Yelloweye Rockfish (*Sebastes ruberrimus*) and Bocaccio (*Sebastes paucispinis*) of the Puget Sound/Georgia Basin

5-Year Review: Summary and Evaluation

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
West Coast Region

Office of Protected Resources
Seattle, WA

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Cover image of juvenile yelloweye rockfish associated with boulder habitat, courtesy of Adam Obaza (Paua Marine Research Group).

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

B.C.	British Columbia, Canada
BRT	Biological Review Team
CCGS	Canadian Coast Guard Ship
CPUE	Catch Per Unit Effort
CV	Coefficient of Variation
DFO	Fisheries and Oceans Canada
DLMtool	Data Limited Model Toolkit
DPS	Distinct Population Segment
DU	Designatable Unit
ESA	Endangered Species Act (United States)
FR	Federal Register
FRT	Fish Receiving Ticket
HBLL	Hard Bottom Longline
LB-SPR	Length Based Spawning Potential Ratio
MaxEnt	Maximum Entropy Model
MBES	Multibeam Echosounder Surveys
MRFSS	Marine Recreational Fisheries Statistical Survey
MSEtool	Management Strategy Evaluation Toolkit
MU	Management Unit
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OM	Operating Model
PCA	Punch Card Area
PSEMP	Puget Sound Ecosystem Monitoring Program
PSMFC	Pacific States Marine Fisheries Commission
RCA	Rockfish Conservation Area (Canada)
RecFIN	Recreational Fishery Information Network
ROV	Remotely Operated Vehicle
RPN	Recovery Priority Number
R/V	Research Vessel
SAFS	School of Aquatic and Fishery Sciences (University of Washington)
SARA	Species at Risk Act (Canada)
SJI	San Juan Islands
SPR	Spawning Potential Ratio
SRA	Stock Reduction Analysis
SS	Stock Synthesis Model
SS-CL	Stock Synthesis Model with Catch and Length Composition
SS-LO	Stock Synthesis Model with Length Only
TAC	Total Allowable Catch
U.S.	United States
USBL	Ultra Short Baseline
UW	University of Washington
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
YOY	Young-of-the-Year

1 General Information

1.1 Executive Summary

In 2010, distinct population segments (DPSs) of three rockfish species occupying the Puget Sound/Georgia Basin were listed under the Endangered Species Act (ESA): canary rockfish and yelloweye rockfish as threatened, and bocaccio as endangered. In 2016, an evaluation of data and information acquired since the listing determined that Canary rockfish could be removed from the listing but that the status of yelloweye rockfish and bocaccio DPSs had not changed. Canary rockfish were subsequently de-listed based on the new genetic data, but yelloweye rockfish and bocaccio remain listed. Here, we perform a second periodic review of the status of the DPSs and, again, determine that their respective statuses remain unchanged because neither delisting nor downlisting criteria have been met. We describe substantial efforts since the prior status review to: acquire new data on the abundance, distribution, and size composition of the populations; better evaluate the status of each DPS using objective metrics to monitor ongoing recovery; compile and synthesize biological and ecological knowledge from a variety of sources; and systematically work with partners to reduce threats to population viability. We then apply all available new knowledge to an evaluation of the five listing factors identified in the ESA to reach our final status conclusion for this evaluation iteration.

1.2 Reviewers

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Dan Tonnes, Washington and Oregon Regional Aquaculture Coordinator (Past Rockfish Recovery Coordinator)

1.3 Methodology Used to Complete This Review

The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) initiated a 5-year review of the Puget Sound/Georgia Basin DPSs of yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*S. paucispinis)* in March of 2020. NMFS solicited information from the public through a Federal Register (FR) Notice (85 FR 12905, March 5, 2020) and received substantive comments from a single respondent, the Washington Department of Fish and Wildlife (WDFW). To complete the review, we collected, evaluated, and incorporated all information on yelloweye rockfish and bocaccio, and those related species previously used as proxies for life history and ecology parameters, that had become available since April of 2016, the date of the last review (Tonnes et al. 2016). As a result, this review is based on the best available scientific and commercial data. We include relevant recent research on yelloweye rockfish and bocaccio from within the range of the DPSs, as well as within open waters off the Pacific Coast of both the United States and Canada. To provide additional insight on population conditions and threats, and to inform the status of these listed species within the Puget Sound/Georgia Basin when data are lacking, we also include recent research on rockfish species with similar life history (e.g., quillback rockfish *S. maliger*).

1.4 Background

1.4.1 Federal Register Notice Citation Announcing Initiation of This Review

The notice announcing the initiation of this 5-year review and requesting information from the public was published on March 5, 2020 (85 FR 12905), and entitled Endangered and Threatened Species; Initiation of 5-year reviews for eulachon, yelloweye rockfish, bocaccio, and green sturgeon.

1.4.2 Listing History

On April 9, 2007, NMFS received a petition from Mr. Sam Wright (Olympia, Washington) to list populations of five rockfish species occupying Puget Sound as endangered or threatened species under the ESA and to designate critical habitat accordingly. On October 5, 2007, NMFS found that this petition did not present substantial scientific or commercial information to suggest that the petitioned actions may be warranted (72 FR 56986, October 5, 2007). On October 29, 2007, NMFS received a supplementary letter from Mr. Wright presenting information not included in the April 2007 petition, and requesting reconsideration of the decision not to initiate a review of the species' status. NMFS considered the supplemental information as a new petition and concluded that there was enough information in this new petition to warrant conducting status reviews for all five species.

NMFS initiated the status review for the species on March 17, 2008 (73 FR 14195). The agency then established a Biological Review Team (BRT), which completed the status review in December 2009 (Drake et al. 2010). The BRT determined that yelloweye rockfish (*Sebastes ruberrimus*), canary rockfish (*Sebastes pinniger*), and bocaccio (*Sebastes paucispinis*) occupying waters of Puget Sound and the Georgia Basin inland of the Victoria Sill represent DPSs. Section 3 of the ESA defines "species" as including "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Under the DPS policy used by both the U.S. Fish and Wildlife Service and NMFS (61 FR 4722, February 7, 1996), a population segment is considered a DPS if it is both discrete from other populations within its taxon and significant to its taxon. According to the policy, quantitative measures of genetic or morphological discontinuity can be used to provide evidence for discreteness, and occupation of a substantive geographic range can provide evidence of significance. Due to a lack of genetic data for yelloweye rockfish, canary rockfish, and bocaccio, the BRT based their DPS recommendations, in part, on NMFS' 2001 status review of copper, quillback, and brown rockfish in Puget Sound (Stout et al. 2001). Based on available genetic information, this review concluded that DPSs of copper, quillback, and brown rockfish occupied Puget Sound proper, defined as marine waters south of Admiralty Inlet and east of Deception Pass (Stout et al. 2001). The 2010 review determined that the Puget Sound/Georgia Basin DPS of bocaccio was at high risk of extinction throughout all of its range and that the Puget Sound/Georgia Basin DPSs of yelloweye rockfish and canary rockfish were at moderate risk of extinction throughout all of their range (Drake et al. 2010). On April 28, 2010, NMFS published a final rule listing the Puget Sound/Georgia Basin DPSs of yelloweye rockfish and canary rockfish as threatened, and bocaccio as endangered under the ESA (75 FR 22276, Table 1).

To better assess the boundaries of the DPSs established by the BRT at listing, we undertook a cooperative research venture in 2014 with the WDFW, Fisheries and Oceans Canada (DFO), and several local angling clubs/organizations. Utilizing fin tissue samples previously collected by the WDFW and DFO during population monitoring efforts, supplemented with newly collected samples from directed hook-and-line sampling at "hotspots" identified through local ecological knowledge and recent remotely operated vehicle (ROV) surveys, we evaluated population discreteness for yelloweye and canary rockfish (Tonnes et al. 2017; Andrews et al. 2018; 2019). Insufficient samples were available to consider bocaccio. Results indicated that the DPS for yelloweye rockfish was discrete from coastal populations and that the northern boundary needed to be extended to include Johnstone Strait at the northern end of Vancouver Island. However, the review also showed that the DPS for canary rockfish was not discrete from coastal waters. As a result, geographic expansion of the yelloweye DPS and removal of canary rockfish from the federal list of threatened and endangered species was proposed on July 6, 2016 (81 FR 43979) and finalized on January 23, 2017 (82 FR 7711). This action represented the first-ever delisting of a marine fish. The same rulemaking action also modified the DPS descriptions for both yelloweye and bocaccio to include fish residing within the footprint of the DPS rather than those fish originating from the DPS (82 FR 7711) and updated the description of the yelloweye rockfish geographical boundaries to include an area farther north into Johnstone Strait in Canada.

Federal Register Notices: 75 FR 22276, April 28, 2010 - Endangered and Threatened Wildlife and Plants: Threatened Status for the Puget Sound/Georgia Basin Distinct Population Segments of Yelloweye and Canary Rockfish and Endangered Status for the Puget Sound/Georgia Basin Distinct Population Segment of Bocaccio Rockfish.

82 FR 7711, January 23, 2017 - Endangered and Threatened Species; Removal of the Puget Sound/Georgia Basin Distinct Population Segment of Canary Rockfish from the Federal List of Threatened and Endangered Species and Removal of Designated Critical Habitat, and Update and Amendment to the Listing Descriptions for the Yelloweye Rockfish DPS and Bocaccio DPS.

Table 1. Listed Species and ESA Classification of DPSs under 75 FR 22276.

Entity Listed	Classification
Puget Sound/Georgia Basin bocaccio	Endangered
Puget Sound/Georgia Basin canary rockfish	Threatened*
Puget Sound/Georgia Basin yelloweye rockfish	Threatened

* Status was subsequently removed by 82 FR 7711 based on new genetic data.

1.4.3 Associated Rulemakings

Critical Habitat Designation: 79 FR 68042, November 1, 2014 - Endangered and Threatened Species; Designation of Critical Habitat for the Puget Sound/Georgia Basin Distinct Population Segments of Yelloweye Rockfish, Canary Rockfish, and Bocaccio.

Change in ESA Status and Critical Habitat Removal for Canary Rockfish and DPS Boundary Modification for Yelloweye Rockfish DPS: 82 FR 7711, January 23, 2017 - Endangered and Threatened Species; Removal of the Puget Sound/Georgia Basin Distinct Population Segment of Canary Rockfish from the Federal List of Threatened and Endangered

Species and Removal of Designated Critical Habitat, and Update and Amendment to the Listing Descriptions for the Yelloweye Rockfish DPS and Bocaccio DPS.

1.4.4 Review History

NMFS completed the first periodic review of the status of listed rockfishes in 2016 (Tonnes et al. 2016). NMFS concluded that, based on the best available scientific and commercial data, the Puget Sound/Georgia Basin population of canary rockfish no longer met the definition of a DPS and should be delisted. NMFS also concluded that, based on limited new data, no change was needed in the classification of the DPS for yelloweye rockfish or bocaccio; thus, their respective statuses were retained as threatened and endangered.

1.4.5 Species' Recovery Priority Number at Start of 5-year Review

In 1990, guidance was issued for assigning listing and recovery priority numbers (RPN) to ESA-listed species based on the magnitude of the threat, recovery potential, and conflict with development activities or other economic activities (55 FR 24296, June 15, 1990). Values could range from 1 (high) to 12 (low). The prior 5-year review assigned yelloweye rockfish an RPN of 7 and bocaccio an RPN of 3 (Tonnes et al. 2016) based on this guidance. Subsequently, refined criteria were described in the Recovery Priority Guidelines (84 FR 18243; April 30, 2019) to help direct limited agency resources for recovery implementation based on: a) demographic risk; b) recovery potential, which includes how well the threats are known, U.S. jurisdiction over management and protective actions, and certainty that the actions will be effective; and c) whether the species is, or may be, in conflict with economic activities. Under this new guidance, values may range from a high of 1 to a low of 11 and can be paired with the letter C to reflect the potential for conflict with economic activities.

The Puget Sound/Georgia Basin DPS of Bocaccio currently has an RPN of 7C, and the Puget Sound/Georgia Basin DPS of Yelloweye Rockfish currently has an RPN of 9C, as reported in the ESA Fiscal Year 2017-2018 Report to Congress, and updated in 2021. The RPN of 7C for bocaccio reflects: a) a high level of demographic risk, as a consequence of extremely low population size and diffuse distribution; b) low to moderate recovery potential, given that over half of the area of the DPS lies in Canadian waters and recovery in U.S. waters has not accelerated measurably after broad-scale reduction of the major threat (fishery exploitation); and c) a high likelihood of conflict with fishery and nearshore development activities during ongoing recovery implementation. The RPN of 9C for yelloweye rockfish reflects a moderate level of demographic risk, given higher abundance and demonstrated reproductive activity that has produced successful settlement, and recovery potential and conflict evaluations largely mirroring bocaccio.

1.4.6 Recovery Plan Creation

NMFS initiated recovery planning for listed rockfish in 2013 with the appointment of a Recovery Team made up of scientists and resource managers from the University of Washington, the WDFW, the Northwest Indian Fisheries Commission, NOAA's West Coast Regional Office, and NOAA's Northwest Fisheries Science Center. After peer review, and review by the government of Canada, the state of Washington, and the Puget Sound treaty tribes in early 2015, the final recovery plan (hereafter Rockfish Recovery Plan) was released in October of 2017 (NMFS 2017b).

The Rockfish Recovery Plan provided a comprehensive description of yelloweye rockfish and bocaccio biology, ecology, factors contributing to their listing, conservation measures currently in place, and existing research/monitoring efforts focused on all of these knowledge domains. The plan used this information to establish a long-term, multidisciplinary recovery strategy for downlisting (bocaccio) and delisting (both species) after the fulfillment of objective biological and threats-based conservation criteria. Crucially, the plan included a task-driven implementation schedule and cost estimates to serve as a road map for recovery actions through the first five federal fiscal years (October 1 through September 30) after publication. Appendix A provides an updated accounting of plan implementation to date, covering the first six years of formalized federal recovery, and several efforts recommended in the plan are discussed in detail below as they relate to stock status and evaluation of contemporary threats to species viability and persistence.

Recovery Plan: National Marine Fisheries Service. 2017. Rockfish Recovery Plan: Puget Sound/Georgia Basin yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*Sebastes paucispinis*). National Marine Fisheries Service. Seattle, WA. 152 pp + App.

1.4.7 Recovery Plan Implementation

Since the recovery plan finalization in 2017, NMFS has actively worked with a broad array of partners to complete high-priority projects, and both maintain and develop long-term initiatives, in accordance with the plan's implementation schedule (NMFS 2017b; Appendix A). Partners in both the U.S. and Canada have included: municipal, county, regional, state, and other federal agencies; tribes in the greater Salish Sea region; non-profit entities such as aquaria and conservation advocacy groups; academic institutions; and special interest groups (e.g., fishing clubs). Working independently and in diverse collaboratives, these partners have conducted scientific research across various disciplines, implemented outreach activities focused on members of the public of varying demographics, and modified policies and laws at multiple tiers to benefit listed rockfish and their environment. Details of activities directly relevant to the evaluation of species status during the first seven years of recovery implementation (2017-23) are reviewed in the analysis below, with details on progress toward completion of additional activities summarized in Appendix A. The full suite of activities in the implementation schedule constitutes a holistic approach to recovery; however, many are not connected to direct biological assessment of species status and, thus, are not discussed in detail in this status review.

From 2020-23, the global COVID-19 pandemic affected daily life around the globe in unprecedented ways. Directly germane to the implementation of the Rockfish Recovery Plan, field surveys, in-person outreach, and nearly every other activity involving close contact within and among staff at NMFS and partner entities ceased entirely for two or more years and phased back in slowly after this. As a result of this disruption, several planned activities did not occur on schedule, and many others required innovative use of technology and novel workflows to achieve results. Despite this, substantial progress was made on several analytical efforts directly related to quantifying species recovery relative to established criteria, as detailed below. Work not completed during this timeframe is no less important for having been delayed, and will remain on the implementation schedule until complete (Appendix A).

2 Review Analysis

2.1 Application of the 1996 Distinct Population Segment (DPS) Policy

2.1.1 Is the species under review a vertebrate?

DPS Name	Yes	No
Puget Sound/Georgia Basin Bocaccio	X	
Puget Sound/Georgia Basin Yelloweye Rockfish	X	

2.1.2 Is the species under review listed as a DPS?

DPS Name	Yes	No
Puget Sound/Georgia Basin Bocaccio	X	
Puget Sound/Georgia Basin Yelloweye Rockfish	X	

2.1.3 Was the DPS listed prior to 1996?

DPS Name	Yes	No
Puget Sound/Georgia Basin Bocaccio		X
Puget Sound/Georgia Basin Yelloweye Rockfish		X

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?

DPS Name	Yes	No
Puget Sound/Georgia Basin Bocaccio		X
Puget Sound/Georgia Basin Yelloweye Rockfish		X

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

DPS Name	Yes	No
Puget Sound/Georgia Basin Bocaccio	X	
Puget Sound/Georgia Basin Yelloweye Rockfish	X	

The primary biological recovery metric identified in the Rockfish Recovery Plan (NMFS 2017b) is the spawning potential ratio (SPR) (Shepard 1982; Goodyear 1993). Calculated as a ratio of the reproductive potential existing in a population under a given fishing pressure relative to reproductive potential in the unfished condition, SPR has been used to set fishing reference points for diverse fisheries since the 1980s (Shepard 1982; Mace and Sissenwine 1993). In a series of publications in 2015, however, Hordyk and colleagues showed that in the absence of population biomass estimates, but with an adequate, stock-wide sample of length distribution and estimates of growth rate and natural mortality, SPR could be used to compare the current status of a population to an equilibrium reference condition in the absence of directed fishing pressure (Hordyk et al. 2015a; 2015b; Prince et al. 2015). This novel formulation of SPR, termed the length based-SPR (LB-SPR), is broadly applicable to conservation planning and assessment because it allows recovery planners to construct a base model for an unexploited, or lighted exploited, state where historic length distribution data are available. This base then serves as a reference point for fishing pressure intensity ranging down to truly incidental bycatch, allowing managers to compare current reproductive capacity and expected population growth. Length distributions obtained from surveys at regular, or irregular, intervals can then be used iteratively to track recovery progress.

2.2.2 Are recovery criteria adequate?

Given available data from fisheries monitoring and population surveys, the LB-SPR recovery criteria are adequate to track population recovery of ESA-listed yelloweye rockfish and bocaccio over time but may be more challenging to apply to bocaccio given extremely low encounter rates during surveys (see below). In the Rockfish Recovery Plan, conservative LB-SPR thresholds were identified that must be met with high confidence for several assessment cycles before downlisting (bocaccio) and/or delisting can be considered (NMFS 2017b). Criteria were established for bocaccio across the whole of the DPS and for yelloweye rockfish in two separate management units: Hood Canal and the remainder of the DPS (Table 2). Management units (or MUs) for yelloweye rockfish were based on the ability to differentiate fish occupying these two areas based on genetic attributes, suggesting a degree of reproductive isolation (Andrews et al. 2018).

Table 2. Biological downlisting/delisting criteria for Puget Sound/Georgia Basin Bocaccio and Yelloweye Rockfish DPSs as identified in the Rockfish Recovery Plan (NMFS 2017b). Criteria are shown for the entire DPS for bocaccio except for two management units (MUs) for yelloweye rockfish. All criteria must be met with at least 80% confidence during each sampling event.

Species (MU)	Criteria Type	Scenario	Length Based Spawning Potential Ratio (LB-SPR)	Minimum Time at Target (Number of sampling events)
Bocaccio	Downlisting	A	10% (and inc.)	15 yrs (4+)
Bocaccio	Delisting	A	15% (and inc.)	15 yrs (4+)
Bocaccio	Delisting	B	≥20%	10 yrs (3+)
Bocaccio	Delisting	C	≥25%	5 yrs (2+)
Yelloweye (Non-Hood Canal)	Delisting	A	15% (and inc.)	25 yrs (5+)

Yelloweye (Non-Hood Canal)	Delisting	B	20-24%	15 yrs (4+)
Yelloweye (Non-Hood Canal)	Delisting	C	≥25%	10 yrs (3+)
Yelloweye (Hood Canal)	Delisting	A	20-24%	15 yrs (4+)
Yelloweye (Hood Canal)	Delisting	B	≥25%	10 yrs (3+)

The threats-based recovery and delisting criteria identified in the Rockfish Recovery Plan were developed explicitly to address the five ESA listing factors: destruction, modification, or curtailment of habitat or range; over-utilization for commercial, recreation, scientific, or educational purposes; disease/predation; inadequate regulatory mechanisms; and other factors affecting the continued existence of the species (NMFS 2017b). Details for a wide variety of direct and indirect threats are provided in the plan, and appropriate metrics for each are used to set criteria that will reduce the impacts of these threats on rockfish populations. If these criteria are met, the ecosystem requirements rockfish need to maintain long-term viability should be suitable to ensure population persistence into the foreseeable future. Recent activities relevant to all threat-based criteria are included in Appendix A alongside other plan implementation actions.

2.2.3 Have Recovery Criteria Been Met?

The biological criteria for downlisting (bocaccio) and delisting require multiple sampling events over several years, with each providing a representative sub-sample of population length composition for the entire DPS (bocaccio) or each of two MUs (yelloweye rockfish). The shortest evaluation period possible for delisting is 5 years and requires a >25% increase in LB-SPR for bocaccio in only 3-5 years (Table 2). Because of these temporal constraints, variability in the extent of surveys conducted since 2008 (see below), and population survey efforts by the WDFW being delayed due to the COVID-19 pandemic, data does not exist to determine whether biological downlisting or desilting criteria have been fully met. Novel modeling (see *Section 2.3.1.2.5 New Catch and Length Models*) for the non-Hood Canal management unit of yelloweye rockfish (Min et al. 2023), however, suggests that while the population reached very low levels in the 1990s, low fishery removals for over two decades have resulted in the population being highly likely to be over the 25% threshold for SPR set in the Rockfish Recovery Plan (NMFS 2017b). Fully meeting recovery criteria for this population is a matter of maintaining a stable population over two additional sample periods, but biological criteria have not yet been met.

While progress has been made toward meeting several threats-based criteria, the full suite of criteria related to multiple threats has not yet been met. For some threats, such as bycatch and derelict fishing gear, significant progress has been made to reduce population-level impacts. For others, such as toxic contaminants and ocean acidification, fundamental science is still needed to develop appropriate conservation responses (Table 3 and Appendix A). Habitat-focused conservation of the Puget Sound/Georgia Basin region, at large, is a multifaceted and expensive endeavor that rarely focuses on listed rockfish, but typically includes them as an integral ecosystem component. A rare exception is the creation of the Puget Sound Kelp Conservation and Recovery Plan (Calloway et al. 2020), the genesis of which was a demonstrated need to protect nearshore critical habitat for listed rockfish, though it grew to also address the needs of several other species. Management of rockfish-focused fisheries, disease, and predation, however, have ESA-listed rockfish as their primary focus. Fishery regulations explicitly to conserve listed rockfish began at listing in 2010 and have since been refined to address specific regulatory needs. Research on rockfish diseases and, in large part, predation has not followed suit, with little work completed to date within the DPSs. A detailed assessment of progress toward threats-based criteria associated with each of the ESA listing factors is provided below (*Section 2.3.2 Five-Factor Analysis*).

Table 3. Summary of threats-based recovery criteria identified in the Rockfish Recovery Plan (NMFS 2017b) and a high-level synopsis of progress made toward meeting each criterion. Additional details for projects relevant to each criterion are available in Appendix A.

Listing Factor	Threats-Based Recovery Criterion	Summary of Progress Towards Criterion
Destruction, Modification, or Curtailment of Habitat or Range	*Nearshore habitats.* Nursery habitats protected from adverse development and determined to be sufficient (size and quality) to meet essential requirements of juvenile bocaccio	Existing regulations provide substantial protection, but compliance varies. Puget Sound Kelp Conservation and Recovery Plan, Kelp Forest and Eelgrass Meadow Health and Conservation Plan, and Floating Canopy Kelp Vital Sign indicator created since 2020 outline a variety of protections for nearshore habitats.
	Derelict Fishing Gear. Programs in place to require reporting, preventing, and removing derelict gear demonstrated to result in harm to listed rockfish or their habitat	Reporting, prevention, and removal programs continue to operate, resulting in a substantial reduction in threat from derelict gear. With most legacy nets now removed, the focus is turning to broad-scale removal of shrimp and crab pots.
	Contaminants/Bioaccumulants. Contaminant levels in listed rockfish, prey species, surrogate rockfish populations, or occupied habitats indicate reduction/slowing of legacy contaminant accumulation	Ongoing monitoring of other species and habitats continues; however, focused monitoring of trends in rockfishes is limited. Legacy contaminants still occur at levels that influence ecosystem health and carrying capacity.
	Nutrients. Management actions and programs in place to prevent/reduce nutrient inputs such that effects of nutrient inputs (food chain, hypoxia) are not limiting recovery	A broad suite of local and regional actions addressing nutrient inputs are ongoing, but direct impacts to rockfish recovery remain poorly understood due to a lack of focused research.
	Invasive species/Non-native Species. Invasive species that can affect habitat are found not to limit recovery. Programs in place to remove or mitigate the effects of invasive species on listed rockfish and habitats	Programs are in place to address known invasive species and detect new non-natives, but direct impacts to rockfish recovery remain poorly understood due to a lack of focused research.
Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes.	*Bycatch/Catch.* Listed rockfish are protected by fishery regulations and research permitting sufficient to support increased abundance, biomass, spatial structure, and diversity. Bycatch is mitigated through descending device use and safe handling techniques when it occurs	Current regulations and permitting have greatly reduced the impacts of these threats. Descending devices are required to be "rigged and ready for use" in key fisheries and safe handling practices are widely publicized. Outreach and enforcement to evaluate the effectiveness of fishery regulations and bycatch mitigation is ongoing.
Disease/Predation	*Disease.* Sufficient knowledge exists to determine that disease and parasite effects on productivity and survival are likely not limiting recovery	Limited directed research has not documented specific disease or parasitism concerns that reduce population productivity or result in high mortality.
	Predation. Monitoring of predation on listed rockfish demonstrates that it is not limiting recovery	There is limited directed research on rockfish consumption by predators to evaluate effects on recovery, but see Hatchery Releases section below.
Inadequate Regulatory Mechanisms	*Habitat.* Programs are in place to protect and restore where necessary, rearing and adult habitats	Existing regulations are in place and provide substantial protection, but compliance varies. Numerous place-based efforts to protect juvenile and adult habitat are underway.

	Fisheries. Enforcement adequately controls bycatch and poaching	Bycatch and poaching of rockfish remain among the many priorities of enforcement efforts. Efforts are largely localized to high-use areas and fisheries due to limited personnel and resources.
	Contaminants/Bioaccumulants. Regulations in place to limit the introduction of harmful contaminants and remove large, known areas of contaminated sediments, producing evidence of decreasing levels of contaminants in listed rockfish, prey species, surrogate rockfish populations, or habitats	Regulations are broadly in place but ever-evolving to address contaminants of emerging concern. No recent data are available to evaluate contaminant reductions in rockfish, key prey, or their habitats.
Other Factors Affecting the Species' Continued Existence	*Hatchery Releases.* Research determines if/how hatchery-released salmon affect listed rockfish recovery and releases determined to reduce recovery potential subsequently controlled or mitigated	Analysis combining hatchery release magnitude with dietary data and rockfish productivity in a bioenergetics framework concluded that hatchery salmon releases are not inhibiting recovery.
	Climate Change and Ocean Acidification. Research was undertaken to better understand and adapt to effects of climate change and ocean acidification, resulting in action to reduce effects so they do not limit recovery	Research has been initiated to evaluate the effects of acidification and water chemistry variation on sensitive larval stages of yelloweye; however, results are not yet available. No such research has been initiated for bocaccio.
	Oil Spills. Effective oil spill prevention and response plans in place for the Puget Sound/Georgia Basin	Plans are in place to address oil spills in the region. Modeling has identified key settlement sites for heavy, sinking oils and overlaid these with known rockfish habitat.
	Genetic Changes. Research was conducted to understand the extent of inbreeding and hybridization in listed rockfish, and neither found to limit recovery	Research has not yet been initiated to address inbreeding or hybridization in listed rockfish.

2.3 Updated Information and Current Species' Status

2.3.1 Habitat and Biology

Puget Sound and the Georgia Basin make up the southern portion of the Salish Sea, located on the Pacific Coast of North America, and are connected to the Pacific Ocean by the Strait of Juan de Fuca. Puget Sound is a fjord-like estuary covering 6,039.3 square kilometers. The marine benthic habitats of the region consist of a series of interconnected subbasins largely separated by relatively shallow sills (~20-50 m), except where the Whidbey Basin meets the Main Basin, and these contribute to fast water currents during portions of the tidal cycle. The sills restrict water exchange and movement of biota among subbasins and, in combination with bathymetry, freshwater input, and tidal exchange, influence environmental conditions ranging from water quality to temperature (Ebbesmeyer et al. 1984; Burns 1985; Rice 2007). As a result of these hydrologic patterns, each subbasin differs in biological condition; depth and bottom slope; subtidal benthic and intertidal habitats; and shoreline composition and condition (Downing 1983; Ebbesmeyer et al. 1984; Burns 1985; Rice 2007; Drake et al. 2010; Greene et al. 2015; van Duivenbode 2018).

The best available science on bocaccio and yelloweye rockfish biology, life history, and ecology was summarized in the pre-listing status assessment (Drake et al. 2010) and subsequently updated in the first 5-year status assessment (Tonnes et al. 2016) and the Rockfish Recovery Plan (NMFS 2017b). Both species are exclusively marine, mate via internal fertilization, bear live young after a period of internal incubation, disperse as plankton for several months after release, settle into specific habitats as young-of-the-year, associate with complex structure throughout their post-settlement lives, consume a wide variety of benthic and demersal prey, have the potential to live for decades, reach a size-based refuge from many predators, and are characterized by episodic peaks in successful recruitment. Yelloweye rockfish may live for over 110 years and associate quickly with hard substrates in the 20-30 m depth range at settlement, while bocaccio typically live no more than 50 years and spend a juvenile period associated with nearshore macroalgae and eelgrasses before settling into deep-water, rocky habitats as subadults.

2.3.1.1 New Information on Species Biology and Life History

Since the last status review in 2016, three primary sources have provided new information about the distribution, abundance, and overall population health of the portion of the Puget Sound/Georgia Basin Yelloweye Rockfish DPS: 1) a series of ROV surveys led by the WDFW; 2) historical catch reconstructions lead by the University of Washington (UW) School of Aquatic and Fishery Sciences (SAFS) for U.S. portions of the DPS and DFO for Canadian portions of the DPS; and 3) a scuba-based citizen science program that reports encounters with young-of-the-year (YOY) rockfish.

For the ROV surveys, details of vehicle deployment, data collection from recorded video, and data analysis to produce density and population estimates are provided in Appendix B. While these sampling and analysis methods have remained largely consistent since 2008, the geospatial coverage and objectives of survey effort have varied substantially from year to year, making creation of an abundance/density trend by direct comparison across survey efforts impossible. Descriptions of the coverage and major objectives of survey efforts within the DPSs since 2008 can be found in Appendix C, and are also available in: Pacunski et al. (2013) for 2008; Pacunski et al. (2020) for 2010; Lowry et al. (2022) for 2012-13; and from Robert Pacunski or Kathryn Meyer at the WDFW for 2015+16, and in 2018 (unpublished data).

The UW SAFS catch reconstruction was also used to formulate novel population models for both of the yelloweye rockfish MUs, and bocaccio, in U.S. waters of the DPSs. For the historical catch reconstruction in U.S. portions of the DPS, detailed descriptions of data sources, analytical assumptions and methods, and a discussion of sources of model uncertainty can be found in Appendix D and Min et al. (2023). Results of the reconstruction, and implications for our understanding of yelloweye rockfish population status as a consequence of newly generated population models, are discussed. The catch reconstructions for Canadian portions of the DPS were integrated into a management strategy evaluation completed in 2021 (Haggarty et al. 2022). Efforts to integrate DFO results with the UW SAFS models are presented. While substantial new information is presented here, no estimates of historic (pre-fishery) nor present-day abundance or biomass of yelloweye rockfish or bocaccio exist across the full extent of the DPSs based on a single survey method or model. This lack of information is due, in part, to the international nature of the geographic bounds of the DPSs and, in part, to the fact that survey methods that adequately sample deep-water, complex habitats are logistically difficult, time-intensive, and costly to implement.

For the YOY rockfish program, divers conduct timed, roving surveys and identify several morphotypes of rockfishes, largely during their first year of life. Detailed sampling methods are provided by Obaza and Tonnes (2017) and Obaza et al. (2019; 2021). Yelloweye rockfish YOY are distinct from other rockfishes found within the boundaries of the DPS because they are bright red or orange and have two conspicuous white stripes along each flank. As such, yelloweye rockfish are reported as a unique category during these YOY surveys. From 2015-22, the survey effort was largely haphazard, relying on individual divers to determine when and where to sample. Once baseline information about habitat and seasonality had been obtained, however, a more formal sampling structure was established in 2023 (Obaza et al. 2023). Recent encounters with YOY rockfish are summarized below (see *2.3.1.2.3 Young-of-the-year Citizen Science Program Observations*) as an indicator of successful settlement in select areas of the DPS.

While all research efforts endeavored to also collect and analyze data for bocaccio in U.S. waters of the Puget Sound/Georgia Basin DPS, encounters have been so rare in recent years that none were successful in adequately addressing contemporary abundance or distribution of the species. The catch reconstruction was successful in re-interpreting historical catch data, however. Limited recent encounters with bocaccio are described below, both from surveys targeting ESA-listed rockfish and other sampling efforts that take them as bycatch and reflect the scarcity of individuals throughout the DPS.

2.3.1.2 Abundance, Population Trends, Demographic Features, or Demographic Trends

2.3.1.2.1 Recent Population Estimates from ROV Surveys

ROV surveys conducted since 2008 within the Puget Sound/Georgia Basin DPS have found the most yelloweye rockfish in Canadian waters (Table 4). This finding is in line with the history of removals from the DPS, as the fishery in the Canadian portion of the DPS has been, and is, considerably more robust (Palsson et al. 2009; DFO 2011; see below). While these surveys represent the best source of encounter information for both yelloweye rockfish and bocaccio in U.S. waters of the DPSs, each survey has varied in geospatial coverage as the sampling program has developed and modeling methods have been refined (Appendices B and C). Only one region (the San Juan Islands) has been surveyed repeatedly, with abundance estimates of 47,407 (Coefficient of Variation [CV] = 24.8%) in 2008, 114,494 (CV = 33%) in 2010, and 19,059 (CV = 33.4%) in 2018 (Table 4; Pacunski et al. 2013; 2020; WDFW unpublished data). While these surveys all covered the same geographic region, the apparently large and rapid swings in estimated abundance are biologically implausible and, most likely, the result of differing survey designs and objectives, as noted above. The 2010 survey, which had the highest estimate, did not use habitat information in selecting transect sites. Thus, the area over which average species density was multiplied was much higher than in other surveys, which focused efforts on narrow bands of predicted yelloweye rockfish habitat. Interestingly, the 2012-13 survey employed the same habitat-naïve, randomized design over the whole of the U.S. portion of the DPSs; however, encounters of yelloweye rockfish were so rare (n=5) that even expansion to this considerable survey footprint resulted in a population estimate (77,170, 45% CV) lower than that produced for the San Juan Islands alone in 2010 (Lowry et al. 2022). The 2015+16 Puget Sound ROV surveys, which had the highest number of completed transects, indicate that within Puget Sound more yelloweye rockfish are found in Hood Canal (11,576, 29.5% CV) than in the rest of Puget Sound Proper (6,256, 29.4% CV). Note that these surveys replicated efforts across two distinct sampling frames in 2015 and 2016, as opposed to the 2012-13 survey, in which sampling spanned calendar years.

Largely due to staffing, funding, and sampling platform limitations, efforts to estimate rockfish abundance using an ROV in the Puget Sound/Georgia Basin region over the last decade have been localized. The efforts have employed various sampling designs, relied on different habitat suitability models, and rarely sampled the same region in multiple years (Appendix C). Though the program has evolved substantially, data from these efforts cannot be used to produce a DPS-wide, statistically accurate time series of estimated population abundance. The recent acquisition of a larger, more capable flagship survey vessel (the *R/V Salish Rover*) in 2020 should increase sampling efficiency. Combined with honing in on the standard application of maximum entropy (MaxEnt) models and stratified sampling designs, future efforts should be consistent enough to allow trend analysis in the coming decades. Currently, however, for a given survey year in a given region, the ROV program can provide length distribution curves when the encounter rate is high enough. This length information can be used to objectively assess the LB-SPR recovery metric, as detailed below.

Table 4. Summary of yelloweye rockfish abundance estimates from all ROV surveys conducted within the DPS since 2008. The habitat types surveyed are indicated at the end of each survey name; rock = complex, hard-bottom substrates were the focus; all = systematic random survey of habitat in proportion to its occurrence; high/medium stratum = estimate from a specific stratum predicted using a Maximum Entropy habitat suitability model.

Survey	Region	Year(s)	Abundance	CV (%)
2008 San Juan Islands, rock	San Juan Islands	2008	47,407	24.8
2010 San Juan Islands, all	San Juan Islands	2010	114,494	33
2012-13 Puget Sound, all	Greater Puget Sound	2012-13	77,170	45
2015+16 Puget Sound, rock	Puget Sound Proper (excluding Hood Canal)	2015+16	6,256	29.4
2015+16 Puget Sound, rock	Hood Canal	2015+16	11,576	29.5
2018 San Juan Islands, rock	San Juan Islands	2018	19,059	33.4
2018 Gulf Islands - High Stratum	Gulf Islands (Inside)	2018	83,783	34.3
2018 Gulf Islands - Medium Stratum	Gulf Islands (Inside)	2018	58,887	71.8
2018 Strait of Georgia *CCGS Vector* – all	Strait of Georgia (CAN)	2018	1,613,716	14.3

2.3.1.2.2 Catch Reconstructions

Beginning in 2020, staff with the UW SAFS partnered with NMFS and the WDFW to evaluate historical harvest records and explicitly quantify removals of yelloweye rockfish and bocaccio from the DPSs to refine recovery expectations. Details of the methods for this work are contained in Appendix D, and a complete accounting can be found in Min et al. (2023). The results provide the first species-specific estimates for removals of yelloweye rockfish and bocaccio from greater Puget Sound from 1920-2020.

For the majority of both commercial and recreational fishery history within Puget Sound, catches of rockfish were reported at the coarse level of "rockfish" or in broad market categories (e.g., red snapper) without distinguishing among species within the genus. In the most complete published estimate of rockfish removals, Palsson et al. (2009) reported both commercial and recreational catches as total rockfish because of this record-keeping limitation. These catch estimates formed the basis for the new catch reconstruction; however, modifications were necessary to achieve the taxonomic and spatiotemporal resolution needed to provide explicit data for yelloweye rockfish and bocaccio (Appendix D; Min et al. 2023). First, species composition data from various recent sources were applied to estimate the proportion of total rockfish catches represented by yelloweye rockfish and bocaccio. Second, because recent research found evidence for two genetically differentiable populations of yelloweye rockfish within the DPS (one in Hood Canal and one within the rest of the Puget Sound/Georgia Basin) (Andrews et al. 2018), all removals from Hood Canal were separated from the rest of the DPS and reported as an independent data series. In addition to these modifications, the temporal extent of rockfish catch estimates was extended with data from the WDFW through 2019 (the most recent year for which complete data were available), and additional data sources were used to extend the recreational catch time series back to 1938.

There are multiple sources of uncertainty for both commercial and recreational fishery catch reconstructions, such as a lack of reliable species composition data in many years, periods of known underreporting or landings, coarse geographic resolution, and an unknown level of unreported discards and releases. To capture the range of plausible removals encompassed within this uncertainty, catch scenarios designated as "high," "medium," and "low" were employed (Appendix D; Min et al. 2023). The "medium" catch scenario served as the "most likely" estimate, while the "high" and "low" scenarios attempted to capture plausible upper and lower bounds of uncertainty under various specified assumptions.

When all catch scenarios were combined, the commercial catch data for yelloweye rockfish showed two primary periods of low-level harvest for the Hood Canal population: in the 1940s and late 1970s (Figure 1). Estimates of catch during the second period were largely similar to the scenario modeled because the commercial catch reporting program requiring location-specific reports was relatively mature by that point, producing little uncertainty in landings. However, catches were the largest for the non-Hood Canal population from the mid-1970s to the mid-1990s, with a brief decline in the late 1980s (Figure 2; Min et al. 2023). For bocaccio, commercial catch was highest in the late 1970s to early 1980s, with a smaller peak comparable to that of the non-Hood Canal yelloweye rockfish population in the 1940s (Figure 3). For all three populations, catch pulses in the 1940s coincided with World War II and the nation's pressing need for inexpensive protein sources in the post-war recovery period.

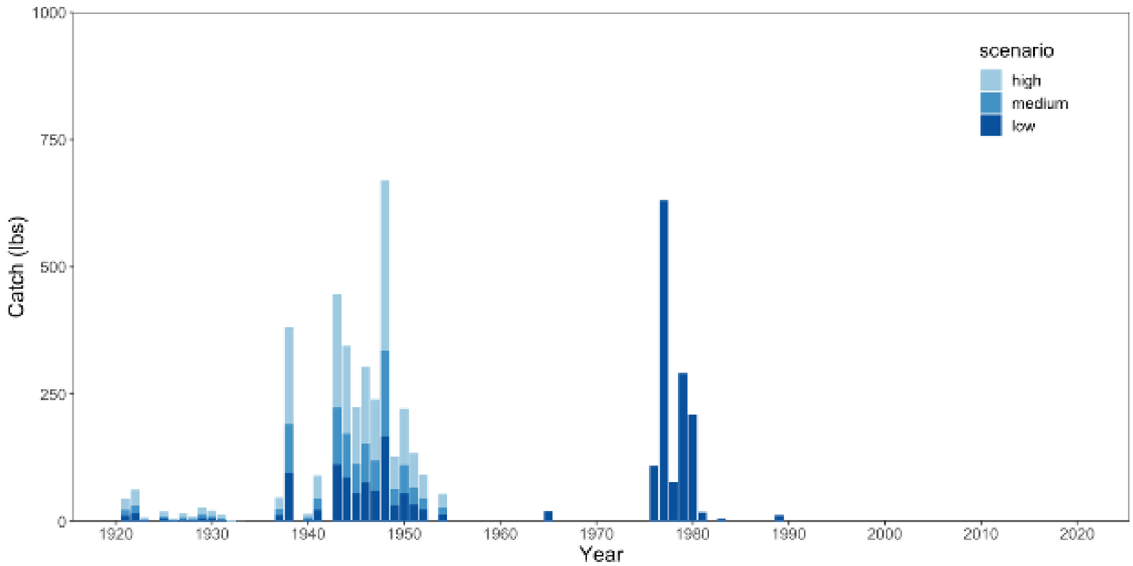

Figure 1. Estimated commercial catch of the Hood Canal population of yelloweye rockfish through time. For the catch scenarios, the stacked bars show the differences between the different catch scenarios, such that the high catch scenario is the sum of all three stacked bars.

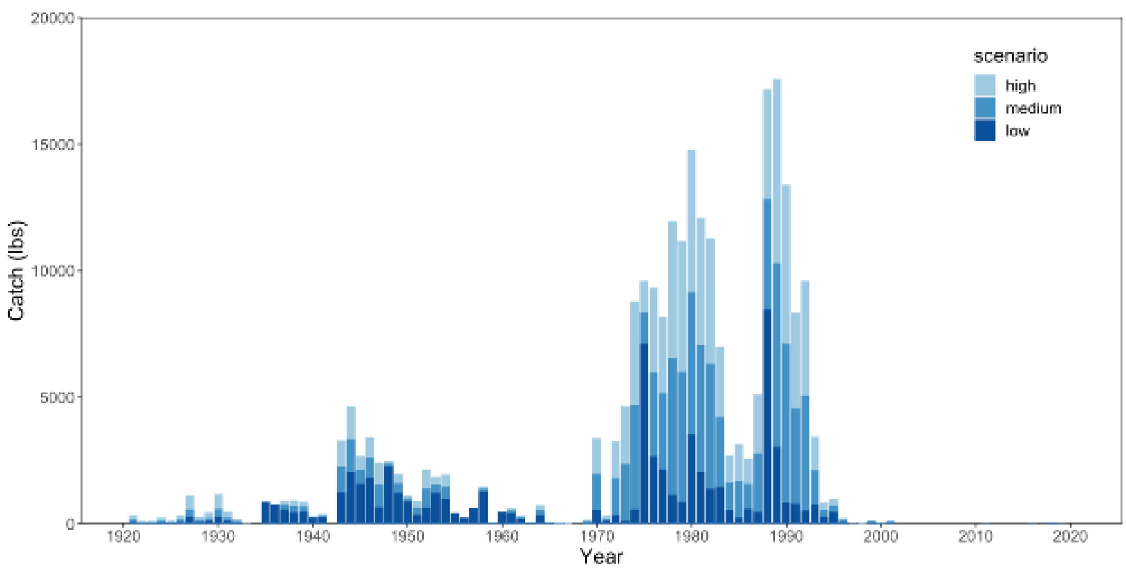

Figure 2. Estimated commercial catch of the non-Hood Canal population of yelloweye rockfish for the U.S. portion of the DPS through time. For the catch scenarios, the stacked bars show the differences between the different catch scenarios, such that the high catch scenario is the sum of all three stacked bars.

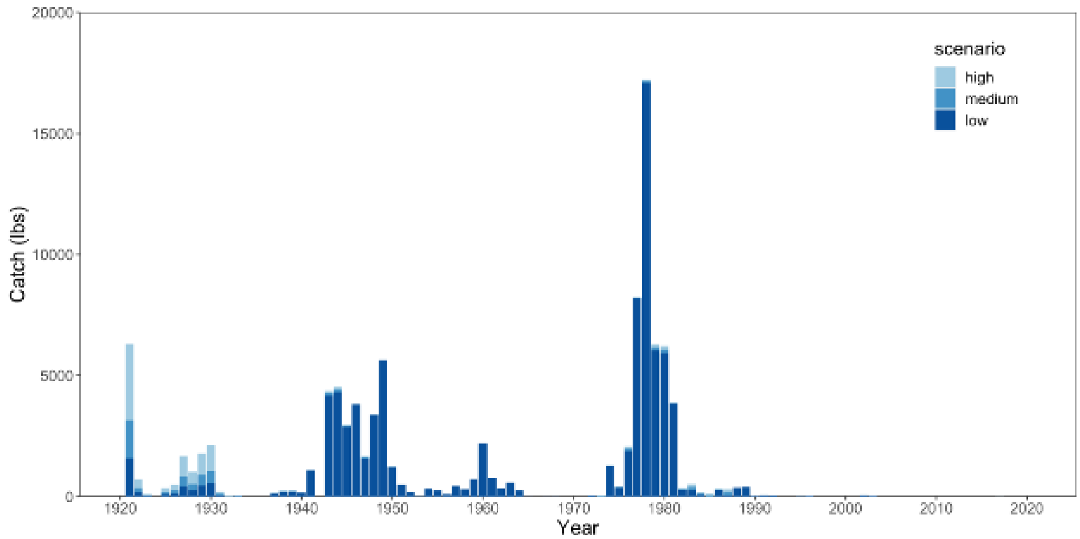

Figure 3. Estimates commercial catch of bocaccio for the U.S. portion of the DPS. For the catch scenarios, the stacked bars show the differences between the different catch scenarios, such that the high catch scenario is the sum of all three stacked bars.

For recreational catch, when all of the catch scenarios were combined a pronounced peak was apparent during the late 1970s and early 1980s for all three populations (Figures 4, 5, and 6). For bocaccio, recreational catch exhibited a strong peak period in the late 1970s, whereas yelloweye rockfish catch occurred at a more consistent rate over a broader period.

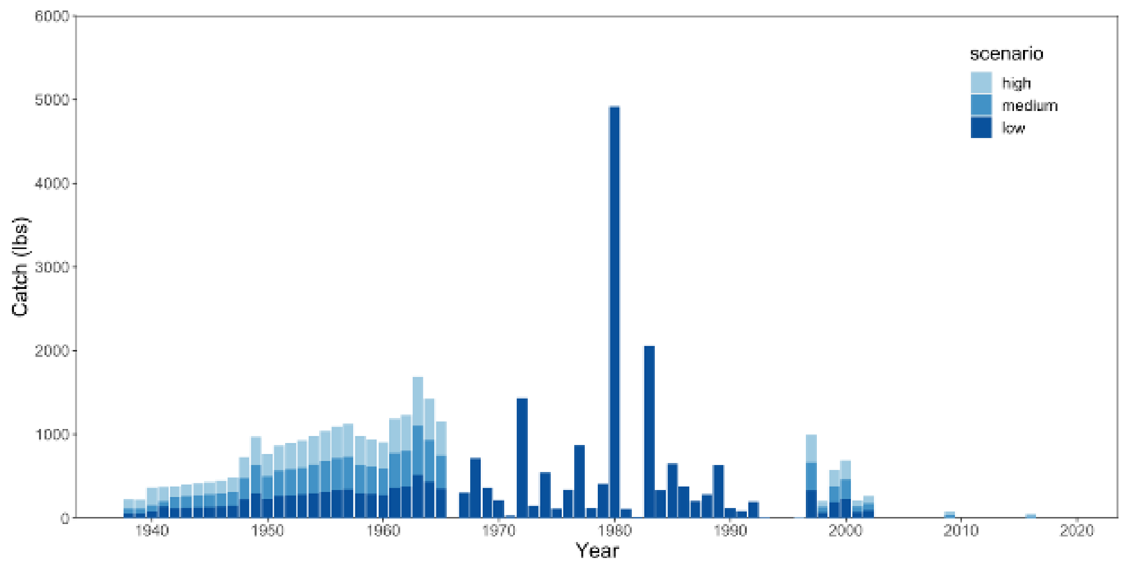

Figure 4. Hood Canal population yelloweye rockfish recreational catch through time. For the catch scenarios, the stacked bars show the differences between the different catch scenarios, such that the high catch scenario is the sum of all three stacked bars. From 1966-94, variations among catch scenarios affected data only from the Strait of Juan de Fuca; thus, it is not reflected here.

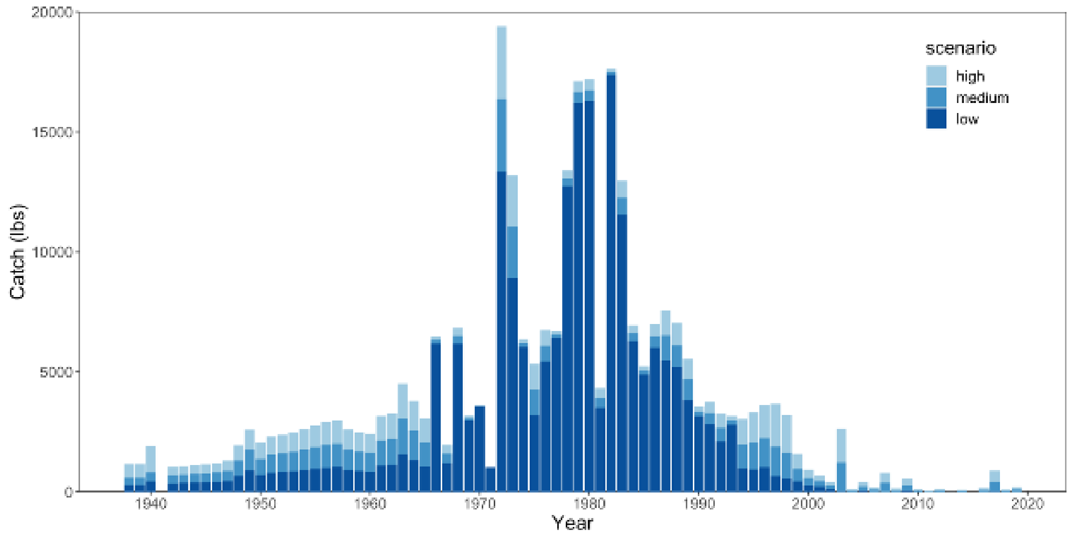

Figure 5. Non-Hood Canal population yelloweye rockfish recreational catch for the U.S. portion of the DPS through time. For the catch scenarios, the stacked bars show the differences between the different catch scenarios, such that the high catch scenario is the sum of all three stacked bars.

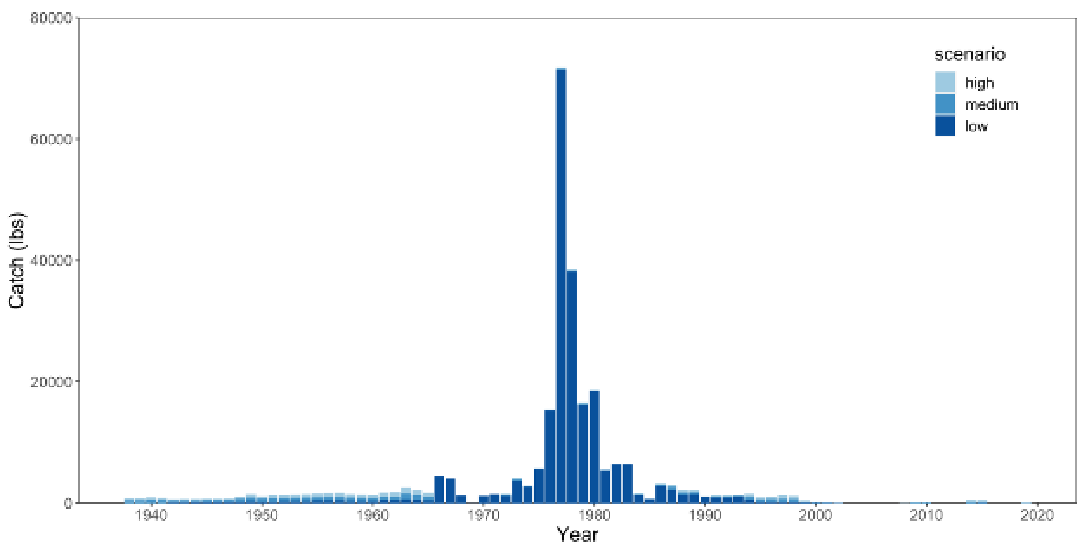

Figure 6. Bocaccio recreational catch for the U.S. portion of the DPS. For the catch scenarios, the stacked bars show the differences between the different catch scenarios, such that the high catch scenario is the sum of all three stacked bars.

For comparison to U.S. waters of the Puget Sound/Georgia Basin DPSs, catches for the Canadian portions were taken from the recently completed management strategy evaluation for the Inside Population of Yelloweye Rockfish (Haggarty et al. 2022) (Canadian portion of the yelloweye rockfish DPS managed by DFO) and the coast-wide assessment of bocaccio in waters of British Columbia (DFO 2020). With the exception of the Strait of Juan de Fuca and the outer/western portion of Queen Charlotte Strait, the stock boundary for Inside Yelloweye Rockfish aligns exactly with the Canadian portion of the DPS, as modified by federal rulemaking in 82 FR 7711.

Bocaccio are exceptionally rare in the Canadian portion of the DPS (Pietsch and Orr 2015; Anderson et al. 2019; DFO 2020), thus harvest data are unavailable.

Catches of yelloweye rockfish from Canada are shown in Figure 7, with the various catch scenarios from the U.S. portion of the DPS also plotted. These catch histories indicate that the Canadian portion of the DPS contains the majority of the population, and removals from Canada dwarf those from the U.S. portion of the DPS. The results of this stock's recently completed DFO assessment are reported in Haggarty et al. (2022) and integrated into a discussion of novel population modeling on the U.S. side of the border below.

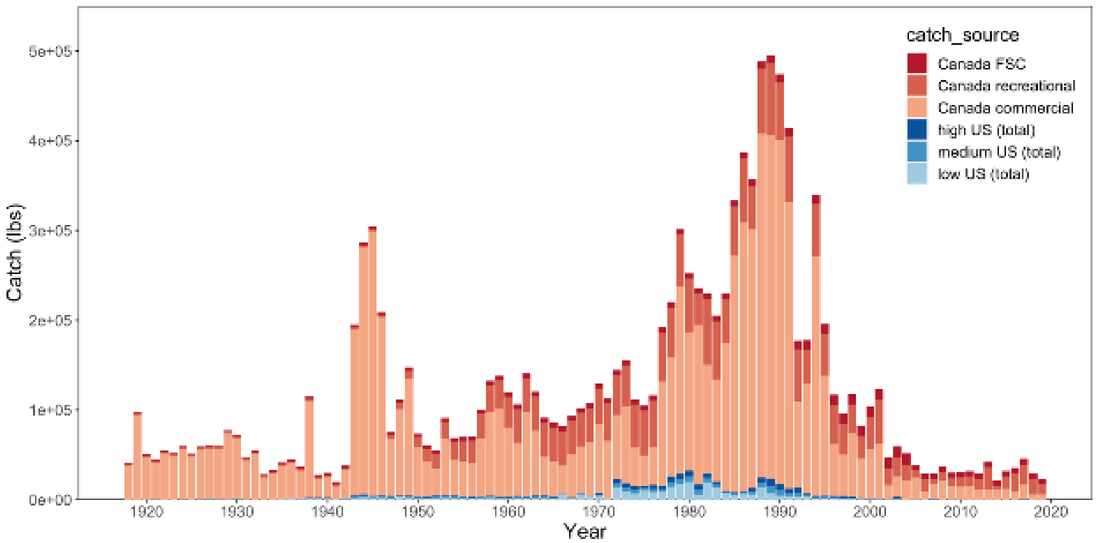

Figure 7. Yelloweye rockfish catch history for the Canadian and U.S. portions of the Puget Sound/Georgia Basin DPS. Canadian catch is divided into FSC (First Nations food, social, and ceremonial), recreational, and commercial catch; U.S. catches are shown as the combined commercial and recreational catch scenarios.

2.3.1.2.3 Young-of-the-year Citizen Science Program Observations

In the late 1980s and early 1990s, the WDF/WDFW conducted a variety of scuba-based surveys to document the distribution and habitat associations of young-of-the-year (YOY) and juvenile rockfishes of all species in greater Puget Sound (e.g., Matthews 1989; Norris 1991; Doty et al. 1995; West et al. 1995). Having established baseline data, YOY were then included in survey efforts for all age classes of rockfish through 2010 on a limited geographic basis (LeClair et al. 2018). In 2015, efforts to expand the spatiotemporal survey coverage of YOY observations were reinvigorated through a NMFS-funded citizen science program that leveraged collaborative engagement from several entities with professional dive capacity (e.g., the WDFW, Seattle Aquarium, SeaDoc Society) (Obaza and Tonnes 2017). This program has continued to expand since its inception (Obaza et al. 2019; 2021), and the once haphazard method of data collection driven by diver site preference was recently formalized into a strategic sampling plan to guide future surveys (Obaza et al. 2023). Due to the relative rarity of YOY/juvenile yelloweye rockfish and bocaccio, the program uses more common rockfish species (e.g., quillback rockfish, Puget

Sound rockfish *S. emphaeus*) as proxies for listed rockfish settlement, given their similar ecological needs.

Since 2015, YOY surveys have occurred in all subbasins of the DPSs within U.S. waters, with many sites being sampled repeatedly and geographic coverage spread broadly within most subbasins (Figure 8). Efforts are underway to expand surveys into the Canadian portion of the DPSs. So far, over 1500 surveys have been completed representing over 200 hours of bottom time, many in the last three years (Obaza et al. 2021; Adam Obaza, Paua Marine Research Group, pers. comm). Several thousand YOY rockfish have been observed during the surveys; however, only five of these individuals were yelloweye rockfish, and no bocaccio have been seen. All five yelloweye were observed after 2021, demonstrating recent reproductive success within the DPS, albeit at nominally detectable levels using this depth-limited survey approach.

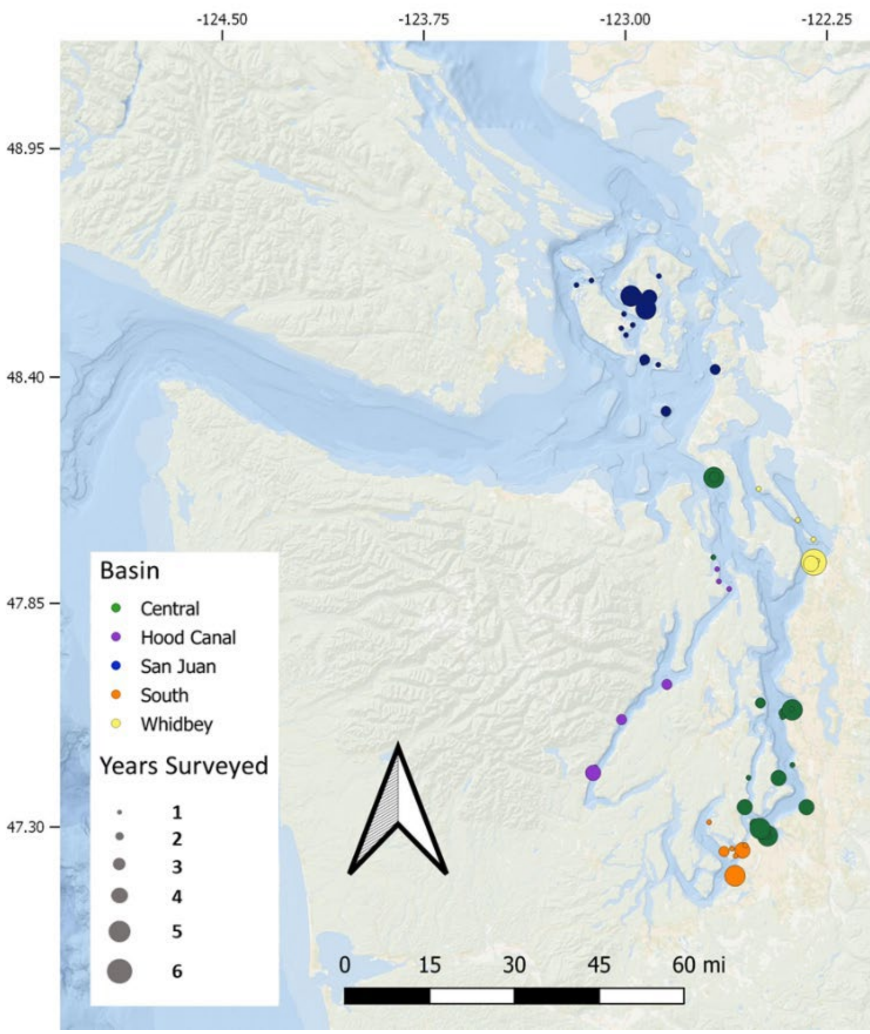

Figure 8. Young-of-the-year (YOY) rockfish survey locations in the southern Salish Sea from 2015-20. Point size indicates annual effort, and color corresponds to subbasin. From Obaza et al. (2021).

2.3.1.2.4 Recent Bocaccio Detections

Bocaccio are exceptionally rare within the Puget Sound/Georgia Basin DPS. Since 1987, only 15 have been observed through research surveys in the U.S. portion of the DPS: two from WDFW bottom trawl surveys; nine during ROV surveys; and four during dedicated hook-and-line research projects. Since 2010, WDFW Recreational Fishery Information Network (RecFIN) estimates indicate that as many as 87 individuals have been encountered by recreational anglers, with 77 of these encountered during trips targeting salmon and 75% of total encounters occurring in the San Juan Islands (Kraig and Scalici 2019; 2020; 2021; 2022; Eric Kraig, WDFW, pers. comm). Variance associated with these estimates is regularly high due to low encounter rates, however, and reporting relies on proper species identification by anglers, which has been shown to be problematic for bocaccio (Sawchuk 2012; Sawchuk et al. 2015). As such, these are likely overestimates heavily influenced by misidentification and error inflation. Management of bocaccio in British Columbia waters focuses entirely on the outer coast and does not estimate abundance in the inside waters of the Salish Sea (DFO 2020). The scarcity of bocaccio observations precludes a statistical analysis of encounters, but details are provided here as evidence of the comparative rarity of the species relative to yelloweye rockfish.

The WDF/WDFW has conducted benthic trawl surveys in Puget Sound since 1987. In 1987, 1989, and 1991, they conducted semi-stratified-random surveys of most of Puget Sound (Quinnell and Schmitt 1991; Palsson et al. 2009). From 1994-97 and 2000-07, surveys were annual, stratified-random surveys focusing on individual subbasins (Palsson et al. 1998; 2003; Blaine et al. 2020). In 2008, surveys began sampling annually at fixed index sites (Figure 9) throughout Puget Sound (Jennifer Blaine, WDFW, pers. comm). While bocaccio are primarily associated with complex, high-relief habitats, they can also be found on mudflats adjacent to these features (Love et al. 2002), and are frequently encountered in bottom trawl surveys on the U.S. West Coast (Keller et al. 2017). However, despite a combined effort of several thousand hauls, only two have been caught within the DPS boundaries since 1987, both in the northern San Juan Islands in 2018 (Figure 10). These two individuals were 33 and 35 cm in total length, corresponding to approximately two years of age (He et al. 2016). These encounters coincide with an exceptionally large 2016 cohort (44 times the average recruitment) observed off the coast of British Columbia (DFO 2020). Modeling of larval dispersal indicates that rockfish larvae released on the coast can reach Puget Sound (Andrews et al. 2021); however, while this may suggest some connectivity between regions, too few bocaccio samples have been obtained from within the DPS to assess population connectivity via genetic analysis.

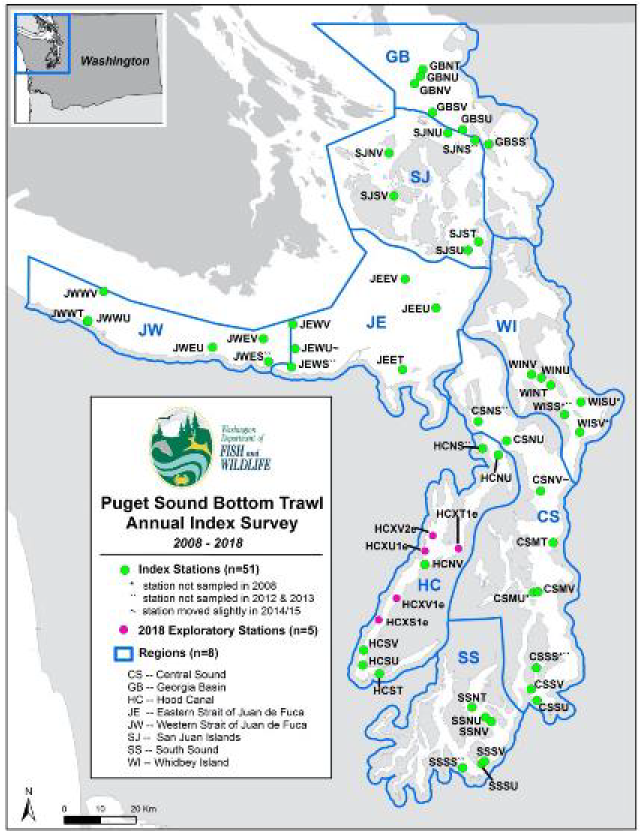

Figure 9. Trawl site locations for annual WDFW Puget Sound bottom trawl index surveys. Image from Jennifer Blaine, WDFW.

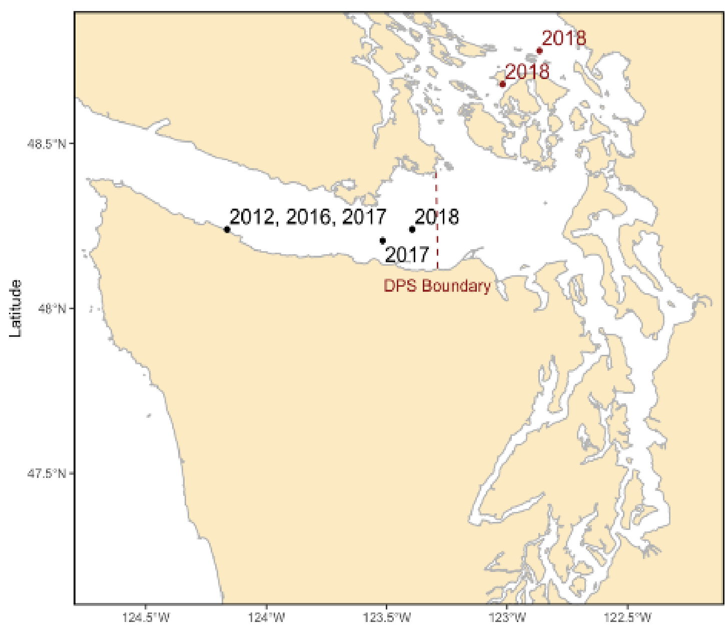

Figure 10. Locations of bocaccio observed during WDFW trawl surveys in greater Puget Sound, labeled with capture year. The WDFW has surveyed a set of 51 index sites annually in May/June since 2008 (Figure 9). Date labels in red font reflect captures inside the DPS boundary.

ROV surveys conducted by the WDFW (see *Section 2.3.1.2.1 Recent Remotely Operated Vehicle Surveys* and Appendix C for survey descriptions) have encountered nine bocaccio since 2008 (Figure 11). Four of these observations were made during site explorations on complex habitats, which occurred outside of formal surveys. Observations have primarily occurred in the San Juan Islands and central Puget Sound; however, since ROV surveys target benthic fishes by driving close to the seafloor and angling the camera downward (Pacunski et al. 2013; 2020; Appendix B), some bocaccio may have been present in the water column but not detected. Although adult bocaccio are found in the highest densities near complex substrates, they are also known to form midwater aggregations (Field et al. 2009). Bocaccio, particularly younger individuals, are commonly found off-bottom over substrate, rather than directly associated with it, and can be found 30 m or more off of the substrate (Love et al. 2002). Thus, while yelloweye rockfish are primarily found resting on the substratum (Love et al. 2002) and are well-surveyed by the benthic ROV, there is a higher probability that bocaccio are missed. YOY/Juvenile bocaccio, however, have never been documented inside the DPS during dedicated scuba survey efforts described above (Obaza and Tonnes 2017; Obaza et al. 2019; 2021), and recreational fishing encounters by mid-water salmon anglers are also rare (Kraig and Scalici 2019; 2020; 2021; 2022), so the likelihood that ROV surveys are missing considerable numbers of fish is low.

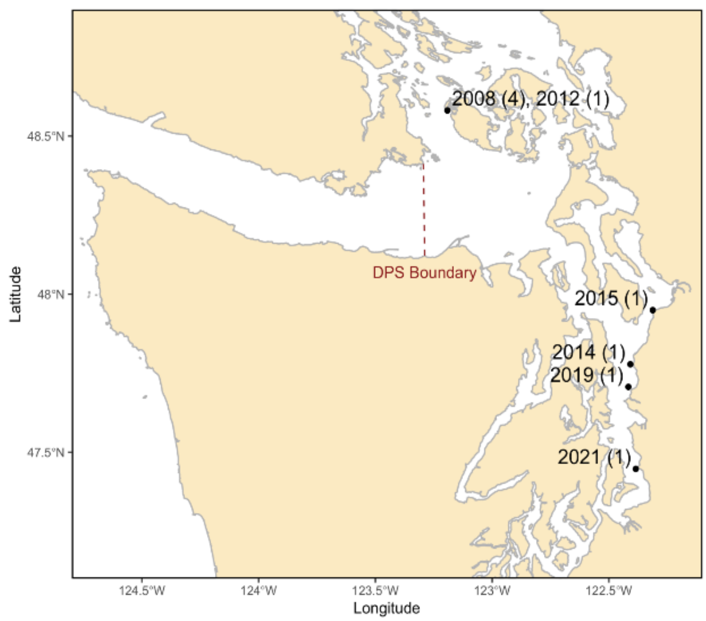

Figure 11. Locations where bocaccio have been observed during WDFW ROV surveys since 2008. Number of fish observed is listed in parentheses after the year.

A hook-and-line research project conducted in 2014-15 that targeted ESA-listed yelloweye rockfish and bocaccio only caught three bocaccio during 1,040 angler hours, despite consulting local recreational anglers, fishing captains, marine managers, and other sources of knowledge to target these species (Andrews et al. 2018). Two bocaccio (48 and 63 cm fork length) were caught near the Mukilteo ferry terminal in June 2015, and one (73 cm) was caught in Port Susan in October 2015. Since 2015, hook-and-line research efforts have encountered only one additional adult bocaccio, in 2022, as part of a study to identify terminal tackle likely to reduce rockfish bycatch (Kelly Andrews, NOAA Fisheries, pers. comm).

While there have historically been reports of bocaccio from some inlets in British Columbia and the Strait of Georgia (COSEWIC 2002), a review of data from the DFO Hard Bottom Long Line (HBLL) survey, which has surveyed the Canadian portion of the Puget Sound/Georgia Basin DPS since 2003, found no bocaccio (Anderson et al. 2019). This finding indicates that presently, the species is exceptionally rare/absent in the Canadian portion of the Puget Sound/Georgia Basin DPS, and B.C.-wide management of the species excludes this region from consideration (DFO 2020).

2.3.1.2.5 New Catch and Length Models

To estimate absolute spawning biomass and stock status and investigate contemporary relative to historical population size for bocaccio and both MUs of yelloweye rockfish, length data from hook-and-line research projects and the catch histories described in *Section 2.3.1.2.2 Catch Reconstructions* were analyzed with Stock Synthesis (SS) using catch and length compositions (SS-CL) (Min et al. 2023). SS is an integrated stock assessment framework that accommodates "data-poor" to "data-rich" scenarios, making it useful under an array of situations (Methot and Wetzel 2013). SS-CL uses the SS framework, but includes only catch and length data as opposed to the diverse data sources common to "data-rich" fisheries (i.e., abundance indices from multiple, independent sources) (Rudd et al. 2021). SS-CL can generate low-bias estimates of key population quantities (including stock status) with as little as one year of length data, though performance improves with more robust data series. Here, life history parameters for each listed rockfish population are from the most recent stock assessments for the West Coast stocks of these species (Gertseva and Cope 2017; He and Field 2017; DFO 2020). For bocaccio, natural mortality and growth were taken from the Canadian stock, with fecundity and maturity taken from the California stock.

SS-CL was applied to three catch scenarios (high, medium, and low) for each population: non-Hood Canal yelloweye rockfish (U.S. waters only); Hood Canal yelloweye rockfish; and bocaccio (U.S. waters only). Genetic research has validated a single yelloweye rockfish population spanning U.S. and Canadian waters of the DPS, excluding Hood Canal (Andrews et al. 2018). Canadian waters were excluded from this analysis because DFO recently completed a complementary assessment of yelloweye rockfish in British Columbia inside waters (Haggarty et al. 2022). In the recent publication on the rebuilding plan for yelloweye rockfish in British Columbia inside waters, DFO estimated that biomass in 2019 was less than 50% of unfished and extinction risk over the next 100 years was very low, even with a constant catch policy of 15 metric tons annually (Haggarty et al. 2022). The DFO assessment for Inside Yelloweye Rockfish is further discussed below. For bocaccio, DFO does not recognize a self-sustaining population in inside waters and, thus, does not include waters of the DPS in their formal status assessments (DFO 2020).

Length data were taken from three research projects conducted within the DPSs: Washington et al. (1978), which included data from 1974-77; Andrews et al. (2018), which included data from 2014-15); and an unpublished, NMFS-led lingcod bycatch study conducted from 2017-19 (Kelly Andrews, NOAA Fisheries, pers comm). Length composition data available from recreational catch sampling were not included because of their bias toward larger, recreationally retained individuals during periods when retention was legal. Due to small sample size, data from Andrews et al. (2018) and the lingcod bycatch project were combined. Length compositions from the two time periods (1970s and 2010s) were used, assuming they represent recreational fishery selectivity. While three bocaccio were caught in 2015 and two yelloweye from Hood Canal were caught in 1975, these small sample sizes were not representative and were excluded from the model. For the three populations, the number of usable lengths from each time period was: bocaccio – 21 from the 1970s, 0 from the 2010s; yelloweye rockfish, Hood Canal – 0 from 1970s, 16 from 2010s; yelloweye rockfish, non-Hood Canal – 28 from 1970s, 62 from 2010s (Min et al. 2023).

Given the highly uncertain catch history for the Hood Canal yelloweye rockfish population (Figures 1 and 4), it was also modeled using two length-only approaches to evaluate how vagueries in catch estimates affect the understanding of population trends. These two model formulations were: Stock Synthesis using length compositions only (SS-LO); and the length-based spawning potential ratio (LB-SPR) method (Min et al. 2023). SS-LO uses the same parameterizations as SS-CL; LB-SPR relies on the use of the life history parameters natural mortality (*M*) and the *K* parameter from the von Bertalanffy growth equation to calculate the ratio *M*/*K*, as well as maximum theoretical length (L_{inf}) and size at maturity to estimate the SPR using size composition data from the fishery (Hordyk et al. 2016). The LB-SPR method also assumes steepness = 1, whereas SS-LO retains the value of 0.72 as used in the SS-CL models.

The non-Hood Canal population of yelloweye rockfish (U.S. waters only) exhibited declining abundance relative to an unfished state starting around 1970, with a minimum abundance in 1994 (high and medium catch scenarios) or 1992 (low catch scenario), followed by slow population growth through 2021 (Figure 12). Despite low sample size resulting in high uncertainty for these estimates, the temporal trend generally aligns with fishery management efforts over the decades that sought to reduce harvest impacts (Palsson et al. 2009; NMFS 2017b). While best-fit estimates indicate spawning output was around 72-74% of unfished in the early 1990s, the uncertainty envelope indicates that population size may have decreased to near zero during this period (Figure 12). By 2000, however, the near complete closure of both commercial and recreational fisheries targeting yelloweye rockfish led to very low removals for almost 25 years. With the deterministic recruitment assumed by the SS-CL model, in the absence of directed harvest, the model suggests that the population rebounded substantially, with the lower bound of the 95% confidence interval for all catch history scenarios approaching the common management target for exploited stocks of 40% of unfished biomass (Min et al. 2023). The best fit of the model indicates that relative spawning output in 2021 was around 85% of unfished, and the 95% lower bounds of the uncertainty were at 41% of unfished. Thus, the model suggests that while it was probable that the non-Hood Canal yelloweye rockfish population reached very low levels in the 1990s, near-zero harvest for over two decades resulted in the population being highly likely to be over the 25% threshold for SPR set in the Rockfish Recovery Plan (NMFS 2017b). One caveat to this assessment is that the effects of changes in productivity (e.g., highly reduced or complete recruitment failure) on the SPR calculations for this population were not investigated (Min et al. 2023). At this time, we have no evidence to suggest that recruitment failure has occurred in the recent past, or is currently occurring.

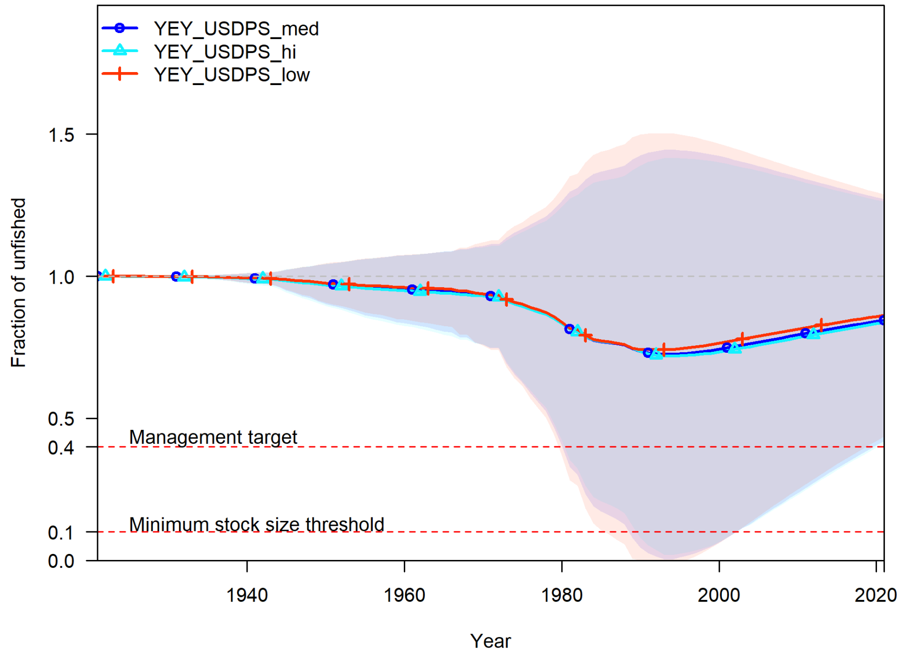

Figure 12. Relative spawning population output for non-Hood Canal yelloweye rockfish stock (U.S. waters only). The three lines correspond to the three catch scenarios, with the associated uncertainties shown by the shaded areas.

The Canadian portion of the yelloweye rockfish DPS is managed by DFO under the name Inside Yelloweye Rockfish and was designated a major fish stock in the fall of 2020 (Haggarty et al. 2022). It was also re-assessed by the Committee on the Status of Endangered Species in Canada (COSEWIC) that same year and recommended for a status change from Species of Concern to Threatened under the Species at Risk Act (SARA) (COSEWIC 2020). The geographic boundaries of this designatable unit (DU) align closely with the Puget Sound/Georgia Basin DPS boundaries, except for the western portion of Queen Charlotte Strait and the Strait of Juan de Fuca (though an adjustment to these boundaries to match the extent of the DPS has been proposed) (Figure 13). For this review, we consider the Inside Yelloweye Rockfish DU to be representative of the Canadian portion of the non-Hood Canal population of the Puget Sound/Georgia Basin DPS of yelloweye rockfish.

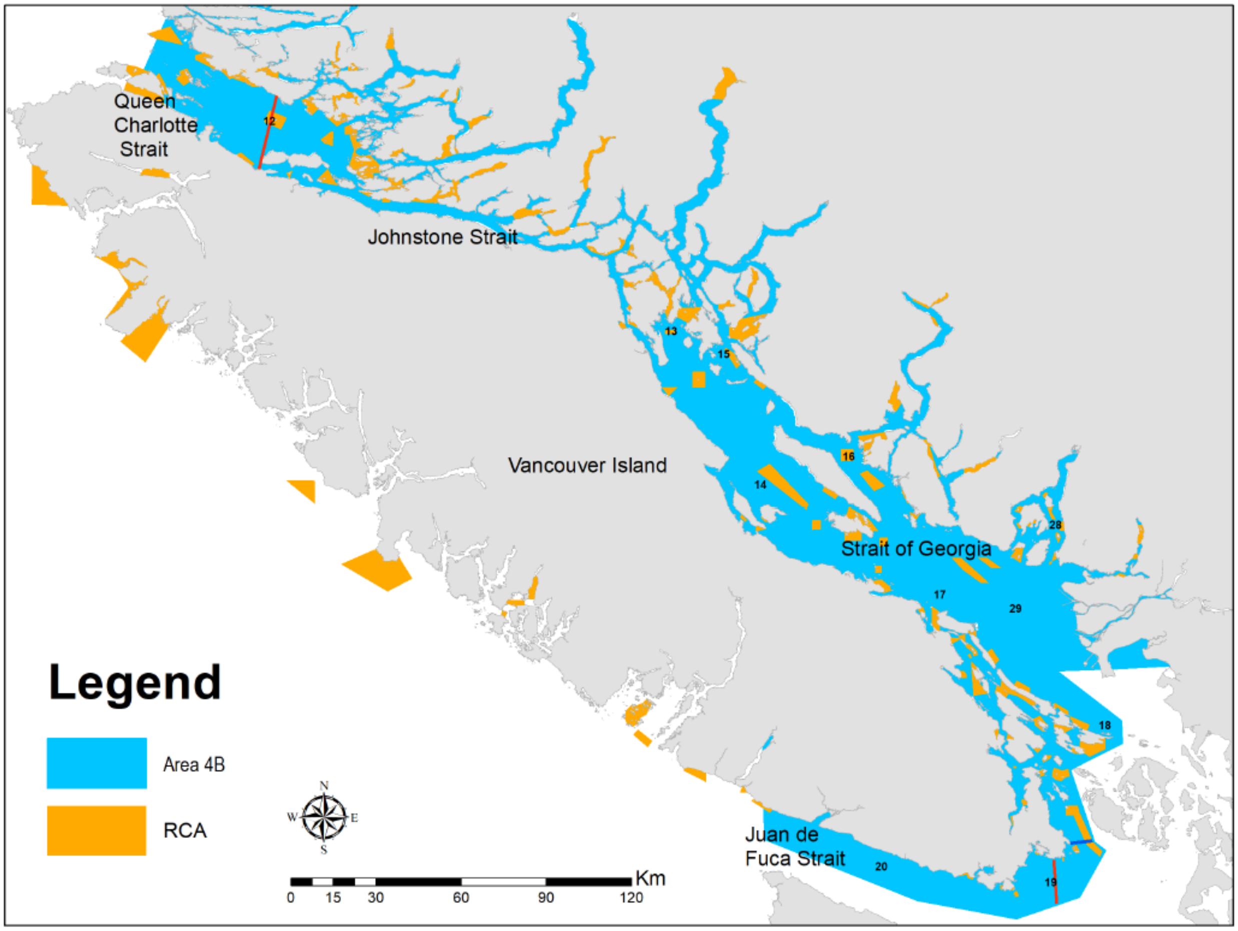

Figure 13. Map of Canadian waters of the Salish Sea showing rockfish conservation areas (RCAs) and the boundaries of the Inside Yelloweye Rockfish designatable unit (DU). Red lines indicate a proposed adjustment to the range for the DU, based on recent genetic evidence. Marine catch reporting areas are numbered. Figure from Haggarty et al. (2022).

In 2021, DFO completed an analysis of rebuilding strategies for the Inside Yelloweye Rockfish DU, which included modeling the stock's population dynamics through 2019 (Haggarty et al. 2022). Far more data were available for the analysis than for the U.S. portion of the DPS, as this region is actively fished (Figure 7) and DFO conducts annual fishery-independent surveys. The stock dynamics model used by DFO for this stock was implemented through the Data Limited Methods toolkit (DLMtool) (Carruthers and Hordyk 2018; 2019) and DLMTool's companion software package, Management Strategy Evaluation toolkit (MSEtool) (Huynh et al. 2019). In brief, DLMtool specifies operating models (OMs) that represent major components of a real fished system (population dynamics of the stock, fishery dynamics, observation processes, and management implementation), then MSEtool implements stock reduction analysis (SRA) (Kimura and Tagart 1982; Walters et al. 2006), which is effectively a statistical catch-at-age model that estimates combinations of historical fishing mortality and recruitment consistent with observed data. The parameter values specified in the OM are passed to the SRA model, which fits the OM to historically observed catches, indices of abundance, and available years of age-composition data. For this stock, age composition data are primarily from the DFO hard bottom longline (HBLL) survey, and indices of abundance are from the HBLL survey, the Dogfish

Survey, and three commercial catch per unit effort (CPUE) series. Details of the OMs are available in Appendix E and Haggarty et al. (2022). Here, comparison is made between the base model used by DFO and modeling results for the U.S. portion of the non-Hood Canal population of yelloweye rockfish.

The temporal trends for both the Canadian and U.S. portions of the non-Hood Canal population of the DPS are superficially similar: declining until the 1990s/2000s, followed by a period of steady recovery under greatly reduced fishing pressure (Figure 14). However, the status of the Canadian portion of the population differs from the U.S. portion in two key ways. First, while the U.S. portion of the population declined until the early 1990s, reaching a minimum biomass in 2002 (Figure 14), the Canadian population continued to decline (Figure 7). Canadian catches declined from a peak of ~214 metric tons (470,000 pounds) in 1989, but significant regulatory changes in 2002 led to a 75% decline in commercial catch from 2001 levels (Yamanaka and Logan 2010). This is contrasted with the regulatory history in Puget Sound, where significant regulatory actions, such as banning bottomfish jig and troll gear (the primary commercial gear by which yelloweye rockfish were caught) and decreasing rockfish daily bag limits in the recreational fishery, were enacted a decade earlier, in the early 1990s (Palsson et al. 2009). Second, the Canadian portion of the population has been experiencing slower recovery and remains at lower relative biomass levels compared to the U.S. portion of the population, due to continued fishing in Canadian waters with a 15-metric tons annual total allowable catch (TAC) (Haggarty et al. 2022).

The relative status of the Canadian portion of the population indicates that the Canadian stock is currently at a lower proportion of unfished biomass than the U.S. portion. For the U.S. population, the relative depletion in 2021 is estimated to be at 85% of unfished, and the 95% lower bounds of the uncertainty are at 41% of unfished. For the Canadian stock, the median value is 32% of unfished (95% quantiles 15.1% to 68.4% of unfished). Again, this reflects the continued fishing pressure on the Canadian portion of the population compared to the absence of fishing mortality for the U.S. portion of the population, coupled with the deterministic recruitment assumed by the model. These results demonstrate that stock status for both the Canadian and U.S. portions of the non-Hood Canal population are above the 25% threshold set in the Rockfish Recovery Plan (NMFS 2017b) and that the lower bounds of the 95% quantiles are both above the 15% threshold, indicating that recovery in progressing on both sides of the international border.

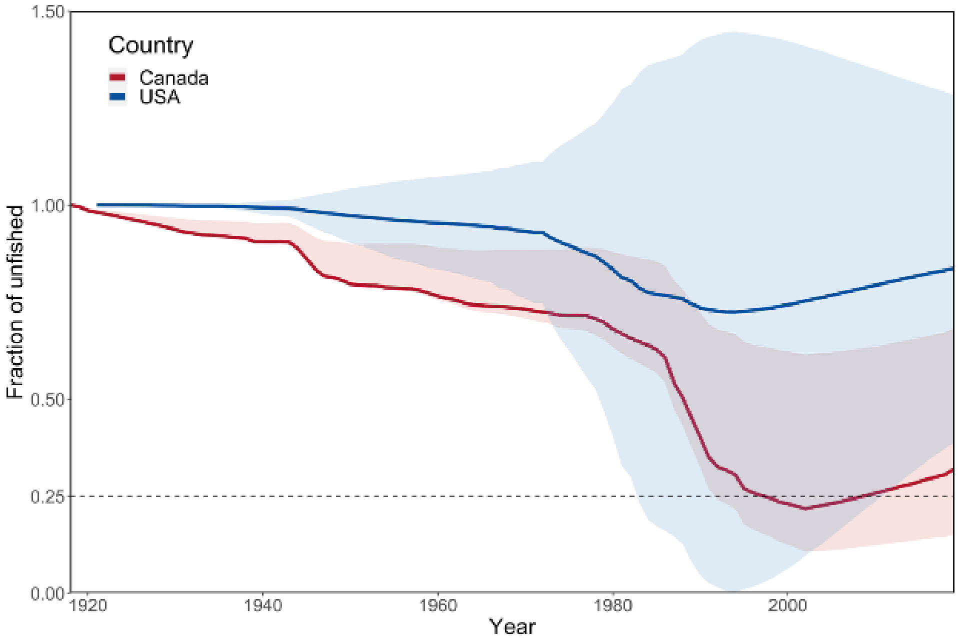

Figure 14. Stock status for yelloweye rockfish, non-Hood Canal population, showing the models fit to the Canadian portion of the population (red) and the United States portion of the population (blue). The United States model fit is the one fit to the medium catch scenario in Figure 12; the Canadian model is from Haggarty et al. (2022).

The absolute spawning stock biomass indicates that the Canadian portion of the non-Hood Canal Puget Sound/Georgia Basin DPS is considerably larger than the U.S. portion (Min et al. 2023). Median estimates of unfished biomass suggest that the Canadian portion of the population is approximately ten times larger than the U.S. portion (4,334 mt vs. 418 mt). However, because of the differences in recovery and historical fishing pressure, the differences in population size are reduced from unfished levels. In 2019, the last year of the DFO model, the median estimate of the Canadian portion of the population was four times the median estimate of the U.S. portion.

Owing to an uncertain catch history, the temporal trend for the Hood Canal population of yelloweye rockfish is highly uncertain and gives inconsistent results among models. In the SS-CL model that assumes catch is known without error, the population declines until the early 1980s, similar to the non-Hood Canal population model, but a slow and steady recovery trajectory follows the decline (Figure 15). Overall, population decline is mild, reaching only 71% of unfished biomass in the high catch scenario. However, the constraint of "knowing" catch restricts the uncertainty estimated in the model. With no historical length composition data, the model is fitting to only the 2010s length distribution, which is assumed to be representative of a high relative stock status given the low overall removals over time (Min et al. 2023).

The SS-LO and LB-SPR models predict a substantially worse population status than the SS-CL model. The SS-LO model estimates the population is at 7.5% (95% CI 0.06 – 0.09 based on asymptotic variance estimation) of unfished, and the LB-SPR model gives an SPR estimate of 0.16 (95% CI 0 – 1 based on length sample sizes) (Min et al. 2023). Still, neither model properly fits the length data, and the quality of the length composition is questionable given the rapid declines between the 1970s and 2010s. With the questionable inputs (both catch and length compositions) and the inconsistent results from the three different model runs, there is a very high degree of uncertainty in the status of the Hood Canal yelloweye rockfish population and a reliable evaluation of its status cannot be made. This modeling effort, however, serves as an initial baseline to inform future sampling and validates the need to obtain a robust, current length composition data set from this genetically differentiable region.

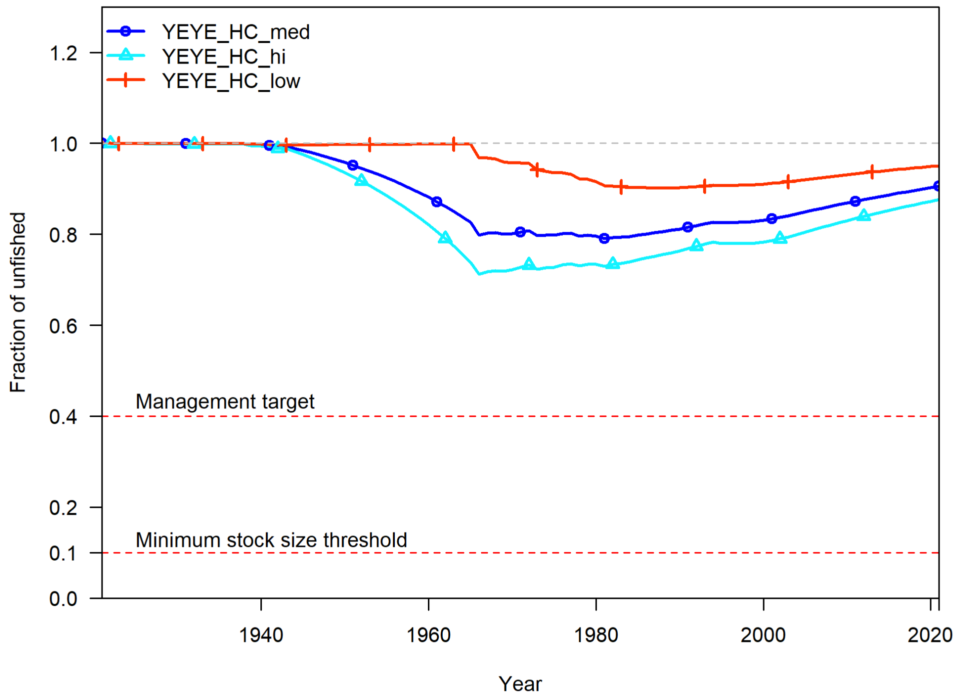

Figure 15. Relative spawning population output for the Hood Canal yelloweye rockfish stock. The three lines correspond to the three catch scenarios. Uncertainties are too small to visualize at this scale.

For bocaccio, the SS-CL predicts a gradual decline until around 1975, when the stock was depleted by high catches in the late 1970s (Figures 3 and 6) until it reached values as low as 1% of unfished (Figure 16). Because there is no recent length data, however, the model indicates a very wide range of uncertainty that balloons after 2000, with biomass in 2021 estimated to be anywhere from 0-250% of unfished. The median estimate, which estimates stock size to be 32% in 2021, is the result of assumed deterministic recruitment; however, a bocaccio population of this size in U.S. waters of the DPS is inconsistent with recent observations that indicate bocaccio remain exceedingly rare (see *2.3.1.2.4 Recent Bocaccio Detections*). The lack of recovery suggests that recruitment failure may have repeatedly occurred over the last 30 years (during which time fishing mortality has been near zero). This lack of observed recruitment is consistent with the hypothesis explored in the ESA status assessment that preceded listing (Drake et al. 2010) that bocaccio are not a self-sustaining population within greater Puget Sound, but are instead the result of intermittent connections to episodic recruitment events occurring in coastal waters of B.C. and Washington. A concerted effort is currently underway to collect genetic samples from bocaccio occurring inside the boundaries of the DPS to address this possibility.

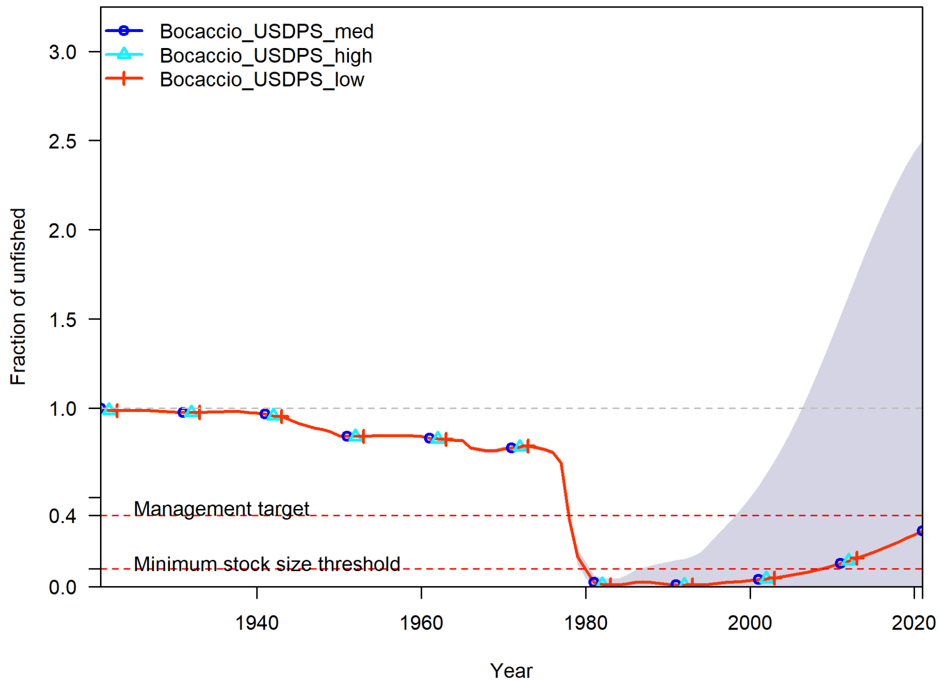

Figure 16. Relative spawning population biomass for bocaccio. The three overlapping lines correspond to the three catch scenarios, with the associated uncertainties shown in the shaded areas.

2.3.1.3 Genetics, Genetic Variation, or Trends in Genetic Variation

The most recent genetic assessment of population demography within the Puget Sound/Georgia Basin DPS for yelloweye rockfish occurred in 2015-16 (Andrews et al. 2018) and was included in our last 5-year status update (Tonnes et al. 2016). In brief, this assessment found that yelloweye rockfish inside the DPS were distinct from those on the outer coast of Washington and British Columbia, and that yelloweye rockfish in Johnstone Strait grouped with fish included in the DPS. As a result of this assessment, the northern boundary of the DPS was extended to incorporate these genetically allied fish in Johnstone Strait (82 FR 7711). Further, this study demonstrated that yelloweye rockfish occupying Hood Canal could be genetically differentiated from conspecifics elsewhere in the DPS. This conclusion was acknowledged in the Rockfish Recovery Plan for yelloweye rockfish, wherein delisting criteria were set independently for the Hood Canal MU (NMFS, 2017b; Table 2). Additional genetic assessments are not currently planned for the yelloweye rockfish DPS.

The 2015-16 genetic survey also sought to obtain samples to assess the validity and geographic definition of the bocaccio DPS, but did not capture sufficient numbers of fish to do so. Collaborative research with Lorenz Hauser at UW, the WDFW, and NOAA Fisheries is actively targeting bocaccio observed during recent ROV surveys throughout the DPS with a renewed hook-and-line sampling effort. If the researchers obtain a sufficient number of samples, genetic evaluation will occur following the methods of Andrews et al. (2018).

2.3.1.4 Taxonomic Classification or Changes in Nomenclature

There have been no changes in taxonomic classification or scientific nomenclature for either bocaccio or yelloweye rockfish since the last status review.

2.3.1.5 Spatial Distribution, Trends in Spatial Distribution, or Historic Range

Since the last status review (Tonnes et al. 2016), new genetic information (Andrews et al. 2018) resulted in changes to the boundary of the DPS for yelloweye rockfish in 2017 (82 FR 7711). Specifically, we expanded the extent of the DPS to incorporate waters northwestward of Campbell River, B.C., into Johnstone Strait as far west as Malcolm Island, including several inlets and channels separating islands and peninsulas in this region (Figure 17*).* This update to the DPS definition expanded the area considered during population assessments to align with the northern boundary already in use by DFO (Haggarty et al. 2020), allowing more direct incorporation of readily available abundance estimates. The change also increased the historical baseline distribution, and therefore abundance, of yelloweye rockfish. Estimates for the Inside Yelloweye Rockfish DU have extrapolated data from elsewhere in the Strait of Georgia to this data-limited region for some time, however, and the status of the whole of the DU was used as a proxy for the status of the Canadian portion of the DPS (Tonnes et al. 2016). In addition to recognizing population connectivity with this new zone, 82 FR 7711 changed the definition of the DPS to include not only individuals residing within the newly revised DPS boundary, but also those originating from waters in the DPS.

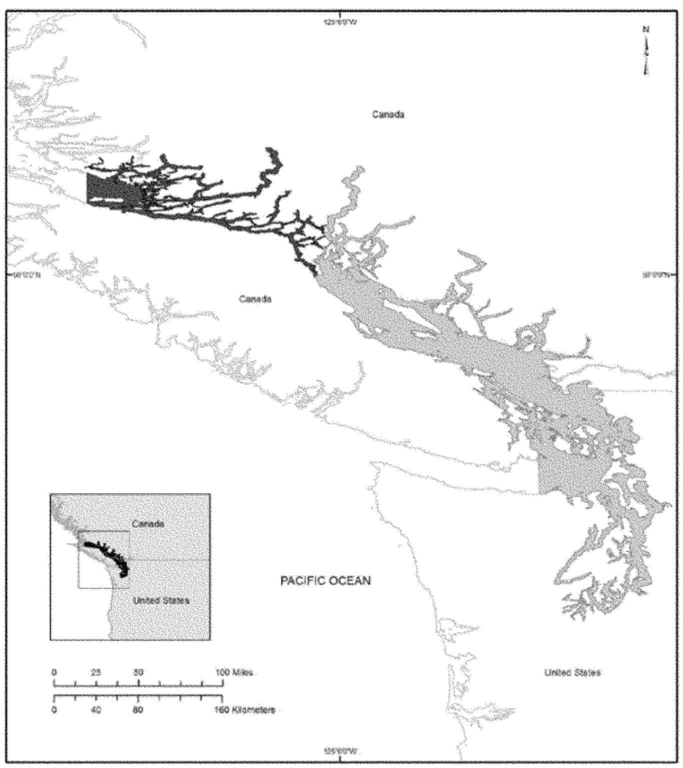

Figure 17. The extent of the Puget Sound/Georgia Basin Yelloweye Rockfish DPS in 2016 prior to new genetic evidence was obtained (gray shading), and after this evidence was used to extend the DPS boundary northward (black shading) in 2017 (82 FR 7711).

Research to obtain new genetic information from listed rockfish in 2015-16 fell short of obtaining enough samples to evaluate boundaries of the Puget Sound/Georgia Basin Bocaccio DPS (Andrews et al. 2018), though efforts are ongoing. As a result, the boundaries of the DPS remain unchanged; however, we made the same update to the definition of the DPS to include not only individuals residing within the boundaries but also those originating from waters of the DPS (82 FR 7711). As noted above, bocaccio encounters within the DPS have been exceptionally rare in recent years. While juvenile bocaccio have been encountered during trawl surveys in a pattern that suggests an eastward influx of settlement from the Strait of Juan de Fuca into the San Juan Islands (Figure 10), these areas are already included in the known range of the species/DPS.

2.3.1.6 Habitat or Ecosystem Conditions

Since the last status review (Tonnes et al. 2016), several synoptic evaluations of habitat and ecosystem conditions in the Salish Sea and adjacent reaches of the northeast Pacific Ocean have been completed, all of which contain elements of historical trend analysis and/or projection of future impacts from global climate change (e.g., Garfield and Harvey 2016; Harvey and Garfield 2017; Harvey et al. 2018; 2019; 2020; 2021; Chandler et al. 2018; PSEMP Marine Waters Workgroup 2019; 2021; Boldt et al. 2020; Khangaonkar et al. 2019; 2021; Sobocinski 2021). Furthermore, each of these assessments reports substantial, and in some cases unprecedented, shifts in physical, chemical, and biological aspects in the last decade that have sweeping consequences. Pervasive increases in sea surface temperature and decreases in pH have been accompanied by aberrant mortality events in fish, birds, and marine mammals; disease outbreaks in invertebrates and forage species; and loss of biogenic habitats such as kelp forests and eelgrass meadows. In many cases, both the frequency and intensity of extreme weather and upwelling events, and biological responses to them, are predicted to increase into the foreseeable future. Unfortunately, little direct information exists to assess sublethal or lethal thresholds for any specific environmental parameters associated with such events on listed rockfish. NOAA recently funded IBSS, Inc. and the Point Defiance Zoo and Aquarium to begin examining the effects of water quality parameters on larval yelloweye rockfish.

As reviewed by the Independent Scientific Advisory Board (2007), average annual air temperatures in the Pacific Northwest have increased by approximately 1.8°F (1°C) since 1900, nearly twice that for the previous hundred years. Global average temperature under the high emissions scenario (SSP3-7.0) is projected to increase approximately 6.5°F (3.6°C) by the end of the century (IPCC 2023). This change in surface air temperature has already modified, and is likely to continue to modify, marine habitats occupied by listed rockfish; however, a great deal of uncertainty is associated with predicting specific changes in timing, location, and magnitude of future climate change and species-specific impacts on rockfish. Still, research on the west coast of Vancouver Island has shown that some rockfish species benefit from increased temperature and modified upwelling regimes, while others do not (Markel and Shurin 2020). Variation in settlement can also be strongly influenced by drivers of wind and current direction and intensity, leading to high interannual variability in recruitment (Markel et al. 2017; Andrews et al. 2021).

Several effects of climate change have influenced, and will continue to influence, habitat within the DPSs, including increased ocean temperature and stratification of the water column, decreased pH, and intensity and timing changes of coastal upwelling (ISAB 2007; IPCC 2023). These ongoing changes will alter primary and secondary productivity, shifting marine community structure (Doney et al. 2012). These perturbations may, in turn, alter trophic dynamics, growth, productivity, survival, and habitat usage of listed rockfish. Decreasing pH reduces carbonate availability for shell-forming invertebrates, affecting survival and spatiotemporal availability of prey (Feely et al. 2010). Further research is needed to understand the possible implications of such changes on trophic functions in Puget Sound and how they may affect rockfish. Thus far, studies conducted in other areas have shown that effects will be variable (Ries et al. 2009) and site- and species-specific (Miller et al. 2009; Harvey et al. 2012). There are natural biological and physical functions in regions of the Salish Sea, especially in Hood Canal and South Puget Sound, that cause the water to be corrosive and hypoxic, such as restricted circulation and mixing, respiration, and strong stratification (Newton and Van Voorhis 2002; Feely et al. 2010). Such areas may be especially susceptible to climate change-fueled physiochemical alterations that exceed the adaptive capacity of listed rockfish. Given that the yelloweye rockfish population inhabiting Hood Canal displays a divergent genetic profile from populations elsewhere in the DPS (Andrews et al. 2018), impacts from corrosive water and hypoxia here may substantially impede recovery in this MU.

2.3.1.7 Other: Critical Habitat

The Critical Habitat designation and Rockfish Recovery Plan describe a suite of habitat characteristics and ecological components that must be readily available for listed rockfish to flourish, as well as priority actions to monitor and, as needed, restore these components (79 FR 68042; NMFS 2017). For juvenile bocaccio, this includes nearshore, vegetated habitats that provide diverse prey and shelter. For juvenile yelloweye rockfish, and adults of both species, this includes deep-water, complex rocky habitats that also provide adequate prey, shelter, and proximity to mates. For all life stages of both species, physiochemical water quality parameters and toxic contaminants must be within ranges that they can physiologically tolerate. While ROV and scuba surveys continue to collect information that refines our understanding of habitat-specific patterns of distribution within the DPSs (e.g., Pacunski et al. 2020; Lowry et al. 2022; Obaza et al. 2021), there is not yet sufficient new information to consider a reevaluation of the underlying definitions of what constitutes critical habitat and where it is located.

2.3.2 Five-Factor Analysis

2.3.2.1 Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Rockfish habitats within the boundaries of the DPSs face a wide array of potential threats, which vary greatly from place to place with regard to their immediacy, breadth, and severity (Palsson et al. 2009; Drake et al. 2010; NMFS 2017). Foremost among these threats are nearshore development, release of toxic contaminants, and ecosystem-level alteration due to global climate change (COSEWIC 2020). As noted in *Section 2.3.1.6 Habitat or Ecosystem Conditions*, several recent syntheses of environmental conditions have determined that the Puget Sound/Georgia

Basin ecosystem has experienced substantial contemporary variation in physical, chemical, and biological attributes that affect listed rockfish. These changes range from altered flow and upwelling patterns, to elevated temperature and reduced pH, to decreased habitat availability, to prey base alteration, to increased predator prevalence (PSEMP Marine Waters Workgroup 2019; 2021; Khangaonkar et al. 2019; 2021; Berry et al. 2021; Sobocinski 2021). For deep-water adult habitat, ROV survey efforts and habitat suitability modeling have demonstrated that substantial amounts of adequate, currently unoccupied habitat exist in both U.S. and Canadian portions of the DPSs (Pacunski et al. 2013; 2020; 2022; Lowry et al. 2022; WDFW Marine Fish Science Unit, unpublished data). Nearshore, vegetated habitats utilized by YOY and juvenile bocaccio, and to a lesser degree yelloweye rockfish, are also prevalent throughout the range of the DPSs; however, slow declines have been observed in seagrasses since 2016 (Christiaen et al. 2022) and regionally dramatic declines have been recently observed for canopy-forming kelps (Berry et al. 2019; 2021). Given the current estimated or inferred abundance of listed rockfish species, habitat availability and suitability are not considered the major factors limiting the pace of recovery. Still, ensuring quality habitats remain plentiful enough to accommodate population growth in the coming years is crucial to long-term species viability.

Several long-standing regulatory directives and programs designed to conserve sensitive nearshore habitats in the Salish Sea directly benefit rockfishes and their habitats. Examples include, but are not limited to: Shoreline Master Programs, Fish and Wildlife Habitat Conservation Areas, Essential Fish Habitat, Marine Protected Areas, and Rockfish Conservation Areas. More recently, a coalition of partners released the Puget Sound Kelp Conservation and Recovery Plan (Kelp Plan; https://nwstraits.org/our-work/kelp/), which evaluated the state of knowledge for kelp species in the area and made research and policy recommendations to promote long-term protection (Calloway et al. 2020). In March of 2023, a workshop was convened to assess the initial implementation of this plan, including evaluating progress on key research and formalizing an approach to deliver specific policy guidance to regulators. A report summarizing implementation progress was produced (Whitty and Oster 2023), and recommendations to better integrate science into policy were distributed to natural resource management entities in April of 2023 (Jeff Whitty, Northwest Straits Commission, pers. comm.). Ongoing implementation of the Kelp Plan will result in a stronger science-based conservation policy that protects nearshore habitats used by listed rockfish.

Two additional efforts to conserve nearshore habitats within the boundaries of the DPS are of note, despite both being in the early stages of development. First, as part of the United Nations Decade of Ocean Science, in 2022 the Quadra Centre for Coastal Dialogue worked with partners to create the BC-WA Kelp Node. This coalition of Canadian and U.S. researchers, resource stewards, policymakers, and educators serves as a transboundary entity to evaluate science and policy impacting kelp conservation in the Salish Sea. It encompasses six working groups focused on topics spanning basic biology to consideration of ecosystem services. By standardizing survey techniques, ensuring data interoperability, and promoting transparent data sharing, this entity hopes to improve kelp management throughout the DPSs in the coming decade. Second, is a major nearshore vegetation conservation effort, the development of a Statewide Kelp and Eelgrass Health and Conservation Plan, led by the Washington Department of Natural Resources (WA DNR). Under direction from the Washington State Legislature through Senate Bill 5619, this collaboratively developed plan will identify at least 10,000 acres of kelp and eelgrass habitat to conserve and/or recover by 2040. After several public meetings, a draft prioritization plan identifying likely “high priority areas” was released for final public review (Harbison and Showalter 2023), and in 2024 subbasin-specific work will occur to finalize focal locations. As with the efforts of the kelp node, future implementation of this plan is expected to improve long-term protections of nearshore habitats within the DPSs to the direct benefit of listed rockfishes and the ecosystems they rely upon.

2.3.2.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Recreational and commercial fisheries for Puget Sound/Georgia Basin yelloweye rockfish and bocaccio in U.S. waters of the DPSs were progressively curtailed over a 20-year period from the mid-1980s through the mid-2000s (Palsson et al. 2009). In 2010, the remaining commercial fisheries with a likelihood of impacting these species were closed, and retention by recreational anglers was prohibited under state law (WDFW 2010). These fishery management actions, together with extensive outreach to the angling public and the implementation of a requirement to have a descending device ready to use when fishing for bottomfish (WDFW 2017), have largely reduced fishery impacts in U.S. portions of the DPSs, as documented in regular monitoring reports (Kraig and Scalici 2019; 2020; 2021; 2022). In 2011, the WDFW developed a fishery conservation plan covering recreational bottomfish and commercial shrimp beam trawl fisheries (WDFW 2011), and NMFS issued an incidental take permit in 2012. Though this permit expired in 2017, the WDFW continues to apply conservative fishery management practices (e.g., depth limit when targeting bottomfish, retention of all rockfish prohibited), and they have submitted a conservation plan to obtain a new permit. Since 2010, the total fishery impact ceiling has been set at 5,000 lbs but has not approached this ceiling in any year (WDFW 2011).

Direct and incidental take of ESA-listed species, including listed rockfish, is regulated through a series of permitting processes, depending on the nature and scale of the action (https://www.fisheries.noaa.gov/permits-and-forms#protected-resources). For listed rockfishes, aggregate authorized scientific take is maintained at levels below five percent of the best estimate of population abundance in the U.S. portion of the DPSs. The most recent authorization (NMFS 2023) approaches this level (4.3 percent) for bocaccio but is well under this level (0.2 percent) for yelloweye rockfish.

In the Canadian portion of the DPSs, directed harvest of yelloweye rockfish is allowed at low levels, but bocaccio is a minor component of rockfish biomass and only managed in “outside waters” westward of the DPS (DFO 2020; 2021). Harvest/collection is not considered an appreciable threat to yelloweye rockfish in Canadian inside waters, and data indicate the population has been stable for 20 years (COSEWIC 2020; DFO 2021).

2.3.2.3 Disease or Predation

Since the last status review, no new information has become available pertinent to assessing the impacts of disease or predation on listed rockfishes. Broad-scale ecosystem and food web changes noted in *Section 2.3.1.6 Habitat or Ecosystem Conditions* have occurred in recent years, but there is no direct evidence to indicate that such changes are currently limiting the recovery potential of either species.

2.3.2.4 Inadequacy of Existing Regulatory Mechanisms

Regulations to address many of the primary factors (e.g., fishing, nearshore habitat degradation) affecting population size for both yelloweye rockfish and bocaccio have effectively stemmed direct and indirect causes of mortality (Tonnes et al. 2016; NMFS 2017b). Ongoing conservation actions associated with fishery management will become increasingly important as recovery progresses, population size increases, and encounters become more frequent. For yelloweye rockfish, this is already beginning to occur, as evidenced by both population modeling and recent encounters with YOY during the targeted sampling program (Min et al. 2023; Obaza et al. 2023; Adam Obaza, pers. comm.). Efforts are underway to issue a new incidental take permit to the WDFW for recreational groundfish, shrimp trawl, and shrimp pot fisheries occurring within the DPSs to formalize regulatory requirements to implement conservation actions beneficial to listed rockfish.

Broad-scale ecosystem change due to natural and anthropogenic forcing factors represents a substantial threat to the long-term persistence of listed rockfish. Authority exists under a variety of statutes and regulations to address these impacts, as noted in *Sections 2.3.2.1* and *2.3.2.2* above, though financial and personnel resources are often limited to enforce this authority. While these limitations can lead to shifting priorities across species, the Rockfish Recovery Plan implementation schedule clearly lays out actions crucial for rockfish conservation (NMFS 2017b). Regulatory capacity is present but must be applied at the ecosystem, coast-wide, and global scale to be effective.

2.3.2.5 Other Natural or Manmade Factors Affecting Continued Existence

The final rule listing rockfish discussed a number of natural or manmade factors affecting their continued existence, including intraspecific and interspecific competition, derelict fishing gear, habitat degradation, and climate change (75 FR 22276). The final rule designating critical habitat (79 FR 68042), first 5-year status review (Tonnes et al. 2016), and final Rockfish Recovery Plan (NMFS 2017b) considered new data pertinent to these same factors and no additional threats have been identified since the listing. Kelp aquaculture is in the early stages of development in the greater Puget Sound portion of the DPSs, but data are not yet available to indicate how this activity will affect rockfish status or habitat availability. In Canada, pervasive ecosystem alteration and anthropogenic climate change impacts recently prompted COSEWIC to recommend changing the inside waters population from Special Concern to Threatened (COSEWIC 2020). These particular factors have been addressed in *Section 2.3.1.6, Habitat or Ecosystem Conditions*.

2.4 Synthesis

After being revised in 2017 to encompass Johnstone Strait and include all fish residing in, rather than originating from, this new geographic boundary (82 FR 7711), the Puget Sound/Georgia Basin DPS of yelloweye rockfish is biologically valid. Insufficient information exists to determine whether the same can be said for bocaccio. Until new genetic or demographic data are available, the only modification to the bocaccio DPS is that it includes all fish encountered within the geographic boundaries identified in 2010 (82 FR 7711), as opposed to those originating from this region (75 FR 22276). A recovery plan for both DPSs was finalized in 2017, laying out quantitative biological and threats-based recovery criteria (NMFS 2017b). Substantial progress has been made toward filling scientific gaps and reducing several threats to levels that do not substantially impede recovery (Appendix A), but biological recovery criteria have not yet been completely met. In part, this lag is due to the inherent biological characteristics of the species that limit rapid recruitment and population growth, potentially necessitating decades to recover.

Since the last 5-year status review (Tonnes et al. 2016), substantial new biological information pertinent to the status of both listed rockfish DPSs is available from ROV surveys, scuba-based YOY surveys, recreational fisheries bycatch data, and a comprehensive catch reconstruction (see *Section 2.3.1.2, Abundance, Population Trends, Demographic Features, or Demographic Trends*). For the yelloweye rockfish DPS, this allowed a novel evaluation of population status relative to a new baseline, with estimates indicating substantial recent population growth (Min et al. 2023). Under some catch scenarios, population status in the U.S. portion of the DPS, excluding Hood Canal, now meets or exceeds minimum recovery criteria over one evaluation cycle. When combined with recent observations of YOY yelloweye rockfish at several locations within the DPS, positive progress toward recovery is apparent. Still, these biological recovery criteria must meet minimum thresholds over several evaluation cycles before delisting can be considered. For bocaccio, since encounters within the DPS have been exceptionally rare in recent years, a parallel evaluation of population status could not occur, and progress toward meeting biological recovery criteria cannot be assessed.

At present, direct take of yelloweye rockfish and bocaccio for fishery, scientific, and educational purposes is well regulated and low relative to the estimated population size within each DPS, though, for bocaccio, this estimate is based on very limited information. Sufficient, adequate habitat exists in deeper waters of the DPSs and is protected as Critical Habitat (79 FR 68042). In nearshore habitats utilized by YOY and juvenile bocaccio, a suite of regulations and statutes overlap to provide substantial habitat protection, and evaluations of gaps in the application of these authorities have resulted in targeted recommendations to improve conservation (e.g., Whitty and Oster 2023). Despite this, broad-scale, pervasive ecological degradation due to natural and anthropogenic climate change continues to threaten the long-term persistence of rockfish populations. Proactive, concerted enforcement of rules and regulations, and thoughtful ecosystem-based management of regional natural resources will be needed to ensure recovery of listed rockfishes.

Based on the evaluation of progress toward addressing threats and meeting recovery criteria, and the five-factor analysis, the Puget Sound/Georgia Basin DPS of yelloweye rockfish remains at moderate risk of extinction, and the Puget Sound/Georgia Basin DPS of bocaccio remains at high risk. Taking into account current and expected future conservation actions, the respective status assignments of threatened and endangered remain accurate.

3 Results

3.1 Recommended Classification

No change is recommended regarding the classification of the Puget Sound/Georgia Basin yelloweye rockfish DPS as threatened or to the classification of the Puget Sound/Georgia Basin bocaccio DPS as endangered. Though novel evaluation of historical catch data and the findings of a new population model suggest that yelloweye rockfish may be closer to the unfished state than previously recognized, the DPS does not yet meet the objective criteria identified in the recovery plan for delisting (NMFS 2017b). Insufficient data are available to perform a similar analysis for bocaccio at this time.

_____**Downlist to Threatened**
_____**Uplist to Endangered**
_____**Delist** *(Indicate reason for delisting per 50 CFR 424.11):*
  _____*The species is extinct*
  _____*The species does not meet the definition of an endangered or a threatened species*
  _____*The listed entity does not meet the statutory definition of a species*
__*X*__**No change is needed**

3.2 New Recovery Priority Number

Since the last 5-year status review, new guidance was issued regarding the assignment of RPNs, and the values were changed from 7 to 9C for yelloweye rockfish and 3 to 7C for bocaccio (see *Section 1.4.5, Species' Recovery Priority Number at Start of 5-year Review*). No changes are recommended to the current recovery numbers for either the Puget Sound/Georgia Basin Yelloweye Rockfish DPS or the Puget Sound/Georgia Basin Bocaccio DPS.

4 Recommendations for Future Actions

The Rockfish Recovery Plan is the primary guide for identifying future actions to target and address limiting factors and threats for the Puget Sound/Georgia Basin DPSs of yelloweye rockfish and bocaccio (NMFS 2017b). Actions identified in the plan are designed such that their completion, or ongoing commitment to their implementation, will improve the status of listed rockfish to a point where downlisting (bocaccio only) and delisting (both DPSs) can occur. Appendix A evaluates the implementation of all of the actions in the recovery plan to date.

The following actions are priorities for the next five years:

Fisheries

- Continue to reduce impacts from bycatch of listed rockfish by promoting: relocation of angler effort when rockfish are encountered, use of descending devices to improve survival after barotrauma, and targeted enforcement efforts during peak fishery seasons.
- Account for bycatch in all remaining fisheries for which encounters with rockfish are documented but not regularly reported on an annual basis.

- Evaluate efforts to increase angler awareness of fisheries regulations, knowledge of rockfish life history, and species identification ability by conducting systematic surveys of the angling public. Refine outreach strategy appropriately.

Habitat

- Collaborate with partners to protect and restore nearshore vegetated habitat through ongoing implementation of the Puget Sound Kelp Conservation and Recovery Plan and Statewide Kelp and Eelgrass Health and Conservation Plan.
- Research the effects of noise, contaminants, ocean acidification, and climate change on the mortality, productivity, and behavior of listed rockfish at various life stages.
- Protect and restore benthic habitat areas by cleaning up contaminated sediments and implementing reporting, response, and retrieval programs for derelict fishing gear.
- Improve benthic habitat mapping and habitat characterization in areas south of the San Juan Archipelago.

Population Monitoring and Evaluation

- Assess the genetic structure of bocaccio and improve knowledge of habitat use across various life stages, locations of population centers, and individual movement patterns.
- Conduct fishery-independent population abundance and spatial structure surveys.
- Expand the YOY monitoring program in alignment with the collaboratively developed monitoring plan for the southern Salish Sea, and coordinate with Canadian colleagues to bolster efforts in northern portions of the DPSs.

NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Puget Sound/Georgia Basin Distinct Population Segments of Bocaccio and Yelloweye Rockfish

Current Classification:

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X__ No change is needed

Review Conducted By:

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

Approve____________________________ Date: _March 4, 2024_

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

_____Concur _____ Do Not Concur

Signature RAUCH.SAMUEL.DEAN.1365850948 Digitally signed by RAUCH.SAMUEL.DEAN.1365850948 Date: 2024.04.12 15:49:17 -04'00' Date_______

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7 Appendices

Appendix A. Modified implementation schedule from the Recovery Plan for Puget Sound/Georgia Basin yelloweye rockfish and bocaccio (NMFS 2017b) with expenditures estimated therein, and task-specific progress made since inception. Realized expenses are estimates based on NMFS outlays, both directly and through grants to partners, and verified expenses of partner entities, as available. Values likely underestimate total expenditures.

Yelloweye Rockfish and Bocaccio Research and Recovery Actions *(action is for both species unless otherwise indicated in the comments section)*						
Action Number	**Action Description**	**Priority Number**	**(*)Lead Entities and Potential Partners**	**Estimated Expenses (5 years)**	**Realized Expenses (7 years)**	**Progress to Date**
1. Actions to enable a greater understanding of listed rockfish population abundance, distribution, diversity, genetics, demographics, ecology, and habitat associations						
1.1	Fishery-independent population abundance and spatial structure ROV surveys (nearshore and/or deep water).	1	*WDFW, *NMFS, PS Treaty Tribes, Seattle Aquarium, DFO	$1,000,228	$640,100	Several local surveys were conducted in 2018 in the San Juan Islands, Gulf Islands, and Canadian Strait of Georgia.
1.1.1	Regular ROV survey monitoring to observe changes in population abundance, distribution, diversity, genetics, demographics, and habitat associations.	1	*WDFW, *NMFS, PS Treaty Tribes, Seattle Aquarium, DFO	$0	$91,000	These surveys are planned to occur every five years. As the last was in 2015+16, the next was planned for 2021 in Puget Sound Proper but was cancelled partway through due to the COVID-19 pandemic. It is now planned for 2024.
1.2	Benthic habitat mapping and rockfish habitat characterization	1	*WDFW, *NMFS, NWFSC, USGS, TNC, SeaDoc Society, DFO, DNR, Academia	$155,000	$155,000	Video imagery from ROV surveys has been used in conjunction with fish encounters and remotely sensed measurements of depth, rugosity, and other habitat characteristics to refine models of rockfish habitat suitability.
1.2.1	Research output of action 1.2 will be used to develop a probabilistic habitat model and report to assess spatial structure	1	*WDFW, *NMFS, NWFSC, USGS, TNC, SeaDoc Society, DFO, DNR, Academia	$51,667	$44,000	Maximum entropy (MaxEnt) models have been created and refined. Reports documenting the development and use of these models are being drafted.
1.2.2	Supplemental multibeam bathymetry data collection	2	*WDFW, *NMFS, NWFSC, USGS, TNC, SeaDoc Society, DFO, DNR, Academia	$410,128	$3,000	This need has not yet been funded. A prioritized list of key areas was developed to guide future efforts.
1.3	Assessment of historical fishing and scientific records and grey literature	1	*WDFW, *NMFS, *NWFSC, DFO, Academia	$169,686	$150,000	Markus Min (University of Washington graduate student with Mark Scheuerell) and Larry LeClair and Greg Lippert (WDFW) have conducted exhaustive searches. See Min et al. (2023). An additional WDFW report is being drafted.

1.3.1	Development of method to integrate multiple types of historical data to establish an understanding of baseline abundance and size structure	1	*WDFW, *NMFS, *NWFSC, DFO, Academia	$38,750	$32,000	See Min et al. (2023) for results for yelloweye rockfish. Insufficient data were recovered for bocaccio to establish historical baselines.
1.4	Assess genetic structure in DPSs, effective dispersal distances, and population size	1	*NMFS, *NWFSC, *WDFW, DFO, Seattle Aquarium, Academia	$311,644	$300,400	Funding from SeaDoc Society to Lorenz Hauser (UW) and colleagues to support genetic work. Funding from NMFS to the WDFW to collect additional bocaccio tissue samples. See Andrews et al. (2021) for modeled dispersal processes and putative impacts on population structure.
1.4.1	Develop a model to determine genetic thresholds of inbreeding and hybridization within the DPSs	1	*NMFS, *NWFSC, *WDFW, DFO, Academia	$32,292	$0	This action has not yet been funded.
1.5	Annual YOY surveys in each of the management units	1	*WDFW, *NMFS, NWFSC, REEF, SeaDoc Society, Seattle Aquarium, PS Treaty Tribes, NWSI, DNR, Academia	$771,384	$360,000	Adam Obaza and Amanda Bird (Paua Marine Research Group) work with professional and citizen scientists to conduct YOY surveys on a broad spatiotemporal basis. The WDFW, Seattle Aquarium, Harbor WildWatch, Point Defiance Zoo and Aquarium, and other partners also conduct surveys. Comprehensive monitoring plan completed in 2023 (Obaza et al. 2023). Engagement in process to establish Canadian counterpart.
1.6	Larval surveys in each management unit	2	*NMFS, *WDFW, PS Treaty Tribes, DFO, USACOE, Academia	$198,783	$0	This need has not yet been funded.
1.6.1	Research output of action 1.6 will be used to develop a connectivity model	2	*WDFW, *NWFSC, *NMFS, Academia	$240,144	$60,000	A larval dispersion and connectivity model has been developed based on limited larval surveys for yelloweye rockfish (Andrews et al. 2021).
1.7	Assess home range and movement of various life stages of ESA-listed rockfish	2	*WDFW, *NWFSC, *NMFS, Academia	$97,788	$30,000	Limited tagging of yelloweye rockfish has occurred. Bocaccio are currently too rare to effectively study in this way.
1.8	Develop population models to evaluate critical life stages dictating rockfish population growth	2	*WDFW, *NWFSC, *NMFS, Academia	$51,667	$20,000	Jason Cope (NOAA Fisheries) has made progress on this topic but needs larval and juvenile data to continue model development.
1.9	Develop and assess statistical methods for integrating multiple historical and present sources of data on rockfish size structure and abundance into informative indices of current trends in rockfish size and abundance	1	*WDFW, *NWFSC, *NMFS, Academia	$95,314	$70,000	See Min et al. (2023) for results for yelloweye rockfish, including the first objective status determination for the non-Hood Canal, U.S. portion of the DPS. Insufficient data were recovered for bocaccio to project recovery trajectory.

1.10	Conduct and/or further assess comparative studies of rockfish abundance and demographic structure inside and outside of established marine reserves/MPAs in Puget Sound/Georgia Basin to establish knowledge baseline	1	*WDFW, *NWFSC, *NMFS, Seattle Aquarium, REEF, SeaDoc Society, Wild Fish Conservancy, Academia, DFO	$226,256	$160,000	Surveys occurred in 2018 in the Canadian Strait of Georgia to compare abundance and size distribution inside and outside of rockfish conservation areas. Dana Haggarty (DFO), Robert Pacunski (WDFW), and Dayv Lowry (NOAA Fisheries) are drafting report. Similar surveys in U.S. waters of the DPSs have not occurred.
			2. Fisheries management consistent with recovery goals			
2.1	Account for all catch and bycatch with statistically valid techniques	1	*WDFW, *PS Treaty Tribes, *DFO, *NMFS	$787,500	$470,000	The WDFW and DFO have developed standard methods for estimating recreational and commercial catch in many fisheries, but issues with species identification, discard mortality, etc. impede application. Anne Beaudreau (UW) leading project to assess ongoing outreach needs for species identification.
2.1.1	Further assess fisheries by integrating ROV survey data and additional bycatch risk data	1	*WDFW, *PS Treaty Tribes, *DFO, *NMFS	$155,000	$0	This need has not yet been funded.
2.2	Ensure that anthropogenic mortality falls within accepted risk-adverse precautionary guidelines at appropriate scales	1	*NMFS, *WDFW, *PS Treaty Tribes, *DFO	$193,750	$100,000	Descending devices are required to be rigged and ready in recreational bottomfish fisheries throughout the DPSs, and considerable effort has gone into educating the public about bycatch mortality. Descending devices are also required in Canadian portions of the DPSs.
2.3	Establish areas not subject to potential anthropogenic mortality (marine protected areas (MPAs) or rockfish conservation areas (RCAs))	1	*WDFW, *NMFS, *PS Treaty Tribes, *NWIFC, other interested parties	$4,427,780	$0	Though a network of RCAs exists on the Canadian side of the border, and numerous MPAs exist on the U.S. side, additional development of place-based conservation areas has not been funded since 2017.
2.3.1	Monitoring and adaptive management of MPAs/RCAs	1	*WDFW, *NMFS, *PS Treaty Tribes, *NWIFC, other interested parties	$293,128	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
2.4	Implement measures to avoid and mitigate barotrauma; conduct further research on both avoidance and mitigation	1	*NMFS, *WDFW, *PS Treaty Tribes, NWFSC, Academia, SeaDoc Society, recreational and/or commercial fishers, Aquaria	$735,060	$345,000	Extensive outreach efforts have been engaged in by partners, from handing out thousands of descending devices, to producing signs, fliers, and pamphlets about rockfish conservation and the impacts of barotrauma. Additional research on how this outreach has affected fishing practices, is currently being conducted (lead, Anne Beaudreau)
2.5	Assess long-term survival and productivity of recompressed yelloweye rockfish and bocaccio in the wild and take appropriate management actions	1	*NMFS, *WDFW, *PS Treaty Tribes, NWFSC, Academia, SeaDoc Society, recreational and/or commercial fishers, Aquaria	$556,920	$0	This need has not yet been funded. Work done in Oregon and Alaska with yelloweye rockfish is illustrative, but does not account for environmental factors unique to the DPSs that could affect survival.
2.6	Additional enforcement of fishery regulations	1	*WDFW, *PS Treaty Tribes, *NWIFC, *NMFS	$685,060	$0	Additional, targeted funds have not been expended to meet this need.

3. Protection, restoration, and research of rockfish habitats and the Puget Sound/Georgia Basin ecosystem						
3.1	Nearshore (< 30 m) protection/restoration	1	*WDFW, *NMFS, *NWSF, NWS Commission, DNR, MRCs, Academia, Fishers	$0	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.1.1	Continue to prevent, report, and remove derelict fishing gear from nearshore environments.	1	*WDFW, *NMFS, *NWSF, NWS Commission, DNR, MRCs, Academia, Fishers	$86,423	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.1.2	Assess potential of native kelp (and possibly eelgrass) restoration projects through mapping projects and begin kelp restoration R&D plantings.	1	*WDFW, *DNR, *NMFS, PS Restoration Fund, NWS Commission, NWSI, MRCs, *NWSF, Academia, Fishers	$3,715,625	$1,600,000	Partners convened several workshops from 2016-19 and produced the Puget Sound Kelp Conservation and Recovery Plan (Calloway et al. 2020). The Puget Sound Restoration Fund (PSRF) has conducted several restoration outplants and continues to refine efforts to perform commercial scale restoration.
3.1.3	Assess non-indigenous species to determine if they are degrading or impairing rearing habitats.	3	*WDFW, *DNR, *NMFS, Sea Doc Society, MRCs, REEF, Academia	$180,942	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.2	Protect and restore deepwater (> 30 m) benthic habitat	1	*WDFW, *NMFS, *NWSF, MRCs, Local Fishers and Fisher Groups	$0	$0	This need has not yet been funded.
3.2.1	Continue programs to prevent, report, and remove derelict fishing gear from deep-water environments	1	*WDFW, *NMFS, *NWSF, MRCs, Local Fishers and Fisher Groups	$5,653,525	$4,800,000	Partners continue to support reporting, response, and removal efforts with attention turning from nets to pots over the last several years.
3.2.2	Assess sediment disposal practices to determine if they are limiting recovery	2	*NMFS, *USACOE, *EPA, ECY	$127,043	$127,043	NOAA Fisheries completed a series of consultations with the Army Corps of Engineers to demonstrate that sediment disposal has a minor impact on listed rockfishes and is not limiting recovery.
3.2.3	Assess if artificial reefs are needed for listed rockfish recovery	3	*WDFW, *NMFS, NWFSC, Academia, Interested Angling Organizations	$60,177	$0	Funding for this need was not anticipated in the first five years of recovery plan implementation.
3.3	Assess impact of bioaccumulants and other contaminants on listed rockfish survival, health, productivity, and behavior	1	*NMFS, *WDFW, *ECY, *EPA, NWFSC, Academia	$642,820	$0	This need has not yet been funded.

3.3.1	Clean up (or cap) contaminated sediments, reduce contaminant inputs	1	*ECY, *WDFW, *NMFS, *USACOE, *EPA	$0	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.4	Prevent and reduce nutrient input	1	*ECY, *NMFS, *WDFW, Local and State Jurisdictions, Residents	$0	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.5	Develop ecological models to evaluate critical life stages dictating rockfish population growth, and understand the impacts climate change, OA, predation, and competition may have to limit recovery	1	*NWFSC, *NMFS, *WDFW, ECY, DNR, Academia	$0	$0	Funding for this need was not anticipated in the first five years of recovery plan implementation.
3.5.1	Predict, assess, and manage for habitat changes as related to climate change, OA, and synergistic effects in the DPSs	1	*NWFSC, *NMFS, *WDFW, ECY, DNR, Academia	$285,942	$0	This need has not yet been funded.
3.5.2	Determine conditions under which predation could limit recovery	2	*NWFSC, *NMFS, *WDFW, Sea Doc Society, Academia	$333,884	$0	This need has not yet been funded.
3.5.3	Determine the potential for interspecific competition to limit recovery within in the DPSs, using field studies	3	*NWFSC, *NMFS, *WDFW, SeaDoc Society, Academia	$154,942	$0	This need has not yet been funded.
3.6	Assess disease to determine if it is limiting recovery	2	*NWFSC, *NMFS, Academia, SeaDoc Society, Aquaria	$77,500	$0	This need has not yet been funded.
3.7	Assess effects of hatchery salmon releases to determine if they are limiting recovery	2	*WDFW, *NMFS, *NWFSC, PS Treaty Tribes	$555,384	$140,000	Working with Dave Beauchamp (USGS/UW), NMFS developed a predation model to estimate hatchery salmon impacts on larval rockfishes.
3.8	Evaluate effects of anthropogenic noise on ESA-listed rockfish behavior and productivity to determine if it is limiting recovery	3	*WDFW, *NMFS, NWFSC, Academia	$477,885	$0	This need has not yet been funded.
3.9	Continue oil spill prevention and response	2	*ECY, *EPA, *NMFS	$0	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.10	Continue state and federal review of permitted activities to minimize impacts to rockfish habitats and their prey-base	1	*NMFS, *WDFW, *ECY, *DNR, *Army Corps of Engineers, *EPA, *DFO	$0	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.
3.11	Continue to enforce habitat protection laws and regulations; improve as warranted to protect listed rockfish habitat	1	*NMFS, *WDFW, *ECY, *DNR, *Army Corps of Engineers, *EPA, *DFO	$0	$0	This action is continuing under funding sources not attributed to the Rockfish Recovery Plan.

			4. Implement Education and Outreach Plan			
4.1	Improve rockfish identification and documentation of bycatch	1	*WDFW, *NMFS, *PS Treaty Tribes, NWIFC, Seattle Aquarium, NWSI, MRCs, Recreational and Commercial Fishers	$297,235	$297,235	Partners have spent considerable time and effort to develop online, in-hand, and on-site tools to assist anglers and divers with rockfish identification so that information provided during surveys and other interviews is accurate to the greatest degree practicable.
4.2	Encourage avoidance of rockfish and educate anglers why it is preferred over release at depth/increase use of best practices to mitigate barotrauma. Improve rockfish identification and documentation of bycatch	1	*WDFW, *NMFS, *PS Treaty Tribes, NWIFC, NWSI, MRCs, Recreational and Commercial Fishers Seattle Aquarium,	$197,235	$140,000	Webpages and pamphlets are the primary tools used to educate the public about best practices to avoid impacting listed rockfish. Partners have spent considerable time and effort to develop online, in-hand, and on-site tools to assist anglers and divers with rockfish identification so that information provided during surveys and other interviews is accurate to the greatest degree practicable.
4.3	Improve knowledge of rockfish life history and habitat usage, the role rockfish play in the ecosystem, and current efforts to recover rockfish.	1	*WDFW, *NMFS, *PS Treaty Tribes, NWSI, MRCs, Recreational and Commercial Fishers, NWIFC.	$61,120	$61,120	Partners have spent considerable time and effort giving in-person talks, creating videos, and producing promotional materials to educate the public about rockfish recovery. Working with artist and biologist Claudia Makayev, NMFS produced the Rockfish Kids Book for middle school and high school students.
4.4	Improve understanding of rockfish fishing regulations.	1	*WDFW, *PS Treaty Tribes, *NMFS, NWSI, MRCs, Recreational and Commercial Fishers	$61,120	$31,000	Regulations are published online and in print annually, but the COVID pandemic limited in-person education and outreach. Such outreach is now ramping back up and should soon be back to 2019 levels.
4.5	Continue the Cooperative Research Program, create an Innovative Fishing Program and other outreach projects to further cooperative fishing research and fishers' engagement in rockfish recovery	1	*NMFS, *WDFW, *NWFSC, PS Treaty Tribes, SeaDoc Society, Recreational and Commercial Fishers	$196,875	$50,000	Collaborative initiatives are ongoing for various projects, but were somewhat stifled by the COVID pandemic.
			5. Secure financial support for ESA-listed rockfish recovery			
5.1	Seek a variety of types of funds, including Federal, state, and private grants over a long time frame	1	All	$0	$0	This working is ongoing and has been successful for a variety of projects, as demonstrated above.
5.2	Establish cooperative funding agreements among state, Federal, and private entities to avoid redundancy and extend the scope of available funds	1	All	$0	$0	This work is ongoing and continues to be a challenge given the many partners involved at a variety of jurisdictional levels.
	TOTAL Cost (First 7 Years of plan implementation)			$24,850,606	$10,276,898	Outlays have been ~41.3% of estimated costs.

Appendix B. Remotely operated vehicle deployment, data collection, and data analysis protocols

For all surveys between 2008 and 2020, with the exception of the 2018 Strait of Georgia survey, the WDFW-owned ROV "Yelloweye" (a Saab Seaeye Falcon platform) was deployed from the 12-m *R/V Molluscan* (Pacunski et al. 2013; 2020; Lowry et al. 2022; WDFW unpublished data). The 2018 survey of sites in the Strait of Georgia was a collaborative effort among the WDFW, NOAA Fisheries, and Fisheries and Oceans Canada (DFO), the latter of which owns and operates the platform used for the survey, the 39.7-m *CCGS Vector*.

In addition to the standard lighting and electronics package offered by Saab Seaeye, the Yelloweye was equipped with a lighting package consisting of two to three, 180-lumen, constant-intensity LED lights mounted ~40 cm forward of and 10 cm above the camera on a custom-built frame. In order to minimize backscatter in turbid water conditions, and to provide maximum lighting of the benthic habitats being sampled, the lights were aimed downward approximately 45°. Standard definition video recordings were collected with a 0.35-lux high resolution electronic color camera mounted on a tilt motor at the front of the vehicle, with the camera pointed downwards at a 30-35° angle below the horizontal. This tilt angle was occasionally changed when needed for organism identification or when avoiding obstacles. A pair of 5-mW green lasers (520 nm wavelength) were mounted at a separation distance of 10 cm and aimed at the center of the camera's field of view; this 10 cm distance was used as a point of reference for estimating transect width and fish lengths. As of 2012, the Yelloweye was also equipped with a sonar head to aid in navigation, including both avoidance of large obstacles and detection of high-relief habitat. In order to track the Yelloweye's path, a Linkquest ultra short baseline (USBL) acoustic positioning system was employed. The true position of the vehicle was calculated in real time relative to the position of the survey vessel using Hypack 2010 Hydrographic Survey software, and these positional data were recorded for subsequent analysis.

ROV transect protocol

The ROV deployment and transect protocol is described in detail in Pacunski et al. (2013; 2020) and Lowry et al. (2022). At each station, a strip transect approach was employed, with a target transect duration of 15-60 minutes, depending on survey design, regardless of path length. When the current speed was <1 knot, the Yelloweye was driven into the prevailing current at an average speed over ground of 0.25–0.33 m/s. However, when current velocities exceeded 1 knot, transects were conducted by drifting with the current, using the vehicle's thrusters to slow to a speed acceptable for capturing reviewable video. Transects were typically oriented parallel to the nearest shoreline and achieved a relatively consistent depth, except when prevented by current velocity/direction or navigational hazards. Under normal conditions, this protocol yielded a transect length of 500-600 m over 30 minutes; however, considerable variation sometimes occurred due to bottom complexity, visibility, and other exigent factors. Transects were always conducted as close as possible to the pre-determined station location unless unmarked hazards to navigation presented a risk to the crew, vessel, or vehicle. In these cases, stations were either dropped from the survey plan or moved to the next nearest location with similar bathymetry and presumed bottom composition. No transects were conducted at depths <9.1m (30m) to avoid shoreline obstructions and potential entanglements in kelp.

Video review and annotation

Video was recorded onto HI-8 videotapes (2008) or as MPEG2 digital video (2010 and after) using video capture software that varied across the years. Video was overlaid with vehicle depth, attitude (pitch and roll, in degrees), an additional unique station identifier, local time, and vehicle position (latitude/longitude). Following the survey, an annotator reviewed transect videos to identify and count fish and certain commercially important invertebrates, as well as to categorize the substrate. Substrates were characterized using the percent composition method of Stein (1992) and modified habitat subclasses of Greene et al. (1999). Substrate categories consisted of mud (M), sand (S), pebble (P), gravel (G), cobble (C), shell/shell hash (H), bedrock (R), and boulder (B).

Every 30 (± 5) seconds of elapsed video time, the video reviewer recorded the following into a Microsoft Access database: time, vehicle position, depth, laser width (relative to the reviewer's screen), and substrate type (primary and secondary). Throughout video review, all fish greater than 10 cm in total length (due to camera resolution) and certain invertebrate species were identified to the lowest possible taxonomic level; yelloweye rockfish and bocaccio were among the taxa designated as "high priority taxa" for each of the surveys, and observations of these species were entered into the database with time, ROV position, depth, and substrate information. For an individual organism to be included in the count, at least half of its body length had to pass through the video below the horizontal plane of the laser dots. This practice helped to reduce the number of unidentified organisms, increasing precision and accuracy of density and abundance estimates.

Occasionally, issues such as problems with the lighting package or poor video quality (resulting from the vehicle being too far off the bottom or high turbidity) impaired video annotation. These video segments were marked as "off bottom," excluded from analyses, and the transect area calculation was adjusted accordingly. When considerable "off bottom" time occurred during a transect a decision was often made to extend transect duration to produce the desired quantity of usable video for annotation. In some cases, this resulted in transited length of a transect being as much as 25% above target distance.

Estimating area swept per transect

Area swept (A_i) per transect was estimated by multiplying the length (L_i) of each transect by the mean width ($\overline{W}_i$) of the transect, as calculated by averaging the width of the video screen relative to the laser dots across all video segments, as described in Pacunski et al. (2008). Vehicle transect lines were produced from the Hypack tracking data using the procedure described in Pacunski et al. (2016). In short, the length of each transect was calculated by clipping the raw tracking data to match the video transect start and end times and removing any unusable video, editing in Hypack and/or ArcGIS to remove spurious location fixes, and smoothing in ArcGIS using the PAEK algorithm (surveys prior to 2015) or the "rSmooth" package in R (2015 and after) prior to calculating a final transect length. Adjustments were not made to transect paths to account for three-dimensionality of the benthos, making transect lengths in complex habitat potential underestimates. To minimize this effect during video capture, ROV pilots were instructed to methodically cover ground to the degree practicable, moving along ridges and walls rather than up and down them.

Estimating species abundance and Coefficient of Variation

To estimate the abundance of a species within the survey area, the first step was to estimate taxon densities for individual transects (D_i) by dividing the species count (A_i) by the transect area:

$$D_i = \frac{C_i}{L_i W_i} = \frac{C_i}{A_i}$$

The mean stratum density ($\overline{D}_s$) for each species was then the sum of the individual transect densities divided by the number of transects (N_s) occurring within a specified depth or habitat stratum (which varied with survey design):

$$\overline{D}_s = \frac{\sum_{i=1}^{N} D_i}{N_s}$$

The variance of the mean stratum density was calculated as:

$$Var(\overline{D}_s) = \frac{\sum_{i=1}^{N} (D_i - \overline{D}_s)^2}{N_s - 1}$$

Total abundance (P) in numbers of individuals for each survey stratum was the product of stratum surface area (SA_s) and the mean taxon density ($\overline{D}_s$):

$$P = SA_s \overline{D}_s$$

SA_s varied by survey design and was variously based on habitat type predicted from maps and expert knowledge (2008), completely random selection (2010-13), or habitat suitability modeled based on past survey efforts (2015-18). Details are provided in Pacunski et al. (2016; 2020), Lowry et al. (2022), and unpublished data from the WDFW.

Coefficients of variation for each taxon (as percentages) were calculated as the standard deviation of mean stratum density ($\overline{D}_s$) divided by the product of the square root of the station count (N_s) multiplied by the mean stratum density ($\overline{D}_s$):

$$CV = \frac{\sqrt{Var(\overline{D})}}{\sqrt{N} * \overline{D}} * 100$$

Appendix C. Geospatial coverage of remotely operated vehicle surveys from 2008 through 2018

Recent distribution, abundance, and habitat association information produced by ROV surveys conducted by the WDFW in collaboration with NOAA Fisheries, using the methods described in Appendix B, are provided here (Pacunski et al. 2016; 2020; Lowry et al. 2022; WDFW unpublished data). Details of surveys completed since 2008 are provided so that differences in survey objectives can be clearly understood. This is crucial to framing understanding of current yelloweye rockfish status because these data were combined with a novel analysis of catch reconstructions of recreational and commercial harvest from 1920-2020 in the U.S. portion of the DPSs (Appendix D) to develop a new population model for yelloweye (Min et al. 2023). This model was then used to evaluate the likelihood of meeting objective recovery criteria specified in the recovery plan (NMFS 2017b).

The WDFW has conducted ROV surveys in Puget Sound since 2008 to assess rockfish of all species, greenlings, and other marine fishes associated with complex habitat. In some cases, this has meant looking at “simple” habitats, such as mud and sand flats, to validate the assumption that focal species do not occur there in appreciable numbers. Here, we draw upon published accounts of encounters with yelloweye rockfish and bocaccio from ROV surveys conducted in the San Juan Islands in 2008 (Pacunski et al. 2013) and 2010 (Pacunski et al. 2020), U.S. waters of the Southern Salish Sea (Lowry et al. 2022), as well as unpublished analysis of surveys conducted in 2015, 2016, and 2018 within subsections of the DPS on both sides of the international border. While yelloweye rockfish are frequently encountered during ROV surveys, bocaccio are not; therefore, analysis of ROV data focus on estimating yelloweye rockfish abundance only, but not bocaccio encounters when they occurred. For details on ROV deployment, data collection from video recordings, and data analysis protocols that apply across all surveys see Appendix B.

2008 San Juan Islands Survey

In 2008, the WDFW conducted the first of its ROV surveys in the San Juan Islands as a pilot effort to test new methods of assessing fish occurrence and abundance on complex benthic habitats (Pacunski et al. 2013). This survey utilized a stratified random design to survey rocky habitats identified through multibeam echosounder (MBES) surveys and expert review of bathymetric charts. The study area was divided into two strata based on a depth cutoff of 36.6 m (120 ft): “shallow rock” and “deep rock.” The 120-ft depth cutoff corresponds to the maximum allowable fishing depth for bottomfish later put into place by the WDFW in 2010 to protect rockfish from barotrauma. In total, 136 transects were completed in the shallow stratum and 71 transects were completed in the deep stratum (Figure A-1), with 1 and 38 yelloweye rockfish seen in the shallow and deep strata, respectively. Four bocaccio were observed, all on the same transect in the deep stratum.

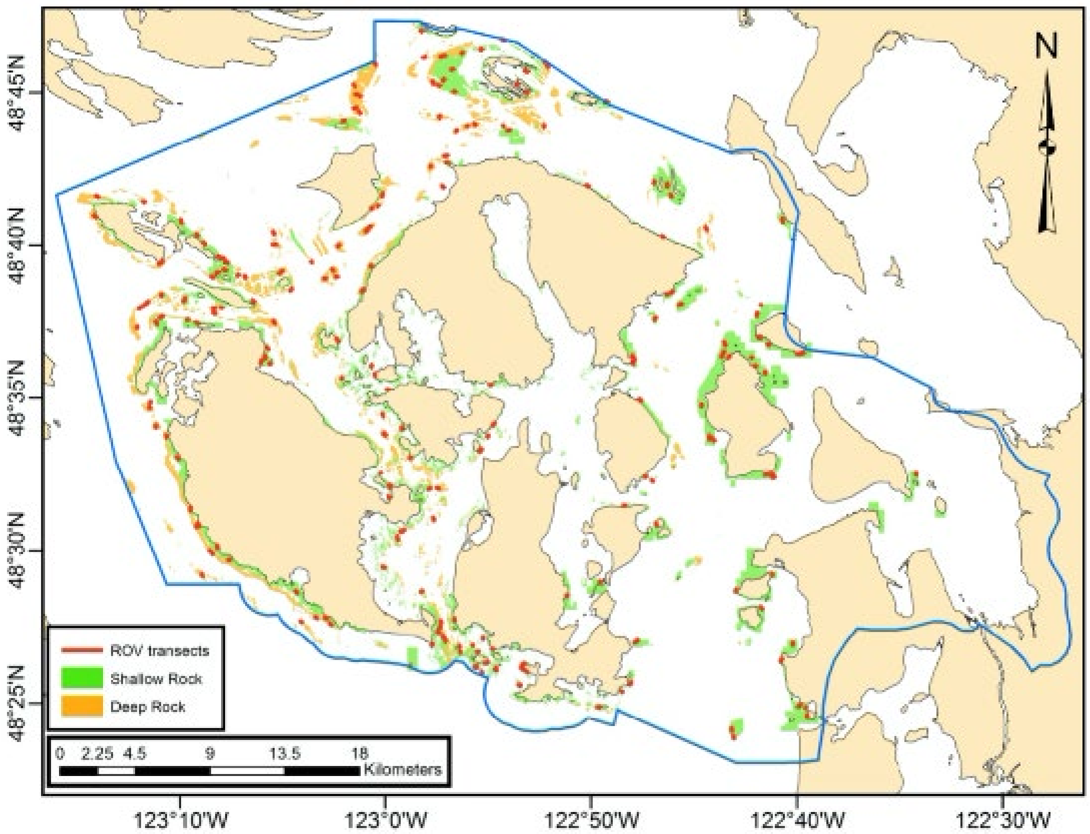

Figure A-1. Rocky habitat polygons of the San Juan Islands interpreted from backscatter data from a multibeam echosounder, expert review of bathymetric charts, and previous nearshore rocky surveys conducted by the Washington Department of Fish and Wildlife. ROV transect paths are shown in red.

2010 San Juan Islands Survey

The 2010 San Juan Islands survey (Pacunski et al. 2020) served as a complementary pilot study to the 2008 San Juan Islands survey, as a different sampling design was utilized to survey the same study area. After random placement of a grid over the region, this survey followed a systematic sampling design to explore all available habitat types, rather than focusing on only rocky habitat (Figure A-2). This approach was taken to determine if a single sampling tool (the ROV) could be used to obtain population estimates for species traditionally sampled by trawling, as well as those occupying untrawlable habitats. It also served as a mechanism to challenge the assumption that species typically associated with complex habitats, such as rockfish, *always* occur in association with complex habitats.

The survey area was partitioned into two strata, Western and Eastern, as the 2008 survey (Pacunski et al. 2013) revealed that most rock-associated species, including yelloweye rockfish and bocaccio, occurred mainly in the western San Juan Islands. Because of this, and to evaluate the effect of sampling density on population estimate accuracy and precision, stations were spaced closer together within the Western stratum (2,100-m intervals) than the Eastern stratum (3,000-m intervals). One hundred-eleven transects were completed in the Western stratum (16 yelloweye rockfish, 0 bocaccio) and 55 transects were completed in the Eastern stratum (0 yelloweye rockfish, 0 bocaccio) (Figure A-2).

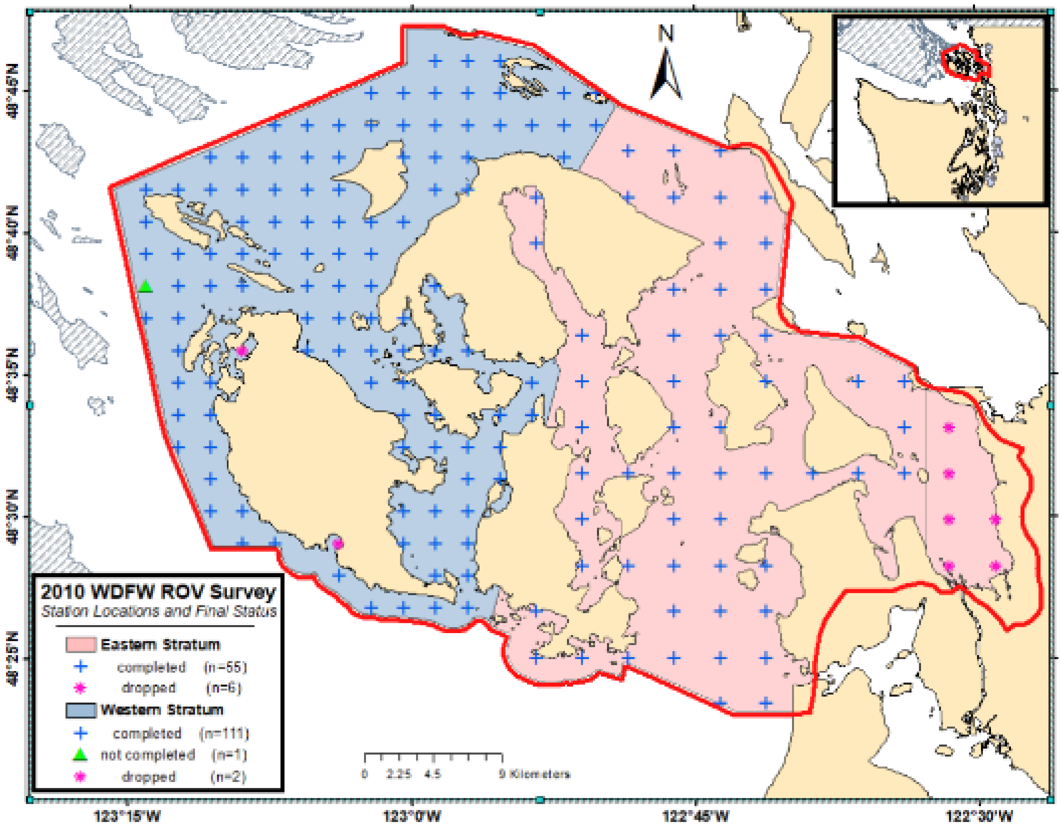

Figure A-2. Locations of ROV transects in the 2010 systematic random survey of the San Juan Islands, WA.

2012-13 Southern Salish Sea Survey

Having demonstrated that a systematic sampling design starting from a random location could effectively sample benthic fishes occurring on all substrate types in a single region, in 2012 the WDFW expanded this survey design to all U.S. waters of the DPSs, and westward into the Strait of Juan de Fuca (Lowry et al. 2022). After considering vessel transit capabilities and past precedents for sampling time, a grid with a knot spacing of 5.1 km was used to place 215 stations throughout all subbasins, without regard for substrate type (Figure A-3). With such a large area to cover and so few stations to glean data from, transect duration was set at 60 minutes, which was twice the duration used in any WDFW ROV survey to date. Sampling effort was also initially parsed into three temporal strata (morning [0001-0800], day [0801-1600], and night [1601-0000]), but this additional stratification was later dropped from the analysis.

Due to inclement weather and conflict with shipping lanes and traffic, 18 of the planned 215 stations could not be completed (Figure A-3). An additional six station were dropped from the analysis because after video conversion it was determined that visibility was inadequate to allow confident identification of many species. At the remaining 191 stations, five yelloweye rockfish were encountered, but no bocaccio were observed. The abundance and biomass estimates generated for nearly all benthic fishes typically associated with complex habitats were underestimated by this sampling design because 90%+ of stations were placed on mud and sand flats, which make up the vast majority of available substrate in the region. For yelloweye rockfish, and a few other species, this estimation error was exacerbated by their rarity (Lowry et al. 2022).

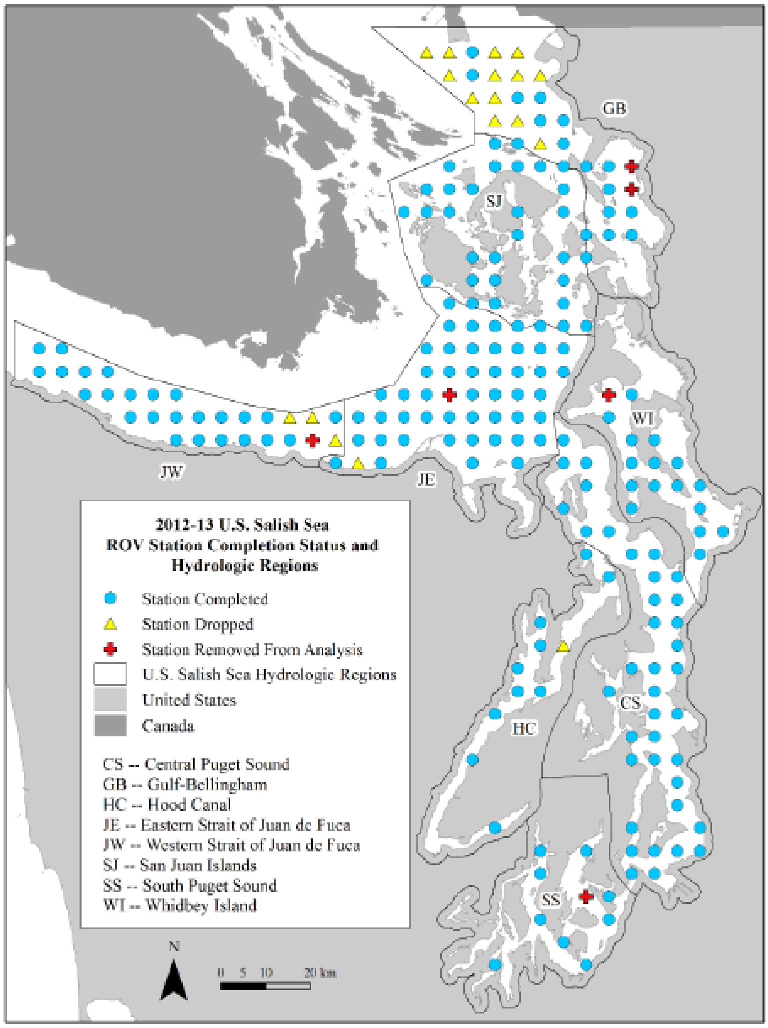

Figure A-3. Locations of ROV transects in the 2012-13 systematic random survey of U.S. waters of the Southern Salish Sea, which includes all U.S. waters of the DPSs.

2015+16 Puget Sound Survey

The WDFW and NOAA Fisheries partnered to conduct a focused two-year survey covering Puget Sound proper in 2015 and again in 2016 (Figure A-4). This effort sought to estimate the abundance and size distribution of yelloweye rockfish and bocaccio in Puget Sound, in support of recovery metrics under development at that time (i.e., LB-SPR). Rather than using a systematic design to assess all habitat and obtain information on the full suite of benthic fishes in the region, this survey used a maximum entropy (MaxEnt) model, a machine learning method that predicts habitat suitability for the species of interest (Phillips et al. 2006). MaxEnt is a presence-only model, with a lack of presence not implying absence. The dependent data used in the model were all confirmed locations of yelloweye rockfish (N=25) and canary rockfish (N=9) (still listed as threatened in 2015) from prior ROV survey efforts within Puget Sound. Only a single location where four bocaccio were encountered was available at the time the model was developed, so bocaccio did not factor into model parameterization. The final model included depth, seafloor roughness, and current speed as the independent variables that predicted habitat suitability for yelloweye and canary rockfish.

The MaxEnt model produced a rasterized probability distribution map of suitable habitat, with each cell assigned a percent probability of being suitable. From this map, the study region was stratified into high (50-100%), medium (26-50%), and low (0-25%) strata. Sampling effort was then distributed as 60% in the high stratum, 20% in the medium stratum, and 20% in the low stratum to account for imprecision in model design and to provide additional evidence for lack of occurrence in areas deemed unsuitable. Random stations were then generated within these strata (Figure A-4).

A total of 805 transects were completed across the two years: 515 in the high stratum, 161 in the medium stratum, and 129 in the low stratum (Figure A-4). No ESA-listed rockfish were observed in the medium or low strata, providing support for the ability of the model to identifying a lack of suitability. Sixty-two yelloweye rockfish and one bocaccio were observed in the high stratum; of the 62 yelloweye rockfish observed, 37 occurred in Hood Canal.

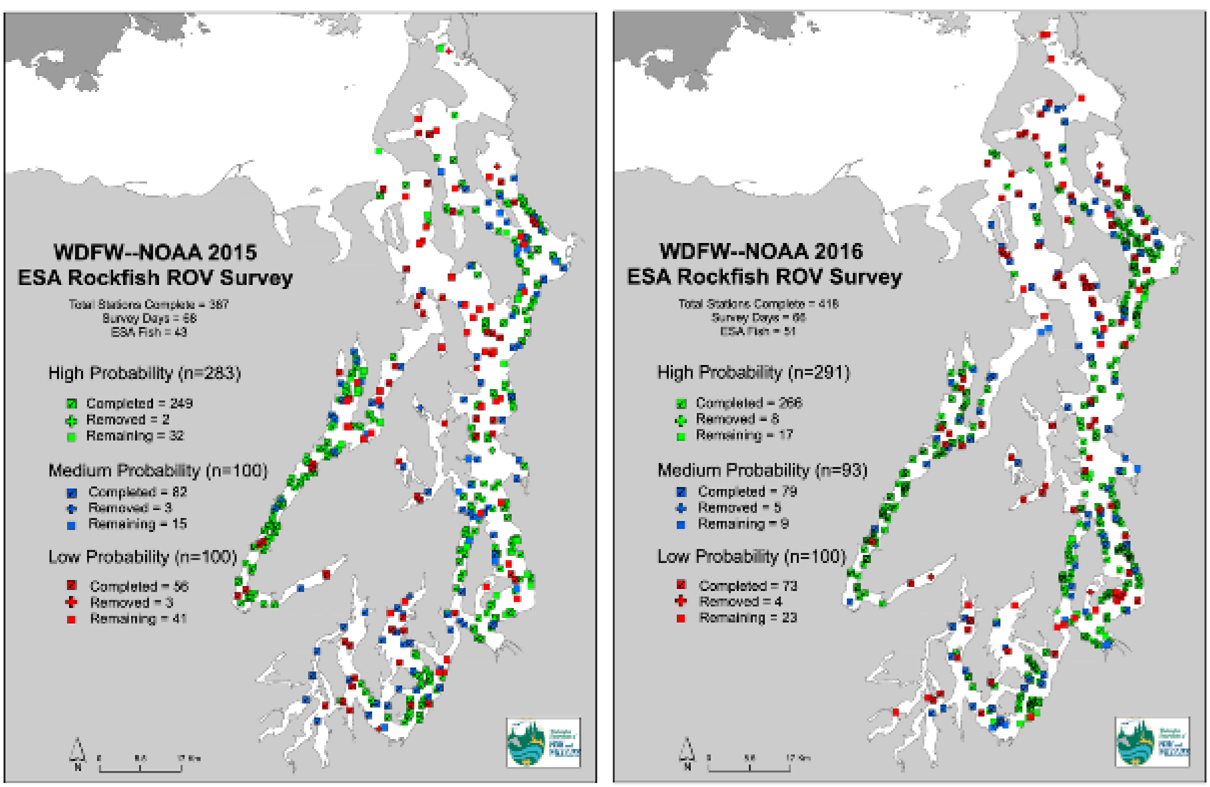

Figure A-4. Locations of ROV transects in the 2015+16 survey of Puget Sound proper. Stations sampled in 2015 are shown in the left panel and stations sampled in 2016 are shown in the right panel.

2018 San Juan Islands Survey

In 2018, the San Juan Islands were surveyed again, this time utilizing a MaxEnt model to predict suitable habitat, similar to the 2015+16 Puget Sound proper survey. Again, the focus was on obtaining abundance estimates and length distribution data for ESA-listed rockfishes to support recovery metrics, though various other species were also counted and measured. Depth, seafloor roughness, and bottom current speed were once again used as the independent variables in the model, but only yelloweye rockfish occurrences were used as the dependent variable due to a nearly complete lack of bocaccio data in the region and the delisting of canary rockfish. For this iteration, the survey area was divided into only two strata, a high stratum (>25% probability) and a low stratum (<25% probability). The thresholds defining the strata differed from those used in 2015+16 such that they resulted in all previously verified observations falling into the high stratum, and because varying the cutoffs did not appreciably change stratum size. To accommodate some randomly selected stations not being surveyable due to extreme currents and limited tide windows, a set of secondary stations were also identified. Fifty-one transects were completed in the high stratum and 9 were completed in the low stratum (Figure A-5); 14 yelloweye rockfish were seen in the high stratum and none in the low stratum.

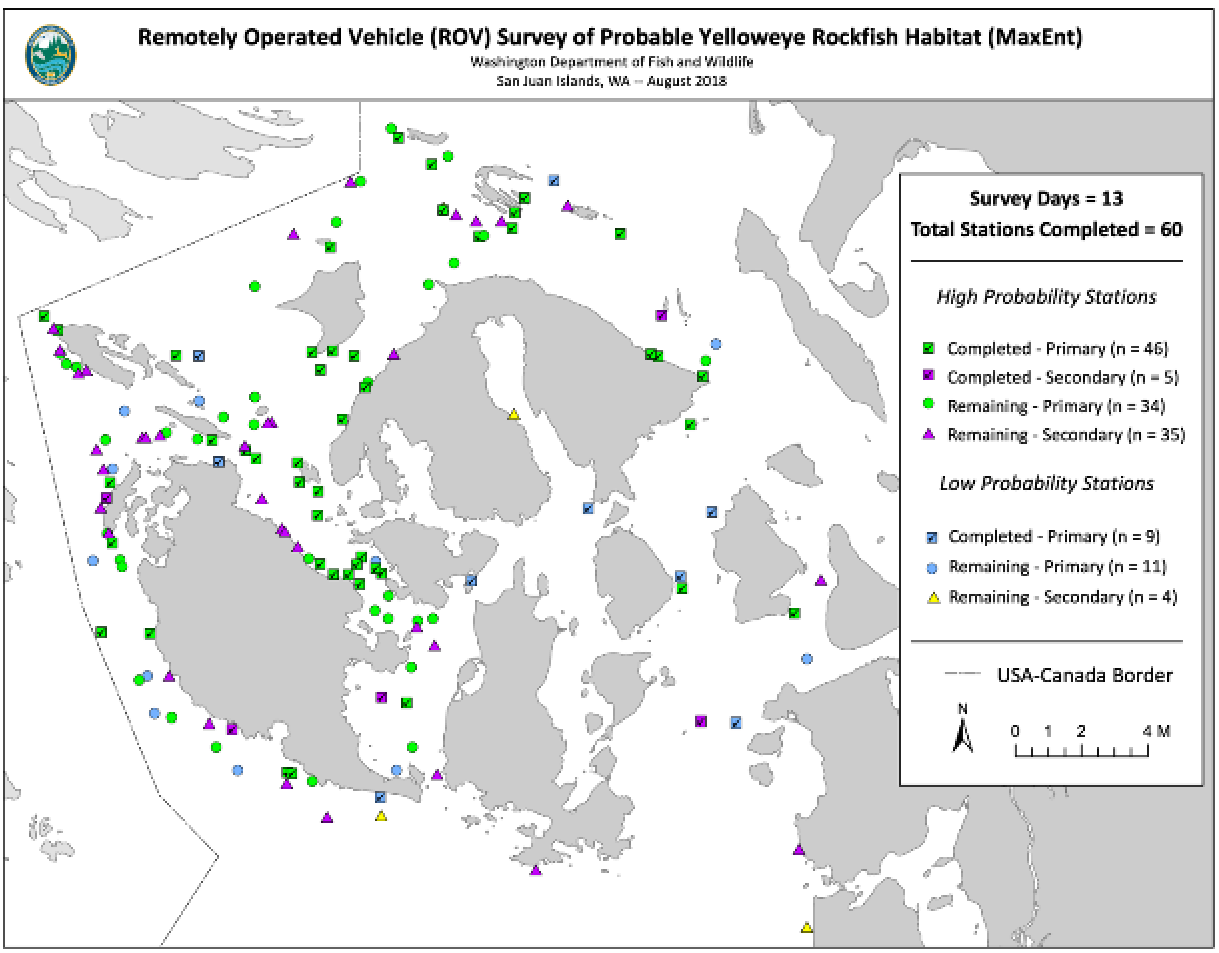

Figure A-5. Locations of ROV transects in the 2018 survey of the San Juan Islands, WA.

2018 Gulf Islands Survey

In 2018, a survey was undertaken in the Gulf Islands in British Columbia by the WDFW and DFO. The goal was to estimate population abundance and length distribution for the inshore rockfish complex, defined by DFO as including yelloweye, quillback, copper, china, black, and tiger rockfish. This survey again used a MaxEnt model to create a map of suitable habitat, using the same independent variables of depth, seafloor roughness, and bottom current and only yelloweye rockfish occurrences from DFO scientific surveys as the dependent variable. The probability map was divided into the same strata as the 2015+16 Puget Sound survey of high (>50%), medium (26-50%), and low (0-25%). Forty transects were completed in the high stratum, 17 in the medium stratum, and 11 in the low stratum (Figure A-6). Forty-nine, four, and zero yelloweye rockfish were observed in the high, medium, and low strata, respectively. As with other recent surveys, no bocaccio were observed.

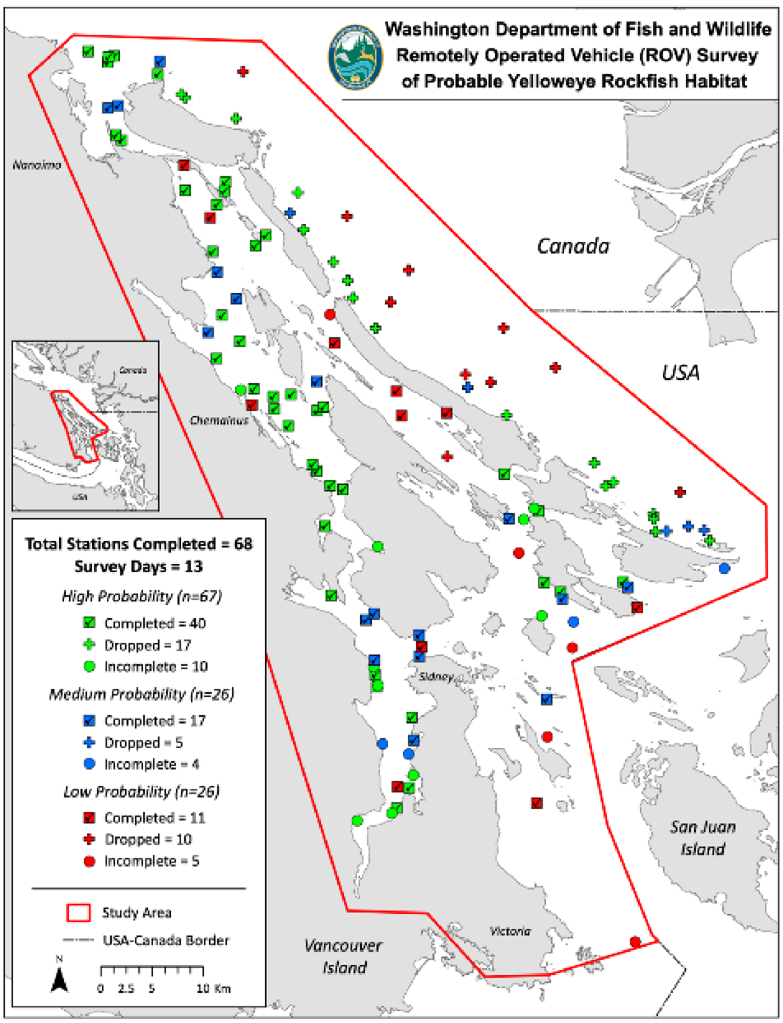

Figure A-6. Locations of ROV transects in the 2018 survey of the Gulf Islands, British Columbia.

2018 Strait of Georgia CCGS Vector *Survey*

This survey, undertaken as a collaboration among the WDFW, DFO, and NOAA Fisheries, sought to estimate density and length composition of inshore rockfish species and lingcod inside and outside of several Rockfish Conservation Areas (Marliave and Challenger 2009; Yamanaka and Logan, 2010), and to inform the LB-SPR metric for yelloweye rockfish in the Canadian portion of the DPS. It used a MaxEnt model, but with slightly different independent variables than the 2018 Gulf Islands survey. For this survey, the independent variables were depth, slope, bottom current, vector ruggedness measure, and bathymetric position index. The latter two variables are derived from remotely sensed bathymetric data and serve as indicators of seafloor bumpiness and relative topography, respectively. Because this survey aimed to survey a suite of species rather than focusing on yelloweye rockfish and bocaccio, occurrences of all inshore rockfishes and lingcod were used as the dependent variable. The survey area was divided into a high stratum (>25%) and a low stratum (<25%) as in the 2018 San Juan Islands survey. Eighty-four transects were surveyed in the high stratum, but only one in the low stratum (Figure A-7). One hundred ninety-eight yelloweye rockfish were observed in the high stratum and none in the low stratum, dramatically exceeding the total number of yelloweye encountered in the U.S. portion of the DPS in all surveys conducted since 2008.

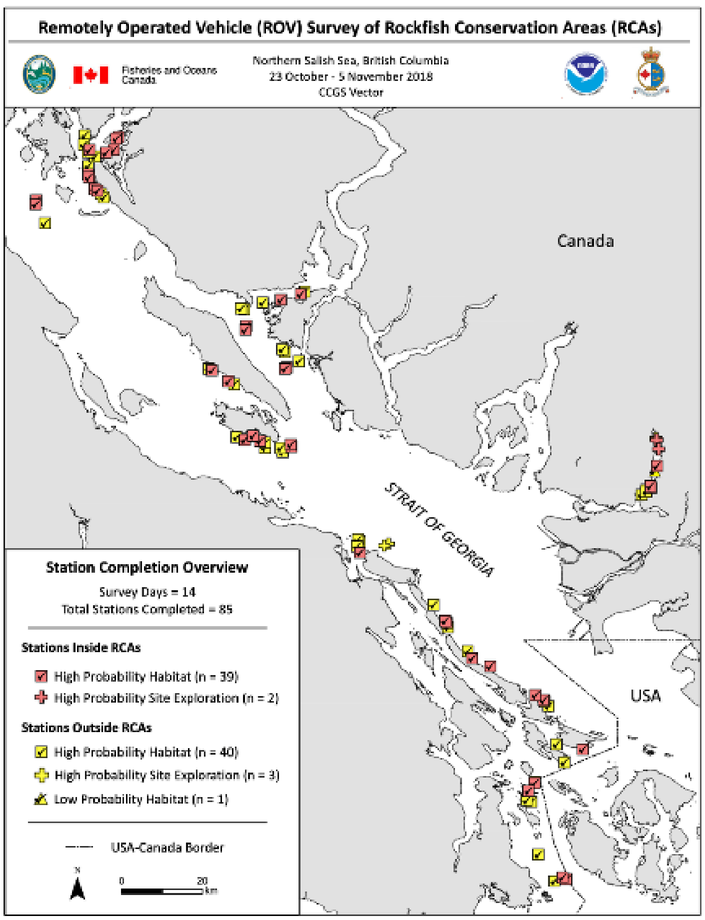

Figure A-7. Locations of ROV transects in the 2018 survey of the Strait of Georgia, British Columbia.

Appendix D. Methodological details of historical catch reconstruction for yelloweye rockfish and bocaccio (excerpted with minor changes from Min et al. [2023])

Commercial Catch Reconstruction

Total rockfish catch in U.S. waters of the DPSs

In 1921, the Washington state legislature established a Department of Fisheries and Game and passed legislation requiring quarterly reporting of catches by licensed fishermen for tax purposes (Nye 1982). While efforts were made to monitor catch prior to 1921, this legislation initiated collection of the first reliable landings statistics. Statistical reporting of fish landings tracked the payment of taxes based on the number of individuals landed, which was later converted to poundage (Nye 1982). While these data have known issues, including unreported catch to avoid taxation, limited spatial resolution, and the possibility of the inclusion of landings from outside Puget Sound (Nye 1982), they represent the best estimates of rockfish landings from Puget Sound until 1935, when the fish ticket system was introduced. All rockfish landings were reported in a single market category, and do include gear information, which is essential for estimating the proportion of these catches that consist of yelloweye rockfish and bocaccio.

In 1935, the Washington Department of Fisheries (WDF) overhauled the state's fisheries statistic system (Nye 1982). Laws required the submission of individual, daily catch records on fish tickets, which allowed collection of uniform, specific data using a standardized format, rather than the blank tickets that were previously issued. These new fish tickets represented a vast improvement from the previous tax-based data collection system. This dataset has critical information on catch area and gear type, which was the basis of parsing catch estimates for Hood Canal from the rest of Puget Sound and prorating total rockfish catch to species. In 1953, the WDF introduced an interview system that produced refined estimates of catch starting in 1955. This system supplemented the information obtained from fish tickets by stationing biologists at ports of landing, where they interviewed captains of fishing vessels to ascertain species caught, area of catch, and type and number of discards (Alverson 1957), adding considerable confidence to statistical estimates.

In 1970, coinciding with increased effort and catch of groundfish in Puget Sound, the WDF began publishing detailed reports on groundfish catches (Schmitt et al. 1991). These reports summarize data from Fish Receiving Tickets (FRTs), which document landings in pounds and document gear, vessel, date, port of landing, and Marine Fish-Shellfish Management and Catch Reporting Area. FRTs were required to be submitted to the WDF by processors purchasing fish or shellfish from vessels. Landings of rockfishes were not reported by species on FRTs, but the WDF applied species composition data from field sampling of commercial data to prorate the total rockfish catch to species.

Since 2004, the WDFW (generated by merging the Department of Fisheries and Department of Wildlife in 1994) has used the Fish Ticket Landing System to record commercial catches. Species are recorded at the time of landing; while yelloweye rockfish are a reporting category, bocaccio are included in the "shelf rockfish" category along with 12 other rockfish species. However, commercial catches for this time period are very low for both yelloweye rockfish and bocaccio (<100 pounds annually) due to a number of significant regulatory changes, including: prohibition of bottom trawling south of Admiralty Inlet in 1989, and in Admiralty Inlet, the eastern Strait of Juan de Fuca, and the San Juan Islands in 1994; and prohibition of bottomfish jig and troll gears in the San Juan Islands in 1984, and east of Sekiu in 1992 (Palsson et al. 2009). In 2010, the remaining State-sponsored commercial groundfish fisheries (e.g., set net, set line, bottomfish pot) were closed in greater Puget Sound to protected listed rockfish (WDFW 2010).

Species composition

The WDFW has used species composition data from field samples of commercial catch to prorate "total rockfish" commercial catch by species from 1970 to the present. Field samples of catch by gear type and region were reported by Pedersen and Bargmann (1986) and were applied to rockfish catches for 1970-1987 (Schmitt et al. 1991). Subsequent to this report, observations of commercial catches were made for 1989, 1990, 1991, and 1993, when the last observations of commercial rockfish compositions were taken (Palsson et al. 2009). By the mid-1990s, landings from the commercial groundfish fishery in Puget Sound were in steep decline and field samples of commercial catch were no longer taken. For this novel reconstruction, catch composition data collected in 1989, 1990, 1991, and 1993 were applied to rockfish catches from 1988-2003.

To estimate catches of yelloweye rockfish and bocaccio from 1921 through 1969 the practice of using species composition information from commercial fisheries by gear type and region presented in Pedersen and Bargmann (1986) was generally followed. An exception being that, starting in 1955, catch statistics report "red snapper" along with "general rockfish." Catches of "red snapper" are assumed to be yelloweye rockfish from 1955-69, as "red snapper" was the common name for *S. ruberrimus* during this time period (Kincaid 1919; Smith 1937). Commercial catches from 1921-33 were based on tax receipts rather than fish ticket as noted above, and therefore lack region-specific information. To apply the region-specific catch compositions from Pedersen and Bargmann (1986), the distribution of catch by region from fish ticket data was applied to divide the 1921-33 catch into regions.

Catch scenarios

1921-33

For most of the history of removals, a primary source of uncertainty is the mismatch between DPS boundaries (Figure A-8) and administrative marine fish management and catch reporting regions (Figure A-9). The main area of concern is region 3 (Strait of Juan de Fuca), only the eastern portion of which falls inside the boundary of the DPSs. Particularly for yelloweye rockfish, this is also an area of high historical catch. However, for this earliest time period, catch is reported only on the district level, i.e. Puget Sound, and further parsing of landings is not possible. Therefore, we applied fixed factors to the Sound-wide catch estimates to determine the various catch scenarios:

1. **High Catch Scenario:** Catches are multiplied by a factor of two.
2. **Medium Catch Scenario:** Catches are not scaled.
3. **Low Catch Scenario:** Catches are multiplied by a factor of 0.5.

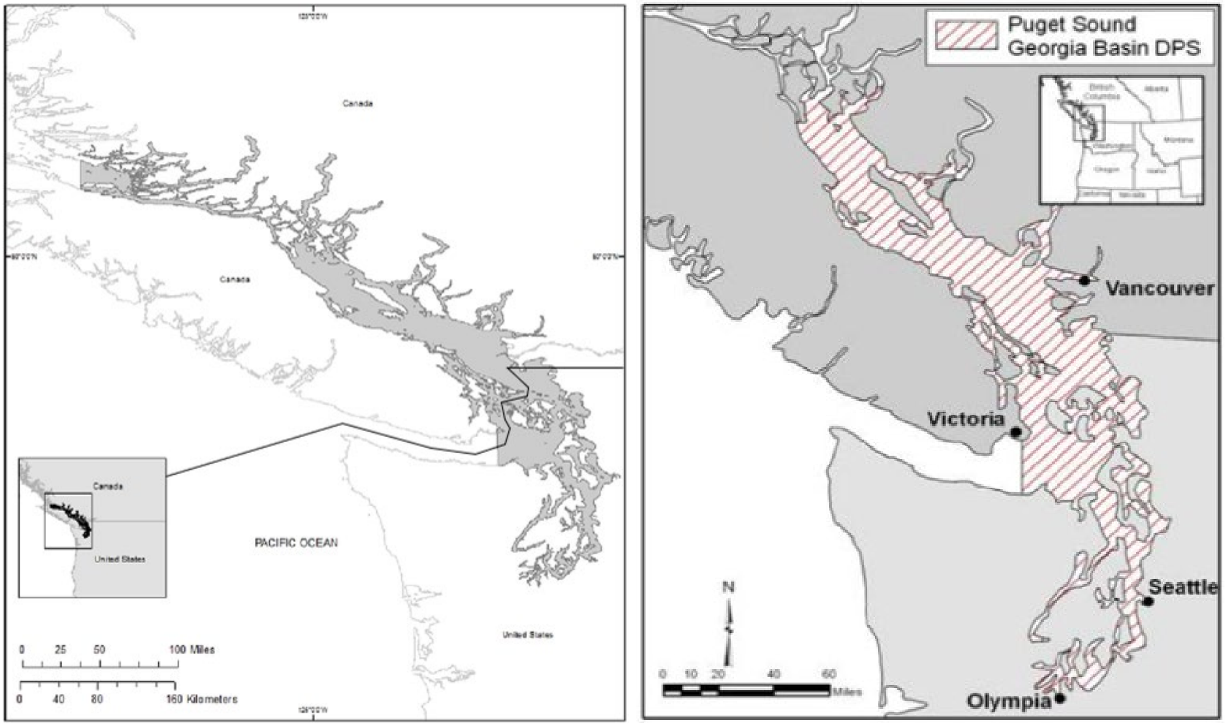

Figure A-8. Puget Sound/Georgia Basin Yelloweye Rockfish DPS boundaries, updated 2017 (left panel), and Bocaccio DPS boundaries (right panel).

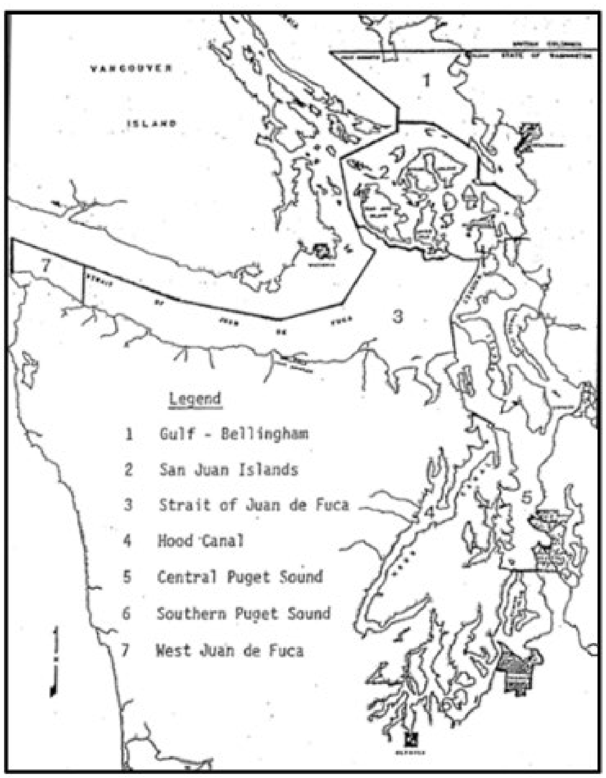

Figure A-9. Historical Washington Department of Fisheries (WDF) marine fish management and catch reporting regions of Puget Sound. Map from Schmitt et al. (1991).

1935-54

Starting in 1935, catch data exist at the level of the marine fish management and catch reporting regions of Puget Sound detailed in Figure A-9. Therefore, catch scenarios for this time period concern the treatment of region 3 (Strait of Juan de Fuca), which is partially inside the DPS. Data from all other regions was taken at face value. Catch scenarios for both species are as follows:

1. **High Catch Scenario:** All catch from the region 3 is included.
2. **Medium Catch Scenario:** Half of the catch from region 3 is included.
3. **Low Catch Scenario:** None of the catch from region 3 is included.

1955-69

For the catch scenarios for this time period, the source of uncertainty that is addressed is again the mismatch between the DPS boundaries (Figure A-8) and the marine fish management and catch reporting regions (Figure A-9). However, because gear types that caught bocaccio were not recorded for this time period in the Strait of Juan de Fuca (Pedersen and Bargmann 1986), there are only catch scenarios for yelloweye rockfish, which was reported as “red snapper”:

1. **High Catch Scenario:** All “red snapper” from region 3 is included.
2. **Medium Catch Scenario:** Half of the “red snapper” from region 3 is included.
3. **Low Catch Scenario:** None of the “red snapper” from region 3 is included.

1970-2003

For the catch scenarios for this time period, the source of uncertainty that is addressed is again the mismatch between the DPS boundaries and the marine fish management and catch reporting regions. Thus, the catch scenarios for this time period are as follows:

1. **High Catch Scenario:** All catch from region 3 is included.
2. **Medium Catch Scenario:** Half of the catch from region 3 is included.
3. **Low Catch Scenario:** None of the catch from region 3 is included.

2004-20

For yelloweye rockfish, there are no catch scenarios for this period because the WDFW explicitly tracked commercial landings. However, for bocaccio the catch scenarios concern the proportion of the “shelf rockfish” category estimated to be made up of this species. While no catch composition data exists for the “shelf rockfish” category from Puget Sound for this time period, anecdotal evidence suggests that bocaccio are very rare; experienced field samplers have not encountered them in over 30 years (Greg Bargmann, pers. comm.). Therefore, the catch scenarios are as follows:

1. **High Catch Scenario:** 5% of the “shelf rockfish” catch is bocaccio.
2. **Medium Catch Scenario:** 0% of the “shelf rockfish” catch is bocaccio.
3. **Low Catch Scenario:** 0% of the “shelf rockfish” catch is bocaccio.

Recreational Catch Reconstruction

Estimation of total rockfish catches

As noted in Palsson et al. (2009), monitoring the recreational bottomfish fishery in Puget Sound has been a significant challenge for the WDFW; however, the recreational fishery was the dominant source of rockfish landings from the 1970s thought the 2010s due to broadscale commercial closures (Palsson et al. 2009). Yelloweye rockfish and bocaccio, being strongly associated with untrawlable habitat (hard/rocky bottom with complex structure), were never a major part of bottom trawl landings, which was the primary commercial gear used to harvest rockfish (Palsson et al. 2009). While Palsson et al. (2009) estimated recreational rockfish harvest back to 1970, here estimates are expanded back to 1938, when the WDF first attempted to gather catch statistics on recreational bottomfish fishing.

From 1938-41, the WDF Annual Bulletin included a report on recreational fishing statistics, which focused on catch estimates for various salmon species but also estimated catches for some broad groupings of bottomfish (e.g., rock cod, lingcod, sole). Fishing statistics were obtained through monthly reports from saltwater boathouses, which rented boats to anglers. Catch report forms were distributed to all boathouses of record by the WDF, with completion and return of these forms being entirely voluntary; this resulted in reporting rates of 50-60% (WDF 1938; 1939; 1940; 1941). In addition to containing the number of fish caught, the reports also included the number of fisherman days, boathouses reporting, and total boathouses of record. Many limitations of the data are noted in the reports, including:

1. Reporting was voluntary, thus catch from many boathouses went unreported.
2. Only catch from the summer months was consistently reported, with reports peaking from May through August.
3. Reports were only submitted by boathouses; private anglers were not accounted for.
4. There are no species composition data. In 1940 and 1941, “rock cod” and “red snapper” were included as reporting categories, but in 1938 and 1939 only “rock cod” was a reporting category.
5. The locations of boathouses are not reported, thus effort/catch cannot be attributed to a specific region or locality.

In order to address these shortcomings, the following modifications were made to the published data:

1. To calculate effort from boathouses that did not report catches, the mean number of fisherman days per boathouse that reported data was calculated for each month. This value was then multiplied by the number of boathouses known to have not reported data and added to the total number of fisherman days from boathouses that reported, thus producing an estimate for total effort across all boathouses.
2. For the months that were not reported in some years but were reported in other years, the number of rock cod and red snapper caught were estimated by taking the mean of that month across all years where that month was reported. For December and January, which were never reported, the mean catch in November across all years was used, as this was

assumed to be most similar to these winter months. This likely results in an overestimate of harvest, providing a conservative buffer against sources of underestimation.

3. To account for private boat ownership, data from the 1949 WDF Annual Bulletin (WDF 1949) were applied. The first year private boats were accounted for in recreational landing statistics was 1949, and this report states that boat counts indicated an average of about 30 private craft for every 100 rented boats during the busiest part of the season, and seven for every 100 in winter months (November through February). To convert this to a ratio of private boats to rented boats, the "busiest part of the season" was assumed to be August, with exponential growth assumed from February to August and exponential decay assumed from August to November. These month-specific ratios were then multiplied by the estimated total effort of all boathouses to arrive at an estimate of total effort across rented boats and private boats. This estimated total effort (fisherman days) was then multiplied by the CPUE (for rock cod and red snapper separately) in terms of fish per fisherman day for the reporting boathouses to arrive at a total estimated catch.
4. Reports of "red snapper" were assumed to be yelloweye rockfish, as detailed above. However, "red snapper" was only reported in 1940 and 1941, and the percentage of boathouses that separated "red snapper" from "rock cod" is unknown for these years (i.e., zero reported and zero caught cannot be distinguished). There are no estimates of the proportion of bocaccio from these landing statistics, thus a fixed value in line with later observed bocaccio catch proportions was used. Catch composition data is further addressed in the *Species composition* and *Catch scenarios* sections.
5. To align harvest estimates with genetic population boundaries for yelloweye rockfish (NMFS 2017a; Andrews et al. 2018), total catch was divided into Hood Canal and non-Hood Canal categories. To achieve this, a map of boathouses from 1957 (Figure A-10) was used to determine the relative number of boathouses by region, which revealed that approximately 16% of all boathouses were in Hood Canal. Thus, 16% of total estimated catch for this period was allocated to Hood Canal. While this map was generated some 16 years after the catch data were collected, it represents the most contemporaneous accounting of boathouse locations available.

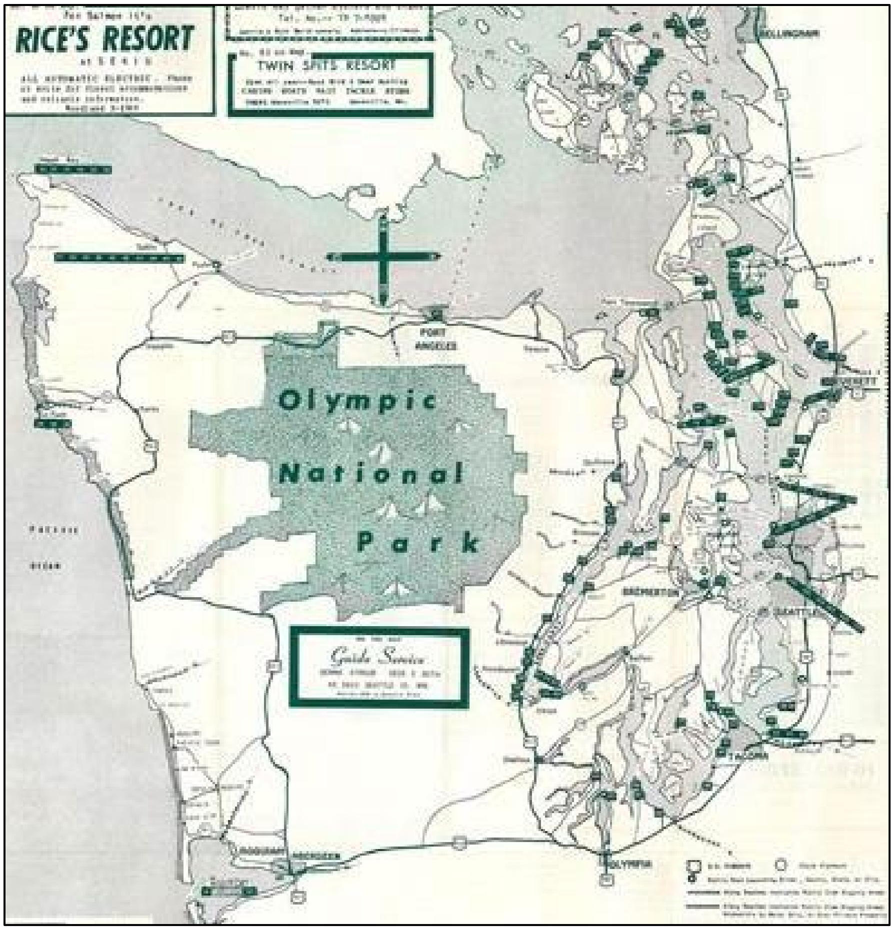

Figure A-10. Map of boathouses in greater Puget Sound (green squares) in 1957. This map was part of the Center for Wooden Boat's "Fish On!" exhibit, documenting the history of the recreational salmon fisheries in Puget Sound.

Recreational fishing statistics were also reported for 1942, but with only about 10% of boathouses reporting (due to creation of a new reporting system), these data were excluded from our analysis. Following this last, unsuccessful report, estimation of catch statistics for bottomfish were abandoned until 1965. To estimate catches for 1942-65, catch statistics were interpolated using a combination of catch records from salmon anglers and a dockside creel survey of hook-and-line anglers, paralleling methods previously used for the period from 1970-2003 (Palsson et al. 2009, and see below). During this time period, Washington marine anglers were primarily salmon oriented:

> At present, the majority of Washington's sport anglers consider most bottomfish as "scrap fish" and the ratio of the number retained in the harvest to the number actually caught appears extremely low in all areas. One primary concept responsible for the discarding of bottomfish, and retarding expansion of the fishery, is the conviction among Washington anglers that catches involving anything less than salmon have little prestige. (Buckley 1967)

However, as evidenced by reports before and after this 1942-65 data gap, bottomfish catches were not negligible. The majority of catch occurred incidentally when anglers were targeting salmon. To estimate catches of rockfish during this time period, we first calculated the mean CPUE (rockfish per angler day) across all sport fishing statistical reports from 1938-41. We then multiplied this CPUE by estimates of total angler days in Puget Sound published in WDF annual bulletins from 1942-65. Estimates of total angler days were published for most years; any missing values were imputed using linear interpolation (Figure A-11). Catches were apportioned to Hood Canal and non-Hood Canal using the same proportions as for 1938-41 (i.e., 16% of catch allocated to Hood Canal).

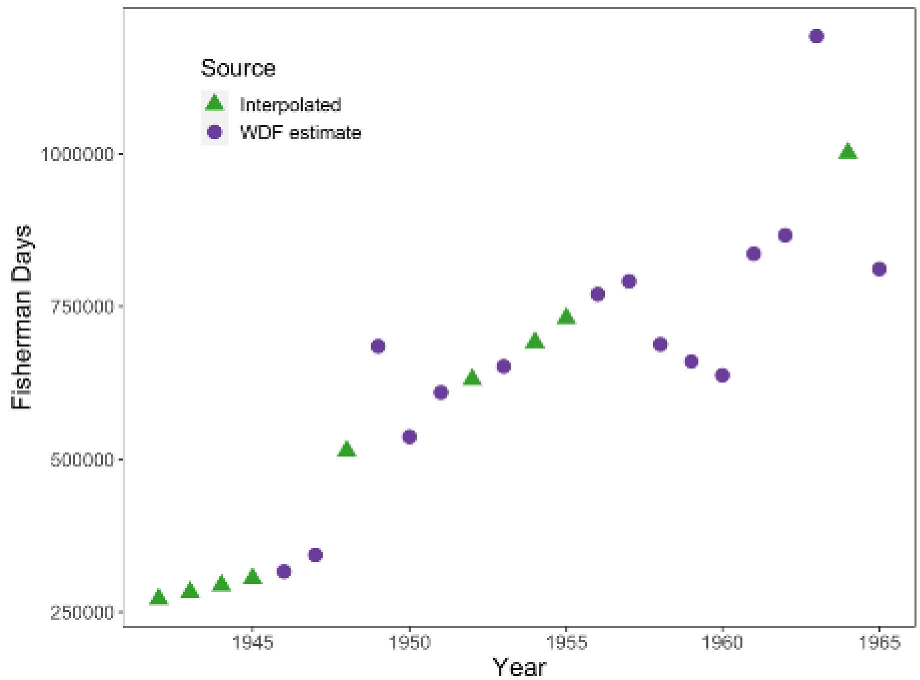

Figure A-11. Fisherman days per year in greater Puget Sound. Estimates for years with missing data (green triangles) were imputed using linear interpolation.

Brought about by interest in monitoring the growing fishery, the WDF first attempted to estimate total recreational bottomfish catch in 1965 (Buckley 1967). This initiated a series of reports on the recreational bottomfish fishery for 1965-73 that all used a similar approach (Buckley 1967; 1968; Buckley and Satterthwaite 1970; Bargmann 1977). In short, WDF technicians already sampling the recreational salmon fishery secondarily recorded data on bottomfish harvest. Total bottomfish catch and effort were estimated by extrapolating sampled bottomfish harvest to the total effort from the recreational salmon fishery.

The 1965-73 reports contain rockfish catch at the species level, but species identifications for these reports are questionable. Technicians attempted to identify bottomfish to species, but if this was not possible (due to insufficient time for positive identification or lack of certainty) fish were recorded at the family level. It is also noted that, in 1965, several samplers were still learning to identify species on sight (Buckley 1967), calling estimates from this year into question. After exploring the data and considering species identification uncertainty the decision was made to remove the 1965 report (Buckley 1967) from further consideration. This was because of anomalously high values for yelloweye rockfish, with the report estimating this species comprised 22.7% of rockfish caught in Hood Canal and 15.4% of rockfish caught in South Puget Sound. These values are over an order of magnitude higher than later observations taken in the same areas by trained samplers through the federal Marine Recreational Fisheries Statistical Survey (MRFSS) (Witzig et al. 1992; Palsson et al. 2009). The most likely explanations for these anomalous values include incorrect species identification and/or the extrapolation of a small sample size (only six technicians covered all of Puget Sound and the Strait of Juan de Fuca) to total effort from the recreational salmon fishery. Rockfish catches for 1965 were, thus, estimated using the methods for the 1942-65 timeframe, while catch from the reports covering 1966-69 were included, as reported, in the analysis. Palsson (1987) recalculated bottomfish sport fishery catches from 1970 onwards with higher confidence species identifications from MRFSS, and these values were preferred over the report by Bargmann (1977) covering 1970-73.

From 1970-94, the WDF estimated catch from the recreational bottomfish fishery through a combination of catch records from salmon anglers and a dockside creel survey of hook-and-line anglers (Palsson et al. 2009). This process continued from 1994-2003 after the WDFW was merged with the Department of Wildlife to form the WDFW, creating a continuous data series from 1970-2003. Punch cards were required to be returned by salmon anglers, from which the number of salmon trips were estimated. The creel survey was used to determine bottomfish catch per trip, which was then multiplied by the number of trips per month and area to estimate total bottomfish harvest (Palsson 1987). However, this reliance on the recreational salmon fishery to estimate bottomfish catch proved problematic following large-scale salmon closures from 1994-2003. Consequently, bottomfish catch and effort estimates were severely underestimated during this time period (Palsson et al. 2009); this limitation is addressed in the *Catch scenarios* section.

Since 2003, the WDFW has conducted surveys of the recreational fishery through a telephone survey of licensed anglers to estimate fishing effort and dockside creel surveys that estimate species-specific catch rates (e.g., Kraig and Scalici 2019; 2020; 2021; 2022). This new system removed the reliance on salmon fisheries for bottomfish catch estimates. Importantly, this reporting system also allows for the collection of information on released rockfish, which was previously not estimated.

Species compositions

Estimating the species composition of recreational bottomfish catches in Washington is a persistent problem, particularly for rockfishes, which many anglers are unable to identify to species (Sawchuk 2012; Sawchuk et al. 2015). Estimating catch of ESA-listed yelloweye rockfish and bocaccio over time, however, requires knowledge of the proportional representation of these species across years. Species composition data at a resolution finer than "North Puget Sound" and "South Puget Sound," as was reported in Palsson et al. (2009), is crucial for assessing DPS status for two reasons. First, in the Rockfish Recovery Plan (NMFS 2017b), it was determined that the Hood Canal yelloweye rockfish population can be genetically differentiated from the rest of the Puget Sound/Georgia Basin DPS (Andrews et al. 2018), and separate recovery goals were set for these management units (main document Table 2; NMFS 2017b). Second, yelloweye rockfish and bocaccio are not evenly distributed throughout the

DPSs, meaning that region-specific estimates of proportional representation in recreational catch are required to avoid spatial bias in harvest estimation. For this second reason, separate species compositions for Punch Card Areas 6-13 (Figure A-12) were calculated; areas 1-5 are outside the DPS boundary (Figure A-8) and thus were not relevant for this analysis. Note that Punch Card Areas were re-named Marine Fish-Shellfish Management and Catch Reporting Areas by the WDF in 1980 and that boundaries have changed, both subtly and substantially, over the years. For a complete review see Evans (1998).

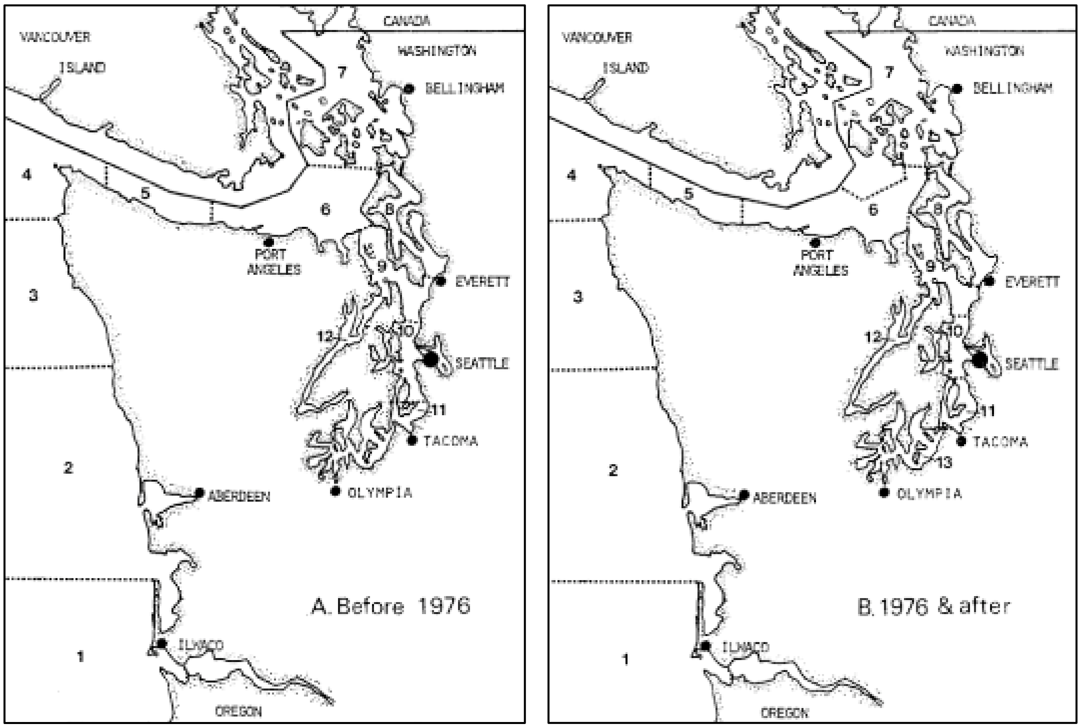

Figure A-12. Washington Department of Fisheries (and later Fish and Wildlife) Punch Card Areas. A.) Boundaries before 1976; B.) Boundaries 1976 and after.

Prior to 2003, when WDFW samplers were first trained to identify rockfish, the most accurate species identification came through the federal MRFSS program, which sampled recreational catch in greater Puget Sound in 1980-86, 1989, and 1996-2003 (Witzig et al. 1992; Palsson et al. 2009). MRFSS employed personnel trained in rockfish identification to both interview bottomfish anglers and identify catch. These observations were the primary source of species composition data used to estimate the number of yelloweye rockfish and bocaccio in the "total rockfish" category. Secondary sources of species composition data were the WDF recreational bottomfish fishery reports covering 1965-67 (Buckley 1967; 1968; Buckley and Satterthwaite 1970). Proportions of yelloweye rockfish and bocaccio in the reports from 1965-67 and the MRFSS species composition data from 1980-2003 are summarized in Tables A-1 and A-2. Because sample sizes were relatively small, MRFSS observations were summarized across all years of the survey. These appear to show a decrease, or steady state, in both yelloweye rockfish and bocaccio as a proportion of total rockfish catch between the 1965-67 and 1980-2003 time periods, but there is considerably less confidence in species composition data from the earlier period. Additionally, for yelloweye rockfish, reports of "red snapper" in the recreational catch from 1938-41 were interpreted as being yelloweye rockfish and used to inform the proportion of total rockfish catch, as sources from around this time period indicate that “red snapper” referred to *S. ruberrimus* (Kincaid 1919; Smith 1937). Dividing the number of “red snapper” by the total number of rockfish (“rock cod” + “red snapper”) yielded an estimated percentage of 0.83% of rockfish reported as yelloweye rockfish across all boathouses. However, this is almost certainly an underestimate, as it is highly likely that some boathouses were not separating “red snapper” from “rock cod.” This uncertainty is addressed in *Catch scenarios*.

Table A-1. Yelloweye rockfish proportions from reports by Buckley (1967; 1968) and Buckley and Satterthwaite (1970), for the years 1965-67, and MRFSS (1980-2003). For the MRFSS data, the number of yelloweye rockfish and the total rockfish sample size are shown in parentheses; these data are not available for the reports covering the years 1965-67. The punch card areas (PCA) are those shown in Figure A-12; note that area 13 (South Puget Sound) was part of area 11 prior to 1976 and, therefore, is absent from the species composition data for 1965-67.

PCA	Buckley/Buckley and Satterthwaite (1965-67)	MRFSS (1980-2003)
6	2.6%	1.8% (13/737)
7	2.3%	1.5% (61/3951)
8	0%	0.5% (4/838)
9	0.6%	0.7% (8/1076)
10	1.6%	0.5% (9/1747)
11	7.3%	0.5% (11/2432)
12	4.2%	1.3% (8/624)
13	NA	0% (0/2437)

Table A-2. Bocaccio proportions from reports by Buckley (1967; 1968) and Buckley and Satterthwaite (1970), for the years 1965-67, and MRFSS (1980-2003). For the MRFSS data, the number of bocaccio and the total rockfish sample size are shown in parentheses; these data are not available for the reports covering the years 1965-67. The punch card areas (PCA) are those shown in Figure A-12; note that area 13 (South Puget Sound) was part of area 11 prior to 1976 and therefore is absent from the species composition data for 1965-67.

PCA	Buckley/Buckley and Satterthwaite (1965-67)	MRFSS (1980-2003)
6	0%	0.4% (3/737)
7	0%	0% (0/3951)
8	0%	0.2% (2/838)
9	0.8%	0% (0/1076)
10	0%	0.2% (3/1747)
11	2.6%	0.2% (6/2432)
12	0%	0% (0/624)
13	NA	0.3% (8/2437)

Catch scenarios

For each time period, which for the purposes of this report are defined by the data sources and methods used to estimate the catch of ESA-listed species, catch scenarios were developed to capture the range of plausible removals. Different scenarios were applied during each time period, based on sources of uncertainty specific to the data sources or the methodology used to estimate catch. However, for data sources where catch was reported in a summarized format, the options for developing catch scenarios were more limited. Scenarios are reported in reverse chronological order, and/or in broad strata then more narrow windows within these strata, because more recent or programmatic data were sometimes used to inform historical patterns during periods with limited information, as described above.

2003-19

The WDFW combined creel and telephone survey, which is the primary source of catch data for this time period, includes estimates of both rockfish catch and releases, as well as variance in these estimates (e.g., Kraig and Scalici 2019; 2020; 2021; 2022). The catch scenarios for this period are derived from these variance estimates, as well as from applying different mortality rates to released fish. Because yelloweye rockfish retention became prohibited in 2002, the majority of uncertainty for this time period concerns the treatment of released fish. A study of yelloweye rockfish caught at a depth of 18-72 m found that 99% of individuals released at depth survived, whereas only about 22% released at the surface were able to re-submerge and, presumably, survive (Hochhalter and Reed 2011). Therefore, the depth of release is the most important factor in survival of released yelloweye rockfish.

Interviews of anglers conducted in 2011 revealed that only 3% of boat-based anglers reported using a descending device (Sawchuk 2012; Sawchuck et al. 2015). In response to this, Puget Sound Anglers and the WDFW began outreach in 2012 to local anglers to enhance their ability to identify rockfish and use rapid-submergence techniques to reduce the effects of barotrauma. Additionally, in recent years, thousands of descending devices have been distributed to local anglers by the WDFW, Puget Sound Anglers, the Pacific States Marine Fisheries Commission (PSMFC), and NOAA Fisheries to aid in these efforts. Rockfish identification materials have also been distributed via the internet, as pamphlets, as laminated identification sheets, and even as large metal signs posted at high-use boat ramps. The effects of these efforts on the proportion of anglers correctly identifying rockfish and using descending devices is unknown, but it is likely that many anglers still do not use descending devices when releasing rockfishes. As of July 1, 2017, recreational bottomfish and halibut anglers in Washington have been required to have a descending device onboard, rigged, and ready to use for returning fish to depth in an effort to reduce release mortality (WDFW 2017). As descending device use statistics are unavailable, the catch scenarios for this time period concern the likelihood of descending device use and variance in estimates of catch and releases:

1. **High Catch Scenario:** One standard deviation is added to the creel survey estimates of both catch and releases of yelloweye rockfish and bocaccio. Use of descending devices is assumed to be constant at 3% over the entire time period, meaning 97% of rockfishes are released at the surface, and only 22% of these survive.
2. **Medium Catch Scenario:** The creel survey estimates of both catch and releases of yelloweye rockfish and bocaccio are used. Descending device usage is assumed to have increased over time, leading to a mean usage of 10% over the entire time period. The remaining 90% of rockfishes are released at the surface, and only 22% of these survive.

3. **Low Catch Scenario:** One standard deviation is subtracted from the creel survey estimates of both catch and releases of yelloweye rockfish and bocaccio. Descending device usage is assumed to have increased substantially over time, leading to a mean usage of 25% over the entire time period. The remaining 75% of rockfishes are released at the surface, and only 22% of these survive.

1970-2002

Estimates of recreational bottomfish catch published by the WDF/WDFW are the basis for this time period. Palsson (1987) estimated bottomfish catches from 1970-85, and prorated most of the total rockfish catch to species using species composition data from MRFSS; some catch was still classified as "unidentified." However, for data from 1986-2002, which used the same catch estimation methods as for 1970-85, catch had not been previously prorated to species. Therefore, we applied region-specific species composition data from MRFSS from 1980-2003 (Tables A-1 and A-2) for this time period (as well as to the "unidentified" rockfish from 1970-85) to estimate catch of yelloweye rockfish and bocaccio.

For catch scenarios during this time period, the source of uncertainty addressed is the mismatch between punch card area boundaries (Figure A-12) and DPS boundaries (Figure A-8). The main area of concern was PCA 6 (East Strait of Juan de Fuca), which is only partially inside the DPSs. Particularly for yelloweye rockfish, this is also an area of high historical catch. Catch scenarios for this time period are as follows:

4. **High Catch Scenario:** All catch from the East Strait of Juan de Fuca (PCA 6) is included.
5. **Medium Catch Scenario:** Half of the catch from the East Strait of Juan de Fuca (PCA 6) is included.
6. **Low Catch Scenario:** None of the catch from the East Strait of Juan de Fuca (PCA 6) is included.

1994-2002

The period from 1994-2002 must include an additional catch estimate modification from that applied to the period from 1970-93, because of severe closures in the recreational salmon fishery that began in 1994. Because fishing effort was based on the recreational salmon fishery, this resulted in incomplete bottomfish catch estimates until 2003, when the creel survey began. While the estimates of bottomfish catch can be treated as minimum estimates for this time period, we instead multiplied them by an arbitrary factor in an attempt to better reflect true removals. To accomplish this, the catch scenarios from the previous time period (1970-2002) are adjusted only for the period after 1993 as follows:

1. **High Catch Scenario:** All catch from the East Strait of Juan de Fuca (PCA 6) is included. Catch of yelloweye rockfish and bocaccio are multiplied by a factor of 3.
2. **Medium Catch Scenario:** Half of the catch from the East Strait of Juan de Fuca (PCA 6) is included. Catch of yelloweye rockfish and bocaccio are multiplied by a factor of 2.

3. **Low Catch Scenario:** None of the catch from the East Strait of Juan de Fuca (PCA 6) is included. Catch of yelloweye rockfish and bocaccio are not adjusted.

1966-1969

For the catch scenarios for this time period, the source of uncertainty addressed is the same as the one for the data from 1970-2002: the mismatch between the PCA and DPS boundaries. Thus, the catch scenarios for this time period are as follows:

4. **High Catch Scenario:** All catch from the East Strait of Juan de Fuca (PCA 6) is included.
5. **Medium Catch Scenario:** Half of the catch from the East Strait of Juan de Fuca (PCA 6) is included.
6. **Low Catch Scenario:** None of the catch from the East Strait of Juan de Fuca (PCA 6) is included.

1942-1965

The primary source of uncertainty addressed by the catch scenarios for this time period is species composition data. The closest estimate in time, from Buckley (1967; 1968) and Buckley and Satterthwaite (1970) that cover the years 1965-67, have some anomalously high values for yelloweye rockfish, which may have been due to issues with the sampling design, but may also represent changes in species composition over time. The other species composition data, from MRFSS, is more reliable but also covers a time period that is much later (1980-2003). Therefore, we use these two sources of catch composition data (Tables A-1 and A-2) to examine the sensitivity of catch estimates when different species compositions are applied. The MRFSS catch compositions generally have lower proportions of ESA-listed species, particularly yelloweye rockfish (but note that bocaccio encounter rates are uniformly near zero), than the data from 1965-67; therefore, the MRFSS data is treated as the lower catch scenario and the 1965-67 data as the higher catch scenario resulting in the following:

1. **High Catch Scenario:** Catch composition data for the years 1965-67 from Buckley (1967; 1968) and Buckley and Satterthwaite (1970) applied.
2. **Medium Catch Scenario:** Catch composition data for the years 1965-67 from Buckley (1967; 1968) and Buckley and Satterthwaite (1970), and for the years 1980-2003 from MRFSS, averaged and applied.
3. **Low Catch Scenario:** Catch composition data for the years 1980-2003 from MRFSS applied.

1938-1941

For this time period, the largest source of uncertainty is once again species composition data. In particular, while yelloweye rockfish are reported (as “red snapper”) in 1940 and 1941, because of the lack of standardization in reporting, it is likely that not all boathouses were reporting “red snapper” and some were including them in the “rock cod” category. Additionally, because “red snapper” was not a reporting category in 1938 and 1939, these years again must be treated differently from 1940 and 1941, where “red snapper” was partially reported. Therefore, for yelloweye rockfish, the following catch scenarios were applied:

1. **High catch scenario:** In years where "red snapper" is listed, all of the other rockfish catch is prorated to red snapper, based on the mean proportion of total rockfishes that are "red snapper" from 1940-41, and is added to the "red snapper" catch. In years where no red snapper is reported (1938 and 1939), catch was prorated based on mean proportion of total rockfishes that are "red snapper" from 1940-41 * 2.
2. **Medium catch scenario:** In years where "red snapper" is listed, half of the rockfish catch is prorated to red snapper, based on the mean proportion of total rockfishes that are "red snapper" from 940-1941, and is added to the "red snapper" catch. In years where no red snapper is reported (1938 and 1939), catch was prorated based on mean proportion of total rockfishes that are "red snapper" from the years 1940-41.
3. **Low catch scenario:** In years where "red snapper" is listed, it is the only yelloweye rockfish catch. In years where no red snapper is reported (1938 and 1939), catch was prorated based on mean proportion of total rockfishes that are "red snapper" from 1940-41 * 0.5.

For bocaccio, there was no reported catch for this time period. Therefore, the proportion of catch that is bocaccio is the main source of uncertainty addressed in the catch scenarios. Proportions are chosen that are in line with proportions from MRFSS (Table 2):

1. **High catch scenario:** 0.5% of the “rock cod” catch is bocaccio.
2. **Medium catch scenario:** 0.25% of the “rock cod” catch is bocaccio.
3. **Low catch scenario:** 0% of the “rock cod” catch is bocaccio.

Limitations and Remaining Sources of Uncertainty

This catch reconstruction effort sought to capture a range of plausible catch histories through the use of different scenarios. When possible, time-varying approaches were used to condition these scenarios, based on uncertainties specific to different time periods. However, there are still remaining sources of uncertainty that were not addressed quantitatively.

One remaining source of uncertainty is in species composition data applied to rockfish catches, both commercial and recreational. Species composition data have been collected sporadically by the WDF/WDFW and MRFSS program, and temporal coverage is severely lacking. This led to the application of commercial catch composition data from the 1980s to the preceding decades, as no other viable data exist. In the recreational fishery, confidence in species composition data prior to 1980 was low. As only a single source of species composition data with no associated uncertainty values was often present, there were no alternatives to quantitatively inform catch scenarios. Therefore, species composition data introduced a large amount of uncertainty but, in the absence of alternative information, this uncertainty could not be adequately accounted for.

The second major source of uncertainty is the discard rate, particularly in the recreational fishery. The discard rate in the commercial fishery is poorly known, but is thought to be small compared to the amount of landed fish because of the relatively high value of all rockfish species (Palsson et al. 2009). From 1979-84, during the height of the trawl fishery, the WDF placed observers on trawlers in Puget Sound and found only trace amounts of rockfish were discarded (Bargmann et al. 1985). Because rockfish are commercially valuable, there would have been little reason for fishers to discard them prior to the implementation of the 500-pound daily limit in 1998, and much of the DPSs had already been closed to trawling by 1994. Subsequent to 1998, few trawl landings were found to reach the maximum daily limit of 500 pounds of rockfish.

Discard rates in the recreational fishery are thought to be quite substantial (Buckley 1967), and to vary significantly over time, but no quantitative estimates are available prior to 2003. This is a significant source of uncertainty in the removal history from the recreational fishery, as yelloweye rockfish and bocaccio released at the surface have very low rates of survival (Hochhalter and Reed 2011). Additionally, significant regulatory changes occurred around the time the creel survey began (i.e., a ban on retention of yelloweye rockfish and a complete closure of Hood Canal to bottomfish fishing), which meant that catch to release ratios from the creel survey could not be applied to previous years. Without any quantitative information on variation in the discard rate over time, we were not able to include this major source of uncertainty in the catch scenarios.

Appendix E. Operating models for DFO assessment of Inside Yelloweye Rockfish

In their management strategy evaluation (MSE) of different potential management plans for rebuilding Inside Yelloweye Rockfish, DFO established six different operating models (OMs) to capture various uncertainties about the stock. These operating models were divided into a "reference set" of core OMs that include the most important uncertainties, and a "robustness set" that capture a wider range of less plausible uncertainties. The four reference set OMs were as follows:

(1) Base: A baseline OM;
(2) Low catch: An OM reflecting an alternative assumption about the magnitude of historical catch during the period 1986-2005;
(3) Episodic recruitment: An OM allowing for episodic (rare but large) future recruitment events;
(4) Estimate HBLL selectivity: An OM estimating selectivity in the Hard Bottom Longline (HBLL) survey.

The two robustness set OMs were as follows:

(A) Low M: An OM that assumes lower natural mortality than the other OMs;
(B) High HBLL CV: An OM that assumes a higher coefficient of variation in the future HBLL survey.

More detail about these OMs can be found in Haggarty et al. (2022).

Absolute spawning stock biomass (metric tons) estimates from these various OMs are presented in Figure A-13, and stock status (relative spawning stock biomass) estimates are presented in Figure A-14. As the OMs (3) Episodic Recruitment and (B) High HBLL CV both address future uncertainty rather than uncertainty in the historical period, these OMs have the same results as the (1) Base OM for estimating current stock size and status. All OMs estimate a similar unfished stock size, except for (2) Low catch, which has a lower stock size due to lower historical removals (Figure A-13). Stock status estimated by the OMs (1) Base and (2) Low catch are similar, with median estimated current stock size over 25% of unfished (Figure A-14). However, (4) Estimate HBLL selectivity OM and (A) Low M OM both estimate that the current stock size is less than 25% of unfished, with the (A) Low M OM in particular producing a median stock size estimate of only 11.7% of unfished. This OM, which used a lower mean in the distribution for *M* than the other OMs, reflects the possibility that the stock could be less productive than assumed in the other OM scenarios.

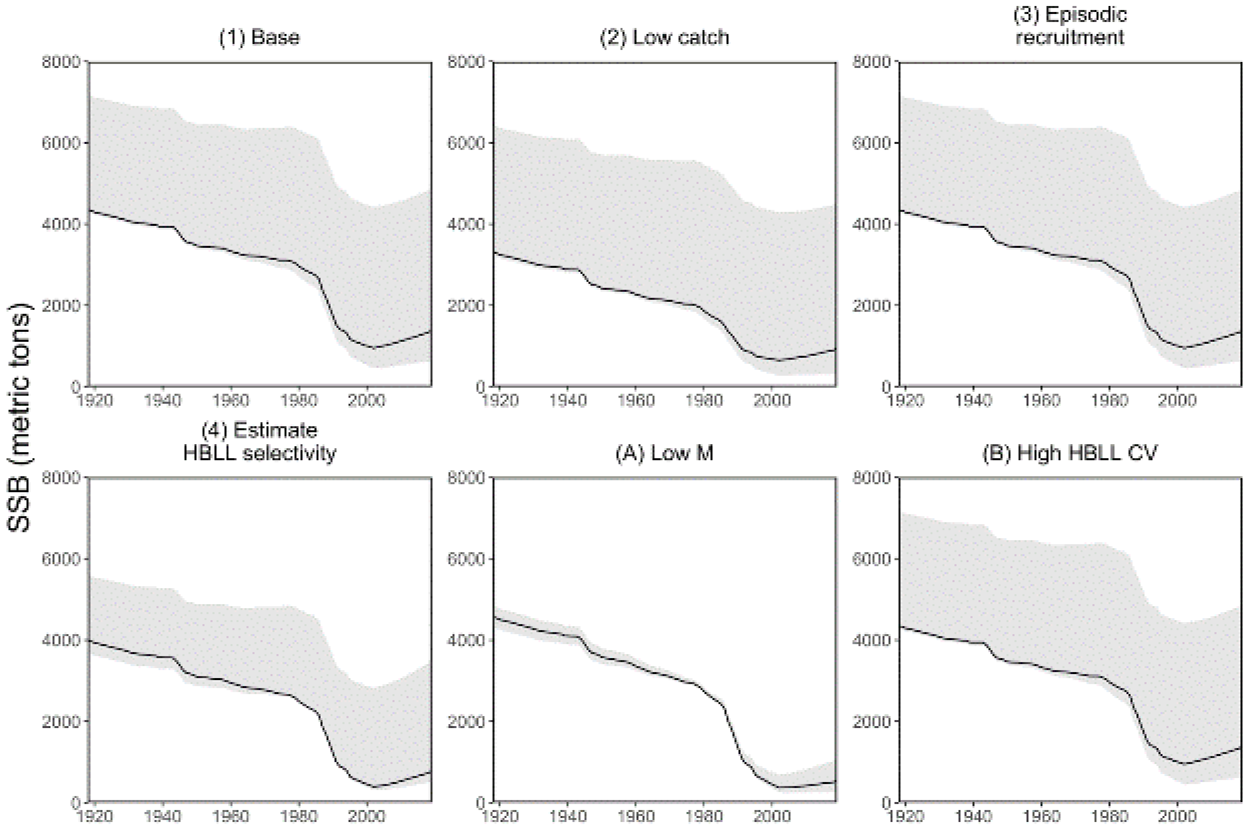

Figure A-13. Spawning stock biomass from the six different operating models (OMs) established by Fisheries and Ocean Canada (DFO) for the assessment of the Inside Yelloweye Rockfish design table unit (DU).

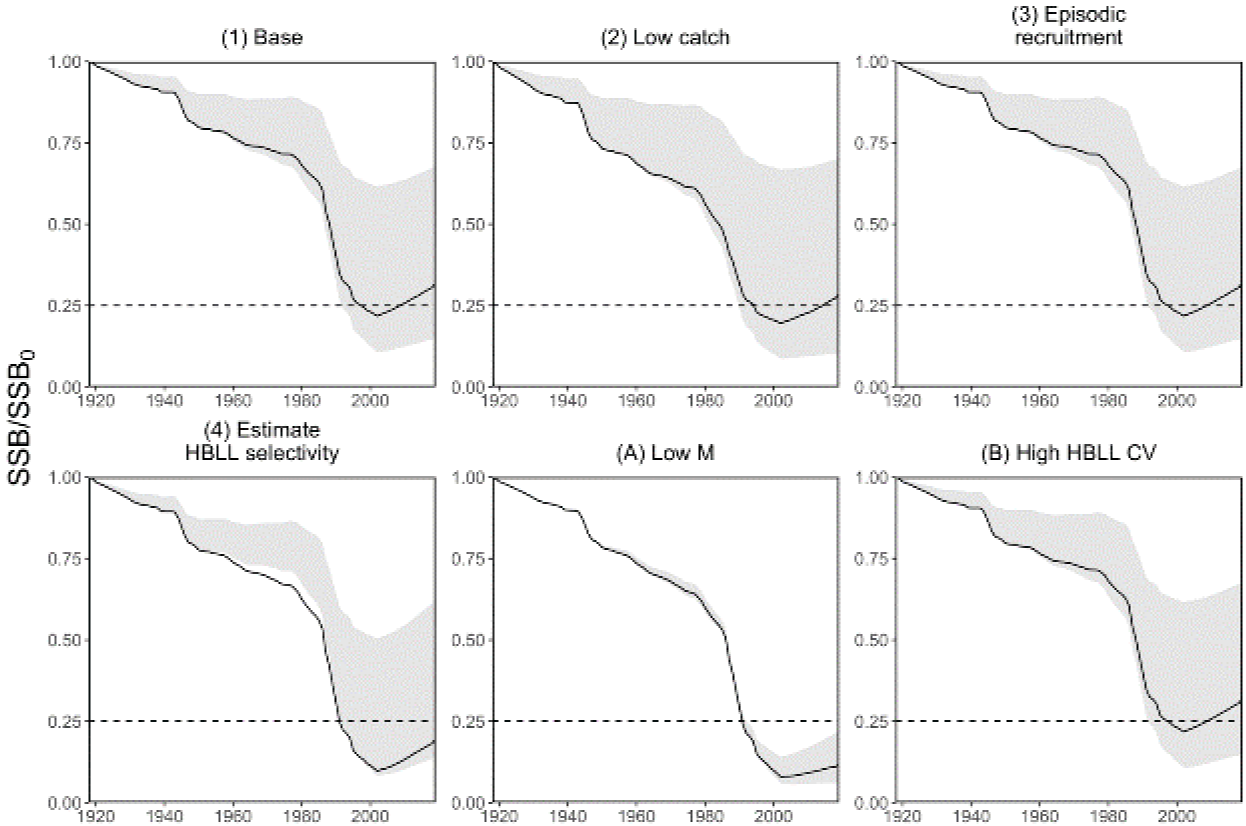

Figure A-14. Stock status (spawning stock biomass/unfished spawning stock biomass) from the six different operating models (OMs) established by Fisheries and Oceans Canada (DFO) for the assessment of the Inside Yelloweye Rockfish designatable unit (DU).