, outputs, and input variables for each of the sablefish DTL models.

Sector	Prediction Output	Regression Inputs
LEN	Landings per boat	Weekly trip limit + bimonthly trip limit
	# of vessels	Price (inflation adjusted) + weekly trip limit
OAN	Landings per boat	Weekly trip limit
	# of vessels	Period adjuster + weekly trip limit
LES	Total fleet-wide landings	Weekly trip limit + price (inflation adjusted)
OAS	Landings per boat	Bimonthly trip limit + weekly trip limit
	# of vessels	Bimonthly trip limit + weekly trip limit

2.7.1.2 Model Input Data

Landings and catch data were acquired from PacFIN Comprehensive FT database using the "GMT Sablefish Flags." This flag initially assigns vessel-daily landings data to each sector based on the fields described in https://pacfin.psmfc.org/wp-content/uploads/2022/05/PacFIN_Comprehensive_Fish_Tickets.pdf.

All sablefish landings are required to be reported on electronic fish tickets. For the LEN sector, the software tracks landings accumulation by vessel against their sablefish endorsed tier permits. If the vessel has active sablefish endorsed primary tier permits attached, the season is open, and there is room on the attached permits, landings are counted as primary. When either the tier permits on the vessel are exhausted or the season ends, landings are then counted as DTL. The algorithm in the software adheres to the specific Federal regulations concerning primary and DTL landings in 50 CFR 660.232. If a vessel is not landing against a tier permit but has a fixed gear endorsement (with or without a trawl endorsement), then it is landed in LE. If only a trawl endorsement is present, it is OA. To separate by area, all landings south of the INPFC Conception area (Mexico/U.S. border to Point Conception) are counted against the limits south of 36° N. lat., while all other landings are considered north of 36° N. lat.

Table 2-20. PacFIN codes used to assign vessel-daily landings and catch data to each sector.

Field	Value	Description
Council_Code	**P**	**PFMC only**
Is IFQ landing	**F**	**No IFQ landings included**
PacFIN Species Code	**SABL**	**Sablefish Only**
Round_weight_lbs	**>0**	**Must have landed at least 1 pound of sablefish**
Participation group code	**C**	**Commercial tickets only**
Removal type code	**Not in "R" or "E"**	**Not research or EFP**
PacFIN group gear code	**Not in "TWL" or "TWS"**	**No trawl gear used**

2.7.1.3 Accounting for Discards and Discard Mortality

The sablefish catch share for the LEFG sectors north of 36° N. lat. is divided amongst the primary sector and the DTL sector, the latter of which is reduced to account for discard mortality by multiplying the DTL catch share by 19 percent (observed discard rate estimate) and by 20 percent (discard mortality rate estimate), resulting in the LEN landings target. The same rates are applied to the OA DTL sector north of 36° N. lat. catch share. For the sectors south of 36° N. lat., the observed discard rate is 9 percent, and the same discard mortality rate is applied (20 percent). Landings should fall within the sector-specific landings targets in order to ensure that the total harvest guideline is not exceeded. The GMT compares model-projected landings to each sector's landings target to set appropriate trip limits. The estimated discard rate used by the GMT was calculated using the report "Estimated Discard and Catch of Groundfish Species in the 2020 US West Coast Fisheries" by Somers et al. (2021). The discard mortality rate estimate was taken from information in Davis (2001) and Schirripa and Colbert (2006). Schirripa (2008) used experimental data and sea surface temperature to predict varying release mortality by gear. The GMT considered that Davis (2001) demonstrated high sensitivity to temperature and deck time, and that Schirripa and Colbert (2006) demonstrated high variability of predicted discard mortality informed by sea surface temperature data, and adopted an estimate of 20 percent. This value was also used in the 2021 update assessment (Kapur*, et al.* 2021).

2.7.2 Nearshore Model

The Nearshore fishery comprises small vessels operating off the coasts of Oregon and California operate under state limited entry programs but are also considered Federal OA vessels as they harvest federally-managed species. While the fishery predominately caters to the live fish markets as they receive much greater prices for live "plate-sized" fish, there is also a smaller secondary component that caters to the fillet markets. Federally-managed species that comprise the fishery are nearshore rockfishes, lingcod, cabezon, California scorpionfish, and kelp greenling.

In terms of catch accounting, all landings for the nearshore fishery are recorded on fish tickets. However, discard mortality has to be estimated since less than 20 percent of total trips are observed each year. To estimate total discard mortality for both observed and unobserved trips, discards from the portion of observed trips are applied to the unobserved trips by the WCGOP. This same general approach is also used to project future discard mortality for the nearshore (described in greater detail below).

2.7.2.1 Methods for Projecting Nearshore Landings and Discard Mortality

Separate approaches are used to project future landings and discard mortality for the nearshore fisheries. Landings are projected using three different approaches: (1) full attainment of landings targets is assumed for high attainment stocks (e.g., Oregon black rockfish); (2) via trip limits models for stocks where changes are proposed (e.g., lingcod and canary rockfish); and (3) via trend analysis (including averages where trend is flat) for low attainment stocks of which regulations are similar to the past.

To project total economic value associated with nearshore landings, the total ex-vessel price (i.e., paid to the fishermen) associated with these landings is expanded to include the "multiplier" effects that these landings also generate to processors, fishery-related businesses (e.g., boat yards), and coastal communities in general. In short, the value generated by fishing extends far beyond just the price paid to fishermen. These secondary effects of additional value as fish sale proceeds trickle throughout coastal communities are generated using the IO-PAC model (not just for the nearshore fishery, but for all fisheries).

Future discard mortality projections are produced by the nearshore model, which was designed to directly mimic the procedures used by WCGOP to estimate post-season "actual" catch. This mimicry is important since the WCGOP estimates are the official mortality source used in the management of the nearshore fishery. Mismatches would compromise the ability of the model to reliably produce projections to meet management objectives.

The GMT concluded that the main source of inaccuracy with the nearshore model has been very high volatility in annual bycatch rates that are used by WCGOP for estimates of catch. Since the annual bycatch rates fluctuate by a large degree from year to year and cannot be accurately predicted at this time, this means that the bycatch rate inputs from the nearshore model that are based on averages will oftentimes differ from the annual bycatch rates (and sometimes by large degrees).

The main issue with the nearshore model has therefore been an overreliance in the accuracy of the point estimate projections. Until the annual bycatch rates can be better predicted, the nearshore model projections should be only viewed as “ball-park” estimates. The GMT has developed a preliminary bootstrap model to project the uncertainty associated with future nearshore projections, but more work needs to be done until it can be used for management purposes.

In regards to methodology, the nearshore model uses a multi-species bycatch rate approach that is depth- and area-specific (described in detail in 2009-2010 FEIS). A walk-through of how the model works is provided in Table 2-21.

Table 2-21. Estimation process and data sources used in the nearshore model to project discard mortality of overfished rockfish.

	STEP 1:				STEP 2:	STEP 3:				STEP 4:				STEP 5:				STEP 6:				STEP 7:			
	Bycatch rates by depth from WCGOP observed trips				Users enters projected Landings of targets	Depth of Landings provided by WCGOP				Landings of each species split by depth = Step 2 x Step 3. Then summed (black shading)				Discarded mt computed = Bycatch rates (Step 1) by depth applied to sum of landings by depth				Discard mortality rates applied to discarded mt (from step 5)				Discarded mortality by depth = Step 5 x Step 6. Sum is the total mortality			
	Depth bin (fathoms)					Depth bin (fathoms)				Depth bin (fathoms)				Depth bin (fathoms)				Depth bin (fathoms)				Depth bin (fathoms)			
	0-10	11-20	21-30	30+		0-10	11-20	21-30	30+	0-10	11-20	21-30	30+	0-10	11-20	21-30	30+	0-10	11-20	21-30	30+	0-10	11-20	21-30	30+
Bycatch stock																									
Yelloweye Rockfish	0.003	0.012	0.043	0.003	0.000	53.6%	46.4%	0.0%	0.0%					0.318	1.533	0.196	0.005	28%	45%	67%	100%	0.089	0.690	0.131	0.005
Target stocks																									
Black Rockfish					120.000	47.1%	51.0%	1.4%	0.5%	56.53	61.16	1.69	0.62												
Cabezon					23.385	40.6%	55.9%	3.2%	0.2%	9.51	13.08	0.75	0.05												
Lingcod					65.000	37.5%	59.5%	2.1%	0.9%	24.40	38.65	1.34	0.61									**TOTAL MORTALITY = 0.915 MT**			
Black and Yellow Rockfish					0.017	0.0%	42.9%	57.1%	0.0%	0.00	0.01	0.01	0.00												
Blue/Deacon Rockfish					7.458	26.3%	70.6%	2.6%	0.6%	1.96	5.26	0.19	0.04												
Brown Rockfish					0.017	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00												
China Rockfish					6.498	30.5%	65.1%	3.7%	0.7%	1.98	4.23	0.24	0.04												
Copper Rockfish					1.007	38.1%	58.7%	3.2%	0.0%	0.38	0.59	0.03	0.00												
Gopher Rockfish					0.045	78.2%	21.8%	0.0%	0.0%	0.04	0.01	0.00	0.00												
Grass Rockfish					0.222	100.0%	0.0%	0.0%	0.0%	0.22	0.00	0.00	0.00												
Nearshore Rockfish Unid					0.000	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00												
Olive Rockfish					0.000	57.1%	42.9%	0.0%	0.0%	0.00	0.00	0.00	0.00												
Quillback Rockfish					1.307	17.1%	70.2%	11.8%	1.0%	0.22	0.92	0.15	0.01												
Greenling Unid					0.000	29.6%	70.4%	0.0%	0.0%	0.00	0.00	0.00	0.00												
Kelp Greenling (Oregon)					18.144	49.7%	49.2%	1.0%	0.2%	9.01	8.92	0.18	0.03												
Painted Greenling					0.000	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00												
						Total landings by depth =				104.3	132.8	4.6	1.4												

2.7.3 *Individual Fishing Quota Projection Model*

2.7.3.1 Introduction

The role of this model is to produce two outputs for use in the biennial harvest specifications and management measures package: 1) projections of total annual IFQ sector fishing mortality (hereafter referred to as "catch" or "total catch") of each stock under a suite of allocations and 2) projections of annual vessel-level landings for input to the Commercial Fisheries Landings Distribution Model, followed by the IO-PAC for subsequent economic analysis. The model is not intended as an inseason management tool. The model projects catch of IFQ stocks only; stocks managed with trip limits are not included.

Catch projections are produced using a combination of three methods based on attainment of vessel quota, average annual vessel catch, and bycatch of non-target species. The fishery is stratified into two fleets (whiting vs. non-whiting) with separate sets of predictions based on the proportion of Pacific whiting caught on each trip. Corresponding uncertainty estimates are produced as bootstrapped 95 percent prediction intervals. The model is written in R. See Matson et al. (2017) for a full description of all but the bycatch module. The bycatch module was adapted to the Matson et al. (2017) model for the 2019-2020 harvest specifications cycle.

2.7.3.2 Methods

Inputs to the model include catch data at the fishing trip level for each vessel (with separate landings and discard estimates for each stock), IFQ quota pounds (QP) data for each vessel, annual fishery allocation amounts for each IFQ stock, and proposed fishery allocations ("alternatives") under which catch is to be predicted. Each alternative consists of a set of proposed values for future allocations of quota pounds to the fishery, with a single fishery-level value for each stock. Fishery-level quota pounds from the alternative are then distributed among vessels, according to the fleet allocation distribution in the most recent year. Fleet size (i.e., number of vessels participating in the fishery) for the prediction year is assumed to be the same as in the most recent year of data available.

The bycatch method employed predicts catch of each designated bycatch species using weighted average annual vessel-specific bycatch rates according to their ratio to aggregate target catch in shelf or slope species groups. Each of the 30 species categories is designated as "target" or "bycatch" and "shelf" or "slope" in the model input files. Those estimated bycatch rates are then used to project mortality of bycatch species, according to the predicted catch amounts for appropriate target stocks. Uncertainty is estimated in the same way for bycatch species as for target stocks, which is using bootstrap-simulated distributions.

2.7.3.3 Input Data, Configuration, Tuning, and Fit

Model input data were queried from the NMFS IFQ Program Vessel Account System, including debited catch (with WCGOP-estimated discard mortality rates applied) and quota data, and were aggregated to the vessel-species-year level. Data were queried on December 18, 2021 for the shorebased whiting IFQ sector (roughly one month after targeted whiting fishing in that sector had concluded) and January 3, 2022 for the non-whiting IFQ sector, since fishing in the non-whiting fleet continues year-round. Querying on these two days enabled the use of complete catch data through the most recent available data year (2021) in the model for both fleets and enabled work to commence on the whiting fleet first (during December) for practical workload management.

The model was configured with two fleets: shorebased whiting and non-whiting. Trips in which total catch was greater than or equal to 50 percent Pacific whiting were designated as "whiting" trips, which is consistent with Federal regulations. All other trips were designated as "non-whiting" trips. Trips were defined as vessel days, which eliminated problems with split tickets, and total catch was used to define fleets rather than landings.

Years 2016 through 2021 were used as reference data for the model this cycle. After running hindcasts for a range of weighting schemes (linear, exponential, uniform, etc.), years 2019 through 2021 were equally weighted at 1,000 times that of 2016 through 2019, which produced the best fit in hindcasts (tied with an exponential weighting scheme). This also produced lower residuals for both sablefish and lingcod, the two target species with the most variation among allocations. The result was typical in that the most recent data normally produce a better fit by capturing current attainment trends among species, market conditions, etc. Although the low level of catch in year 2020 was unprecedented for the groundfish fishery overall, including IFQ (particularly non-whiting), the fishery has not yet shown a full return to pre-pandemic catch and attainment levels. Thus, uniform weighting of the pre-pandemic year of 2019 together with 2020 and 2021 was thought to be a reasonably balanced approach for modeling near-term future catches.

Allocation values for Pacific whiting and Pacific halibut were fixed at 2021 levels as placeholders, because the stocks are internationally managed outside the Council process. Thus, the predictions for the shorebased whiting fleet, including bycatch species, are uniform among alternatives. Since the prediction for targeted Pacific whiting in the whiting fleet is fixed, bycatch predictions are also invariant among alternatives. Predictions for the non-whiting fleet were modeled separately for each alternative and did vary accordingly with each stock's typical response to changes in allocations.

The model uses three different prediction methods, including attainment, average catch, and bycatch rate-based approaches. The choice between attainment and average catch methods is mediated by a parameter, while bycatch species are designated a priori and are modeled using bycatch rates and computed using either shelf or slope groups of target stocks as designated. The attainment threshold parameter (ATP), which informs the model on how to choose between employing the attainment-based or average historical catch-based projection method, was optimized for each stock separately. Initial settings of the ATP were accomplished using 1 minus the R-squared value of catch versus allocation of each species so that species whose catch shows a high correlation with allocation were predicted predominantly using the attainment-based method (along a continuum), while the converse was true for the catch-based method. ATP values were then optimized by profiling annual residuals over the range of ATP values from 0 to 1 at 0.1 increments using hindcasts and informed by the full IFQ annual time series, with an emphasis on most recent data. Following setting ATP values, fit in a hindcast of predicted catch vs. expanded 2021 catch for the non-whiting sector was $R^2 > 0.98$.

The model was then calibrated to maximize accuracy of predicting 2021 expanded catch to the point of $R^2 \sim 0.999$, using three built-in adjustment parameters. Stocks were tuned using target prediction methods first, after which bycatch species were configured, due to the influence of target stocks on the denominator of bycatch ratios.

For the non-whiting fleet, all species besides Pacific halibut and yelloweye rockfish were modeled as target species using the mix of attainment-based and historical catch-based methods mediated by the ATP. Pacific halibut and yelloweye rockfish were modeled as slope and shelf bycatch species, respectively. For the whiting sector, Pacific whiting was modeled as the only target species, and all others were modeled as bycatch species, irrespective to slope or shelf habitat.

2.7.3.4 Considerations and Assumptions

The projections reflect data that include surplus carryover trends for 2016-2021. If no carryover can be issued in the projected years, then the actual future catch could be somewhat less than projected, or if fishers are aware, they could strive to catch all available sablefish within the quota year, which could potentially inflate attainment.

This is also relevant considering that surplus carryover cannot be issued within the IFQ fishery for species for which the ACL equals the ABC. The court ruling Conservation Law Foundation v. Pritzker, No. 13-00821 (D.D.C. Apr. 4, 2014), stated that under the plain language of 302(h)(6) of the MSA, 16 U.S.C. § 1852(h)(6), neither the Council nor NMFS may establish a total potential catch level that exceeds the ABCs recommended by the SSC. This total potential catch level includes surplus carryover in the IFQ fishery.

Although the current model has the ability to project selected species as bycatch, target species predictions are not presently mediated by species composition among different, yet co-occurring IFQ species categories, such as Dover sole-Thornyhead-Sablefish (DTS). Any potentially dependent changes in thornyheads or Dover sole concurrent with projected increased sablefish catch are not reflected in the predictions, yet this feature is slated for potential addition in a future version of the model.

Projections for the shorebased whiting sector were constrained to 2021 levels, since the Pacific whiting allocation was fixed at the 2021 level among all alternatives (as a placeholder), and the overall purpose of the analysis was not to predict whiting catch, which is an internationally managed species with a separate process. All other species in the whiting sector were modeled as bycatch fixed at 2021 bycatch rates. Although fixed to 2021 fleet levels, making the whiting sector projections using the model allowed distribution of landings among vessels for use in downstream economic impact analysis and summation with the non-whiting sector projections for consideration of projected IFQ fishery impacts as a whole.

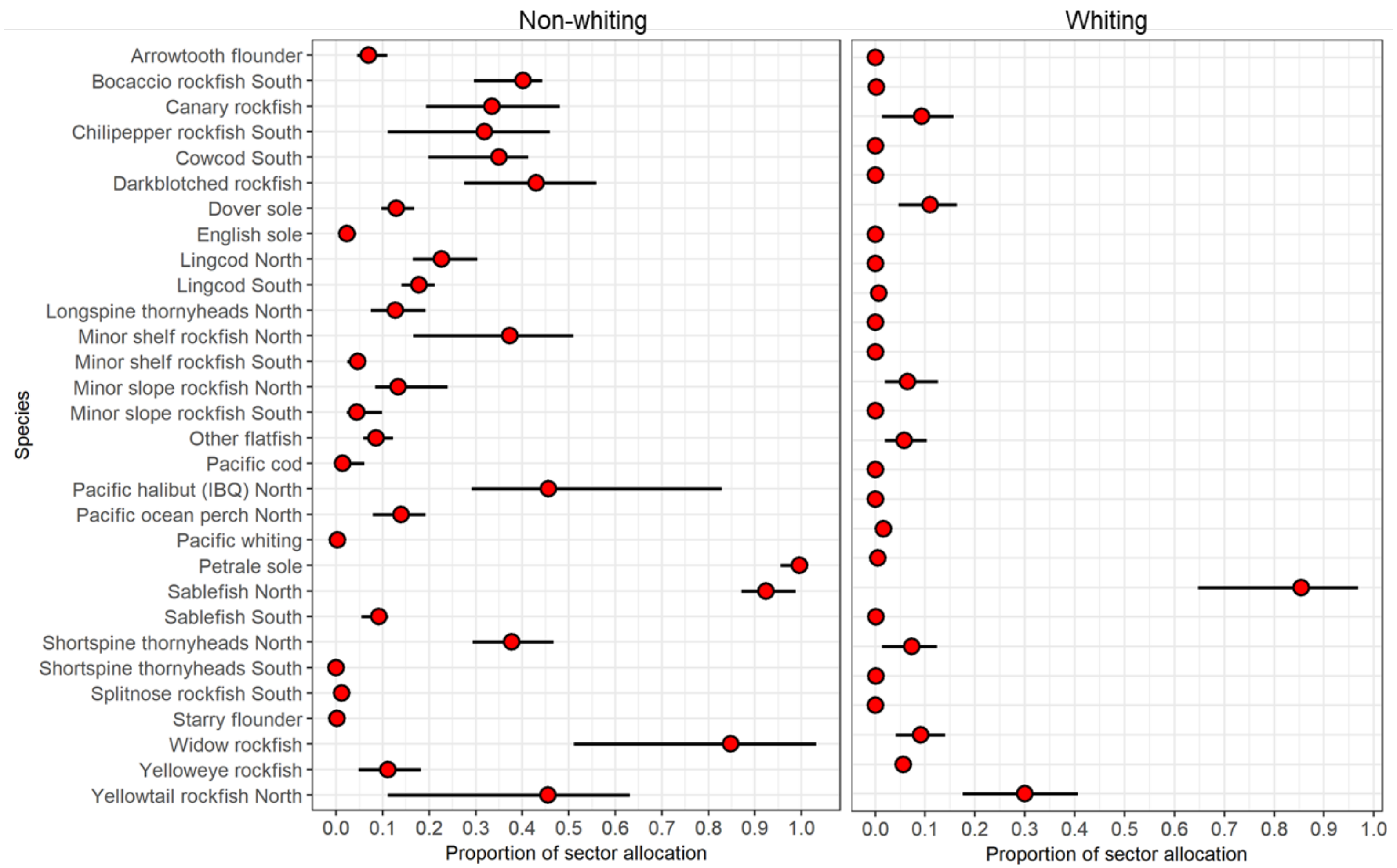

Figure 2-134. Example plots of point projections (from 2023-2024 biennium) with accompanying prediction intervals (as the proportion of each respective allocation), showing relative uncertainty surrounding each projection by species and sector, at the fleet level.

2.7.4 *Washington Recreational Fishery Model*

The Washington Ocean Sampling Program (OSP) generates catch and effort estimates for the recreational boat-based groundfish fishery, which are provided to Pacific States Marine Fisheries Commission (PSMFC) and incorporated directly into the RecFIN database. The OSP provides catch in total numbers of fish, and also collects biological information on average fish size, which is provided to RecFIN to enable conversion of numbers of fish to total weight of catch. Boat egress from the Washington coast is essentially limited to four major ports, which enables a sampling approach to strategically address fishing effort from these ports. Effort estimates are generated from either exit or entrance counts of boats leaving coastal ports while catch per effort is generated from boat intercepts at the conclusion of their fishing trip. The goal of the program is to provide information to RecFIN on a monthly basis with a one-month delay to allow for inseason estimates. For example, estimates for the month of May would be provided at the end of June. Some specifics of the program are:

- **Exit/entrance count** – boats are counted either leaving the port (as early as 3:00 AM - end of the day) or entering the port (approximately 8:00 AM through end of the day) to give a total count of sport boats for the day.

- **Unit of sample** – The unit of sample used by the OSP is a single boat trip.

- **Interview** – boats are encountered systematically as they return to port; anglers are interviewed for target species, number of anglers, area fished, released catch data and depth of fishing (non-fishing trips are recorded as such and included in the effort expansion). The OSP collects information on released catch but does not collect information on the condition of the released fish. However, the angler provides a depth at which the majority of rockfish were encountered allowing for; released catches to be post-stratified as live or dead based upon an assumed species- specific discard mortality rate. Onboard observers are deployed on charter vessels throughout the salmon season primarily to observe hatchery salmon mark rates but also to collect rockfish discard information on these trips.

- **Examination of catch** – catch is counted and speciated by the sampler. Salmon are electronically checked for coded wire tags and biodata are collected from other species.

- **Sampling Rates** – vary by port and boat type. Generally, at boat counts less than 30, the goal is 100 percent coverage. The sampling rate goal decreases as boat counts increase (e.g., at an exit count of 1500, sample rate goal is 30 percent; over 300, sample rate goal is 20 percent). Overall sampling rates average approximately 50 percent coastwide through March-October season.

- **Sampling Schedules** – due to differences in effort patterns, weekdays/weekend days are stratified separately. Usually, both weekend days and a random 3 of 5 weekdays are sampled.

- **Personnel** – OSP sampling staff include three permanent biologists coordinating data collection, one permanent biologist generating in-season estimates of groundfish catch, one

Natural Resource Scientist overseeing the program, approximately twenty-four port samplers, and two on-board observers.

- **Volume of Data** – Between 20,000 and 30,000 boat interviews completed per season coastwide.

2.7.4.1 Data Expansion Algorithms

Algorithm for expanding sampled days:

$$P_t = \frac{Exit\ Count}{Total\ Boats\ Sampled} * P_s\ sampled$$

Where:

P_s = any parameter (anglers, fish retained, fish released) within a stratum,
P_t = total of any parameter with stratum for the sample day

Algorithm for expanding for non-sampled days:

$$Total\ Weekday\ Catch = \frac{\Sigma(P_t) on\ sampled\ weekdays}{\#\ of\ weekdays\ sampled} * \#\ of\ weekdays\ in\ stratum$$

$$Total\ Weekend\ Catch = \frac{\Sigma(P_t) on\ sampled\ weekend\ days}{\#\ of\ weekend\ days\ sampled} * \#\ of\ weekend\ days\ in\ stratum$$

$$Total\ catch\ in\ stratum = Total\ Weekend\ catch + Total\ weekday\ catch$$

Notes on Data Expansion:

Salmon and halibut catch estimates are stratified by week; catch estimates for all other species are stratified by month. All expansions are stratified by boat type (charter or private), port, area, and target species trip type (e.g., salmon, halibut, groundfish, and albacore).

2.7.4.2 Washington Recreational Fishery Impact Modeling

Projected impacts for Washington's recreational fishery are essentially based upon recent years harvest as estimated by the OSP and incorporated in RecFIN. This is especially true if recreational regulations remain consistent.

WDFW doesn't use a formal model to produce estimates of projected impacts under various management measure scenarios but has relied instead on an ad hoc approach that uses historical catch on a case-by-case basis to evaluate impacts to overfished species.

2.7.4.3 Angler Effort

WDFW's approach to estimating projected impacts was reviewed and approved by the SSC Economics and Groundfish Subcommittees (SSC E-G/F) in the fall of 2012. With the review, the SSC E-G/F recommended a retrospective analysis of effort projections compared to post-season effort estimates for past biennial harvest specifications and management measures cycles to better understand the historical performance of Washington's ad hoc approach. Angler effort has increased since 2011. Projected fishing effort follows the same trend as actual fishing effort.

2.7.4.4 Inseason Catch Projections for 2023-2024

Inseason catch projections are based upon the most recent OSP estimates and incorporated in RecFIN (with a one-month time lag) with subsequent months extrapolated from the pre-season catch projections. Beginning in 2009, depth dependent mortalities have been applied uniformly to all discarded fish coast wide through RecFIN. It should be noted that the precision of recreational groundfish catch estimates based upon previous seasons will continue to be influenced by factors such as the length and success of salmon, albacore, and Pacific halibut seasons, as well as weather and other unforeseen factors.

2.7.5 Oregon Recreational Fishery Model

Groundfish mortality associated with regulatory scenarios for each alternative were projected using the Model of Oregon Recreational Groundfish (MORG), which was reviewed by the SCC and found to "use appropriate data and methods and provides a sound basis for management decisions" prior to the 2015-2016 Groundfish Biennial Specifications Process (PFMC 2015).

The model, described below, has been updated since the review to incorporate all process recommendations made by the SSC (e.g., inclusion of variances to provide measures of uncertainty). Additional updates were made to accommodate new data sources (e.g., mortality rates for rockfish released with descending devices and the proportion of fish release with the devices) and to increase ease of use for users to manipulate model inputs (e.g., a user interface "switchboard" was developed for all model inputs."

2.7.5.1 Landings and Discard Mortality Estimation

The MORG produces projections of landings and discard mortality for thousands of combinations of regulation options (i.e., bag limit, size limit, depth closures, and season closures). To produce these projections, MORG manipulates the exact same data inputs that the sport fishery monitoring survey, the Oregon Recreational Boat Survey (ORBS) uses to estimate total landings, discard mortality, and effort. In short, the MORG manipulates the data sets ORBS uses to estimate total catch and effort and then reruns the estimates in the same manner as done by ORBS.

Since MORG functions by manipulating the data sets used by ORBS to estimate catch and effort, it is important to first understand the process and data inputs used by ORBS to estimate total sport catch and effort. To estimate these factors, ORBS assumes un-sampled boats catch the same as sampled boats. In finer detail, ORBS obtains catches from a portion of boats intercepted by the dockside survey for a given trip type (e.g., Newport charter boats) and assumes the un-sampled boats of that similar trip type caught same (strata and domains used to lump similar trips include boat type, port, week, area fished). And by statistical definition, ORBS estimates total catch and effort by multiplying catch rates (catch per boat) for each trip type to the portion of total boats (sample and un-sampled) from that same trip type.

2.7.5.2 Landings and Discard Mortality Projections

As stated above, the two main survey components used to estimate total catch and effort are the dockside survey and the total boat survey. The MORG projects catch and effort for regulatory options by manipulating the dockside survey interviews by adjusting what the anglers caught and where they fished, and then reruns the total catch and effort estimates using the same ORBS procedures (along with variance computations). By manipulating the individual trips, this provides the greatest ability to adjust multiple regulations at once – and is manipulating what truly occurs in the fishery.

And to account for total effort, which is used to expand the dockside interviews to total catch and effort, a variety of approaches have been taken. Until recently, the average angler trips were used because the number of trips was relatively consistent across years; however, to account for a major spike in total effort since 2015 (i.e., from ~60,000-70,000 per year prior to 2015 to a record ~110,000 in 2015 and over 100,000 through August in 2017), the model uses a "stair-step" effort ramp with the assumption that 2023-2024 will also have similar amounts of high effort.

2.7.5.3 MORG Model Components

- **Bag limit model component:** The bag limit model adjusts the landings of individual anglers to not exceed the proposed (new) daily bag limit, and any previous landings above the bag limit are converted to discards (with discard mortality rates applied). For example, if three anglers landed nine black rockfish and discarded six with a bag limit of seven, the catches for a bag limit of one would be three black rockfish landed (one per angler) and 12 discarded (six originally discarded plus the six of nine that were landed, but now had to be thrown back). And in a reverse situation where the bag limit is increased, anglers would be able to retain more of their discards (and the mortality rate of these fish would be changed to the discard mortality rate to 100 percent).
- **Size limit model component:** The size limit component functions very similarly to the bag limit component, but is more uncertain since lengths of discarded fish are unknown (and are assumed to match the distribution obtained by the sport observer survey, which records the sizes of discarded fish). For example, if the size limit is decreased to 10" from a current no size restriction, the model forces anglers to discard any catch below 10" (which are then converted to discards with discard mortality rates applied) and they can retain any of their catch above 10".
- **Area closure model component:** The area closure component primarily models projections of catch and effort pertaining to depth closures, as depth is the most common area closure used in the sport fisheries (to limit yelloweye rockfish interactions). The depth closure component differs from the bag and size limit components; instead of converting landings to discards or vice versa, the depth model moves anglers from areas that become closed to open areas. To do this, the model excludes trips that occur in closed areas from the dataset, and then gives a greater weighting to the existing trips in open areas. The main assumption is that no effort is lost due to area closures; rather that all effort shifts to open areas (this assumption based on historical data that shows the number of trips years with depth restrictions did not appear to decrease compared to years without).
- **Seasonal closure model component:** The season model component functions rather simply by forcing effort to be zero during closed times. This may result in an underestimate of catch and effort since some anglers may continue to fish during closed periods by practicing catch-and-release (which would result in discard mortality). While the effects

of complete season closures may be uncertain, it was deemed reasonable to expect that most anglers would stop fishing if unable to harvest their catch. Further, season closures are the least desired regulation option, and are only used when all other regulatory options have failed to limit mortality to acceptable levels.

- **Regional catch and effort component:** Following review of MORG, the SSC recommended that the model produce regional catch and effort estimates. With one reason being that the economic multipliers used to expand the base value of recreational trips (trip expenditures; money spent on fuel, tackle, etc.) to total economic impacts to communities differ throughout regions in Oregon (i.e., "multiplier" effect of the based spending creating additional value as it cycles through the economy from business to business until all is leaked to outside the community). While regional catch and effort has not yet been coded for in the model, it is a future goal. To complete regional modeling, both data sets (dockside intercept and total effort) could be filtered for the desired region prior to rerunning the estimation procedures.
- **Multivariate predictors of effort:** At the SSC review, ODFW demonstrated that weather (wind, waves, and wind*wave interaction) and strength of other fisheries (e.g., salmon) are related to sport groundfish effort (but not factors such as economic indicators and other environmental factors) and thus explored whether inclusion of these factors could help model performance (via use of a hybrid GLM / manipulation model). However, following further investigation ODFW concluded that while these factors may affect sport groundfish effort (and thus catch), weather and strength of other fisheries cannot be accurately predicted, and thus cannot be used as explanatory variables in MORG at this time.
- **Other features and specifications:** While MORG is simple in concept, hundreds of pages of code are required account for the approximately 60,000 (and counting) regulatory options for which MORG provides projections for. As such, MORG includes a user interface that allows users, even without any familiarity of the fisheries or modeling details, to simply adjust regulations in order to create projections for different regulation scenarios.

In addition to being able to adjust regulations, users may also adjust alpha to create projection intervals to their desired level of risk tolerance (e.g., 75 percent if more risk tolerant, 95 percent if more risk adverse). This inclusion of measures of uncertainty is new and addresses the main SSC recommendation during the model review.

Finally, MORG is a dual function inseason tracking tool (of actual landings) and projection model combined. When actual catch and effort are added, projections from that timeframe are replaced with the true values and the remainder of the year remains projections. This allows managers to closely monitor and manage the fishery throughout the year.

2.7.6 California Recreational Groundfish Fishery Model

2.7.6.1 Groundfish Fishery Projection Model

The anticipated mortality for select groundfish in the California recreational fishery under various season structure options are modeled using the RecFISH model. The model was developed in 2004 under contract with MRAG Americas, with subsequent augmentation of catch by depth and time parameters by California Department of Fish and Wildlife (CDFW). RecFISH allows projection of catch by depth and season length in each of the five groundfish management areas.

2.7.6.2 Model Description

The model incorporates proportion of catch by depth and time from historical unregulated periods and recent estimates of mortality in each management area to project mortality under given various season structures. The RecFISH model is a catch-based model as opposed to an effort-based model and has been previously reviewed by the SSC.

2.7.6.3 Methods

A step by step explanation of the methodology used in the RecFISH model can be found in greater detail in Appendix B of the 2015-2016 FEIS; no changes were implemented during this cycle and is incorporated by reference. The model utilizes catch data from a recent regulated year ("base year") and expands that catch for the entire "unregulated" year. The assumption is that the historical proportion of catch by time and depth is representative of what will occur in the future. While this presents some uncertainties (discussed below) measures are available to mitigate this risk. For the 2023-2024 biennial cycle, catch data from the 2017 through 2019 and January through October 2021 recreational fishery was used as the base years. Utilizing the most recent years' data captures recent trends and is likely more reflective of future fishing behavior. The COVID-19 pandemic, beginning in 2020 and continuing into 2021, impacted catch data collection. The California Recreational Fisheries Survey (CRFS) program did not conduct sampling activities from mid-March through June 2020. When sampling activities resumed in July 2020, only the minimal necessary data were collected. Catch data for 2020 are not used in the RecFISH model as they are incomplete and do not capture total fishery removals for the year.

The expected magnitude of unregulated catch by depth and time for the base years is back-calculated to reflect mortality during an unregulated year. This is performed for each management area and species within the model by expanding mortality during the regulated period by what would be expected from an unregulated fishery using the historical proportion of catch by depth and time from unregulated years. In expanding baseline catch data from regulated seasons to all depths and months, data from other areas were used to supplement the existing historical data.

Further, historical data for California can only be stratified north and south of Point Conception (34° 27' N. lat.). However, estimates of catch by time north of Point Conception during this period were dominated by the San Francisco and Central Management Areas where more effort was exerted over more months than north of Point Arena. As a result, for select species the proportion of catch by time from Oregon was used in the Northern and Mendocino Management Areas due to greater similarity in the timing of the fishery than that of the fishery south of Point Arena (38° 57.5' N. lat.). Contemporary depth strata information from the 2019-2020 all depth fishery in the Northern and Mendocino Management Areas and the boat-based fishery from 2021 in the Southern Management Area where the depth limit was the 100 fm RCA contour line were used to augment the historic depth strata data.

To account for depth dependent mortality rates, base catch in each month and depth bin is multiplied by the average proportion of catch from discarded fish (reported discarded live + reported discarded dead) in the base years described above for each species and management area. This results in the expected tonnage of discarded fish. The species-specific depth dependent mortality rates (by 10 fm depth bin) derived by the GMT (or suitable proxy) are applied to the discarded catch to provide an estimate of the expected discards for each depth bin. The resulting discard mortality estimate is added to the expected tonnage of retained catch to provide a projection of total mortality for each depth bin and month. This is used as the "base season" reflecting the mortality expected in an unregulated fishery.

The model also takes into account effort shifts that are likely to occur with varying depth restrictions. If depths are restricted to 20 fm or 30 fm, the model accounts for effort which would have occurred in deeper depth bins shifting to the shallower depth bins, by applying an increase of 39.3 percent and 27.6 percent, respectively.

Projected mortality from the desired depth and season is obtained by summing the projected mortality values for each month and depth bin by species or species group in each management area. Projected mortality is then summed by the relevant management areas to obtain the total projected mortality in relation to the relevant management area (i.e., statewide, or north and south of Cape Mendocino 40° 10' N. lat.).

Once mortality projections are complete adjustments can be made to account for increases or decreases in mortality resulting from other management measures (e.g., bag limits). The anticipated percent reduction or increase in mortality expected from such management measures are estimated using recent CRFS data and the RecFIN bag limit analysis tool.

Each management cycle post model adjustments are made to immediate model outputs when review of the output does not align with recent catch trends or expected changes in catch under various management measures. The post model adjustments may be based on recent or historic catch trends when regulations were similar or dis-similar. Post model adjustments for several species were made in this analysis, are primarily based on 2021 projected end of year total mortality, and also take into account the following information:

- Depth restrictions in the Mendocino, San Francisco, and Southern Management Areas were relaxed beginning in 2021 and projected catch for cowcod, deeper nearshore rockfish species, and select shelf rockfish species are increased compared to RecFISH model projections.

- Sub-bag limits for black rockfish, canary rockfish, and cabezon were removed beginning with the 2021 season and RecFISH outputs are adjusted using the RecFIN bag limit tool and actual 2021 total mortality.

2.7.6.4 Model Uncertainty

While the RecFISH model is the best available science, there are some known uncertainties which are explained here. For some species, few data are available to inform the model, which is particularly the case for species with deeper depth distributions, such as the shelf and slope rockfish species, or species for which retention is prohibited or encounters are infrequent. For these species and depth bins projected impacts may vary from actual impacts.

The model also assumes that fishing behavior during the historic period will be representative of the current fishery. However, many changes have occurred in the fishery which has likely affected behavior and distribution of fishing effort. For example, Marine Protected Areas have been established, closing some areas to recreational fishing which were previously accessible during the "unregulated years."

It is also assumed the fishing behavior during the historic period and current fishery will be representative of fishing behavior under proposed management measures. If significant changes to management measures are made to the fishery, substantial changes to angler behavior may occur, which the model cannot predict.

Opportunities in other fisheries may also cause model projections to deviate from actual impacts. For example, opportunity in the salmon fishery affects effort and participation in the groundfish fishery. In good salmon years, there is less effort in the groundfish fishery and in poor salmon years groundfish effort is much higher.

The COVID-19 pandemic has resulted in numerous impacts to fishery performance. Many local municipalities and harbor districts took action to limit or close launching facilities at the beginning of the pandemic, which directly affected the recreational private fleet and Commercial Passenger Fishing Vessel (CPFV) operations. Typically, angler effort in the recreational fishery increases considerably from March through June as the boat-based groundfish fisheries open in successive management areas in the state, and access to fishing grounds typically increases with improved weather and ocean conditions. With varied accessibility, anglers continued to fish in higher than expected numbers in some areas, while others were at normal or lower than expected effort. Catch estimates for the 2020 season differed significantly than projected in the 2019-2020 harvest specification analyses due to impacts from the pandemic.

Along with the availability of other fisheries, changes in oceanographic conditions can cause actual impacts to deviate from projections. For example, in 2015, abnormally warm waters caused a shift in the distribution of many species. In central California, anglers shifted some effort from groundfish to bonito, which are not normally encountered in the region.

2.7.7 Estimating Effort for Use in the Input Output Pacific Coast Fishery Model

The Northwest Fishery Science Center (NWFSC) Input Output Pacific Coast Fishery (IO-PAC) is designed to estimate the changes in economic contributions and economic impacts resulting from policy, environmental, or other changes that affect fishery harvest. IO-PAC was built by customizing the Impact Analysis for Planning (IMPLAN) regional input-output software. The original methodology employed in developing this model was similar to that used in the Northeast Region Commercial Fishing Input-Output Model (Steinback and Thunbgerg 2006). The development and design of IO-PAC is documented in detail in Leonard and Watson (2011). The model was subsequently updated as part of an ongoing effort to continually improve the IO-PAC model with the latest available data and improvements in regional impact modeling capabilities. Substantial changes were made to model construction, new commercial fishing sectors were added, and a recreational fishing component was added, and these changes are documented in the final environmental impact statement for the 2015-2016 groundfish harvest specifications and management measures (PFMC and NMFS 2015). The current version of IO-PAC is detailed therein, except that there have been several data updates. This section summarizes the data updates that have been made since the documentation in PFMC 2015.

The data updates made include the following: 1) the underlying IMPLAN data is changed from the 2012 base year to 2014, 2) the fish-ticket (landings) data from PacFIN changed from 2014 to 2016, 3) the commercial vessel production functions incorporate the latest data from the voluntary Limited Entry and Open Access Surveys conducted by the Northwest Fisheries Science Center, 4) it incorporates the latest data collected as part of the EDC program, and 5) it incorporates 2012 data from the charter vessel surveys completed by the Northwest and Southwest Fisheries Science Centers. Table 2-22 provides a summary of the data that is currently used in IO-PAC and its application.

Table 2-22. IO-PAC data sources, applications, and year of data incorporation into the model.

Data Year	OA Survey	LEFG Survey	Marine Rec. Exp. Survey	WA and OR Charter Vessel Survey	CA Charter Vessel Survey	EDC DATA	EDC Data	IMPLAN	PacFIN Fish Ticket
	2012	2012	2011	2012	2012	2016	2015	2014	2014
Application									
Commercial Vessels									
Production Functions	X	X				X			X
Vessel Industry Output				X	X	X		X	X
Vessel Employment	X	X				X			X
Processors									
Production Functions						X	X	X	
Processor Industry Output						X	X	X	X
Processor Employment						X	X	X	X
Recreational Fishing									
Expenditures			X						
Charter Prod. Functions				X	X				
Charter Industry Output			X	X	X				
Charter Employment			X	X	X				
Non-Fishing Data								X	

2.7.8 Commercial Landings Distribution Model

The purpose of the commercial fishery landings distribution model (LDM) is to inform the PFMC's management processes by projecting where PacFIN Port Code Identifier (PCID) landings are likely to occur under a set of alternative scenarios (e.g., alternative ACLs or management measures). The projected landing ports can then be mapped onto Port Area aggregations to allow comparison of the geographic distribution of ex-vessel revenues under the alternatives. Since all the alternatives are modeled consistently, projections from the LDM facilitate comparison of the alternatives in an apples-to-apples fashion.

A list of Port Areas, and underlying PCIDs, is shown in Table 2-23 and Table 2-24. Although used primarily to inform the groundfish management processes, the LDM methodology can be applied to analyze any West Coast fishery. In the case of groundfish, ex-vessel revenue results from the LDM, aggregated by Port Area, are fed directly into the IO-PAC input-output and vessel net revenue projection models, where they are used to calculate and compare economic impacts under the different alternatives[13].

2.7.8.1 Data Elements

The core of the LDM is a recent-year commercial fishing landings data report from the PacFIN data system. The standardized PacFIN daily (vdrfd) or monthly (vfcmrfd) vessel landing summary or other summary queried tables can be used for this purpose.

For analyzing the alternative 2023-2024 groundfish management specifications, a table of monthly landings for 2021 was used.

Key data elements of the LDM provided by the PacFIN landings data report include:

- Inventories of all species (SPIDs including nominal and market categories after application of species composition factors), round weights and ex-vessel values landed by port (i.e., PCID).
- Assignment of landing vessel IDs to current groundfish Federal limited entry permits, if applicable.
- Assignment of each landing to a fisheries management sector (dahl_sector).
- Distribution of species landings and ex-vessel revenues by landing vessel ID.
- Distribution of species landings and ex-vessel revenues among first receivers (Processor ID).
- This historical information forms one of baselines against which changes under the management alternatives can be measured.

[13] IO-PAC is a set of regional economic impact models constructed using landings data, vessel expenditure estimates, and secondary economic data to estimate income and employment impacts resulting from a change in the distribution of commercial fishery landings. It is maintained by Northwest Fisheries Science Center (NWFSC) and used by the Pacific Fishery Management Council (PFMC) to estimate economic impacts of West Coast fishery management actions.

2.7.8.2 Model Description

Groundfish landings records in the vessel landings table are categorized by fisheries sector (PacFIN "dahl_sector"). This categorization is based on limited entry permit status, PFMC catch area, landing port, species and gear used. The fisheries sector categories align with the GMT fishery sector projection models listed below. The GMT models project landings in each of five fishery sectors under the management alternative as part of their overall analysis of harvest specifications and management measure alternatives.

The next step is to compute the base year percentage of landings for each fishery sector by each combination of Area, Vessel (or Permit) ID, Species Identifier (SPID) and PCID. The "area" used for this calculation varies according to the resolution of the corresponding fishery sector projection model, as noted below. The percentages are then applied to the results from the GMT fishery sector projection models to estimate the geographic distribution of landings across ports in each fishery.

To project the geographic distribution of landings under the alternatives, results from the commercial fisheries sector landings projection models are applied to the landings percentages calculated from the landings data as noted above. Unless indicated otherwise (by the GMT model results or the proposed management measures) landings under the alternatives are assumed to occur in the same ports in proportion to landings observed in the base year. Only landings of the main economic groundfish species that are modeled for each fishery sector are of concern in the LDM. Landings of non-groundfish species, incidentally caught groundfish species, and overfished species such as yelloweye are generally not modeled, as these are not managed under the Groundfish FMP or do not generate significant revenues in federally- managed groundfish fisheries.

The level of detail carried over from the GMT models to the LDM varies considerably by fisheries sector. The most detailed results are produced by the TRAT IFQ catch projection model which generates a table of projected landings by species category for each participating vessel/groundfish permit ID.

More aggregated results are used to link the LDM with the non-IFQ fishery sector models. For example, aggregate sablefish catch projected by the non-nearshore fisheries model is used to model sablefish landings by the non-nearshore LE, OA, and tribal fixed gear sectors north of 36° N. lat. Unless otherwise indicated, each PCID north of 36° N. lat. is expected to receive the same proportions of coastwide LEFG, OA, and tribal sablefish landings under each alternative during the biennial cycle as it received in the base year landings data.

Linkage between the LDM and the nearshore fisheries model is similar, except that additional area detail in the nearshore model is incorporated to distribute projected landings of nearshore groundfish species to ports (PCIDs) in Oregon and in California north and south of 40°10' N. lat. in proportion to where those landings occurred in the base year vdrfd data table.

The main features, model inputs and additional procedures used for integrating landings information in the LDM are described below:

- **TRAT IFQ catch projection model:** Projected groundfish target species landings by each vessel/permit participating in the IFQ fishery. The list of IFQ target species projected includes sablefish, longspine thornyhead, shortspine thornyhead, Dover sole, arrowtooth flounder, petrale sole, English sole, other flatfish, and Pacific whiting, among others. Incidental landings of non-target IFQ and overfished species are also projected by the model, however these landings are not generally relevant for economic analysis.
- **Non-nearshore fisheries model**: Projected maximum aggregate landings of sablefish by vessels participating in the LEFG, OA DTL, and tribal fisheries north of 36° N. lat. Only projected sablefish landings are used in the economic analysis. To date sablefish landings south of 36° N. lat. have not been explicitly modeled by the GMT. Instead, the ratios of sablefish ACLs specified under each alternative are compared with landings and ACLs observed in the base year, and the resulting ratios are applied to project sablefish landings in ports south of 36° N. lat. under the alternatives.
- **Nearshore fisheries model:** Projected aggregate landings by area (Oregon, California north of 40°10′ N. lat., and California south of 40°10′ N. lat.) of nearshore target species (black rockfish, blue/deacon rockfish, cabezon, kelp greenling, lingcod, and other minor nearshore rockfish) by vessels participating in the fixed gear OA fishery. Catch of canary and yelloweye rockfish are also projected, although landings of those species have not been relevant for economic analysis of the nearshore sector.
- **At-sea Pacific whiting fisheries model:** Projected allocations of Pacific whiting to the at-sea catcher processor and mothership fisheries sectors, constrained by allocations of anticipated relevant constraining species and observed bycatch rates, if applicable.
- **Tribal fisheries model:** Projected total Pacific whiting (shoreside and at-sea) and non-Pacific whiting groundfish target species landings by the tribal groundfish fisheries off the Washington Coast.

2.7.8.3 Sectors in the Landings Distribution Model

IFQ Sector

Information in the final end-of-year run for the most recent year from the IFQ catch projection model is used to adjust base year landings for IFQ fishery participants. This step produces a calibrated landings report that can be linked with IFQ catch projections generated for each groundfish management option or alternative. Projected landings by vessels (i.e., permits) are assumed to be distributed to ports based on where those vessels landed as reported in the base year landings data. Note: Although Pacific whiting harvest is regulated separately from the non-whiting groundfish specifications process, whiting landings by vessels/permits participating in the IFQ fishery are also modeled using this method. For purposes of comparison, sometimes a range of Pacific whiting harvests is associated with the groundfish harvest alternatives being analyzed; or alternatively, a single, fixed Pacific whiting catch scenario is assumed to apply under all the alternatives analyzed.

Non-Nearshore Sectors

Total sablefish landings projected under each option or alternative by the non-nearshore fisheries model for fixed gear LE, OA-DTL and tribal fisheries north of 36° N. lat. are distributed to participating vessels and PCIDs, as shown in Table 2-23 and Table 2-24 in proportion to where sablefish landings were recorded in the base year landings data. For areas south of 36° N. lat. a different procedure is used. The ratio of sablefish landings in the base year to the alternative sablefish ACL is calculated. This ratio is then applied to the corresponding ACL projected under each option or alternative to estimate total sablefish landings south of 36° N. lat. under the management scenarios. Estimated total landings are then distributed to vessels and associated landing ports south of 36° N. lat. in proportion to where sablefish landings were recorded in the base year landings data.

Nearshore Sector

For the fixed gear OA fishery, total projected nearshore target species landings projected by the nearshore sector model under each option or alternative are distributed to participating vessels and landing ports in the same proportions observed in the base year landings data. Nearshore target species distributed in this manner include black rockfish, blue/deacon rockfish, cabezon, kelp greenling, lingcod, and other minor nearshore rockfish. Nearshore fishery landings projected by the nearshore OA model are split into three catch area stratifications: California south of 40°10′ N. lat., California north of 40°10′ N. lat., and Oregon. Note that sablefish landings by the tribal sector are projected using the non-nearshore sector models.

At-sea Pacific Whiting Sectors

Total projected Pacific whiting catch under the alternatives in the two nontribal at-sea Pacific whiting fisheries (catcher processers and motherships) is distributed in proportion to catch during the base year. Pacific whiting harvest is regulated separately from the non-whiting groundfish specifications process, but for purposes of comparison a range of Pacific whiting harvests is sometimes analyzed along with the alternative groundfish harvest specifications.

Tribal Groundfish Sector

Total projected landings and deliveries under each option or alternative by the tribal groundfish fisheries, including shoreside and at-sea Pacific whiting, are distributed among ports that participated in those fisheries in proportion to those ports' participation during the base year.

2.7.8.4 Assumptions and Caveats

Major simplifying assumptions used in the analysis include:

- Average ex-vessel prices observed in the base year will carry over to the projection period(s).
- Average annual ex-vessel prices are assumed to apply in each port no matter when during the year the landings occur.
- There is no cross-hauling of raw product. That is, landings in a given port are not shipped elsewhere for processing.

One concern with this approach is that the more ex-vessel prices deviate from the range of prices observed in the base year, the more inaccurate projected revenue impacts may be. However, if better information is available on future ex-vessel price trends, it is certainly possible to incorporate this type of information into the revenue projections.

Landings and revenue impacts projected by the LDM are used with the IO-PAC model to estimate community income impacts under the management alternatives. To the degree that processing activities, vessels' home ports, or the residences of owners and workers are located in the ports of landing, then a larger portion of the economic impacts generated by these landings will accrue to the port. However, to the extent that processing activities, vessels' home ports, or the residences of workers and owners are located elsewhere historical landings patterns may or may not be representative of the impact of these activities in the local economy. For example, if landings are made in one port but vessels' home ports or crew's residences are elsewhere, or if first receivers transport landings to another place for processing, then at least a portion of the projected income and employment impacts may be attributed to the wrong port or region.

2.7.8.5 Results

Results from the LDM are used as inputs to estimate community income and employment impacts and vessel sector net revenues under the alternatives. Projected landings and ex-vessel revenues by species, fishery sector and port are applied to impact coefficients estimated using the IO-PAC model to generate community personal income and employment impacts under each management alternative. Projected landings and ex-vessel revenues by groundfish fishery sectors coupled with vessel cost estimates derived from IO-PAC are also used to estimate aggregate net revenues accruing to vessel owners participating in West Coast groundfish fisheries. The resulting estimates are then used to compare economic impacts across the range of groundfish management alternatives under consideration.

Table 2-23. List of Washington and Oregon Port Groups and associated PacFIN Port Codes (PCIDs) in the Landings Distribution.

Port Group Area	County	PCID	Port Name
WASHINGTON			
Puget Sound	Whatcom	BLN	Blaine
	Whatcom	BLL	Bellingham Bay
	San Juan	FRI	Friday Harbor
	Skagit	ANA	Anacortes
	Skagit	LAC	La Conner
	Snohomish	ONP	Other North Puget Sound Ports
	Snohomish	EVR	Everett
	King	SEA	Seattle
	Pierce	TAC	Tacoma
	Thurston	OLY	Olympia
	Mason	SHL	Shelton
North Washington Coast	Jefferson	TNS	Port Townsend
	Clallam	SEQ	Sequim
	Clallam	PAG	Port Angeles
	Clallam	NEA	Neah Bay
	Clallam	LAP	La Push
South & Central WA Coast	Grays Harbor	CPL	Copalis Beach
	Grays Harbor	GRH	Grays Harbor
	Grays Harbor	WPT	Westport
	Pacific	WLB	Willapa Bay
	Pacific	LWC	Ilwaco/Chinook
	Klickitat	OCR	Other Columbia River Ports
OREGON			
Columbia River	Multnomah	CRV	Pseudo Port Code for Columbia River
Astoria-Tillamook	Clatsop	AST	Astoria
	Clatsop	GSS	Gearhart - Seaside
	Clatsop	CNB	Cannon Beach
	Tillamook	NHL	Nehalem Bay
	Tillamook	TLL	Tillamook / Garibaldi
	Tillamook	NTR	Netarts Bay
	Tillamook	PCC	Pacific City
Newport	Lincoln	SRV	Salmon River
	Lincoln	SLZ	Siletz Bay
	Lincoln	DPO	Depoe Bay
	Lincoln	NEW	Newport
	Lincoln	WLD	Waldport
	Lincoln	YAC	Yachats
Coos Bay	Lane	FLR	Florence
	Douglas	WIN	Winchester Bay
	Coos	COS	Coos Bay
	Coos	BDN	Bandon
Brookings	Curry	ORF	Port Orford
	Curry	GLD	Gold Beach
	Curry	BRK	Brookings

Table 2-24. List of California Port Groups and associated PacFIN Port Codes (PCIDs) in the Landings Distribution Model.

Port Group Area	County	PCID	Port Name
CALIFORNIA			
Crescent City	Del Norte	CRS	Crescent City
	Del Norte	ODN	Other Del Norte County Ports
Eureka	Humboldt	ERK	Eureka (Includes Fields Landing)
	Humboldt	FLN	Fields Landing
	Humboldt	TRN	Trinidad
	Humboldt	OHB	Other Humboldt County Ports
Fort Bragg	Mendocino	BRG	Fort Bragg
	Mendocino	ALB	Albion
	Mendocino	ARE	Arena
	Mendocino	OMD	Other Mendocino County Ports
San Francisco (incl. Bodega Bay)	Sonoma	BDG	Bodega Bay
	Marin	BOL	Bolinas
	Marin	TML	Tomales Bay
	Marin	RYS	Point Reyes
	Marin	OSM	Other Son. and Mar. Co. Outer Coast Ports
	Marin	SLT	Sausalito
	Alameda	OAK	Oakland
	Alameda	ALM	Alameda
	Alameda	BKL	Berkely
	Contra Costa	RCH	Richmond
	San Francisco	SF	San Francisco
	San Mateo	PRN	Princeton
	San Francisco	SFA	San Francisco Area
	San Francisco	OSF	Other S.F. Bay and S.M. Co. Ports
Monterey	Santa Cruz	CRZ	Santa Cruz
	Monterey	MOS	Moss Landing
	Monterey	MNT	Monterey
	Monterey	OCM	Other S.C. and Mon. Co. Ports
Morro Bay	San Luis Obispo	MRO	Morro Bay
	San Luis Obispo	AVL	Avila
	San Luis Obispo	OSL	Other S.L.O. Co. Ports
Santa Barbara	Santa Barbara	SB	Santa Barbara
	Santa Barbara	SBA	Santa Barbara Area
	Ventura	HNM	Port Hueneme
	Ventura	OXN	Oxnard
	Ventura	VEN	Ventura
	Ventura	OBV	Other S.B. and Ven. Co. Ports
Los Angeles	Los Angeles	TRM	Terminal Island
	Los Angeles	SPA	San Pedro Area
	Los Angeles	SP	San Pedro
	Los Angeles	WLM	Wilmington
	Los Angeles	LGB	Long Beach
	Orange	NWB	Newport Beach
	Orange	DNA	Dana Point
	Orange	OLA	Other LA and Orange Co. Ports
San Diego	San Diego	SD	San Diego
	San Diego	OCN	Oceanside
	San Diego	SDA	San Diego Area
	San Diego	OSD	Other S.D. Co. Ports

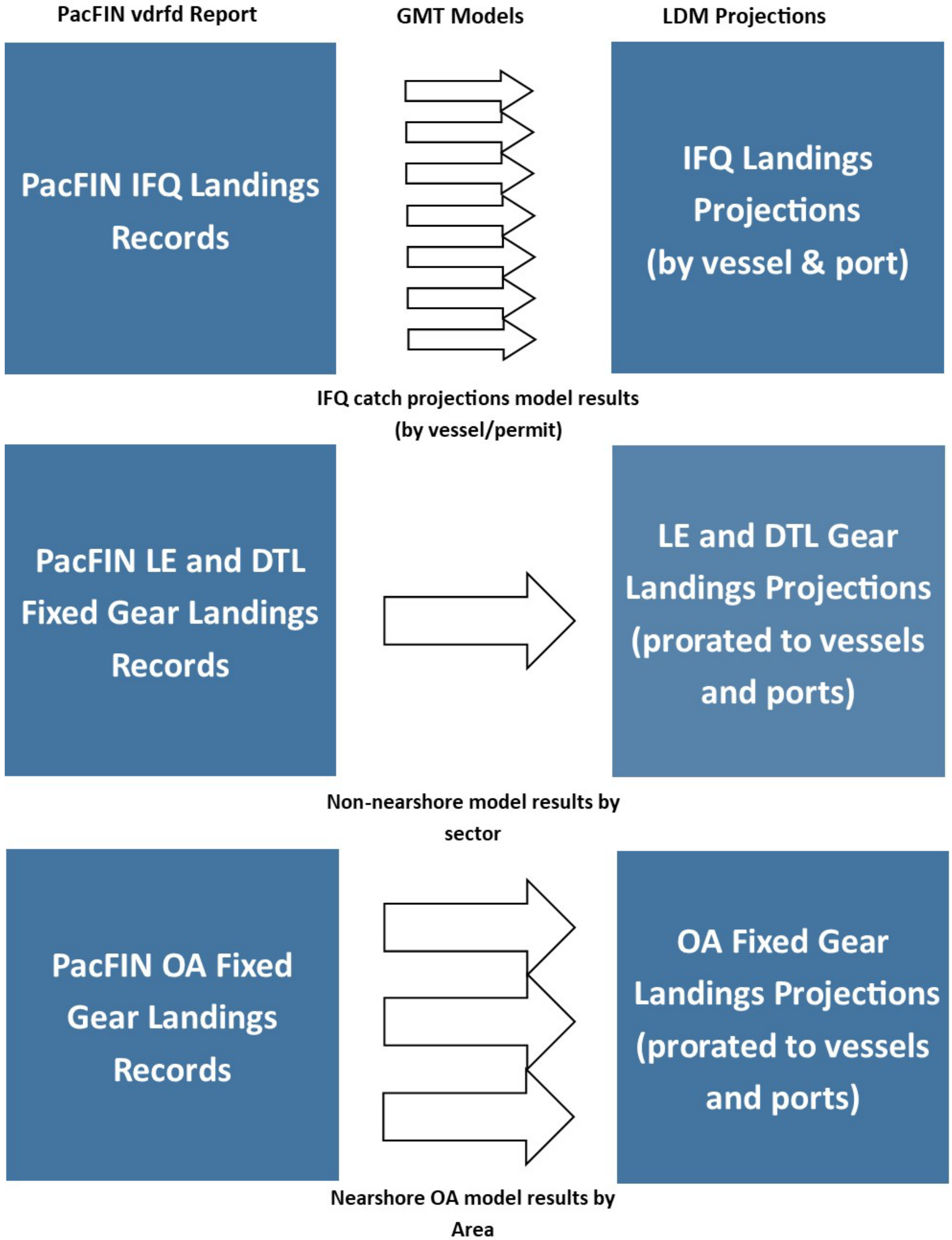

Figure 2-135. Illustration of linkages between base year data and GMT landings projections used in the LDM.

Note: Results from the at-sea Pacific whiting fisheries and tribal fisheries models are incorporated in similar fashion.

2.7.8.6 Estimated Commercial Vessel Net Revenue Impacts of the Alternatives

In order to project how changes in future landings may affect costs, we form a model where the landings (*L)* for each groundfish species (s), as well as their respective interactions, are associated with the natural log of non-labor variable costs (*VC*), for each vessel (*i*) and year (*t*) (equation 1). Key variable costs vary by sector and include fuel, bait, ice, food, observer coverage, and electronic monitoring. Intuitively, we would expect costs to increase when a vessel catches a greater quantity of fish, and interactions allow for cost complementarities between species. The economic rationale behind using a logarithmic function to model non-labor variable costs is that marginal costs increase with landings.

$$\ln(VC_{it}) = \sum_s L_{its} + \sum_s \sum_{r,r\neq s} L_{its} L_{itr} + \epsilon_{it} \quad (1)$$

First, we project non-labor variable costs for each alternative by inputting forecasted landings by species into the regression estimates from equation (1). Then, to obtain projected wages, we calculate the historical proportion of wages (wp) to variable costs net revenues based on actual recorded wages and apply them to projected variable cost net revenues. The intuition here is that wages are typically paid out as shares of variable costs net revenues. Wage projections are based on actual recorded wages.

Finally, fixed costs, including vessel and on-board equipment, fishing gear, moorage, and insurance are aggregated from survey data by sector for all vessels that fished in 2020. We impute these fixed costs using sector-specific means for any vessels not in the survey sample.

Total costs net revenues (*TCNR*) are calculated as revenues (*R*), less projections of non-labor variable costs (*VC*), wages (labor), cost recovery fees (*CR*), buyback fees (*BB*), and fixed costs (*FC*) in equation (2). Cost recovery fees and buyback fees were calculated using rates of 3.0 percent and 3.5 percent of revenue, respectively.

$$TCNR = R - VC - (R - VC) * wp - FC - CR - BB \quad (2)$$

2.8 The Groundfish Harvest Specification Framework and Harvest Specifications for Fisheries in 2023 and Beyond

At the national level, National Standard 1 Guidelines at 50 CFR §600.310 define harvest specifications and what must be considered when specifying them. FMP Chapter 4 describes the framework for biennial specifications. The OFL, ABC, and the ACL for each stock is based on the best scientific information available including endorsed stock assessments, changes in SSC-endorsed stock categories, or changes in SSC-endorsed sigma values (i.e., variances used to estimate the uncertainty in estimating OFLs. Any revised or new HCRs adopted by the Council and used to determine specifications for the subject biennial period become the new default for future biennial management cycles.

West Coast groundfish stocks are managed under a harvest specification framework that considers scientific and management uncertainties. The first specification is the OFL, which is the MSY estimated for the stock and the legal harvest limit beyond which constitutes overfishing. The OFL is determined either by applying the harvest rate estimated to result in a biomass capable of sustaining MSY (i.e., F_{MSY}) recommended by the Council's SSC to an estimate of exploitable biomass in the case of assessed stocks or through an approved data-limited method (e.g., DCAC or DB-SRA) in the case of unassessed stocks. Regardless of the method or data informing the calculation of an OFL, there is scientific uncertainty in the estimation of an OFL. The FMP mandates a precautionary buffer to account for this uncertainty by prescribing an ABC harvest level that is less than the OFL. A further reduction from the ABC can be specified when setting an ACL that accounts for management uncertainty, socioeconomic considerations, ecological considerations, conservation objectives, and/or other considerations the Council and NMFS wish to address. Since the ACL can be set equal to the ABC, the ABC is the highest harvest level that can be specified for West Coast groundfish stocks.

The Groundfish FMP further specifies the framework for harvest specifications as follows, "… the harvest controls from the previous biennium (referred to as default harvest control rules, or default HCRs) are applied to the best available scientific information to determine the numerical values of the harvest specifications for the next biennial period. The default HCR would establish the harvest specifications based on the F_{MSY} (or proxy value) used in the previous biennium applied to the best current estimate of stock biomass to determine the OFL. The ABC is determined by applying the uncertainty buffer used in the previous biennium except that if the P* approach was used, the same P* value used in the previous biennium is applied. The ACL is determined using the appropriate method for current stock status, if known.

Default HCRs were used to determine 2023 and 2024 harvest specifications for all stocks and stock complexes, except for Oregon black rockfish and California quillback rockfish, for which new HCRs were decided in the 2023 and 2024 harvest specifications process. Draft 2023 and 2024 harvest specifications under default harvest control rules are found in Report GMT008 on PacFIN's Apex dashboard. Final specifications are available in Report GMT015. Currently, this report provides the final 2021 and 2022 harvest specifications. The report will be updated with final 2023 and 2024 harvest specifications when the final rule is published, which is anticipated in December 2022.

The following sections describe the harvest specification framework.

2.8.1 Overfishing Limits

The OFL is the MSY harvest level associated with the current stock abundance and is the estimated or proxy MSY harvest level, which is the harvest threshold above which overfishing occurs. The methods for determining OFL are based on the best available science and the recommendation of the SSC; therefore, alternatives are not developed for this reference point.

The OFL is calculated by applying a deterministic or proxy MSY harvest rate (denoted F_{MSY}) to the estimated exploitable biomass of a managed stock. The F_{MSY} harvest rate may be converted to an SPR (spawning per recruit at the current population level relative to that at the stock's unfished condition). For ease of comparison among stocks and to standardize the basis of rebuilding calculations, it is useful to express any specific fishing mortality rate in terms of its effect on SPR. Given fishery selectivity patterns and basic life history parameters, there is a direct inverse relationship between F and SPR (Figure 2-136). When there is no fishing, each new female recruit is expected to achieve 100 percent of its spawning potential. As fishing intensity increases, expected lifetime reproduction declines due to this added source of mortality. Conversion of F into the equivalent SPR has the benefit of standardizing for differences in growth, maturity, fecundity, natural mortality, and fishery selectivity patterns and, as a consequence, the Council's SSC recommends that it be used routinely.

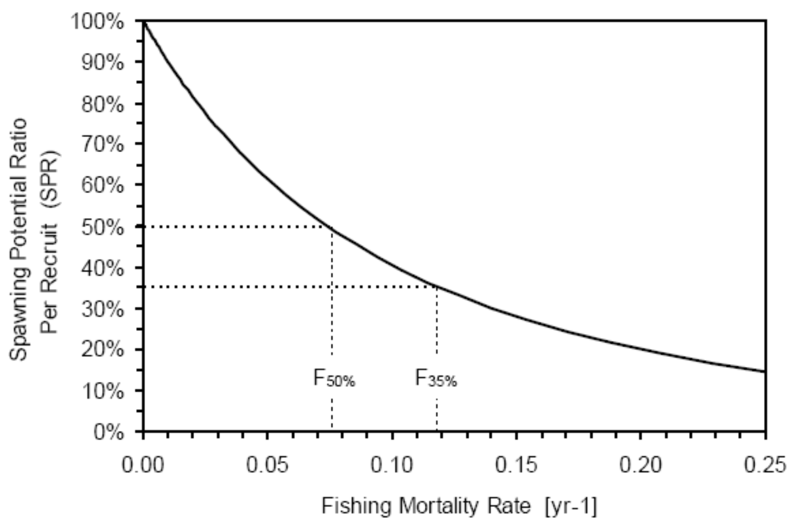

Figure 2-136. Relationship between SPR and instantaneous fishing mortality rate (F) for a hypothetical rockfish.

Amendment 23, which was adopted in December 2010 and implemented in 2011, revised the descriptions of species categories used in the development of harvest specifications. The first category (category 1) includes species with relatively data-rich quantitative stock assessments that are developed on the basis of catch-at-age, catch-at-length, or other data. Recruitments are estimated for category 1 stocks. OFLs and overfished/rebuilding thresholds can generally be calculated for these species. The second category (category 2) includes species for which some biological indicators are available yet data informing an assessment are limited (e.g., estimates of year class strength). Category 2 assessments include data-moderate assessments where catch data and one or more indices of abundance inform the status and biomass of the stock, but age and length compositional data are excluded. This type of assessment allows for a more expeditious assessment review than the category 1 full assessments, which require a rigorous review process[14], thus enabling more stocks to be assessed in an assessment cycle. The third assessment category (category 3) includes minor species which are caught and where the only available information is catch. When setting the 2021 and 2022 OFLs for category 1 or 2 species, F_{MSY} harvest rate proxies were applied to estimates of exploitable biomass for assessed stocks (Table 2-25). Proxies are used because there is insufficient information for most Pacific Coast groundfish stocks to establish a species-specific F_{MSY}. The FMP allows default harvest rate proxies to be modified as scientific knowledge improves for a particular species. Catch-based methods are generally used to determine the OFL for category 3 species.

Table 2-25. Proxy harvest rates by taxa for setting overfishing limits for West Coast groundfish stocks in 2021 and 2022.

Taxa	SPR Harvest Rate
Rockfish	50%
Elasmobranchs	50%
Roundfish	45%
Pacific Whiting	40%
Flatfish	30%

New stock assessments and revised assessment projections recommended by the SSC for use in setting biennial harvest specifications were approved by the Council for setting the 2021 and 2022 biennial harvest specifications. Results from new assessments conducted in 2019 were used to determine 2021 and 2022 harvest specifications for cabezon, cowcod south of 40°10' N. lat., big skate, longnose skate, petrale sole (update assessment), sablefish, gopher and black-and-yellow rockfishes (assessed as a complex of two species), and widow rockfish (update assessment). All new harvest specifications are affected by the new sigma values endorsed by the SSC and adopted by the Council which increased the ABC buffers and reduced ABCs and ACLs relative to what they would have been under the old sigma/P* values. Catch-only projections updated the new harvest specifications in the most recent assessments for black rockfish (CA, OR, and WA), blackgill rockfish (S. of Cape Mendocino), the blue/deacon rockfishes complex (CA only), canary rockfish, China rockfish, darkblotched rockfish, Dover sole, lingcod, rougheye/blackspotted rockfish, longspine thornyhead, and shortspine thornyhead with actual total catches replacing the removal assumptions in the respective assessments for these stocks. New data-poor assessments

[14] The review process for new full assessments includes a STAR panel review and a subsequent review by the Council's SSC. Only those assessments that are endorsed by the SSC are considered for formal adoption in the Council process.

were conducted for cabezon in Washington and cowcod between Pt. Conception and 40°10' N. lat.

Two data-limited methods, DCAC and DB-SRA, have been used to determine most of the category 3 OFLs since 2011. These methods were recommended for determining 2021 and 2022 OFLs for unassessed stocks, for which there are enough relevant data. The average historical catch approach was used to determine OFLs for stocks where the historical catches were too sparse to use DCAC or DB-SRA.

2.8.2 Acceptable Biological Catches

The ABC is an annual catch specification that is the stock or stock complex's OFL reduced by an amount associated with the scientific uncertainty in estimating the OFL. Under the FMP harvest specification framework, scientific advice that is relatively more uncertain will result in ABCs that are relatively lower, all other things being equal (i.e., a precautionary reduction in catch will occur due purely to scientific uncertainty in estimating the OFL). The ABC is an SSC-recommended catch level that ACLs may not exceed. As explained in more detail below, the SSC developed a two-step approach referred to as the P* approach for determining ABCs. In the P* approach, the SSC determines the amount of scientific uncertainty associated with estimating the OFL in stock assessments, referred to as the sigma (σ) value. The Council then chooses its preferred level of risk of overfishing, a policy decision, which is designated as the overfishing probability (P*). The SSC then applies the P* value to the sigma value to determine the amount by which the OFL is reduced to establish the ABC. The SSC's recommendations for sigma and the reductions from OFL associated with different P* values are science-based recommendations; therefore, alternatives to these values are not analyzed. New sigma values were decided to inform ABCs in 2021 and beyond.

Sigma values and the associated ABC buffers are greater for stocks with greater uncertainty in the OFL estimate. The SSC assigned each species in the groundfish fishery to one of three categories based on the level of information available about the species. Table 2-26 shows the criteria used by the SSC to categorize stocks. Sigma values and the associated ABC buffers are highest for relatively data-limited category 3 stocks, lesser for data-moderate category 2 stocks, with data-rich category 1 stocks having the lowest sigma values and smallest ABC buffers.

The SSC evaluated two analytical approaches to inform new sigmas used to determine ABCs in 2021 and beyond (Table 2-27). The first approach used to calculate the baseline sigmas is an update of the meta-analysis of biomass variance of category 1 groundfish and coastal pelagic species (CPS) stocks used to calculate the status quo sigmas (Ralston*, et al.* 2011). The revised meta-analysis evaluated the uncertainty on projected OFLs and more thoroughly evaluated recruitment stochasticity. The second approach (time-varying sigmas) characterized the increased uncertainty associated with using projected OFLs from older assessments. Since true population dynamics will likely differ from expected or assumed dynamics in an assessment projection, there is increased uncertainty in future spawning output and projected OFLs as the projection period increases.

The approach used to determine the baseline sigma for category 1 stocks conducted 25-year projections for each assessment starting in 1998, 2003, and 2008, and set fishing mortality to the F_{MSY} proxy for those years, with stochastic recruitment. One-year projections derived across 15 years for each of the two or three assessments were used for each species. The standard errors for the recruitment deviations for the years before the start of the projection period were set to those for the estimated recruitment deviations from the most recent ten years of the assessment. The resulting sigma using this is 0.439. The new analyses were restricted to benchmark assessments conducted using recent versions of the stock synthesis software (from 2009 to present) and technical constraints prevented the use of seasonal models (e.g., for Pacific sardine). To account for the limitations associated with having only a subset of groundfish species in the analysis, the SSC recommended that the value chosen for sigma from the full set of species (including CPS) be scaled by the ratio of the sigma from the updated historical biomass approach (0.389) and from the subset of species used for this analysis (0.342). The SSC recommended a baseline sigma value of 0.50 (= 0.439*(0.389/0.342)) for category 1 stocks. The SSC recommended baseline sigma values of twice the category 1 value for category 2 stocks (1.0) and four times that value for category 3 stocks (2.0), which were the status ratios between these stock categories.

Time-varying sigmas apply to ABCs for category 1 and 2 stocks beginning in 2021. The OFLs from category 3 analyses are constant; therefore, time-varying sigmas do not apply to category 3 stocks. The approach used to calculate the time-varying sigmas was based on deterministic projections of spawning biomass starting from a low state of nature relative to base-model projections of spawning biomass in category 1 stock assessments. The low state of nature was constructed so that starting spawning biomass is consistent with the previous value for sigma (0.36) with a probability of 25 percent. Projections for both the base model and the low state of nature were based on an assumption of full attainment of the ABCs derived from the base model, which causes the two projections to diverge with the rate of divergence reflecting the population dynamic characteristics of the stock. The SSC recommended applying the relative rate of increase in sigma (7.5 percent of the baseline value with each additional year) to the baseline category 1 and 2 sigmas of 0.5 and 1.0, i.e.,

Sigma (years since assessment) = (baseline sigma) * (1.0 + (years since assessment – 1) * 0.075).

The projection year resets to 1 when a full or update assessment is conducted; the projection year will not reset following a catch-only projection.

Table 2-26. Criteria used by the SSC to categorize stocks based on the quantity and quality of data informing the estimate of OFL. Stock categories are used in deciding 2021 and 2022 ABCs that accommodate the uncertainty in estimating OFLs.

Category	Sub-category	Criteria
Category 1 - Data rich stocks. OFL based on F_{MSY} or F_{MSY} proxy from model output. ABC based on P* buffer.		
1	a	Reliable compositional (age and/or size) data sufficient to resolve year-class strength and growth characteristics. Only fishery-dependent trend information available. Age/size structured assessment model.
1	b	As in 1a, but trend information also available from surveys. Age/size structured assessment model.
1	c	Age/size structured assessment model with reliable estimation of the stock-recruit relationship.
Category 2 - Data moderate. OFL derived from model output (or natural mortality).		
2	a	M*survey biomass assessment (as in Rogers 1996).
2	b	Historical catches, fishery-dependent trend information only. An aggregate population model is fit to the available information.
2	c	Historical catches, survey trend information, or at least one absolute abundance estimate. An aggregate population model is fit to the available information.
2	d	Full age-structured assessment, but results are substantially more uncertain than assessments used in the calculation of the P* buffer. The SSC will provide a rationale for each stock placed in this category. Reasons could include that assessment results are very sensitive to model and data assumptions, or that the assessment has not been updated for many years.
Category 3 - Data poor. OFL derived from data-limited methods using historical catch.		
3	a	No reliable catch history. No basis for establishing OFL.
3	b	Reliable catch estimates only for recent years. OFL is average catch during a period when stock is considered to be stable and close to B_{MSY} equilibrium on the basis of expert judgment.
3	c	Reliable aggregate catches during period of fishery development and approximate values for natural mortality. Default analytical approach DCAC.
3	d	Reliable annual historical catches and approximate values for natural mortality and age at 50% maturity. Default analytical approach DB-SRA.

Table 2-27. Relationship between P* and the percent reduction of the OFL for deciding the ABCs in 2021 and beyond for category 1, category 2, and category 3 stocks. Sigmas and ABC buffers increase with the number of years since the last assessment for category 1 and 2 stocks.

Year since assessment	Category 1 (baseline σ = 0.5)				
	P*				
	0.45	0.4	0.35	0.3	0.25
1	6.1%	11.9%	17.5%	23.1%	28.6%
2	6.5%	12.7%	18.7%	24.6%	30.4%
3	7.0%	13.6%	19.9%	26.0%	32.1%
4	7.4%	14.4%	21.0%	27.5%	33.8%
5	7.8%	15.2%	22.2%	28.9%	35.5%
6	8.3%	16.0%	23.3%	30.3%	37.1%
7	8.7%	16.8%	24.4%	31.6%	38.7%
8	9.1%	17.6%	25.5%	33.0%	40.2%
9	9.6%	18.3%	26.5%	34.3%	41.7%
10	10.0%	19.1%	27.6%	35.5%	43.2%
11	10.4%	19.9%	28.6%	36.8%	44.6%
12	10.8%	20.6%	29.6%	38.0%	46.0%
13	11.3%	21.4%	30.7%	39.2%	47.3%
14	11.7%	22.1%	31.6%	40.4%	48.6%
15	12.1%	22.9%	32.6%	41.6%	49.9%
Year since assessment	**Category 2 (baseline σ = 1.0)**				
	P*				
	0.45	**0.4**	**0.35**	**0.3**	**0.25**
1	11.8%	22.4%	32.0%	40.8%	49.1%
2	12.6%	23.8%	33.9%	43.1%	51.6%
3	13.5%	25.3%	35.8%	45.3%	54.0%
4	14.3%	26.7%	37.6%	47.4%	56.2%
5	15.1%	28.1%	39.4%	49.4%	58.4%
6	15.9%	29.4%	41.1%	51.4%	60.4%
7	16.7%	30.7%	42.8%	53.3%	62.4%
8	17.4%	32.0%	44.4%	55.1%	64.2%
9	18.2%	33.3%	46.0%	56.8%	66.0%
10	19.0%	34.6%	47.6%	58.5%	67.7%
11	19.7%	35.8%	49.0%	60.1%	69.3%
12	20.5%	37.0%	50.5%	61.6%	70.8%
13	21.2%	38.2%	51.9%	63.1%	72.2%
14	22.0%	39.4%	53.3%	64.5%	73.6%
15	22.7%	40.5%	54.6%	65.9%	74.9%

	Category 3 (constant σ = 2.0)				
	P*				
	0.45	0.4	0.35	0.3	0.25
	22.2%	39.8%	53.7%	65.0%	74.0%

2.8.2.1 Considerations for Deciding the Overfishing Probability (P*) When Specifying an Acceptable Biological Catch

The overfishing probability metric (P*) is technically defined as the probability of overfishing a stock based on the scientific uncertainty in estimating the OFL. Interpretation of this definition has generated much discussion in the Council's harvest specification decision-making process. Either P* is interpreted narrowly as the actual probability of overfishing, or P* is considered more broadly as the Council's level of tolerance towards the risk that the OFL will be exceeded. Both viewpoints have merit, but the latter view has more utility in the Council process and is a more accurate representation of how the P* value is decided.

The one problem with the literal definition of P* is that the SSC has recommended a baseline value of sigma (0.50) for category 1 stocks, which are stocks that have assessments with estimated recruitment deviations (i.e., the strength of individual year classes is estimated). Nevertheless, category 1 assessments vary greatly both in the degree of uncertainty and how that uncertainty is characterized in the assessment model. It is common that one or more parameters are either estimated outside the model or assumed based on the assessment scientist's best judgment. In such cases, the uncertainty associated with that parameter is also not estimated nor characterized in any way within the assessment. For example, the 2019 sablefish assessment (Haltuch*, et al.* 2019) appeared to estimate current biomass with significant uncertainty. However, within that assessment many of the key parameters that affect the estimated biomass such as growth and natural mortality are explicitly estimated within the model. The confidence interval associated with the ending year biomass estimate appears quite large relative to other assessments since the uncertainties associated with estimated growth and natural mortality are included within the overall assessment uncertainty. This compares to many other assessments, such as splitnose rockfish in 2009 (Gertseva*, et al.* 2009) or longspine thornyhead in 2013 (Stephens and Taylor 2013) where many parameters are assumed and fixed (e.g., natural mortality and steepness) because there is insufficient information to estimate these parameters in the assessment. In these cases, the biomass variances tend to underestimate the actual uncertainty.

The spectrum of assessment approaches vary between fully Bayesian models with most key parameters estimated (e.g., sablefish in 2019) to deterministic models with most parameters fixed (e.g., longspine thornyhead in 2013). Within the spectrum are parameter estimations using informed or diffuse priors. Given this variety of approaches and the degree to which uncertainty is characterized, it is hard to pursue a formulaic approach where the P* decision hinges on the scientific uncertainty associated with estimating the OFL. For the most part, the relative uncertainty in estimating the OFL is addressed with the SSC's sigma specification, which is only intended to broadly distinguish between assessments along the data-limited to data-rich continuum. The Council's P* decision is therefore most appropriately considered as a risk assessment given many sources of uncertainty regarding the true state of nature for a stock.

2.8.3 Annual Catch Limits

ACLs are specified for each stock and stock complex that is "in the fishery" as specified under the FMP framework. An ACL is a harvest specification set equal to or below the ABC in consideration of conservation objectives, management uncertainty, socioeconomic considerations, ecological considerations, and other factors (e.g., rebuilding considerations) needed to meet management objectives. Sector-specific ACLs may be specified in cases where a sector has a formal, long-term allocation of the harvestable surplus of a stock or stock complex. The ACL counts all sources of fishing-related mortality including landed catch; discard mortalities; research catches; and set-asides for tribal catches, incidental catches in non-groundfish fisheries, and EFPs.

Under the FMP, the biomass level that produces MSY (B_{MSY}) is defined as both the target biomass and the precautionary threshold. When the biomass for an assessed category 1 or 2 stock falls below the precautionary threshold, the harvest rate will be reduced to help the stock return to the B_{MSY} level. If a stock biomass is larger than B_{MSY}, the ACL may be set equal to or less than the ABC. Because B_{MSY} is a long-term average, the true biomass could be below B_{MSY} in some years and above B_{MSY} in other years. Even in the absence of overfishing, biomass may decline to levels below B_{MSY} due to natural fluctuations in recruitment. The MSST is the biomass threshold for declaring a stock overfished. When spawning stock biomass falls below the MSST, a rebuilding plan must be developed that determines the strategy for rebuilding the stock in the shortest time possible while considering impacts to fishing-dependent communities and other factors. As an overfished stock rebuilds above the MSST yet is still below B_{MSY}, the stock is categorized as rebuilding. When spawning stock biomass is below B_{MSY} yet above the MSST and the stock is not managed under a rebuilding plan, the stock is considered to be in the precautionary zone. The current proxy B_{MSY} and MSST reference points for West Coast groundfish stocks are as follows:

- Assessed flatfish stocks: B_{MSY} = 25 percent of initial biomass or $B_{25\%}$; MSST = 12.5 percent of initial biomass or $B_{12.5\%}$ (PFMC and NMFS 2011); and
- All other assessed groundfish stocks: B_{MSY} = 40 percent of initial biomass or $B_{40\%}$; MSST = 25 percent of initial biomass or $B_{25\%}$.

These reference points are only used to manage assessed stocks since they require estimates of spawning stock biomass and relative depletion.

West Coast groundfish stocks are managed with harvest control rules that calculate ACLs below the ABCs when spawning biomass is estimated to be in the precautionary zone. These harvest control rules are designed to prevent a stock from becoming overfished. The FMP defines the 40-10 harvest control rule for stocks with a B_{MSY} proxy of $B_{40\%}$ that are in the precautionary zone. The analogous harvest control rule for assessed flatfish stocks is the 25-5 harvest control rule. Both ACL harvest control rules are applied after the ABC deduction is made. The further the stock biomass is below the precautionary threshold, the greater the reduction in ACL relative to the ABC, until at $B_{10\%}$ for a stock with a B_{MSY} proxy of $B_{40\%}$ or $B_{5\%}$ for a stock with a B_{MSY} proxy of

$B_{25\%}$, the ACL would be set at zero[15] (Figure 2-137). These harvest policies foster a quicker return to the B_{MSY} level and serve as an interim rebuilding policy for stocks that are below the MSST. The Council may recommend setting the ACL higher than what the default ACL harvest control rule specifies as long as the ACL does not exceed the ABC, complies with the requirements of the MSA, and is consistent with the FMP and National Standard Guidelines. Additional precautionary adjustments may be made to an ACL if necessary to address management uncertainty, conservation concerns, socioeconomic concerns, ecological considerations, and the other factors that are considered when setting ACLs.

The ACL serves as the basis for invoking AMs, which are management measures or mechanisms used to address any management uncertainty that may result in exceeding an ACL. If ACLs are exceeded more often than 1 in 4 years, then AMs, such as catch monitoring and inseason adjustments to fisheries, need to improve or additional AMs may need to be implemented. Additional AMs may include setting an annual catch target (ACT), which is a specified level of harvest below the ACL. The use of ACTs may be especially important for a stock subject to highly uncertain inseason catch monitoring. A sector-specific ACT may serve as a HG for a sector or may be used strategically in a rebuilding plan to attempt to reduce mortality of an overfished/rebuilding stock more than the rebuilding plan limits prescribe.

The Council has the discretion to adjust the ACLs for uncertainty on a case-by-case basis. In cases where there is a high degree of uncertainty about the condition of the stock or stocks, the ACL may be reduced accordingly. Most category 3 species are managed in a stock complex (such as the rockfish complexes and the Other Flatfish complex) where harvest specifications are set for the complex in its entirety. For stock complexes, the ACL will be less than or equal to the sum of the individual component ABCs. The ACL may be adjusted below the sum of component ABCs as appropriate.

[15] The lower $B_{10\%}$ and $B_{5\%}$ thresholds in the precautionary ACL harvest control rules are used to establish the slope of the ACL curve in Figure 2-138. These precautionary ACL control rules only apply for stocks in the precautionary zone ($B_{MSY} > B_{CURRENT} >$ MSST). A rebuilding plan governs the ACL harvest control rule for any stock that falls below the MSST and is designated as overfished.

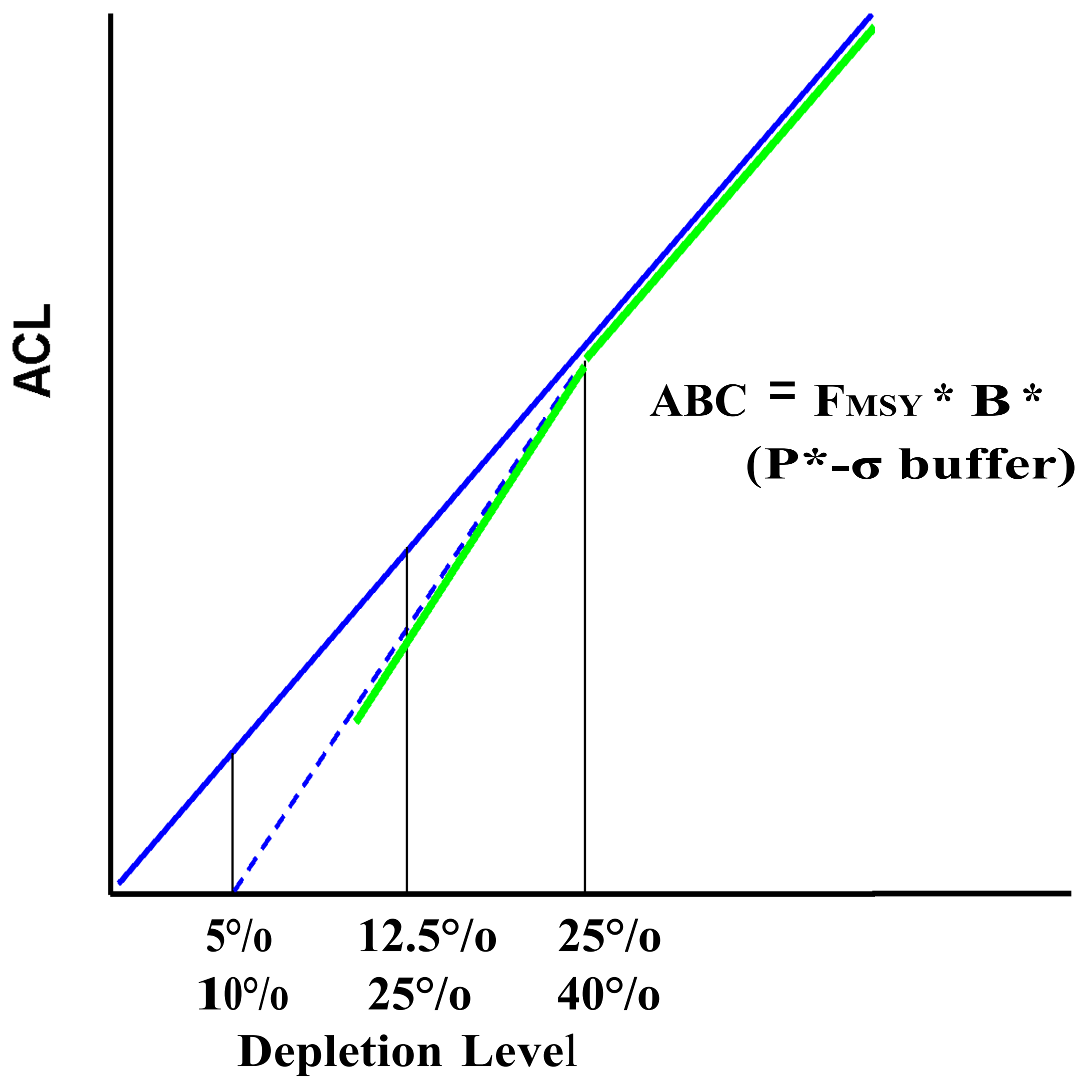

Figure 2-137. Conceptual diagram of the 25-5 and 40-10 ACL harvest control rules used to manage assessed West Coast flatfish and other groundfish species, respectively, that are in the precautionary zone.

CHAPTER 3 LANDINGS AND REVENUE IN COMMERCIAL, TRIBAL, AND RECREATIONAL PACIFIC COAST GROUNDFISH FISHERIES

This chapter was generated using R Markdown. Commercial and tribal fishery data from the Pacific Fishery Information Network (PacFIN) data system was accessed from within the R environment and last refreshed for production of this chapter on May 18, 2020 with data through the previous year. Recreational fishery data was provided by Ed Waters, who compiled state level data provided by GMT representatives.

3.1 Commercial Fishery

Commercial and tribal fishery reporting reflects the kinds of data presented in a series of tables maintained in the PacFIN Answers environment. Non-confidential versions of these tables may be viewed on and downloaded from the Groundfish SAFE page on the Council's website.

Non-confidential data have been used as the source for the tables and figures in this report. If a data value is attributed to fewer than three vessels or processors the data are considered confidential. In limited instances this requirement may affect the totals reported in the tables.

Some of the sections below report landings and revenues by fishery sectors. Fishery managers frequently view groundfish fisheries by these sectors. These sectors are defined by the permit status of participating vessels, gear type, target species, and various other historical factors.

3.1.1 Long-Term Trends in Landings and Revenue

Figure 3-1 shows shoreside groundfish landings (panel a) and inflation adjusted ex-vessel revenue (panel b) trends since 1981. The solid horizontal lines show one standard deviation above and below the mean, represented by the dotted line. Groundfish landings reached their highest point in 2017 at 184,951 metric tons. Ex-vessel revenue was at its maximum in 1987 at $138.80 million.

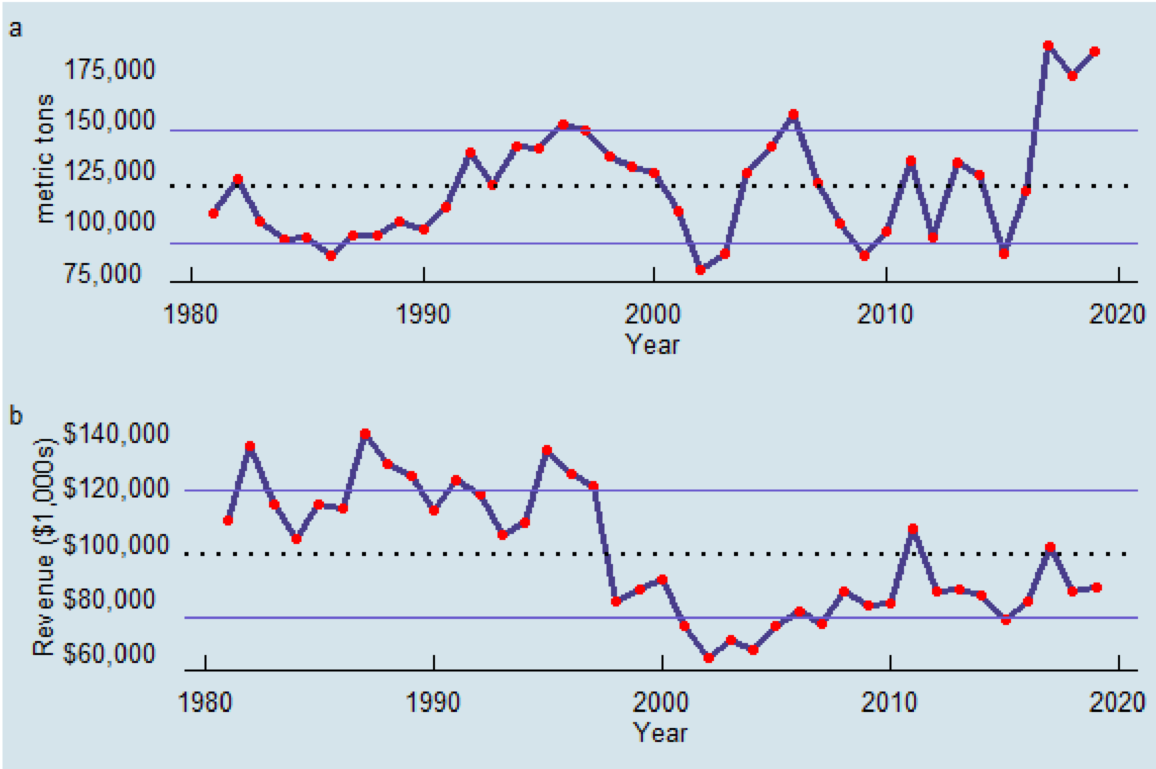

Figure 3-1. Proportion of shoreside commercial and tribal groundfish landings (top) and inflation-adjusted ex-vessel revenue for groundfish species.

3.1.2 Landings by Species (Tables 2a & b)

Table 3-1 shows annual average annual shoreside landings and revenue for groundfish species and species groups for the last ten years, 2010- 2019. Pacific whiting dominates landings by weight while sablefish accounts for the largest share of ex-vessel revenue. Dover sole, rockfish, petrale sole, and thornyheads account for most of the rest of landings and revenue accounting for 95 percent of total landings.

Table 3-1. Shoreside commercial and tribal groundfish landings (mt) (left panel) and ex-vessel revenue in inflation-adjusted, $1,000s, (right panel) by species or species group; annual average last 10 years.

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
P. Whiting	101,697	78.3%	$22,035	25.9%
Dover Sole	7,365	5.7%	$7,281	8.5%
Rockfish	6,382	4.9%	$8,099	9.5%
Sablefish	5,380	4.1%	$31,919	37.4%
Petrale Sole	2,157	1.7%	$6,078	7.1%

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Thornyheads	1,786	1.4%	$4,401	5.2%
Arrowtooth flounder	1,559	1.2%	$391	0.5%
Other Groundfish	1,486	1.1%	$1,104	1.3%
Other Flatfish	716	0.6%	$788	0.9%
Lingcod	514	0.4%	$1,609	1.9%
P. Cod	409	0.3%	$510	0.6%
English Sole	259	0.2%	$196	0.2%
Other Roundfish	117	0.1%	$824	1.0%

Figure 3-2 shows the long-term trend in landings (panel a, mt) and ex-vessel revenue (panel b, inflation adjusted dollars) of sablefish, Pacific whiting, and all other remaining groundfish species. As noted above, by weight, Pacific whiting has become a much larger fraction total groundfish catch. While sablefish and whiting have come to dominate in terms of revenue, rockfish were a much larger component of catch until the mid-1990s.

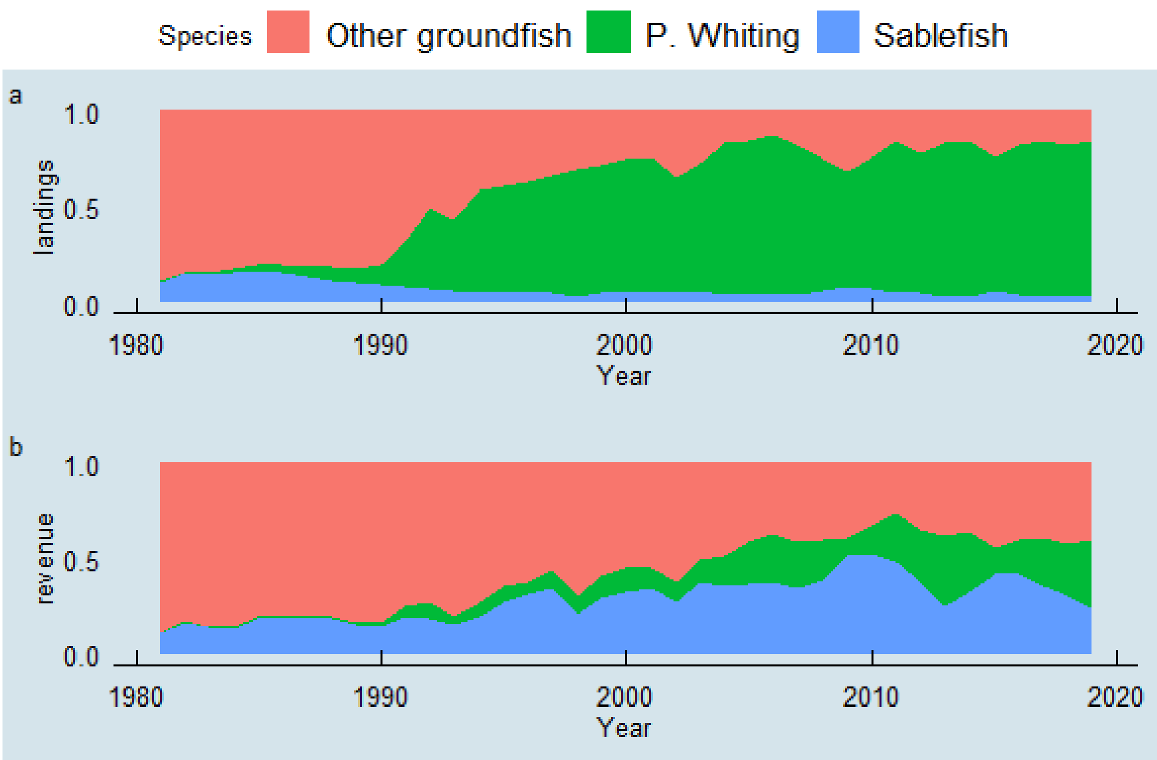

Figure 3-2. Proportion of landings (panel a) and revenue (panel b) by principal species groups.

3.1.3 *Shoreside Non-whiting IFQ Fishery (Tables 4a & b, Tables 5a & b)*

This sector catches a variety species with trawl and fixed gear and is managed under an IFQ program. Sablefish and some flatfish are the main revenue earners for vessels not targeting Pacific whiting.

Table 3-2 shows 2010- 2019 annual average landings and revenue for the shoreside non-whiting IFQ trawl fishery. Dover sole accounts for the largest share of revenue at 25.5 percent followed by sablefish at 24.7 percent. Over this period ex-vessel revenue amounted to $281.36 million. (Only species with average landings comprising at least 0.5 percent of catch are displayed in the table.)

Table 3-2. Shoreside non-whiting trawl IFQ fishery landings (mt) and ex-vessel revenue in inflation-adjusted, $1,000s, by species or species group; annual average last 10 years. Species and species groups are ranked from largest to smallest by ex-vessel revenue.

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Dover Sole	7,259	35.9%	$7,178	25.5%
Sablefish	1,555	7.7%	$6,950	24.7%
Petrale Sole	1,993	9.8%	$5,615	20.0%
Rockfish	3,878	19.2%	$3,274	11.6%
Thornyheads	1,551	7.7%	$2,155	7.7%
Other Groundfish	1,062	5.2%	$889	3.2%
Lingcod	316	1.6%	$647	2.3%
Other Flatfish	609	3.0%	$596	2.1%
Arrowtooth flounder	1,525	7.5%	$383	1.4%
P. Cod	188	0.9%	$258	0.9%
English Sole	190	0.9%	$137	0.5%

Table 3-3 shows annual average landings and revenue in the non-trawl component of the shoreside IFQ fishery in the last 10 years, 2010-2019. Landings and revenue are almost entirely sablefish in contrast to the trawl component of the IFQ fishery. In this fishery sablefish accounts for the largest share of revenue at 98.4 percent followed by thornyheads at 0.8 percent. Total revenue for the period was $50 million, which is 18 percent of shoreside trawl IFQ landings. (Only species with average landings comprising at least 0.1 percent of catch are displayed in the table.)

Table 3-3. Shoreside IFQ - Non-trawl landings (mt) and ex-vessel revenue in inflation-adjusted ($1,000s) by groundfish species or species group; annual average last 10 years. Species and species groups are ranked from largest to smallest by ex-vessel revenue.

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Sablefish	796	96.0%	$4,898	98.4%
Thornyheads	9	1.0%	$40	0.8%
Rockfish	12	1.5%	$20	0.4%
Lingcod	3	0.4%	$8	0.2%
Other Groundfish	4	0.5%	$3	0.1%
Dover Sole	2	0.3%	$3	0.1%
Non-groundfish	1	0.2%	$1	0.0%

3.1.4 Non-nearshore Fixed Gear Sector (Tables 8a & b)

Fixed gear (longline and pot) fisheries are divided between limited entry and open access from a regulatory standpoint, but fishery managers more commonly determine management measures for nearshore fisheries and those targeting deeper water species further offshore. The non-nearshore fishery primarily targets sablefish and also lands thornyheads (species in the rockfish family).

Table 3-4 shows annual average landings and revenue for the non-nearshore fixed gear fishery for the last 10 years, 2010-2019. The species composition in this sector is similar to the IFQ non-trawl sector, which also uses longline gear to target sablefish, the predominant species in terms of both landings and revenue. In this fishery sablefish accounts for 86.4 percent of revenue followed by thornyheads at 9.9 percent. Total revenue for the period was $191 million.

Table 3-4. Non-nearshore fixed gear sector landings (mt) and ex-vessel revenue in inflation-adjusted ($1,000s) by groundfish species or species group; annual average last 10 years. Species and species groups are ranked from largest to smallest by ex-vessel revenue.

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Sablefish	2,437	85.5%	$16,491	86.4%
Thornyheads	162	5.7%	$1,882	9.9%
Non-groundfish	29	1.0%	$298	1.6%
Blackgill rockfish	41	1.4%	$140	0.7%
Other Slope Rockfish	28	1.0%	$60	0.3%
Other Groundfish	75	2.6%	$55	0.3%
Rougheye Rockfish	30	1.1%	$54	0.3%

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Other Roundfish	16	0.6%	$51	0.3%
Shelf Rockfish	5	0.2%	$21	0.1%
Other Rockfish	7	0.3%	$18	0.1%
Flatfish	7	0.2%	$9	0.0%
Spiny Dogfish	11	0.4%	$7	0.0%

Unlike most groundfish which have a trawl and non-trawl allocation, sablefish north of 36° N. lat. is managed with allocations that were established under Amendment 6 (see Figure 6-1 of the Groundfish FMP). The non-nearshore fishery targeting sablefish is comprised of the primary tier fishery, the LE DTL fishery, and the OA DTL fishery. Table 3-5 below provides a historical estimate of total mortality of sablefish north in each of these sectors from 2009-2020.

Table 3-5. Non-trawl total mortality (mt) for sablefish north of 36° N. lat. by sector, 2009-2020. Source: PacFIN for landings a/ and WCGOP GEMM for discard b/.

Year	LEFG Primary	LEFG DTL	OA
2009	1901.3	403.9	530.5
2010	1752.1	614.9	426.9
2011	1511.6	489.0	442.8
2012	1423.1	260.6	268.0
2013	1045.8	191.3	152.4
2014	1100.4	148.0	266.8
2015	1346.2	203.2	420.1
2016	1446.0	241.9	397.7
2017	1453.8	282.1	439.6
2018	1479.9	245.7	379.1
2019	1456.0	194.5	369.0
2020	1317.9	161.2	189.8

Note: The WCGOP GEMM estimates landings and discards for sablefish in the directed halibut fishery. Unlike all other groundfish species though where mortality in this fishery is counted in the "off-the-top" deductions, sablefish mortality is accounted for in the sector in which the vessel is participating.

a/ Landings apportioned using the GMT_SABLEFISH_CODE

b/ Discard mortality is calculated by proportioning the sablefish discard mortality in the directed Pacific halibut fishery by the landings in each sector and adding it to the estimated discard mortality for each of the three non-trawl sablefish sectors (LEFG primary, LEFG DTL, OA).

3.1.5 Nearshore Fixed Gear Sector (Tables 9a & b)

Table 3-6 shows annual average landings and revenue for the nearshore fixed gear fishery, 2010-2019. This fishery primarily catches a variety of rockfish species; other nearshore rockfish accounts for 20.4 percent of revenue followed by black rockfish at 19.8 percent. Total revenue for the period was $41 million. (Species with average landings less than 0.5 mt are excluded from the table.)

Table 3-6. Nearshore fixed gear sector landings (mt) and ex-vessel revenue in inflation-adjusted ($1,000s) by groundfish species or species group; annual average last 10 years. Species and species groups are ranked from largest to smallest by ex-vessel revenue.

Species	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Other Nearshore Rockfish	50	10.9%	$826	20.4%
Black Rockfish	161	35.3%	$802	19.8%
Cabezon	50	11.0%	$572	14.1%
Lingcod	78	17.1%	$491	12.1%
Gopher Rockfish	25	5.5%	$446	11.0%
Brown Rockfish	23	5.0%	$357	8.8%
Kelp Greenling	19	4.3%	$227	5.6%
Other Rockfish	26	5.7%	$182	4.5%
Blue Rockfish	13	2.8%	$65	1.6%
Non-groundfish	7	1.5%	$52	1.3%
Flatfish	3	0.6%	$26	0.7%
Other Groundfish	1	0.3%	$3	0.1%

3.1.6 Comparison of Shoreside Fishery Sectors (Tables 12a & b)

Table 3-7 summarizes annual average groundfish landings and revenue by shoreside fishery sectors for the last 10 years including the shoreside whiting sector. (Other sectors in Groundfish SAFE Tables 12a & b are combined as Other, because they account for a small fraction of total groundfish landings and revenue.) Trawl fisheries account for 63 percent of revenue from these sectors. The shoreside whiting fishery accounts for 79.5 percent of landings but only 27.7 percent of total groundfish revenue, reflecting the fact that this is a high volume, low unit value fishery.

Table 3-7. Annual average groundfish landings (mt) and ex-vessel revenue in inflation-adjusted, $1,000s, last 10 years, by shoreside fishery sector.

Fishery Sector	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Shoreside IFQ Trawl (Non-whiting)	20,208	16.3%	$28,092	35.2%
Shoreside IFQ Trawl (Whiting)	98,779	79.5%	$22,121	27.7%
Non-Nearshore Fixed Gear	2,935	2.4%	$19,588	24.5%
Shoreside IFQ Non-trawl	828	0.7%	$4,974	6.2%
Nearshore Fixed Gear	451	0.4%	$4,000	5.0%
Other	1,060	0.9%	$1,037	1.3%

Figure 3-3 below show annual landings and revenue trends by fishery sector, in the 10 years, 2010-2019. Table 3-8 shows for each fishery sector which year in the last 10 had the highest ex-vessel revenue.

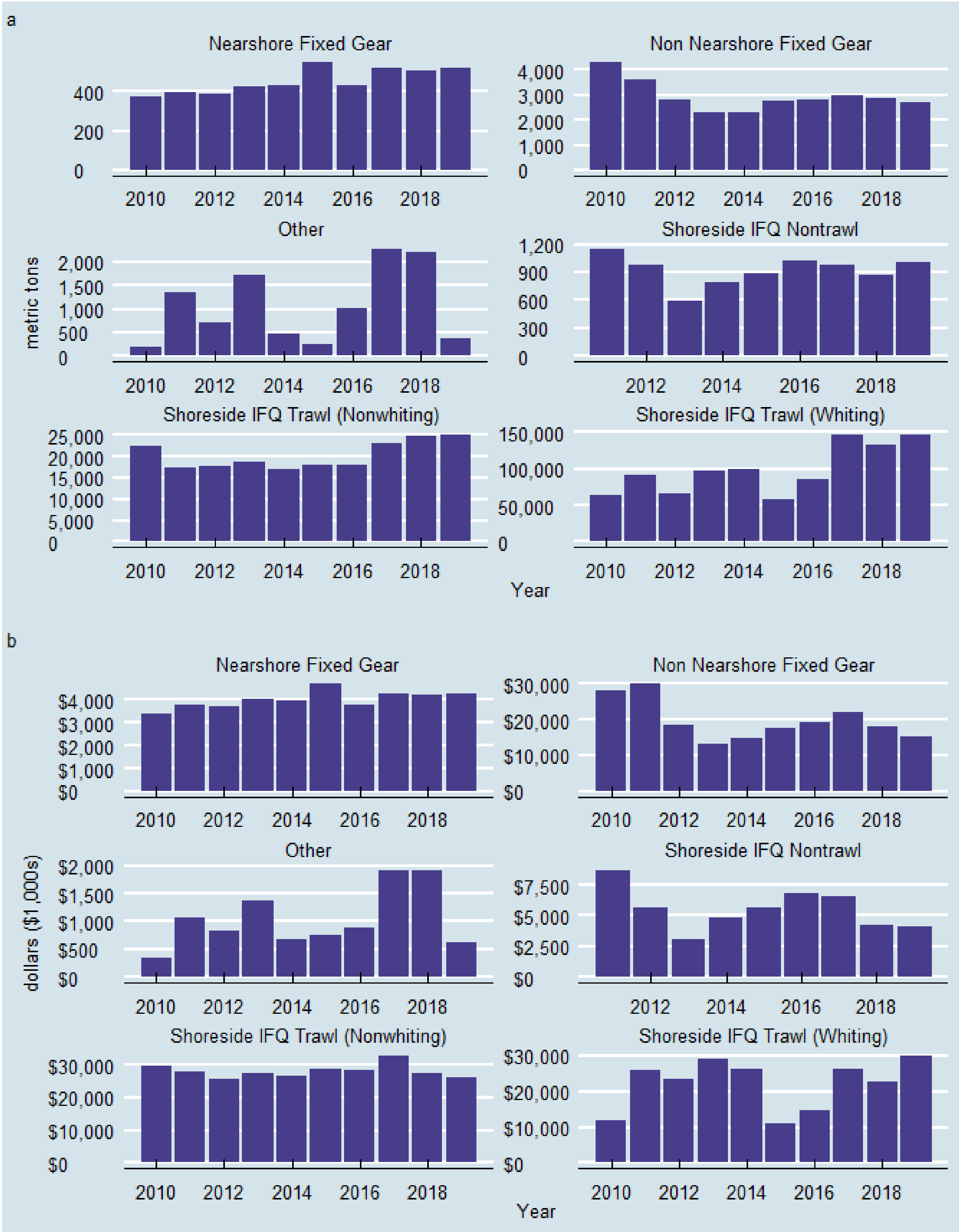

Figure 3-3. Trends in fishery sectors landings (panel a) and inflation adjusted revenue (panel b).

Table 3-8. Shoreside trawl and fixed gear sectors landing and revenue in the year with maximum revenue, last 10 years.

Fishery Sector	Year	Metric Tons	Revenue ($1,000s)
Shoreside IFQ Trawl (Whiting)	2019	147,145	$30,037
Shoreside IFQ Trawl (Non-whiting)	2017	23,175	$32,829
Non-Nearshore Fixed Gear	2011	3,632	$29,884
Nearshore Fixed Gear	2015	544	$4,688

3.1.7 At-Sea Pacific Whiting Sectors (Tables 14a & b)

The three Pacific whiting sectors – at-sea catcher-processor, at-sea mothership, and shoreside – are managed to fixed allocations of 34 percent, 24 percent, and 42 percent respectively, although actual landings have varied somewhat from these allocations. Table 3-9 shows average annual landings and revenue for the three Pacific whiting sectors, which catch almost exclusively Pacific whiting. During this period, this species' share amounted to 99.4 percent of the catch by weight.

Figure 3-4 shows landings and revenue trends, 2010-2019, for the whiting catcher/processor and mothership sectors.

Table 3-9. For Pacific whiting at-sea sector, annual average groundfish landings (mt) and ex-vessel revenue in inflation-adjusted, $1,000s, by the shoreside fishery sector.

At-sea Sector	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Whiting Catcher-Processor	91,181	37.8%	$20,892	37.9%
Whiting Mothership	51,525	21.3%	$12,039	21.9%
Shoreside IFQ Trawl (Whiting)	98,779	40.9%	$22,121	40.2%

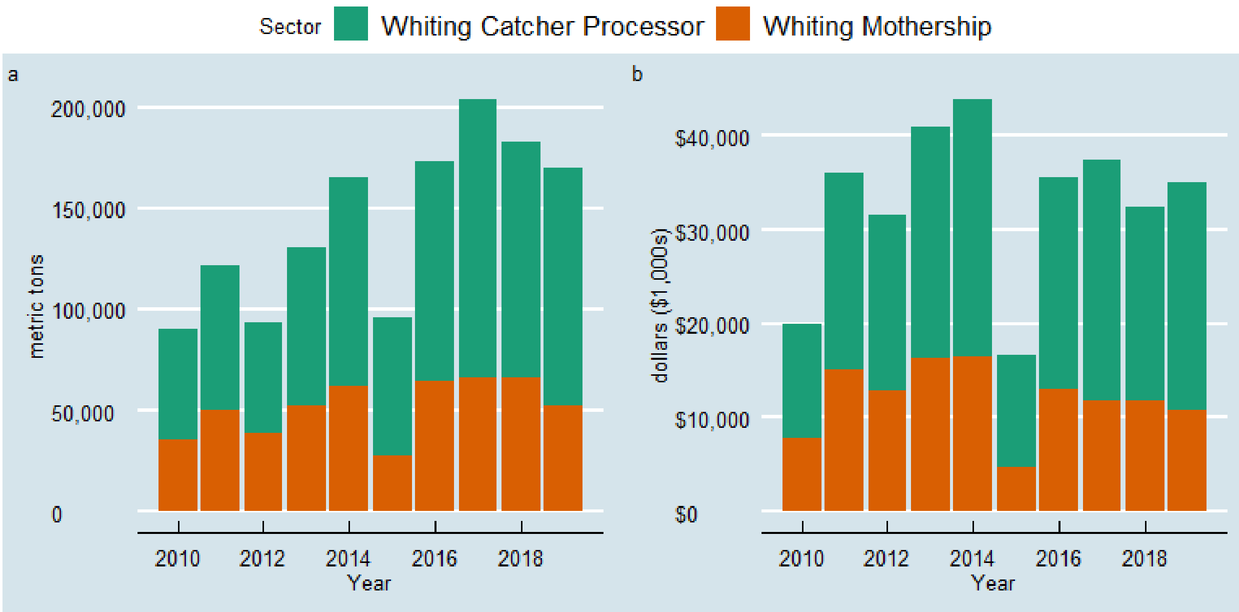

Figure 3-4. Landings (panel a) and inflation adjusted ex-vessel revenue (panel b) in the Pacific whiting catcher-processor and mothership sectors in the last 10 years.

3.1.8 Seasonality of Landings (Tables 15a & b)

Figure 3-5 shows average monthly landings by fishery sector, 2015-2019. The Pacific whiting fishery begins in May; shoreside sector landings peak in August, while the at-sea sectors show higher landings in May, a steep drop in the summer, and a resurgence in the fall. These fleets are mainly fishing in Alaska during the summer months (confidential data is excluded in the plot). Non-whiting trawl landings peak early in the year and remain fairly steady through the summer and fall. Non-nearshore fixed gear landings show distinct peaks in May and September. This reflects the April 1-October 31 primary season for limited entry vessels possessing tier limit allocations. Open access vessels participate in this fishery fish under trip limits as do limited entry vessels outside the primary season.

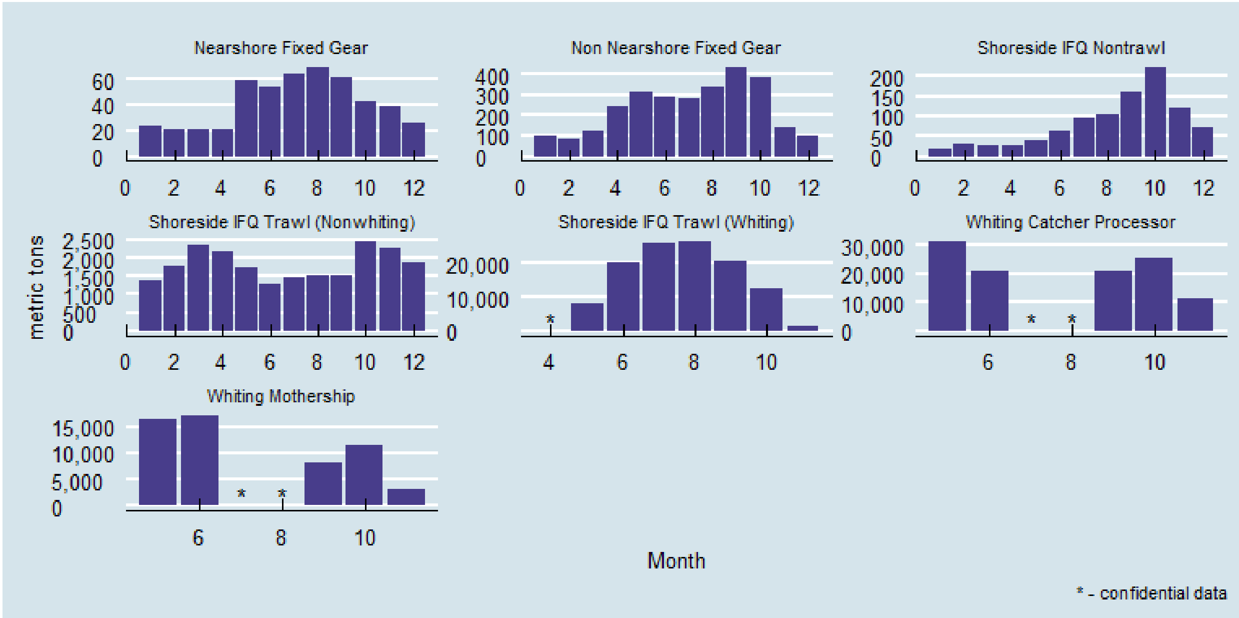

Figure 3-5. Average monthly landings (mt) by fishery sector in the last 5 years.

3.1.9 Landings and Participation by Port Group (Tables 18a & b, Table 20, Table 23)

The Groundfish SAFE tables present regional landings by IOPAC port groups. IOPAC is a regional input/output model developed by the NWFSC to estimate income and employment impacts from fishing. These impact estimates are part of the environmental impact evaluation of groundfish biennial harvest specifications and management measures. For a list of the ports included in IOPAC port groups see Table 9 in NOAA Technical Memorandum NMFS-NWFSC-111, Description of the Input-Output Model for Pacific Coast Fisheries by Jerry Leonard and Phillip Watson (June 2011).

Table 3-10 shows recent average annual landings and inflation adjusted revenue by port group, 2015-2019.

Table 3-10. Groundfish landings (mt) and ex-vessel revenue in inflation adjusted dollars, $1,000s by IOPAC port group, annual average in the last 5 years.

Port Group	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Puget Sound	1,282	0.9%	$3,449.60	4.1%
North WA Coast	1,339	0.9%	$3,711.06	4.4%
South and Central WA Coast	43,994	29.9%	$9,190.26	11.0%
Astoria	53,848	36.6%	$22,401.96	26.8%

Port Group	Metric Tons		Revenue ($1,000s)	
	Average	Percent	Average	Percent
Tillamook	48	0.0%	$254.20	0.3%
Newport	36,587	24.9%	$16,417.40	19.7%
Coos Bay	1,657	1.1%	$3,902.74	4.7%
Brookings	1,634	1.1%	$3,975.24	4.8%
Crescent City	236	0.2%	$822.24	1.0%
Eureka	3,060	2.1%	$5,198.66	6.2%
Fort Bragg	1,530	1.0%	$3,581.00	4.3%
Bodega Bay	74	0.1%	$552.44	0.7%
San Francisco	415	0.3%	$1,233.80	1.5%
Monterey	278	0.2%	$1,322.52	1.6%
Morro Bay	437	0.3%	$2,963.58	3.5%
Santa Barbara	361	0.2%	$3,354.40	4.0%
Los Angeles	70	0.0%	$533.68	0.6%
San Diego	100	0.1%	$661.94	0.8%

Figure 3-6 shows groundfish landings and inflation adjusted ex-vessel revenue by state, 2010-2019. In Washington, ex-vessel revenue during this period was highest in 2011 at $26.4 million; Oregon revenue peaked in 2017 at $54.3 million; and in California it peaked in 2011 at $28.2 million.

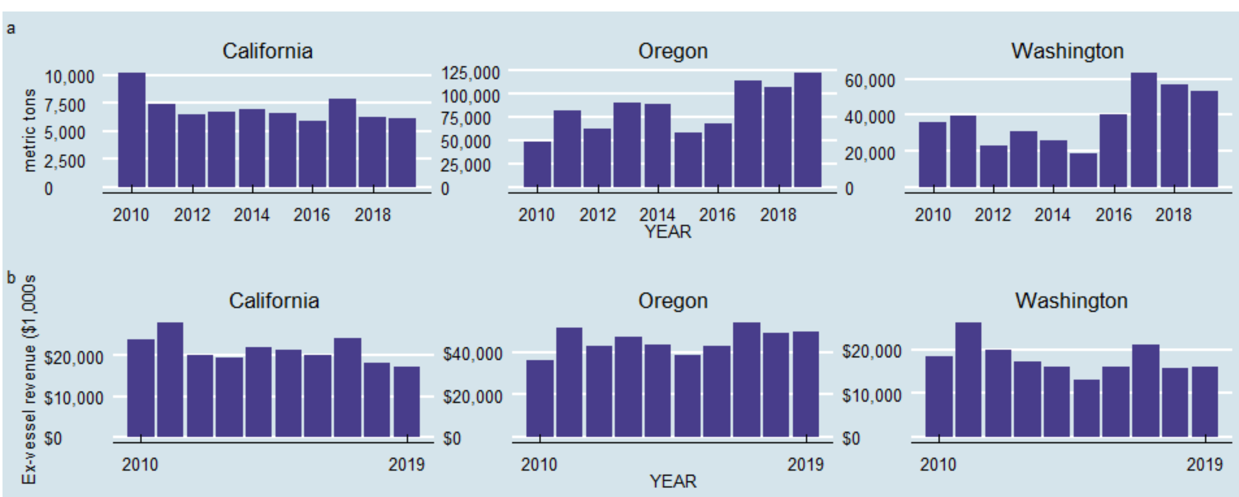

Figure 3-6. Groundfish landings (panel a) and inflation-adjusted ex-vessel revenue (panel b) by state over the past 10 years.

Table 3-11 shows average annual groundfish landings (mt) and Table 3-12 shows average annual ex-vessel revenue from 2015 to 2019 by port group and the main groundfish fishery sectors. (The data in this table are from a customized query based on SAFE landings and revenue Table 20.)

Table 3-11. Average annual landings (mt) by port group and fishery sector. (*Excluded for confidentiality.)

Port Group	Nearshore Fixed Gear	Non-Nearshore Fixed Gear	Shoreside IFQ Non-trawl	Shoreside IFQ Trawl (Non-whiting)	Shoreside IFQ Trawl (Whiting)
Puget Sound	-	267	62	695	-
North WA Coast	-	104	-	*	-
South and Central WA Coast	-	177	86	733	39,101
Astoria	1	100	263	9,072	43,496
Tillamook	36	11	-	-	-
Newport	14	399	294	4,009	31,719
Coos Bay	10	194	42	1,386	-
Brookings	174	157	*	1,286	-
Crescent City	77	53	*	105	-
Eureka	9	104	-	2,947	-
Fort Bragg	22	331	12	1,158	-
Bodega Bay	1	72	-	-	-
San Francisco	15	76	40	262	-
Monterey	23	176	32	44	-
Morro Bay	86	140	105	93	-
Santa Barbara	23	306	9	-	-
Los Angeles	6	56	-	-	-
San Diego	3	94	-	-	-

Table 3-12. Average annual inflation-adjusted ex-vessel revenue ($1,000s) by port group and fishery sector. (*Excluded for confidentiality.)

Port Group	Nearshore Fixed Gear	Non-Nearshore Fixed Gear	Shoreside IFQ Non-trawl	Shoreside IFQ Trawl (Non-whiting)	Shoreside IFQ Trawl (Whiting)
Puget Sound	-	$1,810	$401	$990	-
North WA Coast	-	$610	-	*	-
South and Central WA Coast	-	$1,217	$479	$377	$5,741
Astoria	$4	$688	$1,672	$10,920	$8,616
Tillamook	$183	$68	-	-	-
Newport	$80	$2,775	$1,776	$4,989	$6,575
Coos Bay	$74	$1,400	$312	$2,035	-
Brookings	$1,099	$859	*	$1,944	-
Crescent City	$364	$288	*	$165	-
Eureka	$52	$595	-	$4,545	-
Fort Bragg	$233	$1,271	$40	$2,010	-
Bodega Bay	$6	$542	-	-	-
San Francisco	$153	$581	$83	$361	-
Monterey	$346	$837	$53	$70	-
Morro Bay	$1,232	$854	$520	$271	-
Santa Barbara	$289	$2,884	$97	-	-
Los Angeles	$61	$454	-	-	-
San Diego	$22	$625	-	-	-

Table 3-13 shows measures of port engagement and dependence on groundfish fisheries based on inflation adjusted ex-vessel revenue from 2015 to 2019. Engagement measures the proportion of coastwide revenue flowing to a port, while dependence measures how much of total ex-vessel revenue in each port comes from the groundfish fishery. As reflected in the landings data reported above, the most three most engaged port groups are Astoria (28 percent), Newport (21 percent), and South and Central WA Coast (10 percent). The ports most dependent on groundfish are Astoria (53 percent), Fort Bragg (38 percent), and Morro Bay (36 percent). Coastwide dependence on groundfish is 19 percent.

Table 3-13. Engagement (groundfish ex-vessel revenue by port group as percent of ex-vessel coastwide revenue) and dependence (groundfish ex-vessel revenue in port as percent of total ex-vessel revenue in port), using inflation adjusted dollars in the last five years.

Port Group	Engagement	Dependence
Washington	**15%**	**13%**
Puget Sound	4%	32%
North WA Coast	1%	30%
South and Central WA Coast	10%	11%
Not specified	0%	0%
Oregon	**59%**	**31%**
Astoria	28%	53%
Tillamook	0%	6%
Newport	21%	31%
Coos Bay	5%	12%
Brookings	5%	24%
Not specified	0%	0%
California	**26%**	**12%**
Crescent City	1%	5%
Eureka	7%	33%
Fort Bragg	5%	38%
Bodega Bay	1%	6%
San Francisco	2%	5%
Monterey	2%	9%
Morro Bay	4%	36%
Santa Barbara	4%	8%
Los Angeles	1%	3%
San Diego	1%	9%
Not specified	0%	44%

3.2 Tribal Fishery

Because tribes have sovereign rights to manage their fisheries, the tribal sectors do not have an equivalent regulatory dimension like the commercial sectors discussed above. The Makah Tribe participates in whiting fisheries with both a mothership and shorebased component. SAFE Table 14a & b report landings by the whiting sectors including tribal shorebased and mothership sectors.

The tribal non-whiting sector is defined by groundfish landings other than whiting and, thus, includes a variety of gear types. While all four coastal tribes have longline fleets, only the Makah Tribe currently has a trawl fleet. Table 3-14 shows 2010-2019 annual average landings and inflation-adjusted ex-vessel revenue for tribal fisheries by gear type, grouped by sablefish and other groundfish. It is modeled on SAFE Table 13. Over this period sablefish caught by hook and line accounted for the most ex-vessel revenue at $13.92 million. This was followed by other groundfish caught by trawl, accounting for $6.41 million.

Table 3-14. Groundfish landings (mt) and inflation adjusted ex-vessel revenue in tribal fisheries by species group and gear, annual average in the last 10 years.

	Gear	Metric Tons		Revenue ($1,000s)	
		Average	Percent	Average	Percent
Other Groundfish					
	Hook-and-line	49	6%	$130	3%
	Trawl	478	61%	$1,282	30%
	Troll	8	1%	$19	0%
	Other	1	0%	$8	0%
Sablefish					
	Hook-and-line	242	31%	$2,785	65%
	Trawl	10	1%	$45	1%
	Troll	0	0%	$2	0%
	Other	*	*	*	*

Figure 3-7 shows annual tribal non-whiting groundfish landings (panel a) and inflation-adjusted ex-vessel revenue (panel b), 2010-2019.

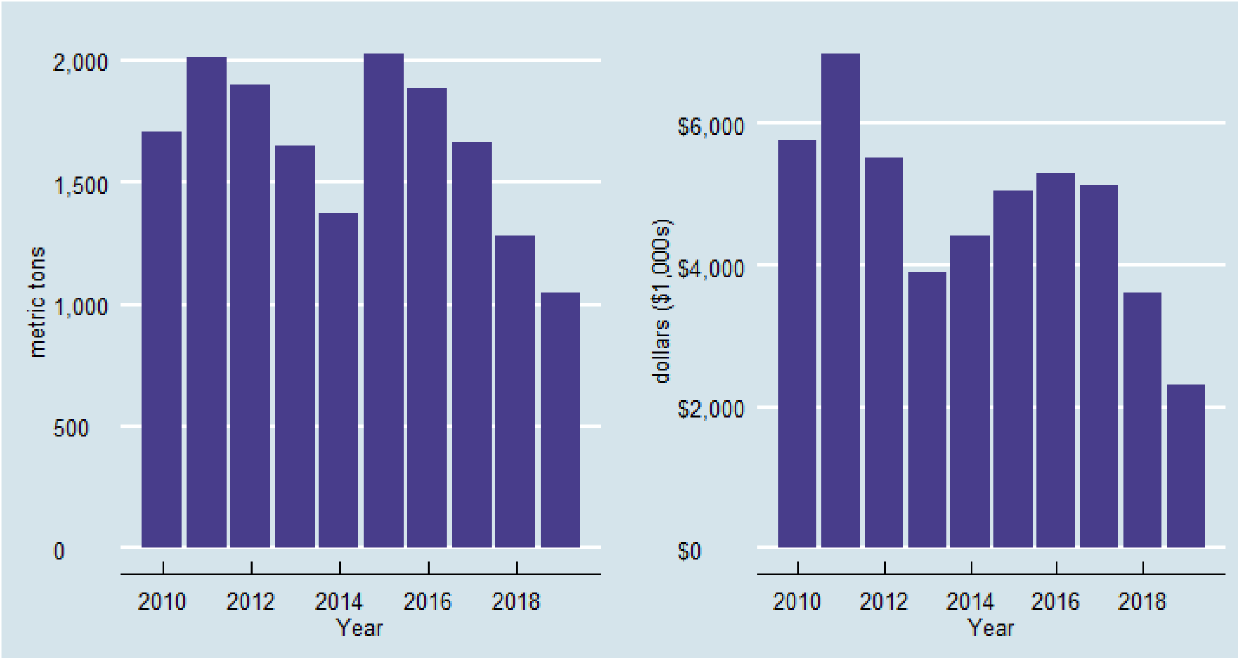

Figure 3-7. Annual landings and inflation-adjusted revenue in shoreside non-whiting tribal fisheries.

3.3 Recreational Fishery

Recreational fisheries are an important part of fishery-related economic activity. Because recreational catch is not sold, it is more difficult to impute the economic value of these fisheries. Recreational fisheries are broadly subdivided between private anglers and commercial passenger fishing vessels, commonly referred to as charter vessels. Private anglers fish from shore or from their own boats, while charter vessels take paying passengers. There are two other non-boat-based fishing modes, from the shoreline (beach/bank) and from man-made structures such as piers. These two modes account for relatively little angler effort directed towards bottomfish/halibut. Trip types are not specified with respect to the species managed under the Groundfish FMP but bottomfish and halibut directed trips represent the best approximation of groundfish directed trips.

Table 3-15 shows recreational fishing effort from 2008 to 2018. Fishing from vessels accounts for most bottomfish/halibut effort with charter vessels accounting for 54 percent and private vessels a further 32 percent. For other targets fishing from shore represents a larger share of total effort.

Table 3-15. Recreational fishing effort by mode in the last 10 years. (Source: GMT, Ed Waters.)

Mode	Groundfish and Halibut		Other	
	Average	Percent	Average	Percent
Charter	515,614	54%	132,897	5%
Private	308,016	32%	441,892	18%

Mode	Groundfish and Halibut		Other	
	Average	Percent	Average	Percent
Beach/Bank	0	0%	885,179	36%
Man-made	127,811	13%	1,002,095	41%

Figure 3-8 shows recreational fishing effort (angler trips) by mode for trips directed towards groundfish/halibut and other species by year. Total fishing effort has generally varied without trend year to year.

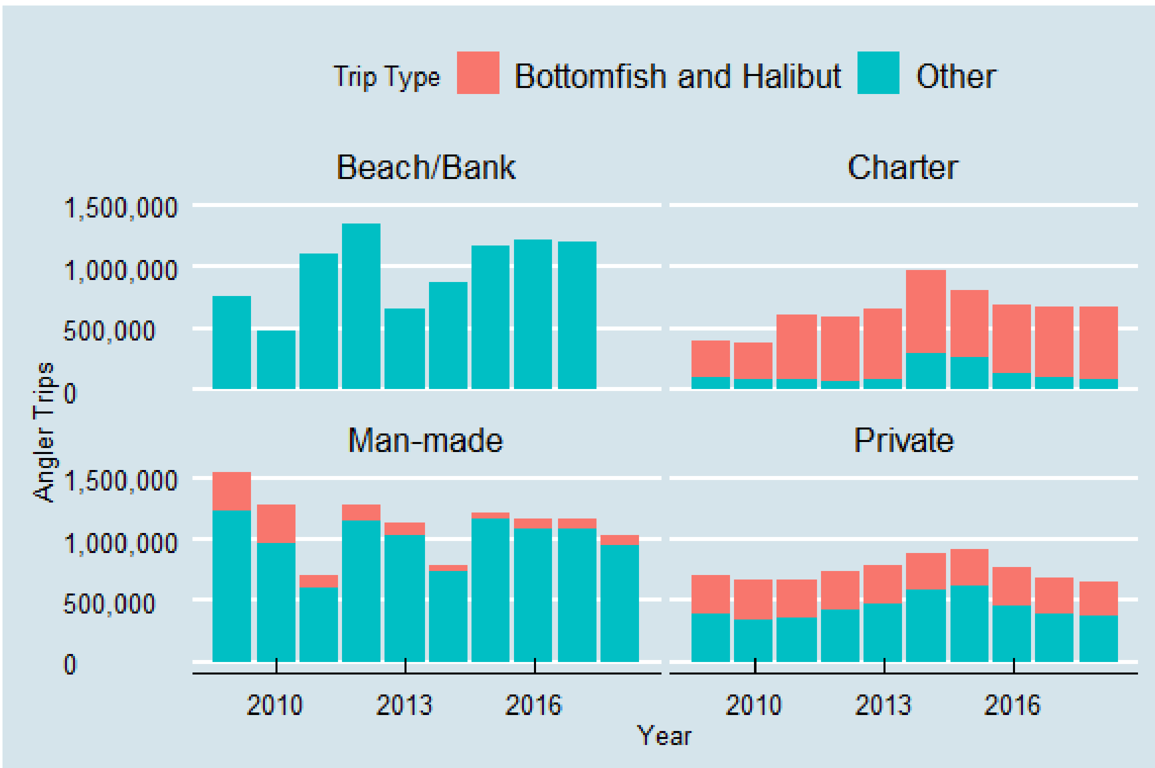

Figure 3-8. Total angler trips by year, mode, and trip type. (Source: GMT, Ed Waters.)

Figure 3-9 shows bottomfish/halibut directed angler trips by state broken out by charter and private boat trips. Note that the y-axis is scaled to the total amount of angler effort in each state and it can be seen that California accounts for the vast majority of bottomfish/halibut angler fishing effort on the West Coast.

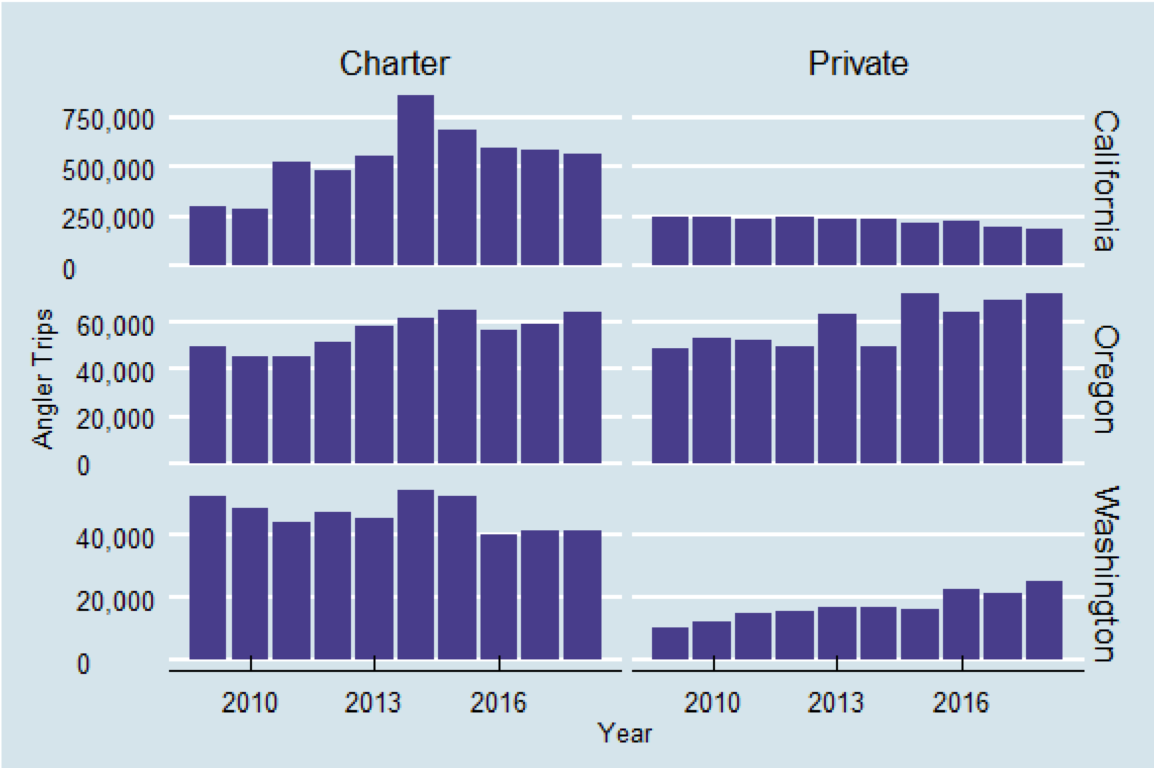

Figure 3-9. Bottomfish/halibut angler trips by year, state, and trip type. Beach/bank and man-made modes excluded. (Source: GMT, Ed Waters.)

Figure 3-10 shows a more fine-grained break down of bottomfish/halibut angler effort by district or region. In this figure the y-axis is scaled to the total amount of effort in each region. The Southern California Bight accounts for the majority of fishing effort on the West Coast.

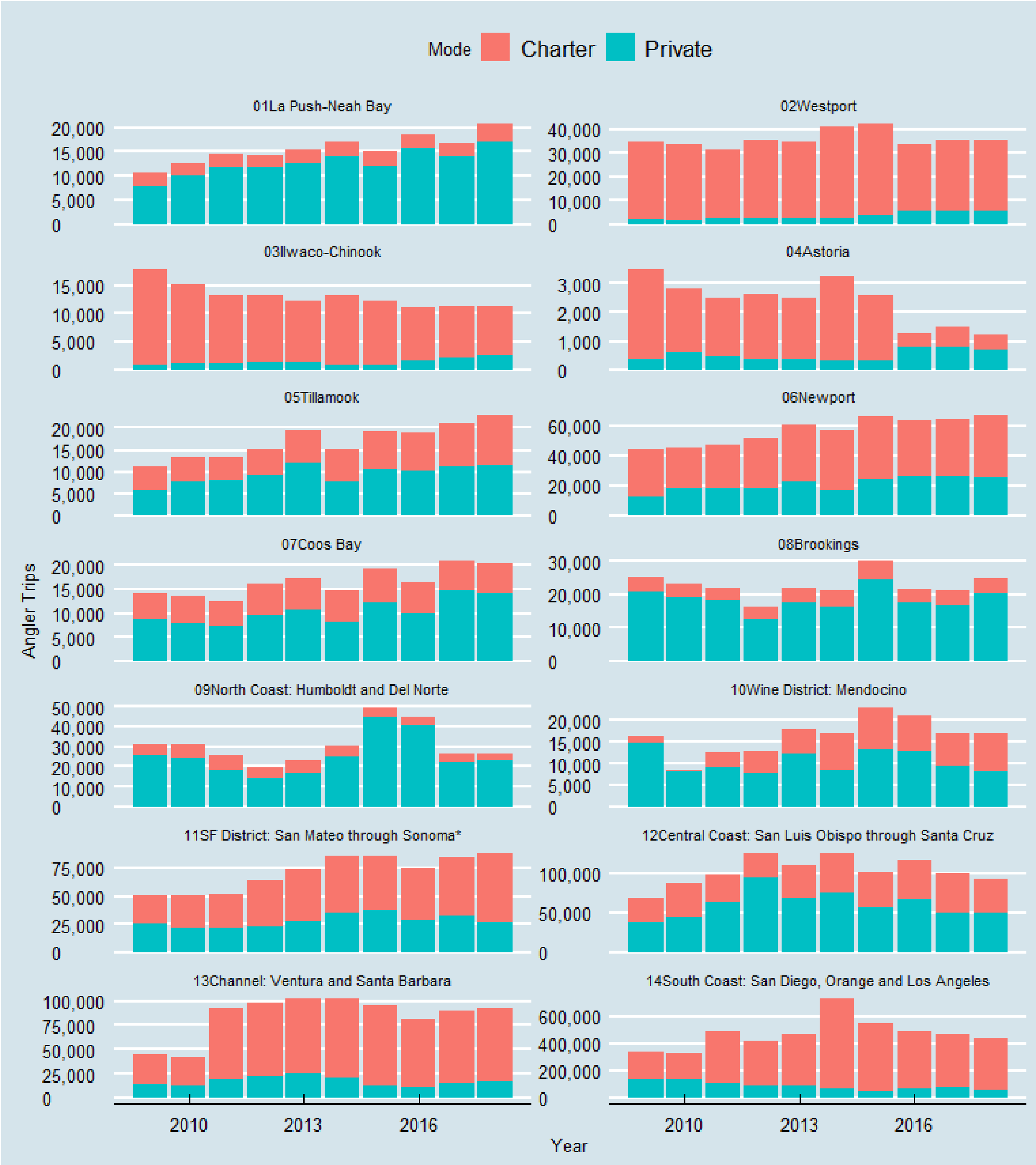

Figure 3-10. Bottomfish/halibut angler trips by year region, and mode. Beach/bank and man-made modes excluded. (Source: GMT, Ed Waters.)

Table 3-16 shows the values represented in Figure 3-10. The most angler trips occur in the South Coast: San Diego, Orange, and Los Angeles region at 49.4 percent of the coastwide total.

Table 3-16. Average annual bottomfish/halibut angler trips by type and percent by region. (Source: GMT, Ed Waters.)

Region	Charter	Private	Total	Percent
La Push-Neah Bay	2,900	12,622	15,522	2%
Westport	32,188	3,495	35,683	4%
Ilwaco-Chinook	11,714	1,352	13,066	1%
Astoria	1,877	498	2,375	0%
Tillamook	7,586	9,401	16,987	2%
Newport	35,721	20,851	56,572	6%
Coos Bay	6,105	10,376	16,482	2%
Brookings	4,363	18,319	22,682	2%
North Coast: Humboldt and Del Norte	5,294	25,540	30,835	3%
Wine District: Mendocino	5,929	10,365	16,293	2%
SF District: San Mateo through Sonoma*	43,241	27,830	71,071	7%
Central Coast: San Luis Obispo through Santa Cruz	42,138	60,556	102,694	11%
Channel: Ventura and Santa Barbara	66,938	17,047	83,985	9%
South Coast: San Diego, Orange, and Los Angeles	382,515	89,764	472,280	49%

CHAPTER 4 ESSENTIAL FISH HABITAT

Essential fish habitat (EFH) for groundfish was first established in 1998 under FMP Amendment 11, and in response to the MSA reauthorization of 1996. EFH was revised significantly and finalized in 2006 as part of Amendment 19 to the groundfish FMP.

The EFH regulations call for a review of EFH elements at least every five years. The most recent review was initiated in December 2010 and concluded in April 2018, after being combined with final action to consider removing the trawl RCA.

The Council took final action on FMP Amendment 28 to reopen the groundfish trawl RCA off Oregon and California to bottom trawling, and to modify the current configuration of EFH Conservation Areas (EFHCAs) where groundfish bottom trawl gear is prohibited coastwide. This includes a new EFHCA prohibiting groundfish bottom trawl gear in most of the Southern California Bight. The Council also took final action to prohibit use of all groundfish bottom contact gear in waters deeper than 3,500 meters. (EEZ waters deeper than 3500 m are not designated as groundfish EFH, hence the regulatory avenue for this action was the MSA discretionary authorities at 303b(2), 303b(3), and 303b(12)). The action did not affect non-trawl RCAs, the trawl RCA off Washington, the use of midwater trawl gear within any of the trawl RCAs, nor any of the EFHCAs in the tribal usual and accustomed fishing areas off the Washington coast.

CHAPTER 5 SAFETY AT SEA

National Standard 10 (NS10) guidelines interpreting the MSA state, "Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea". During preparation of any FMP, FMP amendment, or regulation that might affect safety of human life at sea, the Council should consult with the United States Coast Guard (USCG) and the fishing industry as to the nature and extent of any adverse impacts. This consultation may be done through a Council advisory panel, committee, or other review of the FMP, FMP amendment, or regulations.

There are many ways in which an FMP may avoid or provide alternative measures to reduce potential impacts on safety of human life at sea. The following is a list of some factors that could be considered when management measures are developed:

1) Setting seasons to avoid hazardous weather.
2) Providing for seasonal or trip flexibility to account for bad weather (weather days).
3) Allowing for pre- and post-season ''soak time'' to deploy and pick up fixed gear, so as to avoid overloading vessels with fixed gear.
4) Tailoring gear requirements to provide for smaller or lighter gear for smaller vessels.
5) Avoiding management measures that require hazardous at-sea inspections or enforcement if other comparable enforcement could be accomplished as effectively.
6) Limiting the number of participants in the fishery.
7) Spreading effort over time and area to avoid potential gear and/or vessel conflicts.
8) Implementing management measures that reduce the race for fish and the resulting incentives for fishermen to take additional risks with respect to vessel safety.

The Council consults with the USCG on safety-at-sea considerations through a non-voting USCG seat on the Council and through the Council's enforcement advisory body, the Enforcement Consultants. The Council also has considered safety-at-sea factors when deciding groundfish management measures. For example, the sablefish fishery for LEFG permit holders with a sablefish endorsement fish their tier limits any time during the April to October primary season, which allows fishermen to fish when weather conditions are amenable to fishing safely. Likewise, the rationalized trawl fishery, managed using a system of IFQs and harvest cooperatives, has reduced the propensity to race for fish in that fishery and enhanced safety-at-sea. In general, most of the groundfish fishery has also limited participation through a limited entry system.

The National Institute for Occupational Safety and Health (NIOSH) is the Federal government agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH recently completed an in-depth study of commercial fishing fatalities in the United States during 2000-2009. The purpose of the study was to identify the most hazardous fisheries around the country and to describe the unique safety issues in each. NIOSH published a report on fatal occupational injuries in the West Coast commercial fishing industry. During 2000-2009, 86 commercial fishing deaths occurred off the US. West Coast, an average of 9 per year. Almost 70 percent of the deaths were caused by drowning following a vessel disaster (e.g., sinking, capsizing, fire, etc.) in which the crew was forced to abandon ship. For two years (2001 and 2006), vessel disasters were the sole cause of commercial fishing fatalities. About one-quarter (24 percent) of fatalities were the result of falls overboard. The remaining fatalities were due to traumatic injuries sustained on-board, while diving, or on shore. The NIOSH report identified the highest fatality rate in the Dungeness crab fishery followed by the Columbia River Tribal salmon fishery.

Vessel disasters often result in multiple fatalities. The 58 deaths due to vessel disasters during 2000-2009 took place in 32 separate incidents. Vessel disasters were usually caused by a sequence of events, starting with an initiating event. The most common initiating events were flooding, being struck by a large wave, and crossing a river bar during hazardous conditions. In addition, severe weather conditions contributed to 78 percent of vessel disasters. During 2000-2009, 21 Dungeness crab fishermen died in 10 separate vessel disasters. There were also 16 other vessel disasters in which all the fishermen survived. Crossing a bar in hazardous conditions led to 40 percent of fatal vessel disasters. None of the non-fatal vessel disasters involved crossing a bar. Vessel instability led to both fatal and non-fatal disasters but was slightly more likely to be involved in fatal disasters. Several initiating events only resulted in non-fatal vessel disasters, such as flooding and striking rocks.

Falls overboard accounted for 24 percent of all fatalities in the West Coast commercial fishing industry during 2000-2009. Falls overboard were caused most often by tripping or slipping on deck and by entanglement in fishing gear. Factors that contributed to falls overboard were working alone on deck (52 percent), using alcohol or drugs (19 percent), and poor weather conditions (14 percent). None of the victims of falls overboard were wearing a Personal Flotation Device (PFD).

The NIOSH report recommended the following to prevent or mitigate injuries and fatalities from vessel disasters, falls overboard, or on-board injuries:

Vessel Disasters

- Take a marine safety class at least once every 5 years - Safety training for fishermen is available, affordable, and saves lives. All fishermen should learn and know how to use basic lifesaving equipment like immersion suits, life rafts, Emergency Position Indicating Radio Beacons (EPIRBs), and fire extinguishers.
- Do monthly drills: Abandon ship, Flooding, Fire - Safety training equips fishermen with survival skills and knowledge. Monthly drills give fishermen an opportunity to practice and re-enforce those skills.
- Test immersion suit for leaks - When watertight, immersion suits provide thermal protection and flotation in cold water. If an immersion suit has leaks, it will provide less protection from cold water. Instructions for inflation testing immersion suits are available at https://www.amsea.org/.
- Heed weather forecasts and avoid fishing in severe sea conditions - Hazardous weather conditions contributed to nearly 80 percent of vessel disasters off the West Coast during 2000-2009, and the deaths of 52 fishermen. Make the decision to stay in port when the

seas are too rough for your vessel to operate in. Keep track of forecasts and seek shelter before the storm arrives or intensifies beyond the safe operating limits of your vessel.

- Maintain watertight integrity - Flooding is the most common initiating event for vessel disasters on the West Coast. Inspect and maintain the hull of your vessel and all through-hull fittings. When seas are rough, ensure that watertight doors and hatches are sealed. Inspect and test high water alarms regularly.

Falls Overboard

- Wear a PFD on deck - Falls overboard occur without warning or time to prepare. A PFD stowed away onboard will not help float a fisherman who has fallen overboard. Wearing a PFD on deck is the single most important thing a fisherman can do to increase survivability following a fall overboard. There are many new styles of PFDs which have been evaluated by fishermen in real working conditions and are comfortable to work in on deck. Results of the NIOSH PFD study are available at www.cdc.gov/niosh/topics/fishing.
- Utilize a man overboard alarm system - Man overboard alarms are devices which alert others instantly to a fall overboard emergency, even if the fall was not witnessed. Systems vary in features and cost, but even the most inexpensive and basic system can save lives by immediately sounding an alarm if a fisherman falls overboard. Some of these systems can also benefit fishermen who work alone on small vessels by shutting down the engine if the sole operator falls overboard. This gives the fisherman, especially one prepared by wearing a PFD, a chance to get back to the vessel and re- board it.
- Conduct monthly man-overboard drills - If you fell overboard, would you want it to be the first time your crewmates tried to recover a man-overboard? Practicing man-overboard recovery procedures is essential for a crew to perform well in an actual emergency.
- Install bulwarks or rails at a minimum height of 36 to 39 inches.

On-Board Injuries

- Install emergency stop (e-stop) devices on deck machinery - Deck machinery, especially deck winches, are particularly hazardous and result in many fatal and non-fatal injuries. Emergency-stop buttons have been developed specifically for deck machinery on fishing vessels and can be adapted and retrofitted onto any winch or other machinery. More information about e-stops for fishing vessels can be found at www.cdc.gov/niosh/topics/fishing.
- The Coast Guard recommends vessels carry all required safety and survival equipment as required for the vessels operating parameters. You can generate a checklist for a particular vessel by using the "Checklist Generator". Then have a Coast Guard dockside examiner on board to inspect the condition of each of the required items.

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